



Nunatak Vegetation Monitoring in the Southwest Alaska Inventory & Monitoring Network

Summary Report, 2005–2016

Natural Resource Report NPS/SWAN/NRR—2020/2138



**ON THIS PAGE**

Double Glacier South (nunatak), Lake Clark National Park and Preserve, July 2016.

Photo credit: NPS/JAMES WALTON

ON THE COVER

Resurveying transects at the Wosnesenski Glacier site, Kenai Fjords National Park, August 2016.

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Nunatak Vegetation Monitoring in the Southwest Alaska Inventory & Monitoring Network

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Abstract

This report presents results of nunatak vegetation monitoring efforts in 2016 at Kenai Fjords National Park (KEFJ) and Lake Clark National Park and Preserve (LACL) by the Southwest Alaska Inventory & Monitoring Network (SWAN). In 2005, the SWAN implemented a long-term monitoring program to assess status and trends in nunatak vegetation in KEFJ and LACL. The SWAN field crew visited eight sites to collect data relating to species richness, frequency, and vegetation structure. The 2016 field season marked the first revisit (second sampling event) at seven of the eight sites. Vascular species richness remained relatively stable over the first ten years of monitoring, with most sites showing a gain or loss of only two to three taxa. Vascular species turnover was highest at lower-elevation sites, suggesting that there may be an influx of new species establishing at these sites, and a loss of previously recorded species. Three low-elevation sites (Petrof, Tuxedni, South Double Glacier) recorded net species losses, while the remaining sites recorded species gains, in terms of vascular species counts. At the lowest of these sites (Petrof), we recorded one new exotic species, the common dandelion (*Taraxacum officinale*), which had not been observed in 2005.

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Introduction

Nunataks are exposed mountain peaks or ridges surrounded by glacial ice. In Alaska, they occur primarily along the northern Gulf of Alaska, where heavy snowfall maintains large glacier complexes in the Fairweather, Chugach, Kenai, and southern Alaska ranges. Existing nunatak communities are often geographically isolated, and some may represent modern analogs for communities that survived the Last Glacial Maximum (LGM), approximately 20,000 years before present (Manley and Kaufmann 2002). In addition to harboring regional or globally rare species (e.g., Vittoz et al. 2008), these high alpine environments can play an important role in the re-establishment of plant and animal communities in newly deglaciated areas (Jørgensen et al. 2011).

Mountain environments are experiencing some of the greatest rates of warming related to climate change, globally (Mountain Research Initiative 2015). Alpine plants are adapted to low temperatures and, in Alaska, to a short growing season, which makes them particularly sensitive to a warming climate. A number of studies have reported changes in species distributions, accelerated species turnover, and increases in species richness near mountain summits (Lenoir et al. 2008, Chen et al. 2011, Pauli et al. 2012, Steinbauer et al. 2018).

In 2005, the SWAN and Alaska Natural Heritage Program (AKNHP) conducted a vascular plant inventory at eleven nunatak and near-glacial sites in Lake Clark National Park and Preserve (LACL) and Kenai Fjords National Park (KEFJ) to supplement previous inventories at lower elevations (2001–2004; Miller et al. 2006). In addition, the SWAN collected baseline data at eight of these sites for long-term monitoring of the vascular plant communities (Miller et al. 2006). Monitoring objectives for nunatak communities were to assess trends in vegetation composition (e.g., species richness, diversity) and structure (e.g., species height).

In 2016, we conducted the first re-survey at seven of the monitoring sites. This report summarizes results of the 2005 and 2016 sampling events.

Methods

Miller and others (2006) describe in detail the study area and methods used for sampling monitoring sites. Below, we briefly describe the general approach, as well as 2016 additions (from Miller et al. 2010) to the sampling design. For those interested in more information, please see the reports cited above and available at <https://irma.nps.gov/DataStore/Reference/Profile/631687> and <https://irma.nps.gov/DataStore/Reference/Profile/2124834>.

Site Selection Criteria and Sampling Design

We used a geographic information system (GIS) to select locations in 2005 using the following criteria: (1) sites ≥ 1.5 km from the ice margin; (2) ≥ 25 ha in area; and (3) at least some portion of the site must be flat enough to safely support a helicopter landing (Miller et al. 2006). In both parks, we attempted to secure a reasonable north-south distribution of sites, although logistical constraints (topography, distance from helibase, ice cover) limited the survey area in LACL. Based on the above criteria, we selected eight sites (three sites in LACL and five sites in KEFJ) for monitoring in 2005. One of the sites, near Tuxedni Glacier in LACL, was located on the ice margin (periglacial), and so did not meet the first criterion. Kenai Fjords sites occurred over metasedimentary-derived soils (GRI 2010b) while LACL sites were over igneous-derived soils (GRI 2010a). In 2016, we revisited seven of the sites established in 2005 (Figure 1; Table 1; Appendix A). We dropped the eighth site, near Holgate Glacier in KEFJ, due to safety considerations at the landing zone.

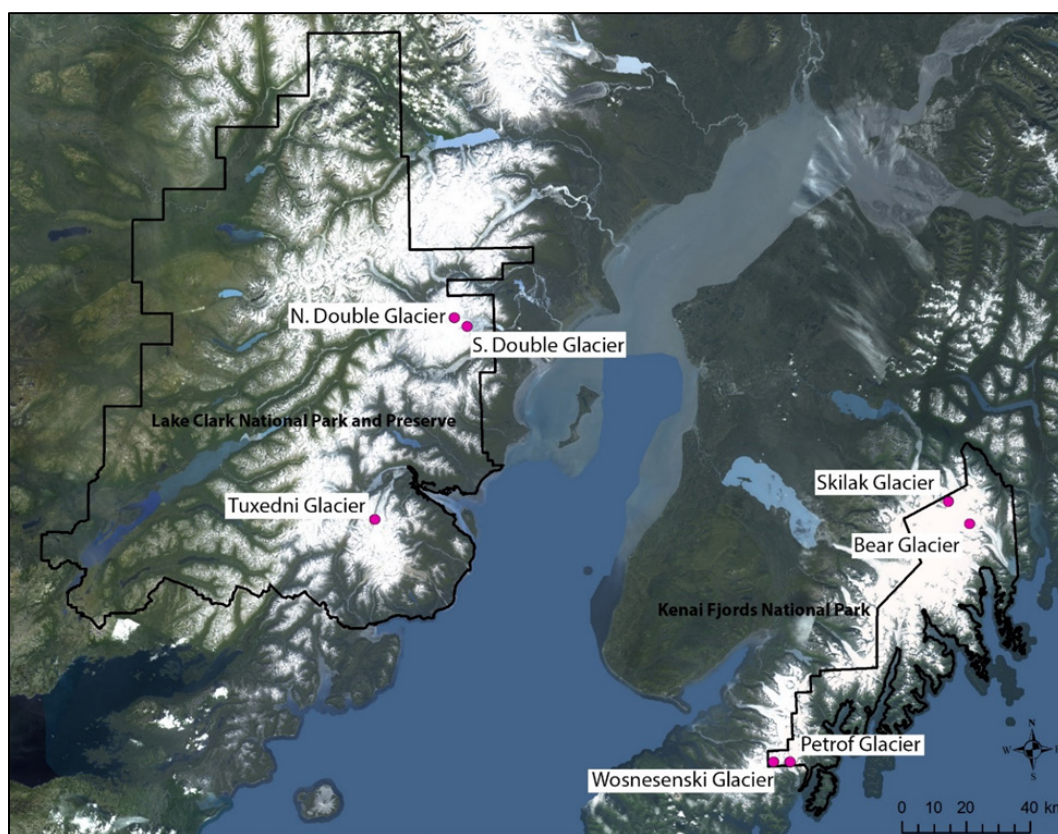


Figure 1. Nunatak monitoring site locations surveyed in 2005 and 2016.

Table 1. Nunatak monitoring site descriptions for sites surveyed in 2005 and 2016.

Park	Glacier complex	Latitude (DD)	Longitude (DD)	Elevation (m)	Community
Kenai Fjords	Skilak (N. Harding)	60.1445	-149.895401	1,420	Dry alpine meadow
Kenai Fjords	Bear (N. Harding)	60.0777	-149.782806	1,360	Barren rock and fellfield
Kenai Fjords	Wosnesenski (S. Harding)	59.4441	-150.945801	1,050	Dry alpine meadow
Kenai Fjords	Petrof (S. Harding)	59.4415	-150.855804	650	Dwarf heath-shrub
Lake Clark	N. Double	60.7126	-152.658005	1,115	Dry alpine meadow
Lake Clark	S. Double	60.6882	-152.586197	930	Dry alpine meadow
Lake Clark	Tuxedni	60.1539	-153.129593	760	Dwarf heath-shrub

At each monitoring site, we established two to three permanent 30-m transects within vegetation communities considered representative of the full extent of the nunatak and perceived to have the greatest cover (area) within the site. We established transect endpoints using a simple random start within the vegetation community. The seven monitoring sites surveyed in 2016 will be revisited every ten years as part of the SWAN's vital signs monitoring program (see [Appendix A](#) for supplemental site information).

Field Data Collection

In 2016, we recorded species cover using two different protocols:

1. We used methods outlined in Miller et al. (2006) to allow direct comparisons to data collected in 2005. Vascular plant frequency (presence/absence) was recorded in nested 0.25-m² and 1-m² quadrats at 3-m intervals along the right side of each 30-m transect, as viewed from the 0-m endpoint on the tape-line (Figure 2).
2. We used a modified version of Miller et al. (2010) to align future nunatak survey data with the SWAN protocol for ground-based monitoring of vegetation using a Generalized Random Tessellation Stratified (GRTS) survey design, consistent with the methods we have used to sample alpine plots elsewhere in the SWAN parks. We used the 30-m transect lines at the nunatak sites that had been established in 2005, and sampled nested quadrats at 7-m intervals in 2016, rather than establishing new 30-m transect lines in a 30-m by 30-m grid as in the Miller et al. (2010) protocol. The one exception was at the Skilak site, where the meadow was large enough that we could establish a 30-m by 30-m grid within the vegetation community, in addition to the pre-existing 2005 transect array. We quantified vascular plant cover (presence/absence) and vegetation structure (height class) using point-intercept transects recorded at 50-cm intervals along the 30-m transects, within four vertical height strata (≤ 50 cm, 50–100 cm, 100–400 cm, >400 cm; Figure 2). Bryophytes (mosses, liverworts) and lichens were recorded as separate cover classes. We recorded the frequency of vascular plants, bryophytes, and macrolichens in nested 0.0625-m², 0.25-m², 1-m² (vascular only), and 4-m² (vascular only) quadrats at 7-m intervals, starting at the 0-m endpoint of the transect (Figure 2). Due to time

constraints, we were unable to survey nonvascular taxa at Bear Glacier (KEFJ). Samples recorded at 7-m intervals, following the Miller et al. (2010) protocol, are referred to as ‘GRTS 2016’ samples in Appendix B.

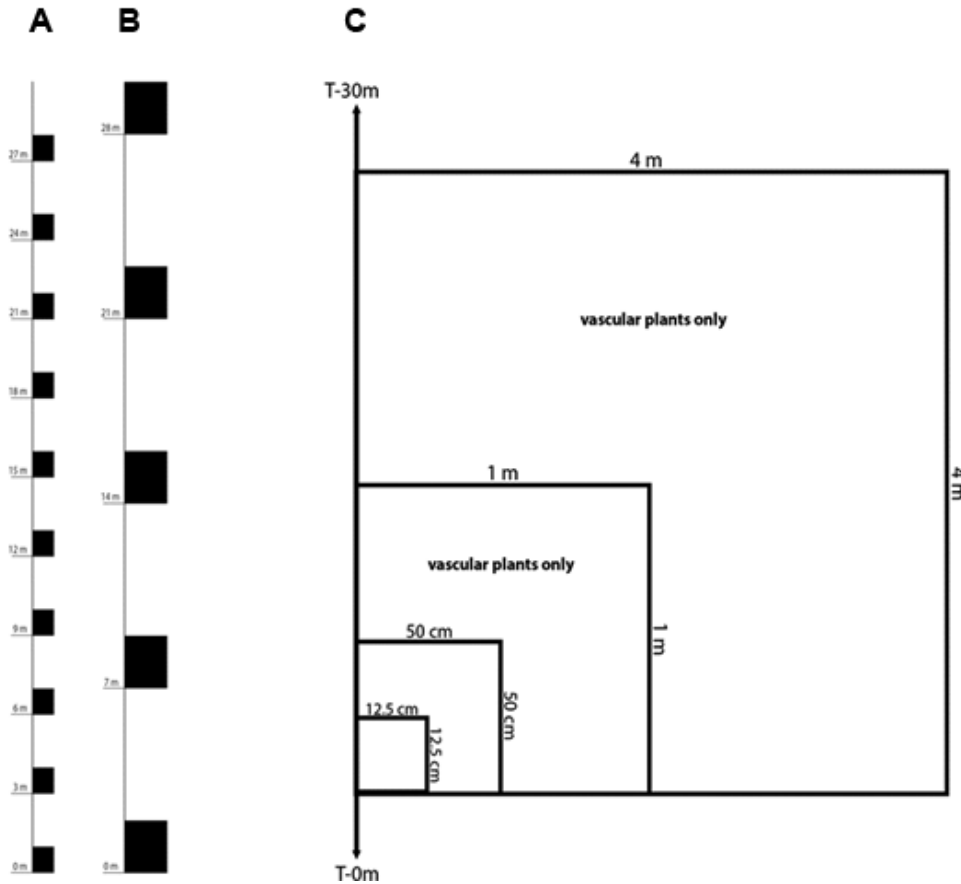


Figure 2. Layout of transects and nested quadrats for sampling species frequency. (A) A 30-m transect showing quadrat layout every 3-m. (B) A 30-m transect showing quadrat layout every 7-m. (C) Nested quadrat used to survey plant frequency. Transects zero (0-m) endpoints were located at lower slope positions, with transects trending upslope to 30-m. Nested quadrats were located on the looker’s right of each transect, when standing at the 0-m endpoint.

We collected all unknown species for later identification and retained a subset of herbarium collections at the National Park Service (NPS) Alaska Regional Office. We also took a series of photos that included views up and down each transect (from the 0-m and 30-m endpoints), views of the dominant community or communities at the site, and views of the representative landforms and geology. Quadrat photos were taken from a height of approximately 1.5-m and at a downward angle of approximately 90° from the plot margin.

We also estimated vascular and nonvascular frequencies for 0.25-m² quadrats (Appendix B), consistent with data collected in 2005. In 2016, we added frequency estimates in 0.016-m² quadrats (nonvascular), and 4-m² quadrats (vascular), following the Miller et al. (2010) protocol (Figure 2c).

For the purpose of this report, we have summarized only the 1-m² and 0.25-m² frequency data, as we estimated frequencies for those frame sizes during both sampling events (2005, 2016). We also report nonvascular frequencies (0.25-m²), which were recorded in 2016 only (Appendix B).

Data Analysis

Community Composition and Site Characteristics

We used non-metric multidimensional scaling (NMS) in PC-ORD 7 (McCune and Mefford 2016) to ordinate plots in species space using 2016 vascular and nonvascular quadrat frequency data collected using the Miller et al. (2010) survey method. Nomenclature primarily followed the Flora of North America (FNA 1993+) for vascular plants and bryophytes and Esslinger (2018) for macrolichens. The ordination enabled us to examine the relationship between species' abundance (frequency) and environmental variables such as elevation, ground cover attributes, and climate covariates. Prior to analysis, we removed species found in two or fewer plots to reduce noise from rare or inadequately sampled taxa. We excluded nonvascular (bryophyte + lichen) data from the ordination, since we had those data only for the second sampling date (2016). The updated species matrix consisted of 48 taxa by 6 sites. We used the Sørensen index (Beals 1984) to calculate the distance matrix for the ordination. The significance of the best fit was evaluated using a Monte Carlo test that compared final axes to those calculated from 250 runs of randomized data. We calculated Pearson correlation coefficients to assess the relationship of species to the ordination axes.

We also modeled community relationships, as described by NMS scores, to environmental variables using nonparametric multiplicative regression (NPMR; McCune 2006) in HyperNiche 2 (McCune and Mefford 2009), allowing nonlinear responses. We used a set of environmental variables to relate patterns in community structure and cover to habitat attributes. Those variables measured at the plot included elevation, latitude and longitude. Variables collected on transects (in the same manner as vegetation cover on transects) included soil, rock, gravel, litter, bryophyte, lichen, and cryptogamic crust. GIS-derived variables included slope and aspect. Other derived variables included vascular plant richness, bryophyte richness, lichen richness, and nonvascular (bryophyte + lichen) richness. Gridded climate data came from ClimateWNA (Wang et al. 2016; <http://www.climatewna.com/>), a climate data set for western North America based on the Parameter Regression of Independent Slopes Model (PRISM) interpolation method for current climate, and using the CRU-TS 2.1 and CRU-TS 3.22 data sets. We extracted mean annual air temperature, longitude, mean annual precipitation, frost-free period, and percent precipitation as snow, for all sites.

Changes in Community Composition through Time

We calculated vascular plant species richness (S), Shannon (H') and Simpson (D) diversity indices, evenness (E) and cover for each plot in PC-ORD 7 (McCune and Mefford 2016) using the repeated 1-m² quadrat data collected in 2005 and 2016. The Shannon and Simpson index values were converted into effective number of species for each site (H_e and D_e, respectively). This allowed diversity metrics to be compared directly to species richness at the sites, within and among sample years, and based on counts of distinct species in the community (Jost 2006). As S, H_e, and D_e approach the same value, species begin to be equally abundant across a site. Larger differences in these values reflect an increasing number of uncommon species and a decrease in abundant species.

We used Wilcoxon signed ranks tests in R (R Core Team 2017) to determine whether site-level species richness differed between 2005 and 2016.

In order to examine changes in species composition through time, we sought species groupings based on 2005 and 2016 vascular community composition using two-way hierarchical agglomerative cluster analyses in PC-ORD 7 (McCune and Mefford 2016). Two-way cluster analysis combines independent clustering of sample units and species into a single diagram. Plots are combined into groups based on compositional dissimilarity as measured with Euclidean (Pythagorean) distance. The data were relativized by species maximum counts to diminish, but not eliminate, the influence of species totals on species clustering. We used Ward's Method as the linkage method and looked at changes in species' presence/absence across years, within each site.

Results and Discussion

Community Composition and Site Characteristics

Most species found on the nunataks were widely distributed arctic and boreal species, tolerant of a wide range of climates and soil types (FNA 1993+, Brodo et al. 2001). Certain species have adaptations for long-distance dispersal by wind (*anemochory*, e.g., *Dryas*) or animals (*zoochory*, e.g., *Trisetum spicatum*). Most bryophytes and lichens, and several vascular plant species are able to reproduce vegetatively (e.g., *Carex*, *Salix*) or can survive long periods under unsuitable conditions for sexual reproduction (e.g., *Bistorta vivipara*).

We recorded eighty-seven vascular plant taxa across the seven monitoring sites surveyed in 2005 and 2016 (Table 2). Common taxa in LACL, occurring at all sites during both survey years, included *Artemisia arctica*, *Campanula lasiocarpa*, *Empetrum nigrum*, *Harrimanella stellariana*, *Kalmia procumbens* (= *Loiseleuria procumbens*), *Luzula arcuata* subsp. *unalaschkensis*, *Salix rotundifolia*, and *Vaccinium uliginosum*. Common taxa in KEFJ included *Carex lachenalii*, *Luzula arcuata* subsp. *unalaschkensis*, and *Rhodiola integrifolia*. In KEFJ, we also found evidence of mountain goats (hair, scat) at every site but Bear Glacier. Across all sites, species richness (S) tended to decrease with elevation and distance from the coast (Figure 3). Sites in close proximity to the coast (e.g., Petrof, Wosnesenski, Tuxedni) supported a rich assemblage of mesic or snowbed species, while sites at higher elevations and further from the coastline tended to be drier and support primarily fellfield and dry alpine meadows. Bryophyte and lichen composition, as measured in 0.25-m² quadrats in 2016, showed high species richness at some of the well-established, higher elevation sites (Appendix B, Table B1). Lower elevation sites (e.g., S. Double, Tuxedni, Petrof) contained many bryophytes that are known to inhabit wide ecological and elevation gradients (FNA 1993+) but supported relatively few lichens. These were mostly widespread, common, ascending growth-form lichen taxa (e.g., *Cetraria*, *Cladonia*, *Stereocaulon*) that are also known to inhabit a range of ecological conditions, including alpine and dwarf shrub tundra (Brodo et al. 2001). High-elevation sites hosted a broad suite of both bryophyte and lichen taxa likely due to a number of factors, including decreased vascular plant competition and increased availability of microhabitats.

Table 2. Percent frequency of vascular plant taxa in 1-m² quadrats observed in 2005 and 2016. A dash (–) indicates no sample.

Category	Species Name	Lake Clark National Park and Preserve						Kenai Fjords National Park							
		N. Double (n=20) 2005	N. Double (n=20) 2016	S. Double (n=30) 2005	S. Double (n=30) 2016	Tuxedni (n=30) 2005	Tuxedni (n=30) 2016	Skilak (n=30) 2005	Skilak (n=30) 2016	Bear (n=20) 2005	Bear (n=20) 2016	Petrof (n=30) 2005	Petrof (n=30) 2016	Wosnesenski (n=30) 2005	Wosnesenski (n=30) 2016
Grasses	<i>Agrostis exarata</i>	–	–	–	–	–	–	–	–	–	–	–	13.3	–	–
	<i>Agrostis mertensii</i>	–	–	–	–	13.3	–	–	–	–	–	23.3	76.7	–	35.7
	<i>Anthoxanthum monticola</i> subsp. <i>alpinum</i>	10.0	30.0	10.0	10.0	–	–	–	13.3	11.1	11.1	–	–	3.5	3.6
	<i>Calamagrostis canadensis</i>	–	–	–	–	–	–	–	–	–	–	13.3	16.7	–	–
	<i>Festuca brachyphylla</i>	–	–	–	–	–	–	–	–	–	–	16.7	–	27.6	–
	<i>Phleum alpinum</i>	–	–	–	–	–	–	–	–	–	–	–	30.0	–	–
	<i>Poa alpina</i>	–	–	–	–	–	20.0	–	10.0	–	–	–	–	–	–
	<i>Poa arctica</i>	–	–	3.3	3.3	–	–	60.0	50.0	–	–	–	–	–	–
	<i>Poa glauca</i>	–	–	–	–	–	–	–	–	–	–	100.0	100.0	31.0	78.6
	<i>Poa paucispicula</i>	–	–	–	–	–	–	–	–	–	–	13.3	–	17.2	42.9
	<i>Poa</i> sp.	–	10.0	–	–	–	–	–	20.0	–	–	–	–	–	–
	<i>Trisetum spicatum</i>	25.0	15.0	13.3	–	13.3	–	–	–	–	–	83.3	93.3	58.6	35.7
	<i>Vahlodea atropurpurea</i>	–	–	–	–	43.3	50.0	–	–	–	–	–	–	–	–
Sedges-rushes	<i>Carex lachenalii</i> (incl. <i>C.</i> <i>phaeocephala</i>)	–	–	–	–	–	–	16.7	6.7	16.7	11.1	60.0	80.0	6.9	3.6
	<i>Carex macrochaeta</i>	–	–	–	–	53.3	53.3	–	–	–	–	–	–	–	–
	<i>Carex mertensii</i>	–	–	–	–	–	–	–	–	–	–	16.7	40.0	–	–
	<i>Carex microchaeta</i>	100.0	100.0	100.0	93.3	–	6.7	60.0	63.3	83.3	72.2	–	–	62.1	64.3
	<i>Carex micropoda</i>	–	–	13.3	10.0	73.3	80.0	26.7	26.7	–	–	40.0	40.0	–	3.6
	<i>Carex</i> sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	3.6
	<i>Juncus biglumis</i>	–	–	–	–	–	–	3.3	–	–	–	–	–	–	–
	<i>Luzula arcuata</i> subsp. <i>unalaschkensis</i>	85.0	75.0	83.3	80.0	20.0	20.0	66.7	73.3	55.6	77.8	13.3	30.0	93.1	78.6
	<i>Luzula piperi</i>	–	–	10.0	13.3	76.7	63.3	3.3	–	–	–	100.0	93.3	–	–
	<i>Luzula spicata</i>	–	–	–	–	–	–	–	–	–	–	–	–	10.3	10.7
	<i>Luzula</i> sp.	–	–	–	–	–	3.3	–	–	–	–	–	–	–	–

Table 2 (continued). Percent frequency of vascular plant taxa in 1-m² quadrats observed in 2005 and 2016. A dash (–) indicates no sample.

Category	Species Name	Lake Clark National Park and Preserve						Kenai Fjords National Park							
		N. Double (n=20) 2005	N. Double (n=20) 2016	S. Double (n=30) 2005	S. Double (n=30) 2016	Tuxedni (n=30) 2005	Tuxedni (n=30) 2016	Skilak (n=30) 2005	Skilak (n=30) 2016	Bear (n=20) 2005	Bear (n=20) 2016	Petrof (n=30) 2005	Petrof (n=30) 2016	Wosnesenski (n=30) 2005	Wosnesenski (n=30) 2016
Forbs	<i>Androsace</i> sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	7.1
	<i>Anemone narcissiflora</i>	–	–	–	–	–	–	–	–	–	–	3.3	–	–	–
	<i>Antennaria monocephala</i>	100.0	90.0	53.3	33.3	3.3	–	40.0	33.3	5.6	5.6	–	–	–	–
	<i>Antennaria rosea</i> subsp. <i>pulvinata</i>	–	–	–	–	16.7	13.3	–	–	–	–	46.7	66.7	58.6	71.4
	<i>Arabis kamchatica</i>	–	–	–	–	–	–	–	–	–	–	10.0	20.0	–	–
	<i>Artemisia arctica</i>	100.0	100.0	70.0	50.0	13.3	3.3	86.7	96.7	–	5.6	3.3	6.7	89.7	92.9
	<i>Astragalus alpinus</i>	–	–	–	–	–	–	–	–	–	–	–	–	31.0	28.6
	<i>Bistorta vivipara</i>	10.0	–	–	–	13.3	10.0	–	–	–	–	–	–	31.0	28.6
	<i>Campanula lasiocarpa</i>	95.0	90.0	66.7	50.0	3.3	33.3	63.3	66.7	11.1	22.2	–	–	75.9	85.7
	<i>Campanula rotundifolia</i>	–	–	–	–	–	–	–	–	–	–	6.7	6.7	–	7.1
	<i>Cardamine bellidifolia</i>	–	–	–	–	–	–	10.0	33.3	–	22.2	3.3	–	13.8	3.6
	<i>Cerastium beeringianum</i>	–	–	–	–	–	–	–	–	–	–	–	–	14.0	3.6
	<i>Chamaenerion angustifolium</i>	–	–	–	–	6.7	6.7	–	–	–	–	3.3	6.7	–	–
	<i>Chamaenerion latifolium</i>	–	–	–	–	–	–	–	–	–	–	76.7	83.3	6.9	7.1
	<i>Coeloglossum viride</i>	–	–	–	–	–	–	–	–	–	–	–	3.3	–	–
	<i>Draba</i> sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	10.7
	<i>Epilobium hornemannii</i>	–	–	–	–	56.7	–	–	–	–	–	80.0	93.3	–	–
	<i>Erigeron humilis</i>	–	–	–	–	–	–	–	–	–	–	–	–	13.8	25.0
	<i>Erigeron peregrinus</i>	–	–	–	–	3.3	40.0	–	–	–	–	–	–	–	–
	<i>Gentiana glauca</i>	35.0	75.0	–	–	3.3	3.3	–	–	–	–	–	–	–	–
	<i>Geum rossii</i>	–	–	–	–	–	–	–	–	–	–	3.3	–	51.7	57.1
	<i>Hieracium triste</i>	–	–	–	–	73.3	56.7	–	–	–	–	3.3	10.0	–	–
	<i>Lloydia serotina</i> var. <i>serotina</i>	45.0	25.0	–	–	–	–	–	–	–	–	–	–	79.3	57.1
	<i>Luetkea pectinata</i>	–	–	13.3	13.3	96.7	100.0	–	–	–	–	96.7	96.7	–	–
	<i>Lupinus nootkatensis</i>	–	–	3.3	–	83.3	80.0	–	–	–	–	100.0	100.0	–	–
	<i>Minuartia macrocarpa</i>	–	–	–	–	–	–	13.33 (4)	13.33 (4)	–	–	–	–	31.0	32.1
	<i>Minuartia rubella</i>	–	–	–	–	–	–	–	–	–	–	–	–	3.5	–

Table 2 (continued). Percent frequency of vascular plant taxa in 1-m² quadrats observed in 2005 and 2016. A dash (–) indicates no sample.

Category	Species Name	Lake Clark National Park and Preserve						Kenai Fjords National Park							
		N. Double (n=20) 2005	N. Double (n=20) 2016	S. Double (n=30) 2005	S. Double (n=30) 2016	Tuxedni (n=30) 2005	Tuxedni (n=30) 2016	Skilak (n=30) 2005	Skilak (n=30) 2016	Bear (n=20) 2005	Bear (n=20) 2016	Petrof (n=30) 2005	Petrof (n=30) 2016	Wosnesenski (n=30) 2005	Wosnesenski (n=30) 2016
Forbs (continued)	<i>Papaver radicatum</i> subsp. <i>alaskanum</i>	–	–	–	–	–	–	–	–	–	–	–	–	3.5	3.6
	<i>Pedicularis</i> sp.	–	–	–	–	3.3	–	–	–	–	–	–	–	–	7.1
	<i>Pedicularis capitata</i>	–	5.0	–	3.3	–	3.3	–	–	–	–	–	–	–	7.1
	<i>Pedicularis langsдорфii</i>	10.0	–	23.3	–	–	–	–	–	–	–	–	–	–	–
	<i>Pedicularis verticillata</i>	–	–	–	3.3	–	–	–	–	–	–	–	–	27.6	–
	<i>Polemonium pulcherrimum</i>	–	–	–	–	–	–	–	–	–	–	3.3	10.0	10.3	10.7
	<i>Potentilla hyparctica</i>	–	–	–	–	–	–	36.7	30.0	11.1	11.1	–	–	41.4	42.9
	<i>Rhodiola integrifolia</i>	–	–	3.3	–	–	–	3.3	6.7	11.1	11.1	13.3	3.3	93.1	89.3
	<i>Sagina nivalis</i>	–	–	–	–	–	–	–	–	–	–	3.3	–	–	–
	<i>Saxifraga bronchialis</i>	–	–	–	–	–	–	–	3.3	–	–	6.7	6.7	55.2	60.7
	<i>Saxifraga nivalis</i>	–	–	–	–	–	–	–	–	–	–	–	–	3.5	–
	<i>Saxifraga punctata</i>	–	–	–	–	–	–	3.3	–	–	–	–	–	41.4	39.3
	<i>Sibbaldia procumbens</i>	–	5.0	–	–	10.0	10.0	16.7	26.7	–	–	56.7	76.7	13.8	14.3
	<i>Silene acaulis</i>	–	–	–	–	–	–	10.0	13.3	–	–	13.3	6.7	24.1	32.1
	<i>Solidago multiradiata</i>	–	–	–	–	–	–	–	–	–	–	–	–	6.9	3.6
	<i>Stellaria longipes</i>	–	–	–	–	–	–	30.00 (9)	20.00 (6)	–	–	40.0	63.3	6.9	14.3
	<i>Taraxacum officinale</i>	–	–	–	–	–	–	–	–	–	–	–	6.7	–	–
	<i>Veronica wormskjoldii</i> subsp. <i>wormskjoldii</i>	–	–	–	–	26.7	16.7	–	–	–	–	6.67 (2)	43.3	–	–
	<i>Viola langsдорфii</i>	–	–	–	–	3.3	–	–	–	–	–	–	–	–	–
Ferns and allies	<i>Athyrium filix-femina</i>	–	–	–	–	–	–	–	–	–	–	3.3	3.3	–	–
	<i>Cryptogramma acrostichoides</i>	–	–	–	–	–	–	–	–	–	5.6	–	–	–	–
	<i>Diphasiastrum alpinum</i>	–	–	3.3	–	73.3	76.7	16.7	16.7	–	–	–	–	–	–
	<i>Huperzia selago</i>	–	25.0	–	–	10.0	13.3	–	–	–	–	–	–	62.1	39.3

Table 2 (continued). Percent frequency of vascular plant taxa in 1-m² quadrats observed in 2005 and 2016. A dash (–) indicates no sample.

Category	Species Name	Lake Clark National Park and Preserve						Kenai Fjords National Park							
		N. Double (n=20) 2005	N. Double (n=20) 2016	S. Double (n=30) 2005	S. Double (n=30) 2016	Tuxedni (n=30) 2005	Tuxedni (n=30) 2016	Skilak (n=30) 2005	Skilak (n=30) 2016	Bear (n=20) 2005	Bear (n=20) 2016	Petrof (n=30) 2005	Petrof (n=30) 2016	Wosnesenski (n=30) 2005	Wosnesenski (n=30) 2016
Dwarf shrubs	<i>Cassiope lycopodioides</i>	–	–	30.0	33.3	6.7	16.7	–	–	–	–	–	–	–	–
	<i>Cassiope tetragona</i>	55.0	40.0	–	–	–	–	–	–	–	–	–	–	–	–
	<i>Diapensia lapponica</i>	75.0	70.0	30.0	36.7	–	–	–	–	33.3	33.3	3.3	–	10.3	10.7
	<i>Dryas integrifolia</i>	40.0	40.0	–	–	–	–	–	–	–	–	–	–	–	–
	<i>Empetrum nigrum</i>	10.0	20.0	70.0	83.3	53.3	60.0	–	3.3	–	–	–	–	–	–
	<i>Harrimanella stelleriana</i>	15.0	10.0	36.7	50.0	100.0	100.0	–	–	–	–	–	–	–	–
	<i>Kalmia procumbens</i>	40.0	45.0	10.0	20.0	43.3	23.3	–	–	–	–	–	–	–	–
	<i>Phyllodoce aleutica</i>	–	–	–	–	3.3	–	–	–	–	–	–	–	–	–
	<i>Salix arctica</i>	5.0	70.0	3.3	10.0	–	–	–	–	–	–	3.3	3.3	–	–
	<i>Salix polaris</i>	–	–	–	–	6.7	13.3	–	–	–	–	–	–	–	–
	<i>Salix rotundifolia</i>	100.0	100.0	96.7	96.7	33.3	23.3	10.0	10.0	5.6	11.1	–	–	89.7	85.7
	<i>Vaccinium uliginosum</i>	30.0	40.0	30.0	33.3	20.0	23.3	–	–	–	–	–	–	–	3.6

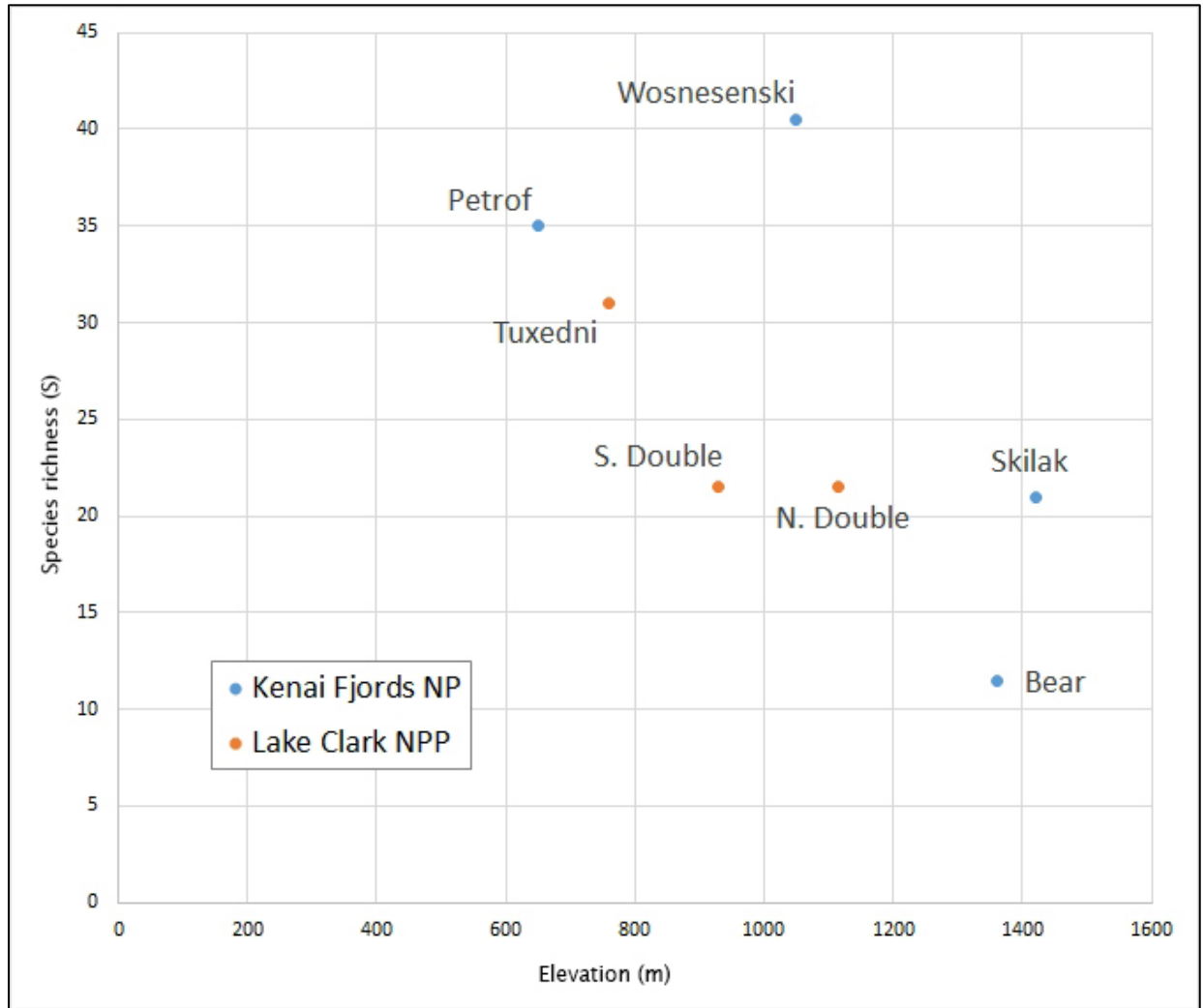


Figure 3. Vascular plant species richness (S) recorded in 1-m² quadrats (n = 20 at Bear and N. Double, n = 30 for all other sites) in 2016 decreases with elevation across the seven sites in KEFJ and LACL.

Vascular species cover, recorded by point-intercept along transects, also reflected variation in the abundance of major vascular species in LACL and KEFJ. Dwarf shrubs were the dominant cover type across all sites in LACL but were notably sparse to absent across sites in KEFJ, which saw greater cover in a broad suite of graminoids and forbs (Appendix B, Table B2). As such, four dwarf shrub species in LACL (*Diapensia lapponica*, *Empetrum nigrum*, *Harrimanella stelleriana*, *Vaccinium uliginosum*), and two sedge-rush species in KEFJ (*Carex microchaeta*, *Luzula arcuatata* subsp. *unalaschkensis*) showed high constancy (lowest mean difference in percent cover) and should be the most straightforward species to monitor for changes in cover using this protocol. We recorded several taxa through point-intercept sampling in 2016 that were not captured in the Miller et al. (2006) nested-quadrat protocol. One species, *Eurybia sibirica* (= *Aster sibiricus*) was recorded only once at Tuxedni and was not recorded elsewhere in the study area. Other species captured from point-intercept surveys, but not recorded in 2005 and 2016 nested-quadrat surveys, included *Anthoxanthum monticola* subsp. *alpinum* (= *Hierochloa alpina*; Tuxedni), *Poa alpina* (Petrof), *Carex*

microchaeta (Petrof), *Cassiope tetragona* (S. Double), and *Phyllodoce aleutica* (Petrof). *Minuartia rubella* was also a newly recorded species for Wosnesenski during the point-intercept surveys.

As part of the 2016 sampling effort, we compared 0.25-m² plot frequency data using the Miller et al. (2006) and Miller et al. (2010) protocols. Results of the comparison indicated that decreasing sampling effort by 50% resulted in a 20% reduction in species counts, on average, across sites; i.e., species counts using the Miller et al. (2010) protocol captured 67%–100% of the number of taxa captured by the Miller et al. (2006) method (Appendix B, Tables B3–B4). Because the two sampling designs used quadrats arrayed at different intervals along the transects (3-m vs. 7-m intervals, respectively; Figure 2), the two samples represented different areas of the plot and sometimes included different species lists (Appendix B, Tables B3–B4). Both designs captured the dominant taxa, but we often missed less abundant taxa using the Miller et al. (2010) protocol, which has been implemented at alpine monitoring sites elsewhere in the parks. Adherence to the Miller et al. (2006) protocol, while more labor intensive, will ensure that our composition data are consistent with the 2005 baseline. We will incorporate cover estimates using the Miller et al. (2010) point-intercept method into future sampling and will use the 2016 data as a baseline.

Vascular and nonvascular community composition at the six sites sampled in 2016 was strongly related to geographic, climate, and substrate variables (2-dimensional stress = 0.00; Figure 4). Bear Glacier was excluded from the analysis, since we were unable to survey nonvascular taxa at that site. The first ordination axis described 62.0% of the vegetation community variation and was best predicted by elevation and litter cover (NPMR: $xR^2 = 0.53$), while the second ordination axis described 31.9% of community variation and was best predicted by longitude (a geographic variable most strongly correlated with mean annual temperature (MAT) and frost free period (FFP) within the study area) and bryophyte cover (NPMR: $xR^2 = 0.73$; Figure 5). Associated with these patterns were relationships with snowfall ($r = 0.63$) and mean annual precipitation ($r = 0.58$) along the first ordination axis, and mean annual temperature ($r = 0.77$) and frost-free period ($r = 0.75$) along the second ordination axis. Substrate variables with strong relationships to the first ordination axis included litter cover ($r = -0.82$), cryptogamic crust cover ($r = 0.64$), and lichen cover ($r = 0.50$). Soil characteristics (not analyzed for this project) in KEFJ (metasedimentary-derived soils) and LACL (igneous-derived soils) may also be affecting species composition.

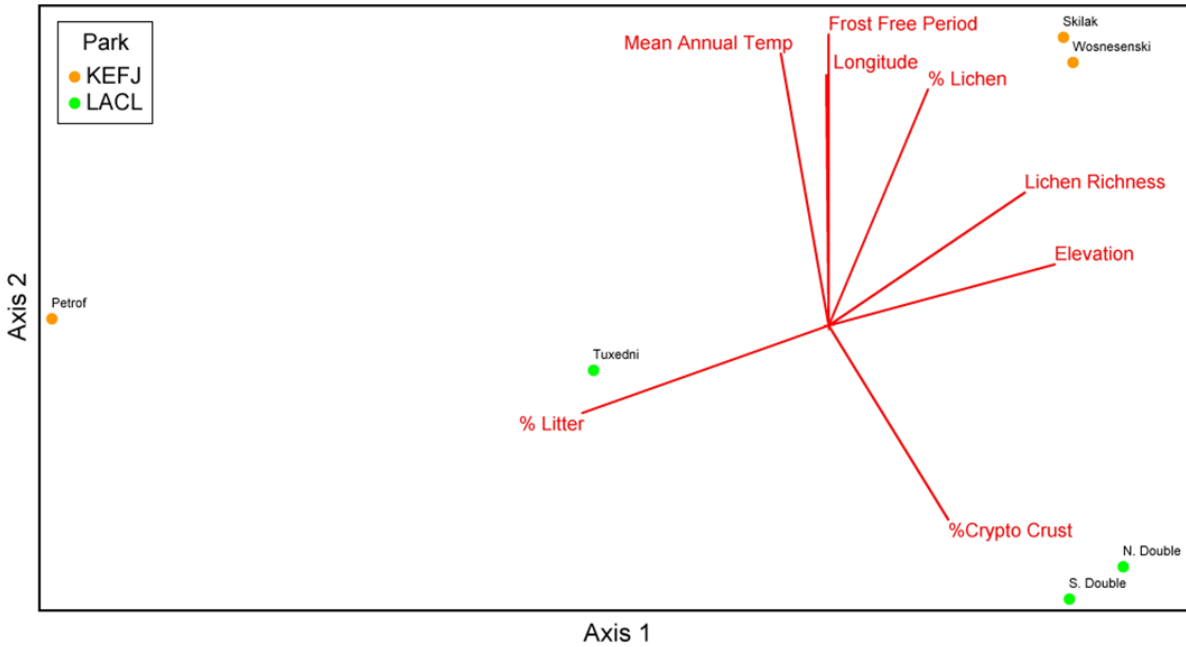


Figure 4. Non-metric multidimensional scaling (NMS) ordination of plots in species space for entire region coded by park. Vectors are overlays of environmental variables with length proportional to their correlation with each axis. An arbitrary cut-off value of $r^2 \geq 0.60$ was used when assessing correlations of environmental variables and diversity estimates with the ordination axes. The Bear Glacier site was not included in the analysis, as we do not have nonvascular data from that site.

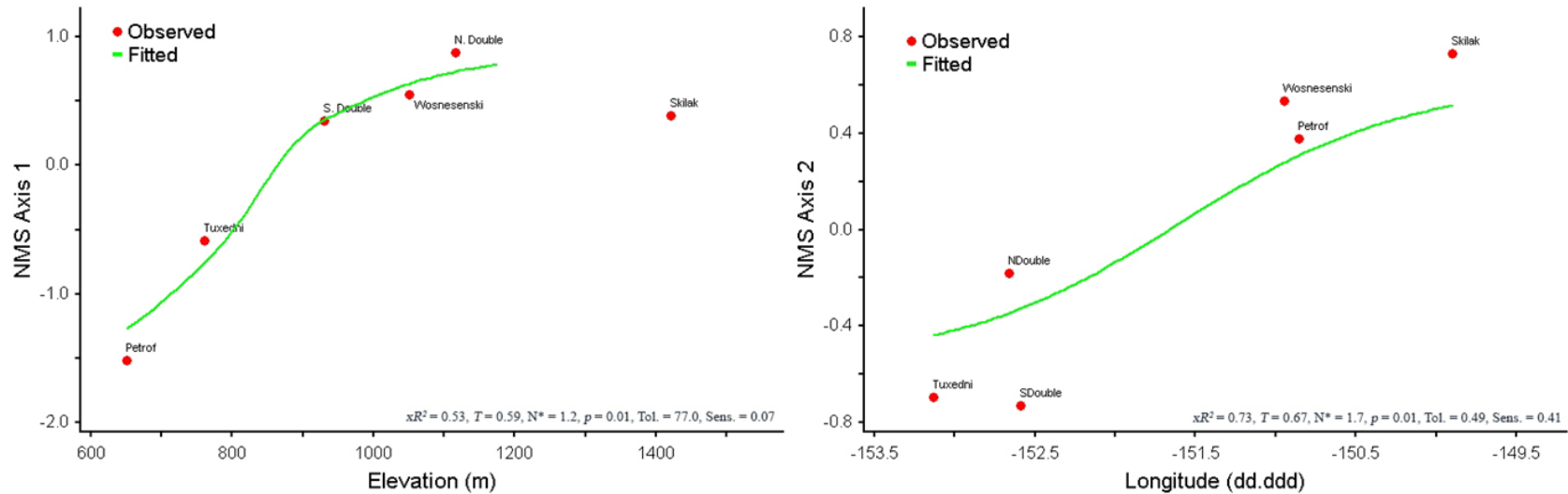


Figure 5. Nonparametric multiplicative regression (NPMR) models relating NMS community axes to the strongest environmental variable for each axis. NMS Axis 1 explained 62.0% of community variation, which was most strongly predicted by elevation (pictured, left) and litter cover. NMS Axis 2 explained 31.9% of community variation, which was most strongly predicted by longitude (a geographic variable most strongly correlated with mean annual temperature (MAT) and frost free period (FFP) within the study area; pictured, right) and bryophyte cover. The Bear Glacier site was not included in the analysis, as we do not have nonvascular data from that site.

Results of the NMS ordination described species composition across a range of site conditions. The suite of species associated with low-elevation sites in our study area, as described by the first ordination axis, included *Luetkea pectinata* ($r = -0.96$), *Luzula piperi* ($r = -0.96$), *Lupinus nootkatensis* ($r = -0.95$), and the moss, *Niphotrichum ericoides* (formerly *Racomitrium ericoides*; $r = -0.93$). High-elevation taxa included *Artemisia arctica* ($r = 0.92$), *Campanula lasiocarpa* ($r = 0.92$), *Luzula arcuata* subsp. *unalaschkensis* ($r = 0.88$), and *Carex microchaeta* ($r = 0.88$). Due to the distribution of our sites across each mountain range, lower-elevation sites also tended to fall closer to the coast than high-elevation sites. Species associated with oceanic sites, as described by the second axis, included *Stellaria longipes* ($r = 0.72$) and the lichens *Thamnolia subuliformis* ($r = 0.77$), *Cladonia gracilis* ($r = 0.72$), and *Lobaria linita* ($r = 0.69$). More interior, sub-oceanic sites were characterized by a high incidence of *Empetrum nigrum* ($r = -0.94$), *Harrimanella stelleriana* ($r = -0.93$), and the mosses *Dicranum scoparium* ($r = -0.85$), and *Politrachum piliferum* ($r = -0.67$).

Changes in Community Composition through Time (2005–2016)

Between 2005 and 2016, we recorded increases in mean vascular species richness (S), averaged across 1-m² quadrats, at the Petrof ($p < 0.001$) and Bear Glacier sites ($p = 0.04$; Figure 6). The site at North Double also showed a marginal, though non-significant increase in mean richness ($p = 0.07$; Figure 6). The remaining four sites showed no change over the last decade. Two-way cluster analysis of the 2005–2016 vascular frequency data showed that aside from changes in species richness, there were few changes in community composition at any of the sites, as portrayed by each site pairing with itself in the final linkage of the dendrogram (Figure 7). When pruned at the 45–55% information level, alpine meadow and fellfield sites (Bear, Skilak, N. Double, S. Double, Wosnesenski) reasonably separated from the dwarf shrub heath and tall herbaceous sites (Petrof, Tuxedni; Figure 7), but did not show measurable within-site changes in composition across the two sampling dates.

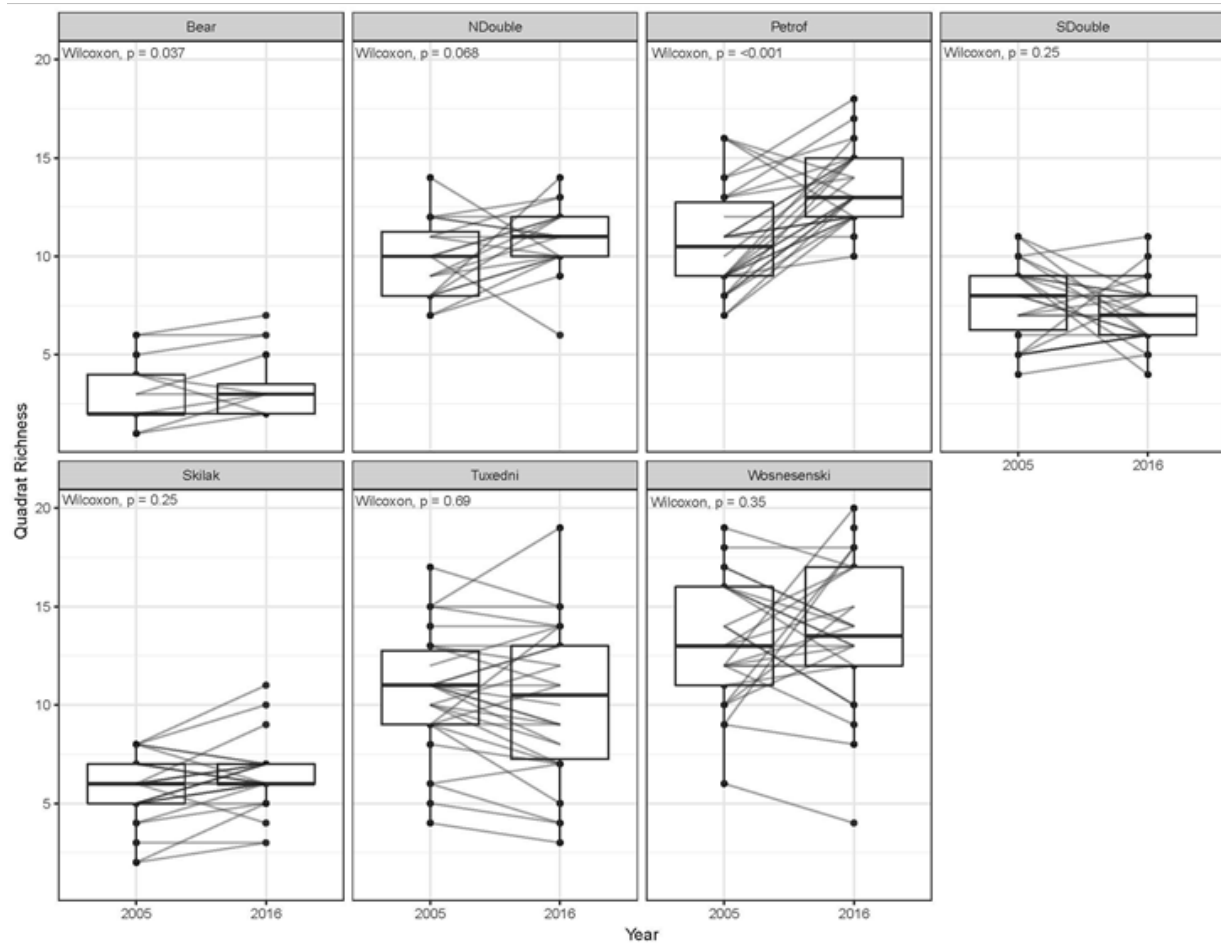


Figure 6. Changes in mean species richness (S) between 2005 and 2016. Species richness values are for individual 1-m² quadrats (n = 20 at Bear and N. Double, n = 30 for all other sites), and gray lines connect data from the same quadrat across two points in time. Wilcoxon sign-rank test significance values are shown for each site.

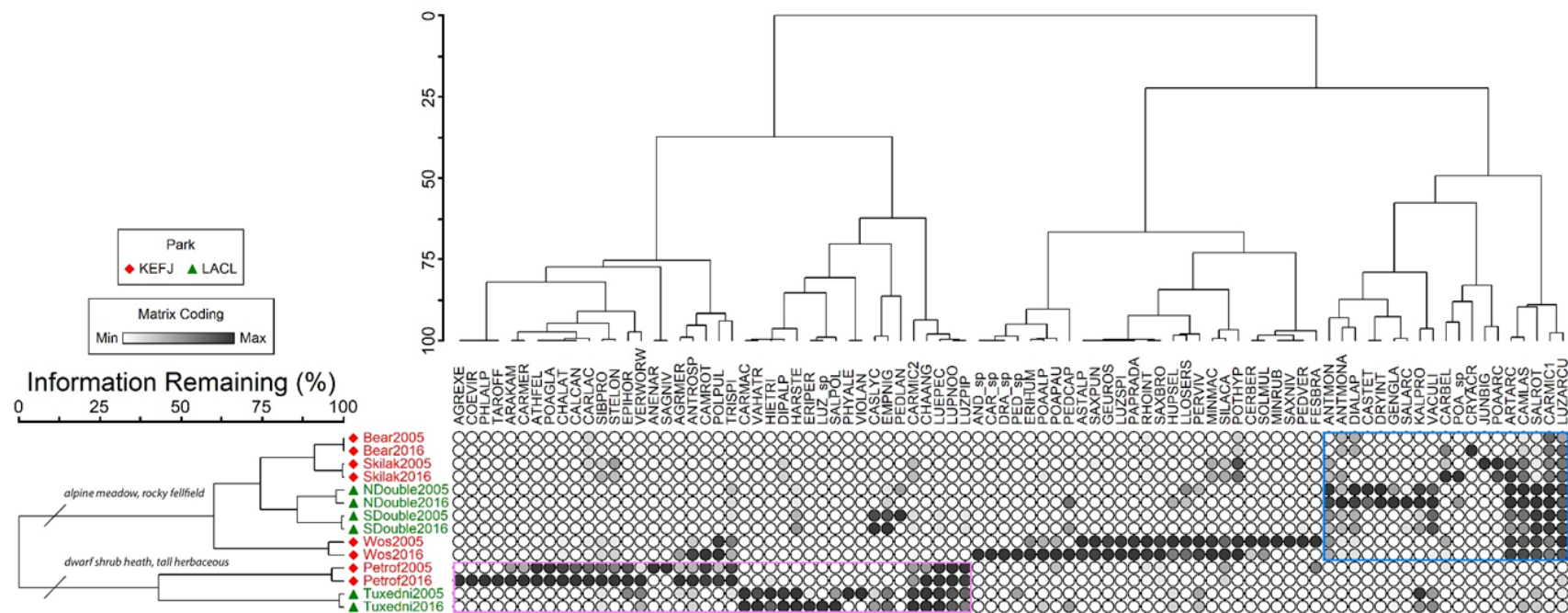


Figure 7. Two-way cluster analysis dendrogram of 2005 and 2016 survey sites and the combined 86 vascular species observed. At the two-cluster site group level, alpine meadow and fellfield sites (Bear, Skilak, N. Double, S. Double, Wosnesenski) reasonably separate from the lower elevation dwarf shrub heath and tall herbaceous sites (Petrof, Tuxedni). Each circle represents relative abundance by column (darker is more abundant). Species codes are a combination of the first three genus and first three species letters (see Table 2 for full names). The purple box highlights the suite of species associated with the lowest elevation sites in KEFJ and LACL, which includes several common species such as *Carex micropoda*, *Chamaenerion angustifolium*, *Luetkia pectinata*, *Lupinus nootkatensis*, and *Luzula piperia*. The blue box highlights frequent widespread species associated with the more alpine sites across both parks, including *Artemisia arctica*, *Campanula lasiocarpa*, *Salix rotundifolia*, *Carex microchaeta*, and *Luzula arcuata* subsp. *unalaschkensis*.

For species that were detected in both years of sampling, differences in estimated frequency ranged between 0% and >100%, but were generally less than 65%. Graminoids, particularly members of the genera *Carex* and *Poa*, showed the greatest variability in frequency between years. Variability in emergence time, lack of identifiable features or inflorescences at the time of sampling, and small (cryptic) individuals may explain why some species were observed in only one year. Differences between species richness (S) and the effective diversity indices (H_e , D_e) indicated that approximately 50–80% of species at each site were common while the remaining species were relatively infrequent (Table 3). Tuxedni, Bear, Petrof and Wosnesenski showed the greatest disparity among species' abundance, whereas the Double Glacier sites and Skilak showed a more even distribution of species (i.e., more species were equally abundant). For sites that showed an increase in mean vascular species richness over time (Petrof, Bear, N. Double; Figure 6), the change appeared to be largely due to an increase in the frequency of grasses, sedges, and forbs in 1-m² quadrats.

At the Petrof Glacier site, located on the Grewingk-Yalik Glacier Complex, the increase in mean species richness was accompanied by 30%–300% increases in several common early-successional forbs (e.g., *Veronica wormsjkoldii*, *Stellaria longipes*, *Arabis kamchatica*) and graminoids (*Agrostis mertensii*, *Luzula arcuata* ssp. *unalaschensis*) that appeared to be well-adapted to well-drained, rocky sites (Figure 7). Photos from 2016 showed an increase in moss cover in many quadrats, which has likely provided a seedbed for newly establishing species. We also recorded a roughly 2-fold increase in *Carex mertensii* (17% to 40%; Table 2), a sedge typically found in lowland and montane areas (FNA 2002, Tande and Lipkin 2003). New species recorded in 2016 included grasses (*Agrostis exarata*, *Phleum alpinum*), an orchid (*Coeloglossum viride*), and the non-native common dandelion, *Taraxacum officinale* (Table 2). We estimated the dandelion population at approximately 50 individuals, concentrated near the top of the meadow. The increase in mean species richness at Petrof, estimated from 1-m² quadrats, was in contrast to the decrease in the total species count at the site (Table 3). Species recorded in 2005, but missing in 2016, included several alpine forbs (*Anemone narcissiflora*, *Cardamine bellidifolia*, *Geum rossii*) and an alpine dwarf shrub (*Diapensia lapponica*).

In 2005, we speculated that Petrof might be transitioning from a community dominated by snowbed species (e.g., *Sibbaldia procumbens*, *Luetkea pectinata*) to one dominated by low- to mid-elevation species (e.g., *Calamagrostis canadensis*, *Carex mertensii*, *Lupinus nootkatensis*), presumably due to late 20th-century warming and a lengthening of the snow-free season (Miller et al. 2006, Cherry et al. 2017). By 2016, *Calamagrostis* had increased only slightly (13% to 17% frequency), and *Luetkea* and *Lupinus* had remained stable at 97%–100% (Table 2). *Carex mertensii* was the only low- to mid-elevation species that showed a measurable increase in abundance through time. The frequency of *Sibbaldia procumbens*, a common snowbed species, increased from 57% to 77%, negating our prediction that snowbed species might be on the decline. However, the loss of several alpine species and the increase in early-successional forbs and graminoids (e.g., *Veronica*, *Stellaria*, *Arabis*, *Agrostis*, *Luzula*) suggest that community composition at this site is indeed changing.

Table 3. Site-level vascular plant diversity as measured from 1-m² quadrat frequency sampling following Miller et al. (2006). As S, H_e, and D_e approach the same number, species begin to be equally abundant across a site, while large differences reflect an increasing number of uncommon species and a decrease in abundant species. Species richness values (S) represent total species counts for each site.

Measurement	Lake Clark National Park and Preserve						Kenai Fjords National Park							
	N. Double 2005	N. Double 2016	S. Double 2005	S. Double 2016	Tuxedni 2005	Tuxedni 2016	Skilak 2005	Skilak 2016	Bear 2005	Bear 2016	Petrof 2005	Petrof 2016	Wosnesenski 2005	Wosnesenski 2016
S ^a	20.000	22.000	23.000	20.000	33.000	30.000	20.000	22.000	10.000	13.000	35.000	32.000	37.000	43.000
E ^b	0.908	0.920	0.865	0.884	0.873	0.892	0.877	0.892	0.822	0.840	0.837	0.882	0.905	0.894
H ^c	2.719	2.843	2.712	2.647	3.051	3.033	2.628	2.756	1.892	2.154	2.977	3.056	3.269	3.364
D ^d	0.924	0.934	0.919	0.915	0.942	0.941	0.913	0.921	0.800	0.844	0.935	0.945	0.955	0.959
H _e ^e	15.170	17.170	15.060	14.110	21.140	20.760	13.850	15.740	6.630	8.620	19.630	21.240	26.290	28.900
D _e ^f	13.190	15.130	12.350	11.820	17.300	17.060	11.440	12.610	4.990	6.390	15.360	18.180	22.030	24.100

^a S = number of species at the site-level

^b E = Evenness = H' / ln(S) = similarity of species frequencies

^c H' = Diversity = - sum (P^{*}ln(Pⁱ)) = Shannon`s diversity index

^d D = Simpson`s diversity index for infinite population = 1 - sum (Pⁱ*Pⁱ) where Pⁱ = importance probability in element *i* (element *i* relativized by row total)

^e H_e = expH' = effective number of species based on Shannon's diversity index

^f D_e = 1/(1-D) = effective number of species based on Simpson's diversity index

Photos of the Petrof site suggest that lupine (*Lupinus nootkatensis*) cover has decreased over time while graminoid cover has increased (Appendix A, Figures A6-2–A6-4). However, frequency data from the 0.25-m² and 1-m² plots showed no measurable change in lupine abundance between 2005 and 2016 (Table 2; Appendix B, Table B4). Lupine, a nitrogen fixer, is another early colonizer in many nutrient-poor sites and can facilitate the establishment of nitrophilous (nitrogen-loving) species in its wake, including many grasses. Future sampling at these sites will include repeat measurements of species cover using point-intercept.

Petrof is the lowest elevation site in our study (650 m), and its proximity to the ice margin could situate it closer to vegetated coastal areas that serve as a source of windborne seeds, including those from dandelions (*Taraxacum officinale*). The site's location could also make it more accessible to animals that could carry seeds onto the site. In 2005 and 2016, mountain goats were present at Petrof. In 2016, we recorded goat grazing on ferns (*Dryopteris* spp.), grasses and sedges (*Poa* spp., *Carex mertensii*), and forbs, including woolly hawkweed (*Hieracium triste*) and dwarf fireweed (*Chamerion latifolium*). Mountain goats have also been using the Skilak and Wosnesenski sites, where we found hair and scat in 2016.

At the Bear Glacier site, a barren, high-elevation site on the north end of the Harding Icefield, our species count increased from nine taxa in 2005 to twelve in 2016. The species-poor community and lack of soil development suggests that a short snow-free season limits plant colonization. Newly recorded species were the alpine forbs, *Artemisia arctica*, *Cardamine bellidifolia*, and a fern, *Cryptogramma acrostichoides*. The abundance of the previously recorded taxa remained stable, with the exception of *Campanula lasiocarpa*, which showed a 2-fold increase, and *Luzula arcuata* ssp. *unalaschensis*, which showed a 40% increase between 2005 and 2016 (Table 2, Figure 6).

At the North Double Glacier site, located north of the Drift River, we found a marginal, non-significant increase in mean species richness, likely due to the addition of several new taxa (e.g., *Poa* spp., *Sibbaldia procumbens*, *Huperzia selago*). We also found 2- to >10-fold increases in several other species (e.g., *Anthoxanthum monticola* ssp. *alpinum* = *Hierochloa alpina*; *Gentiana glauca*; *Empetrum nigrum*; *Salix arctica*; Table 2, Figure 6 and Figure 7). The increase in arctic willow (*Salix arctica*) at this site is noteworthy and followed the 2009 eruption of Mount Redoubt, which left a deposit of ash and fine tephra. Members of the genus *Salix* are known to have ectomycorrhizal (ECM) fungal symbionts that support their colonization or re-establishment in nutrient-poor sites, including young volcanic deposits (e.g., Wood and del Moral 1988, Nara 2006). The presence of ECM fungi can enhance the survival and growth of the willow host in these environments, and can facilitate the establishment of a suite of other, secondary species.

Vascular species richness has remained relatively stable over the first ten years of monitoring at these sites in LACL and KEFJ, with most sites showing a gain or loss of only two to three taxa. Vascular species turnover was highest at lower-elevation sites, indicating that there may have been an influx of new species, and a loss of previously recorded species; i.e., the three lowest-elevation sites (Petrof, Tuxedni, South Double Glacier) recorded net species losses, while the remaining sites recorded species gains, in terms of total vascular species counts (Table 4). Petrof, however, showed an

increase in mean species richness at the quadrat scale, suggesting that many species may be increasing in abundance (i.e., evenness [E]), even as total species counts have declined (Figure 6).

Studies of community change in other mountainous regions have shown increasing species richness at alpine sites, and an over-representation of more warm-adapted species, attributed primarily to a shift in species ranges to higher elevations (Lamprecht et al. 2018). Studies from the European Alps have suggested that changes in species composition should appear first at the alpine-nival ecotone, defined by the permanent snowline and the boundary between snow-tolerant (e.g., snowbed) species and alpine species that are less tolerant of snow cover (Gottfried et al. 2011, Lamprecht et al. 2018). Here, we saw high species turnover at Petrof, due in large part to the establishment of a new suite of grasses and forbs in well-drained areas, and the loss of several alpine species that had been present in low abundance in 2005. Species that were abundant in 2005 remained so in 2016. Future sampling should capture additional changes in composition at these sites, likely tied to changes in snow depth and snow season length.

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Appendix A. Supplemental Site Information

LACL – Double Glacier (North)

Initial Survey Date: 28 July 2005.

1st Resurvey Date: 23 July 2016.

LACL Digital Geologic Map (GRI 2010a): Undifferentiated bedrock (volcanic and plutonic igneous).

LACL Landcover (Golden and Spencer 1998): Gravel and Sparsely Vegetated.

LACL Map Ecotype (Wells et al. 2013): Alpine Rocky Barrens and Shrublands.

Table A1. Double Glacier (North) nunatak monitoring coordinates (T3 data not shown).

Site	Latitude (NAD83)	Longitude (NAD83)	Elevation (m)
T1-0m (no Tag #)	60.71293443	-152.6581403	1115.9
T1-30m	60.71267006	-152.6580911	1123.9
T2-0m (Tag #5)	60.71293257	-152.6579901	1116.6
T2-30m	60.71267252	-152.6580418	1122.0

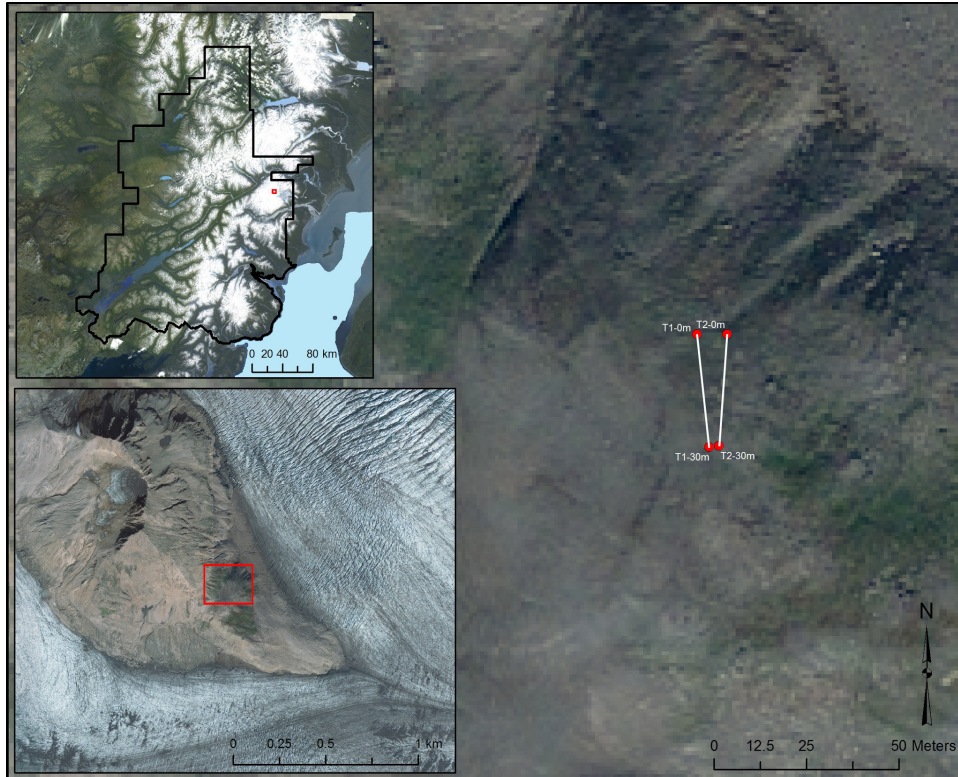


Figure A1-1. Double Glacier (North) nunatak monitoring site, LACL.

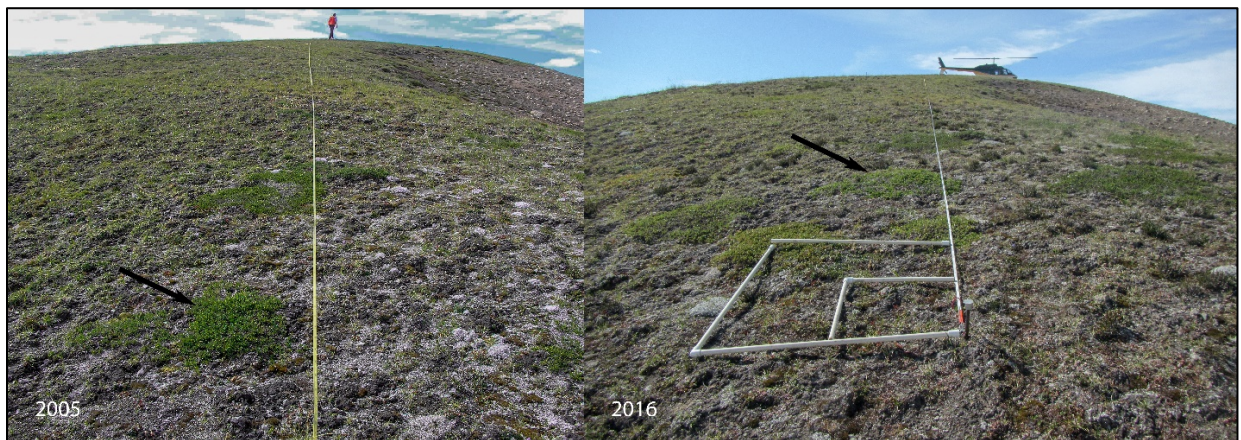


Figure A1-2. Paired photo of Transect 1 looking north in 2005 and 2016, Double Glacier (North) nunatak monitoring site, LACL. Black arrows denote reference point for same *Vaccinium uliginosum* plant.

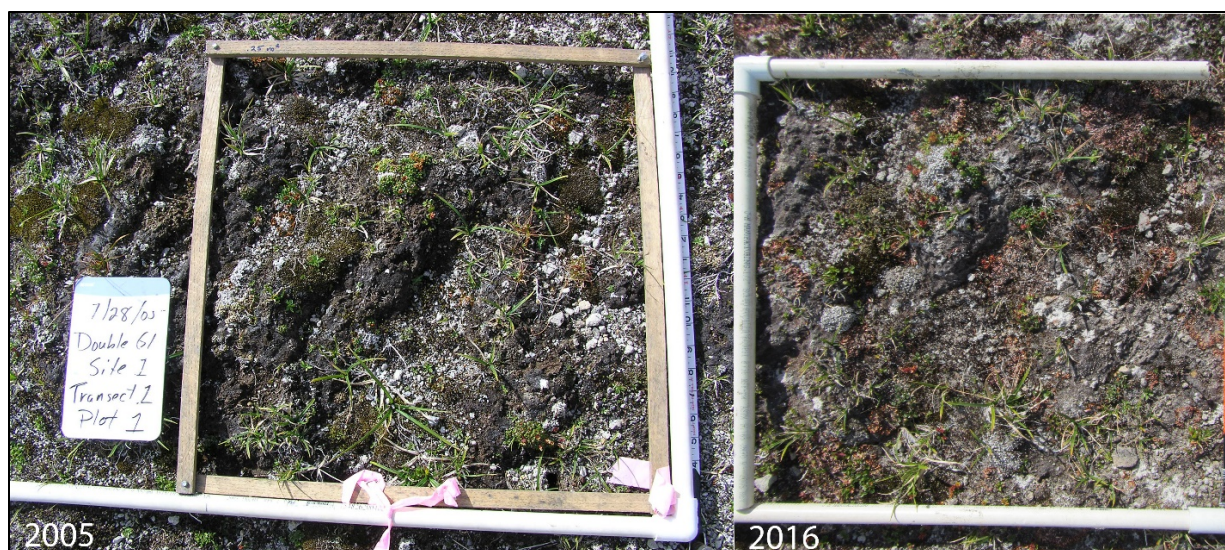


Figure A1-3. Photo pair of 0.25-m² quadrat at 0-m on Transect 1, for 2005 and 2016, Double Glacier (North) nunatak monitoring site, LACL. *Luzula* and cryptogamic crust remain little changed as the dominant cover taxa in this quadrat.

LACL – Double Glacier (South)

Initial Survey Date: 28 July 2005.

1st Resurvey Date: 23 July 2016.

LACL Digital Geologic Map (GRI 2010a): Glacially scoured bedrock (volcanic and plutonic igneous).

LACL Landcover (Golden and Spencer 1998): Gravel and Sparsely Vegetated.

LACL Map Ecotype (Wells et al. 2013): Maritime Upland Rocky Barrens, Shrublands, and Forests.

Table A2. Double Glacier (South) nunatak monitoring coordinates.

Site	Latitude (NAD83)	Longitude (NAD83)	Elevation (m)
T1-0m (Tag #6)	60.68828508	-152.5862041	925.6
T1-30m	60.68828655	-152.5856618	930.5
T2-0m (Tag #7)	60.68834123	-152.5858758	927.6
T2-30m	60.68850659	-152.5854399	931.1
T3-0m (Tag #8)	60.68868533	-152.5852391	932.8
T3-30m	60.68856531	-152.5847637	938.5

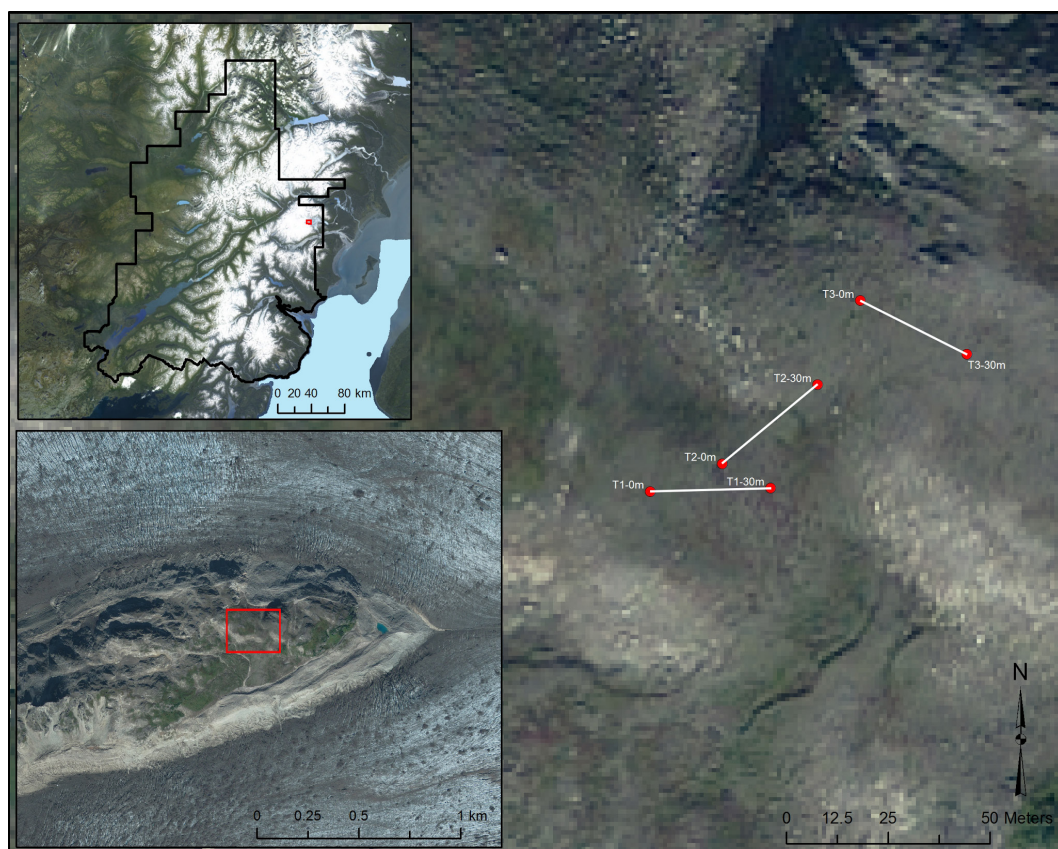


Figure A2-1. Double Glacier (South) nunatak monitoring site, LACL.



Figure A2-2. Paired photo of Transect 2 looking southwest, Double Glacier (South) nunatak monitoring site, LACL.



Figure A2-3. Photo pair of 0.25-m² quadrat at 0-m on Transect 1, for 2005 and 2016, Double Glacier (South) nunatak monitoring site, LACL. *Luzula* is the dominant cover in this quadrat, with some moderate dieback observed in 2016. Greenup may have been delayed by late-melting snow in 2016.

LACL – Tuxedni Glacier

Initial Survey Date: 27 July 2005.

1st Resurvey Date: 24 July 2016.

LACL Digital Geologic Map (GRI 2010a): Undifferentiated bedrock (volcanic and plutonic igneous).

LACL Landcover (Golden and Spencer 1998): Gravel and Sparsely Vegetated.

LACL Map Ecotype (Wells et al. 2013): Alpine Rocky Barrens and Shrublands.

Table A3. Tuxedni Glacier nunatak monitoring coordinates.

Site	Latitude (NAD83)	Longitude (NAD83)	Elevation (m)
T1-0m (Tag #1)	60.15397929	-153.1296715	764.7
T1-30m	60.15392495	-153.1301044	783.6
T2-0m (Tag #2)	60.15413341	-153.1296455	763.2
T2-30m	60.15426315	-153.1292836	746.8
T3-0m (Tag #3)	60.15358644	-153.1280502	744.1
T3-30m	60.15350255	-153.128545	754.7

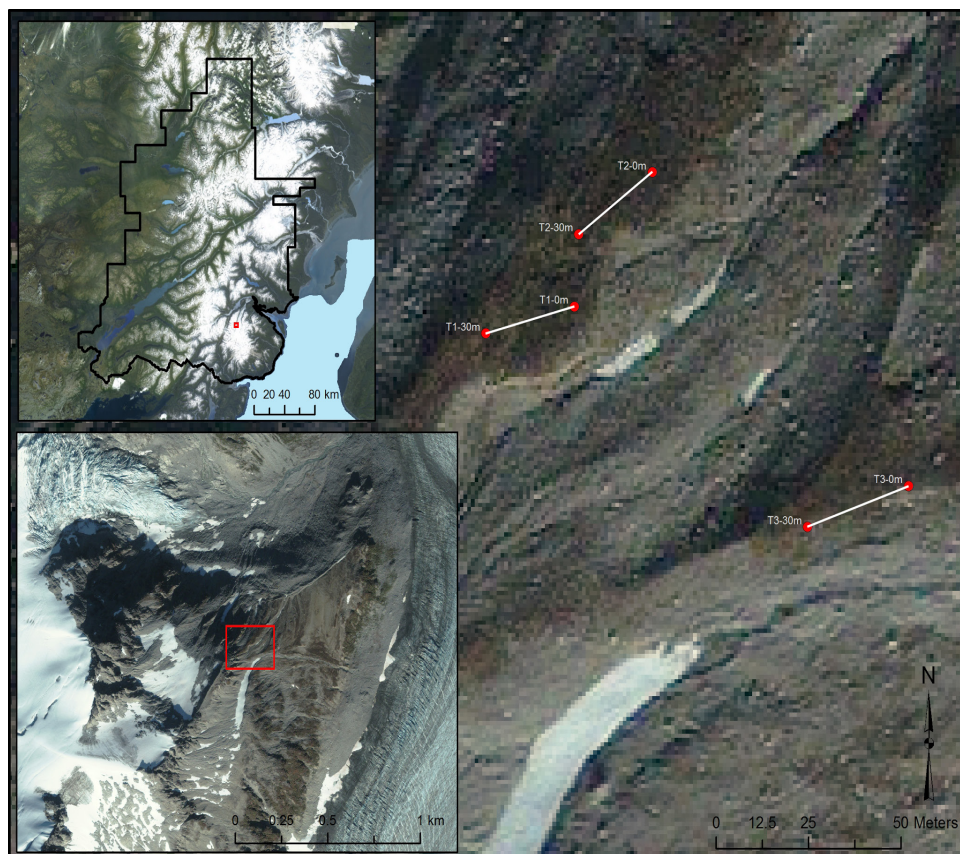


Figure A3-1. Tuxedni Glacier periglacial monitoring site, LACL.



Figure A3-2. Paired photo of Transect 1 looking northeast in 2005 and 2016, Tuxedni Glacier periglacial monitoring site, LACL.

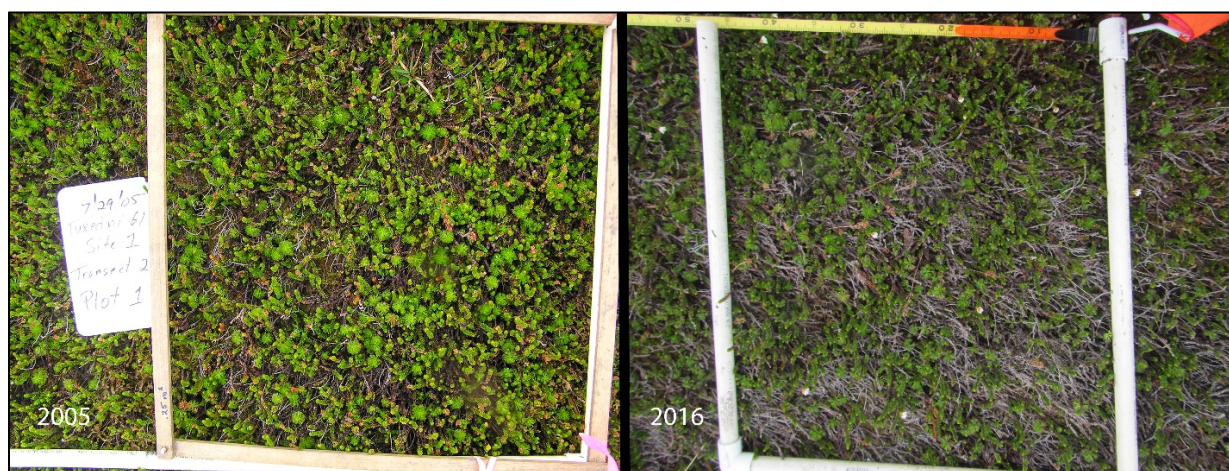


Figure A3-3. Paired photo of 0.25-m² quadrat at 0-m on Transect 2, in 2005 and 2016, Tuxedni Glacier periglacial monitoring site, LACL. *Harrimanella stellariana* is the dominant groundcover in this quadrat, with little to no dieback observed in 2005 and moderate dieback observed in 2016. Greenup may have been delayed by late-melting snow in 2016.

KEFJ – Skilak Glacier

Initial Survey Date: 6 August 2005.

1st Resurvey Date: 17 July 2016.

KEFJ Digital Geologic Map (GRI 2010b): Valdez Group, metasedimentary rocks, undivided.

KEFJ Ecological System (Boggs et al. 2008): High Alpine Herbaceous.

KEFJ Map Ecotype (Wells et al. 2014): Alpine Barrens and Partially Vegetated.

Table A4-1. Skilak Glacier nunatak monitoring plot coordinates (Miller 2005).

Site	Latitude (NAD83)	Longitude (NAD83)	Elevation (m)
T1-0m (Tag #11)	60.14485359	-149.8954014	1422.1
T1-30m	60.14459497	-149.895563	1421.9
T2-0m (Tag #12)	60.14438693	-149.8956538	1419.8
T2-30m	60.14411551	-149.8956235	1425.4
T3-0m (Tag #13)	60.14477522	-149.8951591	1418.0
T3-30m	60.14454442	-149.8954472	1420.6

Table A4-2. Skilak Glacier nunatak monitoring plot coordinates (Miller 2016).

Site	Latitude (WGS84)	Longitude (WGS84)	Elevation (m)
T1-0m	60.144532	-149.895722	1420.2
T1-30m	60.144802	-149.895697	1417.2
T2-0m	60.144529	-149.895482	1419.8
T2-30m	60.144798	-149.895439	1420.5
T3-0m	60.144532	-149.895198	1417.7
T3-30m	60.144803	-149.895186	1420.0

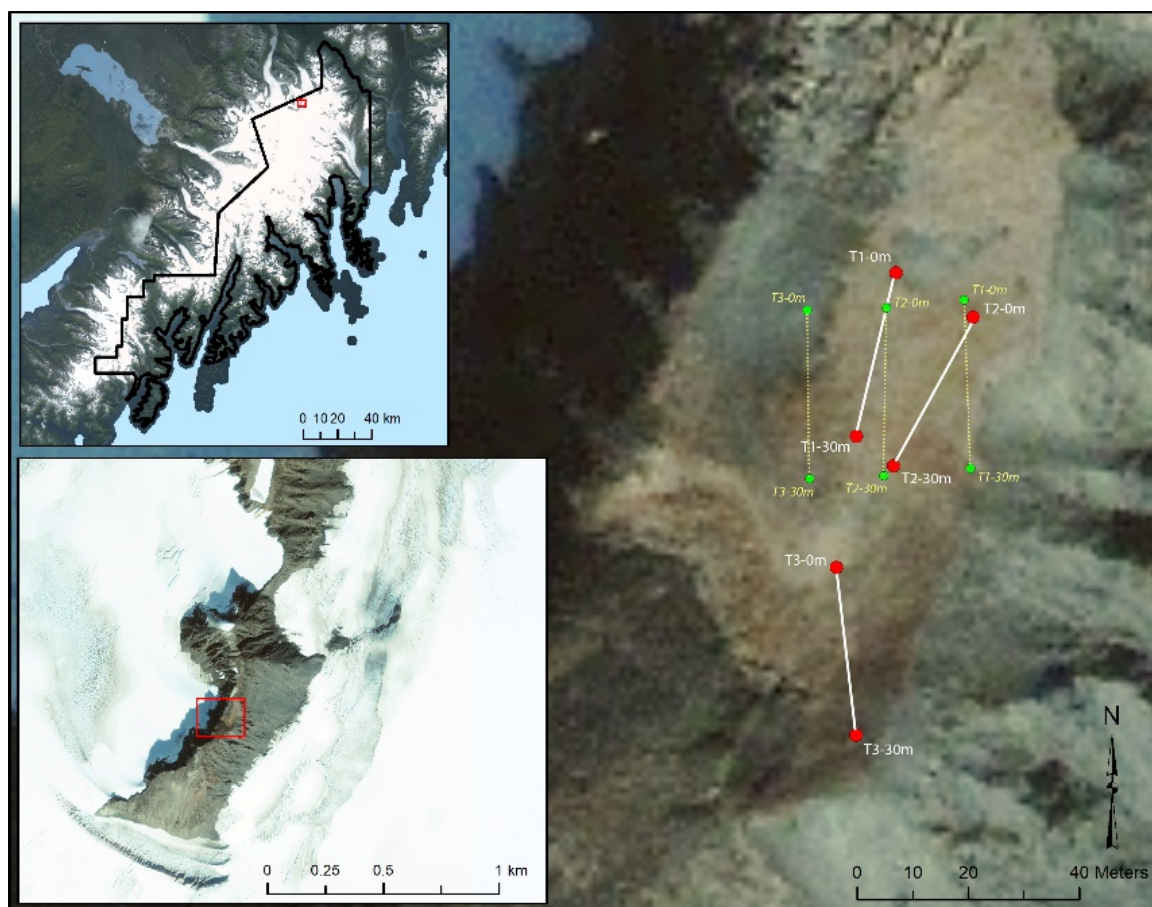


Figure A4-1. Skilak Glacier nunatak monitoring site, KEFJ. Red points with white connecting lines are Miller (2005) survey transects installed in 2005. Green points with yellow dotted lines are Miller (2010) survey transects installed in 2016.



Figure A4-2. Paired photo of Transect 1 looking south in 2005 and 2016, Skilak Glacier nunatak monitoring site, KEFJ.

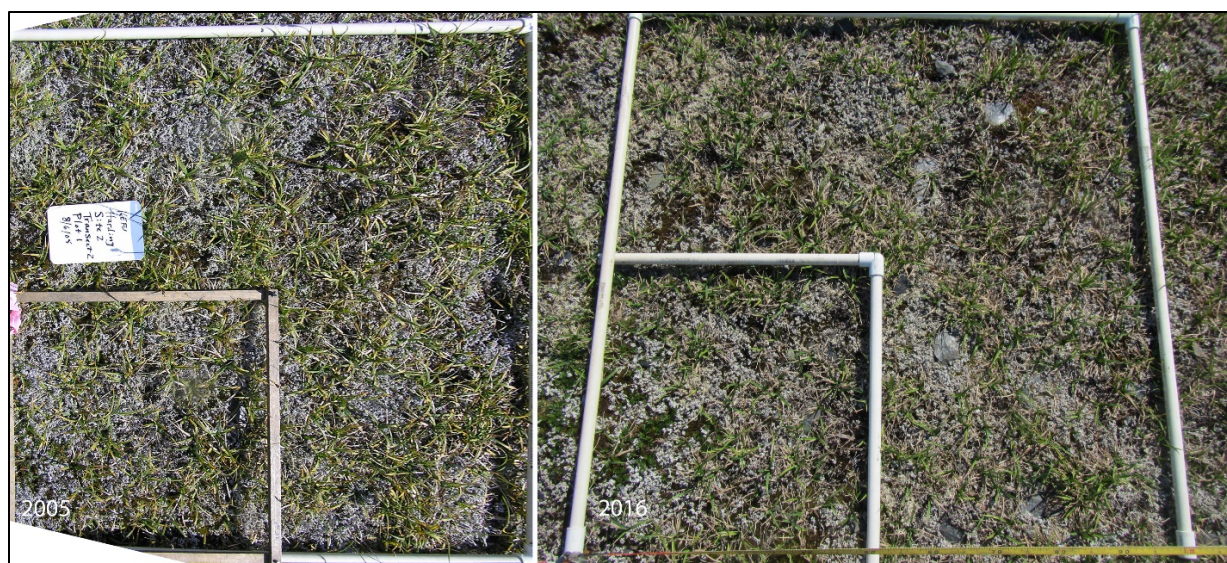


Figure A4-3. Paired photo showing 1-m² quadrat at 0-m of Transect 2, in 2005 and 2016, Skilak Glacier nunatak monitoring site, KEFJ. *Luzula* and the lichen *Stereocaulon* are the dominant cover elements in both survey years.

KEFJ – Bear Glacier

Initial Survey Date: 6 August 2005.

1st Resurvey Date: 17 July 2016.

KEFJ Digital Geologic Map (GRI 2010b): Valdez Group, metasedimentary rocks, undivided.

KEFJ Ecological System (Boggs et al. 2008): High Alpine Herbaceous.

KEFJ Map Ecotype (Wells et al. 2014): Alpine Barrens and Partially Vegetated.

Table A5. Bear Glacier nunatak monitoring coordinates.

Site	Latitude (NAD83)	Longitude (NAD83)	Elevation (m)
T1-0m (Tag #9)	60.07793442	-149.7830668	1356.1
T1-30m	60.07771779	-149.7827649	1358.5
T2-0m (Tag #10)	60.07779986	-149.7826884	1355.6
T2-30m	60.07753984	-149.7827322	1359.5

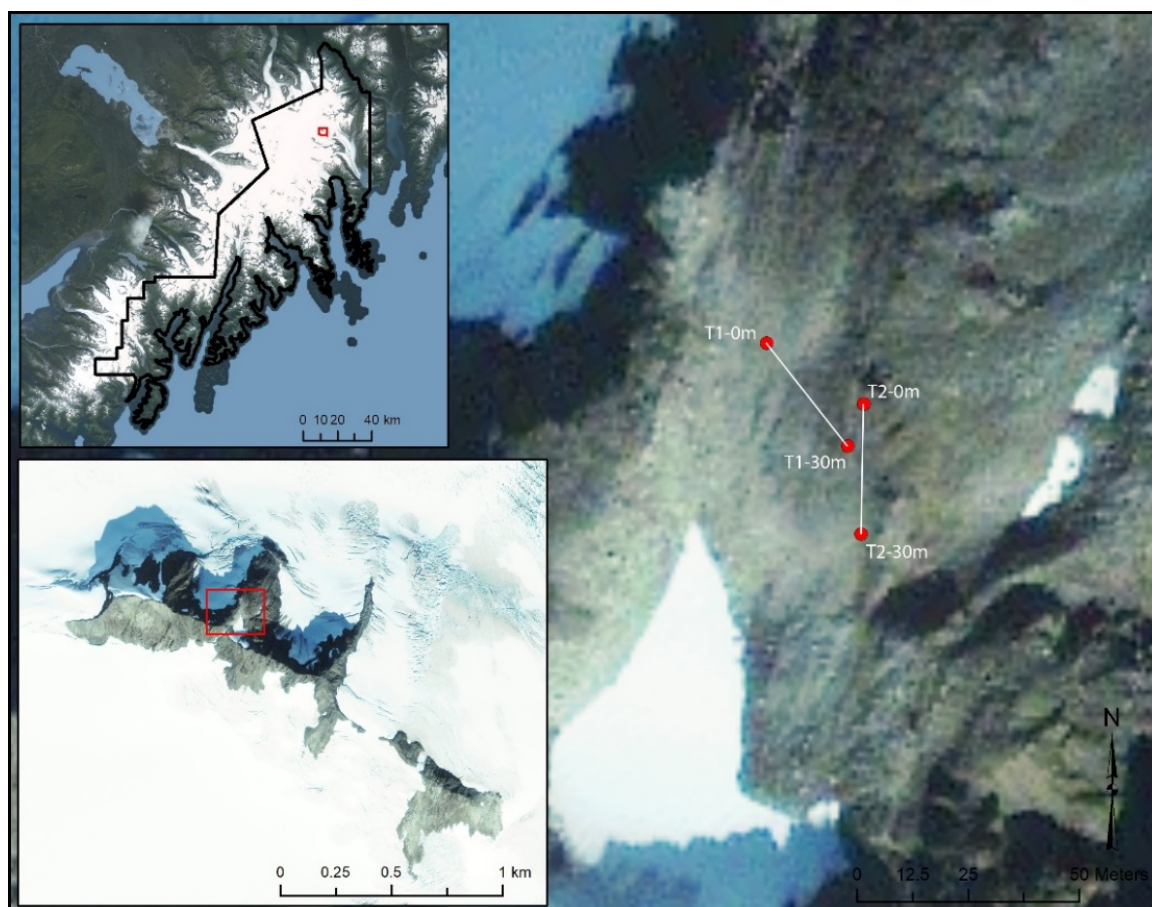


Figure A5-1. Bear Glacier nunatak monitoring site, KEFJ.

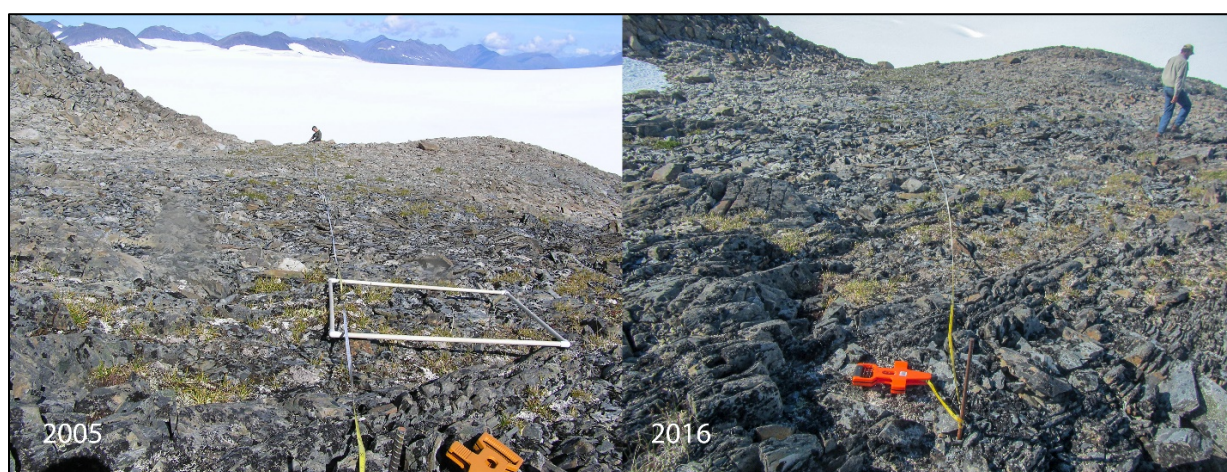


Figure A5-2. Paired photo of Transect 1 looking southeast in 2005 and 2016, Bear nunatak monitoring site, KEFJ.

KEFJ – Petrof Glacier

Initial Survey Date: 9 August 2005.

1st Resurvey Date: 31 August 2016.

KEFJ Digital Geologic Map (GRI 2010b): McHugh Complex, undivided (metasedimentary).

KEFJ Ecological System (Boggs et al. 2008): High Alpine Herbaceous.

KEFJ Map Ecotype (Wells et al. 2014): Alpine Barrens and Partially Vegetated.

Table A6. Petrof Glacier nunatak monitoring coordinates.

Site	Latitude (NAD83)	Longitude (NAD83)	Elevation (m)
T1-0m (Tag #16)	59.44449179	-150.9454638	643.7
T1-30m	59.44443518	-150.9459408	648.2
T2-0m (Tag #17)	59.44398856	-150.9461531	637.1
T2-30m	59.44402373	-150.9466165	647.7
T3-0m (Tag #18)	59.44418892	-150.9457651	634.7
T3-30m	59.44403254	-150.9459467	633.5

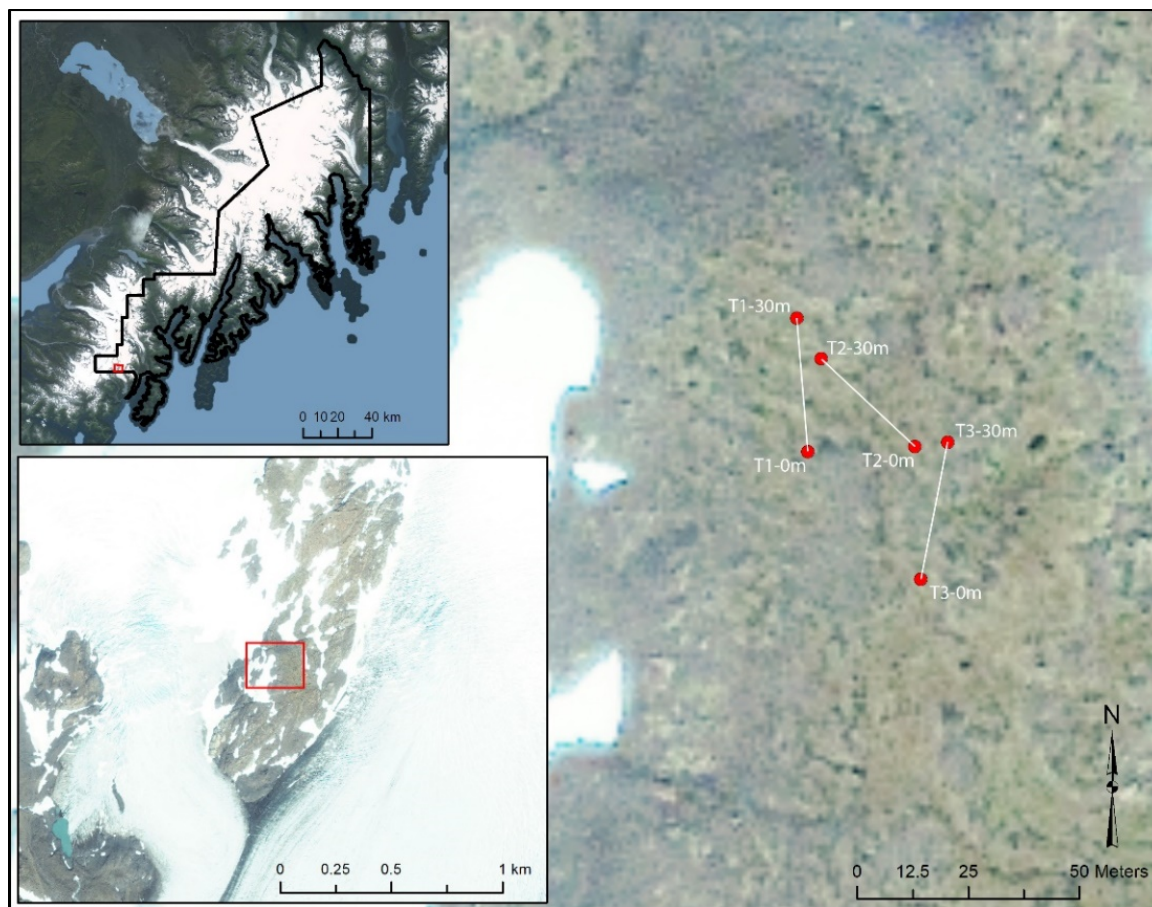


Figure A6-1. Petrof Glacier nunatak monitoring site, KEFJ.

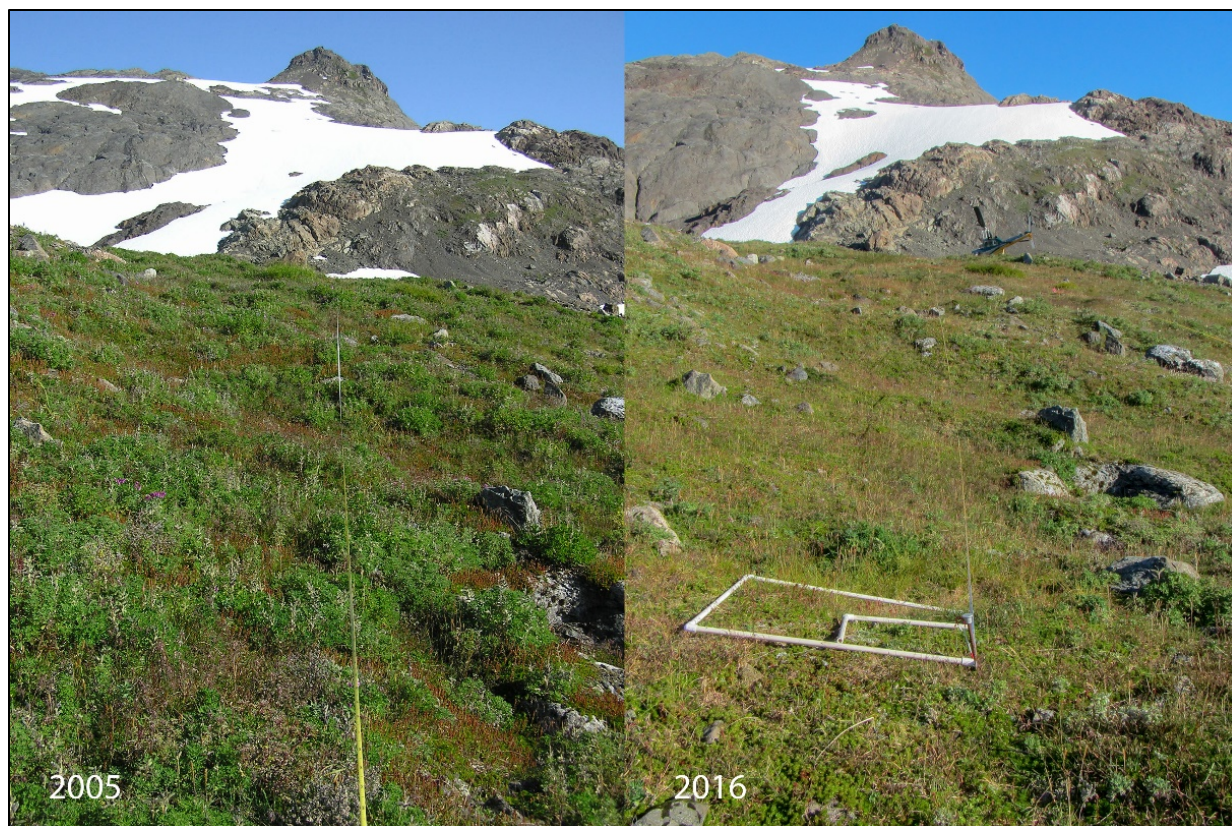


Figure A6-2. Paired photos showing Transect 1 in 2005 and 2016, Petrof Glacier nunatak monitoring site. Over the ten year survey period there has been a conspicuous transition from *Lupinus nootkatensis* to *Lutkea pectinata* cover across the hillslope. The later sampling date in 2016 may have facilitated the identification of late-flowering graminoids.



Figure A6-3. Photo pair of 0.25-m² quadrat at 0-m on Transect 1, for 2005 and 2016, Petrof Glacier nunatak monitoring site, KEFJ. Over the ten-year survey period the dominant herbaceous cover in this quadrat has transitioned from *Lupinus nootkatensis* to *Lutkea pectinata*.



Figure A6-4. Photo pair of 0.25-m² quadrat at 24-m on Transect 1, for 2005 and 2016, Petrof Glacier nunatak monitoring site, KEFJ. Over the ten-year survey period the dominant cover in this quadrat has transitioned from *Lupinus nootkatensis* to *Carex* spp., *Lutkea pectinata*, and moss.

KEFJ – Wosnesenski Glacier

Initial Survey Date: 8 August 2005.

1st Resurvey Date: 31 August 2016.

KEFJ Digital Geologic Map (GRI 2010b): McHugh Complex, undivided (metasedimentary).

KEFJ Ecological System (Boggs et al. 2008): High Alpine Herbaceous.

KEFJ Map Ecotype (Wells et al. 2014): Alpine Barrens and Partially Vegetated.

Table A7. Wosnesenski Glacier nunatak monitoring coordinates.

Site	Latitude (NAD83)	Longitude (NAD83)	Elevation (m)
T1-0m (Tag #16)	59.44449179	-150.9454638	1030.9
T1-30m	59.44443518	-150.9459408	1045.1
T2-0m (Tag #17)	59.44398856	-150.9461531	1070.6
T2-30m	59.44402373	-150.9466165	1085.7
T3-0m (Tag #18)	59.44418892	-150.9457651	1051.9
T3-30m	59.44403254	-150.9459467	1063.3

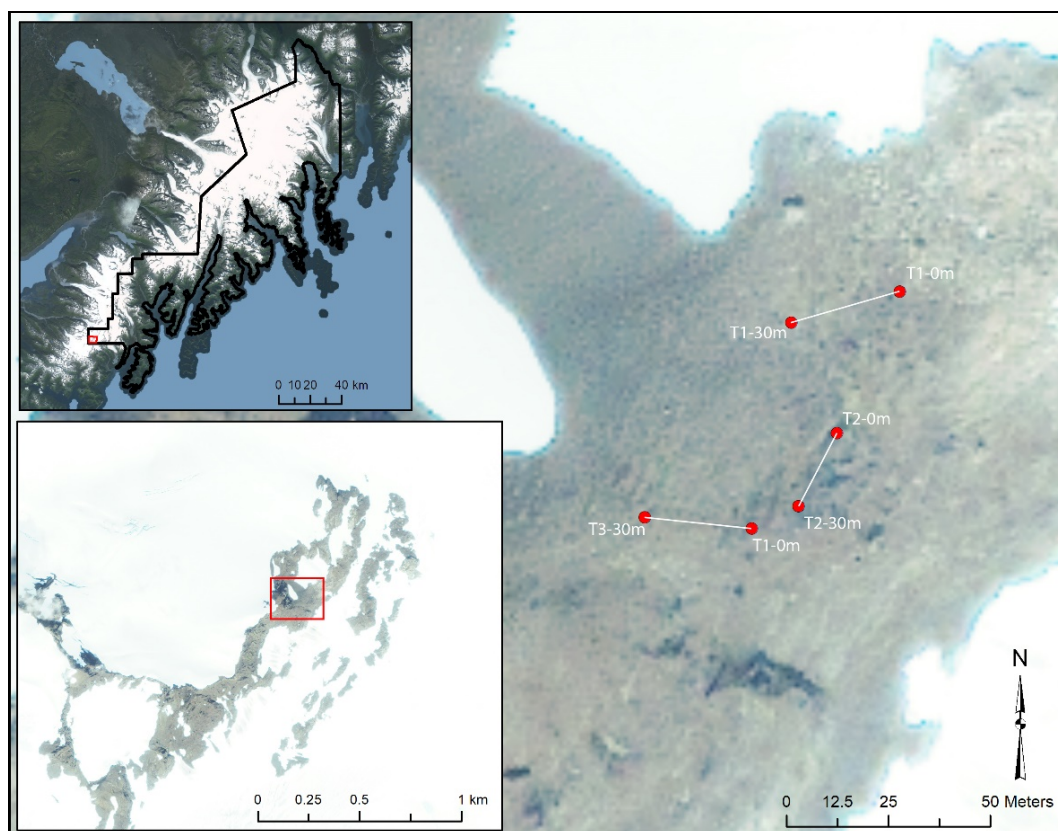


Figure A7-1. Vosnesenski Glacier nunatak monitoring site, KEFJ.



Figure A7-2. Paired photo of Transect 1 looking west in 2005 and 2016, Wosnesenski Glacier nunatak monitoring site, KEFJ.

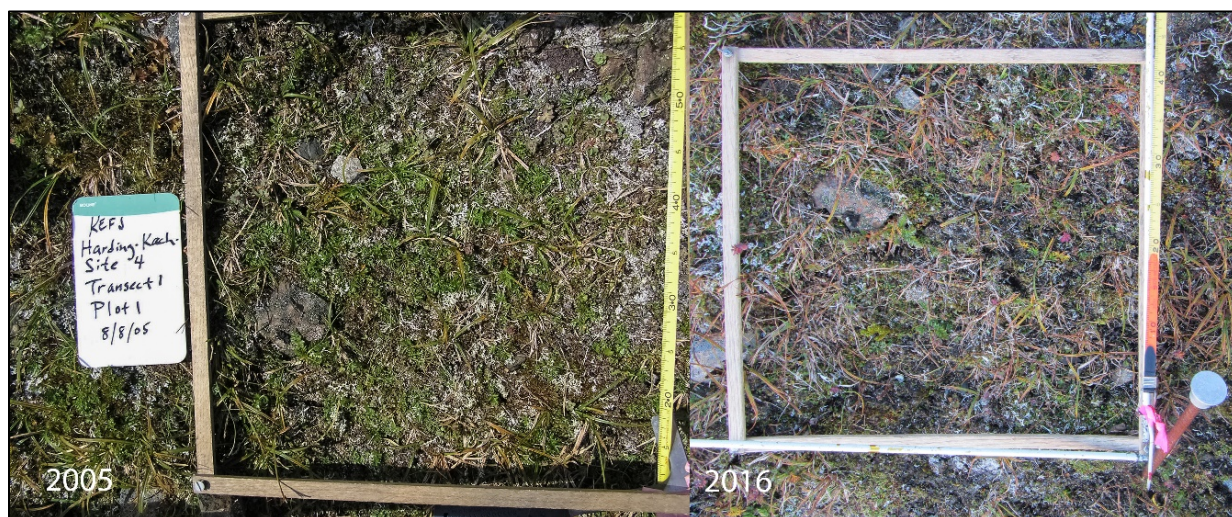


Figure A7-3. Photo pair of 0.25-m² quadrat at 0-m on Transect 1, for 2005 and 2016, Wosnesenski Glacier nunatak monitoring site, KEFJ. *Luzula* and *Cladonia* remain little changed as the dominant cover taxa in this quadrat for both survey years.

Appendix B. Supplementary Tables

Table B1. Percent frequency of nonvascular species in 0.25-m² quadrats in Lake Clark National Park and Preserve and Kenai Fjords National Park (2016 data only). Methods follow Miller et al. (2010), with nonvascular frequency recorded in three quadrats per transect (n = 9 quadrats per plot). Due to time constraints, we were unable to collect nonvascular data for the Bear Glacier site. A dash (–) indicates no sample.

Category	Species Name	Lake Clark National Park and Preserve			Kenai Fjords National Park		
		N. Double	S. Double	Tuxedni	Skilak	Petrof	Wosnesenski
Mosses	<i>Andreaea rupestris</i>	–	–	–	11.1	11.1	66.7
	<i>Aulacomnium turgidum</i>	–	–	–	11.1	–	–
	<i>Bartramia ithyphylla</i>	–	–	–	–	–	50.0
	<i>Brachythecium</i> sp.	–	–	–	–	–	16.7
	<i>Brachythecium erythrorrhizon</i> var. <i>erythrorrhizon</i>	–	–	–	–	100.0	33.3
	<i>Bucklandiella heterosticha</i>	77.8	33.3	–	–	–	16.7
	<i>Conostomum tetragonum</i>	11.1	11.1	11.1	–	–	33.3
	<i>Dicranum acutifolium</i>	–	–	–	66.7	–	–
	<i>Dicranoweisia crispula</i>	–	–	–	11.1	11.1	50.0
	<i>Dicranum scoparium</i>	–	88.9	77.8	–	–	16.7
	<i>Hylocomiastrum pyrenaicum</i>	–	–	–	–	–	83.3
	<i>Hylocomium splendens</i>	–	–	–	22.2	–	16.7
	<i>Hypnum plicatulum</i>	–	–	–	55.6	–	33.3
	<i>Kiaeria starkei</i>	33.3	–	–	–	–	–
	<i>Niphotrichum canescens</i> subsp. <i>canescens</i>	–	–	–	77.8	–	83.3
	<i>Niphotrichum ericoides</i>	–	22.2	44.4	–	55.6	16.7

Table B1 (continued). Percent frequency of nonvascular species in 0.25-m² quadrats in Lake Clark National Park and Preserve and Kenai Fjords National Park (2016 data only). Methods follow Miller et al. (2010), with nonvascular frequency recorded in three quadrats per transect (n = 9 quadrats per plot). Due to time constraints, we were unable to collect nonvascular data for the Bear Glacier site. A dash (–) indicates no sample.

Category	Species Name	Lake Clark National Park and Preserve			Kenai Fjords National Park		
		N. Double	S. Double	Tuxedni	Skilak	Petrof	Wosnesenski
Mosses (continued)	<i>Oligotrichum hercynicum</i>	–	11.1	–	–	–	–
	<i>Paraleucobryum enerve</i>	–	–	–	–	–	66.7
	<i>Pleurozium schreberi</i>	–	–	–	11.1	–	83.3
	<i>Pogonatum urnigerum</i>	–	–	–	–	33.3	16.7
	<i>Pohlia cruda</i>	33.3	–	–	–	–	–
	<i>Pohlia crudoides</i>	–	–	–	22.2	–	–
	<i>Pohlia nutans</i>	–	–	11.1	11.1	33.3	16.7
	<i>Polytrichastrum alpinum</i> var. <i>alpinum</i>	–	–	11.1	–	11.1	–
	<i>Polytrichum hyperboreum</i>	22.2	–	–	100.0	–	–
	<i>Polytrichum juniperinum</i>	–	44.4	22.2	–	–	50.0
	<i>Polytrichum piliferum</i>	88.9	77.8	33.3	–	11.1	33.3
	<i>Ptychostomum</i> sp.	–	–	–	11.1	–	–
	<i>Ptychostomum creberrimum</i>	–	–	–	–	–	16.7
	<i>Racomitrium lanuginosum</i>	100.0	–	–	22.2	–	–
	<i>Rhizomnium nudum</i>	–	–	11.1	–	–	–
	<i>Rhytidiopsis robusta</i>	–	–	11.1	–	–	–
	<i>Rhytidiadelphus squarrosus</i>	–	–	–	–	22.2	–
	<i>Sanionia uncinata</i>	–	–	–	–	44.4	33.3

Table B1 (continued). Percent frequency of nonvascular species in 0.25-m² quadrats in Lake Clark National Park and Preserve and Kenai Fjords National Park (2016 data only). Methods follow Miller et al. (2010), with nonvascular frequency recorded in three quadrats per transect (n = 9 quadrats per plot). Due to time constraints, we were unable to collect nonvascular data for the Bear Glacier site. A dash (–) indicates no sample.

Category	Species Name	Lake Clark National Park and Preserve			Kenai Fjords National Park		
		N. Double	S. Double	Tuxedni	Skilak	Petrof	Wosnesenski
Mosses (continued)	<i>Sciuro-hypnum oedipodium</i>	–	–	33.3	–	–	–
	<i>Timmia austriaca</i>	–	–	–	–	–	66.7
Liverworts	<i>Anastrophyllum</i> sp.	–	–	11.1	–	–	–
	<i>Anthelia juratzkana</i>	66.7	88.9	11.1	–	–	33.3
	<i>Barbilophozia lycopodioides</i>	–	–	–	–	–	16.7
	<i>Barbilophozia sudetica</i>	–	77.8	22.2	11.1	–	16.7
	<i>Cephalozia bicuspidata</i>	–	33.3	–	–	–	–
	<i>Diplophyllum taxifolium</i>	–	–	44.4	–	–	50.0
	<i>Gymnomitrium corallioides</i>	66.7	33.3	11.1	–	–	–
	<i>Lophozia</i> sp.	–	–	–	–	–	33.3
	<i>Lophozia wenzelii</i>	100.0	–	–	–	–	–
	<i>Macrodiplphyllum imbricatum</i>	–	–	–	–	–	33.3
	<i>Marsupella</i> sp.	–	11.1	–	–	–	–
	<i>Neoorthocaulis floerkei</i>	–	–	22.22 (2)	–	–	–
	<i>Schistochilopsis incisa</i> var. <i>incisa</i>	–	–	–	–	–	16.7
	<i>Sphenolobus minutus</i>	11.1	–	–	–	–	–

Table B1 (continued). Percent frequency of nonvascular species in 0.25-m² quadrats in Lake Clark National Park and Preserve and Kenai Fjords National Park (2016 data only). Methods follow Miller et al. (2010), with nonvascular frequency recorded in three quadrats per transect (n = 9 quadrats per plot). Due to time constraints, we were unable to collect nonvascular data for the Bear Glacier site. A dash (–) indicates no sample.

Category	Species Name	Lake Clark National Park and Preserve			Kenai Fjords National Park		
		N. Double	S. Double	Tuxedni	Skilak	Petrof	Wosnesenski
Lichens	<i>Cetraria ericetorum</i> subsp. <i>reticulata</i>	11.1	–	–	–	–	–
	<i>Cetraria islandica</i> subsp. <i>crispiformis</i>	100.0	11.1	–	77.8	–	83.3
	<i>Cetraria islandica</i> subsp. <i>islandica</i>	–	–	77.8	–	–	–
	<i>Cladonia amaurocraea</i>	–	–	–	11.1	–	–
	<i>Cladonia arbuscula</i>	44.4	11.1	11.1	88.9	–	66.7
	<i>Cladonia bellidiflora</i>	–	–	11.1	11.1	–	16.7
	<i>Cladonia borealis</i>	66.7	11.1	–	22.2	–	66.7
	<i>Cladonia gracilis</i>	55.6	–	–	88.9	–	83.3
	<i>Cladonia kanewskii</i>	44.4	–	11.1	–	–	–
	<i>Cladonia phyllophora</i>	–	–	–	–	–	33.3
	<i>Cladonia pyxidata</i>	11.1	–	–	–	–	16.7
	<i>Cladonia rangiferina</i>	–	–	–	55.6	–	–
	<i>Cladonia uncialis</i>	–	–	–	–	–	16.7
	<i>Dactylina ramulosa</i>	–	–	–	11.1	–	–
	<i>Leptogium lichenoides</i>	–	–	–	–	–	16.7
	<i>Lobaria linita</i>	11.1	–	–	44.4	–	83.3
	<i>Melanelia hepaticum</i>	–	–	–	11.1	–	–
	<i>Nephromopsis cucullata</i>	–	–	–	22.2	–	–

Table B1 (continued). Percent frequency of nonvascular species in 0.25-m² quadrats in Lake Clark National Park and Preserve and Kenai Fjords National Park (2016 data only). Methods follow Miller et al. (2010), with nonvascular frequency recorded in three quadrats per transect (n = 9 quadrats per plot). Due to time constraints, we were unable to collect nonvascular data for the Bear Glacier site. A dash (–) indicates no sample.

Category	Species Name	Lake Clark National Park and Preserve			Kenai Fjords National Park		
		N. Double	S. Double	Tuxedni	Skilak	Petrof	Wosnesenski
Lichens (continued)	<i>Peltigera aphthosa</i>	–	–	–	11.1	–	83.3
	<i>Peltigera didactyla</i>	11.1	–	–	–	–	–
	<i>Peltigera extenuata</i>	–	–	–	11.1	–	–
	<i>Peltigera malacea</i>	22.2	–	–	44.4	–	–
	<i>Peltigera polydactylon</i>	–	–	–	–	–	16.7
	<i>Peltigera scabrosa</i>	–	–	–	11.1	–	–
	<i>Peltigera</i> sp.	–	–	–	11.1	–	33.3
	<i>Protopannaria pezizoides</i>	11.1	–	–	–	–	33.3
	<i>Psoroma hypnorum</i>	–	–	–	11.1	–	66.7
	<i>Solorina crocea</i>	88.9	–	–	44.4	–	50.0
	<i>Stereocaulon alpinum</i>	44.4	–	–	100.0	11.1	–
	<i>Stereocaulon paschale</i>	–	–	–	–	–	50.0
	<i>Stereocaulon</i> sp.	77.8	55.6	–	–	–	33.3
	<i>Thamnolia subuliformis</i>	22.2	–	–	88.9	–	66.7
	<i>Umbilicaria cylindrica</i>	–	–	–	–	–	16.7
	<i>Umbilicaria hyperborea</i>	–	11.1	–	11.1	–	33.3
	<i>Vestergrenopsis elaeina</i>	–	–	–	–	–	16.7

Table B2. Percent cover by species for vascular taxa and selected abiotic/biotic variables in Lake Clark National Park and Preserve and Kenai Fjords National Park (2016 data only). Means (± 1 SE) are shown for all growth forms. Cover was estimated by point-intercept along 30-m transects, following methods in Miller et al. (2010). All cover elements were within the 0–50 cm height class. A dash (–) indicates no sample.

Category	Species Name	Lake Clark National Park and Preserve			Kenai Fjords National Park			
		N. Double (n=3)	S. Double (n=3)	Tuxedni (n=3)	Skilak (n=3)	Bear (n=2)	Petrof (n=3)	Wosnesenski (n=3)
Grasses	<i>Agrostis exarata</i>	–	–	–	–	–	0.6 (0.6)	–
	<i>Agrostis mertensii</i>	–	–	–	–	–	6.2 (3.1)	2.8 (2.8)
	<i>Anthoxanthum monticola</i> subsp. <i>alpinum</i>	3.4 (3.4)	–	0.6 (0.6)	–	–	–	–
	<i>Calamagrostis canadensis</i>	–	–	–	–	–	5.6 (5.6)	–
	<i>Poa alpina</i>	–	–	1.1 (1.1)	–	–	22.6 (6.2)	–
	<i>Poa arctica</i>	–	–	–	0.6 (0.6)	–	1.1 (1.1)	–
	<i>Poa glauca</i>	–	–	–	–	–	1.1 (1.1)	3.3 (1.6)
	<i>Trisetum spicatum</i>	–	–	–	–	–	1.7 (1)	1.8 (1)
Sedges-rushes	<i>Carex</i> sp.	–	–	1.7 (1.7)	–	–	–	–
	<i>Carex lachenalii</i>	–	–	–	2.8 (0.6)	–	0.6 (0.6)	0.6 (0.6)
	<i>Carex macrochaeta</i>	–	–	0.6 (0.6)	–	–	–	–
	<i>Carex mertensii</i>	–	–	–	–	–	0.6 (0.6)	–
	<i>Carex microchaeta</i>	5.1 (1)	6.8 (2)	0.6 (0.6)	13.6 (7.4)	5.9 (0.8)	3.4 (1)	8.1 (4.1)
	<i>Carex micropoda</i>	–	–	–	7.3 (7.3)	–	–	–
	<i>Luzula arcuata</i> subsp. <i>unalaschensis</i>	–	–	–	9.6 (1.1)	1.7 (1.7)	0.6 (0.6)	3.1 (0.8)
	<i>Luzula piperi</i>	–	–	–	–	–	9.6 (4.4)	–
	<i>Luzula spicata</i>	–	–	–	–	–	–	0.6 (0.6)

Table B2 (continued). Percent cover by species for vascular taxa and selected abiotic/biotic variables in Lake Clark National Park and Preserve and Kenai Fjords National Park (2016 data only). Means (± 1 SE) are shown for all growth forms. Cover was estimated by point-intercept along 30-m transects, following methods in Miller et al. (2010). All cover elements were within the 0–50 cm height class. A dash (–) indicates no sample.

Category	Species Name	Lake Clark National Park and Preserve			Kenai Fjords National Park			
		N. Double (n=3)	S. Double (n=3)	Tuxedni (n=3)	Skilak (n=3)	Bear (n=2)	Petrof (n=3)	Wosnesenski (n=3)
Forbs	<i>Antennaria monocephala</i>	0.6 (0.6)	1.1 (1.1)	–	1.1 (0.6)	–	–	–
	<i>Antennaria rosea</i> subsp. <i>pulvinata</i>	–	–	–	–	–	0.6 (0.6)	4.2 (2.4)
	<i>Artemisia arctica</i>	5.1 (1.7)	–	–	6.2 (1.5)	–	–	7.2 (4.3)
	<i>Astragalus alpinus</i>	–	–	–	–	–	–	1.7 (1.7)
	<i>Bistorta vivipara</i>	–	–	–	–	–	–	1.1 (1.1)
	<i>Campanula lasiocarpa</i>	1.1 (1.1)	–	–	–	–	5.6 (1.5)	0.6 (0.6)
	<i>Chamaenerion angustifolium</i>	–	–	–	–	–	0.6 (0.6)	–
	<i>Chamaenerion latifolium</i>	–	–	–	–	–	1.1 (0.6)	–
	<i>Epilobium hornemannii</i>	–	–	–	–	–	5.6 (1.5)	–
	<i>Eurybia sibirica</i> (= <i>Aster sibiricus</i>)	–	–	1.1 (0.6)	–	–	–	–
	<i>Geum rossii</i>	–	–	–	–	–	–	3.5 (1.6)
	<i>Lloydia serotina</i> var. <i>serotina</i>	–	–	–	–	–	–	0.6 (0.6)
	<i>Luetkea pectinata</i>	–	0.6 (0.6)	28.2 (5.7)	–	–	48.6 (12.6)	–
	<i>Lupinus nootkatensis</i>	–	–	5.6 (2.8)	–	–	7.3 (3)	–
	<i>Minuartia macrocarpa</i>	–	–	–	0.6 (0.6)	–	–	–
	<i>Minuartia rubella</i>	–	–	–	–	–	–	0.6 (0.6)
	<i>Potentilla hyparctica</i>	–	–	–	–	–	–	0.6 (0.6)

Table B2 (continued). Percent cover by species for vascular taxa and selected abiotic/biotic variables in Lake Clark National Park and Preserve and Kenai Fjords National Park (2016 data only). Means (± 1 SE) are shown for all growth forms. Cover was estimated by point-intercept along 30-m transects, following methods in Miller et al. (2010). All cover elements were within the 0–50 cm height class. A dash (–) indicates no sample.

Category	Species Name	Lake Clark National Park and Preserve			Kenai Fjords National Park			
		N. Double (n=3)	S. Double (n=3)	Tuxedni (n=3)	Skilak (n=3)	Bear (n=2)	Petrof (n=3)	Wosnesenski (n=3)
Forbs (continued)	<i>Rhodiola integrifolia</i>	–	–	–	–	–	–	2.4 (0.5)
	<i>Saxifraga bronchialis</i>	–	–	–	0.6 (0.6)	–	–	1.7 (1.7)
	<i>Sibbaldia procumbens</i>	–	–	0.6 (0.6)	1.7 (1.7)	–	11.3 (7.5)	0.6 (0.6)
	<i>Silene acaulis</i>	–	–	–	0.6 (0.6)	–	–	0.6 (0.6)
	<i>Stellaria longipes</i>	–	–	–	–	–	2.3 (1.5)	–
	<i>Veronica wormskjoldii</i> subsp. <i>wormskjoldii</i>	–	–	–	–	–	0.6 (0.6)	–
Ferns and allies	<i>Diphasiastrum alpinum</i>	–	–	16.9 (5.2)	5.6 (5.6)	–	–	–
	<i>Huperzia selago</i>	–	–	–	–	–	–	0.7 (0.7)
Dwarf shrub	<i>Cassiope tetragona</i>	1.7 (1.7)	0.6 (0.6)	–	–	–	–	–
	<i>Diapensia lapponica</i>	2.8 (0.6)	–	–	–	0.8 (0.8)	–	0.6 (0.6)
	<i>Dryas integrifolia</i>	11.3 (5.9)	–	–	–	–	–	–
	<i>Empetrum nigrum</i>	4 (3.1)	18.6 (8.7)	15.3 (2)	–	–	–	–
	<i>Harrimanella stelleriana</i>	0.6 (0.6)	1.7 (1)	52 (2.5)	–	–	–	–
	<i>Kalmia procumbens</i> (= <i>Loiseleuria procumbens</i>)	1.1 (0.6)	0.6 (0.6)	3.4 (2.6)	–	–	–	–
	<i>Phyllodoce aleutica</i>	–	–	–	–	–	1.1 (1.1)	–
	<i>Salix rotundifolia</i>	7.3 (3)	6.8 (1)	–	2.3 (2.3)	–	–	26.8 (9.1)
	<i>Vaccinium uliginosum</i>	5.1 (1)	11.9 (6.4)	9.6 (9.6)	–	–	–	–

Table B2 (continued). Percent cover by species for vascular taxa and selected abiotic/biotic variables in Lake Clark National Park and Preserve and Kenai Fjords National Park (2016 data only). Means (± 1 SE) are shown for all growth forms. Cover was estimated by point-intercept along 30-m transects, following methods in Miller et al. (2010). All cover elements were within the 0–50 cm height class. A dash (–) indicates no sample.

Category	Species Name	Lake Clark National Park and Preserve			Kenai Fjords National Park			
		N. Double (n=3)	S. Double (n=3)	Tuxedni (n=3)	Skilak (n=3)	Bear (n=2)	Petrof (n=3)	Wosnesenski (n=3)
Abiotic / Biotic cover elements	Mineral soil	16.9 (6.1)	–	2.8 (1.1)	0.6 (0.6)	–	–	–
	Cryptogamic crust	15.3 (2.6)	10.2 (4.9)	0.6 (0.6)	–	–	–	3.8 (1.4)
	Gravel	1.7 (1)	56.5 (4.6)	0.6 (0.6)	11.3 (8)	28.8 (8.5)	4.5 (3)	9.8 (2.5)
	Lichen	12.4 (0.6)	–	3.4 (0)	46.3 (9.9)	28 (0.8)	–	29.2 (5.2)
	Litter	11.9 (3.5)	14.1 (5.6)	22 (4.3)	6.8 (1.7)	2.5 (0.8)	22 (2)	5.4 (0.7)
	Moss	23.2 (4.6)	4.5 (2.5)	16.4 (4.4)	18.1 (0.6)	1.7 (0)	33.9 (12.3)	32.6 (8.1)
	Rock	–	2.3 (1.5)	1.1 (0.6)	1.1 (0.6)	54.2 (3.4)	7.3 (3.1)	26.6 (14.8)
	Scat (mountain goat)	–	–	–	–	–	–	1.4 (1.4)

Table B3. Percent frequency of vascular plant taxa in 0.25-m² quadrats, as observed in Lake Clark National Park and Preserve in 2005 and 2016, following methods outlined in Miller et al. (2005), and in 2016, following GRTS sampling methods in Miller et al. (2010). A dash (–) indicates no sample.

Category	Species Name	N. Double			S. Double			Tuxedni		
		2005 (n=30)	2016 (n=30)	2016 GRTS (n=15)	2005 (n=30)	2016 (n=30)	2016 GRTS (n=11)	2005 (n=30)	2016 (n=30)	2016 GRTS (n=9)
Grasses	<i>Agrostis exarata</i>	–	–	–	–	–	–	–	–	–
	<i>Agrostis mertensii</i>	–	–	–	–	–	–	–	–	–
	<i>Anthoxanthum monticola</i> subsp. <i>alpinum</i>	–	20.0	20.0	6.7	6.7	–	–	–	–
	<i>Calamagrostis canadensis</i>	–	–	–	–	–	–	–	–	–
	<i>Festuca brachyphylla</i>	–	–	–	–	–	–	–	–	–
	<i>Phleum alpinum</i>	–	–	–	–	–	–	–	–	–
	<i>Poa</i> sp.	–	10.0	–	–	–	–	–	–	–
	<i>Poa alpine</i>	–	–	–	–	–	–	–	13.3	22.2
	<i>Poa arctica</i>	–	–	–	–	3.3	–	–	–	–
	<i>Poa glauca</i>	–	–	–	–	–	–	–	–	–
	<i>Poa paucispicula</i>	–	–	–	–	–	–	–	–	–
	<i>Trisetum spicatum</i>	25.0	15.0	20.0	3.3	–	–	6.7	–	–
	<i>Vahlodea atropurpurea</i>	–	–	–	–	–	–	30.0	26.7	44.4
Sedges-rushes	<i>Carex lachenalii</i>	–	–	–	–	–	–	–	–	–
	<i>Carex macrochaeta</i>	–	–	–	–	–	–	43.3	26.7	22.2
	<i>Carex mertensii</i>	–	–	–	–	–	–	–	–	–
	<i>Carex microchaeta</i>	100.0	100.0	100.0	100.0	93.3	100.0	–	6.7	–

Table B3 (continued). Percent frequency of vascular plant taxa in 0.25-m² quadrats, as observed in Lake Clark National Park and Preserve in 2005 and 2016, following methods outlined in Miller et al. (2005), and in 2016, following GRTS sampling methods in Miller et al. (2010). A dash (–) indicates no sample.

Category	Species Name	N. Double			S. Double			Tuxedni		
		2005 (n=30)	2016 (n=30)	2016 GRTS (n=15)	2005 (n=30)	2016 (n=30)	2016 GRTS (n=11)	2005 (n=30)	2016 (n=30)	2016 GRTS (n=9)
Sedges-rushes (continued)	<i>Carex micropoda</i>	–	–	–	10.0	10.0	9.1	60.0	60.0	66.7
	<i>Juncus biglumis</i>	–	–	–	–	–	–	–	–	–
	<i>Luzula arcuata</i> subsp. <i>unalaschkensis</i>	65.0	60.0	46.7	63.3	40.0	45.5	20.0	16.7	11.1
	<i>Luzula piperi</i>	–	–	–	10.0	13.3	9.1	63.3	30.0	22.2
	<i>Luzula spicata</i>	–	–	–	–	–	–	–	–	–
Forbs	<i>Androsace</i> sp.	–	–	–	–	–	–	–	–	–
	<i>Antennaria monocephala</i>	94.4	80.0	80.0	36.7	26.7	27.3	3.3	–	–
	<i>Antennaria rosea</i> subsp. <i>pulvinata</i>	–	–	–	–	–	–	16.7	6.7	–
	<i>Arabis kamchatica</i>	–	–	–	–	–	–	–	–	–
	<i>Artemisia arctica</i>	100.0	95.0	80.0	53.3	36.7	18.2	3.3	–	11.1
	<i>Astragalus alpinus</i>	–	–	–	–	–	–	–	–	–
	<i>Bistorta vivipara</i>	5.0	–	–	–	–	–	10.0	3.3	6.7
	<i>Campanula lasiocarpa</i>	88.9	90.0	93.3	53.3	30.0	36.4	3.3	13.3	22.2
	<i>Campanula rotundifolia</i>	–	–	–	–	–	–	–	–	–
	<i>Cardamine bellidifolia</i>	–	–	–	–	–	–	–	–	–
	<i>Cerastium beeringianum</i>	–	–	–	–	–	–	–	–	–
	<i>Chamerion angustifolium</i>	–	–	–	–	–	–	6.7	3.3	11.1
	<i>Chamerion latifolium</i>	–	–	–	–	–	–	–	–	–

Table B3 (continued). Percent frequency of vascular plant taxa in 0.25-m² quadrats, as observed in Lake Clark National Park and Preserve in 2005 and 2016, following methods outlined in Miller et al. (2005), and in 2016, following GRTS sampling methods in Miller et al. (2010). A dash (–) indicates no sample.

Category	Species Name	N. Double			S. Double			Tuxedni		
		2005 (n=30)	2016 (n=30)	2016 GRTS (n=15)	2005 (n=30)	2016 (n=30)	2016 GRTS (n=11)	2005 (n=30)	2016 (n=30)	2016 GRTS (n=9)
Forbs (continued)	<i>Coeloglossum viride</i>	–	–	–	–	–	–	–	–	–
	<i>Draba</i> sp.	–	–	–	–	–	–	–	–	–
	<i>Epilobium hornemannii</i>	–	–	–	–	–	–	43.3	–	–
	<i>Erigeron humilis</i>	–	–	–	–	–	–	–	–	44.4
	<i>Erigeron peregrinus</i>	–	–	–	–	–	–	3.3	26.7	–
	<i>Gentiana glauca</i>	10.0	40.0	40.0	–	–	–	3.3	–	–
	<i>Geum rossii</i>	–	–	–	–	–	–	–	–	–
	<i>Hieracium triste</i>	–	–	–	–	–	–	60.0	26.7	66.7
	<i>Lloydia serotina</i> var. <i>serotina</i>	30.0	15.0	33.3	–	–	–	–	–	–
	<i>Luetkea pectinata</i>	–	–	–	6.7	6.7	18.2	90.0	100.0	89.9
	<i>Lupinus nootkatensis</i>	–	–	6.7	3.3	–	–	73.3	43.3	55.6
	<i>Minuartia macrocarpa</i>	–	–	–	–	–	–	–	–	–
	<i>Minuartia rubella</i>	–	–	–	–	–	–	–	–	–
	<i>Papaver radicatum</i> subsp. <i>alaskanum</i>	–	–	–	–	–	–	–	–	–
	<i>Pedicularis</i> sp.	–	–	–	–	–	–	–	–	–
	<i>Pedicularis capitata</i>	–	5.0	6.7	–	3.3	–	–	–	–
	<i>Pedicularis langsдорffii</i>	5.0	–	–	10.0	–	–	–	–	–
	<i>Pedicularis verticillata</i>	–	–	–	–	3.3	–	–	–	–

Table B3 (continued). Percent frequency of vascular plant taxa in 0.25-m² quadrats, as observed in Lake Clark National Park and Preserve in 2005 and 2016, following methods outlined in Miller et al. (2005), and in 2016, following GRTS sampling methods in Miller et al. (2010). A dash (–) indicates no sample.

Category	Species Name	N. Double			S. Double			Tuxedni		
		2005 (n=30)	2016 (n=30)	2016 GRTS (n=15)	2005 (n=30)	2016 (n=30)	2016 GRTS (n=11)	2005 (n=30)	2016 (n=30)	2016 GRTS (n=9)
Forbs (continued)	<i>Polemonium pulcherrimum</i>	–	–	–	–	–	–	–	–	–
	<i>Potentilla hyparctica</i>	–	–	–	–	–	–	–	–	–
	<i>Rhodiola integrifolia</i>	–	–	–	–	–	–	–	–	–
	<i>Saxifraga bronchialis</i>	–	–	–	–	–	–	–	–	–
	<i>Saxifraga nivalis</i>	–	–	–	–	–	–	–	–	–
	<i>Saxifraga punctata</i>	–	–	–	–	–	–	–	–	–
	<i>Sibbaldia procumbens</i>	–	–	–	–	–	–	6.7	6.7	–
	<i>Silene acaulis</i>	–	–	–	–	–	–	–	–	–
	<i>Solidago multiradiata</i>	–	–	–	–	–	–	–	–	–
	<i>Stellaria longipes</i>	–	–	–	–	–	–	–	–	–
	<i>Veronica wormskjoldii</i> subsp. <i>wormskjoldii</i>	–	–	–	–	–	–	10.0	6.7	–
	<i>Viola langsдорffii</i>	–	–	–	–	–	–	3.3	–	–
Ferns and allies	<i>Diphasiastrum alpinum</i>	–	–	–	3.3	–	–	70.0	76.7	55.6
	<i>Huperzia selago</i>	–	15.0	–	–	–	–	3.3	3.3	–
Dwarf shrubs	<i>Bistorta vivipara</i>	–	–	–	–	–	–	–	–	11.1
	<i>Cassiope lycopodioides</i>	–	–	–	10.0	26.7	–	6.7	10.0	–
	<i>Cassiope tetragona</i>	33.3	25.0	46.7	–	–	18.2	–	–	–

Table B3 (continued). Percent frequency of vascular plant taxa in 0.25-m² quadrats, as observed in Lake Clark National Park and Preserve in 2005 and 2016, following methods outlined in Miller et al. (2005), and in 2016, following GRTS sampling methods in Miller et al. (2010). A dash (–) indicates no sample.

Category	Species Name	N. Double			S. Double			Tuxedni		
		2005 (n=30)	2016 (n=30)	2016 GRTS (n=15)	2005 (n=30)	2016 (n=30)	2016 GRTS (n=11)	2005 (n=30)	2016 (n=30)	2016 GRTS (n=9)
Dwarf shrubs	<i>Diapensia lapponica</i>	50.0	60.0	46.7	6.7	13.3	–	–	–	–
	<i>Dryas integrifolia</i>	25.0	30.0	53.3	–	–	–	–	–	–
	<i>Empetrum nigrum</i>	5.0	5.0	13.3	56.7	70.0	81.8	50.0	53.3	66.7
	<i>Harrimanella stelleriana</i>	5.0	–	–	26.7	40.0	36.4	96.7	96.7	100.0
	<i>Kalmia procumbens</i> (=Loiseleuria procumbens)	20.0	20.0	26.7	–	3.3	18.2	30.0	20.0	33.3
	<i>Salix arctica</i>	–	55.0	13.3	–	–	–	–	–	–
	<i>Salix polaris</i>	–	–	6.7	–	–	–	–	6.7	11.1
	<i>Salix rotundifolia</i>	100.0	100.0	86.7	96.7	96.7	100.0	23.3	23.3	11.1
	<i>Vaccinium uliginosum</i>	10.0	25.0	26.7	26.7	26.7	27.3	20.0	20.0	22.2

Table B4. Percent frequency of vascular plant taxa in 0.25-m² quadrats, as observed in Kenai Fjords National Park in 2005 and 2016, following methods outlined in Miller et al. (2005), and in 2016, following GRTS sampling methods in Miller et al. (2010). A dash (–) indicates no sample.

Category	Species Name	Bear			Petrof			Skilak			Wosnesenski		
		2005 (n=20)	2016 (n=20)	2016 GRTS (n=0)	2005 (n=30)	2016 (n=30)	2016 GRTS (n=15)	2005 (n=30)	2016 (n=30)	2016 GRTS (n=15)	2005 (n=28)	2016 (n=28)	2016 GRTS (n=11)
Grasses	<i>Agrostis exarata</i>	–	–	–	–	13.3	–	–	–	–	–	–	–
	<i>Agrostis mertensii</i>	–	–	–	16.7	50.0	40.0	–	–	–	–	32.1	36.4
	<i>Anthoxanthum monticola</i> subsp. <i>alpinum</i>	–	5.6	–	–	–	–	–	10.0	–	3.6	3.6	18.2
	<i>Calamagrostis canadensis</i>	–	–	–	6.7	16.7	20.0	–	–	–	–	–	–
	<i>Festuca brachyphylla</i>	–	–	–	3.3	–	–	–	–	–	21.4	–	–
	<i>Phleum alpinum</i>	–	–	–	–	20.0	20.0	–	–	–	–	–	–
	<i>Poa</i> sp.	–	–	–	–	–	–	–	16.7	–	–	–	–
	<i>Poa alpina</i>	–	–	–	–	–	26.7	–	6.7	20.0	–	–	–
	<i>Poa arctica</i>	–	–	–	–	–	–	50.0	46.7	13.3	–	–	–
	<i>Poa glauca</i>	–	–	–	100.0	90.0	60.0	–	–	–	17.9	53.6	36.4
	<i>Poa paucispicula</i>	–	–	–	6.7	–	–	–	–	33.3	3.6	25.0	9.1
	<i>Trisetum spicatum</i>	–	–	–	76.7	83.3	60.0	–	–	–	35.7	17.9	36.4
	<i>Vahlodea atropurpurea</i>	–	–	–	–	–	–	–	–	–	–	–	–
Sedges-rushes	<i>Carex lachenalii</i>	11.1	11.1	–	33.3	60.0	33.3	13.3	3.3	6.7	3.6	3.6	–
	<i>Carex macrochaeta</i>	–	–	–	–	–	–	–	–	–	–	–	–
	<i>Carex mertensii</i>	–	–	–	3.3	16.7	6.7	–	–	–	–	–	–

Table B4 (continued). Percent frequency of vascular plant taxa in 0.25-m² quadrats, as observed in Kenai Fjords National Park in 2005 and 2016, following methods outlined in Miller et al. (2005), and in 2016, following GRTS sampling methods in Miller et al. (2010). A dash (–) indicates no sample.

Category	Species Name	Bear			Petrof			Skilak			Wosnesenski		
		2005 (n=20)	2016 (n=20)	2016 GRTS (n=0)	2005 (n=30)	2016 (n=30)	2016 GRTS (n=15)	2005 (n=30)	2016 (n=30)	2016 GRTS (n=15)	2005 (n=28)	2016 (n=28)	2016 GRTS (n=11)
Sedges-rushes (continued)	<i>Carex microchaeta</i>	61.1	44.4	–	–	–	–	56.7	60.0	46.7	39.3	42.9	45.5
	<i>Carex micropoda</i>	–	–	–	23.3	33.3	–	23.3	23.3	33.3	–	–	–
	<i>Juncus biglumis</i>	–	–	–	–	–	–	3.3	–	–	–	–	–
	<i>Luzula arcuata</i> subsp. <i>unalaschkensis</i>	22.2	27.8	–	10.0	20.0	–	50.0	60.0	93.3	67.9	46.4	36.4
	<i>Luzula piperi</i>	–	–	–	93.3	80.0	80.0	3.3	–	–	–	–	–
	<i>Luzula spicata</i>	–	–	–	–	–	–	–	–	–	7.1	7.1	9.1
Forbs	<i>Androsace</i> sp.	–	–	–	–	–	–	–	–	–	–	7.1	–
	<i>Antennaria monocephala</i>	5.6	5.6	–	–	–	13.3	26.7	20.0	20.0	–	–	–
	<i>Antennaria rosea</i> subsp. <i>pulvinata</i>	–	–	–	33.3	56.7	26.7	–	–	–	50.0	46.4	36.4
	<i>Arabis kamchatica</i>	–	–	–	–	6.7	–	–	–	–	–	–	–
	<i>Artemisia arctica</i>	–	–	–	–	–	–	73.3	80.0	86.7	71.4	78.6	63.6
	<i>Astragalus alpinus</i>	–	–	–	–	–	–	–	–	–	32.1	25.0	36.4
	<i>Campanula lasiocarpa</i>	5.6	11.1	–	–	–	–	53.3	53.3	40.0	67.9	75.0	63.6
	<i>Campanula rotundifolia</i>	–	–	–	3.3	3.3	6.7	–	–	–	–	7.1	–
	<i>Cardamine bellidifolia</i>	–	11.1	–	3.3	–	–	6.7	33.3	46.7	10.7	–	–
	<i>Cerastium beeringianum</i>	–	–	–	–	–	–	–	–	–	7.1	–	18.2
	<i>Chamerion angustifolium</i>	–	–	–	3.3	–	–	–	–	–	–	–	–

Table B4 (continued). Percent frequency of vascular plant taxa in 0.25-m² quadrats, as observed in Kenai Fjords National Park in 2005 and 2016, following methods outlined in Miller et al. (2005), and in 2016, following GRTS sampling methods in Miller et al. (2010). A dash (–) indicates no sample.

Category	Species Name	Bear			Petrof			Skilak			Wosnesenski		
		2005 (n=20)	2016 (n=20)	2016 GRTS (n=0)	2005 (n=30)	2016 (n=30)	2016 GRTS (n=15)	2005 (n=30)	2016 (n=30)	2016 GRTS (n=15)	2005 (n=28)	2016 (n=28)	2016 GRTS (n=11)
Forbs (continued)	<i>Chamerion latifolium</i>	–	–	–	50.0	53.3	46.7	–	–	–	7.1	7.1	–
	<i>Coeloglossum viride</i>	–	–	–	–	3.3	–	–	–	–	–	–	–
	<i>Draba</i> sp.	–	–	–	–	–	–	–	–	–	–	7.1	–
	<i>Douglasia alaskana</i>	–	–	–	–	–	–	–	–	–	–	–	9.1
	<i>Epilobium hornemannii</i>	–	–	–	73.3	90.0	80.0	–	–	–	–	–	–
	<i>Erigeron humilis</i>	–	–	–	–	–	–	–	–	–	10.7	10.7	9.1
	<i>Erigeron peregrinus</i>	–	–	–	–	–	–	–	–	–	–	–	–
	<i>Eurybia sibirica</i>	–	–	–	–	–	–	–	–	–	–	–	9.1
	<i>Gentiana glauca</i>	–	–	–	–	–	–	–	–	–	–	–	–
	<i>Geum rossii</i>	–	–	–	–	–	–	–	–	–	28.6	28.6	18.2
	<i>Hieracium triste</i>	–	–	–	–	10.0	13.3	–	–	–	–	–	–
	<i>Lloydia serotina</i> var. <i>serotina</i>	–	–	–	–	–	–	–	–	–	64.3	35.7	45.5
	<i>Luetkea pectinata</i>	–	–	–	93.3	93.3	93.3	–	–	6.7	–	–	–
	<i>Lupinus nootkatensis</i>	–	–	–	96.7	100.0	66.7	–	–	–	–	–	–
	<i>Minuartia macrocarpa</i>	–	–	–	–	–	–	6.7	3.3	20.0	17.9	17.9	18.2
	<i>Minuartia rubella</i>	–	–	–	–	–	–	–	–	–	3.6	–	9.1
	<i>Papaver radicatum</i> subsp. <i>alaskanum</i>	–	–	–	–	–	–	–	–	–	3.6	3.6	9.1

Table B4 (continued). Percent frequency of vascular plant taxa in 0.25-m² quadrats, as observed in Kenai Fjords National Park in 2005 and 2016, following methods outlined in Miller et al. (2005), and in 2016, following GRTS sampling methods in Miller et al. (2010). A dash (–) indicates no sample.

Category	Species Name	Bear			Petrof			Skilak			Wosnesenski		
		2005 (n=20)	2016 (n=20)	2016 GRTS (n=0)	2005 (n=30)	2016 (n=30)	2016 GRTS (n=15)	2005 (n=30)	2016 (n=30)	2016 GRTS (n=15)	2005 (n=28)	2016 (n=28)	2016 GRTS (n=11)
Forbs (continued)	<i>Pedicularis</i> sp.	–	–	–	–	–	–	–	–	–	–	3.6	–
	<i>Pedicularis capitata</i>	–	–	–	–	–	–	–	–	–	–	7.1	–
	<i>Pedicularis langsдорфii</i>	–	–	–	–	–	–	–	–	–	–	–	–
	<i>Pedicularis verticillata</i>	–	–	–	–	–	–	–	–	–	25.0	–	27.3
	<i>Polemonium pulcherrimum</i>	–	–	–	3.3	3.3	–	–	–	–	7.1	3.6	9.1
	<i>Potentilla hyparctica</i>	11.1	11.1	–	–	–	–	10.0	10.0	13.3	35.7	28.6	45.5
	<i>Rhodiola integrifolia</i>	5.6	–	–	3.3	3.3	–	3.3	6.7	–	89.3	82.1	90.9
	<i>Saxifraga bronchialis</i>	–	–	–	–	3.3	–	–	3.3	6.7	46.4	39.3	54.6
	<i>Saxifraga nivalis</i>	–	–	–	–	–	–	–	–	–	3.6	–	–
	<i>Saxifraga punctata</i>	–	–	–	–	–	–	3.3	–	–	25.0	14.3	–
	<i>Saxifraga</i> sp.	–	–	–	–	–	–	–	–	–	–	–	45.5
	<i>Sibbaldia procumbens</i>	–	–	–	46.7	70.0	66.7	10.0	20.0	20.0	7.1	3.6	–
	<i>Silene acaulis</i>	–	–	–	10.0	3.3	–	3.3	6.7	–	17.9	21.4	9.1
	<i>Solidago multiradiata</i>	–	–	–	–	–	–	–	–	–	7.1	3.6	–
	<i>Stellaria longipes</i>	–	–	–	26.7	56.7	33.3	30.0	16.7	6.7	7.1	10.7	27.3
	<i>Veronica wormskjoldii</i> subsp. <i>wormskjoldii</i>	–	–	–	3.3	26.7	–	–	–	–	–	–	–
	<i>Viola langsдорфii</i>	–	–	–	–	–	–	–	–	–	–	–	–

Table B4 (continued). Percent frequency of vascular plant taxa in 0.25-m² quadrats, as observed in Kenai Fjords National Park in 2005 and 2016, following methods outlined in Miller et al. (2005), and in 2016, following GRTS sampling methods in Miller et al. (2010). A dash (–) indicates no sample.

Category	Species Name	Bear			Petrof			Skilak			Wosnesenski		
		2005 (n=20)	2016 (n=20)	2016 GRTS (n=0)	2005 (n=30)	2016 (n=30)	2016 GRTS (n=15)	2005 (n=30)	2016 (n=30)	2016 GRTS (n=15)	2005 (n=28)	2016 (n=28)	2016 GRTS (n=11)
Ferns and allies	<i>Diphasiastrum alpinum</i>	–	–	–	–	–	–	10.0	16.7	20.0	–	–	–
	<i>Huperzia selago</i>	–	–	–	–	–	–	–	–	–	46.4	28.6	27.3
Dwarf shrubs	<i>Bistorta vivipara</i>	–	–	–	–	–	–	–	–	–	21.4	14.3	18.2
	<i>Cassiope lycopodioides</i>	–	–	–	–	–	–	–	–	–	–	–	–
	<i>Cassiope tetragona</i>	–	–	–	–	–	–	–	–	–	–	–	–
	<i>Diapensia lapponica</i>	11.1	5.6	–	–	–	–	–	–	–	10.7	7.1	18.2
	<i>Dryas integrifolia</i>	–	–	–	–	–	–	–	–	–	–	–	–
	<i>Empetrum nigrum</i>	–	–	–	–	–	–	–	–	–	–	–	–
	<i>Harrimanella stelleriana</i>	–	–	–	–	–	–	–	–	–	–	–	–
	<i>Kalmia procumbens</i> (= <i>Loiseleuria procumbens</i>)	–	–	–	–	–	–	–	–	–	–	–	–
	<i>Salix arctica</i>	–	–	–	3.3	3.3	–	–	–	–	–	–	–
	<i>Salix polaris</i>	–	–	–	–	–	–	–	–	–	–	–	–
	<i>Salix rotundifolia</i>	–	–	–	–	–	–	6.7	6.7	6.7	85.7	85.7	81.8
	<i>Vaccinium uliginosum</i>	–	–	–	–	–	–	–	–	–	–	–	–

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