

**VASCULAR PLANT INVENTORY &
BASELINE MONITORING OF NUNATAK COMMUNITIES
2005**

**LAKE CLARK NATIONAL PARK AND PRESERVE
KENAI FJORDS NATIONAL PARK**



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Acronyms:

I&M	Inventory & Monitoring
SWAN	Southwest Alaska Network
AKNHP	Alaska Natural Heritage Program
LACL	Lake Clark National Park & Preserve
KEFJ	Kenai Fjords National Park
LGM	Last Glacial Maximum

Initial distribution: Southwest Alaska Network

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ABSTRACT

An inventory of nunatak communities in Lake Clark National Park & Preserve (LACL) and Kenai Fjords National Park (KEFJ) in 2005 produced a number of rare and disjunct vascular plant species. The LACL collection consisted of 81 vascular taxa from a total of four sites, including five new records for the Park. Four collections were of species rare within Alaska or globally: *Arabis lemmonii* (G5-S1), *Arnica diversifolia* (G5-S1), *Carex phaeocephala* (G4-S1S2), and *Potentilla drummondii* (G5-S2). Two collections of *Arabis lemmonii*, as well as Rocky Mountain disjuncts *Erigeron compositus* and *Kumlienia cooleyae* (= *Ranunculus cooleyae*) represent significant range extensions to the west. The KEFJ collection consisted of 75 vascular taxa from seven sites and yielded 16 species that were new records for the Park. Three collections from KEFJ were of rare species: *Douglasia alaskana* (G3-S3), *Thlaspi arcticum* (G3-S3), and *Carex phaeocephala* (G4-S1S2). A collection of *Carex albonigra* from a site on the Wosnesenski Glacier represented a significant range extension to the south. The percentage of known taxa in KEFJ increased from 77% to 80% following the 2005 inventory, whereas the percentage of known taxa in LACL remained at 80%. The greatest species numbers occurred at lower elevation sites. Baseline monitoring of nunatak communities was initiated at three sites in LACL and five sites in KEFJ. Species cover and frequency estimates showed that vascular species richness decreased with increasing elevation, and that the suite of dominant species also changed along this gradient. Disturbance via volcanic activity (LACL) and herbivory (KEFJ), and shifts in composition potentially due to changes in growing season length (KEFJ), were evident at several sites. An analysis of imagery from the Harding Icefield (1950-2005) shows a general increase in nunatak extent, although a number of sites appear to be stable or decreasing in area.

EXECUTIVE SUMMARY

Nunataks are exposed mountain peaks or ridges that rise above the surrounding glacial ice. In Alaska, they occur primarily in the National Parks adjacent to the northern Gulf of Alaska (e.g., Lake Clark National Park & Preserve, Kenai Fjords National Park, Wrangell-St. Elias National Park & Preserve, Glacier Bay National Park & Preserve). Nunataks are of interest to biologists because of their geographic isolation and because they may have supported plant and animal populations that survived the Last Glacial Maximum, approximately 20,000 years bp. In addition to harboring regional or globally rare species, nunataks are sensitive to changes in climate and can play an important role in the re-establishment of plant and animal communities in recently deglaciated areas. For these reasons, nunataks were selected as a vital sign for long-term monitoring in the Southwest Alaska Network (SWAN). In 2005, the SWAN and Alaska Natural Heritage Program (AKNHP) conducted a nunatak inventory to supplement previous vascular plant inventories at lower elevations (2001- 2004), and to provide baseline data for long-term monitoring of nunatak communities. We inventoried a total of eleven sites in Lake Clark National Park & Preserve (LACL) and Kenai Fjords National Park (KEFJ), and initiated baseline monitoring at eight sites.

As part of the inventory, we collected 81 unique vascular taxa in LACL, 5 of which were new records for the Park. We found five species of conservation concern (rare within Alaska or globally) in LACL: *Arabis lemmonii* (Lemmon's rockcress), *Arnica diversifolia* (rayless arnica), *Carex phaeocephala* (dunhead sedge), *Potentilla drummondii* (Drummond's cinquefoil), and *Thlaspi arcticum* (arctic pennycress). Collections of *Arabis lemmonii*, *Erigeron compositus* (mountain fleabane) and *Kumlienia cooleyae* (= *Ranunculus cooleyae*; Cooley's false buttercup) represented significant range extensions to the west. The KEFJ collection included 75 taxa, with 16 new records for the Park. Three collections from KEFJ were of rare species: *Douglasia alaskana* (Alaskan rock jasmine), *Thlaspi arcticum*, and *Carex phaeocephala*. A collection of *Carex albonigra* (black and white sedge) represented a significant range extension to the south. The percentage of known taxa in KEFJ increased from 77% to 80% following the 2005 nunatak inventory. The percentage of known taxa in LACL remained unchanged from 80%.

We initiated baseline monitoring of nunatak communities at three sites in LACL and five sites in KEFJ. These sites will be revisited at 3-10 year intervals as part of the SWAN's vital signs monitoring program. Species cover and frequency estimates showed that vascular species richness decreased with increasing elevation. Species composition also changed along the elevation gradient, with a greater number of snowbed species appearing at lower elevations, and fellfield and alpine dry meadow communities appearing at higher elevation, often more interior sites. Visible disturbance on nunataks included past volcanic activity (LACL) and herbivory by mountain goats (KEFJ). Shifts in plant species composition were also evident: at one site on Petrof Glacier in the southern Kenai Mountains (KEFJ), the community appeared to be transitioning from snowbed species to a site dominated by more temperate coastal species (e.g., bluejoint reedgrass (*Calamagrostis canadensis*), Merten's sedge (*Carex mertensii*), and Nootka lupine (*Lupinus nootkatensis*)). The cause of this change is unknown, but may be due in part to a longer snow-free season.

Long-term monitoring of nunatak communities will be essential to our understanding of the potential effects of climate change. An analysis of 1950s and 2005 imagery suggests that nunataks on the Harding Icefield have shown a mean increase in area of 30% over the last 55

years. The greatest changes appear to be occurring near the margins of the ice, where increases in area of up to 66% are estimated. The appearance of coastal species on at least one of the lower elevation nunataks suggests the potential for rapid immigration and establishment of species that were formerly absent at these sites.

INTRODUCTION

Nunataks, or exposed bedrock ridges surrounded by ice, occur in several of the National Parks along the northern Gulf of Alaska. These environments are of interest because of their geographic isolation and their potential to support populations that survived the Last Glacial Maximum (LGM), approximately 20,000 years bp. In addition to harboring regional or globally rare species, nunataks are sensitive to changes in climate and may facilitate the re-establishment of plant and animal communities in recently deglaciated areas. For these reasons, nunataks were selected as a vital sign for long-term monitoring in the Southwest Alaska Network (SWAN). In 2005, the SWAN and Alaska Natural Heritage Program (AKNHP) conducted a nunatak inventory to supplement previous vascular plant inventories at lower elevations (2001- 2004), and to provide baseline data for long-term monitoring of nunatak communities. A total of eleven sites were inventoried in Lake Clark National Park & Preserve (LACL) and Kenai Fjords National Park (KEFJ), eight of which were also used as baseline monitoring sites.

The Inventory and Monitoring (I&M) Program for the National Park Service (NPS) was established by the US Congress in 2000 through the Natural Resources Challenge. The goal of the program was to gather baseline information on, and monitor long-term trends in, natural resources in the parks. Biological inventories addressed three program goals:

- Document at least 90 percent of the species of vertebrates and vascular plants expected to occur in the park,
- Describe the distribution and abundance of species of special concern (e.g., rare or invasive species), and
- Provide information necessary to establish a monitoring strategy, with special reference to particular threats and resource issues within each park.

The Southwest Alaska Network (SWAN) and the Alaska Natural Heritage Program (AKNHP) conducted an inventory of nunatak communities in 2005 to supplement earlier vascular plant inventories of LACL (2001) and KEFJ (2003). The earlier inventories increased our knowledge of the flora at lower elevations, but had not addressed species occurrences in many of the remote, higher elevation areas of the parks. Following the 2003 inventory of KEFJ, the AKNHP recommended sampling of the nunataks on the Harding Icefield, as these sites were expected to harbor disjunct and rare taxa. The objectives of 2005 nunatak inventory were two-fold:

- (1) Conduct an inventory for vascular and nonvascular plants
- (2) Conduct baseline sampling of nunatak communities in support of vital signs monitoring

In addition to the inventory described above, we initiated an analysis of historic and recent imagery to quantify changes in nunatak extent on the Harding Icefield. Methods are similar to those being used to monitor changes in glacier extent (Hall et al. 2005) but utilize higher-resolution images. As with the monitoring component of the nunatak project, this work will provide an ongoing assessment of change in the nunatak environment. Thus, a third objective of the project was the following:

- (3) Estimate change in nunatak extent in support of vital signs monitoring

Ecological background

Multiple glacial advances and retreats over the past 100,000 years have shaped the landscape and communities of the Alaska Range, Cook Inlet, Kodiak, Shelikof Straits and the southeastern Kenai Peninsula (Karlstrom 1964). With the exception of a few areas along the west side of Cook Inlet, the Bonanza and Caribou Hills, and the outer coast of Kenai Fjords, most of south-central and southwest Alaska was covered by ice during the LGM (Manley 2002). Current warming in the Arctic is expected to continue, with additional increases in temperature of approximately 4-7 °C projected over the next century (ACIA, 2004). As a result, glaciers in the northern latitudes have been melting at an unprecedented rate, with the retreat of Alaskan glaciers representing approximately half of the estimated mass loss of ice worldwide (ACIA, 2004).

In southwest Alaska, local climate records indicate a warming of approximately 2 °C in over the last 50 years (Driscoll et al. 2005). The Harding Icefield, largely contained within KEFJ, has shown a net loss of approximately 5% of ice cover during the 35 year period spanning 1950-1985, with roughly 2% of this loss occurring at the margins of nunataks (Rice 1987). Airborne surface elevation profiles of the Harding Icefield conducted in the mid-1990s suggest that the total volume change in the Icefield since the 1950s has been equivalent to an average vertical loss of 21 m of ice (Aðalgeirsdóttir et al. 1998).

A long standing debate regarding the importance of nunataks as glacial refugia has recently been revisited (Brochmann et al. 2003; Petit et al. 2003; Schwöns Wetter et al. 2005). Two alternative views regarding the fate of alpine plants during the Quaternary glaciations suggest that alpine populations were entirely extirpated in glaciated areas and re-colonized only after the retreat of the glaciers, or they survived glaciation *in situ*, on ice-free ridges and re-colonized from there. One of the major lines of evidence for the nunatak hypothesis is that many proposed nunatak regions are floristically rich, suggesting that they acted as refugia to harbor ancestral genotypes (Schwöns Wetter et al. 2004). These areas are assumed to represent genetic hotspots, serving as reservoirs of biodiversity during glacial advances, but also as a source of dispersal to newly exposed areas during interglacial periods (Abbott et al. 2000, Weider & Hobaek 2003, Petit et al. 2003). We have limited evidence for the existence of nunatak refugia in the SWAN, but some ice free areas on the outer coast of KEFJ, and high ridges in the interior of the Kenai Peninsula and coast of LACL are thought to have been present during the LGM (Manley 2002). Identification of these areas is difficult without dating the time of bedrock exposure, but additional clues to site age may be derived from molecular and phytogeographical analyses on selected populations, which could provide an index for the length of time that the population has been isolated.

METHODS

Site selection

We used a GIS to select locations for the 2005 nunatak inventory 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 enable a helicopter landing and reconnaissance. Based on these criteria, we identified three sites in LACL and seven sites in KEFJ and finalized our selections during overflights of the parks. An additional site in LACL, Saddle Mountain, was revisited to supplement collections made during the 2001 inventory. In both parks, we attempted a reasonable north-south distribution of sites, although logistical constraints (topography, distance, ice cover) limited the area that we were able to survey in LACL (Fig 1). We conducted field

work in LACL between July 27-30, 2005, and in KEFJ between August 6-10, 2005. All sites required helicopter access. Site attributes are summarized in Table 1.

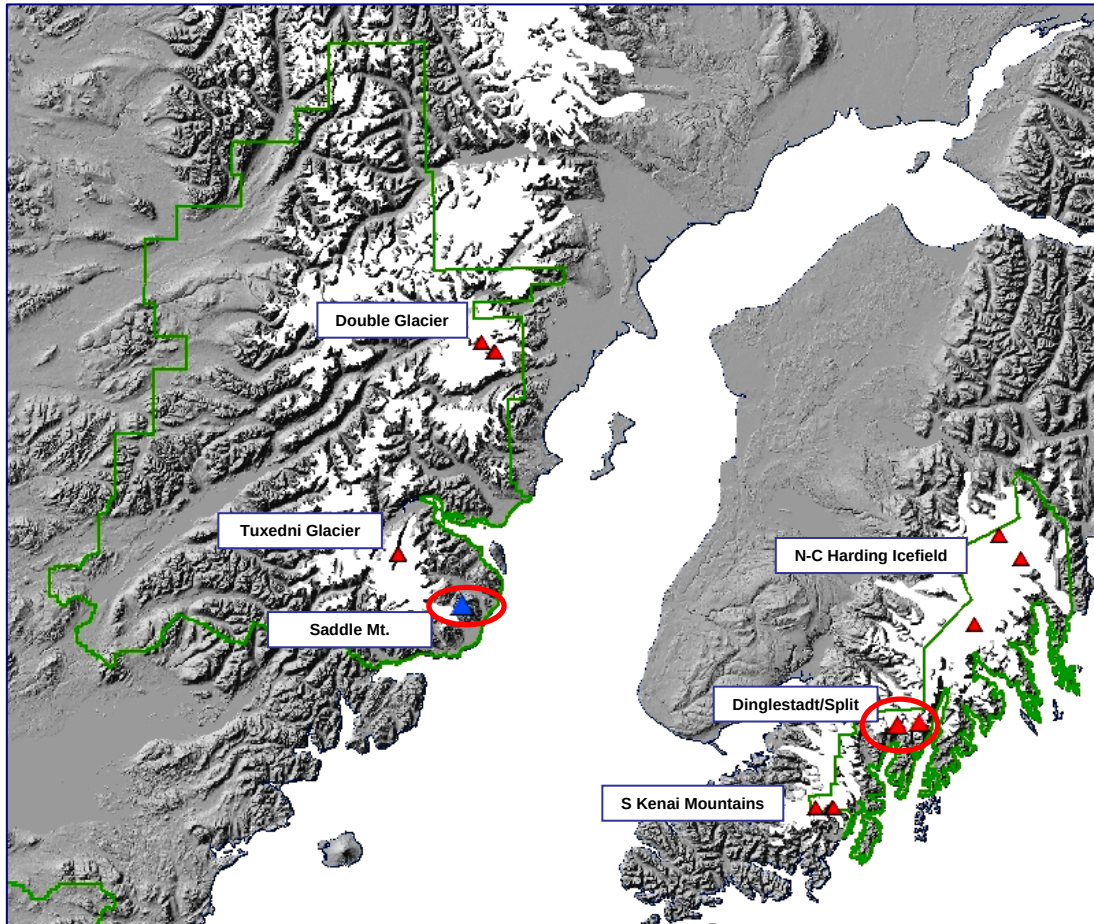


Figure 1. Nunatak sites, 2005. Transects were established for monitoring at all sites but Saddle Mountain in LACL and the Dinglestadt and Split Glacier sites in KEFJ (circled). Site descriptions are organized by sampling region, as in Table 1.

Table 1. Site descriptions. Baseline monitoring was conducted at sites indicated by the dagger (†).

PARK	SAMPLING REGION	GLACIER COMPLEX	LATITUDE (dd.dddd)	LONGITUDE (dd.dddd)	ELEVATION (m)	COMMUNITY
†LACL	Double (north)	Double (North)	60.7126	-152.6580	1115	dry meadow
†LACL	Double (south)	Double (South)	60.6882	-152.5862	930	dry meadow
†LACL	Tuxedni	Tuxedni	60.1539	-153.1296	760	dwarf heath-shrub
LACL	Saddle Mt.	Saddle Mt.	60.0019	-152.8051	850	gravel ridges
†KEFJ	N Kenai Mts.	Bear	60.0777	-149.7828	1360	barren rock; fellfield
†KEFJ	N Kenai Mts.	Skilak	60.1445	-149.8954	1420	dry meadow
†KEFJ	N Kenai Mts.	Holgate-Northwestern	59.9101	-150.0498	1150	dwarf heath-shrub
KEFJ	N Kenai Mts.	Dinglestadt	59.65647	-150.37282	950	barren rock
KEFJ	N Kenai Mts.	Split	59.65208	-150.48946	825	snowbed; mesic graminoid
†KEFJ	S Kenai Mts.	Wosnesenski	59.4441	-150.9458	1050	dry meadow
†KEFJ	S Kenai Mts.	Petrof	59.4415	-150.8558	650	dwarf heath-shrub

Vascular and nonvascular plant collections

We collected vascular and nonvascular (lichen, bryophyte) plant specimens following the protocol of Parker and Murray (1992). Collections were made only where the population was large enough to support the removal of individuals and targeted species not previously recorded in the region, species of conservation concern, and individuals that were not easily identified in the field. Vascular plant collections were extensive, but nonvascular collections were more opportunistic and were generally limited to monitoring areas. As a result, the nonvascular collections should not be considered representative of lichen and bryophyte diversity at a site. We georeferenced collections at each site using a recreational grade GPS (NAD83, decimal degrees; horizontal precision ± 5 m) and recorded site information including slope, aspect, elevation, parent material and associated species. For species of conservation concern, we also estimated the size of the population. We define a population as a group of individuals of the same species that occupy the same locality and are separated from other such groups by more than 1 km.

We submitted vascular plant collections to the University of Alaska-Fairbanks for verification and processing. Nonvascular plant collections were forwarded to the University of British Columbia for determinations. Permanent collections are housed at the University of Alaska Museum, with duplicate specimens housed at the NPS Regional Office in Anchorage and at Kenai Fjords NP headquarters in Seward.

Baseline monitoring

We established two to three permanent 30-m transects in representative communities at eight of the eleven sites (Tables 1). These communities were perceived to have the greatest cover (area) at each site. Whereas not all sites supported communities large enough to monitor (e.g., Dinglestad Glacier), or were periglacial rather than surrounded by ice (e.g., Split Glacier), the sites selected for monitoring did meet the criteria we outlined above (distance from ice, accessibility, presence of well-established vegetation). The Tuxedni Glacier site, while periglacial, was the most accessible site that we could find near the head of the glacier.

We used transects rather than permanent plots to minimize the number of markers necessary for sampling (2 per transect) and thus to reduce visual and physical impacts to the site. Transect endpoints were established using a simple random start within the sampling frame (community). We sampled nested 1.0 m² and 0.25 m² plots at 3 m intervals along one side of each transect using a portable plot frame. Plot corners were not permanently marked but were relocated with sufficient accuracy to derive repeated cover estimates within 10%. We used the nested 1.0 m² and 0.25 m² plots for estimates of frequency (presence/absence), and 0.25 m² plots for visual estimates of cover. We recorded cover for vascular and nonvascular species separately, and collected unknown species for later identification, as outlined above. At each site, we took a series of photos that included views up and down each transect, views of the dominant community or communities, and views of the representative landforms and geology. A digital photo taken from a height of 1.5 m and a downward angle of approximately 90° from the plot margin was used to document all 0.25 m² and 1 m² plots. Transect endpoints were georeferenced using a survey grade GPS (horizontal precision ± 1 m). All GPS locations were differentially corrected to the Kenai, Alaska base station within 30 d of collection.

Plot data (species cover, frequency) were summarized by site. We calculated species diversity and richness indices from 0.25 m² cover and 1.0 m² frequency data, respectively. Estimates of species richness derived from SPECRICH did not differ from species counts, and thus we used the count data to derive species/area estimates. We used linear regression (PROC REG) in SAS to

test for a relationship between species/area and site elevation (an index of temperature, moisture, and distance to edge of ice), and a general linear model (PROC GLM) to examine differences in vegetative cover among sites. Lastly, we used TRENDS to estimate our power to detect temporal trends at these sites (80% power to detect a rate of change of 0.08 with $\alpha=0.05$), using calculated coefficients of variation for species diversity and richness indices.

Genetic analyses

At each site, we collected foliar tissue for DNA analysis as part of a larger study conducted by researchers at the Royal British Columbia Museum and University of Victoria, Canada (PIs Ken Marr, Geraldine Allen). We collected approximately 1 g of tissue from one to several common alpine species (10-15 individuals per species) at each site. Focal species included *Oxyria digyna*, *Bistorta vivipara*, *Sibbaldia procumbens*, and *Campanula lasiocarpa*. The researchers are using DNA markers to study the phytogeography of several widespread arctic and alpine taxa in order to identify historic plant migration patterns. The analyses are being conducted at no cost to the NPS and should contribute to our understanding of the regional flora. Results of the project are expected by 2008.

Image analyses

Analyses of high resolution 1950s, 1990s, and 2005 imagery are in progress for the Harding Icefield and southern Kenai Mountains, KEFJ. As of late June 2006, we have digitized approximately 500 polygons comprising 25-30 nunataks on the 2005 IKONOS imagery (1 m resolution). We have rectified a subset of the 1950s survey photography (1:40,000) and have digitized approximately 115 polygons to date. These polygons are being compared against nunatak boundaries mapped on the USGS orthoquads to resolve the 1950 area estimates. Estimated changes in nunatak extent reported here are calculated from the mapped USGS boundaries (1950-1952) and digitized boundaries from the 2005 IKONOS imagery. Additional high-resolution images (DOQQ, including government use only) from the mid-1990s will be used as an intermediate date in the time series. Acquisition of IKONOS imagery and 1950s survey photography for LACL is expected in 2006 and should enable change detection for the nunatak systems there. Nunatak mapping for KEFJ and LACL is expected to be completed in 2007.

RESULTS

Vascular and nonvascular plant collections

The LACL vascular plant collection consisted of 81 taxa, five of which were new records for the Park (Table 2). Collections of *Arabis lemmonii*, *Erigeron compositus* and *Kumlienella cooleyae* (= *Ranunculus cooleyae*) from the Double Glacier site represented significant range extensions to the west (Table 2). Three collections from the same site were of species of conservation concern, rare in Alaska or globally (Table 3a). An additional suite of rare and disjunct species was found on Saddle Mountain, 80 km (50 miles) to the south (Table 3a).

The KEFJ vascular collection consisted of 75 taxa, 16 of which were new records for the Park (Table 2). A collection of *Carex albonigra* from the Wosnesenski Glacier represented a significant range extension to the south (Table 2). Three collections from the southern Kenai Mountains were of rare species (Table 3a).

Following the 2005 nunatak inventory, the percentage of known taxa in KEFJ increased from 77% to 80%. The percentage of known taxa in LACL remained unchanged (80%). Complete vascular and nonvascular collections for each park are listed in Appendix I. Natural Heritage Program global and state rankings are defined in Table 3b.

Table 2. New vascular plant records for LACL and KEFJ.

LACL	KEFJ
Double Glacier – Northern Site	Northern Kenai Mountains
<i>Arabis lemmonii</i> †*	<i>Arnica griscomii</i>
<i>Carex nigricans</i>	<i>Carex micropoda</i>
<i>Erigeron compositus</i> *	<i>Juncus biglumis</i>
<i>Kumlienia cooleyae</i> * (= <i>Ranunculus cooleyae</i>)	<i>Luzula piperi</i>
	<i>Poa glauca</i>
	<i>Saxifraga nelsoniana</i> ssp. <i>nelsoniana</i>
Saddle Mountain	Wosnesenski Glacier
<i>Arabis lemmonii</i> †*	<i>Carex albonigra</i> *
<i>Arnica diversifolia</i> † (= <i>A. ovata</i>)	<i>Cryptogramma acrostichoides</i>
	<i>Douglasia alaskana</i> †
	<i>Erigeron humilis</i>
	<i>Huperzia selago</i>
	<i>Ranunculus pygmaeus</i>
	<i>Saxifraga nelsoniana</i> ssp. <i>pacifica</i>
	<i>Saxifraga nivalis</i>
† species of conservation concern	Petrof Glacier
* range extension	<i>Epilobium leptocarpum</i>

Table 3a. Species of conservation concern collected in LACL and KEFJ

LACL	KEFJ
Double Glacier – Northern Site	Wosnesenski Glacier
<i>Arabis lemmonii</i> (G5-S1)*	<i>Douglasia alaskana</i> (G3-S3)
<i>Carex phaeocephala</i> (G4-S1S2)	<i>Thlaspi arcticum</i> (G3-S3)
<i>Potentilla drummondii</i> (G5-S2)	
Saddle Mountain	Petrof Glacier
<i>Arabis lemmonii</i> (G5-S1)*	<i>Carex phaeocephala</i> (G4-S1S2)
<i>Arnica diversifolia</i> (G5-S1)	
<i>Carex phaeocephala</i> (G4-S1S2)	
<i>Papaver alboroseum</i> (G3G4-S3)	
<i>Thlaspi arcticum</i> (G3-S3)	* range extension

Table 3b. Alaska Natural Heritage Program global and state rankings.

Global	State
G1: Critically imperiled globally	S1: Critically imperiled in the state
G2: Imperiled globally	S2: Imperiled in the state
G3: Rare or uncommon globally	S3: Rare or uncommon in the state
G4: Apparently secure globally, but with cause for long-term concern	S4: Apparently secure in the state, but with cause for long-term concern
G5: Demonstrably secure globally	S5: Demonstrably secure in the state

Baseline monitoring

We established transects at a total of eight sites across the two parks. Total vascular cover ranged from 5-90%, with the Bear Glacier site (KEFJ) having the lowest cover and fewest species per unit area (Table 4). Nonvascular cover was generally much lower, ranging from 5-20%. However, nonvascular species, primarily the lichen, *Stereocaulon*, comprised approximately 70% of cover at the Skilak Glacier site. We used this pilot data to perform power analyses on community indices (Shannon-Wiener diversity, richness). Our goal was to detect an exponential rate of change of 8% with 80% power ($\alpha = 0.05$). Given the number of plots established at each site, we estimated that we would be able to detect this trend over a period of 9-15 years, although at one site the interval was much longer (23 years; Bear Glacier, KEFJ), and additional plots may be required.

Species composition varied with elevation and site age. Species richness tended to decrease with increasing elevation ($r^2=0.64$; $P=0.17$; $n = 8$), but other factors, including precipitation, proximity to seed sources, and disturbance history also likely influenced species numbers. Lower elevation sites on the coastal side (e.g., Tuxedni Glacier, Petrof Glacier) tended to support a rich assemblage of mesic and/or snowbed species. Higher elevation, more interior sites (e.g., Double Glacier, Skilak Glacier) tended to be drier, and supported primarily fellfield and dry alpine meadows, although the Double Glacier sites also supported more mesic communities. The frequency of occurrence of species recorded in nunatak plots is shown in Appendix II.

Table 4. Community characteristics at monitoring sites. Species/area and richness estimates are derived from 1 m² frequency plots.

Park	Glacier Complex	Parent Material	Dominant Species	Species/Area (no. spp./m ²)	Richness (no. spp.)
LACL	Double (north)	granodiorite	<i>Carex microchaeta</i> ; <i>Diapensia lapponica</i> ; <i>Luzula arcuata</i> ; <i>Salix rotundifolia</i>	1.1	23
LACL	Double (south)	granodiorite	<i>Carex microchaeta</i> ; <i>Empetrum nigrum</i> ; <i>Luzula arcuata</i> ; <i>Salix rotundifolia</i> ; <i>Campanula lasiocarpa</i>	0.8	24
LACL	Tuxedni	granodiorite	<i>Harrimanella stellariana</i> ; <i>Lupinus nootkaensis</i> ; <i>Luzula piperi</i> ; <i>Carex micropoda</i> ; <i>Diphasiastrum alpinum</i>	1.1	40
KEFJ	Bear	metamorphic	<i>Carex microchaeta</i> ; <i>Luzula arcuata</i> ; <i>Diapensia lapponica</i> ; <i>Carex lachanellii</i>	0.6	15
KEFJ	Skilak	metamorphic	<i>Carex microchaeta</i> ; <i>Luzula arcuata</i> ; <i>Poa arctica</i> ; <i>Artemisia arctica</i> ; <i>Sibbaldia procumbens</i>	0.7	20
KEFJ	Holgate-Northwestern	metamorphic	<i>Carex micropoda</i> ; <i>Juncus biglumis</i> ; <i>Luetkea pectinata</i> ; <i>Luzula piperi</i> ; <i>Diphasiastrum alpinum</i>	0.8	20
KEFJ	Wosnesenski	metamorphic	<i>Carex microchaeta</i> ; <i>Luzula arcuata</i> ; <i>Trisetum spicatum</i> ; <i>Salix rotundifolia</i> ; <i>Artemisia arctica</i> ; <i>Campanula lasiocarpa</i> ; <i>Sedum rosea</i>	1.2	39
KEFJ	Petrof	metamorphic	<i>Carex micropoda</i> ; <i>Carex phaeocephala</i> ; <i>Luzula piperi</i> ; <i>Poa alpine</i> ; <i>Trisetum spicatum</i> ; <i>Lupinus nootkaensis</i> ; <i>Epilobium latifolia</i> ; <i>Sibbaldia procumbens</i>	1.3	38

Site descriptions – LACL

Double Glacier

The Double Glacier sites (Fig. 2, 3) supported a diverse flora that contained a number of rare or endemic species. We collected a total of 47 vascular and 52 nonvascular taxa at the two sites. We found four new vascular plant records for the park at the northern site, including three collections that represented potential range extensions to the west (Table 2). Six collections were of species that were expected to occur in the park, but that were previously unconfirmed.

Steep, mesic meadows and crumbling diorite cliffs (Fig. 2) were particularly rich in rare and disjunct species. *Arabis lemmonii* (G5-S1), *Carex phaeocephala* (G4-S1S2), *Potentilla drummondii* (G5-S2), and four species that represented minor to significant range extensions to the west (*Anemone multifida*, *Arabis lemmonii*, *Erigeron compositus*, *Kumlienia cooleyae*) were found in these environments at the northern Double Glacier site. This mesic meadow community was composed of forbs, including *Chamerion angustifolium* (= *Epilobium angustifolium*), *Geranium erianthum*, *Luetkea pectinata*, and *Lupinus nootkatensis*, and sedges (e.g., *Carex microchaeta*). Species that occurred at the base of the weathered cliffs included both drought-tolerant graminoids (e.g., *Festuca brachyphylla*, *Luzula spicata*) and forbs (e.g., *Potentilla uniflora*).

Dry meadow and fellfield communities occurred on the coarse gravel benches below the rock walls at the northern site, and on rolling benches at the southern site. At both sites, transects were established in dry graminoid-dwarf shrub communities dominated by sedges and rushes (*Carex microchaeta*, *Luzula arcuata*), forbs (*Artemisia arctica*, *Campanula lasiocarpa*) and low-stature shrubs (*Salix rotundifolia*). Subdominants included *Diappensia lapponica*, *Empetrum nigrum*, and *Harrimanella stelleriana* (= *Cassiope stelleriana*). The number of vascular species per square meter ranged from 0.8 (southern site) to 1.05 (northern site) in our plots. Site descriptions for all monitoring sites are summarized in Tables 1 and 4.



Figure 2. Double Glacier nunatak (northern site), LACL. Steep mesic graminoid-forb meadows and diorite cliffs (shown right) supported species of conservation concern (*Arabis lemmonii*, *Carex phaeocephala*, *Potentilla drummondii*) and several Rocky Mountain disjuncts. Monitoring transects were established in dry graminoid-dwarf shrub tundra, on the bench below the meadows.



Figure 3. Nunatak (southern site) on Double Glacier, LACL. Photo on left shows prominent trim lines along the northern margin of Double Glacier and characteristic dry graminoid tundra. Pumice from the 1989-1990 Redoubt eruption had markedly reduced nonvascular plant cover in some communities (right). A prominent ash layer (not shown) was present in the top 3-5 cm of the soil profile at both sites.

Volcanic activity appeared to be an important driver of community composition at both sites on Double Glacier, particularly at the southern site which was closer to Mt. Redoubt. Ash and cinder deposits from the 1989-1990 eruption appeared to have reduced lichen and bryophyte cover relative to the northern site (lichens: $df = 1$, $F = 43.45$, $P < 0.001$; bryophytes: $F = 19.31$, $P < 0.001$), and slowed the recovery of dwarf shrubs that were apparently buried following the eruption (Fig. 3). Hoary marmots (*Marmota caligata*) were present at the southern site.

Tuxedni Glacier

The Tuxedni Glacier site (Fig. 4; Table 1, 4) was located on a periglacial ridge on the west side of the glacier. We collected a total of 44 vascular and 19 nonvascular taxa at the site.



Figure 4. Periglacial site, Tuxedni Glacier, LACL. Photo on left shows view of younger, sparsely vegetated lower benches. Mesic dwarf shrub-graminoid tundra contained more maritime species than at Double Glacier, and plant cover was generally greater (right).

We found six species that were expected to occur in the park or were thought to be ‘probably present,’ but that had been previously unconfirmed. We established transects in alpine moist meadow comprised of mesic sedges and grasses (*Carex macrochaeta*, *Vahlodea atropurpurea*), forbs (*Lupinus nootkatensis*, *Hieracium triste*), and dwarf shrubs, (*Harrimanella stellariana* (= *Cassiope stellariana*), *Phyllodoce aleutica*, *Empetrum nigrum*). *Luetkea pectinata*, a snow bed species, occurred in 97% of plots. Arctic ground squirrels (*Spermophilus parryii*) were active at this site.

Saddle Mountain

The Saddle Mountain area (Fig. 5) supported an unusually rich assemblage of rare and disjunct species. We collected 31 vascular taxa at the site, including *Arabis lemmonii* (G5-S1), which had been collected during the 2001 inventory, but at too late a phenological stage to be identified.

In 2005, we found flowering and fruiting individuals that comprised a population of approximately 100 plants (Figs. 5, 12). Fine, eroding mudstone gravels over bedrock provided habitat for this rare *Arabis* and for four other species of conservation concern: *Arnica diversifolia* (G5-S1), *Carex phaeocephala* (G4-S1S2), *Papaver alboroseum* (G3G4-S3), and *Thlaspi arcticum* (G3-S3). Two of these species (*Arabis lemmonii*, *Arnica diversifolia*) were new records for the Park.

Saddle Mountain is not currently surrounded by ice, and we did not establish transects for monitoring at this location. However, it is likely one of several high ridges along the LACL coastline that remained ice-free during the late Wisconsin glaciation (Manley 2002; Fig. 6), and thus may have functioned as a refugium for lower-latitude, continental (cordilleran) and arctic (amphiberinean) disjuncts.



Figure 5. Saddle Mountain, LACL (left). Collections from this site and nearby ridges yielded several species of conservation concern, including *Arabis lemmonii* (right).

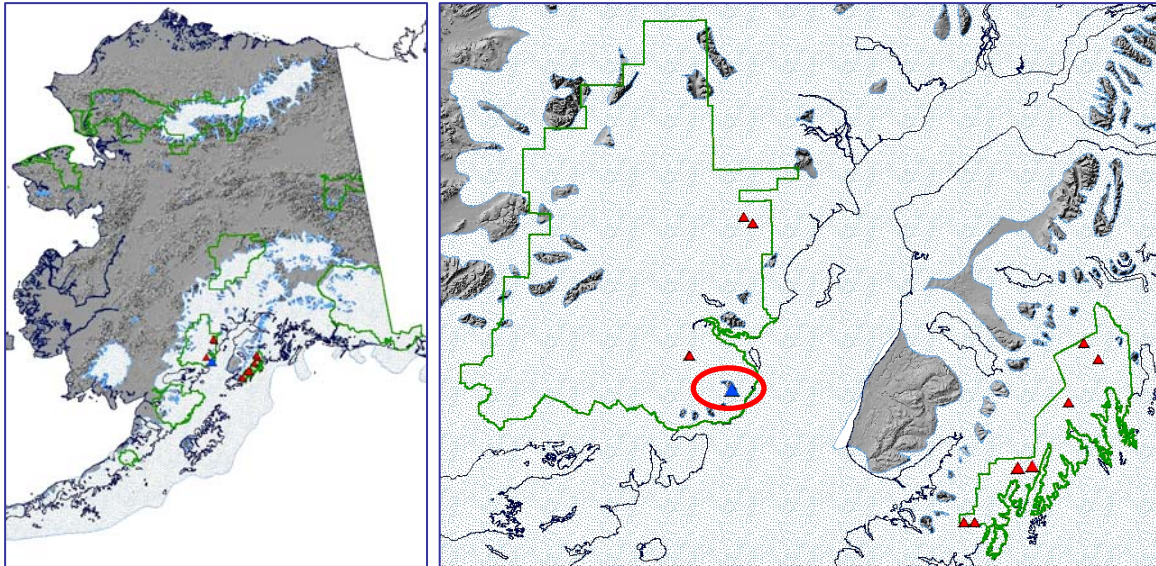


Figure 6. Late Wisconsin glaciation, maximum glacial extent, ca. 20,000 years bp (left) and estimated ice cover in southwest Alaska during the LGM (right). Saddle Mountain (circled) is thought to have remained ice free during this time.

Site descriptions – KEFJ

Northern Kenai Mountains – North-central Harding Icefield

The Northern Kenai Mountain sites supported vegetation ranging from depauperate scree and talus slopes to productive alpine meadow and snowbed communities (Fig. 7). We collected a total of 60 vascular and 25 nonvascular taxa at the five sites that comprised the northern complex. We established transects at three sites on the northern Harding Icefield, and inventoried an additional two sites (Dinglestadt Glacier, Split Glacier) on the central Icefield. The central sites included a young, recently deglaciated ridge on Dinglestadt Glacier that supported a few drought-tolerant rushes (e.g., *Luzula arcuata*, *Luzula piperi*) and ferns (*Dryopteris expansa*), and a lower elevation periglacial bench near Split Glacier that supported a number of wet coastal species and snowbed species, including sedges (*Eriophorum russeolum*, *Carex spectabilis*, *Carex lachenalii*) and mesic grasses (*Deschampsia caespitosa*).

Transects were established at sites on the northern Harding Icefield near Bear Glacier, Skilak Glacier, and Holgate and Northwestern Glaciers. The Bear Glacier site (Site 1; Fig. 6) was characterized by broken shale gravels, talus, and eroding cliffs that supported low vegetative cover (0-20%; Table 1, 4). A site to the southwest, near the head of Skilak Glacier (Site 2; Fig. 7), had well-developed soils and supported a more productive meadow community (30-70% vegetative cover) comprised of many of the same species present at the Bear Glacier site. Lichen cover at the Skilak site (50-80%) was dominated by the fruticose lichen, *Stereocaulon* (i.e., *Stereocaulon arenarium*, *S. botryosum*, *S. alpinum*, *S. spathuliferum*). A third site at the head of Holgate and Northwestern Glaciers (Site 3; Table 1, 4) supported a more mesic community composed of alpine and snowbed sedges and rushes (*Carex micropoda*, *Juncus biglumis*), clubmosses (*Diphasiastrum alpinum* (= *Lycopodium alpinum*), *D. sitchense* (= *L. sitchense*)) and dwarf shrubs (*Phyllodoce aleutica*, *Luetkea pectinata*). This community occurred in gullies and stringer meadows that dissected a steep boulder field.

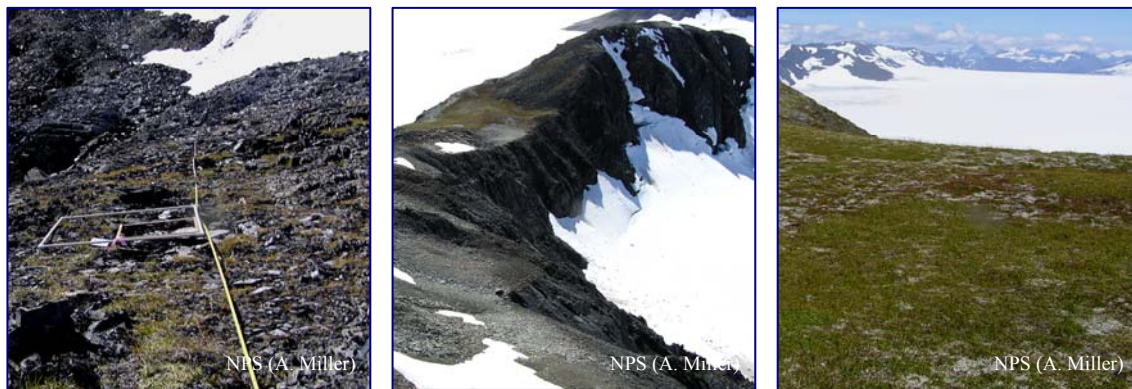


Figure 7. Northern Kenai Mountains-Harding Icefield, KEFJ. Sites ranged from relatively young, with poorly developed soils and vegetation (e.g., Bear Glacier site; left), to older sites with deep soils and high vascular and nonvascular cover (e.g., Skilak Glacier site; center and right). The taxa at each site ranged from more interior (e.g., dry graminoid-dwarf shrub tundra, dominated by *Carex microchaeta* and *Luzula arcuata*) to more coastal and/or snowbed species (e.g., mesic graminoid-dwarf shrub heath, dominated by *Luetkea pectinata*). Two sites that were inventoried but not used for baseline monitoring (Dinglestadt Glacier, Split Glacier sites) were included in this northern Harding Icefield complex.

Southern Kenai Mountains – Petrof-Wosnesenski Glacier Complex

The sites in the southern Kenai Mountains near the head of Wosnesenski (Site 4) and Petrof Glaciers (Site 5) (Fig. 8; Table 1, 4) supported a diverse flora that included both rare and disjunct species. We collected a total of 60 vascular and 16 nonvascular taxa at the two sites. Eight new vascular plant records for the park were collected at the Wosnesenski Glacier site, and one was collected at the Petrof Glacier site. Six collections were of species that were expected to occur in the park, but that were previously unconfirmed (probably present: *Erigeron humilis*, *Huperzia selago*, *Saxifraga nivalis*, *Thlaspi arcticum*; unconfirmed: *Cryptogramma acrostichoides*, *Saxifraga nelsoniana* ssp. *pacifica*). Three of the new collections were of species not originally expected to occur in the park (*Carex albonigra*, *Epilobium leptocarpum*, *Ranunculus pygmaeus*).

Steep, sandy scree slopes, unstable talus, and gravel ridges supported two species of conservation concern (*Douglasia alaskana* (G3-S3), *Thlaspi arcticum* (G3-S3)) at a site near the head of Wosnesenski Glacier (Site 4). Associated species included *Polemonium pulcherimum*, *Arabis kamchatica*, *Erigeron humilis*, *Romanzoffia sitchensis*, and *Saxifraga rivularis*. A collection of *Carex albonigra*, known from Interior Alaska, represented a significant range extension to the south. Moist, herbaceous meadow patches were found in gullies at the base of cliffs and supported species including *Veronica wormskjoldii*, *Phleum commutatum*, and *Saxifraga nivalis*. Alpine dry meadow was the most common vegetated type and was characterized by well developed soils and graminoids (*Carex microchaeta*, *Luzula arcuata*, *Trisetum spicatum*), forbs (*Artemisia arctica*, *Campanula lasiocarpa*, *Sedum rosea*) and dwarf shrubs (*Salix rotundifolia*). We established transects in this type, which was present both on gentle slopes (< 25°) and on the broad ridge that extends to the southwest. Mountain goats (*Oreamnos americanus*) had been active in the area, and the dry meadows showed the effects of their grazing and trampling.

The Petrof Glacier site was likewise diverse and supported a lush, mesic forb-graminoid meadow on gentle slopes and swales. *Carex phaeocephala* (G4-S1S2), a species of conservation concern,

was found at this site. Community composition was unusual in that species generally found at lower elevations near the coast (e.g., *Carex mertensii*, *Calamagrostis canadensis*, *Athyrium filix-femina*, *Lupinus nootkatensis*) were establishing in former snowbed communities that supported *Luetkea pectinata*, *Carex micropoda*, and *Sibbaldia procumbens*. Thus, the plant community was layered and in transition, with snowbed species forming an understory that was being increasingly shaded out by the faster growing, coastal overstory species. Transects established in this community should provide insight into the successional trajectory this site will take. Mountain goats and voles (*Microtus* spp.) were present at the site.



Figure 8. Southern Kenai Mountains, KEFJ. Sites were lower in elevation and closer to the water than sites further north. Species at the Wosnesenski Glacier site (left) were a mix of coastal and boreal, while those from the Petrof Glacier site (right) were primarily coastal. Several species of conservation concern (*Carex phaeocephala*, *Douglasia alaskana*, *Thlaspi arcticum*) were found at these sites. Lupine (*Lupinus nootkatensis*), bluejoint reedgrass (*Calamagrostis canadensis*) and Merten's sedge (*Carex mertensii*) were establishing in former snowbed communities at the Petrof Glacier site (right).

Changes in nunatak extent

A preliminary comparison of nunatak boundaries mapped from the 1950s survey photography and 2005 IKONOS imagery indicated a mean increase in nunatak area of approximately 30% (n = 20; Table 5). A preliminary comparison of the 1950 mapped boundaries (1:40,000) with the rectified 1950s photos suggests that in most cases the mapped delineations may overestimate nunatak extent. Therefore, we consider our current change estimates conservative. The greatest increases in nunatak area appear to have occurred in the northern half of KEFJ, from the Resurrection River south to the Holgate Glacier (mean increase 45%; n = 8), and in the southern Kenai Mountains (mean increase 34%; n = 6). Sites showing the greatest increase in area also tended to be closest to the ice margin (Fig. 9).

Table 5. Estimated change in nunatak extent for selected sites in KEFJ. Differences are calculated between perimeters mapped from the 1950s survey photography and perimeters digitized from 2005 IKONOS imagery. Mapped boundaries derived from the 1950s photography (1:60,000) appear to overestimate nunatak extent. A dagger (†) denotes nunataks visited during the 2005 inventory.

Region	Glacier complex	1950 ha (acres)	2005 ha (acres)	% change
North	Lowell	11.5 (28.4)	21.8 (53.9)	+ 89.8
North	Exit	19.6 (48.5)	26.5 (65.5)	+ 35.1
North	Bear	43.5 (107.4)	33.9 (83.8)	- 22.0†
North	Bear	31.5 (77.9)	48.5 (119.9)	+ 53.9
North	Skilak	90.3 (223.1)	111.0 (274.2)	+ 22.9†
North	Skilak	79.0 (195.3)	133.5 (330.0)	+ 69.0
North	Skilak	5.5 (13.7)	9.8 (24.1)	+ 75.9
North	Skilak	132.7 (327.8)	174.1 (430.2)	+ 31.3
Central	Holgate	39.8 (98.3)	45.4 (112.1)	+ 14.0†
Central	Holgate	61.1 (150.9)	74.0 (182.9)	+ 21.2
Central	Holgate	44.2 (109.1)	46.8 (115.7)	+ 6.0
Central	Northwestern	25.9 (64.0)	22.3 (55.1)	- 13.9
Central	Northwestern	31.1 (76.9)	26.8 (66.1)	- 14.0
Central	Dinglestadt	28.6 (70.7)	37.7 (93.2)	+ 31.8†
South	Nuka	7.3 (18.1)	9.8 (24.2)	+ 33.7
South	Petrof	54.7 (135.2)	90.9 (224.7)	+ 66.2†
South	Wosnesenski	156.1 (385.6)	142.1 (351.2)	- 8.9
South	Wosnesenski	58.3 (144.0)	90.6 (223.8)	+ 55.4†
South	Wosnesenski	29.9 (74.0)	29.2 (72.1)	- 2.6
South	Wosnesenski	14.1 (34.9)	22.6 (55.9)	+ 60.2
Total		2383.8	2958.6	+ 30.2

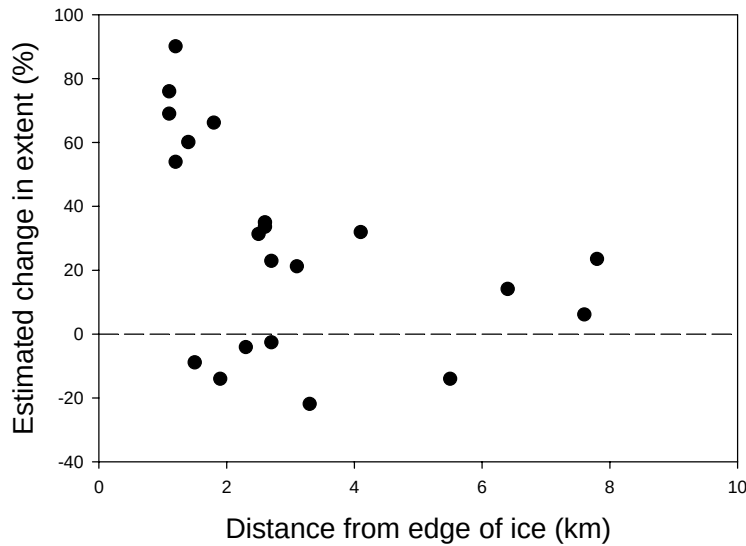


Figure 9. Relationship between the change in nunatak area and minimum distance to the edge of the ice, as measured from 2005 imagery for KEFJ. Positive values on the Y-axis reflect estimated increases in nunatak area; negative values reflect calculated decreases. Sites showing the greatest increases in area were those closest to the ice margin.

DISCUSSION

Species of conservation concern

Nunataks in LACL and KEFJ supported a total of seven species of conservation concern. Several of these taxa are widespread outside of Alaska, but are known from very few sites within the state (e.g., *Arabis lemmonii*, *Potentilla drummondii*, *Arnica diversifolia*). Although not in danger of extinction globally, they are of critical conservation concern in Alaska. These populations often occur at the edge of their range or are otherwise genetically isolated from the core population, and as a result they may be under different selective regimes than populations in the middle of their range. Populations in Alaska are essentially disjunct from those at lower latitudes, and because of limitations to gene flow often show greater ecological, morphological, and evolutionary divergence than populations outside. Additionally, peripheral populations are more likely to suffer from inbreeding depression and low levels of additive genetic variation, rendering them more susceptible to extinction (Newman and Pilson 1997). The collections of *Arabis lemmonii* from Double Glacier and Saddle Mountain are significant because of the rarity of this taxon in Alaska, and because the populations are so widely disjunct from the nearest known populations on the Alaska-Yukon border (Cook and Roland 2002).

A second class of rare species are those that are endemic to Alaska and/or the Yukon Territory, but that are known from a large enough region that they are not considered to be threatened by extirpation. These species are classified as rare or uncommon globally (e.g., *Douglasia alaskana*, *Papaver alboroseum*, *Thlaspi arcticum*), and are likewise rare within the state (i.e., G3-S3; Table 3b). A brief description of each species follows.

Arabis lemmonii Wats (G5-S1)

Arabis lemmonii (Lemmon's rockcress; Figs. 5, 11) occurred at two sites in LACL (northern Double Glacier nunatak (60.7126 °N, 152.6580 °W); Saddle Mountain (60.0019 °N, 152.8051 °W)). An arctic-alpine species that occurs from British Columbia south to California and east to the Rocky Mountains, it is rare in the Yukon Territory (Douglas et al. 1981) and is known from only four locations in the Mentasa and St. Elias Mountains, Alaska (Cook and Roland 2002; Fig. 10). Interestingly, the Canadian populations are reported from the Marble Mountain Nunataks, near the Llewellyn Glacier (ALA database 2006). It occurs on coarse gravel and sandy substrates, on high ridges and rock outcrops. The Saddle Mountain population tended to lack some traits typically associated with *Arabis lemmonii*, suggesting prolonged isolation leading to founder effects, or possibly to genetic drift. The genetic makeup of the Saddle Mountain population may warrant further study, particularly given the proximity of the Double Glacier population 80 km (50 miles) away. Estimated population size was 100 individuals at Saddle Mountain and approximately 40 individuals at Double Glacier.

Arnica diversifolia Greene (pro sp.) (G5-S1)

Arnica diversifolia (rayless arnica; Fig. 11) was found at Saddle Mountain, LACL (60.0089 °N, 152.8107 °W). It is known from a limited number of sites in the Chugach and Talkeetna Mountains and from one site on SW Kodiak Island (Fig. 10). It occurs in mesic sites at mid- to high elevations in the mountains. The species has been described as a complex series of apparent hybrids involving either *A. mollis* or *A. amplexicaulis* and *A. cordifolia* or *A. latifolia* (Cronquist 1955; USDA-NRCS 2003), but is listed as a synonym of *A. ovata* Greene in the *Arnica* treatment

of the Flora of North America (2006). The estimated population size at Saddle Mountain was approximately 50 individuals.

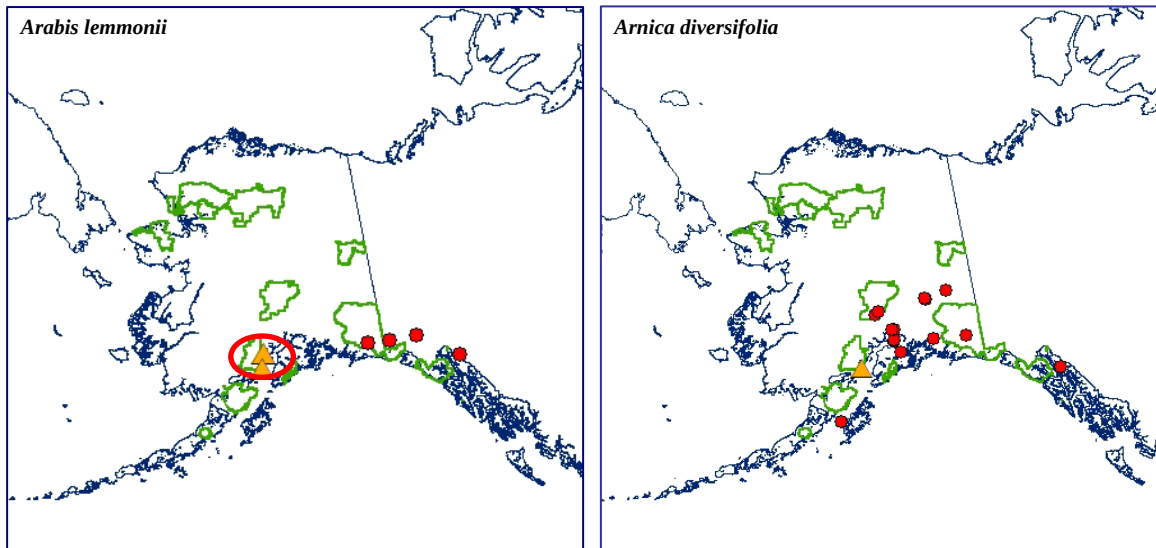


Figure 10. Distribution of *Arabis lemmonii* (G5-S1) and *Arnica diversifolia* (G5-S1) in Alaska and the surrounding region (Hultén 1968; ALA and NPS databases 2006). Previous collections are shown in red. Our collections in LACL are indicated by yellow triangles. A potential range extension to the west is shown for *A. lemmonii* (circled).



Figure 11. *Arabis lemmonii* and *Arnica diversifolia*. Both species were collected from Saddle Mountain, LACL. A second population of *A. lemmonii* was found on the Double Glacier.

Carex phaeocephala Piper (G4-S1S2)

Carex phaeocephala (dunhead sedge) occurred at two sites in LACL (northern Double Glacier nunatak (60.7126 °N, 152.6580 °W); Saddle Mountain (60.1249 °N, 152.8089 °W)) and one site in KEFJ (Petrof Glacier nunatak (59.4415 °N, 150.8558 °W)). The species is found throughout high montane regions of the west (Mastrogriuseppe et al. 2002), but is confined to a few populations in the Coastal Mountains of southeast Alaska, and the Wrangell and Chugach Mountains, and the western Alaska Range. The collections in Kenai Fjords (2003, 2005) are significant range-fillers, linking the highly disjunct western Alaska Range collection with

populations in southeastern Alaska and the Yukon Territory (Fig. 12). Estimated population size was approximately 20 individuals at the Double Glacier site and 50-100 individuals at Saddle Mountain. Recent collections in south central and southwest Alaska suggest that this species may be more common than previously believed.

Douglasia alaskana (Coville & Standl. ex Hultén) S. Kelso (G3-S3)

Douglasia alaskana (Alaska rock jasmine; Fig. 13) was found on the Wosnesenski Glacier nunatak, KEFJ (59.4441 °N, 150.9458 °W). The species is an Alaska-Yukon endemic with a Pacific-coastal distribution. It is considered rare in Alaska and the Yukon Territory (Douglas et al. 1981). It is known in Alaska from the Chugach and Wrangell Mountains (Fig. 12). It is found at high elevations in well-drained sand and gravels, rock crevices, outcrops and scree. The population size at the Wosnesenski Glacier site was estimated at <10 individuals.

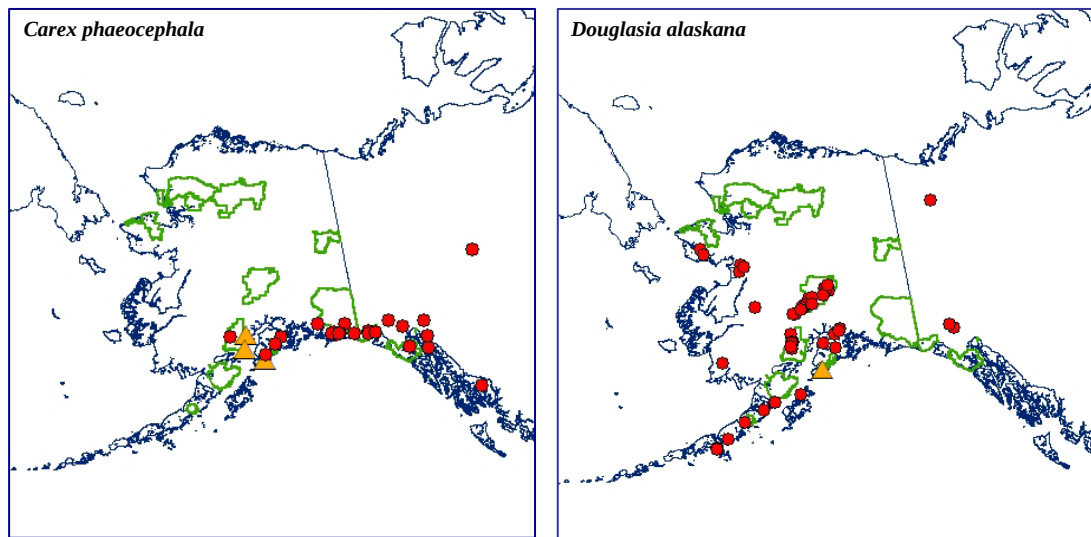


Figure 12. Distribution of *Carex phaeocephala* (G4-S1S2) and *Douglasia alaskana* (G3G4-S3) in Alaska and the surrounding region (Hultén 1968; ALA and NPS databases 2006). Previous collections are shown in red. Our collections in LACL and KEFJ are indicated by yellow triangles.

Papaver alboroseum Hultén (G3G4-S3)

Papaver alboroseum (pale poppy; Fig. 13) occurred at the Saddle Mountain site, LACL (60.0091 °N, 152.8029 °W). The species is found on well drained soils and rock outcrops, from sea-level to at least 2000 m, with population centers in central Alaska and Kamchatka (Russia). In Alaska, it is known from the Chugach, Kenai and Wrangell Mountains, the western Alaska Range and the Alaska Peninsula (Fig. 14). It is also known from at least twenty sites in Kamchatka and the northern Kurile Islands, as well as from northwest British Columbia and the southwest Yukon Territory. Population size at Saddle Mountain was estimated at 20-50 individuals.



Figure 13. *Douglasia alaskana* and *Papaver alboroseum*. *Douglasia* was found on the Wosnesenski Glacier, KEFJ. *Papaver alboroseum* was collected at Saddle Mountain, LACL.

Potentilla drummondii Lehm (G5-S2)

Potentilla drummondii (Drummond's cinquefoil; Fig. 16) was found on the northern Double Glacier nunatak, LACL (60.7126 °N, 152.6580 °W). It is a North American cordilleran species disjunct in Alaska from southern British Columbia, southwest Alberta, and the Cascade Mountains of Oregon, Washington, and northern California (Hitchcock and Cronquist 1961). Collections in Alaska are limited to the Chugach, Talkeetna, and St. Elias Mountains (Cook and Roland 2002; Fig. 14). It is found in forest openings, mesic meadows and high ridges, and at mid- to high elevations in the mountains. Estimated population size was 100-200 individuals.

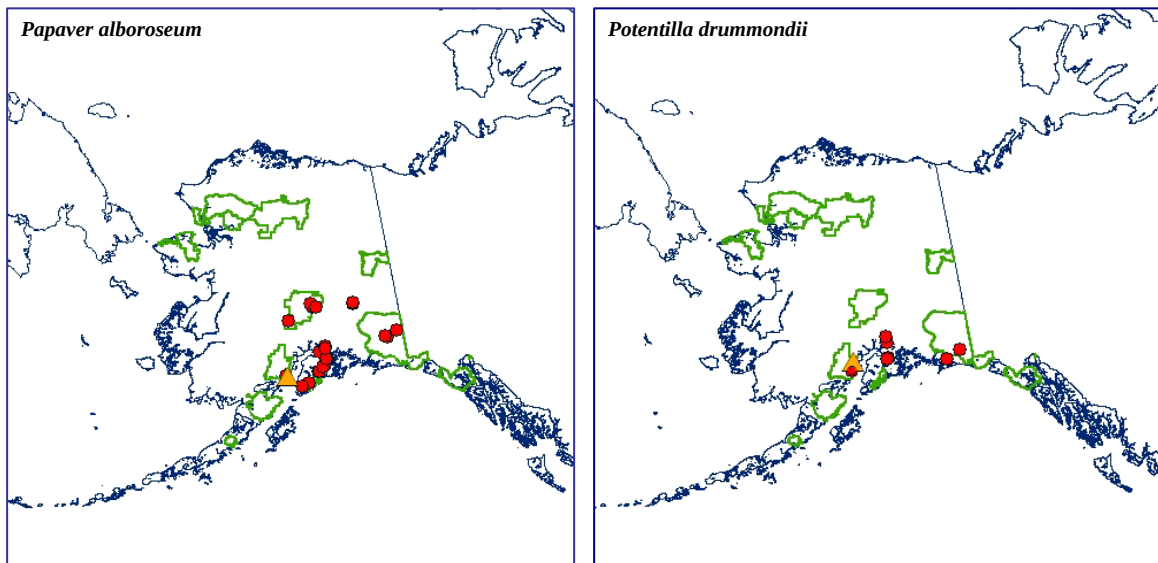


Figure 14. Distribution of *Papaver alboroseum* (G3G4-S3) and *Potentilla drummondii* (G5-S2) in Alaska and the surrounding region (Hultén 1968; ALA and NPS databases 2006). Previous collections are shown in red. Our collections in LACL are indicated by yellow triangles.

Thlaspi arcticum Porsild (G3-S3)

Thlaspi arcticum (arctic pennycress) occurred at Saddle Mountain, LACL (60.1249 °N, 152.8089 °W) and on the Wosnesenski Glacier nunatak, KEFJ (59.4441 °N, 150.9458 °W). It is an Alaska-Yukon endemic with an arctic-alpine distribution and is considered rare in both Alaska and the Yukon Territory (Douglas et al. 1981). In Alaska, it is known from the Wrangell Mountains, and North Campbell Creek Canyon and Windy Creek in the Chugach Mountains (Cook and Roland 2002; Fig. 15). Estimated population size at Saddle Mountain was 20-30 individuals.

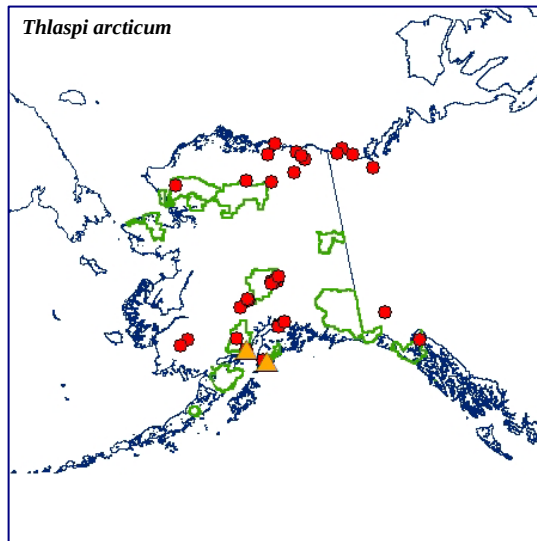


Figure 15. Distribution of *Thlaspi arcticum* (G3-S3) in Alaska and the surrounding region (Hultén 1968; ALA and NPS databases 2006). Previous collections are shown in red. Our collections in LACL and KEFJ are indicated by the yellow triangles.



Figure 16. *Potentilla drummondii* was collected on the Double Glacier (northern nunatak), LACL.

Range extensions and range fillers

LACL

Collections of *Arabis lemmonii*, *Kumlienella cooleyae* (= *Ranunculus cooleyae*), and *Erigeron compositus* from Saddle Mountain and the northern Double Glacier nunatak represent new range extensions to the west. All three are new records for LACL. These collections, and the presence of at least three other Rocky Mountain disjuncts (*Potentilla drummondii*, *Arnica diversifolia*, *Anemone multifida*), suggest that a number of other Rocky Mountain species may have been found in the Alaska Range during interglacial periods. While most populations may have been lost during the intervening glacial advances, a few small populations may have persisted at sites such as the Double Glacier nunatak.

Erigeron compositus (mountain fleabane; Fig. 17) is found from Arizona and California, northeast through the intermountain west and throughout the high latitudes of Canada. In Alaska, *E. compositus* is found in the Copper River, Tanana, and upper Yukon Basins, and in the western Arctic. Our collection of *Erigeron compositus* from Double Glacier was found 175 km (110 miles) from the nearest population near the Turnagain Arm (Fig. 18).

Kumlienia cooleyae (Cooley's false buttercup; Fig. 17) is a snowbank species found in coastal Alaska, British Columbia, and south into western Washington. Collections from southeast Alaska are from the St. Elias and Robinson Mountains, the Alexander Archipelago, and areas along Prince William Sound. Our collection of *Kumlienia cooleyae* from Double Glacier was found 260 km (160 miles) from the nearest populations along western Prince William Sound (Fig. 18).

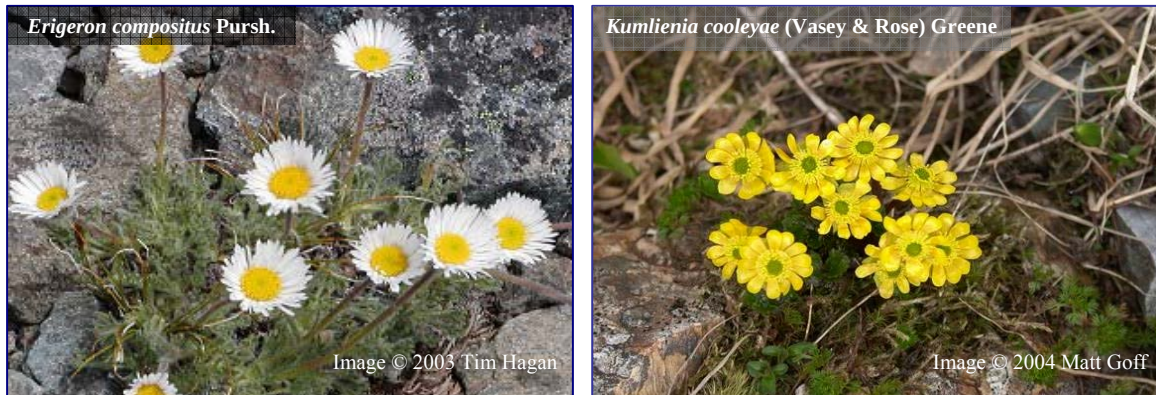


Figure 17. *Erigeron compositus* and *Kumlienia cooleyae*. Collections from LACL (2005) represent significant range extensions to the west. Both species were found at a single site on Double Glacier.

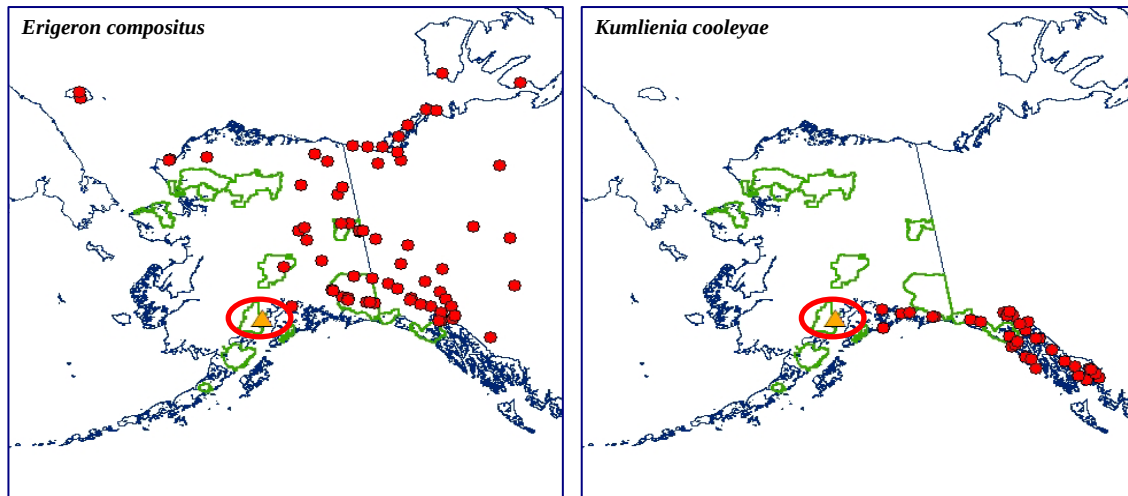


Figure 18. Distribution of *Erigeron compositus* and *Kumlienia cooleyae* in Alaska and the surrounding region (Hultén 1968; ALA and NPS databases 2006). Previous collections are shown in red. Our collections in LACL are shown by yellow triangles and represent potential range extensions to the west (circled).

Anemone multifida (Pacific anemone) is a widespread montane species known from the Yakutat Forelands to the Kenai, Chugach, and Wrangell-St. Elias Ranges, and from a single site in the Brooks Range. Our collection from Double Glacier is the first from the west side of Cook Inlet. The population was found approximately 150 km (90 mi) from the nearest collections at Kachemak Bay (Fig. 19).

Arabis lemmonii (Lemmon's rockcress; Figs. 5, 11), was collected at both Double Glacier and Saddle Mountain and was found approximately 555 km (345 miles) from the nearest collections in Wrangell-St. Elias (Fig. 12). Information regarding its distribution is provided in the previous section (*Species of conservation concern*).

Arnica diversifolia (= *A. ovata*; rayless arnica; Fig. 11) was collected at Saddle Mountain and represents the southernmost population known on the Alaska Peninsula (Fig. 12). Information regarding its distribution is provided in the previous section (*Species of conservation concern*).

KEFJ

A single collection of *Carex albonigra* (black-and-white sedge) from the Wosnesenski Glacier nunatak represents the southernmost collection of this species in the state. *Carex albonigra* is a widespread taxon found at high elevations on rocky slopes and summits. It occurs from California to Arizona, north to Alaska and the Yukon Territory. The Kenai Fjords collection is a new record for the Park and was found approximately 285 km (180 miles) south of the nearest collections in the Knik River drainage (Fig. 19).

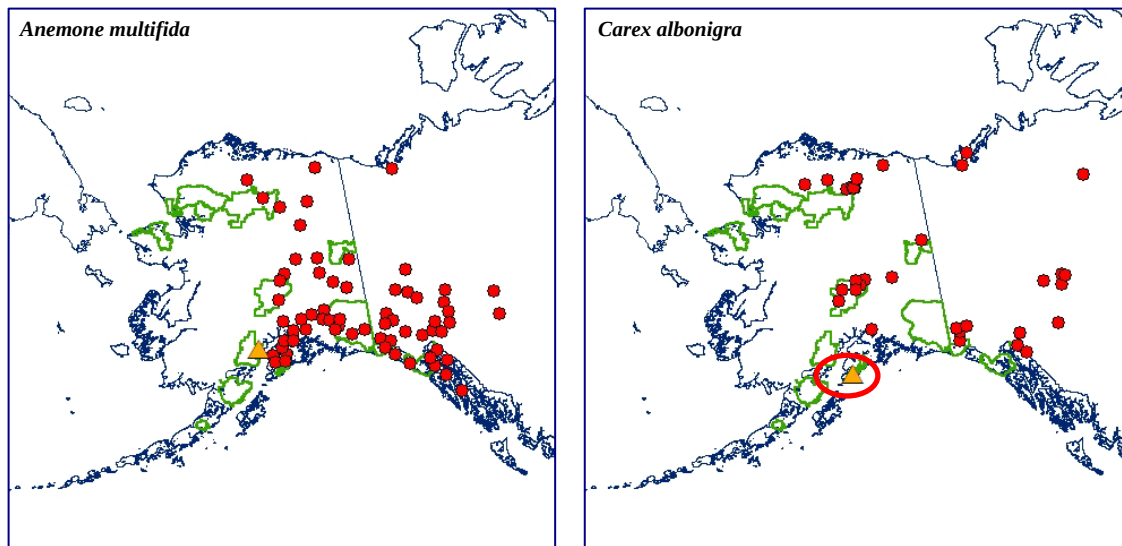


Figure 19. Distribution of *Anemone multifida* and *Carex albonigra* in Alaska and the surrounding region (Hultén 1968; ALA and NPS databases 2006). Previous collections are shown in red. Our collections in LACL and KEFJ are indicated by yellow triangles. A potential range extension to the south is shown for *C. albonigra* (circled). The collection of *Anemone multifida* in LACL is the first record of this species on the west side of Cook Inlet.

Ecological characteristics of nunataks in the Southwest Alaska Network

It is notable that three of the eleven sites supported 90% of the rare and or disjunct species collected. These sites, the northern Double Glacier nunatak (LACL), Saddle Mountain (LACL), and the Wosnesenski Glacier nunatak (KEFJ), may have been ice free long enough for these species assemblages to develop (e.g., during an interglacial period) and persist through the LGM. While there is evidence that Saddle Mountain was ice-free during the LGM (see refs in Manley 2002; Fig. 6), we have little information regarding the age of the two other nunatak sites. However, the high levels of endemism and occurrence of Rocky Mountain disjuncts at both sites is suggestive, and similar species occurrences at sites in the Alps have been consistent with molecular evidence for glacial refugia (Schönswetter et al. 2005).

Results of the ongoing study at the Royal British Columbia Museum and University of Victoria may provide us with a meaningful description of the genetic structure of these alpine populations, and a greater understanding of the glacial history at these sites. Long-term monitoring of the nunatak communities may provide additional information regarding successional pathways and the demography of selected populations. Baseline monitoring indicated that these nunatak communities (northern Double Glacier, Wosnesenski Glacier) were among the most species-rich, and these sites and several others (southern Double Glacier (LACL), Tuxedni (LACL), Skilak (KEFJ)) had the deep, well-developed soils and diverse nonvascular communities indicative of older sites. While we do not have data from adjacent, unglaciated alpine areas, it appears that these nunatak sites are often as floristically rich, if not more so, than alpine sites off of the ice.

While the nunatak sites appear to have remained stable in terms of their glacial history, they are visibly dynamic in response to other drivers. The Double Glacier sites in LACL, for example, appear to be recovering from the 1989-1990 eruption of Mt. Redoubt that buried many of the low shrubs and apparently decimated the nonvascular community. The location of the two nunatak sites relative to Redoubt has resulted in a successional sequence that approximates a chronosequence (via a space for time substitution). The southern site, which is closest to Redoubt, received heavier ash fall and has been slower to recover. The northern site, which is more distant from Redoubt, shows fewer signs of damage.

The Petrof Glacier site in KEFJ is another example of a community in transition. We found lowland coastal species including bluejoint reedgrass (*Calamagrostis canadensis*), Merten's sedge (*Carex mertensii*), and Nootka lupine (*Lupinus nootkatensis*) establishing in snowbed communities dominated by partridgefoot (*Luetkea pectinata*) and small-awned sedge (*Carex microchaeta*). *Luetkea* was persisting under a dense overstory of *Calamagrostis* and *Lupinus*, suggesting that the establishment of the latter species had been relatively recent (e.g., <10 years). Whether the influx of these lowland species was due to changing air circulation patterns (e.g., a change in wind direction, bringing seed from coastal species inland), to reduced snowpack and/or a longer growing season, or to a combination of other factors, is uncertain. It is unusual to find *Luetkea* and *Calamagrostis* together, although warmer temperatures and lower than average snowfall within the last 10-15 years could potentially facilitate the replacement of a snowbed species with faster growing, more drought-tolerant species such as *Calamagrostis*. A comparison of 1950s survey photography and 2005 IKONOS imagery at this site indicates a roughly 66% increase in nunatak extent over the last 55 years (Fig. 20), suggesting a combination of reduced snowfall and/or accelerated melt (ablation).

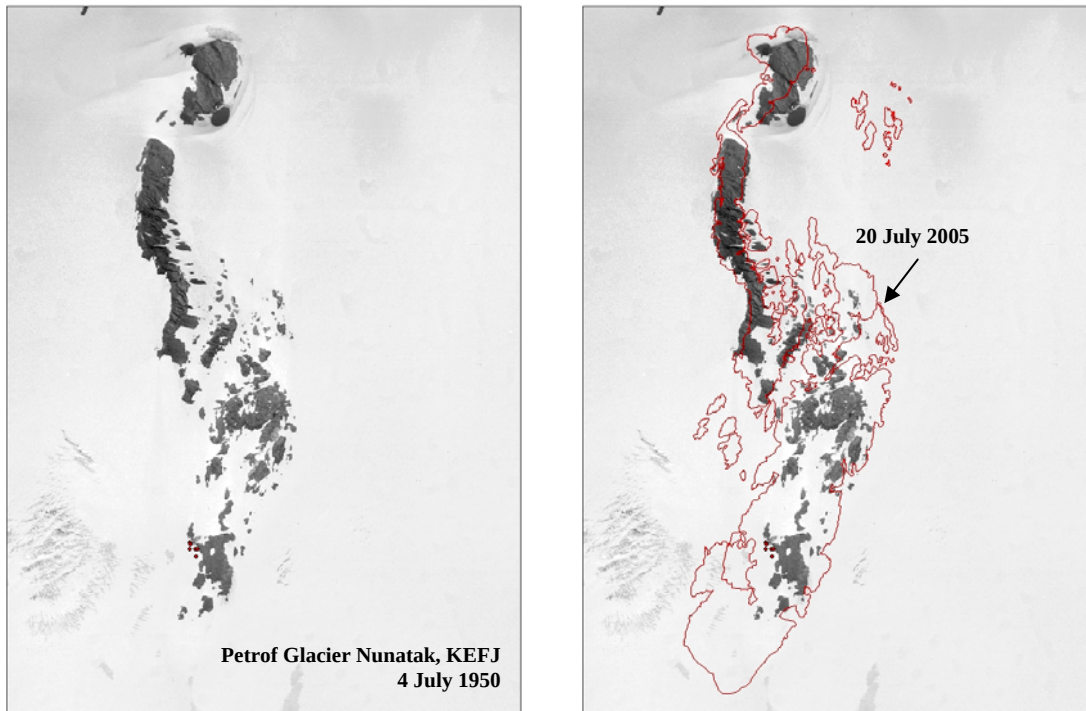


Figure 20. Change in extent of Petrof Glacier nunatak, 1950-2005. Perimeter outlined in red (2005) shows a greater than 7-fold increase in snow- and ice-free area between the two dates. Estimated change in nunatak extent from the 1950s DRGs and 2005 IKONOS is approximately 66%.

This type of change in nunatak extent could facilitate the immigration and establishment of new species, as appears to be happening at the Petrof Glacier site. In such cases, nunataks may be considered sinks for plant migration, although they are not expected to be of any greater risk of invasion by non-native species than recently deglaciated lowland sites. Older sites (e.g., Saddle Mountain) may instead have served as sources of new species to surrounding areas that gradually became ice free. Whether the two *Arabis* populations at Saddle Mountain and Double Glacier (LACL) are genetically related, for example, is uncertain, but it appears that the Saddle Mountain population is unique, perhaps owing to prolonged isolation. It is unclear how previously isolated populations of rare plants will respond to increased opportunities for migration and the encroachment of more common species, especially as nunataks expand and/or become contiguous with larger ice-free regions.

Future monitoring

Protocols are under development to monitor both landscape-level change in the parks, including ice loss, and more localized, community-level change in sensitive plant communities. Future monitoring of species composition on nunataks will occur at 3-5 year intervals for the first 10 years, and then at 5-10 year intervals thereafter. Potential projects associated with nunatak monitoring could include radiometric dating of bedrock surfaces and/or additional genetic analyses for selected nunatak populations (e.g., for several of the Rocky Mountain disjuncts). Ancillary weather station data and ongoing image analyses will supplement the monitoring efforts and increase our ability to document change in these ecosystems.

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Appendix I. Vascular and nonvascular collections, Lake Clark NPP and Kenai Fjords NP, July-August 2005.

Vascular plant collections, 2005 Nunatak Inventory

Lake Clark NPP

Trinomial	Family	Locality
<i>Agrostis mertensii</i>	Poaceae	Double Glacier Nunatak (south) (60.6882, -152.5862)
<i>Agrostis mertensii</i>	Poaceae	Saddle Mt. (60.0019, -152.8051)
<i>Anemone multifida</i>	Ranunculaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Antennaria alpina</i>	Asteraceae	Saddle Mt. (60.0019, -152.8051)
<i>Antennaria rosea</i> ssp. <i>pulvinata</i>	Asteraceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Arabis kamchatica</i>	Brassicaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Arabis lemmonii</i>	Brassicaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Arabis lemmonii</i>	Brassicaceae	Saddle Mt. (60.0019, -152.8051)
<i>Arctagrostis latifolia</i>	Poaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Arctostaphylos alpina</i>	Ericaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Arnica chamissonis</i>	Asteraceae	Saddle Mt. (60.0089, -152.8107)
<i>Arnica diversifolia</i> (= <i>A. ovata</i>)	Asteraceae	Saddle Mt. (60.0089, -152.8107)
<i>Arnica lessingii</i>	Asteraceae	Saddle Mt. (60.0089, -152.8107)
<i>Artemisia arctica</i>	Asteraceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Astragalus polaris</i>	Fabaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Botrychium lanceolatum</i>	Ophioglossaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Botrychium lanceolatum</i>	Ophioglossaceae	Saddle Mt. (60.0089, -152.8107)
<i>Botrychium pinnatum</i>	Ophioglossaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Botrychium pinnatum</i>	Ophioglossaceae	Saddle Mt. (60.0089, -152.8107)
<i>Campanula lasiocarpa</i>	Campanulaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Carex lachenalii</i>	Cyperaceae	Saddle Mt. (60.0089, -152.8107)
<i>Carex lachenalii</i>	Cyperaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Carex microchaeta</i> ssp. <i>nesophila</i>	Cyperaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Carex micropoda</i>	Cyperaceae	Double Glacier Nunatak (south) (60.6882, -152.5862)
<i>Carex micropoda</i>	Cyperaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Carex micropoda</i>	Cyperaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Carex micropoda</i>	Cyperaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Carex nigricans</i>	Cyperaceae	Double Glacier Nunatak (south) (60.6882, -152.5862)
<i>Carex phaeocephala</i>	Cyperaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Carex phaeocephala</i>	Cyperaceae	Double Glacier Nunatak (south) (60.6882, -152.5862)
<i>Carex phaeocephala</i>	Cyperaceae	Saddle Mt. (60.0089, -152.8107)
<i>Cassiope lycopodioides</i>	Ericaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)

Trinomial	Family	Locality
<i>Cassiope tetragona</i>	Ericaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Cerastium beeringianum</i>	Caryophyllaceae	Saddle Mt. (60.0019, -152.8051)
<i>Dasiphora floribunda</i>	Rosaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Diapensia lapponica</i>	Diapensiaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Diphasiastrum sitchense</i>	Lycopodiaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Draba stenoloba</i>	Brassicaceae	Saddle Mt. (60.1249, -152.8089)
<i>Dryas integrifolia</i>	Rosaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Elymus trachycaulus</i> ssp. <i>violaceus</i>	Poaceae	Saddle Mt. (60.0089, -152.8107)
<i>Empetrum hermaphroditum</i>	Empetraceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Epilobium hornemannii</i>	Onagraceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Erigeron compositus</i>	Asteraceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Erigeron peregrinus</i>	Asteraceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Festuca altaica</i>	Poaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Festuca altaica</i>	Poaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Festuca brachyphylla</i>	Poaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Festuca brachyphylla</i>	Poaceae	Saddle Mt. (60.0019, -152.8051)
<i>Harrimanella stellariana</i>	Ericaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Hieracium triste</i>	Asteraceae	Double Glacier Nunatak (south) (60.6882, -152.5862)
<i>Hierochloa alpina</i>	Poaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Huperzia selago</i>	Lycopodiaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Juncus biglumis</i>	Juncaceae	Double Glacier Nunatak (south) (60.6882, -152.5862)
<i>Juncus drummondii</i>	Juncaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Juncus mertensianus</i>	Juncaceae	Double Glacier Nunatak (south) (60.6882, -152.5862)
<i>Kumlienella cooleyae</i>	Ranunculaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Ledum palustre</i>	Ericaceae	Double Glacier Nunatak (south) (60.6882, -152.5862)
<i>Loiseleuria procumbens</i>	Ericaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Luetkea pectinata</i>	Rosaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Lupinus nootkatensis</i>	Fabaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Luzula arcuata</i> ssp. <i>unalaschensis</i>	Juncaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Luzula arcuata</i> ssp. <i>unalaschensis</i>	Juncaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Luzula piperi</i>	Juncaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Luzula spicata</i>	Juncaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Minuartia biflora</i>	Caryophyllaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Minuartia macrocarpa</i>	Caryophyllaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Myosotis asiatica</i>	Boraginaceae	Saddle Mt. (60.0089, -152.8107)
<i>Oxyria digyna</i>	Polygonaceae	Saddle Mt. (60.0089, -152.8107)
<i>Oxyria digyna</i>	Polygonaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)

Trinomial	Family	Locality
<i>Oxytropis jordalii</i>	Fabaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Papaver alboroseum</i>	Papaveraceae	Saddle Mt. (60.0089, -152.8107)
<i>Pedicularis lanata</i>	Scrophulariaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Phyllodoce aleutica</i>	Ericaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Poa alpina</i>	Poaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Poa glauca</i>	Poaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Poa paucispicula</i>	Poaceae	Double Glacier Nunatak (south) (60.6882, -152.5862)
<i>Poa paucispicula</i>	Poaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Polemonium pulcherrimum</i>	Polemoniaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Polygonum viviparum</i>	Polygonaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Potentilla diversifolia</i>	Rosaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Potentilla drummondii</i>	Rosaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Potentilla uniflora</i>	Rosaceae	Saddle Mt. (60.0089, -152.8107)
<i>Potentilla uniflora</i>	Rosaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Potentilla villosa</i>	Rosaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Ranunculus eschscholtzii</i>	Ranunculaceae	Double Glacier Nunatak (south) (60.6882, -152.5862)
<i>Rhodiola integrifolia</i>	Crassulaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Sagina saginoides</i>	Caryophyllaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Salix arctica</i>	Salicaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Salix barclayi</i>	Salicaceae	Double Glacier Nunatak (south) (60.6882, -152.5862)
<i>Salix polaris</i>	Salicaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Salix polaris</i>	Salicaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Salix pulchra</i>	Salicaceae	Double Glacier Nunatak (south) (60.6882, -152.5862)
<i>Salix pulchra</i>	Salicaceae	Saddle Mt. (60.0089, -152.8107)
<i>Salix reticulata</i>	Salicaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Salix rotundifolia</i>	Salicaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Saxifraga bronchialis</i>	Saxifragaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Saxifraga nelsoniana</i>	Saxifragaceae	Saddle Mt. (60.0089, -152.8107)
<i>Saxifraga nelsoniana</i>	Saxifragaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Saxifraga oppositifolia</i>	Saxifragaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Saxifraga rivularis</i>	Saxifragaceae	Saddle Mt. (60.0089, -152.8107)
<i>Senecio lugens</i>	Asteraceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Senecio triangularis</i>	Asteraceae	Double Glacier Nunatak (south) (60.6882, -152.5862)
<i>Sibbaldia procumbens</i>	Rosaceae	Double Glacier Nunatak (north) (60.7126, -152.658)
<i>Sibbaldia procumbens</i>	Rosaceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)
<i>Silene acaulis</i>	Caryophyllaceae	Saddle Mt. (60.0089, -152.8107)
<i>Solidago multiradiata</i>	Asteraceae	Tuxedni Glacier Nunatak (60.1539, -153.1296)

Trinomial

Stellaria longipes
Taraxacum alaskanum
Thlaspi arcticum
Trisetum spicatum
Trisetum spicatum
Vahlodea atropurpurea
Veratrum viride
Veronica wormskjoldii
Viola langsdoeffii

Family

Caryophyllaceae
Asteraceae
Brassicaceae
Poaceae
Poaceae
Poaceae
Liliaceae
Scrophulariaceae
Violaceae

Locality

Saddle Mt. (60.0089, -152.8107)
Tuxedni Glacier Nunatak (60.1539, -153.1296)
Saddle Mt. (60.1249, -152.8089)
Double Glacier Nunatak (south) (60.6882, -152.5862)
Tuxedni Glacier Nunatak (60.1539, -153.1296)
Tuxedni Glacier Nunatak (60.1539, -153.1296)
Double Glacier Nunatak (south) (60.6882, -152.5862)
Tuxedni Glacier Nunatak (60.1539, -153.1296)
Tuxedni Glacier Nunatak (60.1539, -153.1296)

Kenai Fjords NP**Trinomial**

Achillea borealis
Agrostis mertensii
Agrostis mertensii
Agrostis mertensii
Agrostis mertensii
Antennaria alpina
Antennaria alpina
Antennaria alpina
Arabis kamchatica
Arnica grisea
Artemisia arctica
Artemisia arctica
Artemisia arctica
Aster sibirica
Astragalus alpinus
Athyrium filix-femina
Campanula lasiocarpa
Campanula lasiocarpa
Campanula rotundifolia
Cardamine bellidifolia
Carex albonigra
Carex lachenalii
Carex lachenalii
Carex microchaeta ssp. nesophila
Carex micropoda

Family

Asteraceae
Poaceae
Poaceae
Poaceae
Poaceae
Asteraceae
Asteraceae
Asteraceae
Brassicaceae
Asteraceae
Asteraceae
Asteraceae
Asteraceae
Fabaceae
Dryopteridaceae
Campanulaceae
Campanulaceae
Campanulaceae
Brassicaceae
Cyperaceae
Cyperaceae
Cyperaceae
Cyperaceae
Cyperaceae

Locality

near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
near head of Holgate Glacier (59.91723663, -150.0349869)
W fork of Petrof Glacier (59.4426181, -150.8547181)
W fork of Petrof Glacier (59.44437975, -150.8534814)
SE side of Split Glacier (59.652081, -150.4894635)
head of Bear Glacier (60.07826522, -149.7810884)
near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
W fork of Petrof Glacier (59.4426181, -150.8547181)
near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
head of Tustumena Glacier (59.9275883, -150.2060995)
near head of Skilak Glacier (60.14546866, -149.8932434)
near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
SE side of Split Glacier (59.652081, -150.4894635)
near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
W fork of Petrof Glacier (59.44437975, -150.8534814)
near head of Skilak Glacier (60.14546866, -149.8932434)
near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
W fork of Petrof Glacier (59.4426181, -150.8547181)
head of Bear Glacier (60.07826522, -149.7810884)
near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
head of Bear Glacier (60.07826522, -149.7810884)
SE side of Split Glacier (59.652081, -150.4894635)
near head of Holgate Glacier (59.91723663, -150.0349869)
head of Bear Glacier (60.07826522, -149.7810884)

Trinomial	Family	Locality
<i>Carex micropoda</i>	Cyperaceae	lower Dinglestadt Glacier (59.65647185, -150.3728245)
<i>Carex phaeocephala</i>	Cyperaceae	W fork of Petrof Glacier (59.4426181, -150.8547181)
<i>Carex spectabilis</i>	Cyperaceae	SE side of Split Glacier (59.652081, -150.4894635)
<i>Cassiope lycopodioides</i>	Ericaceae	SE side of Split Glacier (59.652081, -150.4894635)
<i>Cochlearia sessilifolia</i>	Brassicaceae	N Arm of Nuka Bay (59.54233829, -150.6618065)
<i>Coeloglossum viride ssp. bracteatum</i>	Orchidaceae	W fork of Petrof Glacier (59.4426181, -150.8547181)
<i>Cryptogramma acrostichoides</i>	Pteridaceae	near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
<i>Cryptogramma acrostichoides</i>	Pteridaceae	lower Dinglestadt Glacier (59.65647185, -150.3728245)
<i>Deschampsia caespitosa</i>	Poaceae	SE side of Split Glacier (59.652081, -150.4894635)
<i>Diphasiastrum alpinum</i>	Lycopodiaceae	near head of Skilak Glacier (60.14546866, -149.8932434)
<i>Diphasiastrum alpinum</i>	Lycopodiaceae	near head of Holgate Glacier (59.91723663, -150.0349869)
<i>Diphasiastrum sitchense</i>	Lycopodiaceae	near head of Holgate Glacier (59.91723663, -150.0349869)
<i>Douglasia alaskana</i>	Primulaceae	near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
<i>Dryopteris expansa</i>	Dryopteridaceae	near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
<i>Dryopteris expansa</i>	Dryopteridaceae	lower Dinglestadt Glacier (59.65647185, -150.3728245)
<i>Epilobium</i>	Onagraceae	near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
<i>Epilobium anagallidifolium</i>	Onagraceae	near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
<i>Epilobium leptocarpum</i>	Onagraceae	W fork of Petrof Glacier (59.4426181, -150.8547181)
<i>Erigeron humilis</i>	Asteraceae	near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
<i>Eriophorum russeolum</i>	Cyperaceae	SE side of Split Glacier (59.652081, -150.4894635)
<i>Festuca brachyphylla</i>	Graminae	near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
<i>Gentiana glauca</i>	Gentianaceae	SE side of Split Glacier (59.652081, -150.4894635)
<i>Hieracium triste</i>	Asteraceae	W fork of Petrof Glacier (59.4426181, -150.8547181)
<i>Hurperzia selago</i>	Lycopodiaceae	near head of Doroshin and Wosnesenski Glaciers (59.44583318, -150.9458046)
<i>Juncus biglumis</i>	Juncaceae	SE side of Split Glacier (59.652081, -150.4894635)
<i>Juncus drummondii</i>	Juncaceae	near head of Holgate Glacier (59.91723663, -150.0349869)
<i>Juncus mertensianus</i>	Juncaceae	W fork of Petrof Glacier (59.44437975, -150.8534814)
<i>Luzula arcuata ssp. unalaschcensis</i>	Juncaceae	head of Bear Glacier (60.07826522, -149.7810884)
<i>Luzula arcuata ssp. unalaschcensis</i>	Juncaceae	near head of Holgate Glacier (59.91723663, -150.0349869)
<i>Luzula arcuata ssp. unalaschcensis</i>	Juncaceae	lower Dinglestadt Glacier (59.65647185, -150.3728245)
<i>Luzula piperi</i>	Juncaceae	lower Dinglestadt Glacier (59.65647185, -150.3728245)
<i>Luzula spicata</i>	Juncaceae	head of Tustumena Glacier (59.9275883, -150.2060995)
<i>Minuartia macrocarpa</i>	Caryophyllaceae	head of Bear Glacier (60.07826522, -149.7810884)
<i>Minuartia macrocarpa</i>	Caryophyllaceae	near head of Skilak Glacier (60.14546866, -149.8932434)
<i>Minuartia macrocarpa</i>	Caryophyllaceae	near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
<i>Minuartia rubella</i>	Caryophyllaceae	near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
<i>Papaver alaskanum</i>	Papaveraceae	near head of Doroshin and Wosnesenski Glaciers (59.44583318, -150.9458046)

Trinomial	Family	Locality
<i>Phleum commutatum</i> var. <i>americanum</i>	Graminae	near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
<i>Phyllodoce aleutica</i>	Ericaceae	near head of Holgate Glacier (59.91723663, -150.0349869)
<i>Poa alpina</i>	Poaceae	W fork of Petrof Glacier (59.4426181, -150.8547181)
<i>Poa arctica</i>	Poaceae	head of Bear Glacier (60.07826522, -149.7810884)
<i>Poa arctica</i>	Poaceae	head of Bear Glacier (60.07826522, -149.7810884)
<i>Poa arctica</i>	Poaceae	near head of Skilak Glacier (60.14546866, -149.8932434)
<i>Poa arctica</i>	Poaceae	near head of Holgate Glacier (59.91723663, -150.0349869)
<i>Poa arctica</i>	Poaceae	head of Tustumena Glacier (59.9275883, -150.2060995)
<i>Poa glauca</i>	Poaceae	head of Tustumena Glacier (59.9275883, -150.2060995)
<i>Poa paucispicula</i>	Poaceae	head of Bear Glacier (60.07826522, -149.7810884)
<i>Poa paucispicula</i>	Poaceae	near head of Skilak Glacier (60.14546866, -149.8932434)
<i>Poa paucispicula</i>	Poaceae	near head of Skilak Glacier (60.14546866, -149.8932434)
<i>Poa paucispicula</i>	Poaceae	W fork of Petrof Glacier (59.44437975, -150.8534814)
<i>Poa paucispicula</i>	Poaceae	near head of Doroshin and Wosnesenski Glaciers (59.44583318, -150.9458046)
<i>Poa paucispicula</i>	Poaceae	SE side of Split Glacier (59.652081, -150.4894635)
<i>Poa paucispicula</i>	Poaceae	near head of Skilak Glacier (60.14546866, -149.8932434)
<i>Poa paucispicula</i>	Poaceae	near head of Skilak Glacier (60.14546866, -149.8932434)
<i>Poa stenantha</i>	Poaceae	W fork of Petrof Glacier (59.4426181, -150.8547181)
<i>Polemonium pulcherrimum</i>	Polemoniaceae	near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
<i>Ranunculus pygmaeus</i>	Ranunculaceae	near head of Doroshin and Wosnesenski Glaciers (59.44583318, -150.9458046)
<i>Romanzoffia sitchensis</i>	Hydrophyllaceae	near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
<i>Sagina nivalis</i>	Caryophyllaceae	near head of Doroshin and Wosnesenski Glaciers (59.44583318, -150.9458046)
<i>Sagina nivalis</i>	Caryophyllaceae	near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
<i>Sagina nivalis</i>	Caryophyllaceae	SE side of Split Glacier (59.652081, -150.4894635)
<i>Salix arctica</i>	Salicaceae	head of Tustumena Glacier (59.9275883, -150.2060995)
<i>Saxifraga bronchialis</i>	Saxifragaceae	head of Bear Glacier (60.07826522, -149.7810884)
<i>Saxifraga caespitosa</i>	Saxifragaceae	near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
<i>Saxifraga ferruginea</i>	Saxifragaceae	near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
<i>Saxifraga nelsoniana</i>	Saxifragaceae	head of Bear Glacier (60.07826522, -149.7810884)
<i>Saxifraga nelsoniana</i> ssp. <i>pacifica</i>	Saxifragaceae	near head of Doroshin and Wosnesenski Glaciers (59.44583318, -150.9458046)
<i>Saxifraga nelsoniana</i> ssp. <i>nelsoniana</i>	Saxifragaceae	lower Dinglestadt Glacier (59.65647185, -150.3728245)
<i>Saxifraga nivalis</i>	Saxifragaceae	near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
<i>Saxifraga rivularis</i>	Saxifragaceae	near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
<i>Sibbaldia procumbens</i>	Rosaceae	near head of Skilak Glacier (60.14546866, -149.8932434)
<i>Sibbaldia procumbens</i>	Rosaceae	near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
<i>Sibbaldia procumbens</i>	Rosaceae	W fork of Petrof Glacier (59.44437975, -150.8534814)
<i>Sibbaldia procumbens</i>	Rosaceae	SE side of Split Glacier (59.652081, -150.4894635)

Trinomial	Family	Locality
<i>Silene acaulis</i>	Caryophyllaceae	near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
<i>Solidago multiradiata</i>	Asteraceae	near head of Holgate Glacier (59.91723663, -150.0349869)
<i>Stellaria calycantha</i>	Caryophyllaceae	W fork of Petrof Glacier (59.4426181, -150.8547181)
<i>Stellaria calycantha</i>	Caryophyllaceae	near head of Doroshin and Wosnesenski Glaciers (59.44583318, -150.9458046)
<i>Stellaria longipes</i>	Caryophyllaceae	near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
<i>Taraxacum alaskanum</i>	Asteraceae	near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
<i>Taraxacum trigonolobum</i>	Asteraceae	W fork of Petrof Glacier (59.4426181, -150.8547181)
<i>Thlaspi arcticum</i>	Brassicaceae	near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
<i>Trisetum spicatum</i>	Poaceae	near head of Holgate Glacier (59.91723663, -150.0349869)
<i>Veronica stelleri</i>	Scrophulariaceae	W fork of Petrof Glacier (59.4426181, -150.8547181)
<i>Veronica wormsjoldii</i>	Scrophulariaceae	near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)
<i>Veronica wormsjoldii</i>	Scrophulariaceae	W fork of Petrof Glacier (59.4426181, -150.8547181)
<i>Woodsia ilvensis</i>	Dryopteridaceae	near head of Doroshin and Wosnesenski Glaciers (59.4458739, -150.943287)

Bryophyte collections, 2005 Nunatak Inventory

Lake Clark NPP

Trinomial	Locality
<i>Andreaea blyttii</i>	Double Glacier (south) (60.688, -152.585)
<i>Arctoa anderssonii</i>	Tuxedni Glacier (60.154, -153.13)
<i>Brachythecium</i> sp.	Tuxedni Glacier (60.154, -153.13)
<i>Ceratodon purpureus</i>	Double Glacier (north) (60.713, -152.658)
<i>Cymodontium suecicum</i>	Tuxedni Glacier (60.154, -153.13)
<i>Dicranoweisia crispula</i>	Tuxedni Glacier (60.154, -153.13)
<i>Dicranum acutifolium</i>	Tuxedni Glacier (60.154, -153.13)
<i>Hygrohypnum alpestre</i>	Tuxedni Glacier (60.154, -153.13)
<i>Marsupellea</i> sp.	Double Glacier (north) (60.713, -152.658)
<i>Oligotrichum hercynicum</i>	Double Glacier (north) (60.713, -152.658)
<i>Pohlia</i> sp.	Tuxedni Glacier (60.154, -153.13)
<i>Polytrichum piliferum</i>	Double Glacier (north) (60.713, -152.658)
<i>Polytrichum sexangulare</i>	Tuxedni Glacier (60.154, -153.13)
<i>Polytrichum sexangulare</i>	Tuxedni Glacier (60.154, -153.13)
<i>Polytrichum sexangulare</i>	Tuxedni Glacier (60.154, -153.13)
<i>Racomitrium canescens</i>	Double Glacier (north) (60.713, -152.658)
<i>Racomitrium muticum</i>	Tuxedni Glacier (60.154, -153.13)
<i>Racomitrium sudeticum</i>	Tuxedni Glacier (60.154, -153.13)
<i>Racomitrium sudeticum</i>	Tuxedni Glacier (60.154, -153.13)
<i>Racomitrium sudeticum</i>	Double Glacier (north) (60.713, -152.658)

Kenai Fjords NP

Trinomial	Locality
<i>Barbilophozia hatcheri</i>	Bear Glacier (60.078, -149.783)
<i>Brachythecium albicans</i>	Petrof Glacier (59.441, -150.856)
<i>Campylopus schimperi</i>	Wosnesenski Glacier (59.444, -150.946)
<i>Dicranoweisia crispula</i>	Wosnesenski Glacier (59.444, -150.946)
<i>Dicranoweisia crispula</i>	Wosnesenski Glacier (59.444, -150.946)
<i>Diplophyllum imbricatum</i>	Wosnesenski Glacier (59.444, -150.946)
<i>Gymnomitrium concinnum</i>	Bear Glacier (60.078, -149.783)
<i>Kiaeria blyttii</i>	Wosnesenski Glacier (59.444, -150.946)
<i>Kiaeria glacialis</i>	Wosnesenski Glacier (59.444, -150.946)
<i>Oligotrichum hercynicum</i>	Bear Glacier (60.078, -149.783)
<i>Polytrichum piliferum</i>	Bear Glacier (60.078, -149.783)
<i>Polytrichum piliferum</i>	Bear Glacier (60.078, -149.783)
<i>Racomitrium canescens</i>	Petrof Glacier (59.441, -150.856)
<i>Racomitrium sudeticum</i>	Bear Glacier (60.078, -149.783)

Lichen collections, 2005 Nunatak Inventory

Lake Clark NPP

Trinomial	Locality
<i>Alectoria ochroleuca</i>	Double Glacier (south) (60.688, -152.585)
<i>Cetraria islandica</i> ssp. <i>crispiformis</i>	Double Glacier (north) (60.713, -152.658)
<i>Cetraria islandica</i> ssp. <i>crispiformis</i>	Double Glacier (south) (60.688, -152.585)

Trinomial

Cetraria islandica ssp. *islandica*
Cetraria nigricans
Cladina mitis
Cladina mitis
Cladonia bellidiflora
Cladonia bellidiflora
Cladonia carneola
Cladonia cervicornis
Cladonia ecmocyna
Cladonia ecmocyna
Cladonia ecmocyna
Cladonia furcata
Cladonia gracilis ssp. *elongata*
Cladonia uncialis
Cladonia uncialis
Cladonia uncialis
Flavocetraria cucullata
Flavocetraria nivalis
Melanelia hepaticum
Nephroma arcticum
Peltigera aphosa
Peltigera leucophlebia
Peltigera leucophlebia
Peltigera malacea
Pseudephebe miniscula
Pseudephebe miniscula
Pseudephebe miniscula
Rhizocarpon geographicum
Solorina crocea
Solorina crocea
Stereocaulon arenarium
Stereocaulon arenarium
Stereocaulon paschale
Stereocaulon paschale
Stereocaulon tomentosum
Thamnolia vermicularis
Thamnolia vermicularis
Tuckermannopsis subalpina
Umbilicaria hyperborea
Umbilicaria hyperborea

Locality

Tuxedni Glacier (60.154, -153.13)
Double Glacier (south) (60.688, -152.585)
Double Glacier (north) (60.713, -152.658)
Tuxedni Glacier (60.154, -153.13)
Tuxedni Glacier (60.154, -153.13)
Tuxedni Glacier (60.154, -153.13)
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Tuxedni Glacier (60.154, -153.13)
Tuxedni Glacier (60.154, -153.13)
Double Glacier (north) (60.713, -152.658)
Double Glacier (north) (60.713, -152.658)
Double Glacier (south) (60.688, -152.585)
Tuxedni Glacier (60.154, -153.13)
Double Glacier (south) (60.688, -152.585)
Double Glacier (south) (60.688, -152.585)
Double Glacier, AK (60.688, -152.585)
Double Glacier (north) (60.713, -152.658)
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Double Glacier (north) (60.713, -152.658)
Tuxedni Glacier (60.154, -153.13)
Double Glacier (north) (60.713, -152.658)
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Tuxedni Glacier (60.154, -153.13)
Tuxedni Glacier (60.154, -153.13)
Tuxedni Glacier (60.154, -153.13)
Double Glacier (north) (60.713, -152.658)
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Tuxedni Glacier (60.154, -153.13)
Double Glacier (north) (60.713, -152.658)
Double Glacier (south) (60.688, -152.585)
Tuxedni Glacier (60.154, -153.13)
Double Glacier (south) (60.688, -152.585)
Tuxedni Glacier (60.154, -153.13)

Kenai Fjords NP**Trinomial**

Cetraria ericetorum ssp. *reticulata*
Cetraria ericetorum ssp. *reticulata*
Cetraria islandica ssp. *crispiformis*
Cetraria islandica ssp. *crispiformis*
Cetraria nigricans
Cladina arbuscula

Locality

Harding Icefield, AK (59.444, -150.946)
Harding Icefield, AK (59.444, -150.946)
Harding Icefield, AK (60.078, -149.783)
Harding Icefield, AK (59.91, -150.05)
Harding Icefield, AK (59.444, -150.946)
Harding Icefield, AK (60.078, -149.783)

Trinomial*Cladonia bellidiflora**Cladonia bellidiflora**Cladonia bellidiflora**Cladonia bellidiflora**Cladonia borealis**Cladonia borealis**Cladonia ecmocyna**Cladonia ecmocyna**Flavocetraria nivalis**Ochrolechia frigida**Peltigera apthosa**Pertusaria geminipara**Stereocaulon alpinum**Stereocaulon arenarium**Stereocaulon botryosum**Stereocaulon spathuliferum**Stereocaulon vesuvianum**Thamnolia vermicularis**Thamnolia vermicularis***Locality**

Harding Icefield, AK (59.91, -150.05)

Harding Icefield, AK (59.91, -150.05)

Harding Icefield, AK (59.444, -150.946)

Harding Icefield, AK (59.444, -150.946)

Harding Icefield, AK (60.078, -149.783)

Harding Icefield, AK (59.91, -150.05)

Harding Icefield, AK (60.078, -149.783)

Harding Icefield, AK (59.444, -150.946)

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Harding Icefield, AK (59.444, -150.946)

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Harding Icefield, AK (60.078, -149.783)

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Harding Icefield, AK (60.078, -149.783)

Harding Icefield, AK (60.078, -149.783)

Harding Icefield, AK (59.91, -150.05)

Harding Icefield, AK (60.078, -149.783)

Harding Icefield, AK (59.91, -150.05)

Appendix II. Frequency of occurrence of common vascular alpine species in monitoring plots. Site numbers correspond to nunatak sites in each park (LACL: 1=Tuxedni; 2=Double (north); 3=Double (south); KEFJ: 4=Bear; 5=Skilak; 6=Holgate-NW; 7=Wosnesenski; 8=Petrof).

Trinomial	LACL		KEFJ					Frequency	
	1	2	3	4	5	6	7	8	% occurrence
<i>Agrostis mertensii</i>	0.13								0.13
<i>Anemone narcissiflora</i>								0.03	0.13
<i>Antennaria alpina</i>	0.17	0.05	0.13			0.5	0.17	0.47	0.75
<i>Antennaria monocephala</i>	0.03	1	0.4	0.05	0.4		0.52		0.75
<i>Arabis sp.</i>								0.07	0.13
<i>Arabis kamchatica</i>								0.03	0.13
<i>Artemisia arctica</i>	0.13	1	0.7		0.87		0.9	0.03	0.75
<i>Calamagrostis canadensis</i>								0.13	0.13
<i>Campanula lasiocarpa</i>	0.03	0.95	0.67	0.05	0.63		0.76	0.03	0.88
<i>Campanula rotundifolia</i>								0.03	0.13
<i>Campanula uniflora</i>				0.05					0.13
<i>Cardamine bellidifolia</i>					0.1		0.14	0.03	0.38
<i>Carex lachenalii</i>				0.15	0.17		0.07	0.03	0.50
<i>Carex macrochaeta</i>	0.53								0.13
<i>Carex mertensii</i>								0.17	0.13
<i>Carex microchaeta</i>		1	1	0.75	0.6		0.62		0.63
<i>Carex micropoda</i>	0.73		0.13		0.27	0.8		0.4	0.63
<i>Carex phaeocephala</i>								0.57	0.13
<i>Cassiope lycopoides</i>	0.07		0.3						0.25
<i>Cassiope tetragona</i>		0.55							0.13
<i>Cerastium beeringianum</i>							0.14		0.13
<i>Chamerion angustifolium</i>	0.07							0.03	0.13
<i>Chamerion latifolia</i>							0.07	0.77	0.25
<i>Diappensia lapponica</i>		0.75	0.3	0.3		0.05	0.1	0.03	0.75
<i>Dryas integrifolia</i>		0.4							0.13
<i>Empetrum nigrum</i>	0.53	0.1	0.7			0.05			0.50
<i>Epilobium sp.</i>								0.8	0.13
<i>Epilobium hornemannii</i>	0.57								0.13
<i>Erigeron sp.</i>							0.14		0.13
<i>Erigeron peregrinus</i>	0.03								0.13
<i>Festuca brachyphylla</i>							0.28	0.17	0.25
<i>Gentiana glauca</i>	0.03	0.35							0.25
<i>Geum rossii</i>							0.52	0.03	0.25
<i>Harrimanella stelleriana</i>	1	0.15	0.37						0.38
<i>Hieracium sp.</i>								0.03	0.13
<i>Hierochloa alpina</i>		0.1	0.1	0.1			0.03		0.50
<i>Hieracium triste</i>	0.73								0.13
<i>Huperzia selago</i>	0.1						0.62		0.25
<i>Juncus biglumis</i>					0.03	0.9			0.25
<i>Lloydia serotina</i>		0.45					0.79		0.25
<i>Loiseleuria procumbens</i>	0.43	0.4	0.1			0.1			0.50
<i>Luetkea pectinata</i>	0.97		0.13			1		0.97	0.50
<i>Lupinus nootkatensis</i>	0.83		0.03					1	0.38

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Species	LACL			KEFJ					% occurrence
	1	2	3	4	5	6	7	8	
<i>Luzula arcuata</i>	0.2	0.85	0.83	0.5	0.67		0.93	0.13	0.88
<i>Luzula piperi</i>	0.77		0.1		0.03	0.75		1	0.63
<i>Luzula spicata</i>							0.1		0.13
<i>Lycopodium alpinum</i>	0.73		0.03		0.17	0.3			0.50
<i>Lycopodium sitchense</i>						0.05			0.13
<i>Minuartia macrocarpa</i>					0.13		0.31		0.25
<i>Minuartia rubella</i>							0.03		0.13
<i>Papaver alaskanum</i>							0.03		0.13
<i>Pedicularis sp.</i>	0.03								0.13
<i>Pedicularis langsдорфii</i>		0.1	0.23						0.25
<i>Pedicularis verticillata</i>							0.28		0.13
<i>Phyllodoce aleutica</i>	0.03					0.05			0.25
<i>Poa sp.</i>							0.1	0.13	0.25
<i>Poa alpina</i>								1	0.13
<i>Poa arctica</i>			0.03		0.6				0.25
<i>Polemonium pulcherrimum</i>								0.03	0.13
<i>Polygonum viviparum</i>	0.13	0.1					0.31		0.38
<i>Potentilla hyparctica</i>				0.1	0.37		0.41		0.38
<i>Primula cuneiflora</i>						0.05			0.13
<i>Sagina sp.</i>								0.03	0.13
<i>Salix arctica</i>			0.03					0.03	0.25
<i>Salix polaris</i>	0.07								0.13
<i>Salix rotundifolia</i>	0.33	1	0.97	0.05	0.1		0.9		0.75
<i>Saxifraga bracteata</i>							0.24		0.13
<i>Saxifraga bronchialis</i>							0.31	0.03	0.25
<i>Saxifraga nivalis</i>							0.03		0.13
<i>Saxifraga punctata</i>							0.41	0.03	0.25
<i>Sedum rosea</i>					0.03		0.93	0.13	0.38
<i>Sibbaldia procumbens</i>	0.1		0.03	0.1	0.03	0.1	0.14	0.57	0.88
<i>Silene acaulis</i>					0.17	0.2	0.24	0.13	0.50
<i>Solidago multiradiata</i>					0.1		0.07		0.25
<i>Stellaria sp.</i>								0.4	0.13
<i>Stellaria longipes</i>					0.3				0.13
<i>Trisetum spicatum</i>	0.13					0.1	0.59		0.38
<i>Vaccinium uliginosum</i>	0.2	0.25	0.13			0.2			0.50
<i>Vahlodea atropurpurea</i>	0.43	0.3	0.3						0.38
<i>Veronica sp. 1</i>								0.03	0.13
<i>Veronica sp. 2</i>								0.03	0.13
<i>Veronica wormsјoldii</i>	0.27								0.13
<i>Viola langsдорфii</i>	0.03								0.13