A DESCRIPTION OF THE VEGETATION OF ANIACKHAK CALDERA


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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>STUDY SITE</td>
<td>4</td>
</tr>
<tr>
<td>Surprise Lake</td>
<td>9</td>
</tr>
<tr>
<td>Habitats of the North Lakeside</td>
<td>14</td>
</tr>
<tr>
<td>Mesic Headlands</td>
<td>14</td>
</tr>
<tr>
<td>Fell-Field</td>
<td>14</td>
</tr>
<tr>
<td>South Facing Walls</td>
<td>15</td>
</tr>
<tr>
<td>Habitats of the East Lakeside</td>
<td>16</td>
</tr>
<tr>
<td>Terrace</td>
<td>16</td>
</tr>
<tr>
<td>Knolls</td>
<td>17</td>
</tr>
<tr>
<td>Lower &amp; Upper Caldera Walls</td>
<td>17</td>
</tr>
<tr>
<td>1931 Eruption Site</td>
<td>18</td>
</tr>
<tr>
<td>METHODS</td>
<td>20</td>
</tr>
<tr>
<td>RESULTS</td>
<td>24</td>
</tr>
<tr>
<td>Plant Communities: North Lakeside</td>
<td>27</td>
</tr>
<tr>
<td>Mesic Headlands</td>
<td>28</td>
</tr>
<tr>
<td>Fell-Field</td>
<td>29</td>
</tr>
<tr>
<td>South Facing Walls</td>
<td>29</td>
</tr>
<tr>
<td>Plant Communities: East Lakeside</td>
<td>30</td>
</tr>
<tr>
<td>Terrace</td>
<td>30</td>
</tr>
<tr>
<td>Knolls</td>
<td>32</td>
</tr>
<tr>
<td>Lower Slopes</td>
<td>32</td>
</tr>
<tr>
<td>Mid &amp; Upper Caldera Walls</td>
<td>34</td>
</tr>
<tr>
<td>1931 Eruption Site</td>
<td>35</td>
</tr>
<tr>
<td>DISCUSSION</td>
<td>37</td>
</tr>
<tr>
<td>Future Research Needs</td>
<td>39</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>41</td>
</tr>
<tr>
<td>APPENDICES</td>
<td>42</td>
</tr>
</tbody>
</table>
INTRODUCTION

During July of 1992, the National Park Service sponsored a 4 week study of the vegetation of Aniakchak caldera. The primary objective was to collect floristic composition, frequency and abundance data for identification and description of plant communities.

Located along the central Alaska Peninsula, Aniakchak caldera is one of a series of volcanoes, known as the Ring of Fire, which encircles the Pacific Ocean. Aniakchak is an enormous steep walled caldera, 10 km in diameter, containing a variety of volcanic features. Surprise Lake, the largest body of water within the caldera, flows through a cleft in the caldera wall and eventually empties into the Pacific Ocean. Still thermally active, the most recent eruption in Aniakchak occurred in 1931 from a vent on the west side of the caldera floor. The eruption blanketed the caldera with up to 0.6 m of ash and resulted in ash fall over much of southwest Alaska. Events such as this have a profound impact on the plant communities within the caldera.

Since its discovery in 1922, only a small handful of scientists have visited the caldera. The first was Father Bernard Hubbard, a geologist-explorer, who visited the caldera before its eruption in 1930, and returned shortly after the eruption in 1931. Some information on pre- and post-eruption conditions can be gleaned from his photos. No further investigation occurred until a 1967 study that recognized the flora as being "of great interest to botany" (Alaska Search 1967) and resulted in the nomination of Aniakchak caldera as a National Natural Landmark. Aniakchak
caldera was incorporated into the National Park System (NPS) in 1978.

The nature of caldera vegetation was completely unknown until 1987 when the Park Service sent a team of 5 biologists, including one botanist, Korem Bosworth, into Aniakchak. During her 3 week stay, Bosworth identified 11 plant communities on the southwest side of Surprise Lake and sampled 7 of these. Photopoints were established by other team members at this time. The following year, 2 additional plant communities, also on the southeast lakeside, were described by Kristeen Sowl, a field technician, who was working in conjunction with Will Cameron on a limnological study of Surprise Lake.

In 1992, with the assistance of funding from the Natural National Landmark program, a 4 week vegetation study was undertaken, the results of which are presented in this report. The overall report format is deliberately similar to that of Bosworth (1987) and is designed to compliment it in such a way as to facilitate a greater overall understanding of caldera vegetation. This study, which focused on the north and east sides of Surprise Lake, yielded valuable baseline information about species composition and community structure in the caldera.

The results of just 4 weeks of field work increased the known flora of Aniakchak by 11% and included numerous range extensions - an indication of how little is known about the vegetation of both the caldera and the Alaska Peninsula as a whole. The 19 newly identified species were collected as vouchers for addition to the King Salmon herbarium. In addition, 14 plant communities (Viereck 1986), 6 of which had not been described previously in the caldera, were identified and mapped.
A plot sampling methodology was developed and used to describe the species composition, frequency and abundance of 4 of the new plant communities. Photopoints were taken to qualitatively document change over time in vegetation due to succession and possible visitor impact.

Finally, a master list of the species present in Aniakchak caldera was prepared. This flora provides important baseline information for further inventory and monitoring efforts as well as providing valuable species distribution data; this is especially important in view of the fact that volcanic areas and warm springs are recognized by the Alaska Rare Plant Working Group as being potential refugia for rare plants.

Wild and pristine places like Aniakchak are more than inherently valuable, they provide us with an opportunity to study natural processes of a completely unaltered ecosystem. But detailed studies, or even effective management, cannot be achieved without a solid baseline understanding of the resource. The 1992 study provides an excellent starting point and lays a framework for future research of the interactions between plants and their environment in this unique and diverse area.
STUDY SITE DESCRIPTION

Situated on the central Alaska Peninsula, midway between the Pacific Ocean and the Bering Sea, Aniakchak caldera is one of a long chain of volcanoes forming the backbone of the Aleutian Range (Figure 1). Located 650 km southwest of Anchorage and 240 km southwest of King Salmon, Aniakchak is remote and isolated. Access, via floatplane from King Salmon, is often difficult due to bad weather and poor visibility, and is further complicated by strong down drafts over the caldera rim which make flying dangerous.

Geologic History. The caldera was formed by the collapse of an andesitic stratovolcano following a catastrophic eruption, which deposited 7 cm of ash as far a5 1100 km away, approximately 3400 years ago (Miller 1990). The caldera, which is believed to be the third largest of its kind in the world, is ~10 km in diameter and encompasses an area of ~35 km². The low point on the caldera floor (Surprise Lake) is 320 m in elevation; the rim averages 1000 m with the highest peaks reaching 1341 m (Figure 2).

Over 20 post-eruption events have resulted in numerous domes, maars, cinder cones and lava flows, including the formation of Vent Mountain, a 1000 m high splatter cone (Miller 1990) from the top of which one can see both the Pacific Ocean and the Bering Sea. The caldera remains thermally active as is evidenced by the presence of several warm springs, as well as at least one area with ground temperatures of 85 C at a depth of 25 cm (Miller 1990).
Figure 1. Location of Aniakchak Caldera on the Alaska Peninsula in southwest Alaska. From Cameron (1992).
Figure 2. Aniakchak caldera (100' contour intervals)
Some have speculated that a deep lake filled the caldera at one time. The lake is thought to have eventually eroded a deep cleft, known as "The Gates", through the limestone deposits of the eastern wall (in Cameron 1992). Surprise Lake, a large (275 ha) lake located along the northeast edge of the caldera floor, may be a relict of the ancient caldera lake. This lake forms the headwaters of the Aniakchak River which flows through The Gates and empties into the Pacific Ocean ~32 km away. Surprise Lake drains 80% of the caldera and is fed by 11 surface inlets and numerous warm and cold springs (Cameron 1992).

**Weather.** Aniakchak caldera, located along the crest of the Aleutian range, is affected by both the Pacific coast and Bristol Bay climatic regimes. The Pacific coast, ~24 km to the east, has a maritime climate characterized by high precipitation and moderate temperatures; Bristol Bay, ~30 km to the west, has a more continental climate with lower precipitation and wider temperature ranges. Weather inside the caldera is affected by shifting air currents which carry weather from the 2 climatic zones, as well as by its own topography. Strong down-drafts often form over the rim causing clouds to flow rapidly down the caldera walls, usually dissipating before reaching the caldera floor. Low ceilings, rain and high winds are common, even when the weather is relatively calm outside the caldera.

Weather data, collected twice daily (morning and evening) for the duration of the 1992 study (24 days), documents a daily average maximum temperature of 58°F, and an average minimum temperature of 46°F. Measurable precipitation was
recorded for 19 days for a total cumulative precipitation of 2.34 inches. Although
much of the precipitation came in the form of light drizzle, 3 events exceeded 0.4
inches of rain in a 24 hour period. Cloud cover was 100% for at least one of the two
daily recording periods for 20 of the days. A total of 6 days of mostly sunny
conditions occurred. Maximum wind speed recorded at the weather station was 34
mph, although surely the winds were in excess of this figure on several occasions.
SURPRISE LAKE STUDY SITE

Aniakchak is located approximately 200 km south of tree-line. The vegetation consists primarily of dwarf shrub/tundra/willow communities. Our sampling focused on Surprise Lake principally because this is where much of the plant life in the caldera is concentrated.

Overview. Although sampling expeditions in 1987 and 1988 (Bosworth 1987, Sowl 1988) yielded a fairly complete description of plant communities on the south and west lakesides, very little was known about the vegetation of the north and east sides of Surprise Lake. This is a function of both access (1.5 hr hike from camp) and the limited scope of vegetation work in the caldera in general. These areas, however, contain unique and interesting features, many of which are not represented elsewhere in the caldera. The contrasts between the north/east sides and the more thoroughly studied south/west sides are readily apparent.

If one were to sit on a boat in the middle of Surprise Lake, two features of the northeast lakeside would immediately distinguish it from the remainder of the lake:

1) the unusually lush, well-developed plant communities along the lake terrace; and
2) the steep caldera walls that rise 1100 ft to form an impressive backdrop to the scene. This is in contrast to the opposite lakeshore which consists of low lava headlands and flat, sweeping ridges interspersed with cinder cones. Further investigation of the northeast lakeside reveals a variety of plant communities, some occurring on the west side as well, and others unique to the north and east sides.
Among the more well-established are open low willow, Crowberry tundra, mesic sedge-herb and, perhaps most noticeably, bluejoint-herb. Why do these communities appear to be so much more well-established than those on the opposite (southwest) lakeshore?

1931 Eruption. The 1931 eruption in Aniakchak was probably the most significant event contributing to the present structure and composition of the vegetation within the caldera. The eruption blanketed the caldera with 0.3-0.6 m of volcanic ash (Hubbard 1931). Bosworth (1987) cites a study in which half this volume of ash (15 cm) was shown to kill all herbs and significantly reduce shrub cover (Antos and Zobel 1985). The severity of the impact on the north and east sides was probably reduced by the presence of the steep caldera walls which quickly sloughed off much of the ash, thus increasing survivorship of relict plants which are integral to post-eruption recovery of vegetation (Bosworth 1987, Antos and Zobel 1985). The vegetation on the west lakeside, as noted by Sowl (1988), not only lacks the steep slopes, but is closer to the blast site. Consequently, this area may have sustained greater losses and is in an earlier stage of ecological succession than the study sites on the northeast lakeside.

Environmental Factors. Other factors which may contribute to the presence of well-established plant communities on the north and east sides of Surprise Lake include:
- **Decreased exposure to wind**: many slopes on the northeast lakeside are protected from the direct impact of easterly winds that frequently howl through The Gates and to some degree from the desiccating southwest winds that commonly blow through Birthday Pass. Sowl (1988) suggests that much of the abrasive windborne ash particles may be dropped as the wind sweeps over Surprise Lake on its way to the north and east shore.

- **Increased sun exposure**: these south to southeast-facing slopes receive favorable exposure to the sun's rays which may benefit plants with regard to photosynthesis and growth, as well as facilitating an earlier snow melt and, consequently, longer growing season. (The effect of shading from caldera walls is unknown.)

- **Increased water availability**: 4 perennial streams and numerous intermittent ones provide plants with the necessary water. In addition, several large snow patches persist into summer, melting slowly and presumably supplying water to adjacent plant communities.

- **Nature of substrata**: Bosworth (1987) referenced a soil study in The Valley of Ten Thousand Smokes in which the volcanic soil conditions made it very difficult for organisms to become established (Cameron 1970). The study also found that the presence of organic-rich, pre-eruption soils were very beneficial to vegetation recovery. Bosworth (1987) believes there are places in the caldera that "could have
been sufficiently protected from the blast of the 1931 eruption and in a position to somehow have the ash quickly eroded off them so that... old organic soil was eventually exposed" (p 75). I expect that areas on the north and east lakeside have indeed retained some of the old organic-rich soil, having been exposed by sloughed off ash. In addition, continued weathering of the sedimentary rock of the southwest-facing caldera walls probably contribute to soil development.

Although plant specimens were collected throughout the caldera, quantitative sampling was confined to the north and east lakesides (Figure 3). The following section contains habitat information for these areas, followed by plant community descriptions.
Figure 3. Surprise Lake areas.

1. West Lake Lava Flow
2. Headwater Inlet Area
3. North Lakeside
4. East Lakeside
5. Lake Outlet
6. The Gates
HABITATS OF THE NORTH LAKESIDE

Mesic Headlands. The north side of Surprise Lake constitutes a relatively small yet distinct habitat. The 150 ft of south-facing slope directly above the lake support the most striking example of a lush, well-developed plant community found within the caldera. This steep slope (35°) is reminiscent of the steep-faced lava headlands of the west lakeshore in that it probably quickly sloughed a large portion of the 1931 ashfall and its plant communities retained many of their original members.

Given its direct south-facing exposure, this mesic slope becomes snow-free early in the summer. In addition, the soils are deep and well developed, another indication that rapid sloughing may have occurred subsequent to the 1931 eruption.

Fell-Field. The steep, mesic, densely vegetated slope rises approximately 150 ft above the lake and abruptly flattens into a dry, windswept fell-field. The substrate consists of ash and gravel, and water drains through the porous material very quickly. A deep east-west trending ravine bisects the north portion of the fell-field, and several smaller gullies drain into it from the caldera walls above. Although the flow of water in the ravine and gullies is seasonal, limited primarily to periods of snow melt and possibly heavy precipitation events, there is still greater plant coverage in these areas. This is due, in part, to the sheltering effect of the drainage from the strong winds that buffet this exposed platform from every side.

Many of the species that have established on this exposed, apparently barren flat
appear to take advantage of even the most minute available shelter. Alpine herbs fill in behind the slightest of wind-blown ridges, in shallow dry gullies and even in depressions formed by caribou trails - creating an interesting mosaic of random green lines across the landscape.

The upper portion of the fell-field begins to slope gently upward, and soon joins the steep caldera walls. A substantial amount of unconsolidated debris has accumulated at the base of the walls, probably the result of recent erosion from above. This forms an unstable substrate, which is strongly influenced by the actions of wind and rain, not at all atypical of the extremely dynamic nature of the caldera as a whole.

**South-Facing Caldera Walls.** Although south-facing, the caldera walls are able to retain sizable snow fields well into the summer. This is due to the shadowing effect of the nearly vertical walls that rise 800 ft above the lower slopes. Snow also holds in wide, shaded crevices high above the lake. The gradual melt-off from these snow fields probably provides some moisture throughout the growing season to the alpine herbs directly below.
HABITATS OF THE EAST LAKESIDE

The east side of Surprise Lake is extensive, covering approximately 3 km of shoreline and 3 km$^2$ in total area. The following description is somewhat canted toward the northern portion of the east lakeside, since the bulk of sampling was conducted there. The southeast lakeside is similar, though it has a slightly different aspect and may be more wind-sheltered.

**Lakeside Habitats:** There are a variety of shoreline habitats along the east lakeshore, each directly influenced by the waters of Surprise Lake. Small (70 ft) stretches of sandy beach alternate with steep lakeside willow slopes and bluejoint-herb communities. There are occasional rocky outcrops and areas of various-sized boulders along the shoreline supporting herbs and grasses. Periodic storm events produce significant white-caps on the lake; during Pacific storms the east lakeshore can experience the force of 2 - 3 ft waves. An examination of photos from May, 1987 also suggest that the shoreline may be seasonally inundated during periods of peak snow-melt.

**Terrace.** Beyond some of the beaches are low-lying areas which were probably under water before the lake receded to its current level. Typically though, a broad, well-vegetated bench (~200 ft wide) forms a terrace between the lake below and the steeper caldera walls above. This terrace appears lush and green from a distance and supports much of the plant biomass on the east lakeside. The substrate, which is

16
composed of a mixture of 1931 ash and eroded material from the caldera walls, seems more developed than soils in other locations. This may be due to the effects of organic material accumulation from the vegetation which, in conjunction with a well-developed moss layer, would aid soil development and water retention. In addition, the terrace is influenced by melt-off from snow fields which linger on caldera walls well into July.

**Knolls.** The terrace supports a wide range of plant communities including small, drier *Empetrum* knolls as well as expansive mesic bluejoint-herb and willow flats. There are 4 perennial streams and numerous ephemeral creeks and gullies which bisect the terrace. As on the north side, these drainages are sheltered from the wind and tend to support narrow corridors of well-developed plant communities.

**Caldera Walls: Lower and Upper Slopes.** The lower caldera walls, just beyond the terrace, are gently sloping at their base and serve as a catchment area for the volumes of sloughed ash and erosional material from above. Some portions of the lower slope are unstable and support little plant growth while others are stabilized and support dwarf alpine communities. After rising at a moderate angle for ~400 ft, the slope steepens considerably. The mid and upper portions of the caldera wall, a rise of 600 - 800 ft, are largely composed of steep, unstable sand/scree slopes. Large boulders and rock slabs have been dislodged from above in places and are slowly migrating downward. Countless gullies and ravines indicate the amount of material being
transported down the slope. In places, where all overlaying ash has been removed, 100 ft vertical cliff bands are exposed. This is the parent material of the original volcano and is composed of exposed Mesozoic and Tertiary sediments. The volcaniclastic rocks are primarily andesitic basalt (Miller 1990). 100 ft sections of columnar basalt occurs here.

1931 ERUPTION SITE

The 1931 eruption in Aniakchak caldera was one of the largest recent eruptions on the Alaska Peninsula. The eruption, which was one of ash (not lava), issued from a steep walled eruption crater, 200 ft deep and 1 km across, located along the west wall of the caldera (Figure 2). Two types of lava are present: "aa" lava, a broken blocky lava covering an area of 20 m by 100 m; and "pahoehoe" lava, a smoother lava covering a much larger area. (Figure 4).
Sketch map of the 1931 eruption site.

Photo of the crater of the 1931 eruption site.

Figure 5. 1931 Eruption site (from Bosworth 1987).
METHODS

Unfortunately, there is no single best way to sample vegetation. The best sampling method for one community may be totally inappropriate for another. Sampling methods are best designed by taking into account the objectives of a study and the structure and scale of the vegetation. The objective of the Aniakchak caldera sampling effort was to collect floristic composition, frequency and abundance data for identification and description of plant communities.

An accurate understanding of the caldera was required before a sampling strategy could be carried out. This was achieved by an intensive initial reconnaissance of the north and east lakesides. Reconnaissance efforts involve two complimentary, yet sometimes competing, elements: 1) familiarizing oneself with the flora, collecting, pressing and keying specimens- an activity requiring attention to detail; and 2) at the same time, pulling back enough to see the big picture on a community level- recognizing habitats and communities, sketching maps. Once an adequate level of confidence in understanding the vegetation was achieved, plot placement was considered.

Plots. After much deliberation, a stratified random sampling methodology similar to that of previous caldera work was adopted (Bosworth 1987). Plots were located within subjectively chosen patches of homogeneous vegetation which were believed to represent distinct communities. Once an area had been chosen, a 40 m x 50 m plot was subjectively placed within it. The plots consisted of a 40 m baseline transect
with (5) 50 m parallel transects placed perpendicular to it at 10 m intervals (Figure 5). Species-area curves were generated for the initial plots to determine the optimal number of quads per plot. Randomization was achieved by using a random number table to determine placement of 4-6 quads along each of 5 parallel transects.

**Herb Quads.** Traditional 1 m wooden herb quads were used. Presence was recorded for all vascular plants, as well as for descriptive placeholders including rock, bare, standing water, lichen, moss and litter. Non-vascular plants were unable to be identified due to lack of expertise. Abundance was recorded using Braun-Blanquet cover classes as follows:

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<td>6-25</td>
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<td>26-50</td>
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Frequency and cover values were calculated from these data by averaging the median value for each cover class. These data are reported in Appendix 5.

Any unknown vascular plants were collected for identification. Specimens collected for this purpose were assigned a collection number corresponding with the plot number, and pressed in the field. Identification was accomplished at camp, or in King Salmon with the aid of a scope and herbarium. If there was any doubt as to the identification of a plant, it was collected.

**Shrub Transects.** Point-count shrub transects were completed in plots containing non-dwarf shrub species (ie. > .5 m high). Two of the parallel herb transects were randomly chosen for this purpose. On each, point intercept data was recorded at 1 m intervals for shrubs (identified to species, including dwarfs which were noted as such), and placeholders including rock, bare and herb. These data were transformed into percent cover estimates of the shrub layer.

**General Plot Information.** General plot information was also collected including a short narrative description of vegetative structure, physical setting of the site, and locational information of sufficient detail to enable site relocation with the aid of plot photos. Additional information included elevation, slope, aspect, percent rock, plot
vegetation type (Viereck 1986), vegetation type within 100 m, evidence of natural or anthropogenic disturbance, mammal sign, birds present, photos (in the 4 cardinal directions), azimuths of baseline and parallel transects, and, when possible, information on soils and geology. Locations were recorded using the UTM system. Plots were marked on xeroxed USGS topographic maps which were attached to each data sheet set. Sample data sheets are presented in Appendix 1.

Plant Identification. Plant specimens which could not be determined to species in the field were collected and documented as outlined above regardless of whether they were encountered on plots or during general cruising. Plants were keyed in the evenings at camp. Those specimens in need of a scope were saved for identification in King Salmon. Both NPS and Fish and Wildlife Service (FWS) herbaria in King Salmon were used for verification, although the accuracy of the Katmai and FWS collections is somewhat dubious. Several misidentifications were discovered and discretion should be exercised in their use. The Aniakchak collection, however, is in good shape and quality control efforts should be made to ensure its continued accuracy.
RESULTS

The species list presented in this report is based on preliminary plant identifications by the author. Questionable determinations are being sent out for verification. Nomenclature follows that of Hulten (1968). The vegetation classification is based on Viereck et al. (1986).

Flora. There are 176 species of vascular plants known to occur in Aniakchak caldera, 19 of which were first encountered during the course of this study. New additions are designated as such in the flora. The flora is presented alphabetically both by family and by genus (Appendices 2 and 3 respectively). Vouchers of all new species were collected for addition to the King Salmon herbarium.

Of interest is an unusual species of Artemisia which is quite common on exposed ridgetops. It keys roughly to A. globularia yet looks very different from those observed at Aniakchak Bay. This species is being sent out for verification. Also, an unusual blue version of the normally white Achillea borealis was observed in the vicinity of Surprise Lake.

The breakdown of taxa by family is as follows:

18 species: Gramineae;
15 species: Compositae, Saxifragaceae;
9 species: Caryophyllaceae, Cyperaceae, Ericaceae, Salicaceae,
Scrophulariaceae;
8 species: Juncaceae, Onagraceae, Rosaceae;
7 species: Orchidaceae;
3-6 species: Cruciferae, Equisetaceae, Gentianaceae, Lycopodiaceae,
    Polygonaceae, Pyrolaceae, Ranunculaceae;
1-2 species: Aspidaceae, Athyriaceae, Campanulaceae, Crassulaceae,
    Cryptogrammaceae, Diapensiaceae, Empetraceae, Geraniaceae,
    Haloragaceae, Hydrophyllaceae, Leguminosae, Ophioglossaceae,
    Papaveraceae, Polemoniaceae, Portulacaceae, Potamogetonaceae,
    Primulaceae, Umbelliferae, Violaceae.

Photopoints. 13 photopoints were taken to duplicate those from 1987. The results
consist of a library of slides on file in King Salmon. A detailed protocol established
by Stroud (1987) was followed.

Plant Communities. A total of 14 plant communities (see Fig. 6) on the northeast
lakeside were identified, 6 of which were previously undescribed in the caldera.
These are presented in Appendix 4 and can be used in conjunction with Bosworth’s
(1987) to obtain a comprehensive roster of known plant communities in Aniakchak
caldera.

Quantitative sampling, as outlined in the Methods section above, was
performed in 4 of the communities (Figure 6). Presence, frequency and cover data
are presented in Appendix 5. A map of plant communities on the north and east
sides of Surprise Lake was also generated (Figure 6) with the intention of facilitating a visual understanding of community placement. Given the complex nature of vegetation, this map is not comprehensive.
Plant communities

1. Mesic sedge-herb meadow
2. Dwarf willow tundra
3. Open low willow
4. Dry graminoid herb - *Elymus*
5. Bluejoint-meadow
6. Crowberry tundra
7. Mesic sedge-herb mdw tundra
8. Bluejoint-herb
9. *Vaccinium* tundra
10. Dwarf willow tundra (*Vaccinium*)
11. Mountain heath tundra
12. Alpine herbs
13. Closed low willow
14. Unvegetated ash slopes

+ These as yet unclassified communities consist of a mix of *Elymus*, *Calamagrostis*, *Salix*, and alpine herbs.

PLANT COMMUNITIES ON THE NORTH AND EAST LAKESIDE (Figure 6)
PLANT COMMUNITIES: NORTH LAKESIDE

**Mesic Headlands.** The steep, south-facing bluff rising 120 ft above Surprise Lake supports one of the most developed plant communities in the caldera. Results from a plot placed in this mesic sedge-herb meadow community (Figure 6, #1) are presented in Appendix 5. The community is dominated by *Carex macrochaeta* (96% frequency, 36% average cover) with a significant umbel (*Angelica lucida*: 100% frequency, 10% cover and *Heracleum lanatum*: 84% frequency, 20% cover) and lupine (100% frequency, 17% cover) component. A wide variety of mixed herbs occur with the *Carex* including *Epilobium angustifolium*, *Solidago multiradiata*, *Geranium erianthum*, *Botrychium lunaria* and *Euphrasia mollis*. Common grasses include *Calamagrostis canadensis*, *Poa arctica*, *Phleum commutatum* and *Elymus arenarius*. Several low willow clumps are scattered throughout the slope (*Salix barclayi* and *S. alaxensis*). Overall vegetative cover is high.

The mesic sedge-herb community grades into closed low willow on the slope below (Figure 6, # 13). *Salix barclayi* and *S. alaxensis* dominate a narrow strip (8 m wide) just above the lake's edge. The willows, which do not exceed 1.5 m in height, are growing on a short but very steep bluff and, viewed from the water's edge below, have a well-developed understory of mixed herbs including *Athyrium felix-femina*. This community has not been sampled.

The width of the mesic sedge-herb and low willow communities appears to be determined, at least partially, by aspect. The vegetation changes at either end as the slope becomes either west-facing or southeast-facing. The upper boundary is clearly
delineated as the slope flattens into a dry, wind-swept fell-field.

**Fell-Field.** The vegetation on the exposed fell-field is similar to the ridgetop communities described by Bosworth (1987) on the southwest lakeside. Cover is low, but many species are in fact present. The more common include *Minuartia macrocarpa*, *Artemisia globularia*, *Saxifraga serpyllifolia*, *Deschampsia caespitosa* and *Luzula wahlenbergii*. *Salix ovalifolia*, a small, prostrate, rather inconspicuous willow, is dominant with >25% cover giving this community the designation of dwarf willow tundra (Figure 6, #2). No plots were placed in this type as it was described in 1987.

The lower (south-most) boundary of the dwarf willow tundra is defined by an abrupt change in slope as the fell-field gives way to the previously-described mesic headland below. A very narrow strip (3 m wide) along this edge is occupied by a different type of dwarf willow tundra dominated by *Salix arctica* and *Rhododendron camtschaticum*. Other alpine herbs are present and cover is greater, giving the appearance of a garden strip.

**South-Facing Caldera Walls.** The caldera walls can be broken into several different categories and habitats. In general, plant cover is extremely low, due primarily to the unstable nature of the substrate. The loose, ashy lower slopes are being pioneered by *Elymus arenarius* which stabilizes the soil and allows other herbs to establish. Although this process is in its early stages, the *Elymus* is well enough established to be noticeable from across the lake as large brown-green patches. Only the most
obvious patches of this dry graminoid-herbaceous community are mapped in Figure 6 (#4). In reality, this community was very difficult to map due to its diffuse nature. No plots were placed in this community.

A discussion of additional plant communities which occur on the steep upper walls of both the north and east lakeside is included in the east lakeside section which follows.

PLANT COMMUNITIES: EAST LAKESIDE.

Terrace. The broad flat terrace which separates the lake from the steep caldera walls supports much of the vegetative biomass on the east lakeside. Although this is a confusing area with indistinct community boundaries, three plant communities are obvious. The first is an open low willow type composed primarily of Salix barclayi with scattered S. alaxensis (Figure 6, #3). It occurs in scattered locations around the perimeter of the lake and generally forms various-sized stands less than 1.5 m in height. The understory of herbs, grasses and subshrubs includes Petasites sp., Festuca rubra, and Achillea borealis. No plots were placed in this community type.

Calamagrostis canadensis, or bluejoint, dominates the remaining two communities, and, although inconspicuous in other caldera locations, is widely distributed on the east lakeside (Figure 6, #5 & #8). Bluejoint-herb and bluejoint-meadow begin to occur on the northeast lakeside in an area that coincides with a shift in aspect to the south-southwest. Bluejoint types are increasingly common as one moves south around the east lakeside, forming dense patches on due west-facing
terraces, as well as on lakeside flats where they form a mosaic pattern with the previously described low willow stands.

The more common of the two communities, bluejoint-herb (Figure 6, #5), is dominated equally by *Calamagrostis canadensis* (100% frequency, 39% cover) and various herbs. The herb component includes *Epilobium angustifolium*, *Lupinus nootkatensis*, *Artemisia arctica*, *Angelica lucida*, and *Stellaria calycantha*. Moss also occurred with high frequency and an average of 35% cover. Results from a plot placed in this community are presented in Appendix 5. In retrospect, it appears that the site chosen for plot work was located a bit too close to the adjacent *Vaccinium* tundra community upslope, as evidenced by increased incidence of new tundra-type species in the northwest end of the plot. This ecotone effect should be considered when reviewing the quantitative data for this community.

Bluejoint-meadow communities (Figure 6, #8) are dominated by *Calamagrostis canadensis* alone, although minor amounts of other grasses and herbs including *Heracleum lanatum*, *Epilobium angustifolium* and *Lupinus nootkatensis* are present. Scattered willows are not uncommon. Griggs (1936) considered bluejoint-meadow to be stable and climax or near climax in southwest Alaska; they seem to develop from bluejoint-herb communities as bluejoint gradually excludes other herbs (in Viereck 1992). In the caldera, however, it seems possible that the willow is invading the bluejoint types and eventually will transform them into bluejoint-shrub or even willow dominated communities. No plots were placed in this community.
Knolls. The terrace also contains several small knolls, usually delineated on either side by deeply incised stream beds. These knolls are typically somewhat elevated, drier and exposed to the full force of the wind. Cover is fairly high although bare ground occurs with 83% frequency and 13% average cover. *Empetrum nigrum* is dominant (96% frequency, 56% average cover). *Loiseleuria procumbens*, *Salix ovalifolia*, *S. arctica*, *Vaccinium uliginosum*, and *Carex nesophila* are common, as are moss species. Results from a plot placed in this crowberry tundra community (Figure 6, #6) are presented in Appendix 5.

Streams and Creekbeds. Four perennial streams, in addition to numerous ephemeral creeks and gullies carved by snow-melt, drain the southwest-facing walls of the caldera. The plant communities associated with stream features range from lush, dense vegetation found along some perennial streams to barren ravines devoid of plant life. No plot work was conducted along stream corridors, and even if it had been, it would not be possible to generalize the information to other areas. For example, Inlet #4 (Cameron 1992) contains a well-developed bluejoint-herb community, while another creek in an adjacent drainage to the east, supports a lush community of mixed herbs. The dry gullies tend to support alpine herb-sedge vegetation primarily due to the shelter afforded by the depressions. Cover is often much lower in these cases.

Lower Slopes. The northeast caldera walls appeared barren when viewed from our
camp across the lake in early July. This was not surprising - many alpine species are inconspicuous, especially at a distance of 1.5 km. By late July though, large patches of "green" could be plainly seen at various heights on the caldera walls. These proved to be the moss *Rhacomitrium canescens*, and although in some cases it was growing in nearly homogeneous mats, more often it was associated with other plant communities.

The moderately sloping, southwest-facing ramps situated above the bluejoint-herb terrace and terminating in the steep, loose slopes of the caldera walls support a dwarf willow tundra community (Figure 6, #10). *Salix ovalifolia* is dominant occurring with 96% frequency and 7% average cover, although *Vaccinium uliginosum* is also very important occurring in scattered clumps throughout the slope with 44% frequency and 14% average cover. Other important species include *Rhododendron camtschaticum*, *Carex nesophila*, *Loiseleuria procumbens*, *Empetrum nigrum*, *Festuca rubra*, *Campanula lasiocarpa* and *Solidago multiradiata*. As mentioned, moss is an important component with 38% average cover and 100% frequency. Results from a plot placed in this community are presented in Appendix 5.

The moderate, lower slopes also support *Vaccinium* tundra dominated by *V. uliginosum* (Figure 6, #9). This community contains many of the same species listed above, the primary difference being in proportions of the members. Though *Vaccinium* tundra was not sampled, it appeared to be more prevalent as one moves southeast around the lake.
Steep Slopes: Mid and Upper Caldera Walls. An unexpected variety of species inhabit the steep caldera walls. Portions of the mid slope which appear brownish-green from a distance are actually being stabilized by sizable patches of evenly spaced *Elymus*, often with various herbs including *Lupinus nootkatensis*, *Achillea borealis*, *Luzula wahlenbergii* and *Minuartia macrocarpa* beginning to succeed it (Figure 6, #4).

In places where overlaying ash has been removed, 100 ft vertical cliff bands are exposed. Colorful gardens of alpine herbs have established in cracks and small benches where organic soil has accumulated (Figure 6, #12). Species include *Oxyria digyna*, *Polygonum viviparum*, *Saxifraga oppositifolia*, *Sedum rosea*, *Rhododendron camtschaticum*, and *Sibbaldia procumbens*.

Additional patches of lush, green vegetation are clearly visible on the high, steep alpine slopes immediately below the rock bands. Again there is a strong moss component present, but the dominant species is *Carex macrochaeta*, which is obviously thriving. Numerous herbs including *Salix arctica*, *Epilobium angustifolium*, *Luzula wahlenbergii* and *Saxifraga unalascensis* also occur in this mesic sedge-herb meadow community (Figure 6, #7). Some high patches have a surprisingly well-developed umbel element as well.

Mid-slope, below the mesic sedge-herb meadow on the south-facing slope lies one of the few examples of mountain heath tundra in the caldera (Figure 6, #11). *Luetkea pectinata* and *Leptarrhena pyrolifolia* are codominate with an element of *Phyllocladus aleutica*. This community was also observed in moist, protected draws
~1.5 km southwest of Surprise Lake, east of point 1685. According to Viereck (1992),
this type is common on alpine slopes and snowbed margins.

**Other Plant Communities.** As mentioned earlier, the northeast side of Surprise Lake
is expansive and complex. The preceding summary is not meant to be a
comprehensive listing. Several other communities may be represented to a lesser
degree than the ones described. Further work is required to achieve a full
understanding of this area - especially on the southeast lakeside.

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**PLANTS COMMUNITIES: 1931 ERUPTION SITE**

The single most striking feature of the 1931 site is the presence of *Stereocaulin*
vesuvianum, a lichen that apparently colonizes fresh lava flows and which blankets
much of the site. (Additional areas with significant *Stereocaulin* coverage were
observed on aa lava flows northeast of Vent Mountain, outside of the 1931 site.)
Even more interesting though is the 360% increase in the number of vascular plants
found in 1992 versus 1987. Our final species list contains 55 species, several of which
had not been encountered elsewhere in the caldera (Appendix 6). This is in
comparison to only 15 species recorded by Bosworth 5 years earlier. How could this
be?

From the rim of the 1931 site, a large 'green' patch is clearly visible. Covering
\~15\% of the floor of the eruption pit on the northeastern side, this green patch was an obvious target in our search for plant life. The vast majority of species recorded in the eruption pit were found in this area.

Snow cover appears significantly greater in 1987 judging from photopoint photos taken at almost the exact same date almost 5 years ago. However, further examination of the photos reveals that although the northeastern section had more snow, the richest portion of all (the north-facing slopes above a deep gully) appeared to be snow-free. It is possible that the area had not been snow-free long enough for herbaceous plants to emerge (late July), but this would not explain why the numerous woody Salix species were not noted in 1987 even though they would have been visible immediately after snow melt.

It is also possible that this area had simply been overlooked in 1987. Perhaps the additional snow cover made the area less obvious. The final possibility, although unlikely, is that plant succession has been proceeding at a phenomenal rate in the last 5 years.
DISCUSSION

Sampling Design. As mentioned above, a stratified random sampling design similar to that used in 1987 and 1988 was adopted for this study. The decision to sample in this manner was a result of a good deal of reading (Barbour 1987, Mueller-Dombois 1974) and telephone consultation with others ecologists. Through the use of this methodology consistency was maintained with previous sampling efforts. Although I am generally satisfied with the sampling design, some improvements can be made.

Species area curves were used to determine the number of quads needed to sample a plant community, however, they do not supply information on the overall size of the plot. This is more critical in areas of high species diversity and very low cover as experienced by Sowl in 1988. Although the nested quad technique, described by Barbour (1987) and used by Wilk (1986) on the Alaska Peninsula, can be used to determine overall plot size, it is very time consuming. We spent an entire day experimenting with nested quads in a crowberry tundra community and were still not satisfied with the results. This is partially due to the fact that as the nested quad grew exponentially in size it came into contact with the ecotone area of an adjacent plant community. Careful placement of nested quads is important.

In an effort to mitigate the time and labor intensiveness of nested quads, it may be better to sample at a larger scale. Since the Alaska Vegetation Classification (Viereck 1986) is divided into 5 hierarchical levels, the nested quad technique could be performed at a more general level of resolution. The results could then be used to determine plot size for all communities which fall within that general category. For
example, the Viereck "level 2" category of graminoid-herbaceous contains 4 different "level 5" plant communities on the northeast lakeside: bluejoint meadow, bluejoint-herb, mesic sedge-herb and dry graminoid-herbaceous. Since all share the physiognomic feature of being graminoid-herbaceous, the plot size derived from a nested quad analysis in one community could be used in each of the others.

**Plot Work.** Some of the difficulties encountered in plot work involved the strong winds and drizzle which are common in the caldera. Extra wire flags were always needed to help hold transects in place. Write-in-the-rain data sheets would have been extremely useful in saving time and reducing the possibility of transcription errors on wet days when data was transferred from field notebooks to data sheets in camp. Perhaps most critical is the need for 2 people on each plot. I performed 3 solo plots in the caldera and feel that the time spent looking up data columns and recording values reduced my ability to focus on the species present.

Although great care was taken in species identification, some genera are universally problematic. These included *Poa, Stellaria, Epilobium,* and *Salix.* As mentioned above, the species reported here are based on preliminary identification and are being subject to verification. Care was also taken to dry pressed specimens in camp. Blotters were changed on a regular basis and the presses were stored near the kerosene heater. These efforts were successful in the caldera, but were discontinued upon arrival in King Salmon. As a result, specimens from a previous trip to Aniakchak Bay developed a mildew problem which was counteracted by
drying specimens in a home oven at a low temperature (<100°F).

**Future Research Needs.** The 1992 study, in conjunction with work done in 1987 and 1988, provides important baseline information about the vegetation in the caldera. Even so, our understanding of this area is very limited. Although many of the major plant communities have been qualitatively described, comparatively little quantitative work has been done. Research of this type will provide community structure data and should be an integral component of future inventory efforts in the caldera and in Aniakchak National Monument and Preserve as a whole.

Although I suspect that the majority of vascular plant species present in the caldera have been recorded, collection efforts have been focused almost entirely on the areas around Surprise Lake. It is likely that some interesting discoveries await the botanist in the more remote and inaccessible regions of the caldera. On the other hand, extremely little is known about the myriad of non-vascular plants in the caldera. Even the most rudimentary list of mosses and lichens is lacking. Although typically more inconspicuous than vascular plants, the non-vasculars are ecologically extremely important components of plant communities. To try to understand caldera vegetation without acknowledging non-vascular plants is like trying to understand a hardwood forest without acknowledging the understory herbs. Future research should focus on the both vascular and non-vascular strata.

In addition to more complete inventory efforts, there is enormous potential for ecological research in the caldera, which is an ecosystem completely unaltered by
man. The 1931 eruption of Aniakchak was one of the largest recent eruptions on the Alaska Peninsula, making the caldera a valuable resource in understanding how such events affect plant distribution and succession.

A comparative study of the 1931 eruption site and a similar eruption pit in the caldera would provide valuable insight into both sites. Finally, long term monitoring of vegetation should be continued and perhaps expanded upon. The current practice of retaking photopoints at 5 year intervals is an inexpensive and informative procedure. More photopoints should be strategically placed in other areas of interest (i.e. northeast lakeside, inlet streams).
REFERENCES


Topo Quad ______
Plot # ______
Date ______
Time ______
UTM ______N/____E

Elev. ______
Slope ______
Aspect ______
% Rock ______

Observers: ____________________________

Site Description:
____________________________________
____________________________________
____________________________________
____________________________________
____________________________________

Vegetation Type: _______________________

Vegetation Within 100 m: _______________________

Rock Type: ____________________________

Water: standing __ flowing __
area m2 ___

Natural Disturbance: _______________________

Anthropological Evidence: _______________________

Mammals: _______________________

Birds: _______________________

Photos: (NESW) _____ yes
P ______ h o t o
#: _______________________

Azimuth of Baseline Transect (1): ______
Azimuth of Parallel Transects ( ea): ______
Appendix 2.

ANIAKCHAK CALDERA FLORA
Alphabetical by family
(Nomenclature follows Hulten (1968))

ASPIDACEAE
Dryopteris dilatata ssp. americana

ATHYRIACEAE
Athyrium filix-femina
Cystopteris fragilis

CAMPANULACEAE
Campanula lasiocarpa ssp. lasiocarpa

CARYOPHYLLACEAE
Cerastium beeringianum var. beeringianum
Cerastium beeringianum var. grandiflorum **
Minuartia macrocarpa
Sagina intermedia
Silene acaulis ssp. acaulis
Stellaria calycantha
Stellaria calycantha ssp. isophylla **
Stellaria crassifolia
Stellaria monantha
Stellaria ruscifolia ssp. aleutica

COMPOSITAE
Achillea borealis
Antennaria monocephala var. monocephala
Antennaria pallida
Arnica chamissonis *
Arnica lessingii ssp. lessingii
Artemisia arctica ssp. arctica
Artemisia borealis **
Artemisia globularia *
Artemisia tilesii
Aster sibiricus
Hieracium triste
Petasites hyperboreus
Petasites frigidus X hyperboreus
Petasites frigidus
Solidago multiradiata var. multiradiata
Taraxacum sp.

CRASSULACEAE
Sedum rosea ssp. integrifolium

CRUCIFERAE
Arabis lemmoni
Arabis lyrata ssp. kamchatica
Cardamine bellidifolia **
Cardamine umbellata
Draba nivalis *

CRYPTOGRAMMACEAE
Cryptogramma crispa **

CYPERACEAE
Carex dioica ssp. gynocrates **
Carex enanderi **
Carex glareosa
Carex kelloggii
Carex lyngbyaei
Carex macrochaeta

* Species not observed in 1992.
** Species new in 1992.
Appendix 2 (cont.)

CYPERACEAE (CONT.)
Carex nesophila
Carex pyrenaica ssp. micropoda **
Carex rariflora *
Eriophorum angustifolium
Eriophorum scheuchzeri

DIAPENSIACEAE
Diapensia lapponica

EMPETRACEAE
Empetrum nigrum

EQUISETACEAE
Equisetum arvense
Equisetum palustre *
Equisetum silvaticum *
Equisetum variegatum

ERICACEAE
Cassiope lycopodioides
Cassiope stelleriana
Ledum palustre ssp. decumbens
Loiseleuria procumbens
Phyllocooe aleutica ssp. aleutica
Rhododendron camtschaticum ssp. camtschaticum
Vaccinium ovalifolium
Vaccinium uliginosum
Vaccinium vitis-idaea ssp. minus

GENTIANACEAE
Gentiana aleutica
Gentiana amarella ssp. acuta
Gentiana tenella
Menyanthes trifoliata **

GERANIACEAE
Geranium erianthum **

GRAMINEAE
Agrostis alaskana
Agrostis borealis **
Arctagrostis latifolia
Arctagrostis latifolia var. arundinacea **
Calamagrostis canadensis
Deschampsia beringensis
Deschampsia caespitosa
Elymus arenarius
Festuca altissima ** (from coast)
Festuca brachyphylla **
Festuca rubra
Hierlochloa odorata **
Hordeum brachyantherum **
Phleum commutatum
Poa alpina
Poa arctica ssp. arctica
Poa arctica ssp. longiculmis **
Poa palustris **
Poa paucisepala ** (from coast)
Trisetum spicatum
Vahlodea atropurpurea

HALORAGACEAE
Hippuris vulgaris

* Species not observed in 1992.
** Species new in 1992.
Appendix 2 (cont.)

JUNCAEAE
Juncus arcticus
Juncus castaneus
Juncus drummondii **
Juncus mertensianus
Luzula arcuata ssp. unalascensis **
Luzula multiflora
Luzula parviflora *
Luzula tundricola **
Luzula wahlenbergii

HYDROPHYLLACEAE
Romanzoffia sitchensis *

LEGUMINOSAE
Lupinus nootkatensis

LYCOPODIACEAE
Lycopodium alpina **
Lycopodium clavatum **
Lycopodium selago *

ONAGRACEAE
Epilobium anagallidifolium
Epilobium angustifolium
Epilobium behringianum
Epilobium glandulosum
Epilobium hormemanni
Epilobium latifolium
Epilobium leptocarpum *
Epilobium luteum *

OPHIOGLOSSACEAE
Botrychium boreale **
Botrychium lunaria
Botrychium lanceolatum **

ORTHIDACEAE
Coeloglossum viride ssp. bracteatum
Corallorrhiza trifida
Listera cordata
Platanthera dilatata ssp. chlorantha

ORTHIDACEAE (cont.)
Platanthera dilatata var. dilatata **
Platanthera obtusata *
Spiranthes romanizzofiana

PAPAVERACEAE
Papaver alaskanum

POLEMONIACEAE
Polemonium acutiflorum
Polemonium boreale

POLYGONACEAE
Koenigia islandica
Oxystyla digyna
Polygonum viviparum
Rumex graminifolius

PORTULACACEAE
Montia fontana ssp. fontana

POTAMOGETONACEAE
Potamogeton praelongus

* Species not observed in 1992.
** Species new in 1992.
Appendix 2 (cont.)

PRIMULACEAE
- Primula cuneifolia ssp. saxifragifolia
- Trientalis europaea ssp. arctica

PYROLACEAE
- Pyrola asarifolia
- Pyrola minor
- Pyrola secunda

RANUNCULACEAE
- Caltha palustris ssp. arctica
- Ranunculus escholtzii
- Ranunculus hyperboreus ssp. hyperboreus
- Ranunculus trichophyllus

ROSACEAE
- Dryas octopetala ssp. octopetala
- Geum macrophyllum ssp. macrophyllum
- Geum rossii
- Luetkea pectinata
- Potentilla palustris
- Potentilla villosa
- Rubus arcticus ssp. stellatus
- Sibbaldia procumbens

SALICACEAE
- Salix alaxensis ssp. alaxensis
- Salix arctica ssp. crassijulis
- Salix barclayi
- Salix ovalifolia
- Salix phlebophylla
- Salix pulchra
- Salix reticulata
- Salix rotundifolia **
- Salix sitchensis

SAXIFRAGACEAE
- Chrysosplenium wrightii
- Leptarrhena pyrolifolia
- Parnassia kotzebuei
- Parnassia palustris
- Saxifraga bronchialis ssp. funstonii
- Saxifraga caespitosa **
- Saxifraga foliolosa var. foliolosa
- Saxifraga hirculus
- Saxifraga lyalli *
- Saxifraga nivalis
- Saxifraga oppositifolia ssp. oppositifolia
- Saxifraga punctata ssp. nelsoniana
- Saxifraga rivularis ssp. flexuosa
- Saxifraga serpyllifolia
- Saxifraga unalaschcensis

SCROPHULARIACEAE
- Euphrasia mollis
- Lagotis glauca *
- Pedicularis capitata
- Pedicularis kanei
- Pedicularis langsdorffii ssp. langsdorffii
- Pedicularis sudetica *
- Pedicularis verticillata

* Species not observed in 1992.
** Species new in 1992.
Appendix 2 (cont.)

SCROPHULARIACEAE (CONT.)
   Veronica serpyllifolia ssp. humifusa
   Veronica stelleri
UMBELLIFERAE
   Angelica lucida
   Heracleum lanatum
VIOLACEAE
   Viola epipsila
   Viola langsдорffii

* Species not observed in 1992.
** Species new in 1992.
Appendix 3.

ANI AKCHAK CALDERA FLORA
Alphabetical by Genus
(Nomenclature follows Hulten (1968))

Achillea borealis
Agrostis alaskana
Agrostis borealis **
Angelica lucida
Antennaria monocephala var. monocephala
Antennaria pallida
Arabis lemmoni
Arabis lyrata ssp. kamchatka
Arctagrostis latifolia
Arctagrostis latifolia var. arundinacea **
Arnica chamissonis *
Arnica lessingii ssp. lessingii
Artemisia arctica ssp. arctica
Artemisia borealis **
Artemisia globularia *
Artemisia tilesii
Aster sibiricus
Athyrion filix-femina
Botrychium boreale **
Botrychium lunaria
Botrychium lanceolatum **
Calamagrostis canadensis
Caltha palustris ssp. arctica
Campanula lasiocarpa ssp. lasiocarpa
Cardamine bellidifolia **
Cardamine umbellata

Carex dioica ssp. gynocrates **
Carex enanderi **
Carex glareosa
Carex kelloggii
Carex lyngbyaei
Carex macrochaeta
Carex nesophila
Carex pyrenaica ssp. micropoda **
Carex rariflora *
Cassiope lycopodioides
Cassiope stelleriana
Cerastium beeringianum var. beeringianum
Cerastium beeringianum var. grandiflorum **
Chrysosplenium wrightii
Coeloglossum viride ssp. bracteatum
Corallorrhiza trifida
Cryptogramma crispa **
Cystopteris fragilis
Deschampsia beringensis
Deschampsia caespitosa
Diapensia lapponica
Draba nivalis *
Dryas octopetala ssp. octopetala
Dryopteris dilatata ssp. americana
Elymus arenarius
Emetrum nigrum
Epilobium anagallidifolium
Epilobium angustifolium
Epilobium behringianum
Epilobium glandulosum

* Species not observed in 1992.
** Species new in 1992.

Updated with verifications from UAF, 5/93
Appendix 3 (cont.)

Epilobium hornemannii
Epilobium latifolium
Epilobium leptocarpum *
Epilobium luteum *
Equisetum arvense
Equisetum palustre
Equisetum sylvaticum *
Equisetum variegatum *
Eriophorum angustifolium
Eriophorum scheuchzeri
Euphrasia mollis
Festuca altaica ** (From Coast)
Festuca brachyphylla **
Festuca rubra
Gentiana aleutica
Gentiana amarella ssp. acuta
Gentiana tenella
Geranium erianthum **
Geum macrophyllum ssp. macrophyllum
Geum rossii
Heracleum lanatum
Hieracium triste
Hierochloe odorata **
Hippuris vulgaris
Hordeum brachyantherum **
Juncus arcticus
Juncus drummondii **
Juncus castaneus
Juncus mertensianus
Koeningia islandica

Lagotis glauca *
Ledum palustre ssp. decumbens
Leptarrhena pyrolifolia
Listera cordata
Loiseleuria procumbens
Luettea pectinata
Lupinus nootkatensis
Luzula arcuata ssp. unalaschensis **
Luzula multiflora
Luzula parviflora *
Luzula tundricola **
Luzula wahlbergii
Lycopodium alpina **
Lycopodium clavatum **
Lycopodium selago *
Menyanthes trifoliata **
Minuartia macrocarpa
Montia fontana ssp. fontana
Oxyria digyna
Papaver alaskanum
Parnassia kotzebuei
Parnassia palustris
Pedicularis capitata
Pedicularis kanei
Pedicularis langsdorffii ssp. langsdorffii
Pedicularis sudetica *
Pedicularis verticillata
Petasites hyperboreus
Petasites frigidus X hyperboreus
Petasites frigidus

* Species not observed in 1992.
** Species new in 1992.
Appendix 3 (cont.)

Phleum commutatum
Phylloclade aleutica ssp. aleutica
Platanthera dilatata var. chlorantha
Platanthera dilatata var. dilatata **
Platanthera obtusa *
Poa alpina
Poa arctica
Poa arctica ssp. longiculmis **
Poa palustris **
Poa pseudosinuata ** (From Coast)
Polemonium acutiflorum
Polemonium boreale
Polygonum viviparum
Potamogeton praetongus
Potentilla palustris
Potentilla villosa
Primula cuneifolia ssp. saxifragifolia
Pyrola asarifolia
Pyrola minor
Pyrola secunda
Ranunculus escholtzii
Ranunculus hyperboreus ssp. hyperboreus
Ranunculus trichophyllus
Rhododendron camarstichticum ssp. camarstichticum
Romanzoffia sitchensis *
Rubus arcticus ssp. stellatus
Rumex Graminifolius
Sagina intermedia
Salix alaxensis ssp. alaxensis
Salix arctica ssp. crassijulis
Salix barclayi
Salix ovalifolia
Salix phlebophylla
Salix pulchra
Salix reticulata
Salix rotundifolia **
Salix sitchensis
Saxifraga bronchialis ssp. funstonii
Saxifraga caespitosa **
Saxifraga foliata var. foliata
Saxifraga hirculus
Saxifraga lyalli *
Saxifraga rivalis
Saxifraga oppositifolia ssp. oppositifolia
Saxifraga punctata ssp. nelsoniana
Saxifraga rivularis ssp. flexuosa
Saxifraga serpyllifolia
Saxifraga unalaskchensis
Sedum rosee ssp. integrifolium
Sibbaldia procumbens
Silene acaulis ssp. acaulis
Solidae multiflora var. multiradiata
Spiranthes romanzoffiana
Stellaria calycantha
Stellaria calycantha ssp. isophylla **
Stellaria crassifolia
Stellaria monantha
Stellaria ruscifolia ssp. aleutica
Taraxacum sp.
Trientalis europaea ssp. arctica

* Species not observed in 1992.
** Species new in 1992.
Appendix 3 (cont.)

Trisetum spicatum
Vaccinium ovalifolium
Vaccinium uliginosum
Vaccinium vitis-idaea ssp. minus
Vahlodea atropurpurea
Veronica serpyllifolia ssp. humifusa
Veronica stelleri
Viola epipsila
Viola langsdorffii

* Species not observed in 1992.
** Species new in 1992.
**Appendix 4. Communities on the North and East Sides of Surprise Lake. Classification according to Viereck et al. (1986).**

<table>
<thead>
<tr>
<th>HABITAT</th>
<th>CLASSIFICATION</th>
<th>COMMUNITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Lakeside</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mesic Headlands:</td>
<td>IIIA(2)f Mesic sedge-herb meadow tundra (sampled)</td>
<td><em>Carex macrochaeta</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Lupinus nootkatensis</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Angelica lucida</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Heracleum lanatum</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Geranium erianthum</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Solidago multiradiata</em></td>
</tr>
<tr>
<td></td>
<td>IIC(1)b Closed low willow (not sampled)</td>
<td><em>Salix barclayi</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Salix alaxensis</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Athyrium filix-femina</em></td>
</tr>
<tr>
<td>Fell-Field:</td>
<td>IID(3)a Dwarf willow tundra (not sampled)</td>
<td><em>Salix ovalifolia</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Festuca rubra</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Minuartia macrocarpa</em></td>
</tr>
<tr>
<td></td>
<td>IID(3)a Dwarf willow tundra (not sampled)</td>
<td><em>Salix arctica</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Rhododendron camtschaticum</em></td>
</tr>
<tr>
<td>S-Facing Walls:</td>
<td>IIIA(2)a Dry graminoid herbaceous-<em>Elymus</em> (not sampled)</td>
<td><em>Elymus arenarius</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>mixed alpine herbs</td>
</tr>
</tbody>
</table>

**East Lakeside**

| Terrace:         | IIC(2)g Open low willow (not sampled)               | *Salix barclayi*                      |
|                  |                                                     | *Salix alaxensis*                     |
|                  |                                                     | *Petasites* sp.                       |
|                  | IIIA(2)b Bluejoint-herb (sampled)                  | *Calamagrostis canadensis*            |
|                  |                                                     | *Achillea borealis*                   |
|                  |                                                     | *Epilobium angustifolium*             |
|                  |                                                     | *Angelica lucida*                     |
|                  |                                                     | *Lupinus nootkatensis*                |
|                  |                                                     | *Carex macrochaeta*                   |
Appendix 4 (cont.). Plant communities on the N and E sides of Surprise Lake.

Terrace (cont.): IIIA(2)a Bluejoint meadow (not sampled)
Calamagrostis canadensis
Heracleum lanatum
Epilobium angustifolium

Knolls:
IID(2)c Crowberry tundra (sampled)
Empetrum nigrum
Loiseleuria procumbens
Salix ovalifolia
Vaccinium uliginosum

Lower Slopes:
IID(2)b Dwarf willow tundra (sampled)
Salix ovalifolia
Vaccinium uliginosum
Loiseleuria procumbens
Empetrum nigrum
Carex nesophila

IID(2)b Vaccinium tundra (not sampled)
Vaccinium uliginosum
subshrubs & herbs

Steep Slopes:
IIIB(1)c Alpine herbs (not sampled)
Oxyria digyna
Saxifraga oppositifolia
Sedum oppositifolia
Sibbaldia procumbens

III A(2)f Mesic sedge-herb meadow tundra (not samp.)
Carex macrochaeta
Epilobium angustifolium
Lupinus nootkatensis

IID(2)d Mountain heath tundra (not sampled)
Luettea pectinata
Leptar rhena pyrolifolia
Phyllo de ce aleutica
### Appendix 5.

**IIIA(2)b (Viereck 1986): BLUEJOINT-HERB COMMUNITY DATA (n=25)**

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>FREQUENCY (%)</th>
<th>AVG. COVER (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calamagrostis canadensis</td>
<td>100</td>
<td>39</td>
</tr>
<tr>
<td>Achillea borealis</td>
<td>100</td>
<td>4</td>
</tr>
<tr>
<td>Moss</td>
<td>96</td>
<td>35</td>
</tr>
<tr>
<td>Epilobium angustifolium</td>
<td>92</td>
<td>4</td>
</tr>
<tr>
<td>Angelica lucida</td>
<td>88</td>
<td>7</td>
</tr>
<tr>
<td>Carex macrochaeta</td>
<td>84</td>
<td>2</td>
</tr>
<tr>
<td>Rubus arcticus</td>
<td>80</td>
<td>10</td>
</tr>
<tr>
<td>Solidago multiradiata</td>
<td>72</td>
<td>6</td>
</tr>
<tr>
<td>Lupinus nootkatensis</td>
<td>60</td>
<td>5</td>
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<tr>
<td>Vaccinium ovalifolium</td>
<td>32</td>
<td>14</td>
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<tr>
<td>Salix barclayi</td>
<td>32</td>
<td>10</td>
</tr>
<tr>
<td>Petasites sp.</td>
<td>32</td>
<td>3</td>
</tr>
<tr>
<td>Epilobium hormemani</td>
<td>28</td>
<td>2</td>
</tr>
<tr>
<td>Salix arctica</td>
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<td>6</td>
</tr>
<tr>
<td>Poa arctica</td>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>Stellaria calycantha</td>
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</tr>
<tr>
<td>Heracleum lanatum</td>
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<td>11</td>
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<tr>
<td>Salix alaxensis</td>
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<td>8</td>
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<tr>
<td>Sibbaldia procumbens</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>Artemisia arctica</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>Elymus arenarius</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Petasites hyperboreus</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Trientalis europaea</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Sedum rosea</td>
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<td>+</td>
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<tr>
<td>Salix ovalifolia</td>
<td>4</td>
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</table>
Appendix 5. Bluejoint-herb cont.

<table>
<thead>
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<th>SPECIES (cont.)</th>
<th>FREQUENCY (%)</th>
<th>AVG. COVER (%)</th>
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<tbody>
<tr>
<td>Campanula lasiocarpa</td>
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<tr>
<td>Arctagrostis latifolia</td>
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<td>+</td>
</tr>
<tr>
<td>Viola langsorffii</td>
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<td>+</td>
</tr>
<tr>
<td>Phleum commutatum</td>
<td>4</td>
<td>+</td>
</tr>
<tr>
<td>Arnica lessingii</td>
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<td>+</td>
</tr>
<tr>
<td>Pyrola asarifolia</td>
<td>4</td>
<td>+</td>
</tr>
</tbody>
</table>
Appendix 5.

IID(2)c (Viereck 1986): CROWBERRY TUNDRA (n=24)

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>FREQUENCY (%)</th>
<th>AVG. COVER (%)</th>
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<tbody>
<tr>
<td>Empetrum nigrum</td>
<td>96</td>
<td>56</td>
</tr>
<tr>
<td>Moss</td>
<td>96</td>
<td>46</td>
</tr>
<tr>
<td>Loiseleuria procumbens</td>
<td>88</td>
<td>12</td>
</tr>
<tr>
<td>Salix ovalifolia</td>
<td>83</td>
<td>5</td>
</tr>
<tr>
<td>Carex nesophila</td>
<td>83</td>
<td>2</td>
</tr>
<tr>
<td>Bare</td>
<td>83</td>
<td>13</td>
</tr>
<tr>
<td>Salix arctica</td>
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<td>5</td>
</tr>
<tr>
<td>Vaccinium uliginosum</td>
<td>24</td>
<td>10</td>
</tr>
<tr>
<td>Rhododendron camtschaticum</td>
<td>21</td>
<td>5</td>
</tr>
<tr>
<td>Sedum rosea</td>
<td>21</td>
<td>2</td>
</tr>
<tr>
<td>Epilobium latifolium</td>
<td>21</td>
<td>2</td>
</tr>
<tr>
<td>Campanula lasiocarpa</td>
<td>17</td>
<td>+</td>
</tr>
<tr>
<td>Solidago multiradiata</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Festuca rubra</td>
<td>8</td>
<td>+</td>
</tr>
<tr>
<td>Arnica lessingii</td>
<td>8</td>
<td>+</td>
</tr>
<tr>
<td>Elymus arenarius</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Lurula arcuata ssp. arcuata</td>
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<td>+</td>
</tr>
<tr>
<td>Minuartia macrocarpa</td>
<td>4</td>
<td>+</td>
</tr>
<tr>
<td>Pedicularis langsdorffii</td>
<td>4</td>
<td>+</td>
</tr>
<tr>
<td>Polygonium viviparum</td>
<td>4</td>
<td>+</td>
</tr>
<tr>
<td>SPECIES</td>
<td>FREQUENCY (%)</td>
<td>AVG. COVER (%)</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>---------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Moss</td>
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<td>38</td>
</tr>
<tr>
<td>Bare</td>
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<tr>
<td>Stereocaulin sp.</td>
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<td>7</td>
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<tr>
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<tr>
<td>Luzula arcuata</td>
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</tr>
<tr>
<td>Festuca rubra</td>
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<td>+</td>
</tr>
<tr>
<td>Empetrum nigrum</td>
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<td>12</td>
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<tr>
<td>Loiseleuria procumbens</td>
<td>52</td>
<td>5</td>
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<tr>
<td>Solidago multiradiata</td>
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<tr>
<td>Vaccinium uliginosum</td>
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<tr>
<td>Rhododendron caatschaticum</td>
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<tr>
<td>Achillea borealis</td>
<td>40</td>
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<tr>
<td>Epilobium latifolium</td>
<td>36</td>
<td>+</td>
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<tr>
<td>Salix arctica</td>
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<tr>
<td>Campanula lasiocarpa</td>
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<td>24</td>
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<tr>
<td>Arnica lessingii</td>
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</tr>
<tr>
<td>Rock</td>
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<tr>
<td>Elymus arenarius</td>
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</tr>
<tr>
<td>Deschampsia caespitosa</td>
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<td>+</td>
</tr>
<tr>
<td>Petasites sp.</td>
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<td>+</td>
</tr>
<tr>
<td>Artemisia arctica</td>
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<td>+</td>
</tr>
<tr>
<td>Minuartia macrocarpa</td>
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<td>4</td>
</tr>
<tr>
<td>Trisetum spicatum</td>
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<td>+</td>
</tr>
<tr>
<td>Polygonium viviparum</td>
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<td>+</td>
</tr>
<tr>
<td>Pedicularis langsdorffii</td>
<td>4</td>
<td>+</td>
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</table>
## Appendix 5.

**IIA(2)f (Viereck 1986): MESIC SEDGE-HERB MEADOW TUNDRA (n=25)**

<table>
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<tr>
<th>SPECIES</th>
<th>FREQUENCY</th>
<th>AVG.COVER</th>
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<tbody>
<tr>
<td>Moss</td>
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<tr>
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<td>17</td>
</tr>
<tr>
<td>Angelica lucida</td>
<td>100</td>
<td>10</td>
</tr>
<tr>
<td>Solidago multiradiata</td>
<td>100</td>
<td>5</td>
</tr>
<tr>
<td>Achillea boreanis</td>
<td>100</td>
<td>4</td>
</tr>
<tr>
<td>Carex macrochelata</td>
<td>96</td>
<td>36</td>
</tr>
<tr>
<td>Epilobium angustifolium</td>
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<td>4</td>
</tr>
<tr>
<td>Epilobium hirsutum</td>
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<td>3</td>
</tr>
<tr>
<td>Poa arctica</td>
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</tr>
<tr>
<td>Haracleum lanatum</td>
<td>84</td>
<td>20</td>
</tr>
<tr>
<td>Calamagrostis canadensis</td>
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</tr>
<tr>
<td>Viola langsdorffii</td>
<td>48</td>
<td>8</td>
</tr>
<tr>
<td>Elymus arenarius</td>
<td>48</td>
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</tr>
<tr>
<td>Phleum commutatum</td>
<td>48</td>
<td>1</td>
</tr>
<tr>
<td>Stellaria calycantha</td>
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<td>+</td>
</tr>
<tr>
<td>Botrychium lunaria</td>
<td>36</td>
<td>+</td>
</tr>
<tr>
<td>Equisetum arvense</td>
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<td>+</td>
</tr>
<tr>
<td>Salix barclayi</td>
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<tr>
<td>Geranium erianthum</td>
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<td>4</td>
</tr>
<tr>
<td>Rubus arcticus</td>
<td>28</td>
<td>3</td>
</tr>
<tr>
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<td>Festuca rubra</td>
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<tr>
<td>Trientalis spicata</td>
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<tr>
<td>Veronica stelleri</td>
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<td>+</td>
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<tr>
<td>Silbeldia procumbens</td>
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<tr>
<td>Salix alaskana</td>
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</tr>
<tr>
<td>Euphrasia mollis</td>
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<td>+</td>
</tr>
<tr>
<td>Coeloglossum viride asp. bracteatum</td>
<td>4</td>
<td>+</td>
</tr>
<tr>
<td>Rhododendron caucasicicum</td>
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<td>+</td>
</tr>
<tr>
<td>Epilobium anagallidifolium</td>
<td>4</td>
<td>+</td>
</tr>
<tr>
<td>Lusula multiflora</td>
<td>4</td>
<td>+</td>
</tr>
<tr>
<td>Petasites hyperboreus</td>
<td>4</td>
<td>+</td>
</tr>
<tr>
<td>Gentiana tenella</td>
<td>4</td>
<td>+</td>
</tr>
<tr>
<td>Cardamine umbellata</td>
<td>4</td>
<td>+</td>
</tr>
</tbody>
</table>

58
(* also observed in 1987)
(** only known to occur at this site)

Agrostis borealis
Antennaria monocephala var. monocephala
Arctagrostis latifolia
Arnica lessonii ssp. lessonii
Aster sibiricus
Athyrium filix-femina *
Campanula lasiocarpa ssp. lasiocarpa
Cardamine bellidifolia *
Carex glareosa
Carex nesophila
Cassiope lycopodioides *
Cerastium beeringianum var. beeringianum
Cryptogramma crispa **
Cystopteris fragilis

Erythronium dilatata ssp. americana *
Euphrasia nigrum *
Epilobium anagallidifolium
Epilobium angustifolium *
Epilobium latifolium *
Pestula brachyphylla
Hieracium triste
Juncus biglumis
Luetkea pectinata
Luzula tundricola
Luzula wahlenbergii *
Lycopodium alpina **
Lycopodium clavatum **
Minuartia macrocarpa
Oxycia digyna *
Petasites frigidus X hyperboreus
Phyllocooe aleutica ssp. aleutica

Polemonium boreale
Potentilla villosa
Pyrola minor
Rhododendron caatschaticum ssp. caatschaticum *
Rumex graminifolius
Salix arctica ssp. crassijulies
Salix barclayi
Salix ovalifolium *
Salix reticulata
Salix rotundifolia **
Salix sitchensis
Saxifraga foliolosa var. foliolosa *
Saxifraga nivalis
Saxifraga punctata *
Saxifraga rivularis ssp. flexuosa
Saxifraga serpyllifolia
Saxifraga unalschoensis
Sedum rosea ssp. integrifolium
Sibbaldia procumbens
Solidago multiradiata var. multiradiata
Stellaria monantha */**
Trisetum spicatum
Veronica stelleri