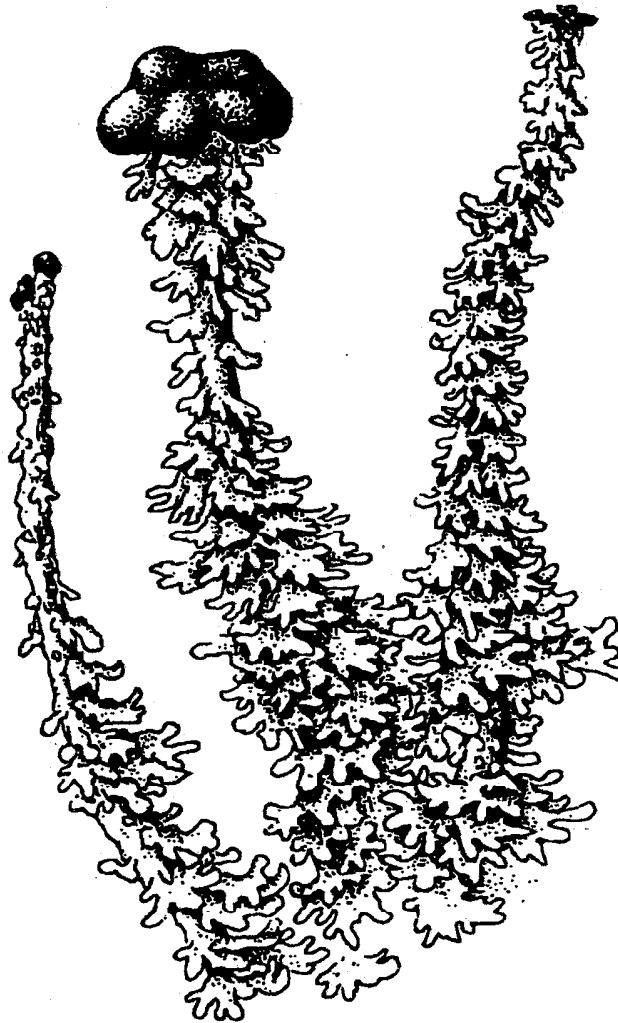


Vascular and Nonvascular Vegetation of Aniakchak Caldera, Alaska

Linda M. Hasselbach
Technical Report NPS/PNROSU/NRTR-95/05



UNITED STATES DEPARTMENT OF THE INTERIOR
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**VASCULAR AND NONVASCULAR VEGETATION
OF ANIAKCHAK CALDERA, ALASKA**

Linda M. Hasselbach

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In addition, the following people contributed their botanical expertise to provide verifications, as well as help with difficult genera. Many thanks to Lewis Anderson, William Buck, Howard Crum, Dan Norris, William Schofield, and Dale Vitt, for the mosses; Bruce McCune for the lichens; and Stanley Welsh for the vascular plants. Funding for this project was provided by the National Natural Landmark program and by Katmai National Park. The staff of Katmai National Park also provided generous logistical support. Alexander Mikulin kindly provided the illustration for the cover.

Finally, while this thesis is all about the 'science' of Aniakchak, I cannot close without acknowledging the power of that strange and wild place. We are fortunate as a society to be able to set aside such places in recognition of their intrinsic value, and I am very fortunate to have had the opportunity to experience the beauty of such an incredible place.

Vascular and Nonvascular Vegetation of Aniakchak Caldera, Alaska

ABSTRACT

Vascular and nonvascular vegetation was sampled on 52 plots representing the widest possible range of geomorphic variation in Aniakchak caldera, Alaska. Data from these plots were analyzed to detect vegetation patterns with respect to environmental gradients.

Nonmetric multidimensional scaling ordination revealed proximity to water as the primary environmental gradient. Plant communities were related to presence of rock (i.e. lava flows, basalt outcrops) as the secondary gradient, and to steepness of slope as the tertiary. Seven vegetation groups were identified with cluster analysis. Discriminant analysis was then used to identify the distinguishing ecological factors and characteristic species associated with each group. A list of 348 vascular and nonvascular species, including habitat reference information, is presented.

Successional processes following the 1931 eruption were discussed with respect to substrate type, nutrient levels and dominance patterns. The abundance of nitrogen-fixing taxa, which accounted for 73% of the total lichen cover, was discussed with regard to their potential role as facilitators of primary succession.

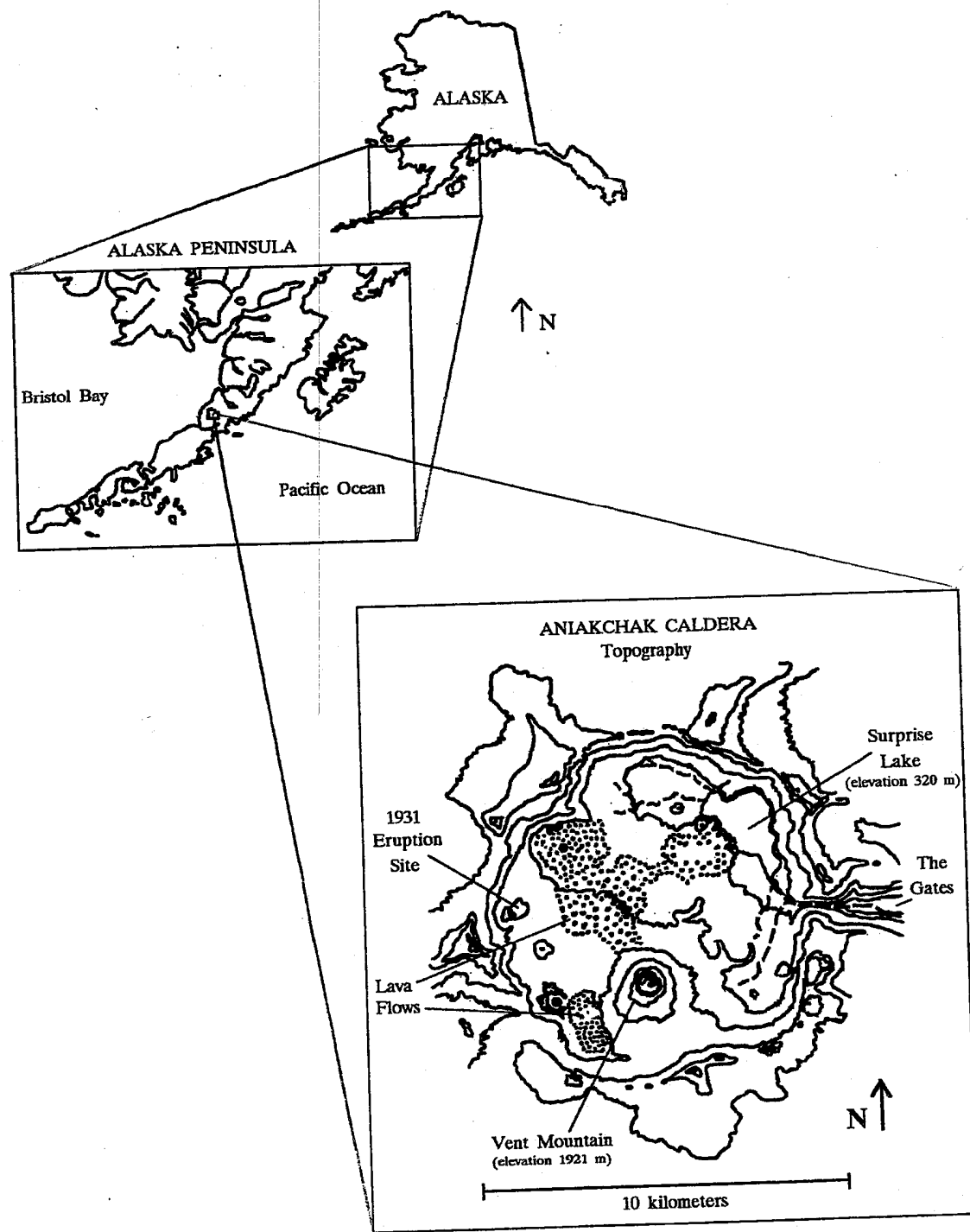
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Chapter I. Introduction

Situated on the central Alaska Peninsula, midway between the Pacific Ocean and the Bering Sea, Aniakchak (56.88°N, 158.17°W) is one of a long chain of volcanoes forming the backbone of the Aleutian Range (Figure 1). Although progress has been made in understanding the vegetation ecology of volcanic areas in many regions of the world (Tagawa et al. 1985, Tsuyuzaki 1987, delMoral & Wood 1988), very little is known about such areas in Alaska, specifically on the Alaska Peninsula. Existing vegetation research on the volcanic peninsula primarily consists of work at Katmai National Park's Valley of Ten Thousand Smokes after the eruption of Novarupta Volcano in 1912 (Griggs 1919 a,b). As both a National Monument and a National Natural Landmark, Aniakchak offers an excellent opportunity to study the natural patterns of an ecosystem unaltered by human impact.

First "discovered" in 1922, the 35 km² caldera was believed to be one of the largest in the world. Father Bernard Hubbard, then head of the Geology Department at Santa Clara University, launched an exploratory trek into the area in 1930. Upon reaching Aniakchak caldera he discovered a "wonderland" of which he wrote enthusiastically: "The amount and variety of life astonished us... the fish, game, and bird life was even surpassed by the variety and profusion of flowers, particularly orchids..." (Hubbard 1931, p. 332). It was during this expedition that Hubbard began to suspect that Mt. Aniakchak was not a dead volcano as commonly assumed, but active to the point of imminent eruption. The proof came on May 1, 1931 when Aniakchak erupted through a side vent in the caldera floor. The eruption lasted 10 days, sending a continuous stream of gases, pumice, rocks and ash into the air.

Figure 1. Location map (modified from Cameron (1992)).



The earth shook, flame and smoke rose thousands of feet high, and the pyrotechnic display of individual lava bombs hurtling through the air combined with the lightening forming in the clouds to make a truly fear-inspiring sight. Thunder added its din to the almost constant explosions of the erupting volcano, and the sides of the mountain reverberated to the crash of falling rocks (Hubbard 1932, p. 56).

Sixty miles to the south, at Chignik, the volume of ashfall was estimated as "a pound per hour to the square foot" (Hubbard 1932). Ashfall was even heavier to the north. On Kodiak Island, Katmai National Monument and points more than 250 km distant, a centimeter of ash covered everything (Hubbard 1932). Within the caldera, ash accumulated to depths of 60 cm (Hubbard 1932).

Hubbard returned to Aniakchak caldera in the weeks following the eruption and wrote:

There was a new Aniakchak, but it was the abomination of desolation, it was the prelude of hell. Black walls, black floor, black water, deep black holes and black vents....no streams coarsed through flower strewn meadows, no grassy slopes led up to former volcanic vents; no glistening glaciers or snowfields broke the monotony of huge crater walls... Beautiful Surprise Lake, nestled under the northern rim, was choked and muddy and black were its shores, and filled its coves... (Hubbard 1932, p. 61).

Obviously a disturbance of this magnitude would be expected to have a profound impact on plant communities within the caldera. Direct references to vegetation effects are scarce in Hubbard's documents, limited to passing comments such as: "we were going through a valley of death in which not a blade of grass or a flower or a bunch of moss broke through the thick covering of deposited ash..." (Hubbard 1932, p. 60).

No further biological investigation occurred until a 1967 reconnaissance 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 (NNL). Aniakchak was incorporated into the National Park Service (NPS) in 1978. NPS biotechnicians performed

short-term vegetation studies in the vicinity of Surprise Lake in 1987 and 1988 (Bosworth 1987, Sowl 1988). In 1992 and 1993, with the assistance of funding from the NNL program, a large scale study was undertaken, the goal of which was to better understand the ecology of the vascular and nonvascular vegetation of Aniakchak caldera as it currently existed, 63 years after the eruption.

The inclusion of nonvascular plants in this study is noteworthy. Too often nonvascular plants are excluded from such endeavors due to their small stature and the taxonomic difficulty associated with their identification. Yet in Aniakchak caldera the prominence of mosses and lichens is readily apparent (Bosworth 1987, Hasselbach 1993). Nonvascular plants are extremely important to the functioning of many plant communities. For example, mosses aid in water retention, nutrient cycling, soil development and stabilization, and provide microsite sheltering for propagules (Longton 1992). Lichens function as nitrogen fixers, provide important forage for caribou and other animals, and also aid in soil development through physical and chemical weathering (Longton 1992). Despite the significance of nonvascular plants, knowledge of these taxa on the Alaska Peninsula is extremely limited, the nearest published work originating at Amchitka Island (Persson 1968, Thomson & Sowl 1989), 700 km southwest of Aniakchak. Therefore, from a floristic standpoint, the inclusion of nonvascular plants fills a void in the existing knowledge of species distribution on the Alaska Peninsula.

This technical report synthesizes the findings of a more detailed thesis entitled *Vascular and Nonvascular Vegetation of the Caldera of Mt. Aniakchak, Alaska*. The original thesis is in the form of two manuscripts:

- I. *Correlation between vascular and nonvascular strata in Aniakchak caldera, Alaska with emphasis on the importance of scale.*

II. *Patterns of vascular and nonvascular vegetation with respect to environmental gradients in Aniakchak caldera, Alaska.*

The purpose of restructuring the thesis into a technical report is to make the information more accessible for management purposes. The reader is referred to the original thesis (available through the NPS in King Salmon, AK or through Oregon State University) for a full account of this work. Raw data are included in the thesis document as well.

This research in Aniakchak caldera was designed to address both the lack of understanding of the vegetation ecology in volcanic landscapes of the Alaska Peninsula, and the lack of distributional data for lichens and mosses. The objectives were: (1) to describe the vegetation of Aniakchak caldera by identifying major vegetative groups and their component species, (2) to determine the environmental factors most important in the separation of the vegetation groups, (3) to identify important environmental gradients and examine the distribution of plant communities in relation to them, and (4) to describe successional patterns following the eruption in 1931. A total of 348 species were documented in Aniakchak as a result of this study. Of these, 305 species (including 164 vascular and 141 nonvascular species) were encountered on the sample plots.

STUDY SITE DESCRIPTION

Aniakchak caldera was formed approximately 3400 years ago by the collapse of an andesitic stratovolcano (Miller 1990). It is 9.5 km in diameter and encompasses an area of approximately 35 km². The lowest point on the caldera floor is 320 m in elevation. The rim averages 1000 m in elevation with the highest point reaching 1341 m. Post-formation volcanic activity within the caldera has resulted in the emplacement of numerous lava domes, maars, eruption pits and lava flows (Miller 1990). The caldera remains thermally active as evidenced by the presence of several warm springs, as well as areas with ground temperatures of 85°C at depths of 25 cm (Miller 1990). The most recent eruption occurred in 1931 from a side vent in the caldera floor. This event blanketed the caldera with up to 60 cm of volcanic ash (Hubbard 1932) and had a significant impact on the vegetation within the caldera (Hubbard 1932). Soils, most of which are derived from ashfall, are well-drained and acidic (pH = 4.8-5.2).

A deep lake filled much of the caldera at one time (McGimsey et al. 1995). This lake eventually breached the caldera rim eroding a deep cleft in the eastern portion of the caldera wall (Cameron 1992). Surprise Lake, a large (275 ha) lake located along the northeast edge of the caldera floor, is a relict of the ancient lake. Surprise Lake drains 80% of the caldera and is fed by 11 surface inlets and numerous warm and cold springs (Cameron 1992).

Due to its position on the crest of the Aleutian Range, the caldera is affected by both the Pacific Coast and Bristol Bay climatic regimes. The Pacific coast has a maritime climate characterized by high precipitation and moderate temperatures; Bristol Bay has a more continental climate with lower precipitation and wider temperature ranges. Weather inside the caldera is affected by shifting air currents that carry weather from the two climate zones (in

Cameron 1992), as well as by its own topography. Low cloud ceilings, rain, and high winds are common, even when the weather is relatively calm outside the caldera. Meteorological data for Aniakchak caldera is limited to weather observations recorded daily for the duration of this study (June 23 to August 23, 1993). During this period, average daily maximum and minimum temperatures were 59°F and 47°F respectively. Measurable precipitation was recorded on 32 days for a cumulative total of 29.4 cm. Maximum recorded wind speed was 100+ km/hr. Winter snow accumulation data is unavailable for the caldera, but ranges from 74 cm at Port Heiden on the Bristol Bay Coast to 150 cm at Chignik on the Pacific Coast (in Cameron 1992).

There are no trees, and relatively few tall shrubs, in Aniakchak caldera. Most of the vegetative biomass is concentrated around Surprise Lake. The lake inlet area has three perennial streams and supports a large subarctic lowland wet sedge meadow (Carex lyngbyaei). The lake outlet area contains a large lowland herb wet meadow with areas of wet bryophytes (Philonotis fontana). The lush headlands and terraces around the lake support bluejoint meadows (Calamagrostis canadensis), open low willow stands (Salix alaxensis and S. barclayi) and mesic mixed herb communities (Lupinus nootkatensis, Epilobium angustifolium, etc.). These areas tend to have high vegetative cover and a diverse flora. Crowberry tundra (Empetrum nigrum) is also well represented on low slopes around the perimeter of the lake (vegetation community nomenclature as used above follows Viereck et al. 1992).

Much of the remainder of the caldera consists of rugged windswept ash fields supporting comparatively few species. The moss Racomitrium ericoides forms large mats, and the dwarf willow Salix stolonifera is also common. Basaltic outcrops support a complex of lichen species including Melanelia stygia, Pseudephebe minuscula, Parmelia saxatilis and several species of Umbilicaria. A cryptogamic crust consisting primarily of liverwort species

(e.g., Cephaloziella spp., Marsupella alpina, Pleuroclada albescens) covers large portions of the ash flows. Lava flows and eruption pits are dominated by nonvascular species including thick carpets of Racomitrium ericoides and R. lanuginosum. Stereocaulon vesuvianum, a lichen with nitrogen-fixing cephalodia, is abundant on lava rock throughout the caldera.

Two vegetation strata are easily recognized in the caldera. The nonvascular layer ranges in height from 1 to 6 cm and is typically appressed to the substrate. It is composed of a wide variety of moss, liverwort, and lichen species. The vascular layer, which seldom exceeds 60 cm in height, consists of a variety of herbs and dwarf willow species.

METHODS

Field Methods

Observations were made on 52 plots from June through August, 1993 (Appendix I). Using knowledge of Aniakchak caldera vegetation from an earlier pilot study (Hasselbach 1992), 18 separate geomorphic features were chosen to represent the widest possible range of diversity within the caldera. Three 0.10 hectare (1000 m²) circular plots were placed within each geomorphic unit with the exception of two smaller units which had two plots apiece.

General site information, including slope, aspect, elevation, topographic position, presence of surface water (m²), distance-to-water (1=water present on plot, 2=water within 100 m of plot, 3=water greater than 100 m from plot), percent rock, percent cryptogamic crust, percent overall vegetative cover, relative vascular cover (%), and relative nonvascular cover (%) was recorded for each plot. Overall vegetative cover on the plots was recorded as an absolute value ranging from 0 to 100%. Vascular and nonvascular cover were designed to reflect the relative abundance of these plants and, as such, always added to 100% (e.g., a plot with an overall vegetative cover of 60% may have relative vascular and nonvascular cover values of 25% and 75% respectively).

Cover for both vascular and nonvascular (moss, liverwort, and macrolichen) species was estimated using the following cover classes: 1=single individual, 2= two individuals to 1%, 3=2-5%, 4=6-25%, 5=26-50%, 6=51-75%, 7=76-100%. A whole-plot method was chosen for recording both vascular and nonvascular cover. Whole-plot estimates of cover yield higher species capture than sampling with many small subplots, especially when vegetation is sparse or patchy (McCune & Lesica 1992) as it is in many areas of the caldera. The disadvantage of the whole-plot method is that it sacrifices a degree of quantitative accuracy (McCune & Lesica

1992). Since little is known about the nonvascular plants of the Alaska Peninsula from a floristic perspective, we wanted to produce the most complete species inventory possible. Soil pH was measured on 4 representative samples using a dye indicator test kit.

Vouchers of all species were collected for residence in the University of Alaska herbarium in Fairbanks. To insure accuracy, representatives of each species were sent to botanical authorities for verification. A list of experts contacted for this purpose appears in the Acknowledgements section. Since no reference exists for keying nonvascular plants on the Alaska Peninsula, a variety of sources from other regions were consulted. These included Lawton (1971), Crum & Anderson (1981), and Norris (1994) for mosses; Schuster (1966), for liverworts; and Thomson (1984), and Goward (1994) for lichens. For especially troublesome genera monographs were also used. Crustose lichens were collected on all plots but were not included due to the time intensive nature of keying this very difficult group. The unidentified crustose lichens currently reside at Oregon State University (contact Dr. Bruce McCune) and may be of value in future studies. Nomenclature of vascular plants follows Hult  n (1968). Nomenclature for lichens, mosses, and liverworts follows Thomson (1984), Anderson et al. (1990), and Schuster (1966) respectively.

Data Analysis

Diversity Measures Gamma diversity (γ) was recorded as the total number of species encountered on the plots. Beta diversity (β) was calculated by dividing the total number of species on all plots by the average number of species on a single plot (Whittaker 1960, 1972). Used in this fashion, β is an indication of the overall amount of species compositional change (or heterogeneity) between plots (Whittaker 1972) rather than the rate of species change along a single gradient. Species richness (S) was measured as the number of species occurring on a

plot. Species diversity, which incorporates both S and the evenness with which species are distributed, was computed using the Shannon-Weaver index (H' ; Shannon & Weaver 1949; as implemented in McCune 1993). Although there are problems with all diversity indices (Peet 1974), the use of H' is appropriate as a means of comparing diversity between the different vegetation groups within the caldera. The entire primary data matrix (52 plots x 305 species) was used in all of the above calculations.

Ordinations Elsewhere (Hasselbach 1995; Masters Thesis), an examination of the relationship between the vascular and nonvascular strata in Aniakchak revealed that they exhibited a relatively high degree of correlation with one another with respect to the primary moisture gradient. Therefore, for the purposes of this report, the vascular and nonvascular strata were combined into a single data set and analyzed collectively.

Prior to analysis, species with fewer than 4 occurrences were removed from the data set reducing the total number of species to 158. Ordinations, using the quantitative version of the Sørensen index (Beals 1984) as the distance measure, were performed with nonmetric multidimensional scaling (NMS) (Kruskal 1964; Mather 1976; as implemented in McCune 1993). The goal of ordination is to simplify complex data sets by arranging plots (or species) in low dimensional space. In this case, ordination reduced the original data matrix from 158 dimensions to 3 (plots are in species-space). The end product is a two-dimensional 'graph' in which similar plots are near each other and dissimilar plots are far apart (e.g., Figure 6). Community patterns (as reflected by the ordination graph) are then compared with environmental information to produce an environmental interpretation of the ordination results. This is achieved by regressing ordination scores for the plots against the separate environmental variables. This operation is performed separately for each axis. The result is a series of correlation coefficients as presented in Table 3. Vector diagrams (Figures 3,4)

provide a visual way of assessing how the environmental correlations relate to one another and to the underlying ordination. In interpreting vector diagrams, one looks at the length (the longer the vector the stronger the correlation) and direction of the vectors relative to the axis-of-interest. For example, in interpreting Axis 2 (i.e. the secondary environmental gradient) in Figure 3, one immediately sees a strong positive correlation of that axis with presence of both nonvasculars and rock, and a strong negative relationship with presence of vascular plants. Given this information, it is up to the researcher to interpret the gradients. In this case, I interpret Axis 2 as a 'rock gradient'.

For the Aniakchak data, initial ordinations revealed a group of 9 sparsely vegetated plots of similar make-up that were forcing the remainder of the plots to be clustered into a tight, uninterpretable mass. Since 8 of these plots also grouped together in the cluster analysis, they were removed from the main ordination and described them separately in the classification section (see Group 7). Three additional plots were identified as outliers (average distance to other plots > 2.00 standard deviations from the overall average distance) and were removed to improve the spread and interpretability of the ordination. Ordination of the final data matrix (40 plots x 158 species) yielded three interpretable axes.

Classification Seven vegetation groups were defined through cluster analysis of 49 plots. Three empty plots were removed to avoid division by zero. Ward's method, an hierarchical agglomerative polythetic procedure (CLUSTER in PC-ORD; McCune 1993), was used to form the groups. To equalize the weighting of the plots, relative Euclidean distance measure was chosen. Discriminant analysis was then used to evaluate the adequacy of this classification by identifying misclassified plots.

Discriminant Analysis (DA) is a statistical method for examining membership of predefined groups based on a set of predictors (e.g., environmental variables). This technique

was used to determine which ecological factors were most important in the separation of the seven groups. In a separate analysis, DA was used to identify characteristic species for each group. To distinguish ecological factors most important in separating groups, the ecological variables for each of the seven vegetation groups were entered simultaneously (Method = DIRECT in SPSS; Norusis 1990), group means for each ecological variable were calculated, and means were compared to determine differences among groups. The ecological variables included elevation, slope, aspect, rock (%), cryptogamic crust (%), overall vegetative cover (%), nonvascular cover (%), standing water (m²), flowing water (m²), and distance-to-water. This procedure was repeated to determine characteristic plant species for each group by simultaneously entering species data.

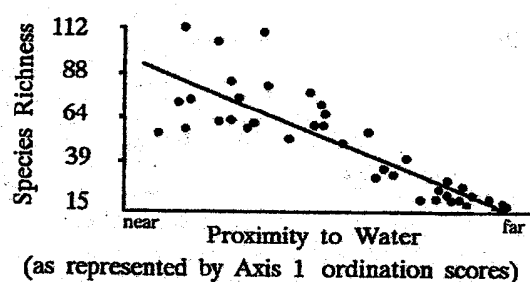
RESULTS AND DISCUSSION

Diversity and Floristics

A total of 348 species were documented in Aniakchak caldera as a result of this study (Table 2, Appendix II). Of these, 305 species (including 164 vascular and 141 nonvascular species) were encountered on the sample plots. Nonvascular plants were underestimated as a result of the omission of crustose lichens from the data set due to their taxonomic difficulty.

The number of species present (S) ranged from 0 to 112 on individual plots, with an average of 41 species per plot (standard deviation=0.87). Figure 2 demonstrates the decline in species richness with distance from Surprise Lake (see Axis 1 ordination results for explanation of horizontal axis). Camping in the caldera is often limited to the coves on the southeast side of Surprise Lake because they are close to drinking water while at the same time affording a significant degree of protection from the frequent and severe winds. Coincidentally, the three richest and most species diverse plots (Plots 4,15,20) occurred on the lava headlands which separate the coves from one another. Travel routes between coves invariably traverse these headland areas. Although well-worn bear trails currently exist, the temptation to simply travel overland, thus trampling the vegetation, is great. Soils in this area are derived from ashfall and are of sandy texture with inherently poor cohesion so they give way under pressure, dislodging mats of vegetation. Although the resiliency of headland vegetation to this sort of disturbance is unknown, it is reasonable to assume recovery time would be slow in such a severe environment especially considering the slow rate of vegetative recolonization since the 1931 eruption. In the event of increased visitation to the caldera impact to these headlands would be of concern.

Figure 2. Species richness as a function of proximity to water.



A total of 53 species (19 vascular and 34 nonvascular) were encountered only once in the sampling of 52 plots (Table 2). Typically, these "rare" taxa occurred on either headlands or in eruption pits. The 15 most frequent taxa (i.e. those occurring on 50% or more of the plots) are noted in Table 2. A total of 22 range extensions were recorded for vascular plants (Appendix III). Range extension information is difficult to ascertain for nonvascular plants due to the general lack of distributional information on the Alaska Peninsula. Overall beta diversity (β) was 7.4 indicating a fairly high degree of heterogeneity between plots. Beta diversity for vascular and nonvascular components separately was 6.7 and 8.5 respectively. Overall species diversity values (H') were similar for vascular and nonvascular plants (Table 1).

Table 1. Mean species diversity indices for plot data set.

	Gamma Diversity (γ)	Species Richness (S)	Beta Diversity (β)	Shannons Diversity Index (H')
all species	305	41	7.4	3.10
vascular species	164	25	6.7	2.53
nonvascular species	141	16	8.5	2.30

An annotated species list (Appendix II), built around the 1994 data, indicates frequency of occurrence, habitat, plot (when applicable), and substrate (for nonvascular plants) on which each species occurred. This list represents a compilation of all verified species found in Aniakchak caldera including those from earlier workers. Habitat data included in this list is intended to be indicative of typical habitats, but is not comprehensive (ie. species may be found in areas other than those indicated by the list).

In addition to the macrophytic species discussed above, a cryptogamic crust also occurs in the caldera. Cryptogamic crusts develop at soil surfaces and usually consist of some combination of tiny mosses, liverworts, lichens, algae (brown, green, blue-green) and fungi (West 1990). Such crusts are common in climatically extreme environments (e.g., desert and tundra) and are known to occur on new volcanic surfaces (West 1990). While the role of cryptogamic crusts in ecosystem processes is poorly understood at present (West 1990), many scientists believe they perform valuable functions. Crusts may enhance soil moisture by increasing interception and infiltration of rain water, slow erosion by water and wind, increase nutrient input and retention, aid in seed lodgement, add organic matter and contribute to soil development (see West 1990 for review).

In Aniakchak, cryptogamic crusts commonly occur in the flat, open, apparently barren portions of the mid and upper caldera floor - areas that are well suited to foot travel by visitors. The impact of human footprints on cryptogamic crust is unknown, although research indicate that most crusts are susceptible to mechanical damage by livestock grazing (Rogers & Lange 1971). Furthermore, some crusts are very slow to recover from disturbance, at least in desert regions (Webb et al. 1988). Impact to cryptogamic crust communities in Aniakchak is another area of concern should visitor use increase.

Table 2.1 Vascular Plant Species.

* indicates species observed on a single plot.

** indicates frequency of occurrence is greater than 50%

<i>Achillea borealis</i> **	<i>Deschampsia beringensis</i>
<i>Agrostis alaskana</i>	<i>Deschampsia caespitosa</i> **
<i>Agrostis borealis</i>	<i>Diapensia lapponica</i>
<i>Angelica lucida</i>	<i>Draba alpina</i> *
<i>Antennaria alpina</i> var. <i>compacta</i>	<i>Draba crassifolia</i>
<i>Antennaria monocephala</i> var. <i>monocephala</i>	<i>Draba nivalis</i> *
<i>Antennaria pallida</i>	<i>Dryas octopetala</i> ssp. <i>octopetala</i>
<i>Arabis lemmoni</i>	<i>Dryopteris dilatata</i> ssp. <i>americana</i>
<i>Arabis lyrata</i> ssp. <i>kamchatica</i>	<i>Elymus arenarius</i>
<i>Arctagrostis latifolia</i> var. <i>latifolia</i>	<i>Empetrum nigrum</i>
<i>Arctagrostis latifolia</i> var. <i>arundinacea</i> *	<i>Epilobium anagallidifolium</i>
<i>Arnica chamissonis</i>	<i>Epilobium angustifolium</i> ssp. <i>macrophyllum</i>
<i>Arnica lessingii</i> ssp. <i>lessingii</i> **	<i>Epilobium behringianum</i>
<i>Artemisia arctica</i> ssp. <i>arctica</i>	<i>Epilobium glandulosum</i>
<i>Artemisia borealis</i>	<i>Epilobium hornemannii</i>
<i>Artemisia globularia</i> *	<i>Epilobium latifolium</i> **
<i>Artemisia tilesii</i>	<i>Epilobium leptocarpum</i>
<i>Aster sibiricus</i>	<i>Epilobium luteum</i>
<i>Athyrium filix-femina</i>	<i>Equisetum arvense</i>
<i>Botrychium boreale</i> *	<i>Equisetum palustre</i>
<i>Botrychium lanceolatum</i>	<i>Equisetum silvaticum</i>
<i>Botrychium lunaria</i>	<i>Equisetum variegatum</i>
<i>Calamagrostis canadensis</i>	<i>Eriophorum angustifolium</i>
<i>Caltha palustris</i> ssp. <i>arctica</i>	<i>Eriophorum scheuchzeri</i>
<i>Campanula lasiocarpa</i> ssp. <i>lasiocarpa</i>	<i>Euphrasia mollis</i>
<i>Cardamine bellidifolia</i>	<i>Festuca altaica</i>
<i>Cardamine umbellata</i>	<i>Festuca brachyphylla</i>
<i>Carex bigelowii</i>	<i>Festuca rubra</i>
<i>Carex dioica</i> ssp. <i>gynocrates</i>	<i>Gentiana aleutica</i>
<i>Carex enanderi</i>	<i>Gentiana amarella</i> ssp. <i>acuta</i>
<i>Carex glareosa</i>	<i>Gentiana tenella</i>
<i>Carex kelloggii</i>	<i>Geranium erianthum</i>
<i>Carex lachenalii</i>	<i>Geum macrophyllum</i> ssp. <i>macrophyllum</i>
<i>Carex lyngbyaei</i>	<i>Geum rossii</i>
<i>Carex macrochaeta</i>	<i>Gymnocarpium dryopteris</i> *
<i>Carex nesophila</i>	<i>Heracleum lanatum</i>
<i>Carex pyrenaica</i> ssp. <i>micropoda</i>	<i>Heuchera glabra</i> *
<i>Carex rariflora</i>	<i>Hieracium triste</i>
<i>Carex spectabilis</i>	<i>Hierlochioe odorata</i>
<i>Cassiope lycopioides</i>	<i>Hippuris vulgaris</i>
<i>Cassiope stelleriana</i>	<i>Hordeum brachyantherum</i>
<i>Cerastium beeringianum</i> var. <i>beeringianum</i>	<i>Juncus arcticus</i>
<i>Cerastium beeringianum</i> var. <i>grandiflorum</i>	<i>Juncus castaneus</i>
<i>Chrysosplenium wrightii</i>	<i>Juncus drummondii</i>
<i>Coeloglossum viride</i> ssp. <i>bracteatum</i>	<i>Juncus mertensianus</i>
<i>Corallorrhiza trifida</i>	<i>Koenigia islandica</i>
<i>Cryptogramma crispa</i>	<i>Lagotis glauca</i>
<i>Cystopteris fragilis</i>	<i>Ledum palustre</i> ssp. <i>decumbens</i>

- Leptarrhena pyrolifolia*
Listera cordata
Loiseleuria procumbens
Luetkea pectinata
Lupinus nootkatensis
Luzula arcuata ssp. *unalaschensis* **
Luzula multiflora
Luzula parviflora
Luzula tundricola
Luzula wahlenbergii ssp. *piperi*
Lycopodium alpina
Lycopodium annotinum var. *annotinum*
Lycopodium clavatum
Lycopodium sabinaefolium var. *sitchense* *
Lycopodium selago
Menyanthes trifoliata
Minuartia macrocarpa
Montia fontana ssp. *fontana* *
Oxyria digyna
Papaver alaskanum
Parnassia kotzebuei
Parnassia palustris
Pedicularis capitata
Pedicularis kanei
Pedicularis langsдорffii ssp. *langsдорffii*
Pedicularis sudetica
Pedicularis verticillata
Petasites frigidus
Petacites frigidus X *hyperboreus*
Petasites hyperboreus
Phleum commutatum ssp. *americanum*
Phyllodoce aleutica ssp. *aleutica*
Platanthera dilatata var. *chlorantha*
Platanthera dilatata var. *dilatata*
Platanthera obtusata
Poa alpina
Poa arctica ssp. *arctica* **
Poa arctica ssp. *longiculmis*
Poa palustris
Poa paucispicula
Polemonium acutiflorum
Polemonium boreale
Polygonum viviparum
Polypodium vulgare ssp. *columbianum* *
Potamogeton praelongus
Potentilla palustris *
Potentilla villosa
Primula cuneifolia ssp. *saxifragifolia*
Pyrola asarifolia *
Pyrola minor
Pyrola secunda *
Ranunculus eschscholtzii
Ranunculus hyperboreus ssp. *hyperboreus* *
Ranunculus trichophyllus
Rhododendron camtschaticum ssp. *camtschaticum*
Romanzoffia unalaschensis
Rubus arcticus ssp. *stellatus*
Rumex graminifolius
Sagina intermedia
Salix alaxensis ssp. *alaxensis*
Salix arctica ssp. *crassijulis*
Salix barclayi
Salix phlebophylla
Salix pulchra
Salix reticulata
Salix rotundifolia
Salix sitchensis
Salix stolonifera **
Sanguisorba stipulata
Saxifraga bronchialis ssp. *funstonii*
Saxifraga caespitosa *
Saxifraga foliolosa var. *foliolosa*
Saxifraga hirculus
Saxifraga lyallii
Saxifraga nivalis
Saxifraga oppositifolia ssp. *oppositifolia*
Saxifraga punctata ssp. *nelsoniana* **
Saxifraga rivularis ssp. *flexuosa*
Saxifraga serpyllifolia
Saxifraga unalaschensis
Sedum rosea ssp. *integrifolium*
Sibbaldia procumbens **
Silene acaulis ssp. *acaulis*
Solidago multiradiata var. *arctica* *
Solidago multiradiata var. *multiradiata*
Spiranthes romanzoffiana
Stellaria calycantha ssp. *isophylla*
Stellaria crassifolia *
Stellaria monantha
Stellaria ruscifolia ssp. *aleutica* *
Taraxacum ceratophorum
Thelypteris phagopteris
Trientalis europaea ssp. *arctica*
Trisetum spicatum **
Vaccinium ovalifolium
Vaccinium uliginosum
Vaccinium vitis-idaea ssp. *minus*
Vahlodea atropurpurea
Veronica serpyllifolia ssp. *humifusa* *
Veronica stelleri
Veronica wormskjoldii
Viola epipsila ssp. *repens*
Viola langsдорffii

Table 2.2. Bryophyte Species.

* indicates species observed on a single plot

** indicates frequency of occurrence is greater than 50%

<i>Andreaea rupestris</i>	<i>Nardia scalaris</i>
<i>Arctoa fulvella</i>	<i>Oligotrichum hercynicum</i>
<i>Aulacomnium palustre</i>	<i>Paludella squarrosa</i>
<i>Aulacomnium turgidum</i> *	<i>Philonotis fontana</i> var. <i>fontana</i>
<i>Barbilophozia hatcheri</i>	<i>Plagiomnium affine</i>
<i>Bartramia ithyphylla</i>	<i>Plagiothecium cavifolium</i>
<i>Brachythecium albicans</i>	<i>Pleuroclada albescens</i>
<i>Brachythecium asperrimum</i>	<i>Pleurozium schreberi</i>
<i>Brachythecium frigidum</i>	<i>Pogonatum urnigerum</i> **
<i>Brachythecium plumosum</i> *	<i>Pohlia cruda</i>
<i>Brachythecium reflexum</i> var. <i>pacificum</i>	<i>Pohlia wahlenbergii</i>
<i>Brachythecium starkei</i> var. <i>starkei</i>	<i>Polytrichastrum alpinum</i>
<i>Bryoerythrophyllum recurvirostre</i>	<i>Polytrichum commune</i>
<i>Bryoxiphium norvegicum</i> *	<i>Polytrichum juniperinum</i>
<i>Bryum bicolor</i>	<i>Polytrichum piliferum</i>
<i>Bryum weigelii</i> *	<i>Polytrichum sexangulare</i>
<i>Calliergon stramineum</i>	<i>Pseudoleskea radicata</i> var. <i>denudata</i> *
<i>Ceratodon purpureus</i>	<i>Pseudoleskea stenophylla</i>
<i>Conostomum tetragonum</i>	<i>Pseudotaxiphyllum elegans</i> *
<i>Cratoneuron filicinum</i>	<i>Ptilidium ciliare</i>
<i>Dichodontium pellucidum</i> *	<i>Racomitrium ericoides</i> **
<i>Dicranella palustris</i> *	<i>Racomitrium fasciculare</i> **
<i>Dicranella subulata</i>	<i>Racomitrium lanuginosum</i>
<i>Dicranowesia crispula</i>	<i>Racomitrium sudeticum</i>
<i>Dicranum angustum</i> *	<i>Rhizomnium punctatum</i>
<i>Dicranum scoparium</i>	<i>Rhytidiadelphus loreus</i> *
<i>Dicranum spadiceum</i>	<i>Rhytidiadelphus squarrosus</i>
<i>Dicranum tauricum</i>	<i>Rhytidialephus triquetrus</i>
<i>Didymodon vinealis</i>	<i>Sanionia uncinata</i>
<i>Diplophyllum albicans</i>	<i>Schistidium apocarpum</i> var. <i>stricta</i>
<i>Diplophyllum taxifolium</i>	<i>Schistidium rivulare</i> var. <i>rivulare</i>
<i>Distichium capillaceum</i>	<i>Sphagnum girgensohnii</i>
<i>Ditrichum flexicaule</i> *	<i>Sphagnum russowii</i>
<i>Drepanocladus aduncus</i>	<i>Sphagnum squarrosum</i>
<i>Eurhynchium pulchellum</i> *	<i>Sphagnum teres</i> *
<i>Grimmia donniana</i> *	<i>Splachnum sphaericum</i>
<i>Grimmia torquata</i> var. <i>torquata</i> *	<i>Splachnum vasculosum</i> *
<i>Gymnomitrium obtusum</i>	<i>Tetraplodon mniodes</i>
<i>Hylocomium splendens</i>	<i>Timmia austriaca</i>
<i>Hypnum lindbergii</i> *	<i>Tortula ruralis</i>
<i>Isopterygium pulchellum</i> *	<i>Warnsdorfia exannulata</i> var. <i>exannulata</i>
<i>Kiaeria falcata</i> *	
<i>Lophozia sudetica</i>	
<i>Marchantia polymorpha</i> var. <i>polymorpha</i>	
<i>Marsupella alpina</i>	
<i>Marsupella ustulata</i>	
<i>Mnium ambiguum</i> *	
<i>Moerckia blyttii</i>	

Table 2.3. Lichen Species.

* indicates species observed on a single plot

** indicates frequency of occurrence is greater than 50%

<i>Allantoparmelia alpicola</i>	<i>Stereocaulon rivulorum</i>
<i>Cetraria islandica</i> ssp. <i>orientalis</i>	<i>Stereocaulon tomentosum</i>
<i>Cladonia arbuscula</i> *	<i>Stereocaulon vesuvianum</i> **
<i>Cladonia mitis</i> *	<i>Thamnolia vermicularis</i>
<i>Cladonia bellidiflora</i> *	<i>Umbilicaria arctica</i> *
<i>Cladonia borealis</i> (= <i>C. coccifera</i>)	<i>Umbilicaria cylindrica</i> *
<i>Cladonia chlorophaea</i>	<i>Umbilicaria hyperborea</i> var. <i>hyperborea</i>
<i>Cladonia cornuta</i>	<i>Umbilicaria hyperborea</i> var. <i>radicicula</i>
<i>Cladonia fimbriata</i>	<i>Umbilicaria proboscidea</i>
<i>Cladonia gracilis</i>	<i>Umbilicaria torrefacta</i>
<i>Cladonia pocillum</i>	<i>Xanthoria candelaria</i>
<i>Cladonia pyxidata</i>	<i>Xanthoria elegans</i> *
<i>Cladonia scabriuscula</i>	
<i>Cladonia stricta</i>	
<i>Cladonia sulphurina</i> *	
<i>Cladonia verticillata</i>	
<i>Lobaria linita</i>	
<i>Melanelia stygia</i>	
<i>Nephroma bellum</i> *	
<i>Omphalodiscus virginis</i>	
<i>Pannaria pezizoides</i>	
<i>Parmelia omphalodes</i> *	
<i>Parmelia saxatilis</i>	
<i>Parmelia sulcata</i> *	
<i>Peltigera aphthosa</i>	
<i>Peltigera canina</i> *	
<i>Peltigera collina</i>	
<i>Peltigera degenii</i>	
<i>Peltigera didactyla</i> var. <i>extenuata</i>	
<i>Peltigera horizontalis</i>	
<i>Peltigera kristonssonii</i> *	
<i>Peltigera membranacea</i>	
<i>Peltigera polydactylon</i> sens. str. *	
<i>Peltigera praetextata</i>	
<i>Peltigera scabrosa</i>	
<i>Peltigera rufescens</i>	
<i>Peltigera venosa</i>	
<i>Physcia caesia</i> *	
<i>Pilophorus robustus</i>	
<i>Placopsis gelida</i> **	
<i>Pseudephebe minuscula</i>	
<i>Pseudephebe pubescens</i>	
<i>Psoroma hypnorum</i>	
<i>Solarina crocea</i> **	
<i>Sphaerophorus fragilis</i> *	
<i>Sphaerophorus globosus</i>	
<i>Stereocaulon alpinum</i>	
<i>Stereocaulon glareosum</i>	

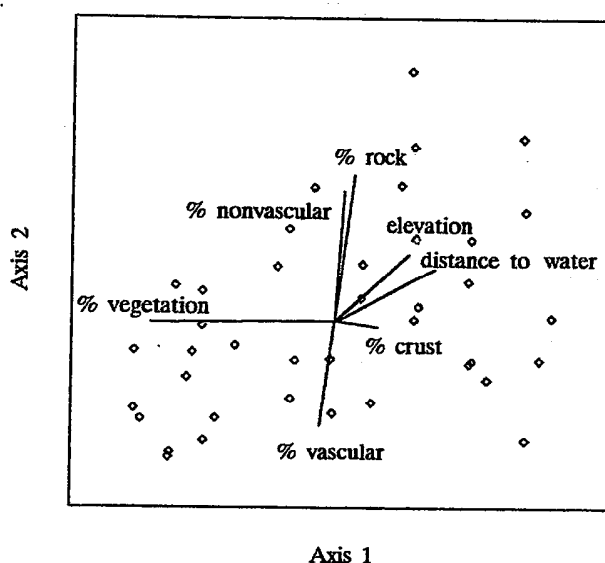
Environmental Gradients

Nonmetric multidimensional scaling (NMS) ordination of 40 plots yielded 3 interpretable axes. The first axis displayed strong correlations with several interrelated factors which, when considered together, were indicative of a single environmental gradient (Table 3, Figures 3,4).

Table 3. Variance explained by the three ordination axes and correlations (r) between those axes and selected variables.

	Axis 1	Axis 2	Axis 3
Variance explained (%)	49.7	29.2	7.3
	r		
elevation	-0.516	0.584	0.152
slope	0.183	-0.237	0.454
aspect	-0.204	0.057	0.140
rock cover (%)	-0.220	0.792	0.312
cryptogamic crust cover (%)	-0.440	-0.069	0.155
overall vegetative cover (%)	0.868	-0.154	-0.035
nonvascular cover (%)	-0.190	0.661	0.325
vascular cover (%)	0.190	-0.661	-0.325
standing water (m ²)	0.304	-0.102	0.166
flowing water (m ²)	0.262	-0.323	-0.102
distance to water (ordered categorical)	-0.645	0.501	0.039

Figure 3. Nonmetric multidimensional scaling ordination of plots in species space. Axes 1 and 2. Triangles represent plots. Radiating lines from the centroid of the point cluster indicate the direction and relative strengths of the correlations with the named variables (see p.11 for assistance with diagram interpretation).



Percent vegetation, a measure of the overall vegetative cover on each plot, demonstrated a strong positive relationship with Axis 1, while distance-to-water, a categorical measure of the proximity of a plot to surface water, demonstrated a strong negative relationship. Taken together, these results reflect the concentration of vegetation in and near areas with surface water in Aniakchak. Furthermore, the first axis displayed a strong negative correlation with elevation. In Aniakchak caldera an increase in elevation implies an increase in distance from Surprise Lake at the caldera lowpoint. Thus, the availability of surface water decreases dramatically with elevation, an effect compounded by the porous, well drained nature of the ashy soils (Bosworth 1987). Therefore, the first axis is interpreted as a moisture (or proximity to water) gradient. This interpretation is corroborated by the positive correlation of such mesophytic species as the moss *Philonotis fontana*

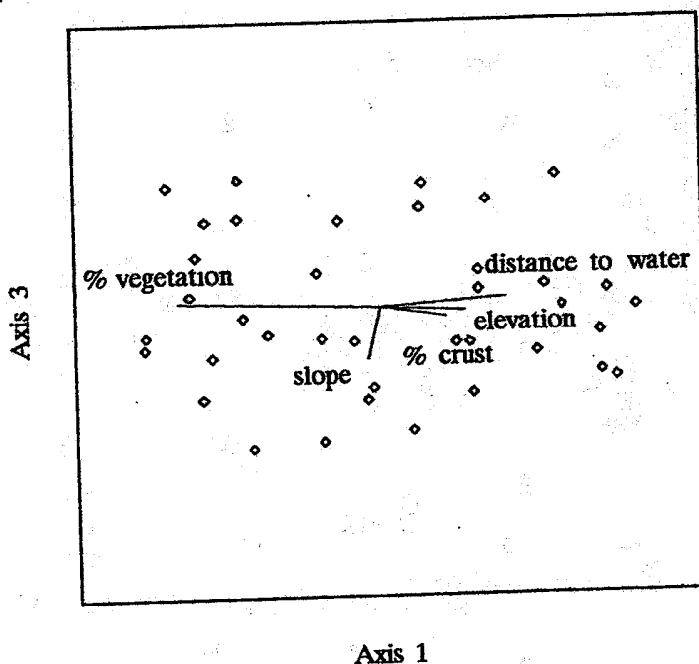
($r=0.35$) and the herb Stellaria calycantha ($r=0.61$) to Axis 1, as well as by negative correlations of such relatively xerophytic species as the moss Racomitrium ericoides ($r= -0.79$) and the herb Luzula arcuata ($r= -0.67$). The amount of surface water was also positively correlated with this axis but perhaps not as strongly as expected since the method of recording this variable (i.e. area of standing and flowing water measured separately on each plot) was not truly indicative of water availability.

Percent cover of cryptogamic crust also exhibited a negative correlation to Axis 1. In Aniakchak caldera, cryptogamic crusts were well developed on comparatively dry surfaces in the mid and upper portions of the caldera. This pattern is consistent with the Axis 1 interpretation.

The separation of plots along the second axis was most strongly related to the amount of rock present (i.e. basalt outcrops, lava flows). On this axis, cover of rock is strongly correlated to the relative cover of nonvascular species (Table 3, Figure 3) reflecting the presence of many epilithic moss and lichen species. Data supporting this interpretation included positive correlations of such rock dwelling species as the lichen Allantoparmelia alpicola ($r=0.43$) and the moss Andreae rupestris ($r=0.46$) to Axis 2, and negative correlations of ground dwelling species such as the liverwort Pleuroclada albescens ($r= -0.36$) and the lichen Peltigera scabrosa ($r= -0.37$).

Axis 3 showed slope emerging as a gradient (Table 3, Figure 4). Although this axis explained only 7.3% of the total variation, it is ecologically meaningful in light of the potential importance of steep slopes in sloughing off ash from the 1931 eruption, thereby facilitating the survivorship of relict vascular species which are known to be important to post-disturbance recovery. This is discussed in detail in the following chapter on succession.

Figure 4. Nonmetric multidimensional scaling ordination of plots in species space. Axes 1 and 3. Triangles represent plots. Radiating lines from the centroid of the point cluster indicate the direction and relative strengths of the correlations with named variables (see p.11 for assistance with diagram interpretation).



Vegetation Groups

Seven vegetation groups were distinguished from a cluster analysis of 49 plots (Figure 5). Partitioning the dendrogram at the seven group level provided both distinct and interpretable groups. The separation of these groups is illustrated by placement of plots in ordination space (Figure 6). Overall, lower elevation, wet plots occupied the lower left portion of the ordination; higher elevation plots with lingering snow occupied the central upper portion; high, rocky plots such as lava flows and eruption pits occupied the righthand portion; less rocky, mid-elevation plots with greater cryptogamic crust cover occupied the lower righthand portion. The central lower section is occupied by dry, steep plots. Discriminant analysis was used to evaluate the adequacy of this classification by using the species data as predictors of group membership. No misclassifications were encountered.

Figure 5. Cluster Analysis.

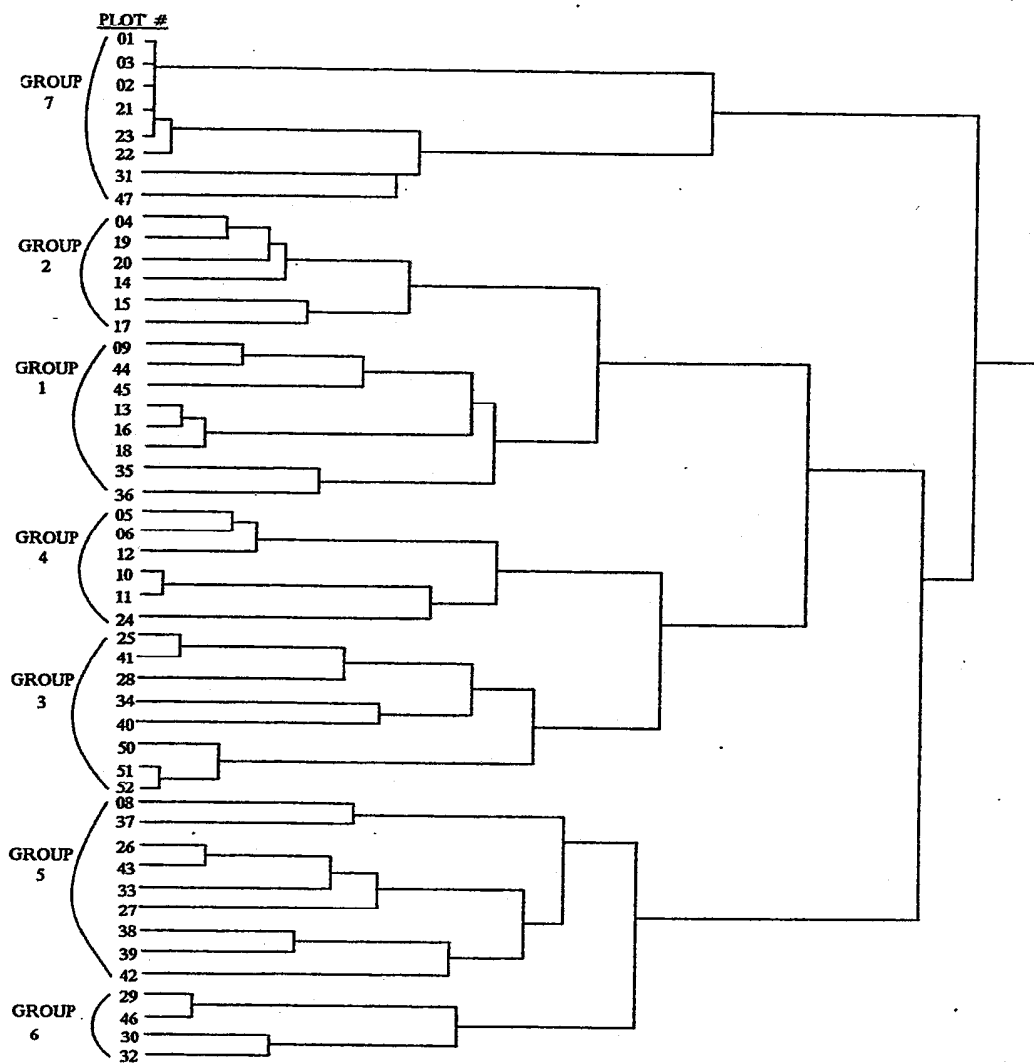
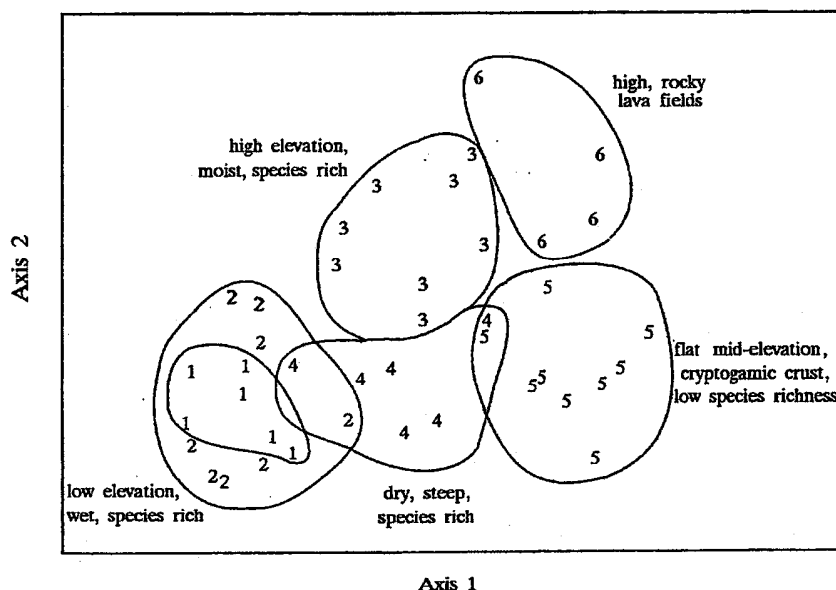


Figure 6. Placement of vegetation groups (as defined by cluster analysis) in NMS ordination space. Vegetation Group 7 (flat, windswept, barren plots) is absent as explained in text (p.12).



Description of groups Discriminant analysis (DA) revealed that 94% of the plots could be correctly classified as to vegetation group based on the environmental variables alone. The first two discriminant functions expressed 80% of the variation among the seven groups. Of the 10 environmental factors considered, 7 differed significantly ($p < 0.05$) among groups, although crust was borderline ($p = 0.04$). Aspect, standing water, and flowing water did not differ among the groups. The insignificance of the latter two factors is likely a reflection of the inadequacy of surface water measurement techniques used. DA was also used to identify characteristic species for each vegetation group. Vegetation groups are presented below (Table 4) in order of their position on the first axis, a moisture gradient (i.e. Group 1 is most strongly influenced by water; Group 7 is least).

Table 4. Characteristics of the seven vegetation groups as determined by discriminant analysis.

Vegetation Group	Characteristic Vascular Species	Characteristic Nonvascular Species	Typical Sites	Distinguishing Ecological Factors	Overall Vegetative Cover (%)	Average Species Richness	Shannon-Weiner Diversity Index
1	<i>Lupinus nootkatensis</i> <i>Salix alaxensis</i> <i>Angelica lucida</i> <i>Arabis lyrata</i> <i>Arctagrostis latifolia</i> <i>Carex macrochaeta</i>	<i>Philonotis fontana</i> <i>Brachythecium frigidum</i> <i>Rhytidiadelphus squarrosus</i> <i>Marchantia polymorpha</i> <i>Peltigera membranacea</i> <i>Peltigera scabrosa</i>	inlet meadows, base of caldera walls	gentle slopes low elevation 5% rock 2% black crust	89	61	3.9
2	<i>Lupinus nootkatensis</i> <i>Rhododendron camtschaticum</i> <i>Salix barclayi</i> <i>Heracleum lanatum</i> <i>Saxifraga punctata</i> <i>Solidago multiradiata</i>	<i>Aulacomnium palustre</i> <i>Sanionia uncinata</i> <i>Stereocaulon tomentosum</i> <i>Cladonia borealis</i> <i>Peltigera aphthosa</i> <i>Psoroma hypnorum</i>	headlands, lakeside areas	steep slopes low elevation 6% rock 3% black crust	87	93	4.3
3	<i>Salix stolonifera</i> <i>Salix rotundifolia</i> <i>Carex pyrenaica</i> <i>Cystopteris fragilis</i>	<i>Stereocaulon vesuvianum</i> <i>Solarina crocea</i> <i>Polytrichum piliferum</i> <i>Dicranum spadicum</i> <i>Arctoa fulvella</i> <i>Racomitrium ericoides</i>	eruption pits, high relief lava	gentle slopes high elevation lingering snow 74% nonvascular cover 37% rock 15% black crust	64	44	3.6
4	<i>Empetrum nigrum</i> <i>Vaccinium uliginosum</i> <i>Salix stolonifera</i> <i>Antennaria pallida</i> <i>Arnica lessingii</i> <i>Aster sibiricus</i>	<i>Pleurozium schreberi</i> <i>Racomitrium ericoides</i> <i>Racomitrium lanuginosum</i> <i>Nardia scalaris</i> <i>Allantoparmelia alpicola</i> <i>Lobaria linita</i> <i>Pseudephebe pubescens</i>	lava domes, midslope of caldera walls	steep slopes mid elevation 12% rock 22% black crust	48	63	3.9

Table III.3. Cont.

5	<i>Salix stolonifera</i> <i>Minuartia macrocarpa</i> <i>Trisetum spicatum</i> <i>Sibbaldia procumbens</i>	<i>Racomitrium ericoides</i> <i>Racomitrium fasciculare</i> <i>Oligotrichum hercynicum</i>	pyroclastic flows, tuff cones	gentle slopes mid elevation 10% rock 27% black crust	9	24	3.0
6	<i>Cardamine bellidifolia</i> <i>Luzula wahlenbergii</i>	<i>Stereocaulon vesuvianum</i> <i>Racomitrium lanuginosum</i> <i>Conostomum tetragonum</i> <i>Pogonatum urnigerum</i>	eruption pits, blocky lava	gentle slopes high elevation 89% nonvascular cover 55% rock 3% black crust	38	22	3.0
7	<i>Deschampsia caespitosa</i> <i>Sagina intermedia</i>	<i>Placopsis gelida</i>	alluvial plains, flat ridgetops	gentle slopes mid elevation 1% rock 3% black crust	2	5	1.7

Group 1 *Flat areas in water-collection zones.* Distinguished by low slopes, Group 1 had high overall vegetative cover (89%) and high species richness. Topographically, plots in this group were found in water collection zones such as toe-slopes and low lying areas subject to seasonal inundation by snow-melt. Some of the areas had saturated or shallowly flooded soils. Presence of rock and cryptogamic crust was minimal. These sites supported lush mesic mixed forb and lowland herb wet meadow communities dominated by herbs (Lupinus nootkatensis), mosses (Rhytidiadelphus squarrosus, Philonotis fontana) and widely scattered shrubs (Salix alaxensis). Typical sites include inlet and outlet meadows and the bases of caldera walls in some cases (Figure 7).

Group 2 *Steep, low elevation slopes near lakeside.* While similar to Group 1 in its high overall vegetative cover (87%), low elevation, and proximity to water, Group 2 is distinguished by steep slopes. Species richness and diversity were greatest in this group, possibly due to a combination of water availability and the ash-sloughing effect of steep slopes that enhanced survivorship of relict plants after the 1931 eruption (Hasselbach & McCune, in prep.). In addition, the desiccating effect of wind on low growing plants may be mitigated by the sheltering effect provided by the presence of tall shrubs and umbels, and by the overall high biomass which are characteristic of this group. Presence of rock and cryptogamic crust was minimal. Plant communities include mesic mixed herb and open tall willow communities dominated by a variety of shrubs (Salix barclayi, S. arctica), herbs (Heracleum lanatum, Saxifraga punctata, Solidago multiradiata), mosses (Sanionia uncinata) and lichens (Peltigera aphthosa, Stereocaulon tomentosum). Typical sites include headlands and lakeside areas (Figure 8).

Group 3 *High elevation, flat, species rich sites protected from wind.* Although surface water was not present, these sites tended to hold snow longer due to the effect of both topographic shading and north-facing exposures. Species richness was high, perhaps as a result of increased moisture availability from lingering snow melt. This group was distinguished from other waterless, high elevation sites by the higher overall vegetative cover (64%) which may be a result of wind protection from high relief lava fields. In addition, there was a strong rock/nonvascular component on the lava flows associated with this group reflecting the presence of subdominant amounts of the lichen Stereocaulon vesuvianum as well as a variety of bryophyte species. Vascular plants were uncommon. Presence of cryptogamic crust was minimal. Typical sites include bottoms of eruption pits and well-vegetated, high relief lava fields (Figure 9).

Group 4 *Mid-elevation sites on dry, steep slopes.* These sites were windy and exposed yet still supported an average of 48% overall vegetative cover. Species richness values were noticeably high. That the two most species rich groups (Groups 2 and 4) were correlated most strongly with steep slopes is another indication of the importance of steep slopes in sloughing ash and enhancing vascular plant recovery as discussed in Hasselbach and McCune (in prep.). A well developed cryptogamic crust consisting primarily of liverwort species (e.g., Cephaloziella spp., Marsupella alpina) was prominent. A moderate amount of rock was present. Vascular and nonvascular plants were equally represented in the alpine herb (Salix stolonifera, Arnica lessingii, Racomitrium ericoides) and Empetrum tundra (Empetrum nigrum, Vaccinium uliginosum, Lobaria linata) communities characteristic of this group. Typical sites include lava domes and midslope portions of caldera walls (Figure 10).

Group 5 *Mid-elevation sites in dry, flat areas.* This group was distinguished from Group 4 by lower slopes, greatly reduced overall vegetative cover (9%), and decreased species richness. These areas were wind-swept and ash covered. Cryptogamic crust was well developed and little rock was present. Plant communities consisted of widely spaced Salix stolonifera, patches of Racomitrium ericoides and scattered herbs. Typical sites include pyroclastic flows and tuff cones (Figure 11).

Group 6 *Rocky, flat, dry, high elevation sites with some degree of wind protection.* This group is similar to Group 3 in that it consisted of protected eruption pit and lava flow sites with moderate species richness. Unique in its high rock content and the associated dominance of nonvascular plants (89% of vegetation present), this group had moderate overall vegetative cover (38%) and little cryptogamic crust. Typical sites include eruption pits (e.g., the 1931 eruption site) with blocky lava blanketed by Stereocaulon vesuvianum (Figure 12).

Group 7 *Flat, dry, wind-swept, barren.* Expansive areas of loose, unconsolidated material subject to desiccating winds. Overall vegetative cover was extremely low (2%) consisting primarily of crustose lichen species and a few tiny moss sprigs established in the shelter of small rocks. Little rock or cryptogamic crust was present. Typical sites include flat, open ridgetops and large alluvial fans (Figure 13).

Figure 7a. Surprise Lake.



Figure 7b. Vegetation Group 1.



Figure 9. Vegetation Group 3.

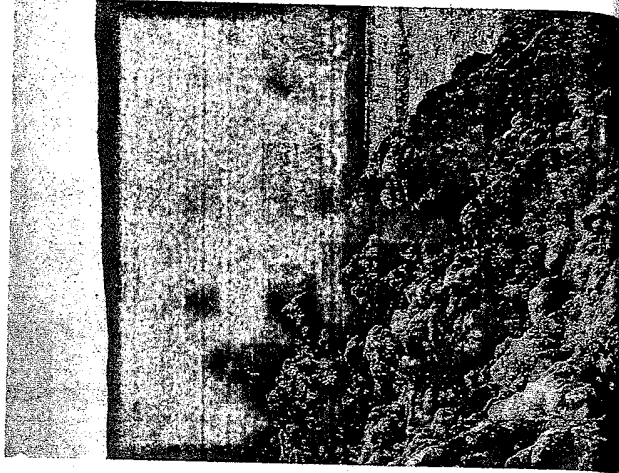


Figure 8. Vegetation Group 2.



Figure 10. Vegetation Group 4.

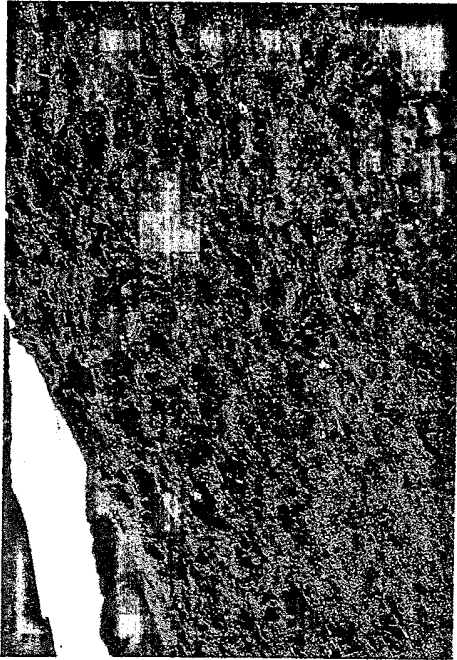


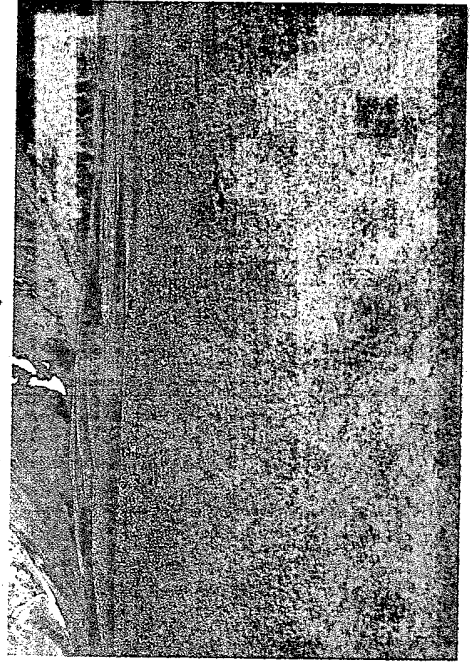
Figure 11. Vegetation Group 5.



Figure 12. Vegetation Group 6.



Figure 13. Vegetation Group 7.



Chapter II. Succession

The 1931 eruption in Aniakchak caldera was a significant disturbance event which typified the sort of cyclic events that have been influencing vegetation communities in the caldera since its formation. One important aspect of disturbance is that it initiates successional sequences. For the purposes of this report, succession is defined as "the changes observed in an ecological community following a perturbation that opens up a relatively large space" (Connell & Slatyer 1977). A disturbance event such as the 1931 eruption may influence substrate types, nutrient levels and dominance patterns. These factors are discussed in relation to their role in the vegetation recovery in Aniakchak caldera.

The 1931 eruption buried the previous plant communities under up to 60 cm of ash, providing a new substratum in many places for primary succession. Development of early successional vegetation in volcanic areas is often limited by the lack of fixed nitrogen in the ash (Vitousek & Walker 1987). In severe environments such as Aniakchak, the process of facilitation, whereby colonizing species improve the environment for later successional species, is believed to be important (Chapin et al. 1994). The prevalence of nitrogen-fixing taxa may directly enhance the growth of associated species in primary succession (del Moral & Wood 1993). In Aniakchak nitrogen-fixing taxa are exceedingly common, especially in the higher ashfields. The most abundant lichen in the caldera, Stereocaulon vesuvianum (9% of the overall lichen abundance), has nitrogen-fixing cephalodia and is known to colonize relatively young lava flows (Thomson 1984). Placopsis gelida is another ubiquitous nitrogen-fixing lichen in the caldera, as are Peltigera species and Lobaria linita. In total, 73% of the lichen cover (or 44% of the species present) was composed of nitrogen-fixing species. And although

we have no specific data, it is possible that some of the mosses present in the caldera also contribute to nitrogen fixation by hosting epiphytic cyanobacteria (Longton 1992). Finally, Lupinus nootkatensis, the sixth most abundant vascular plant in the caldera, is also notable for its nitrogen-fixing ability.

In addition to being nitrogen-poor, volcanic ash is also very acidic. Soil pH in Aniakchak ranges from 4.8 to 5.2. Few species can colonize such acidic substrata. It is conceivable that nonvascular plants have somewhat of an advantage in such conditions because they lack roots and thus are not as integrally connected with the soil as a typical rooted vascular plant. It is of interest to note the absence of nitrogen-fixers in the cryptogamic crust, which is known to contain cyanobacteria in arid regions (West 1990). The absence of cyanobacteria in Aniakchak crust can probably be attributed to the high acidity of the ashy soils (Belnap pers. comm., in West 1990).

The recovery of vegetation after disturbance is to a large extent dependent on how large a fraction of the original community survived the disturbance (Halpern 1989). After a large scale and severe disturbance all species must disperse from outside, while after a small scale, low intensity disturbance regeneration from surviving individuals may be more important. Therefore, the size and composition of the available species pool after the disturbance event strongly influences the subsequent recolonization pattern. Also important is the life history strategies of colonists, and different modes of propagule dispersal.

In Aniakchak, the vascular and nonvascular strata exhibited different responses to the 1931 disturbance as shown through separate NMS ordinations which were performed for each strata. Both ordinations had similar coefficients of determination: Axis 1 accounted for approximately 57% of the total variation in each ordination, while Axis 2 accounted for

approximately 18%. For both vascular and nonvascular ordinations, Axis 1 is interpreted as a strong proximity to water gradient. This has little relevance to successional patterns, but Axis 2 does.

An examination of both vascular and nonvascular ordinations and correlation coefficients corroborates the regression results reveals different patterns among their strata with respect to their secondary gradients. Although both strata were similarly related to presence of rock as a secondary gradient ($r^2=0.32$ for each), the vascular strata exhibited a correlation to slope ($r^2=0.34$), while the nonvascular stratum was unrelated to slope ($r^2=0.01$).

The strong relationship between nonvascular species and rock is easily explained as an expression of the importance of rock as a substrate for certain lichen and moss species. But why are the strata responding differently to slope? There are many reasons to expect vascular and nonvascular plants to respond differently to environmental gradients (Slack 1977; During 1979; Lee and LaRoi 1979). Nonvascular plants have no roots and lack a well developed vascular system. Consequently they are unable to draw upon substrate resources in periods of drought (During 1979). Their growth is largely controlled by moisture conditions that may fluctuate widely (Herben 1987). Thus they respond more rapidly than vascular plants to changes in water availability (During 1979; Herben 1987). Furthermore, due to their small size, it has been suggested that nonvascular plants respond to smaller scale environmental variation so that a wider range of substrates are available for their use (i.e. they experience greater habitat heterogeneity) (McCune & Antos 1981b). Similarly, a greater range of microclimatic conditions are available to them, at least in forests (McCune & Antos 1981b).

In Aniakhak, however, the differential response of layers may be linked more directly to the history of the site. The 1931 eruption blanketed the entire area with up to 60 cm of ash

(Hubbard 1932). Steeper slopes would tend to slough the ash more readily, enhancing survivorship of relict individuals. These survivors have been shown to be important to post-eruption recovery for vascular plants (Zobel & Antos 1992). Plants of flatter surfaces would likely die (Antos & Zobel 1985), resulting in low survivorship of vascular plants in such places. So one could reasonably expect a positive correlation between abundance of vascular plants and slope.

Many nonvascular plants are considered "pioneer" or "early successional" species (Longton 1992). The absence of a similar slope response by nonvascular plants may be due to their ability to quickly colonize disturbed areas. In the caldera, the nonvascular biomass is dominated by species of the genus Racomitrium (Hasselbach & McCune, in prep.) which is particularly adept at colonizing disturbed or "immature substratum" (Tallis 1959). Therefore, following the high mortality associated with the 1931 eruption (Hubbard 1932), it is likely that nonvascular plants, Racomitrium species in particular, quickly recolonized both flat and sloping areas, in addition to surviving on the slopes where ash was sloughed off. Thus the different relationships of the strata may be a reflection of disturbance colonization in the caldera.

An alternative, or perhaps contributing, explanation for the differential response of the strata to slope in Aniakchak caldera concerns the scale at which the slope parameter was measured. Numerous basaltic outcrops with near-vertical faces are found in relatively flat areas within the caldera. These outcrops support a variety of rock dwelling lichen and moss species. Ash would have sloughed readily from these steep surfaces, presumably enhancing survivorship of resident species; the slope, however, was measured at a plot-wide scale (0.10 ha) which is not reflective of the smaller scale variation represented by the rock faces.

CONCLUSION

This study provided a better understanding of the vegetation ecology of Aniakchak caldera. In addition to fulfilling the objectives of examining environmental gradients, identifying major vegetation groups, and determining the environmental factors most important in the separation of the groups, this research has underscored two areas of potential concern for managers of Aniakchak National Monument:

(1) Aniakchak caldera supports areas of remarkably high species richness and diversity particularly in the immediate vicinity of Surprise Lake (Figure III.2). The three most species rich plots were located on the headlands which separate protected coves from one another. Due to the rugged terrain and extreme wind exposure of most areas of the caldera, potential camp sites are limited to these coves. In the event of increased visitation to the caldera, these rich and fragile areas would be negatively impacted. Considering the slow recovery of caldera vegetation in the 64 years since the last eruption, such damage may have long-term effects.

(2) The presence of large amounts of cryptogamic crust is also of interest to resource managers. The crust is inconspicuous and often occurs in high elevation, apparently barren portions of the caldera. Such areas are naturally well suited to foot travel by visitors. Cryptogamic crusts may enhance soil moisture, slow erosion by water and wind, increase nutrient input and retention, aid in seed lodgement, add organic matter and contribute to soil development. Crusts are susceptible to damage by trampling and can be very slow to recover from disturbance. If Aniakchak is to continue to function as an intact ecosystem, human impact to these areas should be minimized.

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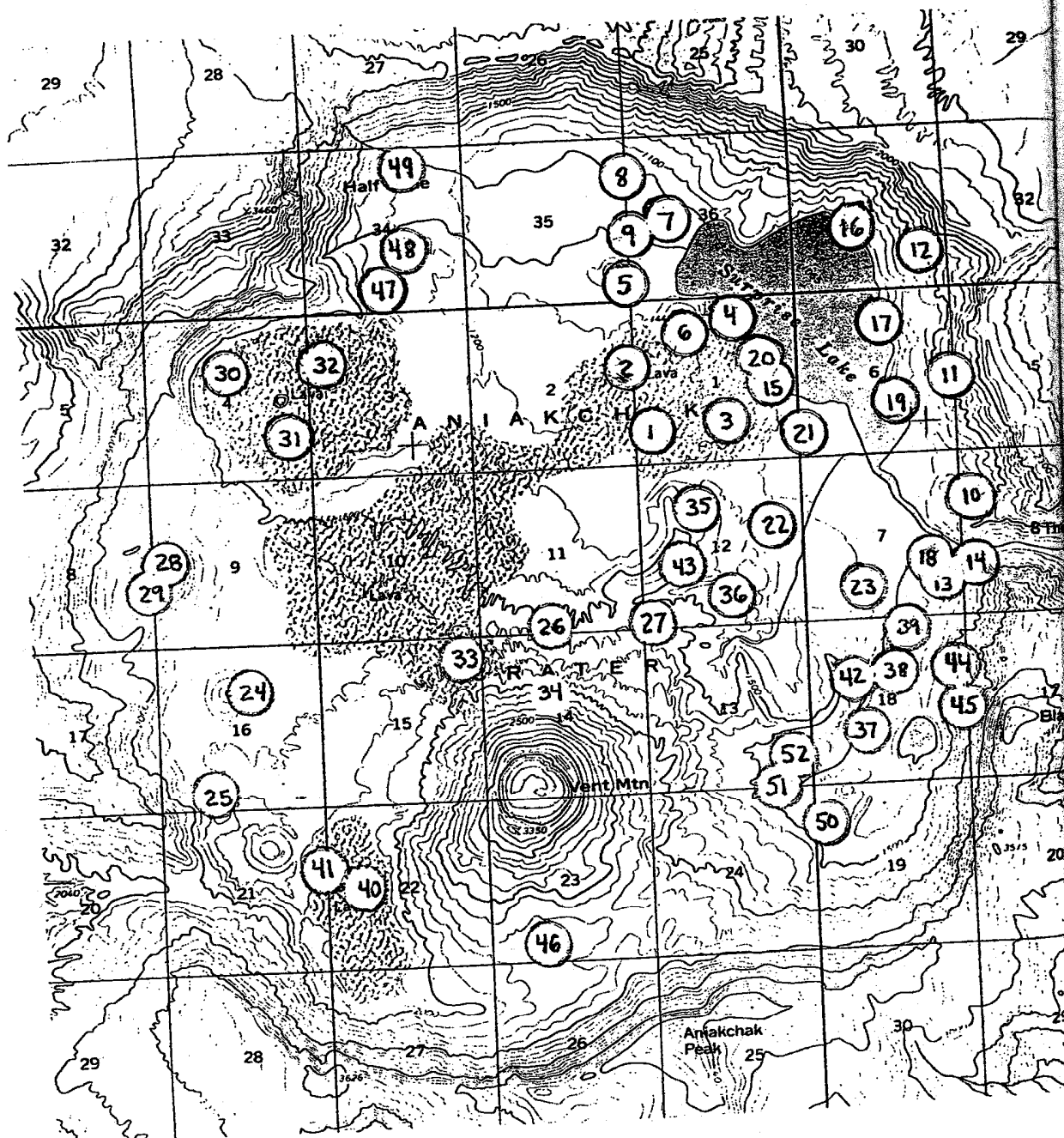
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Appendices

Appendix I. Plot locations.

<u>Geomorphic Feature</u>	<u>Plot Number</u>
Old Lava Ridgetop	1, 2, 3
Headlands	4, 15, 20
Lava Domes	5, 6, 24
Inlet Meadow	7, 8, 9
Midslope Caldera Walls	10, 11, 12
Gates Meadow	13, 14, 18
Lower Slope - Lakeside	16, 17, 19
Outlet Alluvium	21, 22, 23
Inlet Alluvium	47, 48, 49
Eruption Pits	25, 28, 29
Vent Mtn. Pyroclastic Flow	26, 27, 33
Half Cone Lava Flow	30, 31, 32
Gully	34, 35, 36
Maar Lake Lava Flow	37, 38, 39
Tuff Cones	42, 43
Vent Mtn. Lava Flow	40, 41, 46
Naknek Toeslope	44, 45
Lava Outwash Plain	50, 51, 52

Appendix I. Cont. Plot locations.



Appendix II. Annotated species list for Aniakhak caldera. Habitat codes: a=inlet meadow, b=outlet meadow, c=lakeside lava headlands, d=lower slope of caldera wall (above lake), e=midslope of caldera wall (above lake), f=flat lava ridgetops, g=lava domes, h=eruption pits, i=gullies on lower slopes of Vent Mtn., j=Vent Mtn. pyroclastic flows, k=Half Cone lava flow, l=Vent Mtn. lava flow, m=Maar Lake lava flow, n=tuff cones, o=Naknek toe slope (above Maar Lake stream), p=lava outwash plain (above Maar Lake), q=outlet alluvium, r=inlet alluvium. Habitat and plot locations are cross-referenced in Appendix I. Occurrence ratings (uncommon, common, very common) are based on quantitative data and augmented by subjective observation.

VASCULAR PLANTS

Species	Occurrence	Habitat	Plots
<i>Achillea borealis</i> Bong.	very common	a,b,c,d,e,f,g,i,m,n,o,p	1,3,4,5,6,9,11,12,13,14,15,16,17,18,19,20,34,35,36,37,38,39,42,43,44,45,50,52
<i>Agrostis alaskana</i> Hult.	common	c,d,h,i,j,k,m,o	15,17,19,20,26,28,32,34,35,36,39,44
<i>Agrostis borealis</i> Hartm.	common	b,d,g,h,m,o	14,19,24,28,37,44
<i>Angelica lucida</i> L.	common	a,b,c,d,i	4,9,13,14,16,17,18,19,20,35
<i>Antennaria alpina</i>	common	c,i	4,35
<i>Antennaria monocephala</i> DC. var. <i>monocephala</i>	common	c,d,e,g,i,j	4,5,6,10,11,12,15,19,20,24,26,34
<i>Antennaria pallida</i> E. Nels.	common	c,g,h,i,j	5,6,15,20,26,28,34,36
<i>Arabis lemmingi</i> S. Wats.	uncommon		
<i>Arabis lyrata</i> L. ssp. <i>kamchatica</i> (Fisch.) Hult.	common	a,b,d,k,o	9,14,16,19,30,44,45
<i>Arctagrostis latifolia</i> (R. Br.) Griseb. var. <i>latifolia</i>	common	a,b,c,d,g,i,o,p	4,5,9,13,14,15,16,17,18,19,36,44,45,52
<i>Arctagrostis latifolia</i> (R. Br.) Griseb. var. <i>arundinacea</i> (Trin.) Griseb.	uncommon	d	
<i>Arnica chamissonis</i> Less.	uncommon		
<i>Arnica lessingii</i> Greene ssp. <i>lessingii</i>	very common	b,c,d,e,g,h,i,j,m,n,o,p	4,5,6,10,11,12,13,14,15,16,17,18,19,20,24,25,26,28,34,35,36,37,39,43,44,45,50,51,52

<i>Artemisia arctica</i> Less. ssp. <i>arctica</i>	common	c,d,e,g,i,j	5,11,12,15,17,20,26,34,35,36	
<i>Artemisia borealis</i> Pall.	common	b,c,d,e,o	10,11,14,19,20,44	
<i>Artemisia globularia</i> Bess.	uncommon	e	12	
<i>Artemisia tilesii</i> Ledeb.	common	b,c,d	4,13,15,17,18,19	
<i>Aster sibiricus</i> L.	common	a,b,c,d,e,g,m,n,o	5,9,11,14,18,19,20,37,42,43,44	
<i>Athyrium filix-femina</i> (L.) Roth	common	c,h,i,o	15,25,28,35,36,45	
<i>Botrychium boreale</i> (E. Fries) Milde	uncommon	c	4	
<i>Botrychium lanceolatum</i> (Gmel.) Angstr.	uncommon	c	4,15	
<i>Botrychium lunaria</i> (L.) Sw.	uncommon	c	4,15	
<i>Calamagrostis canadensis</i> (Michx.) Beauv.	common	c,d	15,17,19	
<i>Caltha palustris</i> L. ssp. <i>arctica</i> (R. Br.) Hult.	common	a	7,8	
<i>Campanula lasiocarpa</i> Cham. ssp. <i>lasiocarpa</i>	very common	b,c,d,e,g,h,i,j,m,n,o,p	4,5,6,10,11,12,14,15,16,17,19,20,24,26,27,28,34,35,36,39,42,43,45,52	
<i>Cardamine bellidifolia</i> L.	common	h,k,l,o	25,28,30,32,40,45,46	
<i>Cardamine umbellata</i> Greene	common	b,c,d,o	4,13,14,15,16,18,44	
<i>Carex bigelowii</i> Torr.				
<i>Carex dioica</i> L. ssp. <i>gynocrates</i> (Wormsk.) Hult.	uncommon			
<i>Carex enanderi</i> Hult.	common	a,b	8,13,18	
<i>Carex glareosa</i> Wahlenb.	common	b,g	18,24	
<i>Carex kelloggii</i> W. Boott	common			
<i>Carex lachenalii</i> Schkuhr	common	a,b	9,13,14	

<i>Carex lyngbyaei</i> Hornem.	common	a	7,8	
<i>Carex macrochaeta</i> C.A.Mey.	common	a,b,c,d,f,i,o,p	3,9,13,14,16,17,18,19,20,34,35,36,44,45,52	
<i>Carex nesophila</i> Holm	common	a,b,c,d,i,j,m,n,p	8,13,15,16,17,19,26,27,34,38,39,43,50	
<i>Carex pyrenaica</i> Wahlenb. ssp. <i>micropoda</i> (C.A.Mey.) Hult.	uncommon	h,i,l,p	25,34,40,50,51,52	
<i>Carex rariflora</i> (Wahlenb.) J. E. Sm.	uncommon			
<i>Carex spectabilis</i> Dew.	common	c,e,f,g	1,2,4,5,6,10,11,12,24	
<i>Cassiope lycopioides</i> (Pall.) D. Don	uncommon	i		
<i>Cassiope stelleriana</i> (Pall.) DC.	common	i,o	34,36,45	
<i>Cerastium beerianum</i> Cham. & Schlecht. var. <i>beerianum</i>	common	b,c,d,e,g,h	4,6,10,11,14,16,18,19,28,42	
<i>Cerastium beerianum</i> Cham. & Schlecht. var. <i>grandiflorum</i> (Fenzl) Hult.	common	a,b,c		
<i>Chrysosplenium wrightii</i> Fr. & Sav.	common	c,e,h	4,10,11,25	
<i>Coeloglossum viride</i> (L.) Hartm. ssp. <i>bracteatum</i> (Muhl.) Hult.	common	b,c	4,13,15	
<i>Corallorrhiza trifida</i> Chatelain	uncommon			
<i>Cryptogramma crispa</i> (L.) R. Br.	uncommon	h	25,28	
<i>Cystopteris fragilis</i> (L.) Bernh.	common	b,c,e,h,i,l,o	4,11,13,15,20,25,28,29,36,40,41,45	
<i>Deschampsia beringensis</i> Hult.	common	a,b,c,d	8,14,15,16,17,18	
<i>Deschampsia caespitosa</i> (L.) Beauv.	very common	a,c,d,e,f,g,h,i,j,k,m,n,p,q,r	1,2,3,4,5,6,9,10,11,12,19,22,24,26,27,28,30,31,32,33,34,37,38,39,42,43,51,52	
<i>Diapensia lapponica</i> L.	uncommon			
<i>Draba alpina</i> L.	uncommon	e		

<i>Draba crassifolia</i> Graham	uncommon			
<i>Draba rivalis</i> Graham	uncommon	e	11	
<i>Dryas octopetala</i> L. ssp. <i>octopetala</i>	uncommon			
<i>Dryopteris dilatata</i> (Hoffm.) Gray ssp. <i>americana</i> (Fisch.) Hult.	common	d,h,o	19,25,28,29,45	
<i>Elymus arenarius</i> L.	very common	a,b,c,d,f,i,k,m,n,o,p	1,2,3,4,9,13,14,15,16,17,18,19,20,32,35,36,39,42,44,45,47,50,51,52	
<i>Empetrum nigrum</i> L.	very common	b,c,d,e,g,h,i,m,o,p	4,5,6,10,11,12,14,15,16,17,18,19,20,28,35,36,39,44,50,52	
<i>Epilobium anagallidifolium</i> Lam.	common	d	19	
<i>Epilobium angustifolium</i> L. ssp. <i>macrophyllum</i> (Haussk.) Hult.	common	a,c,d,e,g,h,i,l,o	4,9,12,15,16,17,24,25,28,35,40,41,45	
<i>Epilobium behringianum</i> Haussk.	common	b,c,i	13,15,20,36	
<i>Epilobium glandulosum</i> Lehm.	common	b,d	14,17,18	
<i>Epilobium hornemannii</i> Rchb.	common	a,b,c,d,h,o,p	9,14,15,16,17,19,28,44,45,50	
<i>Epilobium latifolium</i> L.	very common	a,b,c,d,e,g,h,i,k,l,m,n,o,p	4,6,9,11,12,13,14,15,16,17,18,19,20,24,25,28,30,31,32,34,35,36,38,39,40,41,42,44,45,50,51,52	
<i>Epilobium leptocarpum</i> Haussk.	common	c,h,i	4,25,34,35	
<i>Epilobium luteum</i> Pursh.	uncommon			
<i>Equisetum arvense</i> L.	common	a,b,c,d,g	4,6,8,9,13,15,16,17,18,20,24	
<i>Equisetum palustre</i> L.	uncommon			
<i>Equisetum silvaticum</i> L.	uncommon			
<i>Equisetum variegatum</i> Schleich.	uncommon	b		

<i>Eriophorum angustifolium</i> Honck.				
<i>Eriophorum scheuchzeri</i> Hoppe	common			
<i>Euphrasia mollis</i> (Ledeb.) Wettst.	common	a,c,d		4,9,17,20
<i>Festuca altaica</i> Trin.	uncommon			
<i>Festuca brachyphylla</i> Schult.	common	b,d,e,g,h,k,n		5,6,10,11,14,19,24,25,32,43
<i>Festuca rubra</i> L.	common	a,b,c,d,e,g,n		4,5,6,9,11,12,14,15,16,17,18,19,20,42
<i>Gentiana aleutica</i> Cham.Schlecht.	common	c,d,i		4,15,17,19,20,35
<i>Gentiana amarella</i> L. ssp. <i>acuta</i> (Michx.) Hult.				
<i>Gentiana tenella</i> Roth.		c		
<i>Geranium erianthum</i> DC.	uncommon	(d)		
<i>Geum macrophyllum</i> Willd. ssp. <i>macrophyllum</i>	uncommon	b		18
<i>Geum rossii</i> (R. Br.) Ser.	common	e,g,p		5,6,10,11,12,52
<i>Gynnocarpium dryopteris</i> (L.) Newm.	uncommon	h		28
<i>Heracleum lanatum</i> Michx.	common	b,c,d		4,16,17,18,19,20
<i>Heuchera glabra</i> Willd.	uncommon	o		45
<i>Hieracium triste</i> Willd.	common	h,i,p		25,34,35,36,50,51,52
<i>Hierochloa odorata</i> (L.) Wahlenb.	uncommon	d		
<i>Hippuris vulgaris</i> L.	common	a		7
<i>Hordeum brachyantherum</i> Nevski	uncommon	a		
<i>Juncus arcticus</i> Willd.	common	a,b		8,9,13,18
<i>Juncus castaneus</i> Sm.	common	a,b,d		9,19

<i>Juncus drummondii</i> E. Mey.	uncommon	i,p	34,36,50,51	
<i>Juncus mertensianus</i> Bong.	common	a	9	
<i>Koenigia islandica</i> L.	common	a,b,d	8,17,18,19	
<i>Lagotis glauca</i> Gaertn.	common	e	11,12	
<i>Ledum palustre</i> L. ssp. <i>decumbens</i> (Ait.) Hult.	uncommon	c,d	17,20	
<i>Leptarrhena pyrolifolia</i> (D. Don) Ser.	common	b,c,i,o	15,18,35,36,45	
<i>Listera cordata</i> (L.) R. Br.	common	i	36	
<i>Loiseleuria procumbens</i> (L.) Desv.	common	c,d,e,g,i	4,5,6,12,15,17,19,20,35	
<i>Luetkea pectinata</i> Bong.	common	h,i,l,n,o,p	25,29,34,35,36,40,42,44,45,50,51,52	
<i>Lupinus nootkatensis</i> Donn.	very common	a,b,c,d,f,i,m,n,o	1,3,4,9,13,14,15,16,17,18,19,20,36,39,42,44,45	
<i>Luzula arcuata</i> (Wahlenb.) Sw. ssp. <i>unalaschensis</i> (Buchenau) Hult.	very common	b,c,d,e,f,g,h,i,j,k,l,m,n,o,p	1,3,4,6,10,11,12,14,15,17,18,19,20,24,25,26,27,28,31,32,33,34,35,37,38,39,40,41,42,43,44,46,51,52	
<i>Luzula multiflora</i> (Retz.) Lej.	common	a,b,c,d,g	6,9,15,17,18,19,20	
<i>Luzula parviflora</i> (Ehrh.) Desv.	common	h,i,l,m,o,p	28,35,36,37,41,44,45,50,51,52	
<i>Luzula tundricola</i> Gorodk.	uncommon	b,g	5,13	
<i>Luzula wahlenbergii</i> Rupr. ssp. <i>piperi</i> (Cov.) Hult.	common	b,e,g,h,i,k	12,18	
<i>Lycopodium alpinum</i> L.	common	c,i,o,p	20,34,35,36,45,52	
<i>Lycopodium annotinum</i> L. ssp. <i>annotinum</i>	uncommon	i,o	36,45	
<i>Lycopodium clavatum</i> L.	uncommon	h,i	28,35,36	
<i>Lycopodium sabinaefolium</i> Willd. var. <i>sitchense</i> (Rupr.) Fern.	uncommon	i	36	

<i>Lycopodium selago</i> L.	common	c,h,i,o	4,15,20,28,34,45	
<i>Menyanthes trifoliata</i> L.	uncommon	b		
<i>Minuartia macrocarpa</i> (Pursh) Ostenf.	very common	b,c,d,e,g,i,j,m,n	4,5,6,10,11,12,14,18,19,20,24,26,27,33,34,38,39,43	
<i>Montia fontana</i> L. ssp. <i>fontana</i>	uncommon	a	8	
<i>Oxyria digyna</i> (L.) Hill	common	g,h,k,l,n,o	24,25,30,31,41,42,45	
<i>Papaver alaskanum</i> Hult.	common	e,o	11,44	
<i>Parnassia kotzebuei</i> Cham. & Schlecht.	common	a,b,c,d,e,g	4,5,6,9,11,14,15,18,19,20	
<i>Parnassia palustris</i> L.	uncommon	c		
<i>Pedicularis capitata</i> Adams	common	c,g,o	4,5,6,20,45	
<i>Pedicularis kanei</i> Durand ssp. <i>kanei</i>	common	g	5,6	
<i>Pedicularis langsдорffii</i> Fisch. ssp. <i>langsдорffii</i>	common	c,d,e,g,i	4,5,6,10,11,12,15,17,20,34	
<i>Pedicularis sudetica</i> Willd.	common	b,c,i,j	15,18,26,27,36	
<i>Pedicularis verticillata</i> L.	common	b,d	13,14,16,17,18	
<i>Petasites frigidus</i> (L.) Franch.	common	a,b,c,g,h,i,o,p	4,5,6,9,13,25,28,36,44,51	
<i>Petasites frigidus</i> X <i>hyperboreus</i>	common			
<i>Petasites hyperboreus</i> Rydb.	common	b,c,d,i	14,15,16,17,18,19,20,34	
<i>Phleum commutatum</i> Gandoger var. <i>americanum</i> (Fourn.) Hult.	common	a,b,c,d,i,o	4,9,13,15,16,17,18,19,20,35,36,44	
<i>Phylodoce aleutica</i> (Spreng.) Hult. ssp. <i>aleutica</i>	common	c,i,o,p	4,34,35,36,44,45,50	
<i>Platanthera dilatata</i> (Pursh) Lindl. var. <i>chlorantha</i> Hult.	common	a,b,c	4,9,15,18,20	
<i>Platanthera dilatata</i> (Pursh) Lindl. var. <i>dilatata</i>	uncommon			

<i>Platanthera obtusata</i> (Pursh) Lindl.	uncommon	i	35	
<i>Poa alpina</i> L.	common		10,14,44	
<i>Poa arctica</i> R. Br. ssp. <i>arctica</i>	very common	a,b,c,d,e,g,h,i,k,l,m,n, o,p	5,6,9,11,12,13,14,15,16,17,18,19,20,24,28,30,32, 36,38,40,42,43,44,45,50	
<i>Poa arctica</i> R. Br. ssp. <i>longiculmis</i> Hult.	uncommon			
<i>Poa palustris</i> L.	uncommon			
<i>Poa paucispicula</i> Scribn. & Merr.	uncommon	g,h	24,28	
<i>Polemonium acutiflorum</i> Willd.	common	b,n	18,43	
<i>Polemonium boreale</i> Adams	common	e,g	11	
<i>Polygonum viviparum</i> L.	common	b,c,d,e,g,i	5,6,10,11,12,13,15,17,18,20,34,36,	
<i>Polypodium vulgare</i> L. ssp. <i>columbianum</i>	uncommon	h	28	
<i>Potamogeton praelongus</i> Wulf.	common	aquatic		
<i>Potentilla palustris</i> (L.) Scop.	uncommon	a	8	
<i>Potentilla villosa</i> Pall.	very common	b,c,d,e,g,k,o	4,5,6,10,11,12,14,15,17,19,20,24,32,45	
<i>Primula cuneifolia</i> Ledeb. ssp. <i>saxifragifolia</i> (Lehm.) Sm. & Forrest	common			
<i>Pyrola asarifolia</i> Michx.	uncommon	b	13	
<i>Pyrola minor</i> L.	common	b,c,d,g,i,o	4,5,13,14,15,16,17,18,19,20,34,35,36, 44,45	
<i>Pyrola secunda</i> L.	uncommon	c	20	
<i>Ranunculus eschscholtzii</i> Schlecht.	uncommon	b,o	13,45	

<i>Ranunculus hyperboreus</i> Roth. ssp. <i>hyperboreus</i>	common	a	8	
<i>Ranunculus trichophyllus</i> Chaix	common	a		
<i>Rhododendron camtschaticum</i> Pall. ssp. <i>camtschaticum</i>	common	b,c,d,e,g,i,j,m,o	4,5,6,10,11,12,15,17,18,20,27,35,36,38,39,45	
<i>Romanzoffia unalaschensis</i> Bong.	uncommon	b		
<i>Rubus arcticus</i> L. ssp. <i>stellatus</i> (Sm.) Boiv. emend. Hult.	common	b,c,d,e,o	4,11,12,13,14,15,16,17,18,19,20,45	
<i>Rumex graminifolius</i> Lamb.	common	a,b,d,e,g,j,n,o	5,6,9,10,11,12,14,16,18,19,24,26,27,33,43,44	
<i>Sagina intermedia</i> Fenzl.	common	b,c,e,f,g,h,i,k,m,o	1,2,3,4,10,11,12,14,15,18,24,25,30,32,33,38,44	
<i>Salix alaxensis</i> (Anderss.) Cov. ssp. <i>alaxensis</i>	common	a,b,c,d,e,i,m,o,p	4,9,12,13,14,15,16,17,18,19,36,37,44,45,50	
<i>Salix arctica</i> Pall. ssp. <i>crassijulis</i> (Trautv.) Skvortz.	very common	a,b,c,d,e,g,i,k,m,o	4,5,6,9,10,11,12,13,15,16,17,19,20,24,32,35,36,39,45	
<i>Salix barclayi</i> Anderss.	common	a,b,c,d,h,i,n,o	4,9,13,14,15,16,17,18,19,20,25,28,35,42,45	
<i>Salix phlebophylla</i> Anderss.	uncommon			
<i>Salix pulchra</i> Cham.	uncommon	a,m	8,37	
<i>Salix reticulata</i> L.	uncommon	b,c,g,o	4,5,13,15,18,20,45	
<i>Salix rotundifolia</i> Trautv.	uncommon	g,h,i,m,o	24,25,28,37,39,40,41,44,45	
<i>Salix sitchensis</i> Sanson	common	b,c,i,o	4,13,20,35,45	
<i>Salix stolonifera</i> Cov.	very common	a,b,c,d,e,f,g,h,i,j,k,l,m,n,o,p	1,5,6,8,9,10,11,12,13,14,16,17,18,19,20,24,25,26,27,28,30,32,33,34,35,36,37,38,39,40,41,42,43,44,45,50,51,52	
<i>Sanguisorba stipulata</i> Raf.	uncommon	a		
<i>Saxifraga bronchialis</i> L. ssp. <i>funstonii</i> (Small) Hult.	common		4,5,6,10,11,12,14,19	

<i>Saxifraga caespitosa</i> L.	uncommon	a	9	
<i>Saxifraga foliolosa</i> R. Br. var. <i>foliolosa</i>	common	f,h	2,28	
<i>Saxifraga hirculus</i> L.	common	b	18	
<i>Saxifraga hyallii</i> Engler	common	a,b,e	9,12,18	
<i>Saxifraga nivalis</i> L.	common	c,e,g	6,10,11,15	
<i>Saxifraga oppositifolia</i> L. ssp. <i>oppositifolia</i>	uncommon	c,e,g,o	6,10,11,12,20,45	
<i>Saxifraga punctata</i> L. ssp. <i>nelsoniana</i> (D. Don) Hult.	very common	a,b,c,d,e,g,h,k,l,m,o,p	4,5,6,9,11,12,13,14,15,18,19,20,24,25,28,29,30,32,3 8,40,41,44,45,46,50,51,52	
<i>Saxifraga rivularis</i> L. ssp. <i>flexuosa</i> (Sternb.) Engler & Irmsch.	common	b,h,o	13,25,45	
<i>Saxifraga serpyllifolia</i> Prush	common	b,c,d,e,g,h,i,j,l,o	4,5,6,10,11,12,14,18,19,20,25,27,28,33,34,41,44,45	
<i>Saxifraga unalaschensis</i> Sternb.	common	c,d,g,h,j,k,l,m,n,o	4,5,6,19,24,25,30,33,38,39,41,42,44	
<i>Sedum rosea</i> (L.) Scop. ssp. <i>integrifolium</i> (Raf.) Hult.	common	a,b,c,d,e,g,i,j,o	4,5,6,9,10,11,12,13,14,15,16,17,18,19, 20,24,26,34,35,36,44,45	
<i>Sibbaldia procumbens</i> L.	very common	a,b,c,d,e,f,g,h,i,j,k,l, m,n,o,p	1,4,9,10,11,12,13,14,15,16,17,18,19,20,24,25,26, 28,32,33,34,36,37,38,39,40,42,43,44,45,50,51,52	
<i>Silene acaulis</i> L. ssp. <i>acaulis</i>		b,e	10,14	
<i>Solidago multiradiata</i> Ait. var. <i>arctica</i> (DC.) Fern.	uncommon	d	16	
<i>Solidago multiradiata</i> Ait. var. <i>multiradiata</i>	common	a,c,d,e,f,g,i,j	3,4,5,6,9,10,15,17,19,20,26,35	
<i>Spiranthes romanzoffiana</i> Cham.	common	c		
<i>Stellaria calycantha</i> (Ledeb.) Bong. ssp. <i>isophylla</i> (Fern.) Fern.	common	a,b,c,d,g,i,o	4,5,8,14,15,16,17,18,19,20,36,44	
<i>Stellaria crassifolia</i> Ehrh.	uncommon	o	45	
<i>Stellaria monantha</i> Hult.	common	a,b,c,d,e,g,h	5,9,11,14,17,20,28	

<i>Stellaria ruscifolia</i> Pall. ssp. <i>aleutica</i> Hult.	uncommon	m	38	
<i>Taraxacum ceratophorum</i> (Ledeb.) DC.	common	a,b,c,g	4,9,13,15,18,24	
<i>Thelypteris phagopteris</i> (L.) Slosson	uncommon	c,p	4,52	
<i>Trientalis europaea</i> L. ssp. <i>arctica</i> (Frisch.) Hult.	common	c,d	15,17	
<i>Trisetum spicatum</i> (L.) Richter	very common	b,c,d,e,g,h,i,j,l,n,o,p	4,5,6,10,11,12,14,15,16,17,18,19,20,24,25,26,27,28,33,34,35,36,41,43,44,52	
<i>Vaccinium ovalifolium</i> Sm.	uncommon	d		
<i>Vaccinium uliginosum</i> L.	common	a,b,c,d,e,g,h,i,j,l,n,p	4,5,6,9,10,12,14,15,16,17,18,19,20,26,27,34,35,36,40,43,52	
<i>Vaccinium vitis-idaea</i> L. ssp. <i>minus</i> (Lodd.) Hult.	common	c,d,g	4,5,17,20	
<i>Vahlodea atropurpurea</i> (Wahlenb.) E. Fries	common	c,i,o	15,20,34,35,36,44	
<i>Veronica serpyllifolia</i> L. ssp. <i>humifusa</i> (Dickson) Syme	common	b	18	
<i>Veronica stelleri</i> Pall.	common	c,o	4,15,18,45	
<i>Viola wormskioldii</i>	uncommon			
<i>Viola epipsila</i> Ledeb. ssp. <i>repens</i> (Turcz.) Becker	common	d	17,19	
<i>Viola langsдорffii</i> Fisch.	common	c	4,15,20	

BRYOPHYTES						
Species	Occurrence	Habitat	Plots	Substrate		
<i>Andreaea rupestris</i> Hedw.	common	c,e,g,j,k,m	6,10,12,15,20,26,27,30,32,38,39	rock		
<i>Arctoa fulvella</i> (Dicks.) Bruch & Schimp. in B.S.G.	common	e,h,i,j,l,m,p	12,25,27,34,35,37,39,40,50,51,52	soil		
<i>Aulacomnium palustre</i> (Hedw.) Schwaegr.	common	a,b,c,d	4,9,15,18,19,20	ground		
<i>Aulacomnium turgidum</i> (Wahlenb.) Schwaegr.	uncommon	g	5	ground		
<i>Barbilophozia hatcheri</i> (Evans) Loeske	common	b	14	soil, ground		
<i>Bartramia ithyphylla</i> Brid.	common	c,e,g,i,k,m,o	4,5,6,10,11,15,20,30,32,34,35,36,38,39,45	rock, crevice		
<i>Brachythecium albicans</i> (Hedw.) Schimp. in B.S.G.	common	d,e	11,16	ground		
<i>Brachythecium asperinum</i> (Mitt.) Sull.	common	h,i,o	28,36,45	ground		
<i>Brachythecium frigidum</i> (C. Mull.) Besch.	common	a,b,c	9,18,20	ground		
<i>Brachythecium plumosum</i> (Hedw.) schimp. in B.S.G.	common	c	20	ground		
<i>Brachythecium reflexum</i> (Starke in Web. & Mohr) Schimp var. <i>pacificum</i> Ren. & Card. in Roll.	uncommon	i,o	35,44	ground		
<i>Brachythecium starkei</i> (Brid.) Schimp. in B.S.G. var. <i>starkei</i>	uncommon	d,j	17,36	ground		
<i>Bryoerythrophyllum recurvirostre</i> (Hedw.) Chen	uncommon	c,h	15,20,28	rock, soil		
<i>Bryoxiphium norvegicum</i> (Brid.) Mitt.	uncommon			rock		
<i>Bryum bicolor</i> Dicks.	uncommon			ground		
<i>Bryum weigelii</i> Spreng. in Biehler	uncommon	c	15	ground		
<i>Calliergon stramineum</i> (Brid.) Kindb.	uncommon	a,b	8,18	ground		

<i>Ceratodon purpureus</i> (Hedw.) Brid.	common	a,b,c,d,o	4,8,9,13,16,17,19,44	rock, soil, ground
<i>Conostomum tetragonum</i> (Hedw.) Lindb.	very common	e,g,h,i,j,k,l,m	12,24,26,28,29,30,32,34,36,39,40, 41,46	rock
<i>Cratoneuron filicinum</i> (Hedw.) Spruce				ground
<i>Dichodontium pellucidum</i> (Hedw.) Schimp.	uncommon	c,g	5,15	soil
<i>Dicranella palustris</i> (Dicks.) Crundw. ex Warb.	uncommon	a	9	ground
<i>Dicranella subulata</i> (Hedw.) Schimp.	uncommon	i	36	squirrel hole
<i>Dicranowesia crispula</i> (Hedw.) Lindb. ex Milde	very common	b,c,d,h,i,m,o,p	4,13,14,15,17,20,25,29,37,40,41,44,4 5,50,51,52	rock, soil
<i>Dicranum angustum</i> Lindb.	uncommon	c	4	ground
<i>Dicranum scoparium</i> Hedw.	common	c,d,g,h,i	4,5,6,15,17,20,28,35	ground
<i>Dicranum spadiceum</i> Zett.	uncommon	c,g,h,i,l,m,o,p	5,15,25,28,29,34,35,36,39,40,41,45,4 6,50,51,52	soil, ground
<i>Dicranum tauricum</i> Sapeh	uncommon			soil, ground
<i>Didymodon vinealis</i> (Brid.) Zand.	uncommon	c,e	11,15	rock
<i>Diplophyllum albicans</i> (L.) Dum.	common	c,h	4,28,29	soil, ground
<i>Diplophyllum taxifolium</i> (Wahlenb.) Dum.	common	h,q	21,25,28	soil, ground
<i>Distichium capillaceum</i> (Hedw.) Bruch & Schimp. in B.S.G.	uncommon	c	4,15,20	rock, ground
<i>Dirichium flexicaule</i> (Schwaegr.) Hampe	uncommon	c	15	soil, ground
<i>Drepanocladus aduncus</i> (Hedw.) Warnst.	uncommon	a,b	8,13	ground
<i>Eurhynchium pulchellum</i> (Hedw.) Jenn.	uncommon	h	25	soil

<i>Grimmia donniana</i> Sm.	uncommon	g	6	rock
<i>Grimmia torquata</i> Hornsch. in Grev. var. <i>torquata</i>	uncommon	c	20	rock
<i>Gymnomitrium obtusum</i> Lindb.	common	h,k	25,32	soil, ground
<i>Hylacomium splendens</i> (Hedw.) Schimp. in B.S.G.	uncommon	c	15,20	ground
<i>Hypnum lindbergii</i> Mitt.	uncommon	c	20	rock
<i>Isoterygium pulchella</i> (Hedw.) Iwats.	uncommon			soil, ground
<i>Kiaeria falcata</i> (Hedw.) Hag.	uncommon			
<i>Lophozia sudetica</i> (Nees in Hueb.) Grolle	common	c,h,i,l	15,25,28,34,46	soil, ground
<i>Marchantia polymorpha</i> L.	common	b,c,d	4,13,15,16,18,19	soil
<i>Marsupella alpina</i>	common	q	21	soil, ground
<i>Marsupella ustulata</i> (Hueb.) Spruce	common	c	4	soil, ground
<i>Mnium ambiguum</i> H. Mull.	uncommon	c	15	rock
<i>Moerckia blyttii</i> (Moerck) Brockn.	uncommon	a,c,q	4,9,21	soil, ground
<i>Nardia scalaris</i> S. Gray	common	a,g,h,j,k,p	5,9,24,25,30,32,33,50	soil, ground
<i>Oligotrichum hercynicum</i> (Hedw.) Lam. & D.C.	common	j,l,m	33,38,40,41	soil, rock
<i>Paludella squarrosa</i> (Hedw.) Brid.	common	a		
<i>Philonotis fontana</i> (Hedw.) Brid. var. <i>fontana</i>	common	a,b,c	8,9,13,15,20	ground, rock
<i>Plagiommium affine</i>	common	b,c	14,15,18	ground
<i>Plagiothecium cavifolium</i> (Brid.) Iwats.	uncommon	c	15,20	squirrel hole
<i>Pleuroclada albescens</i> (Hook.) Spr.	common	h,i	29,34,40,41	soil, ground

<i>Pleurozium schreberi</i> (Brid.) Mitt.	common	a,c,d,g,h,i	4,5,6,9,15,17,28,34,35	ground
<i>Pogonatum urnigerum</i> (Hedw.) P. Beauv.	very common	a,b,c,d,e,f,g,h,i,j,f,l, m,n,o,p	1,2,3,6,9,10,11,12,14,15,17,20,24, 25,26,27,28,30,31,32,33,35,38,39, 40,41,42,43,44,45,46,50,51,52	soil
<i>Pohlia cruda</i> (Hedw.) Lindb.	common	c,d,e,g,h,i	4,6,11,15,17,20,24,25,28,29,36	soil, ground
<i>Pohlia wahlenbergii</i> (Web. & Mohr) Andrews	common	b,c,d,g,i,o	6,14,19,20,35,44	soil, ground
<i>Polytrichastrum alpinum</i> (Hedw.) G.L.Sm.	common	g	5	soil
<i>Polytrichum commune</i> Hedw.	common	h,i,l	25,28,29,34,40	soil
<i>Polytrichum juniperinum</i> Hedw.	common	a,b,c,d,g,h,i,o,p	5,8,9,13,14,15,16,17,18,19,20,25,28 35,36,44,45,50	soil, ground
<i>Polytrichum piliferum</i> Hedw.	very common	c,d,e,g,h,i,j,k,l,p	4,5,12,15,19,20,24,25,27,28,32,34, 35,36,40,41,51,52	soil, rock
<i>Polytrichum sexangulare</i> Brid.	common	e,l	12,41	rock
<i>Pseudoleskea radicata</i> (Mitt.) Mac. & Kindb. var. <i>denudata</i> (Kindb.) Wijk & Marg.	uncommon	c	4	soil, ground
<i>Pseudoleskea stenophylla</i> Ren. & Card. in Roll.	common	c,d	15,16,19,20	woody twig
<i>Pseudotaxiphyllum elegans</i> (Brid.) Iwats.	uncommon	h	28	soil, ground
<i>Ptilidium ciliare</i> (L.) Hampe	common	d,g	6,17	soil, ground
<i>Racomitrium ericoides</i> (Web. ex Brid.) Brid.	very common	a,b,c,d,e,f,g,h,i,j,k,l, m,n,o,p,q,r,t	1,2,3,4,5,6,9,10,11,12,14,15,16,18, 19,20,21,22,23,24,25,26,27,28,30, 31,32,33,34,35,36,37,38,39,40,41, 42,43,44,45,46,50,51,52	soil, ground, rock
<i>Racomitrium fasciculare</i> (Hedw.) Brid.	very common	b,c,d,e,g,h,i,j,k,l,m, n,p	4,5,6,10,12,14,15,17,19,24,26,28,29 30,32,33,34,37,38,39,40,41,42,43,46 50,51,52	rock

<i>Racomitrium lanuginosum</i> (Hedw.) Brid.	common	b,c,d,e,g,h,k,l,m	4,5,6,10,11,12,14,15,16,17,19,20,25 28,29,30,32,38,40,41,46	soil, ground
<i>Racomitrium sudeticum</i> (Fucnk) Bruch & Schimp in B.S.G.	common	b,g,l,m,p	13,24,37,38,40,41,46,50,51,52	rock
<i>Rhizomnium punctatum</i> (Hedw.) T.Kop.	common	a,b,c,n	9,13,18,20,43	soil, ground
<i>Rhytidadelphus loreus</i> (Hedw.) Warnst.	uncommon	h	28	ground
<i>Rhytidadelphus squarrosus</i> (Hedw.) Warnst.	very common	a,b,c,d,g,i,o	4,5,9,13,14,15,16,17,18,20,34,35,36, 45	ground
<i>Rhytidadelphus triquetrus</i> (Hedw.) Warnst.	very common	c,d,g	4,5,15,17,19,20	ground
<i>Sanionia uncinata</i> (Hedw.) Loeske	very common	a,b,c,d,e,g,h,i,o	4,5,6,9,11,13,14,15,16,17,18,19,20, 28,35,44,45	ground
<i>Schistidium apocarpum</i> var. <i>stricta</i>	common	b,c,d,e	4,11,14,15,19,20	rock
<i>Schistidium rivulare</i> (Brid.) Podp. var. <i>rivulare</i>	common	c	15	rock
<i>Sphagnum girgensohnii</i> Russ.	uncommon	c	4,20	ground
<i>Sphagnum russowii</i> Warnst.	uncommon	g,h	5,28	ground
<i>Sphagnum squarrosus</i> Crome	uncommon	a,b	8,18	ground
<i>Sphagnum teres</i> (Schimp.) Angstr. in Hartm.	uncommon	b	18	ground
<i>Splachnum sphaericum</i> Hedw.	uncommon	b	9,13	soil, ground
<i>Splachnum vasculosum</i> Hedw.	uncommon	a	9	soil, ground
<i>Tetraplodon mniodes</i> (Hedw.) Bruch & Schimp. in B.S.G.	common	b,c,d,g	4,5,14,16,19,20	soil, ground, rock
<i>Timmia austriaca</i> Hedw.	common	c,g,i,o	4,5,6,15,20,34,36,45	soil
<i>Torula ruralis</i> (Hedw.) Gaertn. et al.	common	c,d	4,15,17	rock

<i>Warnsdorffia exannulata</i> (Schimp. in B.S.G.) Loeske var. <i>exannulata</i>	uncommon	a	8	ground
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LICHENS

Species	Occurrence	Habitat	Plots	Substrate
<i>Allanoparmelia alpicola</i> (Th. Fr.) Essl.	very common	e,g	5,6,10,12	rock
<i>Cetraria islandica</i> ssp. <i>orientalis</i> (L.) Anch.	common	c,d	19,20	ground
<i>Cladonia arbuscula</i> (Wallr.) Hale	uncommon	d	19	ground
<i>Cladonia mitis</i> (Sandst.) Hale & W. Culb.	uncommon	g	5	ground
<i>Cladonia bellidiflora</i> (Ach.) Schaer.	uncommon	h	25	ground
<i>Cladonia borealis</i> (= <i>C. coccifera</i> (L.) Willd.)	very common	b,c,d,e,g,h,i	4,5,6,12,14,15,17,29,20,25,28,29,34,41	ground
<i>Cladonia chlorophaea</i> (Florke) Spreng.	common	c,h,i	20,25,28,35	ground
<i>Cladonia cornuta</i> (L.) Hoffm.	common	d,h	16,25,29	rock,ground
<i>Cladonia fimbriata</i> (L.) Fr.	common	d,o	45,17	ground
<i>Cladonia gracilis</i> (L.) Willd.	common	c,h,g	4,6,25,28	ground
<i>Cladonia pocillum</i> (Ach.) O.Rich.	uncommon	c	20	ground
<i>Cladonia pyxidata</i> (L.) Hoffm.	common	b,d,e	10,13,19	ground
<i>Cladonia scabriuscula</i> (Del. in Duby) Nyl.	common	c,d,e,h,i	4,12,16,20,29,35	ground
<i>Cladonia stricta</i> (Nyl) Nyl.	uncommon	h,i	28,41	rock,ground

<i>Cladonia sulphurina</i> (Michx.) Fr.	uncommon	h	28	ground
<i>Cladonia verticillata</i> (Hoffm.) Schaer.	common	b,c,h	14,15,28	ground
<i>Lobarina linia</i> (Ach.) Rabenh.	very common	a,b,c,d,e,g,h,i,o,p	4,5,6,9,10,11,12,13,14,15,16,18,19,20,28,34,35,36,44,50,51,52	ground
<i>Melanella stygia</i> (L.) Essl.	very common	b,c,e,g,h,i,j,l,m	4,5,6,10,11,12,14,24,28,33,34,38,41,46	rock
<i>Nephroma bellum</i> (Spreng.) Tuck	uncommon	(d)		woody twig
<i>Omphalodiscus virginis</i> (Schaer.) Schol.	uncommon	g,k	6,32	rock
<i>Pannaria pezizoides</i> (Web.) Trev.	common	c,e,g,h,l	6,12,15,24,25,28,41	ground
<i>Parmelia omphalodes</i> (L.) Ach.	uncommon	g	6	rock
<i>Parmelia saxatilis</i> (L.) Ach.	common	c,d,e,g	4,5,12,15,17,20	rock
<i>Parmelia sulcata</i> Tayl.	uncommon	d	17	rock
<i>Peltigera aphthosa</i> (L.) Willd.	very common	a,b,c,d,e,g,h,i,o,p	4,5,6,9,10,11,12,14,15,18,19,20,28,34,35,36,44,45,50,52	ground
<i>Peltigera canina</i> (L.) Willd.	uncommon	a	9	ground
<i>Peltigera collina</i> (Ach.) Schrad.	uncommon			ground
<i>Peltigera degenii</i> Gyelnik	uncommon			
<i>Peltigera didactyla</i> (With.) Laundon var. <i>extenuata</i> (Nyl.) Goffinet & Hastings	uncommon	a,c,g	5,6,9,20	ground
<i>Peltigera horizontalis</i> (Huds.) Baumg.	uncommon	b,c	13,15	ground
<i>Peltigera kristenssonii</i> Vitik.	uncommon	c,d	4,16	ground
<i>Peltigera membranacea</i> (Ach.) Nyl.	very common	a,b,c,d,e,g,h,i,o,p	4,5,6,9,10,11,12,13,14,15,16,18,19,20,29,34,36,44,45,50	ground

<i>Peltigera polydactylon</i> (Neckert) Hoffm.	uncommon				
<i>Peltigera praetextata</i> (Floerke ex Sammerf.) Zopf	uncommon	c,p	20,52		ground
<i>Peltigera scabrosa</i> Th. Fr.	common	a,b,c,d,g,h,i,l	5,9,13,15,16,18,19,20,25,28,34,35,36,41		ground
<i>Peltigera rufescens</i> (Weis) Humb.	uncommon				
<i>Peltigera veniosa</i> (L.) Baumg.	uncommon	e,g,h	6,11,25		soil,ground
<i>Physcia caesia</i> (Hoffm.) Furttohr	uncommon				rock
<i>Pilophorus robustus</i> Th. Fr.	uncommon	c,g	4,5		rock
<i>Placopsis gelida</i> (L.) Lindsay	very common	b,c,d,e,f,g,h,i,j,k,l,m,n,o,p,q	1,2,3,4,5,6,10,11,12,14,16,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,37,38,39,40,41,42,43,44,50,51,52		rock
<i>Pseudephebe minuscula</i> (Nyl. ex Arn.) Brodo & Hawksw.	common	c,e,g,h,p	6,12,15,28,51		rock
<i>Pseudephebe pubescens</i> (L.) Choisy	common	c,e,j	10,12,20,26,27		rock
<i>Psoroma hypnorum</i> (Vahl) S. F. Gray	common	b,c,d,e,g,h,i,o,p	4,6,10,11,12,14,15,16,18,19,20		ground
<i>Solarina crocea</i> (L.) Ach.	very common	c,d,e,g,h,i,j,k,l,m,n,p	4,5,6,10,11,12,19,20,24,26,27,28,29,30,32,33,34,35,36,38,39,40,41,43,45,46,50,51,52,53		soil
<i>Sphaerophorus fragilis</i> (L.) Pers.	uncommon	g	5		ground
<i>Sphaerophorus globosus</i> (Huds.) Vain.	uncommon	c,g	6,20		soil
<i>Stereocaulon alpinum</i> Laur.	common	d,i,j,m,n,o,p	16,27,34,35,37,43,44,51		soil,ground
<i>Stereocaulon glareosum</i> (Savicz) Magn.	uncommon	aj	9,33		soil
<i>Stereocaulon rivulorum</i> Magn.	common	c,e,g,h,o,p	6,10,11,12,15,20,28,45,52		soil,ground

<i>Stereocaulon tomentosum</i> E. Fries	common	b,c,d,g,h,i,p	4,5,14,16,19,25,36,52	soil, ground
<i>Stereocaulon vesuvianum</i> Pers.	very common	b,c,e,g,h,i,j,k,l,m,n,p	4,5,6,10,12,14,15,20,24,25,26,28,29,30,32,34,36,37,38,39,40,41,43,46,50,51	rock
<i>Thamnotia vermicularis</i> (Sw.) Ach. ex Schaer.	uncommon	g	5,6	ground
<i>Umbilicaria arctica</i> (Ach.) Nyl.	uncommon	p	50	rock
<i>Umbilicaria cylindrica</i> (L.) Del. in Duby	uncommon	m	39	rock
<i>Umbilicaria hyperborea</i> (Ach.) Hoffm. var. <i>hyperborea</i>	common	c,h,j,l,m	20,25,26,33,38,39,41,46	rock
<i>Umbilicaria hyperborea</i> (Ach.) Hoffm. var. <i>radicicula</i> Zett.	uncommon	g,k	6,32	rock
<i>Umbilicaria proboscidea</i> (L.) Schrad.	common	b,e,g,i,j	5,6,10,11,12,14,27,33,34	rock
<i>Umbilicaria torrefacta</i> (Lightf.) Schrad.	common	c,g,k	4,5,6,20,32	rock
<i>Xanthoria candelaria</i> (L.) Arn.	uncommon	d	17	rock
<i>Xanthoria elegans</i> (Link.) Th. Fr.	uncommon	c	20	rock

Appendix III. Range extensions according to Hultén (1968).

Asteraceae

*Antennaria pallida**Artemisia borealis**Hieracium triste*

Caryophyllaceae

*Stellaria crassifolia**Stellaria ruscifolia* ssp. *aleutica**Stellaria calycantha* ssp. *isophylla*

Cyperaceae

*Carex bigelowii**Carex pyrenaica* ssp. *micropoda**Carex rariflora*

Equisetaceae

Equisetum variegatum

Ericaceae

Vaccinium ovalifolium

Gentianaceae

Gentiana tenella

Juncaceae

Juncus drummondii

Orchidaceae

Listera cordata

Poaceae

*Poa alpina**Poa paucispicula*

Pyrolaceae

Pyrola secunda ssp. *secunda*

Salicaceae

*Salix phlebophylla**Salix sitchensis*

Saxifragaceae

*Parnassia palustris**Ranunculus eschscholtzii*

Scrophulariaceae

Pedicularis langsдорffii ssp. *langsдорffii*