New Hampshire Natural Heritage Inventory
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Alpine and Subalpine Vegetation of the White Mountains, New Hampshire

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A Quick Overview of the NH Natural Heritage Inventory's Purpose and Policies

The Natural Heritage Inventory is mandated by the Native Plant Protection Act of 1987 (NH RSA 217-A) to determine protective measures and requirements necessary for the survival of native plant species in the state, to investigate the condition and degree of rarity of plant species, and to distribute information regarding the condition and protection of these species and their habitats.

The Natural Heritage Inventory provides information to facilitate informed land-use decision-making. We are not a regulatory agency; instead, we work with landowners and land managers to help them protect the State's natural heritage and meet their land-use needs.

The Natural Heritage Inventory has three facets:

Inventory involves identifying new occurrences of sensitive species and classifying New Hampshire's biodiversity. We currently study more than 600 plant and animal species and 140 natural communities. Surveys for rarities on private lands are conducted only with landowner permission.

Tracking is the management of occurrence data. Our database currently contains information about more than 4,000 plant, animal, and natural community occurrences in New Hampshire.

Interpretation is the communication of Natural Heritage Inventory information. Our goal is to cooperate with public and private land managers to help them *protect* rare species populations and exemplary natural communities.

cover: Trail-less summit ridge of Imp Mt., New Hampshire

All photographs in this report are by Daniel Sperduto

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SUMMARY

The vegetation of New Hampshire's Presidential Range has been the subject of considerable study over the past 150 years. In contrast, alpine and subalpine summits elsewhere in the White Mountains have received relatively little attention from botanists, ecologists, and land managers, with a few notable exceptions. This report considers alpine and subalpine vegetation throughout the White Mountains, and is part of a broader systematic inventory of the floristics, plant communities, environmental attributes, and human factors associated with alpine vegetation in the northeastern United States. In addition, we seek to inform stewardship of alpine species and communities by identifying their locations, significance, and associated management issues.

We have documented 35 peaks outside the Presidential Range in New Hampshire with alpine or subalpine vegetation, all of which are at least one acre in size, and most of which are greater than five acres. Twenty-four of these peaks are over 4000' elevation, and 11 are lower but generally higher than 3500'. All contain heath/krummholz communities, and more than half have some dwarf shrub/sedge-rush meadows or barrens typical of higher alpine areas. Some of these peaks have naturally rugged summits with essentially no soil. Franconia Ridge, Bondcliff, Guyot, Baldface Ridge, Moosilauke, Cannon Mountain, the Mahoosuc Range, and the Shelburne-Moriah vicinity contain the great majority of the acreage, with more than 600 acres total. Of these, only Franconia Ridge and South Twin exceed climatic treeline at 4900 feet. We have also documented numerous lower elevation cliffs, talus slopes, river gorges, and rocky ridges that have certain alpine or subalpine affinities.

There are approximately 70 plant species in alpine areas of the White Mountains that are either rare in New Hampshire or restricted to alpine and subalpine habitats. There is a distinct decrease in the diversity of alpine-restricted species from larger and higher peaks to lower and smaller peaks. More than 200 other species of vascular plants are documented from alpine peaks and other habitats with alpine affinities. Many of these are found only in areas protected by late-melting snowpacks above treeline or on subalpine or lower elevation ledges. Overall plant composition relates well to elevation range, area, and range of soil moisture conditions.

Alpine zones typically consist of complex community mosaics in which patches of vegetation cover or grow among a matrix of bedrock, stone, talus, and/or gravel with or without thin organic soil layers. We have defined five major groups of alpine and subalpine plant communities from the data set, plus a sixth group of montane vegetation transitional to subalpine heath/krummholz found on lower ridges and ledges. Each of these major groups can be divided into two or more finer-scale communities for a total of 13 alpine/subalpine types (15 total with montane types). Some of these communities and constituent species are restricted to the higher peaks, while others are restricted to lower subalpine peaks.

Human use and impacts vary considerably among peaks. Most retain significant areas of largely natural vegetation with localized zones of trampled vegetation, soil erosion, and unofficial trail development. A few peaks are trail-less and remain intact, while several have been heavily trampled or reduced to gravel or bedrock with little hope of recovery at current recreational levels. Fires have certainly modified the extent of total open habitat on some subalpine peaks, although most were likely open to some extent prior to European settlement. At most summits, some combination of stewardship efforts will be needed to retain or stabilize existing natural vegetation, or in some cases to rehabilitate denuded areas.

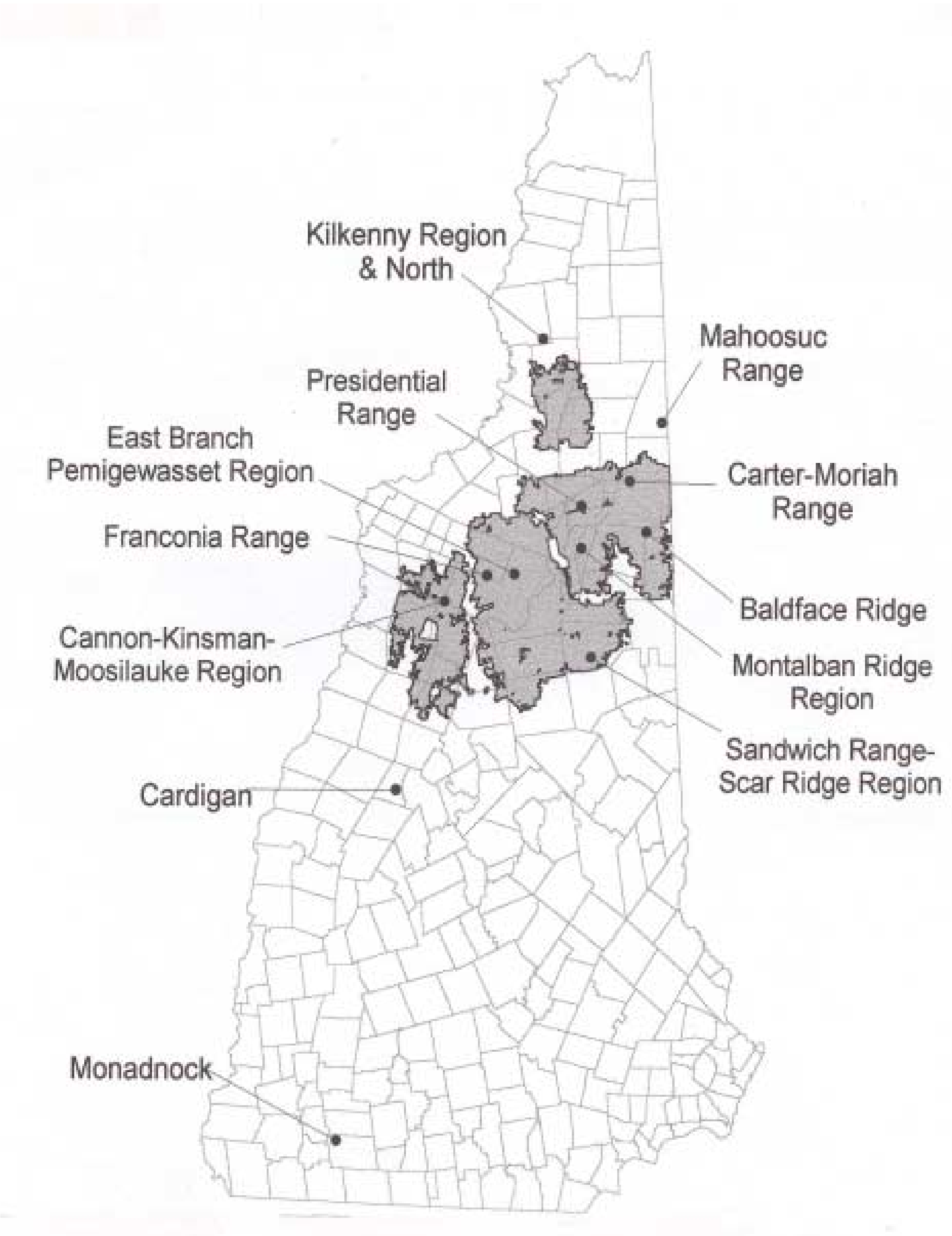


Figure 1. General regions of alpine and subalpine areas in New Hampshire.

INTRODUCTION

The alpine zone of New Hampshire occurs at high elevations above treeline in the White Mountains where severe climatic conditions prevail and a community of low mat-forming shrubs, sedges, rushes, grasses, mosses, and lichens dominate. The flora is most similar to that of the eastern Canadian Arctic and coastal barrens. Sixty-two percent of the plant species in the Presidential Range are restricted to alpine tundra. Among these, *Prenanthes boottii* (Boott's rattlesnake-root) is endemic to northeastern U.S. alpine areas, *Potentilla robbinsiana* (Robbin's or dwarf cinquefoil) is endemic to the White Mountains, and *Geum peckii* (mountain avens) is endemic to the White Mountains and several stations in Nova Scotia, giving New Hampshire and other New England tundra a distinct floristic signature. Permafrost and frost phenomena characterize parts of the Presidential Range, the largest and most diverse of the region's alpine areas. The vegetation is exposed to high winds, a short growing season, low temperatures, heavy cloud cover and fog, high precipitation and fog interception, and mostly well drained soils with low nutrient availability and high organic matter content.

At a global scale, treeline follows a latitudinal gradient corresponding approximately to the 10-12^{o} Celsius July isotherm, and, consequently, declines in elevation with increasing latitude (Cogbill and White 1991; Cogbill *et al.* 1997). In New Hampshire, climatic treeline occurs at approximately 4900' elevation. However, alpine and subalpine vegetation can be found at lower elevations due to local compensating factors (e.g. wind-exposed ridges and summits with shallow, poorly developed soils, or fire histories). These lower elevation alpine areas are generally smaller and have communities with fewer alpine-restricted species. Figure 1 shows the distribution of alpine and subalpine peaks and ledges in New Hampshire.

Some subalpine summits or ridgelines may have been originally opened by fires of natural or human origin, sometimes pushing the ecosystem over the "resiliency threshold" (Bormann and Likens 1979) where recovery to original forest could take centuries due to loss of soil. Other examples, particularly many subalpine sites with severe exposures, appear to have been open for at least many centuries based on the earliest accounts, although fire may have altered the proportion of forest versus open and woodland area (Whitney and Moeller 1982).

Bliss (1963) contends that snow accumulation and atmospheric moisture gradients are the most important factors influencing plant communities of the Presidential Range. Snow accumulation is, in turn, influenced by aspect, topography, and degree of exposure to prevailing winds. Although these variables are clearly important, elevation is also a key determinant when considering the full spectrum of alpine and subalpine vegetation in the White Mountains.

In a broad sense, variation among alpine communities can be thought of as corresponding to five major groups of vegetation that relate to certain environmental conditions:

1. *Diapensia* heath barrens on the most exposed, snow-free sites;
2. herb and herb-heath snowbank communities in lee positions with late-melting snowpacks;
3. bogs on poorly drained concavities on ridges and sometimes on slopes;
4. dwarf shrub/sedge-rush tundra without trees; and

5. heath/krummholz communities on somewhat lower peaks where a broader diversity of montane shrubs mix with krummholz and alpine shrubs.
Within this array, higher and lower elevation counterparts can be recognized.

As treated here, alpine and subalpine areas include treeless and partially wooded exposures with krummholz (trees <1.5-2 m height) that contain species absent from low to mid elevations. The most broadly distributed of these species, present in some combination at nearly all sites, include *Vaccinium uliginosum* (alpine bilberry), *Empetrum atropurpureum* (purple crowberry) and/or *Empetrum nigrum* (black crowberry), and the lichen *Cetraria islandica*. Slightly lower elevation ridges (e.g. red spruce and red pine woodlands) with taller trees generally lack these species but occasionally have *Vaccinium vitis-idaea* (mountain cranberry) which is ubiquitous at higher elevations. The larger and higher peaks have more alpine-restricted species such as *Carex bigelowii* (Bigelow's sedge), *Juncus trifidus* (highland rush), *Hierochloe alpina* (alpine sweet grass), *Diapensia lapponica* (diapensia), *Solidago cutleri* (Cutler's goldenrod), *Salix uva-ursi* (bearberry willow), and *Betula minor* (small birch). High elevation ledges and landslides in forested settings, "cold-air talus slopes," and lower elevation rocky mountain stream or river banks may also harbor what are generally considered alpine species (*Juncus trifidus*, *Empetrum atropurpureum*, *Agrostis mertensii*, *Geum peckii)* or other species that reach the southern terminus of their North American distribution in montane areas of northern New England, including *Draba incana* (lance-leaved draba), *Hieracium robbinsonii* (Robbin’s hawkweed), and *Pinguicula vulgaris* (butterwort).

METHODS

Data Collection

This project represents a synthesis of original data compiled by the authors and existing data from the literature and herbarium specimen records. Potential alpine and subalpine exposures were identified from personal knowledge of the study area and review of topographic maps, aerial photographs, plant and community records in the NH Heritage Biological and Conservation Data System (BCD), additional herbaria records, published literature and unpublished reports, leads from knowledgeable individuals, descriptions in Appalachian Mountain Club hiking guides, and articles on early exploration of the mountains published in *Appalachia*. All of the major high elevation exposures outside the Presidential Range (generally above 4000') and many of the moderately high elevation ones (generally above 3000') were visited at least once by one or both authors, and/or existing data was compiled from other sources.

An attempt was made to document the following characteristics of each summit:

1. *Total flora* of vascular plants. Fruticose lichens, *Sphagna*, and other bryophytes were documented from many but not all sites.
2. *Total area* (acres/hectares) of alpine or subalpine vegetation beyond continuous forest (generally the area with krummholz less than 1.5-2 m in height), as measured or estimated in the field or reconstructed from aerial photos.

3. *General description* of summit or ridge, including bedrock and surficial deposits, slope, aspect, range of vegetation structure, dominant and minor vegetation associations, elevation range, fire history, trampling impacts, and trail maintenance needs.

One to several plots were established in each of the major vegetated associations present at a site. Two hundred-three 5 x 5 m plots, or averages of contiguous 1 m^2 plots along transects, were placed in areas of relatively homogenous vegetation and environmental conditions by the authors. In some cases, smaller plots were used if a contiguous 25 m^2 area was not available. 10 x 10 plots were used in some heath/krummholz expressions due to the larger sizes of individual plants or clones.

At each plot, the following data were recorded: percent cover of all vascular species and certain non-vascular species (generally recorded to the nearest percent when less than 25%, and nearest 5% when over 25%); aspect; slope; slope position; and elevation. At a subset of these samples the following were recorded: percent cover of bedrock, stone, gravel, sand, and litter; vegetation height (by strata); direction of krummholz flagging; soil depth and profile description; estimated extent of the sampled association present at the site (actual or proportion of total area); and representativeness/notable variation of associations at the site.

Data Analysis

Floristic data representing two different spatial scales were analyzed: (1) the total floras of each peak (sites) beyond continuous krummholz; and (2) plant associations as recorded in plot data. Analyses were conducted on 203 plots collected by the authors and on a larger data set including an additional 105 plots collected by Bliss (1963; pers. comm. 1996), Wiser (1993; pers comm. 1997), Doyle *et al.* (1987), and Fahey (1976; pers. comm. 1989). These data were analyzed using multi-variate techniques included in PC-ORD software (Ver. 2.0, MjM Software Design) and Nested Temperature Calculator (Ver. December 1997; Atmar and Patterson 1995; Atmar and Patterson 1993; Patterson 1987). We used PC-ORD programs, including TWINSPAN and DECORANA (Hill 1979) and CANOCO (Ter Braak 1988), to classify and ordinate peak floras and plot data, and Nested Temperature Calculator for additional analyses of the degree of nestedness of peak floras. We also extracted and summarized vegetation and environmental data directly from spreadsheets for groups of plots and sites derived from these programs.

Classification attempts to group the array of diversity, represented by a data set, into meaningful clusters or groups. These groups represent different segments along an often continuous gradient of change in vegetation and environmental conditions. Two-way Indicator Species Analysis (TWINSPAN) uses a polythetic divisive classification method based on a reciprocal averaging (Hill 1979) that reveals patterns of association among species and samples (plots). The results include a species-by-plots matrix that groups plots together that have similar combinations of species, and differentiates them from other groups that have dissimilar associations of species. TWINSPAN breaks any given data-set into two groups based on the strongest floristic differences in the data, and continues to break each resulting group into two more groups until a specified number of separations have been achieved. It is up to the interpreter to decide where the splits lose ecological meaning and become arbitrary.

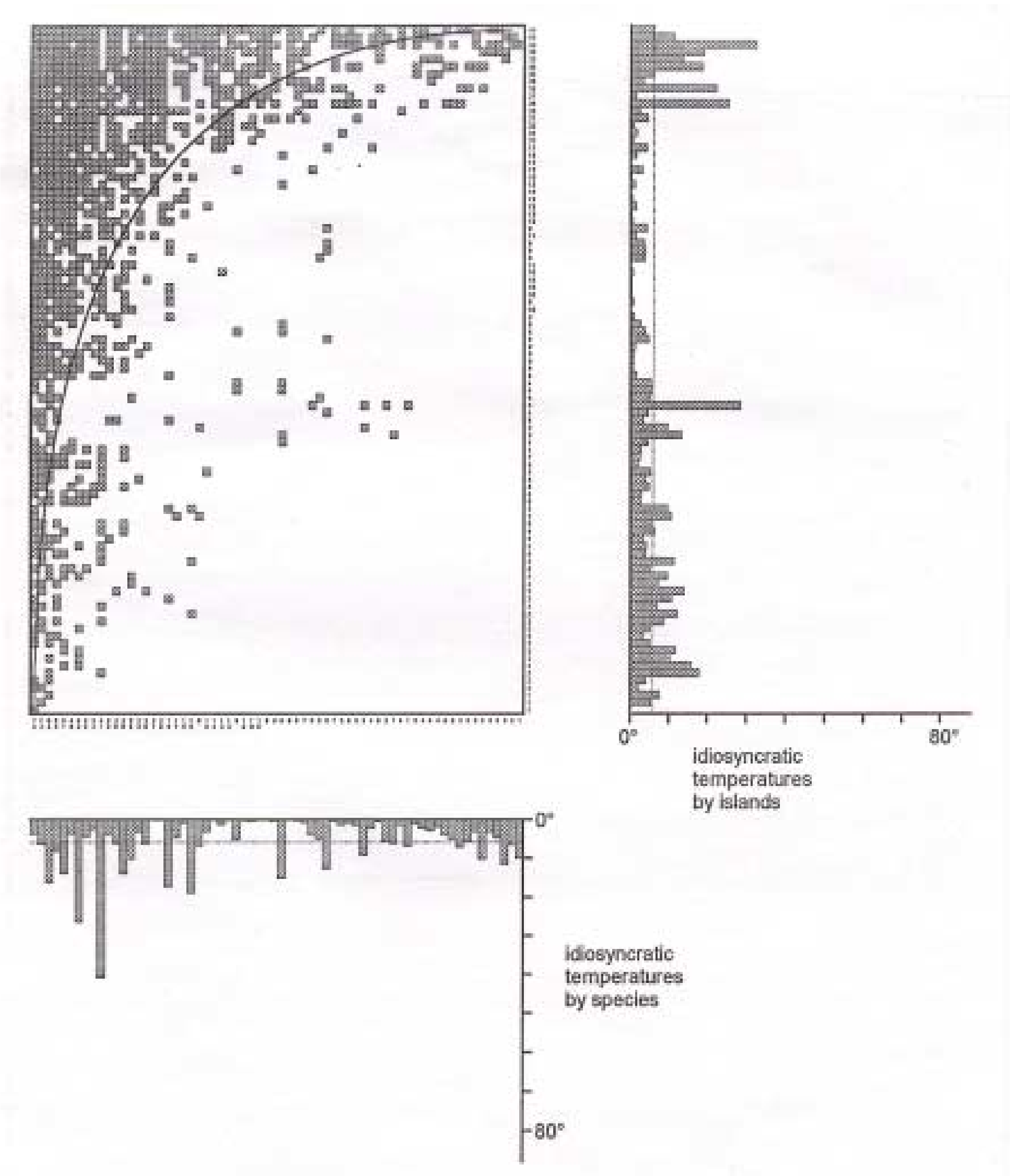


Figure 2. Top Left: A matrix of maximally ordered species presences among alpine and subalpine sites in New Hampshire with 94 sites in rows and 66 species in columns, showing a highly significant nested structure with a temperature of 5.9 degrees. The line in the matrix indicates the zone of maximum nestedness where presences are expected above and to the left of the line.
Top Right: The idiosyncratic temperatures of individual sites.
Bottom: The idiosyncratic temperatures of individual species.

Detrended Correspondence Analysis (DECORANA) ordinates species and sample plots through reciprocal averaging techniques (Hill 1979). The graphic result is an ordination along two or more axes that reflect differences between plots and species. DECORANA does not force plots into groups like TWINSPAN, but does provide a graphic portrayal of how similar or different individual plots are from one another in a common "ecological space."

Canonical Community Ordination (CANOCO) combines ordination with regression analyses to portray relationships of species and plots with environmental parameters (Ter Braak 1988). These multivariate techniques have become popular in ecology, especially in the attempt to classify and ordinate large data sets into ecologically meaningful groups. They have a high utility for helping discern patterns, but they do not provide test results with statistical significance in the same way as analysis of variance, regression, and correlation techniques.

Nested Temperature Calculator (NTC) tests the hypothesis that the species on islands form a perfect nested set. This condition is represented by all species in the richest flora showing a consistent loss of the progressively rarer species (presumably because of ease of extinction) until only the most common species are left in the smallest flora. The NTC then calculates a "temperature," akin to entropy of the variance from this ideal nested structure. Here, 0 degrees is perfectly nested and 100 degrees is totally disordered. It also calculates a temperature for random association of all the species within the islands (in the case of eastern alpine floras, about 72 degrees) against which the actual temperature can be tested for nestedness.

The result of NTC is a matrix of species presences among sites which is ordered for maximal packing with sites in the rows and the species in columns. In general, the sites with the most species are at the top and the species occurring in the most sites are at the left. The line is the limit of species presences assuming maximal nesting, and separates the expected presences from the unexpected region of the matrix. Absences to the upper left or presences to the lower right of the line are deviations from the nestedness and are the basis of the matrix temperature. This temperature is similar to entropy and is simply the average deviation of the actual matrix compared to the ideal fully nested pattern. It also allows for the temperature of each site and species to be calculated separately and compared to the overall temperature. These species/site temperatures are plotted in the adjacent figures (sites to the right and species below the overall figure) and are considered idiosyncratic if they greatly exceed the average for the whole matrix.

RESULTS & DISCUSSION

Floristic Composition & Distribution

We have documented over 270 species at more than 80 alpine and subalpine peaks or other habitats with alpine affinities (ledges, talus, ravines) in northern New England and New York. The NTC for 66 true alpine species on 94 White Mountain summits or ledges gives a highly significant nested structure (Figure 2) with a temperature of 5.9 degrees. The Alpine Garden island forms the reference flora and the remaining disorder (idiosyncratic temperatures) are concentrated in several of the islands with rich floras in the Presidential Range (mostly ravines or exposed flats). The majority of the moderately rich floras are very "cool" with only Diamond Peak having a significant idiosyncratic temperature (meaning the flora of Dead Diamond Peak is anomalous due to the lack of alpine species and the presence of a single circumboreal species).

In contrast, most of the lesser peaks with small alpine floras have slightly elevated temperatures, indicating a few species rarer than the sizes of their floras connotes, but none are highly idiosyncratic. The alpine species which significantly add to the idiosyncratic temperature are those which are found scattered on some lower peaks, such as *Empetrum atropurpureum*, *Agrostis borealis* (boreal bent-grass), *Paronychia argyrocoma* var. *albimontana* (silvering), *Potentilla tridentata* (three-toothed cinquefoil), *Juncus trifidus*, *Vaccinium boreale* (alpine blueberry), *Rubus chamaemorus* (baked apple berry or cloudberry), and *Luzula parviflora* var. *melanocarpa* (small-flowered black woodrush). As hypothesized, the majority of the alpine species "behave" well and are regularly restricted to progressively richer summits as their rarity increases. For example, *Vaccinium vitis-idaea* and *Vaccinium uliginosum* var. *alpinum* are the most common and most widespread, while *Potentilla robbinsiana* and *Oxyria digyna* (mountain sorrel) are rare and restricted to sites with high species richness.

A classification of summits based on a TWINSPAN analysis run just on 70 alpine-restricted or otherwise rare species reveals a pattern similar to that produced by NTC. The loss of diversity of alpine restricted/rare species is clear as one moves from higher and larger peaks to lower and smaller peaks. This continuous truncation of alpine species richness with decreasing elevation (absence of certain species) defines the TWINSPAN groups more strongly than does the presence of rare species restricted to lower summits. The major groups from this analysis are shown in Figure 3 (the full TWINSPAN table, and peaks included in each group, is presented in Appendix 4).

Figure 3. Major groups of summits sorted by the presence or absence of 70 plant species.

1. **High elevation and large alpine peaks (Presidential Range, Franconia Ridge, Moosilauke, Bondcliff)** - 48 species are largely restricted to these summits, ridges, and ravines, including *Rhododendron lapponicum* (Lapland rosebay), *Geum peckii*, *Phyllodoce caerulea* (mountain-heath), and *Luzula spicata* (spiked woodrush).
   a. Alpine Garden and ravines which include *Cassiope hypnoides* (moss bell-heather), *Epilobium hornemannii* (Hornemann's willow-herb), *Arnica lanceolata* (arnica), and other snowbank or wet-site species.
   b. Drier ridges and summits which lack these snowbank species.

2. **Lower or smaller alpine and subalpine peaks** - These peaks typically lack all of the 48 species from higher peaks but contain up to 22 other alpine/subalpine restricted species. However, some have several rare species which are absent from higher peaks, including *Calamagrostis lacustris* (pond reed bent-grass), *Paronychia argyrocoma* var. *albimontana* (silvering), *Pinus banksiana* (jack pine), *Geocaulon lividum* (northern comandra), and *Oryzopsis canadensis* (Canadian rice-grass).
   a. Peaks that still contain *Carex bigelowii*, *Diapensia lapponica*, and sometimes *Solidago cutleri*, *Hierochloe alpina*, and *Salix uva-ursi.*
   b. Peaks that lack most or all of the above species, but still usually have *Juncus trifidus*, *Agrostis mertensii* (boreal bentgrass), *Minuartia groenlandica* (mountain sandwort), *Vaccinium boreale*, and *Huperzia selago* (northern fir clubmoss).
   c. Lower peaks with little else but *Vaccinium uliginosum*, *Empetrum nigrum* or more frequently *E. atropurpureum*, *Vaccinium vitis-idaea*, and *Cetraria islandica*.

3. **High elevation cliffs, landslides, and exposed notches** - Few if any alpine species are present in these areas except *Juncus trifidus* and *Agrostis mertensii*.

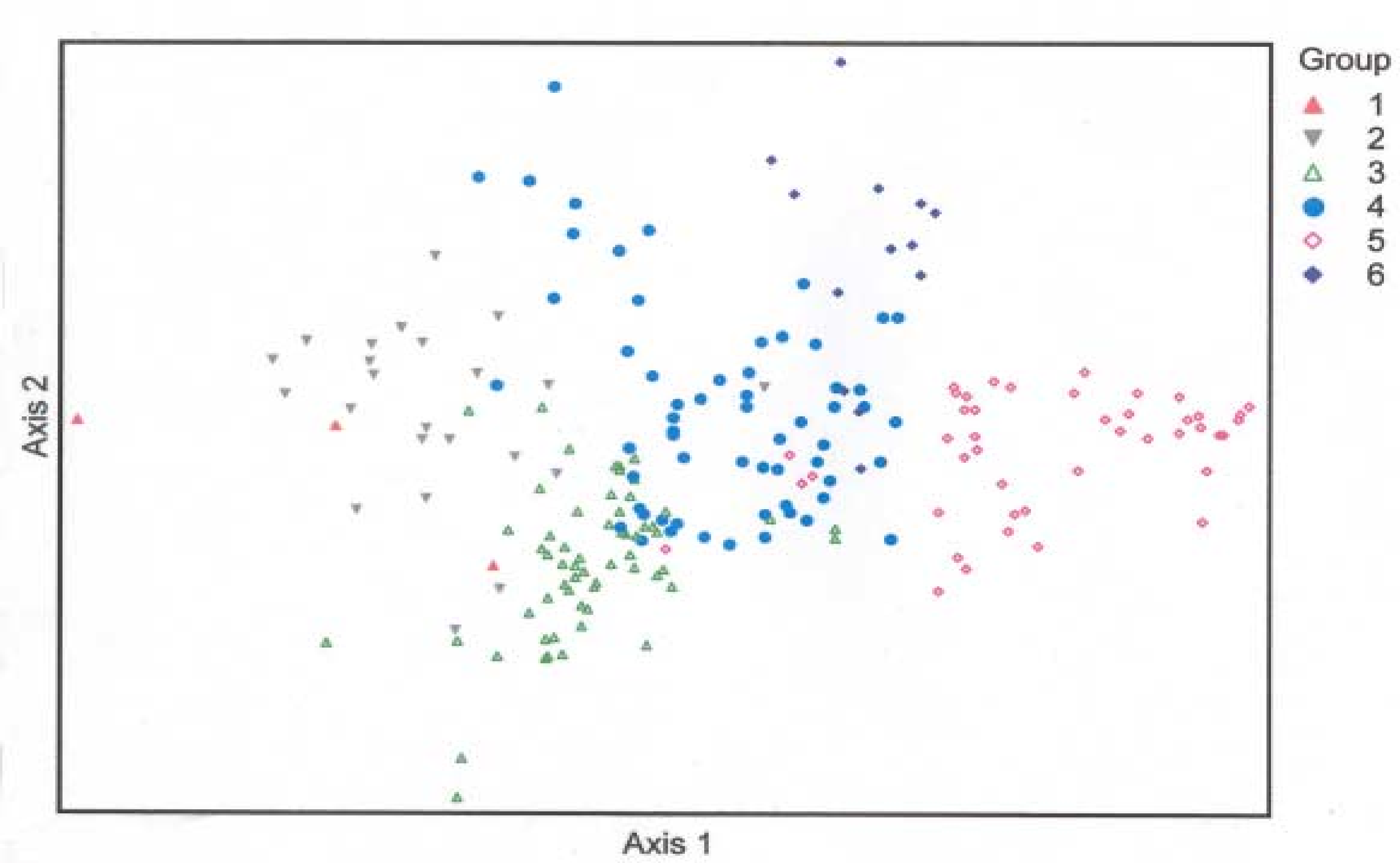


Figure 4. DECORANA graph of 203 plots showing the six major groups of alpine and subalpine natural communities. Group 1 = Alpine herbaceous snowbank and herbaceous-heath meadows. Group 2 = Diapensia shrublands. Group 3 = Dwarf shrub/sedge-rush meadows. Group 4 = Heath/krummholz. Group 5 = Subalpine bogs and subalpine heath snowbanks. Group 6 = Red spruce/heath/cinquefoil rocky ridges and moist montane heath woodlands.

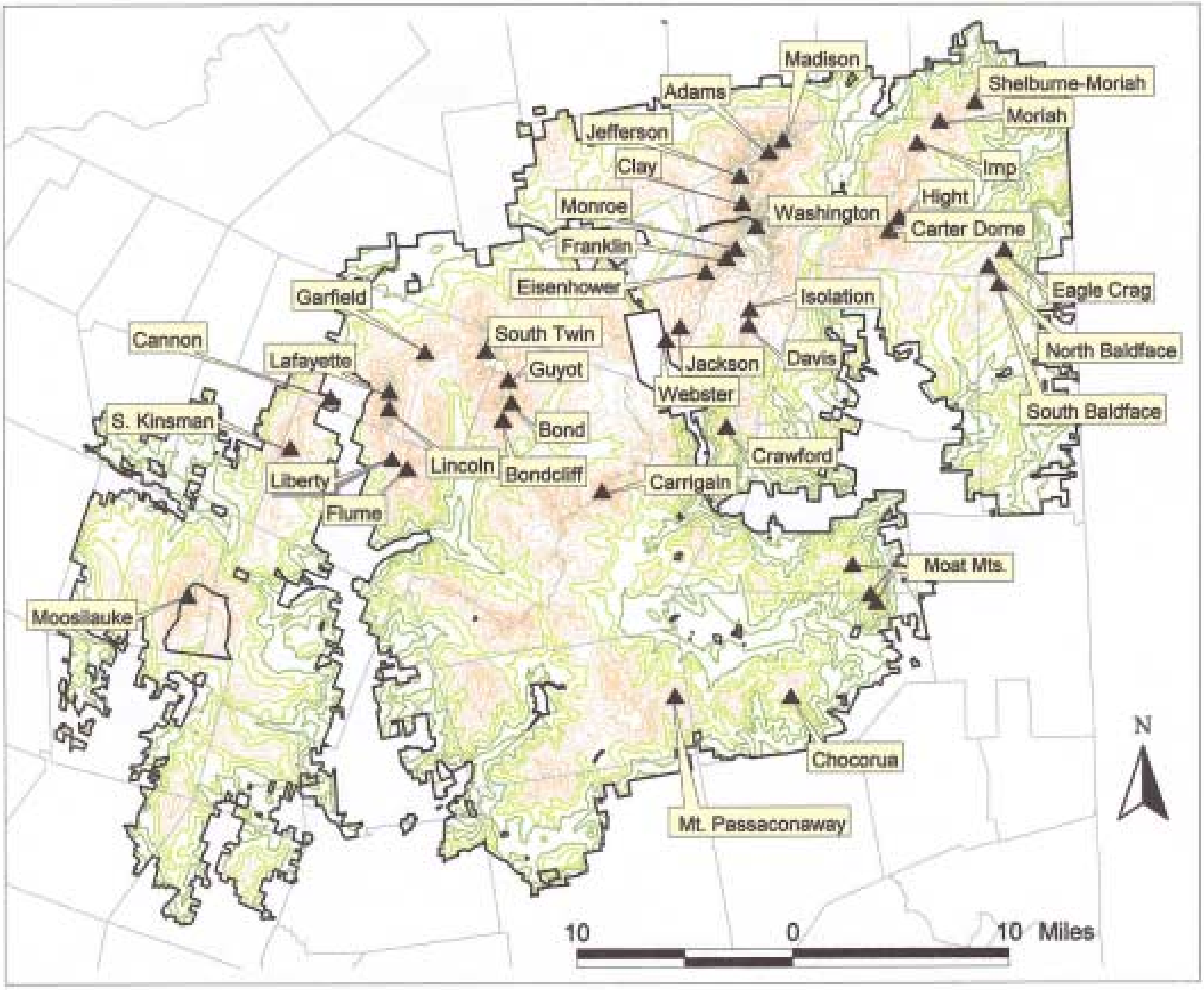


Figure 5. The locations of major alpine and subalpine peaks in the White Mountain National Forest in New Hampshire.

There has been very little study of bryophytes and lichens in alpine and subalpine areas of the White Mountains, with the exception of *Sphagnum* mosses (Cleavitt *et al*., 1999). Limited collections from some of these peaks by the authors and N. Cleavitt have revealed alpine species that are rare in northeastern North America, including *Cynodotium schisti* on Mt. Success (by Sperduto in 1995) and *Sphagnum lindbergii* on Mt. Jackson (by Cleavitt in 1995). These collections are indicative of a high potential for other important non-vascular species from alpine areas in the region.

Natural Community Composition & Distribution

We have defined five major groups of alpine and subalpine plant communities from our data, and a sixth group of montane vegetation which is found on lower ridges and ledges, and is transitional to subalpine heath/krummholz. The groups relate to major differences in soil moisture and substrate, longevity of snowpack, elevation, and degree of exposure. Each of these major groups can be divided into two or more finer-scale communities for a total of 13 alpine/subalpine types (15 total with montane types). Only three of the six major groups, and of seven of the 15 finer community types, can be related to equivalent counterparts in Bliss' classification from the Presidential Range (Bliss 1963). Only one of the 15 types was only represented by samples from the data sets of Bliss (1963) or Wiser (1993). All of the types described by Doyle *et al.* (1987) and Fahey (1976) can be related to these natural communities.

TWINSPAN groups are detailed in a dendrogram presented in Appendix 2. A DECORANA graph of all 308 plots is presented in Appendix 5. Appendix 5 also shows the centroid positions of species from all 308 plots overlayed across the same ecological space and indicates the tendencies of species towards certain groups. In Figure 4, the major community groups are overlayed on a DECORANA graph using just the 203 plots collected by the authors. Figure 4 shows the subalpine bogs at far right, alpine snowbanks in a broad scatter at the left, Diapensia shrublands at center left, dwarf shrub/sedge-rush communities at lower left, heath/krummholz at approximate center, and rocky ridges and moist montane heath woodlands at upper right.

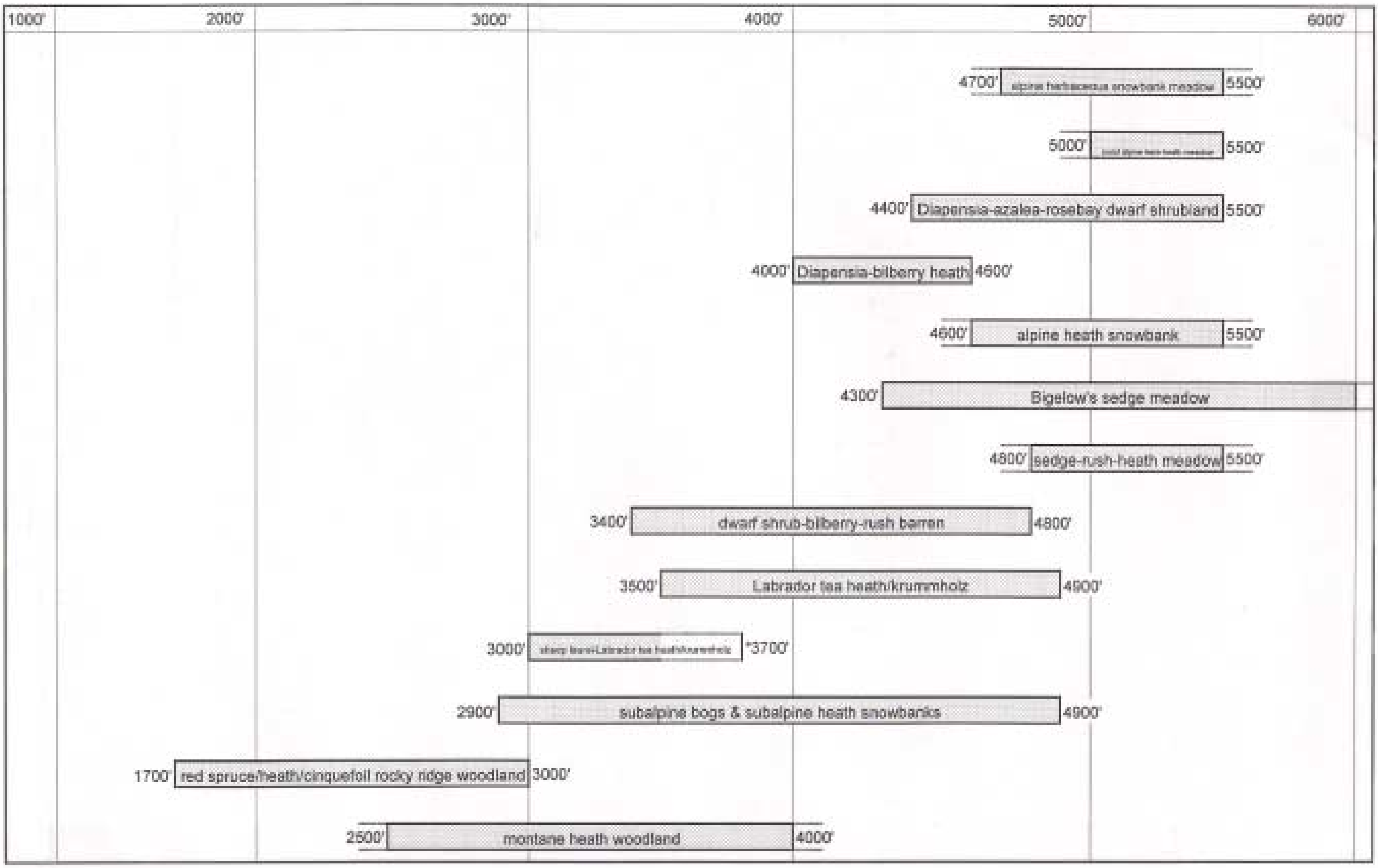
A summary of all the major and minor alpine peaks and related cliffs, talus, and other habitats and the communities present at each are listed geographically in Appendix 1. Figure 5 shows the locations of major alpine and subalpine peaks in White Mountains in New Hampshire.

Summary descriptions of the 15 natural communities are presented below. A bracket -- [or] -- indicates when the upper and/or lower elevation limit may extend farther than indicated by plot data (Figure 6 shows the elevational distribution of the alpine and subalpine natural communities). More detailed descriptions will be included in a classification of New Hampshire communities to be published by the NH Natural Heritage Inventory.

Despite the volume of data which has been collected within the Presidential Range, there has been a geographic bias towards certain areas on Mt. Washington; additional sampling is warranted in the ravines and other areas of Mt. Washington and the northern Presidentials, on alpine cliffs, and on certain other peaks in New Hampshire, Maine, Vermont, and New York. Little work has been done on non-vascular plants throughout alpine areas in the Northeast.

Figure 6. Elevation Ranges of Alpine, Subalpine, and Selected Montane Natural Communities (in feet)

Elevation ranges are approximate. ______ indicates that the upper or lower limit is uncertain.



1. **Alpine herbaceous snowbank and herbaceous-heath meadows:**
   a. Alpine herbaceous snowbank meadow: Local, late-melting snowpacks allow herbaceous montane lowland plants to persist high into the alpine zone along with alpine plants. Some are associated with seepage zones, which are generally absent from heath snowbanks. Composition varies from herb to herb and heath dominated mixes. Characteristic species include *Deschampsia flexuosa* (common hairgrass), *Solidago macrophylla* (large-leaved goldenrod), *Vaccinium cespitosum* (dwarf bilberry), *Clintonia borealis* (blue bead lily), *Coptis trifolia* (goldthread), and *Carex brunnescens* (brownish sedge) along with alpine restricted species absent from lower elevation snowbanks (e.g. *Carex bigelowii*). [4700-5500']
   b. Moist alpine herb-heath meadow: Moist tundra (e.g. near streams or snowbanks) dominated by a diverse mix of forbs, sedges, and heath shrubs including *Geum peckii*, *Tricophorum cespitosum* (deer's-hair sedge, formerly *Scirpus cespitosa*), *Polygonum viviparum* (viviparous knotweed), *Salix uva-ursi*, *Campanula rotundifolia* (harebell), *Carex scirpoidea* (scirpus-like sedge), and *Prenanthes boottii*. In New Hampshire, found only in Alpine Garden. [5000-5500

Photos 1 & 2. Alpine herbaceous snowbank meadows.
The left photo shows an example along a stream at the top of Tuckerman's Ravine, with *Veratrum viride*, *Solidago macrophylla*, *Platanthera dilatata*, and *Houstonia caerulea.* The right photo shows an example on Mt. Clay. Plants restricted to this community and seen here are *Castilleja septentrionalis* (center) with (background) *Veratrum viride*, *Luzula parviflora* var. *melanocarpa*, *Platanthera dilatata*, *Solidago macrophylla*, and *Houstonia caerulea*.

2. **Diapensia shrublands**: Exposed dwarf shrublands, usually on mineral soils, with abundant *Diapensia lapponica* and mixtures of *Rhododendron lapponicum*, *Loiseleuria procumbens* (alpine azalea), *Carex bigelowii*, and *Juncus trifidus*.
   a. Diapensia-azalea-rosebay dwarf shrubland: More diverse alpine compositions found at higher elevations, with *Loiseleuria procumbens, Rhododendron lapponicum, Salix uva-ursi*, *Solidago cutleri*, and *Carex bigelowii*. 4400-5500'
   b. Diapensia-bilberry heath: Less diverse Diapensia heaths found at lower elevations which usually lack the species (particularly *Loiseleuria procumbens* and *Rhododendron lapponicum*) diagnostic of Diapensia-azalea-rosebay dwarf shrublands. 4000-4600'

Photos 3 & 4. Diapensia shrublands.
The left photo shows a Diapensia-azalea-rosebay dwarf shrubland on Boot Spur of Mt. Washington. Diapensia lapponica forms low domes and occurs with several other alpine species, including a low cover of *Salix uva-ursi*, *Carex bigelowii*, *Juncus trifidus*, *Rhododendron lapponicum*, and *Loiseleuria procumbens*.
The right photo shows a Diapensia-bilberry heath on Mt. Guyot. Note the *Diapensia lapponica* domes with a lower diversity of accompanying alpine species.

3. **Dwarf shrub/sedge-rush meadows**: This is the dominant but variable alpine meadow community of higher alpine peaks which is characterized by various mixtures of bilberry and cranberry dwarf heaths, *Carex bigelowii*, and *Juncus trifidus*. Krummholz is absent or in low abundance.

   a. Alpine heath snowbank: The classic mixture of *Vaccinium uliginosum* and cranberry heath, *Carex bigelowii*, and *Juncus trifidus* is supplemented with *Ledum groenlandicum* (Labrador-tea), *Empetrum nigrum*, *Vaccinium cespitosum*, and montane lowland herbs where late melting snowbanks occur at high elevations. *Phyllodoce caerulea* and *Cassiope hypnoides* might also be expected in this community. [4600-5500']

   b. Bigelow's sedge meadow: *Carex bigelowii* dominates with minor amounts of *Minuartia groenlandica* and dwarf heaths. 4300-6000]

   c. Sedge-rush-heath meadow: Mixtures of *Carex bigelowii*, *Juncus trifidus*, and dwarf heath and other shrubs; at lower elevations rush-heath mixtures with less sedge are a prominent variant (rush-heath has been alternatively treated as its own community by Bliss, 1963). [4800-5500]

   d. Dwarf shrub-bilberry-rush barren: This community is found in exposed situations, generally at lower elevations than other sedge-rush-heath communities but above 3400'. It is dominated by *Vaccinium uliginosum* and *Vaccinium vitis-idaea* along with other dwarf shrubs, particularly *Empetrum atropurpureum* and/or *Potentilla tridentata* on mineral or shallow organic materials over mineral substrate. It is intermediate between heath/krummholz and sedge-rush-heath communities; it lacks the abundance of *Kalmia angustifolia* (sheep laurel), *Ledum groenlandicum*, and krummholz of heath/krummholz *and* has a lower abundance of *Carex bigelowii* and *Juncus trifidus* than found in sedge-heath-rush. 3400-4800'

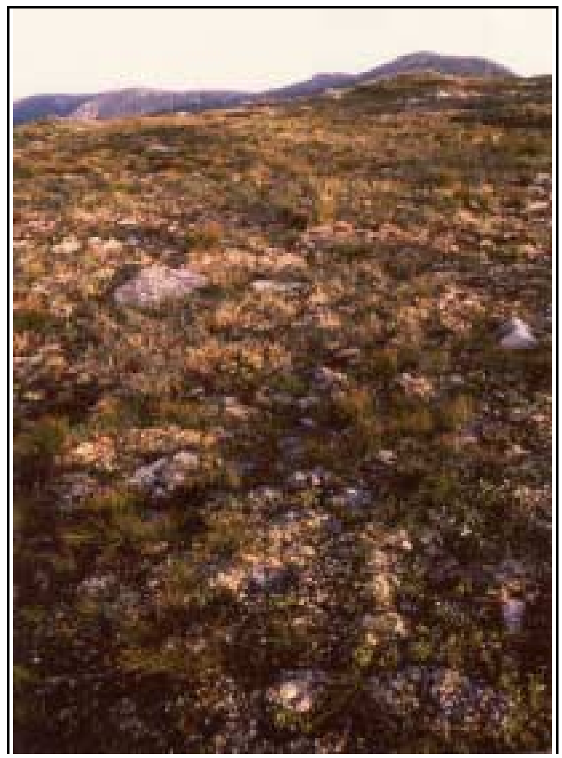
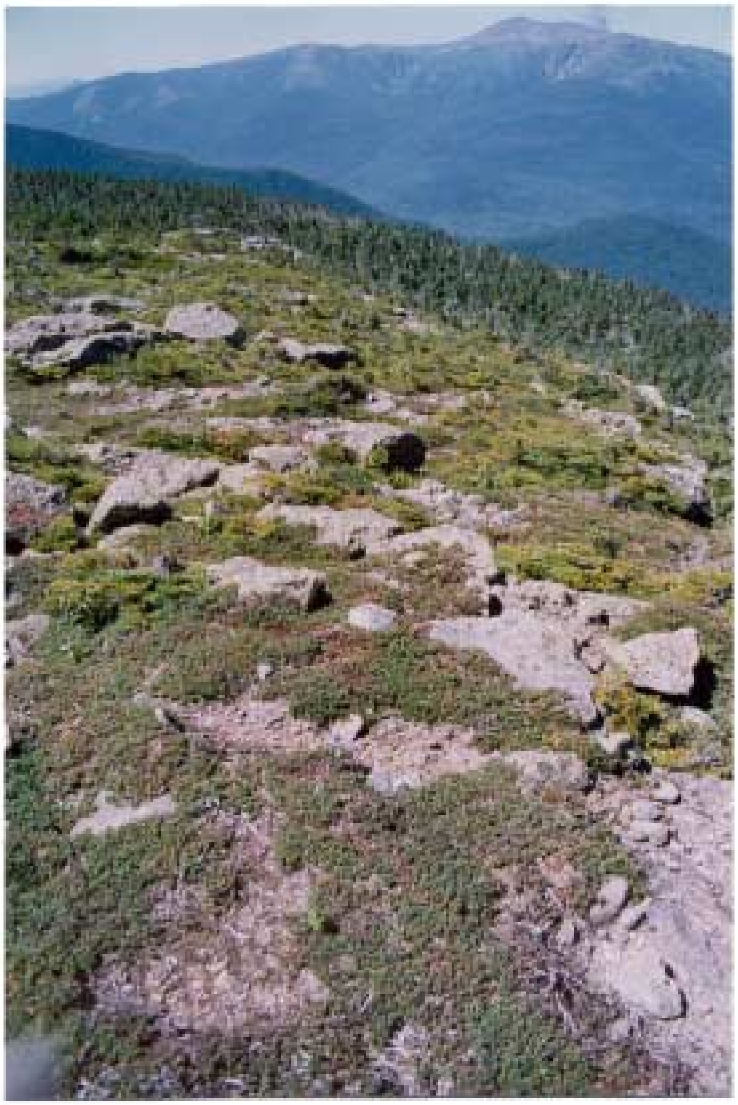
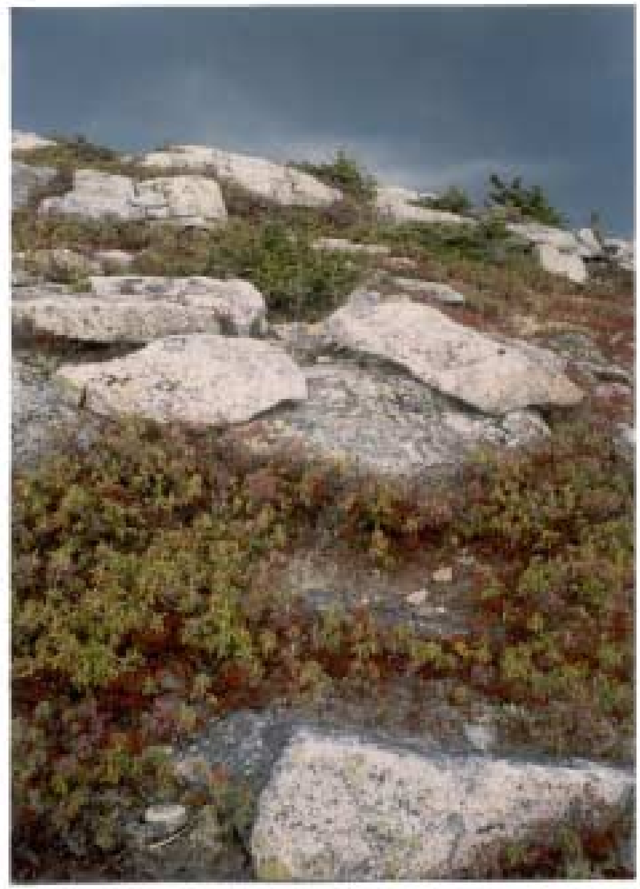


Photo 5. Sedge-rush-heath meadow near Boot Spur.





Photos 6 & 7. Heath/Krummholz.
The left photo shows Labrador tea heath/krummholz on Mt. Hight. Note the patchy mosaic of *Vaccinium uliginosum* and other dwarf shrubs (foreground) mixing with low krummholz and rocks (background).
The right photo shows a Sheep laurel-Labrador tea heath/krummholz on the summit ridge of South Baldface. This particular example lacks *Ledum groenlandicum*. *Kalmia angustifolia* is green, *Rhododendron canadense* is pink, and *Vaccinium* species are darker red.
Additional heath/krummholz photos appear in Appendix 7.

4. **Heath/Krummholz**: Bilberry and cranberry heaths are joined by various mixtures of *Ledum groenlandicum*, *Kalmia angustifolia*, and blueberries without higher elevation alpine species such as *Carex bigelowii, Juncus trifidus, Diapensia lapponica, Rhododendron lapponicum,* and *Loiseleuria procumbens*. The lichens *Cladina rangiferina*, *Cetraria islandica*, and *Cladina alpestris* are common and often abundant. Both types occur as nearly pure dwarf shrublands (<10-15 cm tall) to mixtures with up to 60% krummholz (<1.5-2 meters tall trees), and are generally found on peaks lower than the climatic treeline at 4900'. Continuous krummholz is also common and may form from various combinations of *Picea mariana* (black spruce), *Picea rubens* (red spruce), *Abies balsamea* (balsam fir), and *Betula papyrifera* var. *cordifolia* (heartleaf birch).

   a. Labrador tea heath/krummholz: Found between 3500-4900' elevation where *Kalmia angustifolia*, *Rhododendron canadense* (rhodora), and *Nemopanthos mucronatus* (mountain holly) are usually absent. *Abies balsamea* and *Betula papyrifera* var. *cordifolia* krummholz are common, with *Picea rubens* occasional at the lower end and *Picea mariana* at the higher end of the elevation range. *Empetrum atropurpureum* (more common than *E. nigrum*), *Vaccinium uliginosum*, *Vaccinium vitis-idaea*, and occasionally *Vaccinium boreale* are among the dwarf shrubs. 3500-4900'

   b. Sheep laurel-Labrador tea heath/krummholz: Found on peaks and ridges between 3000-3500' (3700'), and characterized by a mix of *Kalmia angustifolia* and *Ledum groenlandicum*. Heart-leaf birch and balsam fir krummholz are frequent or abundant, and *Picea rubens* is more common than *P. mariana*. *Rhododendron canadense* and *Nemopanthos mucronatus* are occasional. *Vaccinium angustifolium* (early low blueberry) is more common than at higher elevations. 3000-3500' (3700')

Photo 8. Heath/Krummholz.
Labrador tea heath/krummholz on West Peak, Bigelow Range (ME). *Ledum groenlandicum* in flower.

Photos 9 & 10. Subalpine bogs and subalpine heath snowbanks.
The top photo shows a wet alpine/subalpine level and sloping bog on Mt. Success. The sloping bog includes *Eriophorum vaginatum, Trichophorum cespitosum,* Sphagnum, and *Rubus chamaemorus*.
The bottom photo shows a subalpine heath snowbank/sloping bog on the steep lee slope of Mt. Hight's summit. The wetland has moderate to deep heath on peat soil with an understory of Sphagnum moss.
Additional subalpine bogs and subalpine heath snowbank photos appear in Appendix 7.

5. **Subalpine bogs and subalpine heath snowbanks**: Sloping and level peatlands occur in concavities on ridges, and on slopes where some combination of limited drainage, the "fog-belt" subalpine climate, late melting snowpacks, and/or self-maintaining *Sphagnum* mats contributes to peat accumulation. These peatlands are dominated primarily by lowland bog plants, but are usually accompanied by subalpine plants. This broad classification would be improved by incorporating bryophyte composition. 2900-4900'

   a. Wet alpine/subalpine level and sloping bog: Mostly level to slightly sloping peatlands generally above 3500' are dominated by *Sphagnum* mosses (including *S. capillifolium*, *S. fuscum*, *S. rubellum, S. russowii, S. lescurii*), and are differentiated from lowland peatlands by subalpine plants such as *Empetrum nigrum*, *Vaccinium uliginosum*, and *Rubus chamaemorus*. This type is wetter (more permanently saturated) than the next type, as indicated by such plants as *Vaccinium oxycoccos* (small cranberry), *Eriophorum vaginatum* (cotton grass), and various other wetland obligate species, and by the absence of *Cetraria islandica* and other lichens. *Sphagnum* is a constant.

   b. Subalpine wooded heath snowbank, slope bog, and bog margin: Shallow to moderately deep peat layers (25-80+ cm) are found where deeper snows accumulate (e.g. on lee slopes of peaks or near krummholz margins), on drier borders of bogs, and on other moist slopes where *Sphagnum* maintains growth and peat accumulates. Higher cover of krummholz (mostly *Picea mariana* and *Abies balsamea*), abundant lichens including *Cetraria islandica* and *Cladina rangiferina*, and an absence of such wet site species as *Vaccinium oxycoccos* and *Eriophorum vaginatum* are characteristic; *Ledum groenlandicum* and *Kalmia angustifolia* are common. The moderately deep peat layer, abundance of *Picea mariana*, and presence of either *Sphagnum*, *Chamaedaphne calyculata* (leatherleaf), and/or *Rubus chamaemorus* differentiates this type from sheep laurel-Labrador tea heath/krummholz.

   c. Sliding fen: Shallow peat bogs on 5-30^{o} slopes on brow of alpine or subalpine cliffs are rare in the White Mountains. *Calamagrostis pickeringii* (Pickering's reed bent-grass), *Sphagnum compactum* and other bog plants are found in these peatlands. Elsewhere in the region sliding fens presumably become super-saturated from a major rain event and slides off the cliff before peat build-up resumes (pers. comm., David Hunt 1999).

Photo 11. Sliding fen at the top of Cannon Cliff on Cannon Mtn., with heath shrubs, *Trichophorum cespitosum*, *Calamagrostis pickeringii*, growing on shallow peat soils dominated by an understory of Sphagnum moss.

Photos 12 & 13. Red spruce/heath/cinquefoil rocky ridges and moist montane heath woodlands.
The top photo shows a red spruce/heath/cinquefoil rocky ridge woodland on South Baldface. Note the taller trees and montane shrubs and herbs on shallow dry soils over bedrock (*Nemopanthos mucronatus* in right foreground, *Danthonia compressa* (tufted oat-grass) clumps in center).
The bottom photo shows a montane heath woodland on a flat ridge on Zealand Mtn. Note the taller trees, montane shrubs (such as *Kalmia angustifolia* in flower) on shallow peat soils over bedrock. Alpine species are absent.

The following communities are present in the data set but are not true alpine or subalpine communities. They are transitional to subalpine heath/krummholz, and are referenced here to distinguish them from the higher counterparts described above.

6. **Red spruce/heath/cinquefoil rocky ridges and moist montane heath woodlands**: These montane communities are technically not alpine or subalpine because of the absence of common subalpine species such as *Vaccinium uliginosum* and *Cetraria islandica*. See Sperduto (1997) for more detailed descriptions.

    a. <u>Red spruce/heath/cinquefoil rocky ridge woodland</u>: This community is found on dry to dry-mesic open and woodland ridgelines below 3000' with *Picea rubens*, lowland heath shrubs and herbs, and *Potentilla tridentata* on open ledgey areas. Jack pine rocky ridge woodlands are floristically similar. 1700-3000'.

    b. <u>Montane heath woodland</u>: This community is found on mesic to wet-mesic sites with shallow peat soils on flat ridges and slopes near the transition to heath/krummholz or boggy areas at other scattered locations in the White Mountains (e.g. Zealand Ridge), especially the slopes of the upper East Branch of the Pemigewasset River watershed (i.e. Shoal and Ethan Pond area, North Bald Cap area). It is essentially similar to subalpine heath snowbanks without the subalpine species, has a taller woodland structure (25-60% cover, >2 m tall), and a robust (40-150 cm tall) shrub layer. It is dominated by a woodland canopy of *Picea mariana* and/or *P. rubens, Abies balsamea*, and a robust (moderate height to tall) heath shrub layer with *Rhododendron canadense*, *Nemopanthos mucronatus*, *Ledum groenlandicum*, *Kalmia angustifolia*, and *Viburnum nudum* var. *cassinoides* (witherod). Shallow peat occurs over bedrock or silty gravel. [2500-4000']

Selected Air-Photo Delineations

Twelve alpine summits in the White Mountains are delineated on air photos in Appendix 3. These peaks were all surveyed within the last five years and represent much of the area of alpine and subalpine vegetation outside the Presidential Range in the White Mountains. Delineations of all of the White Mountain peaks is beyond the scope of this report. These delineations are just one interpretation of the alpine exposures of these peaks. They include all treeless alpine communities and heath/krummholz patches beyond the line of solid, continuous krummholz or balsam fir scrub (> 2 m tall) which is usually distinguishable by shadow/texture differences on aerial photos. Krummholz dominated areas with a distinguishable component of heath or rock intermixing at a fine scale were included in these delineations. Field observations indicate that dwarf heaths are a significant component of these areas, such as on Guyot summit, east edge of Bondcliff, portions of Shelburne-Moriah Mt. and Carter Dome SE ridge. In some cases, krummholz patches of less than approximately 0.25-0.5 acre in size were included in the delineations. A finer-scale approach that delineated smaller minimum polygons or excluded heath/krummholz mixes that lack rock or gravel exposures would produce smaller total areas.

Some talus slopes and other features adjacent to the summits are also delineated, but are not considered a significant element of the alpine or subalpine vegetation (these are indicated in italics in the caption of each photo).

Photos 14,15, & 16. Trampled Vegetation
The top right photo shows the trampled summit of Mt. Liberty (looking north towards Franconia Ridge), the bottom right the trampled summit of Mt. Bond. These areas are so denuded and eroded that restoration is not feasible. The left photo shows how bootleg trail proliferation and trampling can cut through and erode peat veneer soils under Labrador tea

Stewardship Considerations

Human use and impacts vary considerably among peaks. Most retain significant areas of largely natural vegetation but have localized zones of trampled vegetation, soil erosion, and unofficial trail development that degrade the overall condition. A few peaks are trail-less and remain intact, several have trails but very little impact, and several others have been heavily trampled or reduced to gravel or bedrock with little hope of recovery at current recreational levels. The summits of some of these trampled peaks were likely denuded decades ago, and in the case of Mt. Lafayette, by late last century (Cogbill 1994). Fires have certainly modified the extent of total open habitat on some subalpine peaks, although most were likely open prior to European settlement.

While robust in their ability to withstand harsh weather conditions, and resistant or resilient to light foot traffic, many alpine and subalpine plants are not well adapted to the heavy recreational traffic they receive. Sedge meadows are probably the most resistant to trampling, whereas dwarf heath shrubs and certain forbs are among the more susceptible plants. The organic veneer soils that support many alpine associations are readily eroded down to their gravel or rock base under heavy traffic and without adequate time to revegetate. Sparse dwarf shrubs typical of exposed and naturally unstable habitats (e.g. frost-churned gravel) are also easily reduced to their gravel bases. A detailed reconstruction of the history of human use on Franconia Ridge and case studies of rehabilitation attempts is instructive (Cogbill 1994).

Mountain stewards have employed numerous techniques to protect alpine areas in the northeastern United States. At many alpine and subalpine White Mountain summits, the condition of the vegetation is neither intractably degraded nor permanently stable (given current recreational use). Some combination of stewardship tools will need to be employed to ensure that the existing natural vegetation is retained or stabilized or, in certain areas, to rehabilitate denuded areas. One of the key tools is encouraging hikers to remain on trails or unvegetated areas. Effective stewardship actions must begin with a broader recognition of vulnerable alpine and subalpine vegetation on peaks and ledges beyond the Presidential Range and Franconia Ridge.

The best combination of tools for alpine stewardship is certainly debatable. However, the following approaches are appropriate and, in some cases, critical to maintaining or improving the current condition of alpine vegetation.

1. Ongoing trail maintenance (including tread way definition/trail design, erosion control, selective use of scree-walls, deterrents against off-trail travel, and discouragement of bootleg trail development).

2. On site education (such as signs near the krummholz transition zone, selective use of summit stewards, and training of shelter, hut, and trail crews) and off site education (such as trailhead signs, hiker and climber literature and guides, and education programs).

3. Selective rehabilitation using natural revegetation techniques (such as facilitating natural revegetation through traffic control and limited placement of rocks or branches to provide some initial shelter for denuded sites).

Appendix 6 provides observations from the past six years of deleterious impacts to alpine and subalpine natural communities on selected New Hampshire peaks.

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