

**THE ECOLOGY OF SUB-ALPINE PLANT COMMUNITIES
OF THE SUMMITS OF ACADIA NATIONAL PARK**

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INTRODUCTION

In the late 1970's, Dr. William Drury, a noted Mount Desert Island ecologist, was asked by Acadia National Park to assess the varied habitat types found in the park and to develop a list of those of special interest. The combination of a comparatively mild maritime climate moderated by the waters of the Gulf of Maine and rocky substrate accommodates plant species at the northern limits of their range while the "high hills" provide sites where arctic alpine species are found.

Drury (1980) identifies several habitats, which are unique or seldom found in other parts of the United States. Three upland habitats of special interest include 1) the sunny, dry ridges and rocky outcrops which support more southern species such as Pitch Pine, *Pinus rigida*, Bear Oak, *Quercus ilicifolia*, *Corema conradii*, and *Hudsonia tomentosa*; 2) the rocky and well-drained soils where Jack Pine, *Pinus banksiana*, a more northerly species is found; and 3) the shallow mineral soils of the summits where arctic alpine species, *Arenaria groenlandica*, *Hypericum gentianoides*, *Barton virginica*, along with shrub species such as *Juniperus communis*, *Kalmia augustifolia*, and *Pyrus melanocarpa* are all found. These krummholz-meadow heath communities are found on the low mountain summits of Acadia National Park.

By the mid-1990's, Acadia National Park documents its concern that visitor use of some summit areas may be adversely affecting the flora which includes sub-alpine and alpine species rare in Maine or rare in the Park (Acadia National Park Natural Resource Management Plan, 1990).

Recreational use of alpine and sub-alpine mountain areas increased dramatically in the 1970's in New York, Vermont, New Hampshire, and Maine (Doucette and Kimball, 1990). In many areas hikers using recreational trails often wander off them, trampling vegetation and causing extensive erosion (Synder, 1974; Willard and Marr, 1970). Many alpine and sub-alpine plants cannot withstand extensive trampling and for this reason summit plant communities have been degraded (Doucette and Kimball, 1990). Visitor impact has altered species composition within plant communities (Streeter, 1971) on summits throughout New England (Johnson, pers. comm.). Conversely, a 24-year comparison of vegetation in a permanent plot receiving no visitor impact on an Adirondack mountain summit showed that species composition did not change significantly (Ketchledge and Leonard, 1984).

Table 1 lists summit species rare or uncommon in Acadia National Park, including all state listed species. On Cadillac Summit, for example, one of the most visited sites in the Park, visitors often stray from the concrete path around the summit and roam freely across the summit. Visitors have also created "social" trails by building cairns around many of the summits. This is especially apparent on Penobscot and Sargent mountains where many visitors leave park-designated trails to follow social trails, trampling vegetation and hastening erosion.

In 1993 the National Park Services undertakes studies to gain a better understanding of these special communities, implement quantitative long-term monitoring, and identify any potential factor that may be adversely affecting them. The objectives of this study are to: 1) characterize summit vegetation in terms of community associations and map distribution of these

TABLE 1. PLANT SPECIES FOUND ON SUMMITS THAT ARE RARE OR UNCOMMON IN ACADIA NATIONAL PARK

This list includes state listed species and species that are not significantly rare at state or federal levels but that were identified as rare by Rand and Redfield (1894), overlooked by them and reported by Stebbins (1929), or shown by Greene (1990) to be less common than previously believed.

<u>SPECIES</u>	<u>STATE/LOCAL STATUS</u>
1. <i>Amelanchier bartramiana</i>	Locally Rare
2. <i>Bartonia virginica</i>	Locally Rare
3. <i>Calamagrostis stricta</i> subsp. <i>inexpansa</i>	Threatened NEPCoP 2 - Regionally Rare
4. <i>Carex buxbaumii</i>	Locally Rare
5. <i>Carex houghtonii</i>	Locally Rare
6. <i>Corema conradii</i>	Watch List
7. <i>Huperzia appalachiana</i> (formerly <i>Lycopodium selago</i>)	NEPCoP - Indeterminant
8. <i>Juncus secundus</i>	Locally Rare
9. <i>Lycopodium selago</i>	Special Concern
10. <i>Minuartia groenlandica</i>	Watch List
11. <i>Minuartia glabra</i>	NEPCoP 2(a) - Regionally Rare
12. <i>Prunus depressa</i>	Locally Rare
13. <i>Quercus ilicifolia</i>	Locally Rare
14. <i>Selaginella rupestris</i>	Locally Rare
15. <i>Vaccinium boreale</i>	NEPCoP 1 - Globally Rare

communities; 2) generally assesses levels of visitor use and apparent vegetation effects from this use; and 3) recommends appropriate mitigation actions for heavily affected areas.

BACKGROUND

The flora of mountain summits in Acadia National Park is mostly known, although most work focuses on documenting presence of individual species (Greene, 1990; Feeley and Drury, 1980; Wise, 1970; Rand and Redfield, 1894) rather than characterizing plant communities associated with the summits. Table 2 presents the most current plant species lists for the mountain summits (Gregory 1998).

Two works document plant communities of Mount Desert Island. Moore and Taylor (1927) describe various plant associations in relation to successional stages of plant community development; and Kuchler (1956) presents a map of the southeastern portion of Mount Desert Island from Somes Sound east and from what is now Rt. 233 south at 1:25,000 and records the physiognomy and floristic composition of each plant community present.

Considerable work has been done elsewhere in New England describing plant communities and associated species on mountain summits (Cogbill and Hudson, 1990; Vogelmann et al., 1989; May and Davis, 1978; Bliss, 1963). A landmark work of this type in the northeastern United States is by Bliss (1963), who identifies 9 community types occurring in the Presidential Range Alpine Area of New Hampshire and presents factors contributing to their formation, composition and distribution. These include edaphic factors (e.g., soil depth, moisture and chemistry), climatic factors (e.g., summer humidity, fog, snow depth, and wind speed and direction), and geographic factors (e.g., slope, aspect, elevation)(Bliss, 1963). In addition, anthropogenic factors

such as the impact of recreational use can significantly alter the distribution and composition of these communities (Doucette and Kimball, 1990; Streeter, 1971).

Moore and Taylor (1927) describe the various plant associations on Mount Desert Island, their developmental or successional stages, and related climate and soil factors. Their work contains a vegetation map of the island with 8 types of forest communities, marsh, bog, rock, and burns. Although their work does not specifically describe summits, their list of 13 "pioneer herb and low shrub" species, inhabiting "drier rocky sites" are dominant on the summits today (see Table 3).

May and Davis (1978) essentially use Bliss's community classification to describe alpine tundra communities on 8 mountain summits in Maine. They give brief descriptions of 8 community types and the dominant species in each. Cogbill and Hudson (1990) are the first investigators to use quantitative methods to characterize vegetation above treeline on Mt. Katahdin. They describe five community types: alpine heath, Diapensia, sedge meadow, snowbank, and krummholz, and their typical associated species. Their work revises that of May and Davis (1978).

Mountain summits in Acadia National Park are significantly lower in elevation than those in the aforementioned studies. Nor are the summits of Acadia part of the arctic alpine zone which is found predominately within the Arctic Circle with small pockets of persistent remnant arctic alpine zones found above 18,000 m an examples of which includes the arctic alpine zone atop

Mt. Katahdin within Baxter State Park in the State of Maine. However, the abrupt transition from full-grown dense forest to the open mixed meadow and heath vegetation with exposed, treeless summits with shallow soils where alpine species such as *Lycopodium selago* (alpine clubmoss), *Minuartia groenlandica* (mountain sandwort), *Scirpus cespitosus* var. *callosus* (deer grass), and *Vaccinium vitis-idaea* var. *minus* (mountain cranberry) (Greene, 1990) are found with islands of trees or krummholz or dwarf shrub would warrant labelling the summit zones of Acadia as a part of the “subalpine belt” (Bliss, 1969). Kuchler (1956) classifies many of the mountain summits in this region as sub-alpine.

Table 2. Pioneer Herbs and Low Shrubs on Drier Rocky Sites

Pyrus melanocarpa

Danthonia spicata

Vaccinium angustifolium

Juniperus communis var. *depressa*

Kalmia angustifolia

Actostaphylos uva-ursi

Pteridium aquilina

Dryopteris spinulosa var. *intermedia*

Aralia nudicalis

Hudsonia ericoides (not all sites)

STUDY DESIGN

a. Site Selection

In order to characterize the vegetation community types the 30 summits over 300 feet in elevation on Mount Desert Island were evaluated for selection as study sites. Seven of these rise over 1,000 feet, and all of these except Bernard mountain have treeless, exposed bedrock summits which support rare plants (see Table 4). There are 2 summits over 300 feet in elevation within Park boundaries on Isle au Haut, one has a large amount of exposed bedrock and supports several rare plant species. The one summit on Schoodic Peninsula is primarily Jack pine (Pinus banksiana) forest. Three summits on Mt. Desert Island and one on Isle au Haut were selected (Table 4).

Information on plant species, densities, soil depth, soil type and estimated level of visitor impact (light, moderate, heavy) were collected on the three selected summits.

b. Species Lists and Preliminary Distribution Maps

Vegetation communities on each of the summits listed in Table 4 are characterized and described and a list of all vascular plant species found above the 300 m (1000 ft.) contour line for the 3

Table 3. Mountain Summits in Acadia National Park in Study

Mt. Desert Island

- Cadillac Mt. (466.34 m/1540 ft.) Figure 1
- Pemetic Mt. (391.36 m/1284 ft.) Figure 2
- Sargent Mt. (418.49 m/1373 ft.) Figure 3

Isle au Haut

- Duck Harbor Mt. (91.44 m/300 ft.) Figure 4

Mount Desert summits and 75 m (229 ft.) for Isle au Haut are compiled. Preliminary distribution maps of plant communities are indicated on vegetation maps created from infra-red aerial photos (1979) as a base to ground truth. These were then be overlaid onto a Landsat image and compared to field observations and transect data.

c. Belt Transects

Four line transects were established on each of: Cadillac, Sargent, and Pemetic summits to determine distribution and composition of plant communities, factors which influence their distribution and evaluate where visitor impact occurs. Transects, permanently marked for relocation (marked by drilling a small plug in the rock and painting it), are run from the summit (highest elevation or a permanently marked point nearby) north, south, east and west (true direction) and end either at the 300 m contour or 20 m into treeline (forest vegetation but not a forest pocket). Transects generally divide summits into quarters (see Appendix 1). Species present, cover class (including extent of bare rock and gravel), soil depth and type are measured within each m^2 every fifth meter starting at m 0 along the right side as you look down the transect from the summit a distance of 500m. Presence of a park-designated trail within each m^2 are noted as well as the level of visitor impact defined as none, light or heavy (see sample data sheet Appendix 2). From the 500m mark to the 300m contour line the same measurements are taken every 25th meter. Lastly, photographs were be taken from the 4 principal compass bearings, looking from higher elevation to lower elevation along the transect line.

d. Long-Term Monitoring Plots

A pair of 10 x 10 m plots, permanently marked for relocation, have been established in each identified major community type on each of the three summits to monitor visitor impact and long-term change in an intensive manner. Each pair of plots is positioned away from the line transects, one straddling an existing park-designated trail, the second, a control plot positioned at approximately the same elevation and aspect, but without signs of visitor use. Location of each plot is mapped and photographed. Both natural and anthropogenic data have been collected within 9 m² plots within the 10 meter plots. Natural factors include: species, and maximum height of woody vegetation; edaphic factors include: soil depth and type; and climatic factors include: presence of ice, snow depth and date of snow melt. Anthropogenic factors measured will include: visitor impact, and changes within the plot. Two meter quadrats within each 10 x 10 meter plot will be mapped and photographed. Meteorological data from Cadillac summit will supplement climatic data collected within the permanent plots.

e. Assessing Visitor Use

We will assess the level of visitor use on Cadillac, Pemetic and Sargent summits. The number of visitors to these summits will be estimated using electric eye counters strategically placed on trails leading to the summits. See figure 4. Cadillac summit is the only summit that can be accessed by car; traffic counts will be taken and included in our study. In addition, Park

personnel stationed on the summits will note how visitors use their time while on the summits on one sunny day and one foggy day in June, July, August, and September.

f. Data Analysis

The plant species transect data were used to identify plant community associations. TWINSpan (Two Way Indicator Species Analysis) an algorithm developed by Hill (1979) produces an incidence matrix from which a Braun-Blanquet phytosociological table is derived. It is a polythetic (multi-species), hierarchical, and divisive approach to community classification.

GEOGRAPHIC INFORMATION SYSTEM MAPPING

The Park's geographic information system (GIS) which uses an ARC/INFO digital format have been used to define and map summit areas and associated plant communities and species present.

A vegetation map derived from color infra-red aerial photos (1979) are a part of the GIS database. These data will be ground-truthed and related to plant communities present on the summits from transect and permanent plot data. Transects and permanent plot locations will be entered into the GIS. Field data will be stored in a d-Base format which can interface with ARC-INFO.

RESULTS

1. Cadillac Mountain Summit

The flora of Cadillac Mountain summit is the most diverse of all the summits. Eighty-eight individual species were observed in plot and transects with over 200 species observed on Cadillac. Plant species, percent cover, soil depth, soil type, and an estimate of visitor use impacts were recorded in a total of 122 individual meter square plots. Clustering along intervals was apparently unrelated to spatial location along the transects.

The immediate summit of Cadillac is primarily a developed zone with a parking lot and visitor service areas. The south-facing slopes are heavily wooded where a deep organic mineral soil has developed. Here a Spruce-Fir forest community dominates. Collection of data on Cadillac was limited to the subalpine zone on the north-facing slopes.

TWINSpan analysis identified four major clusterings on Cadillac Mountain summit. The clusterings indicated by this computer analysis confirms what is easily recognizable on summits. The krummholz-meadow heath communities of Cadillac are broken down into four distinct plant community types. Although the numbers of species found on Cadillac are numerous the community clusterings found on both Sargent and Pemetic were found to be nearly identical.

On the very summit bare rock supports Yellow-stain Lichen with *Potentilla tridentata* found growing in crevasses where mineral soil has accumulated. Other species found here include *Danthonia spicata*, *Vaccinium vitis-idaea*, and *Carex communis*. As transects descend from the summit away from the most heavily visitor use areas of the summit, heath species dominated communities arise sporadically where pockets of mineral and some organic soil is present. A heath meadow community dominated by *Deschampsia flex*, *Carex communis*, *Danthonia spicata*, *Solidago randii*, and Moss sp. Other pockets of vegetation encountered are composed of a woody scrub community with other woody Ericaceae species present. Those on Cadillac are dominated by *Kalmia angustifolium*, *Vaccinium angustifolium*, *Pyrus melanocarpa*, *Prunus virginiana*.

A fourth community is a Birch Forest Community dominated by dwarfed birch, *Betula populifolia*, often associated with individual conifers, *Abies balsamea*, *Picea rubens*, or even *Pinus strobus*. Other species found in the Birch Forest Community are *Alnus crispa*, *Aster acuminatus*, *Aster umbellatus*, and *Trientalis borealis*.

2. Sargent Mountain Summit

The plant species diversity was very high on Sargent with 97 species or categories found within 193 individual meter square plots. Clustering along intervals was apparently unrelated to spatial location along the transects.

TWINSPAN analysis identified three major clusterings on Sargent Mountain. These include: 1) a community category which we call a bare rock community comprised almost solely of *Potentilla tridentata* growing on shallow mineral soils which accumulates in crevices formed by frost heaving. This community dominates closest to the very top of the summits. 2) A heath community comprised by *Potentilla tridentata*, *Vaccinium vitis-idaea*, *Scirpus cespitosus*, *Deschampsia flexuosa*, *Carex communis*, *Kalmia angustifolia*, *Vaccinium angustifolium*, and *Pyrus melanocarpa* is the dominant plant community on this summit. Shrub communities comprised of *Kalmia angustifolia*, *Vaccinium vitis-idaea*, and *Pyrus melanocarpa* exist but are found infrequently. Similarly small forested communities are found infrequently. However, unlike other summits a Oak-Alder Forest Communities are found in addition to the more Birch dominated communities.

3. Pemetic Mt. Summit

The flora of Pemetic Mountain is the least diverse of all the summits. Only 94 individual species were found within transects. Plant species, plant cover, soil depth, soil type, and an estimate of visitor use impacts were recorded in a total of 101 individual meter square plots. Clustering along intervals was apparently unrelated to spatial location along the transects.

TWINSPAN analysis identified four major clusterings on Pemetic Mountain. Similar to Sargent and Cadillac, the immediate summit is primarily dominated by lichen cover rocks with *Potentilla tridentata* found growing in crevasses where mineral soil has accumulated. Other species found

here include *Danthonia spicata*, *Vaccinium vitis-idaea*, and *Carex communis*. A heath community dominated by *Gaylussacia baccata*, *Potentilla tridentata*, *Vaccinium vitis idea*, *Deschampsia flex*, *Carex communis*, *Vaccinium angustifolium*, and *Danthonia spicata*.

A third clustering a woody scrub dominated by *Kalmia angustifolia*, *Vaccinium angustifolia*, *Pyrus melanocarpa*, *Aster acumonatus*, and *Nemopanthus mucronata*. The fourth community, Birch Forest Community, is dominated by *Betula populifolia*, *Maianthemum canadense* with *Abies balsamea*, *Acer rubrum*, *Betula papyrifera*, *Picea rubens*, and other species. Again as similar to Cadillac and Sargent Mts., these sculpted, espaliered, krummolz type of forest communities will support more forest species where enough organic and mineral soil can support the establishment of these species.

4. Duck Harbor Mt. Summit

Visitor Use Patterns

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Appendix 5. Plant Species Found in Transects and Plots By Community Type

Cadillac Mt. Summit

Barren Rock/Gravel Community

Juniperus communis
Potentilla tridentata
Prenanthes trifoliata
Bare soil

Scrub Community

Kalmia angustifolia
Vaccinium angustifolia
Pyrus melanocarpa
Prunus virginiana

Heath Community

Carex communis
Danthonia spicata
Deschamsia flexuosa
Moss sp
Solidago randii

Birch Forest Community

Betula populifolia
Mianthemum canadense
Abies balsamea
Aster acuminatus
Aster marophyllus
Aster novi-belgii
Aster umbellatus
Empetrum nigrum
Fragaria virginiana
Nemopanthus mucronata
Pinus strobus
Potentilla simplex
Rhinanthus crista-galli

Rosa virginiana
Spirea latifolia
Trientalis borealis

Other Species present:

Achillea millefolium
Agrostis alba
Agrostis scabra
Amelanchier sp.
Aralia nudicaulis
Arctostaphylos uva-ursi
Aster nemoralis
Cornus canadensis
Derrilla locicera
Euphrasia randii
Festuca capillata
Festuca rubra
Gaylussacia baccata
Hudsonia ericoides
Hypericum gentianoides
Juncus bufonius
Lycopodium obscurum
Lysimachia quadrifolia
Minuartia groenlandica
Oryzopsis canadensis
Panicum depauperatum
Picea rubens
Pteridium aquilinum
Quercus rubra
Rhododendron canadense
Rubus allegheniensis
Scirpus cespitosus
Taraxacum officinale
Trifolium repens
Vaccinium vitis-idaea
Viburnum cassinoides

Sargent Mt. Summit

Barren Rock Community

Bare soil
Potentilla tridentata

Scrub Community

Kalmia angustifolia
Vaccinium angustifolia
Pyrus melanocarpa
Bog mat
Carex communis

Heath Community

Agrostis scabra
Carex communis
Cladonia sp.
Danthonia spicata
Deschamsia flexuosa
Hypericum gentianoides
Moss sp.
Potentilla tridentata
Prenanthes trifolia
Scirpus cespitosus
Solidago randii
Vaccinium vitis-idaea

Birch Forest Community

Aster acuminatus
Aster umbellatus
Betula papyrifera
Betula populifolia
Carex debilis
Nemopanthus mucronata
Picea rubens
Pyrus americana
Rubus allegheniensis
Spiraea latifolia
Viburnum cassinoides

Species associated w/Birch:

Agrostis scabra
Aralia nudicalis
Carex paupercula
Cornus Canadensis
Eriophorum
Hypericum gentianoides
Kalmia angustifolium
Lycopodium obscurum
Lysimachia quadrifolia
Moss sp.
Potentilla tridentata
Rhododendron canadense
Trientalis borealis

Oak-Alder Forest Community

Acer rubrum
Alnus crispa
Brachyelystrum erectum
Calamagrostis canadensis
Diervilla lonicera
Gaylussaccia baccata
Ilex verticillata
Oryzopsis canadensis
Prunus virginiana
Pteridium aquilium

Other species present:

Abies balsamea
Amelanchier sp.
Bartonia virginica
Coptis groenlandica
Juncus bufonius
Juniperus communis
Lilium philadelphicum
Lycopodium clavatum
Lycopodium selago
Minuartia groenlandica
Rosa virginiana

Thuja occidentalis

Pemetic Mt. Summit

Barren Rock Community

Moss Sp.
Potentilla tridentata
Vaccinium vitis-ideae

Scrub Community

Kalmia angustifolia
Vaccinium angustifolia
Pyrus melanocarpa
Aster acuminatus
Nemopanthus mucronata

Heath Community

Carex communis
Danthonia spicata
Deschamsia flexuosa
Gaylussaccia baccata
Juniperus communis
Moss sp
Potentilla tridentata
Thuja occidentalis
Vaccinium vitis-idaea

Birch Forest Community

Abies balsamea
Acer rubrum
Alnus crispa
Amelanchier spp.
Alnus crispa
Betula papyrifera
Betula populifolia
Clintonia borealis
Cornus canadensis
Lycopodium Complanatum
Lycopodium obscurum

Mianthemum canadense
Picea rubens
Pinus strobus
Prunus virginiana
Pteridium aquilinum
Rhododendron canadense
Rubus allegheniensis
Viburnum cassinoides

Other species present:

Aster umbellatus
Cladonia sp.
Hypericum gentianoides
Prenanthes trifoliata
Scirpus caspitous
Scirpus cyperinus
Solidago randii
Spirea latifolia
Tridentalis borealis