United States
Department of
Agriculture

Forest Service

Northeastern Forest Experiment Station

Research Paper
NE-553

1985

Rehabilitation of Alpine Vegetation in the Adirondack Mountains of New York State

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Abstract

Alpine communities of dwarf shrub and herbaceous vegetation in the Adirondack Mountains occur on only 20 isolated summits in the high peaks region. These limited communities, composed in part of rare northern species, are in danger of destruction from hiker trampling and subsequent erosion. On the two highest peaks, Mt. Marcy and Mt. Algonquin, much of the alpine communities immediately around the summits have already been lost. Unless corrective measures are taken, the remaining 40 acres of alpine vegetation may in time be lost. This paper describes field experiments in using sod-forming grasses from lower elevations as soil stabilizers, and discusses the effects of fertilizing and transplanting native vegetation as part of an integrated management plan for rehabilitating alpine plant communities in the Adirondacks. Results show that it is possible to stabilize severely degraded alpine communities by seeding exposed humus and detritus with bluegrass (*Poa pratensis* L.) or red fescue (*Festuca rubra* L.) and fertilizing with a complete fertilizer and lime. When the treated areas are protected from further hiker impact, native vegetation returns; first a mat of mosses develops under the grasses, then seedlings or rhizomes of vascular plants slowly invade the site.

Problem

Alpine vegetation on Adirondack summits is fragile because of shallow, nutrient-poor soils, a short growing season, and harsh microclimatic conditions (Kalinowski 1983; Ketchledge 1982; LeBlanc 1981; Cate 1974). The additional stress of trampling by hikers destroys vegetation and leads to erosion of the underlying organic soil mantle. The problem for land managers is to develop techniques to stabilize the eroding surfaces long enough for native plants to return, once human trespass is reduced.

Background

The Adirondack high peaks are formed from domes of anorthosite rock, which is highly resistant to weathering. Twenty peaks extend above timberline and support an alpine zone covering 83 acres; vascular plant communities occupy 41 acres, with 1 acre or more on each of 7 peaks and less than 1 acre on another 13 (DeNunzio 1972). These are local subclimax communities positioned on relatively smooth rock surfaces and exposed to severe climatic stresses. They are found on windswept slopes with insufficient soil depth to support trees. In contrast, the more protected surfaces of rock fissures and depressions support a krummholz community composed of black spruce (*Picea mariana* [Mill.] B.S.P.) and balsam fir (*Abies balsamea* [L.] Mill., dwarfed primarily by desiccating winter winds. In several cases, the krummholz occurs above timberline at elevations similar to or slightly higher than the alpine community on the same peaks, indicating the protective value of the winter snow fields on these summit islands (LeBlanc 1981).

The soil of the alpine plant community is essentially an unconsolidated organic mat overlying a thin layer of mineral grains formed by slow weathering of the parent material. The mat is composed of peat moss of great age, where vascular plants have rooted and now contribute their organic remains. The surface is stabilized by a plant community dominated by alpine bilberry (*Vaccinium uliginosum* L.), deer-grass (*Scirpus caespitosus* L.), black spruce, balsam fir, and lesser amounts of 93 other species of vascular plants (Ketchledge 1984; Ketchledge and Leonard 1982; Phelps 1970). The soil can be described as a Lithic Borofolist (Soil Survey Staff 1975). (See Table 1.)

The typical profile has an Oi layer of partially decomposed sphagnum-woody peat, held together by woody roots and buried stems. This overlies a greasy black humus Oa layer and the thin layer of leached, II C mineral grains just above bedrock. The mineral layer presumably supplies small amounts of most essential nutrients except nitrogen. The pH of the humus layer ranges around 3.8 while the bedrock is slightly acid to near neutral. The peat, lacking woody tissue, is highly susceptible to trampling under a range of moisture conditions. When near saturation, which is its moisture condition most of the year, the peat is easily deformed at the surface and crushing of the mat occurs along with mechanical damage to the vegetation. As the peat dries toward the end of summer, or during droughty periods, the peat becomes resilient and somewhat more resistant to crushing and compaction. However, the surface is extremely dry and scuffs easily and may even be blown away by the wind where it is bare of vegetation. The peat may also be dry in winter without snowcover, and is very susceptible to wind erosion. In cold weather, especially in late fall or early spring, only the surface may freeze to a depth of 2 to 3 cm. This

Table 1.—Typical Lithic Borofolist profile description: Mt. Colden

Horizon	Depth (cm)	Description
Oi	0–11	Light brown fibric material, *Sphagnum* spp., roots of grasses and alpine shrubs, 15 percent coarse fragments, pH 3.9
Oa	11–28	Black decomposed sapric material with 10 percent anorthosite grains, fine sand, pH 3.8
II C	28–29.5	Bleached anorthosite fine-to-medium sand grains, with some mixed sapric material, pH 4.0
II R	29.5	Anorthosite bedrock, coarsely jointed and impermeable

Range in characteristics: The observed soils may be as shallow as 9 cm, with each horizon reduced in thickness proportionately, and with less obvious development of the II C, which may be no more than a thin layer several grains in thickness. As the profile thickens, such as in fissures or bedrock depressions, the Oa thickens at a greater proportion than the other horizons. One profile had a thickness of 38 cm, and a clearly developed Oa horizon, absent in the shallower profiles. The Oa horizons appear to be near field capacity when observed in the spring and fall; whereas the Oi may become quite dry in late summer, during winter when bare, or during periods of low rainfall. During heavy rains, water may be observed seeping from the lithic contact surface where a profile has been transversed by a hiking trail, or eroded away.

crust collapses under foot traffic, shearing the frozen peat and any vegetative roots contained in it. Subsequent drying allows the sheared edge to collapse, increasing its susceptibility to wind erosion. Hence, peat is a poor traffic surface in almost any condition.

Unlike alpine meadows elsewhere in the northeastern United States, these communities contain few sod-forming graminoids. The three most abundant native grasses, boreal bentgrass (*Agrostis borealis* Hartm.), sweetgrass (*Hierocloe alpina* [Sw.] R&S), and alpine cottongrass (*Eriophorum alpinum* L.), are occasionally found on deeper soils but are all clump species and do not spread laterally to bind the soil matrix. Only deer-grass (*Scirpus caespitosus* L.) and, to a lesser extent, Bigelow's sedge (*Carex bigelowii* Torr.) appear highly resistant to trampling by recreationists; indeed, these graminoids typically constitute the last surviving cover of vascular plants where human impact is the greatest.

Once the plant cover is damaged by trampling, wind appears to be the major destructive factor, killing stems and roots by desiccation and drying and eroding the peat and humus surfaces. Trails quickly wear through the mat to bedrock. Thereafter, lateral undercutting by wind and water expands the areas of destruction so that larger segments are dislodged. It is easy to see the greatly accelerated damage to these high peaks communities: the large bleached areas of recently exposed rock surfaces contrast markedly with the darker, lichen-covered surfaces that have been exposed for longer periods. Destruction of the plant-soil mat leaves a serviceable, indestructible rock surface for general recreation purposes, but also creates less pleasant pockets of muck in depressions downslope. However, the primary resource problem is loss of the rare and delicate plant species found nowhere else in the State of New York.

Trails through the alpine zone are affected mainly by water and traffic erosion. Gullies cut through the deeper soil to bedrock and make trails wet and mucky throughout most of the hiking season. Damage to krummholz and meadow can be ameliorated by careful trail location and diversion of water from trails whenever possible. Similar problems on lower slopes are discussed elsewhere by Ketchledge and Leonard (1970) and Ketchledge (1971; 1974). Preserving alpine flora is more complex. Stabilizing degraded soils is an integral part of the solution, and establishing sod-forming grasses from lower elevations may be a useful management tool.

Methods

Initial Work

Mt. Dix, elevation 4,857 feet, has a narrow strip of alpine vegetation which has been seriously affected by the main trail over the summit. Efforts to rehabilitate this site began in 1967. First, clumps of native *Agrostis borealis* were transplanted to eroded peat areas and fertilized, but did very poorly. Small test plots of a standard lawn grass seed mixture with fertilizer were more successful. Further tests of grass seed and fertilizer were carried out over the following 2 years with promising results. The extreme acidity of the soil indicated that liming might be beneficial. Quicklime (hydrated lime) gave negative results, possibly because it was caustic to the plants or disrupted the Ca/Mg balance in plant nutrition. All further tests used Mg-containing (dolomitic) agricultural ground limestone. These initial results suggested that grass species from lower elevations, supplemented with fertilizer and lime, would help to stabilize eroding areas and protect the native alpine community from further deterioration.

Refinement of Techniques

To refine this technique, test plots of various grass species and fertilizer combinations were established in June 1971. Mt. Colden, elevation 4,714 feet, with 0.6 acres of alpine meadow, was selected as the test area. Its summit vegetation had been seriously degraded by summit-lounging and camping as well as by multiple trails.

Fertilizer Tests

A 1/40-acre area was seeded to a mixture of 2 lb red fescue, 1 lb Kentucky bluegrass, and ½ lb redtop (*Agrostis alba* L.) (approximately equal numbers of seeds from each species) and different combinations of fertilizer were applied. Results are summarized in Table 2.

Table 2.—Effects of fertilizer treatments on grass establishment: Mt. Colden, 1971

Treatment with grass seeding in June	Elemental rate lb per acre	Grass establishment by September
Superphosphate	104 lb P	Failure
with lime	a	Poor
Superphosphate and Urea	104 P 150 N	Satisfactory
with lime	a	Good
Superphosphate Ammonium nitrate	104 P 110 N	Satisfactory
with lime	a	Good
12-24-12 Fertilizer	120 N 106 P 100 K	Good
with lime	a	Best

[a]Limed at 1000 lb/acre ground dolomitic limestone.

These results indicate that N is more limiting than P, that the source of N is not critical, and that K is beneficial but not critical. Limed areas were more successful than unlimed ones. The modest rate of liming probably affected the pH of the soil surface only, but may have also improved supplies of Ca and Mg as critical nutrient elements.

Grass Species Tests

Test plots of grasses were established on a 1/20-acre area fertilized with 12-24-12, with half of each plot also limed. The species or varieties seeded were common Kentucky bluegrass, common red fescue, "Nugget" Kentucky bluegrass, and "Arctared" red fescue (both Alaskan varieties), "Highland" colonial bentgrass (*Agrostis tenuis* Sibth.) and common redtop. These species have been used successfully in arctic revegetation trials (Johnson and Van Kleve 1976). By the first autumn, the bluegrass and fescue plots were equally successful, with over 50 percent initial cover where limed and 10 percent cover where unlimed. They were generally unsuccessful on exposed peat surfaces which happened to occur mostly on the unlimed area. Both *Agrostis* species showed poorer take and initial growth. The plots were fertilized periodically between 1972 and 1980.

By the end of the second growing season, both bluegrasses and fescues covered well where present, but areas of exposed peat remained unvegetated. Both Alaskan varieties showed slightly slower growth but greener color, suggesting better adaptation to the nutrient status of the site, with "Nugget" bluegrass particularly better adapted than the common variety. Patches of colonial bentgrass did well on more favorable microsites, while the redtop was sparse despite its reputation for tolerance of acidic, poorly-drained conditions. In September 1972, 10 permanent 50-cm-square plots were established throughout the seeded areas on Mt. Colden to monitor vegetation changes in greater detail. From periodic observations through 1980, it appears that the grasses are weakly holding where established; bluegrass in particular is showing some vegetative expansion. However, the area must be refertilized every few years to maintain the grass cover.

The bluegrasses, and to a lesser extent the fescues, were heavily grazed during the second growing season (1979) and thereafter, predominantly by varying hare (*Lepus americanus* Eryleben). However, colonial bentgrass, which has an agricultural reputation for low palatability, was not grazed and consequently reached full development and flowering. Concern that this selectivity might permit the relatively tall bentgrass to spread too aggressively has proven unfounded, as the species has not advanced beyond its initial areas of establishment. Closer examination of the native shrubs showed a history of browsing also. Thus herbivore food habits must be considered a controlling factor in the natural growth of these alpine communities, and may be a selective factor in determining species composition also. The varying hares move from the spruce-fir forest and the krummholz transition zone into the open summit areas to feed during the summer season. Grazing provides regular mowing of the introduced grass, keeping it in scale with the natural dwarf flora and, incidentally, providing a pleasant recreational surface for the human visitors. However, in ecological terms, the attraction of succulent, high-nutrient grass could have other consequences. Either grazing of grass could take pressure off native vegetation as a food source or it could support a larger herbivore population to feed on native flora when the grass is dormant or snow-covered. The impact of herbivores needs further study.

Vegetational Dynamics

Annual monitoring of all test sites reveals three phases in the recovery process of treated areas:

First, it takes three seasons to develop a continuous cover of grasses, because of such environmental hazards as loss of seed from the site by wind removal or bird depredation. If the annual fertilizer and lime treatment is discontinued after the third season, the introduced grasses go into a gradual decline lasting 3 to 6 years, depending upon the intensity of initial treatment.

Second, as the vigor of the grasses declines in succeeding seasons, native vascular plants from healthy nearby stands do not invade the treated sites; rather, the native bryophytes, primarily mosses, become established. Most important, *Pohlia nutans* [Hedw.] Lindb., a common cushion moss throughout the northern forest region, invades the treated sites, and within a few seasons forms a continuous cover wherever the site was previously fertilized. Various other native mosses, liverworts, and lichens, about a dozen species in all, soon invade and dominate the site as the grasses wither away.

Third, few vascular plants appear able to invade the treated sites successfully until the surface is covered by a carpet of mosses. The first vascular plant to pioneer the moss cover is the mountain sandwort *Arenaria groenlandica* [Rets.] Spend., which invades by seedlings; it is followed a season or so later by vegetation spread onto the site by rhizomes of several native plants, particularly Bigelow's sedge and the three-tooth cinquefoil (*Potentilla tridentata* Solender ex Ait.) Within a few seasons, either seedlings or sprouts of numerous alpine natives reappear on the treated sites in low numbers, including both such floristic rarities as the fir clubmoss (*Lycopodium selago* L.) and the vegetatively dominant alpine bilberry.

Although establishment of a moss cover is vigorous and relatively rapid over a 4- or 5-year period, the return of vascular plants is very slow, even on areas that have received additional treatment with lime and fertilizer. Where undisturbed by hiker traffic, the moss carpet appears to thicken at the rate of approximately half an inch a season; by contrast, vascular plants appear at a rate of only one to two seedlings or sprouts per square foot of surface per year. The continuous carpet of moss, if protected from human impact, appears resistent to both water and wind erosion, but the reestablishment of the vascular plant community must be measured in decades rather than years.

Where not protected from hikers, the new moss carpet may be destroyed within a single season, as seen in the main trail over the crest of Mt. Dix where we began our tests in 1967. Recovered vegetation on either side of the trail itself, however, appeared to hold its own. When the moss carpet is broken by hiker impact, it is lifted and destroyed by winds, and site erosion resumes. The mosses therefore appear to be more persistent and better adapted to the natural site conditions of the summits than the planted grasses, but less resistant to hiker impacts. Similarly, on Algonquin Peak, where the main trail has been rerouted onto the rocks, the treated damaged areas have responded vigorously and appear well on the way to recovery as a stable community.

Treatment of Other Summits

From these test plot results, a standard treatment was developed for use on other deteriorating alpine areas on Adirondack summits:

—Kentucky bluegrass (preferably "Nugget"): 1 lb/20 milacres (870 ± sq ft) or bluegrass ½ lb plus red fescue ½ lb/20 milacres
—Fertilizer at 20 lb/20 milacres 12-24-12 or equivalent rate
—Dolomitic (Ca/Mg) agricultural ground limestone 40 lb/20 milacres (1 ton/acre)
—Refertilization on the following year and every few years thereafter

This treatment has been applied annually to eroding alpine areas on five other Adirondack peaks over a 12-year period by volunteers from the Adirondack Mountain Club, the Adirondack Fortysixers, and students from the New York State Ranger School. In general, alpine areas in early stages of damage have been stabilized in a few years of treatments, but areas with more extensive vegetation destruction and erosion have required repeated treatments for several years to stabilize the soil (Ketchledge and Leonard 1971, 1972; Ketchledge 1973a, 1973b, 1975).

Conclusion

Rehabilitation of denuded sites by the use of sod-forming grasses may be a useful initial measure to halt degradation of alpine plant communities in the Adirondacks. However, this method must be combined with user management and education to solve the problems of hiker impact on these inherently fragile areas.

The success of grass establishment depends upon the substrate, as is illustrated by a typical cross-section of the disturbed community (Fig. 1).

Low-elevation, sod-forming grasses are generally effective in covering and stabilizing exposed or accumulated humus along trail edges and other damaged areas. They have not proven as effective in colonizing exposed peat, however; the seedlings apparently are unable to grow vigorously in such a nutrient-poor medium and extreme microclimate. When well established on humus, though, grass provides effective protection along trails and "lounging areas" during the summer and early fall. The introduced grass can be damaged easily in early spring when the soil is waterlogged and grass cover is weakest. The experience of 12 seasons on Algonquin Peak shows that grass may be maintained for several years only if fertilized annually. Without treatment, the grass withers and is soon replaced by a continuous carpet of mosses that is only slowly replaced by native vascular plants. The grass cannot withstand heavy recreational traffic, nor campfires occasionally built by some thoughtless visitors. Accordingly, the restoration of summit vegetation must be viewed as only one step in an integrated summit management program aimed primarily at directing the flow of visitors off the meadows and out onto the resistant rock surfaces. Most important, the trail path itself must be built up with native rocks to provide a stone pathway wherever it is impossible to reroute the trail over the bedrock; this procedure has been most successful on Algonquin Peak where the Conservation Department summer rangers have constructed three such pathways across sections of delicate alpine meadow. Similarly, we have overcome wind erosion on various exposed sites by packing loose rocks on the bare humus banks and then treating the edges with seed, lime, and fertilizer as on flat surfaces of damaged meadow.

Management of hiker traffic, using such methods as rerouting trails over bare rock, marking trails clearly to avoid widespread wandering, and discouraging camping above timberline, is necessary to prevent degradation on any high summit. Education of the hiking public must be a key element in resource management; in general, the public is amenable to restrictions when it understands the reasons behind them. Similarly, updated recreational practices should be stressed; camping stoves, for example, should replace open wood fires.

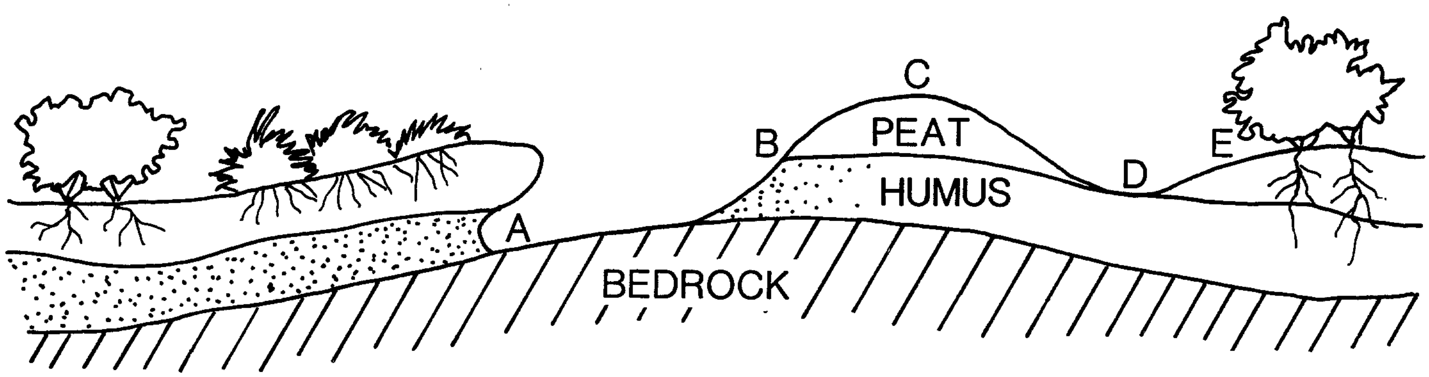

Figure 1.—Typical cross-section of disturbed community.

A. Undercut trail edge: Continuing deterioration of trail edge and adjacent vegetation.
B. Trail edge with exposed humus (Oa): Grass established easily in humus, stabilizes edge and is quite resistant to trampling.
C. Exposed peat (Oi): Grass establishment very slow, requiring repeated treatment. Moss cover more readily established, effective for site protection but vulnerable to hiker damage. Little recovery of severely damaged shrubs.
D. Humus accumulation in hollow: Grass establishment rapid and effective, except in very wet bottom of hollow. Occasional reestablishment of alpine herbs, especially mountain sandwort and three-toothed potentilla.
E. Edge of less-damaged shrubs or krummholz: Grass establishment effectively protects edge from further deterioration. Shrubs may show some growth in response to fertilizer.

In 1980, the Department of Environmental Conservation inaugurated a policy prohibiting overnight camping above 4,000 feet elevation in the Adirondacks, as recommended by recreational leaders (Ketchledge 1977, 1979). New generations of recreationists seeking "pioneering" experiences and lacking ecological sensitivity, however, make continuing educational efforts necessary. Inviting volunteer efforts by hikers to rehabilitate such areas may have positive results beyond the economic and labor savings, by developing their awareness and acceptance of management techniques and the basic problems of human impact on such rare and fragile areas.

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ODC 907.32

Keywords: alpine rehabilitation; fertilization.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1985—505-028/537

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