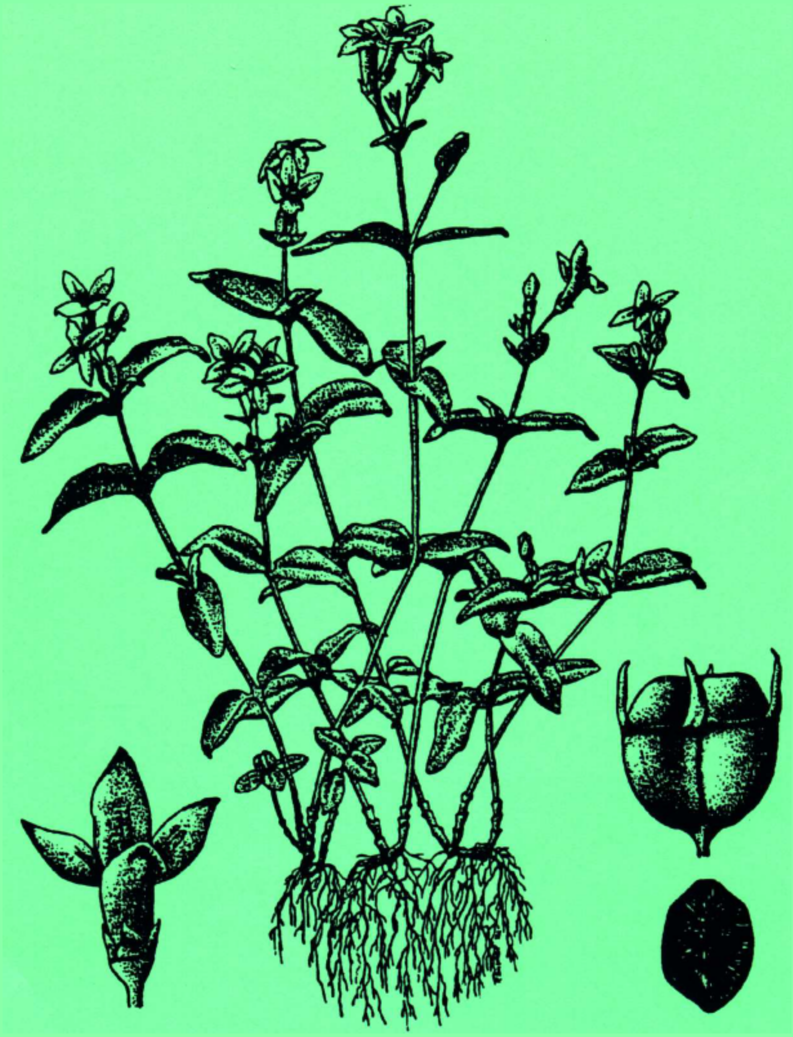
RECOVERY PLAN'

Roan Mountain Bluet

(Hedyotis purpurea var. montana)



U.S. Fish and Wildlife Service
Southeast Region
Atlanta, Georgia

RECOVERY PLAN

for

Roan Mountain Bluet (*Hedyotis purpurea* (L.) Torrey & Gray var. *montana* (Small) Fosberg)

Abstracted from a report by

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for

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U.S. Fish and Wildlife Service
Atlanta, Georgia

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Literature citations should read as follows:

U.S. Fish and Wildlife Service. 1996. Roan Mountain Bluet Recovery Plan. Atlanta, GA. 46 pp.

Acknowledgement:

The cover drawing is a 1992 illustration of the species by P. Savage for the U.S. Fish and Wildlife Service's Asheville, North Carolina Field Office.

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5430 Grosvenor Lane, Suite 110
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Current Species Status: *Hedyotis purpurea* var. *montana* is federally listed as an endangered species. It historically occurred at nine sites but is currently known from only eight sites, all in North Carolina (including one population that formerly extended into Tennessee).

Habitat Requirements and Limiting Factors: This rare herb grows on high-elevation cliffs and rock outcrops in and around grassy balds. It is threatened by recreational activities, recreational and residential development, collection, succession to woody species, and possibly forest decline associated with air pollution and introduced insects.

Recovery Objective: Delisting.

Recovery Criteria: Roan Mountain bluet will be considered for delisting when at least nine self-sustaining populations are protected to such a degree that the species no longer qualifies for protection under the Endangered Species Act.

Actions Needed:

1. Survey suitable habitat for additional populations.
2. Monitor and protect existing populations.
3. Conduct research on the biology and management needs of the species.
4. Establish new populations in former habitat or rehabilitate marginal populations to the point where they are self-sustaining.
5. Conduct necessary management activities at all key sites.
6. Review recovery progress and revise plan as necessary.

Total Estimated Cost of Recovery: Because so little is yet known about actions needed to recover this species, it is impossible to estimate costs beyond the first few years of work (in $000s):

YEAR	NEED 1	NEED 2	NEED 3	NEED 4	NEED 5	TOTAL
FY 1	3.0	6.0	46.0	3.0	10.0	68.0
FY 2	3.0	6.0	43.0	3.0	10.0	65.0
FY 3	3.0	6.0	38.0	3.0	10.0	60.0
TOTAL	9.0	18.0	127.0	9.0	30.0	193.0

Date of Recovery: Ten years from initiation of serious restoration efforts, assuming management access and permission from the several agencies and landowners involved.

TABLE OF CONTENTS

PART I

INTRODUCTION

Background and Description

Roan Mountain bluet (*Hedyotis purpurea* var. *montana*) is a rare, cespitose perennial herb endemic to a few scattered mountaintops north of the Asheville Basin in North Carolina and, formerly, Tennessee. It grows on gravelly talus associated with cliff ledges and exposed slopes and outcroppings on balds. Because of its rarity and vulnerability to threats, Roan Mountain bluet was federally listed as endangered on April 5, 1990 (U.S. Fish and Wildlife Service [Service] 1990). It is also listed as endangered by the State of North Carolina (Weakley 1991) and by the State of Tennessee (Somers 1989). This plan is abstracted from a larger study conducted by Saunders (1993).

Current and Historical Distribution

Within the past few years, Federal and State agencies have documented the existence of eight populations of Roan Mountain bluet, all on mountain peaks in northwestern North Carolina (Ashe, Avery, Watauga, and Mitchell Counties). An additional population was last observed in 1980 (Gaddy 1983) at a site in Yancey County, North Carolina, but the population has not been reconfirmed since then, despite several search efforts, and is now presumed to be extirpated. The cause of this extirpation is not clear but probably reflects a combination of successional change, small population size, and trampling by hikers. The Tennessee portion of the Roan Mountain population also may now be extirpated.

Most of the populations are spread among cliff ledges that are difficult to census without climbing gear. Current estimates of population size are based on crude visual estimates of the numbers of plant clumps found in accessible portions of these populations.

Each of the three largest populations--Grandfather Mountain, Roan Mountain, and Bluff Mountain--reportedly contains 1,000 or more plant clumps. However, these populations are highly fragmented, and individual colonies within each population rarely contain more than 250 clumps. Each of the five smallest populations--Three Top Mountain, Paddy Mountain, Phoenix Mountain, Rich Mountain, and Hanging Rock--probably contains less than 100 plant clumps. Populations have not been counted or mapped until recently; therefore, it is not known if the populations are maintaining themselves.

Description, Ecology and Life History

Roan Mountain bluet is a cespitose perennial herb with erect or ascending, unbranched or weakly terminally branched stems to 21 centimeters (cm) tall from a basal winter rosette. Cauline leaves are opposite, sessile, and typically ovate, 0.8 to 3.0 cm long and 0.6 to 1.3 cm wide. Flowers are reddish purple and funnel-shaped; the corolla has four lobes that are shorter than the 8- to 12-millimeter (mm)-long tube. Like other bluets, this species is heterostylous with two flower morphs. In the pin form, the pistil style is longer than the stamen filaments; whereas, in the thrum form, the style is shorter than the filaments. The inflorescence is few-flowered, consisting of a terminal simple cyme, and sometimes having from one to four lateral simple cymes arising from the uppermost stem nodes. Flowering occurs from late May through August or September, with peak flowering usually in June and July. The mature fruits are subglobose capsules, 2.0 to 4.0 mm long and 2.0 to 4.0 mm wide, semi-inferior and bilocular, with axial placentae bearing as many as 24 ovules. Capsules dehisce along a single apical suture in late August through September (Terrell 1959; Fosberg 1954; Kral 1983; Radford *et al.* 1968; Boyer 1990; B. Saunders, personal observations). This variety is easily distinguished from other bluets by its relatively large reddish purple flowers, relatively small sessile ovate leaves, compact stature and clump-forming growth habit, and its exposed mountaintop habitat.

Roan Mountain bluet is a geographically restricted variety of *Hedyotis purpurea*--a variable species native to the Eastern United States known from New Jersey south to Georgia and west to Illinois, Missouri, and Oklahoma. There is disagreement about the proper taxonomic position of Roan Mountain bluet, although its morphological distinctiveness is undisputed. The first disagreement concerns the proper generic name--*Hedyotis* or *Houstonia*. Early authorities (Small 1933, Gleason and Cronquist 1963) recognized *Houstonia*. Lewis (1961) reorganized part of the Rubiaceae, advocating the merging of New World *Houstonia* with *Oldenlandia* and Old World *Hedyotis* under *Hedyotis*, retaining the original taxa as subgenera. Subsequent studies of karyotypes (Lewis 1962) and pollen and seed characteristics (Lewis 1965, Lewis and Terrell 1962, Terrell *et al.* 1986) have supported and refined Lewis's reorganization. However, Terrell (1975) has argued, from his examination of type specimens, that the new subgenera are sufficiently distinct, based on nontrivial characters, and that they should be elevated to full generic rank, restoring *Houstonia*.

Yelton (1974) argued that Roan Mountain bluet deserves full species rank after failing to obtain viable seeds when he crossed members of the bluet population from Roan Mountain with members of two high-altitude populations of the *purpurea* variety from the same region. Terrell (1978) criticized this study based on the small number of populations involved and the likelihood that the diploid *montana* variety was populations of the more widespread but morphologically similar diploid race (Lewis and Terrell 1962). However, Terrell (1959) earlier observed that localized isolating mechanisms occur frequently throughout the range of *Hedyotis purpurea*, with morphological intermediates being absent from some sites but present at others. In addition, localized morphological isolation is now known from Bluff Mountain, where a population of Roan Mountain bluet grows almost side by side with a *purpurea* variety population (North Carolina Natural Heritage Program 1991). This observation also refutes the suggestion that the *montana* variety is a dwarfed, high-altitude ecotype of *Hedyotis purpurea.*

Terrell (1959) notes three acceptable synonyms for Roan Mountain bluet--*Hedyotis purpurea* (L.) Torrey & Gray var. *montana* (Small) Fosberg (Fosberg 1954), *Houstonia purpurea* L. var. *montana* (Small) Terrell (Terrell 1959), and *Houstonia montana* Small (Small 1933). Recent regional authorities have not reached a decision as to the preferred name. At the generic level, Duncan and Foote (1975) and Gleason and Cronquist (1991) recognize *Hedyotis*, while Radford *et al.* (1968), Wofford (1989), and Weakley (in preparation) recognize *Houstonia.* At the species level, Terrell (1959, 1978) and Radford *et al.* (1968) treat Roan Mountain bluet as a variety, while Wofford (1989) and Weakley (in preparation) treat it as a distinct species, restoring the tradition of Small (1933). The emerging consensus seems to be treatment as a full species, *Houstonia montana.*

Roan Mountain bluet grows on rocky exposures at high elevations of 1,400 to 1,900 meters. Wiser (personal communication, 1993) found that bedrock geology is critical in the distribution of this species. The bedrock of all Roan Mountain bluet sites is mafic (i.e., basic). All the Ashe County sites and the Rich Mountain site are on amphibolite (Ashe formation); the Roan Mountain sites are on magmatic biotite-horneblende gneiss, with metadiabase dikes throughout; the Hanging Rock site is on metabasalt (Montezuma member of the Grandfather Mountain formation); and the Grandfather Mountain sites are on meta-arkose (a felsic rock) in areas where veins of epidote (a mafic mineral) are present. This contrasts with the other high-elevation rocky-summit sites in the Southern Appalachians that are invariably on felsic (i.e., acidic) rock.

The soil substrate is usually metamorphic in origin and is acidic. Traditionally, mafic rock is considered to give rise to soils high in calcium, magnesium, and pH. Wiser (personal communication, 1993) found differences in soils of mafic versus felsic outcrops, but with regard to different nutrients, the soils over mafic rock were higher in boron, phosphorus, and copper and lower in organic matter and sodium. In some situations, soils over mafic rock were high in calcium, magnesium, and pH. Therefore, though mafic rock has the potential to produce outcrop soils that are high in pH and these cations, it does not always happen. Wiser (personal communication,

1993) also noted, in comparing presence versus absence data, that there was a correlation between relatively high levels of boron and iron and the presence on the Roan Mountain bluet.

The plants typically grow in gravel-filled pockets found on north- or northwest-facing cliff-ledges or on talus slopes associated with outcrop exposures on the south or southwest slopes of mountain balds. Winter freezes and thaws can churn gravelly substrates, potentially burying or exposing seeds, dislodging rooted plants, and exposing new substrate for recolonization. During the growing season, these sites are often bathed by water condensing from up-welling air, frequent mountain fogs, passing mid-elevation clouds, or summer thunderstorms. Although outcrop soils are relatively high in organic matter compared to typical mineral soils, they are still shallow. Therefore, once moist conditions pass, the soils drain rapidly and dry out within 2 or 3 days.

Plants growing on most cliff microsites receive direct sunlight for less than half the day. Wiser (personal communication, 1993), in comparing presence versus absence data, found a correlation between relatively low levels of solar radiation and the presence of Roan Mountain bluet (potential solar radiation decreases with an increasing north aspect and slope steepness). Plants growing on the talus slopes of balds potentially receive more hours of direct light, but their lower leaves are often shaded by neighboring forbs. Frequent fog and clouds further reduce the amount of light the plants receive during the growing season. Surface temperatures are moderated throughout the year by winds and the thermal mass of rock outcroppings.

Roan Mountain bluet grows in high-elevation rocky summit plant communities (Schafale and Weakley 1991), though some outcrop sites are found on grassy balds and include representatives of that community as well. Common woody associates include *Rhododendron catawbiense*, *Abies fraseri*, *Picea rubens*, *Menziesia pilosa*, *Sorbus americana*, and *Leiophyllum buxifolium*. Common vascular herbaceous associates include *Saxifraga michauxii*, *Heuchera villosa*, *Campanula divaricata*, *Krigia montana*, *Huperzia* (Lycopodium) *selago*, *Arabis lyrata*, *Sibbaldiopsis* (Potentilla) *tridentata*, *Danthonia compressa*, *Deschampsia flexuosa*, *Solidago glomerata*, *Aster acuminatus*, *Scirpus caespitosus*, *Carex misera*, *Carex brunnescens*, *Paronychia argyrocoma*, and *Sedum telephioides*. Three federally listed rare plant species also frequently occur in the immediate vicinity of Roan Mountain bluet--*Geum radiatum* (endangered), *Solidago spithamaea* (threatened), and *Liatris helleri* (threatened). Wiser (personal communication, 1993) found five species that occurred with Roan Mountain bluet in 75 percent of her study plots (10 m x 10 m)--*Saxifraga michauxii*, *Athyrium filix-femina* ssp. *asplenioides*, *Paronychia argycoma*, *Heuchera villosa*, and *Carex misera*. *Carex misera* was once a candidate for Federal listing but was reclassified after it was found to be more abundant than previously thought. *Athyrium filix-femina* ssp. *asplenioides* was considered the best indicator species, though it was only moderately predictive. *Hedyotis* may require somewhat larger and better-drained gravel-filled pockets than most of the other rare herbaceous species and may be slightly more tolerant of shade and herbaceous competition.

Roan Mountain bluet populations may be better described as metapopulations; each population consists of a series of discrete subpopulations isolated from each other by 100 meters to several kilometers of intervening habitat. It is unknown whether these subpopulations survive indefinitely; each may be threatened either because of natural biological processes, such as successional encroachment by native plants or the local build-up of pathogens or herbivores, or because of vegetational destruction caused by severe weather conditions such as freeze/thaw cycles, downpour-induced landslides, or lightning-ignited fires.

Consequently, the basic criterion for population persistence has two components:

1. Persistence of a local subpopulation requires sufficient reproduction and recruitment to offset plant mortality and to regenerate genetic variation.

2. Persistence of the entire metapopulation might require the colonization and establishment of new subpopulations to replace dying subpopulations and the adaptive genetic variation that they contained.

The first ecological study of Roan Mountain bluet was recently conducted in two local population isolates growing on talus slopes found on the Roan Mountain massif (Saunders, in preparation). Because of time constraints, demographic census plots could not be revisited during the growing season; therefore, no objective mortality or recruitment data is available. Most of the field work focused on the reproductive phases of the life cycle. Basic demographic results are now being analyzed and should be available shortly.

Survey botanists have traditionally counted clumps of Roan Mountain bluet, considering each clump a multi-stemmed individual. However, several observations suggest that a single plant clump may contain many genetic individuals. Both pin and thrum heterostyly forms are found intermingled within plant clumps, suggesting at least two genotypes. Because heterostyly essentially has a simple genetic basis (Solbrig 1966), these flower morphs serve as overt genetic markers to differentiate individuals within a clump. Along with the basal shoot orientation and the tight clustering of rhizome buds and subsequent winter rosettes, these observations suggest that multi-stemmed individuals occupy an area of no more than 5 cm in diameter. This apparent limit on the size of an individual plant is also supported by the rhizome lengths observed in herbarium specimens of Roan Mountain bluet.

The four main flower visitors, listed in decreasing order of probable pollination effectiveness (based on field observations of frequency, pollen loads, and movement distances), were small staphylinid beetles, bumblebees, syrphid flies, and ants. A field experiment showed that hand-pollination, using mixed pollen donors, could not boost the percentage of seeds set above the 50 percent level achieved by natural pollinator activity. The hand-pollination study also provided insight into the breeding system and genetic integrity of the Roan Mountain study population. Plants of both heterostyly morphs did not set seeds when self-pollinated but did set normal levels of seeds when cross-pollinated with pollen from the opposite morph. This suggests that this population of Roan Mountain bluet is self-incompatible, as is expected in a heterostylous breeding system. Moreover, plants that were hand-pollinated, using neighboring pollen donors, set seeds just as well as naturally pollinated plants and just as well as plants that were hand-pollinated using distant, presumably unrelated, pollen donors. Inbreeding depression was not evident in the study population.

Asexual propagation occurs in late summer when Roan Mountain bluets begin to produce basal rosettes from rhizome buds. Field observations revealed some evidence of fungal pathogens and vertebrate grazing in the study population during late summer. Trampling impact by visitors was also evident at another location.

Conclusions based on single-season studies of a subset of stages in the life cycle are necessarily tenuous and difficult to generalize from the medium-sized talus slope study populations to cliff-ledge populations. Nevertheless, recent field experience suggests that talus slope populations of Roan Mountain bluet may be dynamic, with annual fluctuations in the number of stems produced by a single plant and with moderate turnover of plants each year. The species probably relies on both asexual propagation and seedling recruitment to replace shoot losses to disease, herbivores, or gradual overtopping by taller neighboring vegetation. Seedling recruitment probably requires bare soil or a sparsely vegetated substrate. Frost-heaving of substrates is probably capable of burying freshly dispersed seeds and exposing any dormant seeds, but this process remains to be studied. It is not clear whether an appreciable persistent seed bank exists and contributes a significant fraction of each year's seedling recruitment.

Cliff-ledge populations are probably more precarious because opportunities for on-site retention of dispersed seeds and seedling establishment appear to be limited. These populations are probably more static and reliant on the survival of individual plant rhizomes coupled with limited clonal expansion.

Further work is needed on seed-bank dynamics, seedling recruitment, and shoot mortality. Additional attention should be directed to reproductive studies of cliff-side populations and small populations.

Threats and Population Limiting Factors

Habitat destruction poses the most immediate and prevalent threat to most extant populations of Roan Mountain bluet. This destruction occurs in three forms--commercial, recreational, or residential development at privately owned sites; trampling of populations at accessible cliff- or trail-side locations on national forest lands (Cooper *et al.* 1977, Gaddy 1983); and erosional loss of cliff-side habitat created by uprooting and wind-throw of high-altitude trees. The impact of all three threats appears to be increasing steadily.

Cliff-top plants probably represent the functional heart of cliff-side populations. Loss of cliff-top plants removes the only natural source of propagules for the uppermost portion of cliff-side populations. These losses could subsequently create a cascading loss of plants downslope as cliff-top propagules no longer colonize lower ledges. Erosional losses also increase slumping of vegetation mats and probably reduce the accumulation of gravel in depressions on cliff ledges. Both processes reduce the amount of usable habitat available in a Roan Mountain bluet population.

Successional encroachment by native and exotic plants also poses a long-term threat to many populations (Massey *et al.* 1980, Kral 1983), particularly those found on mountain balds where new habitat may not be regenerating (Schafale and Weakley 1990). Others (Wiser, personal communication, 1993) believe that because succession on these rock outcrops is extremely slow, it is not a significant threat and that clipping or trimming "competing" species could change the local microclimate, making the bluet potentially vulnerable to increased exposure or erosion. Wiser, however, believes the Big Bald population may be threatened by succession.

Conservation Efforts

In North Carolina, the Natural Heritage Program, the North Carolina chapter of The Nature Conservancy (TNC), and the Service are working with landowners to protect and manage Roan Mountain bluet sites. The TNC owns part of one cliff-side site and is monitoring and protecting its populations by limiting public visitation. The U.S. Forest Service owns the Roan Mountain site (and the historic Big Bald site) and is trying to protect the species by placing new recreational facilities away from known locations and by creating innocuous natural barriers to discourage access and trampling at heavily used locations. Unfortunately, these barriers have not proven particularly effective in alleviating visitor impacts at scenic public recreation areas where the Roan Mountain bluet grows.

Fortunately, current landowners support conservation efforts at all three large sites. Potential recovery success is highest for the Roan Mountain population, found entirely on national forest lands. Federal law mandates protection of this population, and cooperation has been established with the U.S. Forest Service. Potential recovery success is also high for the Grandfather Mountain population. Much of this population is in remote or inaccessible areas, and the private landowner has shown a serious conservation commitment by donating a conservation easement that protects much of the bluet's habitat. He has also rerouted visitor traffic at one popular location to protect two other federally threatened plant species. Recovery efforts are also promising for the third large population--The Nature Conservancy's Bluff Mountain Nature Preserve. However, most of this population is on steep cliff sides, just beyond the preserve's property boundaries, and will require further work.

The North Carolina Arboretum in Asheville recently became an allied facility of the Center for Plant Conservation. They have proposed to serve as the seed-storage and plant-propagation facility for Roan Mountain bluet and have established a collection of specimens in cooperation with the North Carolina Plant Conservation Program.

The Endangered Species Act (Act) regulates trade in protected species and prohibits taking of the species from Federal land without a permit. Section 7 of the Act provides for additional protection of the habitat from impacts related to federally funded or authorized projects. For listed plant species, such as Roan Mountain bluet, the 1988 amendments to the Act also prohibit the malicious damage or destruction of plants on Federal land. The 1988 amendments also prohibit the removal, cutting, digging, damage, or destruction of a plant in knowing violation of any State law or regulation, including State criminal trespass law and the Plant Conservation Act of 1979.

Roan Mountain bluet is listed as endangered by the States of North Carolina and Tennessee. In North Carolina, State law prohibits the collection of listed plant species without both the landowner's written permission and a State collection permit from the North Carolina Department of Agriculture's Plant Conservation Program. State law also regulates trade in listed species (North Carolina General Statute 106,19B; 202.12-202.22). In Tennessee, the Rare Plant Protection and Conservation Act of 1985 prohibits the taking of listed species without the permission of the landowner or manager and regulates commercial sale or export (Tennessee Code Ann., Chapter 242, Sections 11-26-201 to 11-26-214, Public Acts of 1985).

While Federal and State status provide substantial legal protection to endangered and threatened species, particularly on Federal property, these laws regulate, but do not prevent, all collection or trade. Roan Mountain bluet has an attractive flower and growth habit, and while it is not currently a significant component of the horticultural trade, this situation could change.

PART II

RECOVERY

A. Recovery Objectives

The goal of this recovery plan is to remove Roan Mountain bluet (*Hedyotis purpurea* var. *montana*) from the Federal endangered species list. Delisting will be considered when at least nine self-sustaining populations exist, and they are protected to such a degree that the species no longer qualifies for protection under the Endangered Species Act.

A self-sustaining population is self-regenerating and maintains sufficient genetic variation to enable it to survive and respond to natural habitat changes. Sexual reproduction and recruitment are vital elements of a self-sustaining population. The requirement for nine populations is based on the documented historical distribution of the species. However, little is known about the biology of Roan Mountain bluet and the nature of its habitat, much less its management. Consequently, the requirement for nine self-sustaining populations may change as more is learned about the species and recovery objectives are reevaluated.

A population will be considered adequately protected when landowners and cooperating agencies have implemented the management actions necessary for population persistence and when the population is protected from present or foreseeable natural and human-related threats that might jeopardize its persistence.

B. Narrative Outline

1. Protect existing populations and essential habitat. Because of increasing threats to Roan Mountain bluet and its highly fragmented distribution at all sites, all eight extant populations should be protected. A careful census of each population is needed in order to establish interim protection, monitoring, and management priorities.

    1.1 Develop interim research and management plans in conjunction with landowners. Little is known about the specific management practices needed to ensure the long-term survival of Roan Mountain bluet. Consequently, interim plans will urge landowners to avoid site alteration. Where trampling or rock climbing threatens to destroy colonized habitat, trails should be rerouted or closed. Where small woody plants threaten to choke out a patch of bluets, selective clipping should be evaluated as a method to provide interim relief.

    1.2 Search for additional populations. More systematic and widespread efforts are needed to delineate old populations and to search for new ones. Potential search habitat should be prioritized after consulting three information sources: (1) geological (locating sites where mafic rock is present) and topographic (northerly aspect and steep slopes that provide reduced levels of solar radiation) maps; (2) Natural Heritage Program data bases that contain known occurrences of other cliff-ledge and talus-slope species; and (3) microhabitat studies that may further explain why Roan Mountain bluet is absent from some rocky-summit sites, including sites in the Craggy and Black Mountains (perhaps due to a lack of mafic rock or low levels of boron and iron - see Wiser [personal communication, 1993]). Because Roan Mountain bluets frequently grow with several other federally listed plants, search efforts for targeted rare species should be coordinated and pooled.

    1.3 Determine habitat protection priorities and alternatives. Protection efforts should first focus on the three largest Roan Mountain bluet populations. Conservation groups should be urged to purchase these cliffs in order to discourage recreational use or commercial or industrial development.

        Phoenix Mountain and Paddy Mountain also deserve high protection priority because of their pristine condition and/or vigorous populations. The Hanging Rock population is particularly endangered because of its small size and the possibility of further recreational development.

1.4 Provide habitat protection. The greatest possible protection should be sought for the populations that are most critical to the species' recovery. Protection must include the habitat needs of a population plus sufficient buffering land to reduce threats to the integrity of the site.

Fee simple acquisition and conservation easements provide the most durable and effective protection. If landowners are not willing to negotiate such agreements, short-term leases or management agreements can provide interim protection. These measures may lead to greater protection in the future, as personal interactions strengthen mutual respect and responsibility for species conservation.

2. Determine and implement necessary management for long-term reproduction, establishment, maintenance, and vigor. New subpopulations may need to be established periodically in order to replace any that may eventually die out. For all populations, plant numbers, reproduction, and electrophoretic variation should be monitored. Within selected population units, the following management efforts should occur: (1) census the life-cycle stages and follow individual plants to estimate population size and rates of vegetative survival, reproduction, and recruitment; (2) test for reproductive or recruitment limitations that jeopardize local persistence; (3) characterize buffering or compensatory processes that reduce the long-term impact of short-term reductions in survival, reproduction, or recruitment; and, (4) identify habitat and seed characteristics that permit colonization, germination, and establishment in new habitat.

2.1 Determine population size for all populations. Variability will affect the statistical detection of population changes and the biological establishment of thresholds that should trigger closer monitoring, investigation, or intervention. Census data should include counts of seedlings, rosettes, and stems. For selected sites during germination, additional seedling censuses should be conducted at 2- to 4-day intervals in order to detect seedlings that emerge and survive for only a few days before disappearing. During flowering, data should include the proportion of flowering stems and the number of flowers per stem. During fruiting, data should include the proportion of fruiting stems, the number of swollen fruits and aborted fruits per stem, and from dissections of a small collection of fruiting stems, the number and proportion of ovules that produced viable seeds. Simple microsite information should be collected, such as ordinal rankings of canopy cover and cover of common herbaceous species, substrate, topography, and hydrology over a multi-year period.

2.2 Study abiotic and biotic features of the species' habitat. Demographic problems can jeopardize the persistence of a population. Life-cycle censuses (Task 2.1) can isolate the period and developmental stage in which most problems appear and, with field observations of plant condition, can suggest one or more possible explanations. However, two problems--reproductive failure and recruitment failure--are particularly serious because they warn of near-term extinction and irreversible loss of genetic variation.

2.2.1 Conduct controlled pollination tests. Controlled pollination tests, such as those described in Saunders (1993), should be conducted to assess the adequacy of natural pollination and possible inbreeding depression.

2.2.2 Assess recruitment and seed-bank dynamics. Sexual reproduction cannot replace lost plant genotypes unless the seeds germinate and the seedlings survive. Poor seed germination occurs when few seeds are exposed to suitable germination conditions or when few seeds are capable of germination. One approach is to census seeds and their condition throughout the year, but this requires the removal of soil samples that may injure plants and jeopardize future recruitment. A better approach is to try to relieve the possible limitations of seedling recruitment.

A complementary concern is the demographic consequences of poor seedling recruitment. Some plants maintain substantial persistent seed banks in the soil; this permits them to survive years of unfavorable germination conditions or to buffer recruitment against erratic seed production.

Studies of recruitment failure and seed-bank dynamics can be combined. The two most probable causes of recruitment limitation are the inadequate retention of viable seeds and the suppression of seed germination by increasing vegetative cover of other species.

2.3 Conduct long-term demographic studies. Until more is known about the demography of Roan Mountain bluet, it is not possible to identify comparable species that might provide quantitative guidelines for the appraisal and management of this species. The only general demographic guidelines are those that qualitatively describe the life-cycle stages that predominate in each of the four stages of the vegetational sequence--reproduction, dispersal, establishment, and maintenance. From a demographic perspective, vegetative survival and sexual reproduction are the stages of the life cycle that are most crucial to a population's persistence as it reaches its senescent phase. From a genetic perspective, breeding population size and the variation in individual reproductive success are probably the two most important parameters for understanding how rapidly a population loses genetic variation (Crow and Kimura 1970).

2.3.1 Monitor fruiting plants and capsule diameters. Fruiting plants should be monitored in order to directly measure the size of the successful breeding population. Capsule diameters could be measured to evaluate seed set indirectly through its allometric relation to capsule size.

2.3.2 Develop electrophoretic sampling methods to monitor patterns of genetic variation. Measure electrophoretic protein variation using leaf tissue to survey the genetic variation in all remaining populations of the species. This would provide information on the genetic variation present in the species as a whole. In addition, this survey would identify "hot spots" of genetic variation, if they exist, and populations that are genetically depauperate. From a management perspective, populations that are genetically rich might be the most desirable source for seeds or plants for reintroduction to a historic site from which the species has been extirpated. Populations that are genetically depauperate are candidates for an infusion of genetic variation, particularly if the populations show evidence of decline.

If difficulties arise with electrophoretic protein variation methodology, DNA analysis could provide a more sensitive and less biased alternative to enzyme electrophoresis, but it is currently more technically demanding, time-consuming, and costly (Schaal *et al.* 1991).

2.3.3 Compare electrophoretic value to published values. When electrophoretic monitoring of Roan Mountain bluet begins, the same measures of genetic variation can be calculated and compared to the range of published values (Hamrick and Godt 1989, Hamrick *et al.* 1991). For a number of reasons, comparison with its closest relative, *Hedyotis purpurea* var. *purpurea* would be valuable. First, most of the life history characteristics of the taxa are likely to be similar. As allozyme reviews have shown, life history characteristics of species are correlated with levels of genetic variation. Second, the two species share an evolutionary past. Comparison of the two taxa would place differences in levels of genetic variation in historical perspective. If levels of genetic variation are similar between the two taxa, then Roan Mountain bluet, despite its restrictive distribution, is likely to have experienced a greater number of genetic bottlenecks than its relative, and reduced genetic variation is thus an unlikely explanation for its rarity. If levels of genetic variation in Roan Mountain bluet are diminished compared to the more widespread variety, at least two possibilities exist. First, Roan Mountain bluet may contain just a subset of the alleles found in the widespread variety. This would suggest Roan Mountain bluet underwent a recent genetic bottleneck event in the process of splitting from the widespread variety. Alternatively, if the levels of variation are reduced, but alleles are not shared, this suggests that the taxa diverged sufficiently long ago to develop significant genetic differences and that Roan Mountain Bluet has experienced significant genetic drift since diverging. Finally, it is possible, but unlikely, that Roan Mountain bluet is the progenitor of the more widespread taxon. In summary, comparing the genetic variation in the two taxa would provide a context for assessing the level of genetic variation found in Roan Mountain bluet.

The most useful comparison for Roan Mountain bluet with species in the allozyme reviews mentioned above should be with other narrow endemic species. Further, it would be informative to compare genetic distance to geographic distance.

2.4 Determine the effects of past and ongoing habitat disturbance. The natural creation of usable habitat affects both how often a new subpopulation can become established and how long an established subpopulation can persist. Usable habitat and the natural processes that create it need to be identified and characterized. Additionally, the capacity of seeds to reach these habitats needs to be measured. Field observations, life-cycle census data on recruitment, and recruitment experiments will provide preliminary explanations that can then be tested using a simplified recruitment experiment.

2.4.1 Determine seed shadow and the suitability of potential habitat for recruitment. Design basic colonization experiments to test for the presence and intensity of a seed shadow and the suitability of potential habitat for recruitment. A series of paired, small-scale treatments, with the nature of the treatments depending on the findings of studies within existing subpopulations (i.e., small-scale vegetation removal with and without seed over-sowings), is likely the most feasible.

Several of these colonization experiments should be conducted in the immediate vicinity of existing subpopulations. By repeating the treatment pairs along a transect extending outward from an existing distributional boundary, the spatial extent of the seed shadow can be mapped. Other experiments should be conducted at Big Bald and at other locations believed to support Roan Mountain bluet, as well as at locations that currently support some endemic plant associates of the bluet. If these experiments reveal a seed bank, they may help establish the potential longevity of seed banks, either with the help of historical occupancy records that may appear in scientific publications or herbarium records.

2.4.2 Characterize those natural processes that create habitat that can be colonized. It may be difficult to characterize those natural processes that infrequently create usable habitat, with the possible exception of large fires or landslides (both of which may leave detectable scars). It would be surprising if the same processes were involved in both talus-slope and cliff-side subpopulations.

On talus slopes, vegetation removal probably occurs through frost heaving, occasional fire, or possibly through periodic outbreaks of disease or increased herbivore pressure that destroys plant patches dominated by clonal species. To quantify frost heaving, which causes burial and exposure of seeds as well as the uprooting of plants, it may be useful to photograph plots in the fall and spring.

On cliff faces, frost heaving may also prove effective, but the scouring effects of wind-thrown trees, small landslides, and ice movements may prove more important in uprooting plants and generating recruitment habitat. It is likely that a significant proportion of bluet recruitment may also occur along the margins of rapidly expanding vegetational mats produced by mosses or spreading rhododendron roots. These finely textured surfaces may be able to trap seeds, prevent them from being washed away, and act as seedling nurseries that permit juvenile plants to establish root systems that reach downward into cracks and crevices.

2.5 Define criteria for self-sustaining populations based upon the data obtained from Tasks 2.1 through 2.4. To evaluate and manage a rare species like Roan Mountain bluet, it is necessary to have an understanding of how its populations have persisted in the past and the capacity of these populations to persist into the future. The approach here first splits the problem into two parts--the persistence of individual subpopulations and the persistence of each metapopulation.

2.5.1 Assess subpopulation persistence using guidelines emerging from Tasks 2.1 through 2.4. Persistence of a subpopulation requires sufficient reproduction and recruitment to offset plant mortality and to regenerate genetic variation. Monitoring trips (2.3.1) will provide a periodic assessment of local habitat conditions and educated guesses as to the frequency of recurring transient threats (such as trampling) and the rate at which chronic threats (such as successional encroachment) reduce recruitment, reproduction, and adult survival.

Monitoring data will also provide evidence of reproductive success, and life-cycle censuses will provide evidence of recruitment and seed production. If neither reproduction or recruitment is evident, a subpopulation is probably senescent and is not likely to recover without intervention. If reproduction is evident, but not recruitment, a subpopulation is or may be slowly senescent and may be able to recover on its own if natural processes sporadically create suitable germination habitat. If both reproduction and recruitment are evident and no immediate threat is present, a subpopulation is either self-sufficient or declining very slowly.

To detect significant trends in the data, the variation that normally occurs in a self-sustaining subpopulation must first be determined. This will require several years of monitoring one or more populations.

2.5.2 Project subpopulation persistence under current conditions. The life-cycle censuses provide estimates of the numbers of individuals in different life-cycle stages--seeds, seedlings, nonreproductive plants, and reproductive plants. Because these censuses follow individual plants, they also provide stage-specific estimates of survival, growth, and reproduction that represent the probability of an individual in one life-cycle stage being found in each other stage the following year.

For projecting future numbers, these probabilities are placed in columns and when multiplied by the observed number of individuals in each life-cycle stage, produce the number of individuals expected in each life-cycle stage the next year. This tabular multiplication process can be repeated using the resulting stage distribution from the last multiplication as the initial stage distribution in the next multiplication. This iterative process generates the population trajectory expected from a simple extrapolation of current vital rate estimates. If this projected trajectory declines over a period of years, individuals are not replacing themselves and the modeled population is not self-persistent.

This mathematical tool provides several quantitative results that are extremely useful. First, it quantifies population growth rate and self-persistence. Second, it is useful for detecting changes in vital rates in the recent past. The projection process usually generates a stable distribution of developmental stages that reflect the vital rates measured. This distribution can be compared with the observed distribution of stages that depend primarily on unmeasured vital rates from previous years. Third, the model can be used to predict how long the population would persist if reproduction or recruitment fails by replacing the stage transition values with zeros and iterating or keeping track of the number of individuals dying each year in order to obtain the distribution of deaths over a period of time. This distribution provides a useful measure of turnover for a senescent population and gives an idea of how long it can tolerate regenerative failure before being lost.

The modeling process becomes an evolving quantitative test of how well the causes and consequences of population dynamics are understood. Consequently, the projective criteria for population persistence should improve as more is learned about Roan Mountain bluet. It also provides a means to assess potential management options by quantifying their predicted consequences.

2.5.3 Project genetic variation. Projection of genetic variation is difficult, but there are three approaches that would be possible given initial survey data, the demographic information, and perhaps some genetic monitoring of the populations. First, a stage-transition model could be fit to allele frequency classes in order to project changes in allele distribution, but the transitions will probably be slow enough that it will not be possible to get reliable estimates. The gain and loss of alleles through the low-frequency class will also be difficult to quantify, as the detection of all alleles is not likely unless hundreds of individuals are sampled in each subpopulation. A second approach is to explore the observed statistical dependence of various measures of genetic variation on population size and other demographic attributes by fitting regression models. A third, more difficult approach is to quantify inbreeding depression, if present, and project its demographic consequences.

2.5.4 Prospective evaluation. One of the most immediate needs is to identify extinction threats and scenarios for Roan Mountain bluet. This information will help managers develop prospective criteria they can use to evaluate and manage bluet subpopulations.

2.5.4.1 Identify the most significant threats. To help identify the most significant threats, a useful first step is to identify the most vulnerable stage of the life cycle in existing subpopulations. Further reduction in this stage is most likely to cause a dramatic decline in population size and genetic variation.

2.5.4.2 Identify transient threats to subpopulations. The next step is to identify transient threats to subpopulations and analyze the impact of the population bottlenecks they create. Roan Mountain bluet currently faces several intermittent and localized threats--natural extremes of weather that may affect any stage of the life cycle are now exacerbated by visitor trampling. It is possible that some populations require fire to expose mineral soils for seedling establishment or to thin shading canopy. If this is found to be true, long-term fire suppression also constitutes a threat.

The most probable extinction scenarios involving transient threats involve either an unusual sequence of recurring conditions that cause great cumulative impact or a threat that requires a long recovery period during which the population may be further damaged by threats that would otherwise have had limited effect.

2.5.5 Identify chronic threats to subpopulations and potential population responses. Roan Mountain bluet appears to face three potentially widespread and enduring threats--successional encroachment, habitat destruction, and possibly air pollution effects. Chronic threats are difficult to evaluate because: (1) their onset is usually gradual and their effects often subtle so that many years must pass to magnify their cumulative impact and permit an unequivocal identification of cause; (2) chronic changes also affect associated plant and animal species, which may cause unanticipated indirect effects on Roan Mountain bluet; and (3) the time scales involved are sufficient to permit genetic adaptation that can introduce additional predictive difficulties.

2.5.5.1 Specify threats observed in the life-cycle censuses. Some insight is possible by projecting the consequences of some environmental variation observed in the life-cycle censuses. Using one or more of the environmental measurements collected from permanent census plots, they can be grouped into two or more categories. Different sets of size-specific mortality and size-change rates can then be calculated for each. This method generates projected population growth and turnover rates under different specified sets of environmental conditions. By comparing rate estimates, it is possible to identify those environmental changes that might drastically alter population size and those conditions that have little effect. It is also possible to study potential fluctuation in distributional boundaries by using habitat type and spatial position to group census plots.

The possibility exists for indirect negative effects on Roan Mountain bluet through threats to interdependent species. For example, a variety of insects visit bluet flowers, and most of these insects also visit a variety of other plant species. Roan Mountain bluet can probably tolerate moderate changes in the abundance of its pollinators and probably exerts little influence over their abundance, with the possible exception of a small staphylinid beetle. However, indiscriminate use of nonselective insecticides could threaten all pollinators at sites where fir trees are sprayed in order to control adelgid outbreaks.

On cliff faces, bluet recruitment may depend on the special nursery environments created within mats of moss or dense fibrous roots produced by many ericaceous plants. These mats may trap seeds and prevent them from being washed down the cliff. The chronic threat of acid deposition could endanger recruitment establishment in three ways. By lowering soil pH, it can increase the release of toxic metals, disrupt mycorrhizal associations (Jackson and Mason 1984), or kill nursery plants (Watson 1971, Whittaker 1975, Jackson and Mason 1984).

Little is known about the indirect effects of competitors, although densely rhizomatous or woody species probably exert the greatest effects on bluet recruitment and, to a lesser extent, on adult growth rates.

Finally, the impacts of herbivores and pathogens are not known, nor is anything known about the possible role played by animals in the creation of localized recruitment habitat through soil disturbance or vegetation removal.

2.5.5.2 Be prepared to manage inbreeding depression. As mentioned in the introduction, no inbreeding depression was evident in one population examined. Should future research produce evidence of inbreeding depression, one simple approach would be to build up the size of the population by alleviating other sources of mortality or reduced fecundity, then let the population naturally purge itself of detrimentals until it is capable of reexpanding on its own.

2.5.6 Assess metapopulation persistence. Persistence of the entire population requires the colonization and establishment of new subpopulations to replace any subpopulations that may die out and the adaptive genetic variation that the dying subpopulation contained.

Ideally, there should be a self-sustaining mix of subpopulations at each site that includes an adequate number of weakly connected asynchronous or anti-synchronous subpopulations to ensure a constant source of new recruits for the reestablishment of new subpopulations as new habitat is recreated by natural processes (Levin 1976).

2.5.6.1 Identify usable habitat and determine capability of freshly produced seeds to reach these sites in sufficient numbers to establish a new self-sustaining subpopulation; analyze the life span of existing populations and compare it to the frequency with which suitable habitat is generated by natural processes.

2.5.6.1.1 Identify suitable habitat. The life-cycle census provides environmental measures that correlate with recruitment in existing subpopulations, and the recruitment experiment tests for factors that limit and permit recruitment. Potential sites for new subpopulations can first be screened by identifying locations with similar abiotic environments or with some of the frequent, endemic plant associates of Roan Mountain bluet. Historic records may also identify a few former locations for bluet subpopulations. The suitability of these potential sites can then be tested by performing the same small-scale recruitment experiment used within existing subpopulations using a variety of experimental methods, such as removing competing vegetation; removing litter, lichens and mosses; and exposing bar soil for colonization.

2.5.6.1.2 Determine capability of freshly produced seeds to reach suitable habitat. The recruitment experiment also helps determine how close in space and time new habitat must be created in order to permit natural colonization and establishment. Clusters of small-scale recruitment treatments can be repeated at intervals along transects, extending outward from the boundaries of existing subpopulations. These results reveal the cumulative dispersal distance of seeds and help establish the maximum distance that separates suitable sites from seed sources. The recruitment experiments performed within existing subpopulations provide estimates of germination probabilities for seeds that enter a persistent seed bank and remain viable for 2 or 3 years. These data can be used to extrapolate a maximum viable life span for seeds that enter a soil seed bank and establish the maximum interval between the loss of seed reproduction in a senescent subpopulation and the regeneration of habitat following the extinction of a subpopulation.

2.5.6.1.3 Determine rate of habitat regeneration. The slow rate of habitat regeneration and deterioration requires indirect estimates of the time intervals between foundings and extirpations. If it seems reasonable to assume that habitat creation has historically been adequate, then the observed proportions of subpopulations in the colonization, establishment, maturation, and senescent phases reflect the relative lengths of the four phases. Instead, if it is possible to estimate the lengths of each phase, then the observed proportions of subpopulations in the colonization, establishment, maturation, and senescent phases can be compared to the proportions expected. This comparison can be based on relative phase lengths to test the recent historical adequacy of natural habitat regeneration. Several types of records provide information on the lengths of single or multiple phases--meteorological patterns summarized in National Weather Service records; the dating of slowly healing disturbance scars left by fires, landslides, and fallen trees; and the aging of mature trees of local colonizing species found at Roan Mountain bluet sites.

If fire is found to have been an agent of new habitat patch creation, it will be necessary to simulate this natural process by conducting controlled burns or by manually opening new patches for colonization.

2.6 Implement appropriate management techniques as they are developed from previous tasks. Most techniques for overall habitat management will involve the up-scaling of methods used in the experimental studies of recruitment and pollination in selected subpopulations supplemented with techniques developed from horticultural studies. However, up-scaled efforts sometimes produce unexpected results, particularly when vegetation is removed. Consequently, pilot studies of these methods should be implemented as soon as possible to troubleshoot techniques, evaluate the feasibility of their large-scale application, and make sure they effectively meet their intended objectives.

2.6.1 Subdivide local population units. Subdivide local population units into three classes (imminent risk of extirpation, suspected decline, and self-persistent) based on objective and subjective evidence of population decline and loss of recruitment or reproduction, turnover rate, or increase in threats. Preliminary population size criteria are primarily based on theoretical estimates of the genetic requirements for a "minimum viable population" for a fairly dynamic, outbreeding plant species with little seed dormancy (Franklin 1980). Definitions of these levels follow.

Level I - Imminent Risk of Extirpation - A subpopulation is placed in this category if it is not self-sustaining and it faces imminent and irreversible genetic impairment.

Preliminary criteria for this classification include recruitment failure and either (1) a total subpopulation size of 250 or fewer genetically distinct individuals; (2) a 20 percent reduction in genetic variation; (3) a 20 percent reduction in seed set accompanied by a 20 percent decline in subpopulation size; or, (4) a 50 percent decline in population size attributed to a continuous threat.

While it may not be economically feasible to determine all of the information for the above criteria, Level I subpopulations will require close annual monitoring, diagnostic field studies, and active habitat management in order to prevent further death of the remaining plants. Ideally, the standard reproductive census should be expanded to include precisely mapped plants so that each plant can be followed individually over a period of time to determine rates of survivorship and mortality. For some sites, diagnostic field studies could include a test for inbreeding depression that uses pollen donors from the nearest subpopulation (not also classified as Level I).

Level II - Suspected Decline - A subpopulation is placed in this category if it does not appear to be self-sustaining and does not face imminent danger of irreversible genetic impairment.

Preliminary criteria for this classification include recruitment failure or near-failure and either (1) a total subpopulation size of less than 2,000 genetically distinct individuals; (2) a 10 percent reduction in genetic variation; (3) a 10 percent reduction in seed set accompanied by a 20 percent decline in population size; or, (4) a 25 percent reduction in subpopulation size attributed to a continuous threat.

As in Level I, Franklins's criteria are not feasible for Roan Mountain Bluet. There are no subpopulations as large as 2,000 individuals, and their genetic distinctiveness is not possible to monitor. Level II subpopulations, however, should be monitored every 3 years by conducting the fruiting-stem census described in the monitoring project. Management should include site visits every 1 or 2 years to monitor threats and restore sufficient habitat in order to boost recruitment and prevent further decline. Field studies should be initiated in this subpopulation or in a comparable surrogate to examine how identified threats affect vital rates and the rate of population decline.

Level III - Self-persistent - A subpopulation is placed in this category if it is self-sustaining and maintains healthy levels of genetic variation.

Preliminary criteria for this classification include evidence of consistent successful reproduction and recruitment and either (1) a total population size of more than 5,000 genetically distinct individuals and no evidence of numerical decline or continuous threat or (2) direct empirical evidence of population stability including nondeclining population size, nondeclining genetic variation, or a recruitment rate sufficient to offset the mortality of adult plants.

Level III subpopulations should be monitored every 5 years by conducting the fruiting-stem census described in the monitoring project. They also should be visited every 2 or 3 years to note habitat changes and threats. These subpopulations do not require any active management as long as sites receive adequate protection.

2.6.2 Develop management alternatives. Two major options exist for population management--reinvigorate a declining subpopulation or establish a new one. In principle, the choice should reflect the historic patterns of extinction and colonization in which the life-history characteristics of Roan Mountain bluet have evolved. In practice, however, logistical constraints and the nature of anthropogenic threats may dictate management choices.

Although accidental introduction of a disease agent cannot be ruled out, most of the proposed habitat management techniques are not likely to harm Roan Mountain bluet. These techniques can be implemented as soon as possible in Level I or Level II subpopulations.

Where augmentation of a declining population is indicated, initial management should be conservative, using only seeds or greenhouse plants derived from the same target population. When we know more about the genetic makeup of populations, it would be desirable to experiment with increasing the diversity within a depauperate population by the addition of material from a more diverse population. Ideally, it would be good to follow the fate of the original gene pool after the infusion of new material.

2.7 Develop techniques and reestablish populations in suitable habitat within the species' historic range. Preliminary work will develop the propagation and transplant techniques necessary to establish new subpopulations of Roan Mountain bluet. This work can be conducted both off- and on-site. After stabilization, habitat restoration, and expansion of existing sites, the reestablishment of historic sites and the establishment of new populations should have highest recovery priority.

2.7.1 Conduct off-site horticultural studies. These studies can both characterize the germination and cultural requirements of the species and test and refine reliable techniques for sexual and asexual propagation. These propagation methods will not only provide the plant material needed to conduct additional research, supplement existing populations, or establish new populations, but they will also create a valuable set of tools for intensive genetic management (e.g., controlled mating programs). Similarly, the development of a nondestructive cloning method, using traditional or tissue culture techniques, will permit the rescue of extant genetic variation from a dying subpopulation and the creation of a duplicate genetic population off-site in case on-site management fails.

2.7.2 Conduct on-site field studies. These studies can evaluate the feasibility of sowing seeds and transplants and the expansion of existing subpopulations by the creation of new habitat patches for colonization. Intra-subpopulation studies are preferable as they avoid the introduction of diseases, pests, or foreign genotypes into native subpopulations.

2.8 Introduce/reintroduce the species into appropriate habitat. In many ways, Big Bald is the most promising site for reintroducing Roan Mountain bluet. It supported a population 12 years ago, and the site is reasonably well-protected based on the current management plan for Pisgah National Forest. This site would double the number of bald populations for Roan Mountain bluet. The sole extant bald population at Roan Mountain is the least fragmented and relatively large population remaining. Consequently, Roan Mountain should be able to provide ample seeds and genotypes that should be generally adapted to bald and talus-slope habitats.

The goal of all reintroductions should be to establish a Level III subpopulation as rapidly as possible in order to preserve the genetic variation contained in the founders. Consequently, enough germination habitat must be prepared to meet the minimum population size for a Level III subpopulation. This will likely require a mid- to late-summer burn to remove as much organic matter as possible, followed by some raking and weeding to remove surviving root stocks. At Big Bald, it may be desirable to leave a portion of the site fallow after burning to see if any viable bluet seeds remain.

The number of founders establishes a maximal limit for the amount of genetic variation the new subpopulation will contain for quite some time. To provide the maximum amount of adaptive genetic variation, at least 200 sibship samples containing at least 10 good seeds should be removed from the nearest vigorous population found in the same type of habitat. Seeds could be randomized and sown and should then be nature allowed to take its course in selecting those suitable for the habitat.

3. Maintain and expand cultivated sources for the species and provide for the long-term maintenance of selected populations in cultivation. Horticultural studies can contribute to recovery efforts in three ways. First, they provide valuable insight into the developmental patterns and growth habits of individual plants--difficult observations to obtain from field populations in natural habitats. Second, horticultural studies test the true environmental requirements of a species and help distinguish habitat preferences from habitat requirements. Third, horticultural studies eventually generate plant material that can be used directly to replenish or reintroduce the species into native habitat. The same material may also be used to establish experimental populations in natural habitat for perturbation studies of novel threats or natural factors.

   Horticultural care is also necessary to maintain the integrity of germ-plasm samples removed from selected populations. If a targeted population has reasonable seed set, a representative seed sample should be collected over a period of several years (Marshall and Brown 1975, Falk and Holsinger 1991). Mature seeds should be separately collected by sibship from randomly selected maternal plants. The multiple-year requirement broadens the genetic sample beyond those genotypes that happen to produce ripe seeds at the particular time of a collection visit.

Together, these sibship seed-collection procedures overcome the collection biases and the undocumented, systematic loss of phenological variation that occurs during the collection and storage of traditional, haphazard, bulk seed samples (Allard 1970). Genetically based variation in seed viability and germination requirements and in the timing of flowering and seed maturation provides one of the most significant sources of ecologically relevant variation for adaptation. By shifting the timing of its life cycle, a species can accommodate almost any environmental change as long as the impact of the change is restricted to a particular time of year and a particular developmental stage. If, however, a targeted population has poor seed set, asexual propagation techniques (including tissue culture) should be developed to permit the cloning of naturally occurring individuals in the targeted population.

4. Enforce laws protecting the species and/or its habitat. Federal and State enforcement agents whose jurisdiction includes the known range of *Hedyotis purpurea* var. *montana* should be made aware of the threats to the species and be able to identify specimens. Wherever collecting is a potential problem, signs should be posted explaining the prohibitions against taking of these plants (without specifying the species, so as not to draw undesirable attention).

5. Develop materials to inform the public about the status of the species and the recovery plan objectives. Public support for the conservation of Roan Mountain bluet could greatly encourage landowner assistance in conservation efforts, particularly at those sites that may be adversely affected by the creation or expansion of resorts and recreation facilities. However, informational material should not identify the plant's precise locations in order to discourage vandalism to, or collection of, wild populations.

   Informational materials should stress pragmatic reasons for species conservation as well as intellectual, aesthetic, or moral considerations. Background information about the pharmacological, agricultural, or economic properties of the species, its congeners, or other plant family relatives will help address the questions frequently posed by laypersons. Additional information should be provided about known or suspected bio-indicator properties of the species.

   5.1 Prepare and distribute news releases and informational brochures. Informational materials should be prepared about the status, significance, and recovery of the species. News releases should be distributed to major newspapers in the species' range and to smaller newspapers in the vicinity of the species' habitat. Interpretive displays and brochures should be developed for use on public land or in public schools. These materials should stress the fragility of this rare plant's habitat.

5.2 Prepare articles for popular and scientific publications. Published articles are necessary to inform local citizens and public officials about the need to protect Roan Mountain bluet in its native habitat and to encourage their enthusiastic cooperation in conservation efforts. Scientific publications should identify the most pressing needs for further studies and seek the assistance of college and university researchers who have studied this or closely related species.

6. Annually assess the success of recovery efforts for the species. The timely review of new information and evaluation of ongoing programs is essential to ensure that full recovery occurs as rapidly and efficiently as possible. Monitoring information may reveal new problems or require shifts in the allocation of resources to monitoring, research, and management projects. Population performance should be compared to preestablished targets, and more rigorous or frequent monitoring programs should be implemented if populations decline below preestablished thresholds. Pilot and full-scale management projects should also be reviewed to ensure their continuing effectiveness.

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PART III

IMPLEMENTATION SCHEDULE

Priorities in column one of the following Implementation Schedule are assigned as follows:

1. Priority 1 - An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

2. Priority 2 - An action that must be taken to prevent a significant decline in species population/habitat quality or some other significant negative impact short of extinction.

3. Priority 3 - All other actions necessary to meet the recovery objective.

Key to Acronyms Used in This Implementation Schedule

FWS - U.S. Fish and Wildlife Service
TE - Endangered Species Division of the U.S. Fish and Wildlife Service
LE - Law Enforcement Division of the U.S. Fish and Wildlife Service
FA - Other Federal Agencies - Includes the U.S. Forest Service and National Park Service
R4 - Region 4 (Southeast Region), U.S. Fish and Wildlife Service
SCA - State Conservation Agencies - State plant conservation agencies of participating States. In North Carolina, these are the Plant Conservation Program (North Carolina Department of Agriculture) and the Natural Heritage Program (North Carolina Department of Environment, Health, and Natural Resources); in Tennessee, the Natural Heritage Program (Tennessee Department of Environment and Conservation).

ROAN MOUNTAIN BLUET IMPLEMENTATION SCHEDULE

Priority	Task Number	Task Description	Task Duration	Responsible Agency FWS	Responsible Agency Other	Cost Estimates ($000's) FY1	FY2	FY3	Comments
1	1.1	Develop interim research and management plans in conjunction with landowners.	Continuous	R4/ES	SCA, FA	1.0	1.0	1.0	Concurrent with Task 1.3
1	1.3	Determine habitat protection priorities and alternatives.	Continuous	R4/ES	SCA, FA	1.0	1.0	1.0	Concurrent with Task 1.1
1	1.4	Provide habitat protection.	Continuous	R4/ES	SCA, FA				Cost not determinable
1	2.1	Determine population size for all populations.	3 years	R4/ES	SCA, FA	3.0	3.0	3.0	
1	2.5.4.1	Identify the most significant threats.	2 years	R4/ES	SCA, FA	1.0	1.0		Concurrent with Task 2.1.
1	2.5.4.2	Identify transient threats to subpopulations.	2 years	R4/ES	SCA, FA	1.0	1.0		Concurrent with Task 2.1.
1	2.5.5.1	Specify threats observed in the life-cycle censuses (Task 2.1).	3 years	R4/ES	SCA, FA	1.0	1.0	1.0	Concurrent with Task 2.1.
1	4.0	Enforce laws protecting the species and/or its habitat.	Continuous	R4/ES, LE	SCA, FA	1.0	1.0	1.0	
1	6.0	Annually assess the success of recovery efforts for the species.	Continuous	R4/ES	SCA, FA	1.0	1.0	1.0	
2	1.2	Search for additional populations.	Continuous	R4/ES	SCA, FA	1.0	1.0	1.0	
2	2.2.1	Conduct controlled pollination tests.	2 years	R4/ES	SCA, FA	10.0	5.0		Concurrent with Task 2.1.
2	2.2.2	Assess recruitment and seed-bank dynamics.	3 years	R4/ES	SCA, FA	3.0	3.0	3.0	Concurrent with Task 2.1.
2	2.3.1	Monitor fruiting plants and capsule diameters.	3 years	R4/ES	SCA, FA	1.0	1.0	1.0	Concurrent with Task 2.1.
2	2.3.2	Develop electrophoretic sampling methods to monitor patterns of genetic variation.	3 years	R4/ES	SCA, FA	10.0	7.0	7.0	Concurrent with Task 2.3.3.
2	2.3.3	Compare electrophoretic value to published values.	3 years	R4/ES	SCA, FA	1.0	1.0	1.0	Concurrent with Task 2.3.2.
2	2.4.1	Determine seed shadow and the suitability of potential habitat for recruitment.	3 years	R4/ES	SCA, FA	3.0	3.0	3.0	Concurrent with Task 2.1.
2	2.4.2	Characterize those natural processes that create habitat that can be colonized.	3 years	R4/ES	SCA, FA	3.0	3.0	3.0	Concurrent with Task 2.1.

ROAN MOUNTAIN BLUET IMPLEMENTATION SCHEDULE (continued)

Priority	Task Number	Task Description	Task Duration	Responsible Agency FWS	Responsible Agency Other	Cost Estimates ($000's) FY1	FY2	FY3	Comments
2	2.5.1	Assess subpopulation persistence using guidelines emerging from Tasks 2.1 through 2.4.		R4/ES	SCA, FA				After Tasks 2.1 through 2.4 have been completed.
2	2.5.2	Project subpopulation persistence under current conditions.		R4/ES	SCA, FA				After Tasks 2.1 through 2.4 have been completed.
2	2.5.3	Project genetic variation.		R4/ES	SCA, FA				After Tasks 2.1 through 2.4 have been completed.
2	2.5.5.2	Be prepared to manage for control of inbreeding depression.		R4/ES	SCA, FA				After Tasks 2.1 through 2.4 have been completed.
2	2.5.6.1.1	Identify suitable habitat.	3 years	R4/ES	SCA, FA	5.0	5.0	5.0	
2	2.5.6.1.2	Determine capability of freshly produced seeds to reach suitable habitat.	3 years	R4/ES	SCA, FA	5.0	5.0	5.0	
2	2.5.6.1.3	Determine rate of habitat regeneration.	5 years	R4/ES	SCA, FA	2.0	2.0	2.0	
2	2.6.1	Subdivide local population units.		R4/ES	SCA, FA				After Tasks 2.1 through 2.4 have been completed.
2	2.6.2	Develop management alternatives.		R4/ES	SCA, FA				After Tasks 2.1 through 2.4 have been completed.
2	2.7.1	Conduct off-site horticultural studies.	3 years	R4/ES	SCA, FA	2.0	2.0	2.0	
2	2.7.2	Conduct on-site field studies.		R4/ES	SCA, FA				After Tasks 2.1 through 2.4 have been completed.
2	2.8	Introduce/reintroduce the species into appropriate habitat.		R4/ES	SCA, FA				After Tasks 2.1 through 2.4 have been completed.

ROAN MOUNTAIN BLUET IMPLEMENTATION SCHEDULE (continued)

Priority	Task Number	Task Description	Task Duration	Responsible Agency FWS	Responsible Agency Other	Cost Estimates ($000's) FY1	FY2	FY3	Comments
2	3.0	Maintain and expand cultivated sources for the species and provide for long-term maintenance of selected populations in cultivation.	Continuous	R4/ES	SCA, FA	1.0	1.0	1.0	
3	5.1	Prepare and distribute news releases and informational brochures.	Continuous	R4/ES	SCA, FA	2.0	2.0	2.0	Results of ongoing research are needed to develop brochures and displays.
3	5.2	Prepare articles for popular and scientific publications.	Continuous	R4/ES	SCA, FA	2.0	2.0	2.0	

PART IV

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