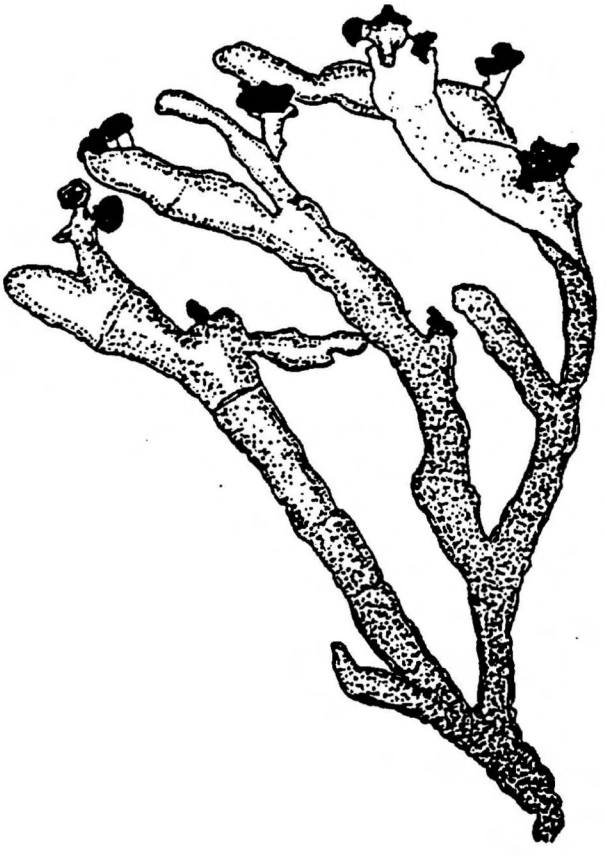
U.S. Fish & Wildlife Service

Recovery Plan for the Rock Gnome Lichen

(Gymnoderma lineare) (Evans) Yoshimura and Sharp



Southeast Region
Atlanta, Georgia

RECOVERY PLAN

for

Rock Gnome Lichen
(*Gymnoderma lineare*) (Evans) Yoshimura and Sharp

Prepared by
Nora A. Murdock
Asheville Field Office
U.S. Fish and Wildlife Service
Asheville, North Carolina

and

Keith Langdon
Great Smoky Mountains National Park
Gatlinburg, Tennessee

for

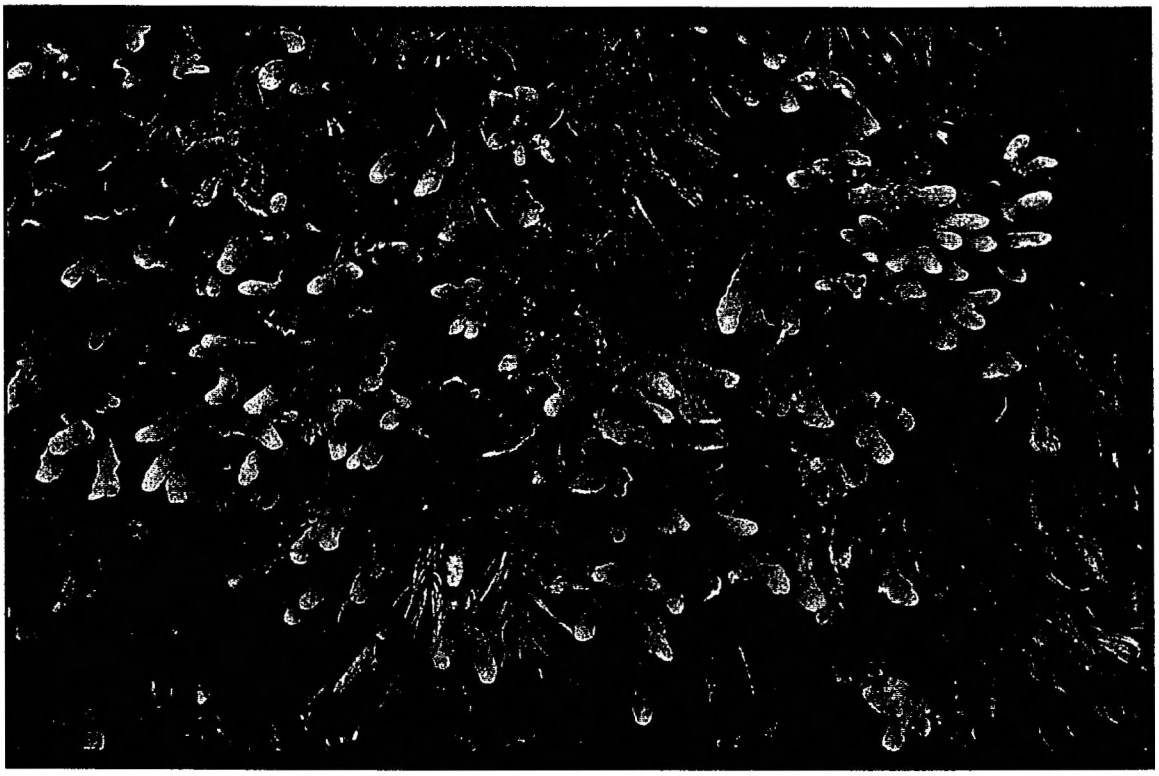
U.S. Fish and Wildlife Service
Southeast Region
Atlanta, Georgia

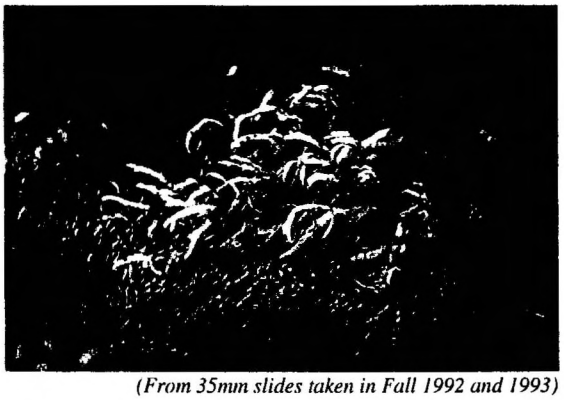
Approved: _____
Acting Regional Director, U.S. Fish and Wildlife Service

Date: September 30, 1997

Gymnoderma lineare

Great Smoky Mountains National Park, Swain County, NC





(From 35mm slides taken in Fall 1992 and 1993)

TOP - Healthy, vigorous Gymnoderma growing in moss, apothecia are black, see red circle.

LEFT - Gymnoderma thalli at a deteriorating occurrence of the lichen on a cliff.

RIGHT - Older (white) dying thalli, with incipent thalli developing underneath.

Recovery plans delineate reasonable actions that are believed to be required to recover and/or protect listed species. Plans published by the U.S. Fish and Wildlife Service are sometimes prepared with the assistance of recovery teams, contractors, State agencies, and other affected and interested parties. Plans are reviewed by the public and submitted to additional peer review before they are adopted by the U.S. Fish and Wildlife Service. Objectives of the plan will be attained and any necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not obligate other parties to undertake specific tasks and may not represent the views nor the official positions or approval of any individuals or agencies involved in developing the plan, other than the U.S. Fish and Wildlife Service. Recovery plans represent the official position of the U.S. Fish and Wildlife Service **only** after they have been signed by the Director or Regional Director as **approved**. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

By approving this recovery plan, the Regional Director certifies that the data used in its development represent the best scientific and commercial information available at the time it was written. Copies of all documents reviewed in the development of the plan are available in the administrative record located at the Asheville Field Office in Asheville, North Carolina.

Literature citations should read as follows:

U.S. Fish and Wildlife Service. 1997. Recovery Plan for Rock Gnome Lichen (*Gymnoderma lineare*) (Evans) Yoshimura and Sharp. Atlanta, GA. 30 pp.

Acknowledgements

The cover illustration was used with permission from Isao Yoshimura and Aaron J. Sharp. *A Revision of the Genus Gymnoderma*. American Journal of Botany 55(5):635-640. 1968.

The color photographs of the species are on the page following the title page. The U.S. Fish and Wildlife Service thanks Eric Pauley for the top photograph and Keith Langdon for the two smaller photographs. Michael Kunze of the National Park Service is responsible for the formatting and digitizing of the page and photographs.

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EXECUTIVE SUMMARY

Current Status: *Gymnoderma lineare* is federally listed as an endangered species. It is currently known from 35 locations (26 in North Carolina, 7 in Tennessee, 1 in South Carolina, and 1 in Georgia).

Habitat Requirements and Limiting Factors: This rare lichen grows only in areas of high humidity, such as high-elevation vertical rock faces that are frequently bathed in fog or in deep gorges at lower elevations. It is threatened by collection, logging, and habitat disturbance due to heavy use by hikers and climbers. It is also indirectly threatened by exotic insect pests and possibly air pollution, which are contributing to the demise of the Fraser fir forests at higher elevations in the Southern Appalachians.

Recovery Objective: Downlisting followed by delisting.

Recovery Criteria: Rock gnome lichen will be considered for downlisting when there are at least 30 populations stable over 5 years and within protective ownership; it will be considered for delisting when there are at least 40 populations stable for a minimum of 10 years, and when all of these populations are in protective ownership as defined in the downlisting criteria on page 6.

Actions Needed:

1. Survey suitable habitat for additional populations.
2. Monitor and protect existing populations.
3. Conduct research on the biology of and threats to the species.
4. Establish new populations or rehabilitate marginal populations to the point where they are self-sustaining.
5. Investigate and conduct necessary management activities at all key sites.

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

Year	Need 1	Need 2	Need 3	Need 4	Need 5	Total
1998	20.0	7.0	49.0	30.0	5.5	111.5
1999	10.0	4.5	33.0	15.0	5.5	68.0
2000	10.0	3.5	33.0	15.0	5.5	67.0
2001	-0-	3.5	29.0	10.0	?	42.5
TOTAL	40.0	18.5	144.0	70.0	16.5	289.0

Date of Recovery: Impossible to determine at this time.

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PART I

INTRODUCTION

Gymnoderma lineare, first described by Evans (1947) as *Cladonia linearis* from material collected in Tennessee, is a squamulose lichen in the reindeer moss family. It is endemic to the mountains of North Carolina and Tennessee, where it occurs on high-elevation cliffs or in deep river gorges at middle elevations where the humidity is always high. Due to its rarity and vulnerability to threats, this species was federally listed as endangered by the U.S. Fish and Wildlife Service (Service) on January 18, 1995 (Service 1995). Rock gnome lichen is listed as threatened by the State of North Carolina (Amoroso and Weakley 1997). Tennessee does not include nonvascular plants on its list of endangered and threatened species. The single populations in South Carolina and Georgia have only recently been discovered, so neither State has added the species to its official State list yet. The International Association of Lichenologists lists this species in its "Red Listed Lichens of the World" as critically endangered (Thor 1996).

Current and Historical Distribution

Only 35 populations of rock gnome lichen are currently known to exist. [NOTE: For the purposes of this recovery plan, populations have been defined somewhat arbitrarily due to the lack of knowledge about this species' genetics and distribution mechanisms. For streamside habitats, we are defining a population to be all those individuals within the same local drainage. For cliff habitats, we are defining a population as individuals occupying the same cliff complex where they are separated from other populations by significant areas of unsuitable habitat.] Five populations are known to have been extirpated. The remaining populations are in Mitchell (two populations), Jackson (five), Yancey (four), Swain (one), Transylvania (four), Buncombe (four), Avery (two), Ashe (two), Haywood (one) and Rutherford (one) Counties, North Carolina; Greenville County (one), South Carolina; Rabun (one) County, Georgia; and Sevier (seven) and Carter (part of this one population is on the State line with Mitchell County, North Carolina) Counties, Tennessee. The reasons for the disappearance of the five extirpated populations are undocumented; however, one is believed to have been destroyed by highway construction. Most of the formerly occupied sites are subjected to heavy recreational use by hikers, climbers, and sightseers. Collectors are known to have impacted the species at several sites. In addition, the coniferous forests, particularly those dominated by Fraser fir at the high-elevation sites, are being decimated by exotic insects and possibly by air pollution. Only 7 of the remaining 33 populations cover an area larger than 2 square meters (2.4 square yards). Most are 1 meter (3.3 square feet) or less in size. It is not known what constitutes a genetic individual in this species, and it is possible that each of these small colonies or patches consists of only a single clone (Weakley 1988).

Over the past decade several of the currently extant populations have undergone significant declines (Paula DePriest, Smithsonian Institution, personal communication, 1992; Karin Heiman, Environmental Consultant, personal communication, 1992), some within as little as 1 year (Alan Smith, Mars Hill College, personal communication, 1992).

Description, Ecology, and Life History

Gymnoderma, a primitive lichen group, was considered a monotypic genus for over a century, until its revision by Yoshimura and Sharp (1968). These authors reclassified Evans' (1947) *Cladonia linearis* as *Gymnoderma lineare* on the basis of its short and solid podetia that lack symbiotic algae. *Gymnoderma lineare* is the only member of this genus occurring in North America; the other two species occur in the mountains of Japan and Eastern Asia, including the Himalayas (Yoshimura and Sharp 1968).

Gymnoderma lineare occurs in rather dense colonies of narrow straps (squamules). The only similar lichens are the squamulose species of the genus Cladonia. *Gymnoderma lineare* has terminal portions of the strap-like individual lobes that are blue-gray on the upper surface and generally shiny white on the lower surface; near the base they grade to black (unlike squamulose *Cladonia*, which are never blackened toward the base) (Weakley 1988, Hale 1979). Hale's (1979) description of the species reads as follows: "Squamules dark greenish mineral grey; lower surface white to brownish toward the tips, weakly corticated; podetia lacking but small clustered apothecia common on low tips; K plus yellow (atranorin)." Weakley further describes the species as having squamules about 1 millimeter across near the tip, tapering to the blackened base, sparingly and subdichotomously branched, and generally about 1 to 2 centimeters long (though they can be longer or shorter, depending on environmental factors). The squamules are nearly parallel to the rock surface, but the tips curl away from the rock, approaching or reaching a perpendicular orientation to the rock surface. The fruiting bodies (apothecia) are borne at the tips of the squamules and are black (contrasting to the brown or red apothecia of *Cladonia* spp.) (Weakley 1988). The apothecia are borne singly or in clusters, usually at the tips of the squamules but occasionally along the sides; these have been found from July through September (Evans 1947, North Carolina Natural Heritage Program records 1991). The apothecia are either sessile or borne on short podetia 1 to 2 millimeters in height, and the largest of these have a diameter of about 1 millimeter, with most being much smaller. The apothecia are cylindrical in shape and radial in symmetry (Evans 1947). The primary means of propagation of this lichen appears to be asexual, with colonies spreading clonally.

Gymnoderma lineare (Evans) Yoshimura and Sharp is endemic to the Southern Appalachian Mountains of North Carolina, South Carolina, Tennessee, and Georgia and occurs only in areas of high humidity, either at high elevations, where it is frequently bathed in fog, or in deep gorges at lower elevations. In Tennessee it is apparently restricted to the Great Smoky Mountains and Roan Mountain.

The rocks on which this lichen grows are of several types, including igneous, metamorphic, and metasedimentary rocks such as quartz diorite, garnet-rich biotite, muscovite and quartz schist, quartz phyllite, metagraywacke, metaconglomerate, and metarkoses containing feldspar and chlorite, amphibole, hornblende, and feldspar gneiss (Massey *et al.* 1980).

The climate of occupied sites is described by Morgan (1980) as being:

> . . . a boreal microthermal climate . . . cooler and wetter than local and sectional climate. The general area has warm and moderately wet summers, moderately cold and moderately dry winters, and a short freeze-free period.

Annual rainfall at four occupied sites has ranged from 41 to 102 inches, with snowfall ranging from 4 to 101 inches. Average winter temperatures range from 5 degrees to 48 degrees Fahrenheit, and average summer temperatures range from 49 degrees to 73 degrees Fahrenheit (National Climatic Data Center, Asheville, North Carolina).

Gymnoderma lineare is primarily limited to vertical rock faces where seepage water from forest soils above flows at (and only at) very wet times. It appears that the species needs a moderate amount of light but that it cannot tolerate high-intensity solar radiation. It does well on moist, generally open, sites with northern exposures, but needs at least partial canopy coverage where the aspect is southern or western. It is almost always found growing with the moss *Andreaea* (and/or *Grimmia*) in these vertical intermittent seeps. This association makes it rather easy to search for, due to the distinctive reddish brown color of *Andreaea* (black with *Grimmia*) that can be observed from a considerable distance (Weakley 1988). Most populations occur above 5,000 feet elevation. Other common associates of this species include *Huperzia appalachiana (=selago)*, *Stereocaulon* sp., *Scirpus cespitosus*, *Carex misera*, *Rhododendron* spp., *Saxifraga michauxii*, *Krigia montana*, *Heuchera villosa*, *Geum radiatum* (federally endangered) and sometimes *Juncus trifidus* and *Houstonia purpurea* ssp. *montana* (federally endangered). The high-elevation coniferous forests adjacent to the rock outcrops and cliffs most often occupied by the species are dominated by red spruce (*Picea rubens*) and a Federal species of concern, Fraser fir (*Abies fraseri*), with northern hardwoods such as sugar maple (*Acer saccharum*), yellow birch (*Betula alleghaniensis*), mountain maple (*Acer spicata*), mountain ash (*Sorbus americanus*), and beech (*Fagus grandifolia*) mixed in.

Very little specific information is available on the life history and population biology of rock gnome lichen. The growth rates and distribution mechanisms for this species are entirely unknown. What constitutes a genetic individual is also unknown.

Threats and Population Limiting Factors

Although some populations are declining and vanishing for reasons that are, in many cases, not clearly understood, there are several major threats to the remaining lichen populations. Five historically known populations of this species have been completely extirpated. The reasons for the disappearance of the species at most of these sites are undocumented; however, one is believed to have been destroyed by highway construction. Most of the formerly occupied sites are subjected to heavy recreational use by hikers, climbers, and sightseers. In addition, the coniferous forests, particularly those dominated by Fraser fir at the high-elevation sites, are being decimated by the balsam wooly adelgid, an exotic insect pest, and possibly by air pollution. Widespread mortality of mature fir due to the balsam wooly adelgid has resulted in locally drastic changes in microclimate, including desiccation and increased temperatures.

Numerous lichen species are known to be sensitive to air pollution, especially sulfates (Lawrey 1987, Nash and Sigal 1979, Pearson and Rodgers 1982, Puckett 1976, St. Clair 1987, Sigal and Taylor 1979). Documented declines of lichen species have been recorded in the forests of Europe and nearby large industrial cities around the world. Martin and Noble (1996) collected small amounts of *G. lineare* in 1993 and 1994 and performed analyses on the chemical composition of the tissue. Elemental analysis of *G. lineare* had concentrations lower than those found in other lichen species near large industrial areas. Nevertheless, the results indicate that those *G. lineare* colonies in the poorest health had a higher content of sulfur compounds than colonies which appeared to be healthy. Furthermore, the species appears to have specific environmental needs. For example, the pH limit is narrow (4.8 to 5.6), and any decrease in the pH of the air may cause declines in the health of *G. lineare* (Martin and Noble 1996). In 1993 the estimated pH of the rainfall where this lichen is found ranged between 4.3 and 4.5 (Southern Appalachian Man and the Biosphere [SAMAB] 1996). Deposition of sulfates in the Southern Appalachians is among the highest in the United States. Average wet deposition values range between 25 and 34 kg/ha/year (SAMAB 1996) where *G. lineare* is found. Though the wet deposition values are high, this estimate may be two to three times higher when sulfates from dry deposition and cloud water are also included. Therefore, total sulfate deposition to *G. lineare* may range between 50 and 100 kg/ha/year (SAMAB 1996). The initial research indicates there is a high likelihood that current and previous air pollution levels, especially from sulfates, may be contributing to the decline of this species (Bill Jackson, U.S. Forest Service, personal communication, 1997).

In addition to the threat of the balsam wooly adelgid to the Fraser fir, there are more impending threats to associated tree species. The hemlock wooly adelgid, another exotic insect pest, is moving southward from its point of introduction, with the potential for killing all the hemlocks within its path. In the Shenandoah National Park in Virginia, there is now scarcely a single adult hemlock that is not infested with the adelgid in the 300-square-mile area of the park. The insect was reported in northern North Carolina in

1995 (Jim Brown, U.S. Forest Service, personal communication, 1995). The loss of the hemlocks from the riparian zones of Southern Appalachian streams could drastically alter the microclimate of these sites to the detriment of the rock gnome lichen and a number of other species. Several other exotic pests or diseases threaten the tree species that shelter some rock gnome lichen sites, including beech bark disease and the European mountain ash sawfly.

The continued existence of this species is also threatened by trampling and associated soil erosion and compaction; other forms of habitat disturbance due to heavy recreational use of the habitat by hikers, climbers, and sightseers; as well as by development for commercial recreational facilities and residential purposes. It is also potentially threatened by logging, collectors, and directly or indirectly by air pollution.

Only 8 of the remaining 35 populations cover an area larger than 2 square meters. Most are 1 meter or less in size. It is unknown what constitutes a genetic individual in this species, and it is possible that each of these small colonies or patches consists of only a single clone (Weakley 1988). Over the past decade several of the currently extant populations have undergone significant declines (DePriest, personal communication, 1992; Heiman, personal communication, 1992), some within as little as 1 year (Smith, personal communication, 1992). Although all but five of the remaining populations are in public ownership, many continue to be impacted by collectors, recreational use, and environmental factors. Although no populations are known to have been lost as a result of logging operations, it is interesting to note that most of the remaining stream corridor populations occur in areas of old-growth forest.

Conservation Efforts

In North Carolina, where most of the remaining populations survive, the Natural Heritage Program, The Nature Conservancy, and the Fish and Wildlife Service are working with landowners to ensure the protection and management of rock gnome lichen sites. The Nature Conservancy, which owns parts of two sites in North Carolina, is monitoring and protecting those populations by limiting the number of visitors. Populations located on Blue Ridge Parkway land in North Carolina are being monitored and protected by the National Park Service. In Tennessee, the National Park Service (Great Smoky Mountains National Park) is monitoring and protecting its populations from collection and trampling and has restricted access to one of the most vulnerable sites to protect it from overuse (this latter site is habitat for two other endangered species, in addition to the lichen). The National Park Service is also taking this lichen into consideration during a major trail rehabilitation project planned for 1998 and 1999. The U.S. Forest Service is attempting to protect populations on the Pisgah and Nantahala National Forests by avoiding occupied sites when constructing new recreational facilities and by erecting barriers to minimize trampling on heavily used sites. Although several techniques have been tried, this latter problem is a difficult one to effectively control without compromising the aesthetics of

some of the more scenic public recreation areas on the national forests and national parks. The U.S. Forest Service is also participating in the rangewide monitoring program coordinated by the Service. The U.S. Forest Service, National Park Service, and the Fish and Wildlife Service have cooperatively funded investigations of the lichen's response to air pollution at different sites.

PART II

RECOVERY

A. Recovery Objectives

The goal of the Fish and Wildlife Service and other conservation agencies is to provide protection and recovery of this and other threatened and endangered species to the point where they no longer need the protection of the Endangered Species Act and can be removed from the Federal list. This recovery objective is considered an interim goal because of the lack of data on biology and management requirements of the species. As new information is acquired, the estimate of populations required for the species' survival may be readjusted. The recovery objective for rock gnome lichen will be reassessed at least annually in light of any new information that becomes available.

Rock gnome lichen (*Gymnoderma lineare*) will be considered for downlisting when at least 30 populations are stable over 5 years (not more than a 10-percent cumulative decline in coverage at each stable population and no extirpation of other populations over the 5-year monitoring period) and these 30 populations are in protective ownership (either on public land, such as parks and forests, where the managing agency is providing continuous monitoring and protection for the species, or on private land, where a long-term protection/management agreement with the owner is in place). The species will be considered for delisting when at least 40 populations are stable for a minimum of 10 years (not more than a 10-percent cumulative decline in coverage at any one of the stabilized populations and no extirpation of other populations over the 10-year monitoring period), and all these populations are in protective ownership as defined in the downlisting criteria.

The first step toward recovery will be protection and management of all extant populations to ensure their continued survival. Little is known about the life history and habitat requirements of this species. Therefore, it will be necessary to conduct detailed demographic studies and ecological research for the purpose of gaining the understanding needed to develop appropriate protection and management strategies. The ultimate effects of various kinds of habitat disruption must be determined and, if necessary, prevented. Active management required to ensure continued survival and vigor must be defined and carried out.

B. Narrative Outline

1. **Protect existing populations and essential habitat.** Only 33 populations of rock gnome lichen are currently known to exist, all within the States of North Carolina, South Carolina, Georgia, and Tennessee. Until more is known about the species' biology, genetic diversity, and specific habitat requirements and about the measures necessary to protect the integrity of occupied sites, all existing populations should be protected. The long-term survival of 40 populations is believed to be essential to the recovery of the species as a whole.

   1.1 **Develop interim research and management plans in conjunction with landowners.** Little is known about specific management practices necessary to ensure the long-term survival of this species. Therefore, immediate emphasis will be on protection (e.g., prevention of site alteration), in cooperation with the landowners, until appropriate management procedures have been developed through research. Where trampling or other forms of habitat degradation pose an immediate threat to the species, immediate protection measures (e.g., redesigning or rerouting of trails, etc.) should be initiated. Pre- and post-management demographic studies should provide important insights into management needs.

   1.2 **Search for additional populations.** Although several intensive searches for the species have been conducted within historic habitat, a thorough, systematic effort to locate additional populations is still needed (very small populations are easily missed in less intensive efforts). Searches should be preceded by an examination of geological and topographic maps and aerial photographs to determine potential habitat and to develop a priority list of sites to search. The species seems to favor high-elevation cliff faces as well as mid-elevation streams with large boulders and little or no history of fires, clear-cut logging, or recent extensive landslides. Rock types that are ultramafic or have some degree of mafic component should be searched first, since the most robust populations of spreading avens (a rare species often associated with rock gnome lichen) are on these rock types (Susan Wiser, University of North Carolina at Chapel Hill, personal communication, 1991). Many of the areas that may support additional populations of the species consist of vertical cliff faces, which will require the utilization of experienced rock climbers. A master database should be maintained, containing maps of areas that have been searched with negative results, as well as locations of known and newly discovered populations, so that efforts are not duplicated (see Data Sheet #1 in the Appendix). The use of GIS modeling, based on site characteristics, geology, disturbance history, etc., should be investigated as an aid to fulfilling this task and to assist with possible reintroductions in the future, as described in Task 2.7.

   1.3 **Determine habitat protection priorities.** Because of the small number of existing populations and the pervasive threats to the habitat, it is essential to protect as many populations as possible. However, efforts should be

concentrated first on the sites in protective ownership, or where current private landowners are cooperative, and where the largest and most vigorous populations occur. Except for threats from air pollution and uncontrollable exotic organisms, potential success of recovery efforts is high on lands administered by the National Park Service and the U.S. Forest Service. Protection is mandated on these lands by Federal law, and cooperation has already been established. Ownership by The Nature Conservancy similarly assures protection from all threats other than air pollution and forest decline due to exotic pests.

1.4 **Evaluate habitat protection alternatives.** Effective protection should be obtained for as many existing populations as possible. Fee simple acquisition or conservation easements provide the greatest degree of protection. However, it is unknown as yet how much buffer land around each population is necessary to protect the integrity of occupied sites. Protection through management agreements or short-term leases may provide adequate short-term protection but should only be considered as intermediate steps in the process of ultimately providing for permanent protection. Short-term protection strategies may be necessary if private landowners are not interested in, or monies are not available for, the acquisition of conservation easements or fee simple title. Agreements with adjacent landowners should be developed to prevent inadvertent adverse alterations of the habitat. Fee simple acquisition will be pursued only on a willing-seller basis.

2. **Determine and implement management necessary for long-term reproduction, establishment, maintenance, and vigor.** Protection of the species' habitat is the obvious first step in ensuring its long-term survival, but this alone may not be sufficient. Habitat management may be necessary to allow the species to perpetuate its life cycle over the long term. However, since very little is known about this species, information on its genetic diversity, population biology, and ecology is necessary before effective management guidelines can be formulated and implemented.

2.1 **Determine population size and stage-class distribution for all populations.** Population size and stage-class distribution data are essential to predicting what factors may be necessary for populations to become self-sustaining (Menges 1987). Such data are needed for the existing populations and for any newly discovered populations. This task should be combined with the work described under Task 1.2. This will ensure that funds are utilized in the most efficient manner.

2.2 **Study abiotic and biotic features of the species' habitat.** An understanding of the nature of the habitat occupied by the species is essential to the long-term survival and recovery of rock gnome lichen. It is currently unknown how habitat for this species is created or maintained. Investigation should focus on community dynamics, while including species-specific work. Monitoring studies should include populations within a wide range of habitats,

both altered and undisturbed. Permanent plots should be selected and established to determine the relationship between abiotic factors (such as rock substrate type and pH, substrate movement in fluvial populations, soil moisture content and pH, and light intensity) and biotic factors (such as reproduction and degree of competition and predation). This information is necessary to determine if active management is needed to ensure the continued vigor of existing populations and to select good sites for restoration or reintroduction. Research will be necessary to determine the consequences of habitat desiccation due to drought and to loss of adjacent forest communities. Particularly for the populations occupying vertical cliff faces, the death of the large older firs has left a sunny void that will not be filled by regenerating seedlings for many years.

Relationships with competing species must be investigated. Rock gnome lichen is a successional pioneer, like many lichens, found only on bare rock in areas with some exposure (but usually not full exposure) to direct sunlight. The rather abrupt die-off of mature firs in the vicinity of rock gnome lichen populations may adversely affect this rare species in the long run as microclimate becomes hotter and drier. Severe declines noted in recent years at several high-elevation rock face sites have often been in areas where the adjacent fir-dominated forest had died.

The decline of the mature forest at many of the remaining sites poses a number of threats, either directly or indirectly. The rather sudden loss of anchoring trees on steep slopes can compromise the integrity of the underlying soil, contributing to catastrophic landslides. Also, the unstable nature of rock types, particularly in the Great Smokies, has led to landslides. Populations within protected areas (such as national parks) that are not otherwise subject to serious threats can thus be lost. For instance, probably the largest remaining population exists at one stream site in the Great Smoky Mountains National Park, yet this entire site could be wiped out by a single large-scale landslide (technically termed "debris slide"). According to Art Schultz (U.S. Geological Survey, personal communication, 1996), "The area in the vicinity of Mt. LeConte has the largest block colluvial deposits in the eastern United States, south of the glacial limits," which makes this a very landslide-prone landscape.

Continued research is needed on the role that air pollution is having on the species, particularly to determine the effect of sulfates and other anions. Other recovery strategies may not improve the status of the species if acidic deposition is the primary factor in the species' decline and/or death. Additional samples of tissue and substrate may need to be collected for future studies. Current estimates are that three to five samples per colony will need to be taken from 10 to 15 populations. Concurrent studies should also include an analysis of compounds found in lichen tissue, and further work should be conducted to describe the structure of *G. lineare* at the colony and population level.

The effects and exact interactions between this species and potential competitors are unknown, as is the relationship between *Gymnoderma lineare* and other plant and animal species that may be essential to its survival.

2.3 Conduct long-term demographic studies. Long-term systematic monitoring of populations and site conditions, including the type and status of tree species that may be providing shade or protecting the sites from heavy run-off, is crucial for detecting changes in rock gnome lichen populations. Declines appear to be happening rapidly in some cases, and when the lichens fall or are blown off the rock, there is no evidence left of their existence. Long-term demographic studies, using permanent plots, should be initiated as soon as possible (see the Appendix for monitoring protocol). What constitutes an individual of this species has not yet been defined (see Task 2.7). Plots should be visited annually, preferably by the same person, for at least 5 consecutive years. The locations of individual clumps should be mapped or photographed, and the data collected should include overall clump size. Larger plots surrounding each of the smaller, more intensively measured and mapped plots should be monitored for the establishment of new clumps. Any changes in the habitat within each plot (loss of the adjacent forest, soil disturbance, increases or decreases in light intensity, pH, moisture, etc.) should be noted at each visit. Investigations should be made of image-processing technologies to accurately determine cover in individual colonies and to establish greater precision in detecting changes over time. Growth rates of thalli and lateral growth rates of individual patches need to be determined.

2.4 Determine the effects of past and ongoing habitat disturbance. Establishment and long-term monitoring of permanent plots may be the most effective means of assessing the effects of disturbance. Appropriate methodology for this must be determined but will likely include the measurement of many of the parameters specified in Tasks 2.2 and 2.3.

2.5 Define criteria for self-sustaining populations and develop appropriate habitat management guidelines based upon the data obtained from Tasks 2.2 through 2.4. There is currently insufficient data to determine what this species requires in order for populations to be self-sustaining. Research as described under Tasks 2.2 through 2.4 should provide the information needed to protect and manage occupied habitat so that the continued survival of healthy populations is assured.

2.6 Implement appropriate management techniques as they are developed from previous tasks. Where the large-scale death of the fir forest has left rock-face sites without shade, the possibility of replanting spruce (which is not subject to the balsam wooly adelgid) should be investigated. Once this technology has been thoroughly researched and proven to be effective for the entire community, it should be considered for sites occupied by rock gnome lichen. The response of this species to such interventions should be intensively monitored.

2.7 **Develop techniques and reestablish populations in suitable habitat within the species' historic range.** Techniques for the propagation and reestablishment of this species must be developed. Once this has been done, movement of plants from very threatened sites (including extremely desiccated habitats) to sites with spruce and/or better conditions should be considered. Genetics studies to compare populations and to define what constitutes an individual within a population should be undertaken once this technology has been developed. However, no sampling should be done from extremely small populations unless the technology is developed for nondestructive sampling (such as clipping small bits from the ends of thalli where the tissue might quickly regrow).

Cultivation techniques should be summarized and disseminated to appropriate organizations and individuals. Reintroduction efforts will be conducted in cooperation with knowledgeable personnel at private nurseries, botanical gardens, and the Center for Plant Conservation. Transplant sites must be closely monitored to determine success and to adjust methods of reestablishment.

It is crucial that the causes of recent declines be identified and alleviated before large-scale reintroduction efforts are undertaken.

3. **Maintain and expand cultivated sources for the species and provide for the long-term maintenance of selected populations in cultivation.** Maintaining the genotypes of small, isolated populations in cultivation should be of high priority. The techniques for doing this are currently unknown and should be investigated.

4. **Enforce laws protecting the species and/or its habitat.** The Endangered Species Act prohibits the taking of this and other endangered species from Federal land without a permit and also regulates trade. Section 7 of the Act provides additional protection of the habitat from impacts related to federally funded or authorized projects. In addition, for listed plants, the 1988 amendments to the Act prohibit: (1) their malicious damage or destruction on Federal land; and, (2) their removal, cutting, digging, damaging, or destroying in knowing violation of any State law or regulation, including State criminal trespass law.

   Rock gnome lichen is listed as threatened in North Carolina, where State law prohibits the taking of the species without a permit and the landowner's written permission and regulates trade in the species (North Carolina General Statute 19-B, 202.12-202.19). The species is not listed in Tennessee because it is a nonvascular plant.

5. **Develop materials to inform the public about the status of the species and the recovery plan objectives.** Public support for the conservation of rock gnome lichen could play an important part in encouraging landowner assistance and conservation efforts. This is especially true for the populations that occur in areas

being adversely affected by expanding development of resorts and commercial recreation facilities. Informational materials should not identify the plant's locations so as not to increase the threat of taking.

The Southern Appalachian Mountain Initiative (SAMI) and similar groups should be informed about the effects of air pollution on *G. lineare*. SAMI is a cooperative of eight State air pollution control agencies working with Federal land managers and industry, utility, and environmental representatives to reduce air pollution impacts to natural resources at Class I areas (such as the Great Smoky Mountains National Park and Joyce Kilmer/Slickrock Wilderness) and other areas of concern. Locations where the lichen may occur may be considered by SAMI as "areas of concern." If SAMI is successful, emission management options implemented beyond the Clean Air Act Amendments of 1990 may result in enough sulfate reductions to improve the health and survival of the species (Jackson, personal communication, 1997).

5.1 **Prepare and distribute news releases and informational brochures.** News releases concerning the status and significance of the species and recovery efforts should be prepared and distributed to major newspapers in the range of the species, as well as to smaller newspapers in the vicinity of the species' habitat. On public land, interpretive displays and brochures should be developed, focusing on the fragile nature of this rare plant's habitat.

5.2 **Prepare articles for popular and scientific publications.** The need to protect the species in its native habitat and cooperation among local, State, and Federal organizations and individuals should be stressed. Scientific publications should emphasize additional research that is needed and solicit research assistance from colleges and universities that have conducted studies on this or closely related species.

6. **Annually assess the success of recovery efforts for the species.** Review of new information, evaluation of ongoing actions, and redirection, if necessary, is essential for assuring that full recovery is achieved as quickly and efficiently as possible.

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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

ES - Endangered Species Division, U.S. Fish and Wildlife Service.
FS - U.S. Forest Service.
FWS - U.S. Fish and Wildlife Service.
LE - Law Enforcement Division, U.S. Fish and Wildlife Service.
NPS - National Park Service.
R4 - Region 4 (Southeast Region), U.S. Fish and Wildlife Service.
SCA - State Conservation Agencies - State plant conservation agencies in North Carolina and Tennessee: North Carolina Plant Conservation Program (North Carolina Department of Agriculture), North Carolina Natural Heritage Program (North Carolina Department of Environment, Health, and Natural Resources); Tennessee Division of Natural Heritage (Tennessee Department of Environment and Conservation); South Carolina Department of Natural Resources; and the Georgia Department of Natural Resources.

ROCK GNOME LICHEN IMPLEMENTATION SCHEDULE

Priority	Task Number	Task Description	Task Duration	Responsible Agency		Cost Estimates ($000s)			Comments
				FWS	Other	FY1	FY2	FY3	
1	2.2	Study abiotic and biotic features of the species' habitat.	5 years	R4/ES	NPS, FS, SCA	97.0	97.0	94.0	
1	4.0	Enforce laws protecting the species and/or its habitat.	Ongoing	R4/ES	NPS, FS, SCA	2.0	2.0	2.0	
1	2.5	Define criteria for self-sustaining populations and develop appropriate habitat management guidelines.	1 year	R4/ES	NPS, FS, SCA			5.0	
1	2.6	Implement appropriate management techniques as they are developed from previous tasks.	Unknown	R4/ES	NPS, FS, SCA	?	?	?	
2	1.1	Develop interim research/management plans.	2 years	R4/ES	NPS, FS, SCA	5.0	5.0		
2	1.3	Determine habitat protection priorities.	1 year	R4/ES	NPS, FS, SCA	1.0			
2	1.4	Evaluate habitat protection alternatives.	2 years	R4/ES	NPS, FS, SCA	1.0	1.0		
2	2.1	Determine population size and stage-class distribution.	5 years	R4/ES	NPS, FS, SCA	15.0	15.0	15.0	
2	2.3	Conduct long-term demographic studies.	Ongoing	R4/ES	NPS, FS, SCA	16.0	6.0	6.0	
2	2.4	Determine the effects of past and ongoing habitat disturbance.	3 years	R4/ES	NPS, FS, SCA	8.0	4.0	4.0	
2	2.7	Develop techniques and reestablish populations.	Ongoing	R4/ES	NPS, FS, SCA	20.0	10.0	10.0	

ROCK GNOME LICHEN IMPLEMENTATION SCHEDULE

Priority	Task Number	Task Description	Task Duration	Responsible Agency		Cost Estimates ($000s)			Comments
				FWS	Other	FY1	FY2	FY3	
3	1.2	Search for additional populations.	3 years	R4/ES	NPS, FS, SCA	20.0	10.0	10.0	
3	3.0	Maintain and expand cultivated sources for the species and provide for long-term maintenance of selected populations in cultivation.	3 years	R4/ES	NPS, FS, SCA	10.0	5.0	5.0	
3	5.1	Prepare and distribute news releases and informational brochures.	Ongoing	R4/ES	NPS, FS, SCA	2.0	1.0	1.0	
3	5.2	Prepare articles for popular and scientific publications.	Ongoing	R4/ES and LE	NPS, FS, SCA	1.0	0.5	0.5	
3	6.0	Annually assess success of recovery efforts for the species.	Ongoing	R4/ES	NPS, FS, SCA	0.5	0.5	0.5	

PART IV

LIST OF RECIPIENTS

The following agencies, organizations, and individuals were mailed copies of this recovery plan. This does not imply that they provided comments or endorsed the contents of this plan.

Mr. George Dodson
Environmental Planner
Department of the Air Force
77 Forsyth Street, SW., Suite 295
Atlanta, Georgia 30335-6801

*Dr. William H. Redmond
Regional Natural Heritage Project
Tennessee Valley Authority
Norris, Tennessee 37828

*Director of Stewardship
The Nature Conservancy
1815 N. Lynn Street
Arlington, Virginia 22209

*Center for Plant Conservation
Missouri Botanical Garden
P.O. Box 299
St. Louis, Missouri 63166

*Department of Botany
National Museum of Natural History
Smithsonian Institution
Washington, DC 20560

Traffic U.S.A.
World Wildlife Fund
1250 24th Street, NW., Suite 500
Washington, DC 20037

The Garden Club of America
598 Madison Avenue
New York, New York 10022

*Dr. John Warden
Department of Biology
Upper East Tennessee State University
Johnson City, Tennessee 37601

Dr. Susan H. Lathrop, Executive Director
American Association of Botanical
Gardens and Arboreta, Inc.
786 Church Road
Wayne, Pennsylvania 19087

New England Wildflower Society, Inc.
Garden in the Woods
Hemenway Road
Framington, Massachusetts 01701

*Dr. Janice Coffey Swab
Conservation Committee
American Society of Plant Taxonomists
Meredith College
Hunter Hall
3800 Hillsborough Street
Raleigh, North Carolina 27607-5298

Mr. Bob McCartney
Woodlanders
1128 Colleton Avenue
Aiken, South Carolina 29801

*Mr. Rob Gardner
Curator of Rare Plants
North Carolina Botanical Garden
University of North Carolina - Chapel Hill
CB# 3375, Totten Center
Chapel Hill, North Carolina 27599-3375

Mr. Jim Burnette, Jr.
North Carolina Department of Agriculture
Pesticide Section
P.O. Box 27647
Raleigh, North Carolina 27611

*Dr. Albert Radford
Department of Botany
University of North Carolina - Chapel Hill
Chapel Hill, North Carolina 27514

Mr. Morgan Sommerville
Appalachian Trail Conference
c/o U.S. Forest Service
P.O. Box 2750
Asheville, North Carolina 28802

Ms. Katherine Skinner, Director
The Nature Conservancy
4011 University Drive, Suite 401
Durham, North Carolina 27707

Dr. D. Lynn Cox
Executive Director
Southern Appalachian Highlands Conservancy
34 Wall Street
Asheville, North Carolina 28801

*Dr. Eugene Wofford
Curator of Herbarium
Department of Botany
University of Tennessee
Knoxville, Tennessee 37916

*Ms. Ruby Pharr
111 York Street
Morganton, North Carolina 28655

*Dr. Dan Pittillo
Department of Biology
Western Carolina University
Cullowhee, North Carolina 28723

*Dr. Richard Bruce
Highlands Biological Station
P.O. Drawer 580
Highlands, North Carolina 28741

*Dr. James Matthews
Department of Biology
University of North Carolina - Charlotte
Charlotte, North Carolina 28213

*Dr. I. W. Carpenter, Chairman
Biology Department
Appalachian State University
Boone, North Carolina 28607

Chief
U.S. Forest Service
P.O. Box 2417
Washington, DC 20013

*Ms. Linda Pearsall, Director
North Carolina Department of Environment,
Health, and Natural Resources

*Dr. James Perry, Chairman
Biology Department
University of North Carolina - Asheville
Asheville, North Carolina 28804

Mr. Edward Schell
416 Lambeth Drive
Johnson City, Tennessee 37601-1042

*Dr. Leo Collins
Forestry, Fisheries and Wildlife Division
Tennessee Valley Authority
Norris, Tennessee 37828

*Dr. Murray A. Evans
Botany Department
University of Tennessee
Knoxville, Tennessee 37916

*Dr. Bob Kral
Biology Department
Vanderbilt University
Box 1705, Station B
Nashville, Tennessee 37235

Mr. John Ramey
Forest Supervisor
U.S. Forest Service
P.O. Box 2750
Asheville, North Carolina 28802

Mr. Robert Joslin
Regional Forester
U.S. Forest Service
1720 Peachtree Road, NW., Suite 800
Atlanta, Georgia 30367

*Mr. Cecil Frost
North Carolina Department of Agriculture
Plant Conservation Program
P.O. Box 27647
Raleigh, North Carolina 27611

Mr. Hugh Morton
Grandfather Mountain, Inc.
P.O. Box 128
Linville, North Carolina 28646

Mr. John R. Taylor, Jr.
2410 Bessemer Avenue
Greensboro, North Carolina 27405

Division of Parks and Recreation
Natural Heritage Program
P.O. Box 27687
Raleigh, North Carolina 27611

*Mr. Reginald Reeves, Director
Endangered Species Division
Tennessee Department of Environment
and Conservation
401 Church Street
8th Floor, L&C Tower
Nashville, Tennessee 37243-0447

Mr. John Sharpe, Superintendent
Mount Mitchell State Park
Route 5, Box 700
Burnsville, North Carolina 28714

Mr. Gary Everhardt, Superintendent
National Park Service
Blue Ridge Parkway
400 BB&T Building
One Pack Square
Asheville, North Carolina 28801

Forest Supervisor
Cherokee National Forest
U.S. Forest Service
P.O. Box 2010
Cleveland, Tennessee 37320

Ms. Karen Wade, Superintendent
National Park Service
Great Smoky Mountains National Park
107 Park Headquarters Road
Gatlinburg, Tennessee 37738

Mr. Todd Morse
President and General Manager
Chimney Rock Park
P.O. Box 39
Chimney Rock, North Carolina 28720

*Dr. David K. Smith
Department of Botany
University of Tennessee
437 Hesler Biology Building
Knoxville, Tennessee 37996-1100

*Dr. Aaron J. Sharp
Department of Botany
University of Tennessee
437 Hesler Biology Building
Knoxville, Tennessee 37996-1100

Frank H. Neal Heirs
c/o Mr. Joe Neal
P.O. Box 505
Jefferson, North Carolina 28640

Mr. James S. Bagwell
Big Tom Wilson Preserve
Route 6, Box 838
Burnsville, North Carolina 28714

*Mr. Alan Smith
P.O. Box 887
Mars Hill, North Carolina 28754

*Mr. Jamey Donaldson
127 Carver Road
Hampton, Tennessee 37658

*Dr. Paula DePriest
Smithsonian Institution
Botany Department
Washington, DC 20560

*Dr. Sherry Pittam
The Smithsonian Institution
Department of Botany
NHB 166
Washington, DC 20560

Mr. Wayne Owen, Botanist
U.S. Forest Service
Boise National Forest
1750 Front Street
Boise, Idaho 83702

*Ms. Sylvia Duran Sharnoff and
Mr. Stephen Sharnoff
2406 Roosevelt Avenue
Berkeley, California 94703

*Dr. Bob Cook
Arnold Arboretum
125 Arborway
Jamaica Plain, Massachusetts 02130

*Dr. Peter White, Director
North Carolina Botanical Garden
University of North Carolina - Chapel Hill
CB# 3375, Totten Center
Chapel Hill, North Carolina 27599-3375

*Ms. Karin Heiman
50 Rector Branch Road
Marshall, North Carolina 28753

Ms. Debra Owen
North Carolina Department of Environment,
Health, and Natural Resources
Water Quality Section
4401 Reedy Creek Road
Raleigh, North Carolina 27607

Dr. Lonnette G. Edwards
USDAFS - SEFES
Department of Forestry
Clemson University
Clemson, South Carolina 29634-1003

Mr. Julius T. Johnson
Director of Public Affairs
Tennessee Farm Bureau Federation
P.O. Box 313
Columbia, Tennessee 38401

The Nature Conservancy
Eastern Regional Office
201 Devonshire Street, 5th Floor
Boston, Massachusetts 02110

The Nature Conservancy
Southeastern Regional Office
P.O. Box 2267
Chapel Hill, North Carolina 27514

The Nature Conservancy
50 Vantage Way, #250
Nashville, Tennessee 37228-1504

Fish and Wildlife Reference Service
5430 Grosvenor Lane, Suite 110
Bethesda, Maryland 20814

Mr. Glen Gaines
Savannah River Forest Station
P.O. Box 710
New Ellenton, South Carolina 29841

*Georgia Department of Natural Resources
Freshwater Wetlands and Heritage Inventory
2117 U.S. Highway 278, SE.
Social Circle, Georgia 30279

*Dr. Gary B. Blank
North Carolina State University
Box 8002
Raleigh, North Carolina 27695-8002

Mr. Randy C. Wilson, Section Manager
Nongame and Endangered Wildlife Program
North Carolina Wildlife Resources Commission
1142 I-85 Service Road
Creedmoor, North Carolina 27522

Mr. Al Sherk
USGS/Biological Resources Division
12201 Sunrise Valley Drive
Mail Stop 301
Reston, Virginia 20192

Mr. Robert Abernethy
Halliburton Nus Environmental Corporation
900 Trail Ridge Road
Aiken, South Carolina 29803

Mr. W. M. Baughman
Westvaco Corporation
1226 Cooper Store Road
Moncks Corner, South Carolina 29461

Environmental Protection Agency
Hazard Evaluation Division - EEB(TS769C)
401 M Street, SW.
Washington, DC 20460

Project Manager (7507C)
Environmental Protection Agency
Endangered Species Protection Program
Environmental Fate and Effects Division
Office of Pesticide Programs
401 M Street, SW.
Washington, DC 20460

U.S. Forest Service
Wildlife, Fisheries, and Range
1720 Peachtree Road, NW.
Atlanta, Georgia 30367

Dr. Lynn Wike
Savannah River Technology Center
Building 773-42A
Aiken, South Carolina 29802

Mr. John E. Cely, Coordinator
Nongame and Endangered Species
South Carolina Department of Natural Resources
P.O. Box 167
Columbia, South Carolina 29202

Ms. Alice Gustin
Publisher/Editor
Land Use Chronicle
P.O. Box 468
Riverton, Wyoming 82501

Program Manager
Division of Boating and Inland Fisheries
North Carolina Wildlife Resources Commission
Archdale Building
512 N. Salisbury Street, Room 442
Raleigh, North Carolina 27604-1188

Mr. Rich Owings
The North Carolina Arboretum
100 Frederick Law Olmsted Way
Asheville, North Carolina 28806

Mr. Larry Robinson
U.S. Natural Resources Conservation Service
1835 Assembly Street, Room 950
Columbia, South Carolina 29201

Ms. Robin Roecker
U.S. Forest Service
4931 Broad River Road
Columbia, South Carolina 29210

Mr. Fred C. Schmidt
Head, Documents Department - KW
The Libraries
Colorado State University
Fort Collins, Colorado 80523-1019

Mr. Robert Hatcher
Tennessee Wildlife Resources Agency
Ellington Agricultural Center
P.O. Box 40747
Nashville, Tennessee 37204

U.S. Forest Service
Chattahoochee-Oconee National Forests
P.O. Box 9
Blairsville, Georgia 30514

*Dr. Harriet Gillett
World Conservation Monitoring Centre
219 Huntingdon Road
Cambridge CB3 ODL
United Kingdom

***Independent Peer Reviewer**

APPENDIX

Standardized Protocol for Monitoring Rock Gnome Lichen *(Gymnoderma lineare)* on High-Elevation Vertical Rock Faces

Introduction

The standardized monitoring protocol set forth herein has been developed to systematically and consistently monitor the status of the Federally endangered rock gnome lichen (*Gymnoderma lineare*, G2S2) on high elevation vertical rock faces.[1] Scientists hypothesize that the size and vigor of rock gnome lichen populations are in decline rangewide due to the singular and/or cumulative effects of habitat loss, recreational trampling (i.e., scraping), air pollution, and declining canopy cover in surrounding forest. Permanent belt transects, photomonitoring, and field observations are employed to monitor habitat integrity, patch coverage, and general patch health over time. Initially, the monitoring program is intended to yield baseline data that will result in a range of expected norms for each monitoring parameter at various sites.

1. Goals
   - Goal 1: To continually evaluate the status and trends of rock gnome lichen populations and to "raise a red flag" if one or more populations suffer a precipitous decline over time.
   - Goal 2: To identify and evaluate current and potential stresses.
   - Goal 3: To use such information to adapt management with the ultimate purpose of maintaining population size and vigor rangewide.

2. Objectives
   1) Observe and document the general health of *G. lineare* patches at selected study sites.
   2) Determine whether the coverage of *G. lineare* within individual transects and collectively within each study site changes over time
   3) Observe and document evidence of trampling, canopy cover decline, or other noticeable environmental or anthropogenic stresses and relate to monitoring data.

Establishing Belt Transects

At each vertical cliff face, one or more belt transects should be established. Transects are always 1 m. wide but may vary in length depending upon the extent of the patch. Generally, transect length will range from 2-6 m. The following should be considered in establishing transects:

---

[1]Methodology was cooperatively developed in October 1995 at a meeting of scientists and resource managers sponsored by the U.S. Fish and Wildlife Service, Endangered Species Field Office (Asheville, NC).

[2] Standard quality assurance procedures should be followed regarding data validation and verification.

- transects should be stratified based on impact/stress level, population density, and other pertinent site characteristics (e.g., cliff face aspect, proximity to seepage).
- a minimum of 5% of the total rock gnome lichen population coverage at each site should be sampled in transects. Record the estimated percentage of total population coverage contained in the transects at each site on Data sheet #1.
- if possible, transect endpoints should extend slightly (0.25-0.5 m.) beyond the edges of a patch so that drilling and possible leaching do not impact sensitive populations and so that patch expansion or constriction along its horizontal edges can be determined.
- if possible, situate transects such that the face of the cliff that a transect crosses is relatively consistent and without significant shifts in direction.

The beginning and endpoints of each transect should be permanently marked by drilling a hole into the cliff and hammering in a silicon or epoxy-tipped, orange-painted stainless steel nail.

Monitoring Methodology

Censusing these transects requires two people. The easiest way to census the transects is for one person to hold the quadrat against the cliff and relay cover estimates to the second person, whose responsibility it is to record the data.

1. Site Characteristics

Use Data Sheet #1 to record site characteristics and field observations. Ensure that all descriptions are clear and complete! If you are unfamiliar with assessing a certain characteristic (e.g., geology of the area), leave it blank while in the field. Some of the information can be obtained from USGS quads or other information readily available at the office.

2. Coverage

The cover area of rock gnome lichen within each belt transect is determined using a 0.5m. x 0.5m. sampling quadrat. One easy method for constructing the grid is to use ½" diameter PVC pipe with holes drilled through the pipe at 5cm. intervals. PVC elbow joints can be used as quadrat corners. Fishing line is threaded through the holes along both axis's to form a 100 square grid. The squares on the top and bottom of the grid are lettered A through J, while the squares along the sides are numbered 1 through 10.

To monitor the belt transects, stretch a meter tape along the length of the transect and loop it around the two nails to form a taut transect baseline. The side of the grid with letters on it is placed along the meter tape (see Figure 1). Beginning above the baseline at the 0.0 m. point, the quadrat is placed and monitored at contiguous 0.5 m. intervals along the transect in a clockwise manner, first above and then below the meter tape. Keep the meter tape as taut as possible so that the quadrats are located consistently from year to year. If the meter tape begins to sag, tighten it up by twisting it around the endpoint nails.

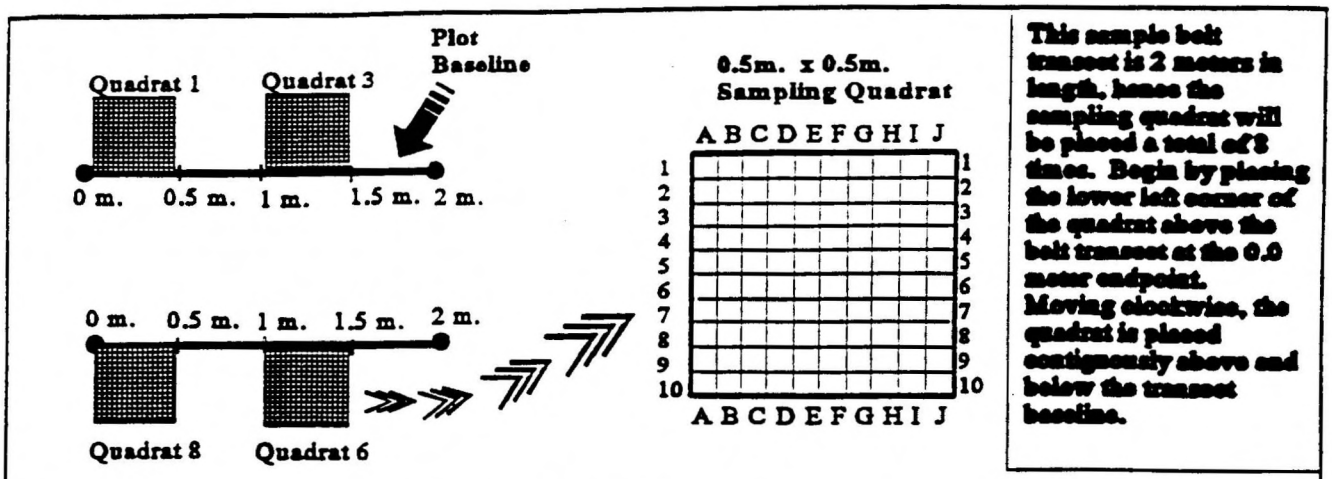

Figure 1. Illustration of how to place sampling quadrats along plot baseline.

The presence of rock gnome lichen in each grid square is estimated and recorded on graphed data sheets (Data Sheet # 2) as follows:

"X" if it occupies 76-100% of the square
"/" if it occupies 51-75% of the square
"Q" if it occupies 26-50% of the square
"T" if it occupies up to 25% of the square.

3. General Health

The general health of rock gnome lichen is recorded for each transect. General health is classified as good, fair or poor, based upon patch appearance. A patch is considered to be in "good" health if it is moist and is the normal gray-green color, and if black fruiting bodies are observed on the tips of the squamules. A patch is considered to be in "fair" health if it is slightly drier and the longer squamules are curled up and brownish. The patch is considered to be in poor health if the majority of the patch is dry, brown, and curled up (i.e., majority of patch showing signs of necrosis).

4. Photomonitoring

Habitat photos should be taken while standing at an established photopoint in front of each transect. Be sure to fill out all of the photomonitoring information (e.g., film type, lens) listed on Data Sheet #1. Using a fisheye lens, one photo should be taken facing straight out, or perpendicular, looking away from the cliff face. Record the compass bearing for the direction in which this photo was taken. Additional fisheye lens photos should be taken at compass bearings plus and minus 45° from the original direction. For example, if the compass bearing directly away from the cliff face is 27°, then the second and third photos would be taken at bearings of 72° and 342°. A second permanent photopoint should be established to photomonitor the location of any seepages with respect to the transects. Use a regular 35mm. lens to photodocument the closeness of any cliff seepages to each transect. Place some object in the photo that will give a sense of scale; for example, a meter tape would be effective.

Additionally, photos should be taken of each quadrat containing rock gnome lichen. Place the

quadrat grid against the cliff face and focus your shot solely on the quadrat. These photopoints will not be permanent, and your distance from the quadrat when taking the photo is not particularly important. Attempt to have the quadrat occupy the entire picture frame (by zooming in or out) and try not to shoot at an angle when possible. Use a flash if necessary. Make sure to record the transect and quadrat number for each photo.

Data Calculation

Each sampling quadrat square has an area of 25 cm^2. Coverage for each transect is calculated using the following equation:

$$\text{Total Coverage} = 25cm^2[\sum\text{"X"} + 0.75(\sum\text{"/"}) + 0.5(\sum\text{"Q"}) + 0.25(\sum\text{"T"})]^*, \text{ whereby}$$

$\sum$"X" is the # of squares in which *G. lineare* occupies 76-100% of the square
$\sum$"/" is the # of squares in which *G. lineare* occupies 51-75% of the square
$\sum$"Q" is the # of squares in which *G. lineare* occupies 26-50% of the square
$\sum$"T" is the # of squares in which *G. lineare* occupies up to 25% of the square

In addition, the total number of squares in which rock gnome lichen is present is recorded for each quadrat and summed for each transect.

*It is recognized that using these multipliers will result in some overestimation of coverage. However this method has been selected for consistency (it is already in use by The Nature Conservancy for their populations) and for its sensitivity in detecting population declines.

DATA SHEET # 1 - *Gymnoderma lineare* Site Description Date:

General Site Characteristics

Site/Population Location: _____

_____

_____

Quadrangle: _____ Elevation: max. _____ min. _____

Geology of the Area: _____

Forest Type: Old-growth _____ Second Growth _____ Slope Aspect: _____

Natural Community/Vegetation Type: _____

_____

Major Canopy Species: _____

_____

Major Subcanopy Species: _____

_____

Major Herbaceous/Groundcover Species: _____

_____

Evidence of Disturbance (forest disease, insect problems, fire, lightning, windthrow, tree mortality, trampling): _____

_____

Proximity to Water Source (seepage, stream): _____

Additional Site Comments: _____

Description of Colonies

Description of Colonies/Patches: _____

_____

Number of Colonies Present at the Site (Estimate if necessary): _____

Estimate of Total Coverage At Site (m^2): _____

Estimated Percentage of Site's Total Population Coverage Contained in Transects: _____

Photomonitoring

Description of Photopoints and Photos: _____

_____

_____

_____

_____

Time of Day: _____ Cloud Cover: _____

Film Type and Speed (should be Kodachrome 200 if possible): _____

Lens Type: _____ Flash Used on Photo #s: _____

Data Sheet 2: Gymnoderma lineare Transects **Page**

Study Site:
Date:
Transect #:
Transect Length:
Number of Quadrats:
General Health:
General Site Comments:

<u>Legend:</u>
4 – 76-100% of square covered
3 – 51-75% of square covered
2 – 26%-50% of square covered
1 – up to 25% of square covered

Quadrat #
Distance Along Transect (m):
Above or Below Transect:
Comments:

	A	B	C	D	E	F	G	H	I	J
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

Quadrat #
Distance Along Transect (m):
Above or Below Transect:
Comments:

	A	B	C	D	E	F	G	H	I	J
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

Quadrat #
Distance Along Transect (m):
Above or Below Transect:
Comments:

	A	B	C	D	E	F	G	H	I	J
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

Quadrat #
Distance Along Transect (m):
Above or Below Transect:
Comments:

	A	B	C	D	E	F	G	H	I	J
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

EQUIPMENT CHECKLIST FOR *GYMNODERMA LINEARE* MONITORING PROGRAM

1. To Establish Transects:

___ portable, battery-powered drill (preferably a hammer drill for added drilling power)
___ masonry drill bit
___ hammer
___ stainless steel nails (2 per transect)
___ epoxy
___ mixing utensil for epoxy
___ meter tape
___ compass

2. For Transect Monitoring:

___ 0.5m. x 0.5m. sampling quadrat (subdivided into 100-square grid, each square being 5cm. x 5 cm.)
___ meter tape
___ duct tape
___ data sheets

3. For Photomonitoring

___ 35 mm. camera
___ fish-eye lens, macro lens, regular 35 mm. lens
___ flash
___ Kodachrome 200 color film
___ labeling material (chalkboard/chalk or paper/magic markers
___ data sheets