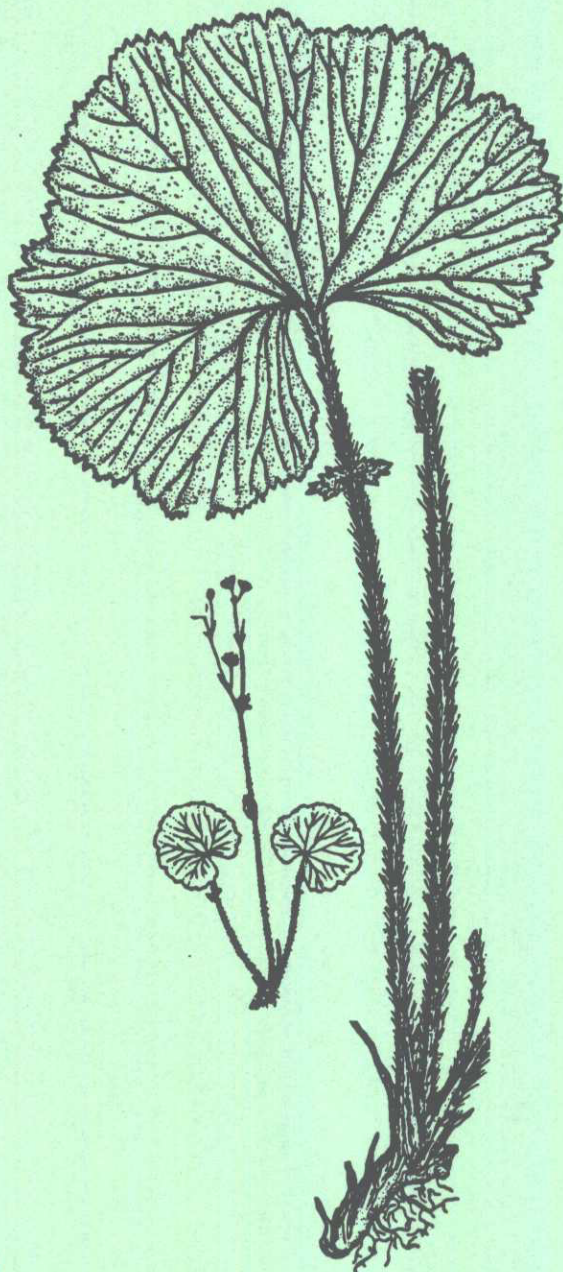


RECOVERY PLAN

Spreading Avens

(*Geum radiatum*)



U.S. Fish and Wildlife Service

RECOVERY PLAN

for

Spreading Avens (Geum radiatum) Rafinesque

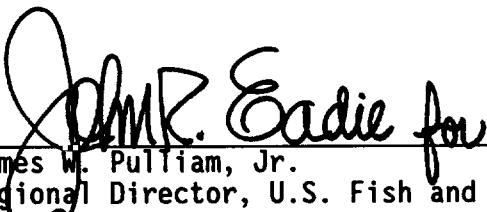
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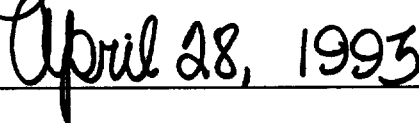
for

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

Approved:


James W. Pulliam, Jr.
Regional Director, U.S. Fish and Wildlife Service

Date:


April 28, 1993

Recovery plans delineate reasonable actions which are believed to be required to recover and/or protect the species. Plans are prepared by the U.S. Fish and Wildlife Service, sometimes with the assistance of recovery teams, contractors, State agencies, and others. Objectives will only be attained and funds expended contingent upon appropriations, priorities, and other budgetary constraints. Recovery plans do not necessarily represent the views nor the official positions or approvals of any individuals or agencies, other than the U.S. Fish and Wildlife Service, involved in the plan formulation. They represent the official position of the U.S. Fish and Wildlife Service only after they have been signed by the Regional Director or 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.

Literature citations should read as follows:

U.S. Fish and Wildlife Service. 1993. Spreading Ravens Recovery Plan. Atlanta, Georgia. 32 pp.

Additional copies of this plan may be purchased from:

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

Telephone: 301/492-6403 or
1-800/582-3421

Fees for recovery plans vary, depending upon the number of pages.

Acknowledgment:

The illustration for the cover was done by Susan Sizemore.

EXECUTIVE SUMMARY

Current Status: Geum radiatum is federally listed as an endangered species. It is currently known from 11 locations (9 in North Carolina, 1 in Tennessee, and 1 on the line between the two states).

Habitat Requirements and Limiting Factors: This rare herb is typically found growing in full sun on high-elevation cliffs, rock outcrops, and grassy balds. It is threatened by heavy recreational use, recreational and residential development, collection, and possibly by desiccation and erosion due to the forest decline associated with air pollution and introduced insects.

Recovery Objective: Delisting.

Recovery Criteria: Spreading avens will be considered for delisting when there are at least 16 self-sustaining populations that 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 of 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: 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 (in \$1,000's):

<u>Year</u>	<u>Need 1</u>	<u>Need 2</u>	<u>Need 3</u>	<u>Need 4</u>	<u>Need 5</u>	<u>Total</u>
1993	10	22.5	18	22.5	5	78.0
1994	10	4.5	18	10.5	5	48.0
1995						
1996						
1997						
1998						
1999						
2000						

DATE OF RECOVERY: Impossible to determine at this time.

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PART I

INTRODUCTION

Spreading avens (*Geum radiatum*), sometimes called Appalachian avens or cliff avens, is a rare perennial herb endemic to a few scattered mountaintops in western North Carolina and eastern Tennessee. It grows on the shallow acidic soils of high-elevation cliffs, outcrops, and steep slopes and on gravelly talus associated with cliffs, often in full sun. Due to its rarity and vulnerability to threats, the species was federally listed as endangered on April 5, 1990 (U.S. Fish and Wildlife Service 1990). Spreading avens is listed as endangered by the State of Tennessee (Somers 1989) and as endangered/special concern in North Carolina (Weakley 1991).

Current and Historical Distribution

Only 11 populations of spreading avens are currently known to exist. Five populations are known to have been extirpated. The remaining populations are in Ashe, Avery, Transylvania, Watauga, Mitchell, Buncombe, and Yancey Counties, North Carolina, and Sevier and Carter Counties, Tennessee. The reasons for the disappearance of the five extirpated populations are undocumented. However, most of the sites have been subjected to heavy recreational use by hikers, climbers, and sightseers. Over the past decade, at least four of the currently extant populations have undergone significant population declines (ranging from 67 percent to 96 percent); four others have suffered declines of lesser magnitude. Only three are known to have maintained relative stability during the same period.

Description, Ecology, and Life History

Spreading avens is 1 of 18 North American species in the genus *Geum*. Described by Andre Michaux in 1803 from material collected in North Carolina (1974), *Geum radiatum* is a perennial herb with basal rosettes of leaves arising from horizontal rhizomes. Bright yellow actinomorphic flowers are borne in an indefinite cyme atop a stem 2 to 5 decimeters tall. Flowering occurs from June through September; fruiting occurs from August through October. The fruit is a hemispheric aggregate of hirsute achenes, 7 to 9 millimeters in diameter (Small 1903, Wofford 1989, Kral 1983, Radford *et al.* 1964, Massey *et al.* 1980). This species can be distinguished easily from other Southeastern *Geum* species by its showy yellow flowers and by the large terminal lobes and greatly reduced lateral lobes on the basal leaves (Massey *et al.* 1980, Morgan 1980). *G. radiatum*, along with the similar *G. peckii* of New Hampshire's White Mountains, is sometimes placed into the separate genus *Sieversia* (Brown 1823). Brackley (unpublished) has theorized that these species, along with *G. calthifolium* (a closely related taxon with a northern amphi-Pacific distribution), may have evolved from a single ancestral taxon that was widely distributed in the higher latitudes of North America during the pre-Wisconsin era. After the glacial retreat and the warming of the climate, the Appalachian plants were isolated in

relictual habitats and were subject to intense selection and random fixation that resulted in both groups' becoming homogenic populations. Brackley further states:

The herbaceous genera of the genus Geum are thought to have developed during the tertiary. The subgenus Acomastylis probably arose through hybridization and amphiploidy of now-extinct diploid species. The montane plants with persistent styles may be the most ancient. At some point(s) in evolution an "adaptive shift" must have occurred in the group that led from the condition of wind-borne fruits to animal dispersal mechanisms. This shift was associated with the colonization of a lowland forest habitat (Stebbins 1974). The remaining group of ancient Geum stock that survived Pleistocene glaciation is now restricted to mountainous or arctic areas.

The genus Geum, first described by Linnaeus, was based on Geum urbanum and originally included five species. Robert Brown (1823) separated those species with long straight pubescent styles into the genus Sieversia. In Bolle's 1933 classification, Geum was split into five separate genera--Sieversia, Neosieversia, Acomastylis, Erthrocoma, and Geum. Hara (1935) placed G. radiatum in the genus Parageum. Currently accepted taxonomic treatment places this species in the genus of Michaux's original description (Raynor 1952, Gajewski 1957, Robertson 1974, Brackley unpublished).

Spreading avens grows in pioneer perennial herb communities at high-elevation rocky sites, with aspects ranging from west-southwest through north-northeast (S. Wiser, University of North Carolina, personal communication, 1991), where it is exposed to direct sunlight for at least part of the day. Populations occur at altitudes ranging from 1,400 to 1,911 meters. Occupied sites at higher elevations are surrounded by spruce-fir or by northern hardwoods containing scattered spruce. The Ashe County, North Carolina, sites are surrounded by high-elevation red oak forest. Other sites are surrounded by heath and/or grassy balds, with some adjacent to balds above and northern hardwood forest below (Wiser, personal communication, 1991; Schafale and Weakley 1990).

The soils on which spreading avens grows (typic haplumbrepts, udorthents, and entisols) are generally shallow and acidic (pH 4-5), uniform, dark brown, coarse-loamy, and without distinct horizons. The soil usually collects in the cracks and crevices of the underlying rock, where it varies in depth from 2 to 36 centimeters. (In a few instances, the soil may be deeper; 36 centimeters represents the maximum capacity of the measuring instruments used.) At the Cloudland population on Roan Mountain in Mitchell County, North Carolina, the soils are atypically deep and of the Burton series (Morgan 1980). Substrate types are variable but include various 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).

The hydrology of occupied sites is generally uniform and moderately to well drained. Soils are intermittently saturated by rain, melting snow, high-elevation fogs, and downslope drainage (Morgan 1980). Consistent moisture may be one of the most important habitat requirements of this species. B. Johnson (University of Georgia, personal communication, 1991) has stated:

Most soils are almost continuously moist, often dripping wet. Many sites are often shrouded in dense fog that may make a significant contribution to available moisture and also reduce evaporation by minimizing exposure to full sunlight.

However, soils at some of the occupied sites are subject to desiccation in the summer due to their exposed positions and generally shallow depths (Wiser, personal communication, 1991).

Common associates of this species include Athyrium asplenioides, Vaccinium erythrocarpon, Sorbus americana, Abies fraseri, Picea rubens, Kriqia montana, Deschampsia flexuosa, Lycopodium selago, Leiophyllum buxifolium, Menziesia pilosa, Rhododendron catawbiense, Aster spp. (including A. divaricatus and A. acuminatus), Carex spp. (including C. misera and C. brunnescens), Paronychia argyrocoma, Scirpus cespitosus, Solidago spp. (including S. glomerata and S. roanensis), Heuchera villosa, Saxifraga michauxii, and various mosses and grasses. Some of the sites are also occupied by Liatris helleri and/or Solidago spithamea, species that are already federally listed as threatened, and by Hedyotis purpurea var. montana, which is listed as endangered. Gymnoderma lineare and Calamagrostis cainii, candidates for Federal listing, occur at some of these sites. Juncus trifidus and Huperzia selago, northern disjuncts that are uncommon in the Southern Appalachians, are also found at some of the sites.

Very little specific information is available on the life history and population biology of spreading avens. An individual plant is generally defined as a basal rosette of leaves stemming from a rhizome. These rosettes can measure up to 225 square centimeters. Usually no more than two flowering stems are produced by a rosette. New plants can be produced through sexual or asexual means. Evidence of both types of reproduction is present at some of the sites. With the genetic markers recently developed by University of Georgia researchers, it should be possible to determine the number of genotypes occurring in populations. If the number of genotypes is significantly lower than the number of individuals, concern for the long-term survival of the population would be justified (Hamrick and Godt, personal communication, 1991). As Morgan (1980) states:

One could speculate that small units relatively isolated from other units could have started from seed. Population clusters along cracks in the underlying rock would suggest that those individuals originated from rhizomes by asexual reproduction.

The relative importance of sexual and asexual reproduction to this species is unknown. Stage-class data collected by Morgan (1980) from five populations showed seedlings present at only two sites, where they made up 4.2 to 8.5 percent of the populations. Small plants, defined as having one to two leaves and being up to 2 centimeters in width, comprised from 20.1 to 31.1 percent of the observed populations. Medium plants (two to three leaves, 5 to 10 centimeters in width) constituted 31.7 to 47.7 percent of the populations, and large plants (three or more leaves, greater than 10 centimeters in width, 15 centimeters or more in height) made up 21.2 to 48.2 percent of the observed populations. The percentage of flowering plants within a population ranged from 3.4 to 21.6 percent. Such a small proportion of flowering individuals could increase the level of inbreeding due to self-fertilization (Hamrick and Godt, University of Georgia, personal communication, 1991).

Hamrick and Godt (personal communication, 1991), in their genetic analyses of spreading avens (see Tables 1 and 2), observed that there was an excess of homozygotes in all five of the populations tested, consistent with the observation that seed germination and production may be low due to inbreeding depression. However, a deficiency of heterozygotes could also be due to the patchy distribution of genotypes. If different allele frequencies occur in different sections of a population but sampling occurs across the population, there will be an apparent deficiency of heterozygotes (the Wahlund effect). This points out the need for quantitative measures of fine-scale genetic structure. Otherwise, one might erroneously conclude that inbreeding is occurring when it is not (Hamrick, personal communication, 1992).

Table 1. Genetic variation in Geum radiatum. P is the percent loci that are polymorphic, A_p is the number of alleles per polymorphic locus, and H_e is the genetic diversity or expected heterozygosity.

A. Variation within the species.

Taxa	Loci Examined	P	A_p	H_e
<u>Geum radiatum</u>	25.0	28.0	2.57	0.098
Other endemic species (n = 154)	18.0	44.0	2.99	0.110
Short-lived herbaceous species (n = 185)	16.9	43.4	2.73	0.125

B. Variation averaged across populations.

Taxa	Loci Examined	P	A_p	H_e
<u>Geum radiatum</u>	25.0	23.2	2.22	0.074
Other endemic species (n = 154)	18.0	27.3	2.58	0.076
Short-lived herbaceous species (n = 185)	16.9	28.3	2.39	0.098

Table 2. Levels of genetic diversity in populations of Geum radiatum. P is the percent loci that are polymorphic, A_p is the number of alleles per polymorphic locus, H_o is the observed heterozygosity, H_e is the genetic diversity or expected heterozygosity, and I is the mean genetic identity of the population within the other four populations.

Population	Sample Size	P	A_p	H_o	H_e	I
PX	60	28.0	2.14	0.056	0.091	0.969
RM	72	28.0	2.43	0.050	0.086	0.958
GF	48	24.0	2.33	0.049	0.066	0.947
CT	48	20.0	2.20	0.054	0.064	0.966
CG	34	16.0	2.00	0.050	0.061	0.947

Following is a summary of Hamrick and Godt's genetic work on this species (personal communication, 1991):

Five populations of Geum radiatum have been analyzed electrophoretically.... As a species, G. radiatum has less genetic diversity relative to the average short-lived herbaceous species and the average endemic species that have been electrophoretically analyzed (Table 1A). The relatively low level of genetic diversity in G. radiatum is also evident when average values of diversity are examined at the population level (Table 1B). Most (84%) of the variation found in the five populations was found within populations, with about 16% due to differences among populations. Mean genetic identity among populations was 0.958. ...the two largest populations, in terms of numbers of individuals, also had the highest percent of polymorphic loci, and the highest genetic diversity values.... In each of the five populations the observed level of heterozygosity was less than that expected with random mating. This may indicate that G. radiatum is self-compatible and that selfing or inbreeding due to matings between relatives occurs.

From a genetic standpoint the Geum population from Phoenix Mountain is the most suitable as a source of propagules for restoration work. The Phoenix population has the highest level of genetic diversity, and the highest mean genetic identity with other populations. Demographic considerations and population vigor must also be taken into consideration in determining the source population(s) used for restoration.

Morgan (1980) reported observing many insects visiting the flowers, but these were not identified. She speculates:

These large showy, yellow flowers are probably insect pollinated and attract visitors and/or pollinators by means of nectar and pollen from numerous anthers in addition to size and color of the flowers themselves.

Massey et al. (1980) also reported observations of Hymenoptera visiting the flowers. F. Brackley (Keene State College, personal communication, 1992; Brackley and Burger 1980) has observed flies on this species. Although the similar Geum peckii is known to be self-pollinating, it exhibits increased seed-set when pollinated by flies (Brackley, personal communication, 1992). Pollination studies are needed to determine which among the numerous insect visitors are truly effective at accomplishing pollination of this species. In addition, quantitative studies of the mating system based on the analysis of genetic markers could be used to estimate the degree of selfing/outcrossing.

Morgan (1980) observed that most populations showed signs of leaf damage by some unidentified insect, particularly in the latter part of the summer. This damage appeared to be minimal. One population was found to be infested with aphids, but plants appeared unaffectedly vigorous.

Hamrick (1989) and Hamrick and Godt (1989), in their investigations of allozyme diversity in plants, found that geographic range and breeding systems were the best predictors of plant genetic diversity at the population level. These authors predicted that, "Endemic species...might be expected to consist of smaller, more ecologically limited populations that have experienced population bottlenecks during their evolutionary history." Sherman-Broyles et al. (1992) state:

Species with limited geographic distributions that occur in small, isolated populations pose special problems for the conservation of genetic diversity. Both the species and its individual populations are not only susceptible to extinction but they may have also lost much of their genetic diversity due to a limited number of reproductive individuals. Recent reviews of the plant allozyme literature have shown that the geographic range of a species has a large effect on the amount of genetic diversity maintained by the species. Endemic species have fewer polymorphic loci, fewer alleles per polymorphic locus and less than 50% of the genetic diversity of more widespread species.

Genetic analysis of this species is currently ongoing in conjunction with population restorations on National Park Service lands in the Great Smoky Mountains National Park and on the Blue Ridge Parkway (Hamrick et al. 1991; Hamrick and Bratton 1990; B. Teague, National Park Service, personal communication, 1991; K. Langdon, National Park Service, personal communication, 1991). As part of this restoration effort, spreading avens (along with several other rare species) is being propagated from seed for return to sites where plants have declined or disappeared. Controlled pollination studies are also underway at several populations. Poor seed germination success and observations of decreased plant vigor in small, isolated populations could be indicative of inbreeding depression. However evidence of such depression is only circumstantial at this point (Johnson, personal communication, 1991). Since it is likely that some of the populations have gone through bottlenecks in the past, it would be enlightening to experimentally determine the species' response to severe reductions in numbers of breeding individuals. Basic research is needed on the reproductive mechanisms of spreading avens, along with continued genetic analysis of the clonal structure and of the mating system.

Threats and Population Limiting Factors

Although populations are declining and vanishing for reasons that are, in many cases, not clearly understood, destruction and adverse modification of habitat poses a major threat to the remaining avens populations. Thirty-one percent of the historically known populations have been extirpated, and only 11 populations remain. The continued existence of spreading avens and many of its rare associates is threatened by trampling and associated soil erosion and compaction due to heavy use of the habitat by recreationists such as hikers, climbers, and sightseers (Gaddy 1983, Cooper *et al.* 1977), as well as by development for commercial recreational facilities and residential purposes. Habitat on steep cliff faces may be vulnerable to rock climbers but is safe from most casual visitors. The most favorable habitat, however, may occur on relatively flat ledges at the top of cliffs and high outcrops. These sites may be particularly vulnerable to visitors (Johnson, personal communication, 1991). Since spreading avens is a mid-successional species, some of the populations may also be threatened by the encroachment of competing shrubs. Since this type of succession is ordinarily a slow process, this is not considered by most to be an immediate threat to the survival of the species (Massey *et al.* 1980, Kral 1983). Construction of new trails, other recreational improvements, significant increases in intensity of recreational use, or intensive development without regard for the welfare of this species could further threaten its continued existence. Most of the remaining populations occupy a very small total area. Six of the remaining populations have fewer than 50 plants remaining in each, with three of these having fewer than 10 plants each. Over the past decade, at least four of the currently extant populations have undergone significant population declines (ranging from 67 to 96 percent); four others have suffered declines of a lesser magnitude. Only three are known to have maintained relative stability during the same period. One of the privately-owned sites has been developed as a commercial recreation facility; development of a second site as a ski resort is currently underway. The third privately-owned site is owned in part by The Nature Conservancy and is therefore partially protected. The remaining three sites in private ownership are unprotected, with residential development currently underway at two of the sites. The five sites in public ownership are located in scenic areas that annually attract large numbers of visitors.

In recent years, dramatic declines have occurred in spruce-fir forests adjacent to spreading avens habitat. This is due, at least in part, to airborne pollution and an exotic insect, the balsam wooly adelgid. Impacts of the forest decline on this rare herb cannot be accurately assessed at this time. Even though the species is a mid-successional pioneer requiring exposure to full sunlight, the complete removal of the canopy at these high-elevation sites may result in excessive desiccation of the moist habitat occupied by the species. This theory would seem to be supported by the fact that fruiting stems have often been observed to wither before seed can be

set in populations on naturally drier sites (Morgan 1980; Massey et al. 1980; Johnson, personal communication, 1990). However, Johnson (personal communication, 1991) has observed this phenomenon at shaded sites as well. Another possibility for the premature senescence of fruiting stems is inferior or inviable embryos (due to high proportion of selfing) or disease of a fungal or viral origin. This latter possibility has potentially serious implications for transplantaion efforts between populations. In addition, at sites where all the mature trees are now dead, aggressive invading species such as Rubus spp. are starting to dominate sites where they were not formerly present, choking out other vegetation. The rhizomes of spreading avens are believed to be capable of surviving for decades (Prince and Morse 1985), but continued failure in seed production or clonal spread poses a definite threat to long-term survival and recovery of the species. Although Geum radiatum has been found to be resistant to ozone in experimental treatments (Langdon, personal communication), the direct effects of acid precipitation on this species are unknown. As stated above, existing conditions at most of the occupied sites may be indicative of low genetic variability within populations, which makes it more important to maintain as much habitat and as many of the remaining colonies as possible.

At several sites, significant declines have been noted in the past decade, in the absence of overt habitat changes. Possible explanations include inbreeding depression, desiccation due to successive drought years in the mid-1980s, or disease. Systematic research is needed to illuminate the problems and their remedies. Since many sites on public land have been severely damaged by visitors, they may provide distorted views of the habitat requirements for spreading avens (Johnson, personal communication, 1991). High priority should be given to the protection and study of the few remaining pristine sites.

Conservation Efforts

In North Carolina, where 9 of the remaining 11 populations survive, the State Natural Heritage Program, The Nature Conservancy, and the U.S. Fish and Wildlife Service are working with landowners to ensure the protection and management of spreading avens sites. The Nature Conservancy, which owns part of one site in North Carolina, is monitoring and protecting that population by limiting the number of visitors. The U.S. Forest Service is attempting to protect populations in the Pisgah and Cherokee 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 forests.

As previously mentioned, restoration efforts are underway at two severely diminished populations on National Park Service lands in the Great Smoky Mountains National Park in Tennessee and the Craggy Mountains on the Blue Ridge Parkway in North Carolina. Preliminary genetic analyses and initial transplanting experiments look promising (Johnson, personal communication, 1991).

PART II

RECOVERY

A. Recovery Objectives

Spreading avens (Geum radiatum) will be considered for delisting when there are at least 16 self-sustaining populations in existence that are protected to such a degree that the species no longer qualifies for protection under the Endangered Species Act. (see criteria below). A self-sustaining population is a reproducing population that is large enough to maintain sufficient genetic variation to enable it to survive and respond to natural habitat changes. The number of individuals necessary and the quantity and quality of habitat needed to meet this criterion will be determined as one of the recovery tasks. The populations should be distributed throughout the species' historic range.

This recovery objective is considered an interim goal because of the lack of data on the biology and management requirements of the species. As new information is acquired, the estimate of self-sustaining populations required for the species' survival may be readjusted. The recovery objective for spreading avens will be reassessed at least annually in light of any new information that becomes available.

The first step toward recovery will be the 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. Detailed demographic studies and ecological research are needed in order 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. Therefore, spreading avens shall be considered for removal from the Federal list when the following criteria are met:

1. It has been documented that at least 16 self-sustaining populations exist and that necessary management actions have been undertaken by the landowners or cooperating agencies to ensure their continued survival.
2. All of the above populations and their habitat are protected from present and foreseeable human-related and natural threats that may interfere with the survival of any of the populations.

B. Narrative Outline

1. Protect existing populations and essential habitat. Only 11 populations of spreading avens are currently known to exist, all within the States of North Carolina 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 16 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 the 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, consisting of only a few plants, 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 areas with over 1,200 meters in elevation, a west-southwest to north-northeast aspect, bare rock, a high degree of exposure, and no history of fires or landslides. Rock types that are ultramafic or have some degree of mafic component should be searched first; the most robust populations are on these rock types (Wiser, personal communication, 1991). Many of the areas that may support additional colonies or populations of the species consist of vertical cliff faces, which will require the utilization of experienced rock climbers. (The National Park Service has recently funded additional survey work on Blue Ridge Parkway lands.)

A master data base should be maintained, containing maps of areas that have been searched with negative results, as well as locations of known populations, so that efforts are not duplicated.

- 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. There is a greater potential for success with recovery efforts that occur on lands administered by the National Park Service and the U.S. Forest Service, where protection is mandated by Federal law and cooperation has already been established. Nature Conservancy ownership assures the protection of the Bluff Mountain population from all threats other than forest decline due to pollution and exotic insects.
- 1.4 Evaluate habitat protection alternatives. The greatest possible protection should be obtained for those existing populations that are considered critical to the recovery of the species. Fee simple acquisition or conservation easements provide the greatest degree of protection. However, it is not yet known 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 these 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 agreeable to, or monies are not available for, acquisition of conservation easements or fee simple title. Conservation agreements with adjacent landowners should be developed to prevent inadvertent adverse alteration of the habitat.
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 spreading avens. Currently, it is not known how habitat for this species is created or maintained. Investigations 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 soil depth and type, soil moisture content and pH, and light intensity) and biotic factors (such as reproduction, germination, 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. Some of this data has been collected at the Craggy Mountain population on the Blue Ridge Parkway and in the Great Smoky Mountains National Park (Johnson, personal communication, 1991). Additional research encompassing the known range of spreading avens, including 90 percent of the known localities for this species, is underway by Wiser (personal communication, 1991).

Research will be necessary to determine the consequences of habitat desiccation due to drought and the loss of adjacent forest communities. Also, investigation is needed to determine the cause of the arrested fruit development documented in several of the smaller populations. Possible causes for this could include severe desiccation at crucial stages of development, viral or other disease problems, inbreeding, pollution, etc. Research is needed to document the actual causes of these problems and to provide guidance as to how to stop or reverse the decline. Wherever possible, experiments should be conducted using cultivated plants (grown from collected seed), as natural populations may be too sensitive or too depauperate to be risked.

The vectors of seed dispersal should be determined and their effectiveness under different ecological and spatial conditions should be assessed. Major pollinators need to be determined. Although various bees have been observed visiting the flowers, specific species pollinators and pollination mechanisms remain unidentified. As stated by Brackley (personal communication, 1992), it is important to ascertain if seed set is enhanced by pollinators. If the plant-pollinator association is specific and the pollinator has become rare, this could have significant implications for the long-term survival of the species.

The relative importance of sexual and vegetative reproduction to the long-term survival of the species is unknown and must be determined for effective management and protection to take place. Relationships with competing species must be investigated. Spreading avens is a successional pioneer, unable to survive under the climax forest adjacent to the open areas it occupies. However, the rather abrupt die-off of mature firs in the vicinity of avens populations may adversely affect this rare herbaceous species in the long run as the microclimate becomes hotter and drier and aggressive weeds invade the habitat. The effects and exact interactions between this species and potential competitors are unknown, as is the relationship between Geum radiatum and other plant and animal species that may be essential to its survival.

- 2.3 Conduct long-term demographic studies. Long-term demographic studies should be conducted in permanent plots located within each study site established for habitat analysis. Plots should be visited annually, preferably by the same person, for at least 4 consecutive years. The locations of individual plants of all stage-classes should be mapped or photographed; data collected should include overall plant size, the number and size of leaves, inflorescence size, fruit size and number, and seed set. Larger plots surrounding each of the smaller, more intensively measured and mapped plots, should be monitored for seedling or shoot establishment. Seedlings should be mapped and measured. Within the larger plots, overall species composition should be recorded (with a cover score given to each species) so that changes in the surrounding vegetation can be determined. Any changes in the habitat within each plot (soil disturbance, increases or decreases in light intensity, pH, etc.) should be noted at each visit.

- 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. Experimental habitat management that mimics different disturbance regimes is also needed. This could be done on potential, but unoccupied, habitat using introduced plants from cultivated stock.
- 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. Currently, there is not sufficient 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.
- 2.7 Develop techniques and reestablish populations in suitable habitat within the species' historic range. Transplantation and reintroduction should be undertaken only after the genetic composition of the individual populations are known and the possibility of disease transfer has been eliminated. Restoration of populations should maximize genetic variation through the use of material from several maternal sources and by using a sufficient number of propagules (at least 50 survivors) to prevent genetic drift or inbreeding depression. Plants used for restoration should be seed-derived. Collection of seeds should not adversely affect wild populations since there seems to be little recruitment via seeds. In addition, seedlings would represent a wider array of genotypes than vegetatively propagated plants, increasing the chances of restoration success. Allozyme analyses could be used to screen seedlings meant for restoration (to identify those seedlings that are the result of selfing) so that these plants could be excluded from the restoration efforts. Techniques for the propagation and transplantation of this species 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 in order to determine success and to adjust the 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 long-term maintenance of selected populations in cultivation. Maintaining the genotypes of small, isolated populations in cultivation should be of high priority. Seed or vegetative propagules should be collected as soon as possible from all populations that are still healthy enough to tolerate such harvest. A ready source of cultivated material should ease the threat of taking from wild populations.
4. Enforce laws protecting the species and/or its habitat. Spreading avens is not currently known to be a significant part of the horticultural trade, but this could become a threat in the future. The Endangered Species Act prohibits taking of the species from Federal lands without a permit and 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 lands and (2) their removal, cutting, digging, damaging, or destroying in knowing violation of any State law or regulation, including State criminal trespass law.

Spreading avens is listed as endangered/special concern in North Carolina, where State law prohibits 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 listed as endangered in Tennessee, where State-listed plants are afforded legal protection by the Rare Plant Protection and Conservation Act of 1985, Tennessee Code Ann., Chapter 242, Sections 11-26-201 to 11-26-214, Public Acts of 1985. This statute prohibits the taking of listed species without permission of the landowner or manager and regulates commercial sale and export.

These statutes focus on regulating, but not preventing, trade in endangered and threatened species and on reducing the threat to wild populations from illicit collectors. Since spreading avens is relatively easy to propagate from seed (Johnson, personal communication, 1991), the establishment

of propagation programs and the dispersal of cultivated stock to botanical gardens and nurseries might ease the threat of taking from wild populations.

5. Develop materials to inform the public about the status of the species and the recovery plan objectives. Public support for the conservation of spreading avens 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 the 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.

- 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 within the range of the species, as well as to smaller newspapers in the vicinity of the species' habitat. On public lands, interpretive displays and brochures should be developed, focusing on the fragility 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 the 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 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

- FWS - U.S. Fish and Wildlife Service
ES - Ecological Services
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 Ecological Services Division (Tennessee Department of Environment and Conservation).
CPC - Center for Plant Conservation

IMPLEMENTATION SCHEDULE

PRIOR- ITY #	TASK #	TASK DESCRIPTION	TASK DURATION (Years)	RESPONSIBLE PARTY			COST ESTIMATES (\$000'S)			COMMENTS
				FWS		Other	FY 1993	FY 1994	FY 1995	
				Region	Division					
1	1.1	Develop interim research and management plans in conjunction with landowners.	2 years	4, 5	ES	SCA	5.0	5.0	---	
3	1.2	Search for additional populations.	3 years	4, 5	ES	SCA	20.0	10.0	10.0	
1	1.3	Determine habitat protection priorities.	1 year	4, 5	ES	SCA	1.0	---	---	
1	1.4	Evaluate habitat protection alternatives.	2 years	4, 5	ES	SCA	1.0	1.0	---	
2	2.1	Determine population size and stage-class distribution for all populations.	2 years	4, 5	ES	SCA	15.0	15.0	---	
1	2.2	Study abiotic and biotic features of the species' habitat.	5 years	4, 5	ES	SCA	10.0	8.0	8.0	

IMPLEMENTATION SCHEDULE

PRIOR- ITY #	TASK #	TASK DESCRIPTION	TASK DURATION (Years)	RESPONSIBLE PARTY			COST ESTIMATES (\$000'S)			COMMENTS
				FWS		Other	FY 1993	FY 1994	FY 1995	
				Region	Division					
2	2.3	Conduct long-term demographic studies.	5 years	4, 5	ES	SCA	16.0	6.0	6.0	
2	2.4	Determine the effects of past and ongoing habitat disturbance.	3 years	4, 5	ES	SCA	8.0	4.0	4.0	
2	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.	1 year	4, 5	ES	SCA	---	---	5.0	
2	2.6	Implement appropriate management techniques as they are developed from previous tasks.	Unknown	4, 5	ES	SCA	?	?	?	

IMPLEMENTATION SCHEDULE

PRIOR- ITY #	TASK #	TASK DESCRIPTION	TASK DURATION (Years)	RESPONSIBLE PARTY			COST ESTIMATES (\$000'S)			COMMENTS
				FWS		Other	FY 1993	FY 1994	FY 1995	
				Region	Division					
3	2.7	Develop techniques and reestablish populations in suitable habitat within the species' historic range.	5 years	4, 5	ES	SCA	---	20.0	10.0	
3	3	Develop a cultivated source of plants and provide for long-term seed storage.	3-5 years	4, 5	ES	SCA, CPC	5.0	5.0	1.0	
1	4	Enforce laws protecting the species and/or its habitat.	Ongoing	4, 5	ES	SCA	2.0	2.0	2.0	
3	5.1	Prepare and distribute news releases and informational brochures.	Ongoing	4, 5	ES	SCA, CPC	2.0	1.0	1.0	
3	5.2	Prepare articles for popular and scientific publications.	Ongoing	4, 5	ES	SCA, CPC	1.0	0.5	0.5	

IMPLEMENTATION SCHEDULE

PRIOR- ITY #	TASK #	TASK DESCRIPTION	TASK DURATION (Years)	RESPONSIBLE PARTY			COST ESTIMATES (\$000'S)			COMMENTS
				FWS		Other	FY 1993	FY 1994	FY 1995	
				Region	Division					
3	6	Annually assess success of recovery efforts for the species.	Ongoing	4, 5	ES	SCA, CPC	0.5	0.5	0.5	

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