Recovery Plan for the Spruce-fir Moss Spider

Microhexura montivaga

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

RECOVERY PLAN

for the

Spruce-fir Moss Spider (*Microhexura montivaga*)

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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. 1998. Recovery Plan for the Spruce-fir Moss Spider. Atlanta, GA. 22 pp.

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EXECUTIVE SUMMARY

Current Status: The spruce-fir moss spider is listed as endangered; no critical habitat has been designated for this species. The species is historically known from four mountain peaks in western North Carolina and one in eastern Tennessee. In North Carolina the species has been recorded from Mount Mitchell, Yancey County; Grandfather Mountain, Avery and Caldwell Counties; and Mount Collins and Clingman's Dome, Swain County. In Tennessee the species has been recorded only from Mount LeConte in Sevier County.

Small, relic populations of *Microhexura montivaga* still survive on Grandfather Mountain in North Carolina and on Mount LeConte in Tennessee. However, suitable habitat for the spider appears to be limited and highly threatened, particularly on Grandfather Mountain. The Mount Mitchell population is believed to be extirpated; a portion of the Mount LeConte population that was associated with the mature spruce-fir forest appears to have been extirpated; and both the Mount Collins and Clingman's Dome populations, if still present, are extremely small, with only one spruce-fir moss spider having been found at each of these two sites during surveys conducted in 1991. Habitat at all four of these sites has been severely degraded.

Habitat Requirements and Limiting Factors: The species' typical habitat appears to be associated with moist, well-drained moss mats growing on rocks and boulders in well-shaded situations in mature high-elevation conifer forests dominated by Fraser fir, *Abies fraseri*, often with scattered red spruce, *Picea rubens*. These forests are deteriorating rapidly, primarily because of mortality of the fir due to balsam woolly adelgid (an exotic insect pest) infestations and possibly air pollution and other factors not yet fully understood. The spider, and possibly its prey base, requires situations of high and constant humidity. The loss of forest canopy leading to increased light and decreased moisture on the forest floor (resulting in desiccation of the moss mats) appears to be the major threat to the spruce-fir moss spider's continued existence.

Recovery Objective: Delisting.

Recovery Criteria: Downlist from endangered to threatened status when the following criteria are met: (1) through protection and enhancement of existing populations and successful reestablishment or discovery of additional populations, a total of four distinct viable populations exist within a significant portion of the species' historic range; (2) each of the four populations show evidence of successful reproduction; (3) all four populations and their habitats are protected from present and foreseeable threats; and (4) all four populations remain stable or increase over a period of at least 15 years.

Delist when the following criteria are met: (1) through the protection of both existing populations and the successful establishment or discovery of additional populations, a

total of six distinct viable populations exist within a significant portion of the species' historic range; (2) each of the six populations shows evidence of successful reproduction; (3) all six populations and their habitats are protected from present and foreseeable threats; and (4) all six populations remain stable or increase over a period of at least 15 years.

Actions Needed:

1. Protect existing populations and essential habitat.
2. Search for additional populations and/or habitat suitable for reintroduction efforts.
3. Develop artificial holding and propagation techniques and, if feasible, establish captive populations.
4. Determine the feasibility of augmenting extant populations and reestablishing populations within the species' historic range and reintroduce where feasible.
5. Develop and implement cryogenic techniques to preserve the species' genetic material.
6. Develop and implement a program to monitor spruce-fir moss spider population levels and habitat conditions at each of the sites.
7. Annually assess the overall success of the recovery program and recommend actions (changes in recovery criteria, continue to protect, implement new measures, other studies, etc.).

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

Year	Need 1	Need 2	Need 3	Need 4	Need 5	Need 6	Total
1999	26.5*	6.0	10.0	10.0	5.0	2.0	59.5*
2000	31.5*	6.0	10.0	5.0	2.0	---	54.5*
2001	26.5*	6.0	1.0	5.0	2.0	2.0	42.5*
TOTAL	84.5*	18.0	21.0	20.0	9.0	4.0	156.5*

*Habitat improvement costs needed for the species' management will not be known until the magnitude of specific threats and measures for eliminating them are determined through research.

Date of Recovery: The delisting and downlisting dates cannot be estimated at this time. A time period of at least 15 years is likely necessary in order to document the stability of populations. However, this number is dependent on determining the life span of the species.

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PART I

INTRODUCTION

The spruce-fir moss spider, *Microhexura montivaga* Crosby and Bishop, is a rare and remarkable species living in an equally remarkable community--the high-elevation spruce-fir forests of the Southern Appalachian Mountains. These high-elevation forests are dominated by Fraser fir, *Abies fraseri* (Pursh.) Poir., and red spruce *Picea rubens* Sarg., and have a distinct affinity for the northern conifer forests centered in Southeastern Canada. The southern spruce-fir forest is separated from the northern forest by a considerable distance and is broken up into a number of mountaintop "islands." Both the northern and southern spruce-fir forests most likely represent portions of a common ancestral association that occupied a southern range ahead of the Labrador ice sheet. The northward retreat of the spruce-fir forest at the end of the Ice Age isolated small populations on mountaintops in the Southern Appalachians. Today the southern spruce-fir association is characterized by an abundance of endemic species, among which the Fraser fir is prominent, and by other species disjunctly distributed between the northern and southern forests. This characterization appears to be true across all taxonomic lines and results in a unique and fascinating association providing a tremendous and largely unrealized scientific resource and a wealth of diversity.

One of the smallest known mygalomorphs, *Microhexura montivaga,* is arguably the most distinctive of the known spiders of the southern spruce-fir forest. It was discovered in 1923 (Crosby and Bishop 1925) by sifting mosses at the summit of Mount Mitchell in the Black Mountains of North Carolina, the highest point in Eastern North America. It was found to belong to a family of mygalomorph spiders, the Dipluridae, which is otherwise composed of large tropical and subtropical spiders. Mygalomorph spiders are members of the primitive spider suborder Mygalomorphae and are sometimes referred to as tarantulas due to the inclusion of the large hairy spiders of the family Theraphosidae. *Microhexura idahoana* Chamberlin and Ivie, found in the Pacific Northwest, is the only other species in the genus and is similar in habits to *M. montivaga*. After publication of the original description, almost nothing more was learned about the spider until 1977 when *M. montivaga* was essentially rediscovered at the type locality by Drs. Frederick Coyle and William Shear. The subsequent work (Coyle 1981, Coyle 1985) represents the bulk of what is presently known of the biology and behavior of the spider.

In 1989 a survey of the spiders of the high-elevation forests of the Great Smoky Mountains National Park revealed that populations of *M. montivaga* had declined dramatically since the work reported by Coyle only a few years earlier (Harp 1991, 1992). The most obvious reason for the decline was the general decline of the Fraser fir due to the apocalyptic ravages of an imported insect, the balsam wooly adelgid, *Adelges piceae* Ratzeburg (Busing *et al.* 1988). A concerted effort was then made to assess the status of *M. montivaga* in the Great Smoky Mountains National Park (Harp 1991). The results of these surveys revealed that the spider was in significant decline and nearly extinct

throughout much of its reported range. Because nearly three-fourths of the spruce-fir forest is found within the boundaries of the Great Smoky Mountains National Park, the species' decline was considered sufficiently serious to warrant consideration for listing under the Endangered Species Act. In 1994 a survey was made of the remaining range of the spruce-fir forest outside the national park boundary. The spider was found to be surviving at only one additional site. Due to the species' history of population loss and decline and the extreme vulnerability of the surviving populations, *M. montivaga* was listed as endangered by the U.S. Fish and Wildlife Service (Service) on February 6, 1995 (Service 1995).

Taxonomic Status

The genus *Microhexura* has been reviewed by Coyle (1981). *Microhexura montivaga* Crosby and Bishop is one of two species belonging to the genus *Microhexura* in the family Dipluridae. Diplurids belong in the primitive spider suborder Mygalomorphae, which are often popularly referred to as "tarantulas." Mygalomorphs are most easily distinguished from the so-called true spiders, suborder Araneomorphae, by the fact that they have two pairs of book lungs and by the mode of articulation of the cheliceral fangs, which (in mygalomorphs) open and close along a plane running parallel to the long axis of the body. Thus, the fangs do not oppose each other in the manner of the more advanced suborder. This arrangement requires a mygalomorph to raise its body and extend the fangs in order to strike.

The "sheet-web tarantulas" of the family Dipluridae are predominantly large tropical spiders whose presence is made conspicuous by horizontal sheets of silk leading through a silk funnel into tubular retreats hidden under stones and vegetation (Gertsch 1979). The members of this family are recognized by the absence of the abdominal tergite and possession of only four spinnerets, two of which, the laterals, are relatively long. Only two genera of Dipluridae, *Euagrus* and *Microhexura*, are found in the United States. *Euagrus* species are medium to large spiders that build their sheets and funnels in rocky situations in the arid Southwest.

The genus *Microhexura* was defined (Crosby and Bishop 1925) on the basis of the median furrow (fovea) of the cephalothorax being longitudinal. The males have a spur on the tibiae of the first pair of legs that is used to clasp the female during mating. The genus is presently considered to contain only two species--*M. montivaga* and *M. idahoana*. The two are distinguished by geographic distribution and by features of the male genitalia (Coyle 1981). They are otherwise similar in both morphology and habits. *Microhexura idahoana* is found in the mountains of the northwestern states of Washington, Idaho, Oregon, and Montana.

Distribution

Microhexura montivaga is historically known from four mountain peaks in western North Carolina and one in eastern Tennessee (Coyle 1981). In North Carolina the species has been recorded from Mount Mitchell, Yancey County; Grandfather Mountain, Avery and Caldwell Counties; and Mount Collins and Clingman's Dome, Swain County. In Tennessee the species has been recorded only from Mount LeConte in Sevier County.

Reproducing populations of *M. montivaga* still survive on Grandfather Mountain in North Carolina (Harp 1992; authors' personal observations, 1995) and on Mount LeConte in Tennessee (Coyle 1997). The Mount Mitchell population is believed to be extirpated (Harp 1992), and both the Mount Collins and Clingman's Dome populations (if still present) are extremely small, with only one spruce-fir moss spider having been found at each of these two sites in recent years (Harp 1991). Habitat associated with mature spruce-fir forests at all three of these sites has been severely degraded. Surveys have been conducted at several other areas within high-elevation spruce-fir forests in the Southern Appalachian Mountains that appeared to provide habitat suitable for *M. montivaga*, but the species was not found at any of these sites (Harp 1992).

Habitat, Life History, and Ecology

The optimal habitat of *M. montivaga* appears to be moss mats growing on rocks and boulders in humid, well-shaded situations in association with mature fir trees (Coyle 1981,1997; Harp 1991, 1992). These moss mats are generally from 1 to 4 centimeters thick and are well drained. They cannot be too dry, because the spider is quite sensitive to desiccation. Neither can they be too wet, because large drops of standing water can also be a threat.

An ongoing survey of the spiders of the Great Smoky Mountains National Park by Dr. Frederick A. Coyle, Western Carolina University, and a recent study of the population of the spruce-fir moss spider on Mount LeConte (Coyle 1997) support earlier findings (Coyle 1981; Harp 1991, 1992) that the spider is virtually restricted to mature spruce-fir/fir forests. In his study of the population of *M. montivaga* on Mount LeConte, Coyle (1997) reported finding the species "only in stands containing many old (well over 25 years of age) fir trees and in areas where patches of fir containing old trees interface with heath communities." In both these situations, Coyle (1997) reported finding the spider "only on or in the vicinity of rock outcrops." Searches of other habitats (rock outcrop heath, old fir without outcrops, young fir stands, and openings of early succession herbaceous vegetation) have failed to locate occurrences of the species (Coyle 1997; Coyle, personal communication, 1998).

While moss mats on inclined surfaces of rock outcrops and boulders appear to be the optimal microhabitat of *M. montivaga*, the spider has also been found under moss and

litter mats at the base of rock outcrops (Coyle 1981), under moss on loose rock at the base of rock outcrops (Coyle 1997), and in litter/humus under flat rocks (about 15 millimeters thick and 200 to 1,350 cm^2 large) lying on the ground in well-shaded situations in the vicinity of rock outcrops (Coyle 1997). The species has also rarely been found in moss mats on tree trunks (Coyle 1981), in moss mats on logs (Harp 1992), and on well-drained, well-shaded ground in or under needle and/or heath litter and moss (Coyle 1997).

The moss species that have been found associated with *M. montivaga* have been identified as *Polytrichum pallidesetum* Funck, *Dicranodontium denudatum* (Brid.) E. G. Britt ex Williams (Harp 1992), and *D. asperulum* (Mitt.) Broth. (Coyle 1997). Coyle (1997) reported, in his study of *M. montivaga* on Mount LeConte, that in the area studied the spider was found exclusively in *D. asperulum*.

Coyle (1981) describes the webs of *M. montivaga* as silk tubes sandwiched into the interface between the moss mat and boulder surface. The silk tubes are normally undamaged when the moss is pulled up and away from the boulder and remain attached to the undersurface of the moss mat. The tubes are typically broad and flattened, with short side branches. The presence of the spider is easily detected because of these thin-walled tubes. Some of the tubes extend into the vegetative interior of the moss mat (Harp 1991). The spider has not been observed taking prey in the wild nor is there any record of prey having been found in *M. montivaga* webs, but the abundant springtails (*Collembola* sp.) found in moss mats with the spiders provide the most likely source of food. They have been observed to take springtails in captivity (David Hodge, Lousville Zoological Park, personal communication, 1998). Possible predators and competitors of *M. montivaga* include pseudoscorpions, centipedes, carabid beetles, and other spiders. A number of araneomorph spiders are commonly found in the same moss as the spruce-fir moss spiders. These include the common hahniid, *Neoantistea magna* (Keyserling), and agelenids such as *Coras* sp.

Females of the species *M. montivaga* lay their eggs in June (Coyle 1981), with spiderlings emerging during September. A female with an egg sac was observed on Mount LeConte on August 4, 1990 (Harp, personal observation, 1990). The egg sac of the species is thin-walled, nearly transparent, and may contain seven to nine eggs (Coyle 1981). The female remains with the egg sac and, when disturbed, will carry the sac with her fangs. When carrying the egg sac, females walk in a "tip-toe" fashion, with the legs fully extended. Males mature during September and October, evidently at either 2 or 3 years of age (Coyle 1997). Adult males can be easily recognized by the specialization of the pedipalp tarsus as an intromittent organ, as is usually the case for spiders, and by the more unusual modification of a spur on the ventral surface of the tibiae of the first pair of legs. The spur and a corresponding concavity of the metatarsus of the same leg are used in clasping the female during mating. Mating behavior has been described in detail (Coyle 1985).

Modes of dispersal of spiderlings from the parental moss mats are unknown. Ballooning is a possibility, because penultimate males of *M. idahoana* have been collected as "windblown fallout" on snow fields on Mount Rainier (Coyle 1981). Ballooning spiders use a sheet of silk played out into a wind current as a kite to carry them into the air. No such collections have been made of ballooning *M. montivaga*; but if they do in fact balloon, they might be capable of an effective mode of dispersal over long distances. Even short-range dispersal between moss mats has not been documented for this species. Pitfall trap and Berlese funnel sampling done in the area of the Mount LeConte population have yet to yield any specimens of *M. montivaga* (Lambden *et al.* 1994; P. Lambden, University of Tennessee at Knoxville, personal communication, 1990). The life span of this species is unknown, although Coyle (1997) has estimated that males reach sexual maturity at just over 2 or 3 years of age based on size class distributions of collections on Mount LeConte. Long life span is a primitive trait characteristic of mygalomorphs whose females continue to molt after maturity. Actual life span of females in this species could be any number of years. Viable populations should contain individuals of all size classes in a stable age distribution.

Threats

The primary threat to, and reason for the recent decline of, *Microhexura montivaga* at the majority of the sites from which it has been recorded appears to be associated with the loss of suitable moss habitat due to the decline of the Fraser fir. As previously stated, the species appears to be very sensitive to desiccation and requires situations of high and constant humidity. Loss of the forest canopy (primarily the Fraser fir, the dominate canopy species in the forest stands where the spider has been found), leading to increased light and decreased moisture on the forest floor (resulting in desiccation of the moss mats), appears to be the major cause of the loss of the spruce-fir moss spider on Mount Mitchell and the recent decline and possible loss (additional surveys are needed to verify this) of the Mount Collins and Clingman's Dome populations.

Fraser fir at all four of these sites--Mount Mitchell, Mount Collins, Clingman's Dome, and Mount LeConte--have suffered extensive mortality, believed to be primarily due to infestation by the balsam wooly adelgid, *Adelges picea* (Homoptera, Adelgidae). The balsam wooly adelgid is a nonnative insect pest believed to have been introduced into the Northeastern United States from Europe around 1900 (Kotinsky 1916, Eagar 1984). The adelgid was first detected in North Carolina on Mount Mitchell (the type locality for the spruce-fir moss spider) in 1957 (Speers 1958), though it was likely established at that site as early 1940. From Mount Mitchell, the adelgid spread to the Fraser fir communities throughout the Southern Appalachians (Eagar 1984). Most mature Fraser firs are easily killed by the adelgid (Amman and Speers 1965), with death occurring within 2 to 7 years of the initial infestation (Eagar 1984). The Fraser fir trees on Grandfather Mountain that still support the spruce-fir moss spider have not yet suffered the extensive mortality that has occurred (and is occurring) at the other spruce-fir forest sites known to support (or to

have supported) populations of the spider. However, infestations of the fir by the adelgid have recently been detected at this site (J. Thompson, The Nature Conservancy, personal communication, 1996), and the future of this population is highly uncertain.

In addition to the balsam woolly adelgid, the combined effects of several other factors are also believed to be stressing and contributing to the decline of the high-elevation spruce-fir forest stands. While reasons for the decline of red spruce are complex and controversial, regional-scale air pollution, in combination with other stress factors, has been implicated to have played a role in the deterioration of the health of high-elevation red spruce in the Southern Appalachians (Johnson *et al.* 1992). Site deterioration due to past land use history (past logging and burning practices in the Southern Appalachians) has also been identified as a possible factor contributing to the decline in the health of spruce-fir forests in the Southern Appalachians (Peart *et al.* 1992). The death and thinning of the canopy trees within these stands also cause the remaining trees to be more susceptible to exposure shock (Nicholas et al. 1992), wind, and other storm damage.

The restricted range of each of the surviving populations of spruce-fir moss spider causes them to be extremely vulnerable to extirpation from a single event or activity, such as a drought, severe storm, wildfire, land-clearing or timber-harvesting operation, pesticide/herbicide application, etc. In addition, the spider and the moss mats it inhabits are very fragile and easily destroyed by human trampling. The Grandfather Mountain population appears to be restricted to the moss mats on a single rock outcrop and a few surrounding boulders. Trampling or other significant disturbance of the moss mats or damage to the surrounding vegetation shading the mats could result in the extirpation of this population.

PART II

RECOVERY

A. Recovery Objectives

The immediate goal of this recovery plan is to maintain the only known surviving populations of the spruce-fir moss spider and, to the extent possible, protect its remaining habitat from present and foreseeable threats. Currently, there are only two known reproducing populations of *Microhexura montivaga*--one on Grandfather Mountain in North Carolina and one on Mount LeConte in Tennessee. Lack of proper protection and management of these populations will preclude recovery of the species and will ultimately lead to the species' extinction in the wild.

The ultimate goal is to restore and maintain viable populations[2] of the spruce-fir moss spider within a significant portion of its historic range and remove the species from the Federal List of Endangered and Threatened Wildlife and Plants.

Reclassification to threatened:

The spruce-fir moss spider will be considered for downlisting to threatened status when the likelihood of the species' becoming extinct in the foreseeable future has been eliminated by the achievement of the following criteria:

1. Through protection of existing populations, successful establishment of reintroduced populations, or the discovery of additional populations, a total of four distinct viable populations exist. These four populations shall be distributed throughout a significant portion of the species' historic range. (The needed size of the populations will be established after further studies of the species' biology and genetics have been completed.)

2. Biological and ecological studies have been completed and any required recovery measures developed and implemented from these studies are showing signs of success, as evidenced by an increase in population density and/or an increase in the amount of habitat occupied by each of the four populations. Evidence that these four populations are stable or increasing, under natural conditions (without outside

[2]Viable population - A naturally reproducing population that is large enough to maintain sufficient genetic variation to enable it to evolve and respond to natural environmental changes. The number of individuals needed and the amount and quality of habitat required to meet this criterion will be determined for the species as one of the recovery tasks.

efforts), over at least a 15-year period (see Date of Recovery, page iv.) is considered necessary for downlisting.

3. Where habitat has been degraded, noticeable improvements in the quality of the spider's habitat have occurred.

4. Each of these four populations and their habitats are protected from any present and foreseeable threats that would jeopardize their continued existence.

The spruce-fir moss spider will be considered for removal from the Federal List of Endangered and Threatened Wildlife and Plants when the likelihood of the species' becoming threatened in the foreseeable future has been eliminated by the achievement of the following criteria:

1. Through protection of existing populations, successful establishment of reintroduced populations, or the discovery of additional populations, a total of six distinct viable populations exist. These six populations shall be distributed throughout a significant portion of the species' historic range.

2. Biological and ecological studies have been completed and any required recovery measures developed and implemented from these studies are showing signs of success, as evidenced by an increase in population density and/or an increase in the amount of habitat occupied by each of the six populations. Evidence that these six populations are stable or increasing over at least a 15-year period (see Date of Recovery, page iv.) is considered necessary for delisting.

3. Where habitat has been degraded, noticeable improvements in the quality of the spider's habitat have occurred.

4. Each of these six populations and their habitats are protected from any present and foreseeable threats that would jeopardize their continued existence.

B. Narrative Outline

1. **Maintain existing populations and essential habitat.** At present there are only two known reproducing populations of *M. montivaga*--one on Grandfather Mountain in Avery and Caldwell Counties, North Carolina, and one on Mount LeConte in Sevier County, Tennessee. If the species is to survive and expand its range, protection of the existing populations and remaining areas of suitable habitat is vital. Unless immediate steps are taken to stop the decline of the species and to protect and secure these relict populations, the species will likely be extinct in the wild in the very near future.

   1.1 **Enforce laws protecting the species and its habitat**. The Endangered Species Act prohibits the taking of this and other federally endangered or threatened species without a permit. Section 7 of the Act provides additional protection to the species and its habitat from impacts related to federally funded or authorized projects or activities.

   1.2 **Conduct life history research on the species.** Detailed knowledge is needed with regard to the species' life cycle, including such factors as reproduction, food requirements, movement patterns, means of dispersal, age and growth, and mortality rates. Unless the life cycle and environmental requirements of all life history stages of the species are defined, recovery efforts may be inconsequential or misdirected.

   1.3 **Characterize the species' habitat requirements (relevant physical, biological, and chemical components).** In order to focus management and recovery efforts on specific problems within the species' habitat, we need to have a detailed knowledge of the habitat requirements of the species (including such factors as moisture and temperature requirements, etc.); community structures of associated flora and fauna; and how these biotic and abiotic factors affect reproduction, growth, and habitat suitability. Also, in order to manage for the species' long-term survival, it is essential that we have a knowledge of the environmental requirements of all life history stages of the species and an understanding of the nature of the habitat occupied by the species.

   1.4 **Identify present and foreseeable threats to the species and implement research and management actions to eliminate them**. The National Park Service manages the site supporting the Mount LeConte population, and The Nature Conservancy manages the site supporting the Grandfather Mountain population. Both the National Park Service and The Nature Conservancy have implemented measures (e.g., rerouting trails and trail closures) that will help to protect these populations from trampling or other forms of disturbance

associated with the recreational use of these areas. Because of the fragility of the moss mat habitat, visitors should be prohibited from off-trail use of the areas inhabited by the spider, and researchers and employees should be educated about the microhabitats used by the species before working in these areas.

The primary threat to the Grandfather Mountain population of the species and the primary factor that appears to have resulted in the recent extirpation of the spider at other high-elevation spruce-fir forest sites appears to be the loss of mature Fraser firs due to infestations of the balsam woolly adelgid. Many of the fir trees on Grandfather Mountain have recently been documented to be infested by the adelgid. Unless a means of controlling the adelgid and/or offsetting the mortality of the fir can be found (e.g., developing/utilizing resistant strains of fir, providing artificial means of shading the moss mats, etc.), this population of the spider will likely be extirpated in the very near future. The experience and expertise of the National Park Service, U.S. Forest Service, Tennessee Valley Authority, and researchers working on adelgid control measures will be invaluable in developing and implementing measures to protect the moss mats supporting the Grandfather Mountain population of the spider. The area where the spider occurs on Grandfather Mountain is relatively small, but it is remote. The feasibility of treatment of selected fir trees with insecticidal soap (potassium oleate, a biodegradable fatty acid) is under investigation. However, significant logistical and procedural challenges are presented because of the remoteness of the area, the difficulty in treating the trees, and the necessity of protecting the moss mats inhabited by the spider from any insecticidal treatments.

Numerous other factors are also likely threatening the long-term existence of the spruce-fir moss spider. The majority of the high-elevation spruce-fir forests of the Southeast have suffered extensive changes and declines in size and/or vigor during the past century as a result of a number of factors--past logging and burning practices, storm damage, atmospheric pollution, climatic changes, disease, insect damage, exposure shock, and others not yet fully understood. Additional research is necessary to help understand the extent to which these factors may be affecting the quality of spruce-fir moss spider habitat and to help develop the management actions necessary to mitigate these effects.

1.5 Conduct genetic studies necessary to determine the number of individuals required to maintain a viable population and the genetic viability of existing populations. Long-term management of spruce-fir moss spider populations will require a knowledge of the genetic composition of each population and the number of individuals necessary to maintain genetic

viability as well as an understanding of the factors that affect viability. To the maximum extent possible, such studies should develop and use techniques that minimize the sacrifice of individuals from natural populations (examples include the nonlethal analysis of individuals; use of small, excised tissue samples; use of individuals from production of an experimental, cultured population; and the development of these techniques using more common surrogate species). The technique called polymerase chain reaction, PCR, is standard in molecular biology labs and can be used to extract genetic information using only small pieces of spiders, even spiders that have been preserved in ethanol for many years.

2. **Search for additional populations and/or habitat suitable for reintroduction efforts.** It is possible that some relic populations have been missed, and further study may yield additional populations and/or suitable habitat for reintroduction. Also, surveys are needed to record and monitor any future range reductions or expansions.

3. **Develop artificial-holding and propagation techniques and, if feasible, establish captive populations**. Because of the difficulties in controlling the balsam wooly adelgid and reversing the decline of the species' habitat, there is an immediate need to develop techniques for holding and propagating the spruce-fir moss spider. This action is needed in order to preserve genetic material from the surviving populations and to allow for the reestablishment of extirpated populations or the augmentation of existing populations if it becomes necessary and feasible to do so. Mr. David Hodge, Louisville Zoological Park, initiated a captive-holding/propagation program in 1992. Although he has been able to maintain the species in captivity for over 4 years, no egg sacs or other evidence of successful mating has been observed thus far (D. Hodge, personal communication, 1998).

   The development of artificial-holding/propagation techniques and, if feasible, the establishment of captive populations would allow for the reestablishment of extirpated populations of the spider (if the species' habitat at sites from which it has been extirpated can recover to a point where it is feasible to do so). Population augmentation would be another possibility if it is determined that a surviving population has been reduced in number to a point where its viability and survival are threatened. The number of individuals necessary to maintain viability will be determined in Task 1.5. Captive populations will also allow for some level of research into the behavior and life history of the spider that may be impossible to obtain in the wild.

4. **Determine the feasibility of augmenting extant populations and reestablishing populations within the species' historic range and reintroduce where feasible.**

If surveys conducted under Task 2 determine that the species is still surviving on Mount Collins, Clingman's Dome, or in other areas, but at very low numbers, the need for augmenting these populations should be determined. For the species to survive in these areas, it may be necessary to supplement these populations to enable them to reach a viable size. Also, there may be areas within the species' historic range that could support reestablished populations. However, because the Grandfather Mountain and Mount LeConte populations are the only sources of individuals for transplants at the present time and are themselves relatively small, it is vital that these populations be protected in order for them to increase in size before any transplants using individuals from the wild are attempted or a successful captive propagation program for the species can be established.

4.1 Develop a successful technique for reestablishing and augmenting populations.

4.2 Coordinate with appropriate Federal and State agency personnel, local governments, and interested parties to identify habitat suitable for augmentation and reintroduction.

4.3 Augment existing populations where needed, establish new populations within the species' historic range, and evaluate success. Using the techniques developed in Task 4.1, introduce and monitor success.

4.4 Implement the same protective measures for any introduced populations as outlined for established populations.

5. **Develop and implement cryogenic techniques to preserve the species' genetic material until such time as conditions are suitable for reintroduction.** Artificial propagation techniques may result in the production of juvenile and/or adult spiders for transplants. However, at this time habitat conditions within the species' historic range may not be suitable for reintroduction efforts to succeed. Cryogenic preservation of the spruce-fir moss spider could maintain genetic material from all the extant populations until habitat is suitable for the reestablishment of the species (much like seed banks for endangered plants). Additionally, if a population were lost to a catastrophic event, cryogenic preservation could allow for the eventual reestablishment of the population using genetic material preserved from that population.

6. **Develop and implement a program to monitor population levels and habitat conditions of existing populations as well as newly discovered, introduced, or expanding populations.** During and after recovery actions are implemented, the status of the species and its habitat must be monitored to assess any progress toward recovery. Quantitative samples should be taken in order to determine

densities of adults and juveniles. Monitoring should be conducted on at least a biennial schedule. Because of the fragility of the moss mat habitat, monitoring should be conducted by trained personnel familiar with the techniques for locating the spider while minimizing disturbance to its habitat.

7. **Annually assess overall success of the recovery program and recommend action (changes in recovery criteria, delist, continue to protect, implement new measures, other studies, etc.).** The recovery plan must be evaluated periodically to determine if it is on track and to recommend future actions. As more is learned about the species and as conditions change, recovery criteria may need to be modified.

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PART III

IMPLEMENTATION SCHEDULE

Priorities in column 1 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 - Ecological Services Division, U.S. Fish and Wildlife Service.
FA - Other Federal Agencies - Includes the National Park Service, U.S. Forest Service, and U.S. Environmental Protection Agency.
FWS - U.S. Fish and Wildlife Service.
LE - Law Enforcement Division, U.S. Fish and Wildlife Service.
R4 - Region 4 (Southeast Region), U.S. Fish and Wildlife Service.
SCA - State Conservation Agencies - Includes the Tennessee Department of Environment and Conservation; Tennessee Wildlife Resources Agency; North Carolina Wildlife Resources Commission; North Carolina Department of Agriculture; and North Carolina Department of Environment, Health, and Natural Resources.
TNC - The Nature Conservancy.

SPRUCE-FIR MOSS SPIDER IMPLEMENTATION SCHEDULE

Priority	Task Number	Task Description	Task Duration	Responsible Agency		Cost Estimates ($000s)			Comments
				FWS	Other	FY1	FY2	FY3	
1	1.1	Enforce laws protecting the species and its habitat.	Continuous	R4/ES and LE	FA, SCA	0.5	0.5	0.5	
1	1.2	Conduct life history research.	3 years	R4/ES	FA, SCA, TNC	6.0	6.0	6.0	
1	1.3	Characterize the species' habitat requirements.	5 years	R4/ES	FA, SCA, TNC	10.0	10.0	10.0	
1	1.4	Identify present and foreseeable threats and implement research and management activities to eliminate them.	3 years	R4/ES	FA, SCA, TNC	?	?	?	
1	3	Develop artificial holding and propagation techniques.	Ongoing	R4/ES	Contract	10.0	10.0	1.0	
2	1.5	Determine number of individuals required to maintain viable population.	1 year	R4/ES	Contract	---	5.0	---	
2	2	Search for additional populations and suitable habitat for reintroduction.	3 years	R4/ES	FA, SCA, or Contract	6.0	6.0	6.0	
2	4	Develop techniques and reintroduce species back into historic habitat and, if needed, augment existing populations.	Unknown	R4/ES	Contract	10.0	5.0	5.0	
2	5	Develop and utilize cryopreservation techniques.	Unknown	R4/ES	Contract	5.0	2.0	2.0	

SPRUCE-FIR MOSS SPIDER IMPLEMENTATION SCHEDULE

Priority	Task Number	Task Description	Task Duration	Responsible Agency		Cost Estimates ($000s)			Comments
				FWS	Other	FY1	FY2	FY3	
2	6	Develop and implement a monitoring program.	Ongoing	R4/ES	FA, SCA	2.0	---	2.0	Biannual.
3	7	Annually assess recovery program and modify program and plan where required.	Ongoing	R4/ES	FA, SCA	---	---	---	

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