Spruce-fir Moss Spider
(Microhexura montivaga)

5-Year Review:
Summary and Evaluation

U.S. Fish and Wildlife Service
Southeast Region
Asheville Ecological Services Field Office
Asheville, North Carolina

5-YEAR REVIEW

Spruce-fir Moss Spider *(Microhexura montivaga)*

I. GENERAL INFORMATION

A. Methodology used to complete the review: This review was conducted by the lead recovery biologist for the spruce-fir moss spider in the Asheville Field Office, Asheville, North Carolina. A notice of the initiation of this five-year review was published by the U. S. Fish and Wildlife Service (Service) in the *Federal Register* (73 FR 43947) on July 29, 2008, and a 60-day comment period was opened. Pertinent status data were obtained from the recovery plan, published papers, unpublished reports and personal communications with land managers and experts on this species. A draft of this document was internally reviewed by John Fridell (Asheville North Carolina Field Office) and Shane Hanlon (Abingdon Virginia Field Office) and peer reviewed by three experts familiar with the spruce-fir moss spider (Appendix A).

B. Reviewers

Lead Region - Southeast Region: Kelly Bibb, 404-679-7132
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C. Background

1. **Federal Register Notice citation announcing initiation of this review:** 73 FR 43947, July 29, 2008.

2. **Species status:** Stable (2013 Recovery Data Call). Reported as stable given the species' continued presence at sites; however, there continues to be no means of confidently determining population levels or trends.

3. **Recovery achieved:** 1 (0-25% recovery objectives achieved).

4. **Listing history:**

   Original Listing
   FR notice: 60 FR 6968
   Date listed: February 6, 1995; effective date March 8, 1995
   Entity listed: species
   Classification: endangered

5. **Associated rulemakings:** Critical habitat – 66 FR 35547, July 6, 2001.

6. **Review History:**
   Final Recovery Plan – 1998.
   Recovery Data Call – 2013 – 1998.

7. **Species' Recovery Priority Number at start of review (48 FR 43098):** The recovery priority number assigned to spruce-fir moss spider is a 5, indicating a high degree of threat and a low recovery potential for this species.

8. **Recovery Plan:**
   Name of plan: Recovery Plan for the Spruce-fir Moss Spider (*Microhexura montivaga*).
   Date issued: September 11, 1998.

II. REVIEW ANALYSIS

A. Application of the 1996 Distinct Population Segment (DPS) policy

Is the species under review listed as a DPS? No. The Endangered Species Act defines species as including any subspecies of fish or wildlife or plants, and any distinct population of a species of vertebrate wildlife. This definition limits listing DPS to only vertebrate species of fish and wildlife. Because the species under review is an invertebrate, and the DPS policy is not applicable, the application of the DPS policy to the species' listing is not addressed further in this review.

B. Recovery Criteria

1. **Does the species have a final, approved recovery plan containing objective, measurable criteria?** Yes.

2. **Adequacy of recovery criteria.**

   a. **Do the recovery criteria reflect the best available and most up-to-date information on the biology of the species and its habitat?** Yes.

   b. **Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria?** Yes, but the criteria were written very broadly due to the lack of information on this species. As a result, they can be interpreted to cover the 5 listing factors, but more specific information should be included in future plan revisions. Additionally, climate change was not addressed in the 5 listing factors. Other new threats to consider are increased development and recreation.

3. List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information.

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 achievement of the following criteria:

Recovery Criterion 1. Through protection and enhancement 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' historical range. (The needed size of the populations will be established after further studies of the species' biology and genetics have been completed).

Even though the spruce-fir moss spider was discovered in 1923 (Crosby and Bishop 1925), most of the work on this species did not begin until the 1980s, after the destructive logging of the early 1900s and after most of the mature Fraser fir (*Abies fraseri*) trees were killed by the balsam woolly adelgid (*Adelges piceae*). These two major events undoubtedly altered and limited the range of the spruce-fir moss spider and as a result, the historic range of the species is unknown. At the time of listing, five populations of spruce-fir moss spiders were known to exist on three disjunct mountain ranges: one on Mt. Mitchell, one on Grandfather Mountain, and three in the Great Smoky Mountains (one on Mt. LeConte, Mt. Collins and Clingmans Dome). The Mt. LeConte population was the only occurrence in Tennessee. The remainder of the sites were in North Carolina. Of these, one was believed extirpated (Mt. Mitchell), two were thought to be extremely small and close to extirpation (Mt. Collins and Clingmans Dome), and two still had reproducing populations (Grandfather Mountain and Mt. LeConte) (Harp 1991, 1992). Since that time, new populations have been discovered and populations believed extirpated have been re-found.

Today, the spider exists on 22 mountain tops along six geographically isolated mountain ranges (Coyle 2009). One or more distinct rock outcrop populations or subpopulations exist within each mountain range. These six montane populations occur in the Virginia Balsam Mountains (Virginia), Grandfather Mountain (North Carolina), Roan Mountain (North Carolina/Tennessee), Black Mountains (North Carolina), Plott Balsam Mountains (North Carolina), and Great Smoky Mountains (North Carolina/Tennessee). The most recent surveys conducted by Dr. Coyle (2009) were the most comprehensive to date with sampling efforts in all areas with suitable habitat in the southern Appalachian Mountains. New populations were discovered in areas not previously surveyed in the Virginia Balsams in

Virginia and the Plott Balsams in North Carolina. This extends the range of the species north and south, but these populations appear to be extremely small and vulnerable.

While the discovery of new sites brings the total number of populations to six, uncertainty remains regarding their viability. Due to the difficulties with studying this small, cryptic spider, the size of populations needed to ensure the survival of this species is still unknown and important questions remain regarding the species biology and genetic health. Additionally, uncertainty over the threats to the habitat and species, as explained later in this review, leave the viability of populations in serious question.

Recovery Criterion 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. There is evidence that these four populations are stable or increasing, under natural conditions (without outside efforts), over at least a 15-year period.

Some advancement has been made on biological/ecological studies for this species, but much about this spider's life history and demographics remains unknown and requires additional study. Although some measures have been implemented (i.e., surveys for potential reintroduction sites, trail closures and reroutes, eliminating fir seedling collection in areas where it might affect the species or limit future habitat, etc.), studies and efforts to hold and propagate the species, develop methods for controlling adelgid infestations, and addressing some of the other most serious threats and factors limiting the species' recovery have been largely unsuccessful. As new information becomes available, required recovery measures will have to be developed or modified. Additionally, while long-term, intensive surveys are needed to answer questions about population status and trends, there still is no way to survey for the spider that is not damaging and potentially destructive to the microhabitat on which it relies. This makes regular monitoring to determine population trends challenging. Sporadic status surveys have been conducted over the twelve years since the recovery plan was written and from this limited survey work, it appears some populations may be stable or increasing while others are struggling. Based on comparisons with past years data, four of the montane populations appear to be at least currently stable (Black Mountains, Great Smoky Mountains, Grandfather Mountain and Roan Mountain) while the status of the remaining two appears uncertain (Virginia Mountains and Plott Balsams) (Coyle 2009).

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

Spruce-fir forests in the Southern Appalachians (and across the range of the spider) have been drastically altered by past logging practices and introduced pests; and represent one of the most endangered forest types in the U.S. The

balsam woolly adelgid has decimated Fraser fir forests throughout the Southern Appalachians since its arrival in the mid 1900s, eliminating 95% of the mature fir from high elevation forests (Wear and Greis 2002). While fir trees have regenerated resulting in improved habitat conditions in some stands, regeneration is patchy with fir continuing to decline in some areas. For example, mature trees are still dying in some areas in the Great Smoky Mountains National Park, but have stabilized in others with some patches of remaining old growth and some regeneration (Glenn Taylor, Great Smoky Mountains National Park, pers. comm. 2010). Similarly, some mature stands remain on Grandfather Mountain (e.g. the north face of Callaway Peak) and spotty regeneration is occurring, but there have been recent adelgid outbreaks (Jesse Pope, Grandfather Mountain Stewardship Foundation, pers. comm. 2010). Patterns of regeneration appear to be highly variable and potentially complex and may be influenced by concurrent impacts of balsam wooly adelgid and acid deposition (Stehn 2009). Of great concern is the potential for this next cohort of Fraser firs to succumb to the pest in the same manner as the last generation. The adelgid is most successful at invading the trunks of mature trees and as a result, it can take 20-30 years for fir to become susceptible to the adelgid. Any recent improvement in habitat may be short-lived as regenerated trees are just starting to reach the age when they are most susceptible to infestation. With added concerns about the future effects of climate change and atmospheric pollution on both Fraser fir and red spruce (*Picea rubens*), the fate of these forests and the spider is uncertain.

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

While most of the populations are under public ownership, at least one is under private ownership (Plott Balsams). Additionally, there are sometimes competing objectives for land under public ownership (e.g. vista management, recreational development) resulting in threats to the species. The spider also continues to be threatened by introduced pests, pollution, and climate change in protected and unprotected sites.

[Note: The spruce-fir moss spider will be considered for delisting when the above criteria have been met for six populations (as opposed to the four populations necessary for downlisting).]

C. 1. Updated Information and Current Species Status

A. Biology and Habitat

The following sections summarize information that has become available largely since development of the 1998 recovery plan.

New information on the species' biology and life history:

The spruce-fir moss spider is endemic to the spruce-fir forests of the Southern Appalachians. Found only on the highest mountain peaks in North Carolina, Tennessee, and Virginia, this spider belongs to the family Dipluridae and is one of the world's smallest mygalomorph spiders. Mygalomorph spiders are members of the primitive spider suborder Mygalomorphae. Most of what is known about the biology and life history of the spruce-fir moss spider was uncovered by Dr. Coyle (1981, 1985) in the 1980s and can be found in the recovery plan (USFWS 1998). Key pieces of information remain a mystery including the spider's life span, dispersal mechanisms, prey, and predators.

Abundance, population trends (e.g. increasing, decreasing, stable), demographic features, or demographic trends:

Surveys, funded by the Service, National Park Service, and U.S. Forest Service, have been conducted sporadically since the spider was listed in 1995. Dr. Coyle conducted status surveys in the Great Smoky Mountains in 1997 and 2004 and on Roan Mountain in 1999. The most comprehensive surveys were recently conducted by Dr. Coyle (2009) beginning in 2007 and ending in 2009. These surveys were conducted across the species' known range and in areas outside of the known range. Surveys have not been of sufficient intensity or frequency to reveal abundance and populations trends, but they do provide insight into the health of existing populations.

In the 1980s, the species appeared to decline dramatically at Clingman's Dome and Mt. Mitchell as a result of Fraser fir mortality and desiccation of the bryophyte mats that support the spider (Coyle pers. obs. *as cited in* Coyle 2009). Additionally, as reported in the recovery plan (USFWS 1998), marked population declines were reported by Harp (Harp 1991, 1992, author's pers. ob. 1995). Questions have arisen about some declines reported by Harp since Coyle later discovered healthy populations in areas formerly surveyed by Harp (Coyle 2004). It is unknown how much of those declines were true declines and how much were the result of survey design. Coyle (2004) suggested that increases observed by him in the Great Smoky Mountains were largely due to effectiveness of search effort rather than true increases in the park over the 13 year time period between surveys. Results seem to suggest this was the case in other areas as well (e.g., Roan Mountain).

Since listing, the spider has persisted in areas where it was initially discovered and has been found in new areas. Out of the six montane populations, two (Black Mountains and Great Smoky Mountains) appear to be large and relatively healthy based on information collected on relative abundance (Coyle 2009). Grandfather and Roan Mountain may also support relatively large populations. The populations at the northern and southern extent of the range are small and at risk. Very few spiders were found on Whitetop and Pine Mountains in Virginia and relative abundance was very low in the Plott Balsams in North Carolina where the

spider may be restricted to a single small patch of habitat on private land (Coyle 2009).

Demographic features and trends of this species are still largely unknown. While the most recent sampling effort by Coyle (2009) was not intensive enough to say anything meaningful about age structure, it is worth noting that 19% of spiders found were small juveniles, 47% were large juveniles, and 34% were adults. This is similar to the percentage of juveniles found in previous studies in the Great Smoky Mountains (Coyle 2004, 2009). Out of the 29 adult spiders found in the most recent surveys, 28 were females and one was a male (Coyle 2009). This is not surprising given that adult females are long-lived and can be found any time of the year, adult males are short-lived existing only from late September to December, and most surveys were conducted during the spring and summer months when one would expect to find more females (Fred Coyle, Western Carolina University, pers. comm. 2010). Additionally, adult males abandon their webs and wander in search of females while females remain in their webs and are therefore easier to find (Fred Coyle, Western Carolina University, pers. comm. 2010). Thirty-two percent of the females (nine individuals) were carrying egg sacs. Those with egg sacs were found on Grandfather Mountain and in the Black Mountains. Searches of other mountain ranges were conducted either before or after the period when egg-sacs are present.

Genetics, genetic variation, or trends in genetic variation:

Dr. Hedin and Dr. Coyle recently completed a molecular study of the genetic/evolutionary relationships among the six montane populations using primarily non-destructive sampling of autotomised or shed legs (Coyle 2009, Hedin 2014). The technique to extract genomic DNA from fresh legs and run PCR analysis was tested and a protocol developed by Dr. Costa using *M. idahoana*, the far more common western U.S. sister species (James Costa, Western Carolina University, pers. comm. 2003). The purpose of the work was to use DNA sequence data from multiple genes to assess genetic structure and gene flow between and within the six geographically isolated populations (Coyle 2009, Hedin 2014).

The results of Dr. Hedin's work indicate that there are indeed six primary genetic lineages, but they are not simply aligned with the six isolated mountain ranges as expected. Instead the data indicate the lineages deviate in two obvious ways: 1) two divergent genetic units exist in the Black Mountains, and 2) the Plott Balsam population is not genetically distinct from the Great Smoky Mountains population (Hedin 2014). While additional work is needed to determine if these different genetic lineages actually represent different species, it is clear that all are important for conserving genetic diversity. These results will also help inform any future augmentation and reintroduction efforts.

Taxonomic classification or changes in nomenclature:

There has been no change in the classification or nomenclature of this species.

Spatial distribution, trends in spatial distribution, or historic range (e.g. corrections to the historical range, change in distribution of the species' within its historic range, etc.):

The spruce-fir moss spider continues to be confined to a handful of isolated, high elevation peaks supporting fir or spruce-fir forests. It was discovered in 1923 on Mt. Mitchell (Crosby and Bishop 1925) and prior to listing was known from Grandfather Mountain, Mt. Mitchell, and three mountains in the Great Smoky Mountains (Mt. LeConte, Clingman's Dome, and Mt. Collins) (USFWS 1998). Since the completion of the recovery plan, the spruce-fir moss spider has been discovered on Roan Mountain (Coyle 1999). Additionally, a park-wide survey conducted within Great Smoky Mountains National Park in 2004 found the spider on three additional mountains along the North Carolina/Tennessee border (Mt. Love, Mt. Chapman, and Mt. Buckley) (Coyle 2004). During that survey, a total of 40 spiders (including females with egg sacs and juveniles) were found occupying 12 sites, eight of which were new. It is important to note that one population, below Clingman's Dome, was nearly gone. This is a site where a population was known to be relatively large and healthy in the 1970s. The most recent surveys found the spider on an additional thirteen mountains across the Southern Appalachians. These mountains are primarily in the Black Mountains, but also in the Virginia and Plott Balsams (Coyle 2009).

Many of the areas recently surveyed by Dr. Coyle had either not been extensively searched in the past or had not been searched at all. These surveys extend the range of the species north and east into Virginia and south into the Plott Balsams in southwestern North Carolina and expand the number of occupied counties to fourteen. It can now be found in Avery, Buncombe, Caldwell, Haywood, Jackson, Mitchell, Swain, Watauga, and Yancey counties in North Carolina; Carter and Sevier counties in Tennessee; and Grayson, Smyth, and Washington counties in Virginia. Dr. Coyle's work increased the number of known montane populations from four to six (Coyle 2009). Dr. Coyle also searched extensively for the spider in West Virginia, but failed to find it or any suitable habitat. Coyle (2009) stated that given his most recent surveys and the lack of habitat south and west of areas with spiders, he is now reasonably confident the general geographic boundaries of the spider's distribution are known.

Spruce-fir forests continue to occur only on the highest mountain peaks, forming sky islands. Despite occurrences at additional sites, these areas continue to be isolated and fragmented. Recent regeneration of Fraser fir may have improved habitat connectivity in some areas, but any gains may be short-lived if regenerated fir becomes infested by balsam woolly adelgid. Additionally, the habitat is likely to become more fragmented as a result of climate change and other stressors (e.g., pollution, pests, development).

Habitat:

As more sites with spiders are found, a clearer picture has emerged of both the habitat and microhabitat needs of this species. The spider is largely found in fir and spruce-fir forests over approximately 1646 meters (5400 feet) in elevation and on slopes with northerly aspects. It has been found at elevations as low as ~1620 meters (5300 feet), but is most often found at sites over 1830 meters (6000 feet). Areas with old fir on north facing slopes appear to be optimal habitat. Interestingly, the recent discovery of the spider on top of Whitetop Mountain in Virginia puts it outside the current range of Fraser fir and represents the only record of this species in pure red spruce. This led Dr. Coyle to search other stands of spruce outside the range of Fraser fir in West Virginia, but these searches were unsuccessful. Based on these surveys and library research, there appears to be a paucity of suitable habitat north and east of the newly discovered western Virginia sites (Coyle 2009). The sites where Dr. Coyle found the spider in Virginia were also at relatively low elevations (1620-1676 meters) which can be explained by the fact that climate zone altitudes and consequently the spruce-fir zone, decrease with increasing latitude (Coyle 2009). Coyle (1999) found that spruce-fir forests on tops of mountains with gentle slopes, south facing slopes and northern hardwood forests and other communities below 1676 meters (5500 feet) did not provide the proper habitat or microhabitat for the species on Roan Mountain and this appears to be the case in other areas as well.

Recent surveys confirm that the prime microhabitat consists of humid, but well-drained bryophyte mats on sheltered, well-shaded (primarily northerly-facing) rock outcrops (Coyle 1997, 1999). The spiders' tubular webs are primarily found in the mat-rock interface and secondarily in spaces within these mats (Coyle 2009). The spider does not inhabit thick, wet mosses like *Sphagnum* spp. or thin dry mosses. *Microhexura* also does not appear to use bryophyte mats on trunks, logs, or the ground (Coyle 2009). It was however, found in a new microhabitat during surveys on Mt. LeConte (Coyle 1997), where spiders were discovered under small, flat rocks lying on the ground in well shaded areas in the vicinity of rock outcrops. In this microhabitat, they were still found living at the interface of rock and humus, but below the rock instead of above as in more typical microhabitat. Bryophyte mats that harbored the spider were distinguished by those that did not by two distinct features: 1) the mat included a thin layer of moist soil and/or humus between it and the rock surface and 2) the mat was moderately (often 10-40mm), but not extremely thick (Coyle 1999, 2004).

The importance of mosses in the genus *Dicranodontium* has been well documented (Coyle 1997, 1999, 2004, 2009). Additionally, the liverwort of the genus *Bazzania* is a common component of many bryophyte mats where the spider has been found (Coyle 2004, 2009). Both can serve as useful indicators for the spider, but these bryophytes have an extensive range and many areas with these genera are devoid of the spider (Coyle 1999). The most recent surveys

(Coyle 2009) revealed that other bryophytes including the mosses *Polytrichum*, *Dicranum*, and *Brotherella* and the liverworts *Scapnia*, *Herbertus*, and *Lepidozia* can provide adequate substrates for the spider.

There are approximately 74,500 hectares (184,000 acres) of high-elevation, spruce-fir/northern hardwood forests in the Southern Appalachians and only 4,050 hectares (10,000 acres) above ~1780 meters (5800 feet) in elevation where most fir resides and this habitat is predicted to decline (SAMAB 1996b). Given the specific microhabitat requirements of *Microhexura*, the amount of habitat suitable for this species is considerably smaller than these estimates. Coyle (2009) did a rough estimate of favorable habitat during his extensive surveys by using topographic maps, literature, and site visits. He defined suitable habitat as areas with spruce-fir and/or fir stands with north-facing slopes steep enough to support northerly facing rock outcrops. He estimated a total of 255 hectares (630 acres) of suitable habitat in the areas he visited in southwest Virginia (including Mt. Rogers where he failed to find *Microhexura*), Grandfather Mountain, Roan Mountain, Black Mountains, Great Smoky Mountains, and Plott Balsam Mountains. The Black Mountains contained the largest areas of favorable habitat. He failed to find any favorable habitat in the areas he searched in West Virginia or in the Great Balsam Mountains in North Carolina.

2. Five-Factor Analysis

a. Present or threatened destruction, modification or curtailment of its habitat or range:

The Service's 1995 listing of the spruce-fir moss spider as endangered, 1998 recovery plan, and 2001 rule designating critical habitat all identify significant threats to the species continued existence including loss of Fraser fir and red spruce due to forest pests, air pollution, past land use practices, climate change, and trampling as a result of recreation and other disturbances. These same factors continue to threaten the existence of the spruce-fir moss spider today. In fact, spruce-fir forests of the Southern Appalachians are considered the second most critically endangered ecosystems in the United States with greater than a 98% decline since European settlement (Noss et al. 1995). While most high elevation forests are under public ownership and have some level of protection, residential development is a concern on private lands in the Plott Balsams and Black Mountains.

The most significant known threat to the spruce-fir moss spider continues to be loss of habitat due to the decline of red spruce and Fraser fir. The spruce-fir moss spider is extremely sensitive to changes in moisture. Loss of forest canopy results in locally drastic changes in the microclimate, which can lead to desiccation of the bryophyte mats on which the spider depends for its survival. Conversely, too much moisture also puts the spider at risk.

The most obvious contributor to the decline of Fraser fir is the balsam woolly adelgid. The adelgid was first discovered in the Southern Appalachians on Mt. Mitchell in 1957 and was likely introduced from Europe as early as the 1930s (SAMAB 1996b). Mature Fraser fir trees are highly susceptible to infestation and this introduced pest has caused extensive mortality of Fraser firs and vast changes in high elevation forest composition and structure in the southeast. Some remnant old growth fir trees remain and regeneration is occurring in some areas resulting in dense, even-aged thickets of fir. There is hope that succeeding generations of fir will develop some resistance and/or adelgid population will stabilize, but it is unknown what will happen as the current cohort reaches the age when trees are most susceptible to infestation. Additionally, there are questions about whether future generations of fir trees will continue to produce viable seeds. There is no reliable method to treat for balsam woolly adelgid and it continues to kill fir trees in the Southern Appalachians. Dr. Coyle has found the spruce-fir moss spider in bryophyte mats in well-shaded areas on north facing rock outcrops even where the canopy was sparse. These areas appear to provide an important refuge for the spider, but there is currently no way to predict if the spider will survive if Fraser fir completely disappears (Coyle 2004).

Another potential source of tree mortality and decreased vigor is air pollution. Pollution in the form of acid deposition from rain and fog can have adverse impacts on forest health and productivity including that of red spruce and Fraser fir. Spruce-fir forests in the Southern Appalachians receive some of the highest rates of acid deposition in North American (Weathers et al. 2006 *as cited in* Stehn 2009, SAMAB 1996a). Ozone is another air pollutant but little is known about its impacts on high elevation forests (SAMAB 1996a).

There are likely complex interactions affecting spruce-fir forests that have yet to be fully realized. For example, data suggests there may be combined interactions between loss of canopy from balsam woolly adelgid and chronic acid deposition (Stehn 2009). Additionally, acid deposition may be contributing to reduced ecological resiliency of spruce-fir forests. There are also concerns over possible cascading effects as a result of the loss of mature fir trees. For example, fir mortality can result in decreased vigor of surrounding trees as remaining fir trees and adjacent spruce trees become more susceptible to storm and other damage.

The threat of climate change was not addressed at the time of listing or in the recovery plan. Climate change predictions vary, but continued warming and an increase in the rate of warming is expected in the southeast (Karl et al. 2009). Changes in precipitation are less clear, but may be characterized by more frequent droughts and an increase in the occurrence of heavy downpours (Karl et al. 2009). The future of climate at high mountain sites is particularly uncertain as much of the climate at these sites is orographically determined. If fog and orographic cloud cover persist, they will ameliorate the effects of warming and drought, but if they are disrupted, climate change effects will be much more drastic (NC NHP 2010).

More frequent droughts would likely lead to drying of the moist microhabitats needed by the spider. An increase in precipitation could also prove detrimental to the spider. It is unclear why the spruce-fir moss spider does not inhabit wet moss mats, but an increase in pathogens and a decrease in prey availability are two possible explanations (Fred Coyle, Western Carolina University, pers. comm. 2010). There is also the potential for additional loss of fir; a boreal relict already restricted in range. If temperatures in the Southern Appalachians increase and precipitation decreases, it is anticipated that the areal extent of boreal forests will decrease (NC NHP 2010). A reduction of suitable habitat would directly affect the spider and increase the genetic isolation of populations. Finally, it is important to note that climate change could exacerbate existing threats to the spruce-fir moss spider (e.g., increased susceptibility of spruce-fir to forest pests).

b. Overutilization for commercial, recreational, scientific, or educational purposes:

Illegal collection of moss does exist on public lands though most likely occurs at low to mid elevations at easily accessible sites. While it does not appear to be a threat at this time, it could be a threat in the future. Another concern is the impacts of trampling due to recreation (refer to Factor E).

c. Disease or predation:

We have no new data indicating that disease or predation is a threat to this species.

d. Inadequacy of existing regulatory mechanisms:

As indicated at the time of listing, neither the State of North Carolina nor the State of Tennessee includes arachnids on their lists of endangered and threatened wildlife. This is also true of the State of Virginia and therefore the species receives no State protection.

While most high elevation habitat is on public lands, there are some concerns with residential development in some areas. Unless it is a known site, the Service generally does not have an opportunity to review projects on private land under Section 7 of the Endangered Species Act, unless a federal permit or federal funding is involved.

e. Other natural or manmade factors affecting its continued existence:

With an ever-increasing number of visitors recreating in the Southern Appalachians and a rise in demands for specific recreation opportunities, development of infrastructure to support recreation and the recreation itself pose a threat to the spider at protected and unprotected sites. Both the spider and the

moss mats it inhabits are very fragile and easily destroyed by trampling or other disturbance. The risk of destruction of microhabitat from trampling is of particular concern at sites close to trails. Coyle (1999) suggested that boulder climbing by visitors may have been one of the factors contributing to the scarcity of suitable moss habitat for the spider in the areas on Roan Mountain. Of the sites visited by Coyle during his recent surveys (Coyle 2009), most sites appeared relatively protected due to the steepness of the terrain, but a few sites were at risk. Even a small amount of disturbance has the potential to wipe out a population or subpopulation. Recreation can also be the impetus for leaving areas open that might otherwise revert to spruce or fir forests (e.g., maintaining man-made balds).

Even the survey techniques used to locate the spider threaten its' sensitive habitat. These techniques involve pulling back pieces of moss to expose the rock-moss interface where the spider resides. It is unknown how long it takes for the moss to reattach itself or re-grow. Coyle (2009) cautions biologists about the negative impacts surveying can have on bryophyte mats and recommends surveys be limited in frequency and intensity.

Boreal forests in the southeast were already fragmented following glacial retreat and are restricted to the highest peaks in the Southern Appalachians. The extensive mortality of Fraser fir has resulted in highly fragmented stands within these sky islands leading to additional concerns over habitat connectivity and dispersal. The distribution of this species is further restricted by its' specific microhabitat requirements including north facing rock outcrops and moist bryophyte mats. As a result, the spruce-fir moss spider exists in primarily small, isolated populations leaving the species vulnerable to catastrophic events. There are also concerns over the genetic health of remaining populations.

D. Synthesis

Since the development of the 1998 recovery plan, the spruce-fir moss spider has received additional attention from biologists and research and monitoring efforts have expanded. Despite the additional work, there continues to be a lack of vital information on population abundance and trends, life history, and demographic parameters. This is in part due to the difficulty in studying such a small, cryptic species. Surveys can be very destructive to the microhabitat and while additional information is needed to expand on and meet existing recovery criteria, care must be taken in conducting surveys. Surveys must be conducted by trained personnel familiar with the spiders' habitat and techniques for finding the species while minimizing disturbance.

While the recent discovery of new populations provides some good news, these new occurrences probably represent previously overlooked populations and not necessarily expansion. The unique and restricted habitat and specific microhabitat requirements of this Southern Appalachian endemic greatly limit its range under the best of circumstances. There has been some improvement in Fraser fir stands since

the mass mortality in the 70s and 80s, but regenerated trees will likely become infested. As a result of this and other factors, there is great uncertainty over the future of Fraser fir and the spruce-fir moss spider. The spruce-fir moss spider continues to be in danger of extinction because of its small/isolated populations with likely limited gene flow and significant threats from habitat loss/fragmentation, introduced pests and diseases, and likely pollution and climate change. Therefore, the Service recommends that the spruce-fir moss spider continue to remain classified as endangered.

III. RESULTS

Recommended Classification

__X__ **No change is needed**

IV. RECOMMENDATIONS FOR FUTURE ACTIONS

- Identify surrogate parameters to qualify and/or quantify each population and develop GIS analysis of existing and potential habitat to monitor over time.

- Up to this point, surveys have been conducted sporadically. There is a need to develop and implement a program to monitor population levels and habitat conditions of existing populations, but surveys need be done by trained personnel in a manner that minimizes negative impacts to microhabitat.

- Initiate studies on the ecology of bryophytes that appear important to the spider.

- Expand studies on microhabitat requirements to include data collection on microclimate.

- Initiate detailed studies on the biology of the spruce-fir moss spider's nonendangered sister species, *Microhexura idahoana*, to gain insight into the biology of the spruce-fir moss spider to guide recovery efforts in the wild and to inform captive breeding attempts. As more is learned concerning the species' microhabitat requirements and genetic studies have been completed, efforts should be reinitiated for holding the species in captivity and conducting controlled propagation for establishing refugia populations and for population augmentation and/or reintroduction as necessary and feasible.

- Educate land managers on the identification of potential habitat, so that they can recognize and avoid it in their every day work. Also work with land managers to measure and protect populations from visitor impacts. Dr. Coyle developed an identification and natural history summary, which has and will continue to greatly assist with this effort.

- Work to protect sites on private lands in the Plott Balsams and Black Mountains.

- In addition to the species specific recommendations listed above, there are also habitat based information needs that if known, would greatly assist in evaluating the status of and conserving the spruce-fir moss spider. These actions include determining the impacts of air pollution and climate change on the future availability of spruce-fir forests in the Southern Appalachians; identifying ecological relationships between species, their habitats and the biological, physical and chemical habitat components; effectively mapping and/or modeling spruce-fir habitats both within and between islands; researching forest management and restoration techniques that will benefit the habitat and associated species including the spruce-fir moss spider.

V. REFERENCES

Coyle, F.A. 1981. The mygalomorph spider genus Microhexura (Araneae, Dipluridae). Bull. Amer. Mus. Nat. Hist., 170:64-75.

Coyle, F.A. 1985. Observations on the mating behavior of the tiny mygalomorph spider, *Microhexura montivaga* Crosby & Bishop (Araneae, Diplouridae). Bull. Brit. Arachnol. Soc., 6(8):328-330.

Coyle, F.A. 1997. Status survey of the endangered spruce-fir moss spider, *Microhexura montivaga*, on Mount LeConte. Unpublished report to the U.S. Fish and Wildlife Service, Asheville, NC. 19 pp.

Coyle, F.A. 1999. Status survey of the endangered spruce-fir moss spider, *Microhexura montivaga*, on Roan Mountain. Unpublished report to the U.S. Fish and Wildlife Service, Asheville, NC. 9 pp.

Coyle, F.A. 2004. Status survey of the endangered spruce-fir moss spider, *Microhexura montivaga*, in the Great Smoky Mountains National Park. Unpublished report to the U.S. Fish and Wildlife Service, Asheville, NC. 16 pp.

Coyle, F.A. 2009. Status survey of the spruce-fir moss spider, *Microhexura montivaga*. Unpublished report to the U.S. Fish and Wildlife Service, Asheville, NC. 22 pp.

Crosby, C.R. and S.C. Bishop. 1925. Two new spiders from the Blue Ridge Mountains of North Carolina (Araneina). Entomological News 36:142-146.

Harp, J.M. 1991. Status of the spruce-fir moss spider in the Great Smoky Mountains National Park. Unpublished report to the National Park Service, U.S. Department of the Interior. 12 pp plus appendix.

Harp, J.M. 1992. A status survey of the spruce-fir moss spider, *Microhexura montivaga*. Unpublished report to the North Carolina Wildlife Resources Commission, Nongame and Endangered Wildlife Program, and the U.S. Fish and Wildlife Service, Asheville, North Carolina, 30pp.

Hedin, M. 2014. Genetic analysis of the spruce-fir moss spider, *Microhexura montivaga*. Unpublished report to the U.S. Fish and Wildlife Service, Asheville, NC. 27 pp.

Karl, T.R., J.M Melillo, and T.C. Peterson (Eds.). 2009. Global Climate Change Impacts in the United States. Cambridge University Press.

North Carolina Natural Heritage Program (NC NHP). 2010. Ecosystem Response to Climate Change: Assessment of Effects and Adaptation Strategies.

Noss, R.F., LaRoe, E.T., Scott, J.M., 1995. Endangered Ecosystems of the United States: A Preliminary Assessment of Loss and Degradation, Biological Report 28, USDI National Biological Service, Washington, DC, 58 pp.

Southern Appalachian Man and the Biosphere (SAMAB). 1996a. The Southern Appalachian Assessment Summary Report. Report 1 of 5. Atlanta: U.S. Department of Agriculture, Forest Service, Southern Region.

Southern Appalachian Man and the Biosphere (SAMAB). 1996b. The Southern Appalachian Assessment Terrestrial Technical Report. Report 5 of 5. Atlanta: U.S. Department of Agriculture, Forest Service, Southern Region.

Stehn, S.E. 2009. Influence of exogenous disturbance on bryophyte community assemblage and tree regeneration dynamics in Southern Appalachian spruce-fir forests. Unpublished Master's thesis. Michigan Technological University, Michigan. 111 pages.

U.S. Fish and Wildlife Service. 1998. Recovery Plan for the Spruce-fir Moss Spider. Atlanta, GA. 22pp.

Wear, D.N. and J.G. Greis. 2002. *Southern forest resources assessment: summary report.* General Technical Report SRS-54. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station.

Weathers, K. C., S.M. Simkin, G.M. Lovett, and S.E. Lindberg. 2006. Empirical modeling of atmospheric deposition in mountainous landscapes. Ecological Applications 16: 1590–1607.

U.S. FISH AND WILDLIFE SERVICE

5-YEAR REVIEW Spruce-fir moss spider (*Microhexura montivaga*)

Current Classification: Endangered

Recommendation resulting from the 5-Year Review:

__X__ No change needed

Review Conducted By:

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

Approve _____ Date 8-1-14

REGIONAL OFFICE APPROVAL:

for

Lead Regional Director, Fish and Wildlife Service

Approve _____ Date 7-10-14

for

Cooperating Regional Director, Fish and Wildlife Service

Approve _____ Date 12/2/2014

APPENDIX A: Summary of peer review for the 5-year review of the spruce-fir moss spider (*Microhexura montivaga*)

A. Peer Review Method: A draft 5-year review was sent to each of the following biologists, as an attachment to an email, requesting their review and any other changes or additions that should be included in the document. All reviewers have extensive knowledge of this and/or similar species.

1. Dr. Fred Coyle, Professor of Biology Emeritus, Western Carolina University, Cullowhee, NC

2. Glenn Taylor, Biologist, Great Smoky Mountains National Park, Gatlinburg, TN

3. Stephen Hall, Invertebrate Zoologist, NC Natural Heritage Program, Raleigh, NC

B. Peer Review Charge: Peer reviewers were asked to conduct a scientific review of the technical information presented. Reviewers were not asked to comment on the legal status of the species.

C. Summary of Peer Review Comments: Reviewers responded by email. Comments received were minor and mostly editorial in nature. Reviewers provided additional information concerning the status of certain populations, clarification of threats to the species, and recommendations for future actions. For example, Dr. Coyle commented that it has not been determined why the spider does not inhabit wet bryophyte mats and that drowning may not be as likely as increased pathogens or decreased prey availability. The text on page 13 was changed to reflect this information. Two reviewers provided additional references related to climate change. These references were added on page 13.

D. Response to Peer Review: Recommendations from the reviewers were evaluated and incorporated into the document as appropriate. Editorial comments and requests for clarification in the text were also incorporated where appropriate.