Carolina Northern Flying Squirrel
(Glaucomys sabrinus coloratus)

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

Carolina Northern Flying Squirrel *(Glaucomys sabrinus coloratus)*

I. GENERAL INFORMATION.

A. Methodology used to complete the review. This review was conducted by the lead recovery biologist for this species in the Asheville Ecological Services Field Office, Asheville, North Carolina (NC). A notice of the initiation of this 5-year review was published by the U.S. Fish and Wildlife Service (Service) in the *Federal Register* (72 FR 54057) on September 21, 2007, and a 60-day comment period was opened. The Service sent a request for updated information on the current status of the Carolina northern flying squirrel to 32 individuals who are considered to be experts with regard to this subspecies. These individuals included federal and state agency personnel who are responsible for monitoring and managing the subspecies and knowledgeable members of the academic community who have conducted research on its status, distribution, and ecology. The information provided in response to this request, as well as information in our files, was used to complete this review. A draft of this document was internally reviewed by Geoff Call and Shane Hanlon in cooperating Service field offices. It was also peer reviewed by four experts familiar with the Carolina northern flying squirrel. Comments and information received were evaluated and incorporated as appropriate (see Appendix A).

B. Reviewers.

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

Lead Field Office - Robert Currie (retired) and Susan Cameron (current staff), Asheville Ecological Services Field Office, Asheville, NC, 828-258-3939.

Cooperating Region - Northeast Region: Mary Parkin, 617-417-3331.

Cooperating Field Offices - Geoff Call, Tennessee Ecological Services Field Office, Cookeville, Tennessee (TN), 931-528-6481; and Shane Hanlon, Southwestern Virginia (VA) Ecological Services Field Office, Abingdon, VA, 804-693-6694.

C. Background.

1. ***Federal Register* notice citation announcing initiation of this review:** 72 FR 54057, September 21, 2007.

2. **Species' status:** Stable (2010 and 2011 Recovery Data Calls). Reported as stable, given this species' continued presence at sites; however, there continues to be no reliable means of confidently determining population levels or trends. The NC Wildlife Resources Commission (NCWRC) continues to monitor the status of the NC populations and is working on refining traditional survey methods and

developing new survey methods. Monitoring of the TN population has been initiated and will be expanded in the future. Surveys for the species on the Cherokee Indian Reservation in western NC that were initiated in 2007 successfully located a previously unknown population of the species in 2008. Surveys continued in 2009 and 2010. Little is known about the species' status in southwestern VA. Work on the genetic structure of this subspecies is continuing at the University of NC, Wilmington. Work is underway to develop a rapid survey technique for this species using acoustic detectors.

3. **Recovery achieved:** 2 (2=26 to 50 percent recovery objectives achieved).

4. **Listing history:**

   Original listing:
   FR notice: 50 FR 26999.
   Date listed: July 1, 1985, effective date July 31, 1985.
   Entity listed: Subspecies.
   Classification: Endangered.

5. **Associated rulemakings:** None.

6. **Review history:** A formal 5-year review of the status of the Carolina northern flying squirrel was initiated by the Service on November 6, 1991 (56 FR 56882). This review was completed in 1992, and endangered status was maintained for the subspecies based on responses to that review. Subsequent to that formal review, the Service informally reviewed the status and progress toward recovery at least annually (Recovery Data Call) and sometimes more often. The results of these reviews were summarized on a periodic basis, usually biennially, in Reports to Congress on the Recovery of Threatened and Endangered Species. Throughout this period the status of the Carolina northern flying squirrel was believed to be stable, with 26 to 50 percent of the identified recovery tasks having been completed.

   Final Recovery Plan – September 24, 1990.

   Recovery Data Call – 2011, 2010, 2009, 2008, 2007, 2006, 2005, 2004, 2003, 2002, 2001, 2000, 1999, and 1998.

7. **Species' Recovery Priority Number at start of review (48 FR 43098):** The Recovery Priority Number for the Carolina northern flying squirrel is 6c. This designation indicates that the subspecies is subject to a high degree of threat, has a low recovery potential, and its protection may conflict with development or some other economic interest.

8. **Recovery plan:** Name of plan: Appalachian Northern Flying Squirrels, (*Glaucomys sabrinus fuscus* and *Glaucomys sabrinus coloratus*) Recovery Plan. Date issued: September 24, 1990.

II. REVIEW ANALYSIS.

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

1. **Is the species under review listed as a DPS?** No.

2. **Is there relevant new information that would lead you to consider listing this species as a DPS in accordance with the 1996 policy?** No.

B. Recovery criteria.

1. **Does the species have a final, approved recovery plan containing objective, measurable criteria?** This species does have a final, approved recovery plan. While the recovery criteria were considered adequate at the time the plan was developed, they are not objective and measureable. Furthermore, the recovery plan was developed 20 years ago, and because of the limited information available when written, the recovery criteria were very general and actions are, for the most part, combined and generalized for both *G. s. coloratus* and *G. s. fuscus*.

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?** No. Much has been learned in the 20 years since the recovery plan was developed. New information has become available on the species' biology, habitat, and threats.

   b. **Are all of the five listing factors that are relevant to the species addressed in the recovery criteria?** No.

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.** While there is a need to update the recovery criteria for the Carolina northern flying squirrel, there is still value in the existing recovery criteria as they provide a benchmark for progress. An analysis of progress made toward these criteria is provided below, and further analysis is provided in the subsequent sections.

   Downlisting criteria. We have not met the downlisting criteria for the Carolina northern flying squirrel. It will be considered for downlisting to threatened status when:

   1. **Squirrel populations are stable or expanding (based upon biennial sampling over a 10-year period) in a minimum of 80 percent of all**

Geographic Recovery Areas (GRAs). The Carolina northern flying squirrel has been found in nine mountain ranges (GRAs) spanning NC, TN, and VA (Service 1990, Weigl et al. 1999). Surveys for Carolina northern flying squirrels have been occurring annually since 2003 in seven of the nine GRAs, with most GRAs being monitored additional years. In the case of the remaining two GRAs, one has not been monitored because it is privately owned and access has not been granted, and the other has been monitored inconsistently in recent years because of funding issues.

Although extensive amounts of valuable data have been collected, at this point these surveys cannot reliably determine population status and trends. This is largely a result of the cryptic nature of this mammal. While recent surveys have documented the species in three additional counties in NC (Laseter 2008, Kelly 2008), extending its range in two of the GRAs, there has been an overall decline in the number of detections since 2004 (Kelly 2008). It is not known if recent rangewide declines in the capture of flying squirrels reflect true population declines or simply changes in occupancy due to other factors (e.g., weather, natural den availability). Work is underway to develop new survey techniques (e.g., acoustic monitoring) and improve old techniques by incorporating detectability.

2. **Sufficient ecological data and timber management data have been accumulated to assure future protection and management.** While some progress has been made to address this criterion, much remains to be learned about the ecological needs of this species. Additional information is also needed on timber management in portions of the range.

3. **GRAs are managed in perpetuity to ensure: (a) Sufficient habitat for population maintenance/expansion and (b) habitat corridors, where appropriate elevations exist, to permit migration among GRAs.** This has yet to be accomplished. At least portions of seven of the eight GRAs in NC/TN are under state or federal ownership; however, one entire GRA (Long Hope Valley) is privately owned. Flying squirrels were documented at this site in the early 1990s, but biologists have not been given access to the property to conduct additional surveys. The Nature Conservancy is working with the landowners to put a portion of the property under conservation easement, but these efforts have been hampered. Portions of the Great Balsams and Plott Balsams are also unprotected and are vulnerable to development. The GRA in VA is under federal ownership.

   Additionally, there are conflicts of interest in some of the protected GRAs. For example, the National Park Service attempts to balance management of vistas, roads, and recreation areas with management of the squirrel. Likewise, the U.S. Forest Service attempts to balance sometimes conflicting objectives such as recreation and timber management. It

appears that sufficient habitat for population maintenance is maintained despite conflicting management, but it is unclear if sufficient habitat is being managed for expansion or to allow for habitat corridors that connect GRAs.

There is a need to restore or introduce spruce to certain areas where it was thought to have been historically or where pests continue to decimate the conifer component of the habitat (e.g., the Unicoi Mountains, an area that is currently losing all of its hemlocks). Spruce restoration will help with population maintenance, and possibly expansion, in some areas.

Delisting criteria. Delisting will be possible when, in addition to the above factors, it can be demonstrated that:

4. **The existence of the high-elevation forests on which the squirrels depend is not itself threatened by introduced pests, such as the balsam wooly adelgid, or by environmental pollutants, such as acid precipitation or toxic substance contamination.** High-elevation forests continue to face multiple threats. The balsam woolly adelgid continues to threaten Fraser fir trees, and the hemlock adelgid is now threatening Eastern and Carolina Hemlocks. Hemlock trees may provide an important alternative conifer component at lower elevations that do not support spruce (e.g., the Unicoi Mountains). Beech bark disease is killing large numbers of American beech trees (*Fagus grandifolia*), an important northern hardwood species that provides nesting habitat for the Carolina northern flying squirrel. Acid precipitation and other environmental pollution continue to be a concern. Acid precipitation can impact forest health and productivity. In an attempt to address some of these issues, biologists are working on plans to restore or introduce spruce to some areas to offset the loss of conifer species. Additionally, climate change has the potential to exacerbate these threats and add additional stressors to high-elevation forests in the Southern Appalachians.

C. Updated information and species' current status.

1. **Biology and habitat:** The following sections summarize information that has become available largely since development of the 1990 recovery plan.

   a. **New information on the species' biology and life history.** The northern flying squirrel (*Glaucomys sabrinus*) is a wide-ranging nocturnal, nonhibernating, gliding mammal found from the Pacific Northwest across Canada and the northern United States. The Carolina northern flying squirrel (*Glaucomys sabrinus coloratus*) is found at the southern limit of the species' range at high elevations in the Southern Appalachians. A description of the Carolina northern flying squirrel is provided in the Service's recovery plan (1990). It is distinguished from the West Virginia (WV) northern flying

squirrel (*Glaucomys sabrinus fuscus*) by its larger size, longer tail length, and brighter coloration (Handley 1980). The southern flying squirrel (*Glaucomys volans*) generally occurs at lower elevations and is distinguished by its smaller size, difference in fur coloration, and several anatomical features (Service 1990).

Food sources for the Carolina northern flying squirrel include fungi, lichens, staminate cones, insects, and other animal matter (Service 1990, Weigl et al. 1999, and Loeb et al. 2000). Truffles have been found as the major food source in other populations of northern flying squirrels. It has been assumed that the diet of the Carolina northern flying squirrel is similar to that of northern flying squirrels in the northwestern United States, which is comprised primarily of truffles and lichens (Service 1990). Weigl et al. (1999) found a variety of fungal spores in fecal samples of northern flying squirrels in NC, TN, WV, and VA. Six genera of hypogeous fungi (underground; truffles) were identified. *Geospora* was the most commonly eaten truffle, followed by *Elaphomyces*. A variety of epigeous spores (above ground; mushrooms) were also present. Loeb et al. (2000) found that the presence and abundance of truffles in the Southern Appalachians was strongly associated with the presence and importance of spruce at the micro and macro habitat levels. In contrast, hardwoods such as beech and yellow birch (*Betula alleghaniensis*) were the dominant species in plots with no truffles and with low truffle production. Results from this study suggest that spruce-fir and mixed spruce-fir/northern hardwood forests may be important because they support truffles and represent important foraging habitat for the Carolina northern flying squirrel.

Northern hardwood stands, particularly those containing yellow birch, may be especially important for nesting (Weigl et al. 1999, Chris McGrath, NCWRC, personal communication, 2010). Nests are constructed with shredded birch bark and are often found in natural cavities in live and dead trees in northern hardwood species such as yellow birch and American beech (Weigl et al. 1999, Weigl et al. 2002 and Hackett and Pagels 2003). Carolina northern flying squirrels also use dreys constructed of twigs enclosing a nest composed of shredded yellow birch bark. Dreys are most often found in spruce trees but have also been found in deciduous trees and hemlocks in northern hardwood forests (Weigl et al. 1999, Weigl et al. 2002). This subspecies has been documented using underground dens in the Unicoi Mountains, and subterranean dens may provide additional habitat not previously thought to be significant (Weigl et al. 2002, Kelly 2008).

This squirrel is somewhat social and will often den in small groups and may remain in family groups even after young become independent (Weigl et al. 1999). Weigl et al. (1999) found that Carolina northern flying squirrels have relatively small home ranges (3 to 15 hectares) on Roan Mountain, the size of which can vary with sex and season. A study in the Unicoi Mountains

revealed larger home range sizes (3.3 to 51.4 hectares, with an average of 15.9 hectares) and much larger home ranges for males than females (Weigl et al. 2002). It was unclear why home ranges were larger in the Unicoi Mountains, but this might have been a function of factors such as more widely distributed food resources or mating activity (Weigl et al. 2002, Hughes 2006). It is known that squirrels are capable of going on long forays (especially males) of over 1.5 kilometers (Weigl et al. 1999, Weigl et al. 2002, Hughes 2006). However, little is known about the ability of this animal to disperse long distances, possible movement between populations across unsuitable habitat, and rate of dispersal required to sustain viable metapopulations (Weigl et al. 1999, Smith 2007).

b. **Abundance, population trends, demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends.** At the time it was added to the Federal List of Endangered and Threatened Wildlife and Plants, the Carolina northern flying squirrel was known from only four areas--Roan Mountain (TN and NC), Great Smoky Mountains National Park (TN and NC), Mt. Mitchell (NC), and Whitetop Mountain (southwestern VA). In 1986, the NCWRC initiated an extensive presence/absence and mark-recapture surveys for the Carolina northern flying squirrel in NC. This study was completed in 1991 and resulted in an increase in the known occurrences of the squirrel in NC and provided additional information on their ecology (Weigl et al. 1999). This study was followed by additional monitoring efforts conducted by the NCWRC. Kelly (2008) reported that the NCWRC has continuously monitored Carolina northern flying squirrel populations since 1996. This project started with one GRA in 1996, and by 2003 it had been expanded to include all but one of the GRAs located in NC identified in the recovery plan (Service 1990). The only GRA not included in their surveys is Long Hope Valley. This site is privately owned, and access is restricted. Monitoring efforts primarily relied on nest-box surveys, supplemented occasionally with live-trapping.

Kelly (2008) reported that 7,617 individual nest-box checks were conducted, with 923 Carolina northern flying squirrels detected (129 of these detections were recaptures) between 1996 and 2007. The number of squirrels detected annually has varied throughout the study, with the highest number of detections occurring in 2004, followed by a significant decrease in detections in subsequent years. Because of this variability in detections, it is difficult to establish current population levels or trends for the NC population of the squirrel. The reasons for this variation are unknown but may be related to the squirrel's preference for, and abundance of, natural cavities or that nest-box captures may tend to be greatest during periods of very cold weather (McGrath 2002). While it is preferred to check nest boxes on days with cold temperatures to maximize captures, surveys are sometimes conducted during days with mild temperatures simply because of the large numbers of boxes

that need to be checked within a given season. Work is underway to develop a plan for sustainable, long-term monitoring of Carolina northern flying squirrels through modifying existing survey methods and developing new sampling methods (Kelly 2008).

Considerably less is known about northern flying squirrel populations in TN and VA. The VA population was monitored from 1985 through 1996 by VA Department of Game and Inland Fisheries (VDGIF) and others (Reynolds et al. 1999). Since 1996, the U.S. Forest Service has continued to monitor the population annually; however, because of limited captures, the current size and trends of this population cannot be determined (Rick Reynolds, VDGIF, personal communication, 2008). Surveys in TN have not been frequent or intensive enough to evaluate the status of the Carolina northern flying squirrel in that state. The U.S. Forest Service recently initiated nest-box surveys in the Cherokee National Forest in the Unicoi Mountains and on Roan Mountain in TN. Additional information relative to TN populations may become available in the future.

Little is known about the demographics of the Carolina northern flying squirrel. The collection of demographic information has been hampered by low recapture rates and ear-tag loss. The northern flying squirrel can be relatively long-lived (4 to 7 years) and has a low reproductive rate (generally a single litter annually, with two to five young) (Weigl et al. 1999, Weigl 2007, Kelly 2008). It is possible that this species has boom or bust years in terms of productivity, depending on environmental conditions. A preliminary analysis of the mark-recapture data collected by the NCWRC in the Great Balsam Mountains indicates low survival, but this could be an issue of tag loss (Kelly 2008). In spite of the increase in northern flying squirrel studies since the time of listing, we have surprisingly little information on the species' life history and population biology and know very little about most population parameters and long-term temporal and spatial trends (Weigl 2007).

c. **Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.).** Arbogast et al. (2005) found that the northern flying squirrels of the Southern Appalachians are genetically distinct from and have lower levels of genetic variability than conspecific populations elsewhere. Browne et al. (1999) stated that small population sizes and low genetic variability of the squirrels in the Southern Appalachians increases the risk of inbreeding and loss of evolutionary flexibility. Wartell (2004) is conducting an analysis of the genetic structure of the Carolina northern flying squirrel and evaluating gene flow between the various GRAs. As of 2004, tissue samples had been collected from 276 individuals, and analysis of this material is continuing. Though previous studies of Carolina northern flying squirrel genetics have not included samples from VA, work is underway to examine the genetics of the southwestern VA

population of the squirrels (Christine Kelly, NCWRC, personal communication, 2010).

d. **Taxonomic classification or changes in nomenclature.** Based upon his examination of morphometrics and pelage color of two northern flying squirrel specimens, C. O. Handley thought that the southwestern VA population was intermediate between *G. s. coloratus* and *G. s. fuscus* (Fies and Pagels 1991). The recovery plan included the southwestern VA population with *G. s. coloratus* for purposes of recovery. However, it was pointed out that the taxonomic identity of this population should be determined by an examination of additional specimens (Service 1990). Reynolds et al. (1999) examined morphometrics of 51 individuals from the Mt. Rogers area and found that tail length was within the range reported by Weigl et al. (1999) for *G. s. coloratus*. As mentioned previously, the southwestern VA population is included in this review of the Carolina northern flying squirrel; however, this is a tentative assignment, and additional studies need to be conducted to resolve the taxonomic status of this population.

e. **Spatial distribution, trends in spatial distribution (e.g., increasingly fragmented, increased numbers of corridors, etc.), or historic range (e.g., corrections to the historical range, change in distribution of the species within its historic range, etc.).** The Carolina northern flying squirrel is a Pleistocene relict in the Southern Appalachians that is confined to a handful of isolated high-elevation peaks and ridges that support spruce-fir and northern hardwood forests. Fossil remains indicate a much larger range during the Pleistocene and early Holocene (Service 1990).

The squirrel continues to persist in the seven GRAs monitored in NC and has recently been found in several newly surveyed areas within two of these GRAs. As previously mentioned, the eighth GRA in NC--Long Hope Valley--has not been surveyed since the early 1990s. Since listing, this subspecies has been documented in 13 western counties, including Avery, Ashe, Watauga, Caldwell, McDowell, Mitchell, Yancey, Buncombe, Transylvania, Haywood, Jackson, Swain, and Graham. In addition to surveys in the seven GRAs, nest boxes have been posted in two state-owned properties (Elk Knob State Park and Beech Creek Bog) and on the Cherokee Indian Reservation. While the presence of northern flying squirrels has not been confirmed at Elk Knob or Beech Creek, it has been confirmed on the Cherokee Indian Reservation, adjacent to Great Smoky Mountains National Park (Laseter 2008).

In VA, the northern flying squirrel is currently known only from the Mt. Rogers National Recreation Area, along the crest of Mt. Rogers, and on Whitetop Mountain in Smyth and Grayson Counties. This GRA contains

approximately 7,800 acres of habitat that is believed to be suitable for the subspecies (Reynolds, personal communication, 2008).

The Carolina northern flying squirrel is known from three areas in TN (Carter, Monroe, and Sevier Counties). It was found on the TN side of Roan Mountain and on Mount Kepart in the Great Smoky Mountains National Park during the Weigl et al. study (1999) and was first discovered on the TN side of the Unicois in 1987 (Weigl et al. 2002). Although little survey and monitoring work has been conducted recently in TN, surveys in NC along the state line revealed that the species is present at five locations immediately adjacent to TN in the Great Smoky Mountains National Park (Stiver et al., unpublished report, no date), in the Unicoi Mountains along the Cherohala Skyway (Weigl et al. 2002, Kelly 2008), and on Roan Mountain (Kelly 2008). A 1991 survey of selected sites in TN (Unaka Mountain and the Unicoi Mountains) and NC failed to find the Carolina northern flying squirrel in TN while seven were found in NC. However, the authors noted that additional surveys were needed since the study allowed for only 5 trap-nights per given location (Grant et al. 1991).

f. **Habitat conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem).** The Carolina northern flying squirrel occupies high-elevation forests and is most often encountered at the ecotone between northern hardwood and spruce or spruce/fir forests. While some combination of northern hardwoods and conifers (particularly spruce and fir) appear important to support these animals (Service 1990), they have been found in other less typical areas. McGrath and Patch (2003) found this species in low densities in spruce-fir forests that grade into high-elevation red oak forests in the Balsam Mountains of NC. Additionally, while rarely captured in pure conifer stands or pure hardwood stands, this subspecies can live in pure northern hardwoods as evidenced by its persistence in the Unicoi Mountains of NC and TN.

Habitat features important to the Carolina northern flying squirrel include old trees and abundant woody debris (habitat characteristics associated with old-growth forests), cool and moist conditions, substantial ground cover, and some degree of openness under the canopy (Weigl et al. 1999). This habitat exists at high elevations, typically above 1,372 meters (4,500 feet) and is most often found on north-facing mountainsides and drainages. This restricts the amount of potential habitat to a small number of "sky islands" that support spruce-fir/northern hardwood forests.

Spruce-fir/northern hardwood forests are among the rarest and most threatened forest types in the south (White el al. 1993, Wear and Gries 2002). This habitat has shrunk since the last ice age and remains only on the highest peaks. Habitat quality and quantity are expected to decrease due to various

factors, including introduced pests/disease, pollution, development, and climate change.

Weigl et al. (1999) provided a rough estimate of approximately 39,000 hectares of potential habitat, based primarily on suitable elevation and aspects. This estimate did not account for the inclusion of unsuitable habitat within high-elevation areas; therefore, the actual amount of available habitat may be much lower (McGrath and Patch 2003). The NCWRC and its partners attempted to refine estimates through habitat modeling. McGrath and Patch (2003) and McGrath (2003) developed and tested a vegetation-based model for the Carolina northern squirrel in two of the GRAs (Black-Craggy Mountains and Great Balsams). They found that although the model could not be relied upon to predict the actual plant communities that existed on the ground, it was a useful tool in predicting the distribution of squirrels when combined with other sources of information. As noted by the authors, the reason for difficulties in predicting the plant communities likely stems from past land use. Logging practices during the late 1800s and early 1900s depleted the organic soils in some areas, resulting in the regeneration of northern hardwoods where spruce formerly existed. Therefore, the model may be useful in identifying areas for future spruce restoration efforts since topographical conditions were used to construct the model (McGrath 2003). The model has also proven very useful in project review and identification of potential sites for additional surveys in the two GRAs for which it was developed. Lastly, the model has shown that northern flying squirrels do occur in high-elevation red oak forests where they transition to spruce or where other key habitat components are present (i.e., conifers, seeps, birch), though at lower abundance, and will move through it to access preferred habitat (Kelly 2008).

2. **Five-Factor Analysis:**

   a. **Present or threatened destruction, modification or curtailment of its habitat or range.** Habitat loss and fragmentation are significant threats to the Carolina northern flying squirrel, which already has a restricted and fragmented distribution. There has been an increase in residential development in the Southern Appalachians, and the human population is expected to continue to grow. Actual and potential loss and fragmentation of habitat to residential development threatens two GRAs (the Plott Balsams and Long Hope Valley). The loss of habitat in the Plott Balsams would break up connectivity with neighboring GRAs, and the loss of habitat in Long Hope Valley could result in the loss of an entire recovery area (Kelly 2008). Research is needed on potential impacts from timber-management practices. If not conducted with protection of the squirrel in mind, timber management adjacent to areas supporting the species could adversely affect the species.

In addition to habitat loss due to residential development, activities to accommodate an increasing demand for recreation at high elevations are also a significant threat (e.g., construction of parking areas and roads; vista management). For example, the construction of a high-elevation highway (Cherohala Skyway) in the Unicoi Mountains GRA resulted in a barrier to squirrel movement. This barrier has effectively cut the population into two isolated segments (Weigl et al. 2002, Hughes 2006). The long-term solution to this problem is the reestablishment of large trees adjacent to the highway from which the squirrels can glide across the road without traveling on the ground and increasing their vulnerability to predation. In the interim, the NCWRC has, in cooperation with the U.S. Forest Service and Duke Energy, erected three sets of power poles adjacent to the highway to provide artificial crossing structures. Squirrel use of these experimental structures will be monitored by the NCWRC for several years (Kelly 2008).

An additional example of potential impacts from recreational development can be found along the Blue Ridge Parkway (Parkway), which traverses several of the Carolina northern flying squirrel GRAs. Two components of Parkway management that may impact flying squirrels are the maintenance of scenic vistas and the scenic view-sheds established to enhance the visitor's experience. The National Park Service has determined that there are 193 vistas or view-sheds along the Parkway that are within areas known to support northern flying squirrels or are within suitable habitat. In order to minimize threats to the squirrel, these areas need to be managed in a way that ensures the key components of the squirrel's habitat are maintained and expanded. The National Park Service is working with the Service and the NCWRC toward achieving this goal (Kelly 2008).

Forest pests and diseases are significant indirect threats to the existence and recovery of the Carolina northern flying squirrel, with the balsam woolly adelgid, hemlock woolly adelgid, and beech bark disease threatening the habitat this species occupies. The loss of fir and hemlock trees and declines in spruce trees may result in serious degradation of squirrel habitat since conifers are an important component of their habitat. American beech trees provide a significant number of dens for Carolina northern flying squirrels and are being killed in large numbers by beech bark disease. This may result in an increase in available den sites in the short term but could, in the long term, result in the loss of a significant den resource (Kelly 2008).

The balsam woolly adelgid was recognized as a threat to the species in the recovery plan (Service 1990). There continues to be no effective, widely available control mechanism for this imported pest, and it continues to kill fir trees in the Southern Appalachians. The Unicoi Mountain GRA is unique in that it does not contain any spruce or fir trees, and the closest spruce stands are 45 kilometers away (Weigl et al. 1999). In this GRA, hemlocks may provide an important habitat component needed by the squirrels. They have

been found denning in hemlocks, but it is not known if the hemlock plays a role in the diet of the flying squirrel (Kelly 2008). The hemlock adelgid is expanding in the Southern Appalachians and is killing almost all the hemlocks. The U.S. Forest Service began treatment (using biological controls) of some of the hemlocks in the Unicoi Mountains in 2007, and the NCWRC has initiated a spruce restoration project in the Unicoi Mountains. It is not known at this time if spruce stands can be reestablished quickly enough to replace the hemlocks that are being lost to the adelgid (Kelly 2008).

b. **Overutilization for commercial, recreational, scientific, or educational purposes.** This is not known presently and was not recognized at the time of listing as a threat to the species. However, flying squirrels are highly desirable as pets; thus, collection for the pet trade is at least a potential threat.

c. **Disease or predation.** The internal nematode parasite *Strongyloides robustus* has been identified as a potential problem for Carolina northern flying squirrels (Weigl et al. 1999). This parasite is commonly found in southern flying squirrels. While it apparently does not have significant adverse effects on this species, it can be lethal or seriously debilitating to Carolina northern flying squirrels (Weigl 1968, Weigl et al. 1999). The prevalence of this parasite in Carolina northern flying squirrel populations has increased in recent years, and the role it plays in the viability of squirrel populations is poorly understood (Weigl et al. 1999, Weigl 2007).

The high-elevation habitats where Carolina northern flying squirrels are typically found might offer some protection against the parasite as cold temperatures inhibit the establishment and transmission of *Strongyloides* (Wetzel and Weigl 1994). Additionally, there is some evidence that the availability of conifer foods such as staminate cones, which are consumed by northern flying squirrels, provide certain chemicals (terpenes) that suppress the development of the parasite (Weigl 1968, Weigl et al. 1999). This may, in part, account for the northern flying squirrel's general restriction to high-elevation areas near conifers (Peter Weigl, Wake Forest University, personal communication, 2010; Weigl 2007). Southern and northern flying squirrels rarely co-occur in the Southern Appalachians, and the potentially complex relationship between these two species and the parasite might explain the absence or disappearance of Carolina northern flying squirrels in areas with or invaded by southern flying squirrels.

As previously mentioned, Carolina northern flying squirrels are most often found in conifer/northern hardwood ecotones or mosaics. Southern flying squirrels are typically found in oak and hickory forests at lower elevations as they are somewhat sensitive to cold and rely on cached hard mast for winter survival. When management activities result in the creation of the hardwood stands preferred by southern flying squirrels within or adjacent to northern flying squirrel habitat these areas can be invaded by southern squirrels thus

providing a vector for the spread of the nematode to northern flying squirrels (Weigl et al. 1999). Additionally, logging practices in the late 1800s and early 1900s resulted in the loss of organic topsoil in some areas, which fostered the conversion from spruce to hardwoods during forest regeneration. Also, this likely has led to an expansion of southern flying squirrels and has possibly increased the rate of transmission of the nematode. Transmission rates could continue to increase as a result of activities such as development, which could create corridors for invasion by southern flying squirrels. Furthermore, given that the parasite is sensitive to cold conditions, warming temperatures as a result of climate change could lead to higher rates of infection in northern flying squirrels (Weigl et al. 1999). Many questions remain unanswered regarding the complex relationship between these two species and the parasite, and additional research is needed.

d. **Inadequacy of existing regulatory mechanisms.** The Carolina northern flying squirrel is afforded some protection by state endangered species laws and is state listed as endangered in all three states (NC, TN, and VA) in which it occurs. NC's Endangered Species Act (NC ST § 113-331-337), TN's Nongame and Endangered or Threatened Wildlife Species Conservation Act (TN ST § 70-8-101-112), and VA's Endangered Species Act (VA ST §§ 29.1-563-570) all provide protection against direct take. However, none of these laws extend protection to habitat.

   This species is also afforded protection on public land. The Organic Act and National Forest Management Act and, more specifically, regulations at 36 CFR 2.2 and FSM 2600, offer protections for wildlife on National Park Service and U.S. Forest Service land, respectively. Additionally, as federal agencies, both consult with the Service under section 7 of the Endangered Species Act of 1973, as amended.

   While the majority of Carolina northern flying squirrel habitat is located on federal and state land, some sites are still on private land (e.g., the Plott Balsams and Long Hope Valley). Home construction and other development (e.g., wind projects) on private land are not always subject to the regulations of section 7 of the Endangered Species Act of 1973, as amended. Therefore, these activities could occur without coordination with the Service.

e. **Other natural or manmade factors affecting its continued existence.** Southern flying squirrels not only act as potential vectors for disease, but they also are generally more aggressive than the northern squirrels and have the potential to displace them (Weigl 1978, Weigl et al. 1999). Differences in habitat preferences, diets, and climatic tolerances have largely kept these species separate in the past (Weigl 2007), but this could change in human-altered landscapes. Southern flying squirrels are expanding into higher elevations in more southern latitudes (Odom et al. 2001, Weigl et al. 1999 in Smith 2007). As mentioned above, historic and current habitat

modification likely resulted in the creation of hardwood stands within or adjacent to northern flying squirrel habitat that can be invaded by southern flying squirrels. While direct interspecific competition has not been widely reported, similarities in behavior and shared vital resources (e.g., tree cavities) coupled with expanding oak and hickory forests and warming climate could lead to more interactions (Weigl et al. 1999 in Smith 2007, Weigl 2007).

Climate change could, if it results in appreciable increases in temperatures, threaten the Carolina northern flying squirrel. The squirrel is restricted to small areas with suitable habitat in the Southern Appalachians. These areas form small islands at high elevations and have reduced connectivity between them. If temperatures in the Southern Appalachians increase and precipitation decreases, it is anticipated that the areal extent of boreal forests will decrease. A reduction in suitable habitat would directly affect the squirrel and increase the genetic isolation of the GRAs by further limiting movement and gene exchange between populations. Warming at high elevations could allow for further invasion by southern flying squirrels and increase the viability of parasites such as *Strongyloides* as mentioned previously. Further, climate change may increase the susceptibility of associated forests to exotic and native forest pests and pathogens.

Pollution (in the form of acid rain and inputs of heavy metals) adversely impacts forest health and productivity, including that of the red spruce (Kelly 2008). Furthermore, high levels of mercury, lead, and other heavy metals found in the soils and fungi within the squirrel's habitat may threaten this mycophagous squirrel. Fungi, which form an important component of the flying squirrel's diet, can bioaccumulate heavy metals; this potential threat needs further evaluation.

D. Synthesis. Since the development of the 1990 recovery plan, the Carolina northern flying squirrel has received additional attention from biologists. As a consequence, research and monitoring efforts have expanded. The greatest focus in recent years has been in NC, where this subspecies has been discovered in additional counties, expanding the number and location of known sites within two of the existing GRAs. Overall, numbers of captures in NC have varied widely from year to year, with apparent declines in some GRAs in recent years. The variation may indicate actual declines in populations or may be the result of extraneous factors such as temperature and/or other unidentified variation between surveys. Additionally, this species may undergo population cycles with boom or bust years as a result of varying environmental conditions. Even less is known about population status and trends in VA and TN. While this species has persisted at monitored sites since development of the recovery plan, there is still no reliable means of confidently determining population levels or trends for this species. Population status therefore remains unclear.

While most GRAs are at least partially protected, two remain vulnerable to development. Even with efforts to maintain habitat within protected GRAs, the Service anticipates a loss of spruce-fir/northern hardwood forests as a result of forest pests, human activities, and climate-related threats like reduced precipitation or increased temperature. Furthermore, the lack of protection for privately owned portions of two GRAs and the questionable future existence of potential corridors between GRAs are still of concern.

The Carolina northern flying squirrel remains vulnerable to a series of natural and manmade stressors that threaten its continued existence. The species 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, climate change, introduced pests and diseases, and pollution. Therefore, the Service recommends that the Carolina northern flying squirrel remain classified as endangered.

III. RESULTS.

A. Recommended Classification.

__X__ **No change is needed**

IV. RECOMMENDATIONS FOR FUTURE ACTIONS.

1. Develop and institute improved survey methods that reliably assess the status, population levels, and population trends of the species throughout its range.

2. Determine the distribution and status of populations of northern flying squirrels in TN and southwestern VA using reliable and more intensive surveys of the areas that are currently known to support the species as well as additional sites that appear to provide suitable habitat.

3. Determine the taxonomic status of the southwestern VA population of the northern flying squirrel.

4. Develop predictive models of habitat utilized by the Carolina northern flying squirrel throughout its range in order to provide managers with an additional tool to manage and protect the species as well as provide insight into additional areas that may support the squirrel.

5. Restore spruce where appropriate, and use spruce restoration as a tool to create and maintain corridors to connect GRAs. Concurrently, remaining stands of northern hardwood need to be protected.

6. Establish a group of federal and state biologists and land managers familiar with the species and its requirements who will coordinate activities related to the assessment, protection, and management of the Carolina northern flying squirrel. This group could, if properly constituted, form the core of a team to develop a revised recovery plan.

7. Revise the recovery plan to reflect current knowledge of the Carolina northern flying squirrel, including objective and measurable recovery criteria and updated actions needed to recover the species.

V. REFERENCES.

Arbogast, B. S., R. A. Browne, P. D. Weigl, and G. J. Kenagy. 2005. Conservation genetics of endangered flying squirrels (*Glaucomys*) from the Appalachian Mountains of Eastern North America. Animal Conservation 8:123-133.

Browne, R., P. Weigl, E. Eagleston, and J. Kelly. 1999. Mountain Tops as Islands: I. Genetic Variation among Southern Appalachian Populations of the Endangered Northern Flying Squirrel *Glaucomys sabrinus* (Mammalia:Sciuridae). Pages 205-214 *in* R. P. Eckerlin, ed. Proceedings of the Appalachian Biogeography Symposium. Virginia Museum of Natural History, Special Publication No. 7, Richmond, VA.

Fies, M. L., and J. F. Pagels. 1991. Northern Flying Squirrel, *G. s. fuscus*. Pages 583-584 *in* K. Terwilliger, ed. Virginia's Endangered Species. McDonald and Woodward Publishing Company, Blacksburg, VA.

Grant, J. H. II, E. R. Smith, M. C. Stockton, and J. C. Graf. 1991. Survey for the northern flying squirrel in the southern Appalachian Mountains of North Carolina and Tennessee, 1991. Unpublished report to U.S. Forest Service, Cherokee National Forest, Cleveland, TN. 31 pp.

Hackett, H. M., and John F. Pagels. 2003. Nest site characteristics of the endangered northern flying squirrel (*Glaucomys sabrinus coloratus*) in Southwest Virginia. Am. Mid. Nat. 150:321-331.

Handley, C. O. 1980. Northern Flying Squirrel. Pages 513-516 *in* D. W. Linzey, ed. Endangered and Threatened Plants and Animals of Virginia. VPI and State University, Blacksburg, VA.

Hughes, R. S. 2006. Home ranges of the endangered Carolina northern flying squirrel in the Unicoi Mountains of North Carolina. Proc. Annu. Conf. Southeast Assoc. Fish and Wildl. Agencies 60:19-24.

Kelly, C. 2008. Letter to the U.S. Fish and Wildlife Service in response to the 5-year review of the Carolina northern flying squirrel. March 14, 2008. North Carolina Wildlife Resources Commission, Division of Wildlife Management. Raleigh, NC.

Laseter, B. R. 2008. Letter to the U.S. Fish and Wildlife Service in response to the 5-year review of the Carolina northern flying squirrel. March 14, 2008. Fish and Wildlife Associates, Whittier, NC.

Loeb, S. C., F. H. Tainter, E. Cazares. 2000. Habitat associations of hypogeous fungi in the Southern Appalachians: Implications for the endangered northern flying squirrel, *Glaucomys sabrinus coloratus.* American Midland Naturalist. 144(2):286-296.

McGrath, C. 2002. Northern flying squirrel population monitoring. Annual Performance Report. Nongame and Endangered Wildlife Program, North Carolina Wildlife Resources Commission, Raleigh, NC. 4 pp.

------. 2003. Northern flying squirrel habitat modeling and assessment in the Black Mountains. Annual (Final) Performance Report. Nongame and Endangered Wildlife Program, North Carolina Wildlife Resources Commission, Raleigh, NC. 15 pp.

McGrath, C., and S. Patch. 2003. Using a terrain-based vegetation model to map Carolina northern flying squirrel distribution. Proc. Annu. Conf. Southeast Assoc. Fish and Wildl. Agencies 57:243-251.

Odom, R. H., W. M. Ford, J. W. Edwards, C. W. Stihler, and J. M. Menzel. 2001. Developing a habitat model for the endangered Virginia northern flying squirrel (*Glaucomys sabrinus fuscus*) in the Allegheny Mountains of West Virginia. Biological Conservation 99:245-252.

Reynolds, R. J., J. F. Pagels and M. L. Fies. 1999. Demography of the northern flying squirrel. Pro. Annu. Conf. Southeastern Assoc. Fish and Wildlife Agencies 53:340-349.

Smith, W. P. 2007. Ecology of *Glaucomys sabrinus*: habitat, demography, and community relations. Journal of Mammalogy 88(44):862-881.

Stiver, W. H., L. Konz, and R. Klein. Not dated. Potential impacts of Gregory Ridge prescribed fire on northern flying squirrels in Great Smoky Mountains National Park. Unpublished report. National Park Service, Gatlinburg, TN. 17 pp.

U.S. Fish and Wildlife Service. 1990. Appalachian northern flying squirrels (*Glaucomys sabrinus fuscus*) (*Glaucomys sabrinus coloratus*) recovery plan. Region 5, U.S. Fish and Wildlife Service, Newton Corner, MA. 52 pp.

Wartell, A. M. 2004. Abstract. Genetic structure and gene flow in the Carolina northern flying squirrel (*Glaucomys sabrinus coloratus*). 84th Annual Meeting of the American Society of Mammalogists, June 12-16, 2004, Humboldt State University, Arcata, CA.

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

Weigl, P.D. 1968. The distribution of the flying squirrels, *Glaucomys volans* and *G. sabrinus*: an evaluation of the competitive exclusion idea. Doctoral dissertation, Duke University, Durham, NC.

------. 1978. Resource overlap, interspecific interactions, and the distribution of the flying squirrels *Glaucomys volans* and *G. sabrinus*. American Midland Naturalist 100:83-96.

------. 2007. The northern flying squirrel (*Glaucomys sabrinus*): A conservation challenge. Journal of Mammalogy 88(4):897-907.

Weigl, P. D., Travis W. Knowles, and Allen C. Boynton. 1999. The distribution and ecology of the northern flying squirrel, *Glaucomys sabrinus coloratus*, in the southern Appalachians. North Carolina Wildlife Resources Commission, Nongame and Endangered Wildlife Program, Division of Wildlife Management. Raleigh, NC. 93 pp.

Weigl, P. D., R. S. Hughes, and D. C. Battle. 2002. Study of northern flying squirrel populations along the Cherohala Skyway: Questions of fragmentation and ecology in the southernmost part of the range. Wake Forest University, Winston-Salem, NC. 83 pp.

Wetzel, E. J., and P. D. Weigl. 1994. Ecological implications for flying squirrels (*Glaucomys* spp.) of effects of temperature on the vitro development and behavior of *Strongyloides robustus*. American Midland Naturalist 131:43-54.

White, P. S., E. R. Buckner, J. D. Pittillo, and C. V. Cogbill. 1993. High-elevation forests: spruce-fir forests, northern hardwood forests, and associated communities, pp. 305-337 *in* W. H. Martin, S. G. Boyce, and A. C. Echternacht (eds.). Biodiversity of the southeastern United States: upland terrestrial communities. John Wiley & Sons, Inc., NY.

U.S. FISH AND WILDLIFE SERVICE

5-YEAR REVIEW
Carolina northern flying squirrel (*Glaucomys sabrinus coloratus*)

Current classification: Endangered

Recommendation resulting from the 5-Year Review:

_____ **Downlist to Threatened**
_____ **Uplist to Endangered**
_____ **Delist**
__X__ **No change is needed**

Review conducted by: Robert Currie and Susan Cameron, Ecological Services Field Office, Asheville, NC.

FIELD OFFICE APPROVAL:

Lead Field Supervisor, U.S. Fish and Wildlife Service

Approved _____ Date 8/29/11

REGIONAL OFFICE APPROVAL:

The Regional Director or the Assistant Regional Director, if authority has been delegated to the Assistant Regional Direction, must sign all 5-year reviews.

Lead Regional Director, U.S. Fish and Wildlife Service

for

Approved _____ Date 10/16/11

The Lead Region must ensure that other regions within the range of the species have been provided adequate opportunity to review and comment prior to the review's completion. If a change in classification is recommended, written concurrence from other regions is required.

for **Cooperating Regional Director, Fish and Wildlife Service**

__✓__ Concur _____ Do Not Concur

Signature _____ Date 6/28/13

APPENDIX A:

Summary of Peer Review for the 5-Year Review of the Carolina Northern Flying Squirrel (*Glaucomys sabrinus coloratus*)

A. **Peer Review Method:** An email was sent to the following biologists asking for peer review of the draft 5-year review (these individuals are considered to be species' experts):

1. Christine Kelly, Wildlife Diversity Biologist, Mountain Region, NCWRC, Asheville, NC.

2. Chris McGrath, Wildlife Diversity Program Coordinator, NCWRC, Asheville, NC.

3. Dr. Peter Weigl, Professor of Biology, Wake Forest University, Winston-Salem, NC.

4. Ron Hughes, Wildlife Lands Manager, VDGIF, Remington, VA.

B. **Peer Review Charge:** Peer reviewers were asked to comment on the validity of the data used and identification of any additional information since the recovery plan was completed in 1990 that was not considered in the draft review. Reviewers were not asked to comment on the legal status of the species.

C. **Summary of Peer Review Comments/Report:** Reviewers responded by email. All reviewers agreed that the species should remain classified as endangered and thought the information in the document provided to them was accurate. They did provide some additional references and recommendations that were incorporated into the 5-year review as appropriate.

D. **Response to Peer Review:** Comments received were evaluated and incorporated where appropriate. Many of them were minor and editorial in nature.