Home Ranges of the Endangered Carolina Northern Flying Squirrel in the Unicoi Mountains of North Carolina

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Abstract: A cluster of small populations of the endangered Carolina northern flying squirrel (*Glaucomys sabrinus coloratus*) was discovered 1989 along the scenic Cherohala Skyway, North Carolina, in northern hardwood and mixed hardwood-hemlock (*Tsuga canadensis*) habitats not previously known to support this subspecies. I examined home range of this subspecies from September 1994–March 1996. Based on the Minimum Convex Polygon method, mean annual home range size was 13.9 ha ($N = 7$), mean summer home range size was 8.3 ha ($N = 6$), and mean winter home range was 12.5 ha ($N = 4$). I found no evidence to indicate northern flying squirrels crossed or attempted to cross the right-of-way associated with the Cherohala Skyway. Managers should consider large areas of north-facing high-elevation northern hardwood and mixed northern hardwood forest as potential suitable habitat for *G. s. coloratus*. Though preliminary, my findings provide additional insight into ecology of this rare flying squirrel associated with atypical habitats and indicate roadways may act as a barrier to northern flying squirrels.

Key words: Cherohala Skyway, *Glaucomys sabrinus coloratus*, MCP, northern flying squirrel, home range, roads, North Carolina

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The northern flying squirrel (*Glaucomys sabrinus*) is a small, strictly nocturnal sciurid that has a distribution generally mirroring that of the boreal spruce (*Picea* spp.), fir (*Abies* spp.), and northern hardwood forests across northern North America (Jackson 1961, Weigl 1968, Hall 1981, Linzey 1984, Wells-Gosling and Heaney 1984). Two recognized subspecies (Hall 1981) of northern flying squirrel, *G. s. fuscus* and *G. s. coloratus* occur in small, isolated, and discontinuous distributions through high elevations of the central and southern Appalachian regions and are tied closely to patches of montane boreal forest (Lee et al. 1982, Wells-Gosling and Heaney 1984, Linzey 1984, U. S. Fish and Wildlife Service (USFWS) 1990, Weigl et al. 1999). Both subspecies are perceived as rare and vulnerable to natural and human-induced impacts such as logging, pollution, development, and introduction of the balsam woolly adelgid (*Adelges piceae*) (White 1984). Because of these threats, compounded by a lack of ecological and biological knowledge, both subspecies were afforded protection by the Endangered Species Act in 1985 (USFWS 1990).

In 1989, three individual *G. s. coloratus* were captured by North Carolina Wildlife Resources Commission (NCWRC) researchers in the Whigg Branch drainage near Haw Knob in the Unicoi Mountains, Graham County, North Carolina, adjacent to the not-yet-completed Cherohala Skyway (Weigl et al. 1999). These flying squirrels were captured in mixed northern hardwood/hemlock (*Tsuga canadensis*) habitat. Subsequent surveys revealed several more individual *G. s. coloratus* at two separate sites. The first was 8 km east of the Whigg Branch site along the Skyway near Hooper Bald and the second was 1 km north of Hooper Bald near Huckleberry Knob. Habitat at the two additional sites was comprised of pure northern hardwoods. These populations presented a unique and important opportunity to study this subspecies for several reasons. First, this cluster of populations is the southernmost known for this species in the eastern United States. Second, the pure northern hardwood and mixed northern hardwood/hemlock forests devoid of a red spruce (*P. rubens*)/Fraser fir (*A. fraseri*) component is atypical habitat for this subspecies. Third, an opportunity existed to study impacts of road building on flying squirrel populations. Lastly, additional ecological information such as habitat characteristics, den ecology, home ranges, and movements could be obtained.

Inherent in home range studies is the assumption that size and placement of an animal's home range is a function of abundance and availability of resources (Fridell and Litvaitis 1991, Phillips et al. 1998). Given this assumption, studying home ranges of the Unicoi Mountain populations may provide additional insight into the ecology of *G. s. coloratus* relevant to recovery of this subspecies. To date, home range investigations for both subspecies are limited to five studies, two for *G. s. coloratus* and three for *G. s. fuscus* (Urban 1988, Weigl et al. 1999, Terry 2004, Menzel et al. 2006, and this study). For this paper, I present preliminary home range findings stemming from a more comprehensive investigation of *G. s. coloratus* ecology and roadway impacts on this subspecies in the Unicoi Mountains (Weigl et al. 2002).

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Study Area

My study area encompassed an 18.1 km section of the 66 km long Cherohala Skyway and adjacent forest in the Unicoi Mountains of southwestern Graham County, North Carolina, adjacent to the Tennessee border (Fig. 1). High, forested ridges and peaks with moderate to steep side slopes and narrow valleys characterized topography. Within the study area, the Skyway ranged from 1305 m–1615 m in elevation and was generally positioned on the north sides of mountains, running along the contour, passing through steep drainages and across a few gaps. Aspect of side slopes and drainages within the study area was predominantly northerly, but varied from westerly to southeasterly. Northwest to northeast facing slopes and drainages were characterized by cool, moist, low-light conditions. Cold, swift-flowing streams were common, and networks of small, intermittent, finger-like drainages along with springs and seeps commonly occurred on headwater slopes.

The landscape was entirely forested, except in the Cherohala Skyway right-of-way and a small mountaintop bald (Hooper Bald) located on the eastern end of the study area and south of the Skyway. Uneven-aged northern hardwoods dominated the forest with exception of a few drainages that contained eastern hemlock. Even in these areas, hemlock was typically mixed with hardwoods and was not widely distributed. American beech (*Fagus grandifolia*), yellow birch (*Betula allegheniensis*), and sugar maple (*Acer saccharum*) dominated the northern hardwood forests. Other less abundant hardwood species included yellow buckeye (*Aesculus flava*), Carolina silverbell (*Halesia carolina*), black cherry (*Prunus serotina*), fire cherry (*P. pensylvanicum*), red maple (*A. rubrum*), serviceberry (*Amelanchier arborea*), cucumber magnolia (*Magnolia acuminata*), and earleaf magnolia (*M. fraseri*). Residual large, older trees, likely left over from the latest logging (mid-1900s), punctuated the overstory and were widely dispersed throughout the forest. The shrub layer varied in density and contained hobblebush (*Viburnum alnifolium*), thornless blackberry (*Rubus canadensis*), mountain maple (*A. spicatum*), *Vaccinium* spp., great rhododendron (*Rhododendron maximum*), striped maple (*A. pensylvanicum*), witch hazel (*Hamamelis virginiana*), largeleaf holly (*Ilex montana*), and saplings of overstory species. A great diversity of forbs, mosses, ferns (*Dryopteris* spp. and *Polystichum acrostichoides*), and shining clubmoss (*Huperzia lucidulum*), dominated the ground cover. Moss and lichens grew in abundance on rocks, dead woody material, and live trees and shrubs. Soil depth appeared variable with rocky places and large boulders scattered about. Coarse woody debris was abundant in many places on the forest floor.

Methods

I chose eight trap sites along the Cherohala Skyway (Fig 1). Specifically, I targeted sites at or above 1372 m in elevation on northwesterly to northeasterly facing slopes and drainages based on presence of important habitat characteristics for this species such as cool, moist environment, presence of relict old trees and abundant snags, and abundant coarse woody debris (Payne et al. 1989, Weigl et al. 1999). I placed traps on both sides of the Skyway whenever possible.

I captured flying squirrels in modified Tomahawk #201 live traps (Tomahawk Live Trap Company, Tomahawk, Wisconsin) from 26 September 1994–26 January 1996. Trapping was almost continuous with periodic breaks due to weather and other factors. I spaced traps ≥ 30 m apart and attached them to large trees with the opening flush to the trunk. I baited them with a peanut butter-oatmeal-bacon grease mixture and a piece of apple and covered them with natural materials to provide protection for captured animals. During cold periods I constructed small shelters from half-gallon paper milk and juice cartons and stuffed them with polyfil or cotton batting and placed these inside each trap. I checked and closed the traps each morning (≤ 0900 hours) and reset them in the evening before dark to reduce capture of non-target species.

I removed and transported captured flying squirrels to a safe work area (i.e., inside a vehicle or dwelling). Processing captured flying squirrels was carried out with two or more people. One person restrained the flying squirrel securely in hand while the other obtained and recorded data. I aged, sexed, weighed (g), measured (mm), and ear-tagged each flying squirrel with numbered Monel ear tags (National Band and Tag Company, Newport, Kentucky). I determined age by examining weight and pelage coloration where *G. s. coloratus* adults were >75 g and had brownish gray pelage and juveniles were <75 g and had dark slate gray pelage (P. D. Weigl, Wake Forest University, personal communication). I differentiated between *G. sabrinus* and *G. volans* by measuring hind foot length and examining ventral fur coloration. Northern flying squirrels have a hind foot length >34 mm and white tipped ventral fur with lead gray basal coloration (P. D. Weigl, Wake Forest University, personal communication). I also noted general health and reproductive condition, and collected blood and feces (when available) for allozyme and parasite analyses, respectively. I attached a 3.5–6.0 g AVM model SM1 radiotransmitter (AVM Instruments Company, Ltd., Livermore, California) using a collar-style attachment to adult *G. s. coloratus* >100 g (Weigl et al. 1999). Radiotransmitter life averaged 72 days (range = 31 to 129 days). I released all animals at their original capture site immediately after handling.

From 12 January 1995–23 February 1996, I monitored seven radiocollared flying squirrels in three separate periods using radiotelemetry at three sites along the Skyway: Whigg Branch, Big Junction, and Hooper Bald (Fig. 1). Radiotracking periods were 12 January 1995 –18 May 1995, 30 July 1995–30 September 1995, and 11 October 1995–23 February 1996. I also located diurnal nest sites for each flying squirrel one to three times per week. I recorded radiotelemetry locations and activity for one individual flying squirrel nightly once or twice a week. I monitored flying squirrels using two observers positioned at known locations on or near Skyway, each with a receiver and hand-held three-element Yagi antenna, simultaneously recording direction of the strongest (peak) signal. I established multiple telemetry stations on and adjacent to the Skyway so that observer azimuths (1°–360°) would be as close to 90° as possible. I recorded azimuths ≥ 15 minutes apart to help ensure biological independence of radiotelemetry locations and to decrease possibility of autocorrelation (Swihart and Slade 1985, White and Garrott 1990). I monitored flying squirrels during one or more of three different nightly monitoring periods that included evening sessions (sunset to midnight), morning sessions (midnight to sunrise), or all-night sessions. For each session I recorded general weather conditions, moon phase, sunset/sunrise time, and any other pertinent information.

I used TELEM88 (Coleman and Jones 1988) computer software to generate home range estimates using the Minimum Convex Polygon (MPC) method (Jennrich and Turner 1969). I estimated overall (annual) home ranges using all usable radiotelemetry locations, including den sites, for each individual flying squirrel. I only used radiotelemetry locations with azimuths between 30° and 120° to estimate home ranges. For MCP, reliable home range estimates occur when area-observation curves become asymptotic (indicated by ≤ 10% increase in home range size over three or more successive observation periods) (Phillips et al. 1998, Reynolds and Laundre 1990). Based on area-observation curves, I found that four to nine nights of monitoring provided reliable home range estimates for squirrels included in analyses. For the purpose of

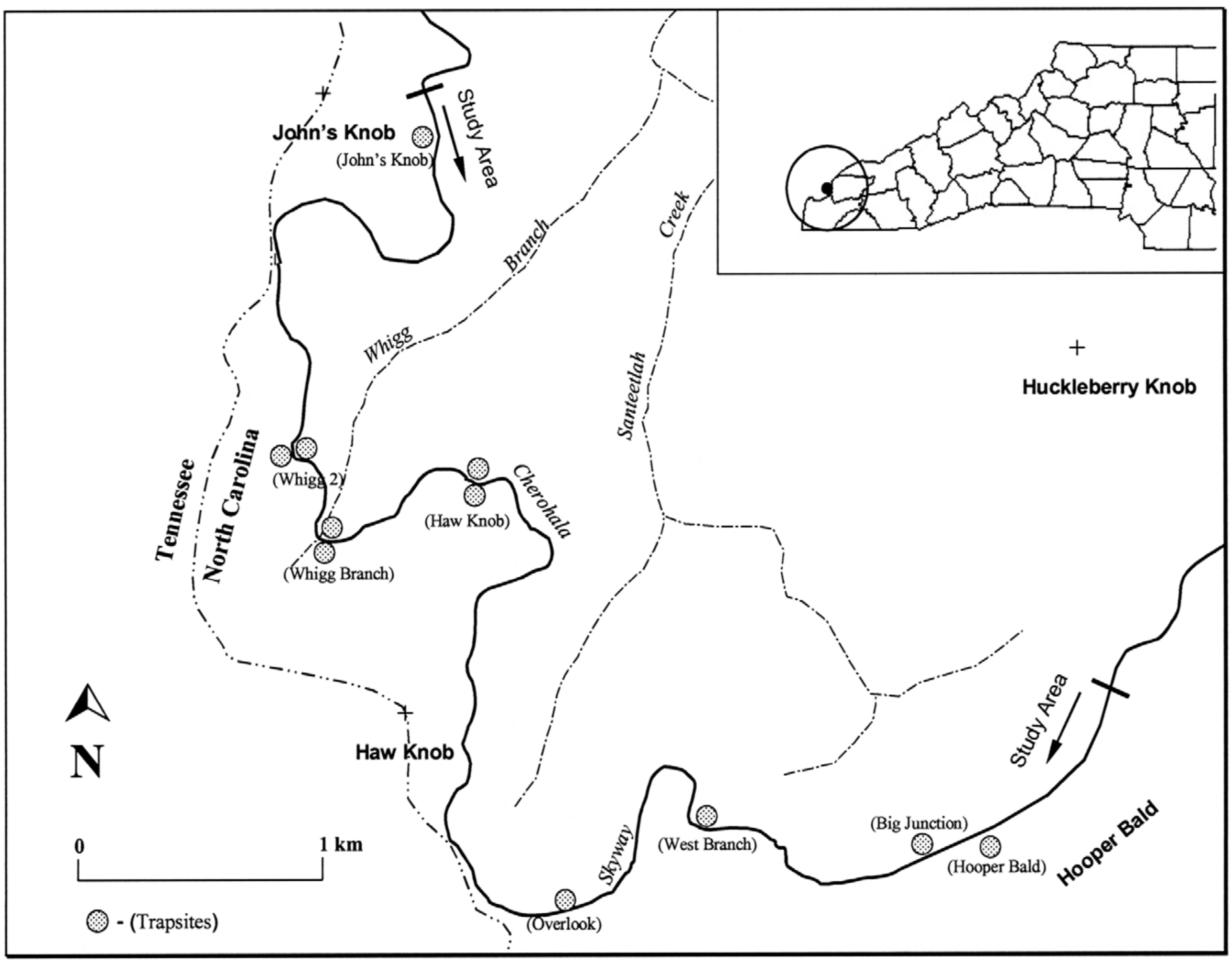

Fig. 1. The 18.1-km section of the Cherohala Skyway and eight trapsites chosen as the study area starting from John's Knob and extending southeastward to Hooper Bald. The study area was located in the Unicoi Mountains of southwestern Graham County, North Carolina.

estimating seasonal home ranges, I used radiotelemetry locations that fell within defined summer and winter seasons. I defined summer (June–September) and winter (mid-October–mid-April) based primarily on changes in climate and vegetative conditions.

After I recorded azimuths taken on test radiotransmitters in the field, I calculated radio telemetry error for sites with actual radiocollared flying squirrels. Mean bearing errors, derived from the differences from actual to estimated bearings of test transmitters (White and Garrott 1990) were 6.8 ° (± 5.8 SD) and 6.9° (± 5.2 SD) for the Big Junction and Whigg Branch sites, respectively.

Results

Trapping during 26 September 1994–24 June 1995 and 26 July 1995–26 January 1996 resulted in 2054 trapnights with 58 captures of 9 male and 16 female northern flying squirrels in five of eight trap sites. I had no escapes and four mortalities. I also captured 12 individual southern flying squirrels (*G. volans*) at two sites, one of which, the Whigg Branch site, also harbored *G. s. coloratus*.

I radiocollared six adult male and four adult female northern flying squirrels and monitored them at four separate sites during 12 January 1995–23 February 1996. I did not collect enough telemetry locations to estimate home ranges for three flying squirrels which included one male and one female whose radiotransmitters both failed and one female that remained outside of effective radiotelemetry range. Home range estimates, therefore, were derived from the remaining seven flying squirrels (Table 1). Four flying squirrels (two males and two females) had radiotelemetry locations that fell within both summer and winter seasons, two males had radiotelemetry locations falling within winter only, and one male had radiotelemetry locations that fell outside summer or winter seasons.

Overall (annual) home range sizes ranged from 3.7–27.7 ha and averaged 13.9 ha (±3.7 SE, N = 7) across the three sites (Table 1). Winter home ranges were from 1.5 ha–27.7 ha and averaged 12.5 ha (±3.3 SE, N = 6), and summer home range size ranged from 2.9 ha–14.8 ha and averaged 8.3 ha (±2.3 SE, N = 4) (Table 1). Mean overall home range size for males was 17.5 ha (N = 5) and for females was 4.9 ha (N = 2). I observed a perceived change in home range size across seasons for two flying squirrels in the Big Junction site but not for those in the Whigg Branch site.

Table 1. Home range estimates (ha) derived using the minimum convex polygon method for seven adult northern flying squirrels radiotracked from three sites along the Cherohala Skyway in the Unicoi Mountains, North Carolina from 12 January 1995–23 February 1996. Winter was mid-October–mid-April and summer was June–September.

Squirrel	Sex	Site	Winter	Summer	Overall	Days tracked	Telemetry locations
No. 3	M	Big Junction	27.7	—	27.7	17	88
No. 12	F	Big Junction	1.5	4.6	5.0	27	112
No. 16	M	Big Junction	24.0	—	24.0	9	64
No. 28	M	Big Junction	7.2	14.8	18.9	26	195
No. 5	F	Whigg Branch	3.6	2.9	4.7	36	257
No. 25	M	Whigg Branch	10.7	11.0	13.0	29	217
No. 19	M	Hooper Bald	—	—	3.7	4	46
Mean ± SE			12.5±3.3	8.3±2.3	13.9±3	151[a]	979[a]

a. Total

Discussion

Because *G. s. coloratus* occurs in small disjunct populations in remote and rugged terrain and because they are not easily captured, I was faced with a small sample size. Consequently, my results are primarily qualitative. Therefore, caution must be exercised when making inferences and drawing conclusions from my findings.

Home range estimates from my study appear to be among the largest previously reported for this species in other areas of North America. For example, Witt (1992) reported mean MCP home range size of 4.2 ha (N = 4) in central Oregon, and Gerrow (1996) found median MCP home range size of 12.5 ha (N = 27) for males and 2.8 ha (N = 23) for females in New Brunswick, Canada. For *G. s. coloratus*, Weigl et al. (1999) found mean overall MCP home range size of 8.9 ha (N = 9) at Roan Mountain and for *G. s. fuscus*. Menzel et al. (2006) reported mean MCP home range to be 59.8 ha (N = 4) for males and 15.9 ha (N = 8) for females in the central Appalachians of West Virginia, the largest home range sizes reported for any subspecies of northern flying squirrel. Differences in home ranges among these studies may be explained in part by affects of small sample sizes, different sampling techniques, or variation in the use of the MCP estimator. For example, MCP is dependent on number of telemetry locations collected, and number and type (e.g., triangulation versus exact locations for den or feeding sites) of radio telemetry locations used may vary across studies.

Regardless, I speculate larger home range sizes in the Unicoi Mountains may in part reflect a pattern of widely distributed and perhaps less abundant resources. In the central and southern Appalachians, *G. sabrinus* is primarily tied to remaining patches of spruce/fir and adjacent northern hardwood forest habitat. Decline of spruce/fir forests in the 20th century was rapid and extensive, primarily a result of long-term human-induced impacts such as logging, burning, and damaging insect pests (White 1984, Weigl et al. 1999, Menzel et al. 2006). Weigl et al. (1999) and Menzel et al. (2006) suspected this habitat degradation likely resulted in less abundant and patchy distributions of resources, which may explain larger home ranges for both Appalachian subspecies in typical habitat. Past logging in the Unicoi Mountains indicates high elevation northern hardwood forests remained largely undisturbed by humans as recently as the early and middle 20th century when selective logging of virgin hardwoods and hemlocks and little or no clearcutting or burning occurred (Joe Bonnett, USDA Forest Service, personal communication). Nevertheless, impacts by logging in the Unicoi Mountains may have led to more scattered and widely distributed resources requiring flying squirrels to range further to meet ecological needs.

Although I could not statistically test for seasonal differences in home range size, a pattern of larger winter home range size for the Big Junction squirrels is suggested by the home range estimates (Table 1). Though speculative, perceived seasonal differences in home range sizes I observed may signify seasonal differences in available resources, social interactions, or energetic needs. To date, only one other study has reported northern flying squirrel home range sizes across seasons. Weigl et al. (1999) found winter home ranges (*mean* = 11.5 ha, *N* = 5) were larger than summer home ranges (*mean* = 6.2, *N* = 5), and suspected this pattern largely corresponded to seasonal changes in abundance and distribution of food resources, particularly hypogeous fungi, and may have reflected social interactions associated with winter breeding. Northern flying squirrels feed on a wide array of foods and are known to switch their diet to meet their nutritional requirements at different times of the year (Maser et al. 1985, North et al. 1997, Weigl et al. 1999, Currah et al. 2000, Mitchell 2001). Weigl et al. (1999) also reported the largest home ranges were during winter for male *G. s. coloratus* which traveled great distances at the time they were in breeding condition (i.e., enlarged and distended testes). In my study, male winter home ranges at the Big Junction site appeared to be the largest (Table 1). And, based on my trapping results, male northern flying squirrels were in breeding condition, which coincided with much of my winter radiotelemetry sessions.

Management Implications

Conservation and management of *G. s. coloratus* presents a challenge to resource managers. Recovery of both Appalachian subspecies rests largely on management and protection of habitat. The mere fact *G. s. coloratus* were found in the Unicoi Mountains in high elevation pure northern hardwood and mixed northern hardwood-hemlock forests without a major coniferous component has important implications relevant to the conservation and recovery of this subspecies. Results from habitat research on Appalachian northern flying squirrels have demonstrated presence of red spruce and/or Fraser fir is an integral component of suitable northern flying squirrel habitat (Payne et al. 1989, USFWS 1990, Weigl et al. 1999, Ford et al. 2004, Menzel et al. 2006). Discovery of the colonies in the Unicoi Mountains indicates that perhaps conifers may be important but not essential in suitable *G. s. coloratus* habitat. In addition, prior records exist of Appalachian northern flying squirrels being captured in northern hardwood-hemlock habitat away from spruce-fir, specifically Blanket Mountain, North Carolina, and Montgomery County, Virginia (*G. s. fuscus*) (USFWS 1990, Weigl et al. 1999). Determining extent and distribution of suitable habitat, potentially including pure northern hardwood and cove hardwood forests, as well as determining status of their populations is important to recovery efforts of the two subspecies.

Mean home range sizes I report appear to be among the largest home ranges reported in the literature (Wells-Gosling and Heaney 1984, Weigl et al. 1999, Menzel et al. 2006). This pattern may indicate that quality of habitat in Unicoi Mountains may be different than habitat elsewhere. Further evaluation of seasonal home ranges may reveal changes in movement patterns or resource selection during different times of the year. Additionally, it is important to determine how flying squirrels partition their home ranges across landscape and how this relates to population densities and habitat.

Despite most of the trapping effort (78%) and all radiotracking effort occurring on both sides of the Skyway, I found no evidence to indicate flying squirrels crossed or attempted to cross the Cherohala Skyway or its right-of-way. Radiocollared flying squirrels occasionally approached the right-of-way, seemingly right up to the forest margin. While there, flying squirrels either stayed in small, localized areas or moved along the forest margin parallel to the right-of-way. The width of the right-of-way in the flying squirrel areas was quite large, averaging 53 m with some widths exceeding 100 m (Weigl et al. 2002). Moreover, the right-of-way was densely vegetated and often steep and rocky with large continuous rows of woody debris. These characteristics, coupled with the fact no radiocollared or eartagged flying squirrel was observed crossing, seems to suggest the Cherohala Skyway and its right-of-way may act as an impediment to northern flying squirrel dispersal. As a consequence, these small, isolated and genetically depauperate (Browne et al. 1999) populations may be further fragmented. Clearly, additional research is needed to ascertain impacts this road may have on the Unicoi Mountain populations of *G. s. coloratus*. Managers should consider all potential negative impacts road construction and other development may have on Carolina northern flying squirrel populations and their habitat.

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