Demography of Northern Flying Squirrels in Virginia

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Abstract: To study the northern flying squirrel *(Glaucomys sabrinus)* in the mountains of Virginia, we monitored 349 nest boxes at 26 sites from October 1985 to May 1996. The northern flying squirrel was captured 112 times at 6 of these sites; 78 individuals were ear-tagged, 11 neonates were not ear-tagged, and 6 escaped. Twelve northern flying squirrels were recaptured at least once. Most of the individuals (84.8%) were captured at 3 sites in Grayson and Smyth counties. The remaining individuals were captured at a fourth site in Grayson County and 2 sites in Highland County. The northern flying squirrel is now documented from 7 sites in 3 Virginia counties. The northern flying squirrel occupied 28 of the 349 nest boxes. The mean number of squirrels/occupied box was 2.1 (range=1–5). The sex ratio of adult squirrels was 1.4 males/female. The juvenile to adult female ratio was 1.2 young/adult female during the breeding season. Eleven litters were observed between 1987 and 1994 and mean litter size was 2.5 (range=1–4). Mean body mass of adult males and adult females was 109.8 g (range=93–126) and 120.6 g (range=98–141), respectively. Reproductive activity was first recorded in December for males and in March for females. Mean tail length for squirrels in Grayson and Smyth counties was 128.3 mm, suggesting this population is more closely related to *G. s. coloratus* than to *G. s. fuscus*.

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The northern flying squirrel *Glaucomys sabrinus* (Shaw), is widely distributed in forested regions of northern North America (Wells-Gosling and Heaney 1984). Its range extends to the south in mountainous portions of both the western and eastern United States. Two subspecies, *G. s. fuscus* (Miller) and *G. s. coloratus* (Handley), are found in high elevation habitats of the southern Appalachian mountains. *G. s. fuscus* is known to occur in eastern West Virginia and western Virginia. The range of *G. s. coloratus* includes the mountains of western North Carolina and eastern Tennessee.

Because of the limited distribution of these subspecies and presumed ongoing threats that include habitat loss, habitat fragmentation, competition with the southern flying squirrel *(G. volans),* a parasitic nematode *(Strongyloides robustus)* carried by the southern flying squirrel that may be fatal to the northern flying squirrel, and other factors (Weigl 1978, U.S. Fish and Wildl. Serv. 1990), both subspecies were listed as endangered by the U.S. Fish and Wildlife Service in 1985.

Prior to 1985, the northern flying squirrel was known in Virginia from only a single specimen from a site in Smyth County collected in 1959 (Handley 1979). Cranford (pers. commun.) reported the capture of 2 northern flying squirrels in 1978 and 2 in 1982 in an eastern hemlock *(Tsuga canadensis)* stand in Montgomery County; however, no voucher specimens or photographs were taken. Additional sampling at this site between May 1986 and March 1991 produced no northern flying squirrel captures. Pagels et al. (1990) reported on records of the northern flying squirrel from Virginia based on the nest box study and other fortuitous observations. Payne et al. (1989) characterized plant communities at all sites where the northern flying squirrel was captured in the southern Appalachians. The 13 sites studied in North Carolina, West Virginia, and Virginia were high-elevation, mesic, and highly disjunct communities characterized by northern hardwood and northern conifer species. Fies and Pagels (1991:583) observed that ". . . the northern flying squirrel is extremely rare in Virginia. Only 2 widely separated populations are known." These populations occupy sites in Grayson and Smyth counties in southwestern Virginia and sites in Highland County, in western Virginia. The specimens from Highland County were characteristic of *G. S. fuscus;* however, based on ventral coloration and tail lengths, 2 specimens from southwestern Virginia were referred by C. O. Handley, Jr. as intergrades of *G. s. fuscus* and *G. s. coloratus* (Fies and Pagels 1991). In 1985, a nest box study was initiated to determine the distribution and collect demographic data on the northern flying squirrel in Virginia. In this paper we report the results of all specimens of northern flying squirrels collected in Virginia during the period 1985 through 1996.

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Methods

We monitored 349 nest boxes at 26 sites throughout the mountains of western Virginia from 1985 to 1996 (Fig. 1). Each site was characterized by either red spruce

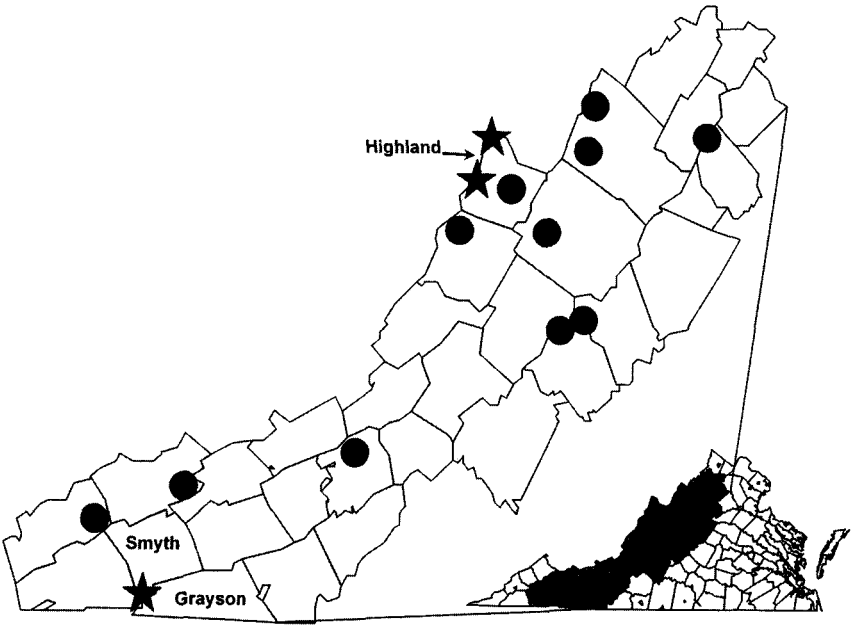

Figure 1. Locations of areas sampled for the northern flying squirrel and areas where northern flying squirrels were captured (stars) in Virginia between 1985 and 1996. Each dot or star can represent more than 1 sample site where sites were in close proximity.

(Picea rubens), red spruce-balsam fir *(Abies balsamea),* northern hardwood or hemlock dominated forest. Depending on habitat size at each site, 6 to 20 nest boxes were installed approximately 50 m apart. Nest boxes were constructed of western red cedar *(Thuja plicata)* with the following dimensions; front access door (40×18×1.9 cm), sides and rear panel (38×14×1.9 cm), bottom panel (25.5×14×1.9 cm), and top panel (19×18×1.9 cm). A 5.4-cm hole was centered 7.6 cm from the top of the box on one of the side panels. Nest boxes were attached to tree boles using 16 penny galvanized nails at heights ranging from 3–5 m. Next boxes were checked 3 to 4 times during the year at most sites, usually twice in the fall and twice in the spring. During some years, several sites were checked only once or twice annually because of time or weather constraints. Nest boxes were checked during daylight hours when the squirrels were inactive. If either species of flying squirrel was present, squirrels were removed from the box and data recorded on age, mass, and reproductive condition. Females were determined to be in reproductive condition by evidence of perforate vagina, palpation or lactation and males by evidence of enlarged and distended testes. Squirrels with a mass ≥70g were determined to be adults (Whitaker and Hamilton 1998). Squirrels were marked with metal ear tags (size 1, Monel tags, Natl. Band and Tag Co., Newport, Ky.) and released at the capture site. Tail length, a character used in separating the subspecies *G. s. coloratus* and *G. s. fuscus,* was recorded for squirrels captured in southwestern Virginia. The

Chi-square test ($P \leq 0.05$) was used to investigate differences in sex ratios for northern flying squirrel captures.

Results and Discussion

Sites and Numbers Captured

Between September 1985 and June 1996 we captured 95 northern flying squirrels 112 times at 6 of the 26 sites sampled. Seventy-eight were ear-tagged, 6 escaped, and 11 neonates were not tagged. Twelve individuals were recaptured 17 times, 8 individuals were recaptured once, 3 individuals were recaptured twice, and 1 individual was recaptured 3 times. Three sites in Grayson and Smyth counties (Mt. Rogers Natl. Recreation Area) accounted for 84.8% of the total individuals captured. The remainder of the individuals were captured at a fourth site in Grayson County (Mt. Rogers Natl. Recreation Area) and 2 sites in Highland County. The 4 sites in Mt. Rogers accounted for 64 (57.1%), 22 (19.6%), 9 (8.1%) and 1 (0.9%) of the total captures, respectively. The 2 sites in Highland County accounted for 15 (13.4%) and 1 (0.9%) of the total captures.

Yearly captures per unit of effort (captures/10 boxes checked) varied from 0.0 to 7.0 (Table 1). Capture rates for 2 sites (Table 1, Sites 1 and 2) with consistent captures on Mt. Rogers usually followed a similar trend from year to year. We captured no squirrels at any site in Virginia during 1992–93. In 1993–94 we found northern flying squirrels at 3 sites (Table 1, Sites 1, 2 and 4) where the species had been previously collected. Weigl et al. (1999) reported an increase in capture success between 1986 and 1990, followed by a decline that reached its lowest level in 1991. Low capture success in Virginia during 1992–93 may have been due to an absence of northern flying squirrels or possibly to other factors (e.g., weather or competition for nest sites with other species) that influenced occupancy rates of nest boxes (Goertz et al. 1975).

Although surveys often yielded no northern flying squirrels, evidence of nest box use was apparent during each survey. However, there was no available method for attributing box use to the northern flying squirrel. Red squirrels *(Tamiasciurus hudsonicus)* and southern flying squirrels are known to construct similar nests. In our study, both of these species used nest boxes that were also used by northern flying squirrels. For example, in Highland County, 1 box contained a female southern flying squirrel with 4 neonates in August 1986, a single northern flying squirrel in April 1987, and 2 red squirrel neonates in March 1990.

Nest Box Use

Of the 349 nest boxes, 28 were occupied by northern flying squirrels. At 1 site (Table 1, Site 1) on Mt. Rogers, northern flying squirrels were found in 13 of the 20 nest boxes. The mean number of squirrels per occupied box was 2.1 (range=1–5). Females in reproductive condition were never found in the same box with an adult male. In addition to northern and southern flying squirrels and red squirrels, we also

Table 1. Number of northern flying squirrels captured/10 boxes checked and the total number captured (in parenthesis) in Virginia from 1986 to 1996. Sites 1 through 4 were located in Grayson and Smyth counties, sites 5 and 6 were located in Highland County.

Year	1986–87	1987–88	1988–89	1989–90	1990–91	1991–92	1992–93	1993–94	1994–95	1995–96
Site 1	0.2 (2)	1.6 (13)	0.9 (7)	1.5 (12)	1.0 (6)	1.6 (9)	0.0 (0)	1.4 (5)	1.4 (8)	0.6 (2)
Site 2	0.4 (4)	0.8 (6)	0.0 (0)	0.6 (5)	0.0 (0)	0.0 (0)	0.0 (0)	0.5 (2)	0.5 (3)	1.3 (2)
Site 3[a]	0.0 (0)	0.0 (0)	0.0 (0)	0.13 (1)	0.0 (0)					
Site 4[b]							0.0 (0)	7.0 (7)	1.0 (2)	0.0 (0)
Site 5	0.17 (1)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
Site 6	0.0 (0)	1.6 (3)	0.0 (0)	0.0 (0)	3.8 (6)	1.5 (3)	0.0 (0)	0.0 (0)	0.0 (0)	1.7 (3)

a. Boxes last checked in May 1991.

b. Boxes installed September 1992, first checked in April 1993.

observed white-footed mice *(Peromyscus leucopus),* deer mice *(Peromyscus maniculatus),* gray squirrels *(Sciurus carolinensis),* tree swallows *(Tachycineta bicolor),* and northern saw-whet owls *(Aegolius acadicus)* in the nest boxes.

Sex Ratios

Downing (1980) indicated that sex ratios can provide information on whether a vertebrate population is within the range needed for normal reproductive performance, but cautioned that data could be biased due to sampling methods. In our study, we captured 36 adult males and 26 adult females, yielding a sex ratio of 1.4 males/female. Although these data suggest that males were more abundant or more likely to be captured than females, the observed sex ratio was not statistically different from 1:1 ($X^2=1.61$, $P>0.10$). In our study, the total number of neonates and juveniles captured (excluding recaptures) included 17 males, 10 females, and one individual of undetermined sex. Although the observed juvenile and neonate sex ratio of 1.7 males/female was not statistically different from 1:1 ($X^2=1.81$, $P>0.10$), it is similar to the juvenile and neonate ratio of 70 males and 39 females (1.79 males/female) reported by Stihler et al. (1995).

Juvenile-to-adult Female Ratio

Measures of natality (number of young/adult female) and rearing success (number weaned) are indicators of population health (Downing 1980). A decline in the percentage of young in the population may indicate low natality or high juvenile mortality. Of the total individuals captured during the reproductive season, 28 were juveniles and 23 were adult females (1.2 young/adult female). The number of juveniles/adult female by year showed no obvious pattern (e.g., in some years no young were captured). The lack of adult females or juveniles in some years did not seem to affect capture success the following year.

Body Mass

The mean body mass of adult males was 108.5 g ($N=42$, SE=9.02, range =85–126) and for adult females was 120.8 g ($N=35$, SE=14.02, range=96–150). Both males and females increased in mass through the winter and spring months with the heaviest mass recorded in May (Table 2). Female mass increases can be attributed, in part, to pregnancy and lactation.

Reproductive Activity

Based on enlarged testes, males became reproductively active in December and they remained reproductively active throughout the winter and spring months. This pattern of reproductive readiness corresponded to that reported in North Carolina (Weigl et al. 1999). Based on lactating females and presence of neonates, reproductive activity was first recorded for females in March; however, nest boxes were not routinely checked in January or February. Although no adult females were reproductively active in December, all adult females captured in May were either pregnant or lactating. Of the adult females captured, 82.6% were observed to be reproductively

Table 2. Mass of adult male and female northern flying squirrels captured in Virginia by sample period, 1986–1996.

Sample period	Mean (g)	Range	SE	*N*
Adult males				
Dec–Jan	103.9	85–118	9.2	17
Feb–Mar	110.5	103–115	3.2	11
Apr–May	112.4	94–126	9.9	14
Adult females				
Dec–Jan	109.9	96–122	8.9	11
Feb–Mar	120.7	98–129	11.6	12
Apr–May	133.7	120–150	9.4	11

active during the breeding season. Reproductive activity varied by season for adult northern flying squirrels (Table 3).

Eleven litters were observed between 1987 and 1994; 1 nest had 1 young, 4 had 2 young, 5 had 3 young, and 1 had 4 young ($\bar{X}$=2.5, SE=0.82). These data corresponded with Weigl et al. (1999) who reported 2 litters of 2 and 3 nestlings respectively, in *G. s. coloratus,* and Stihler (pers. commun.) who found litters of *G. s. fuscus* in West Virginia with up to 5 offspring, but most often with 2–4 young. The mean number of juveniles captured per year was 2.8 (range=0–8).

Two litters of 3 young each were captured on 22 March 1988 and 26 March 1990. The individuals in the 22 March litter measured 88 mm in length and the 26 March litter had young with a mass of 11 g each. Wells-Gosling (1985) reported northern flying squirrels measuring approximately 70 mm at birth and weighing 4–6 g. Assuming the 22 March litter to be 1 week and the 26 March litter to be 2 weeks of age, we estimate both litters were born in mid-March. With a gestation period of 37 days (Muul 1969), copulation probably occurred in early February. Muul (1969), Wells-Gosling and Heaney (1984), and Whitaker and Hamilton (1998) report mating in northern flying squirrels to occur in late March through May. To our knowledge, these two March litters represent the earliest reported birth dates for northern flying squirrels throughout their range.

The latest date that we observed young in the nest was 25 October. Raphael (1984) reported a fall litter for the northern flying squirrel in Humboldt County,

Table 3. Numbers and percentages (in parenthesis) of reproductively active adult northern flying squirrels during breeding season surveys (Dec–Jan, Feb–Mar, and Apr–May for males; Feb–Mar and Apr–May for females) in Virginia 1986–1996.

	Males		Females	
	N Captured	*N* Active	*N* Captured	*N* Active
Dec–Jan	15	8 (53.3)	12	0 (0)
Feb–Mar	11	10 (90.9)	12	8 (66.7)
Apr–May	15	14 (93.3)	11	11 (100)

California. In North Carolina, Weigl et al. (1999) reported captures of a juvenile less than 55 g for the period of 1–15 September and 1–15 October, but litters outside of spring are apparently very rare. Our observation of young northern flying squirrels in late October suggested a long breeding season, or perhaps both an early spring and summer reproductive period. The 2 young found in October, approximately 5 months later than most litters, weighed 65 and 68 g. While little information exists on postnatal development in northern flying squirrels, Linzey and Linzey (1979) and Stapp and Mautz (1991) provided detailed postnatal growth data for the southern flying squirrel. Muul (1969) and Wells-Gosling (1985) suggested growth and development of northern flying squirrels to roughly parallel that of the southern flying squirrel. Using weights and ages of southern flying squirrels (Linzey and Linzey 1979), we estimated this litter to be approximately 20 weeks old, suggestive of an early July birth.

Subspecies

The taxonomic status of the northern flying squirrel in southwestern Virginia (Smyth and Grayson counties) is not adequately determined. Due to the geographic proximity of these populations to *G. s. coloratus* in North Carolina, one might expect specimens from this region to more closely resemble *G. s. coloratus* than *G. s. fuscus*. *G. s. coloratus* is larger and has an average tail length of 134 mm versus 115 mm for *G. s. fuscus* (Handley 1979). Handley examined two available specimens from Mt. Rogers and felt they were intergrades with underparts similar to *G. s. fuscus* and tail lengths intermediate between the 2 subspecies (Fies and Pagels 1991). Tail measurements of the squirrels we captured were very similar to those reported by Weigl et al. (1999) for *G. s. coloratus* in North Carolina and Tennessee. Mean tail length of 51 adults from Mt. Rogers was 128.3 mm (SE=7.9, range=110–150) compared to a mean of 129.1 mm (range=102–160) for 148 specimens from North Carolina and Tennessee.

Conclusions and Management Recommendations

Although capture numbers were low, we believe populations of the northern flying squirrel in Virginia were stable during 1985–1996. Typical northern flying squirrel habitat in Virginia is described as high-elevation, moist conifer-hardwood forest with a component of red spruce, an abundance of snags and corticulous lichens, usually in a cove or a north-facing slope (Payne et al. 1989, Fies et al. 1990, Pagels et al. 1990). The apparent predictor for the northern flying squirrel in Virginia is the presence of red spruce or red spruce-balsam fir. In this study the northern flying squirrel was not captured at sites without spruce or fir, even when boxes were placed in hardwood habitats adjacent to spruce-fir sites occupied by northern flying squirrels. Although apparently atypical, both Weigl (1999) and Stihler (1995) found northern flying squirrels to sometimes utilize other forest types. The lack of northern flying squirrel captures in adjacent hardwood habitats in Virginia might be due to competition with the more abundant and aggressive southern flying squirrel (Weigl 1978)

that was sometimes captured in areas immediately adjacent to occupied northern flying squirrel sites.

Most of the spruce and spruce-fir forests in Virginia are under public ownership. Because this is such a unique habitat type in Virginia, public land managers now take an active role in protecting existing habitat of northern flying squirrels. What may be needed, however, is a landscape-level approach where existing spruce-fir forests are connected through corridors of like habitat.

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