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Winter Home Range and Habitat Use of the Virginia Northern Flying Squirrel (*Glaucomys sabrinus fuscus*)

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Abstract

We radio-tracked two male and one female Virginia northern flying squirrels (*Glaucomys sabrinus fuscus*) in the Allegheny Mountains of West Virginia at Snowshoe Mountain Resort, in winter 2003 and Canaan Valley National Wildlife Refuge in winter 2004, respectively, to document winter home range and habitat use in or near ski areas. Male home range size in the winter was larger than that reported for males during summer and fall, whereas the female home range we observed was smaller than those reported for summer and fall. However, winter habitat use was similar to summer and fall habitat use reported in other studies. Virginia northern flying squirrels foraged and denned in both red spruce (*Picea rubens*)-dominated forests and northern hardwood forests; however, selection of red spruce-dominated forests and open areas was greater than expected based on availability. Use of northern hardwood forest occurred less than expected based on availability. Male squirrels denned near, and routinely crossed, downhill ski slopes and unimproved roads during foraging bouts, whereas the female approached, but did not cross forest edges onto roads or trails.

Cover Photos

Front and back cover chairlift scenes by P. Duncan, Snowshoe Mountain, Inc. Center front, Virginia northern flying squirrel (*Glaucomys sabrinus*) and back cover snowy road scene by C. Stihler, West Virginia Department of Natural Resources.

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INTRODUCTION

The Virginia northern flying squirrel (*Glaucomys sabrinus fuscus*) is a disjunct subspecies of northern flying squirrel that occurs in the central Appalachians (Allegheny Mountains) of east-central West Virginia and northwestern Virginia, south of the species' more continuous distribution in the Northeast and Lake States (Arbogast et al. 2005, Wells-Gosling and Heaney 1984). Similar to the Carolina northern flying squirrel (*G. s. coloratus*) in the southern Appalachians (Blue Ridge Mountains) of North Carolina, Tennessee and southwestern Virginia, the Virginia northern flying squirrel was listed as endangered by the U.S. Fish and Wildlife Service in 1986 (U.S. Fish and Wildlife Service 1990). Since the end of the last glacial maxima, the Virginia northern flying squirrel has been restricted to relict high-elevation red spruce (*Picea rubens*)-dominated forests and northern hardwood forest with a significant red spruce or eastern hemlock (*Tsuga canadensis*) component (Payne et al. 1989, Smith 2007). This subspecies' habitat was further altered and reduced by anthropogenic disturbance resulting from late 19th and early 20th century exploitative railroad logging and subsequent wildfires in the Allegheny Mountains. These activities reduced the extent of red spruce-dominated forests from more than 200,000 ha to approximately 20,000 ha at present (Ford et al. 2004).

The discovery of additional populations of the Virginia northern flying squirrel on both public and private forest lands in the mid-1990s indicates that the subspecies is more widely distributed than formerly thought (Odom et al. 2001). These new records helped initiate comprehensive home range, habitat use, and food-habits research that has provided many additional insights into the subspecies' biology (Ford et al. 2004, Menzel et al. 2004, Menzel et al. 2006b, Mitchell 2001, Reynolds et al. 1999). The current distribution of the Virginia northern flying squirrel in West Virginia lies mainly within the Monongahela National Forest, Canaan Valley National Wildlife Refuge, three areas managed by West Virginia Division of Natural Resources, and a small number of corporate ownerships in Grant, Greenbrier, Pendleton, Pocahontas, Randolph, Tucker, and Webster counties. In Virginia, the subspecies is restricted to western Highland County on the George Washington National Forest and surrounding private land along the West Virginia boundary (Stihler et al. 1995, Menzel et al. 2006a).

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Regionally, the probability of Virginia northern flying squirrel occurrence is greatest at elevations above 1,000 m and in older, second-growth forest stands dominated by montane conifers such as red spruce, Norway spruce (*Picea abies*) or eastern hemlock (Ford et al. 2004, Menzel et al. 2006a). Radio-telemetry work by Menzel et al. (2006b) confirmed that Virginia northern flying squirrel use of stands containing spruce is disproportionately high relative to the availability of these stands in the local landscape. The subspecies occupies and uses northern hardwood forest communities adjacent to stands with a montane conifer component, as most extant red spruce stands are fragmented and contained wholly within a northern hardwood forest matrix. Additionally, snags and live trees with cavities suitable for day-dens probably are more abundant in northern hardwood forests currently than in many red spruce-dominated stands as the region's forests continue to recover from past disturbance (Menzel et al. 2004). Other research has examined the efficacy and applicability of using active forest management and restoration to enhance the quality or further expand the extent of Virginia northern flying squirrel habitat (Rentch et al. 2007, Schuler et al. 2002).

Paradoxically, many aspects of long-term forest management activities intended to improve habitat conditions for the Virginia northern flying squirrel (Rentch et al. 2007) would be challenging to pursue and would necessitate the use of a research recovery permit or incidental take statement to avoid prohibitions associated with the subspecies' current endangered status (Menzel et al. 2006a). This, combined with the realization of a larger distribution, the lack of immediate rangewide threats, and the acquisition of key natural history data allowing for development of forest habitat management strategies, has forced a re-examination of the subspecies' status. Accordingly, in 2006 the U.S. Fish and Wildlife Service proposed removing the Virginia northern flying squirrel from the endangered and threatened species list (*71 Federal Register 75924*).

Although most deleterious forest harvesting activities have ceased where Virginia northern flying squirrels occur and delisting is possible, serious issues regarding the subspecies' conservation remain. These are believed to include habitat impacts from forest health issues, atmospheric acid deposition, and climate change, as well as parasite-mediated competition with southern flying squrriels (*G. volans*) (Arbogast et al. 2005, Mielkl et al. 1986, Pagels et al. 1990, Pauli et al. 2004, Weigl 1978, Wiegl 2007). However, residential and recreational development often associated with the ski industry, is causing drastic habitat degradation in some localized areas via permanent forest clearing (Schuler et al. 2002). Though generally small in extent relative to the entire distribution, such development on private lands in occupied habitat still requires effort to minimize impacts and conduct mitigation measures.[1]

Currently, management for Virginia northern flying squirrel is based on results of research conducted during the growing season and in landscapes unassociated with permanent residential development or high-density winter recreation. Winter ecology of the Virginia northern flying squirrel from high-elevation forests is largely unknown because cold and consistently deep snow cover limit researcher access. As such, Virginia northern flying squirrel management guidelines may not be accurate and effective in addressing development on private land or winter recreation on both private and public land. The objective of our study was to use radio-telemetry to document Virginia northern flying squirrel home range and habitat selection during the winter in or near ski areas with a particular emphasis on response to cleared habitat and forest edge.

MATERIALS AND METHODS

Study Area

Our study was conducted in January-March 2003 at Snowshoe Mountain Resort (SMR) in Pocahontas County, West Virginia and February-March 2004 at Canaan Valley National Wildlife Refuge (CVNWR) in Tucker County, West Virginia. Snowshoe Mountain is a 4,450 ha, four-season resort in the headwaters of the Shaver's Fork area of Cheat Mountain. Initially developed in 1972, SMR contains a winter sports complex of downhill ski slopes and cross-country trails, medium- and high-density housing, and associated development, as well as large intact forest patches than exceed 500 ha in size. The CVNWR was established in 1994 and is comprised

[1]S. Jones, U.S. Fish and Wildlife Service, personal communication.

of 6,424 ha of high-elevation wetlands in the valley floor and upland forests on nearby Cabin Mountain. A network of both groomed and used but unmaintained cross-country ski trails exist on CVNWR. Additionally, CVNWR is adjacent to two downhill ski areas with development similar, though less extensive, to that found at SMR.

The climate at both study sites is montane boreal with abundant annual precipitation ranging from 120 to 150 cm, much of which occurs as snow during the winter months. The growing season is short (<100 days) and below-freezing temperatures can occur in any month of the year (Strasbaugh and Core 1978). Both sites are wholly within the unglaciated Allegheny Mountains and Plateau subprovince of the central Appalachian Mountains. Elevations range from 1,260 to 1,480 m at SMR and 1,200 to 1,320 m at CVNWR. At these elevations, presettlement forest cover was predominately red spruce mixed with some eastern hemlock (Stephenson and Clovis 1983). At SMR, most forest stands are second- or third-growth red spruce. Lesser amounts of northern hardwood stands of sugar maple (*Acer saccharum*), red maple (*A. rubrum*), yellow birch (*Betula alleghaniensis*), American beech (*Fagus grandifolia*) and black cherry (*Prunus serotina*) also occur. Both stand types originated from harvests conducted at the turn-of-the 20th century through the late 1940s (Korstian 1937, Stephenson 1993, Schuler et al. 2002) with northern hardwoods being indicative of areas that burned[2]. Conditions at CVNWR are similar, though northern hardwoods comprise the majority of extant overstory, with red spruce or eastern hemlock-dominated stands occurring as scattered patches (Fortney and Rentch 2003). At CVNWR, many stands were selectively harvested prior to establishment of the refuge[3].

Radio-telemetry

We captured Virginia northern flying squirrels in Tomahawk 201 live traps (14x14x41 cm; Tomahawk Live Trap Co., Tomahawk, WI). We arrayed several transects of 10 to 25 traps along a 10 m spacing in forest patches between active ski slopes. Baited with a mixture of peanut butter, maple syrup, rolled oats, and apples, we affixed traps to trees with shock cords at a height of 1.5 m at SMR from January 27 to February 5, and then again from March 4 to 11, 2003 below Snowshoe Village and into the basin of the Upper Shaver's Fork. Using the same method, we trapped February 25 to 27 and March 15 to 16, 2004 at CVNWR at the headwaters of the Left Fork of Freeland Run adjacent to Forest Road 80, a popular cross-country ski trail leading to the Dolly Sods Wilderness area on the Monongahela National Forest. Portions of these transects at CVNWR were only 800 m south of downhill ski slopes at Timberline Ski Resort. At both sites, we placed polyester batting in traps for bedding and wrapped the trap exterior with heavy-duty duct tape to reduce exposure. We opened traps in the evening prior to sunset and checked them the following morning shortly after sunrise. Following capture, we transported squirrels by snowmobile to office facilities at SMR or White Grass Cross-Country Ski Center at CVNWR for processing. We recorded sex, mass, hind food length, age, and reproductive condition. We determined age by examining mass and pelage and differentiated Virginia northern flying squirrels from southern flying squirrels if hind foot measurements were greater than 34 mm and ventral fur was lead-colored (Wells-Gosling and Heaney 1984, Witt 1992). For recapture identification, we attached uniquely numbered ear tags (National Band and Tag Co., Newport, KY) and SM1-BR radio collars (4.0-5.0 g; AVM Instruments Company, Livermore, CA) to each adult Virginia northern flying squirrel captured. To reduce stress and ensure a proper collar fit, we lightly anaesthetized squirrels with halothane (Halocarbon Laboratories, River Edge, NJ). We transported the squirrels back to their capture site for release after anesthesia effects were no longer apparent.

Photo used with permission from C. Stihler, WV DNR

We used Wildlife Materials TR4-2000S receivers (Carbondale, IL) and three-element Yagi antennas to track radio-collared squirrels at night to determine home

[2]E. Galford, Snowshoe Mountain, Inc., personal communication.

[3]L. Ceperley, U.S. Fish and Wildlife Service, personal communication.

range and habitat use. Our tracking efforts began shortly after sunset and ceased when animal movement ended (typically before or at midnight). We obtained telemetry locations using standard two-station triangulation with readings taken simultaneously to minimize temporal error (Schumtz and White 1990). Stations were located more than 50 m apart to ensure that bearings would be as close to a 90° angle as possible (White 1985). We took bearings at intervals of 14 minutes or more, which was sufficient to avoid autocorrelation between points (White and Garrot 1990) for this subspecies (Menzel et al. 2006b). We also located Virginia northern flying squirrels by day to determine den sites, i.e., tree species, condition (live or snag), diameter at breast height (d.b.h.) and nest type (cavity or dray [leaf]) following Menzel et al. (2004).

Home Range and Habitat Use

We entered UTM coordinates of telemetry stations and triangulation bearings into the LOCATE II software (Pacer Co., Truro, Nova Scotia) to obtain UTM coordinates of squirrel locations. To create estimates of home range for individuals with more than 30 telemetry locations, we entered these UTM coordinates into the Animal Movement Analysis Extension (Hooge and Eichenlaub 2000) in ArcView 3.2 (Environmental Systems Research Institute, Redlands, CA) to calculate both 95 percent confidence interval fixed kernel use distributions and minimum convex polygons. We overlaid telemetry points and home-range estimators on cover type layers generated by supervised classification of 0.6 by 0.6 m resolution true-color ortho-photo 3.75' quadrangle imagery (West Virginia Statewide Address and Mapping Board, Charleston, WV) using the Feature Analyst Extension (Visual Learning Systems, Missoula, MT) in ArcMap 9.1 (Environmental Systems Research Institute, Redlands, CA). Our final habitat types were classified as red spruce-dominated forests (which also contain lesser amounts of eastern hemlock; hereafter "red spruce"), northern hardwood-dominated forest (hereafter "northern hardwood"), open (roads, ski trails, fields and developed areas) and water (small ponds, lakes and wetlands). Regardless of season, Virginia northern flying squirrel habitat use is believed to be understood at the larger landscape-level (first and second order selection; Johnson 1980, Menzel et al. 2006b). Accordingly, we concentrated on third-order selection and we defined the lateral extent of our study areas to be that encompassed by each Virginia northern flying squirrel's 95 percent confidence interval fixed kernel estimates buffered by an additional 300 m. To compare use of habitat types to available habitat types, we calculated mean Euclidean distances from individual squirrel locations to each habitat type along with those for a matching number of random locations. However, our final sample size of Virginia northern flying squirrels was insufficient to meet assumptions required for either Euclidean distance-based analysis (Conner and Plowman 2001) or compositional analysis (Aebischer et al. 1993) thereby limiting us to a descriptive examination of Euclidean distances. In addition, we pooled all locations for all squirrels tracked and conservatively examined habitat selection or avoidance using a chi-square analysis and associated Bonferonni z statistic confidence interval on the proportion of each habitat type observed in a study area (p_i) versus proportion of total habitat areas (p_{io}) as described by Neu et al. (1974).

RESULTS

We captured two male Virginia northern flying squirrels at SMR during approximately 700 trap-nights in 2003 and one female and one male at CVNWR during 90 trap-nights in 2004. All squirrels were adults and both males at SMR were both scrotal. We fitted each individual with a radio collar. The male in 2004 was tracked for one night prior to being killed by an avian predator[4]. For the remaining squirrels, we obtained 221 usable telemetry locations with stabilized home ranges for the males (65 and 116 locations) from March 11 to 22, 2003 at SMR and the female (40 locations) from February 27 to March 15, 2004 at CVNWR. Deep snow cover persisted for the duration of our 2003 and 2004 telemetry efforts. The 95 percent confidence interval fixed kernel distribution home ranges were 37.6 ha (Figure 1a) and 14.1 ha (Figure 1b) for the two males and 3.8 ha for the female (Figure 1c). Values for male minimum convex polygon home ranges were 80.6 ha (Figure 1a) and 63.7 ha (Figure 1b) and that for the

[4]K. Coyle, U.S. Geologic Survey, National Wildlife Health Center, unpublished data.

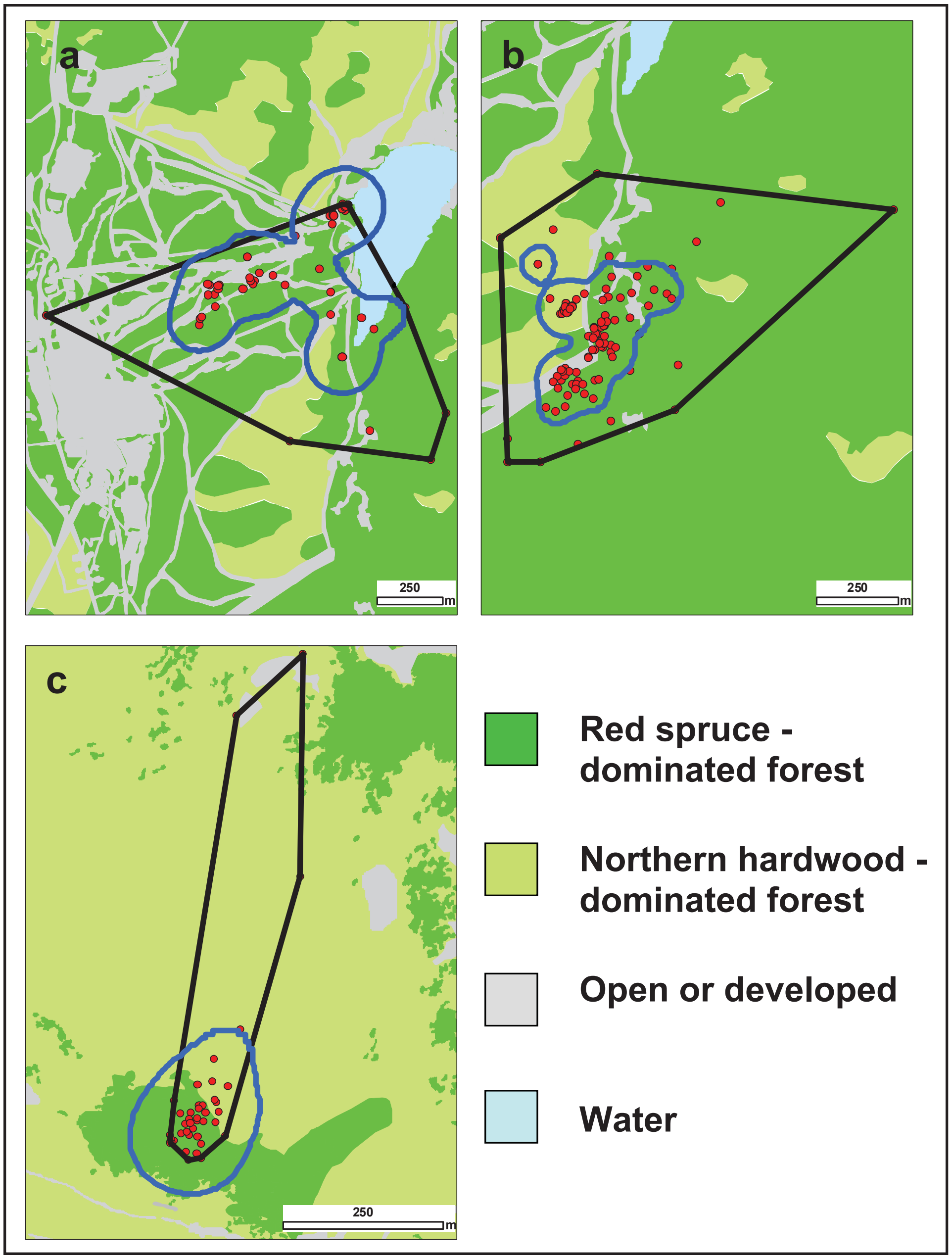

Figure 1.—Winter home ranges of Virginia northern flying squirrels in red spruce-dominated forests, northern hardwood-dominated forests and open habitats, Snowshoe Mountain Resort, Pocahontas County, West Virginia, 2003 (a and b; males) and Canaan Valley National Wildlife Refuge, Tucker County, West Virginia, 2004 (c; female). Telemetry locations are denoted in red. The 95 percent confidence interval fixed kernel estimates are outlined in blue and minimum convex polygons outlined in black. See text for details.

female was 8.4 ha (Figure 1c). The calculated size of one male home range (Figure 1a) was slightly inflated because both estimators included portions of a lake not actually used by the individual.

At SMR, one male used two dray (leaf) nests as dens in live red spruce (tree height = 22.5 m and 17.5 m, tree d.b.h. = 28.9 cm and 30.7 cm) and one cavity den in a live yellow birch with a broken top (tree height = 9.8 m, tree d.b.h. = 28.2 cm) whereas the other male used a dray nest in a live red spruce (tree height = 16.4 m, tree d.b.h. = 19.7 cm). The female at CVNWR denned in a large cavity in an American beech for the duration of our tracking effort (tree height = 12.3 m, tree d.b.h.

= 44.6 cm). All dens occurred in moderately to fully stocked stands. Mean distance from these five dens to an anthropogenic linear opening such as a road or ski run was 83.9 m ± 65.6 m (mean ± standard deviation).

Of the telemetry locations we recorded, 71.5 percent occurred in red spruce, 15.4 percent occurred in northern hardwoods and 13.1 percent occurred in open habitats. Mean distance to red spruce was 8.0 m ± 3.3 m for squirrel locations and 20.2 m ± 13.0 m for randomly generated points. Mean distance to northern hardwoods was 101.6 m ± 53.4 m for squirrel locations and 20.2 m ± 13.0 m for randomly generated points. Mean distance to open habitats was 76.8 m ± 37.6 m for squirrel locations and 73.7 m ± 33.8 m for randomly generated points. Lastly, habitat use was not proportional to availability within the buffered home range areas (X^2 = 21.97, *df* = 3, $P < 0.001$). Red spruce (p_{io} = 0.548) was used more than expected (p_i = 0.716 ± 0.069) based on availability, as was open habitat (p_{io} = 0.128; p_i = 0.135 ± 0.052). Northern hardwoods (p_{io} = 0.267) were used less than expected (p_i = 0.149 ± 0.054) based on availability.

DISCUSSION

Compared to previous Virginia northern flying squirrel research in West Virginia during summer and early fall (Menzel et al. 2006b, Urban 1988), the males we tracked had smaller core use areas as defined by the fixed kernel estimates. However, our minimum convex polygon estimates were far larger than summer and fall estimates (Menzel et al. 2006b, Urban 1988). Home ranges by either of our estimators were larger than those for the several subspecies in the Pacific Northwest where habitat quality is believed to be better (Martin and Anthony 1999, Menzel et al. 2006b, Witt 1992). The home ranges also were larger than those in more similar habitats, such as central Ontario for *G. s. sabrinus* (Holloway and Malcolm 2007b) or for the Carolina northern flying squirrel in the southern Appalachians for winter and summer (Weigl et al. 1999, Weigl et al. 2002). Conversely, the female we tracked had a home-range size congruent with or smaller than the aforementioned studies in the Appalachians and elsewhere. However, female home range-data reported by Menzel et al. (2006b) included animals from study sites in marginal habitat at lower elevations with little montane conifer and recent forest disturbance, thereby possibly increasing home-range size. Females from more similar habitat conditions with greater spruce (red or Norway) cover at higher elevations had summer home ranges similar to what we observed at CVNWR. Weigl et al. (2002) also noted generally larger home ranges of Carolina northern flying squirrels occurring wholly within northern hardwood forests versus forests with a significant red spruce component in the southern Appalachians.

The size disparity between male fixed kernel estimates and minimum convex polygon values in our study, as well as the minimum convex polygon values for males in previous work (Menzel et al. 2006b), may reflect male movements associated with the onset of breeding that could occur from late winter into mid-spring (Reynolds et al. 1999). For the Carolina subspecies, Weigl et al. (2002) hypothesized that resource limitations, such as lower hypogeal fungi abundance, might contribute to larger winter home ranges. However, movement associated with reproductive activity seemed a more parsimonious explanation, particular since both males at SMR were scrotal. The female we tracked did show extensive movements relative to the fixed kernel estimate as her minimum convex polygon was twice as large as the fixed kernel estimate. Nonetheless, with only one female tracked at CVNWR, our data are too limited to make strong inferences.

Den sites we identified were similar to those used during summer months in the Allegheny Mountains, which included dray nests in red spruce (Urban 1988) or Norway spruce and cavities in hardwoods (Menzel et al. 2004). Den selections also were similar to those reported for the southern Appalachians (Hackett and Pagels 2003, Weigl et al. 1999, 2002) and central Ontario inhabiting similar mixed conifer-northern hardwood forest across seasons (Holloway and Malcolm 2007a). Although den availability often is not limiting in second-growth forests (Carey 2002; but see Holloway and Malcolm 2007a), den selection throughout the range of the northern flying squirrel suggests selection for mature forest with structural complexity, including differentiated tree heights, abundant cavities and presence of snags (Smith 2007).

Due to the limited duration of our tracking effort and sample size, we were unable to determine whether squirrels in our study area switched dens frequently, as reported by Menzel et al. (2004) for similar forest stands on the Monongahela National Forest. Den infidelity has been noted across seasons and habitat types throughout the species' range (Cotton and Parker 2000, Hackett and Pagels 2003, Holloway and Malcolm 2007a, Meyer et al. 2005a, Witt 1992), so the likelihood of frequent den-switching during winter is high in the Allegheny Mountains as well. The high proportion of dens consisting of dray nests (60 percent) was not surprising at SMR where the forests are dominated by conifers similar to the Stuart Knob area in West Virginia where Urban (1988) and Menzel et al. (2004) also observed frequent dray nesting. However, Menzel et al.'s (2004) study included northern hardwood-dominated areas in addition to Stuart Knob, thereby accounting for the overall higher proportion of cavity dens in deciduous trees. The two deciduous trees used as winter dens in our study were decadent, with cavities, broken tops and limbs more prevalent in older, mature forest conditions. Many second- or third-growth red spruce stands in the Allegheny Mountains are densely stocked and remain in the stem exclusion phase without any significant differentiation, snag creation or cavity development (Schuler et al. 2002) as is the case at SMR. Higher use of dray nests may be due to limited availability of optimal den trees and cavities in immature forest, but this remains untested (Carey 2003, Menzel et al. 2004). Accordingly, a priority for future research on Virginia northern flying squirrel den selection should focus on stands of mature second-growth red spruce with old-growth residuals that occur in abundance in other parts of the SMR property.

Telemetry data show that these Virginia northern flying squirrels tracked in winter selected red spruce-dominated forests over northern hardwood-dominated forests for foraging activity, as previously shown in the summer for this subspecies (Menzel et al. 2006b, Urban 1988) and the Carolina subspecies (Payne et al. 1989, Weigl et al. 1999). The female at CVNWR also was associated with the isolated patch of red spruce and eastern hemlock that occurred in a more extensive northern hardwood-dominated landscape. It is important to note, however, that both the Virginia and Carolina subspecies do occur in northern hardwood forests with little or no red spruce (but usually with eastern hemlock present) and both will readily use the ecotone between red spruce-dominated stands and stands with a lesser conifer component (Menzel et al. 2006b, Weigl et al. 2002). Red spruce forests contain higher abundances of hypogeous fungi than do northern hardwoods (Bird and McCleneghan 2005, Loeb et al. 2000) due to ectomycorrhizal associations between fungi and host tree species and the moist, shaded conditions with abundant coarse woody debris. These fungi constitute a major diet component for northern flying squirrels in the Appalachians (Mitchell 2001) and elsewhere (Lehmkuhl et al. 2004, Meyer et al. 2005b). Menzel et al. (2006) observed that foraging occurred predominantly in patches with red or Norway spruce whereas dens occurred in northern hardwood forests. Nonetheless, increased amounts of montane conifer, typically red spruce, equate to higher probability of occurrence of Virginia northern flying squirrels (Ford et al. 2004, Menzel et al. 2006a, Odom et al. 2001). Efforts to increase the extent of red spruce-dominated forests and their structural complexity (Carey 2001, 2003) could improve Virginia northern flying squirrel habitat and increase connectivity between occupied patches (Browne et al. 1999, Menzel et al. 2006a, Rentch et al. 2007, Schuler et al. 2002). Despite Weigl's (2007) assertion that there is little direct link between northern flying squirrels and red spruce in the central and southern Appalachians, our study and that of Menzel et al. (2006b) suggests otherwise based on habitat selection. Further, forests dominated by red spruce may support fewer competitors, such as southern flying squirrels that require cacheable high-energy foods, such as acorns, during the winter (Holloway and Malcolm 2007b, Stapp 1992), thereby enhancing northern flying squirrel viability.

The males tracked at SMR inhabited forests in the midst of the largest and most active downhill ski slope in the region. Both individuals were captured less than 25 m from ski runs and both displayed foraging activity bouts when grooming machines were active on the site. A partial impetus of our work was to examine the response of Virginia northern flying squirrel to ski areas and support development of a Habitat Conservation Plan for proposed ski slope expansion into forest stands assumed to be occupied by Virginia northern flying squirrels (BHE Environmental Inc. 2005). Clearly, these individuals did not avoid crossing ski slopes to forage, often moving through island-like patches of forest as the home range illustrations demonstrate (Figure 1a,1b). It is unknown how these movements might be modified or restricted if snow-making activities had been active; this merits future work. Excluding the female from CVNWR, the distance of the males' diurnal den sites was only 18.5 ± 5.0 m from cleared areas such as ski runs or roads. Similarly, the female we tracked at CVNWR occupied an area adjacent to frequently used cross-country ski trails and was within visual and auditory range of a nearby downhill ski slope that was illuminated for night use. Unlike the males at SMR, the female moved to points along forest edges near, and not within openings, where skiing occurred.

Weigl et al. 1999 and Menzel et al. (2006b) observed that male and female Carolina and Virginia northern flying squirrels routinely crossed narrow linear openings in forests, such as unimproved gravel roads, during foraging bouts. Menzel et al. (2006b) recorded more locations in open areas, such as the outside edges of newly harvested northern hardwood-conifer stands, than in mixed mesophytic forests with a northern red oak (*Quercus rubra*) component. However, radio-tagged Carolina northern flying squirrels never crossed a two-lane transmountain road 100 m wide from forest edge to forest edge (Weigl et al. 2002). This suggests a maximum width where an opening becomes either a physical or behavioral barrier to movement. Maximum glide distances for northern flying squirrels are 65 m, though mean glide distances typically are 14 to19 m (Scheibe et al. 2006). Around highly developed portions of SMR near buildings or ski runs intersections, distances between forest patches easily exceed 100 m. However, the majority of ski runs at SMR where we tracked Virginia northern flying squirrels are 35 m wide or less. Ski run width at SMR apparently does not impede movement of male Virginia northern flying squirrels and forest patch size and configuration surrounding the ski runs are still sufficient to support squirrel presence, including reproductively successful females (BHE Environmental Inc. 2005). Whether or not these openings present barriers to foraging and dispersal or reduce foraging efficiency, large amounts of linear edge or cleared area undoubtedly increase the risk of predation for Virginia northern flying squirrels. Though speculative, the male at CVNWR that was a victim of avian predation was discovered across roads and openings avoided by the female during our tracking effort.

Model simulations using demographic data in southeastern Alaska indicate that long-term persistence of northern flying squirrels can be problematic in disturbed habitats or small forest patches (Smith and Person 2007). Long-term monitoring data by the West Virginia Division of Natural Resources and the Virginia Department of Game and Inland Fisheries (Ford et al. 2007, Reynolds et al. 1999, Stihler et al. 1995) show virtually no evidence of localized extirpation since the subspecies was listed as endangered. This factor, combined with the realization that seasonal differences in habitat use appear to be minimal and that the subspecies appears to tolerate some degree of habitat alteration, provides validation for current management prescriptions and mitigation strategies on public and private lands in the region in addressing areas with high-density winter recreation. Still, it is imperative to continue to expand research efforts to link habitat conditions to demographic status of the Virginia northern flying squirrel as the subspecies' status regulatory status changes and development pressures increase in the Allegheny Mountains.

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We radio-tracked two male and one female Virginia northern flying squirrels (*Glaucomys sabrinus fuscus*) in the Allegheny Mountains of West Virginia at Snowshoe Mountain Resort, in winter 2003 and Canaan Valley National Wildlife Refuge in winter 2004, respectively, to document winter home range and habitat use in or near ski areas. Male home range size in the winter was larger than that reported for males during summer and fall, whereas the female home range we observed was smaller than those reported for summer and fall. However, winter habitat use was similar to summer and fall habitat use reported in other studies. Virginia northern flying squirrels foraged and denned in both red spruce (*Picea rubens*)-dominated forests and northern hardwood forests; however, selection of red spruce-dominated forests and open areas was greater than expected based on availability. Use of northern hardwood forest occurred less than expected based on availability. Male squirrels denned near, and routinely crossed, downhill ski slopes and unimproved roads during foraging bouts, whereas the female approached, but did not cross forest edges onto roads or trails.

KEY WORDS: *Glaucomys sabrinus fuscus*, habitat use, home range, skiing, Virginia northern flying squirrel, winter

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