# THE NORTHERN FLYING SQUIRREL IN THE PACIFIC NORTHWEST: IMPLICATIONS FOR MANAGEMENT OF THE GREATER FUNDY ECOSYSTEM

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## INTRODUCTION

Recent investigations in the Pacific Northwest (USA) have evaluated the association of northern flying squirrels (*Glaucomys sabrinus)* with older forests. The prominence of studies on northern flying squirrels in this region has been motivated primarily by the northern flying squirrel's dominance in the diet of the northern spotted owl *(Strix occidentalis caurina),* a federally (USA) listed threatened species, and the California spotted owl *(S o. occidentalis).* Northern flying squirrels have also been studied because of substantial reductions of older forests from timber harvesting and concern for wildlife associated with these forests. Northern flying squirrels, perhaps due to their use of cavities in live and standing dead (snag) trees, were described as "old-growth associated species" (Harris and Maser 1984, Brown 1985:164, Franklin 1988, Carey 1989)

The northern flying squirrel was selected as an indicator of older-forest conditions in the Greater Fundy Ecosystem, New Brunswick. Although the forest structure and composition are very different between forests in the Pacific Northwest and those in eastern North America, we will summarize the results of research done in the Pacific Northwest (northern California, Oregon, and Washington) and suggest how these findings may be relevant for management of forests in the Greater Fundy Ecosystem. In this review, we will also identify gaps in our knowledge of northern flying squirrel biology that are potentially important in assessing the viability of populations in isolated reserves, such as Fundy National Park. Few investigations of northern flying squirrels have been conducted in eastern North America that evaluated the association of this species with older forests, so the results from the Pacific Northwest may provide the best clues as to how well northern flying squirrels may function as indicators of the quality of older forest conditions in the Greater Fundy Ecosystem.

## NATURAL HISTORY OF NORTHERN FLYING SQUIRRELS

Northern flying squirrels are found throughout most forested regions of northern North America, including remnant populations in the southern Appalachian Mountains. They are found in both coniferous and deciduous forests in a variety of stand conditions. Northern flying squirrels are nocturnal and active throughout the year. They are prey for numerous species, primarily owls and medium-sized carnivores (e.g., American marten, *Martes americana*). Their diet consists primarily of fungi and lichens but also includes vegetative components (e.g., flowers, pollen, fruit) and insect matter. Arboreal lichens become increasingly prevalent in the diet during winter months when snow may cover the ground and limit access to fungi. Nest sites are varied and may include cavities in trees or snags, stick nests, "witches broom" (an erratic growth of vegetation caused by the rust disease *Chrysomyxa spp.*), or under logs. Sexual maturity is achieved in approximately one year. Two to four young are typically produced once per year, and are usually born in late spring to early summer. Northern flying squirrels rarely live longer than three years in the wild, although in captivity northern flying squirrels may survive for ≥ 10 years. The species is clearly adapted for gliding motion, with flights as great as 90 m reported. They have been reported to move as fast as 13 km/hr on the ground, although this seems unusual in light of their normally awkward movements on non-bark surfaces. Travel on logs, however, may facilitate movement. The natural history of northern flying squirrels are reported in Davis (1963), Wells-Gosling and Heaney (1984), Maser *et al.* (1985), Maser *et al.* (1986), and Hall (1991).

## FLYING SQUIRREL ECOLOGY IN THE PACIFIC NORTHWEST

### RELATIONSHIP OF SQUIRREL ABUNDANCE TO STAND AGE

Northern flying squirrel abundance has been compared between early and late successional forests in northeastern California (Zabel and Waters, unpublished data), Oregon (Carey *et al.* 1992, Rosenberg and Anthony 1992, Witt 1992, J. Hayes *et al.* unpublished data), and Washington (Carey *et al.* 1992). Forest conditions vary throughout this region in terms of climate, tree species composition, and forest management practices.

In general, old-growth stands (>2OO years old) in these studies possessed characteristics typically ascribed to older forests in the Pacific Northwest: upper canopy composed of large trees (>50 cm diameter at breast height), multi-storied canopy, large snags, and considerable volumes of large-diameter coarse woody-debris (Franklin and Spies 1991). In the California study, shelterwood-logged stands were old-growth fir *(Abies spp.)* stands that had undergone a first-entry shelterwood harvest and intensive site preparation (tractor-pile and bum) following partial tree harvest. These stands were characterized by large trees, little understory development, and highly impacted soils from site preparation techniques (Zabel *et al.* 1992, **Zabel and Waters, unpublished data).**

Young stands (10-90 years old) originated after either clear-cutting or wildfire. The youngest stands examined (10-15 years) were in the Coast Ranges of Oregon (J. Hayes *et al.*, unpublished data). Young stands evaluated by Witt (1992) and by Carey *et al.* (1992) in the Coast Ranges of Oregon ranged from 40-70 years. These two studies were not independent as at least some of those stands examined by Witt (1992) were apparently included in the study by Carey *et al.* (1992). In the Oregon Cascades, young stands ranged from 30-60 years, and most stands (four of five) originated after clear-cutting and prescribed burning (Rosenberg and Anthony 1992). In the California study, young stands were 70-90 years old and had naturally regenerated after wildfire. In western Washington (Olympic Peninsula), young stands ranged from 40-70 years (Carey *et al*, 1992).

The results of these studies suggest a trend of slightly higher densities with increasing stand age (Figure 1). Highest densities were usually found in older stands. However, the differences among stand ages, except in the youngest (10-l5 years), were small, and were not consistent among studies. In the 10-l5 year stands, few squirrels were captured during eight-day trapping sessions throughout the two year study period. No squirrels were captured in two of three stands. However, in the same study, numbers captured in 20-35 year stands were similar to numbers captured in later seral stages (J. Hayes *et al.*, pers. comm.). In the Oregon Cascades, densities were similar between young ($\bar{x}$ = 2.0 squirrels/ha) and old-growth ($\bar{x}$ = 2.3 squirrels/ha) stands (Rosenberg and Anthony 1992). These results are in contrast to those reported by Carey *et al.* (1992) and Witt (1992) in the Coast Ranges of Oregon and the Olympic Peninsula (western Washington). Carey *et al.* (1992) reported higher numbers of northern flying squirrels in old-growth in their Oregon study site ($\bar{x}$ = 1.9 squirrels/ha) and in their Washington study site ($\bar{x}$ = 0.5 squirrels/ha) compared to young stands ($\bar{x}$ = 0.9 and 0.2 squirrels/ha in the Oregon and Washington study, respectively). Witt (1992) reported lower densities, but similar patterns as Carey *et al.* (1992) in the Oregon sites. However, the methods and analyses used by Carey *et al.* (1992) and Witt (1992) to estimate densities were questioned by Rosenberg *et al.* (1994). In northern California, young stands tended to have fewer northern flying squirrels ($\bar{x}$ = 2,3 squirrels/ha) than old-growth stands ($\bar{x}$ = 3.3 squirrels/ha). Shelterwood-logged stands, however, had the lowest densities ($\bar{x}$ = 0.4 squirrels/ha, Zabel and Waters, unpublished data), These studies suggest that the species can be found in relatively high numbers in stands ≥ 35 years, although there appears to be a tendency for higher densities in older stands. However, stand age beyond a certain threshold age (e.g., 10-15 years) was not a good predictor of northern flying squirrel abundance in the Pacific Northwest studies (Figure 1).

The research conducted on northern flying squirrels have focused primarily on abundance patterns rather than on habitat quality as expressed by demographic parameters of survival and fecundity. Density does not necessarily indicate habitat quality because higher numbers can be found in sink habitats that are maintained by more productive source habitats (Van Horne 1983, Pulliam 1988). Comparison of additional demographic parameters must be considered in evaluating habitat quality. Although fecundity and survival rates are key parameters in assessing habitat quality (Van Horne 1983, Pulliam 1988), these characteristics have not yet been reported for northern flying squirrel populations. Characteristics that have been evaluated, however, are similar between young and old stands. In the Oregon Cascades, northern flying squirrel turnover rates (percent of animals not recaptured in a subsequent year), body mass, proportion of juveniles captured, movements, and home range size were similar in young and old-growth stands (Rosenberg and Anthony 1992, K. Martin, unpublished data).

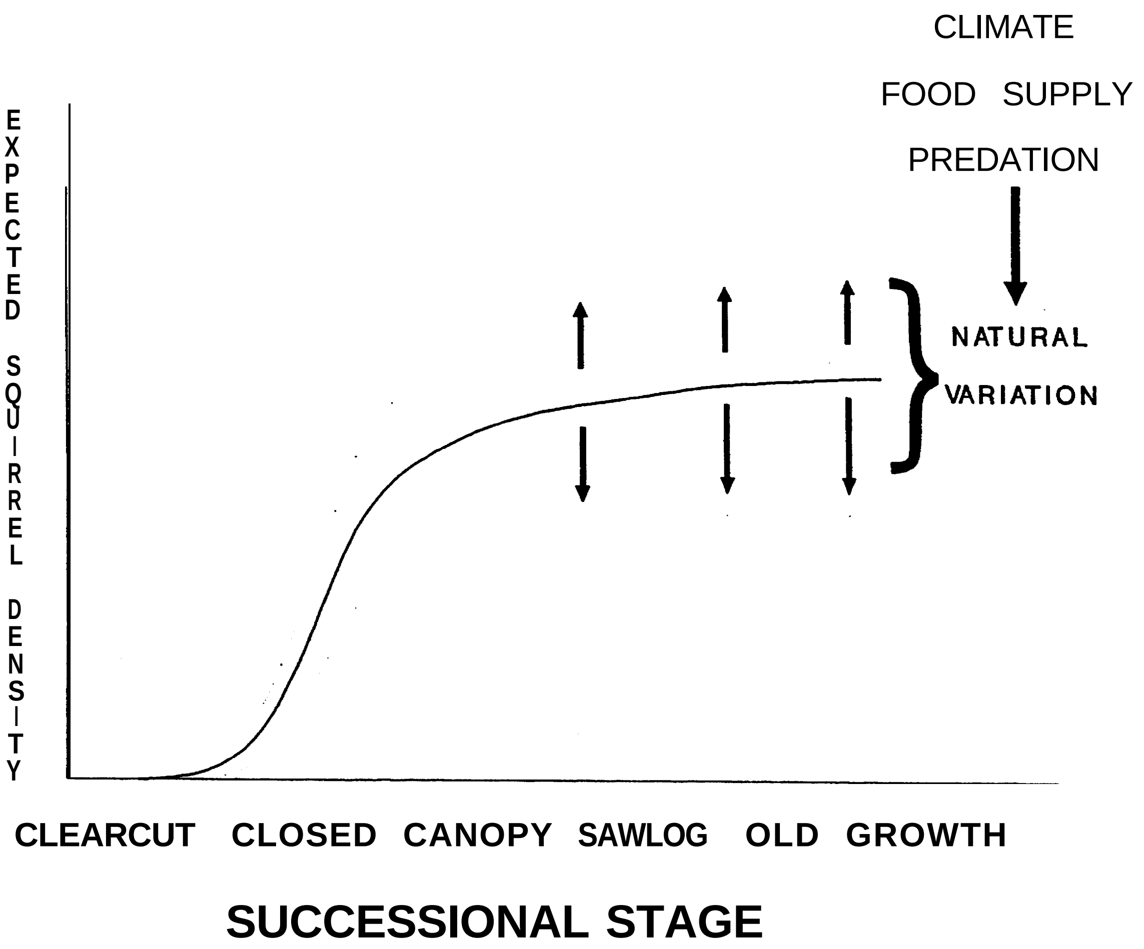


Figure 1. Hypothetical model of the relationship of expected northern flying squirrel density with forest succession. Few or no northern flying squirrels are expected in recent clearcuts. As the clearcuts mature to a closed canopy stage, expected density increases at a high rate, with the rate of increase decreasing as the forest matures. Variation of expected densities occurs primarily through changes in food supply, predation rates, and climate (extrinsic factors), all of which act directly on fecundity and survival rates. We expect forest structure to be more significant in affecting squirrel densities than natural variation of food supply, predation rates, and climate at early successional stages than at later stages. With increasing maturity of the forest, extrinsic factors are predicted to play the major role in affecting densities, thus confounding the affect of stand age. While the relationships shown here are hypothetical, this conceptual model seems to represent the existing data and understanding of the population dynamics of northern flying squirrels in various successional stages in the Pacific Northwest (USA).

## RELATIONSHIP OF SQUIRREL ABUNDANCE TO STRUCTURAL HABITAT COMPONENTS

Forest management affects the structural attributes of the forest, so understanding the relationship of northern flying squirrel abundance with forest structure is critical for successful management The inconsistency of the patterns of abundance may be due to stand-specific differences of critical habitat components, rather than stand-age differences However, the relationships between structural components (e.g., snag densities, shrub cover, canopy cover) and squirrel densities within a forest type (e.g., stand age-class) appear weak, based on work in the Oregon Cascades and in northern California (Rosenberg and Anthony 1992, Zabel and Waters, unpublished data). Interestingly, northern flying squirrel density was not correlated with snag density. Snags, which are used as nest and den sites by northern flying squirrels, were apparently not limiting abundance, due to either sufficient snag densities or use of other nest types. Recent research indicates that the species uses a variety of denning and nesting sites, including cavities in small (<25 cm dbh) snags, stick ("dray") nests built on both snags and trees, and witches broom (Mowrey and Zasada 1984, K. Martin, unpublished data, J. Waters and C. Zabel, unpublished data). For example, in the Oregon Cascades, 110 flying squirrel den sites were located in old and young stands. Most (107 of 110, 97%) of these were located in live trees, and a minimum of 50 (45%) were dray nests (K. Martin, unpublished data). These results suggest that nest sites may not be limiting northern flying squirrel populations in the closed canopy stands examined. We are unaware of reports of relationships of northern flying squirrel densities to habitat components in the other study areas in the Pacific Northwest.

## FOOD AS A LIMIT TO POPULATION SIZE

The one study to investigate the relationship of northern flying squirrel abundance with food resources found a positive correlation. In the California study, Zabel and Waters (unpublished data) sampled sporocarps of hypogeous fungi in each stand in which they estimated flying squirrel abundance. They found a positive correlation between flying squirrel density and sporocarp frequency: frequencies were greatest in the old-growth stands and least in the shelterwood-logged stands. Arboreal lichens were also most abundant in the old-growth stands. A separate study that compared frequency of hypogeous sporocarps among different thinning levels and between broadcast burned and unburned stands failed to find significant treatment effects (Waters *et al.*, in press). The low frequency of hypogeous sporocarps in the shelterwood stands may have been more related to soil disturbance from intensive site preparation than to tree spacing. Further work on sporocarp development among forest seral stages and vegetative and soil characteristics will likely enable further tests of the food-limitation hypothesis and understanding of the inconsistencies in patterns of squirrel abundance among seral stages.

## PREDATION AS A LIMITING FACTOR

Predation is another factor that may influence demography of northern flying squirrel populations. Many species of raptors and some medium-sized forest carnivores (e.g., American marten) prey on northern flying squirrels. The activity of this species throughout the winter may result in increased vulnerability to predators when other small mammals become inactive (e.g., chipmunks [*Tamius spp.*]). Predation may be intense. For example, based on estimates of consumption rates and flying squirrel densities, it is possible that a pair of spotted owls may consume up to 25% of the northern flying squirrel population annually in areas where the owls nest (Rosenberg and Anthony 1992). Such intense predation rates may substantially reduce local population sizes, as has been suggested for northern California (Zabel and Waters, unpublished data), the Oregon Cascades (Rosenberg and Anthony 1992), and the Coast Ranges of Oregon and western Washington (Carey *et al.* 1992). Population sizes of northern flying squirrels are affected by predation, although the level is likely a result of numerous interacting factors such as community composition, prey vulnerability to predators due to forest structure (e.g., Rosenberg *et al.* 1994), and density dependent factors, such as prey switching (e.g., Holling 1959).

## EFFECTS OF LANDSCAPE PATTERNS

We know very little about how northern flying squirrels respond to landscape patterns, such as fragmentation and isolation, despite their potential importance in affecting biological diversity (Wilcox and Murphy 1985, Wilcove *et al.* 1986). The only study we are aware of that reported data on effects of fragmentation on northern flying squirrel populations found decreasing frequency of occupancy as stand size decreased: flying squirrels in northern California were found in 60-80% of stands >23 ha and in <10% of stands that were <7 ha (Rosenberg and Raphael 1986). To assess what constitutes population isolation for this species, we must first understand the likelihood of successful dispersal through landscapes of various seral stages, especially those that would be the most restrictive to northern flying squirrels, such as clearcuts and early seral stages (e.g., <15 years). Northern flying squirrels are likely to be inhibited to move through open areas because of their highly adapted gliding movement, and their apparent difficulty in manoeuvring on non-bark surfaces. Evidence collected by Hayes *et al.* (unpublished data) suggest that stands are rarely used by northern flying squirrels until the stand is characterized by a closed canopy (≥ 15 years in their study area). Zabel and Waters (unpublished data), however, found that the species could move rapidly through shelterwood-logged stands in which tree density averaged only 37 trees/ha. Their observations suggest that partially harvested stands provide adequate dispersal habitat. Northern flying squirrels can glide further from tall trees than short trees, thus there is likely to be an inverse relationship between the number of trees required to provide dispersal habitat and average tree height.

In managed landscapes, habitat patches must be large enough to provide for viable populations for a time period sufficient for seral stage development to provide new habitat patches within the matrix of the surrounding landscape. Succession must be allowed to proceed to a stage that would result in forest structure that would allow dispersal as a minimum, and that would provide suitable habitat (where all life-history requirements can be met) as a preferred goal.

## POTENTIAL LIMITATIONS OF FLYING SQUIRRELS AS AN INDICATOR OF OLDER FOREST CONDITIONS

The northern flying squirrel was selected by the Greater Fundy Ecosystem project as a possible indicator of older forest conditions. This species is being considered on the assumption that it is responsive in one or more demographic parameters to conditions of older forests. Research from the Pacific Northwest has shown that northern flying squirrels are not dependent on old-growth forests, and their abundance is only weakly associated with seral stage beyond the stage of canopy closure (Figure 1). Predation and food supply, interacting with habitat and climate, may be the most important factors that influence northern flying squirrel population dynamics in the Pacific Northwest after canopy closure is reached (Figure 1).

However, forest structure and forest-floor conditions clearly differ between young stands ($\geq$ 35 years old) examined in the Pacific Northwest and those in plantations in the Greater Fundy Ecosystem. If the Fundy plantations reflect the conditions that were observed in the Hayes *et al.* (unpublished data) study of 10-15 year Douglas-fir plantations, then these plantations are unlikely to provide habitat for northern flying squirrels. Thus, the absence of reproducing animals (or very low abundance) may be a reasonable indicator of the lack of structure normally found in forests, but lacking in young plantations. Assessment of northern flying squirrel population characteristics in young plantations in the Greater Fundy Ecosystem will be critical in determining how well northern flying squirrels may indicate forest conditions.

Another potential limitation of using northern flying squirrels as an indicator of forest conditions is the difficulty in assessing changes in abundance of this species because of low capture probabilities and relatively low densities, at least in the Pacific Northwest (Rosenberg *et al.*, in review). Obtaining accurate and precise estimates of abundance or relative abundance requires considerable effort. The effort needed will be a factor in the precision required for monitoring purposes. If capture probabilities are higher in the Fundy region than in the Pacific Northwest, as indicated by S. Gerrow and S. Flemming (pers. corn.), the effort required to estimate abundance will be considerably less. Other techniques to monitor changes in population size, such as visitation rates to track plates (Raphael *et al.* 1986, Carey and Witt 199l), may allow monitoring with considerably less effort than capture-recapture techniques If demographic parameters other than density are not assessed, then caution must be used in interpreting the significance of population-size change to population health (Van Horne 1983, Pulliam 1988).

## FUTURE RESEARCH AREAS

A quantitative comparison of northern flying squirrel populations in plantations, young forests, and older forests in the Greater Fundy Ecosystem is needed to assess the association of this species with conditions of older forests. If the plantations are found to be poor habitat, then quantification of what comprises suitable dispersal habitat will be imperative in assessing viability of populations in a highly managed forest. Research such as proposed by Flemming *et al.* (this report) to monitor movements of displaced northern flying squirrels in isolated patches should be very revealing with respect to how flying squirrels respond to intensively managed forests. Understanding how northern flying squirrel populations respond to landscape patterns will allow scientifically credible management to be conducted on the intensively managed forests surrounding Fundy National Park in ways that will maintain northern flying squirrel populations.

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# USING POPULATION VIABILITY ANALYSIS IN ECOSYSTEM MANAGEMENT AT FUNDY NATIONAL PARK

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