PROJECT UPDATE REPORT

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Habitat Requirements of a Mixedwood Indicator Species: Northern Flying Squirrel

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Brief Description:

This project aims to assess the value of the northern flying squirrel as an indicator of forest management impacts and protection strategies. The northern flying squirrel is listed by DNRE as a species considered associated with mixedwood forest structures, mature forest, and a sensitivity to fragmentation. The primary goal of this project is to develop science-based habitat associations for this forest vertebrate and to quantify the associated landscape cover thresholds that can be used in forest management planning.

Note: we had planned to also study several species of salamander but have recently had to drop them from the design. As we reviewed last year's data on squirrels it became apparent that we will have to alter our trap design, essentially trapping each area for longer periods. This change makes it impossible to also do the planned salamander component. Since there is more interest by provincial forest managers in flying squirrels, and more connection between forestry and flying squirrels, we have retained focus on the flying squirrel component of the project.

Project Objectives:

The purpose of this project is to assess the relationships between density and productivity of selected vertebrate species (northern flying squirrel), and forest type; and to compare overall communities at the landscape level. The design involves a continuum of landscape and stand types, obtained from sites in relatively unmanaged habitat (Fundy National Park) and managed sites.

There are three major objectives:

(1) Determine aspatial (stand structure, stand composition) habitat relationships for northern flying squirrel. This includes stand attributes such as vegetative species composition and the size and physical distribution of species within the stand.

2) Determine spatial (patch size and configuration) habitat requirements and thresholds of vertebrate indicator species.

3) Examine aspatial and spatial habitat requirements for northern flying squirrel to determine if they might serve as better indicator species in upcoming DNRE forest management planning exercises.

Introduction

Landscape ecology frequently addresses questions about spatial heterogeneity, spatial and temporal interactions and the movement of organisms across a variety of scales. A landscape is a heterogeneous unit of area composed of a cluster of interacting homogenous components (Risser et al. 1984; Urban et al. 1987; Forman 1995). Hierarchy theory suggests the study of complex systems may be facilitated when they are subdivided into discrete units operating at different scales, with the lower levels interacting to generate the patterns observed at the broader levels. A broad scale provides the context for the lower levels in the hierarchy (Urban et al. 1987). The explanation of an observed pattern may be sought at the hierarchical level one below the question of interest (Urban et al. 1987; Kotliar and Weins 1990; Levin 1992). Ecological processes may be scale dependent (Turchin 1996). Across-scale studies may be used to control for fine scale characteristics while assessing questions about large scale processes such as the relationship between the pattern (shape, size and arrangement) and the abundance of a landscape attribute (Urban et al. 1987; Dunning et al. 1992).

Species depend on the presence of adequate resources distributed over a variety of scales. The importance of nesting structures, foraging substrate and den sites may be emphasized at the local (microhabitat and forest stand) scale, while the presence of temporary refuges and a forest pattern permitting movement greater relative influence at a broader landscape scale (Saunders et al. 1991; La Polla and Barrett 1993; Taylor et al. 1993; Matthysen et al. 1995; Mönkkönen and Reunanen 1999;). Other important resources may include those offering protection from adverse environmental conditions and structures maximizing predator avoidance (Carey et al. 1992; Carey et al. 1997). Anthropogenic manipulation of forested landscapes may alter animals' access to resources. Populations may be adversely affected by insufficient habitat (landscape composition) as well as an inability to access suitable patches due to the spatial arrangement (landscape pattern) of the remnant patches (Lefkovitch and Fahrig 1985; Taylor et al. 1993; With and Crist 1995; Andrén et al. 1997).

Habitat fragmentation occurs when a continuous habitat is subdivided into smaller pieces, reducing the functional habitat availability beyond the level of actual habitat loss (Lefkovitch and Fahrig 1985; Taylor et al. 1993; Andrén 1994; With and Crist 1995; Fahrig 2002). The fragmentation process may be divided into three independent, but functionally linked components: 1) loss of original habitat, 2) a reduction in habitat patch size and 3) increasing isolation between patches (Andrén 1994). Alone, habitat loss does not necessarily imply habitat fragmentation, as fragmentation depends on the spatial arrangement of remnant patches (Lefkovitch and Fahrig 1985; Dunning et al. 1992; Taylor et al. 1993; Andrén 1994; With and Crist 1995). Traditional fragmentation study designs do not independent assess of the influence of landscape pattern and composition on animal populations, which may further elucidate the mechanisms driving habitat fragmentation effects (Trzcinski et al. 1999).

Anthropogenic activities such as timber harvesting may accentuate natural divisions within heterogeneous forest ecosystems. At a critical threshold of habitat loss, further habitat loss may dramatically alter the spatial continuum of the landscape, restricting the ability of animals to "percolate" across the previously connected patch network (Andrén 1994; With and Crist 1995). Surpassing this critical threshold is expected to disrupt ecological interactions. An improved understanding about the scales at which a species uses and responds to its environment is useful to determine if this theoretical threshold exists in natural systems. Although forest management practices unavoidably alter landscape cover, configuration and forest stand structure, it may be possible to mitigate the effects of landscape configuration with forest planning.

The response of a population to habitat disturbances at various scales may be dependent on species characteristics such as dispersal ability, and perceptual ability (the ability of an animal to distinguish or interpret landscape features using its senses), predation risk and habitat requirements (Reunanen et al. 2000; Zollner 2000). Assessing disturbances solely at a fine scale results in an inability to possible landscape-level influences. Studies conducted at a coarser, landscape-level spatial scale results in a decrease of predictive power due to more numerous inherent variation (Wiens 1989; Rolstad et al. 2002). One solution is to study species-specific responses to heterogeneity across a range of scales (Kotliar and Weins 1990). By statistically controlling for the influence of finer grain (e.g. microhabitat and stand) characteristics, landscape influences may be assessed.

The New Brunswick Department of Natural Resources has proposed the northern flying squirrel (*G. sabrinus*) as an associated "indicator" species of mature mixedwood forest and potentially of effects of habitat fragmentation. Management indicator species may be used as an indirect measure of environmental or biological conditions that are too difficult, inconvenient or expensive to measure directly (Landres et al. 1988). As a gliding, nocturnal habitat specialist associated with old-growth forest characteristics, the northern flying squirrel (*G. sabrinus*) may be vulnerable to habitat fragmentation (Carey 1995; Waters and Zabel 1995; Carey et al. 1997; Taulman et al. 1998; Carey 2000).

In the Pacific Northwest, flying squirrels were most abundant in old-growth stands, with lower densities within regenerative forests (Carey 1989). They were twice as abundant in old-growth stands compared to immature forests which lack old-growth legacies such as snags, decaying coarse woody debris and large living trees with a component of decay (Carey 1995). Witt (1992) reported that flying squirrel densities were greater in optimal old-growth habitats compared to second-growth stands.

The conclusion that the northern flying squirrel is an old-growth specialist is not universally supported. Martin and Anthony (1999) reported no differences in flying squirrel movements, densities or home range sizes between second-growth and old-growth conifer forest stands in Oregon, and Waters and Zabel (1995) concluded that, although flying squirrels were adversely affected by intensive forestry management, they were not old-growth dependent. Regardless, anthropological landscape alterations such as intensive timber harvesting are suspected to negatively impact the northern flying squirrel (Waters and Zabel 1995; Mönkkönen et al. 1997; Taulman et al. 1998; Carey 2000;).

Flying squirrels captured within a contiguous forest and released on the far side of an adjacent clearcut were not observed to cross the clearcuts during homing behaviour, but rather traveled substantially farther distances around the clearcut periphery (Bourgeois 1997).

Within contiguous forests, flying squirrels are probably limited by the distribution and abundance of at least two resources: nesting cavities and food availability (Ransome and Sullivan 1997). Witt (1992) proposed that an increased flying squirrel abundance in old-growth stands was a consequence of den site availability and the presence of a microclimate conducive for hypogeous sporocarp formation, a primary component the species' diet. Older stands produce a greater biomass and diversity of ectomycorrhizal fungi (Waters and Zabel 1995) and Mills (1996) reported that truffles (the fruiting bodies of hypogeous ectomycorrhizae) were absent in clearcuts and reduced in abundance at fragment edges. This possible gradient of truffle distribution may be caused by altered soil characteristics at fragment edges.

Although the northern flying squirrel has been proposed as a mixedwood forest management indicator species, relatively little is known about their forest associations in eastern North America (although see Gerrow 1996; Bourgeois 1997; Vernes 2001; Vernes et al. 2004). The American marten (*Martes americana*) has been widely promoted as an indicator species of healthy old-growth coniferous forests. Research conducted on the marten in Maine suggests this species are limited by coarse woody debris (Payer and Harrison 2002) which most prevalent in, but not restricted to softwood forests. An indicator species management approach depends on our knowledge of forest associations to facilitate appropriate forest management decisions.

A majority of northern flying squirrel studies have been conducted in the western region of North America (Waters and Zabel 1995; Ransome and Sullivan 1997), particularly in the Western Hemlock zones of Oregon (Maser et al. 1986; Carey 1989; Carey et al. 1992; ; Witt 1992; Carey 1995; Carey et al. 1996; Carey 1996; Carey et al. 1997; Carey et al. 1999; Carey 2000). This area is characterized by mild, wet winters (minimum: -2.5 to +2.5°C) and hot summers (maximum: 22-27°C) with an annual precipitation of 100-160cm (Carey et al. 1999). The Atlantic Maritime ecozone is characterized by a cool and humid maritime climate and Acadian transitional forests containing deciduous and boreal tree species including red spruce (*Picea rubens*), balsam fir (*Abies balsamea*), yellow birch (*Betula alleghaniensis*), sugar maple (*Acer saccharum*), red and white pine (*Pinus resinosa*, *P. strobus*) and eastern hemlock (*Tsuga canadensis* (Farrar 1995; Natural Resources Canada 2004). The size (diameter at breast height) and height of trees and the size of coarse woody debris within these Acadian forests are less than those of the Pacific Northwest (Gerrow 1996; Carey et al. 1997; Carey et al. 1999). These climatic and vegetative differences between the forests of western North America and eastern North America result in substantially different stand composition and structure. The large structures purported as “needed” in the Pacific Northwest are rare or absent in northeastern North America.

Currently, little is known about the effect of forest pattern on the northern flying squirrel (*G. sabrinus*) across its entire range. Studies on the larger Siberian flying squirrel (*Pteromys volans*) within managed Finnish boreal forests found occupied patches were not larger than unoccupied patches, although stand level characteristic varied at the home range scale. The same study reported unoccupied patches had more matrix within a 1km radius than occupied patches (Mönkkönen et al. 1997). A later study showed high usage areas contained more suitable breeding habitat patches and were better connected by dispersal corridors compared to random forested areas (Reunanen et al. 2000). The researchers recommended management for broad-scale forest pattern.

The response of *P. volans* to a managed landscape may be sex specific, with only males responding to landscape pattern. In studies by Selonen et al. (2001; Selonen and Hanski 2003), males rapidly crossed the matrix to move between patches in a managed landscape while females restricted their movements to a single patch. The probability of leaving a patch was negatively correlated with patch size (Selonen and Hanski 2003).

The flying squirrel subfamily (Pteromyinae) is represented in the New World by two species, both belonging to the genus *Glaucomys* (*G. sabrinus* and *G. volans*). The northern flying squirrel is the larger of the two species. The average weight of *G. sabrinus* is (88.6 ± 2.0 g for both sexes without controlling for pregnant females, N=50; Ritchie et al. unpublished), is only 64% that of *Pteromys volans* (Freye 1975). Differences in body size can dramatically affect maximum gliding distances and home range size. The latter life-history characteristics are both suggested to influence a species' response to its environment at a coarser scale. The giant flying squirrel (*Petaurista petaurista*) has a maximum gliding distance of 450m (Hutchins 2004). No gliding distance was reported for *P. volans*. The maximum gliding distance reported for *G. sabrinus* is 45.0m, with most glides ranging between 5-25m (Vernes 2001). Differences in gliding ability within the Pteromyinae are expected to affect the sensitivity of the different species to forest fragmentation.

Study Location

Fundy National Park is a relatively small protected area (206km^2) surrounded by a matrix of managed forests, making it a valid study location for this project (Figure 1). Forestry activities (road building, canopy removal from clearcut harvesting etc.) may be isolating northern flying squirrel populations by reducing the number of nesting sites (e.g. snags) and reducing the accessibility of remaining mature forest patches.

Figure 1. Location of the Greater Fundy Ecosystem Intensive Study Area (ISA).

Study Design

1.0 Literature review of the use of indicator species as a forest management tool

The indicator species approach is common in forest management. Recently, the validity of using indicator species in management decisions has been questioned (Lindenmayer 1999; Lindenmayer et al. 2000). A management indicator species must be sensitive to disturbances over which the management agency has control (Caro and O'Doherty 1999), such as the pattern and amount of mature forest cover. The indicator species has been used with varying degrees of success. Before assessing whether flying squirrels are good indicators of landscape composition and configuration, we will carefully assess the validity of the indicator approach to forest management.

Methods

The indicator species management approach will be assessed as an empirical science measure and as a practical tool in forest management through a literature review. Particular attention will be paid to vertebrate species, such as the northern flying squirrel, that may be resource limited by the use of old and large forest characteristics. Other species-specific characteristics examined will include: 1) current biological understanding, 2) sampling ease, 3) home range size, 4) mobility, 5) estimated population size 6) geographic range, 7) ecosystem interactions, and 8) reported sensitivity to environmental disturbances under the control of management agencies (Landres et al. 1988; Caro and O'Doherty 1999).

Whether or not the northern flying squirrel is influenced by landscape pattern is of theoretical interest independent of management concerns. The predicted degree of influence of landscape on animals varies widely, depending on implicit and explicit modelling assumptions (Fahrig 2002) Insufficient empirical information is available to assess which models best represent reality.

Research Question: Does a broader scale than the stand level influence flying squirrels?

To assess the above question, we must first control for local level (stand level) characteristics. We will use a hierarchical study design (Figure 2).

Fundy Model Forest study area

↓

750m radius squirrel landscapes

↓

Old forest patches

↓

Stands
(containing a trapline)

↓

Vegetation plots
(centered at a subset of traps within the trapline)

Figure 2. Hierarchical study design. Each lower level is nested within the levels above it.

2.0 Stand-Level Forest Characteristics

H_{STAND}: The presence of foraging flying squirrels relates to the stand types and structures used in forest management.

For an indicator species to work, its presence should relate to the forest structures and characteristics used in management. A stand is defined according to the New Brunswick forest stand development system based primarily on overstory tree species composition and development stage (Timber Management Branch 1989). *A priori* stand-level models will be generated using information currently available to forest managers in the New Brunswick Geographic Information System database. Following data collection these models and their subsets will be ranked and assessed using multivariate statistical modeling techniques, including Akaike's Information Criterion (Burnham and Anderson 2002) and logistic regression (Hosmer and Lemeshow 2000). The results will be used for further development of adaptive wildlife management strategies for Acadian mixedwood forests.

H_1: Flying squirrels are ecotone species using supplementary resources associated with either deciduous or coniferous forests.

Prediction: The likelihood of detecting a flying squirrel is greatest in mixedwood forests.

Model 1: FS(0,1)= (CON) + (DEC) + CON*DEC

Note* CON= proportion of large (>14cm diameter-at-breast height; (Gerrow 1996) coniferous trees; DEC= proportion of large deciduous trees. Proportions will be calculated out of the total number of trees within the vegetation plots to maintain independence of data. FS(0,1) represents the logit transformation of the conditional mean of the flying squirrel binomial probability (Hosmer and Lemeshow 2000). We predict flying squirrel presence will be positively correlated with the proportion of coniferous and deciduous trees (as represented by the interaction term in Model 1).

2.2

H_2: Stands with greater structural diversity (i.e. greater number of well-represented forest layers) offer greater protection for foraging flying squirrels.

Prediction: Flying squirrel occurrences are more likely in forests with greater structural diversity, as measured by the amount of cover provided by particular forest layers.

STAND MODEL: FS(0,1)= (Model 1) + % Canopy Cover + % Shrub Layer Cover

Methods for Stand Model (2.1 & 2.2)

Vegetative and forest structural information will be assessed using data collected in three 10 x 20m plots located along each trap line. Each vegetation plot will be centered at the point of capture and have a north-south orientation. Within each trapline, an equivalent number of random empty trap locations will be selected as the vegetation plot center. The following measures will be recorded in each plot 1) % canopy cover provided by each canopy layer (as assessed using an ocular tube, 2) tree diameter at breast height (dbh) and 3) tree species composition.

A Type I logistic regression model was selected to explain additional variance in the data set. Unexplained variance will be attributed to the stand level characteristics under the control of forest managers. By later assessing the contribution of microhabitat characteristics, the amount of residual variance within the stand model may be reduced. A strong correlation between microhabitat variables and forest stand type may suggest a more direct influence of these characteristics on the presence of the northern flying squirrel.

Table 1. Structural characteristics of sample stands (M. Betts)

	Regenerating / Sapling	**Young**	**Immature**	**Mature/ Overmature**
Height	2-5m	5-7m	7-12m	12+
Max DBH	6cm	10cm	30cm	None
Age[1]	10-30	30-45	45-70	70+

Table 2. Stand composition characteristics of sample stands (M. Betts)

Habitat Type	**Composition**
Hardwood	>75% hardwood

[1] Does not apply to Mature or Overmature stands that are uneven aged.

Softwood	>75% softwood
Mixedwood	<75% hardwood and <75% softwood

3.0 $H_{LANDSCAPE}$: The occurrence of the northern flying squirrel is influenced by the pattern of old forest cover beyond the contribution of stand-level characteristics.

A major objective of this study is to determine the cause of any landscape effects by statistically assessing the relative, independent contribution of 1) habitat loss and 2) landscape pattern on the distribution of flying squirrels.

Landscape effects may be caused by edge effects, patch size, patch shape or patch isolation.
Through careful site selection, it may be possible to independently assess each of the latter hypotheses. To assess the degree of isolation, the amount of mature forest cover within a 750m radius surrounding the centre of the trapline will be determined using buffer processing techniques in a Geographic Information System program (e.g. ArcView 3.x). A landscape radius of 750m was selected based on 1) northern flying squirrel data gathered during monitoring program of northern flying squirrels within and surrounding Fundy National Park (Ritchie 2002); Ritchie et al. unpublished), 2) the male homerange of the northern flying squirrel in southern New Brunswick (Gerrow 1996) and the maximum distance traveled by flying squirrels during homing behaviour (Bourgeois 1997). Forest stands will be classified as old according stand characteristics reported in the New Brunswick forest inventory database. All old forest stands will then be grouped into forest patches that are homogeneously “old” with respects to inventory stand age.

The four landscape metrics will be independently added to the previously generated within patch and stand model due to insufficient information to justify an *a priori* stepwise process. Variables will then be added in a *post hoc* stepwise fashion, after being ranked by the area under the curve and the least amount of information lost (AIC value). When these values conflict, the area under the curve will be used. When variables are strongly correlated ($p \leq 0.05$), only the best fit variable will be entered into the model.

3.1 H_{L1}: Landscape effects on flying squirrels are caused by patch isolation.

Prediction 1: The presence of flying squirrels is positively associated with the percentage of mature forest cover.

FS(0,1)= (Stand Model) + (% mature forest cover)$^{<1}$

Methods

The amount of mature forest contained within the 78.5ha landscape (500m radius circle) surrounding the center of the trapline will be calculated and converted to a percentage of the total area as a measure of patch isolation. Each landscape will be classified as a high, medium and low cover landscape to facilitate the process of site selection. A low cover landscape is defined as one containing less than 40% mature forest. This is based on the theoretical habitat requirements reported for habitat specialists (With and Crist 1995).

Medium and high cover landscapes were arbitrarily assigned by equally dividing the remaining percentages >40-70% and >70% respectively. Analysis assessing the amount of mature forest cover will use site specific percentages rather than these broad cover categories.

Prediction 2: Flying squirrel presence is negatively associated with the mean distance to the nearest old forest patch.

FS(0,1)= (Stand Model) – (mean distance to nearest old forest patch)

Methods

The degree of landscape fragmentation will be defined by mature forest patch density, a mean nearest neighbour distances, the number of connections larger than 20m between mature forest patches within a 500m radius and the degree of stand aggregation of those stands where northern flying squirrels were detected.

If the mean distance to the nearest old forest patch and the % old forest cover as a measure of isolation are correlated, the variable explaining the greatest amount of the variance will be used during statistical analysis.

3.2 H_{L2}: Landscape effects on flying squirrels are caused by patch size

Prediction: The presence of northern flying squirrels will be positively correlated with mature forest patch size.

FS(0,1)= (Stand Model) + (mature patch size)$^{<1}$

Methods

The matrix surrounding it will define the size of an old natural forest patch. While the classification of northern flying squirrels as old-growth specialists remains controversial (Witt 1992; Waters and Zabel 1995; Gerrow 1996; Carey et al. 1997; Martin and Anthony 1999), the species is consistently associated with second-growth and old-growth forests. However, the species' response to sapling stands and plantations has received little, if any study. Site selection followed a multi-step procedure. The old mature forest patch is the sample unit, although each trapline will be contained within a single stand to reduce the inherent variability of the trapline.

3.3 H_{L4}: The landscape effects on flying squirrels are caused by patch shape.

Prediction 1: The presence of northern flying squirrels will be positively associated with the fractal dimension of old forest patches.

FS(0,1)= (Stand Model) + Fractal dimension

Methods

The patch perimeter: area ratio will be calculated by identifying mature forest patches and recalculating their perimeter and area. The patch perimeter-to-area ratio will be calculated. The log (patch area) will then be regressed against the log (patch perimeter). The fractal dimension will be calculated as: 2/(slope of the regression line).

Prediction 2: The presence of northern flying squirrels will be positively correlated with the ratio of core patch area to the absolute old forest area.

$$FS(0,1) = (\text{Stand Model}) + \frac{\text{Patch core area}}{\text{Old forest patch area}}$$

Patch core area refers to the area of the largest circle that fits within the patch. This is a measure of both patch size and shape. As the ratio of patch core area to the old forest patch area decreases, the shape of the patch becomes less circular and is associated with more edge. If the above measures of shape are correlated, the variable explaining the greatest amount of the variance will be used during statistical analysis.

A total of 273 locations selected according to forest cover and patch size (Table 3) were sampled for 16 days each (4368 trapnights overall).

Table 3: Summary of mature forest trap sites established and trapped in 2003 according to % mature forest cover and patch size.

	Cover Category			
Patch Size Category	Low (<30%)	Medium (30%-<80%)	High (80%-100%)	Grand Total
5	7	8	1	16
10	7	4		11
20	4	9	2	15
50	4	22	1	27
100		15	4	19
200		14	18	32
500		13	17	30
1000		11	24	35
2000		7	13	20
4000		4	10	14
5000		5	7	12
10000+		9	13	22
Grand Total	22	121	110	253

Where flying squirrels were present (Figure 1), the captured animals were ear-tagged for future identification (and to establish a baseline mark-recapture database). Animal weight, sex and reproductive status were recorded. A genetic sample was collected from each individual. A database was created for each variable according to site number, site classification (landscape cover and patch size) and trapping week. Genetic samples collected from each animal were assigned identification numbers and entered into a genetic material library database for future laboratory analysis.

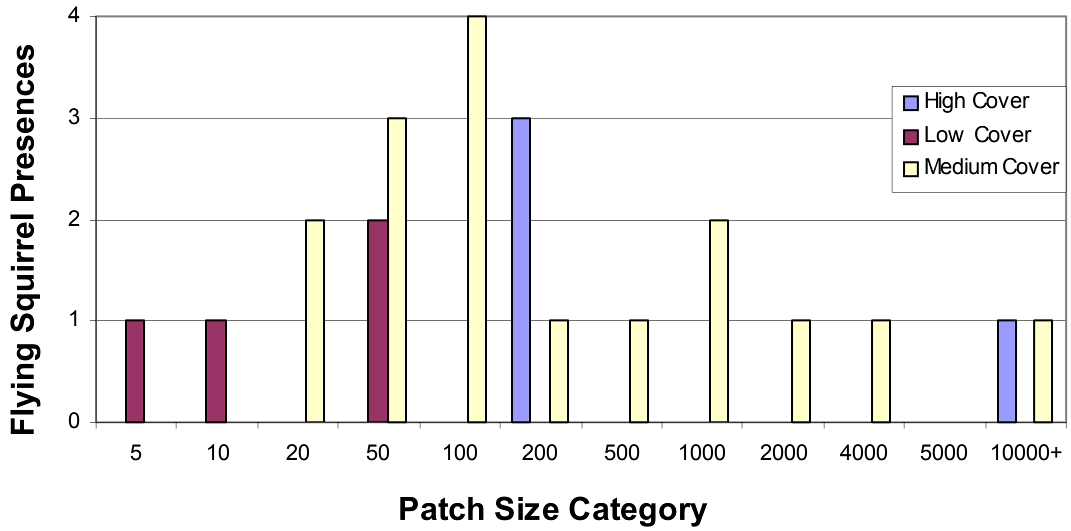

Figure 3. Presence of flying squirrels according to patch size and percentage of mature forest landscape cover

Fifty new mature forest sites were field-checked for suitability according to the attached site classification protocol (adopted from the forest bird project led by M. Betts). New hardwood sampling and plantation sites were randomly selected, field-checked and those deemed suitable were sampled. Maps were generated for each sampled site, as well as for newly established plantation, sapling and mature forest trapping locations. Furthermore, brief site qualitative descriptions were made of all trapping sites. These general observations of new sites will be quantified in the future.

4.0 Microhabitat (Within Stand)

The stand-level variables in Models 1 and 2 are based on forest characteristics available to forest managers in Geographic Information System databases. However, these variables may be only indirectly influencing the occurrence of flying squirrels. Morrison (2001) suggests wildlife studies should focus on "critical limiting niche factors", therein narrowing the scope of research questions to minimize system complexity.

The following models test other variables currently unavailable to forest managers. These variables may explain more variance and may be more biologically relevant for northern flying squirrel populations. In particular, the models address characteristics possibly influencing the availability of ectomycorrhizal fungi, the primary component of northern flying squirrels' diet within the old forests of southern New Brunswick (Gerrow 1996; Vernes et al. 2004). These models were developed using the following predictions

1. Soil conditions will vary according to forest type. Deeper litter, organic soil layers, increasing soil moisture and pH and reduced soil temperature will be found in old natural deciduous-dominated stands.
2. Soil moisture and depth will increase, while soil temperature will decrease with increasing distance from the surrounding matrix (Saunders et al. 1991).
3. Decaying forest structures (e.g. snags and coarse woody debris) contribute to soil moisture retention (Mills 1996; Carey et al. 1999) and an increasingly deep organic soil layer.

$H_{MICROHABITAT}$: Microhabitat effects indirectly influence flying squirrels by altering the availability of truffles.

4.1 H_{MH1}: The microhabitat effects on flying squirrels are caused the greater fungal diversity associated with increased tree species diversity.

Prediction: Flying squirrel occurrence is positively associated with an increasing relative richness in species composition (i.e. decreasing hardwood or softwood stand dominance).

g(FSBI)= (Stand Model) + Shannon-Weiner Index

Methods

Logistic regression will be used to assess if a relationship exists between the relative tree species richness and the presence of flying squirrels. Relative tree species richness will be determined using both vegetation plot data and a geographic information system database. The resulting models will then be compared to the ecotone and matrix effects suggested by Lidicker (1999).

4.2 FS(0,1)= (Model 2) + leaf litter depth + organic soil layer depth + LSnags + CWD + (soil moisture)$^{<1}$ – soil temperature + (soil moisture)$^{<1}$ *leaf litter depth + (soil moisture)$^{<1}$ *soil temperature + (soil moisture)$^{<1}$ *CWD + (soil moisture)$^{<1}$ *Lsnags

Note: LSnags represents large snags

Methods

The soil type, composition (e.g. depth of litter layer, humus and organic layer), pH, soil temperature at the surface of the humus layer, wet weight, dry weight and the ordinal contribution of fungal hyphae to soil composition will be assessed by analyzing soil cores collected from each vegetation plot.

Soil cores will be collected from the corners of each plot. The wet and dry mass of each core will be recorded to determine water retention. The porousness and organic composition of these cores will also be determined. An adjacent soil profile will be sampled for leaf litter and soil layer depth.

4.3 Edge effects on flying squirrels are indirectly caused microclimate alteration suspected to alter local truffle abundance.

Prediction:

FS(0,1)= (Model 2) - (distance from patch edge)$^{<1}$

AND

Soil moisture= Intercept + (distance from patch edge)$^{<1}$

Hyphae= Intercept + (distance from patch edge)$^{<1}$

Organic Soil Layer Depth= Intercept + (distance from patch edge)$^{<1}$

The occurrence of flying squirrels will be negatively associated with the distance to the matrix edge. Matrix was defined as clearcuts and plantations. Old, untreated forest patches completely surrounded by matrix and containing a stand sufficiently large to contain a 360m trapline with a minimum of a 10m buffer were selected as potential sites. This procedure was repeated after a progressive three-stage expansion of the matrix definition to include 1) naturally regenerating stands, 2) sapling stands and 3) young stands (30-45 years).

The above prediction is an indirect measure flying squirrels' detection of heterogeneity due to altered physical conditions caused by fetch as predicted by Saunders et al. (1991).

Methods

Data collected from the above mentioned vegetation plots will be used to assess the microhabitat conditions most strongly associated with flying squirrel captures. During this analysis, the sample unit will be the trap rather than the stand.

Plans for 2004 Field Season

The above-mentioned models will be developed from data from 2003 and 2004 field seasons. Field work will begin in May 2004 and extend until fall 2004, at which point, cold temperatures may influence capture success. If the field work goes as planned then we are hopeful that 2004 will be the last field season on this project.

Analysis of the data will occur in winter 2004, towards final conclusions in winter/spring 2005.

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Appendix 1: Vegetation data collected at each sample point

Data Title	Abbreviation	Codes
Observer	OBS	Initials
Even/Uneven aged	UN/EVEN	1 = EVEN 2 = UNEVEN
Tree age (dominant)	DOMAGE	
Tree age (co-dom)	COAGE	
Sight distance	SIGHT	
Disturbance history	DIST	1 = CC recent 2 = CC old 3 = Thin 4 = Group selection 5 = Highgrade 6 = Burn 8 = Budworm 9 = None
Community Type	COMM	IMWD = immature mixedwood MMWD = mature mixedwood ITH = immature tol hwd MTH = mature tol hwd IIH = immature intolerant hardwood MIH = mature intolerant hardwood SWD = softwood Y = young (use as prefix) S = sapling R = regenerating
Nearest stand boundary	BOUND	Smallest distance (not ranges)
Mature spruce	SPRUCE8	1 = 0 2 = <5 3 = 5-10 4 = >10 5 = 50-75 6 = 75 –100 7 = 100 +
Canopy	CANHT	
Subcanopy 1	SUBHT	
Shrub	SHHT	
Ground cover	GRHT	
Canopy cover	CANCOV	
Subcanopy cover	SUBCOV	
Shrub cover	SHCOV	
Ground cover	GRCOV	
Shrub species	SHSP	
Shrub cover	SHRCOV	S1 = <0.5m

		S2 = 0.5-1m S3 = 1-1.5m S4 =1.5-2m
Herbaceous species	HERBSP	See species codes
Herbaceous cover	HERBCOV	See abundance codes
Tree species	TREESP	See species codes
DBH	DBH	
Snags species	SNAGSP	See species codes
Snag DBH	SDBH	
Snag decay class	SDECAY	See decay codes
Tree size classes	V44CM	Tress >44cm
	V10TOTAL	Trees>10cm
Shrub classes	SWDS2	Softwood shrub stems >0.5m
	HWDS2	Hardwood shrub stems >0.5m
Litter layer	LITTER	Litter coverage (%)
Litter depth	LITTER_D	Litter depth at four corners of sample plot

Appendix 2:

Site Checking Protocol for Establishing New Flying Squirrel Points- 2003

1. Proceed with caution, if any doubt about whether a road is accessible, use bike.
2. Flag (orange stripe and solid pink) all turns off major roads: include a bearing
3. Enter stand at closest distance to UTM coordinate
4. Site to be eliminated as an option if any signs of recent (within the past 25 years) selection cutting, semi-commercial or pre-commercial thinning (various sized stumps) are present.
5. If site is deemed suitable:

a) establish point tree with predetermined point number
b) run a trap-line deeper into the stand along the same bearing
c) flag out from point tree along back-bearing
d) Create an entrance flag with the point number, bearing and distance to point
e) All traps within the trap-line must be located at LEAST 75m from any change in stand type or from any hard edge

6. If site is unsuitable

a) Remove flagging tape from intersections when returning to main road
b) Cross-off UTMs (single line) and add comment about why unsuitable

ALWAYS provide written comment about the site (eg. topography, whether or not the age classification seems appropriate, habitat type, complications of directions or trap-lines etc.)

Any additional information is encouraged.