Fundy Model Forest

~Partners in Sustainability~

Report Title: Habitat Requirements of a Proposed Mixedwood Indicator Species in the Fundy Model Forest

Author: L. Ritchie[1], G. Forbes[1, 2] and M. Betts[1, 2]

Year of project: 2004-05

Principal contact information: [1]New Brunswick Cooperative Fish and Wildlife Research Unit, University of New Brunswick, P.O. Box 44555, Fredericton, NB, E3A 4E6

[2]Greater Fundy Ecosystem Research Group, University of New Brunswick, P.O. Box 44555, Fredericton, NB, E3B 6C2

Natural Resources Canada / Ressources naturelles Canada

Canada

The Fundy Model Forest…
…Partners in Sustainability

"The Fundy Model Forest (FMF) is a partnership of 38 organizations that are promoting sustainable forest management practices in the Acadian Forest region."

Atlantic Society of Fish and Wildlife Biologists
Canadian Institute of Forestry
Canadian Forest Service
City of Moncton
Conservation Council of New Brunswick
Fisheries and Oceans Canada
Indian and Northern Affairs Canada
Eel Ground First Nation
Elgin Eco Association
Environment Canada
Fawcett Lumber Company
Fundy Environmental Action Group
Fundy National Park
Greater Fundy Ecosystem Research Group
INFOR, Inc.
J.D. Irving, Limited
KC Irving Chair for Sustainable Development
Maritime College of Forest Technology
NB Department of the Environment and Local Government
NB Department of Natural Resources
NB Federation of Naturalists
New Brunswick Federation of Woodlot Owners
NB Premier's Round Table on the Environment & Economy
New Brunswick School District 2
New Brunswick School District 6
Nova Forest Alliance
Petitcodiac Sportsman's Club
Red Bank First Nation
Remsoft Inc.
Southern New Brunswick Wood Cooperative Limited
Sussex and District Chamber of Commerce
Sussex Fish and Game Association
Town of Sussex
Université de Moncton
University of NB, Fredericton - Faculty of Forestry
University of NB - Saint John Campus
Village of Petitcodiac
Washademoak Environmentalists

Natural Resources Canada　Ressources naturelles Canada

Canada

Fundy Model Forest Report

HABITAT REQUIREMENTS OF A PROPOSED MIXEDWOOD INDICATOR SPECIES IN THE FUNDY MODEL FOREST

Presented by:

L. Ritchie[1], G. Forbes[1, 2] and M. Betts[1, 2]
[1]New Brunswick Fish and Wildlife Cooperative Unit
[2]Greater Fundy Ecosystem Research Group
E-mail contact: forbes@unb.ca

March 31, 2005

Fundy Model Forest Report
HABITAT REQUIREMENTS OF A PROPOSED MIXEDWOOD INDICATOR SPECIES IN THE FUNDY MODEL FOREST

L. Ritchie[1], G. Forbes[1, 2] and M. Betts[1, 2]

[1]New Brunswick Cooperative Fish and Wildlife Research Unit, University of New Brunswick, P.O. Box 44555, Fredericton, NB, E3A 4E6.
[2]Greater Fundy Ecosystem Research Group, University of New Brunswick, P.O. Box 44555, Fredericton, NB, E3B 6C2.

Executive Summary

The northern flying squirrel has been proposed as an old forest management indicator species. Our study objectives were: 1) to determine the stand level and landscape-level habitat associations of the northern flying squirrel and 2) to assess the use of Geographic Information System (GIS) data for predicting flying squirrel occurrences in the Fundy Model Forest, southern New Brunswick, Canada. A total of 355 study locations were trapped over a three-year study period across a ~15,000km^2 area. Animals were tagged and their weight, sex and reproductive status was recorded. Vegetation composition (species) and structure (forest strata height and cover, tree and snag diameter at breast height, coarse woody debris abundance) were sampled along each trapline. In a model including only the GIS data available to managers, the likelihood of flying squirrel occurrence increased with increasing amounts of old (L1ds=M or O) forest cover and increasing slope of the terrain. The amount of old cover within 2.6 ha explained the most deviance (13.43%). At a local scale, an additional 4.46% of the deviance was explained by the slope of the terrain. The amount of overmature forest cover within the surrounding landscape (radius = 1000m) explained 9.19% of the deviance while controlling for stand level variables. The overall predictive logistic regression model explained ~27% of the deviance. No stand composition parameters remained in the GIS generated model, however preliminary analyses of field sampled vegetation plots suggests northern flying squirrels are associated with large (>20cm dbh) deciduous snags and coniferous trees. The resolution of GIS data may too coarse to assess northern flying squirrels response to within and between stand heterogeneity.

Introduction

Existing knowledge of northern flying squirrel habitat use- Stand Level

The majority of northern flying squirrel (*Glaucomys sabrinus*) research has been conducted in coniferous stands in the Pacific Northwest (i.e. Maser and Maser 1988; Rosentreter 1997; Claridge et al. 1999; Carey 2002; Ransome and Sullivan 2002; 2003). Recent research on the endangered Virginia northern flying squirrel suggests that their presence is strongly associated with the proximity of coniferous forest cover and weakly to elevation. Other topographical variables such as slope had no detectable effect (Odom et al. 2001). In their study, the topographic parameters were used as an indirect measure of forest cover type due to a lack of quantitative vegetation data. Sites were classified as conifer or non-conifer as derived from satellite imagery. The distance to coniferous forest cover was the only vegetation-related attribute assessed in this study. Two categories of mixed forest that were predicted to be at least 50% conifer were included in the conifer classification. An association with coniferous trees, in particular spruce, may relate to mobility. Gerrow (1996) reports witnessing flying squirrels slipping while climbing young deciduous trees with smooth bark. Northern flying squirrels are more likely to land on red spruce or red spruce snags than hardwood species, even when hardwood species occur more frequently in the stand (Vernes 2001).

However, northern flying squirrels may use hardwood-dominated areas as well (1978). Wild captured northern flying squirrels showed no side preference when released in a large cage with *Picea* species on one side and deciduous trees (i.e. *Liquidambar styraciflua*) on the other.

Flying squirrels in mixedwood stands may benefit from increased dietary diversity. Originally research on Northern flying squirrel food habits suggested the species was strictly mycophagous with a diet composed almost exclusively of hypogeous fungi, and arboreal lichens being consumed in the winter. More recent research from the Pacific Northwest suggests that nutrients acquired from non-fungal food items may be more important than previously suspected, composing up to 30% of fecal pellets. The relative consumption of non-fungal food items may be under-estimated during dietary analysis due to differing digestibility. In addition to fungi, northern flying squirrels have been witnessed consuming seeds from *Acer* species, berries, leaf buds and catkins both within the Pacific Northwest and eastern Canada. The northern flying squirrel's macophageous diet may be largely due the prevalence and ease of locating the fungi. However, fungi having low nutritional value and dietary complementation with highly nutritious, non-fungal material may be more important than previously reported.

In eastern North America, northern flying squirrels may be more closely associated with mixedwood forest characteristics than in the Pacific Northwest. Research in the southern Appalachians by Payne et al. (1989) suggests that two endangered subspecies of the northern flying squirrel were associated with mixed red spruce (*Picea rubens*) and yellow birch (*Betula lutea*) or Fraser's balsam fir (*Abies fraseri*) and American beech (*Fagus grandifolia*) stands. These proposed Pleistocene relict populations inhabit high elevation mixed red spruce (*Picea rubens*)-northern hardwood forest patches(Wells-Gosling and Heaney 1984).

The northern flying squirrel has been reported as being closely associated with old-growth forests (Carey 1989). This may be due more overlap between smaller flying squirrel foraging areas relative to those in managed stands. However, the old-growth forest dependency of northern flying squirrels is not universally supported. Ransome and Sullivan (2003) found no difference in northern flying squirrel movement patterns, population density, juvenile recruitment, mass of males, survival, percentage of the population breeding and the amount of time spent in two old-growth and two mature second-growth coniferous study locations in British Columbia. Witt (1992) reports no significant difference between the population density estimates in old-growth and mature second growth forests in western Oregon (second-growth: 0.12 squirrels/ha; old-growth: 0.85 squirrels/ha). Based on similar home range sizes, movement patterns and densities, Martin and Anthony (1999) suggest northern flying squirrels are not old-growth specialists in western Oregon.

A summary of recent research on the northern flying squirrel suggests that, while flying squirrels may not be old-growth dependent, they are likely associated with mature forests and stand legacies. Northern flying squirrels populations are expected to respond to intensive stand manipulation.

Carey et al. (1999b) report that the presence of flying squirrels is related to the presence of coarse woody debris and snags (decadence) and complex canopy structure. It was also proposed that flying squirrel populations might be limited by den availability (Carey et al. 1997). However, Carey (2002) experimentally increased the number of nest sites by providing supplementary nest boxes. The proportion of breeding female flying squirrels did not increase, suggesting dens were not the primary factor limiting flying squirrels in the second-growth Douglas-fir study site.

Although the truffle biomass may not differ between thinned and unaltered old-growth stands, the dominant genera and diversity of truffles available in and found in northern flying squirrel fecal samples is greater in old-growth stands (Carey et al. 2002). A previous study (Carey et al. 1999a) showed that fungal dietary richness was correlated with decadence and canopy stratification. In this study the most abundantly consumed fungal taxa were associated with coarse woody debris.

Relatively little is known about northern flying squirrel habitat associations in northeastern North America and the species response to landscape context has been unstudied to date. Due to the unique composition of the Acadian forest type, the stand associations reported from the Pacific Northwest may not apply. Flying squirrels in southern New Brunswick may select older forest characteristics (Gerrow 1996). Nest trees and snags used were significantly larger than those available within the nearby surroundings. Furthermore, high use areas had larger trees, larger snags, lower tree density, greater structural diversity and higher decadence relative to low use areas.

Landscape Level

The New Brunswick Department of Natural Resources and Energy has identified the northern flying squirrel as a species that could be used as an indicator of old mixedwood forest conditions. The northern flying squirrel has been proposed as a potential tool in setting objectives for stand structural content, amount of mixedwood forest cover and size of mixedwood patches.

Developing science-based habitat forest associations for the northern flying squirrel allows greater confidence in their use as a mixedwood indicator species in Crown land management. The current research is a step towards developing greater knowledge and understanding of ecosystem integrity and the possible stand and landscape-level impacts of forestry on a proposed sensitive mixedwood indicator species. It also provides a scientific basis for the establishment of the northern flying squirrel as a mixedwood indicator species in the 2007 Crown Land management objectives. Before being able to mitigate any possible effects of forest fragmentation, it is essential to first know the species-specific effects of the process, particularly for proposed indicator species.

Relevance to Management

Anthropological landscape alterations such as timber harvesting may influence the distribution of northern flying squirrel populations (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 avoid large open areas during homing behaviour, travelling farther distances under forest cover (Bourgeois 1997).

In addition to its potential as a mixedwood indicator species, the northern flying squirrel plays an important ecological role as a disperser of hypogeous ectomycorrhizal spores (Vernes et al. 2004). Ectomycorrhizal fungi have an obligate symbiotic relationship with trees in the families Pinaceae, Fagaceae and Myrtaceae (Kendrick 1992). These families dominate the mixed Acadian boreal forests of southern New Brunswick. This symbiotic relationship is advantageous to the trees and fungi (Molina and Amaranthus 1990; Rayner 1998; Zangaro et al. 2000; Zangaro et al. 2000). The fungi utilize energy derived from the photosynthates of the host plant. In return, ectomycorrhizal fungi benefit forest ecosystems by increasing the functional surface area of host tree roots, allowing greater nutrient and water extraction from the soil (Molina and Amaranthus 1990; Kendrick 1992). Hypogeous fungi fruit below ground and therefore require a dispersal vector. As mycophagous mammals, flying squirrels are dispersers of hypogeous ectomycorrhizal fungi (Currah et al. 2000; Caldwell 2001; Vernes et al. 2004). Furthermore, the faecal pellets of flying squirrels are potentially a source of a tree root inoculum, increasing fungal colonization (Caldwell 2001). Ectomycorrhizal fungi may increase the growth, development and survival of trees (Molina and Amaranthus 1990).

Project Objectives

The primary objective of our project was to determine the aspatial (stand composition and structure) and spatial (landscape composition and configuration) associations of the Northern flying squirrel in order to assess its use as an indicator species during forest management planning by the Department of Natural Resources and Energy.

Methods

During the study period (2001-2004) a total of 355 study locations were trapped within a ca. 15000km^2 study area in and around the Fundy Model Forest. The study design involved trapping across a continuum of landscape composition and configuration in both managed and unmanaged regions.

Tomahawk (Model 102) and Havahart (Model 1025) live-traps baited with apple and peanut butter were tied to trees at chest height following a successful protocol previously used within in the study area. Traps were set for four consecutive nights at each site along a 60m "point transect" or a 360m trapline with two parallel transects separated by 40m. Each trapping point consisted of 4 traps separated by 20m. Trapline transects consisted of 12 or 13 traps spaced at 30m for a total of 25 traps per site. The traps were wrapped with rain-resistant cartons to protect captured animals from adverse weather conditions. Traps were checked each morning. Animals were ear-tagged with 1g Monel aluminum tags and weighed with a Petzl spring-loaded scale. The animal was released at the point of capture after the recording of the species, sex, weight, and reproductive status.

Vegetation data for many of the study sites had been previously collected at sites in collaboration with M. Betts and K. Vernes. In 2004, three vegetation plots were sampled at each new study site. Measured stand characteristics were similar to those previously collected and included: 1) the height and cover provided by the local forest strata; 2) the species, size and state of decay of trees, snags and coarse woody debris.

Generation of Geographic Information System (GIS) Metrics

We developed a northern flying squirrel stand level model using data available to managers in the New Brunswick Stand Inventory. Analysis of New Brunswick Stand Inventory data using a Geographic Information System such as ArcView increases the ability of managers to make more expedient management decisions, but reduces the likelihood of detecting wildlife responses to their surrounding environment. In light of this, the flying squirrel stand and landscape forest association model presented was developed using an α-level of 0.1. The metrics of interest for Northern flying squirrel biology included stand type, age and structure and topographical variables (Table 1).

Table 1. Geographic Information Systems metrics used to derive stand level model.

Variable Type	item	Metric Description
Stand Type (%SW,HW and MWD, PL surrounding trapping location - see text)	L1funa	Softwood (SW) = BFSP,PINE, CMSW, SPBF, OTSW (Treatment = PL excluded) Hardwood (HW) = CMHW, IHHW, IHTH, THIH, TOHW, INHW, RGHW) Mixedwood(MWD) =BFIH, IHBF, IHSP, SPIH, CMHS, CMSH, RGHS, RGSH, BFTH, SPTH, THBF, THSP Plantations (PL) = treatment recorded as “PL”
Development Stage (%ES, I, M, OM, and OLD cover surrounding site - see text)	L1ds	Early Succession (ES) = C, S, R, Y Immature (I) = I Mature (M) = M Over-Mature (OM) = OM Old (OLD) = M, OM
Stand Structure (ordinal categorical variables)	L1cc L1vs L1dc L1sc	L1cc (cc) =Crown closure L1vs (vs) = Number of canopy layers L1dc (dc) = Density of commercial stems L1sc (sc) = Dbh (cm) for merchantable; Height (m) if unmerchantable)
Topography	Contours	Elevation at trap location(m) Slope of terrain (degrees)
Distance to Stream	IS, PS	Distance (in m) to Intermittent Stream (IS) Distance (in m) to Permanent Stream (PS)

We calculated stand type and development stage metrics 91m (neighbourhood scale), 180m (trapline scale), 500m (preliminary scale of response) and 1km (dispersal scale) radii from each trapping location. We generated GIS metrics by rasterizing the relevant forest coverages and using neighbourhood statistics using ArcView 3.3 Spatial Analyst. Stand structure variables were coded as ordinal categorical variables prior to analysis. We generated a stand model using logistic regression following a stepwise forward selection and backwards elimination procedure with an entrance decision making rule of p=0.20 and removal of p=0.25. We then assessed the effect of landscape-level metrics while controlling for stand level variation.

Results and Discussion

A total of 147 individual flying squirrels were caught over 17, 085 trapnights during the three-year study (n=355; Table 2). Flying squirrels were captured at 47 study locations. The capture success rate for flying squirrels varied substantially across years. Little has been published on northern flying squirrel population fluctuations, although analysis of a long-term dataset in Ontario suggests that flying squirrel populations may be cyclic (Fryxell et al. 1998). Unexplained fluctuations in flying squirrel populations and/or catchability complicate the use of this species as an indicator or monitoring species.

Table 2. Summary of flying squirrel capture rates during study period by year. FLSQ/cTN is the number of flying squirrels caught per site after adjusting for the diurnal capture of red squirrels and trap closures.

Year	Average Capture Rate (FLSQ/cTN) from full data set
2001	3.06 ± 5.12
2003	0.61 ± 2.18
2004	0.07 ± 0.27

We trapped flying squirrels across a range of stand development stages and stand types (Table 3). Trapping effort was focused within old (mature and overmature) forest stands to increase the likelihood of flying squirrel capture success.

Table 3. Breakdown of trapped sites according to stand development stage and stand type classification.

Stand development stage classification	Number of Stands Trapped
Early Successional Development Stage	27
Immature	86
Mature	213
Overmature	29
Stand type classification	
Softwood	74
Hardwood	156
Mixedwood	114
Plantations	8
Unclassified in GIS	3
Total Number of Sites	355

The predictive model (Figure 1) for a subset of the trapping data suggests flying squirrel occurrence is associated with: 1- the amount (%) of old forest cover within their foraging neighbourhood (defined as a 2.6ha area according to Gerrow 1996), 2- the slope of the terrain, and 3- the amount of overmature forest cover within 1km from the point. The resulting model explained 27.2% of the deviance in the data.

$$p(\text{flying squirrel occurrence}) = \frac{e^{0.018\,(OLD) + 0.164\,(slope) + 0.105(Overmature\_1km) - 4.116}}{1 + e^{0.018\,(OLD) + 0.164\,(slope) + 0.105(Overmature\_1km) - 4.116}}$$

Figure 1. Logistic regression model predicting the probability of flying squirrel occurrence using data available in the New Brunswick Stand Inventory database. Model selection was based on stepwise logistic regression using forward selection and backwards elimination.

At the stand level, the amount of old forest cover surrounding trapping location explained the most variance in the data (13.43%, Table 4). A topographic variable (the slope of the terrain) explained ~4.46% of the model deviance. After controlling for local stand variables, the amount of overmature forest within the surrounding landscape (at a radius of 1km) explained an additional ~9% of the deviance.

Table 4. Variables, deviance explained and regression coefficients for the final logistic regression model.

Variable	Coefficient	Std. Error	% Explained Deviance	Wald Statistic
Intercept	-2.918	0.905	-	-
% old stand cover within neighbourhood (r = 91m)	0.018	0.008	13.44	0.002
Slope (degrees)	0.164	0.073	4.46	0.025
% overmature forest cover within landscape (r = 1000m)	0.105	0.047	9.19	0.025

The association of flying squirrel with the amount of old (mature and overmature) stands at a local scale is consistent with work conducted in the Pacific Northwest which suggests that, although northern flying squirrels may not be old-growth dependent-species, their densities are greater in older forests (Figure 2).

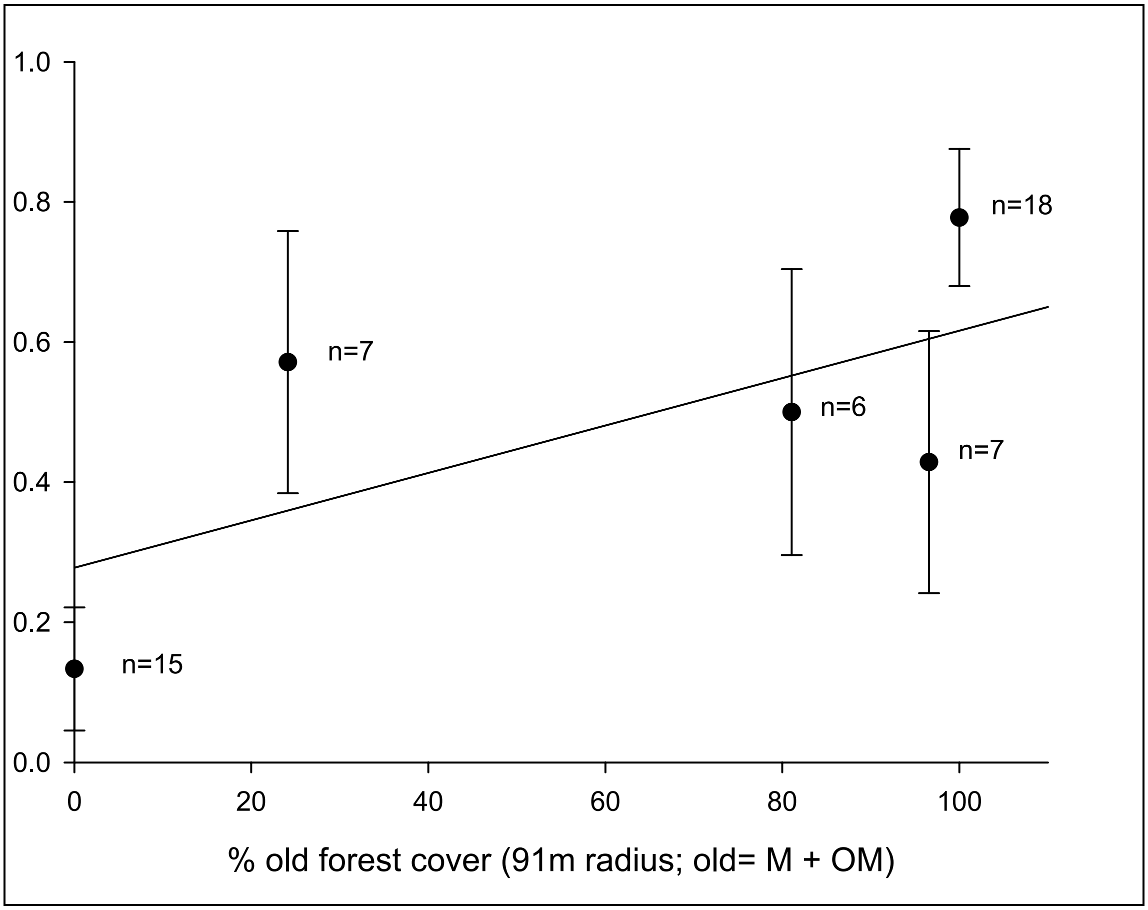


Figure 2. Probability of capturing a flying squirrel along a gradient of % old forest cover surrounding the point. A radius of 91m was used to assess an area of 2.6ha (estimated core area of southern New Brunswick flying squirrels) surrounding each trapping location. The amount of old forest explained 13.44% of the deviance (p=0.002; Map: p12).

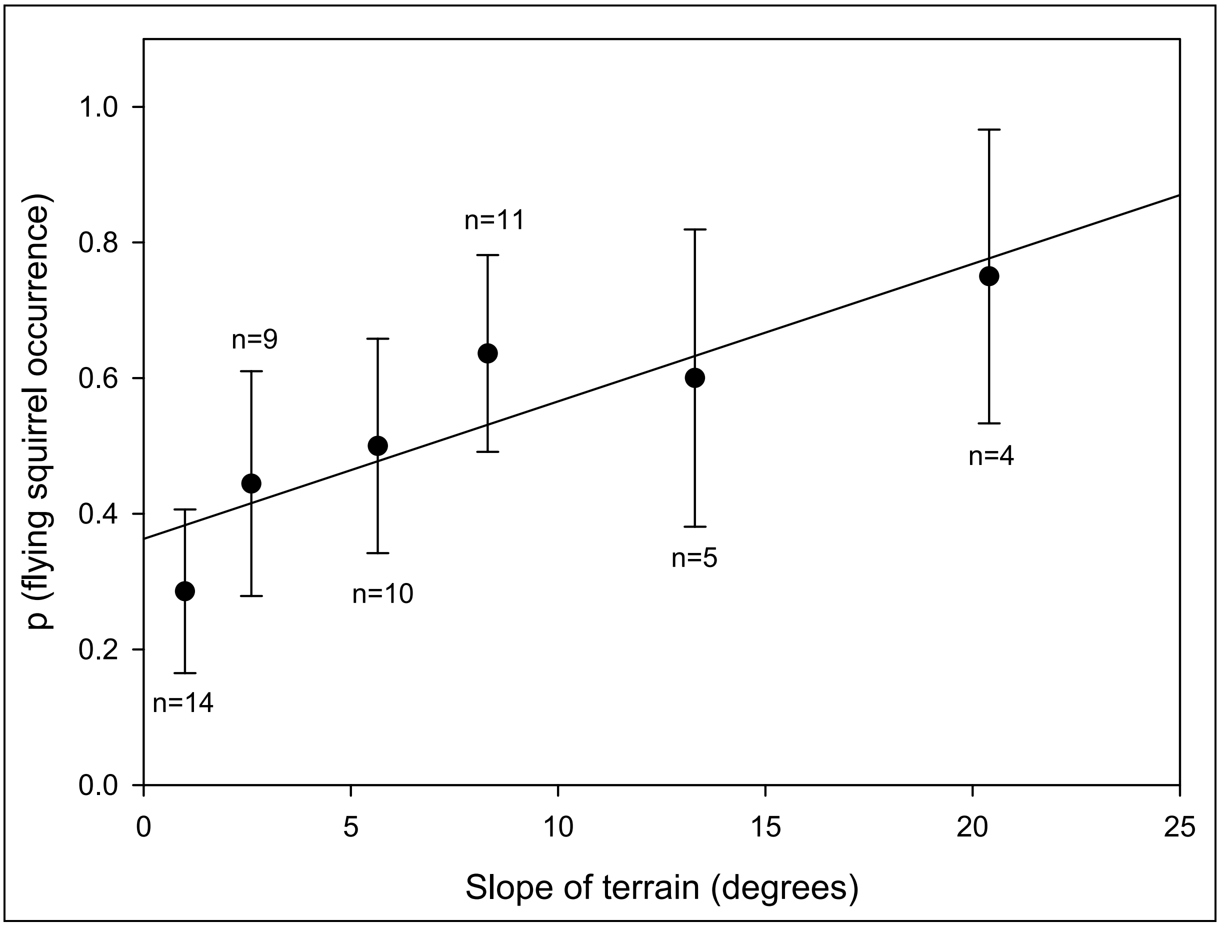


Figure 3. Probability of capturing a flying squirrel relative to the slope of the terrain. Slope explained 4.46% of the deviance (p=0.025; Map p13).

Unlike research done on the endangered Virginia Northern flying squirrel, our model suggests that flying squirrel presence is associated with the slope of the terrain (Odom et al. 2001, here Figures 4 and 5). In the previously mentioned research, flying squirrels were strongly associated with the amount of softwood forest in the surrounding landscape and topographic parameters were used as an indirect measure of forest cover type due to a lack of quantitative vegetation data. In our data set, slope was not strongly correlated with the amount of a particular cover type surrounding the trapping site at 90m or 1km. Flying squirrels may be able to move and therefore forage more efficiently on sloped terrain (Vernes 2001). An alternative explanation is that the resolution of the GIS data does not permit the detection of a relationship between slope and stand type.

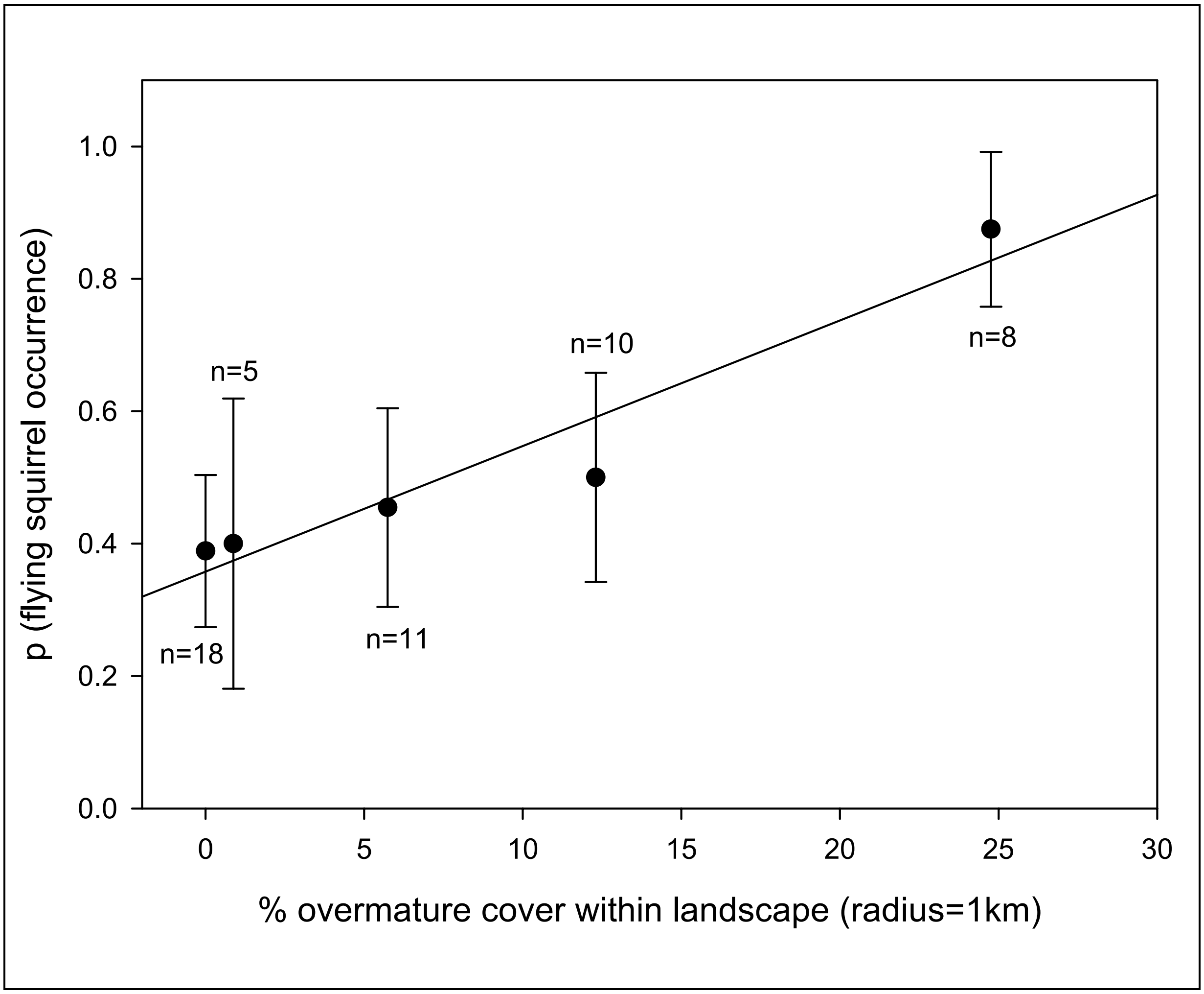
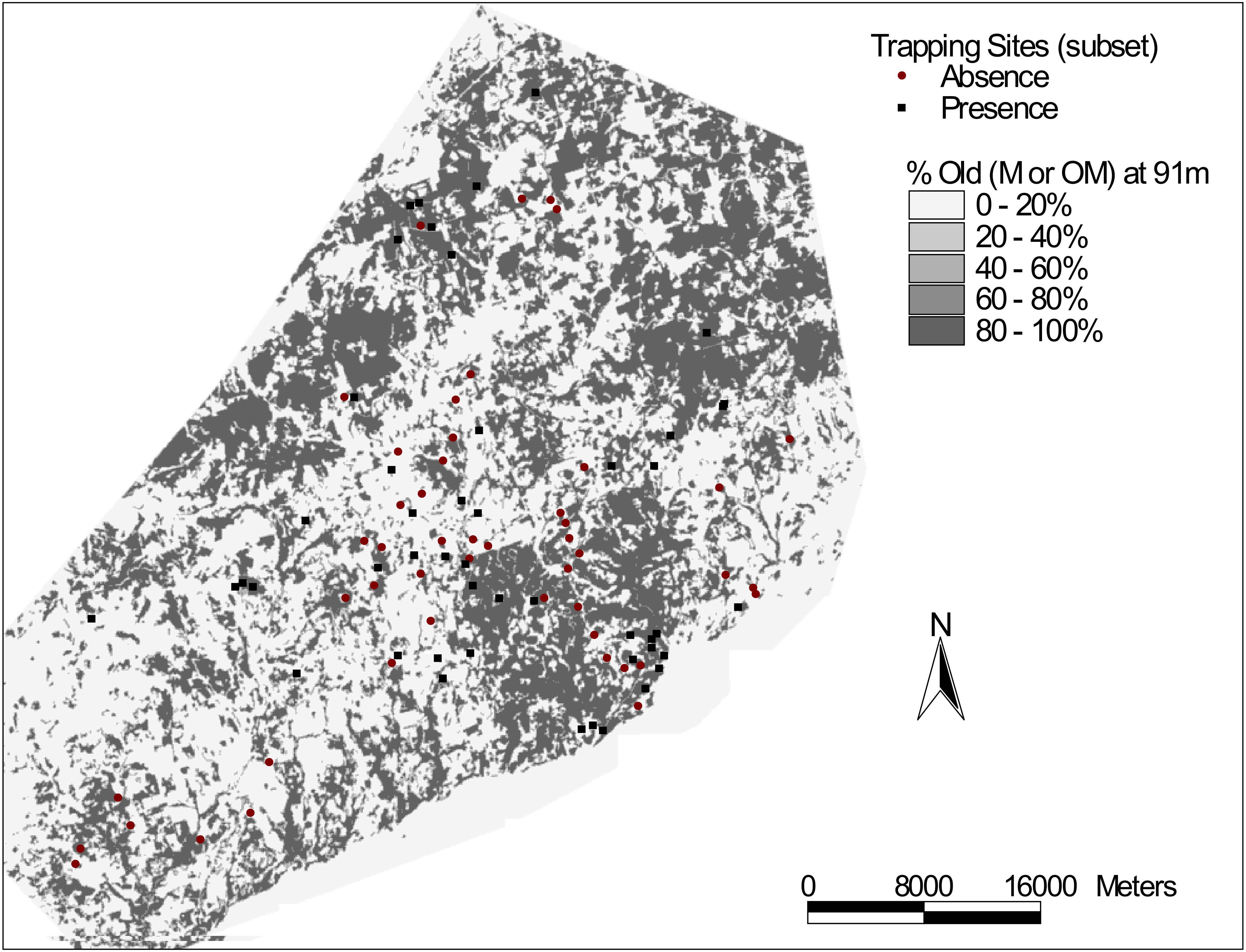
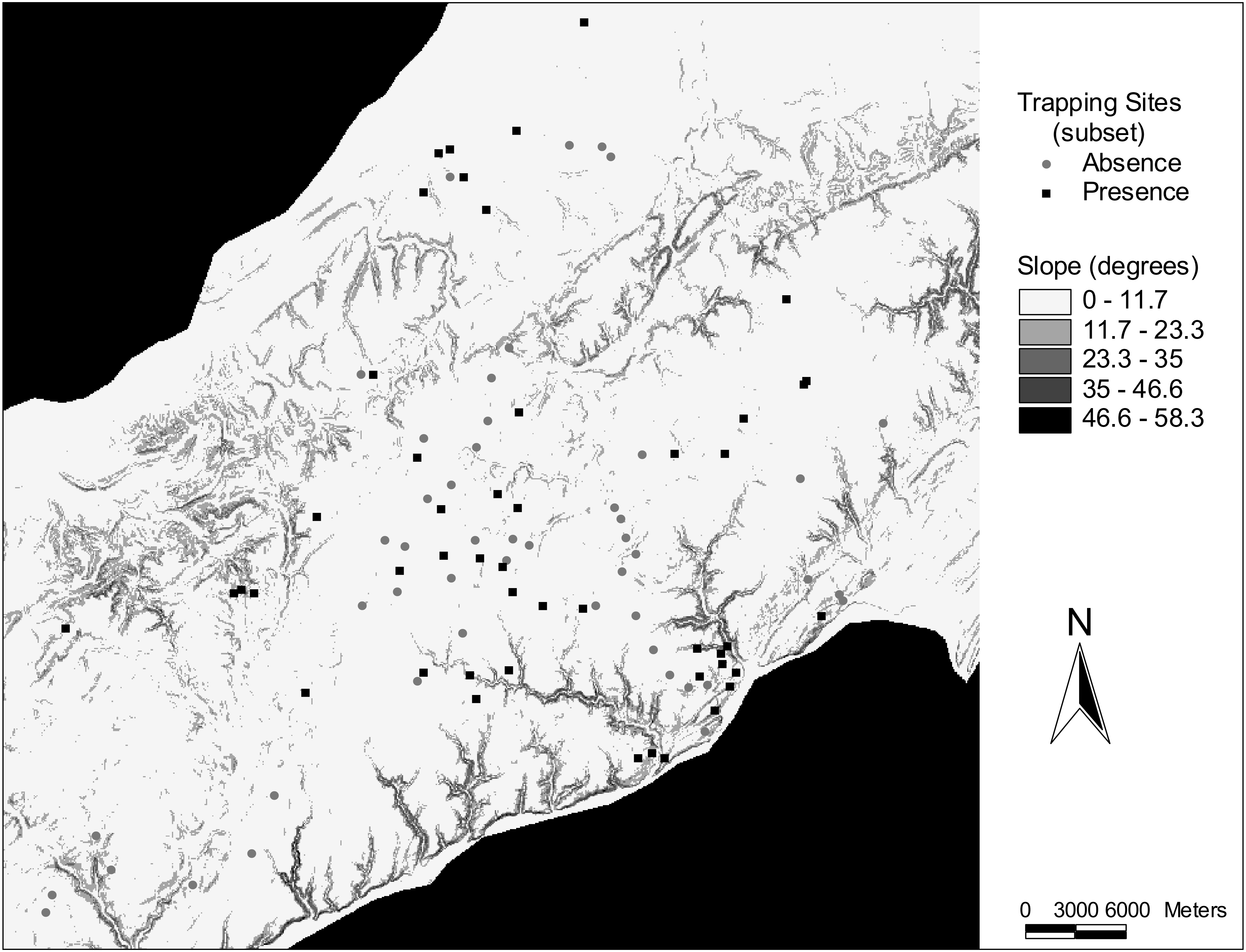
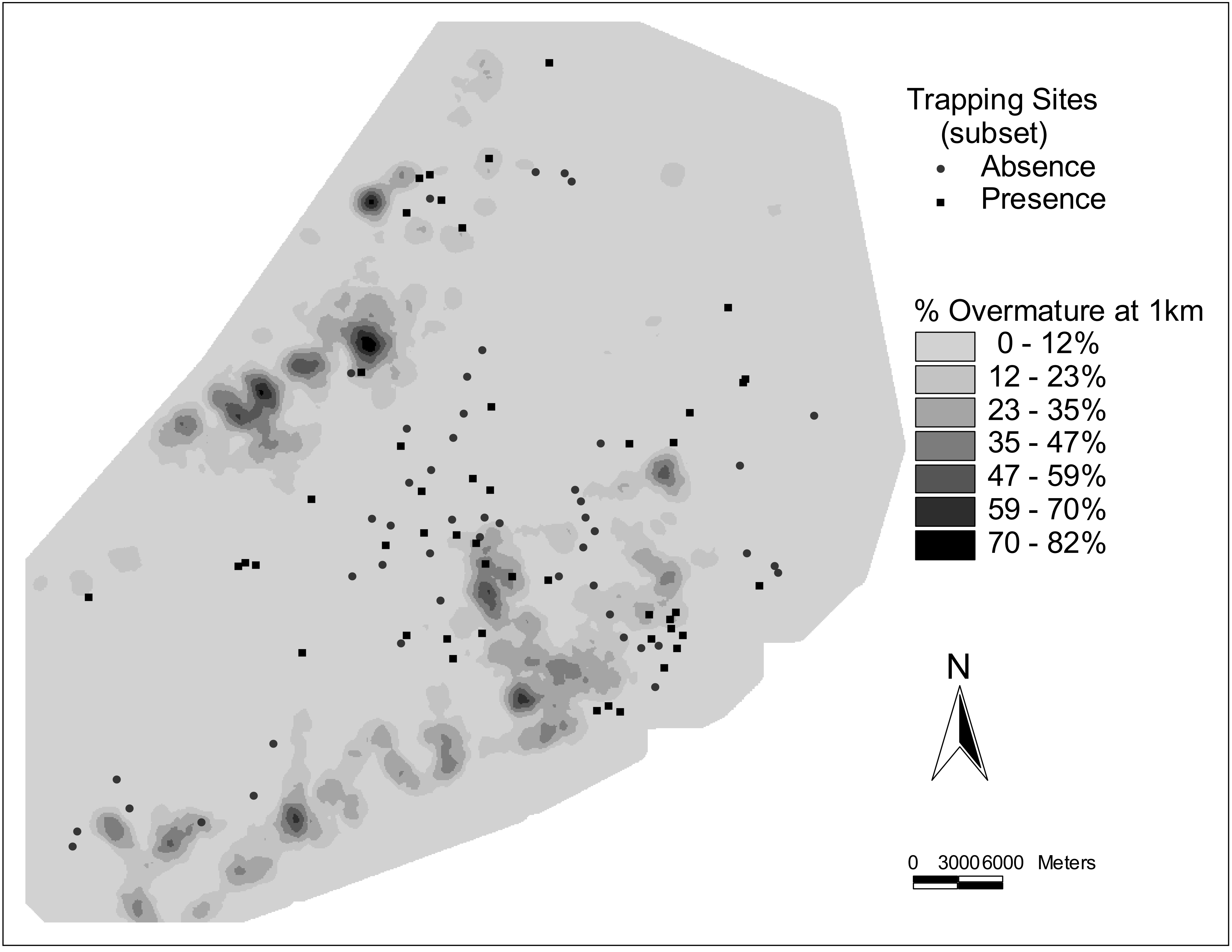


Figure 4. Probability of capturing a flying squirrel relative to the amount of over mature forest cover in the landscape (radius = 1000m). The amount of overmature forest cover explained 9.19% of the deviance (p=0.025; Map p14).

The amount of overmature forest cover within the surrounding landscape (radius = 1000m) explained an additional 9.19% of the deviance while controlling for stand level variables. The estimated coefficient and deviance explained by the amount of overmature forest cover within the landscape suggests an important association, although there is a substantial amount of variability in the data.


Trapping Sites (subset)
Absence
Presence
% Old (M or OM) at 91m
0 - 20%
20 - 40%
40 - 60%
60 - 80%
80 - 100%
N
0
8000
16000
Meters


Trapping Sites (subset)
Absence
Presence
Slope (degrees)
0 - 11.7
11.7 - 23.3
23.3 - 35
35 - 46.6
46.6 - 58.3
N
0 3000 6000 Meters



Trapping Sites
(subset)
Absence
Presence
% Overmature at 1km
0 - 12%
12 - 23%
23 - 35%
35 - 47%
47 - 59%
59 - 70%
70 - 82%
N
0
3000
6000
Meters

Conclusions

The GIS model of northern flying squirrel occurrence within the Fundy Model Forest suggests they are associated with old forest stands, large structural attributes and sloping terrain. The final GIS stand and landscape model model lacks an association of flying squirrels with any form of cover type. This is likely due to the coarseness of the GIS data used to generate the model. Within stand vegetation gathered at the immediate trapping location suggests that flying squirrels are associated with the interaction of large hardwood and softwood structures (trees and snags > 20cm dbh). This more fine scale data also better represents the natural heterogeneity between stands of different cover types classification and within stands of the same cover type. There is likely a risk of using remote sensing data to evaluate wildlife associations, as the power to detect habitat associations is reduced by the coarseness of the available data.

Acknowledgements

This work could not have been completed without the help of numerous people. Financial support was provided by Fundy Model Forest, NSERC, Wildlife Trust Fund, the University of New Brunswick and Fundy National Park. Additional equipment, feedback and logistical support were provided by Dr. Karl Vernes, Jane Watts, Renee Wissink, Fundy National Park staff, DNRE, Irving, Dr. Søren Bondrup-Nielsen and Dr. Dan Keppie. Fieldwork was a team effort by a dedicated crew including Adrian Young, Tiffany Thornhill, Seamus Watters, Beau Sutherland, Ryan McIntyre, Shamim Shakibaei. Additional help was given by Brad Zitske, Adam Hadley, Jon Cormier, Kathleen Pistak, Alex Frank, Erin Whidden and Corey Clarke.

Reference List

Bourgeois,M.C. 1997. An examination of two unconventional methods to assess resource use by two New Brunswick forest mammals: the marten and the northern flying squirrel. MS Acadia University.

Caldwell,I. 2001. The role of the northern flying squirrel in the inoculation of red spruce seedlings with hypogeous ectomycorrhizal fungi. BSc Mount Allison University.

Carey,A.B. 1989. Wildlife associated with old-growth forests in the Pacific Northwest. Natural Areas Journal **9:** 151-162.

Carey,A.B., Kershner,J., and de Toledo,L.D. 1999a. Ecological scale and forest development: Squirrels, dietary fungi and vascular plants in managed and unmanaged forests. Wildlife Monographs **142:** 1-71.

Carey,A.B. 2000. Effects of new forest management strategies on squirrel populations. Ecological Applications **10:** 248-257.

Carey,A.B. 2002. Response of northern flying squirrels to supplementary dens. Wildlife Society Bulletin **30:** 547-556.

Carey,A.B., Colgan,W., III, Trappe,J.M., and Molina,R. 2002. Effects of forest management on truffle abundance and squirrel diets. Northwest Science **76:** 148-157.

Carey,A.B., Kershner,J., Biswell,B., and Dominguez-De-Toledo,L. 1999b. Ecological scale and forest development: Squirrels, dietary fungi, and vascular plants in managed and unmanaged forests. Wildlife Monographs **0:** 1-71.

Carey,A.B., Wilson,T.M., Maguire,C.C., and Biswell,B.L. 1997. Dens of northern flying squirrels in the Pacific Northwest. Journal of Wildlife Management **6:** 684-699.

Claridge,A.W., Trappe,J.M., Cork,S.J., and Claridge,D.L. 1999. Mycophagy by small mammals in the coniferous forests of North America: Nutritional value of sporocarps of Rhizopogon vinicolor, a common hypogeous fungus. Journal of Comparative Physiology B Biochemical Systemic and Environmental Physiology **169:** 172-178.

Currah,R.S., Smreciu,E.A., Lehesvirta,T., Niemi,M., and Larsen,K.W. 2000. Fungi in the winter diets of northern flying squirrels and red squirrels in the boreal mixedwood forest of northeastern Alberta. Canadian Journal of Botany-Revue Canadienne de Botanique **78:** 1514-1520.

Fryxell,J.M., Falls,J.B., Falls,E.A., and Brooks,R.J. 1998. Long-term dynamics of small-mammal populations in Ontario. Ecology **79:** 213-225.

Gerrow,J.S. 1996. Home range, habitat use, nesting ecology and diet of the Northern flying squirrel in southern New Brunswick. MSc. Acadia University.

Kendrick,B. 1992. The Fifth Kingdom. Mycologue Publications, Waterloo.

Martin,K.J. and Anthony,R.G. 1999. Movements of northern flying squirrels in different-aged forest stands of western Oregon. Journal of Wildlife Management **63:** 291-297.

Maser,C. and Maser,Z. 1988. Interactions among squirrels, mycorrhizal fungi and coniferous forests in Oregon, USA. Great Basin Naturalist **48:** 358-369.

Molina,R. and Amaranthus,M. 1990. Rhizosphere biology: ecological linkages between soil processes, plant growth, and community dynamics. Symposium on Management and Productivity of Western Montane Forest Soils 51-57.

Mönkkönen,M., Reunanen,P., Nikula,A., Inkeröinen,J., and Forsman,J. 1997. Landscape characteristics associated with the occurrence of the flying squirrel *Pteromys volans* in old-growth forests of northern Finland. Ecography **20:** 634-642.

Odom,R.H., Ford,W.M., Edwards,J.W., Stihler,C.W., and Menzel,J.M. 2001. Developing a habitat model for the endangered Virginia northern flying squirrel (*Glaucomys sabrinus fuscus*) in the Allegheny Mountains of West Virginia. Biological Conservation **99:** 245-252.

Payne,J.L., Young,D.R., and Pagels,J.F. 1989. Plant community characteristics associated with the endangered northern flying squirrel Glaucomys sabrinus in the southern Appalachians USA. American Midland Naturalist **121:** 285-292.

Ransome,D.B. and Sullivan,T.P. 2002. Short-term population dynamics of Glaucomys sabrinus and Tamiasciurus douglasii in commercially thinned and unthinned stands of coastal coniferous forest. Canadian Journal of Forest Research **32:** 2043-2050.

Ransome,D.B. and Sullivan,T.P. 2003. Population dynamics of Glaucomys sabrinus and Tamiasciurus douglasii in old-growth and second-growth stands of coastal coniferous forest. Canadian Journal of Forest Research **33:** 587-596.

Rayner,A.D.M. 1998. Fountains of the forest: the interconnectedness between trees and fungi. Mycological Research **102:** 1441-1449.

Rosentreter,R. 1997. Northern flying squirrel seasonal food habits in the interior conifer forests of Central Idaho, USA. Northwest Science **71:** 97-102.

Taulman,J.F., Smith,K.G., and Thill,R.E. 1998. Demographic and behavioral responses of southern flying squirrels to experimental logging in Arkansas. Ecological Applications **8:** 1144-1155.

Vernes,K., Blois,S., and Bärlocker,F. 2004. Seasonal and yearly changes in consumption of hypogeous fungi by northern flying squirrels and red squirrels in old-growth forest, New Brunswick. Canadian Journal of Zoology **82:** 110-117.

Vernes,K. 2001. Gliding performance of the northern flying squirrel (*Glaucomys sabrinus*) in mature mixed forest of eastern Canada. Journal of Mammalogy **82:** 1026-1033.

Waters,J.R. and Zabel,C.J. 1995. Northern flying squirrel densities in fir forests of northeastern California. Journal of Wildlife Management **59:** 858-866.

Weigl,P.D. 1978. Resource overlay, interspecific interactions and the distribution of the flying squirrels, *Glaucomys volans* and *G. sabrinus*. American Midland Naturalist **100:** 83-96.

Wells-Gosling,N. and Heaney,L.R. 1984. *Glaucomys sabrinus*. Mammalian Species **229:** 1-8.

Witt,J.W. 1992. Home range and density estimates for the northern flying squirrel, *Glaucomys sabrinus*, in western Oregon. Journal of Mammalogy **73:** 921-929.

Zangaro,W., Bononi,V.L.R., and Trufen,S.B. 2000. Mycorrhizal dependency, inoculum potential and habitat preference of native woody species in South Brazil. Journal of Tropical Ecology **16:** 603-622.