SUSTAINABLE
FOREST
MANAGEMENT
NETWORK

RÉSEAU
DE
GESTION DURABLE
DES FORÊTS

PROJECT REPORTS
2003/2004

Population ecology of marten (*Martes americana)* in the boreal forests of northern Ontario

John Fryxell, Ian Thompson, Tom Nudds, and Jim Baker

February 2004

Related SFM Network Project:
fryxelljpopu6
Population ecology of marten (Martes americana) in the boreal forests of northern Ontario

A NETWORK OF CENTRES OF EXCELLENCE
UN RÉSEAU DE CENTRES D'EXCELLENCE

POPULATION ECOLOGY OF MARTEN (*Martes americana*) IN THE BOREAL FORESTS OF NORTHERN ONTARIO

NSERC/CFS Partnership Program, Forest Ecosystem Science Co-operative Inc., and Sustainable Forestry Management Network/NCE

John Fryxell, Department of Zoology, University of Guelph, Guelph, Ont, N1G 2W1
Ian Thompson, Canadian Forest Service, 1219 Queen St E, Sault Ste Marie, Ont, P6A 5M7
Tom Nudds, Department of Zoology, University of Guelph, Guelph, Ont, N1G 2W1
Jim Baker, Ontario Forest Research Institute, 1235 Queen St, Sault Ste Marie, Ont, P6A 2E5

Project Report, February 2004

Keywords: marten, viability, dispersal, survival, reproduction, source, sink, succession, umbrella, indicator, old growth, landscape, diversity, birds, amphibians, owls

The American marten (*Martes americana*) is a forest carnivore species presumed to rely on patches of mature, conifer-dominated forest for its continuing persistence across a broad, heterogeneous landscape (Buskirk and Powell 1994, Thompson 1994, Thompson and Cogan 1994, Hargis et al. 1999). It has been accordingly designated as an indicator species, whose ecological requirements must be met before any forest harvesting project in Ontario can be approved, as stipulated by Forest Management Guidelines set by the Ontario Ministry of Natural Resources (Watt et al. 1996). Recent scientific literature, however, reports anecdotal and experimental evidence that martens may be able to sustain themselves in regenerating forests with sufficient suitable structure (Thompson et al. 1989, Bowman and Robitaille 1997, Chapin et al. 1998, Potvin et al. 2000, Payer and Harrison 2003). Despite 50 years of intense timber harvesting in Ontario, resulting in reduced availability of mature forest habitat, there has been no demonstrable decline in the numbers of marten harvested by trappers (Novak et al. 1987). These observations are inconsistent with the notion that martens require mature forest to survive and reproduce successfully, thereby challenging the ecological basis for the current Forest Management Guidelines. For the past 3 years, we have been engaged in a collaborative research programme to address the sustainability of martens in regenerating forest landscapes and to assess the utility of martens as an umbrella for other putative old growth species. This document summarizes our research progress to date.

Sustainability of marten populations

The Ontario guidelines can be recast in scientific terms as a working hypothesis that patches of mature forest are refugia, which support source populations of martens that are ecologically sustainable. Regenerating forests, on the other hand, provide sink populations of martens in which deaths exceed births. This is often termed the source-sink hypothesis (Pulliam 1988 and Pulliam and Danielson 1991, Doak and Mills 1994). A plausible alternate hypothesis is that martens have different rates of survival and reproductive success across forest habitats of different successional stage, but can sustain themselves in most forest landscapes, regardless of whether the habitats are composed of regenerating or mature forest stands. Older, socially dominant individuals presumably occupy the best habitats whereas younger, lower ranked individuals are relegated to the poorer tracts. This is often termed the ideal-despotic hypothesis (Fretwell and Lucas 1974). It is even conceivable that the demographic characteristics of marten do not vary with forest successional stage (null hypothesis). Our primary objective is to test the source-sink, ideal-despotic, and null hypotheses, with a long-term aim to further develop, or suitably alter, the Forest Management Guidelines in Ontario.

Towards the latter end, we are also engaged in ancillary studies to better understand factors and mechanisms that influence the sustainability of martens in a heterogeneous forest landscape. First, we are evaluating ecological and social correlates of home range use by individuals of different age, size, and social rank. This will allow much deeper understanding about the habitat variables that actually matter to martens in the boreal forests of Ontario. Second, we need to assess the ecological factors influencing the probability of successful dispersal by juvenile animals, because this variable could be instrumental in determining whether source-sink systems can persist over the long term. Differential reproductive success and variation in dispersal can affect genetic structure for populations in heterogeneous landscapes, which we will evaluate using DNA fingerprinting. Fur-trapping interacts with natural demographic processes in most forests in Ontario in determining marten population trajectories (Fryxell et al. 2001; Haydon and Fryxell 2004). Therefore, we are also quantifying the effect of forest disturbance on marten harvesting rates. Finally, there is theoretical potential for disruption of successful mating in widely-spaced territories in young, regenerating forests, that could have deleterious effects on long-term sustainability.

For the first phase of our programme, we selected a study area near the town of Ear Falls, in NW Ontario. The logged landscape is in the Whiskey Jack Forest managed by Abitibi Consolidated, whereas the unlogged control landscape is in the Trout Lake Forest managed by Weyerhaeuser. A variety of forest types occur in the region, varying along axes of mature versus regenerating, conifer versus mixed composition, and productive lacustrine versus less productive sandy soils and gleisols. Stand age in the unlogged natural-origin landscape is between 40-100 years, whereas the regenerating stands in the logged landscape are 20-50 years old. The study sites cover both lowland and upland sites that vary considerably in soils and annual primary productivity. Wide variability in stand characteristics is essential for the broad industrial application of our research results. Forest Resource Inventory maps for the study area originating from the industrial partners were secured by Phil Elkie of OMNR in a digital ARCView GIS database.

Our marten research team over the past 3 years has included 2 full-time field technicians (Robert Routledge and Phil Wiebe), a dozen short-term field assistants, and 4 graduate students (Michelle Herzog, Mark Andruskiw, Cheryl Johnson, and Thomas Broquet). The graduate student theses will provide a comprehensive picture of marten habitat use and population demography in boreal forest systems that are managed for commercial logging and trapping. Michelle Herzog has completed her M.Sc. thesis on ecological correlates of social dominance in martens, based on scent trials with captive animals. Mark Andruskiw has completed his M.Sc. thesis on the effect of forest structure and prey availability on spatial patterns of prey search and predation success during the winter. He has also measured prey behavioural responses to predation in open versus covered habitat and in relation to stand characteristics. For her PhD thesis, Cheryl Johnson is addressing juvenile dispersal trajectory, dispersal distance and survival during dispersal relative to habitat quality, food availability, marten population density, and landscape configurations. For his PhD thesis, Thomas Broquet is using DNA fingerprinting to test whether habitat fragmentation caused by logging or natural geographic barriers (such as lakes) influence genetic structure of martens and comparing the reproductive success of martens in logged vs unlogged areas.

Habitat characteristics

The first step in our landscape analysis was to conduct detailed forest mensuration, needed to categorize complex forest landscapes of varying stand age, recent burn history, stand composition, and ecological productivity due to variation in underlying geomorphology. We have partitioned the Ear Falls study site into 13 predominant forest types (FRI categories) using ARCVIEW GIS. During the 2001 summer field season, a wide variety of vegetation characteristics were measured in each stand type, including species composition and biomass of the canopy and shrub layer, snag abundance, canopy closure, stem density, ground cover, woody debris, and small mammal abundance. We have sampled 5 replicate stands in each of the 13 forest categories, for a total sample of 65 replicates in each of the logged and unlogged treatments. Inter-stand variation, for these variables is within normal limits for forestry applications. Forest structure data sampled at the stand level using FRI categories will be ultimately extrapolated to the complete landscape, as a means of quantifying ecological variables at the level of individual marten territories. One key difference between logged and unlogged forests is the abundance of coarse woody debris on the forest floor. Our data show a substantial difference between landscapes in the abundance of coarse woody debris (Fig. 1), which can have important impact on foraging success and prey abundance for martens.

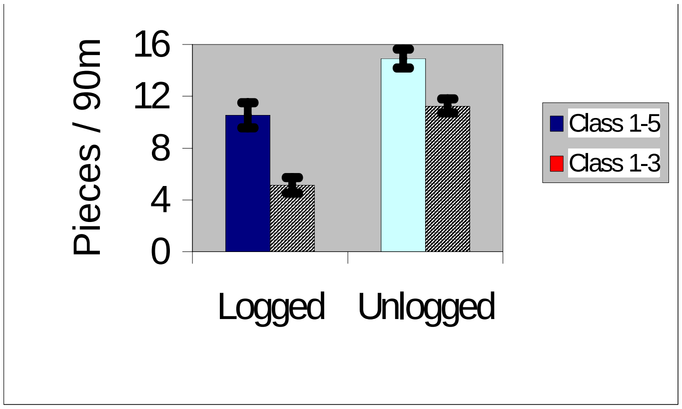


Figure 1. Abundance of coarse woody debris in logged versus unlogged landscapes.

During 2001-3, small mammals were sampled in representative forest stands over 6000 trap nights. Red-backed voles were an order of magnitude more abundant than any other species. Our trapping results suggest differences in vole abundance among stand and landscape treatments (Fig. 2). Because voles are a major component of marten diets, spatial and temporal variation in vole abundance is an obvious candidate for evaluating putative differences in fitness across habitats. Our early data show significant variation at the stand level, due to a positive association between vole abundance and deciduous composition. This suggests that conifer stands, which are often preferred marten habitat, do not necessarily supply higher abundance of prey in this region of Ontario, unlike the Manitouwadge area in central Ontario (Thompson and Colgan 1987, 1991). There is obviously substantial seasonal variation in abundance in both landscapes. Vole abundance was higher in the unlogged landscape in 2001 and 2002 than in the logged landscape, whereas both landscapes had similar vole densities during 2003.

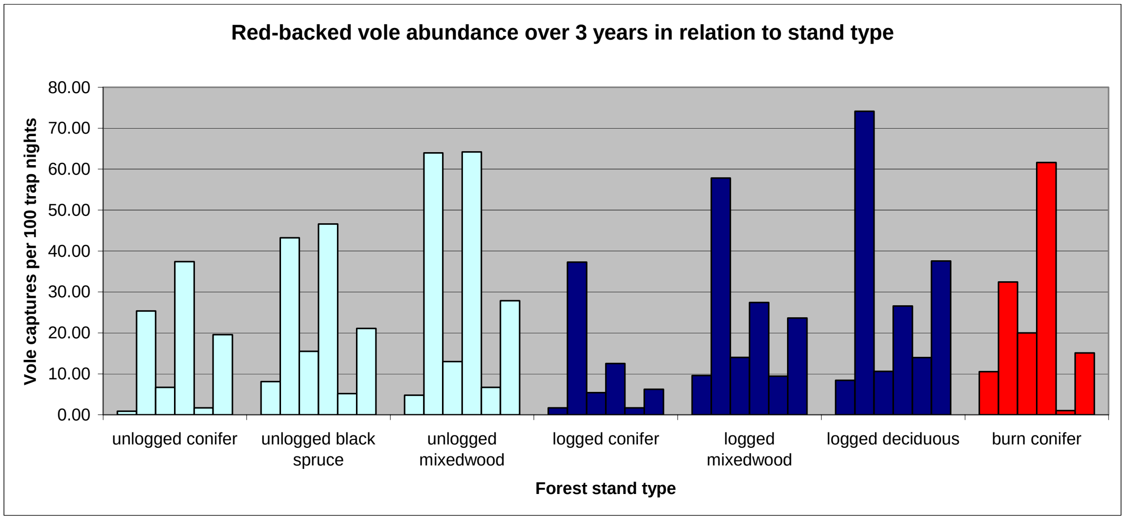


Figure 2. Red-backed vole abundance during spring and fall trapping periods in 2001-2003 in various stand types in logged versus unlogged landscapes in Ear Falls.

Marten demography

The field crew has shown considerable success in live-trapping martens. During 3210 trap nights in the fall of 2001, we captured 97 different martens. Marten density, assessed by captures of new individuals per 100 trap nights, was 33% higher in the unlogged (4.9) than the logged (3.7) landscape (Fig. 3). During the fall of 2002, we live-trapped 85 and 47 new marten (i.e. excluding recaptures) in the unlogged and logged landscapes during a total of 3172 trap nights. Marten density in the unlogged landscape was twice that in the logged landscape (6.3 versus 2.6 marten/100 trap nights, respectively). During 1229 trap nights in the fall of 2003, we captured 43 new individuals. Marten density in 2003 was similar in the two landscapes (Fig. 3), perhaps owing to similarity in prey densities (Fig. 2).

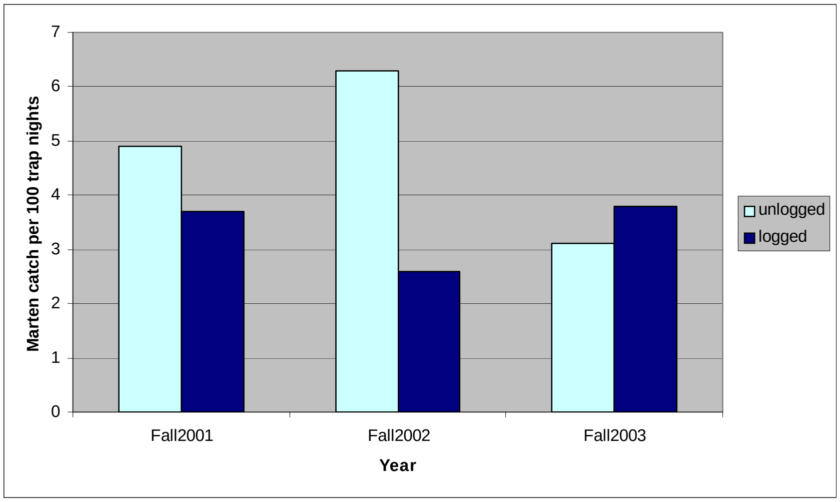


Figure 3. Catch of new martens per 100 trap nights in the logged vs unlogged landscapes.

Variation in marten density over time and space (Fig. 3) was plausibly related to variation in prey density across time and landscape treatment (Fig. 4), although the sample size is too small yet to be conclusive. Similar numerical responses to changing prey availability have been demonstrated in other marten populations (Thompson and Colgan 1987; Fryxell et al. 1999), suggesting that fluctuation in prey abundance is an important source of environmentally-driven variation in marten density in northern boreal forests. As we show later, some of the residual variation around this relation can be explained on the basis of differences in hunting success due to coarse woody debris.

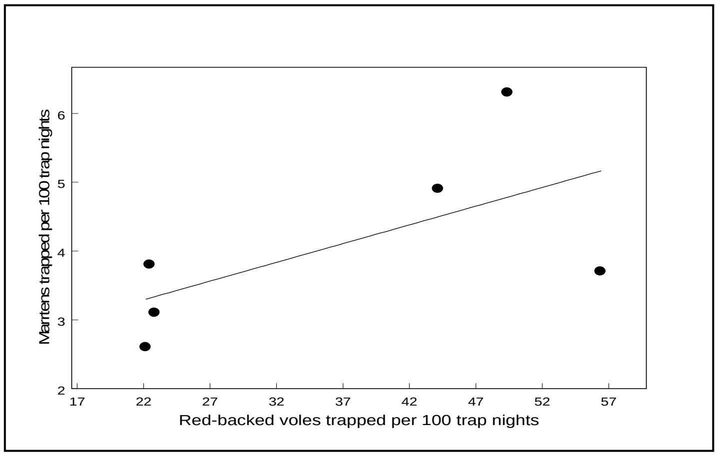


Figure 4. Marten abundance at the landscape scale in relation to red-backed vole abundance at the landscape scale (averaged over each habitat type, with equal weight).

As of the end of 2003, we had a total of 71 active collars. Over 2001-2003, we monitored the fate of 135 radio-marked individuals. An additional sample of 43 individuals has been equipped with radios, but their current whereabouts is unknown, probably because they have moved outside our study area.

We have placed radios on roughly equal numbers of adults and juveniles, with roughly equal representation between the sexes. Preliminary estimates, based on 2001-2 data) suggest that crude rates of natural and trapping mortality have been higher in the logged than the unlogged landscape (Fig. 5). A large part of the mortality stemmed from commercial trapping of animals that ventured away from the areas in which they were originally marked, which clearly emphasizes the importance of coordinating forest habitat management and fur-bearer harvesting policies at a regional landscape level. Fur trapping plays a more important role in adult and juvenile mortality of males, perhaps because they move more than females and are thus more likely to be fur trapped.

Reproductive success has been measured from photographs of young martens at denning sites or from physical symptoms during trapping. Seven adult females reproduced in the unlogged landscape (mean = 2.3 kits/female, SE = 0.47) versus 2 females in the logged landscape (mean = 2 kits/female, SE = 1). These samples are too small as yet to reliably assess whether reproductive rates differed between the logged and unlogged treatments. We determined the locations of natal dens for most of these females, as well as temporary dens used post-parturition, and will increase this sample next spring. Characterizing these dens will help determine site-level requirements for successful reproduction by marten.

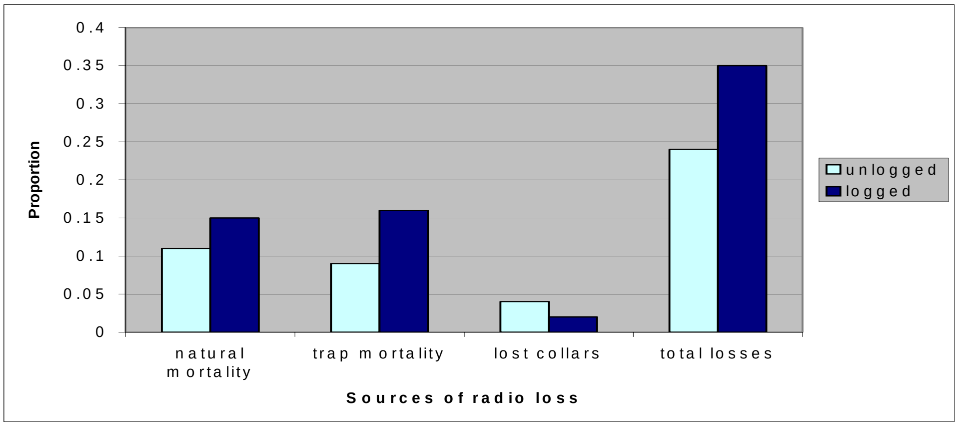


Figure 5. Mortality and radio loss of martens in logged versus unlogged landscapes.

Marten hunting success

Snow tracking of 34 marten, covering >100 km of movement trajectories, indicated that both attack frequency and total hunting success were 50-100% higher in the unlogged forest than in the logged forest landscape (Fig. 6). Coupled with the earlier small mammal trapping results, this suggests that one of the ecological benefits of mature stands may be increased access to prey. Direct evidence of prey captures recorded during snow tracking, coupled with fecal samples and live-trapping data will be used to assess habitat-specific patterns of prey selection by martens.

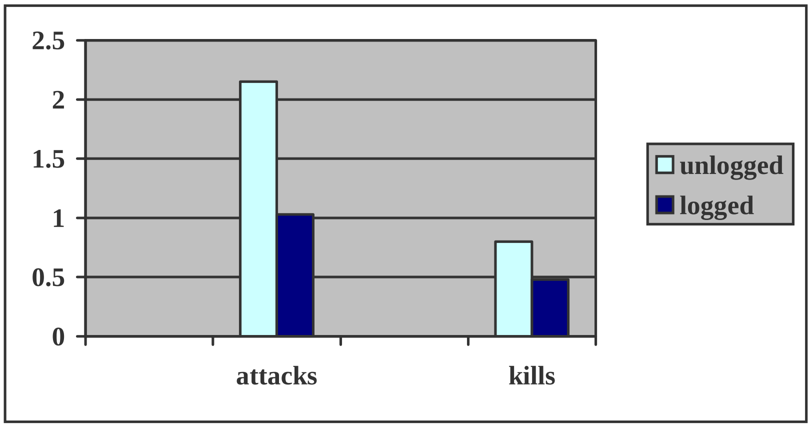


Figure 6. Number of attacks and successful kills per km of searching by martens in unlogged versus logged landscapes.

The emerging data on habitat specific variation in marten density and hunting success suggest that higher marten abundance in mature forest stands may be linked to improved access to prey during winter and/or prey abundance. These critical features need to be considered in setting core requirements and determining habitat-specific capacity to support marten populations. Moreover, these features may respond favorably to changes in forest silvicultural and harvesting techniques.

Home range use and dispersal

A total of 77 adult martens and 128 juveniles have produced telemetry information. Twenty of the adults currently have >30 fixes per year, the lowest threshold at which meaningful home range estimates might be obtained, compared to 8 juveniles.

Dispersal by 84 juveniles was measured during 2001-2002 in logged versus unlogged landscapes (Fig. 7). Dispersal was skewed towards shorter distances in the logged than the unlogged landscape, with most juveniles dispersing <20 km. The tendency for juveniles to disperse shorter distances in the logged landscape may be a consequence of higher costs associated with moving long distances or simply reflect the reduced density of martens in the logged landscape. There is also a hint, however, of a fatter tail in the dispersal distribution in the logged treatment, which could have important implications for viability. This pattern should become better clarified with 3 further years of data.

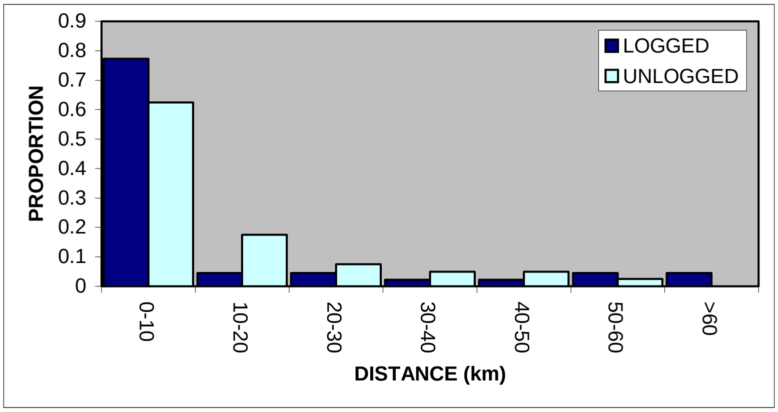


Figure 7. Dispersal distance of juveniles in logged versus unlogged landscapes

Genetic and physiological structure of marten populations

A sample of 90 marten carcasses, from animals captured by commercial trappers in the vicinity of the field study sites, was brought to the University of Guelph during winter 2002. Tissue samples (muscle and hair) were taken for DNA fingerprint analysis by Thomas Broquet. During the fall of 2002, Thomas collected another 131 carcasses for DNA analysis. In addition to this sample, Thomas has also collected hair samples from all live-captured animals (approximately 250 different individuals to date) for DNA microsatellite analysis, which will be used as an independent means of comparing reproductive success in the logged versus unlogged landscapes.

Variation in marten body condition was studied during the winter of 2003, using a sample of 131 marten carcasses obtained from trappers in the Ear Falls region. Condition was defined as the residual variation around strong log-linear regressions between wet mass versus body length. These results showed that males were in significantly better condition than females, due perhaps to reduced breeding costs. More importantly, her results showed that animals trapped from the unlogged landscape were in significantly better condition than those obtained from the logged landscape, probably due to improved predation success (Fig. 8).

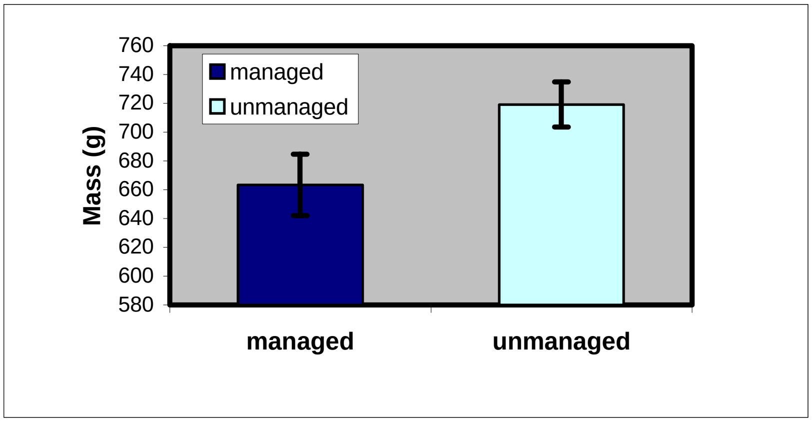


Figure 8. Body mass of adult female martens (after controlling for body length) in logged (managed) versus unlogged (unmanaged) landscapes.

Martens as an umbrella for other species

SFMN has supported the work of three graduate students (Sarah Wyshynski, MSc; Tara Crewe, MSc; and Darren Sleep, PhD) in the lab of T. D. Nudds between May 2001 and the present. The purpose of the work by these students, as it related to the larger project, was to collect data on the distribution and abundance, as appropriate, of as many vertebrate species as possible. This was done on the same landscapes as the demographic data was collected for marten to test, ultimately, the efficacy of marten as an "umbrella species". Details of survey designs, habitats and habitat characteristics sampled, and preliminary results to 2002 were reported in fall 2002.

To avoid the potential problem that these students might have little opportunity to grow as independent researchers within the overall program, they were encouraged to use the opportunity afforded by the overall, targeted research program to develop expanded thesis topics for which they could also use the data. To different extents, their thesis topics thus deviate from "mere" contrasts between landscapes of fire and timber-harvest origins; regardless, all have developed significantly in the areas of model-selection and programming. The two MSc candidates have submitted thesis drafts and will defend by the end of the winter semester 2004; the PhD candidate will be in the field for a final season between 1 March and 30 June 2004 (details of all three projects below).

SFMN also supported the training of nine field assistants over three field seasons 2001-2003. Seven of these were technicians: Aaron Walpole (2001-2), Kayla Wilson (2002), Chris Stratton (2002), Glenn Desy (2002), Mike Gawel (2003), Rowan Barrett (2001) and Lindsay Armer (2001). Three assistants were supported also by either NSERC Undergraduate Summer Research Awards (Karla Falk 2002, Lindsay Armer 2002) or University Undergraduate Research Awards (Ann Nguyen 2003). Nudds supervised Armer's Honours Thesis at UNBC University College of the Cariboo (2002-3) based on data collected while supported by SFMN.

Songbirds and woodpeckers

In 2003, further analysis was conducted on the forest songbird and woodpecker data, which was collected in the 2001 and 2002 field seasons. Using randomized null models, presence/absence and abundance data for forest birds, and Morisita's similarity index, Sarah

Wyshynski investigated whether local boreal bird communities assembled in repeatable patterns that suggest redundancy in the "ecological roles" of species. Redundancy was inferred by evidence that assemblages are formed based on ecological, or functional, rather than taxonomic, characteristics. If redundancy was evident, pairs of bird assemblages classified based on ecological/functional traits, in forest patches of like habitat, would be more similar than if they were classified using the Linnaean system of taxonomy.

Sixty-five forest birds found in the study area were classified into 48 potential "ecological species" based on unique combinations of foraging, nesting and migratory traits. A model was developed for each of the 8 habitat types surveyed for forest birds. For each of these habitat types, 5 random assemblages were created with numbers of individuals equal to the observed assemblages in the 5 replicate stands, for both taxonomic and functional assemblages. Individuals were randomly drawn, without replacement, from aggregate source pools for each habitat type, with probabilities weighted by species relative abundance. Similarity was calculated between all possible pairs of assemblages (n =10) and the mean taxonomic similarity coefficient was then calculated for the 5 random assemblages. This was repeated 1000 times for each habitat type, to generate 95% confidence intervals for Morisita's index of similarity.

The mean taxonomic similarity between observed pairs of assemblages was consistently less ($P < .05$) than the mean taxonomic similarity between pairs of randomly assembled communities indicating that avian assemblages in the boreal forest exhibit highly non-random structure. Boreal bird assemblages were found to be structured based on species' ecological traits, as mean pairwise assemblages for all 8-habitat types were significantly ($P < .05$) more similar when classified into ecological species rather than taxonomic species (Fig. 9). This implies that the identity and abundance of species was changing from patch to patch of similar habitat, due to slight environmental differences or chance, but the overall functional structure of the patches remained alike. With evidence of species compensation occurring, it can be inferred that avian assemblages display a high degree of redundancy in Ontario's boreal forest. Forestry did not appear to influence the manner in which these local avian communities assembled, as assemblages in forests originating from fire and logging both exhibited non-random structure, based on functional roles of the species.

Shifts in community composition are conventionally viewed as a negative consequence of anthropogenic disturbance, and conclusions on the effects of forestry are often drawn from observed structural changes to avian assemblages, such as decreases or increases in species' relative abundances. However, if local communities assemble based on functional characteristics, species with similar ecological traits will replace each other and species turnover could be fairly high between assemblages. Thus, natural fluctuations in species abundances and shifts in community structure could be misinterpreted, and conclusions from these studies may therefore be misleading. Most forestry-bird relationship studies take place over only 1 to 2 years. In this short time period, it may be difficult to distinguish between natural fluctuations in avian populations or declines as a result of forestry. Caution should therefore be used in drawing conclusions about the effects of forestry on bird populations using such short-term investigations.

Results from this study suggest that shifts in avian populations and changes in community structure due to anthropogenic disturbance may have negligible consequences on the ecosystem functions and processes in boreal ecosystems. As one species declines in abundance, density may be compensated by functionally equivalent species in the region. Canada's boreal forest may therefore be much more resilient to anthropogenic disturbance than often argued.

Although some studies indicate that increased biodiversity results in increased ecosystem function, evidence indicates that the concept may not be universal. Thus, maintaining or enhancing species diversity to uphold ecosystem processes may be less significant than frequently alleged.

At present, resource policy predominantly emphasizes conservation of particular ecosystem elements (species) rather than biological integrity. However, because species-centred management is often more of a reactive approach to conservation, than preventative, management efforts have not always proven to be successful. Managing landscapes from a functional approach, where conservation efforts focus on maintaining a diversity of ecological traits, may be more effective in ensuring that the aspects of biodiversity that are critical for maintaining the resilience of an ecosystem are persisting, as well as being strategically and economically more viable. If forest managers plan to shift their focus to maintaining natural processes rather than its elements, more effort needs to be devoted to clearly defining functional groups across assemblages of various fauna that reflect dominant ecosystem functions. Additionally, controls or benchmarks need to be established so that the efficacy of management using functional groups as indicators of ecosystem processes can be assessed. Without reference points in naturally disturbed boreal forest of the region, there are no means to compare the diversity, composition and functions of the anthropogenically disturbed landscapes to measure program success.

Currently, Sarah is developing resource selection functions (RSFs) to predict presence/absence and abundance of songbirds, woodpeckers, amphibians and small mammals in the boreal forest. We are developing models at 2 scales separately and combined. One scale uses habitat features (eg. shrub density, snag density, canopy cover) collected within forest stands and the other uses landscape features (eg. forest type, origin, proximity to other stands, area). This will elucidate what degree of detail is required of to predict presence/absence and abundance of species in the boreal forest. We plan to have these models developed by June 1, 2004.

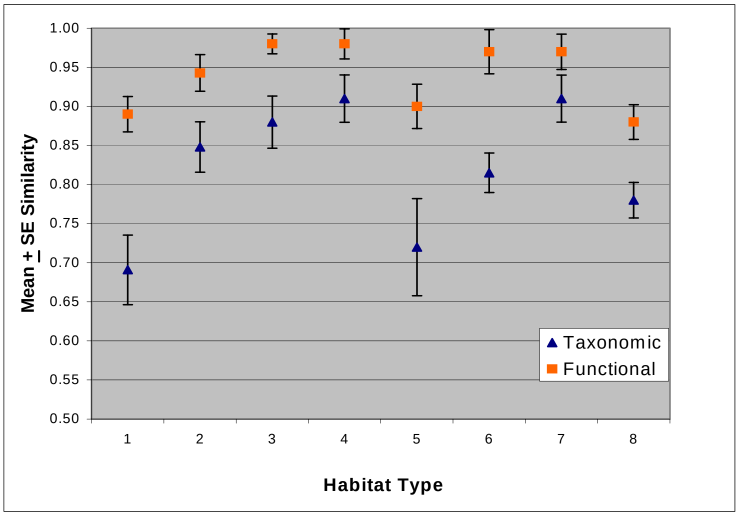


Fig. 9. Mean (n = 10) functional and taxonomic similarity for pairs of avian assemblages observed in 8 habitat types: 1. Fire Conifer Clay, 2. Fire Conifer Sand (>80yr), 3. Fire Mixed Clay, 4. Fire LL Black Spruce, 5. Logging Conifer Clay, 6. Logging Mixed Clay, 7. Logging Deciduous Clay, 8. Fire Conifer Sand (~50yr).

Amphibians

Management programs are often based on estimates of population abundance and therefore rely on the assumption that abundance reflects quality resources and better fitness. If amphibians are distributed according to the Ideal Free Distribution (IFD) model, or if abundance and fitness are both positively correlated with habitat quality, then the assumption is upheld. However, some species can be equally or more abundant in low quality sink habitat where resource availability and fitness are low. Because sink habitats depend on immigration from source habitat for recruitment, management decisions based solely on abundance estimates could result in lowered population size and possibly extinction by decreasing the proportion of source habitat across the landscape.

To test whether American toad (*Bufo americanus*) and wood frog (*Rana sylvatica*) abundance is positively correlated with fitness in the boreal forests of northwestern Ontario, Tara spent two months in the field in 2003, in addition to 2001 and 2002. The data from 2003 are in Table 2. She placed 15 pitfalls (3 arrays) within 24 forest stands (4 habitat types with n = 6; see Table 3). Abundance was estimated as number captured per 100 trap nights, and body condition, estimated by the mass and length of each individual, was used as an index of fitness. Results suggest that the distributions of adults approximate IFD, and the assumption that abundance reflects body condition (fitness) is not violated . Alternatively, results for juvenile amphibians suggest they may be subjected to interference, competitive differences or perceptual constraints, and their abundance should not be used as an index of habitat quality until further work on resource selection and intraspecific interactions has been completed (see Fig 10 example results for American toad).

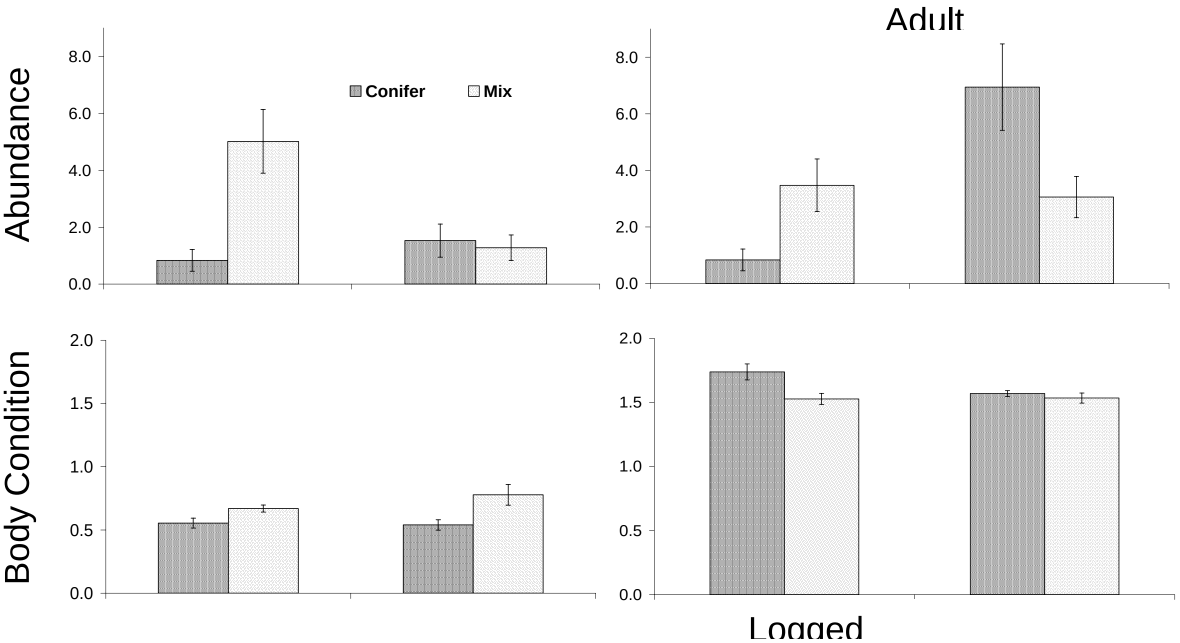
Table 2: Trap effort and success for principal amphibian species in the boreal forest at Ear Falls, ON, May-June 2003.

Landscape	Composition	# Trap Nights	# Wood Frog (Juvenile/Adult)	# American Toad (Juvenile/Adult)
Logged	Conifer	714.5	22/9	6/6
	Mix	717	32/30	36/25
Unlogged	Conifer	720	21/13	11/49
	Mix	713	10/37	9/21
Total		**2864.5**	**85/89**	**62/101**

Table 3: Experimental treatments

Composition	# Logged-origin Stands	# Fire-origin Stands
Mixed	6	6
Conifer	6	6

Figure 10. Mean (± Std. Error) abundance (n = 288) and body condition of juvenile and adult American toads (*Bufo americanus*) in the boreal forests of northwestern Ontario for the four stand types studied.



Landscape variables that will be used in analysis of resource selection are distance to water, distance to nearest stand of similar composition, distance to nearest clearcut, area of forest stand, stand origin (logged vs. unlogged), and stand age. Specific habitat variables measured are coarse woody debris (CWD) loading, CWD class, duff depth (moss and litter), canopy cover, Ecosite type, and invertebrate abundance. Models that incorporate either landscape or habitat variables, or a combination of both, will be compared and ranked using Akaike's Information Criterion for small sample sizes. Analyses of the effect of habitat type on amphibian abundance and body condition is complete, and analysis of resource selection by wood frogs and American toads is underway. Both will be completed by June 1, 2004.

Owls

This project investigates the composition of owl assemblages and species on both fire and harvest origin areas. Goals of this project are two-fold. First, Darren aims to evaluate a policy of natural disturbance pattern emulation and test whether its conservation objectives are met at multiple spatial scales. Second, due to their cryptic nature and large territories, forest owls tend to be overlooked in many studies on avian communities and landscape change, he aims to redress this shortfall. Comparisons will be made at the landscape/assemblage scale, the landscape population scale, and the forest/individual scale. Each resolution tests specific hypotheses that pertain to the effects of fire and harvesting on owl assemblages, populations, or individuals at that scale.

(1) Landscape/species assemblage scale – Nocturnal owl survey data from across northern Ontario will be obtained from BSC. This data will be geo-referenced with landscape and habitat data from the Ontario Ministry of Natural Resources. Forest characteristics will be plotted against a continuum of owl assemblages for both fire and harvest origin areas across a broad range of age classes. Using this technique, Darren will map the successional trajectories of owl assemblages, and determine whether and when assemblages converge

(2) Landscape/population scale – Data generated from (1) will be used, and parameters such as vegetation (dominant species, under-story level, canopy cover, etc.), forest age, and levels of anthropogenic disturbance (proximity to human habitation, roads, etc.), will be used to generate models that best predict the abundance of different species of owl.

(3) Forest unit/individual scale – Field data has been collected on species of owls present on both harvested origin areas (>50 yrs old) and fire origin areas (>70 yrs old) near Ear Falls, ON. Radio-telemetry and nest searching are being used to measure reproductive effort and success, habitat use and survival.

Fieldwork began in 2003 in early March. To measure the distribution and abundance of all owl species on both harvested and fire-origin landscapes, Darren conducted nocturnal owl surveys and conducted nest searches while noting associated measurements when nests were located. In 2002, he conducted 5 nocturnal owl surveys on both logged and unlogged landscapes. In 2003, 18 surveys were conducted, 9 surveys on each of harvested and fire-origin landscapes. All surveys were conducted from early March until early May in each year, and were submitted to Bird Studies Canada for contribution to their Nocturnal Owl Survey program. Increasing the number of times a survey route was run tended to increase the cumulative number of species detected, though the increase was not statistically significant on either harvest-origin ($F = 0.57$, $p = 0.59$) nor fire-origin ($F = 1.23$, $p = 0.35$) landscapes (Fig 11).

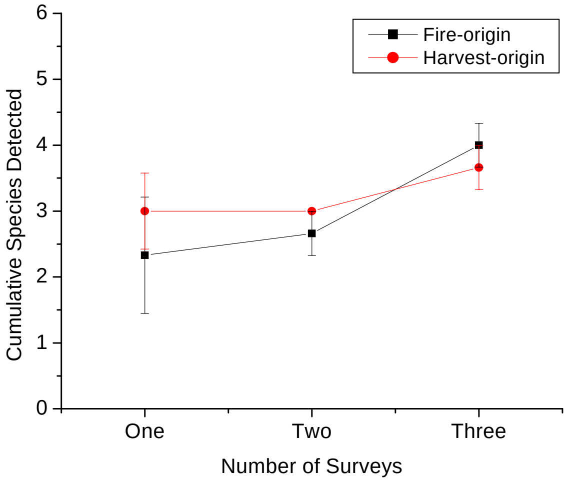


Figure 11: Cumulative species response curves with respect to number of times a survey route is repeated throughout the nesting season. Note that 6 is the maximum number of species to be found on the study site (y-axis).

Reponses to playback surveys differed among species and between years. While Great Gray Owl (*Strix nebulosa*, GGOW) responses reflected diurnal observations in both years, responses from Northern Hawk Owls (*Surnia ulula*, NHOW) did not, with few detections in either year, and an abundance of diurnal observations in 2002 (5 nests, 18 juveniles banded), all in the same areas as the survey routes. There were several differences between the two survey years, but of note was the nearly complete absence of both Great Gray Owls, and Northern Hawk Owls from both the harvest and fire-origin landscapes (Figs 12 and 13). Conversely, responses from Boreal Owls (BOOW, *Aegolius funereus*) were higher.

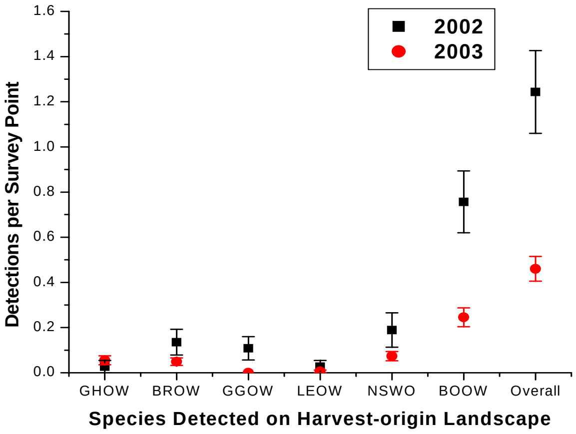


Figure 12: Number of detections per survey point for each species detected on harvest-origin landscapes. Species abbreviations are as follows: GHOW – Great Horned Owl, BROW – Barred Owl, GGOW – Great Gray Owl, LEOW – Long-eared Owl, NSWO – Northern Saw-whet Owl, BOOW – Boreal Owl, NHOW – Northern Hawk Owl. Note significant drop in BROW, GGOW, NSWO and BOOW, contributing to the overall drop in owls detected between the two years.

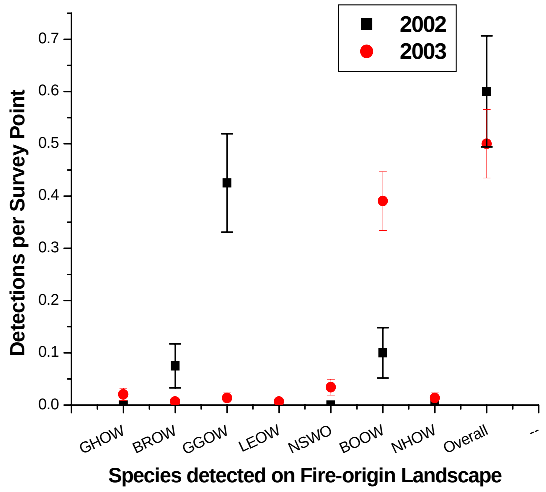


Figure 13: Number of detections per survey point of each species on the harvest-origin landscape. Note significant drops in BROW, and GGOW, with increases in NSWO and BOOW.

Overall, previously harvested areas had greater numbers of owl responses in 2002, while there was little difference between the two landscapes in 2003. As for species composition, landscapes surveyed during 2002 appear to be significantly different from one another, while in 2003, species composition appears to be very similar between both landscapes (Figs 14 and 15). Whether this pattern is biologically accurate, or resulted from increased surveys and therefore better data in 2003 is, at this point, unknown. To test whether these patterns are widespread, work to be done will examine surveys conducted throughout northern Ontario, using Bird Studies Canada's nocturnal owl survey database.

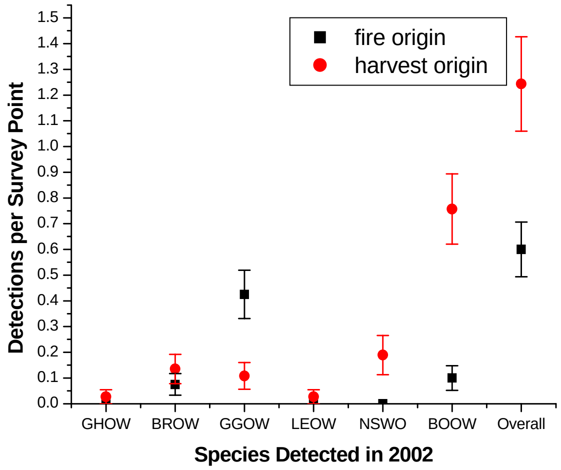


Figure 14: Number of detection per survey point of each species on both harvest and fire-origin landscapes during 2002 surveys.

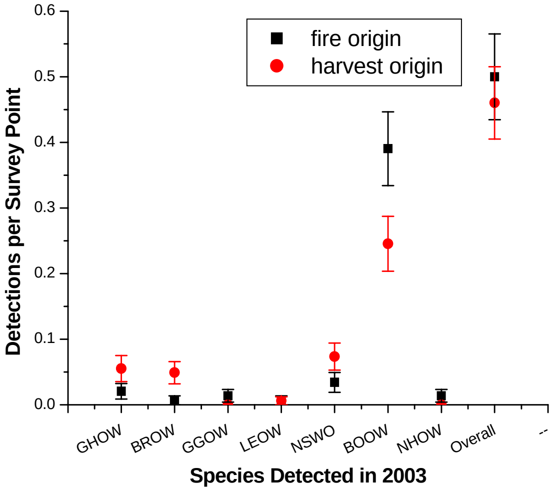


Figure 15: Number of detections per survey point of each species on both harvest and fire-origin landscapes during 2003 surveys. Note higher responses of BOOW on the fire-origin landscape.

Table 4: Number of nests found, examined, and monitored during nest searching in the spring of each year of the study.

Species	2002	2003
GHOW	0	2
BROW	1	1
GGOW	8	0
LEOW	0	0
NSWO	1	0
BOOW	2	5
NHOW	5	0
Total:	17	8

Table 5: Nest parameters measured

Species	#	Number fledged/nest	Nest height (average m)	Stand age (average yrs)	Stand area (average ha)
GHOW	2	2	22.3	144	37.82
BROW	2	2	11.85	85.5	31.85
GGOW	8	1.25	14.96	88.5	43.61
NSWO	1	-	16.1	82	32.83
BOOW	7	-	12.69	98.14	39.54
NHOW	5	3.4	9.82	34.4	379.34
Total:	25				

A third and final field season will take place in the spring of 2004. A banding permit has now been issued for all species, and banding and radio-tagging will resume in spring 2004. Radio-transmitters will be used to locate more nests as well as to estimate territory size, and provide opportunities to collect pellets. While all captured species will be banded, weighed and measured, radio tags will only be applied to species found in significant numbers on both the fire- and harvest origin landscapes. This will allow comparisons to be made for species-specific fitness metrics (e.g. territory size, nesting effort, etc) between the two landscapes. Analysis is ongoing for this project, and thesis writing will be complete in the spring of 2005.

Formal assessment of the utility of martens as an umbrella species will be one of the objectives of the ongoing SFMN project "An integrative, national-scale approach to developing ecological indicators of forest sustainability", headed by Tom Nudds.

Literature cited

Bowman, J.C. and J.–F. Robitaille. 1997. Winter habitat use of American martens within second-growth forest in Ontario, Canada. Wildl. Biol. 3:97-105.

Boyce, M. and L. McDonald. 1999. Relating populations to habitats using resource selection functions. Trends in Ecology and Evolution 14:268-272.

Burnham, K.P. and D.R. Anderson. 1998. Model selection and inference: a practical information-theoretic approach. Springer-Verlag, New York.

Buskirk, S.W., and R.A. Powell. 1994. Habitat ecology of fishers and American martens. Pp. 283-296 *in* S.W. Buskirk, A.S. Harestad, M.G. Raphael, and R.A. Powell (eds.). Martens, Sables, and Fishers: Biology and Conservation. Cornell Univ. Press, Ithaca.

Canadian Council of Forest Ministers (CCFM). 1997. Criteria and indicators of sustainable forest management in Canada: Technical Report. Nat. Res. Can., Ottawa.

Chapin, T. G., D.J. Harrison, and D.D. Katnik. 1998. Influence of landscape pattern on habitat use by American marten in an industrial forest. Cons. Biol. 12:1327-1337.

Cornuet, J.-M., S. Piry, G. Luikart, A. Estoup, and M. Solignac. 1999. New methods employing multilocus genotypes to select or exclude populations as origins of individuals. Genetics 153:1989-2000.

Davis, C. S., and C. Strobeck. 1998. Isolation, variability, and cross-species amplification of polymorphic microsatellite loci in the family Mustelidae. Molecular Ecology 7:1776-1778.

Doak, D.F., & L.S. Mills. 1994. A useful role for theory in conservation. Ecol. 75:615-26.

Fryxell, J.M., J.B. Falls, E.A. Falls, R.J. Brooks, L. Dix, and M.A. Strickland. 1999. Density dependence, prey dependence, and population dynamics of martens in Ontario. Ecol. 80:1311-1321.

Fryxell, J.M., J.B. Falls, E.A. Falls, R.J. Brooks, L. Dix, and M.A. Strickland. 2001. Harvest dynamics of mustelid carnivores in Ontario, Canada. Wildl. Biology 7:151-9.

Goldstein, D. B. 1995. An evaluation of genetic distances for use with microsatellite loci. Genetics 139:463-471.

Hargis, C.D., J.A. Bisonnette, and D.L. Turner. 1999. The influence of forest fragmentation and habitat pattern on American martens. J. Appl. Ecol. 36:157-172.

Haydon, D.T. and J.M. Fryxell. 2004. Using knowledge of recruitment to manage harvesting. Ecology 85:78-85.

Henry, S.E., and L. Ruggiero. 1994. Den use and kit development of marten in Wyoming. Pp. 233-237 *in* I.Thompson (ed.) Proc. XXl IUGB Congr., Halifax, Canada. Can. For. Serv., Chalk River.

Kyle, C. J., C. S. Davis, and C. Strobeck. 2000. Microsatellite analysis of North American pine marten (*Martes americana*) populations from the Yukon and Northwest Territories. Canadian journal of zoology 78:1150-1157.

Paetkau, D., W. Calvert, I. Stirling, and C. Strobeck. 1995. Microsatellite analysis of population structure in Canadian polar bears. Molecular Ecology 4:347-354.

Payer, D.C. and D.J. Harrison. 2003. Influence of forest structure on habitat use by American marten in an industrial forest. Forest Ecol. Manage. 6:1-12.

Potvin, F., L. Bélanger, and K. Lowell. 2000. Marten habitat selection in a clearcut boreal landscape. Conservation Biology 14:844-857.

Pulliam, H.R. 1988. Sources, sinks, and population regulation. Am. Nat. 132:632-651.

Pulliam, H.R. and B.J. Danielson. 1991. Sources, sinks and habitat selection: a landscape perspective on community dynamics. Am. Nat. 137:50-66.

Rousset, F. 1997. Genetics differentiation and estimation of gene flow from F-statistics under isolation by distance. Genetics 145:1219-1228.

Rousset, F. 2000. Genetic differentiation between individuals. Journal of Evolutionnary Biology 13:58-62.

Schneider, R.R., and P. Yodzis. 1994. Extinction dynamics in the American marten. Cons. Biol. 8:1058-1068.

Thompson, I. D., and P.W. Colgan. 1987. Numerical responses of marten to a food shortage in northcentral Ontario. J. Wildl. Mngt. 51:824-834.

Thompson, I. D., I.J. Davidson, S. O'Donnell, and F. Brazeau. 1986. Use of track transects to measure relative occurrence of some boreal mammals in uncut forest and regeneration stands. Can. J. Zool. 67:1816-1823.

Thompson, I. D., and P.W. Colgan. 1990. Prey choice by marten during a decline in prey abundance. Oecol. 83:443-451.

Thompson, I. D., and P.W. Colgan. 1994. Marten activity in mature and logged boreal forests in Ontario. J. Wildl. Mngt. 58:280-288.

Thompson, I. D. 1994. Marten populations in mature and logged forests in Ontario. J. Wildl. Mngt. 58:272-280.

Watt, W.R., J.A. Baker, D.M. Hogg, J.G. McNicol, and B.J. Naylor. 1996. Forest management guidelines for the provision of marten habitat. Ont. MNR Tech. Ser., Sault Ste. Marie.