LANDSCAPE THRESHOLDS AND RESPONSE TO FRAGMENTATION BY ENDANGERED NEWFOUNDLAND MARTEN

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BACKGROUND AND JUSTIFICATION

Newfoundland marten (*Martes americana atrata*) are an endangered subspecies of mustelid that are endemic to the island of Newfoundland. They have been listed by the Committee on the Status of Endangered Species in Canada (COSEWIC), have an active recovery team, and are estimated to number less than 300 individuals (Forsey et al. 1995). Limiting factors associated with declines in marten populations are thought to be associated with loss of late successional forests (Bissonette et al. 1989, Thompson 1991, Buskirk 1992) and direct mortalities associated with non-target capture in traps and snares set for hares and foxes. Habitat loss and fragmentation are important issues in conservation biology, and are often considered the primary threats to biological diversity (Fahrig 1997, With 1997). Habitat loss and fragmentation can lead to a reduction in population size, which can in turn increase the probability of extinction of marten by demographic and/or environmental stochasticity (Burkey 1995).

Recently, the Newfoundland Marten Recovery Team was asked to respond to proposed forest harvesting plans within an area of occupied marten habitat (Main River watershed). Lack of data on responses of Newfoundland marten to landscape-scale habitat change hinder efforts to predict population responses of marten to forest harvesting, and limit the ability of managers to recommend alternative cutting plans that would retain target population levels of marten. Additionally, imbalances in forest age structure in the province (Thompson 1991) are leading to unprecedented harvesting pressure on mature forests, thus there is an immediate need for a tool to reliably predict population responses of marten to alternative forest harvesting scenarios at the scale of the landscape.

Forest management in Newfoundland is increasingly being challenged to justify sustainability of harvesting practices and the effects of clearcutting, intensive forestry, and landscape fragmentation on forest biodiversity. However, information on how to manage forests for biodiversity is often contradictory, and largely constrained by information gaps, differing needs across species, and lack of specific objectives. Further, historical emphasis has been on specific stand-scale management practices

that inevitably benefit some species, harm others, and ignore the influence of the landscape matrix on species-level occurrence and viability. Although fragmentation, reduced size of forest patches, and the trend towards a younger forest have frequently been cited as biodiversity concerns, the empirical link between those changes and wildlife populations has not been well documented. Thus, guidelines for managing for landscape-scale biodiversity are based on unsubstantiated paradigms (i.e., reduce edge, enhance connectivity) without supporting data, precise objectives, or measurable benchmarks based on empirically-based knowledge of the responses of featured species to management actions. These factors have resulted in the under-representation of extensive, landscape-scale planning initiatives to conserve, maintain, and enhance biodiversity in working forest landscapes.

Although most management efforts for marten in Newfoundland have been directed at the scale of the forest stand, recently published data from Maine (Payer and Harrison 1999), Utah (Hargis and Bissonette 1997), and Quebec (Potvin et al. 2000) indicate that marten may be extremely sensitive to landscape-scale fragmentation. Based on radio telemetry data for 350 resident adult marten in Maine, our data indicate that marten are extremely area sensitive and maintain the largest home-range area per unit body weight of any quadraped. This relationship may be even more relevant to conservation of Newfoundland marten, which maintain home- range areas that are a magnitude larger (B. Hearn, unpublished data) than those observed for marten in Maine. Further, Newfoundland marten are territorial and their social structure requires approximately 15-30 km^2 of suitable landscape to maintain a single breeding unit (1 male and 1-2 females). Most wide-ranging top carnivores (e.g., wolves, bobcats, coyotes) are habitat generalists, or are commonly associated with forest disturbances (e.g., lynx). In contrast, our published data from Maine indicate that marten are forest specialists that strongly select against early successional forests when positioning their home ranges on the landscape (Katnik 1992, Payer 1999). Further, marten are the only mammal in northern forests with well-documented responses to fragmentation. On our study sites in Maine, the mean size of forest patches used by marten was 18 times the size of unused patches, used patches were closer to other large patches than were unused patches, and the largest, continuous forest patch within home ranges of marten averaged >75% of their entire home range (i.e., large, continuous patches of forest were required to support a single marten) (Chapin et al. 1998). However, little is known about the response of Newfoundland marten, which evolved in a naturally fragmented landscape, to human-induced changes in landscape characteristics.

Threshold responses of animals to fragmentation can lead to nonlinear population declines that may be catastrophic. Critical thresholds have been cited as "a major unsolved problem facing conservationists" (Pulliam and Dunning 1997) because of the difficulty in predicting the outcome of habitat loss or fragmentation until the threshold is exceeded. A critical threshold is "the point at which there is an abrupt change in a quality, property, or phenomenon" (Turner and Gardner 1991:7). There is a change in the pattern or process that is being measured at the critical threshold, resulting in unpredictable behavior at the threshold (With and King 1997). Critical thresholds imply that initial loss of habitat will only reduce occupancy slightly, but decline may be rapid after some threshold in the proportion of original habitat is reached (Mönkkönen and Reunanen 1999). If a forested landscape is projected as a grid of cells, and forested

habitat is removed a cell at a time, the landscape will include gaps with no forest, but will remain connected as long as cells of habitat remain adjacent and form a continuous cluster. With continued deforestation, the removal of a single cell is enough to break the continuous cluster into two separate clusters; it is at this point that the critical threshold is reached (With 1997).

Indirect evidence from recently published field studies in Utah (Hargis and Bissonnette 1997), Maine (Payer and Harrison 1999), and Quebec (Potvin et al. 2000) suggests that marten may seldom occupy landscapes with greater than 30-40% of the forest in openings or early seral stages. Further, ongoing modeling based on 318 marten-years of radio-tracking data from Maine indicate that occupancy rates of marten decline precipitously and nonlinearly when >10% of home-range-sized landscapes are composed of patches with trees <6 m in height (Hepinstall et al., unpublished). Critical thresholds depend on the landscape context in which habitat patches are embedded, and may differ across landscapes and geographical regions (Andrén 1996, Mönkkönen and Reunanen 1999). "Extinction thresholds" (Lande 1987) resulting from habitat loss can cause a population to crash abruptly and unpredictably. Extinction thresholds define the minimum proportion of suitable habitat necessary for population persistence. Species will be lost long before the critical threshold is reached (Mönkkönen and Reunanen 1999), thus, it is important to determine thresholds in patch occupancy across a range of habitat loss for endangered Newfoundland marten. Knowledge of threshold responses is a powerful conservation tool that enables managers to predict effects of human-induced changes in the landscape (e.g., alternative forest harvest scenarios) on the probability of landscape occupancy by a featured species.

Documenting landscape-level thresholds to fragmentation is a long-term and costly endeavor. Thus, nearly all work that has evaluated fragmentation effects on terrestrial vertebrates has evaluated human influences at the patch- (e.g., incidence functions for forest-dependent birds) or subpatch-scales (e.g., edge distance vs. nest success studies). In the absence of animal-specific responses to forest fragmentation, numerous investigators have resorted to quantifying landscape metrics (e.g., contagion, fractal dimension, edge density), without a means of evaluating their relevance or biological significance. Efforts to quantify landscape metrics have little conservation value unless translated into a currency (i.e., a biologically meaningful measure of habitat quality) and a predictable response of animals to human-induced changes in the predefined currency. Analysis of landscape pattern and structure can consider a large number of metrics such as fractal dimension, evenness, and contagion, but ideally there is only a small set of metrics that explain the important dimensions of pattern and structure on the landscape. This project proposes to define the habitat currencies (e.g., % mature forest in potential home range, landscape metrics) important to Newfoundland marten, to evaluate how changes in the currency affect probability of occupancy of landscapes by marten, and to provide a tool for evaluating the influences of proposed forest harvesting scenarios on landscape-level habitat occupancy by marten.

We would use empirical data collected during a 12-year study of American marten in northern Maine, in conjunction with data collected during a 5-year radio telemetry study in western Newfoundland (B. Hearn), to identify landscape-scale habitat features most closely associated with home range occupancy (i.e., habitat currencies) by the endangered Newfoundland marten. These currencies will be used to evaluate threshold responses of marten to human-induced landscape change and to build and test predictive models of marten occurrence based on landscape characteristics. These

models will greatly enhance the ability of managers to prioritize areas of likely presence for conducting population surveys, to identify areas of potentially suitable habitat that require forest planning, to reliably predict population responses of marten to alternative forest management scenarios, and to evaluate potential population sizes and distribution across large landscapes (as required for conserving a viable metapopulation of marten). Further, we will use the models to generate maps of the distribution of marten habitat in Newfoundland based on probability of occupancy and to develop a spatially explicit recovery strategy for Newfoundland marten.

OBJECTIVES

1) To evaluate and define stand- and landscape-scale currencies that are associated with habitat occupancy by individual marten in Newfoundland based on approximately 150 marten-years of monitoring radiocollared animals in western Newfoundland.

2) To evaluate the influence of landscape and fragmentation metrics on area occupancy of
marten in western Newfoundland based on a comparison of characteristics within and
outside of occupied home ranges of marten.

3) To develop a series of landscape thresholds that can be used as a tool for predicting landscape-scale occupancy of habitat by marten in the Little Grand and Red Indian Lake
areas of western Newfoundland and to compare to thresholds currently being developed from 259 marten ranges in Maine, where home range areas are a full magnitude smaller than in Newfoundland. Use the thresholds to develop a tool for use in predicting population
responses of marten to proposed forest-harvesting scenarios.

4) To evaluate how habitat spatial patterns and disturbances (e.g., fragmentation, timber harvests, insect outbreaks, patch size and isolation), spatial processes (habitat selection) and spatial constraints (landscape permeability, connectivity) interact to determine patterns of use and occupancy of landscapes by marten. Determine whether spatial-use strategies and responses to fragmentation exhibited by marten (with large home ranges) in Newfoundland differ from processes exhibited by American marten at less extensive (e.g., Maine) spatial scales.

5) Use the results of objectives 1-4 to conduct a habitat supply analysis based on the provincial
forest inventory database for Newfoundland. Use the analysis to map and quantify the extent and distribution of suitable habitat, and to evaluate the effects of planned forestry activities on habitat supply across the province.

6) Develop an area explicit, province-wide landscape-scale habitat conservation strategy for
marten in Newfoundland, including the population size of marten that can be maintained on
forest lands.

APPROACH

Our approach for objectives 1 - 3 would employ several steps:

A) Define and map home range boundaries for ca. 150 marten-years of data collected by Brian Hearn in western Newfoundland. Define areas that were surveyed, but unoccupied by marten, and simulate potential home ranges (methods developed at Univ. Maine to randomly simulate ranges will be used).

B) Use existing forest inventory data and "soft updates" to develop ARC/INFO- based vegetation maps for each home range. Use results of companion analyses of habitat selection (B. Hearn's Ph.D. dissertation research), along with results of ongoing studies in Maine to pre-select vegetation classes relevant for evaluating landscape currencies. Plot occupancy of marten versus percent of landscape in vegetation classes to define the combination of suitable vs. unsuitable habitats that marten will occupy at the scale of the home range (i.e., define habitat currency). Statistically compare distribution of the habitat currency between occupied vs. simulated (unoccupied) ranges.

C) Identify relevant landscape metrics based on results of ongoing research at University of Maine. Use results of step B to plot suitable versus unsuitable habitat, and then calculate pre-selected metrics for occupied and unoccupied (simulated) ranges.

D) Use logistic regression or CART modeling approaches to build predictive models and to identify important landscape and vegetation variables most closely associated with presence vs. absence of marten. Test reliability of models using reserved data.

E) Use the most sensitive habitat variables identified in step D to evaluate landscape thresholds. Plot cumulative occupancy rate of marten versus habitat variables to evaluate whether marten a) respond linearly to changes in habitat with extinction near 100% unsuitable habitat; b) respond linearly to the point of matrix fracture (i.e., percolation), or c) show nonlinear (potentially catastrophic) responses to fragmentation.

F) Define currencies and develop easy to use, predictive curves of population response for use by managers to plan landscapes for marten habitat. This tool will also be valuable for quantifying effects of alternative forest management scenarios on

marten populations. We will conduct workshops with forest managers, provincial biologists and recovery team members to explain rationale and use of this tool.

Approach for Objective 4

A) Quantify landscape structure for Newfoundland marten including landscape composition of
habitat types and the physiognomic or spatial arrangement of those habitats. Evaluate finer-scale issues of spatial disturbances (stand-level timber management, insect outbreaks), processes (habitat selection) and spatial constraints (permeability, connectivity, food distribution), on marten use of landscapes in Newfoundland.

B) Chose a model of habitat loss and fragmentation that will best fit the landscape data available for Newfoundland marten: choices include percolation theory (Andrén 1994), Levins-like metapopulations (Lande 1987), neutral models (Gardner et al. 1987), or incidence functions describing how the fraction of occupied habitat depends on patch area and isolation (Hanski 1994). Fit the model to data for Newfoundland marten to generate predictions about the effects of habitat disturbance on marten populations and extinction probabilities. Use the model to evaluate the consequences of different forest management options on marten.

C) Use approaches A & B to compare spatial-use strategies and responses to fragmentation of
 marten in Maine (small home-range size) and Newfoundland (large home ranges).

APPROACH FOR OBJECTIVES 5 & 6

A) Use existing data on responses of marten to forest fragmentation, forest type, and age class from western Newfoundland (B. Hearn) to build a habitat model to predict the occurrence of marten territories on the western Newfoundland landscape.

B) Test the model's ability to predict the spatial distribution of home ranges on the landscape using reserved data.

C) Map the extent and distribution of marten habitat in Newfoundland. Produce a provincial-wide map of potential marten habitat (color-coded based on probability of occurrence).

D) Use the map of marten habitat in conjunction with population objectives established by the Newfoundland Marten Recovery Team to develop a spatially explicit recovery strategy for marten in Newfoundland.

SUPPORTING RESOURCES

This project leverages existing infrastructure, expertise, and the world's largest data set on marten at the University of Maine, with expertise, agency support, and a long-term field project in Newfoundland to address one of the most immediate issues facing the persistence and viability of the Newfoundland marten. Dr. Harrison and Mr. Hearn both serve as members of the Recovery Team for the Newfoundland Marten and are keenly aware of the immediate need for information regarding landscape-scale tolerances and thresholds of marten to forest harvesting in western Newfoundland. University of Maine will provide computer support and a fully equipped GIS lab, support of an existing post-doctoral researcher who is working on similar research questions in Maine, substantial cash towards funding a Ph.D.-level graduate research assistantship and tuition, and general office support.

Daniel Harrison is a full-professor in the Department of Wildlife Ecology at the University of Maine (13 years), and has over 20 years of research experience with forest carnivores. He has supervised the longest running and largest field research projects with eastern coyotes (115 radiocollared animals over 11 years) and American marten (355 radiocollared animals over 12 years). In addition to his academic appointment in Wildlife Ecology, Dr. Harrison is a Cooperating Scientist with the Maine Cooperative Forestry Research Unit, and a Cooperating Professor in the Department of Forest Ecosystem Science. He is a scientific advisor to the Recovery Team for the Newfoundland Marten, has provided expert advice to agencies developing conservation programs for marten in New Brunswick, Nova Scotia, New Brunswick, and Maine, and currently serves on the Commissioner's Advisory Council for Nongame and Endangered Species in Maine.

Dr. Harrison currently serves as major advisor to Brian Hearn, who is a forest wildlife

ecologist with Canadian Forest Service in Corner Brook, Newfoundland. Mr. Hearn is currently in residence at the University of Maine and is working towards his Ph.D. using information recently collected data on movements, habitat selection and cause-specific mortality of ca. 150 radiocollared marten in western Newfoundland. Brian will serve as a collaborating scientist, and will provide location data collected during a 5-year study of marten in western Newfoundland for use in evaluating landscape-level responses, habitat currencies, and thresholds.

Angela Fuller has agreed to fill the proposed Ph.D.-level graduate position. Angela recently (December 1999) completed her M.S. program where she worked on the effects of partial harvesting on American marten and their primary prey in northcentral Maine. She currently works as a Research Associate in the lab of Dr. Harrison, where she has been analyzing habitat selection and interspecific relationships of coyote, red fox, and white-tailed deer in Acadia National Park. She has also been collaborating in the ongoing landscape-level modeling work with marten in Maine.

TIMELINE

The project would begin summer 2001 with objectives 1-3 completed by 31 December 2003. Objectives 4-5 would be completed by December 2004, and objectives 5-6 would be completed by 31 December 2005.

DELIVERABLES

Annual updates of information will be provided at meetings of the Recovery Team. A final written report would be submitted and project results would be presented to sponsors and the Recovery Team. We would also provide maps identifying extent and distribution of habitat for marten and probabilities of occurrence to sponsors. Results would be presented as workshops for sponsors, agency and industry personnel, and the Marten Recovery Team, as a final contract report to project sponsors, as presentations at professional conferences and workshops, and via refereed publications.

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