BOREAL OWLS IN WESTERN NEWFOUNDLAND: USING LOCAL FIELD DATA TO ASSESS HOME RANGE CHARACTERISTICS AND TEST A HABITAT SUITABILITY INDEX MODEL

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BOREAL OWLS IN WESTERN NEWFOUNDLAND: USING LOCAL FIELD DATA TO ASSESS HOME RANGE CHARACTERISTICS AND TEST A HABITAT SUITABILITY INDEX MODEL

By

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Abstract

A habitat suitability index (HSI) model based on scientific literature and expert opinion was developed for the Boreal Owl (*Aegolius funereus*) in western Newfoundland, Canada. Preliminary analyses conducted on the model suggested outputs were most sensitive to variation in home range size, foraging radius, and density of living and dead stems in nesting areas. Over a 2-yr period data were collected on 307 winter point count locations and nine Boreal Owl home ranges using radio telemetry to examine habitat use and test the HSI model. Owls were detected at 24% of point count locations during two breeding seasons. Home range sizes during breeding varied with a median range of 429 ha. Log-ratio compositional analyses of roost locations and home ranges indicated that Boreal Owls do not occupy these sites at random. For roost locations, owls selected old and young softwood stands and avoided bogs, disturbed stands and scrub. Owl home ranges favored old softwood and disturbed stands and avoided old mixedwood and hardwood stands. HSI values produced by the original model did not differ significantly from those updated with local data on home range size. While owls were not occupying sites at random based on HSI values, the model was not able to predict boreal owl presence at levels better than chance alone. The HSI model failed to produce values greater than 0.60 (out of 1.00) suggesting that input values from the literature for other parts of the Boreal Owl range may not be reflective of habitat suitability for Boreal Owls in Newfoundland. Further research is needed to address knowledge gaps about parameters identified as sensitive (nesting habitat and nest tree availability). The island of Newfoundland may also contain far less suitable habitat than other comparable areas of

North America, or Boreal Owls in Newfoundland may be less habitat-specific than previously thought.

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Co-authorship Statement

I conducted this research independently but under the co-supervision of Dr. Ian Warkentin and Ms. Christine Doucet. I was responsible for substantial components of project development and design in collaboration with my committee members. I completed the field studies associated with this project with the assistance of Ms. Sharon Russell and two summer students, Kevin Mitchell and Liz Moulton, who worked under my supervision.

I collected, entered, and analyzed all data based on consultation with Dr. Ian Warkentin, Christine Doucet and Carl Marks. In addition, I interpreted all of the results and wrote the manuscripts that constitute the chapters of this thesis. I have revised the manuscripts based on the advice and comments of my supervisor, and supervisory committee.

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1.0 INTRODUCTION

Animal home ranges are the spatial expressions of behaviors that individuals carry out to survive and reproduce (Burt 1943). Home ranges are thought to reflect the distribution of one or several limiting resources (Powell et al. 1997). Avian home ranges in particular vary greatly depending upon certain life history traits. For example, predatory birds require a much larger area to obtain sufficient food than an omnivorous bird of equivalent body size (Schoener 1968, Jenkins 1981).

Decreases in forest cover due to timber harvesting can reduce habitat quality for some forest birds (Haskell et al. 2002, Leonard et al. 2008). Individuals may be obliged to forage further from nest sites and maintain larger home ranges (Redpath 1995). Conversely, habitat loss due to fragmentation may lead to an area containing so little habitat that an individual may be compelled to reduce the size of its home range, putting a greater strain on available resources. This decrease in habitat quality may adversely affect individual fitness and, where the effect of disturbance is widespread, overall population viability (Hinam and St. Clair 2008, Hakkarainen et al. 2008). Habitat fragmentation may also have more of an effect on wildlife when the quality of the remaining intact habitat is low (Andrén 1994, Fahrig 1998).

Habitat loss and forest fragmentation are widely regarded as major factors contributing to the decline of forest bird populations (Rappole 1996, Schmiegelow and Mönkkönen 2002, Betts et al. 2006, St-Laurent et al. 2009). The most influential cause of forest fragmentation is expansion and intensification of human land use (Burgess and Sharpe 1981, Smith and Lee 2000, Burton et al. 2006). Among those species undergoing decline because of such disturbances, certain life history traits are particularly prominent

(Imbeau et al. 2001). These include habitat-related characteristics, such as large area requirements and association with old growth forests, as well as nesting-related traits, specifically cavity nesting. These traits are predominantly associated with resident species, rather than those which are migratory. Imbeau et al. (2001) suggest that in the conifer stands of Quebec, the boreal species most sensitive to forest change are residents, most of which are cavity nesters reliant on older forests. Old growth forests and their associated inhabitants are of particular concern because it is the older age classes that tend to be reduced in extent the most by short harvest rotation practices designed to maximize timber yields. This places great emphasis on the need to improve forest management strategies to address the growing impact of habitat modification on biological diversity, particularly in the boreal forest (Burton et al. 2006, Bradshaw et al. 2009).

For species closely associated with mature and old forest stands, such as the Boreal Owl (*Aegolius funereus*; Hayward and Hayward 1993) the loss or degradation of forest habitat may lead to significant changes in patterns of use (Hinam 2001), yet detailed knowledge of such interactions is limited for this and many other boreal forest specialists (Schmiegelow and Mönkkönen 2002). As obligate secondary cavity nesters, forest harvesting is closely tied to the loss of nesting habitat (Martin and Eadie 1999, Niemelä 1999). Along with availability of suitable nest sites, prey abundance is another significant predictor of habitat quality for this small-mammal specialist (Korpimäki 1992). Thus forestry operations can adversely affect adult survival (Hakkarainen et al. 2008), but it is not clear how Boreal Owls respond to habitat loss (and possible lowered habitat quality).

One useful tool used by natural resource managers and decision makers to manage wildlife is the habitat suitability index (HSI) model (Brooks 1997). This process ranks habitats in a given region on a numerical scale from least to most suitable for a target species and enables an assessment of the resulting distribution and extent of suitable habitat. During 2004, a HSI model was developed for the Boreal Owl as part of a set of tools for the Western Newfoundland Model Forest (a consortium of industry, government and non-government organizations) as the basis for recommending forest harvesting strategies that would sustain regional biodiversity (Dolter 2005). The model was built using data from across the species' North American range since adequate local data were not available for Boreal Owls in Newfoundland (Côté et al. 2004). The Boreal Owl was chosen as one focal species for this process because of its close association with mature forests and consequent perceived susceptibility to harvesting (Hayward 1997, Koopman et al. 2007). No data on Boreal Owls in Newfoundland were available to build the initial model, as the species had previously only received limited attention on the island. Despite the Boreal Owl's extensive use of contiguous, old-growth forest across much of its range in North America (Bondrup-Nielsen 1978, Palmer 1986, Ryder et al. 1987, Hayward 1989, Holt and Ermatinger 1989), this species persists in western Newfoundland where the landscape is naturally highly fragmented and dominated by small stature, slow growing, balsam fir (*Abies balsamea*; Rowe 1972, Thompson et al. 2003) and stand senescence is relatively early at about 100 yr (Moroni 2006).

Working in balsam fir-dominated forests of western Newfoundland, Canada, the objectives of this project were to: 1) assess the habitat use and home range size of Boreal Owls (Chapter 2), 2) test the most sensitive parameters of the HSI model to examine the model's predictive capabilities, and 3) assess habitat suitability across occupied and unoccupied sites and over time (Chapter 3). Given the highly fragmented nature of the landscape in western Newfoundland I predicted that owl home ranges would be larger in this region than compared to other areas of North America. I also predicted that due to the lack of local data used to create the HSI model, the updated model would more accurately reflect the habitat use patterns of the local population and result in a higher amount of presumed suitable habitat over time. I conducted these studies through point counts, radio-telemetry tracking and GIS-based analysis of the habitat and HSI data. Both data-based chapters were written in the format of complete manuscripts which could be submitted to the peer-reviewed Journal of Raptor Research.

1.1 REFERENCES

ANDRÉN, H. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: A review. *Oikos* 71:355-366.

BETTS, M.G., G.J. FORBES, A.W. DIAMOND, AND P.D. TAYLOR. 2006. Independent effects of habitat amount and fragmentation on songbirds in a forest mosaic: an organism-based approach. *Ecological Applications* 16:1076-1089.

BONDRUP-NIELSEN, S. 1978. Vocalizations, nesting, and habitat preferences of the Boreal Owl (*Aegolius funereus*) in North America. M.S. thesis. Univ. Toronto, ON, CA.

BRADSHAW, C.J.A., I.G. WARKENTIN, AND N.S. SODHI. 2009. Urgent preservation of boreal carbon stocks and biodiversity. *Trends in Ecology & Evolution* 24:541-548.

BROOKS, R.P. 1997. Improving habitat suitability index models. *Wildlife Society Bulletin* 99:82-88.

BURGESS, R.L. AND D.M. SHARPE (EDS.). 1981. Forest island dynamics in man-dominated landscapes. Springer, New York, NY, USA.

BURT, W.H. 1943. Territoriality and home range concepts as applied to mammals. *Journal of Mammalogy* 24:346-352.

BURTON, P.J., C. MESSIER, W.L. ADAMOWICZ, AND T. KUULUVAINEN. 2006. Sustainable management of Canada's boreal forests: Progress and prospects. *Écoscience* 13:234-248.

CÔTÉ, M., F. DOYON, AND N. BERGERON. 2004. Spatially explicit habitat suitability index model for the Boreal Owl (*Aegolius funereus*) in western Newfoundland, version 2. Institut Québécois d'Aménagement de la Forêt Feuillue. Ripon, Québec, CA.

DOLTER, C.S. 2005. Using biodiversity indicators to assess the success of forecasting adaptive ecosystem management: the Newfoundland and Labrador experience *in* C. Aguirre-Bravo, P.J. Pellicane, D.P. Burns, and S. Draggan. [EDS.], Monitoring Science and Technology Symposium: Unifying knowledge for sustainability in the western hemisphere. Proceedings RMRS-P-42CD. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO, USA.

FAHRIG, L. 1998. When does fragmentation of breeding habitat affect population survival? *Ecological Modelling* 105:273-292.

HAKKARAINEN, H., E. KORPIMÄKI, T. LAAKSONEN, A. NIKULA, AND P. SUORSA. 2008. Survival of male Tengmalm's owls increases with cover of old forest in their territory. *Oecologia* 155:479-486.

HASKELL, J.P., M.E. RITCHIE, AND H. OLFF. 2002. Fractal geometry predicts varying body size scaling relationships for mammal and bird home ranges. *Nature* 148:527-530.

HAYWARD, G.D. 1989. Habitat use and population biology of Boreal Owls in the Northern Rocky Mountains, USA. Ph.D. dissertation, Univ. Moscow, ID, USA.

HAYWARD, G.D. 1997. Forest management and conservation of Boreal Owls in North America. *Journal of Raptor Research* 31:114-124.

HAYWARD, G.D. AND P.H. HAYWARD. 1993. Boreal Owl (*Aegolius funereus*), In A. Poole [ED.], The Birds of North America Online Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu.qe2a-proxy.mun.ca/bna/species/063

HINAM, H.L. 2001. Habitat associations of five forest owl species in Manitoba Escarpment with special consideration to forest fragmentation and slope. M.Sc. thesis, Univ. Manitoba. Winnipeg, MB, CA.

HINAM, H.L. and C.C. ST. CLAIR. 2008. High levels of habitat loss and fragmentation limit reproductive success by reducing home range size and provisioning rates of Northern saw-whet owls. *Biological Conservation* 141:524-535.

HOLT, D.W. AND D. ERMATINGER. 1989. First confirmed nest site for Boreal Owls in Montana. *Northwest Naturalist* 70:27-31.

IMBEAU, L., M. MÖNKKÖNEN, AND A. DESROCHERS. 2001. Long term impacts of forestry on birds of the eastern Canadian boreal spruce forests: What can we learn from the Fennoscandian experience? *Conservation Biology* 15:1151-1162.

JENKINS, S.H. 1981. Common patterns in home range-body size relationships of birds and mammals. *American Naturalist* 118:126-128.

KIRK, D.A. 1995. Status report of the Boreal Owl *Aegolius funereus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON, CA.

KOOPMAN, M.E., G.D. HAYWARD, AND D.B. MCDONALD. 2007. High connectivity and minimal genetic structure among North American Boreal Owl (*Aegolius funereus*) populations, regardless of habitat matrix. *Auk* 124:690-704.

KORPIMÄKI, E. 1992. Fluctuating food abundance determines the lifetime reproductive success of male Tengmalm's owls. *Journal of Animal Ecological* 62:606-613.

LEONARD, T.D., P.D. TAYLOR, AND I.G. WARKENTIN. 2008. Space use by songbirds in naturally patchy and harvested boreal forests. *Condor* 110:467-481.

MARTIN, K. AND J.M. EADIE. 1999. Nest webs: A community-wide approach to the management and conservation of cavity-nesting forest birds. *Forest Ecology and Management* 115:243-257.

MORONI, M.T. 2006. Disturbance history affects woody debris dynamics of Newfoundland balsam fir (*Abies balsamea*) stands. *Canadian Journal of Forest Research* 36:3194–3208.

NIEMELÄ, J. 1999. Management in relation to disturbance in the boreal forest. *Forest Ecology and Management* 115:127-134.

PALMER, D.A.1986. Habitat selection, movements and activity of Boreal and Saw-whet owls. M.S. thesis, Colorado State Univ., Ft. Collins, CO, USA.

POWELL, R.A., J.W. ZIMMERMAN, AND D.E. SEAMAN. 1997. Ecology and behavior of North American black bears; home ranges, habitat and social organization. Chapman and Hall, London, UK.

RAPPOLE, J.H. 1996. The importance of forest for the world's migratory bird species *in* M. J. Soulé [ED.], Conservation of faunal diversity in forested landscapes. Chapman and Hall, New York, NY, USA.

REDPATH, S.M. 1995. Habitat fragmentation and the individual: Tawny owls in woodland patches. *Journal of Animal Ecology* 64:652-661.

ROWE, J.S. 1972. Forest regions of Canada. Department of Fisheries and Environment, Ottawa, ON, CA.

RYDER, R.A., D.A. PALMER, AND J.J. RAWLINSKI. 1987. Distribution and status of the boreal owl in Colorado. Pages 169-174 *in* R.W. Nero, R.J. Clark, R.J. Knapton, and

R.H. Hamre [EDS.], Biology and conservation of northern forest owls. USDA Forest Service Gen. Tech. Rep. RM- 142. Fort Collins, CO, USA.

SCHMIEGELOW, F.K.A., AND M. MÖNKKÖNEN. 2002. Habitat loss and fragmentation in dynamic landscapes: avian perspectives from the boreal forest. *Ecological Applications* 12:375–389.

SCHOENER, T.W. 1968. Sizes of feeding territories among birds. *Ecology* 49:123-141.

SMITH, W. AND P. LEE (EDS.). 2000. Canada's forests at a crossroads: An assessment in the year 2000. World Resources Institute, Washington, DC, USA.

ST-LAURENT, M-H., C. DUSSAULT, J. FERRON, AND R. GAGNON. 2009. Dissecting habitat loss and fragmentation effects following logging in boreal forest: Conservation perspectives from landscape simulations. *Biological Conservation* 142:2240-2249.

THOMPSON, I.D., D.J. LARSON, AND W.A. MONTEVECCHI. 2003. Characterization of old "wet boreal" forests, with an example from balsam fir forests of western Newfoundland. *Environmental Reviews* 11:S23-S46.

2.0 HOME RANGE AND ROOST SITE HABITAT CHARACTERISTICS OF BOREAL OWLS (*AEGOLIUS FUNEREUS*) IN WESTERN NEWFOUNDLAND

2.1 ABSTRACT

I examined home range and habitat characteristics of male Boreal Owls (*Aegolius funereus*) in western Newfoundland, as reflected through roost site locations. I determined differences in Boreal Owl habitat use versus forest habitat availability by conducting a compositional analysis of habitat use within home ranges and at the smaller roost-site scale. Based on nine male Boreal Owls captured during the study period, I determined 86 roosting locations. Owls roosted primarily in balsam fir (*Abies balsamea*) trees, but also used black and white spruce (*Picea mariana* and *glauca,* respectively) as well as standing dead snags of unknown species. Stand age at roost sites was categorized primarily as mature, over-mature, or a mixture of both. Home ranges were 429 ha (median; n = 8; range = 0.3-2138.0 ha) during the breeding season. Based on log-ratio compositional analysis, Boreal Owls selected roost sites in mature to over-mature coniferous stands most strongly, followed by young coniferous stands; they avoided mature to over-mature mixedwood stands, scrub and bog habitats. For home ranges, mature-old softwood and disturbed stands were used most, while mixedwood and hardwood stands were avoided.

2.2 INTRODUCTION

Home range characteristics and habitat use reflect the resources needed to support an individual's foraging and reproductive activities (Morse 1980, Powell 2000). Broadly, these factors will influence where an individual may settle across the landscape. Theory also predicts the ideal dimensions of individual home ranges will minimize energy expenditure and predation risk but maximize energy gain to meet the metabolic needs of the occupant (McNab 1963, Gittleman and Harvey 1982, Mace and Harvey 1983). While space use needs generally increase with body size (Jetz et al. 2004), avian home range sizes vary greatly depending upon characteristics such as life history pattern. Carnivorous birds in particular require a much larger area to obtain sufficient food than an omnivorous bird of the same size (Schoener 1968; Peery 2000).

Home range size is also inversely proportional to habitat quality (Newton 1979, Leary et al. 1998, Haskell et al. 2002). Decreases in forest cover due to timber harvesting may reduce habitat quality for some forest birds, leading to larger home ranges (Drolet et al. 1999, Haskell et al. 2002, Leonard et al. 2008) and more generally, can adversely affect individual fitness and population viability (Mazur et al. 1998, Griesser et al. 2007, Hakkarainen et al. 2008).

Habitat loss and forest fragmentation are perceived to lead to declines of forest bird populations (Rappole 1996, Schmiegelow and Mönkkönen 2002), but the precise mechanisms remain poorly understood. Studies have suggested strong correlations between habitat alteration and species loss (Harris and Reed 2002, Betts et al. 2006), but responses are species specific (McGarigal and McComb 1995, Trzcinski et al. 1999), with changes in abundance being related to the manner in which the resulting altered habitat matches the needs of a particular species (St-Laurent et al. 2009). For habitat specialists such as the Boreal Owl (*Aegolius funereus*) the loss or degradation of forest habitat may lead to significant changes in patterns of use (Hinam 2001), but detailed knowledge of such interactions is limited, as it is for many such boreal forest specialists (Schmiegelow and Mönkkönen 2002).

Habitat-use models developed by Sleep (2005) demonstrated differences in response by Boreal Owls in Ontario to fire versus harvest-originating landscapes. But those models developed for one disturbed landscape failed to accurately predict owl locations on the alternate landscape, indicating that Boreal Owls may behave differently depending on the source of disturbance events that created a particular landscape (Sleep 2005). Further, Hakkarainen et al. (2008) found that forestry operations adversely affected adult survival, but it was not clear whether Boreal Owls responded to the habitat loss (and potentially lowered habitat quality) associated with forestry by altering their population density through increased home range size.

As obligate secondary cavity nesters, suitably large cavities for Boreal Owls are found exclusively in older large-diameter trees, when nest boxes are not available (Hayward et al. 1993). Thus harvesting is closely tied to the loss of nesting habitat because forests with trees large enough for cavities suited to Boreal Owls are also prime candidates for harvesting (Wallin et al. 1996, Martin and Eadie 1999, Niemelä 1999). In North America, the Boreal Owl nests mainly in cavities excavated by Pileated Woodpeckers (*Dryocopus pileatus*) and Northern Flickers (*Colaptes auratus*) and are thought to require nesting trees with a minimum diameter at breast height (dbh; at 1.3 m) of 33 cm (Hayward et al. 1993). In eastern Canada, cavity availability is likely a limiting factor for Boreal Owls, primarily due to the restricted availability of large-diameter trees (Kirk 1995). This may be exacerbated on the island of Newfoundland where only the Northern Flicker provides cavities large enough for Boreal Owl nests, and intensive timber management removes many of the large diameter trees and snags which are used by flickers for cavity excavation (Smith et al. 2008). Likewise, cavity availability in Europe is the main limiting factor determining habitat use for Boreal Owls due to the dramatic decline in Black Woodpeckers (*Dryocopus martius*), which previously supplied most of the nest sites (Korpimäki 1981, Lofgren et al. 1986).

Despite the Boreal Owl's extensive use of contiguous, old-growth forest across much of its range in North America (Bondrup-Nielsen 1978, Palmer 1986, Ryder et al. 1987, Hayward 1989, Holt and Ermatinger 1989), this species persists in western Newfoundland where the landscape is naturally highly fragmented and dominated by small stature, slow-growing, balsam fir (*Abies balsamea*; Rowe 1972, Thompson et al. 2003).

In 2006 and 2007, I determined the home range and habitat use of male Boreal Owls in this population, as reflected through roost site locations, in the context of both natural (i.e., insect kills and blowdowns) and anthropogenic (i.e., logging) disturbance. Given the highly fragmented nature of the balsam fir dominated forests in western Newfoundland and the constraints on cavity availability, I predicted that Boreal Owl home ranges would be at the high end of the 229 to 2386 ha range (Hayward et al. 1993, Lane 1997, Belmonte 2005) recorded for individuals in other populations across North America. I examined differences in Boreal Owl habitat use versus forest habitat availability (*sensu* Manly et al. 2002) by conducting a compositional analysis of habitat use within home ranges based on diurnal roost locations during the breeding season. Given that alternative patterns of habitat selection may occur at different spatial scales (Johnson 1980, Aebischer et al. 1993), I also conducted a compositional analysis of the habitat characteristics at the smaller roost-site scale.

2.3 METHODS

2.3.1 Study Area

My study focused on Forest Management District 15 (Fig. 2.1), which encompasses approximately 560,000 hectares of the Western Newfoundland Ecoregion (Damman 1983, Meades and Moores 1994) on the island of Newfoundland, Canada (48°95'N, 57°95'W). This region has a humid climate and relatively long frost-free period compared to other areas of the island, with a mean summer and winter daytime high of 17°C and -6°C, respectively, and annual precipitation of ~1200 mm (Damman 1983). District 15 is heavily forested and has rugged topography underlain by slate and limestone till. Together with the climate, the underlying soils produce conditions that have resulted in the most favorable area for plant growth on the island (Damman 1983, Meades and Moores 1994).

Forests in District 15 are dominated by conifers, mainly balsam fir, with scattered patches of black spruce (*Picea mariana*) that are usually restricted to poorly drained sites and bedrock outcrops (Damman 1983). White spruce (*Picea glauca*), white birch (*Betula papyrifera*), white pine (*Pinus strobus*), red maple (*Acer rubrum*), and eastern larch (*Larix laricina*) also occur at low densities. The dbh in balsam fir-dominated forests is generally <30 cm and senescence usually begins before stands reach 100 yr (Moroni 2006). The forest harvest rotation in Newfoundland is 60–120 yr (S. Balsom, Corner

Brook Pulp and Paper, pers. comm. 2006). Harvesting for paper production began in 1924, although small-scale harvesting has occurred for other purposes since the late 1800s. Many sections of the district have had some level of previous forest harvesting and as of 2003, approximately 24,000 ha of forested land was less than 25 yr of age (K. Powell, Government of Newfoundland and Labrador, pers. comm. 2006). The amount of old growth forest (80+ yr) in Newfoundland has declined with a shift in forest management towards a 60-yr rotation age that may reduce the availability of old forests as wildlife habitat (Thompson et al. 1999).

2.3.2 Habitat Classification

Forest inventory data were obtained from aerial photography collected each year of the study; these data were digitized and classified by the Forest Resources division of the Department of Natural Resources, Government of Newfoundland and Labrador. Forest age and type affect Boreal Owl distribution (Hayward et al. 1993, Lane et al. 1997), so all forest stands were identified by general classification type and age class whenever possible, creating eight categories for these analyses (disturbed, bog, scrub, hardwood, young mixedwood, mature to old mixedwood, young softwood, mature to old softwood; see Table 2.1 for descriptions). It was necessary, due to sample size limitations, to reduce the number of age and stand type parameters from those available in the original dataset (21) to those listed here. These categories were chosen as they reflect biologically relevant habitat for Boreal Owls. Stand ages were grouped based on the notion that Boreal Owls prefer mature to old growth forests (Bondrup-Nielsen 1978, Meehan and Ritchie 1982, Hayward et al. 1993, Lane 1997, Belmonte 2005). Although harvest in this region has typically been restricted to 80+ yr old stands, the recent shift to harvesting on a 60-yr rotation period in high-productivity sites makes it important to examine forest stands 60 yr and greater as one group, hence my pooling of habitat types into those less than or greater than 60 yr.

2.3.3 Study Species

Boreal Owls are small nocturnal raptors with a circumboreal distribution (Hayward et al. 1993) that typically nest in forest stands classified as mature or old growth (Hayward 1994). Due to their small size, secretive nocturnal habits, and relatively large home ranges (up to 2386 ha), little is known about the habitat associations and requirements of the Boreal Owl in North America (Hayward et al. 1993, Lane 1997, Hinam 2001). Based on studies conducted in western and central North America, Boreal Owls tend to be found most often in mature conifer and mixed-wood forests dominated by black spruce, white spruce, balsam fir, as well as areas with substantial stands of balsam poplar (*Populus balsamea)*, trembling aspen (*Populus tremuloides*) and white birch (Bondrup-Nielsen 1978, Meehan and Ritchie 1982, Hayward et al. 1993). Although little is known about Boreal Owl habitat associations from eastern Canada, Bondrup-Nielsen (1978) suggested that they require lowland conifer forests for foraging and roosting but deciduous forests for nesting, with a preference for old forest stands. These forests provide larger diameter trees, facilitating cavity excavation by woodpeckers (Hayward 1994). In Scandinavia, Boreal Owls nest in pine (*Pinus* spp.), spruce (*Picea* spp.), or birch (*Betula* spp.) dominated forests (Norberg 1964, Korpimäki 1981, Solheim 1983), and have been extensively studied through the provisioning of nest boxes (Lofgren et al. 1986, Hayward et al. 1993, Hakkarainen et al. 2001). These studies suggest that mature (60+ yr) spruce forests are important for foraging, particularly in the winter, whereas clearcuts and cultivated fields are used as foraging grounds in the spring (Sonerud 1986, Korpimäki 1988). In France, Boreal Owls use "mountain pine" (*Pinus uncinata* and *P. sylvestris*) forest and mature beech (*Fagus* spp.) stands (Dejaifve et al. 1990) while conifer forests are used for nesting in Germany (König 1969, Jorlitschka 1988).

Prey abundance is a significant predictor of habitat quality for this small-mammal specialist (Korpimäki 1992, Hayward et al. 1993, Hakkarainen et al. 1997a). Foraging habitats in the Rocky Mountains are comprised mainly of mature spruce-fir stands (Hayward et al. 1993), while mature spruce forests are also used for foraging in Norway (Sonerud 1986). These old growth forests are the preferred habitat for red-backed voles (*Clethrionomys gapperi*), one of the Boreal Owl's main food sources (Korpimäki 1981, Hayward et al. 1993). In British Columbia, Sullivan et al. (1999) and Klenner and Sullivan (2003) found red-backed voles to be much more abundant in forested sites than in clearcuts. Moves by owls from forest into open habitat during spring have been linked to temporary increases in the relative availability of small-mammal prey (Hayward et al. 1993). Populations of the traditional prey based for Boreal Owls in Newfoundland (meadow voles, *Microtus pennsylvanicus terraenovae*) occur at very low densities in both open (Folinsbee et al. 1973, B. Rodrigues 2008, unpubl. data) and forested habitat (Thompson and Curran 1995, Sturtevant and Bissonette 1997). However the introduction of red-backed voles to the island in the late 1990s has increased the potential prey base in coniferous forests habitat (Hearn et al. 2006, B. Rodrigues 2008 unpubl. data).

In eastern Canada, the Boreal Owl is thought to start breeding in late April or early May (Gagnon and Bombardier 1995, Lauff 2009), versus late February or early

March in Finland (Korpimäki 1981; Table 2.2). During the late winter/early spring the male will search for nesting cavities. Pair formation begins with singing and, toward the end of courtship, owls rendezvous at potential nest sites where the male deposits food items (Palmer 1986, Hayward 1989). Male Boreal Owls may traverse several kilometers during nocturnal foraging bouts, returning to the nest several times each night to feed the female and young (Korpimäki 1981, Hayward 1989). Hayward et al. (1993) found that Boreal Owls do not return to the same roost on consecutive nights but rather shift from roost to roost over time. Because daytime roosts are thought to represent the end of night-time foraging bouts, locations of consecutive daytime roosts suggest the magnitude of minimum travel distances (Hayward et al. 1993). For a study based in Ontario, 30% of 30 roost sites were in birch or aspen, with the remainder in conifers (Bondrup-Nielsen 1978). In Colorado, all 174 roost sites were located in conifer trees (Palmer 1986).

2.3.4 Trapping and Telemetry

Potential capture locations were identified from point counts conducted for related research on the region-wide distribution of Boreal Owls (see Chapter 3). Thus I captured male owls at locations where they were calling throughout District 15, from April through June in 2006 and 2007 using 6- and 9-m mist-nets set in a V-shape with playback equipment (Nexxtech boombox at 112 dB) and a taxidermic mount of a Boreal Owl placed at the base of the V (Bull 1987). A playback of Boreal Owl *staccato* calls (Bondrup-Nielsen 1978) was broadcast in all cases, and a Boreal Owl mount was used twice to lure owls into the nets. Captured owls were banded with numbered aluminum lock-on bands (CWS Bird Banding Office 2011) and fitted with a 3.0 g radio transmitter (model PD-Z; Holohil Systems Ltd., Carp, ON). The transmitter was attached using the harness method of Rappole and Tipton (1991). Owls were released on site and their locations monitored using a receiver and a 2-element yagi antenna (model TR-4; Telonics Inc., Mesa, AZ), after a minimum 24-hr adjustment period. Diurnal relocation was accomplished by following the signal to the perch tree accessed on foot using available logging roads and various trails to facilitate travel. Helicopter-mounted receivers were also used in 2006 to locate three radio-tagged Boreal Owls that had either strayed away from their usual location or when the transmitter had a reduced range (<500 m). Roost location coordinates were determined using a handheld global positioning system (model GPSmap76; Garmin Ltd., Olanthe KS). The radio-tagged owls were followed for a maximum of three months.

2.3.5 Roost Site Characteristics

For each roost site I determined the roost tree species, dbh (to nearest cm) and estimated average % canopy cover (to the nearest tenth) using a spherical densiometer held facing outwards from the base of the tree for each cardinal direction. A clinometer was used to measure average, maximum stand height within a 11.3 m radius of the roost tree, which along with an assessment of species composition was used to infer stand age and type for the plot. This was later confirmed using provincial forest inventory maps. To ascertain differences in roost site characteristics associated with each species of tree used as a roost site, I used Mood's multi-sample median test (Minitab 2007) followed by a Tukey-type test for multiple comparisons among medians to isolate significant differences among groups (Zar 1999).

2.3.6 Home Range Size

Boreal Owls tend to roost in close proximity to the location of their last foraging session for the night, rather than consistently returning to a particular roost or set of roost trees (Hayward et al. 1987), so this scatter of points can be used to estimate their home range. I calculated home range size for each radio-tagged male using the minimum convex polygon (MCP) tool of Animal Movement Analysis extension (Hooge and Eichenlaub 1997) for Arcview 3.2 (ESRI Redland CA). To compare the relative amount of the different habitat types present in actual home ranges with the habitat available throughout the study area, I used the Animal Movement extension of Arcview to create 80 home range areas which matched the largest reported Boreal Owl home range size in North America (Hayward et al. 1993). From these, 40 were chosen at random to act as surrogate home ranges representing available habitat in the study area while eliminating the possibility of overlap; excluded were any surrogates with more than the average amount of surface water (lakes, ponds and rivers) in the actual owl MCP home ranges, and those with any residential areas. An asymptotic analysis was conducted on the three owls with the highest number of relocations to determine if home range size plateaued within the number of relocations in this study.

2.3.7 Home Range Composition

The proportional composition of habitat types in actual and surrogate random home ranges was analyzed using the log-ratio compositional analysis method (Aebischer et al. 1993). This approach focuses on habitat comparisons assessing the ratio of two habitat types relative to selection for all other types, to avoid the "unit sum constraint" (Aebischer et al. 1993). Analyses were conducted using the program Smith Ecology

Compos Analysis (version 6.2 std.; Smith 2008) which uses a Kruskal-Wallis test to assess differences between observed and expected habitat selections based on a matrix that ranks the importance of habitat types. To assess fine scale habitat selection, I also compared the habitat immediately around each owl roost-site with that available in the random surrogate home ranges. As with the analysis of actual home ranges, these analyses were based on the log-ratio compositional analysis method (Aebischer et al. 1993). Statistics were performed using Minitab (2007) and SPSS (version 11.5; Norusis 2002). Statistical significance was determined at $\alpha = 0.05$ unless otherwise stated.

2.4 RESULTS

Based on nine male Boreal Owls captured during the study period, I determined 86 roosting locations (Table 2.3). Three individuals provided the majority (62%) of locations; these plus two other owls were tracked over periods of 3-3.5 mo. Four Boreal Owls either lost or removed their radio transmitters within days or weeks of attachment; one individual (removed from the home range analysis) provided only two roost locations before the transmitter was lost. Six roost sites were eliminated from analysis due to incomplete field data. Two individuals made substantial shifts in their home range location during the monitoring period.

2.4.1 Roost Site Characteristics

Male Boreal Owls in western Newfoundland roosted primarily in balsam fir trees, but also used black and white spruce as well as standing dead snags of unknown species (Table 2.3). Diameter at breast high differed significantly among groups (Mood's multisample median test: $X^2 = 10.33$, $p = 0.016$; Table 2.4). White spruce was significantly larger than all other species. Balsam fir was significantly different than unknown roost tree species. The canopy cover at roost sites also differed significantly among groups ($X^2 = 8.84$, $p = 0.031$; Table 2.4). Stand age was categorized primarily as mature (52%) to overmature (24%), or a mixture of both (20%) at roost site locations.

2.4.2 Home Range Size

Male Boreal Owl home ranges were 429 ha (median; n = 8; range = 0.3-2138.0 ha) during the sampling period. Removing the two owls with the fewest roost sites locations (BOOW18 = five roost site locations and BOOW19 = four roost site locations) increased home range size to a median of 516 ha (n = 6; range = 54.6-2138.0 ha). The two owls with the largest home ranges (BOOW12 and BOOW16) moved large distances during the season and had to be relocated via helicopter. BOOW16 moved 12.4 km to a new home range area sometime during 14-27 July while BOOW12 moved 13.3 km to a new area sometime during 1 June to 27 July, but after relocation both remained in the new areas. Pre-shift home range size for BOOW16 was 206 ha (n = 13) and post-shift was 62 ha (n = 5). BOOW12 only had two pre-shift telemetry relocations therefore pre-shift home range size could not be calculated, but post-shift home range size was 6 ha (n = 5). Overall, home range size gradually increased with greater number of diurnal relocations for male Boreal Owls (Fig. 2.2).

2.4.3 Roost Site Habitat and Home Range Composition

Based on log-ratio compositional analysis, Boreal Owls did not occupy roost-sites at random ($\Delta = 0.0091$; $X^2 = 37.57$, $p < 0.0001$). Compared with available habitat, Boreal Owls selected mature to over-mature coniferous stands most strongly, followed by young coniferous stands; they avoided mature to over-mature mixedwood stands, scrub and bog habitats for roosting habitat (Table 2.5). Based on log-ratio analysis, Boreal Owl home range habitat composition differed significantly from that of random home ranges ($\Delta = 0.0268$; $X^2 = 28.95$, $p = 0.0001$). A simplified ranking matrix ordered the habitat types in the sequence of preference and ranked habitat types from least to most utilized (Table 2.6). For male Boreal Owl home ranges, mature-old softwood and disturbed stands were used most, while mixedwood and hardwood stands were avoided.

2.5 DISCUSSION

Male Boreal Owls in western Newfoundland occupy breeding season home ranges that are composed disproportionately of disturbed forest stands and patches of older, coniferous trees. Their roost sites were most often located in mature-older forest stands characterized by a high density of small dbh coniferous trees with a limited presence of deciduous trees. These findings are consistent with the characterization of Boreal Owls as requiring a high amount of cover provided by coniferous trees (Hayward et al. 1987) and preferentially selecting landscapes containing uniform coniferous stands with natural openings and clear-cuts close to the forest edge for both nesting and non-nesting activities (Bondrup-Nielsen 1978, Palmer 1986, Hayward 1989, Belmonte 2005).

My home range size estimate is intermediate to those reported for Boreal Owls across North America (Table 2.7). With the exception of the work of Hayward et al. (1993), these studies are all plagued by extremely limited samples sizes. Lane (1997) reported the largest average home range size and speculated that increased movements following nest failure might have influenced his home range size calculation; with estimates averaging 425 ha prior to nest failure. When only paired male Boreal Owls (prior to nest failure) are considered, the average documented home range is 318 ha (range: 142 – 445 ha; Bondrup-Nielsen 1978, Palmer 1986, Jacobsen and Sonerun 1987, Lane 1997, Belmonte 2005). The median home range in the current study, 429 ha, is on the higher end of the range for male Boreal Owls. Only one owl in the current study had a documented nest, but lost his transmitter prior to the nest failing, making it impossible to determine whether any of the large home range estimates in the current study were due to nest failure or failure to mate. Two owls moved large distances during the breeding season (12.4 km and 13.3 km), suggesting that these owls had failed nests or failed to find a mate and relocated due to resource or subsequent breeding needs. Although based on limited information, home ranges are expected to decrease during the breeding season (Palmer 1986, Lane 1997) when the male is the primary food provider during the nesting phase and the female is confined to the cavity tree (Hayward 1994). Similar patterns of seasonal changes in home range size have been found for Eastern Screech Owls (*Megascops asio*; Smith and Gilbert 1984), Barred Owls (*Strix varia*; Fuller 1979, Hamer 1988, Mazur et al. 1998), Great Horned Owls (*Bubo virginianus*; Fuller 1979) and Spotted Owls (*Strix occidentalis*; Glenn et al. 2004). Under these circumstances, males must return to the nest site several times a night, limiting the distance they are able to travel for food. Unpaired males and those associated with failed nests are not confined to the proximity of nest, potentially resulting in an increased home range size. This has been studied to some extent in Eastern Screech Owls and Spotted Owls where, after nest failure or predation of the female, males began to range more widely (Smith and Gilbert 1984, Ganey and Balda 1989).

Estimates of home range size based on frequent re-locations require a minimum number of points in order to be considered valid. It has been suggested that between 10 and 20 diurnal roost site locations were necessary to estimate home range size for Boreal

Owls in Norway (Jacobsen and Sonerud 1987). Home ranges during the breeding season for barred owls reach asymptotic size at approximately 20 locations (Mazur et al. 1998). As mentioned earlier, removal of home range estimates for individuals based on very small sample sizes (three or four sites) does affect the overall mean home range estimate. Past Boreal Owl telemetry studies have obtained an average of between 10 – 20 diurnal relocations per bird (Jacobsen and Sonerud 1987, Hayward et al. 1993, Lane 1997, Belmonte 2005). When taking into consideration only paired male Boreal Owls, the home range size reported in this study is in keeping with the prediction that, due to resource needs, Boreal Owls in western Newfoundland require larger home ranges than in other parts of North America. Decreases in forest cover due to timber harvesting may reduce habitat quality (Drolet et al. 1999, Haskell et al. 2002, Leonard et al. 2008). A lack of suitable nesting cavities due to forest activities added to the need for specific foraging and roosting habitat is likely the cause of larger home ranges. Boreal Owls in this study used mature and old growth, homogenous coniferous forests for roosting. This suggests that these habitat types provide adequate protection from predators. This increased cover may also provide habitat for key prey populations, such as small rodents (Birney et al. 1976, Hakkarainen et al. 1997a).

Although my results are constrained by primarily reflecting the behaviour of three individuals, my results match those of other studies. Roost sites were located almost exclusively in live, coniferous trees with balsam fir and black spruce the predominant roost tree types. Bondrup-Nielsen (1978), Palmer (1986), Hayward et al. (1993), Lane (1997) and Belmonte (2005) all reported that Boreal Owls roosted almost strictly in conifers. Balsam fir may be preferred for roosting because there are few needles and branches close to the trunk where owls tended to roost, but needles and branches are abundant on the outer portion of the trees thus providing adequate cover (Bondrup-Nielsen 1978). Canopy cover ranged from an average of 67% for balsam fir to 78% for black spruce for 91% of the roost sites in this study, which corresponds to the range of 58-63% in Idaho (Hayward et al. 1993). Dense conifer stands are thought to provide better protection from predators and also appear to provide cooler temperatures for Boreal Owls, particularly during summer months (Hayward et al. 1993).

Boreal Owls in this study avoided mixedwood stands and seemed to prefer mature-over mature softwood stands and disturbed forests for foraging. In eastern Canada, Boreal Owls are thought to require lowland conifer forests for foraging and roosting, but deciduous forest stands for nesting (Bondrup-Nielsen 1978). Hardwood stands represented a very small proportion of forest cover in the study area and were largely absent from home ranges and roost sites. This contrasts with the results from assessments of Boreal Owls in Ontario and parts of western North America, where deciduous stands are used for nesting (Bondrup-Nielsen 1978, Lane 1997). My findings also contrast those of Korpimäki (1988), Hayward et al. (1993), Hayward (1997), and Lane (1997), which suggested that Boreal Owls in their study populations preferred mixedwood forests of older age classes. Hayward et al. (1993) found that mixedwood forests contained a high number of potential nesting cavities, but supported small numbers of Boreal Owl prey species: red-backed voles and *Microtus* species. Together, this suggests that Boreal Owls in Newfoundland use a different habitat type for nesting, but may also prefer conifer stands due to prey availability. Red-backed voles are most abundant in older conifer forests (Roy et al. 1995) and avoid non-forested stands (Miller and Getz 1972, Martell and Radvanyi 1977). Disturbed forests were ranked as the second-most utilized habitat by Boreal Owls in Newfoundland; often these were sites with insect disturbances, which may facilitate cavity excavation by woodpeckers. Clear-cut forests, classified under the "disturbed" habitat type, also support high numbers of *Microtus* voles (Folinsbee et al. 1973), which were the most common potential prey species available to the Boreal Owl in Newfoundland until recently. Belmonte (2005) found that forest openings (bare ground, grass, agriculture) occurred more frequently within a 500m buffer surrounding cavity sites of Boreal Owls in Minnesota than around comparable random sites. Previous studies in North America have indicated an association between Boreal Owl breeding sites and such forest openings (Meehan and Ritchie 1982, Herran et al. 1996). Similarly, studies in Fennoscandinavia have shown that forest openings provide foraging habitat and prey species for Boreal Owls (Korpimäki 1988, Jacobsen and Sonerud 1993). It has also been suggested that fledgling production was higher in territories that contained more intensive clear-cuts (Hakkarainen et al. 1997b). This may explain the preference for disturbed habitat within Boreal Owl home ranges; but such habitat types were not present at roost site locations in the current study, suggesting different requirements for owls at different spatial scales (cover for roosting but open habitat for foraging).

Boreal Owls traditionally were thought to have specific habitat needs; Hinam (2001) suggested that this species may have the most specific habitat associations of any boreal forest-dwelling owl in Canada. While Boreal Owls in western Newfoundland did not occupy habitat at random and their habitat needs may well be a key determinant of home range size and location, their habitat associations seem to be much more complex in

Newfoundland. As a part of predator-prey systems, raptor habitat associations are often described through their links to the habitat associations of their primary prey (Janes 1985). As secondary cavity nesters, however, Boreal Owls are also limited by suitable nesting habitat. Thus, natural forest fragmentation, along with intensive timber management in western Newfoundland, likely plays a key role in Boreal Owl home-range habitat associations. The more specialized (and varied) an animal's requirements the greater the area it potentially may need to fulfill those requirements (Morse 1980). Boreal Owls in this study area likely require larger home ranges than typically seen for this species in other parts of its range to compensate for the lack of suitable nesting sites, while also occupying large enough areas to contain the habitat that supports their main prey species. These specific habitat needs exemplify the driving forces behind the Boreal Owl's habitat use in western Newfoundland and highlight the need for appropriate forest management. Management recommendations suited to maintaining Boreal Owl populations in western Newfoundland will be addressed in the final chapter of my thesis.

2.6 REFERENCES

AEBISCHER, N.J., P.A. ROBERTSON, AND R.E. KENWARD. 1993. Compositional analysis of habitat use from animal radio-tracking data. *Ecology* 74:1313-1325.

BELMONTE, L.R. 2005. Home range and habitat characteristics of boreal owls in northeastern Minnesota. M.S. thesis, Univ. Minnesota, St. Paul, MN, USA.

BETTS, M.G., G.J. FORBES, A.W. DIAMOND, AND P.D. TAYLOR. 2006. Independent effects of habitat amount and fragmentation on songbirds in a forest mosaic: an organism-based approach. *Ecological Applications* 16:1076–1089.

BIRNEY, E.C., W.E. GRANT, AND D.D. BAIRD. 1976. Importance of vegetative cover to cycles of *Microtus* populations. *Ecology* 57:1043-1051.

BONDRUP-NIELSEN, S. 1978. Vocalizations, nesting, and habitat preferences of the Boreal Owl (*Aegolius funereus*) in North America. M.S. thesis. Univ. Toronto, ON, CA.

BULL, E.L. 1987. Capture techniques for owls. Pages 291-293 *in* R.W. Nero, R.J. Clark, R.J. Knapton, and R.H. Hamre [EDS.], Proceedings of biology and conservation of northern owls. Gen. Tech. Rep. RM-142. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO, USA.

CANADIAN WILDLIFE SERVICE 2011. Bird Banding Office. Environment Canada, Ottawa, ON, CA.

DAMMAN, A.W.H. 1983. An ecological subdivision of the Island of Newfoundland *in* G.R. Smith [ED.], Biogeography and Ecology of the Island of Newfoundland. Dr W. Junk Publishers, The Hauge, Netherlands.

DEJAIFVE, P.A., C. NOVOA, AND R. PRODON. 1990. Habitat et densiti: de la Chouette de Tengmalm *Aegolius funereus* a 1'extremite orientale des Pyrenees. *Alauda* 58:267-273.

DROLET, B., A. DESROCHERS, AND M.J. FORTIN. 1999. Effects of landscape structure on nesting songbird distribution in a harvested boreal forest. *Condor* 101:699-704.

FOLINSBEE, J.D., R.R. RIEWE, W.O. PRUITT, AND P.R. GRANT. 1973. Ecological distribution of the Meadow Vole *Microtus pennsylvanicus terraenovae*, (Rodentia: Cricetidae), on the Main Island of Newfoundland. *Canadian Field Naturalist* 87:1-4.

FULLER, M.R. 1979. Spatiotemporal ecology of four sympatric raptor species. Ph.D. dissertation, Univ. Minnesota, St. Paul, MN, USA.

GAGNON, C. AND M. BOMBARDIER. 1995. Chouette rayée. Pages 598-601 *in* J. Gauthier and Y. Aubry [EDS.], Les Oiseaux nicheurs du Québec: Atlas des oiseaux nicheurs du Québec méridional. Association québécoise des groupes d'ornithologues, Société québécoise de protection des oiseaux, Service canadien de la faune, Montréal, QC, CA.

GANEY, J.L. AND R.P. BALDA. 1989. Home-range characteristics of Spotted Owls in northern Arizona. *Journal of Wildlife Management* 53:1159-1165.

GITTLEMAN, J.L. AND P.H. HARVEY. 1982. Carnivore home-range size, metabolic needs and ecology. *Behavioral Ecology and Sociobiology* 10:57-63.

GLENN, E.M., M.C. HANSEN, AND R.G. ANTHONY. 2004. Spotted Owl home-range and habitat use in young forests of western Oregon. *Journal of Wildlife Management* 68:33-50.

GRIESSER, M., M. NYSTRAND, S. EGGERS, AND J. EKMAN. 2007. Impact of forestry practices on fitness correlates and population productivity in an open-nesting bird species. *Conservation Biology* 21:767-774.

HAKKARAINEN, H., P. ILMONEN, AND V. KOIVUNEN. 2001. Experimental increase of predation risk induces breeding dispersal of Tengmalm's owl. *Oecologia* 126:355-359.

———, V. KOIVUNEN, AND E. KORPIMÄKI. 1997a. Reproductive success and parental effort of Tengmalm's owls: effects of spatial and temporal variations in habitat quality. *Écoscience* 4:35-42.

———, E. KORPIMÄKI, V. KOIVUNEN, AND S. KURKI. 1997b. Boreal Owl responses to forest management: a review. *Journal of Raptor Research* 31:125-128.

———, ———, T. LAAKSONEN, A. NIKULA, AND P. SUORSA. 2008. Survival of male Tengmalm's owls increases with cover of old forest in their territory. *Oecologia* 155:479-486.

HAMER, T.E. 1988. Home range size of northern Barred Owls and northern Spotted Owls in western Washington. M.Sc. thesis, Western Washington Univ., Bellingham, WA, USA.

HARRIS, R. AND J.M. REED. 2002. Effects of forest-clearcut edges on a forest-breeding songbird. *Canadian Journal of Zoology* 80:1026–1037.

HASKELL, J.P., M.E. RITCHIE, AND H. OLFF. 2002. Fractal geometry predicts varying body size scaling relationships for mammal and bird home ranges. *Nature* 148:527-530.

HAYWARD, G.D. 1989. Habitat use and population biology of Boreal Owls in the Northern Rocky Mountains, USA. Ph.D. dissertation, Univ. Moscow, ID, USA.

———. 1994. [ED.] Flammulated, boreal and great gray owls in the United States: a technical conservation assessment. U.S. For. Serv. Rocky Mountain Forest and Range Experiment Station. Gen. Tech. Report RM-253. Fort Collins, CO, USA.

———. 1997. Forest management and conservation of Boreal Owls in North America. *Journal of Raptor Research* 31:114-124.

HAYWARD, G.D. AND P.H. HAYWARD. 1993. Boreal Owl (*Aegolius funereus*), In A. Poole [ED.], The Birds of North America Online Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu.qe2a-proxy.mun.ca/bna/species/063

———, ———, AND E.O. GARTON. 1987. Movements and home range use by Boreal Owls in central Idaho. Pages 175-184 *in* R.W. Nero, C.R. Knapton, and R.J. Hamre [EDS.], Biology and conservation of northern forest owls: symposium proceedings. U.S. For. Serv. Gen. Tech. Rep. RM-142. Fort Collins, CO, USA.

———, ———, AND ———. 1993. Ecology of Boreal Owls in the Northern Rocky Mountains, USA. *Wildlife Monograms* 24:3-59.

HEARN, B.J., J.T. NEVILLE, W.J. CURRAN, AND D.P. SNOW. 2006. First record of the southern red-backed vole, *Clethrionomys gapperi*, in Newfoundland: implications for the endangered Newfoundland marten, *Martes americana atrata*. *Canadian Field-Naturalist* 120:50–56.

HERRAN, V., S.H. ANDERSON, AND L.F. RUGGIERO. 1996. Boreal owl mating habitat in the northwest United States. *Journal of Raptor Research* 30:123-129.

HINAM, H.L. 2001. Habitat associations of five forest owl species in Manitoba Escarpment with special consideration to forest fragmentation and slope. M.Sc. thesis, Univ. Manitoba. Winnipeg, MB, CA.

HOLT, D.W. AND D. ERMATINGER. 1989. First confirmed nest site or boreal owls in Montana. *Northwest Naturalist* 70:27-31.

HOOGE, P.N. AND B. EICHENLAUB. 1997. Animal movement extension to arcview. ver. 1.1. Alaska Science Center, Biological Science Office, U.S. Geological Survey, Anchorage, AK, USA.

JACOBSEN, B.V. AND G.A. SONERUD. 1987. Home range of Tengmalm's Owl: A comparison between nocturnal hunting and diurnal roosting. Pages 189-192 *in* R.W. Nero, C.R. Knapton, and R.J. Hamre [EDS.], Biology and conservation of northern forest owls: symposium proceedings. U.S. For. Serv. Gen. Tech. Rep. RM-142. Fort Collins, CO, USA.

——— AND ———. 1993. Synchronous switch in diet and hunting habitat as a response to disappearance of snow cover in Tengmalm's Owl (*Aegolius funereus*). *Ornis Fennica* 70:78-88.

JANES, S.W. 1985. Habitat selection in raptorial birds. Pages. 159-188 *in* M.L. Cody [ED.], Habitat selection in birds. Academic Press, Orlando, FL, USA.

JETZ, W., C. CARBONE, J. FULFORD, AND J.H. BROWN. 2004. The scaling of animal space use. *Science* 306:266-268.

JOHNSON, D.H. 1980. The comparison of usage and availability measurements for evaluating resource preference. *Ecology* 61:65-71.

JORLITSCHKA, W. 1988. Untersuchung zur Habitatstruktur von Revieren des Rauhfusskauzes, *Aegolius funereus. Nordschwarzwald. Die Vogelwelt* 109:152-155.

KIRK, D.A. 1995. Status report of the boreal owl *Aegolius funereus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON, CA.

KLENNER, W. AND T.P. SULLIVAN. 2003. Partial and clear-cut harvesting of high-elevation spruce-fir forests: implications for small mammal communities. *Canadian Journal of Forest Research* 33:2283-2296.

KÖNIG, C. 1969. Six-year observations of a population of Tengmalm's owl, *Aegolius funereus*. *Journal of Ornithology* 110:133-147.

KORPIMÄKI, E. 1981. On the ecology and biology of Tengmalm's Owl (*Aegolius funereus*) in southern Ostrobothnia and Suomenselka, western Finland. *Acta Universitatis Ouluensis A 118 Biology* 13:1-84.

———. 1988. Diet of breeding Tengmalm's Owl (*Aegolius funereus*): long-term changes and year-to-year variation under cyclic food conditions. *Ornis Fennica* 65:21-30.

———. 1992. Fluctuating food abundance determines the lifetime reproductive success of male Tengmalm's owls. *Journal of Animal Ecology* 62:606-613.

LANE, W.H. 1997. Distribution and ecology of boreal owls in northeastern Minnesota. M.S. thesis, Univ. Minnesota, St. Paul, MN, USA.

———, D.E. ANDERSON, AND T.H. NICHOLLS. 1997. Habitat use and movements of breeding male boreal owls (*Aegolius funereus*) in Northeast Minnesota as determined by radio telemetry *in* J.R. Duncan, D.H. Johnson, and T.H. Nicholls [EDS.], Biology and Conservation of Owls of the Northern Hemisphere: 2nd International

Symposium. General Technical Report NC-190. US Department of Agriculture, Forest Service, North Central Research Station, St. Paul, MN, USA.

LAUFF, R.F. 2009. First nest records of the Boreal Owl *Aegolius funereus* in Nova Scotia, Canada. *Ardea* 97:497-502.

LEARY, A.W., R. MAZAIKA, AND M.J. BECHARD. 1998. Factors affecting the size of ferruginous hawk home ranges. *Wilson Bulletin* 110:198-205.

LEONARD, T.D., P.D. TAYLOR, AND I.G. WARKENTIN. 2008. Space use by songbirds in naturally patchy and harvested boreal forests. *Condor* 110:467-481.

LOFGREN, O., B. HORNFELDT, AND B.G. CARLSSON. 1986. Site tenacity and nomadism in Tengmalm's owl (*Aegolius funereus*) in relation to cyclic food production. *Oecologia* 69:321-326.

MACE, G.M. AND P.H. HARVEY. 1983. Energetic constraints on home-range size. *American Naturalist* 121:120–132.

MANLY, B.F., L. MCDONALD, D.L. THOMAS, T.L. MCDONALD, AND W.P. ERICKSON. 2002. Resource selection by animals. Statistical design and analysis for field studies. Springer, Berlin DE.

MARTELL, A.M. AND A. RADVANYI. 1977. Changes in small mammal populations after clearcutting in northern Ontario black spruce forest. *Canadian Field-Naturalist* 91:41-46.

MARTIN, K. AND J.M. EADIE. 1999. Nest webs: A community-wide approach to the management and conservation of cavity-nesting forest birds. *Forest Ecology and Management* 115:243-257.

MAZUR, K.M., S.D. FRITH, AND P.C. JAMES. 1998. Barred Owl home range and habitat selection in the boreal forest of central Saskatchewan. *Auk* 115:746-745.

MCGARIGAL, K. AND W.C. MCCOMB. 1995. Relationships between landscape structure and breeding birds in the Oregon coast range. *Ecological Monograms* 65:235–260.

MCNAB, B.K. 1963. Bioenergetics and the determination of home range size. *American Naturalist* 97:133-140.

MEADES, W.J. AND L. MOORES. 1994. Forest site classification manual: a field guide to the Damman forest types of Newfoundland. Second Edition. Western Newfoundland Model Forest, Department of Forestry and Agriculture, and Canadian Forest Service, St. John's, NL, CA.

MEEHAN, R.H. AND R.J. RITCHIE. 1982. Habitat requirements of Boreal and Hawk Owls in interior Alaska. Pages 188-196 *in* W.N. Ladd and P.F. Schempf [EDS.], Raptor management and biology in Alaska and western Canada. USFWS, Anchorage, AK, USA.

MILLER, D.H. AND L.L. GETZ. 1972. Factors influencing the local distribution of red-backed voles (*Clethrionomys gapperi*) in New England. *The University of Connecticut Occasional Papers, Biological Science Series* 2:115-138.

MINITAB, INC. 2007. Minitab 15 Statistical Software, State College, PA, USA.

MORONI, M.T. 2006. Disturbance history affects woody debris dynamics of Newfoundland balsam fir (*Abies balsamea*) stands. *Canadian Journal of Forest Research* 36:3194–3208.

MORSE, D.H. 1980. Behavioral Mechanisms in Ecology, Harvard Univ. Press, MA, USA.

NEWTON, I. 1979. Population ecology of raptors. Buteo Books, Vermillion, SD, USA.

NIEMELÄ, J. 1999. Management in relation to disturbance in the boreal forest. *Forest Ecology and Management* 115:127-134.

NORBERG, R.A. 1964. Studies on the ecology and ethology of Tengmalm's owl (*Aegolius funereus). Var Fagelvarld* 23:228-234.

NORUSIS, M. 2002. SPSS 11.0 guide to data analysis. Prentice Hall, Englewood Cliffs, NJ, USA.

PALMER, D.A. 1986. Habitat selection, movements and activity of Boreal and Saw-whet owls. M.S. thesis, Colorado State Univ., Ft. Collins, CO, USA.

PEERY, M.Z. 2000. Factors affecting interspecies variation in home-range size of raptors. *Auk* 117:511-517.

POWELL, R.A. 2000. Animal home ranges and territories and home range estimators. Pages 65-110 *in* L. Boitani, and T. K. Fuller [EDS.], Research Techniques in Animal Ecology. Columbia University Press, New York, NY, USA.

RAPPOLE, J.H. 1996. The importance of forest for the world's migratory bird species *in* M. J. Soulé [ED.], Conservation of faunal diversity in forested landscapes. Chapman and Hall, New York, NY, USA.

——— AND A.R. TIPTON. 1991. New harness design for attachment of radio transmitters to small passerines. *Journal of Field Ornithology* 62:335-337.

ROWE, J.S. 1972. Forest regions of Canada. Department of Fisheries and Environment, Ottawa, ON, CA.

ROY, L.D., J.B. STELFOX, AND J.W NOLAN. 1995. Relationship between mammal biodiversity and stand age and structure in aspen mixedwood forests in Alberta. Pages 159-188 *in* J.B. Stelfox [ED.], Relationships between stand age, stand structure and biodiversity in aspen mixedwood forests in Alberta. Alberta Environmental Center (AECV95- RI) Vegreville, Alberta. Canadian Forest Service, Edmonton, AB, CA.

RYDER, R.A., D.A. PALMER, AND J.J. RAWLINSKI. 1987. Distribution and status of the boreal owl in Colorado. Pages 169-174 *in* R.W. Nero, R.J. Clark, R.J. Knapton, and R.H. Hamre [EDS.], Biology and conservation of northern forest owls. USDA Forest Service Gen. Tech. Rep. RM- 142. Fort Collins, CO, USA.

SCHMIEGELOW, F.K.A. AND M. MÖNKKÖNEN. 2002. Habitat loss and fragmentation in dynamic landscapes: avian perspectives from the boreal forest. *Ecological Applocations* 12:375–389.

SCHOENER, T.W. 1968. Sizes of feeding territories among birds. *Ecology* 49:123-141.

SLEEP, D.J.H. 2005. Responses of boreal forest owls to landscape pattern originating from fire and timber harvest. Ph.D. dissertation, Univ. Guelph, ON, CA.

SMITH, C.Y., I.G. WARKENTIN, AND M.T. MORONI. 2008. Snag availability for cavity nesters across a chronosequence of post-harvest landscapes in western Newfoundland. *Forest Ecology and Management* 256:641-647.

SMITH, P.G. 2008. Smith Ecology Ltd. Compos Analysis Software, Whales, UK.

SMITH, D.G. AND R. GILBERT. 1984. Eastern Screech Owl home-range and use of suburban habitats in southern Connecticut. *Journal of Field Ornithology* 55:322-329.

SOLHEIM, R. 1983. Breeding frequency of Tengmalm's owl *Aegolius funereus* in three localities in 1974-78. *Proceedings of the Nordic Ornithological Congress* 3:79-84.

SONERUD, G.A. 1986. Effect of snow cover on seasonal changes in diet, habitat and regional distribution of raptors that prey on small mammals in boreal zones of Fennoscandia. *Holarctic Ecology* 9:33-47.

ST-LAURENT, M.H., C. DUSSAULT, J. FERRON, AND R. GAGNON. 2009. Dissecting habitat loss and fragmentation effects following logging in boreal forest: Conservation perspectives from landscape simulations. *Biological Conservation* 142:2240–2249.

STURTEVANT B.R. AND J.A. BISSONETTE. 1997. Stand structure and microtine abundance in Newfoundland: implications for marten. Pages 182-198 *in* G. Proulx, H.N. Bryant, and P.M. Woodard [EDS.], *Martes*: taxonomy, ecology, and management. Provincial Museum of Alberta. Edmonton, AB, CA.

SULLIVAN, T.P., R.A. LAUTENSCHLAGER, AND R.G. WAGNER. 1999. Clearcutting and burning of northern spruce-fir forests: Implications for small-mammal communities. *Journal of Applied Ecology* 36:327-344.

THOMPSON, I.D. AND W.J. CURRAN. 1995. Habitat suitability for marten of second-growth balsam fir forests in Newfoundland. *Canadian Journal of Zoology* 73:2059-2064.

———, H.A. HOGAN, AND W.A. MONTEVECCHI. 1999. Avian communities of mature balsam fir forests in Newfoundland: Age-dependence and implications for timber harvesting. *Condor* 101:311-323.

———, D.J. LARSON, AND W.A. MONTEVECCHI. 2003. Characterization of old “wet boreal” forests, with an example from balsam fir forests of western Newfoundland. *Environmental Reviews* 11:S23-S46.

TRZCINSKI, M.K., L. FAHRIG, AND G. MERRIAM. 1999. Independent effects of forest cover and fragmentation on the distribution of forest breeding birds. *Ecological Applications* 9:586–593.

WALLIN, D.O., F.J. SWANSON, B. MARKS, J.H. CISSEL, AND J. KERTIS. 1996. Comparison of managed and pre-settlement landscape dynamics in forests of the Pacific Northwest, USA. *Forest Ecology and Management* 85:291-309.

ZAR, J.H. 1999. Page 224 and 245 *in* Biostatistical Analysis, 4th Ed. Prentice Hall, Upper Saddle River, NJ, USA.

Table 2.1. Description of habitat types and availability in surrogate Boreal Owl home ranges in Forest Management District 15 of western Newfoundland (based on forest inventory data were obtained from aerial photography).

HABITAT NAME	DESCRIPTION	% OF STUDY AREA
Disturbed	Forest stands subjected to wind or insect mortality; regenerating forest stands between 9 and 20 yr of age; regenerating forest stands between 9 and 20 yr of age subjected to silviculture treatment such as pre-commercial thinning; forest stands subjected to silviculure treatments within the last 8 yr; stands harvested via clearcutting within the last 8 yr	15.2
Bog	Bogs/peatlands	11.5
Scrub	Forest land with >10% crown closure not capable of producing 30 m^3/ha of wood volume at 60 yr	29.8
Hardwood	Pure hardwood stands more than 21 yr of age	0.9
Young mixedwood	Mixed hardwood/softwood stands aged 21-60 yr plus mixed stands of mixed ages less than 60 yr	2.0
Mature to old mixedwood	Mixed hardwood/softwood stands 61 yr or older (mature and over-mature)	8.9
Young softwood	All softwood stands between 21-60 yr of age	10.7

Table 2.1. cont.

Mature to old softwood	All softwood stands 61 yr of age or older (mature and over-mature)	21.2

Table 2.2. Summary of Boreal Owl reproductive phenology and productivity in different regions of its breeding range.

LOCATION[A]	MEDIAN LAYING DATE	LAYING DATES	MEANT CLUTCH SIZE	MEAN NO. YOUNG FLEDGED
Nova Scotia	5 May	20 March to 1 June	3.5	2
Colorado	10 May	17 April to 1 June	3	0.25
Idaho	1 May	12 April to 24 May	3.25	2.3
Minnesota	—	30 March to 12 April	—	—
Finland	3 April	23 February to 7 June	5.6	3.9
Germany	—	—	3.8	3.4

[A] Sources of information: Nova Scotia (Lauff 2009), Colorado (Palmer 1986), Idaho (Hayward 1989), Minnesota (Lane 1997), Finland (Korpimäki 1988), and Germany (Konig 1969).

Table 2.3. Summary telemetry data and roost tree characteristics for male Boreal Owl roost locations, 2006-2007, in western Newfoundland

Owl ID		Capture date to last day of contact	Number of relocations	Home range size (ha)	Number (%) of roost tree species			
					Balsam fir	Black spruce	White spruce	Unknown snags
10		30 May to 17 August 2007	18	435	13(72)	5(28)	0	0
11		14 May to 10 August 2006	18	219	13(76)	3(18)	1(6)	0
12	Pre-shift	16 May to 1 June 2006	1	—	1(100)	0	0	0
	Post-shift	27 July to 28 August 2006	6	6	4(80)	0	0	1(20)
14		13 June to 13 July 2007	7	55	3(43)	2(29)	2(29)	0

Table 2.3. cont.

16	Pre-shift	11 May to 14 July 2006	13	206	6(50)	6(50)	0	0
	Post-shift	27 July to 21 August 2006	5	62	3(60)	2(40)	0	0
17		13 April to 21 August 2006	2	—	2(100)	0	0	0
18		28 April to 27 May 2006	5	73	0	4(80)	0	1(20)
19		29 April to 25 July 2006	4	0.3	0	1(50)	0	1(50)
20		30 April to 7 August 2006	7	423	0	5(83)	0	1(17)
		Total	86		45(56)	28(35)	3(4)	4(5)

Table 2.4. Median roost tree dbh and canopy cover by species, with range in brackets, in Forest Management District 15 of western Newfoundland.

ROOST SITE CHARACTERISTIC	ROOST TREE TYPE (N)				
	Balsam Fir (45)	Black Spruce (28)	White Spruce (3)	Unknown (4)	P value[1]
Roost tree dbh (cm)[2]	11.2 (4.4-24.8)^B	9.8 (4.4-20.2)^C	21.8 (12.2-31.2)^A	6.2 (5.0-7.2)^D	0.016
Canopy cover (%)[2]	66.7 (0-89.5)^B	78.4 (0-95.3)^B	87.8 (73.8-90.5)^A	12.5 (0-54.3)^C	0.031

[1] Mood's Multisample Median Test ($\alpha = 0.05$)

[2] Values with different superscripted letters were significantly different from each other based on Tukey-type post hoc comparisons

Table 2.5. Log-ratio comparisons and rank scores from compositional analysis of roost-site habitat use by male Boreal Owls in Forest Management District 15 of western Newfoundland. Habitat types are defined in Table 2.1. Rank score indicates relative preference for habitat from lowest (0) to highest (7). A positive *t*-value indicates that the column habitat type ranked higher than the row habitat type. A significant *P*-value suggests that confidence in the direction of the relationship is high.

HABITAT		Mature to old softwood	Young softwood	Young mixedwood	Hardwood	Disturbed	Mature to old mixedwood	Scrub	Bog	RANKING
Mature to old softwood	*t, P*	—	-0.8, 0.422	-3.4, 0.00	-3.5, 0.00	-2.8, 0.00	-5.9, 0.00	-5.1, 0.00	-6.3, 0.00	7
Young softwood	*t, P*	0.8, 0.42	—	-2.0, 0.05	-2.3, 0.03	-1.8, 0.08	-4.7, 0.00	-3.7, 0.00	-5.1, 0.00	6
Young mixedwood	*t, P*	3.4, 0.00	2.0, 0.05	—	-1.3, 0.19	-0.8, 0.43	-10.6, 0.00	-4.5, 0.00	-12.6, 0.00	5

Table 2.5. cont.

Hardwood	*t, P*	3.5, 0.00	2.3, 0.03	1.3, 0.19	—	-0.2, 0.87	-5.0, 0.00	-3.1, 0.03	-5.9, 0.00	4
Disturbed	*t, P*	2.8, 0.01	1.8, 0.08	0.8, 0.43	0.2, 0.87	—	-2.5, 0.02	-2.1, 0.04	-2.9, 0.00	3
Mature to old mixedwood	*t, P*	5.9, 0.00	4.7, 0.00	10.6, 0.00	5.0, 0.00	2.5, 0.02	—	-0.1, 0.92	-1.0, 0.34	2
Scrub	*t, P*	5.1, 0.00	3.7, 0.00	4.5, 0.00	3., 0.00	2.1, 0.04	0.1, 0.92	—	-0.5, 0.64	1
Bog	*t, P*	6.3, 0.00	5.1, 0.00	12.6, 0.00	5.9, 0.00	2.9, 0.00	1.0, 0.34	0.5, 0.64	—	0

Table 2.6. Log-ratio comparisons and rank scores from compositional analysis of home-range habitat use by male Boreal Owls in Forest Management District 15 of western Newfoundland. Habitat types are defined in Table 2.1. Rank score indicates relative preference for habitat from lowest (0) to highest (7). A positive *t*-value indicates that the column habitat type ranked higher than the row habitat type. A significant *P*-value suggests that confidence in the direction of the relationship is high.

HABITAT		Mature to old softwood	Disturbed	Scrub	Bog	Young softwood	Young mixedwood	Mature to old mixedwood	Hardwood	RANKING
Mature to old softwood	*t*, *P*	—	-0.2, 0.87	-4.3, 0.00	-7.8, 0.00	-2.0, 0.08	-3.9, 0.01	-4.4, 0.00	-10.4, 0.00	7
Disturbed	*t*, *P*	0.2, 0.87	—	-4.8, 0.00	-5.3, 0.00	-1.9, 0.10	-3.5, 0.01	-4.1, 0.01	-8.8, 0.00	6
Scrub	*t*, *P*	4.3, 0.00	4.8, 0.00	—	-0.3, 0.78	-1.2, 0.28	-2.9, 0.02	-3.6, 0.01	-8.6, 0.00	5

Table 2.6. cont.

Bog	*t*, *P*	7.8, 0.00	5.3, 0.00	0.3, 0.78	—	-1.2, 0.27	-2.8, 0.03	-3.5, 0.01	-7.8, 0.00	4
Young softwood	*t*, *P*	2.0, 0.08	1.9, 0.10	1.2, 0.28	1.2, 0.27	—	-1.4, 0.19	-1.2, 0.26	-2.1, 0.07	3
Young mixedwood	*t*, *P*	3.9, 0.01	3.5, 0.01	2.9, 0.02	2.8, 0.03	1.4, 0.19	—	-0.4, 0.68	-1.4, 0.21	2
Mature to old mixedwood	*t*, *P*	4.4, 0.00	4.1, 0.01	3.6, 0.01	3.5, 0.01	1.2, 0.26	0.4, 0.68	—	-0.9, 0.38	1
Hardwood	*t*, *P*	10.4, 0.00	8.8, 0.00	8.6, 0.00	7.8, 0.00	2.1, 0.07	1.4, 0.21	0.9, 0.38	—	0

Table 2.7. Summary of Boreal Owl home range size in different regions of its breeding range.

HOME RANGE (HA)	SEASON	NOTES	CALCULATION TYPE	LOCATION	SOURCE
667 (n=3, range: 473-949, SE=144)	April-August	Paired home ranges = 445 ha. Number of relocations = 4-12, also used nocturnal relocations	MCP	NE Minnesota	Belmonte (2004)
1,148 (n=11, range: 229-2386, SD=633)	Summer	Number of diurnal relocations = 14-53	Harmonic Mean	N. Rocky Mountains (USA)	Hayward et al. (1993)

Table 2.7. cont.

1202 (n=4, range: 742-1444)	April-June	Paired home ranges = 425 ha. Number of diurnal relocations = 7-29	MCP	NE Minnesota	Lane (1997)
283 (n=3)	Spring-Summer	Paired males	—	Ontario	Bondrup-Nielsen (1978)
142 (n=3, range: 94-226, SD=73)	April-July	Paired males	MCP	Norway	Jacobsen and Sonerud (1987)
296 (n=2)	Summer	Paried males	MCP	Colorado	Palmer (1986)

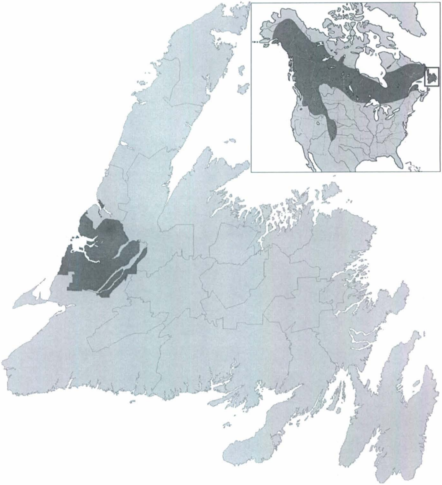


Fig. 2.1. Forest Management District 15 (shaded) on the island of Newfoundland, which is located at the easternmost portion of the Boreal Owl range in North America (see inset). Adapted from Hayward and Hayward (1993).

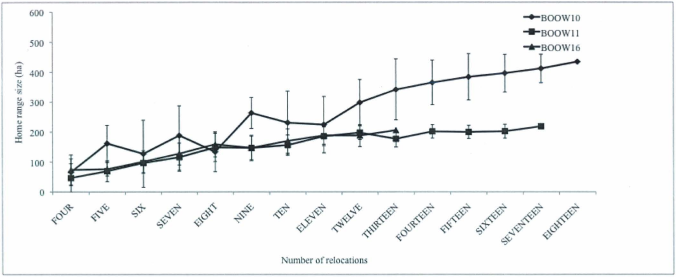


Fig. 2.2. Relationship between the number of radio telemetry locations and Boreal Owl home-range size for male Boreal Owls with most relocations during the breeding seasons of 2006-2007 in western Newfoundland. Values are mean ± sd.

3.0 TESTING A HABITAT SUITABILITY INDEX MODEL FOR BOREAL OWLS IN WESTERN NEWFOUNDLAND USING LOCAL FIELD DATA

3.1 ABSTRACT

I tested a HSI model for the Boreal Owl (*Aegolius funereus*) generated by the Western Newfoundland Model Forest by comparing original model outputs with those generated using independent field data collected in western Newfoundland to create a revised model. In addition, I conducted habitat composition analyses based on HSI values for home ranges and point counts where owls were present versus a random sample of habitat within the general study area. I then evaluated how three different forest harvesting scenarios would affect the amount of suitable habitat available over time. I conducted 310 point counts during the early breeding seasons of 2006 and 2007. Owls were present at 76 of these points with a detection rate of 25%. HSI values typically range from 0 to 1.0, whereas the HSI values for the current study area ranged from 0 to 0.60, while those for point counts ranged from 0.06 to 0.55 and for home ranges extended from 0 to 0.35. While the models correctly predicted the presence of Boreal Owls with success ranging from 85 to 100% among years and model types, overall assessments of chance correctness indicated accuracy was not greater than random expectations. A comparison of three different forest harvesting scenarios was also not significant.

3.2 INTRODUCTION

Advances in harvesting techniques and technology have increased the rate of forest clearing in recent decades, thus raising concerns over the effects of such harvesting on wildlife. There is a need to improve forest management strategies and address the growing impact of habitat modification on biological diversity, particularly in the boreal forest (Bradshaw et al. 2009). One tool to examine wildlife-habitat interactions in the context of changing environmental conditions is the habitat suitability index (HSI) model (Van Horne and Wiens 1991). HSI models numerically assess the capacity of habitat in a given area to support a particular species (Brooks and Temple 1990). The goal of such analyses is to quantify wildlife-habitat interactions and predict sensitivity to disturbances by combining habitat attributes with species life history and demographic information. This process provides a ranking of habitats in a given region from least to most suitable for the target species, and enables an assessment of the resulting distribution and extent of suitable habitat. This modeling process is a valuable tool for comparing alternative land-use plans, identifying potential wildlife refuges, or for quantifying the effects of human activity on wildlife (Van Horne and Wiens 1991).

During 2004, a HSI model based on scientific literature and expert opinion was developed for the Boreal Owl (*Aegolius funereus*) in western Newfoundland, Canada (Côté et al. 2004). This model was part of a suite of tools developed for the Western Newfoundland Model Forest (a consortium of industry, government and non-government organizations) as the basis for recommending forest harvesting strategies that would sustain regional biodiversity (Dolter 2005). The Boreal Owl was chosen as one focal species for this process because it is an obligatory secondary cavity nester associated with mature forests, and consequently will be influenced by harvesting that leads to the loss of suitable habitat (Hayward 1997, Koopman et al. 2007). The HSI model created for Boreal Owls assessed the foraging and nesting habitats conjointly using spatially explicit relationships (Côté et al. 2004) based on data from across the species' North American range. No data on Boreal Owls in Newfoundland were available to build the initial model, as the species had previously only received limited attention on the island.

Among the elements considered as part of model development, the nesting component of the HSI model focused on the percentage of large live and dead trees potentially available to provide nesting cavities for the Boreal Owl (Côté et al. 2004). The foraging component of the model considered suitable habitat as being represented by both the amount of forest cover and the presence of openings where "sit-and-wait" hunting could occur from the forest edge (i.e., within 100 m of that edge) while minimizing predation risk (Côté et al. 2004), by species such as Great Horned Owls (*Bubo virginianus).* This type of edge habitat may be particularly important for Boreal Owls in Newfoundland due to the relative availability and vulnerability of small mammals in forest openings versus interiors (Hayward et al. 1993, Whitman 2001) and the relatively limited small mammal prey base in Newfoundland. The Boreal Owl is a small-mammal specialist (Hayward et al. 1993) and the availability of this prey type has been identified as one determinant of habitat quality due to its association with breeding success (Korpimäki 1992).

Effective use of HSI models requires that they be tested for accuracy and reliability (Block et al. 1994, Brooks 1997). In this study, I used two validation methods to assess the Boreal Owl HSI model: 1) sensitivity analyses and 2) testing the model with empirical data. Sensitivity analyses identified those model parameters that influenced model performance or output the most, and was used to highlight those parameters of the model that needed field-testing to improve predictive accuracy (Stoms et al. 1992). Using field data to validate a HSI model is generally accepted as a robust way of evaluating a model (Brooks 1997). Presence/absence or abundance data can be overlaid on a habitat suitability map to validate the accuracy of the model in a given area (Rickers et al. 1995). But a more powerful test is to combine both field data and sensitivity analyses (Roloff and Kernohan 1999, Mitchell et al. 2002). Using this combination, sensitive parameters in the model can be explicitly tested in the field, and verified or changed to improve model performance. For example, if home range size was determined to be a sensitive model parameter, field studies could focus on providing more accurate estimates of home range size to then be incorporated back into an updated version of the model.

Sensitivity analyses of the boreal owl HSI model developed for western Newfoundland determined that home range size, foraging radius (distance moved by owls when foraging), and density of living and dead stems in nesting areas were the most sensitive parameters in the model (X. Zhu 2004, unpubl. data). Estimates for the former two parameters were initially based on studies conducted in Ontario, Alberta and the northern United States (Bondrup-Nielsen 1978, Hayward et al. 1993, Lane 1997). The density of living and dead stems >30 cm diameter at breast height is thought to influence nesting location of owls based on studies in central and western Canada and the United States (Bondrup-Nielsen 1978, Hayward et al. 1993, Kirk 1995).

I tested the Boreal Owl HSI model generated by the Western Newfoundland Model Forest by comparing original model outputs with those generated using independent field data collected in western Newfoundland to create a revised model. If the landscape in western Newfoundland is significantly different than other regions of North America and Boreal Owls' habitat selection reflects these differences, the revised model would produce more habitat that is assigned higher HSI values. In addition, I conducted habitat composition analyses based on HSI values for home ranges and point counts where owls were present versus a random sample of habitat within the general study area. If boreal owls are selecting specific habitat features, such as contiguous, old-growth forests (Bondrup-Nielsen 1978, Palmer 1986, Hayward 1989, Holt and Ermatinger 1989), then literature-based models would have higher HSI values associated with that habitat, and actual home ranges should contain more of these habitats assigned higher HSI values than randomly placed surrogate home ranges. I also used presence/absence point-count data to examine the model's predictive power. If the model is accurately predicting Boreal Owl occupancy in Newfoundland, then the model should correctly predict the presence or absence of boreal owls better than chance. I then evaluated how three different forest harvesting scenarios would affect the amount of suitable habitat available over time. Given the lack of local data used to create the original HSI model, I predicted that updating the model with local field data would result in a higher amount of presumed suitable habitat over time since the model would be more accurately attributing HSI values to the habitat that boreal owls in the local population are selecting.

3.3 METHODS

3.3.1 Study Area

This study was conducted in Forest Management District 15 of Newfoundland and

Labrador, Canada (48°95'N, 57°95'W; see Fig. 3.1), which is located within the Corner Brook subregion of the Western Newfoundland Ecoregion (Damman 1983) of insular Newfoundland. This region is characterized by hilly to undulating terrain, with a mean summer and winter daytime high of 17°C and -6°C, respectively, and precipitation averaging ~1200 mm/yr (Damman 1983). The climate is humid with a relatively long frost-free period compared to other areas of the island (Damman 1983). District 15 is underlain by slate and limestone till and has some of the most favorable sites for forest growth on the island (Meades and Moores 1994). Other than land that is privately owned, approximately 56% of District 15 is under Industry Tenure and 44% is under Crown Tenure (R. Sutton 2011, pers. comm.).

With a total area of approximately 560,000 ha, 75% of District 15 is managed for industrial forestry purposes (Corner Brook Pulp and Paper Limited 2002, Government of Newfoundland and Labrador 2003). Harvesting for paper production began in 1924, although previous small-scale harvesting had occurred for other purposes since the late 1800s; thus, many sections of the district have had some level of previous forest harvesting. Newfoundland Forest Service policy currently requires that 15-20% of the total productive forest within a district must be older than 80 yr (Government of Newfoundland and Labrador 1990). But since this objective does not indicate a minimum stand size, fragmentation of old-growth stands has the potential to be very high across the landscape. Clearcutting is the primary method of harvesting in the region (Whitaker and Montevecchi 1999).

3.3.2 Study Species

The Boreal Owl is a small, nocturnal raptor with a circumboreal distribution extending from Scandinavia to Siberia in Eurasia, and from Alaska to Newfoundland and Labrador in North America. Boreal Owl males are typically year-round residents, occupying stable home ranges, which include a breeding territory (Hayward et al. 1993). They are obligate secondary cavity nesters that use holes excavated by woodpeckers in large diameter (33 – 112 cm) live and dead trees, as well as natural cavities (Hayward et al. 1993, Heinrich et al. 1999). Such cavities are generally rare in eastern Canadian boreal forests therefore nesting cavities have been identified as a limiting factor (Kirk 1995). As well, intensive timber management directly or indirectly removes many of the large diameter trees and snags that are used for excavation by woodpeckers in this region (Kirk 1995, Smith et al. 2008). During late winter/early spring the male will search for nesting cavities and once a suitable one is found will deposit food items therein as part of the courtship initiation period (Hayward et al. 1993). Aspen (*Populus tremuloides*), pine (*Pinus* spp.) and spruce (*Picea* spp.) trees are all selected for nesting, with a marked preference for aspen in central Canada (Bondrup-Nielsen 1978, Hayward et al. 1993). The only nest found in Newfoundland was in an eastern larch (*Larix laricina*).

The Boreal Owl is primarily a small mammal specialist that consumes shrews (*Sorex* spp.), mice (*Zapus* spp. and *Peromyscus* spp.) and voles (*Clethrionomys* spp. and *Microtus* spp.), although small passerine birds are sometimes also captured (Korpimäki 1981, Hayward et al. 1993). Although there is no direct dietary information for Boreal Owls in western Newfoundland, within the depauperate small mammal community on the island (Thompson and Curran 1995) the main prey species are likely masked shrew (*S.*

cinereus), meadow vole (*M. pennsylvanicus*), and red-backed vole (*C. gapperi*). The assumption that Boreal Owls in Newfoundland prefer to forage from forest edges into open habitat matches the habitat use of the former two potential prey species based on small-mammal trapping data for the island (Tucker 1988), but perhaps not that of the more recently arrived red-backed vole (Sullivan et al. 1999, Klenner and Sullivan 2003, Hearn et al. 2006). The relative abundance of red-backed voles across habitat types has yet to be determined for the island. Although the presence of Boreal Owls is generally associated with dense mature coniferous forests (Bondrup-Nielsen 1978, Lane 1997, Hinam 2001, Belmonte 2007), habitat cover requirements vary by season. During late winter and early spring, Boreal Owls hunt in forest openings, meadows and clear-cuts where there is faster snow melt and easier access to prey, but move into mature forest stands with a limited shrub layer during the summer, fall and winter (Palmer 1986, Hayward et al. 1993). In Newfoundland where the snow season can run from November to June (Abbott and Khan 2009) and breeding is thought to initiate as early as March (Gagnon and Bombardier 1995, Lauff 2009), these open habitats may be more important for foraging during the breeding season than they are in other parts of the owl's range. There are no comparable data for eastern Canada, but in the Rocky Mountains of western North America foraging occurs mainly in mixed stands of spruce and fir (*Abies* spp.) (Hayward et al. 1993); in Norway, mature spruce forests are used for foraging (Sonerud 1986). These mature habitats are preferred because of their high prey density and, in winter, the decreased tendency for snow to form crusts that hinder access to prey (Hayward et al. 1993).

3.3.3 Boreal Owl Habitat Suitability Index Model

3.3.3.1 Habitat classification

Analyses were based on digitized forest inventory data from aerial photography for 2005 and updated with all forest management activity for 2006 and 2007, as classified by the Forest Resources division of the Department of Natural Resources, Government of Newfoundland and Labrador. Terrestrial habitats were divided into "forestable" and "non-forestable" habitats; the latter included woody and non-woody habitats (scrub and stand remnants, bogs and barrens). Forestable habitats were separated into categories based on the general composition and structure (Table 3.1) then tallied across the entire study area. The average age of trees in a stand was assigned to one of 7 age classes corresponding to an age range at increments of 20 yr for the HSI model; mixed age class stands were placed in a separate class (Table 3.2). Age was considered an important characteristic because of how it reflects stand structure and hence suitability for nesting. Mature forests in Newfoundland are characterized as being 41 - 80 yr old with stands rarely reaching 100 yr old before senescence begins (Moroni 2006). The forest harvest rotation in Newfoundland has been 80 - 120 yr (Setterington et al. 2000), but currently could be as short as 60 yr where productivity is high (Smith et al. 2008). Thus for management purposes, it would be informative to examine forest stands 60 yr and older as one group, given both their importance to Boreal Owls as mature forest habitat and their potential value as a target for harvesting. Minimizing the separation of age classes into those < 60 yr and those 60 + yr was also necessary due to the limitations on the number of parameters that could be successfully modeled given the sample sizes available.

3.3.3.2 Model equations

The Boreal Owl HSI assessed nesting and foraging habitats simultaneously using spatially explicit relationships. Focused on a 25 m x 25 m pixel as the base unit, the HSI value for this base unit was calculated as the mean of all pixel HSI values for a particular parameter within a radius of 1784 m (1000 ha) corresponding to a "neighborhood window". This value was based on home range requirements of the Boreal Owl during the breeding season (Hayward et al. 1993). For each base unit, the HSI model was formulated as follows:

$$\mathrm{HSI} = \mathrm{Window}\ (\mathrm{HSI}_{\mathrm{local}})_{1784\ \mathrm{m}}$$

where,

$$\mathrm{HSI}_{\mathrm{local}} = [\mathrm{NESTING}*\mathrm{FORAGING}]^{1/2},$$

and where NESTING and FORAGING representing the suitability model values for the nesting habitat and the foraging habitat components respectively (Côté et al. 2004). For this study, "nesting" referred to the habitat conducive to courtship and breeding, based on the assumption that the presence of a male Boreal Owl indicates adequate breeding resources. This formula allowed partial compensation between nesting and foraging habitat (Van Horne and Wiens 1991).

3.3.3.3 Nesting

The NESTING component of the HSI model reflected breeding habitat quality, which is primarily associated with the abundance of large stems able to support nesting cavities (Bondrup-Nielsen 1978, Hayward et al.1993, Kirk 1995). The density of live and dead stems having a diameter at breast height (dbh) greater than or equal to 30 cm was used to calculate a NESTING component value for each pixel. Different stand and site characteristics can be used to predict the density of large trees (Heinrich et al. 1999). For the current model, species composition, site class, crown density and stand age were chosen to reflect this resource availability. Thus, for each pixel within the study area, the mean density of large trees was equal to the global mean of the density of large trees (calculated for all pixels) multiplied by those four components. The weighting procedure was performed separately for dead and live trees.

3.3.3.4 Foraging

The FORAGING component represented foraging habitat quality. Good foraging habitat quality is largely associated with open areas in close proximity to forest edge, and mature-old growth coniferous forests, where the availability of small rodents and their vulnerability to Boreal Owls are optimal during the breeding and nesting periods (Korpimäki 1981, Hayward et al. 1993, Hinam 2001, Whitman 2001). The FORAGING values were obtained using the sum of the 'Adjusted Foraging Habitat Quality' (AFHQ) values for each pixel unit within a 500 m radius. The AFHQ parameter is a product of cover density categories (water, three different levels of forested areas and openings) and a function of the distance between the centre of the foraging habitat and the nearest forest cover.

3.3.3.5 Model adjustments

The model operated on an input shapefile created in ArcMap 9.2 (ESRI Redlands CA) that was developed from the 2005 forest inventory data for the study area and updated with all forest management activity (cuts, pre-commercial thinning, planting) for 2006 and 2007. This resulted in two input shapefiles for 2006 and 2007. '*Original model outputs*' refer to outputs from 2006 and 2007 created with the original HSI model based on expert opinion and literature review. '*Modified model outputs*' refer to outputs from model runs for both years but using a home range size determined for Boreal Owls in western Newfoundland (see Chapter 2; radius of 1380 m compared to 1784 m).

3.3.4 Point Counts

Point counts were conducted throughout the study area to determine the distribution and habitat associations of Boreal Owls in District 15. These surveys were conducted from mid-July to mid-September of 2005 and mid-February to mid-April, along with August through September, 2006-2007. Transects were randomly selected on existing wood roads and assessed included old-growth coniferous forests, mixed forests, regenerating forests and clear cuts. All surveys were done from a road or trail accessible by truck, all-terrain vehicle or snowmobile. Field surveys consisted of 15-min point counts alternating silent listening periods with broadcasts of Boreal Owl calls (*primary* or *staccato song*, see Bondrup-Nielsen 1984, Hayward et al. 1993) using a Nexxtech compact disc player at 112 dB. Broadcasts were designed to begin with 2-3 min silence followed by 2 min of playback; this sequence was repeated throughout the15 min count period. Surveys began 1 hr after sunset and continued until 1 hr before sunrise on nights with negligible rain or snow and winds less than Beaufort 3 (12-19 km/hr). All point count locations were separated by at least 1 km. Due to an increased detection rate during courtship, only point counts from February to April 2006 and 2007 were used for model testing. Kruskal-Wallis multiple comparison test (Minitab 2007) was used with a Bonferroni correction to compare selected habitat parameters between occupied sites (point counts where owls were detected and Boreal Owl home ranges) and unoccupied sites (random surrogate home ranges). A Tukey-type test for multiple comparisons among medians was used to isolate significant differences among groups (Zar 1999).

3.3.5 HSI Model Testing

3.3.5.1 Surrogate home ranges

In order to represent the HSI values for home-range sized areas available at random locations within the study area, 40 surrogate home ranges were created. Surrogate home range size was chosen as the largest reported home range value in North America (Hayward et al. 1993). I then used the Animal Movement extension of Arcview 3.2 (ESRI Redland CA) to create 80 randomly placed surrogate home ranges, 40 of which were chosen at random. Those surrogates that contained more than the average amount of area covered by water bodies found in the owl MCP home ranges (see Chapter 2) were excluded before selections were made, as were any that contained residential areas.

3.3.5.2 Compositional analyses

Compositional analyses were completed to compare the habitat available within surrogate home ranges with that of point counts where Boreal Owls were present, as well as for actual home ranges of Boreal Owls determined using telemetry (see Chapter 2 for data collection techniques). For each point count where Boreal Owls were detected, the proportion of each habitat type within the 500 m buffer and the representative HSI value was calculated. For actual home ranges, I determined the proportional area of each habitat type and respective HSI values based on minimum convex polygon representations of home range. The respective values were compared to those determined for the 40 random surrogate home ranges and analyzed using the log-ratio compositional analysis method (Aebischer et al. 1993). Compositional analyses were conducted using the program Smith Ecology Compos Analysis 6.2 std. (Smith 2008).

3.3.5.3 Cohen's kappa analysis

Chance correctness of the model was tested using Cohen's MaxKappa statistic. Point counts where owls were present and absent were buffered with a 500 m exclusion zone (so as to not overlap with adjacent points) and this area was used to extract a weighted mean HSI value for each point; these were then analyzed to assess the model's predictive capabilities based on the chance-corrected classification method of Titus and Mosher (1984). However, instead of determining Kappa, a threshold-independent method called MaxKappa (Guisan et al. 1998) was used to lessen the dependence on arbitrarily defining what is considered "suitable" (Hirzel et al. 2006).

3.3.5.4 Tests for differences of distributions and means

To determine if distributions and means of HSI outputs differed between years, Kolmogorov-Smirnov and Student's *t*-tests were performed on HSI values calculated for points where owls were present and absent, as well as for surrogate and actual home ranges.

3.3.6 HSI Model Forward Projections

3.3.6.1 Forest management scenarios

To assess how the amount of suitable habitat available would change over time under different harvesting regimes, I examined the output from forward projection models developed for District 15 on the basis of three scenarios which varied in the spatial distribution of cutblocks and harvest levels. The Business As Usual (BAU) scenario incorporated the current forest management practices in District 15. The minimum industry harvest block (timber harvest areas that are to be cut on areas that fall within Industry Tenure) is 5 ha with a 200 m adjacency (i.e. harvest blocks within 200 m of each other belong to the same harvest block). The minimum crown harvest block (timber harvest areas that are to be cut on areas that fall within Crown Tenure) is 1 ha, with a 200 m adjacency. No maximum block size or green up delay was used (R. Sutton 2010, pers. comm.). The Aggregated (AGR) scenario incorporated a pattern of large "aggregated" harvest blocks across the landscape. The minimum cut block size for this scenario was 100 ha (industry and crown), with a 200 m adjacency, a target cut block size of 300 ha, and a maximum cut block size of 800 ha (R. Sutton 2010, pers. comm.). The Fragmented (FRA) scenario incorporated a pattern of small "fragmented" harvest blocks across the landscape. The minimum cut block size for this scenario was 10 ha (industry and crown), with a 200 m adjacency, a maximum block size of 100 ha, and a 5 yr regeneration delay within 200 m of an adjacent block (Sutton 2010, pers. comm.). A 60-yr harvest schedule was developed with *Woodstock* and *Stanley* (hereafter W-S) *Versions 3.00.0 and 4.5, respectively* (Remsoft Inc. 2004) for each of the three forest management scenarios. Once a W-S run was completed for a given scenario, the forest structure (age and species composition) was outputted for time periods 20, 40 and 60 yr. An initial aspatial schedule was developed using W-S, for a 160-yr planning horizon for district 15 and from this schedule a 60-yr spatial harvest schedule and resultant forest states were creating for all three forest management scenarios (R. Sutton, 2009 pers. comm.).

3.3.6.2 Forward projection testing

Forward projection periods (20-, 40-, 60-yr) for each forest management scenario were compared for differences in distribution of HSI scores with Friedman's two-way ANOVA tests; similarly I assessed HSI score distributions across management scenarios for each projection period. Statistical significance was determined based on using a

Bonferroni correction of $\alpha = 0.05/6 = 0.008$ for these tests. All statistical tests were performed in Minitab v. 16.1.1 (2010) unless otherwise noted. Because of limited improvement in the model following the inclusion of revised home range values, forward projections were only run using the original HSI model parameters.

3.4 RESULTS

3.4.1 Habitat Selection

I conducted 310 point counts during the early breeding seasons of 2006 and 2007 (137 and 173, respectively). Owls were present at 76 of these points (43 and 33 for each year, respectively), with a detection rate of 25% (Fig. 3.2). There were significant differences among occupied (point counts and actual home ranges) and unoccupied (surrogate home ranges) sites in terms of 'disturbed' ($H = 12.53$, $p = 0.002$), 'hardwood' ($H = 14.50$, $p = 0.001$), and 'mature to over-mature mixedwood' ($H = 29.56$, $p = 0.000$) habitat types (Table 3.3). The amount of disturbed habitat was significantly higher in actual home ranges than point counts, and significantly higher in point counts than surrogate home ranges. Mature to over-mature mixedwood habitat was significantly more extensive in surrogate home ranges than point counts, and likewise significantly more common at point counts than in actual home ranges. The amount of disturbed habitat differed among point counts where owls were present, actual home ranges and surrogate home ranges, with home ranges having the most disturbed habitat, followed by point counts; a similar relationship was found among sample locations in the amount of mature to over-mature habitat. The amount of hardwood habitat was significantly higher in surrogate home ranges than either actual home ranges or point counts, while the latter two were equal.

3.4.2 Assessing Habitat Suitability Models

The general relationship between the value of the model components and HSI scores were calculated for both NESTING and FORAGING habitat based on the entire study area. The NESTING value is a function of the density of large trees (Fig. 3.3a). The FORAGING value reflects both cover (Fig. 3.3b) and the distance to the nearest forest edge (Fig. 3.3c).

Model outputs produced HSI values for the entire District 15 study area (Fig. 3.4). Specific HSI values representing point counts where Boreal Owls were present and Boreal Owl home ranges were drawn from these outputs. HSI values typically range from 0 to 1.0, whereas the HSI values for the current study area ranged from 0 to 0.60, while those for point counts ranged from 0.06 to 0.55 and for home ranges extended from 0 to 0.35 (see Tables 3.4a-3.4d).

There was no difference in distribution between original and modified model outputs for the 2006-2007 models' entire study area HSI values ($z = 0.397$; $p > 0.05$ and $z = 0.365$; $p > 0.05$, respectively). There was a difference in distribution between the original and modified model outputs for both the 2006-2007 Boreal Owl point count location HSI values. The 2006 distribution of points where owls were present was skewed towards lower HSI values than 2007 for both original and modified models ($z = 1.916$; $p < 0.01$ and $z = 2.223$; $p < 0.01$, respectively).

3.4.2.1 Compositional analyses

Based on log-ratio analysis, the HSI composition of point counts where Boreal

Owls were present differed significantly from what was available at random in surrogate home ranges across the study area. Thus Boreal Owls appear not to be occupying habitat at random during the early breeding period. Boreal Owls showed a preference for 0.41 + and 0.36-0.40 HSI classes and avoided 0-0.05 and 0.06-0.10 HSI classes. These differences were evident in both the 2006 and 2007 original and modified model outputs (Original model 2006: $\Delta = 0.0205$; $X^2 = 167.14$, $p < 0.001$; Original model 2007: $\Delta = 0.0699$; $X^2 = 87.83$, $p < 0.001$; Modified Model 2006: $\Delta = 0.0279$; $X^2 = 153.88$, $p < 0.001$; Modified Model 2007: $\Delta = 0.0454$; $X^2 = 102.01$, $p < 0.001$).

Nor did Boreal Owls occupy home ranges at random. The HSI values for male Boreal Owl home range differed significantly from what was available for both the 2006 and 2007 original and modified model outputs (Original model: $\Delta = 0.0594$; $X^2 = 167.14$, $p < 0.01$; Modified Model: $\Delta = 0.0311$; $X^2 = 27.77$, $p < 0.001$). Boreal Owls showed a preference for 0.36+ and 0.31-0.35 HSI classes and avoided 0.16-0.20 and 0-0.05 HSI classes.

3.4.2.2 Cohen's kappa analyses

The models correctly predicted the presence of Boreal Owls with success ranging from 85 to 100% among years and model types, with only 5 (7%) of 74 individuals present at locations where the model predicted owls should be absent (Table 3.5). However, all models indicated a large proportion of sites (from 53 to 66% depending upon year and model type) where birds were expected to be present but were indeed absent, and only a relatively small proportion of sites (3 to 31%) which were predicted to be unsuitable and birds were present. Assessments of chance correctness indicated, however, that overall accuracy was not greater than random expectations (Table 3.5).

3.4.3 HSI Model Forward Projections

The aggregated (AGR) scenario was significantly lower at time period 40 compared to the BAU and FRG scenarios ($S = 11.09$, $p < 0.008$). There were no other significant differences within or between forest harvesting scenarios at various time periods. The percentage of habitat in each HSI class for each scenario and each time period are displayed in Fig. 3.5.

3.5 DISCUSSION

Boreal Owls in western Newfoundland occupied locations that were distinct from what was randomly available throughout the study area. For both point counts where Boreal Owls were detected during surveys and the home ranges determined with radio telemetry, there were greater amounts of disturbed habitat and lesser amounts of both hardwood and mature to over-mature mixedwood habitat compared to what was randomly available. These findings are consistent with studies from Colorado and Europe that indicate a preference for mature spruce-fir dominated forests and cleared areas (Korpimäki 1981, Solheim 1983, Palmer 1986, Dejaifve et al. 1990); but contrast the indications that mixedwood and deciduous stands may be of value (Korpimäki 1988, Hayward et al. 1993). This may be linked to differences in nest site selection. In Ontario and parts of western North America, Boreal Owls are thought to use deciduous stands for nesting (Bondrup-Nielsen 1978, Lane 1997). Hayward et al. (1993) found mixedwood forests supported a high number of potential nesting cavities but small numbers of Boreal Owl prey species. This suggests that Boreal Owls in Newfoundland may utilize a different type of habitat for nesting or that hardwood trees found in stands classified as 'softwood' are sufficient for nest sites. Northern Flickers (*Colaptes auratus*) are the sole providers of excavated cavities for Boreal Owls in this region. It is possible that flickers are also avoiding deciduous forests for nesting in western Newfoundland, but the nesting behavior of this species has not been assessed in Newfoundland. Similarly, the potential prey species of boreal owls in Newfoundland are associated with old growth, coniferous forest stands and cleared openings (Folinsbee et al. 1973, Roy et al. 1995). Given that prey abundance is a significant predictor of habitat quality, it likely also contributes to the determination of Boreal Owl habitat preferences in western Newfoundland.

Not surprisingly, Boreal Owls were associated more often with sites having higher HSI values than those randomly available. Though the intent of HSI model processes is for excellent quality habitat to receive high scores (e.g. 0.7-1.0) and for low quality habitat to receive low scores (e.g. 0.0-0.3), such results are not always obtained. The ranges of values produced by my models were relatively low, ranging from 0.0-0.60. A suitable amount of nesting habitat, represented by a high density of large trees, along with appropriate amounts of cover and short distances to forest edge for foraging habitat, are not being represented in the study area at levels that might be comparable to those found in more central portions of the Boreal Owl range in North America. Values remained low even when the models were adjusted in response to the sensitivity analyses (see Results), indicating potential problems with those models in terms of applicability to Newfoundland. Modifications to account for population specific home range size (see Chapter 2), as per the sensitivity analyses, seemed to have only had a limited influence on the performance of the HSI model. It is possible that with more data collection on the most sensitive model parameters (home range, foraging radius, and nest site characteristics), a more comprehensive comparison could be completed between the original HSI model and a model modified with local data. However, Brooks (1997) noted that uncalibrated HSI models often generate scores with maximum values somewhere between 0.3-0.7. Therefore it could be that Newfoundland truly does not have optimal habitat and Boreal Owls are able to survive in sub-optimal conditions. Such circumstances are not unheard of; populations on the periphery of a species' range are not infrequently found to have adapted to what would be marginal habitat for individuals in the central portion of the species' ranges (Kawecki 2008, Romeo et al. 2010) and consequently, the nature of suitable habitat differs between populations at the core of the species' range and those at the edge. It would be valuable to test the current model in other parts of the Boreal Owl range to determine the broader applicability of this model.

The ability of Boreal Owls to persist under habitat conditions which appear less-than-optimal may indicate that they are perhaps less habitat-specific, in this peripheral Newfoundland population. The Newfoundland marten (*Martes americana atrata*), which was long considered an obligate old-forest species with home ranges dominated by mature and over-mature forests (Hearn et al. 2010), is now known to occupy home ranges in Newfoundland with large portions of defoliated forests, regenerating stands, and clearcuts, as well as mature and over-mature forest (Drew 1995, Hearn et al. 2010). Such examples indicate that habitat selection is a complex decision based on a variety of issues. Factors affecting Boreal Owl habitat suitability are availability of suitable nesting cavities and prey availability (Côté et al. 2004). It is quite possible that due to these two factors, the current HSI model is correctly classifying a large amount of sub-optimal habitat which Boreal Owls are occupying. This would support the notion of a sparsely distributed population of Boreal Owls with large home-range sizes needed to fulfill nesting and food requirements.

The predictive capacity of the models tested here was no better than chance, however the vast majority of owls occurred at locations where they were expected and few individuals occupied habitat deemed unsuitable by the model. It is also important to remember that when using presence/absence data, a lack of detection does not necessarily translate to an animal being absent but rather may reflect a lower ability to detect its presence. Therefore caution must be exercised when analyzing these types of data (Burnham 1981, Anderson 2001, Bart et al. 2004). The HSI models developed also suggested that there were many suitable sites, with comparable values to those where Boreal Owls were present, which were not currently occupied. This could indicate a failure to detect a Boreal Owl when in actuality there was a bird present, or an excess of unoccupied suitable habitat. Due to the highly fragmented nature of the habitat in western Newfoundland, I predicted that Boreal Owls would require a large home range to satisfy their resource requirements (see Chapter 2). Larger home ranges would result in a smaller, sparser population in which it would also be more difficult to detect a given individual. This could explain some of the model's inaccuracy for predicting Boreal Owl presence/absence given that the original parameters used for carrying capacity were based on studies from portions of the species' range with both higher habitat quality (e.g. northern Ontario and Alberta; Bondrup-Nielsen 1978), and greater densities of Boreal Owls. A HSI score is assumed to have a positive linear relationship with the potential carrying capacity of the habitat (U.S. Fish and Wildlife Service 1981) and thus, as a result, reducing the carrying capacity value for the models would potentially increase the overall suitability measure of District 15.

The sparse population of Boreal Owls in western Newfoundland may be attributed to a historically small prey population. There is only one native prey species, the meadow vole, on insular Newfoundland (Folinsbee et al. 1973). Other prey species, such as the deer mouse and the masked shrew were only introduced to the island in the late 1960's (Government of Newfoundland and Labrador 2010). Red-backed voles are one of the Boreal Owl's main prey species (Korpimäki 1981) in other areas. In the late 1990's, red-backed voles were introduced to the island of Newfoundland and their population size and distribution have been increasing (Hearn et al. 2006, B. Rodrigues 2008, unpubl. raw data). It is possible that the Boreal Owl population has not yet adapted to this increase in prey resources. If food is limiting then, as red-backed vole populations continue to increase then Boreal Owl population size may also increase. This element may also need to be incorporated into future HSI modeling processes to improve the accuracy of the model.

Another goal of this study was to evaluate the effects of three different forest harvesting scenarios on the amount of suitable Boreal Owl habitat available over time. My results did not support a change in habitat suitability given various forest harvesting which means that BAU is not worse and may be a reflection that natural and anthropogenic fragmentation provide equally useful habitat. This result may not be expected based on other work with Boreal owls elsewhere but this island population seems to be using habitat in a different fashion.

There are two management practices that should be included in a forest management strategy for the Boreal Owl. Because they are obligatory secondary cavity nesters, Boreal Owls are highly dependent on northern flickers, the only primary cavity excavator large enough to provide cavities for the Boreal Owl in Newfoundland. Maintaining large (> 30 cm dbh) trees (dead and alive) after harvesting in green patches through variable retention treatments would be beneficial to primary and secondary cavity nesters. The model should be updated with home range size estimates with at least18 relocations per bird. Future studies should focus on this parameter, as well as obtaining nesting and diet data for Boreal Owls in western Newfoundland.

3.6 REFERENCES

ABBOTT, K.N. AND A.A. KHAN. 2009. Investigations of MODIS snow mapping in a boreal forest watershed. ASPRS 2009 annual conference, Reflection of the past, vision of the future. Baltimore, MD, USA.

AEBISCHER, N.J., P.A., ROBERTSON AND R.E., KENWARD. 1993. Compositional analysis of habitat use from radio-tracking data. *Ecology* 74:1313-1325.

AKÇAKAYA, H.R. AND J.L. ATWOOD. 1997. A habitat-based metapopulation model of the California gnatcatcher. *Conservation Biology* 11:422-434.

ANDERSON, D.R. 2001. The need to get the basics right in wildlife field studies. *Wildlife Society Bulletin.* 29:1294-1297.

BART, J., S. DROEGE, P. GEISSLER, B. PETERJOHN AND C.J. RALPH. 2004. Density estimations in wildlife surveys. *Wildlife Society Bulletin* 32:1242-1247.

BELMONTE, L.R. 2005. Home range and habitat characteristics of boreal owls in northeastern Minnesota. M.S. thesis, Univ. Minnesota, St. Paul, MN, USA.

BLOCK W.M., M.L. MORRISON, J. VERNER AND P.N. MANLEY. 1994. Assessing wildlife-habitat-relationships models: a case study with California oak woodlands. *Wildlife Society Bulletin* 22:549-561.

BONDRUP-NIELSEN, S. 1978. Vocalizations, nesting, and habitat preferences of the Boreal Owl (*Aegolius funereus*) in North America. M.S. thesis. Univ. Toronto, ON, CA.

BONDRUP-NIELSEN, S. 1984. Vocalizations of the Boreal Owl, *Aegolius funereus richardsoni*, in North America. *Canadian Field Naturalist* 98:191-197.

BRADSHAW, C.J.A., I.G. WARKENTIN, AND N.S. SODHI. 2009. Urgent preservation of boreal carbon stocks and biodiversity. *Trends in Ecology and Evolution* 24:541-548.

BROOKS, R.P. 1997. Improving habitat suitability index models. *Wildlife Society Bulletin* 99:82-88.

BROOKS, B.L. AND S.A. TEMPLE. 1990. Habitat availability and suitability for loggerhead shrikes in the Upper Midwest. *American Midland Naturalist* 123:75-83.

BURNHAM, K.P. 1981. Summarizing remarks: Environmental influences. *Studies in Avian Biology* 6:324-325.

CORNER BROOK PULP AND PAPER LIMITED. 2002. Five Year Operating Plan, Forest Management District 15, 2003-2007. Corner Brook, NL, CA.

CÔTÉ, M., F. DOYON, AND N. BERGERON. 2004. Spatially explicit habitat suitability index model for the Boreal Owl (*Aegolius funereus*) in western Newfoundland, version 2. Institut Québécois d'Aménagement de la Forêt Feuillue, QC, CA.

DAMMAN, A.W.H. 1983. An ecological subdivision of the Island of Newfoundland *in* G.R. Smith [ED.], Biogeography and Ecology of the Island of Newfoundland. Dr W. Junk Publishers, The Hauge, Netherlands.

DEJAIFVE, P.A., C.A. NOVA AND R. PRODON. 1990. Habitat et densité de la chouette de Tengmalm (*Aegolius funereus*) a l'extremité orientale des Pyrenees. *Alauda* 58:267-273.

DOLTER, C.S. 2005. Using biodiversity indicators to assess the success of forecasting adaptive ecosystem management: the Newfoundland and Labrador experience *in* C. Aguirre-Bravo, P.J. Pellicane, D.P. Burns, and S. Draggan. [EDS.], Monitoring Science and Technology Symposium: Unifying knowledge for sustainability in the western hemisphere. Proceedings RMRS-P-42CD. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO, USA.

DREW, G.S. 1995. Winter habitat selection by American marten (*Martes americana*): Why old growth? Ph.D. thesis, Utah State Univ. Logan, UT, USA.

ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE. 2008. ArcView v. 3.2-Animal Movement Extention. ESRI: GSI and Mapping Software: Redlands, CA, USA.

FOLINSBEE, J.D., R.R. RIEWE, W.O. PRUITT, AND P.R. GRANT. 1973. Ecological distribution of the Meadow Vole *Microtus pennsylvanicus terraenovae*, (Rodentia: Cricetidae), on the Main Island of Newfoundland. *Canadian Field Naturalist* 87:1-4.

GAGNON, C. AND M. BOMBARDIER. 1995. Chouette rayée. Pages 598-601 *in* J. Gauthier and Y. Aubry [EDS.], Les Oiseaux nicheurs du Québec: Atlas des oiseaux nicheurs du Québec méridional. Association québécoise des groupes d'ornithologues, Société québécoise de protection des oiseaux, Service canadien de la faune, Montréal, QC, CA.

GOVERNMENT OF NEWFOUNDLAND AND LABRADOR. 1990. The Forestry Act. Queen's Printer, St. John's, NL, CA.

GOVERNMENT OF NEWFOUNDLAND AND LABRADOR. 2003. Five-year operating plan for Crown land in forest management district 15 [2003-2008]. Environment and Conservation. http://www.env.gov.nl.ca/env/Env/EA%202001/Project%20Info/1054.htm (accessed 20 March 2010).

GOVERNMENT OF NEWFOUNDLAND AND LABRADOR. 2010. Department of Environment and Conservation: Mammals introduced to Newfoundland. http://www.env.gov.nl.ca/env/snp/programs/education/animal_facts/mammals/#lm2 (accessed 20 March 2010).

GUISAN, A., J.P. THEURILLAT, AND F. KIENAST. 1998. Predicting the potential distribution of plant species in an Alpine environment. *Journal of Vegetation Science* 9:65-74.

HAYWARD, G.D. 1989. Habitat use and population biology of Boreal Owls in the Northern Rocky Mountains, USA. Ph.D. dissertation, Univ. Moscow, ID, USA.

HAYWARD, G.D. 1997. Forest management and conservation of Boreal Owls in North America. *Journal of Raptor Research* 31:114-124.

HAYWARD, G.D. AND P.H. HAYWARD. 1993. Boreal Owl (*Aegolius funereus*), In A. Poole [ED.], The Birds of North America Online Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu.qe2a-proxy.mun.ca/bna/species/063

———, ———, AND E.O. GARTON. 1993. Ecology of Boreal Owls in northern Rocky Mountains, USA. *Wildlife Monograms* 124:1-59.

HEARN, B.J., J.T. NEVILLE, W.J. CURRAN, AND D.P. SNOW. 2006. First record of the Southern Red-Backed Vole, *Clethrionomys gapperi*, in Newfoundland: Implications for the endangered Newfoundland Marten, *Martes Americana atrata. Canadian Field Naturalist* 120:50-56.

HEARN, B.J., HARRISON, D.J., FULLER, A.K., LUNDRIGAN, C.G., AND CURRAN, W.J. 2010. Paradigm shifts in habitat ecology of threatened Newfoundland martens. *Journal of Wildlife Management* 74:719-728.

HEINRICH, R., J. WATSON, B. BECK, J. BECK, M. TODD, R. BONAR, AND R. QUINLAN. 1999. Boreal Owl nesting and roosting habitat, habitat suitability index model, *Version 5.* Foothills Model Forest, AB, CA.

HINAM, H.L. 2001. Habitat associations of five forest owl species in Manitoba Escarpment with special consideration to forest fragmentation and slope. M.S. thesis, Univ. Manitoba. Winnipeg, MB, CA.

HIRZEL, A.H., G. LE LAY, V. HEFLER, C. RANDIN, AND A. GUISAN. 2006. Evaluating the ability of habitat suitability models to predict species presences. *Ecological Modelling* 199:142-152.

HOLT, D.W. AND D. ERMATINGER. 1989. First confirmed nest site or boreal owls in Montana. *Northwest Naturalist* 70:27-31.

KAWECKI, T.J. 2008. Adaptation to marginal habitats. *Annual Review of Ecology, Evolution and Systematics* 39:321-342.

KIRK, D.A. 1995. Status report of the Boreal Owl *Aegolius funereus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ON, CA.

KLENNER, W. AND T.P. SULLIVAN. 2003. Partial and clear-cut harvesting of high-elevation spruce-fir forests: implications for small mammal communities. *Canadian Journal of Forest Research* 33:2283-2296.

KOOPMAN, M.E., G.D. HAYWARD AND D.B. MCDONALD. 2007. High connectivity and minimal genetic structure among North American Boreal Owl (*Aegolius funereus*) populations, regardless of habitat matrix. *Auk* 124:690-704.

KORPIMÄKI, E. 1981. On the ecology and biology of Tengmalm's Owl (*Aegolius funereus*) in southern Ostrobothnia and Suomenselka, western Finland. *Acta Universitatis Ouluensis A 118 Biology* 13:1-84.

———.1988. Effects of territory quality on occupancy, breeding performance and breeding dispersal in Tengmalm's Owl. *Journal of Animal Ecology* 57:97-108.

———. 1992. Fluctuating food abundance determines the lifetime reproductive success of male Tengmalm's Owls. *Journal of Animal Ecology* 62:606-613.

LANE, W.H. 1997. Distribution and ecology of Boreal Owls in northeastern Minnesota. M.S. thesis, Univ. Minnesota, St. Paul, MN, USA.

LAUFF, R.F. 2009. First nest records of the Boreal Owl *Aegolius funereus* in Nova Scotia, Canada. *Ardea* 97:497-502.

MEADES, W.J. AND L. MOORES. 1994. Forest site classification manual: a field guide to the Damman forest types of Newfoundland. Second Edition. Western Newfoundland Model Forest, Department of Forestry and Agriculture, and Canadian Forest Service, St. John's, NL, CA.

MINITAB, INC. 2007. Minitab 15 Statistical Software, State College, PA, USA.

MINITAB, INC. 2010. Minitab 16.1.1 Statistical Software, State College, PA, USA.

MITCHELL, M.S., J.W. ZIMMERMAN, AND R.A. POWELL. 2002. Test of a habitat suitability index for black bears in the southern Appalachians. *Wildlife Society Bulletin* 30:794-808.

MORONI, M.T. 2006. Disturbance history affects woody debris dynamics of Newfoundland balsam fir (*Abies balsamea*) stands. *Canadian Journal of Forest Research* 36:3194–3208.

PALMER, D.A.1986. Habitat selection, movements and activity of Boreal and Saw-whet Owls. M.S. thesis, Colorado State Univ., Ft. Collins, CO, USA.

REMSOFT. 2004. Forest and Timberland Management software. Fredericton, NB, CA.

RICKERS, J.R., L.P. QUEEN, AND G.J. ARTHAUD. 1995. A proximity-based approach to assessing habitat. *Landscape Ecology* 10:309-321.

ROLOFF, G.J. AND B.J. KERNOHAN. 1999. Evaluating reliability of habitat suitability index models. *Wildlife Society Bulletin* 27:973-985.

ROMEO, C., L.A. WAUTERS, D. PREATONI, G. TOSI, AND A. MARTINOLI. 2010. Living on the edge: Space use of Eurasian red squirrels in marginal high-elevation habitat. *Acta Oecologica* 36:604-610.

ROY, L.D., J.B. STELFOX, AND J.W NOLAN. 1995. Relationship between mammal biodiversity and stand age and structure in aspen mixedwood forests in Alberta. Pages 159-188 *in* J.B. Stelfox [ED.], Relationships between stand age, stand structure and biodiversity in aspen mixedwood forests in Alberta. Alberta Environmental Center (AECV95- RI) Vegreville, Alberta. Canadian Forest Service, Edmonton, AB, CA.

SETTERINGTON, M.A., I.D. THOMPSON, AND W.A. MONTEVECCHI. 2000. Woodpecker abundance and habitat use in mature balsam fir forests in Newfoundland. *Journal of Wildlife Management* 64:335-345.

SMITH, P.G. 2008. Smith Ecology Ltd. Compos Analysis Software, Whales, UK.

SMITH, C.Y., I.G. WARKENTIN, AND M.T.MORONI. 2008. Snag availability for cavity nesters across a chronosequence of post-harvest landscapes in western Newfoundland. *Forest Ecology and Management* 256:641-647.

SOLHEIM, R. 1983. Breeding frequency of Tengmalm's Owl (*Aegolius funereus*) in three localities in 1974-1978. *Proceedings of the Nordic Ornithological Congress* 3:79-84.

SONERUD, G.A. 1986. Effect of snow cover on seasonal changes in diet, habitat and regional distribution of raptors that prey on small mammals in boreal zones of Fennoscandia. *Holarctic Ecology* 9:33-47.

STOMS, D.M., W.F. DAVIS, AND C.B. COGAN. 1992. Sensitivity of wildlife habitat models to uncertainties in GIS data. *Photogrammetric Engineering and Remote Sensing* 58:843-850.

SULLIVAN, T.P., R.A. LAUTENSCHLAGER, AND R.G. WAGNER. 1999. Clearcutting and burning of northern spruce-fir forests: Implications for small-mammal communities. *Journal of Applied Ecology* 36: 327-344.

THOMPSON, I.D. AND W.J. CURRAN. 1995. Habitat suitability for marten of second-growth balsam fir forests in Newfoundland. *Canadian Journal of Zoology* 73:2059-2064.

TITUS, K. AND J.A. MOSHER. 1984. Chance-corrected classification for use in discriminant Analysis: Ecological applications. *American Midland Naturalist* 111:1-7.

TUCKER, B.J. 1988. The effects of forest harvesting on small mammals in western Newfoundland and its significance to marten. M.Sc. Thesis, Utah State University, Logan, UT, USA.

U.S. FISH AND WILDLIFE SERVICE. 1981. Standards for the development of suitability index models. *Ecol. Serv. Man. 103.* U.S. Fish and Wildl. Serv., Division of Ecological Services. U.S. Gov. Print. Off., Washington, DC, USA.

WHITAKER, D.M. AND W.A. MONTEVECCHI. 1999. Breeding bird assemblages inhabiting riparian buffer strips in Newfoundland. *Canadian Journal of Forest Management* 63:167–179.

WHITMAN, J. S. 2001. Diets of nesting Boreal Owls, *Aegolius funereus*, in Western interior Alaska. *Canadian Field Naturalist* 115:476-479.

VAN HORNE, B. AND J.A. WIENS. 1991. Forest Bird Habitat Suitability Model and the Development of General Habitat Models. Fish and Wildlife Resource Paper 8. USDI Fish and Wildlife Service, Washington, DC, USA.

ZAR, J.H. 1999. Biostatistical Analysis, 4th Ed. Prentice Hall, Upper Saddle River, NJ, USA.

Table 3.1. Description and average area of each Boreal Owl HSI model habitat type within District 15, western Newfoundland

HABITAT	DESCRIPTION	AVERAGE AREA (%)
Bog	Wet areas of bog or marsh that may include patches of open water	6.5
Rock Barren	Barren rock land without sufficient soil for tree establishment (≤ 10% tree cover)	6.9
Soil Barren	Barren land other than rock which does not support tree vegetation usually due to adverse climatic or soil factors (≤ 10% tree cover)	4.8
Water	Lakes, rivers, streams, ponds	20.5
Remnant Stand	Any portion of a stand that has not been harvested, silviculturally treated, impacted by disturbance that is ≤ 5 ha	2.4
Hardwood Scrub	A stand dominated by hardwood with > 10% crown closure not capable of producing 30 m^3/ha of wood volume at 60 yr	0.2

Table 3.1. cont.

Softwood Scrub	A stand dominated by softwood with > 10% crown closure not capable of producing 30 m^3/ha of wood volume at 60 yr	16.9
Silviculture	Forest stands subject to silviculture within the last 8 yr	0.7
Tree Bog	Wet areas of bog or marsh with ≤ 10% tree cover	0.9
Balsam Fir	A stand where ≥ 75% of the basal area is comprised of balsam fir	19.3
Balsam Fir-Spruce	A stand where ≥ 50% of the basal area is comprised of balsam fir and the remaining basal area is comprised of spruce	6.5
Balsam Fir-White Birch	A stand where ≥ 50% of the basal area is comprised of balsam fir and the remaining basal area is comprised of white birch	4.8
Spruce	A stand where ≥ 75% of the basal area is comprised of spruce	1.7

Table 3.1 cont.

Spruce-Balsam Fir	A stand where ≥ 50% of the basal area is comprised of spruce and the remaining basal area is comprised of balsam fir	2.1
White Birch-Balsam Fir	A stand where ≥ 50% of the basal area is comprised of white birch and the remaining basal area is comprised of balsam fir	1.7
Other	Information not provided	3.6

Table 3.2. Age classes and age codes for forest stands on the island of Newfoundland

AGE CLASS	AGE CODE
0-20 yr (immature)	1
21-40 yr (immature)	2
41-60 yr (mature)	3
61-80 yr (mature)	4
81-100 yr (over-mature)	5
101-120 yr (over-mature)	6
121+ yr	7
Uneven aged	9

Table 3.3. Comparisons of selected habitat parameters (median % value and range) among occupied sites (point counts where owls were detected and Boreal Owl home ranges) and unoccupied sites (random surrogate home ranges), 2006-2007, in western Newfoundland.

	Median % Values and Ranges for^{2}:			
Habitat Parameter	Present Point Counts (N=73)	Home Ranges (N=8)	Surrogate Home Ranges (N=40)	P-value^{1}
Bog	4.8 (0-42.1)	4.0 (1.1-8.2)	4.0 (0-97.5)	0.769
Disturbed	28.4 (0-87.2)^{B}	36.5 (14.0-66.8)^{A}	8.2 (0-55.2)^{C}	0.002
Scrub	10.4 (0-49.4)	8.1 (2.9-33.2)	16.2 (2.4-100)	0.035
Hardwood	0 (0-6.6)^{B}	0 (0-0.1)^{B}	0 (0-13.5)^{A}	0.001
Young softwood	11.3 (0-81.4)	11.1 (0-69.8)	4.6 (0-67.5)	0.091

Table 3.3. cont.

Mature to over-mature softwood	17.3 (0-67.6)	20.9 (3.5-50.8)	16.4 (0-73.3)	0.910
Young mixedwood	0 (0-27.5)	0 (0-2.8)	0 (0-16.5)	0.211
Mature to over-mature mixedwood	0 (0-21.6)^{B}	0 (0-3.7)^{C}	3.3 (0-67.2)^{A}	0.000

[1] Kruskall-Wallis Multiple Comparison Test ($\alpha = 0.05/8$)

[2] Values with different superscripted letters were significantly different from each other based on Tukey-type post hoc comparisons

Table 3.4a. Habitat Suitability Index values and percent of District 15, western Newfoundland classified as high, moderate or low quality Boreal Owl habitat, by year and model type.

		% District 15			
		2006		2007	
HSI	Habitat Quality	Original	Modified	Original	Modified
0.51+	High	0.2	0.3	0.2	0.3
0.46-0.50	Moderate	0.6	0.8	0.6	0.8
0.41-0.45	Moderate	1.2	1.4	1.2	1.4
0.36-0.40	Moderate	2.9	3.5	2.8	3.5
0.31-0.35	Moderate	5.8	5.9	5.7	5.8
0.26-0.30	Moderate	8.0	7.9	7.9	7.8
0.21-0.25	Low	9.7	9.1	9.6	9.0
0.16-0.20	Low	10.6	9.9	10.7	10.0
0.11-0.15	Low	11.9	10.8	12.1	11.0
0.06-0.10	Low	11.8	11.2	11.8	11.2
0-0.05	Low	37.4	39.3	37.4	39.3

Table 3.4b. Habitat Suitability Index values and percent of present point counts classified as high, moderate or low quality Boreal Owl habitat, by year and model type, in western Newfoundland

		% PRESENT POINT COUNTS			
		2006	2007	2006	2007
HSI	Habitat Quality	Original	Modified	Original	Modified
0.51+	High	0.1	0.1	0	0.3
0.46-0.50	Moderate	0.2	0.3	0	0
0.41-0.45	Moderate	0.3	0.8	0.2	0.8
0.36-0.40	Moderate	1.9	3.5	1.7	3.1
0.31-0.35	Moderate	5.6	6.3	5.8	6.0
0.26-0.30	Moderate	11.8	12.2	12.8	16.0
0.21-0.25	Low	45.6	35.0	54.4	46.9
0.16-0.20	Low	14.1	19.6	9.7	10.9
0.11-0.15	Low	17.9	18.1	10.7	8.3
0.06-0.10	Low	2.7	4.1	4.2	5.8
0-0.05	Low	0	0	0.5	2.3

Table 3.4c. Habitat Suitability Index values and percent of Boreal Owl home ranges classified as high, moderate or low quality Boreal Owl habitat, for each model type, in western Newfoundland

		% Actual Home Ranges	
HSI	Habitat Quality	Original	Modified
0.51+	High	0	0
0.46-0.50	Moderate	0	0
0.41-0.45	Moderate	0	0
0.36-0.40	Moderate	0	0
0.31-0.35	Moderate	0	0.2
0.26-0.30	Moderate	9.8	7.1
0.21-0.25	Low	33.3	20.9
0.16-0.20	Low	0.5	5.6
0.11-0.15	Low	32.2	25.6
0.06-0.10	Low	22.0	36.3
0-0.05	Low	2.1	4.4

Table 3.4d. Habitat Suitability Index values and percent of surrogate home ranges classified as high, moderate or low quality Boreal Owl habitat, for each model type, in western Newfoundland

		% Surrogate Home Ranges	
HSI	Habitat Quality	Original	Modified
0.51+	High	0	0
0.46-0.50	Moderate	0	0
0.41-0.45	Moderate	0	0.1
0.36-0.40	Moderate	0.5	1.1
0.31-0.35	Moderate	3.6	3.3
0.26-0.30	Moderate	8.2	7.9
0.21-0.25	Low	22.0	16.0
0.16-0.20	Low	15.7	17.8
0.11-0.15	Low	20.0	15.5
0.06-0.10	Low	8.8	11.5
0-0.05	Low	21.2	26.7

Table 3.5. Cohen's Kappa analysis for the prediction of presence and absence of Boreal Owls by model type and year (percentages are in brackets).

	ORIGINAL MODEL PREDICTIONS				MODIFIED MODEL PREDICTIONS			
	2006		2007		2006		2007	
	Correct	Incorrect	Correct	Incorrect	Correct	Incorrect	Correct	Incorrect
Actual Present	43 (100)	0 (0)	28 (85)	5 (15)	43 (100)	0 (0)	28 (85)	5 (15)
Actual Absent	90 (96)	4 (4)	94 (67)	46 (33)	90 (96)	4 (4)	92 (66)	48 (34)
Kappa statistic	0.0271		0.0872		0.0271		0.0953	
P-value	0.9145		0.9750		0.9145		0.9839	

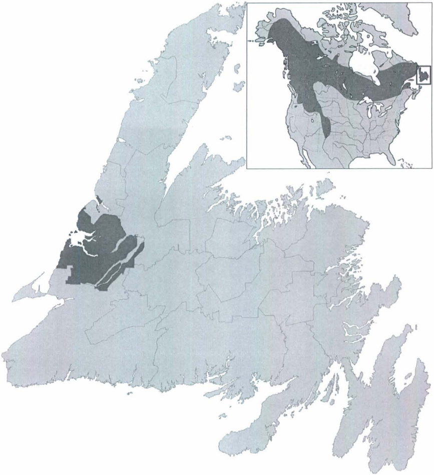


Fig. 3.1. Forest Management District 15 (shaded) on the island of Newfoundland, which is located at the easternmost portion of the Boreal Owl range in North America (see inset). Adapted from Hayward and Hayward (1993).

Fig. 3.2a. Early breeding season 2006-point count locations (present = red circles; absent = black triangles) for Boreal Owls in District 15, western Newfoundland.

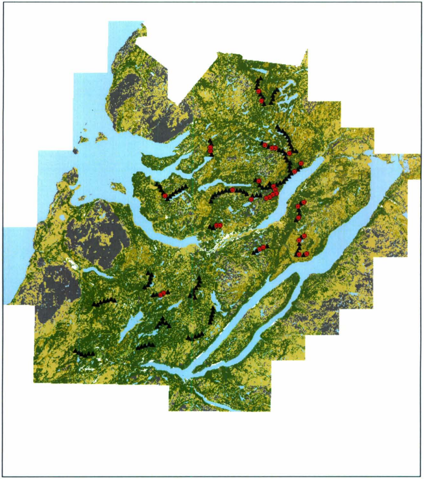


Fig. 3.2b. Early breeding season 2007-point count locations (present = red circles; absent = black triangles) for Boreal Owls in District 15, in western Newfoundland.

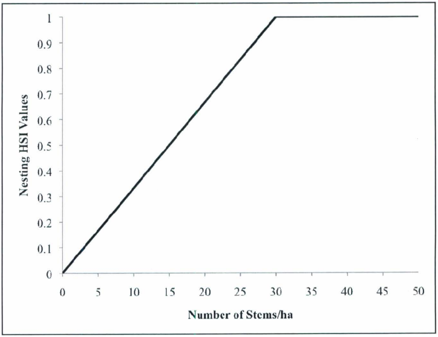


Fig. 3.3a. Relationship between HSI values and Nesting as a function of density of stems.

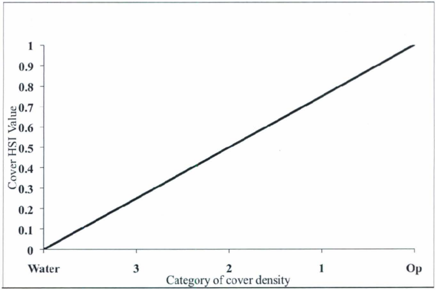


Fig. 3.3b. Relationship between HSI values and cover density (Water, Forest Density Class 1, 2, and 3, and Openings).

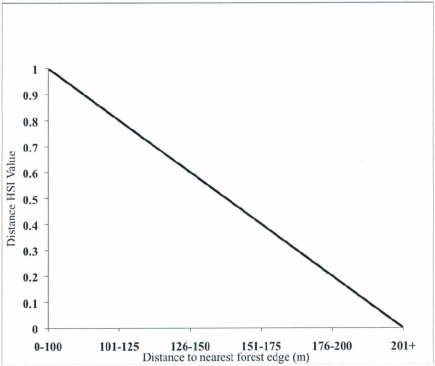


Fig. 3.3c. Relationship between HSI values and distance to nearest forest edge.

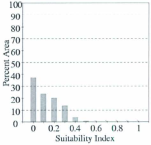
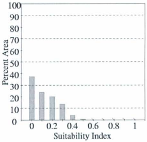
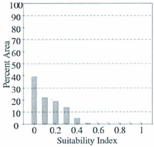
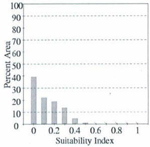
Model Type	Year	
	2006	2007
Original		
Modified		

Fig. 3.4. Percentage of habitat in each HSI class for the study area for both Original and Modified model outputs, yrs 2006 and 2007.

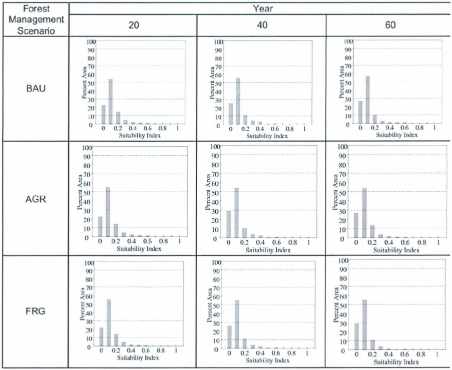


Fig. 3.5. Percentage of habitat within the study area in each HSI class for three forest management scenarios: Business As Usual, Aggregated, and Fragmented; at three time periods: 20, 40, and 60 yrs. in the future.

4.0 GENERAL DISCUSSION

Similar to the results of previous studies elsewhere, I found that male Boreal Owls (*Aegolius funereus*) in western Newfoundland occupied locations characterized by habitat which was distinctive from that randomly available. Within Boreal Owl home ranges and in the area immediately surrounding roost sites, mature and over-mature coniferous forest stands dominated, as was found in Ontario (Bondrup-Nielsen 1978), Colorado (Palmer 1986), Idaho (Hayward 1989), and Minnesota (Belmonte 2005). Hardwood stands represented a very small proportion of forest cover in the study area and were largely absent from home ranges and roost sites. This contrasts with the results from assessments of Boreal Owls in Ontario and parts of western North America, where deciduous stands are used for nesting (Bondrup-Nielsen 1978, Lane 1997). Thus, owls in western Newfoundland may well be selecting different habitat types for nesting than in other parts of the species' North American range. Likewise, although present in small amounts in home ranges and at the roost site locations I examined, mixedwood stands were not actively selected for by owls in my study area. Hayward et al. (1993) found that mixedwood forests supported a high number of potential nesting cavities but small numbers of Boreal Owl prey species. Prey species for owls in Newfoundland appear to be most frequently associated with old growth, coniferous forest stands and open areas (Folinsbee et al. 1973, Roy et al. 1995, Hearn et al. 2010).

Home range size estimates from my research were intermediate to those reported for Boreal Owls across North America. The median home range in the current study, 429 ha, is on the higher end of the range for male Boreal Owls as initially predicted.

However, the results of the asymptote analysis (Fig. 2.2) suggest that 18 relocations may have been insufficient to accurately estimate actual home range size of owls in this study. As discussed earlier (see Chapter 2), other home range research recommend 20-30 points to accurately estimate of home range size, suggesting a potential plateau for my home range size estimate curves somewhat above the values noted in Fig. 2.2. Thus Boreal Owl home ranges in western Newfoundland are likely larger than what was reported here, but further study is needed to determine the number of relocations required to reach an asymptote for these curves, and the resulting home range size estimate.

Boreal Owl habitat needs are a key determinant of home range size and location (Morse 1980, Hakkarainen et al. 2008), occupying larger areas when habitat is sub-optimal. Habitat associations of predatory species are often reflected by the habitat associations of their primary prey (Janes 1985). For Boreal Owls in Newfoundland, the main prey species are likely masked shrew (*Sorex cinereus*), meadow vole (*Microtus pennsylvanicus*), and red-backed vole (*Myodes gapperi*). Since its arrival in Newfoundland in the late 1990s, the red-backed vole population has been increasing in density and expanding its range (Hearn et al. 2006, B. Rodrigues 2008, unpubl. data, Hearn et al. 2010). While long-term data on Boreal Owl distribution and density in Newfoundland does not exist, any failure of this population to expand given an increase in red-backed vole populations would strongly suggest that the availability of suitable nest sites is the key limiting factor for Boreal Owls in this area. Future studies should focus on Boreal Owl diet and locating Boreal Owl nest sites to determine nest habitat characteristics in Newfoundland and thus establish how forest management operations may influence the availability of suitable nesting sites.

A habitat suitability index (HSI) model based on scientific literature and expert opinion was developed for the Boreal Owl in western Newfoundland, Canada (Côté et al. 2004). This model was part of a suite of tools developed for the Western Newfoundland Model Forest as the basis for recommending forest harvesting strategies that would sustain regional biodiversity (Dolter 2005). As demonstrated in Chapter 3, the ranges of HSI values produced by the current models (original and modified) were relatively low. This could indicate that the model is incorrectly classifying suitable habitat as unsuitable. It could also mean that Newfoundland has sub-optimal habitat compared to other regions within the species continental range, yet the Boreal Owl is able to persist. Owls in Newfoundland are on the edge of their range and such peripheral populations may have different habitat requirements or may be more flexible in their resource needs. The apparent limited suitability of this landscape for boreal owls based on the HSI model may thus be a reflection of true differences in habitat needs for this population. Populations on the periphery of a species' range are commonly found to have adjusted to what would be marginal habitat for individuals in the central portion of a species' range (Kawecki 2008, Romeo et al. 2010) and consequently, the nature of suitable habitat changes between populations at the core of the species' range and those at the edge. This rationale support my documentation of a sparsely distributed population of Boreal Owls that requires large home range sizes to fulfill nesting and food requirements because western Newfoundland is comprised of sub-optimal habitat. There were also areas of more densely populated

Boreal Owls where habitat was generally unsuitable but must have contained desirable attributes. Apparent "hot spots" of Boreal Owl activity during point counts are evident in Figs. 3.2a and b, although extended monitoring of the study area would be needed to ascertain the long-term nature of these locations as hot spots of suitable habitat.

The HSI models correctly predicted where Boreal Owls were located and only a small proportion of owls were found at locations where the model indicated they should not occur. The model also suggests that there is an abundance of suitable habitat that is not occupied. There are several possible explanations for this. First, this could reflect true inaccuracy of this model in Newfoundland. The habitat which the model is ascribing as suitable could actually be unsuitable. This would indicate that the model is not distinguishing between suitable and unsuitable habitat due to an inconsistency in Boreal Owl habitat preference compared to other areas of North America. It could also reflect potential home range size discrepancies. As noted above, more telemetry relocations could reveal even larger home range sizes for male Boreal Owls in western Newfoundland. Once this was incorporated into the model, the outputs might not indicate such an abundance of unoccupied yet available habitat. Second, this may have occurred due to a low detection rate during point counts, resulting in locations where owls were present but not detected. This would account for the large number of locations where owls were predicted to occur but not found. Continuing to conduct point counts would help to determine if detection rates were accurate by noting any consistent absences, as long as detectability remains constant over space and time. Temporal, spatial and environmental factors seem to be the main components of accurately detecting a species

(Pollock et al. 2002, Royle 2004). Finally, it could also be that population densities are truly low and there is not enough reproductive output to fill the available habitat. This would suggest a lack of nesting cavities as one potential explanation as to why the population is not able to expand given an increasing abundance of prey. Again, a focus on locating Boreal Owl nest sites could help address this issue by examining clutch size and fledging success, although providing nest boxes in suitable habitat would also help to clarify the nature of productivity in this population.

There were no significant differences between the three proposed forest management scenarios for Boreal Owls. The availability of habitat in the various HSI classes in the forward projection models arising from the different scenarios did not change over the 60-yr period, nor did the values differ among scenario types. My findings suggest that, from a forest management perspective, changing harvesting methods away from currently employed techniques will not influence the amount of suitable Boreal Owl habitat available over time. It could be that, given the naturally fragmented landscape of western Newfoundland, these scenarios do not substantially alter the resulting landscape from the perspective of Boreal Owls. The lack of influence of the size of harvest blocks, as incorporated into the various harvesting scenarios, may not be an issue for managing Boreal Owl habitat, however the manner in which harvesting affects fine-scale features of the environment for Boreal Owls may be important. In particular, retaining large diameter snags (Smith et al. 2008) is likely critical for Boreal Owls due to their requirement for such substrates to provide suitable nesting sites.

Habitat suitability index models are valuable tools when developing land management strategies, but only when crucial assumptions are met and the models are properly validated with independent field data. To further validate the current HSI model, more data are required on the most sensitive parameters. It would also be valuable to test the current model in other parts of the Boreal Owl's range to determine the broader applicability of this model. With the aim of comparing spatially or temporally distinct landscapes however, the HSI modelling process remains a valuable tool for determining more appropriate forest management options. As demands for natural resources continue to grow and wildlife habitats are more extensively influenced by human activities, it will become increasingly important to incorporate the use of such management tools into decision making processes.

4.1 REFERENCES

BELMONTE, L.R. 2005. Home range and habitat characteristics of boreal owls in northeastern Minnesota. M.S. thesis, Univ. Minnesota, St. Paul, MN, U.S.A.

BONDRUP-NIELSEN, S. 1978. Vocalizations, nesting, and habitat preferences of the Boreal Owl (*Aegolius funereus*) in North America. M.S. thesis. Univ. Toronto, ON, CA.

CÔTÉ, M., F. DOYON, AND N. BERGERON. 2004. Spatially explicit habitat suitability index model for the Boreal Owl (*Aegolius funereus*) in western Newfoundland, version 2. Institut Québécois d'Aménagement de la Forêt Feuillue, QC, CA.

DOLTER, C.S. 2005. Using biodiversity indicators to assess the success of forecasting adaptive ecosystem management: the Newfoundland and Labrador experience *in* C. Aguirre-Bravo, P.J. Pellicane, D.P. Burns, and S. Draggan. [EDS.], Monitoring Science and Technology Symposium: Unifying knowledge for sustainability in the western hemisphere. Proceedings RMRS-P-42CD. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO, U.S.A.

HAKKARAINEN, H., E. KORPIMÄKI, T. LAAKSONEN, A. NIKULA, AND P. SUORSA. 2008. Survival of male Tengmalm's owls increases with cover of old forest in their territory. *Oecologia* 155:479-486.

HAYWARD, G.D. 1989. Habitat use and population biology of Boreal Owls in the Northern Rocky Mountains, USA. Ph.D. dissertation, Univ. Moscow, ID, U.S.A.

———, P.H. HAYWARD, AND E.O. GARTON. 1993. Ecology of Boreal Owls in the Northern Rocky Mountains, USA. *Wildlife Monograms* 24:3-59.

HEARN, B.J., J.T. NEVILLE, W.J. CURRAN, AND D.P. SNOW. 2006. First record of the southern red-backed vole, *Clethrionomys gapperi*, in Newfoundland: implications for the endangered Newfoundland marten, *Martes americana atrata*. *Canadian Field Naturalist* 120:50–56.

HEARN, B.J., HARRISON, D.J., FULLER, A.K., LUNDRIGAN, C.G., AND CURRAN, W.J. (2010). Paradigm Shifts in Habitat Ecology of Threatened Newfoundland Martens. *Journal of Wildlife Management* 74:719-728.

FOLINSBEE, J.D., R.R. RIEWE, W.O. PRUITT, AND P.R. GRANT. 1973. Ecological distribution of the Meadow Vole *Microtus pennsylvanicus terraenovae*, (Rodentia: Cricetidae), on the Main Island of Newfoundland. *Canadian Field Naturalist* 87:1-4.

JANES, S.W. 1985. Habitat selection in raptorial birds. Pages. 159-188 *in* M.L. Cody [ED.], Habitat selection in birds. Academic Press, Orlando, FL, U.S.A.

KAWECKI, T.J. 2008. Adaptation to marginal habitats. *Annual Review of Ecology, Evolution and Systematics* 39:321-342.

LANE, W.H. 1997. Distribution and ecology of Boreal Owls in northeastern Minnesota. M.S. thesis, Univ. Minnesota, St. Paul, MN, U.S.A.

MORSE, D.H. 1980. Behavioral Mechanisms in Ecology, Harvard Univ. Press, MA, U.S.A.

PALMER, D.A. 1986. Habitat selection, movements and activity of Boreal and Saw-whet Owls. M.S. thesis, Colorado State Univ., Ft. Collins, CO, U.S.A.

POLLOCK, K.H., J.D. NICHOLS, T.R. SIMONS, G.L. FARNSWORTH, L.L. BAILEY, AND J.R. SAUER. 2002. Large scale wildlife monitoring studies: statistical methods for design and analysis. *Environmetrics* 13, 105-119.

ROMEO, C., L.A. WAUTERS, D. PREATONI, G. TOSI, AND A. MARTINOLI. 2010. Living on the edge: Space use of Eurasian red squirrels in marginal high-elevation habitat. *Acta Oecologia* 36:604-610.

ROY, L.D., J.B. STELFOX, AND J.W NOLAN. 1995. Relationship between mammal biodiversity and stand age and structure in aspen mixedwood forests in Alberta. Pages 159-188 *in* J.B. Stelfox [ED.], Relationships between stand age, stand structure and biodiversity in aspen mixedwood forests in Alberta. Alberta Environmental Center (AECV95- RI) Vegreville, Alberta. Canadian Forest Service, Edmonton, AB, CA.

ROYLE, J.A. 2004. Modeling abundance index data from Anuran calling surveys. *Conservation Biology* 18:1378-1385.

SMITH, C.Y., I.G. WARKENTIN, AND M.T. MORONI. 2008. Snag availability for cavity nesters across a chronosequence of post-harvest landscapes in western Newfoundland. *Forest Ecology and Management* 256:641-647.