UNIVERSITÉ DU QUÉBEC À MONTRÉAL

EFFETS DE LA TAILLE ET DE LA PROPORTION DE LA FORÊT RÉSIDUELLE SUR L'EFFORT D'APPROVISIONNEMENT FORESTIER ET L'INDICE DE QUALITÉ DE L'HABITAT DE TROIS ESPÈCES ANIMALES SELON UNE STRATÉGIE D'AMÉNAGEMENT ÉCOSYSTÉMIQUE EN FORÊT BOÉALE

MÉMOIRE

PÉSENTÉ COMME EXIGENCE PARTIELLE

DE LA MAÎTRISE EN SCIENCES DE L'ENVIRONNEMENT

PAR

JESSICA MARSHALL

Mars 2013

UNIVERSITÉ DU QUÉBEC À MONTRÉAL

THE EFFECTS OF SIZE AND PROPORTION OF RESIDUAL FOREST ON HARVESTING EFFORT AND HABITAT QALITY INDEX OF THREE ANIMAL SPECIES USING ECOSYSTEM BASED MANAGEMENT SCENARIOS IN BOREAL FOREST

THESIS

PRESENTED AS PART OF REQUIREMENTS

FOR THE MASTERS PROGRAM IN ENVIRONMENTAL SCIENCES

BY

JESSICA MARSHALL

March 2013

ACKNOWLEDGEMENTS

I would like to start by thanking my supervisors. Osvaldo Valeria, who pushed me beyond my limits; for always demanding better, teaching me to be resourceful and for keeping your sense of humour during this ardent process, thank you! To Daniel Gagnon, if not for your support, constant encouragement and advice, I would have given up long ago, thank you!

For their contributions to the computer models, thanks to Evan Hovington and Annie Belleau, without whose invaluable help I would have not made it through SELES.

Thanks to Melanie Desrochers and Ingrid Cea-Roa for their contributions to my training in ArcGIS. To Ingrid, whose friendship, constant help, and coffee maker made learning GIS in Spanish until the wee hours of the morning enjoyable! For his last minute help in statistical analyses, thank you, Stéphane Daigle.

I would also like to thank the National Science and Engineering Council of Canada (NSERC), the Sustainable Forest Management Network (SFM Network) centres of Excellence (NCE) and the Roasters Foundation for their financial support.

Finally, thank you to my parents for their support and unending encouragement, you're wonderful. And to my son Marcus, the reason I pursued my education.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

RÉSUMÉ

La faune et la flore de la forêt boréale du Québec sont adaptées aux perturbations naturelles, plus particulièrement aux feux. L'approche écosystémique s'inspirant des dynamiques naturelles propose un avenir prometteur dans le développement des pratiques sylvicoles durables. Des études qui ont comparé les forêts résiduelles laissées par la récolte à celles laissées par les feux démontrent une différence significative entre la fréquence des îlots résiduels et leur configuration, des différences qui ont probablement des impacts importants sur la faune et la flore de la région et sur l'approvisionnement en bois. Six scénarios spatiaux avec 100 répétitions ont été simulés avec le logiciel SELES. Parmi ceux-ci, dix répétitions qui ont atteint nos cibles ont été sélectionnés selon différentes tailles (3000 ha, 15000 ha, et 60000 ha), fréquences et configurations pour évaluer leurs impacts sur l'effort d'approvisionnement. De plus, les effets environnementaux basés sur l'indice de qualité d'habitat pour l'Orignal (*Alces alces*), le lièvre d'Amérique (*Lepus americanus*) et la martre d'Amérique (*Martes americana*) ont également été évalués. Les résultats de ce projet permettent de faire des recommandations quant aux effets de la taille et de la proportion de la forêt résiduelle, selon différentes taille de chantiers de récolte, sur les efforts d'approvisionnement en forêt dominée par l'épinette noire.

Mots clés: Épinette noire, aménagement écosystémique, taille des îlots résiduels, effort d'approvisionnement, qualité d'habitat.

ABSTRACT

The vegetation and wildlife of northern boreal forests in Quebec are adapted to natural disturbances, particularly wildfires. The ecosystem based management approach (EBM) is inspired by such natural dynamics and offers a promising avenue in the development of sustainable forestry practices. Previous studies examining the residual forest patches left by logging compared to those left by wildfires indicate that the shape of residual patches and patterns are significantly different and most probably have an impact on the wildlife of the region, as well as wood procurement efforts. Six spatial scenarios with one hundred repetitions each were simulated in SELES. The ten repetitions that best met our goals were then chosen in order to analyse the impacts of different residual patch size (3000 ha, 15000 ha, 60000 ha), frequency and spatial configuration on harvesting effort. In addition, environmental effects based on habitat quality index for moose (*Alces alces*), hare (*Lepus americanus*) and marten (*Martes americana*) were also evaluated. The results of this project could help in the application of ecosystem based management approaches in black spruce dominated forests, while ensuring a certain level of conservation and biodiversity is maintained.

Key words: black spruce, ecosystem based management, residual patch size, residual patch frequency, harvesting effort, habitat quality index.

GENERAL INTRODUCTION

1.1 The emergence of ecosystem based forest management (EBM)

Since colonization, the forest industry has played an integral economic role in the province of Quebec (Linteau *et al.,* 1983). Logging began in the province's Bas St-Laurent southern region and has since progressed northward. At the time, the premise was that once loggers reached the northern borders of the territory, the southern forests would have regenerated back to their original structure and composition. However, with the increase in market demands from growing populations and the ability to increase harvests through industrialization, forestry has now replaced natural disturbances as the primary stand-replacing force in the Canadian Boreal forests (Gauthier *et al.,* 2008). In fact, Quebec's boreal forest is currently assessed to be the youngest it has ever been throughout history (Bergeron *et al*., 2008). Furthermore, the development of ecological sciences has explained why these presumptions regarding regeneration were far too simplistic when taking into account the complexity and diversity of forest ecosystems (Bergeron *et al.,* 2008).

In the last two decades ecological knowledge as well as socio-economic shifts have changed the Canadian perception of the boreal forest (Perera *et al.,* 2004). The large scale regeneration zones that were left by clear cutting and other logging practices became an increasing public concern with the arrival of human activity in forested areas for recreational purposes. Communities have also been affected by forest activities. These are mainly First Nations communities, and their politics have also gained more public attention in recent years (Gauthier *et al.,* 2008). In sum, the shift in perception is one of environmental concern. The elevated disturbance rates and large cut patterns caused by industrial forestry have created a discussion as to how we should manage our wood resources in order to maintain natural forest processes and patterns (Gauthier *et al.,* 2008). Certain forest companies have also begun to respond to this environmental shift by modifying their practices to be environmentally certified for international markets by the Forest Stewardship Council (FSC), Smart Wood or other certification organizations (Belleau *et al.,* 2008).

A number of the environmental guidelines outlined by certification companies in Quebec and other provinces in Canada (internationally as well) pertain to ecosystem based management approaches (EBM) (MRNFQ, 2009). Ecosystem management approaches emerged in the forest sciences through the observations of forest disturbance regimes. Scientists from regions such as north western Quebec where large natural disturbances are frequent became particularly interested in this phenomenon (Perera *et al*., 2004). According to Bergeron *et al*. (2002), a pioneer of the ecosystem based management approach in Quebec, an EBM approach in the north-western boreal forests would be more cost effective and environmentally effective than restoring and managing the forests that have already been logged further South.

1.2 The theoretical framework behind EBM

Ecosystem based management is an adaptive approach to managing human activities to ensure the coexistence of healthy, fully functioning ecosystems (Perera *et al*., 2004). EBM approaches are often rooted in the study of natural disturbances such as fires, diseases and insect epidemics. The main idea being that the vegetation and wildlife of forest regions are adapted to cyclic natural disturbances, thus, are part of a fully functioning ecosystem. The theory is that logging practices that are inspired by natural disturbances would therefore cause less environmental degradation. The theoretical foundation of this approach is based on three key principles. The first being that (1) natural disturbances are recurrent within forest ecosystems at both spatial and temporal scales, (2) that the vegetation and wildlife of these forest ecosystems are adapted to the intrinsic disturbances of their environments and (3) that a coarse filter approach to the conservation of biodiversity via forest management will maintain existing species (Franklin, 1993; MNRO, 2001).

1.3 Pilot projects adopted in Quebec to assess the acceptability and feasibility of EBM

Even though values such as habitat quality, ecological processes and biodiversity are becoming increasingly important for global communities and thus, forest industries, the application of EBM is still not well developed. One of the reasons is because it is a new concept that the provincial government has just adopted (MRNFQ, 2009). However, the lack of concrete guidelines also makes it increasingly difficult for forest industries to move away from their traditional practices towards new strategies when they still raise several questions including cost-effectiveness (Bergeron *et al.,* 2002). Although previous studies conducted in Quebec have highlighted the importance of EBM indicators such as the composition, fragmentation and configuration of residual forests, the costs of their application are still undetermined. This project is part of one of three pilot projects being conducted in Quebec in order to improve, develop and validate tools for an evaluation of ecosystem based management approaches to allow us to assess its feasibility and acceptability. Since 2008, this project has been in the phase of moving from research to practice by creating a general plan for EBM on a designated forest management unit (FMU 85-51, see figure 1.1).

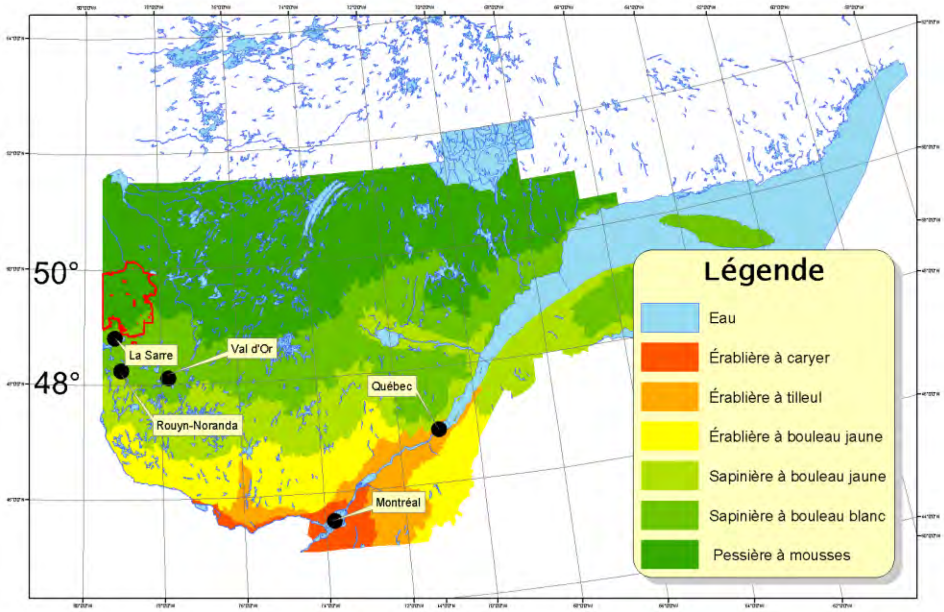


Figure 1.1 Location of the study area (north of La Sarre) and bioclimatic zones (Tembec, 2008).

1.4 The preindustrial fire portrait of north western region of Quebec

The natural disturbance portrait of the north western region of Quebec has been studied extensively. As a result, wildfires are now recognized as the primary natural agent that has shaped the landscape and age structure of the forests over the past few hundred years. The pre-industrial fire portrait of this area was created using archival data, air photos and fieldwork techniques in which the fire history for the past 300 years was reconstructed. The imprints left by fires on the landscape have allowed for the estimation of the fire cycle and the mean age of the forests, which is approximately 148 years old (Bergeron *et al.*, 2002).

The pre-industrial fire portrait has also enabled the identification of fire sizes for the region. What we see is that the most frequent fires are less than 1000 ha, yet only constitute 10% of the total forest burned (Bergeron *et al.,* 2004). In the last sixty years, 55% of the total burned forest is a result of fire sizes ranging from 950 ha to 20 000 ha and the remaining 45% from fires greater than 20 000 ha (Bergeron *et al.,* 2002). The largest fires documented are approximately 67 000 ha (Bergeron *et al.,* 2002).

Interestingly, these studies show that fires do not always have the severity to burn all the trees in a site nor do they burn a site evenly (Belleau *et al.,* 2008). For example, 10 – 35 % of forest cover is left after a fire, and that 1 – 8 % of that quantity is found in small islands of residual forests of 1 – 3 hectares. Also, that 30 – 50 % of affected forest is only partially burnt. The knowledge that fire severity is variable within burns implies major improvements should be made in the amount and configuration of forest retention that should be left within harvested areas (Bergeron *et al.,* 2002).

1.5 Residual forest patches found in natural landscapes

The effects of fire severity create a variety of different spatial configurations of forest retention patches that we do not see in harvested landscapes (Drapeau *et al.,* 2002; Dragotescu, 2008). For example, peninsular blocks, insular blocks, riparian strips, and fragments are different types of retention patches seen in natural landscapes as opposed to landscapes shaped by harvesting (Yelle *et al*., 2009). Studies on such retention patches outline their benefits and the conditions needed within these patches for species maintenance. In addition to the studies conducted by Kafka *et al.* (2001), Bergeron *et al.* (2002), Bennett (2003), Bergeron *et al.* (2007), and Yelle (2009) have provided detailed descriptions of retention patches found in nature that can be used as indicators in the application of EBM.

For instance, riparian strips are located in the moist areas along any body of water and are commonly found after fire disturbances (Yelle *et al*., 2009). They play an important role in the protection of aquatic ecosystems and are often very rich in biodiversity. On the other hand, the insular block is important because it maintains interior forest conditions when it obtains a minimum of 250 meters in width with a size between 50 to 250 hectares (Yelle *et al*., 2009). Insular retention blocks are mostly beneficial for mammals and bird species and may be more financially advantageous for forest companies during the second harvest than cut separators in agglomeration sites (Yelle *et al*., 2009).

Unlike the insular block, the peninsular block is a retention patch that stays connected to a larger forest matrix. It plays an important role in connectivity, re-colonization dynamics and minimizes edge effects by maintaining a good interior forest (Yelle *et al*., 2009). In order to be effective, such peninsular retention patches must have 25 to 200 ha (Yelle *et al*., 2009). Peninsular blocks are also interesting at the financial and operational level because they reduce road construction (Yelle *et al*., 2009). The fragment or small island is also relevant to this study. Fragments are small retention patches that are usually too small to contain an interior forest and are not as interesting for species maintenance (Yelle *et al*., 2009) but can sometimes play a role in connectivity.

Other studies show that important EBM indicators such as the shape, size and fragmentation density of retention forest patches also vary by bioclimatic zones (Perron, 2003; Dragotescu, 2008; Latrémouille, 2008). For example, the mean surface area of retention forests after fire in the Northern Black Spruce domain was found to be greater than that found in the Balsam Fir - White Birch domain. Therefore, bioclimatic information is pertinent in the development of forest management scenarios, and may be an issue for north western Quebec because it differs in composition and structure from the south to the north of its territory.

Disturbances caused by wildfires were found to leave behind residual patch shapes that are more complex than those left by logging (Perron, 2003). The retention patches left by wildfires also appear to be smaller, closer in distance and more frequent than those left by cuts (Dragotescu, 2008; Perron *et al*., 2008). These studies highlight the importance of composition, fragmentation and configuration. All of which are influenced by fire severity and time (Gustafson, 1998).

1.6 Variable retention logging systems

Although it would appear that the incorporation of various types of forest retention patches call for large modifications in logging techniques, other provinces have successfully proven otherwise. In 2002, the province of British Columbia adopted a variable retention system by using a combination of existing logging techniques (Mitchell *et al*., 2002). As a result, ranges in logging treatments from clear cutting, clear cutting with protection of regeneration and soils, to selection cutting can be used to mimic the range of effects found in natural disturbances. Bouchard (2008) also outlined different variable retention cuts that can be used in different stand and age structures. Even if the logging techniques used in British Columbia may not be applicable to Quebec, different species, species sizes and due to bioclimatic factors, the concept of variable retention system logging is promising. Figure 1.2 below shows a management scenario in a pilot project for Tembec Inc., known as the Rainboth site that was executed in 2007-2008. It is an example of an adaptation of variable retention systems for this region. The logging scenario is actually used to incorporate residual patches using an EBM strategy.

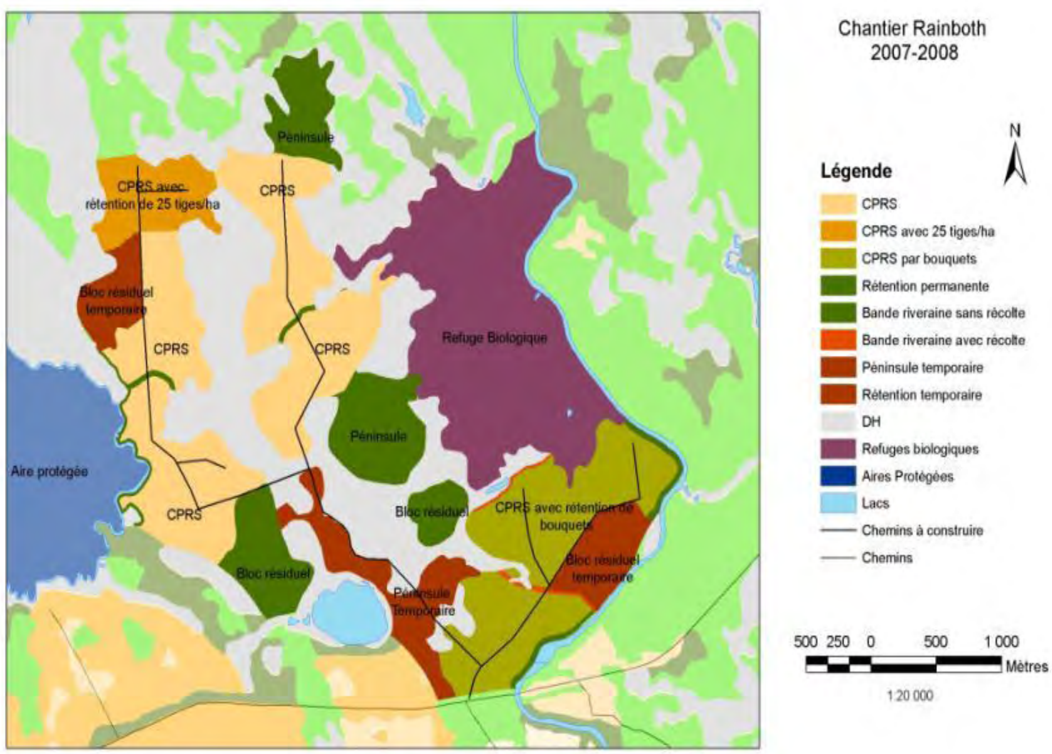


Figure 1.2 The Rainboth Project: An example of a variable retention system (Tembec, 2008).

In figure 1.2, dark green polygons represent permanent insular blocks and peninsula forest residuals, whereas the dark orange ones represent temporary insular blocks and peninsula forest residuals. The light orange polygons represent cutting with protection of regeneration and soils with a minimum retention of 25 trees per hectare while khaki green polygons represent the same cut with retention of clumps. The peach polygons represent cutting with protection of regeneration and soils (CPRS), purple polygons representing biological refugia, and blue polygons are protected areas (Tembec, 2008).

For instance, in figure 1.2, the retention variability mimics the effect that only 30-50 % of stands are partially burnt in an area affected by wildfires (Bergeron *et al.*, 2002). These variable retention techniques also promote a more complex future stand structure that contains more dead wood, provides shelter for species with reduced dispersion capacity and for species that frequent the affected area, promotes habitat diversity and ecological processes linked to soil productivity (Tembec, 2008). In addition, within the site, permanent and temporary peninsular and insular residual blocks are retained, as well as partially harvested and untouched riparian strips.

1.7 The incorporation of spatial analyses in forest management and planning

With the evolution of technology, new complex software programs can now help answer increasingly complex spatial questions in forest management and planning. Spatial analyses at the disturbance-scale can offer the incorporation of more detailed operational planning possibly reducing costs and off site impacts (MacDonald *et al.,* 2000). There are several spatial tools available for such planning such as LANDIS, Patchworks and SELES among others. SELES software is particularly effective for exploring the effects of wildfires on landscape structures at the disturbance-scale (Fall *et al*., 2008). In addition, SELES is not designed for particular landscape types, or sets of processes, thus each model requires detailed parameterization for modelling different scenarios (Fall *et al*., 2008).

Advancement in GIS technology now makes it possible to detect and characterize large-scale temporal changes of multiple forest attributes (Baskent and Yolasigmaz, 1999). Recent studies in landscape and conservation ecology have shown that ecological considerations and their spatial context should be taken into account in the planning and management of forest resources (Galindo-Leal and Bunnell, 1995; Baskent and Yolasigmaz, 1999). Forest landscape history (according to its spatial characteristics) can be deduced from forest inventories produced from aerial photographs or satellite imagery (Pastor and Broschart, 1990; Ripple *et al*., 1991). Hence, spatial characteristics of stands can be used as a basis to establish management objectives (e.g., size of regeneration areas). Such an approach in planning, where the structure and composition of the landscape is taken into account, has been used in several American national forests, where managers recognize the importance of a landscape-scale perspective (Gustafson, 1998).

1.8 Habitat quality index for selected regional fauna

Originally, in Québec, measures were put forth for the protection of animal species themselves. The need to also protect animal habitats became more and more evident starting in the second half of the 20th century. This corresponds to the shift to coarse filter approaches by the Ministry of Natural Resources and Fauna. Species that inhabit north western Quebec require a unique habitat which should be taken into consideration under forest operations. It is important to monitor these focal species (indicator and vulnerable species) amidst anthropogenic activities in order to determine the health of the ecosystem.

One of the boreal regions focal species is the moose (*Alces alces*). Moose tend to inhabit forested areas with young leafy trees or mixed forests near sources of water during summer months (Courtois, 1993; FEIS, 2009). Then when the climate cools in winter months, they move to denser, coniferous forests (FEIS, 2009). Moose actually prefer areas that have recently been disturbed, which make it one of the less vulnerable species of the Abitibi region (Courtois, 1993). Therefore, cuts with protection of soil and regeneration (CPRS) with various retention and insular and peninsular blocks may be favourable for this species, as it could incorporate both the dense coniferous and younger vegetation with which it is associated. However, re-colonization of this species in a disturbed area rarely takes place before 5–6years after disturbance (Caners *et al.,* 2008). In 1993, Courtois identified 5 main variables to determine habitat quality index:

1) An abundant and diversified terrestrial food chain (leaves and deciduous twigs)
2) Access to wetlands (aquatic food, thermal regulation in summer).
3) Flight cover (forest that is less harvested to reduce loss due to hunting and predation).
4) Coniferous protection cover (favoured for thermal regulation at the end of the winter, minimizes energy loss).

5) Specific habitats (saline, calving grounds, etc.).

These diverse variables must intermingle in order to minimize displacement and to permit optimal grazing, rest and ruminating (Bas St-Laurent Forest Model Network, 2003).

The snowshoe hare (*Lepus americanus)* is another focal species. It is larger than a rabbit and is associated with the edge of residual forests and, similar to the moose, disturbed areas (Monthey, 1986). They prefer a mix of deciduous and coniferous forests for food sources (Guay, 1994) and survive in a smaller home range of approximately 10 ha or less (Guay, 1994). Forests with less than 60% cover which permit a denser undergrowth to establish is a necessity for protection against predators (Orr and Dodds, 1982). According to Guay (1994), two parameters are important in habitat quality for this species; (1) the IQHP indicator which calculates the quality of the stand and (2) the IQHÉ indicator which calculates the quality of the eco-tone corresponding to the edge effect between two stands.

The american marten is another focal boreal species mentioned in this thesis. It is a long, slender-bodied weasel about the size of a mink with relatively large rounded ears, short limbs, and a bushy tail. A study in the Abitibi region by Potvin *et al*. (2000) identified that the american marten (*Martes americana*), avoided recently disturbed areas. Due to the fact that 80% of a marten's diet is animal prey (mice, voles) they spend much of their time foraging for food both in trees and on the forest floor. Potvin *et al*. (2000) clearly identifies this mammal with mature forests and a need of a forest cover that lasts over 30 years which signifies that permanent residual blocks (peninsular and insular) and forest massifs may be necessary to maintain this species. According to Larue (1992), the main habitat criteria for marten is based on (1) the composition and density of conifers (CEDC), (2) the developmental stage of the forest (SDEVEL), and (3) stand height and wood debris (DLIGNEUX). The model is expressed by the equation: the cubic root of the dividend of the product of CEDC, SDEVEL and DLIGNEUX divided by three.

1.9 Objectives

The general objective of this project is to create a spatial model in order to evaluate different EBM forest retention scenarios to measure harvesting effort ((m^3/ha*total ha) / total km) and habitat quality index for three animal species. Based on the aforementioned literature, we expect that the greater percentage of residual forests will result in lower harvesting efforts (higher cost estimates) and stronger habitat quality (Perron, 2003, Yelle *et al.*, 2009, Bennett, 2003). However, we would like to test the effects of the patch type, frequency and proportion on estimation of harvesting effort and habitat quality index for moose, marten and hare. In sum, this study is driven by three main objectives:

1) To create a model that can generate variable retention scenarios inspired by wildfire.
2) To calculate the harvesting effort of variable retention logging scenarios based on retention indicators from ecosystem based management studies.
3) To calculate the habitat quality index found in our generated variable retention logging scenarios for three focal boreal animal species.

METHODOLOGY

2.1 Modelling variable retention forest management scenarios based on EBM parameters

SELES (Spatially Explicit Landscape Event Simulator) is a model building and simulation tool that attempts to strike a balance between the flexibility of programming languages to construct novel models and the ease of applying and parameterizing pre-existing models. SELES models have been successfully applied to support forest landscape decision processes for land-use planning (north coast of Quebec, Haida Gwaii and Morice areas in B.C.), natural disturbance management (mountain pine beetle, fires), sustainable forest management planning (upper Mauricie area of Quebec), recovery plans for species at risk (Spotted Owl), habitat connectivity (woodland caribou), and parks planning (www.seles.info). It is useful as a research tool as well as a decision-support tool for management, and for problems related to both conservation and resource management (Fall, 2012).

Our goal was to use SELES to create variable retention scenarios based on ecosystem based forest retention management parameters for further assessment. There are no specific data requirements or limits for SELES. All spatial data must have the same extent and resolution. Inputs can include spatial raster (grid) data (e.g. species, stand age), tables (e.g. volume curves) and parameters (e.g. fire rotation). We were able to build upon an existing fire model by incorporating residual parameters so simulations mimicked wildfire. The following data were required for our models: (1) eco-forest map of our study area, (2) size of logging sites inspired by wildfire, (3) a pre-industrial fire model of our study area, and (4) forest retention parameters.

2.1.2 Study area

Our study area is the forest management unit 85-51 (FMU), located in the mid-western area of the province of Quebec known as the Abitibi region (see figure 1.1). Tembec also shares the management responsibilities of this unit with Norbord industries, another forest company interested in an ecosystems approach. FMU 85-51 extends from latitudes 49’00’- 51’30’ N and longitudes 78’30’- 79’31 W. It covers a surface area of 10 826 km^2 of the 6a- Matagami ecological region in the western extremity of the black spruce feathermoss bioclimatic domain. This is the sub-region of Quebec’s boreal forest, dominated by black spruce (*Picea mariana* Mill), jack pine (*Pinus banksiana* Lamb), and trembling aspen (*Populus tremuloides* Michx). The annual average temperature for this region is -0.7 C° and the annual precipitation is approximately 905 mm. The region is also characterized by clay soil types, a result of the areas post glacial lakes (Belleau and Légaré, 2008). There are a few inhabitants on its territory but it is still frequented by First Nations people, hunters, fishermen, trappers, vacationers, workers, miners and loggers (Tembec, 2008).

2.1.3 Residual forest parameters

In order to create scenarios of different forest residual patches based on EBM indicators, logging site sizes were set according to the mean wildfire sizes identified in the pre-industrial fire portrait for our study area (Belleau *et al*., 2007). Small fires of 3000 ha, medium size fires of 15 000 ha and large fires of 60 000 ha. Data regarding different residual forest patch quantity inspired by wildfire were then grouped in accordance to disturbance size (Kafka *et al.*, 2001; Bergeron *et al.*, 2002; Bennett, 2003; Perron, 2003; Bergeron *et al.*,2007; Dragotescu, 2008; Latrémouille, 2008; Yelle *et al*., 2009) The aim was to create multiple stochastic residual forest patch patterns, shapes and sizes, found in natural landscapes including fragments (small islands), insular blocks, peninsular blocks and riparian strips depending on the size of the disturbance sites being analyzed while remaining within a set of parameters in order to eventually test the effects of residual forest gradients and size on harvesting effort and habitat quality index.

Total residual forest

Bergeron (2008) found that a mean of 5 % of total residual forests were found after fire in Quebec's black spruce dominated Boreal forests, however fire size was not mentioned. Because Quebec's black spruce dominated forests are mostly dominated by small fires of 1000 hectares or less the 5 percent total residual forests deducted by Bergeron (2008) most probably reflects the higher frequency of smaller fires (Perron, 2003). Also, according to Eberhardt and Woodard (1987), from a study of 69 Boreal forest fires in Alberta, a maximum value of 18 % for total residual forests was found after fire and the fires ranged in size from 21 to 17 770 ha for this study. Therefore, in order to include residual forests for fires of 60000 ha, the parameter values have been regrouped to 3-6 %, 12-15 % and 19-22 % total residual forests for fires of 3000, 15000 and 60000 ha respectively (see tables 2.1 to 2.3).

Fragments

According to Perron (2003), 0 to 8 % of total residual forests was found in isolated small islands of 1-3 ha called fragments in fires of up to 35000 ha in black spruce forests. Therefore, in order to omit the percentage of fragments created by fires less than 3000 ha and incorporate fires of 60000 ha a range of values between 2-13 % residual forests in the form of fragments was used (see tables 2.1 to 2.3). The total density of patches ranged from 7 to 37 patches per 100 ha.

Insular and peninsular blocks

The data on insular blocks is much simpler. In order to be maintain mammal and bird species a surface area of 50 to 250 ha of forest must remain (Tembec, 2008; Yelle *et al*., 2009). Peninsular residual patches, which are connected to a forest matrix, must be 25 to 200 ha or more than 500 m long to play a positive role in connectivity and re-colonization dynamics (Tembec, 2008; Yelle *et al*., 2009).

The values from these previous studies were divided into two groups in order to represent A) the minimum retention values and B) the maximum retention values according to disturbance size (see tables 2.1 to 2.3). Because the range in total residual percentages is relatively small, the mean values have been omitted in order to measure a clear difference in variability. Therefore, six different simulations were generated for scenarios A and B for all three fire sizes with ten repetitions each to complete a total of sixty different EBM forest management scenarios. The scenarios are grouped as follows: (S1) represents minimum and (S2) the maximum retention values for perturbations sites of 3000 ha in size; (S3) represents the minimum and (S4) represents the maximum retention values for sites 15000 ha in size; (S5) represents the minimum and (S6) the maximum retention values for sites 60000 ha in size. In addition, the percentage allocated to insular and peninsular blocks are 50/50, an equal division between each. Based on the modified residual forest values mentioned above, that was used to evaluate forest residual management for disturbances of 3000 ha are as follows. (1) S1 consists of 3 % total residual forests including 1% of that forest under the form of fragments and the remaining 2 % under the form of insular blocks (50 ha) and peninsular blocks (25 ha). S2 consists of 6 % total residual forests with 4 % of fragments, with maximum values for insular blocks of 110 ha and peninsular blocks of 70 ha (see table 2.1 for model inputs).

Table 2.1 Residual forest parameters for disturbances of 3000 ha in size

Scenarios*	Total residual forest	Fragments	Insular blocks	Peninsular blocks
S1	3%	1%	50 ha	25 ha
S2	6%	4%	110 ha	70 ha

*S1= minimum EA value and S2= maximum EA value

The modified residual forest values mentioned above, that were used to evaluate forest residual management for disturbances of 15000 ha are as follows. S3 consists of 12 % total residual forests with 6 % under the form of fragments (1 to 3 hectares in size) and the remaining 6 % in insular blocks with a minimum value of 130 ha and peninsular blocks with a minimum value of 85 ha. S4 consists of 15 % total residual forests with 9 % fragments and the remaining insular blocks of 190 ha and peninsular blocks of 130 ha (see table 2.2 for model inputs).

Table 2.2 Residual forest parameters for perturbations of 15000 ha in size

Scenarios*	Total residual forest	Fragments	Insular blocks	Peninsular blocks
S3	12%	6%	130 ha	85 ha
S4	15%	9%	190 ha	130 ha

*S3= minimum EA value and S4= maximum EA value

The modified residual forest values that were used to evaluate forest residual management for disturbances of 60000 ha in size are as follows. S5 consists of 19 % total residual forests with 10 % under the form of fragments and the remaining 9 % under the form of insular blocks with minimum values of 190 ha and peninsular blocks of 145 ha. S6 consists of 22 percent total residual forests with 13 % found in fragments and the remaining 9 % in insular blocks with maximum values of 250 ha and peninsular blocks of 200 ha (see table 2.3 for model inputs).

Table 2.3 Residual forest parameters for perturbations of 60000 ha in size

Scenarios*	Total residual forest	Fragments	Insular blocks	Peninsular blocks
S5	19%	10%	190 ha	145 ha
S6	22%	13%	250 ha	200 ha

*S5= minimum EA value and S6= maximum EA value

In order to accomplish the desired forest residual scenarios in SELES, two models and two sub models were used: a disturbance model, a retention model, a buffer sub model and the Filter Small sub model. (1) A fire model developed by Annie Belleau was adjusted and used as a landscape disturbance model, emulating a logging site shape resembling that of one left by wildfire according to site size parameters (3000 ha, 15000 ha, 60000 ha). (2) The Filter Small sub model, from SELES model garden (www.seles.info), was then used to find unaccounted pixels within the site and delete them. These pixels are representative of areas left un-burnt by wildfire but would have skewed our set forest residual parameters, increasing the sum and size of fragments, blocks and peninsulas significantly. (3) In order to simulate peninsulas, a buffer sub model was used. A buffer was simulated within the disturbance close to the edge of its perimeter. This created an area in which to run the retention model for peninsulas to ensure these residual patches were attached to the larger forest matrix and thus act as a corridor for species. Another buffer was then simulated close to the edge of the first buffer to separate the area in which to run the retention model for insular blocks and fragments to ensure that they didn't attach themselves to the peninsulas and skew set parameters. (4) A residual model was created using the aforementioned fire model, to ensure residuals also resembled wildfire with the incorporation of our aforementioned residual parameters for our scenarios (S1, S2, S3, S4, S5, and S6) (See appendix for scripts).

Output data was classified as follows for each residual patch type by colour; peninsulas-blue, insular blocks-pink and fragments-yellow. Figure2.1 represents an example of a scenario containing the minimum residual forest within a harvest site of 60000 ha (S5). It contains 30 insular blocks with a surface area of 5095 ha, 300 fragments with a surface area of 658 ha and 49 peninsulas with a surface area of 4938 ha. The total amount of planned residual forest in this site is 10691 ha. The first buffer zone is dark gray and is where the blue peninsulas are located. The second buffer zone is white and separates the insular blocks and fragments from peninsulas. In total, ten repetitions of each scenario (S1, S2, S3, S4, S5, and S6) were chosen.

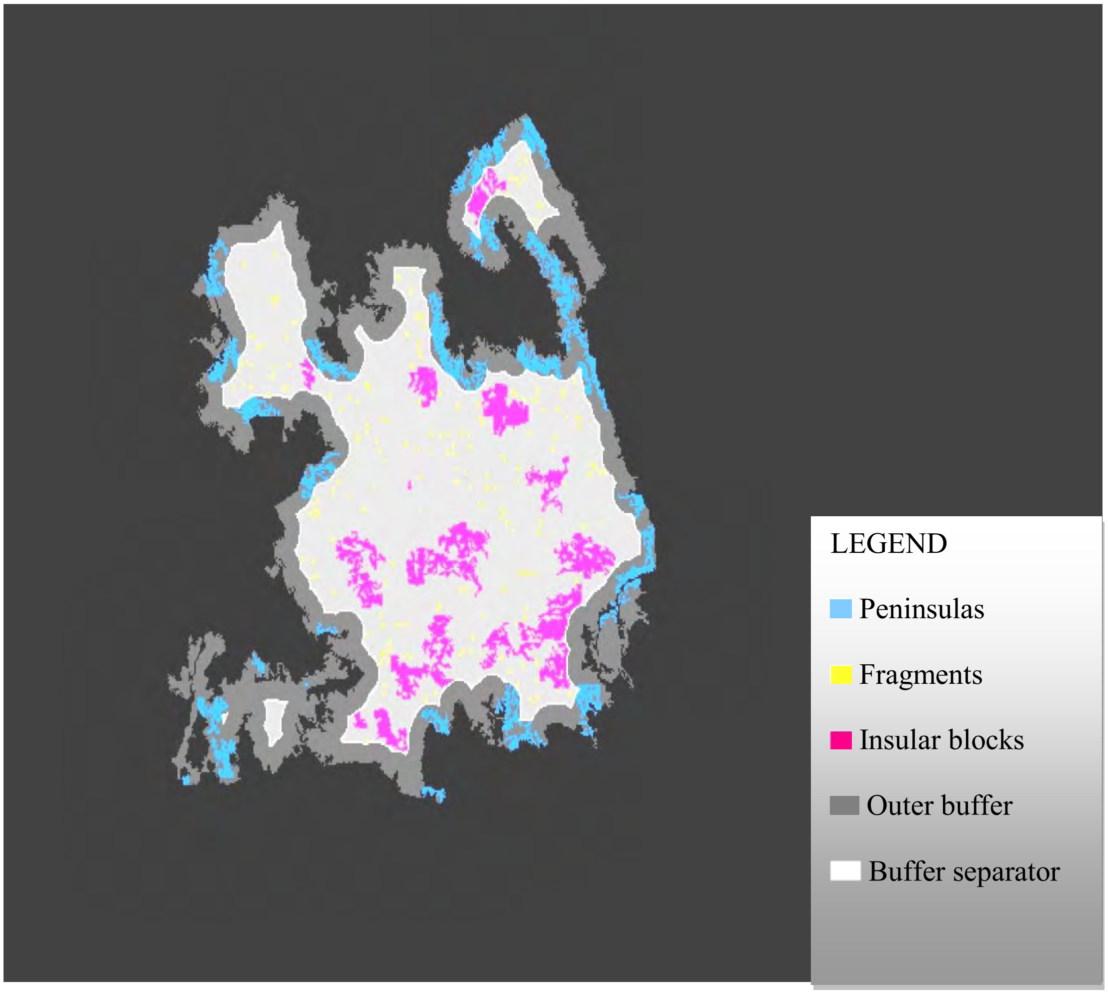


Figure 2.1 SELES retention event simulation of a 60000 ha site with minimum retention parameters (S5). * Peninsulas- blue; Insular blocks- pink; Fragments- yellow

Another example is Figure 2.2 that represents a scenario containing the maximum residual forest within a harvest site of 60 000 ha (S6). It contains 30 insular blocks with a surface area of 5972 ha (pink), 299 fragments with a surface area of 688 ha and 50 peninsulas with a surface area of 6323 ha. The amount of total planned residual forest for this site is 12 983 ha. Once again, the first buffer zone is dark gray and is where the blue peninsulas are located. The second buffer zone is white and separates the insular blocks and fragments from the other buffer zone.

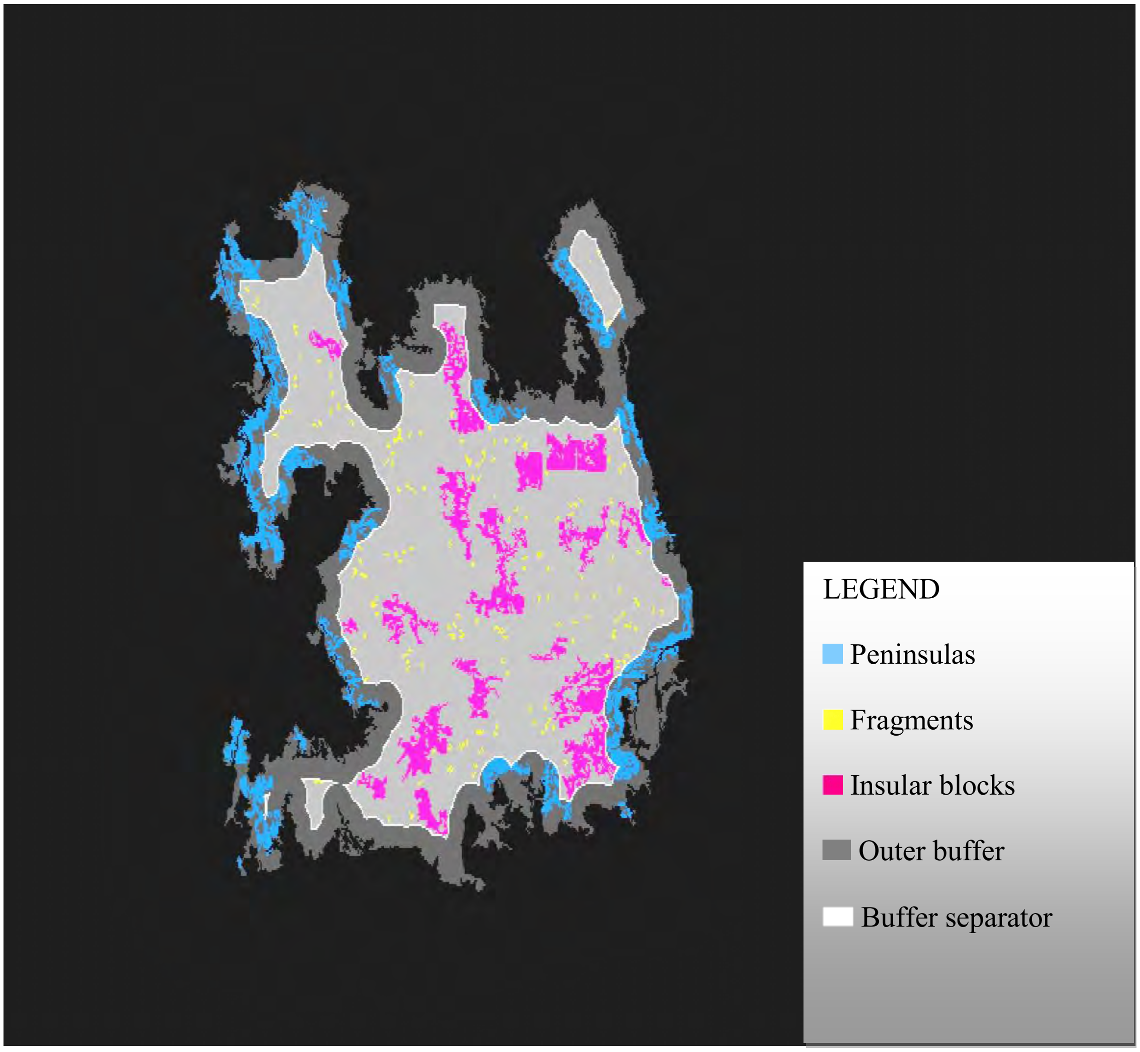


Figure 2.2 SELES retention event simulation of a 60000 ha site with maximum retention parameters (S6).* Peninsulas- blue; Insular blocks- pink; Fragments- yellow

2.2 Calculating the harvest effort of EBM variable retention scenarios

All sixty chosen SELES retention simulation scenarios were transformed from raster file into vector format (polygons) to be transferred to ArcGIS® in order to create variable retention logging scenarios. Two spatial input shape files or feature classes were required to obtain a ratio for harvesting effort: (1) a harvest layer (including planned harvest blocks, the surface area harvested (ha), the tree species, age, height and coverage densities of planned logged forest stands) and (2) a road layer (including the length in km of the road networks constructed to access planned cut blocks).

Eco-forest maps (classification maps that include detailed ecological information for a region) from the provincial government (1995) were over-layed in ArcGIS in order to identify the forested areas, stand types, vegetation types, location of water sources, wetlands, barren lands and other important geographical information, surrounding simulated residual forest patches. Eco-forest maps were essential in the identification of productive forest tree species (Fir, Pine, Spruce and Larch) (Belley, 2002), stand age (90 to 120 years old), stand heights 7 to 22 m (Class 2,3,4) and coverage density of 25 to 80 % (Class B, C, D) (Directions des Inventaires Forestiers, 2009). Once the timber-productive forest was identified, a potential harvest layer was created. Buffers of 20 m were incorporated around water sources and residual forests in order to ensure their ecological integrity.

Road networks were created in ArcGIS within the potential harvest layer. Secondary and tertiary roads were created from a starting point (camp) that connected to a major road outside of planned logging sites. All roads were modeled to the minimum specifications required to transport harvested wood, while protecting the environment, therefore, networks that demanded the least road construction were favoured. Road networks followed the general road construction principles; leaving a minimum of 1 km between roads for harvesting machinery that operate up to 500 m on both sides of a road (MRNFQ, 2009). Once the road networks were set, a buffer of 500 m was created around the roads in order to determine the accessible potential harvest area. Timber-productive forest within this buffer became planned cut blocks. Cut blocks represented approximately 80 % or more of available timber-productive forests across scenarios.

Figure 2.3 shows a 60 000 ha variable retention logging scenario with the maximum forest residual parameters, created in ArcGIS from S6. This scenario size is 68325 ha. The green polygons represent a total of planned residual forests of 12456 ha of which 30 polygons are insular blocks (4662 ha), 300 polygons are fragments (736 ha), and

49 polygons are peninsulas (5640 ha). However, the total amount of non-harvested forest which includes both productive and non-productive forest is 16725 ha. The orange polygons represent harvest blocks consisting of 6925 hectares of harvested productive forest. The black polylines represent the planned road network with a total of 521 km in length and the lime green circles represent points of entry or camps. An attribute table is incorporated to every layer in each map. The tables include information pertaining to each forest stand (height, coverage density, age, tree species, other vegetation types, and landscape types) needed in order to calculate volumes for harvesting effort ratio ((m^3/ha*total ha)/total km)). The smaller image in the upper right corner of figure 2.3 is a close up of an area within this logging site.

The eco-forest map layer for the region was used in order to identify the different volumes for each harvest block by polygon in a logging site. This is an important aspect of the effort estimation because differences in volume values and road access length represent different effects on wood procurement cost (see table 2.4). These estimations were based on basic stand data used in forestry in Quebec (MRNFQ, 2009) and were validated with a Tembec manager and considered a good approximation. Once the volumes were associated to planned cut blocks, an effort ratio was calculated (m^3/ha * total ha)/total km in ArcGIS. The ratio is an estimation of the harvesting effort of each EBM variable retention logging scenario in order to determine cost-effectiveness. The assumption is that as harvesting effort decreases, cost increases.

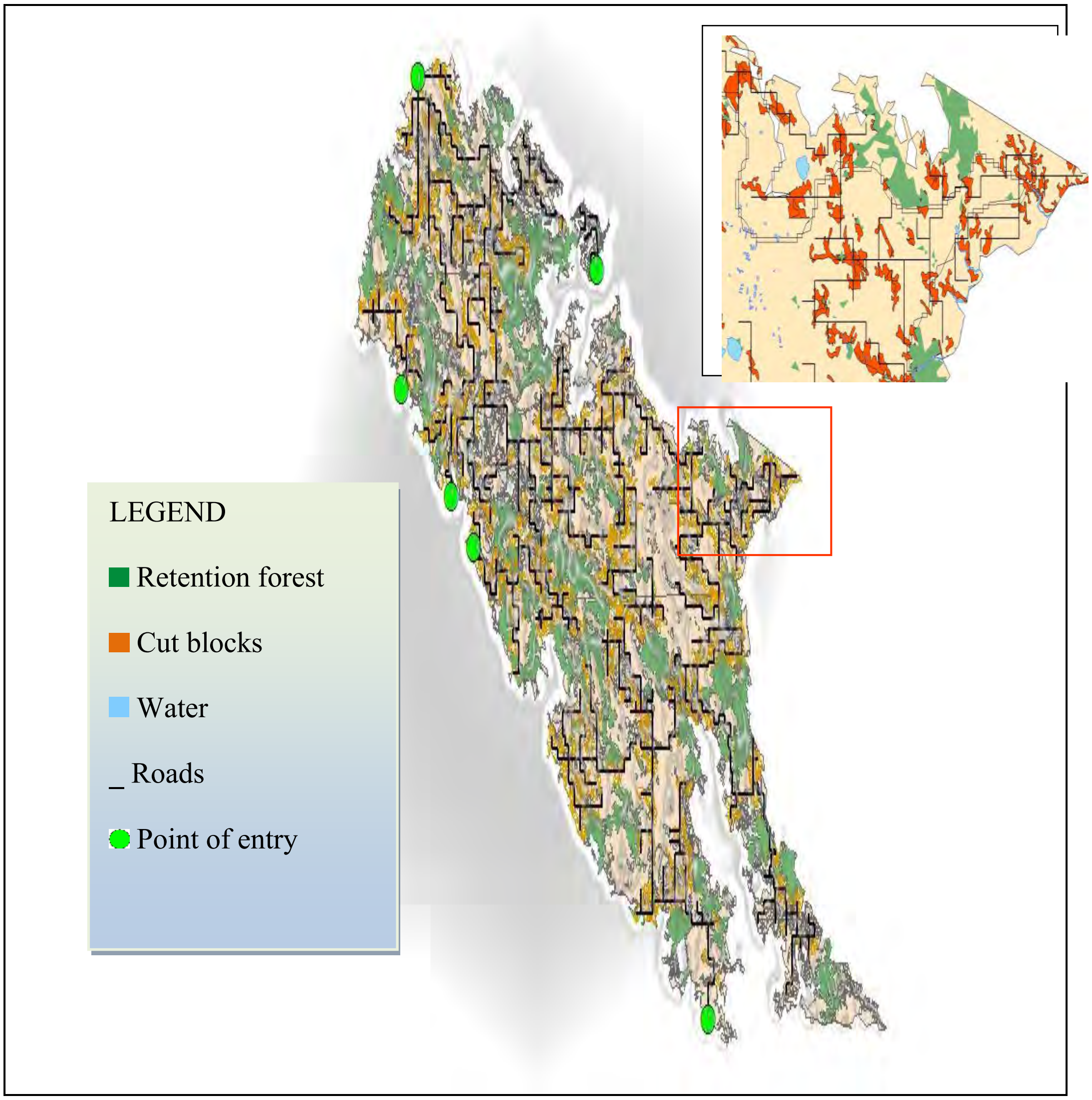


Figure 2.3 Variable retention harvest site of 60000 hectares with maximum retention (S6) * Retention forest-green; Cut blocks- orange; Water-blue; Roads-black polyline; Points of entry-green circles.

Table 2.4 Volume values for different Balsam fir, Pine, Spruce and Larch stands attributes.

Density	Age	Height	m^3/ha
40-80 %	> 90	12-22 m	114
40-80 %	> or = 120	12-22 m	89
25-40 %	120	7-12 m	44

2.3 Calculating the habitat quality of EBM variable retention logging scenarios for three animal species

All sixty variable retention logging scenarios were evaluated individually in relation to environmental conditions associated with moose (*Alces alces*), snowshoe hare (*Lepus americanus*), and marten (*Martes americana*) using the Habitat Quality Index or "Indices de Qualité d'Habitat (IQH)" extension in ArcView version 3.0 (Bas St-Laurent Forest Model Network, 2003). The extension calculates habitat quality based on specific habitat quality index models for various species as well as geographical attributes corresponding to the third decadal provincial timber inventory.

In order to transfer the variable retention logging scenarios to the habitat quality index extension 3.0 in ArcView, a habitat layer was created. A union between the eco-forest map layer and the harvest layer was executed to create a layer called habitat. Polygons belonging to the harvest layer, cut blocks, were modified in order to analyze the harvest site post cuts. In the extension, the model for moose is based on the Courtois (1993) Habitat Quality Index model for moose in Quebec was used.

For snowshoe hare, Guay's (1994) Habitat Quality Index model is used in this extension. The model is based on estimations concerning the capacity that each forest stand has to offer in terms of food and shelter.

For marten, Larue's (1992) Habitat Quality Index is used in extension 3.0. Values are attributed to the composition and density of conifers in a forest stand, parameter CEDC, the developmental stage of the forest stand, parameter SDEVEL and wood debris, parameter DLIGNEUX.

In all three habitat quality index models multiple geographical characteristics must intermingle in order to minimize displacement and to permit optimal grazing or hunting, rest or ruminating for each species, except for the Marten which does not ruminate. All models also use data from the eco-forest map for the region regarding: 1) Species group, 2) Stand type, 3) Age group, 4) Height group, 5) Density group, 6)

Slope group, 7) Non-productive terrain, 8) Mean disturbance, 9) Original disturbance, 10) Year of disturbance, 11) Surface deposit, and 12) Drainage group, for a specific map.

In figure 2.4, harvest blocks are left brown for a better visual appreciation of the management site in its entirety. Non-harvested forest (dark green), planned forest residuals (dark green), water (blue), Alder (light green), wetlands (spotted green) and other coverage types in the eco-forest map (orange). This example is a variable retention logging scenario of 60000 ha with maximum EBM residual forest parameters. It contains 16725 ha of forested area, 774 ha in surface area of water, 38327 ha of wetlands, 417 ha of Alder, 288 ha of dry lands (bright yellow), 13 ha of flood sites, and 15329 ha of Spruce forest stands, to name a few of its characteristics. The image in the upper right corner is a closer look at the bottom left of the logging scenario. The non-harvested forest includes residuals that surround a river, Alder stands, small lakes, logged areas and the large surface area of wetlands.

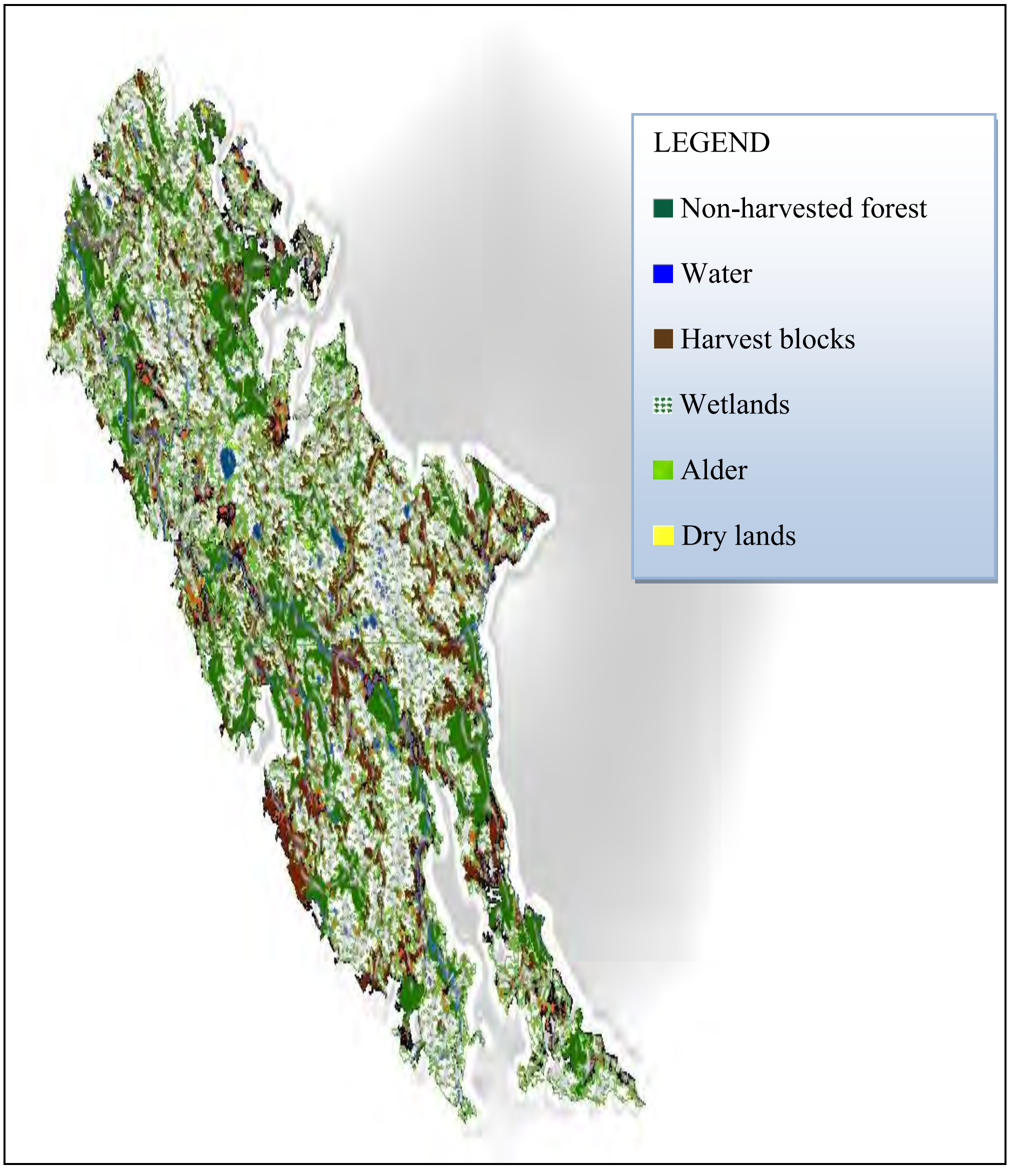


Figure 2.4 A habitat layer for a 60000 ha variable retention logging scenario with maximum forest retention (S6). * Non-harvested forest (including retention)- dark green; Water-blue; Harvest blocks-brown; Wetlands- spotted green; Alder-light green; Dry lands-yellow.

2.4 Correlation measurement analyses

A correlation measurement test with JMP® software from SAS (www.jmp.com) was performed for the scenarios in order to compare the influence of each independent variable (1. site size, 2. total residual forests, 3. frequency of peninsulas, insular blocks and fragments, 4. surface area of peninsulas, insular blocks and fragments, 5. forest harvested, 6. forest non- harvested, 7. forest stand by tree species, 8. forest stand by density, 9. forest stand by height, 10. km of road network, and 11. surface area of other land cover types in relation to harvesting effort and habitat quality index).

Ranking of measurements were based on the Cohen model where 0.5 is large, 0.3 is moderate, and 0.1 is small (Cohen, 1988). The usual interpretation of this statement is that anything greater than 0.5 is large, 0.5-0.3 is moderate, 0.3-0.1 is small, and anything smaller than 0.1 is not worth worrying about.

RESULTS

3.1 EBM forest retention scenarios

The forest retention model we created successfully emulated spatial configuration and shape complexity of forest retention found in natural landscapes post fire. However, set parameters were not attained. This could be due to a number of factors including pre-existing forest conditions and geographical influences such as wetlands, water bodies, pre-harvested zones, and other non timber-productive forested areas encountered in a site during simulation. In hindsight, parameters within the model itself can be adjusted and numerous simulations can run until desired targets are met.

Whether our target parameters were greater, lesser or equal than parameters obtained is shown in table 3.1 for the various retention types studied. Results show that forest retention frequency and amount were more variable than initially expected. Two opposing arguments arise: (1) the greater variability found in our sites reflect the non-deterministic characteristic of natural disturbances and the realistic forest availability found in a forest management unit. Or, (2) residual forest models should be more deterministic in order to attain set parameters even if it influences shape complexity and spatial configuration. We chose to keep our simulations stochastic even if site sizes and retention proportions were slightly skewed. At the end of the day, the goal is to achieve better spatial management for ecosystem function and resilience and not to solely emulate a specific configuration or exact parameter.

Table 3.1 Comparison of results of residual forest proportion in ha and percentage to our initial target parameters across scenarios.

Parameters	Target (ha)	Hectares	Target (%)	%	< or>
Scenario S1					
Total retention	80	133	3	4	<
Fragments	5	6	1	5	<
Insular blocks	55	55	68	41	>
Peninsular blocks	25	25	31	18	<
Scenario S2					
Total retention	190	250	6	8	<
Fragments	10	9	4	5	<
Insular blocks	100	100	53	40	>
Peninsular blocks	70	70	37	28	>
Scenario S3					
Total retention	1800	2303	12	14	<
Fragments	108	83	6	6	
Insular blocks	846	835	47	36	>
Peninsular blocks	846	739	47	32	>
Scenario S4					
Total retention	2250	3290	15	20	<
Fragments	202	180	9	8	>
Insular blocks	1024	1070	45	32	>
Peninsular blocks	1024	1285	45	39	>
Scenario S5					
Total retention	11140	12176	19	17	>
Fragments	1140	600	10	10	
Insular blocks	5130	5124	46	42	>
Peninsular blocks	5130	5474	46	45	>
Scenario S6					
Total retention	13200	13436	22	19	>
Fragments	1716	709	13	13	
Insular blocks	5742	5586	43	42	>
Peninsular blocks	5742	5466	43	40	>

*Note: < under goal, > above goal and = reaches goal

3.2 Harvesting effort for variable retention logging scenarios based on EBM indicators

Table 3.2 shows the mean harvesting effort across scenarios that were calculated in ArcGIS. Site size refers to the average size of the logging site in ha, SA harvested refers to the surface area of timber-productive forest harvested in ha, m^3*ha refers to total volume of timber-productive forest harvested in cubic meters (m^3), km represents the average length of the road network of each site and Harvesting effort calculate for each scenario. Table 3.2 also shows the standard deviation between variables per site size (3000 ha, 15000 ha, 60000 ha). In addition, in the maximum scenarios for logging sites of 15000 ha and 60000 ha, less timber-productive forest was harvested. In 15000 ha logging sites, a standard deviation of 938.49 ha of SA harvested was found between scenarios with minimum and maximum retention. In sites of 60000 ha a standard deviation of 3548.51 ha of SA harvested was found between scenarios with minimum and maximum retention. Figure3.1 illustrates how these results compare to harvesting effort across scenarios.

Table 3.2 Mean and SD across EBM scenarios

Scenario	*Site size*	*SA Harvested*	*m^3*ha*	*KM*	*Harvest Effort*
S1	3099	686	56438	32	1697
S2	3120	949	73435	33	2216
SD	29.54	370.57	32181.62	5.32	366.98
S3	16361	3296	204862	147	1393
S4	16211	2676	151905	142	1083
SD	667.58	938.49	66647.01	23.32	219.20
S5	69245	12818	920795	547	1685
S6	69840	9479	688727	534	1287
SD	2652.66	3548.51	257935.3	67.08	281.42

*SD Standard deviation of by variable for each scenario *TR Total retention.

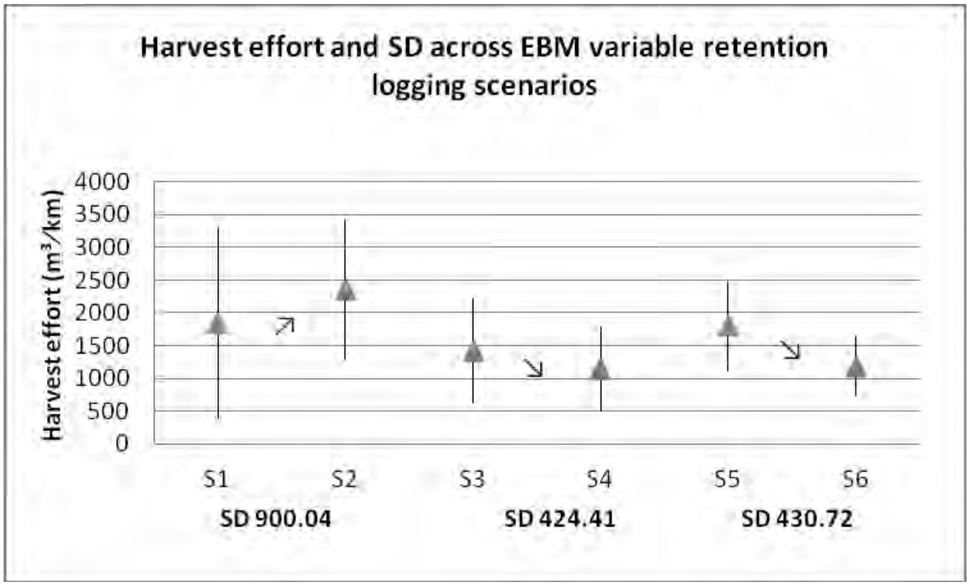


Figure 3.1 Average harvesting effort across scenarios. Lines represent maximum and minimum effort for each. Triangles represent average for each scenario. And SD represents the standard deviation within scenario groups.

The figure 3.1 shows the variability of harvest effort between scenarios. Scenario S2 of 3000 ha show a higher harvest effort. A high harvest effort is related to a lower cost estimate. In, all other maximum retention scenarios, where average SA timber-productive forest harvested is lower and forest retention is higher, lower harvest efforts are found as predicted. The length of road networks (total km) did not seem to be significant as SD between sites is small. However, in order to compare harvesting effort calculations to business as usual scenarios, it is important to note that pre-existing roads were not incorporated. Thus actual harvest effort for our logging scenarios could have been lower had our initial simulations in SELES incorporated pre-existing road networks. Pre-existing road networks were only added post simulation in ArcGIS, however, too many forest retention patches fell directly on roads, so they were not included in this analysis. Table 3.3 outlines the average kilometers of pre-existing road networks for each harvest scenario size.

Table 3.3 Average pre-existing kilometers of road for each scenario

Scenario	*Km*
3000	7
15000	67
60000	323

3.3 Impacts of retention patch types and other forest conditions on harvesting effort

One of the objectives of this project was to evaluate different EBM variable retention logging scenarios in order to calculate their harvesting effort to verify that the greater the percentage of residual forests, the higher the cost (Bennett, 2003; Perron, 2003; Yelle *et al*., 2009). Our results show this to be true, for all sites except our variable retention logging scenarios of 3000 ha with maximum retention. Although S2 scenarios contained maximum retention, they also obtained greater harvesting yields. This could explain why harvesting effort was higher. In order to test what other site variables could be impacting harvesting efforts a correlation analysis was executed.

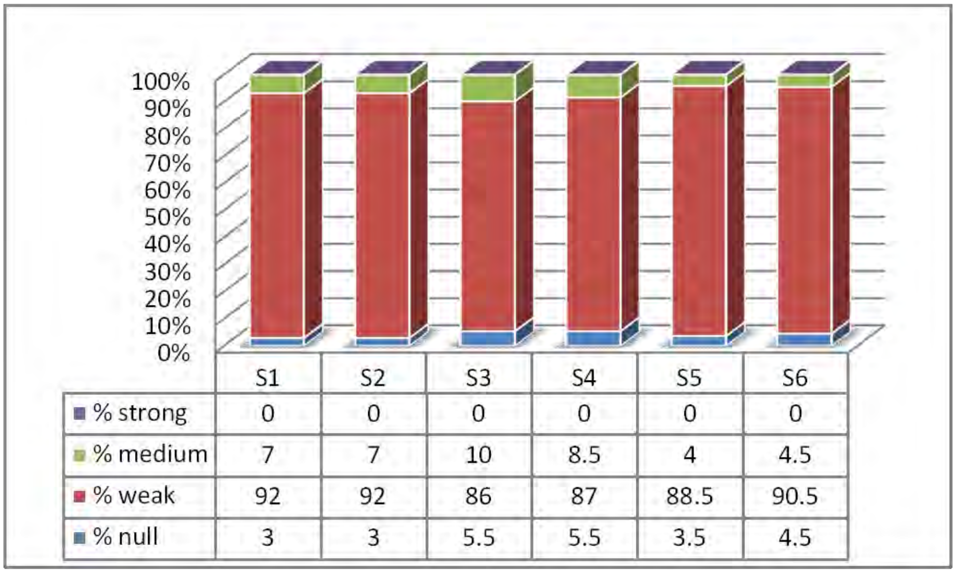
When analyzing the impacts of residual patch type proportion and frequency individually we found that the surface area of insular blocks was the only residual patch type that had a positive relationship with harvesting effort (Table 3.4). Therefore an increase in the proportion of insular block and harvesting effort signifies lower cost estimates. The forest residual that had the greatest relationship to harvest effort was the proportion of fragments. However, the relationship was negative, thus having the most impact on cost estimation. Both the amount of fragments and peninsulas had negative relationships with harvesting effort. However, fragments had the highest correlation measurement (moderate as opposed to low-moderate with harvesting effort). No correlations were found between any of the residual forest patch frequencies and harvesting effort. Other forest conditions were also influential on harvesting effort. The largest relationships found were between harvest effort and forest stands 17 to 22 m high and wetlands. As well as moderate relationships between stands ranging from 90 to 120 years old, stands 50-75% Larch and 25% Spruce, and mature forests. This could be due to the fact that forest stands with such characteristics have higher levels of volume, and therefore decrease effort.

Table 3.4 Correlation measurements (Cohen) for harvest effort across scenarios

Independent Variables (%)	*Measurements*
Total retention w/ buffers	-0,3675
SA insular blocks	0,3198
SA fragments	-0,4118
SA peninsulas	-0,3276
Amount of forest harvested	0,8348
volume	0,9453
Kilometers	0,3042
Wetlands	-0,5241
Barren drylands	-0,3821
Flood sites	-0,3559
Stands 50-75% Larch & 25-50 % Red/Black Spruce	-0,4357
Stands 100 % Larch	-0,3353
Stands 50-75% Red/Black Spruce & 25-50 % Larch	-0,3317
Stands 17-22 m high	0,6181
Stands ranging from 90-120 years old	0,4687
Mature Forest	-0,4117
Stands of 50 years old	-0,3238
Site size	-0,1584

3.4 Impacts of retention patch types and other forest conditions on habitat quality index for moose (*Alces alces*), marten (*Martes americana*), and hare (*Lepus americanus*)

The results of the HQI calculations with extension 3.0 in ArcGIS shown below in figure 3.2 indicate that all EBM variable retention logging scenarios offered mostly weak habitats for moose. Under the Courtois (1993) model for moose, habitats with a weak attraction value are black spruce stands, open areas as a result of harvests or burns that occurred less than 10 years prior, and protection covers of 25 to 60 %. It is important to reiterate that these are conditions post logging. On average there was 0 to 2 % optimal habitat, 4 to 10 % medium habitat and 86 to 92 % weak habitats across our scenarios post cuts for this species.



	S1	S2	S3	S4	S5	S6
% strong	0	0	0	0	0	0
% medium	7	7	10	8.5	4	4.5
% weak	92	92	86	87	88.5	90.5
% null	3	3	5.5	5.5	3.5	4.5

Figure 3.2 Proportion of habitat quality index across scenarios for moose (S1, S2 : 3000 ha ; S3, S4 : 15000 ha ; S5, S6 : 60000 ha).

The HQI results for marten are shown in figure 3.3. Post cuts, there was 0.5 to 4% optimal habitat, 7 to 11.5 medium habitat, 10 to 24.5 weak habitat with null habitat representing the majority of forest available. This could be explained to the low attraction value of Black/ Red spruce dominant stands with low coverage densities of 40 % or less (Larue, 1992). Figure 3.4 shows as expected, mostly null habitat quality for hare. Optimal habitat was found to be lowest for hare at 0 to 0.5 %, even though this species has a smaller home range. On average, 15.5 to 29 % medium habitat quality was found. Across scenarios an average of 7 to 11.5 % weak habitat was found. Under the Guay (1994) model for hare, habitats with a weak attraction value for this species are residual forests that are surrounded by cut blocks, areas in the process of regeneration, or areas that have been harvested 10 years prior or less. This explains the higher percentages of null habitat.

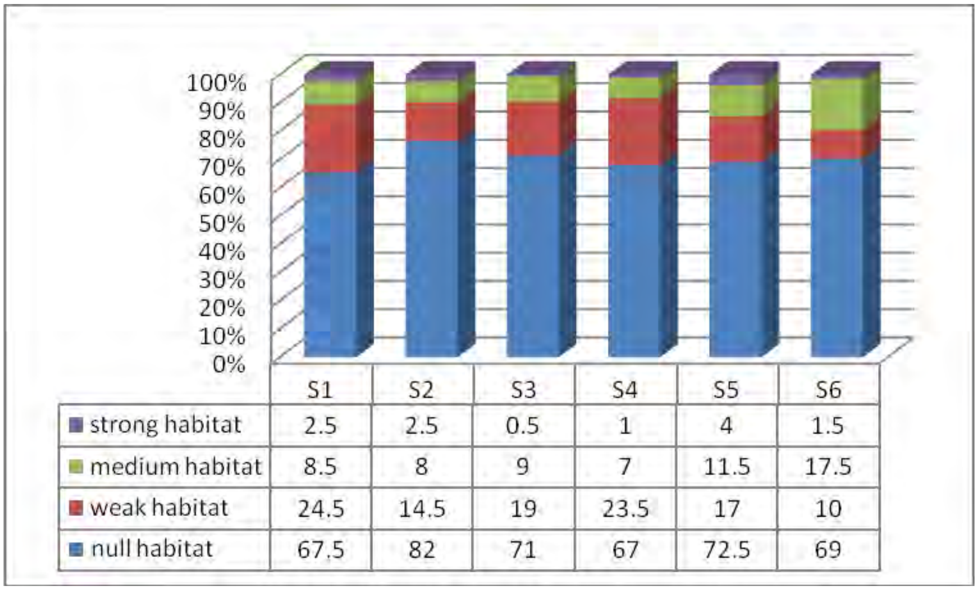


Figure 3.3 Proportion of habitat quality across scenarios for marten (S1, S2: 3000 ha; S3, S4: 15 000 ha; S5, S6: 60 000 ha).

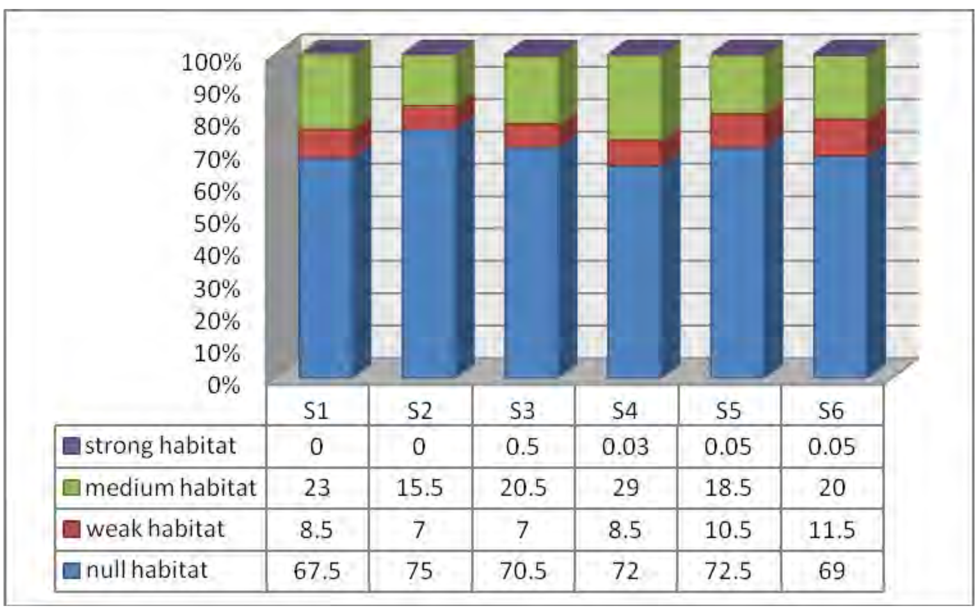


Figure 3.4 Proportion of habitat quality across scenarios for hare (S1, S2: 3000 ha; S3, S4: 15000 ha; S5, S6: 60000 ha).

When comparing our HQI across scenarios for each species to table 3.2, we find that the habitat quality index does not increase with total retention amounts (TR). If it did, we would find that scenarios S2, S4, and S6 (scenarios with maximum forest retention) would be the most favourable. However, for moose, S1 and S2 fared equally, and S3 fared better than S4. Better habitat quality existed in scenarios S1, S3 and S5 for marten, while hare habitat was best in scenarios S1, S4 and S6. In order, to identify the impacts of retention patch types and other forest conditions, correlation measurement analyses were executed for each species (Table 3.5 to 3.7).

Table 3.5 *Correlation measurement test for moose habitat quality (*Alces alces*)*

Variables (%)	*Null*	*Weak*	*Medium*	*High*
Site size	0,5359	0,4241		
Tot. retention w/ buffers	0,5456	0,3976		
N. of insular blocks	0,5433	0,4424		
Area of insular blocks	0,5633	0,4325		
N. of fragments	0,5163			
N. of Peninsulas	0,5386	0,4443		
Area of peninsulas	0,5014			
Harvested		-0,7004		
Vo. * ha (m^3)		-0,6353		
Km of road		-0,674		
Non harvested		0,4023		
Area of fragments		0,4792		

Looking at the weak habitat availability in our variable retention logging sites, the low HQI had significant relationships with the surface area harvested, volume harvested and kilometers of roads, which would all be expected (Table 3.5). As for retention patch types, the frequency of peninsulas and insular blocks had stronger relationships to HQI than their proportions. However, the proportion of insular blocks was also important. The medium and high habitat quality forest areas were related to other factors.

As shown in table 3.6, all forest retention patch type proportions and frequency shared large relationships with medium habitat quality. Smaller relationships were also found with the length of the road networks, the volume and surface area of harvested forest. Interestingly, other forest conditions impacted the percentages of weak and high habitat quality within our scenarios. Even though our scenarios contained the most medium HQI for hare (table 3.7), no relationships were found between medium or high habitat and forest retention patch type proportion or frequency. However, all retention types were associated with weak HQI.

Table 3.6 Correlation measurement test for marten habitat quality *(Martes americanus)*

Variables (%)	*Null*	*Weak*	*Medium*	*High*
Site size	0,6814		0,5714	
Tot. retention w/ buffers	0,6888		0,513	
N. of insular blocks	0,703		0,5558	
Area of insular blocks	0,7291		0,5407	
N. of fragments	0,6842		0,5744	
N. of Peninsulas	0,6957		0,5819	
Area of Peninsulas	0,5847			
Harvested	-0,5975		-0,4299	
Vo. *ha (m^3)	-0,5957		-0,3645	
Km of road	-0,6598		-0,4408	

Table 3.7 Correlation measurement test for hare habitat quality (*Lepus americanus)*

Variables	*Null%*	*Weak%*	*Medium%*	*High%*
Site size	0,6929	0,4874		
Tot. retention w/ buffers	0,6872	0,421		
N. of insular blocks	0,7155	0,4557		
Area of Insular blocks	0,7176	0,4593		
N. of fragments	0,6954	0,4665		
N. of peninsulas	0,7082	0,487		
Area of peninsulas	0,5473	0,3637		
Harvested	-0,6034		-0,4809	
Vol. * ha (m^3)	-0,6358		-0,4194	
Km of road	-0,6483		-0,3058	

The study presented in this thesis investigated the feasibility of implementing forest retention similar to that found in natural landscapes post fire boreal forest. The results clarify certain questions in regards to spatial modelling of forest residuals, and the influences of residual patch type, amount and frequency on harvesting effort and habitat quality index. Table 3.8 summarizes the impacts of each retention patch type by displaying whether a patch type had a positive, negative or null effect on harvesting effort and HQI.

Table 3.8 Impacts of forest retention on harvesting effort and HQI for three animal species

	Harvesting effort	HQI Moose	HQI Marten	HQI Hare
# Insular blocks	↔	↑	↑	↑
SA Insular blocks	↑	↑	↑	↑
# Peninsulas	↔	↑	↑	↑
SA Peninsulas	↓	↔	↔	↑
# Fragments	↔	↔	↑	↑
SA Fragments	↔	↔	↔	↔
TR	↓	↑	↑	↑

* SA- surface area; #-frequency; ↔-no effect; ↑- positive effect; ↓ effect.

DISCUSSION

Many studies have shown that the initial costs of variable retention logging are higher than traditional management options, our study indicates that the increased amount of total forest retention does indeed increase harvesting costs (Phillips, 1996; Pinjuv, *et al.,* 2001) However, increasing the quantity of insular blocks may not be the cause. The results of our analyses show a positive relationship exists between harvesting effort and the surface area of insular blocks. No relationships were found between harvesting effort and any of our retention patch type frequencies. This could be spatially related. In the same way that increased costs due to an increase in peninsulas and fragments, could also be spatially related. The relationship between the spatial configuration of insular blocks, fragments and peninsulas on harvesting costs should be tested further.

In all of our EBM variable retention logging scenarios, for all selected species, high habitat quality had no relationship with residual forest patch types, amount or frequency. This coincides with St-Laurent's *et al.* (2007) study on the effects of residual stand structure and landscape configuration on habitat use by birds and small mammals in managed boreal forest. The results of this study found residual forest type and amount had less effect on species abundance than residual forest quality (i.e. stand structure and composition) (St-Laurent *et al.*, 2007). However, our low habitat quality had the largest relationship with the quantity of fragments and peninsulas in a scenario. This could be explained by the role in connectivity that these residual patch types offer by increasing the amount of habitat available to wildlife in a landscape, and thereby increasing population sizes and the number of species that can live in a landscape (Seiler *et al.*, 1992).

The large percentages of low habitat quality found in our forest management sites can also be explained by several factors, including pre-existing forest conditions. The study area is characterized by widespread distribution of spruces with minimal deciduous tree species, low coverage density, and stands of mainly 120 years old. Past harvesting techniques may also have played a role in the homogenization of the forest conditions (Bergeron *et al*., 2004); as it is commonly known to decrease forest density, create larger areas of even aged stands and in favoring the re-growth of Spruce. However, HQI calculations were done immediately post cuts. One of the major faults of this analysis was not having a control group. HQI should have been tested on scenarios before cuts in order to determine whether pre-existing conditions did in fact influence low habitat quality.

Although moose are noted to prefer areas that have recently been disturbed which make it a less vulnerable species, much like the snowshoe hare of the Abitibi region (Courtois, 1993), our results found large negative relationships with harvest site conditions and habitat quality. This could be supported by previous studies that show a time lapse of 5 to 10 years before moose density increases in an area post disturbance (fire or harvest), coinciding with patterns of forest succession and regeneration (Maier *et al*., 2005; Caners *et al.,* 2008). The large negative relationship to the length of km of planned road networks could be explained by the effects of road density on habitat fragmentation. Previous studies have also found that large mammals in the USA, such as elk, moose and grizzly bear, appear to decrease in numbers as road densities increase (Holbrook and Vaughan, 1985; Mech *et al.,* 1988; Forman *et al*., 1997). Our correlation tests show that habitat quality for moose had a positive relationship with the number of peninsulas found in a site and not the surface area of peninsulas in a site; the number of peninsulas having the largest relationship with habitat quality among all forest retention patch types. Peninsulas could have a greater connectivity effect than fragments in a landscape for larger mammals, decreasing the adverse effects of habitat fragmentation. Both insular block frequency and surface area also increased habitat quality for moose.

To the opposite, marten are known to avoid disturbed areas and prefer mature coniferous forests (Godbout *et al.*2008). This could explain the large negative relationships found between marten habitat quality and (1) the amount in both hectares and (2) cubic meters of forest harvested at a site. The negative relationship found in association to the road density supports the study by Godbout *et al.* (2008) that the fragmentation of the landscape created by roads had adverse effects on marten. For marten, medium habitat quality did however have a large correlation to quantity of total residual forests and surface area of insular blocks in a scenario (table 3.8). Previous studies have indicated that marten populations can establish and reproduce in extensively clear-cut landscapes if residual patches with a mean of 150 ha are maintained (Chapin *et al.*, 1998). In relation to residual forest patch type, the frequency of peninsulas and fragments were largely related to habitat quality. According to Chapin *et al.* (1998), residual patch isolation influences the spatial distribution of marten in a landscape. Interestingly, again the number of peninsulas and not the surface area of peninsulas played a role in marten habitat. The number of fragments in a site also increased habitat quality.

For hare, weak habitat quality was however moderately associated with quantity of total residual forests and surface area of insular blocks in a site. Previous studies have found mega blocks (80 to 300 ha) and the amount of heterogeneous residual forest to have significant relationships with snowshoe hare abundance in a forest management site (Cusson *et al*. 2001; St-Laurent *et al.*, 2007). Lewis *et al.* (2011) also suggested that landscapes in which hare habitat is contiguous, or where hare habitat is surrounded by other patches, support greater snowshoe hare abundance than more fragmented landscapes. In congruence with other studies, we found higher habitat quality associated with forests that were 30 years old and partly deciduous. These stands may provide the prime combination of forage and cover (both thermal and predator avoidance cover) habitat for hares (Koehler, 1990). The younger successional stands and mature forests lack these specific components that are found in the 30-year-old stands, and that are conducive to higher hare use (Newbery *et al.*, 2005).

Natural disturbance based forest management usually acts as a coarse filter by attempting to produce habitat conditions at both stand and landscape scales, using forest from all different successional stages under the argument that wildlife has adapted over the years to similar forest conditions (MNRO, 2001). Results from this study show that high habitat quality index levels were less influenced by residual quantity than by residual quality. Therefore, we suggest that establishing fine filter guidelines, or models, could be beneficial in the beginning of the planning process to fine-tune certain aspects of the coarse filter in respect to forest retention conditions to ensure greater success in species maintenance and habitat quality.

In sum, we do not think that the negative low-moderate relationships between harvesting effort and total residual forest is strong enough an argument to impede the implementation of EBM variable retention logging in Quebec. Our results also show that harvesting efforts were more positively influenced by increased volume of timber-productive forest harvested than lowering total forest retention. Forest companies that have already implemented variable retention logging scenarios in British Columbia have shown ways in which to offset initial costs. For instance, receiving product premiums due to certification from certification companies such as FSC, when customers are prepared to pay more or continuing purchase the wood products for conservation-based forestry is one way to offset costs. In addition, companies can create new economic models through the development of revenue streams from other values such as botanicals, carbon and biodiversity (Binkley *et al*., 2006; IISAK, 2012). Our calculations of harvesting efforts for EBM management for forest retention should be compared to the harvesting efforts of business as usual management sites.

CONCLUSION

Integrating wildlife conservation and forest management is a major issue for sustainability (Lindenmayer, 2003). Natural disturbance based forest management usually acts as a coarse filter by attempting to produce habitat conditions at both stand and landscape scales, using forest from all different successional stages under the argument that wildlife has adapted over the years to similar forest conditions (MNRO, 2001). Results from this study show that high habitat quality index levels were less influenced by residual quantity than by residual quality. Therefore, we suggest that establishing fine filter guidelines, or models, could be beneficial in the beginning of the planning process to fine-tune certain aspects of the coarse filter in respect to forest retention conditions to ensure greater success in species maintenance and habitat quality.

The surface area (ha) of insular blocks specifically, did have a large correlation with increase in habitat quality for moose, hare, and marten. It also found to be the most cost effective retention patch type. In addition, the frequency of peninsulas and fragments of residuals also had a positive impact on habitat quality. Thus, as the number of peninsulas and fragments increased within a harvest site, habitat quality also increased. This could be an important factor in maintaining biodiversity in harvested landscapes by diminishing habitat fragmentation.

The residual parameters we used were based on numerous studies in boreal forest that outlined general indicators of residual patch types, sizes and frequencies found in natural landscapes. They did not however indicate forest patch sizes or frequencies depending on the size of the disturbance site. The parameters we set for peninsulas, insular blocks and fragments depending on the site sizes of 3000, 15000 and 60000 ha can be used as general ecosystem based residual forest management guideline in black spruce dominated boreal forest regions.

Our spatial model using the Spatially Explicit Landscape Events Simulator (SELES) was successful in producing retention scenarios resembling natural landscapes post wildfire. The variable retention model we created can now be used as a tool in the planning of residual forest management. Set parameters can easily be modified to incorporate additional data regarding desired residual characteristics (see appendices for scripts).

Our statistical analyses highlight the importance of residual forest quality (eg. structure and composition) over quantity for medium and high habitat quality index. We suggest that an index habitat quality model such as extension 3.0 be used in the beginning stages of management, even before residuals are spatially simulated in order to determine the optimal locations to plan residuals for better species maintenance and abundance. Temporal simulations would also help observe what landscapes rapidly revert back to a good habitat quality depending on the type and proportion of residual forests simulated. This could be an important planning process in the application of ecosystems based forest management today, considering the current state of our forests (eg. homogenous, even aged, spruce dominant, young).

Forest scientists presume that the application of ecosystems based forestry will promote increasing heterogeneity, composition and structure in future stands. Despite the number of tactical and operational questions that remain unanswered, this thesis has resulted in the creation of (1) a spatial model for residual forest planning and set parameters in terms of the amounts, proportions and frequency of each residual patch type in relation to different logging site sizes, (2) the variable retention logging plans and harvesting effort for 60 ecosystem based residual forest management scenarios, and (3) the habitat quality index for moose, marten and hare within said management sites.

REFERENCES

Baskent, E. Z., Yolasıgmaz, HA. 1999. Forest Landscape Management Revisited. Environmental Management. 24(4): 437–448.

Bas St-Laurent Forest Model Network, 2003. Indices de Qualité d'habitat. Université du Québec à Rimouski. 58 p.

Belleau, A., Bergeron, Y., Fall, A., Gauthier, S., Leduc, A. 2007. Using spatially explicit simulations to explore size distribution and spacing of regenerating areas produced by wildfires: recommendations for designing harvest agglomerations for the Canadian boreal forest. The Forestry Chronicle 83 (1): 72-83.

Belleau, A., Légaré, S. 2008. Projet Tembec vers la mise en œuvre d'une stratégie d'aménagement forestier s'inspirant de la dynamique des perturbations naturelles pour la région nord de l'Abitibi. Aménagement écosystémique en forêt boréale. Presses de l'Université du Québec. Chapitre 19, p. 507.

Belley, D. 2002. La Consummation de Sciages de Sapin, Épinette, Pin Gris et Mélèzes par l'Industrie de la Deuxième et Troisème Transformation du Bois. Ministère des Ressources naturelles direction du développement de l'industrie des produits forestiers. ISBN 2-550-39696-0, 51 p.

Bennett, A. 2003. Linkages in the Landscape: The Role of Corridors and Connectivity in Wildlife Conservation. IUCN Forest Conservation Programme. Conserving Forest Ecosystems Series No.1. ISBN: 2-8317-0744-7, 262 p.

Bergeron, Y., Leduc, A., Harvey, B.D., Gauthier, S. 2002. Natural Fire Regime: A Guide for Sustainable Management of the Canadian Boreal Forest. Silva Fennica 36 (1): 81-95.

Bergeron, Y., Drapeau, P.,Gauthier, S., Grodin, P., Leduc, A.,Nguyen, T. 2004. Developing Forest Management Strategies Based on Fire Regimes in Northwestern Quebec. Columbia University Press, New York. Sustainable Forest Management Network p. 33

Bergeron, Y., Drapeau, P., Gauthier, S., Lecomte, N. 2007. Using knowledge of natural disturbances to support sustainable forest management in the northern Clay Belt. The Forestry Chronicle 83 (3): 326-337

Bergeron, Y. Cyr, D., De Grandpré, L., Drapeau, P., Gauthier, S., Kneeshaw, D., Leduc, A., Morin, H., Vaillancourt, M.A. 2008. Chapter 21 Perspectives. Aménagement écosystémique en forêt boréale. Presses de l'Université du Québec. p.549

Binkley, C., Beebe, S., New, D., Von Hagen, B. 2006. Forestry Investment Strategy for the Coastal Temperate Rainforests of North America. Ecotrust.org. 18 p.

Bouchard, M. 2008. La sylviculture dans un contexte d'aménagement écosystémique en forêt boréale et en forêt mixte. Presses de l'Université du Québec. Aménagement écosystémique en forêt boréale. Chapter 13 p. 335.

Caners, R., Macdonald, E., Belland, R. 2008. Recolonization potential of bryophyte diaspore banks in harvested boreal mixed-wood forest. Department of Renewable Resources, University of Alberta. Plant Ecology. 204 (1): 55-68.

Chapin, T. G., Harrison, D., Katnik, D. 1998. Influence of landscape pattern on habitat use by American marten in an industrial forest. Conservation Biology 12:1327–1337.

Cohen, J. 1988, Statistical Power Analysis for the Behavioural Sciences. Psychological Science 1 (3): 98-101.

Courtois, R. 2003. La conservation du caribou forestier dans un contexte de perte d'habitat et de fragmentation du milieu. Université du Québec à Rimouski .Ph.D Thesis 368 p.

Cusson, M., St-Laurent, M-H., Ferron, J., Caron, A. 2001. Utilisation à court terme de trois types de forêt résiduelle par le Lièvre d'Amérique (Lepus americanus) en forêt boréale. Rapport technique, Université du Québec à Rimouski, Ministère des Ressources Naturelles du Québec, Société de la faune et des parcs du Québec, Rimouski. Gouvernement du Québec ISBN2-550-3819-2, 82 p.

Direction des Inventaires Forestiers. 2009. Normes de cartographie écoforestière Troisième inventaire écoforestier. Ministère des Ressources Naturelles et de la Faune. Gouvernement du Québec. ISBN 978-2-550-54985-7.

Dragotescu, J. 2008. Étude comparative des peuplements forestier après feux et après coupes dans la forêt boréale mixte en Mauricie et au Témiscamingue. Msc. Thesis. UQAM. 62 p.

Drapeau, P., Leduc, A., Giroux, J.-F., Savard, J-P. L., Bergeron, Y. et Vickery, W. L. 2002. Landscape- scale disturbances and changes in bird communities of boreal mixedwood forests. Ecological Monographs. 70 (3): 423-444.

Eberhardt, K.E., Woodward, P.M. 1987. Distribution of residual vegetation associated with large fires in Alberta. Canadian Journal of Forest Research 17: 1207–1212.

Fall, J., Fall, A. 2008. SELES User Guide. http://www.seles.info/index.php?title=Main_Page. [available on line 01/02/2013]

Fall, A. 2012. SELES: A Tool for Modelling Spatial Structure and Change. Gowllan Technlogies Ltd. 8 p.

FEIS. 2009. Fire Effects Information System website. Alces-alces. http://www.fs.fed.us/database/feis/animals/mammal/alal/all.html. [available on line 01/02/2013]

Forman, R.T.T., Friedman, D.S., Fitzhenry, D., Martin, J.D., Chen, A.S. and Alexander, L.E. 1997. Ecological effects of raods: Towards three summary indices and an overview for North America. Harvard University. Conservation Biology, 14 (1): 1-31

Franklin, J. 1993. Preserving Biodiversity : Species, Ecosystems or Landscapes? Ecological Applications, 3 (2): 202-205.

Galindo-Leal, C., Bunnell, F.L. 1995. Ecosystem management: implications opportunities of a new paradigm. Forestry Chronicle 71:601-606.

Gauthier, S., Jetté, J.P., Vaillantcout, M.A., Leduc, A. 2008. Introduction : Les enjeux écologiques de l'aménagement forestier. Aménagement écosystémique en forêt boreale. Presse de l'Université du Québec. P.1.

Godbout, G., Ouellet, J.P. 2008. Habitat selection of American marten in a logged landscape at the southern fringe of the boreal forest. Ecoscience 15: 332-342.

Guay, S. 1994. Modèle d'indice de qualité d'habitat pour le Lièvre d'Amérique (*Lepus americanus*) au Québec. Gouvernment du Québec, MRN, MEF, GIR, technical document 93/6.

Gustafson, E. J. 1998. Quantifying landscape spatial pattern: What is the state of the art? Ecosystems. 1: 143-156.

Holbrook, H.T., Vaughan, M.R. 1985 Influence of roads on turkey mortality. Virginia Polytechnic Institute University. The Journal of Wildlife Management 49 (3): 49, 611-614.

IISAK Inc. 2012. Wood With Respect. Variable Retention Harvesting. http://www.iisaak.com/. [available on line 01/02/2013]

JMP® software. 2012. SAS. www.jmp.com. [available on line 01/02/2013]

Kafka, V., S. Gauthier and Y. Bergeron. 2001. Fire impacts and crowning in the boreal forest: study of a large wildfire in western Quebec. International. Journal of Wildland Fire 10: 119–127.

Koehler, G.M. 1990. Snowshoe Hare, *Lepus americanus*, use of forest successional stages and population changes during 1985-1989 in north-central Washington. Canadian Field-Naturalist 105 :291-293.

Larue, P. 1992. Développement d'un indice de qualité de l'habitat pour la matre d'Amérique (*Martes americana*) au Québec. MLCP, DGRF, GIR, technical document 92/7.

Latrémouille, C. 2008. Impacts D'un Aménagement Forestier Écosystémique Sur La Mosaique Forestière Et Sur Les Coûts D'approvisionnement En Bois : Étude de cas de la forêt d'enseignement et de recherche du lac Duparquet. Msc. Thesis. UQAM. 61 p.

Lewis, C. W., Hodges, K. E, Koehler, G. M., Mills, L. S. 2011. Influence of stand and landscape features on snowshoe hare abundance in fragmented forests. Journal of Mammalogy 92 (3): 561-567.

Lindemayer, D. B. 2003. Integrating wildlife conservation and wood production in Victorian montane ash forests. Pages 47-72 In Towards Forest Sustainability. Island Press. Washington. 1039 p.

Linteau, P.A., Durocher, R., Robert, J.C., Chodos, R. 1983. Quebec, A History 1867 to 1929. Montréal, Boréal Express, 1979, 660 p.

Maier, A., Ver Hoef, J., McGuire, D., Bowyer, T., Saperstein, L., and Maier, H. 2005. Distribution and density of moose in relation to landscape characteristics: effects of scale. Can. J. For. Res. 35: 2233–2243.

McDonald, T.P., Taylor, S.G., Rummer, R.B. 2000. Deriving Forest Harvesting Machine Productivity from Positional Data. USDA Forest Services. Presented at the 2000 ASAE Annual International meeting, paper No. 005011, 7 p.

Mech, L.D., Fritts, S.H., Radde, G.L., Paul, W.J. 1988. Wolf distribution and road density in Minnesota. Wildlife Society Bulletin, 16: 85-87.

Mitchell, S.J., Beese, W.J. 2002. The retention system: reconciling variable retention with the principles of silvicultural systems. The Forestry Chronicle, 78 (3) : 397-403.

MNRFQ. 2009. L'aménagement écosystémique : au cœur de la gestion des forêts. Dossier sur les forêts. Gouvernement du Québec. http://www.mrn.gouv.qc.ca/forets/amenagement/amenagement-ecosystemique.jsp. [available on line 01/02/2013]

MNRO. 2001. Forest Management Guide for Natural Disturbance Pattern Emulation. Technical series. Version 3.1. Ontario Government, Ministry of Natural Resources. Queen's printer for Ontario.40 p.

Monthey, R. W. 1986. Response of snowshoe hares to timber harvesting in northern Maine. Can. Field- Nat. 100:568-570.

Newbury, T.L., Simon, N.P.P. 2005. The effects of clear-cutting on snowshoe hare (*Lepus americanus*) relative abundance in central Labrador. Forest Ecology and Management, 210 :131-142.

Orr, C. D., and D. G. Dodds. 1982. Snowshoe hare habitat preferences in Nova Scotia spruce–fir forests. Wildlife Society Bulletin, 10:147–150.

Pastor, J. and Broschart, M. 1990. The spatial pattern of a northern conifer-hardwood landscape. Landscape Ecology, 4 (1): 55-68.

Perera, A. and Buse, L. 2004. Emulating Natural Forest Landscape Disturbances: A Synthesis. Columbia University Press, New York. P.3-7.

Perron, N. 2003. Peut-on et doit-on s'inspirer de la variabilité naturelle des feux pour élaborer une stratégie écosystémique de répartition des coupes à l'échelle du paysage: le cas de la pessière noire à mousse de l'Ouest au Lac-Saint-Jean. Thesis, Laval University, Laval University Press, Québec. 148 p.

Perron, N., Bélanger, L., Vaillancourt, M.A. 2008. Organisation spatiale des peuplements et de la forêt résiduelle sous régimes de feu et coupes. Aménagement écosystémique en forêt boréale. Presse de l'Université de Québec. Chapitre 6, p.137.

Phillips, E. J. 1996. Comparing Silvicultural Systems in a Coastal Montane Forest: Productivity and Cost of Harvesting Operations. FRDA Report. FERIC Special Report No. SR-109. Her Majesty the Queen in Right of Canada. 42 p.

Pinjuv, G., Daugherty, P.J., Fox, B. 2001. Cost Effectiveness Analysis of Ponderosa Pine Ecosystem Restoration in Flagstaff Arizona's Wildland-Urban Interface. USDA Forest Service. Proceedings RMRS. 22p.

Potvin, F., Bélanger, L., Lowell, K. 2000. Marten habitat selection in a clearcut boreal landscape. Conservation Biology. 14 (3): 844-857.

Ripple, W.J., Bradshaw, G.A and Spies, T.A. 1991. Measuring Forest Landscape Patterns in the Cascade Range of Oregon, USA. Biological Conservation. 57:73-88.

Seiler, A., Eriksson, I.-M. 1997. New approaches for ecological consideration in Swedish road planning. Proceedings of the international conference on "Habitat fragmentation, infrastructure and the role of ecological engineering". The Netherlands: Ministry of Transport, Public Works nd Water Management, Road and Hydraulic Engineering division. P. 253-264.

SELES. 2012. What is seles? www.seles.info. [available on line 01/02/2013]

Spatial Planning Systems. 2008. Patchworks. http://www.spatial.ca/. [available on line 01/02/2013]

St-Laurent, M-H., Ferron, J., Hins, C., Gagnon, R. 2007. Effects of stand structure and landscape charateristics on habitat use by birds and small mammals in managed boreal forest of eastern Canada. Canadian Journal of Forest Research 37: 1298-1309.

Tembec. 2008. Projet Pilote d'aménagement écosytémique pour l'unité d'aménagement forestier 085-51. http://www.tembec-grf-quebec.com/siteIms/ecosystemique.html. [available on line 01/02/2013]

Yelle, V. Paquet, J. Jetté, J. 2009. Guide d'atténuation des impacts visuels causés par les agglomérations de coupes dans le domaine de la pessière à mousses. MRNF. Direction de l'environnement et de la protection des forêts. p. 21-34

APPENDIX A

SELES FIRE MODEL

1) Fire Model/ Harvest Model

Reference: Annie Belleau, Yves Bergeron, Alain Leduc, Sylvie Gauthier and Andrew Fall 2007

The fire model created by Belleau (2007) was developed in SELES. Based on the territory size the fire cycle and the mean fire size that is incorporated into a simulation run, the number of fire events by year is randomly chosen from a Poisson distribution where u is assumed to be the annual average fire occurrence and is equal to:

$$[1]\ \text{FireOccurence} = \frac{\textit{Extent(ha)}}{\text{MeanFireSize(ha)} * \text{FireCycle(yr)}}$$

The size of each fire event is randomly selected from a negative exponential distribution based on mean fire size. The fire start locations are also randomly chosen over the entire grid which represents the selected territory (Belleau et al., 2007)

Once initiated, a modelled fire randomly spreads to one or two of the eight neighbouring cells that have not burnt during the event time step. A fire will then spread until the chosen fire event size is reached. The shape of a fire is not directly controlled, but the alternate spreading to one or two cells of the eight neighbours avoids the creation of a circular shape (non complex). In this model fire shapes appear realistic.

APPENDIX B

SELES VARIABLE RETENTION MODEL

Retention Model (.sel, .lse, .scn scripts)
Blocks model .lse script
LSEVENT: blocks
// The base file to create variables, variable names must be changed in both .sel and .lse to function
DEFINITIONS
GLOBAL CONSTANT: HaPerCell
GLOBAL VARIABLE: BaseTimestep
LAYER: RetentionEvent, Blocks
LAYER: Landuse
LAYER: CommercialMatureForest,StandAge
LAYER: PatchLayer
GLOBAL CONSTANT: BlockClassSize, NumBlockClasses
GLOBAL VARIABLE: BlockSizeDist[], BlockSizeArea[],BlocksSizeTarget[], TotalBlockArea[], BlockAreaById[]
GLOBAL VARIABLE: meanBlockSize, MINBlocksize,MAXBlocksize, NumBlocksTarget
GLOBAL VARIABLE: meanNumBlocks, MINNumblocks, MAXNumblocks, NumBlocks
//Global Constants and variables have an impact on all events. [] signifies that this variable as a value table and is not represented by a number
CLUSTER VARIABLE: BlockExtent,currBlockSize
CLUSTER VARIABLE: NumActiveCells
EVENT VARIABLE: IdBlocks
//Cluster variables control grouped actions
ENDDEF
INITIALSTATE
CommercialMatureForest = 0
INITIALSTATE = 1 // 1 run
ENDIS
RETURNTIME // This determines how your .lse files are executed. So, if time EQ 0 then 0.1 ELSE BaseTimeStep means that 0.1 start making blocks. Each Block, fragment and peninsula will start one decimal from each other ending in reportresults.
RETURNTIME= IF Time EQ 0 THEN 0.2 ELSE 0
IdBlocks = 0
ENDRT
// Only allow initiation in forested cells
EVENTLOCATION
STATIC REGION WHOLE MAP
DECISION (Landuse EQ 2) AND (PatchLayer EQ 2)AND (StandAge > 30)
ENDEL
NUMCLUSTERS meanClusters = meanNumBlocks
nClusters = CLAMP(FLOOR(NORMAL(meanClusters,1)),MINNumblocks,MAXNumblocks) //ROUND(POISSON(meanClusters)) // add in later when things are running
NumBlocksTarget = nClusters
NUMCLUSTERS = nClusters

```
   currBlockSize = 0
   NumActiveCells = 1
ENDNC
PROBINIT // Based on chance of initiation
PROBINIT = 1
IdBlocks = IdBlocks + 1
  // For each opening, select an opening size from an negative exponential distribution
meanExtent = meanBlockSize/HaPerCell
  BlockExtent = CLAMP(NORMAL(meanExtent,1),MINBlocksize, MAXBlocksize)
  BlocksSizeTarget[IdBlocks] = BlockExtent // BlockSizeTarget is to compare what my parameters were compared to what I got.
ENDPI
TRANSITIONS  // I burnt my cell now I need to go somewhere else.
    isDoingBlocks = (BlockExtent > 0) AND (Blocks EQ 0)
IF isDoingBlocks
  Blocks = IdBlocks
     BlockExtent = BlockExtent - 1 // is making blocks
     currBlockSize = currBlockSize + HaPerCell // is adding to it's surface area
                RetentionEvent = 2 // 2 is the value of the pixel
TotalBlockArea = TotalBlockArea + HaPerCell
  ELSE IF (currBlockSize > 0)  //Not still burn (but at least one cell was burn in Fire)
NumActiveCells = NumActiveCells – 1
         IF (NumActiveCells EQ 0)
       BlockClass = MIN(FLOOR(currBlockSize /BlockClassSize), NumBlockClasses -1)
BlockSizeDist[BlockClass] = BlockSizeDist[BlockClass] + 1
       BlockSizeArea[BlockClass] = BlockSizeArea[BlockClass] + currBlockSize
BlockAreaById[IdBlocks ] = currBlockSize
       NumBlocks = IdBlocks
  //TotalBlockArea[IdBlocks] = currBlockSize
      ENDFN
ENDFN
    // Continue if there is still extent to be burned
  // AND if the stand didn't burn during this event already
TRANSITIONS= isDoingBlocks
  ENDTR
// Spread timestep: time is irrelevant for this empirical model.
SPREADTIMESTEP
  SPREADTIMESTEP = -2 // -2 so it all happens at the same time and quickly
  NumActiveCells = NumActiveCells - 1 // simulation complete start to output data
IF (NumActiveCells EQ 0)
       BlockClass = MIN(FLOOR(currBlockSize /BlockClassSize), NumBlockClasses -1)
BlockSizeDist[BlockClass] = BlockSizeDist[BlockClass] + 1
       BlockSizeArea[BlockClass] = BlockSizeArea[BlockClass] + currBlockSize
BlockAreaById[IdBlocks ] = currBlockSize
        NumBlocks = IdBlocks
      //TotalBlockArea[IdBlocks] = currBlockSize
      ENDFN
ENDST
// Spread to the eight neighbours
SPREADLOCATION
  REGION CENTRED(1, 1.5)
```

DECISION (Blocks EQ 0) AND (Landuse EQ 2) AND (PatchLayer EQ 2)AND (StandAge > 30)
ENDSL
NUMRECIPIENTS = MAX(1,ROUND(NORMAL(4,0.5)))// 1.4 instead of 1.5 so the shape is not too square
SPREADPROB
SPREADPROB = 1
NumActiveCells = NumActiveCells + 1
ENDSP
Fragment model lse. Script
LSEVENT: fragments
DEFINITIONS
GLOBAL CONSTANT: HaPerCell
GLOBAL VARIABLE: BaseTimestep
LAYER: RetentionEvent, Fragments
LAYER: FragExclusion, Blocks
LAYER: StandAge, Landuse, PatchLayer
GLOBAL CONSTANT: FragmentClassSize, NumFragmentClasses
GLOBAL VARIABLE: FragmentSizeDist[], FragmentSizeArea[],FragmentAreaById[], FragmentsSizeTarget[]
GLOBAL VARIABLE: meanFragmentSize, MINFragmentsize,MAXFragmentsize, NumFragmentsTarget
GLOBAL VARIABLE: meanNumFragments, MINNumFragments, MAXNumFragments, NumFragments
GLOBAL VARIABLE: TotalFragmentArea
CLUSTER VARIABLE: FragmentExtent,currFragmentSize
CLUSTER VARIABLE: NumActiveCells
EVENT VARIABLE: IdFragments
ENDDEF
INITIALSTATE
INITIALSTATE = 1
ENDIS
RETURNTIME
RETURNTIME= IF Time EQ 0 THEN 0.5 ELSE 0
OVER REGION WHOLE MAP
DECISION (Landuse EQ 2) AND (PatchLayer EQ 2) AND (RetentionEvent EQ 0)
numSimilarNeighbours = 0
numDifferentNeighbours = 0
OVER REGION CENTRED(1, 1.5)
//DECISION (Landuse EQ 2) AND (PatchLayer EQ 2)
similarNeighb = (RetentionEvent EQ 0)
numSimilarNeighbours = numSimilarNeighbours + similarNeighb
numDifferentNeighbours = numDifferentNeighbours + (similarNeighb EQ FALSE)
ENDFN
FragExclusion = IF (numDifferentNeighbours > 0) THEN 0 ELSE 1
ENDFN
//FragExclusion = IF (Landuse EQ 2) AND (RetentionEvent EQ 0) AND (PatchLayer EQ 2) THEN 1 ELSE 0
IdFragments = 0
// Update time since disturbance information
// Need to do this here, since Burnt may include non-forested cells

ENDRT
// Only allow initiation in non-excluded cells
EVENTLOCATION
STATIC REGION WHOLE MAP
DECISION (PatchLayer EQ 2) AND (RetentionEvent EQ 0) AND (Landuse EQ 2) AND (StandAge > 30)
ENDEL
NUMCLUSTERS meanClusters = meanNumFragments
nClusters = CLAMP(NORMAL(meanClusters,1),MINNumFragments,MAXNumFragments) //ROUND(POISSON(meanClusters)) // add in later when things are running
NumFragmentsTarget = nClusters
NUMCLUSTERS = nClusters
currFragmentSize = 0
NumActiveCells = 1
ENDNC
PROBINIT
PROBINIT = 1
IdFragments = IdFragments + 1
// For each opening, select an opening size from an negative exponential distribution
meanExtent = meanFragmentSize/HaPerCell
FragmentExtent = CLAMP(NORMAL(meanExtent,1),MINFragmentsize, MAXFragmentsize)
FragmentsSizeTarget[IdFragments] = FragmentExtent
ENDPI
TRANSITIONS
isDoingFragments = (FragmentExtent > 0) AND (Fragments EQ 0) AND (FragExclusion EQ 1)
IF isDoingFragments
FragmentExtent = FragmentExtent – 1
currFragmentSize = currFragmentSize + HaPerCell
RetentionEvent = 3Fragments = IdFragments
TotalFragmentArea = TotalFragmentArea + HaPerCell
ELSE IF (currFragmentSize > 0) //Not still burn (but at least one cell was burn in Fire)
NumActiveCells = NumActiveCells – 1
IF (NumActiveCells EQ 0)
FragmentClass = MIN(FLOOR(currFragmentSize /FragmentClassSize), NumFragmentClasses -1)
FragmentSizeDist[FragmentClass] = FragmentSizeDist[FragmentClass] + 1
FragmentSizeArea[FragmentClass] = FragmentSizeArea[FragmentClass] + currFragmentSize
FragmentAreaById[IdFragments] = currFragmentSize
NumFragments = IdFragments
ENDFN
ENDFN
// Continue if there is still extent to be burned
// AND if the stand didn't burn during this event already
TRANSITIONS= isDoingFragments
ENDTR
// Spread timestep: time is irrelevant for this empirical model.
SPREADTIMESTEP
SPREADTIMESTEP = -2
NumActiveCells = NumActiveCells – 1
IF (NumActiveCells EQ 0)
FragmentClass = MIN(FLOOR(currFragmentSize /FragmentClassSize), NumFragmentClasses -1)

FragmentSizeDist[FragmentClass] = FragmentSizeDist[FragmentClass] + 1
FragmentSizeArea[FragmentClass] = FragmentSizeArea[FragmentClass] + currFragmentSize
FragmentAreaById[IdFragments] = currFragmentSize
NumFragments = IdFragments
ENDFN
ENDST
// Spread to the eight neighbours
SPREADLOCATION
REGION CENTRED(1, 1.5)
DECISION (Fragments EQ 0) AND (FragExclusion EQ 1) AND (StandAge > 30)
ENDSL
NUMRECIPIENTS = MAX(1,ROUND(NORMAL(1.4,0.1)))
SPREADPROB
SPREADPROB = 1
NumActiveCells = NumActiveCells + 1
ENDSP
Peninsula model les. Script
LSEVENT: peninsula
// The base file to create variables, variable names must be changed in both .sel and .lse to function
DEFINITIONS
GLOBAL CONSTANT: HaPerCell
GLOBAL VARIABLE: Area, MatureForestArea, BaseTimestep
LAYER: RetentionEvent, Peninsulas
LAYER: Landuse
LAYER: CommercialMatureForest,StandAge
LAYER: PatchLayer
GLOBAL CONSTANT: PeninsulaClassSize, NumPeninsulaClasses, MaxPeninsulaSize
GLOBAL VARIABLE: PeninsulaSizeDist[], PeninsulaSizeArea[]
GLOBAL VARIABLE: TotalPeninsulaArea[],PeninsulaAreaById[],PeninsulasSizeTarget[]
GLOBAL VARIABLE: meanPeninsulaSize, MINPeninsulasize,MAXPeninsulasize, NumPeninsulasTarget
GLOBAL VARIABLE: meanNumPeninsulas, MINNumPeninsulas, MAXNumPeninsulas, NumPeninsulas
//Global Constants and variables have an impact on all events. [] signifies that this variable as a value table and is not represented by a number
CLUSTER VARIABLE: PeninsulaExtent,currPeninsulaSize
CLUSTER VARIABLE: NumActiveCells
EVENT VARIABLE: IdPeninsula
//Cluster variables control grouped actions
ENDDEF
INITIALSTATE
CommercialMatureForest = 0
INITIALSTATE = 1 // 1 run
ENDIS
RETURNTIME // This determines how your .lse files are executed. So, if time EQ 0 then 0.1 ELSE BaseTimeStep means that 0.1 start making blocks. Each Block, fragment and peninsula will start one decimal from each other ending in reportresults.

// This commands SELES to look through the grid and select squares that contain Landuse EQ 2 and CommercialmatureForest.
OVER REGION WHOLE MAP
DECISION (Landuse EQ 2)
CommercialMatureForest = IF (StandAge >= 100) THEN 1 ELSE 0
ENDFN
RETURNTIME= IF Time EQ 0 THEN 0.1 ELSE 0
IdPeninsula = 0
OVER REGION WHOLE MAP
DECISION (PatchLayer > 0)
Area = Area + HaPerCell
MatureForestArea = MatureForestArea + ((CommercialMatureForest EQ 1) * HaPerCell)
ENDFN
ENDRT
// Only allow initiation in forested cells
EVENTLOCATION
STATIC REGION WHOLE MAP
DECISION (Landuse EQ 2) AND (PatchLayer EQ 1) AND (StandAge > 30)
ENDEL
NUMCLUSTERS meanClusters = meanNumPeninsulas
nClusters = CLAMP(NORMAL(meanClusters,1),MINNumPeninsulas,MAXNumPeninsulas) //ROUND(POISSON(meanClusters)) // add in later when things are running
NumPeninsulasTarget = nClusters
NUMCLUSTERS = nClusters
currPeninsulaSize = 0
NumActiveCells = 1
ENDNC
PROBINIT // Based on chance of initiation
PROBINIT = 1
IdPeninsula = IdPeninsula + 1
// For each opening, select an opening size from an negative exponential distribution
meanExtent = meanPeninsulaSize/HaPerCell
PeninsulaExtent = CLAMP(NORMAL(meanExtent,1),MINPeninsulasize, MAXPeninsulasize)
PeninsulasSizeTarget[IdPeninsula]=PeninsulaExtent
ENDPI
TRANSITIONS // I burnt my cell now I need to go somewhere else.
isDoingPeninsula = (PeninsulaExtent > 0) AND (Peninsulas EQ 0)
IF isDoingPeninsula
Peninsulas = IdPeninsula
PeninsulaExtent = PeninsulaExtent - 1 // is making blocks
currPeninsulaSize = currPeninsulaSize + HaPerCell // is adding to it's surface area
RetentionEvent = 1 // 1 is the value of the pixelTotalPeninsulaArea = TotalPeninsulaArea + HaPerCell
ELSE IF (currPeninsulaSize > 0) //Not still burn (but at least one cell was burn in Fire)
NumActiveCells = NumActiveCells – 1
IF (NumActiveCells EQ 0)
PeninsulaClass = MIN(FLOOR(currPeninsulaSize /PeninsulaClassSize), NumPeninsulaClasses - 1)
PeninsulaSizeDist[PeninsulaClass] = PeninsulaSizeDist[PeninsulaClass] + 1
PeninsulaSizeArea[PeninsulaClass] = PeninsulaSizeArea[PeninsulaClass] + currPeninsulaSize

PeninsulaAreaById[IdPeninsula] = currPeninsulaSize
NumPeninsulas = IdPeninsula
//TotalPeninsulaArea[IdPeninsula] = currPeninsulaSize
ENDFN
ENDFN
// Continue if there is still extent to be burned
// AND if the stand didn't burn during this event already
TRANSITIONS= isDoingPeninsula
ENDTR
// Spread timestep: time is irrelevant for this empirical model.
SPREADTIMESTEP
SPREADTIMESTEP = -2 // -2 so it all happens at the same time and quickly
NumActiveCells = NumActiveCells - 1 // simulation complete start to output data
IF (NumActiveCells EQ 0)
PeninsulaClass = MIN(FLOOR(currPeninsulaSize /PeninsulaClassSize), NumPeninsulaClasses - 1)
PeninsulaSizeDist[PeninsulaClass] = PeninsulaSizeDist[PeninsulaClass] + 1
PeninsulaSizeArea[PeninsulaClass] = PeninsulaSizeArea[PeninsulaClass] + currPeninsulaSize
PeninsulaAreaById[IdPeninsula] = currPeninsulaSize
NumPeninsulas = IdPeninsula
//TotalPeninsulaArea[IdPeninsula] = currPeninsulaSize
ENDFN
ENDST
// Spread to the eight neighbours
SPREADLOCATION
REGION CENTRED(1, 1.5)
DECISION (Peninsulas EQ 0) AND (Landuse EQ 2) AND (PatchLayer EQ 1)AND (StandAge > 30)
ENDSL
NUMRECIPIENTS = MAX(1,ROUND(NORMAL(4,0.5)))// 1.4 instead of 1.5 so the shape is not too square
SPREADPROB
SPREADPROB = 1
NumActiveCells = NumActiveCells + 1
ENDSP
Retention Model .sel script
Seles Model
Landscape Events:
// .sel files are gross directories to assign your parameters, layers, and variables. They can consist of tons events.
//Disturbance events
blocks.lse DEBUG
fragments.lse DEBUG
peninsula.lse DEBUG
//ReportResults events
ReportResultsRetention.lse DEBUG
// Spatial constants do not change during a simulation.
// The format is:

// LayerName = RasterName
// LayerName
// In the second case, the raster name is assumed to be the same as the layer name
Spatial Constants:
Landuse
PatchLayer
Legends:
LanduseLegend = "gisData\cats\Landuse"
Global Constants:
//////////////////////////
// General constants and parameters
//////////////////////////
//Global Constants and variables have an impact on all events
CellWidth = 100
HaPerCell = (CellWidth^2) / 10000
//Age parameters
AgeClassSize = 100
MaxStandAge = 1500
NumAgeClasses = (MaxStandAge/AgeClassSize)
//BlockSize distribution this is to organize my results
BlockClassSize = 100
MaxBlockSize = 5000
NumBlockClasses = (MaxBlockSize / BlockClassSize)
//FragmentSize distribution
FragmentClassSize = 1
MaxFragmentSize = 10
NumFragmentClasses = (MaxFragmentSize / FragmentClassSize)
//PeninsulaSize distribution
PeninsulaClassSize = 100
MaxPeninsulaSize = 5000
NumPeninsulaClasses = (MaxPeninsulaSize /PeninsulaClassSize)
// Spatial constants usually change during a simulation.
// Format for spatial variables with an initial state:
// outputName[bounds] <- initialStateName
//
// Format for spatial variables with no initial state (initial state of 0):
// outputName[bounds]//
// Bounds can be of the form [min,max] (e.g. [0,MaxStandAge]) or [max] (which assumes a min of 0)
// Bounds are optional for spatial varibles with an initial state (in which case the bounds of the initial state raster are used)
//
// If a different name is desired for the raster than the layer variable, then add "= RasterName"
// before the bounds. This is uncommon. For example:
// StandAge = dynamicAge[MaxStandAge] <- initialAge
Spatial Variables:
//////////////////////////
// Stand information
//////////////////////////

StandAge[MaxStandAge] <- initialStandAge
//////////////////////////
// retention information
/////////////////////////
Fragments [0,300] // Brackets create bounds and this represents the min and max amount of each block, fragment and peninsula
RetentionEvent[0,3]
Blocks [0,30]
Peninsulas [0,50]
FragExclusion[0,2]
/////////////////////////
//CommercialMatureForest
////////////////////////
CommercialMatureForest
Global Variables:
//
// Parameters
BaseTimestep = 1 // Base Time step (in years)
MeanAge = 0
Area = 0
MatureForestArea = 0
//Blocks Parameters
meanBlockSize = 130
MINBlocksize = 10
MAXBlocksize = 300
MINNumblocks = 1
MAXNumblocks = 30
meanNumBlocks = 6
//Fragment Parameters
meanFragmentSize = 4
MINFragmentsize = 1
MAXFragmentsize = 4
MINNumFragments = 1
MAXNumFragments = 300
meanNumFragments =100
//Peninsula Parameters
meanPeninsulaSize = 1000
MINPeninsulasize = 10
MAXPeninsulasize = 300
MINNumPeninsulas = 1
MAXNumPeninsulas = 50
meanNumPeninsulas = 1
LandscapeId = 1
Replicate = 1
//
// Tracking
//Tracking means once the last pixel has been simulated begin to output results.
NumBlocks = 0
NumFragments = 0
NumPeninsulas = 0

NumBlocksTarget = 0
NumFragmentsTarget = 0
NumPeninsulasTarget = 0
TotalPeninsulaArea = 0
TotalBlockArea = 0
TotalFragmentArea = 0
FragmentAreaById[MAXNumFragments,MAXFragmentsize] = 0
BlockAreaById[MAXNumblocks,MAXBlocksize] = 0
PeninsulaAreaById[MAXNumPeninsulas,MAXPeninsulasize] = 0
BlocksSizeTarget[MAXNumblocks,MAXBlocksize] = 0
PeninsulasSizeTarget[MAXNumPeninsulas,MAXPeninsulasize] = 0
FragmentsSizeTarget[MAXNumFragments,MAXFragmentsize] = 0
BlockSizeDist[NumBlockClasses] = 0
BlockSizeArea[NumBlockClasses] = 0
FragmentSizeDist[NumFragmentClasses] = 0
FragmentSizeArea[NumFragmentClasses] = 0
PeninsulaSizeDist[NumPeninsulaClasses] = 0
PeninsulaSizeArea[NumPeninsulaClasses] = 0
Output Frequency: 1
/*
Output Model Frequency:
Blocks Freq: ReportingInterval Directory:".\cell" Type: GRASS COMPRESSED Relative
Fragments Freq: ReportingInterval Directory:".\cell" Type: GRASS COMPRESSED Relative
//ChantierEquien Freq: ReportingInterval Directory:".\cell" Type: GRASS COMPRESSED Relative
// DisturbEvent Freq: ReportingInterval Directory:".\cell" Type: GRASS COMPRESSED Relative
//ChantierEquien Freq: ReportingInterval Directory:".\cell" Type: GRASS COMPRESSED Relative
// RoadsToChantiers Freq: ReportingInterval Directory:".\cell" Type: GRASS COMPRESSED Relative
// RoadsCostMatrix Freq: ReportingInterval Directory:".\cell" Type: GRASS COMPRESSED Relative
// HarvestedArea10000 Freq: ReportingInterval Directory:".\cell" Type: GRASS COMPRESSED Relative
// Harvested Freq: ReportingInterval Directory:".\cell" Type: GRASS COMPRESSED Relative
*/
Retention Model .scn script
Scenario Information
$gisData$ = .\gisData\cell
$SrcgisData$ = ..\modelBuffer\gisBuffer_3000\cell
initialStandAge = $gisData$\age
Landuse = $gisData$\Land_use
PatchLayer =$SrcgisData$\Buffers_3000_13
Model Dimensions: initialStandAge
Retention.sel
LandscapeId = 3000 // This sets the variable LandscapeId to the integer represented by x
Replicate = 1
SimPriority Low Priority // Set low priority for simulation engine
// Set up display
Minimize Static
//Minimize Initial State
Tile

// Move to output folder
cwd S1_1
meanBlockSize = 55
meanNumBlocks = 1
meanFragmentSize = 5
meanNumFragments = 10
meanPeninsulaSize = 25
meanNumPeninsulas = 1
cwd minimum
cwd .\cell
cwd ..\cellhd
cwd ..
SimStart 1 1 low priority
Save RetentionEvent .\cell\RetentionEvent_3000 GRASS COMPRESSED