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Spatially explicit habitat suitability index model for the boreal owl (*Aegolius funereus*) in Western Newfoundland

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VERSION 2.0

January 2004

AKNOWLEDGEMENTS

We would like to thank R. Pouliot, P. Sabbagh and A. Rudy for their participation in the development and the review of this HSI model. We received very constructive and insightful comments from C. Doucet, J. Fenske, T. Moulton and N. Simon. This project has been financially supported by the Western Newfoundland Model Forest through the Model Forest Program of Natural Resources Canada.

SUMMARY

We developed a Habitat Suitability Index model for the boreal owl population dwelling in the Western Newfoundland forest. In the first place, this document presents a comprehensive literature review on the habitat requirements of the boreal owl followed by the model *per se*. The literature review presents food, cover, reproduction and habitat area requirements in order to identify critical conditions that relate to habitat selection, population health and productivity. Based on this information, a model has been developed. The model considers two critical elements: nesting and foraging. Nesting habitat suitability is dependant on the availability of large (diameter at breast height >= 30 cm) live and dead trees (LLDT). In order to model this habitat element, a relationship has been developed, using 661 temporary and permanent sampling plots, between the density of LLDT and stand (composition, density, age) and site attributes (productivity class). The foraging habitat is first classified by the density of the cover, where the more open is the terrestrial habitat the best it is for hunting. However, for complete openings, foraging habitat value is reduced according to the distance to forest cover edge. Such function aim at reproducing the reluctance of the boreal owl to cross large open areas where risk to be predated upon is greater. Both foraging and nesting habitats are then combined spatially by using a sliding window that average nesting and foraging suitability index values in an area of the size of a home range (1000 ha). The model is applied to the actual forest state of District 15. Recommendations at the scale of the stand and the landscape are provided for improving boreal owl habitat quality.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

TABLE OF APPENDICES

1. DESCRIPTION, DISTRIBUTION AND CONSERVATION STATUS

The boreal owl (*Aegolius funereus*), also known as Tengmalm's owl in Eurasia, is a small nocturnal owl (length: 21-28 cm; wingspan: 55-62 cm) ; it is slightly larger than its close relative, the Northern Saw-whet Owl (*Aegolius acadicus)* (Hayward and Hayward, 1993; Sibley, 2000). Neither of these two species have apparent ear tufts, and it is mainly the size and the lightly colored bill that distinguish the boreal owl from the Northern saw-whet owl (Sibley, 2000). The male and the female of the boreal owl have similar plumage characteristics; however, this species shows a remarkable sexual dimorphism, the female being noticeably larger than the male (Hayward and Hayward, 1993). Even though the boreal owl is a predator, its small size makes it a vulnerable prey to larger raptors such as the Northern goshawk (*Accipiter gentilis*) and the great horned owl (*Bubo virginianus*) as well as to mustelids such as martens (*Martes* spp.) (Korpimäki, 1981; Hayward and Hayward, 1993).

The boreal owl has a circumboreal distribution (Johnsgard, 1988). In North America, it is present all-year-round from the tree line (to the South) to the Southern limit of the boreal region (to the North) (Rowe, 1972) and is found from Alaska to Newfoundland (Johnsgard, 1988; Kirk, 1995; Sibley, 2000). Southern populations also occur through the Rocky Mountains in Idaho, Montana and Wyoming (Hayward *et al*., 1993). In Canada, it is presumed to be common because of the extensive boreal habitat available, but little is known about its precise distribution and population status (Kirk, 1995). Although it is considered a year-round resident of the boreal forest, irregular southern movements take place during fall and winter (Catling, 1972; Côté *et al.*, submitted). Young and adult female owls are highly nomadic while adult males are resident (Korpimäki, 1989; Ibarzabal, unpublished data). In Newfoundland, it is considered as an uncommon breeder and it is observed in all seasons but mostly during winter and spring (Mactavish *et al*., 1999).

In spite of the lack of data on population sizes and trends in Canada, the Committee on the status of endangered wildlife in Canada (COSEWIC) classified the boreal owl as a "not at risk" species (Kirk, 1995). However, Imbeau *et al.* (2001) have recently argued that the boreal owl is vulnerable to actual forest management activities in the Eastern Canadian boreal forest.

2. HABITAT USE

3.1 Food requirements

The boreal owl is a small mammal specialist. Shrew (*Sorex* spp.), mice (*Zapus* spp. and *Peromyscus* spp.) and voles (*Clethrionomys* spp. and *Microtus* spp.) represent up to 95 % of its diet ; it can occasionally prey upon small passerine birds, particularly during winter when the availability of small mammals is low (Korpimäki, 1981; Koripmäki, 1989; Hayward *et al.*1993; Whitman, 2001). Chickadee (*Parus* spp.), common redpoll (*Carduelis flammeus*) and red crossbill (*Loxia curvirostra*) are among birds being commonly preyed upon by the boreal owl (Hayward and Hayward, 1993). Prey abundance contributes considerably to habitat quality as it has a significant influence on the breeding success of boreal owl (Korpimäki, 1992; Hakkarainen *et al*., 1997). Kirk (1995) has also identified food supply as one of the limiting factor for boreal owl populations in Canada. Although it is a nocturnal species, the boreal owl hunts during the day, particularly in the Northern part of its range where there is long summer daylight as well as during the later stage of yearlings' development (probably to satisfy yearlings' higher energy requirements) (Korpimäki, 1981). When hunting, the boreal owl usually uses the so-called "sit and wait strategy" : it sits on a low perch, locates a ground-dwelling prey using acoustic clues and then plunges through the shrubs to reach the prey (Johnsgard, 1988; Hayward and Hayward, 1993). Foraging habitats in the Rocky Mountains consist mainly of mature spruce-fir stands (Hayward *et al*., 1993). Mature spruce forests are also used for foraging in Norway (Sonerud, 1986). This type of habitat is preferred because of its high quality for preys (Hayward *et al*., 1993). Moreover, it has better snow conditions during winter (uncrusted snow) and less herbaceous cover during summer, allowing greater prey accessibility (Sonerud, 1986; Hayward *et al.*, 1993). However, according to Whitman (2001), the boreal owl prefers to hunt in small openings in forest stands. In Finland, the boreal owl seldom seems to hunt in open terrain (Korpimäki, 1981). It has been argued that during spring thaw, the boreal owl shifts to more open habitats (clearcuts, meadows) where snow melts faster and where preys are easier to catch (Hayward *et al.*, 1993; Whitman, 2001). Indeed, the boreal owl catches its prey above the snow and is not able to search through thick snow layer (Korpimäki, 1989). Thus a thick or a crusted snow cover protects small mammals against predation by the boreal owl (Korpimäki, 1989).

3.2 Cover requirements

The presence of the boreal owl is generally associated with dense and mature coniferous forests (Johnsgard, 1988). Habitat cover requirements seem to differ between summer and winter (Hayward *et al.*, 1993). During summer, the boreal owl selects dense and shaded sites (with cooler air temperature) for roosting, while less specific roosting site selection seems to occur during winter, probably due to a lower thermal stress for this cold-adapted species (Hayward *et al.*, 1993). However, during both seasons, the boreal owl selects mature spruce-fir and pine stands. In Western Newfoundland, the boreal owl is associated with uncut old-growth (over 80 year-old) balsam fir forests (Gosse and Montevecchi, 2001). The boreal owl roosts in various sites and tree species (Hayward *et al.*, 1993), particularly during southern irruptions (Catling, 1972). It can either roost on a low perch or use a cavity (Korpimäki, 1989; Hayward *et al.*, 1993). Roosting sites change from day to day within home range (Hayward and Hayward, 1993).

3.3 Reproduction requirements

The boreal owl can either be monogamous or polygamous (Korpimäki, 1981). Polygyny and polyandry can occur during high food availability in Finland (Korpimäki, 1981) but has not been documented in North America (Hayward *et al.*, 1993). Clutch size ranges from two to four eggs (zero to three fledglings) in the Rocky Mountains (Hayward *et al.*, 1993) and from one to 10 eggs (zero to eight fledglings) in Finland (Korpimäki, 1981). In Eastern Canada, the boreal owl is thought to start breeding at the end of April or at the beginning of May (Desrosiers and Bombardier, 1995), while breeding in Finland can start as early as the end of February or the beginning of March (Korpimäki, 1981). Sexual maturity is reached within the first year after hatching (Johnsgard, 1988).

In the Rocky Mountains, the boreal owl nests primarily in tree cavities excavated by either a pileated woodpecker (*Dryocopus pileatus*) or a Northern flicker (*Colaptes auratus*) on a live tree or a snag with a DBH (diameter at breast height) ranging from 33 to 112 cm (Hayward *et al.*, 1993; Heinrich *et al.*1999). Other woodpecker cavities such as those excavated by the black-backed and the three-toed woodpeckers (*Picoides arcticus* and *P. tridactylus*) in the Eastern boreal forest are probably too small for the boreal owl (Imbeau, pers. comm.). Thus, habitat limits in pileated woodpecker and common flicker distributions may restrict availability of nesting cavities and therefore boreal owl abundance (Hayward and Hayward, 1993). Nevertheless, the boreal owl can also uses other natural cavities for nesting (Bondrup-Nielson, 1978). Because cavities are generally rare in Eastern Canadian boreal forests, nesting cavities have been identified as another limiting factor for boreal owl populations in Canada (Kirk, 1995). Johnsgard (1988) and Desrosiers and Bombardier (1995) emphasized the importance of protecting old and senescent stands used by *Picidae*, which in turn are crucial for secondary cavity users such as the boreal owl. Indeed, mature and old stands have been found to be preferred for nesting sites (Hayward and Hayward, 1993). When natural cavities are scarce, the boreal owl readily accepts nesting boxes (Korpimäki, 1981; Hayward *et al.*, 1993). In Finland, artificial breeding cavities have played an important part in maintaining populations of secondary cavity users such as the boreal owl (Imbeau *et al.*, 2001). In the "Côte-Nord" region also (Northern shore of the St-Lawrence estuary east of the Saguenay river in Quebec), the boreal owl is known to use nesting boxes (Buidin and Rochepault, 2002). Several tree species can be selected for nesting (aspen, pine and spruce), but data from central Canada have shown a marked preference for aspen *(Populus tremuloides)* (Bondrup-Nielsen, 1978). Natural cavities in aspen (*Populus tremula*) are also frequently used in Finland (Korpimäki, 1981). Artificial and natural cavities are rarely used for more than one breeding season, possibly to avoid nest predation (Löfgren *et al*., 1986; Sonerud, 1985) ; however, a pair can breed in the same nest for two consecutive years when food is abundant (Korpimäki, 1993). The boreal owl tends to stay within the same breeding area when other cavities are available (Wallin and Andersson, 1981; Hayward *et al*., 1993).

In Northeastern Minnesota, territorial males select older upland mixed forests stands and avoid open brush and regenerative stands (Lane *et al*., 2001). In the Rocky Mountains, in a study by Hayward *et al.* (1993), mature mixed-conifer and aspen stands with multi-layered canopy and open understory were chosen for nesting habitat while pure pine stands (*Pinus contorta*) were avoided. In the "Côte-Nord" region of Quebec, sites used for nesting are balsam fir (*Abies balsamea*) and black spruce (*Picea mariana*) or balsam fir and white birch (*Betula papyrifera*) stands (Rochepault and Buidin, unpublished data). In Finland, the boreal owl favours spruce forests as breeding habitat and selects breeding site less than 200 m from open areas (Korpimäki, 1981). When there are suitable cavities (natural or artificial), the boreal owl can nest in or close to open areas such as clear-cuts, edges of bogs or lakes (Korpimäki, 1981; Sonerud, 1986). This is probably linked to low availability of suitable cavities in the forested areas that are generally preferred by the species. The presence of clear-cut areas in boreal owl territories can increase breeding success. In a Finnish study by Hakkarainen *et al*. (1996), owl pairs produced more fledging in territories with high (>30 %) proportions of clear-cut and plantation areas. The authors argued that this results could be related to prey availability, as larger clear-cuts areas sustained higher prey densities than smaller ones in the study area.

3.4 Habitat area requirements

Annual habitat area requirements vary between males and females due to different wintering strategies (Korpimäki, 1989). Male owls are site tenacious while females are nomadic except during periods of high prey availability (Löfgren *et al*., 1986; Korpimäki, 1993). Male boreal owls are resident even during periods of low small mammal availability because they rely more readily on small passerine birds (Korpimäki, 1981; Korpimäki, 1989). This strategy reduces intraspecific competition for food during winter when food is less available; it can also be a competitive advantage for nesting cavities in favour of resident males versus migratory males (usually juveniles) (Lunberg, 1979; Korpimäki, 1989).

In Idaho, Hayward *et al*. (1993) reported annual home ranges for the male boreal owl varying between 814 and 6876 ha. Even though home ranges of several males can overlap, the male defends the territory close to the nest (males mostly call within 100-150 m of their cavity) (Hayward and Hayward, 1993; Hayward *et al*., 1993). Distance between mean centers of activity among neighbouring males varies between 840 m in winter and 1450 m in summer (Hayward *et al*., 1993). The minimum distance reported between nests is comprised between 100 and 500 m (Hayward and Hayward, 1993). In a study by Boutin *et al.* (1995) in the Yukon, the number of pairs of boreal owl ranged from 0.08 to 0.45 per 100 ha over a 5-year period. This range is close to the 0.08 to 0.33 pairs per 100 ha range observed in Finland over a 14-year period study done by Korpimäki (1981).

Individuals can travel several kilometers during nocturnal foraging bouts (Hayward and Hayward, 1993). Distance between consecutive daytime roosts varies from 1540 m in winter and 934 m in summer (Hayward *et al*., 1993).

3. HABITAT SUITABILITY INDEX (HSI) MODEL

3.1 Model assumptions

The following HSI model was developed specifically for Management District 15 in Western Newfoundland. Because there is a lack data for the boreal owl in Newfoundland, the HSI was based on the best scientific literature available (see sections 1 and 2 of the present report) and on the existing HSI models (Knox, 1994; Heinrich *et al.*, 1999). The model is based on the assumption that nesting and foraging habitats are the most important limiting factors for the boreal owl (Kirk, 1995). We did not include a roosting component in the model (as Heinrich *et al*. (1999) did) as nothing in the literature review indicates that it was limiting. Because the amount of foraging habitat in the vicinity of the nesting habitat appears to have a strong pull on the reproductive success (Hakkarainen *et al.*, 1996), our model spatially links the reproductive and foraging habitats and allows partial compensation between these two components (see Van Horne and Wiens 1991 for complete explanations on HSI functions).

3.2 Model equations

This Habitat Suitability Index for the boreal owl (HSI) assessed the nesting and the foraging habitats conjointly using spatially explicit relationships. It is a raster-based model that has been developed in Arc GIS with a Visual Basic.Net user interface (Rudy and Doyon, in prep.). The base unit is a 25 m x 25 m pixel derived form the forest inventory coverage (DFRA forest inventory data). For each pixel, the value of HSI is calculated based on the information included in the DFRA forest inventory database. The mean of the information comprised in all pixels within a certain radius around the center of this pixel (neighborhood statistic technique). We chose a radius of 1784 m, which corresponds to a "neighborhood window" of 1000 ha (Equation 1). This value is based on home range requirements of the boreal owl during the breeding season (Hayward and Hayward, 1993); it also reflects a breeding pair density of 0.001 pair/ha as measured by Boutin *et al.* (1995), Korpimäki (1981) and Bondrup-Nielsen (1978). For each pixel, the HSI model is formulated as follows:

Equation 1: $$\mathbf{HSI = Window\ (HSI_{local})_{1784\,m}}$$

For each pixel, HSI_{local} is calculated as follows:

Equation 2: $$\mathbf{HSI_{local} = [NESTING * FORAGING]^{1/2}}$$

where NESTING and FORAGING are the nesting habitat and the foraging habitat components respectively. This formula allows partial compensation between nesting and foraging habitat (Van Horne and Wiens 1991). Therefore, even with a bad nesting habitat, the overall habitat suitability can be partially compensated if foraging habitat is good.

3.2.1 NESTING

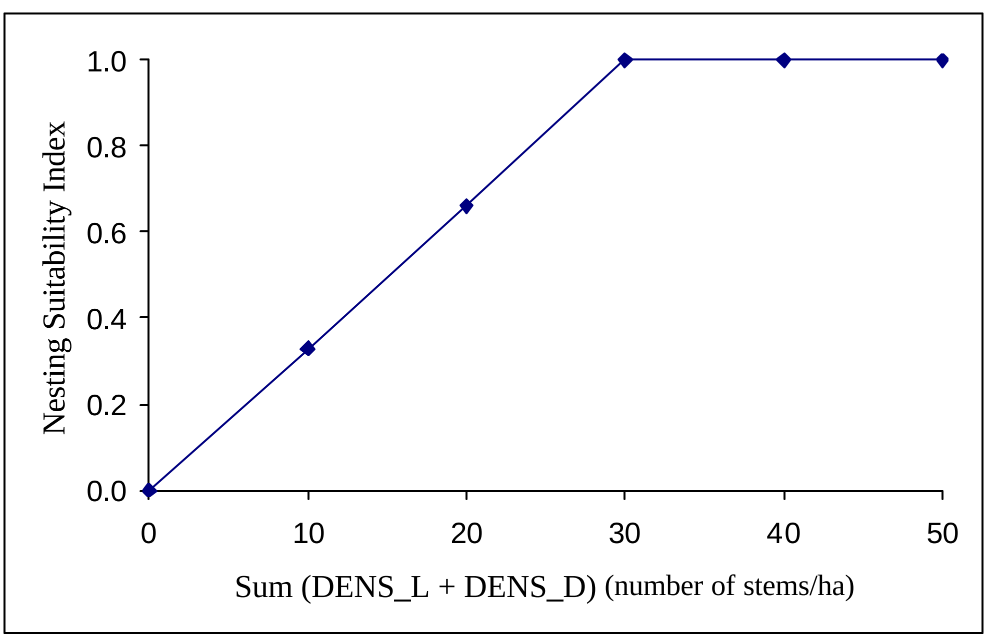
The NESTING component of the HSI represents the breeding habitat quality, which is mainly associated with the abundance of large stems apt to support nesting cavities. Hence, for each pixel, the density of large trees was used to calculate a value for the NESTING component. Live and dead stems with a DBH superior or equal to 30 cm were considered as trees enough large to support nesting cavities. The NESTING component of the model is thus calculated as follows:

Equation 3: **NESTING = [Sum (DENS_L + DENS_D)]**

where:

- DENS_L represents the mean density of live stems with a DBH superior or equal to 30 cm
- DENS_D represents the mean density of dead stems with a DBH superior or equal to 30 cm

The relationship between the value of the NESTING component of the HSI and the density of large trees is shown in Figure 1 and was based on Heinrich *et al*. (1999). Such relationship will need to be empirically tested in the field for



validation.

Figure 1. NESTING suitability index value as a function of density of large trees.

In order to predict the amount of large live and dead trees according to stand parameters that are used in the forest inventory and that will be generated by the harvest scheduler, we build a Special Habitat Element model (SHE). This SHE model uses stand- and site-characteristics that influence large trees density. We use the following variables: species composition, site class, crown density and stand age.

The live large trees (LLT) and dead large trees (DLT) SHE models have been developed using the permanent sample plots (PSPs) and the temporary sample plots (TSPs). In the first place, we calculated the overall mean of the density of large trees (DBH>= 30 cm) for all plots (n=661). This mean was 23.02 trees/ha for live trees and 2.74 trees/ha for dead trees (Table 1). Then, we calculated the mean density of large trees for each class of each variable (species composition= 7 classes, site=4 classes, density=3 classes, and age= 4 classes) used in the SHE model (Table 1). To compute the variable class modifier, we divided the class mean by the overall mean (Table 2).

Table 1. Density of live and dead large (DBH>=30cm) trees by variable classes.

Variable	Live	Dead
Overall	23.018	2.744

Composition	Live	Dead
bF	24.435	2.177
bFhW	41.905	6.905
bFxS	8.140	1.163
hW	20.833	0.000
hWbF	29.412	5.882
xS	3.333	0.000
xSbF	1.974	0.000
Site	Live	Dead
G	36.364	3.896
H	58.750	12.500
M	15.689	1.760
P	2.734	0.781

Density	Live	Dead
1	8.516	1.374
2	24.232	2.796
3	30.046	3.670
Age	Live	Dead
2	8.594	0.000
3	14.474	0.837
4	29.363	4.717
5	27.463	3.079

Table 2. Variable class modifier for the density of live and dead large trees Special Habitat Element model.

Composition	Live	Dead
bF	1.061568	0.793548
bFhW	1.820498	2.516403
bFxS	0.353612	0.423773
hW	0.905077	0.000000
hWbF	1.277756	2.143791
xS	0.144812	0.000000
xSbF	0.085744	0.000000
Site	Live	Dead
G	1.579772	1.419914
H	2.552318	4.555556
M	0.681595	0.641251
P	0.118791	0.284722

Density	Live	Dead
1	0.369988	0.500610
2	1.052748	1.019006
3	1.305304	1.337411
Age	Live	Dead
2	0.373344	0.000000
3	0.628790	0.305157
4	1.275647	1.719078
5	1.193097	1.122058

Thus, for each pixel, the mean density of large trees is equal to the global mean of the density of large trees (23.02 tress/ha for live trees and 2.74 for dead trees) multiplied by the four modifiers that correspond to the four variables listed above (Equation 4 and 5). This weighting procedure is performed separately for dead and live trees. Such model involves no interaction among variable. A statistical procedure using ANOVA could be used to determine significant classes on density. This has not been performed with this model.

Equation 4: $DENS\_L = [MSPCOMP_{Li} * MSITE_{Li} * MDENS_{Li} * MAGE_{Li}) * 23.02]$

Equation 5: $DENS\_D = [MSPCOMP_{Di} * MSITE_{Di} * MDENS_{Di} * MAGE_{Di}) * 2.74]$

where :

$MSCOMP_L$ is the species composition modifier, obtained by dividing the mean density of large live stems of each composition class i (bF, bFhW, bFx[1]S, hW, hWbF, xS, xSbF; see Appendix 1) by the global mean density of large live stems (Table 2)

$MSITE_L$ is the site class modifier, obtained by dividing the mean density of large live stems of each site class i (H, G, M, P; see Appendix 1) by the global mean density of large live stems (Table 2)

$MDENS_L$ is the crown density modifier, obtained by dividing the mean density of large live stems of each density class i (1, 2, 3; see Appendix 1) by the global mean density of large live stems (Table 2)

$MAGE_L$ is the age modifier, obtained by dividing the mean density of large live stems of each age class i (2, 3, 4, 5; see Appendix 1) by the global mean density of large live stems (Table 2)

$MSCOMP_D$ is the species composition modifier, obtained by dividing the mean density of large dead stems of each composition class i (bF, bFhW, bFx[2]S, hW, hWbF, xS, xSbF; see Appendix 1) by the global mean density of large live stems (Table 2)

$MSITE_D$ is the site class modifier, obtained by dividing the mean density of large dead stems of each site class i (H, G, M, P; see Appendix 1) by the global mean density of large live stems (Table 2)

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[1] The letter « x » means any species of the gender. For example, xS means white spruce as well as black spruce. See appendix 1.
[2] The letter « x » means any species of the gender. For example, xS means white spruce as well as black spruce

$MDENS_D$ is the crown density modifier, obtained by dividing the mean density of large dead stems of each density class i (1, 2, 3; see Appendix 1) by the global mean density of large live stems (Table 2)

$MAGE_D$ is the age modifier, obtained by dividing the mean density of large dead stems of each age class i (2, 3, 4, 5; see Appendix 1) by the global mean density of large live stems (Table 2)

All possible combinations of the four variables result in 336 different values for the NESTING component of the HSI (see Appendix 2). A map of the NESTING values for District 15 is found in Appendix 3.

3.2.2 FORAGING

The FORAGING component represents the habitat quality for foraging. In this model, good foraging quality is associated with openings and distance to forest edge. Openings (wetlands, recent natural disturbances, barren-grounds, recent clear-cuts…) are important foraging habitat as the availability of small rodents and their vulnerability to the boreal owl are optimal during the breeding and nesting period (Korpimäki, 1981; Hayward *et al.*, 1993; Whitman, 2001). In regards to the edge effect, we made the assumption that the boreal owl is reluctant to use foraging habitat too far from the forest cover.

To compute the FORAGING suitability index values, we first give a COVER suitability value to each pixel in regards to its stand density (**Figure 2**). For this function, the more open, the better the hunting is. Openings get a value of 1 and water bodies a value of 0. Each pixel is given a value (COVER) corresponding to its cover density (Figure 2, Appendices 4 and 5).

Density of insect damaged stand should adjusted before processing the HSI model in order to take in account the mortality effect of outbreak on stand density. For example, a stand of dennsity1 that has been damaged by insects should have its density reduced to 2 or 1 according to the importance of the damage.

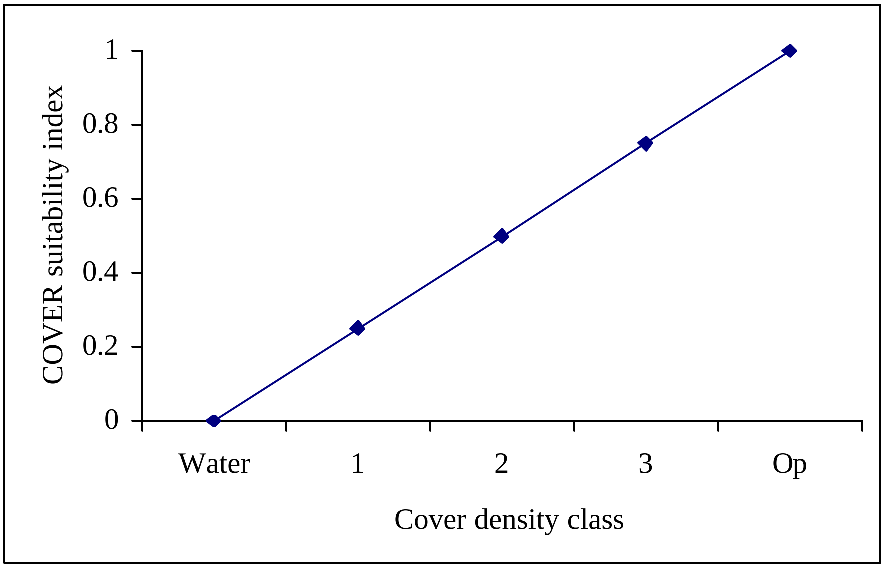

Figure 2. COVER values for the cover density classes.

Where:

Water : water bodies

1: forested habitat with a density of 1

2: forested habitat with a density of 2

3: forested habitat with a density of 3

Op: Openings softwood scrub, stand remnant, cut area (< 5 years old), hardwood scrub, bog, wet bog, rock barren, soil barren, sand, cleared land, right-of-ways, agricultural land

Then, each COVER value is modified in regards to its distance to forest edge. To model such effect, we made the assumption that the boreal owl will hunt within 100 m of a forest cover edge without any perceived risk but will be more and more reluctant to hunt as the distance beyond 100 m increases. This is represented by the DIST suitability index value that is maintained to 1 between 0 and 100 m and then is reduced linearly to 0 as the distance to the nearest forest edge increases and reaches 200 m, beyond which the value stays at 0 (**Figure 3**). The 200 m threshold is based on Korpimäki (1981) findings (see section 2.3). A forest cover is a stand with a density value of 1,2 or 3.

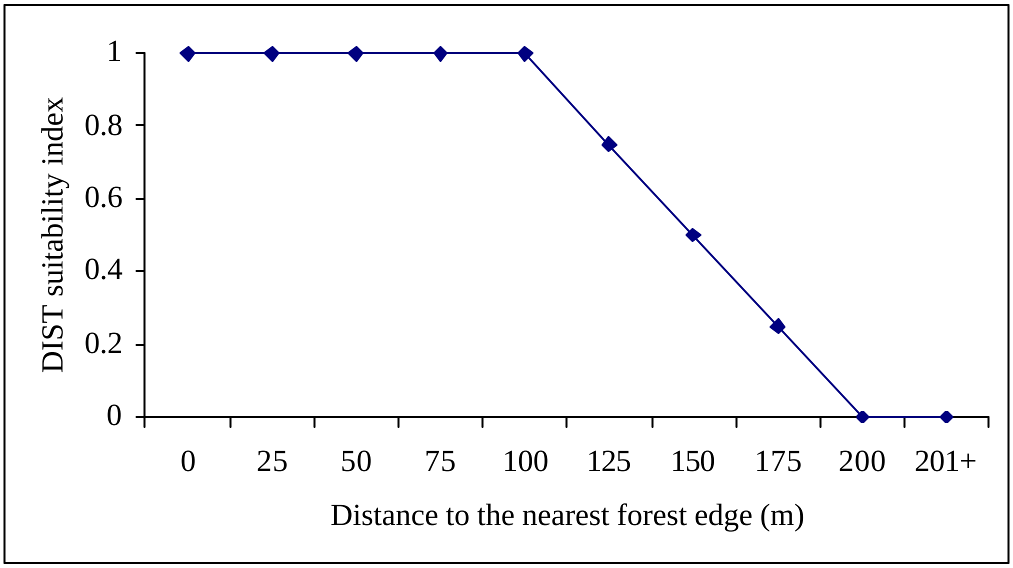

Figure 3. DIST suitability index value as a function of the distance to the nearest forest edge.

This distance-adjusted foraging cover (DAFH) value is therefore calculated by multiplying the COVER value by the DIST value (Equation 6)

Equation 6: **DAFH = COVER*DIST**

A breeding pair will make up its territory where sufficient foraging habitat is available. In order to identify where concentrations of good foraging habitat are, we summed the DAFH values within a 500 m-radius (Equation 7). The 500-m radius was used because it represents the minimum size of a territory sufficient to support a breeding pair. This allows us to give the territory-adjusted foraging habitat (TAFH).

Equation 7: **TAFH = Window (DAFH)** $_{\mathbf{SUM\ 500\ m}}$

We then standardized the TAFH value obtained between 0 and 1 to get a FORAGING suitability index. Standardization has been done with the Equation 8:

Equation 8: **FORAGING = (TAFH value-TAFH Minimum) / (TAFH Maximum-TAFH Minimum)**

In District 15, the TAFH Minimum was 0 and the TAFH maximum was 1257. Therefore, the standardization equation was then

Equation 9: **FORAGING = TAFH / 1257**

Maps of COVER and DIST values are found in Appendices 5 and 6. See also the maps of territory-adjusted foraging habitat (TAFH) values (Appendix 7), FORAGING values (Appendix 8) and HSI_{local} values (Appendix 9).

3.3 RESULTS AND DISCUSSION

In general, the home-range-smoothed habitat suitability index values for the boreal owl are rather high in District 15 according to our model (Figure 5), however, local HSI shows how each pixel contributes to the home-range-smoothed habitat suitability index (appendix 9) and allows to identify particular hot and cold spots. One should consider however the HSI values more as a relative comparison among different forest conditions in the assessed area. It therefore shows only where optimal and unsuitable habitat conditions occur in the landscape according to assumptions includes in the model; it does not show the habitat enough good or too bad to support a breeding pair. Until once empirical data are available to validate the model, it is not recommended to suppose a linear relationship between population level and HSI values. However, for the aim of comparing different landscapes (spatially or temporally distinct), we are quite confident that this HSI is a valuable tool for telling apart better management options. For example, it appears clear with this analysis that certain areas of District 15, such as Governors Pond, between Serpentine and Georges Lakes, and between Georges and Grand Lakes, seem to be more suituable for the boreal owl than others (north of Humber Arm and northeast of Deer Lake).

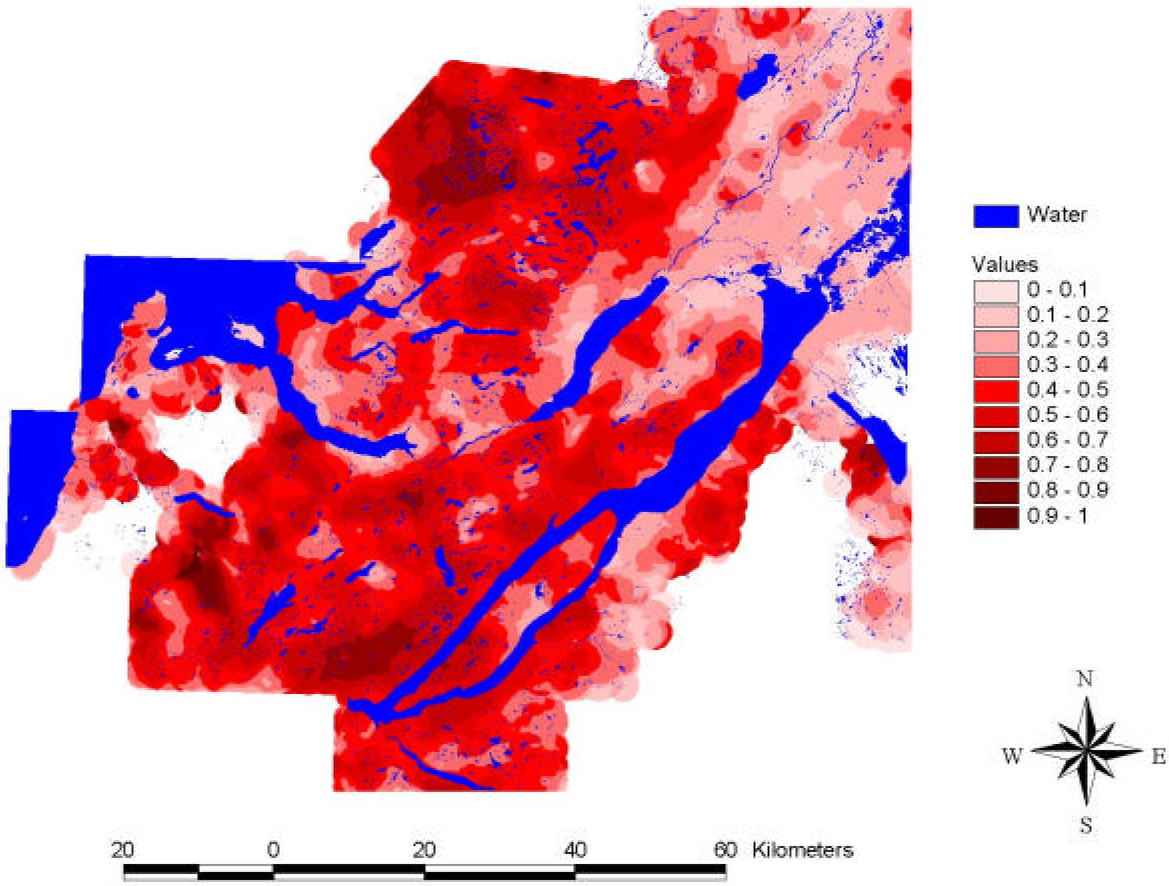

Figure 4. Map of the home-range-smoothed HSI values for the boreal owl in District 15, Nfld, where 0.0 means least suitable and 1.0 most suitable**.**

3.4 EXAMPLES OF FOREST MANAGEMENT RECOMMENDATIONS

Based on the literature review, a forest management strategy that would consider boreal owl habitat quality would include two management practices:

1) At the stand level, being a secondary-cavity user, the boreal owl is highly dependant on large primary excavators (northern flickers, pileated woodpeckers). Maintaining large (>30 cm) trees (dead and alive) after harvesting in green patches through variable retention treatment would probably be highly beneficial to primary and secondary cavity users. Partial, and even catastrophic, hemlock

looper and spruce budworm outbreak disturbances usually maintain a density of large (>30 cm) trees that meet the threshold of 30/ha (Jardon and Doyon, in preparation). If the WNMF wants to emulate patterns created by natural disturbances in its forest practices, variable retention should therefore seriously considered.

2) At the landscape level, the boreal owl will benefit from the adjacency of small opening to forest stands. Such information leads us to recommend, in order to increase the quality of the habitat of the boreal owl, to maintain the mean cutblock size rather small (< 10 ha) and adjacent to old (>60 years) stands that serve as nesting habitat. Cutblock size could be increased if its shape allows a greater perimeter/area ratio (more elongated). An empirical study demonstrating the reluctance to cross openings as a function of gap distance between forest cover would help in designing optimal cutblock shape.

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Appendix 1. Terminology for components of NESTING.

- MSCOMP

bF: balsam fir
bFhW: balsam fir and harwood
bFxS: balsam fir and spruce
hW: hardwood
hWbF: hardwood and balsam fir
xS: Sitka spruce, White spruce, Black spruce or Engelmann Spruce
xSbF: spruce and balsam fir

- MSITE

H: high
G: good
M: medium
P: poor

- MDENS

1: over 75% of crown closure
2: 51-75% of crown closure
3: 26-50% of crown closure

- MAGE

2: 21 - 40 years
3: 41 - 60 years
4: 61 - 80 years
5: 81 – + years

Appendix 2. NESTING values for the 336 possible combinations of the DENS components (MSPCOMP X MSITE X MDENS X MAGE).

COMBINATION	DENS_L	DENS_D	? ?DENS	NESTING
bFxGx1x2	5.33	0.00	5.33	0.18
bFxGx1x3	8.98	0.47	9.45	0.32
bFxGx1x4	18.22	2.66	20.88	0.70
bFxGx1x5	17.04	1.74	18.78	0.63
bFxGx2x2	15.17	0.00	15.17	0.51
bFxGx2x3	25.55	0.96	26.51	0.88
bFxGx2x4	51.84	5.42	57.26	1.00
bFxGx2x5	48.49	3.54	52.02	1.00
bFxGx3x2	18.81	0.00	18.81	0.63
bFxGx3x3	31.68	1.26	32.95	1.00
bFxGx3x4	64.28	7.11	71.39	1.00
bFxGx3x5	60.12	4.64	64.76	1.00
bFxHx1x2	8.61	0.00	8.61	0.29
bFxHx1x3	14.51	1.52	16.02	0.53
bFxHx1x4	29.44	8.54	37.97	1.00
bFxHx1x5	27.53	5.57	33.10	1.00
bFxHx2x2	24.51	0.00	24.51	0.82
bFxHx2x3	41.28	3.08	44.37	1.00
bFxHx2x4	83.75	17.38	101.13	1.00
bFxHx2x5	78.33	11.34	89.68	1.00
bFxHx3x2	30.39	0.00	30.39	1.00
bFxHx3x3	51.19	4.05	55.24	1.00
bFxHx3x4	103.85	22.81	126.65	1.00
bFxHx3x5	97.13	14.89	112.01	1.00
bFxMx1x2	2.30	0.00	2.30	0.08
bFxMx1x3	3.87	0.21	4.09	0.14
bFxMx1x4	7.86	1.20	9.06	0.30
bFxMx1x5	7.35	0.78	8.14	0.27
bFxMx2x2	6.55	0.00	6.55	0.22
bFxMx2x3	11.02	0.43	11.46	0.38
bFxMx2x4	22.37	2.45	24.81	0.83
bFxMx2x5	20.92	1.60	22.52	0.75
bFxMx3x2	8.12	0.00	8.12	0.27
bFxMx3x3	13.67	0.57	14.24	0.47
bFxMx3x4	27.73	3.21	30.94	1.00
bFxMx3x5	25.94	2.10	28.03	0.93
bFxPx1x2	0.40	0.00	0.40	0.01
bFxPx1x3	0.68	0.09	0.77	0.03
bFxPx1x4	1.37	0.53	1.90	0.06
bFxPx1x5	1.28	0.35	1.63	0.05
bFxPx2x2	1.14	0.00	1.14	0.04
bFxPx2x3	1.92	0.19	2.11	0.07

bFxPx2x4	3.90	1.09	4.98	0.17
bFxPx2x5	3.65	0.71	4.35	0.15
bFxPx3x2	1.41	0.00	1.41	0.05
bFxPx3x3	2.38	0.25	2.64	0.09
bFxPx3x4	4.83	1.43	6.26	0.21
bFxPx3x5	4.52	0.93	5.45	0.18
bFhWxGx1x2	9.14	0.00	9.14	0.30
bFhWxGx1x3	15.40	1.50	16.90	0.56
bFhWxGx1x4	31.24	8.44	39.68	1.00
bFhWxGx1x5	29.22	5.51	34.73	1.00
bFhWxGx2x2	26.02	0.00	26.02	0.87
bFhWxGx2x3	43.82	3.05	46.87	1.00
bFhWxGx2x4	88.90	17.17	106.08	1.00
bFhWxGx2x5	83.15	11.21	94.36	1.00
bFhWxGx3x2	32.26	0.00	32.26	1.00
bFhWxGx3x3	54.33	4.00	58.34	1.00
bFhWxGx3x4	110.23	22.54	132.77	1.00
bFhWxGx3x5	103.10	14.71	117.81	1.00
bFhWxHx1x2	14.77	0.00	14.77	0.49
bFhWxHx1x3	24.88	4.81	29.69	0.99
bFhWxHx1x4	50.48	27.07	77.55	1.00
bFhWxHx1x5	47.21	17.67	64.88	1.00
bFhWxHx2x2	42.04	0.00	42.04	1.00
bFhWxHx2x3	70.80	9.78	80.58	1.00
bFhWxHx2x4	143.63	55.10	198.73	1.00
bFhWxHx2x5	134.34	35.97	170.30	1.00
bFhWxHx3x2	52.12	0.00	52.12	1.00
bFhWxHx3x3	87.78	12.84	100.62	1.00
bFhWxHx3x4	178.09	72.32	250.41	1.00
bFhWxHx3x5	166.57	47.20	213.77	1.00
bFhWxMx1x2	3.95	0.00	3.95	0.13
bFhWxMx1x3	6.64	0.68	7.32	0.24
bFhWxMx1x4	13.48	3.81	17.29	0.58
bFhWxMx1x5	12.61	2.49	15.10	0.50
bFhWxMx2x2	11.23	0.00	11.23	0.37
bFhWxMx2x3	18.91	1.38	20.28	0.68
bFhWxMx2x4	38.36	7.76	46.11	1.00
bFhWxMx2x5	35.87	5.06	40.94	1.00
bFhWxMx3x2	13.92	0.00	13.92	0.46
bFhWxMx3x3	23.44	1.81	25.25	0.84
bFhWxMx3x4	47.56	10.18	57.74	1.00
bFhWxMx3x5	44.48	6.64	51.13	1.00
bFhWxPx1x2	0.69	0.00	0.69	0.02
bFhWxPx1x3	1.16	0.30	1.46	0.05
bFhWxPx1x4	2.35	1.69	4.04	0.13
bFhWxPx1x5	2.20	1.10	3.30	0.11
bFhWxPx2x2	1.96	0.00	1.96	0.07
bFhWxPx2x3	3.30	0.61	3.91	0.13
bFhWxPx2x4	6.69	3.44	10.13	0.34

bFhWxPx2x5	6.25	2.25	8.50	0.28
bFhWxPx3x2	2.43	0.00	2.43	0.08
bFhWxPx3x3	4.09	0.80	4.89	0.16
bFhWxPx3x4	8.29	4.52	12.81	0.43
bFhWxPx3x5	7.75	2.95	10.70	0.36
bFxSxGx1x2	1.78	0.00	1.78	0.06
bFxSxGx1x3	2.99	0.25	3.24	0.11
bFxSxGx1x4	6.07	1.42	7.49	0.25
bFxSxGx1x5	5.68	0.93	6.60	0.22
bFxSxGx2x2	5.05	0.00	5.05	0.17
bFxSxGx2x3	8.51	0.51	9.03	0.30
bFxSxGx2x4	17.27	2.89	20.16	0.67
bFxSxGx2x5	16.15	1.89	18.04	0.60
bFxSxGx3x2	6.27	0.00	6.27	0.21
bFxSxGx3x3	10.55	0.67	11.23	0.37
bFxSxGx3x4	21.41	3.80	25.21	0.84
bFxSxGx3x5	20.03	2.48	22.50	0.75
bFxSxHx1x2	2.87	0.00	2.87	0.10
bFxSxHx1x3	4.83	0.81	5.64	0.19
bFxSxHx1x4	9.81	4.56	14.36	0.48
bFxSxHx1x5	9.17	2.98	12.15	0.40
bFxSxHx2x2	8.17	0.00	8.17	0.27
bFxSxHx2x3	13.75	1.65	15.40	0.51
bFxSxHx2x4	27.90	9.28	37.18	1.00
bFxSxHx2x5	26.09	6.06	32.15	1.00
bFxSxHx3x2	10.12	0.00	10.12	0.34
bFxSxHx3x3	17.05	2.16	19.21	0.64
bFxSxHx3x4	34.59	12.18	46.77	1.00
bFxSxHx3x5	32.35	7.95	40.30	1.00
bFxSxMx1x2	0.77	0.00	0.77	0.03
bFxSxMx1x3	1.29	0.11	1.40	0.05
bFxSxMx1x4	2.62	0.64	3.26	0.11
bFxSxMx1x5	2.45	0.42	2.87	0.10
bFxSxMx2x2	2.18	0.00	2.18	0.07
bFxSxMx2x3	3.67	0.23	3.90	0.13
bFxSxMx2x4	7.45	1.31	8.76	0.29
bFxSxMx2x5	6.97	0.85	7.82	0.26
bFxSxMx3x2	2.70	0.00	2.70	0.09
bFxSxMx3x3	4.55	0.30	4.86	0.16
bFxSxMx3x4	9.24	1.71	10.95	0.37
bFxSxMx3x5	8.64	1.12	9.76	0.33
bFxSxPx1x2	0.13	0.00	0.13	0.00
bFxSxPx1x3	0.22	0.05	0.28	0.01
bFxSxPx1x4	0.46	0.28	0.74	0.02
bFxSxPx1x5	0.43	0.19	0.61	0.02
bFxSxPx2x2	0.38	0.00	0.38	0.01
bFxSxPx2x3	0.64	0.10	0.74	0.02
bFxSxPx2x4	1.30	0.58	1.88	0.06
bFxSxPx2x5	1.21	0.38	1.59	0.05

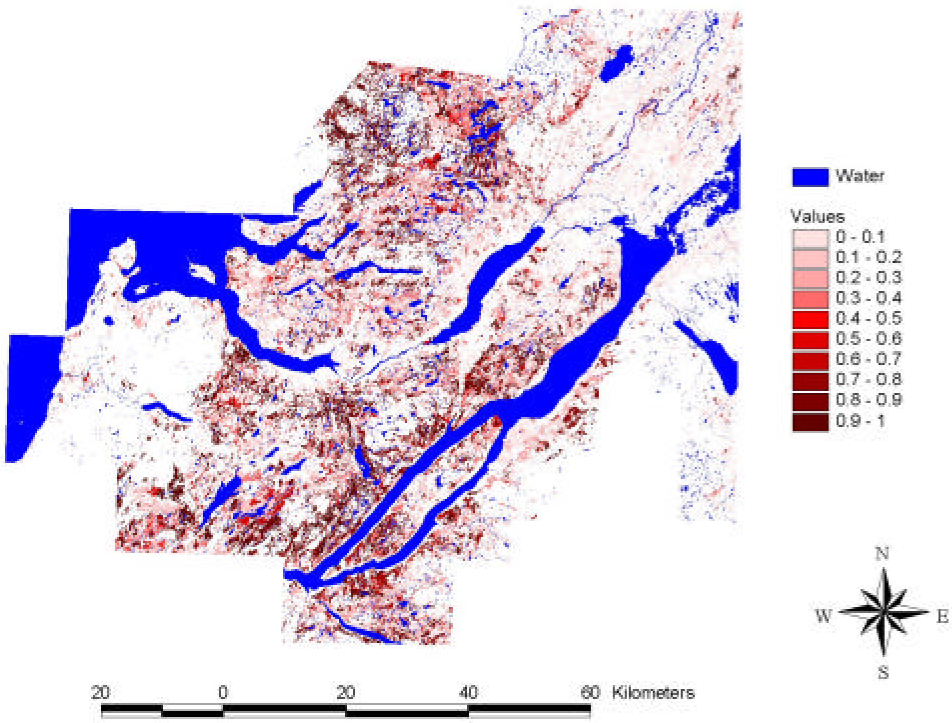
bFxSxPx3x2	0.47	0.00	0.47	0.02
bFxSxPx3x3	0.79	0.14	0.93	0.03
bFxSxPx3x4	1.61	0.76	2.37	0.08
bFxSxPx3x5	1.51	0.50	2.00	0.07
hWxGx1x2	4.55	0.00	4.55	0.15
hWxGx1x3	7.66	0.00	7.66	0.26
hWxGx1x4	15.53	0.00	15.53	0.52
hWxGx1x5	14.53	0.00	14.53	0.48
hWxGx2x2	12.94	0.00	12.94	0.43
hWxGx2x3	21.79	0.00	21.79	0.73
hWxGx2x4	44.20	0.00	44.20	1.00
hWxGx2x5	41.34	0.00	41.34	1.00
hWxGx3x2	16.04	0.00	16.04	0.53
hWxGx3x3	27.01	0.00	27.01	0.90
hWxGx3x4	54.80	0.00	54.80	1.00
hWxGx3x5	51.26	0.00	51.26	1.00
hWxHx1x2	7.34	0.00	7.34	0.24
hWxHx1x3	12.37	0.00	12.37	0.41
hWxHx1x4	25.10	0.00	25.10	0.84
hWxHx1x5	23.47	0.00	23.47	0.78
hWxHx2x2	20.90	0.00	20.90	0.70
hWxHx2x3	35.20	0.00	35.20	1.00
hWxHx2x4	71.41	0.00	71.41	1.00
hWxHx2x5	66.79	0.00	66.79	1.00
hWxHx3x2	25.91	0.00	25.91	0.86
hWxHx3x3	43.64	0.00	43.64	1.00
hWxHx3x4	88.54	0.00	88.54	1.00
hWxHx3x5	82.81	0.00	82.81	1.00
hWxMx1x2	1.96	0.00	1.96	0.07
hWxMx1x3	3.30	0.00	3.30	0.11
hWxMx1x4	6.70	0.00	6.70	0.22
hWxMx1x5	6.27	0.00	6.27	0.21
hWxMx2x2	5.58	0.00	5.58	0.19
hWxMx2x3	9.40	0.00	9.40	0.31
hWxMx2x4	19.07	0.00	19.07	0.64
hWxMx2x5	17.84	0.00	17.84	0.59
hWxMx3x2	6.92	0.00	6.92	0.23
hWxMx3x3	11.65	0.00	11.65	0.39
hWxMx3x4	23.64	0.00	23.64	0.79
hWxMx3x5	22.11	0.00	22.11	0.74
hWxPx1x2	0.34	0.00	0.34	0.01
hWxPx1x3	0.58	0.00	0.58	0.02
hWxPx1x4	1.17	0.00	1.17	0.04
hWxPx1x5	1.09	0.00	1.09	0.04
hWxPx2x2	0.97	0.00	0.97	0.03
hWxPx2x3	1.64	0.00	1.64	0.05
hWxPx2x4	3.32	0.00	3.32	0.11
hWxPx2x5	3.11	0.00	3.11	0.10
hWxPx3x2	1.21	0.00	1.21	0.04

hWxPx3x3	2.03	0.00	2.03	0.07
hWxPx3x4	4.12	0.00	4.12	0.14
hWxPx3x5	3.85	0.00	3.85	0.13
hWbFxGx1x2	6.42	0.00	6.42	0.21
hWbFxGx1x3	10.81	1.28	12.09	0.40
hWbFxGx1x4	21.93	7.19	29.12	0.97
hWbFxGx1x5	20.51	4.69	25.20	0.84
hWbFxGx2x2	18.26	0.00	18.26	0.61
hWbFxGx2x3	30.76	2.60	33.35	1.00
hWbFxGx2x4	62.40	14.63	77.03	1.00
hWbFxGx2x5	58.36	9.55	67.91	1.00
hWbFxGx3x2	22.64	0.00	22.64	0.75
hWbFxGx3x3	38.14	3.41	41.54	1.00
hWbFxGx3x4	77.37	19.20	96.57	1.00
hWbFxGx3x5	72.36	12.53	84.89	1.00
hWbFxHx1x2	10.37	0.00	10.37	0.35
hWbFxHx1x3	17.46	4.09	21.56	0.72
hWbFxHx1x4	35.43	23.06	58.49	1.00
hWbFxHx1x5	33.14	15.05	48.19	1.00
hWbFxHx2x2	29.50	0.00	29.50	0.98
hWbFxHx2x3	49.69	8.33	58.02	1.00
hWbFxHx2x4	100.81	46.94	147.75	1.00
hWbFxHx2x5	94.29	30.64	124.93	1.00
hWbFxHx3x2	36.58	0.00	36.58	1.00
hWbFxHx3x3	61.61	10.94	72.55	1.00
hWbFxHx3x4	125.00	61.61	186.61	1.00
hWbFxHx3x5	116.91	40.21	157.12	1.00
hWbFxMx1x2	2.77	0.00	2.77	0.09
hWbFxMx1x3	4.66	0.58	5.24	0.17
hWbFxMx1x4	9.46	3.25	12.71	0.42
hWbFxMx1x5	8.85	2.12	10.97	0.37
hWbFxMx2x2	7.88	0.00	7.88	0.26
hWbFxMx2x3	13.27	1.17	14.44	0.48
hWbFxMx2x4	26.92	6.61	33.53	1.00
hWbFxMx2x5	25.18	4.31	29.49	0.98
hWbFxMx3x2	9.77	0.00	9.77	0.33
hWbFxMx3x3	16.45	1.54	17.99	0.60
hWbFxMx3x4	33.38	8.67	42.05	1.00
hWbFxMx3x5	31.22	5.66	36.88	1.00
hWbFxPx1x2	0.48	0.00	0.48	0.02
hWbFxPx1x3	0.81	0.26	1.07	0.04
hWbFxPx1x4	1.65	1.44	3.09	0.10
hWbFxPx1x5	1.54	0.94	2.48	0.08
hWbFxPx2x2	1.37	0.00	1.37	0.05
hWbFxPx2x3	2.31	0.52	2.83	0.09
hWbFxPx2x4	4.69	2.93	7.63	0.25
hWbFxPx2x5	4.39	1.91	6.30	0.21
hWbFxPx3x2	1.70	0.00	1.70	0.06
hWbFxPx3x3	2.87	0.68	3.55	0.12

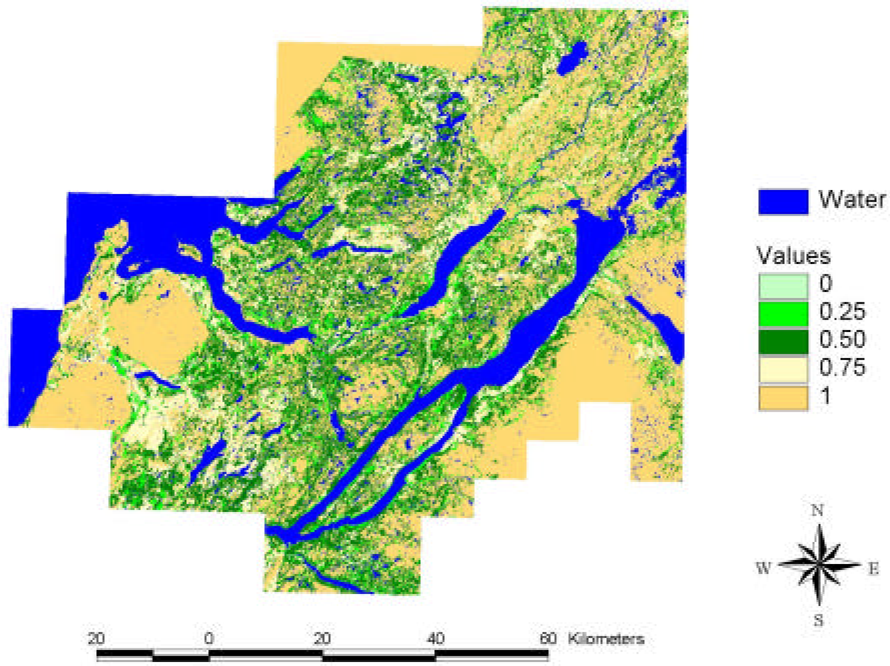
hWbFxPx3x4	5.82	3.85	9.67	0.32
hWbFxPx3x5	5.44	2.51	7.95	0.27
xSxGx1x2	0.73	0.00	0.73	0.02
xSxGx1x3	1.23	0.00	1.23	0.04
xSxGx1x4	2.49	0.00	2.49	0.08
xSxGx1x5	2.32	0.00	2.32	0.08
xSxGx2x2	2.07	0.00	2.07	0.07
xSxGx2x3	3.49	0.00	3.49	0.12
xSxGx2x4	7.07	0.00	7.07	0.24
xSxGx2x5	6.61	0.00	6.61	0.22
xSxGx3x2	2.57	0.00	2.57	0.09
xSxGx3x3	4.32	0.00	4.32	0.14
xSxGx3x4	8.77	0.00	8.77	0.29
xSxGx3x5	8.20	0.00	8.20	0.27
xSxHx1x2	1.18	0.00	1.18	0.04
xSxHx1x3	1.98	0.00	1.98	0.07
xSxHx1x4	4.02	0.00	4.02	0.13
xSxHx1x5	3.76	0.00	3.76	0.13
xSxHx2x2	3.34	0.00	3.34	0.11
xSxHx2x3	5.63	0.00	5.63	0.19
xSxHx2x4	11.43	0.00	11.43	0.38
xSxHx2x5	10.69	0.00	10.69	0.36
xSxHx3x2	4.15	0.00	4.15	0.14
xSxHx3x3	6.98	0.00	6.98	0.23
xSxHx3x4	14.17	0.00	14.17	0.47
xSxHx3x5	13.25	0.00	13.25	0.44
xSxMx1x2	0.31	0.00	0.31	0.01
xSxMx1x3	0.53	0.00	0.53	0.02
xSxMx1x4	1.07	0.00	1.07	0.04
xSxMx1x5	1.00	0.00	1.00	0.03
xSxMx2x2	0.89	0.00	0.89	0.03
xSxMx2x3	1.50	0.00	1.50	0.05
xSxMx2x4	3.05	0.00	3.05	0.10
xSxMx2x5	2.85	0.00	2.85	0.10
xSxMx3x2	1.11	0.00	1.11	0.04
xSxMx3x3	1.86	0.00	1.86	0.06
xSxMx3x4	3.78	0.00	3.78	0.13
xSxMx3x5	3.54	0.00	3.54	0.12
xSxPx1x2	0.05	0.00	0.05	0.00
xSxPx1x3	0.09	0.00	0.09	0.00
xSxPx1x4	0.19	0.00	0.19	0.01
xSxPx1x5	0.17	0.00	0.17	0.01
xSxPx2x2	0.16	0.00	0.16	0.01
xSxPx2x3	0.26	0.00	0.26	0.01
xSxPx2x4	0.53	0.00	0.53	0.02
xSxPx2x5	0.50	0.00	0.50	0.02
xSxPx3x2	0.19	0.00	0.19	0.01
xSxPx3x3	0.32	0.00	0.32	0.01
xSxPx3x4	0.66	0.00	0.66	0.02

xSxPx3x5	0.62	0.00	0.62	0.02
xSbFxGx1x2	0.43	0.00	0.43	0.01
xSbFxGx1x3	0.73	0.00	0.73	0.02
xSbFxGx1x4	1.47	0.00	1.47	0.05
xSbFxGx1x5	1.38	0.00	1.38	0.05
xSbFxGx2x2	1.23	0.00	1.23	0.04
xSbFxGx2x3	2.06	0.00	2.06	0.07
xSbFxGx2x4	4.19	0.00	4.19	0.14
xSbFxGx2x5	3.92	0.00	3.92	0.13
xSbFxGx3x2	1.52	0.00	1.52	0.05
xSbFxGx3x3	2.56	0.00	2.56	0.09
xSbFxGx3x4	5.19	0.00	5.19	0.17
xSbFxGx3x5	4.86	0.00	4.86	0.16
xSbFxHx1x2	0.70	0.00	0.70	0.02
xSbFxHx1x3	1.17	0.00	1.17	0.04
xSbFxHx1x4	2.38	0.00	2.38	0.08
xSbFxHx1x5	2.22	0.00	2.22	0.07
xSbFxHx2x2	1.98	0.00	1.98	0.07
xSbFxHx2x3	3.33	0.00	3.33	0.11
xSbFxHx2x4	6.76	0.00	6.76	0.23
xSbFxHx2x5	6.33	0.00	6.33	0.21
xSbFxHx3x2	2.45	0.00	2.45	0.08
xSbFxHx3x3	4.13	0.00	4.13	0.14
xSbFxHx3x4	8.39	0.00	8.39	0.28
xSbFxHx3x5	7.85	0.00	7.85	0.26
xSbFxMx1x2	0.19	0.00	0.19	0.01
xSbFxMx1x3	0.31	0.00	0.31	0.01
xSbFxMx1x4	0.63	0.00	0.63	0.02
xSbFxMx1x5	0.59	0.00	0.59	0.02
xSbFxMx2x2	0.53	0.00	0.53	0.02
xSbFxMx2x3	0.89	0.00	0.89	0.03
xSbFxMx2x4	1.81	0.00	1.81	0.06
xSbFxMx2x5	1.69	0.00	1.69	0.06
xSbFxMx3x2	0.66	0.00	0.66	0.02
xSbFxMx3x3	1.10	0.00	1.10	0.04
xSbFxMx3x4	2.24	0.00	2.24	0.07
xSbFxMx3x5	2.10	0.00	2.10	0.07
xSbFxPx1x2	0.03	0.00	0.03	0.00
xSbFxPx1x3	0.05	0.00	0.05	0.00
xSbFxPx1x4	0.11	0.00	0.11	0.00
xSbFxPx1x5	0.10	0.00	0.10	0.00
xSbFxPx2x2	0.09	0.00	0.09	0.00
xSbFxPx2x3	0.16	0.00	0.16	0.01
xSbFxPx2x4	0.31	0.00	0.31	0.01
xSbFxPx2x5	0.29	0.00	0.29	0.01
xSbFxPx3x2	0.11	0.00	0.11	0.00
xSbFxPx3x3	0.19	0.00	0.19	0.01
xSbFxPx3x4	0.39	0.00	0.39	0.01
xSbFxPx3x5	0.37	0.00	0.37	0.01

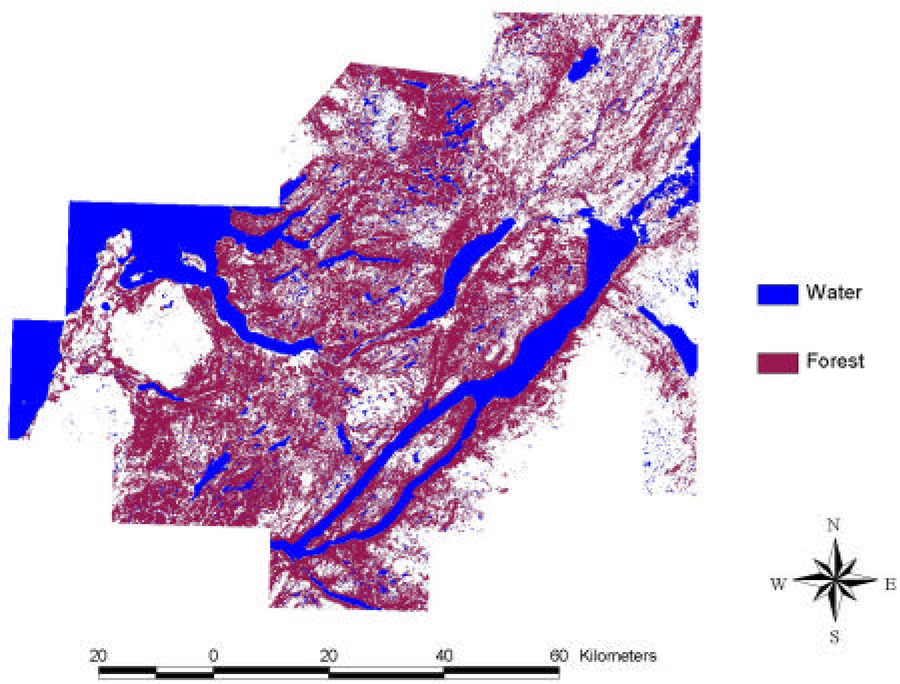
Appendix 3. Map of the NESTING suitability index values in District 15, Nfld, where 0.0 means least suitable and 1.0 most suitable



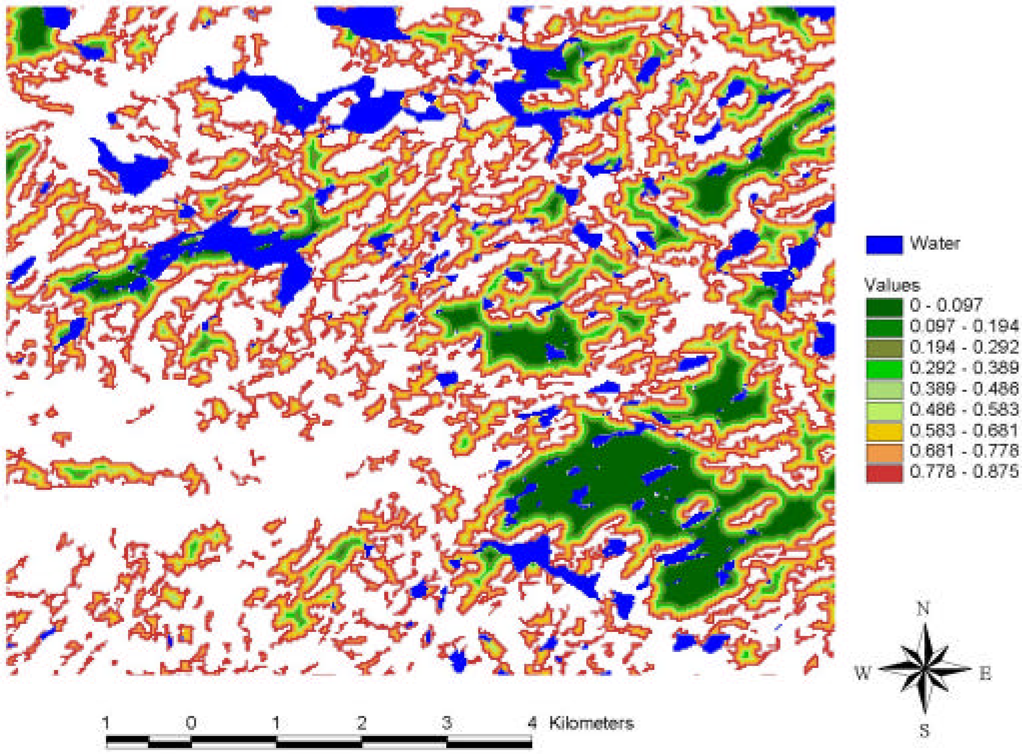
Appendix 4. Map of the COVER suitability index values in District 15, Nfld, where 0.0 means least suitable and 1.0 most suitable.



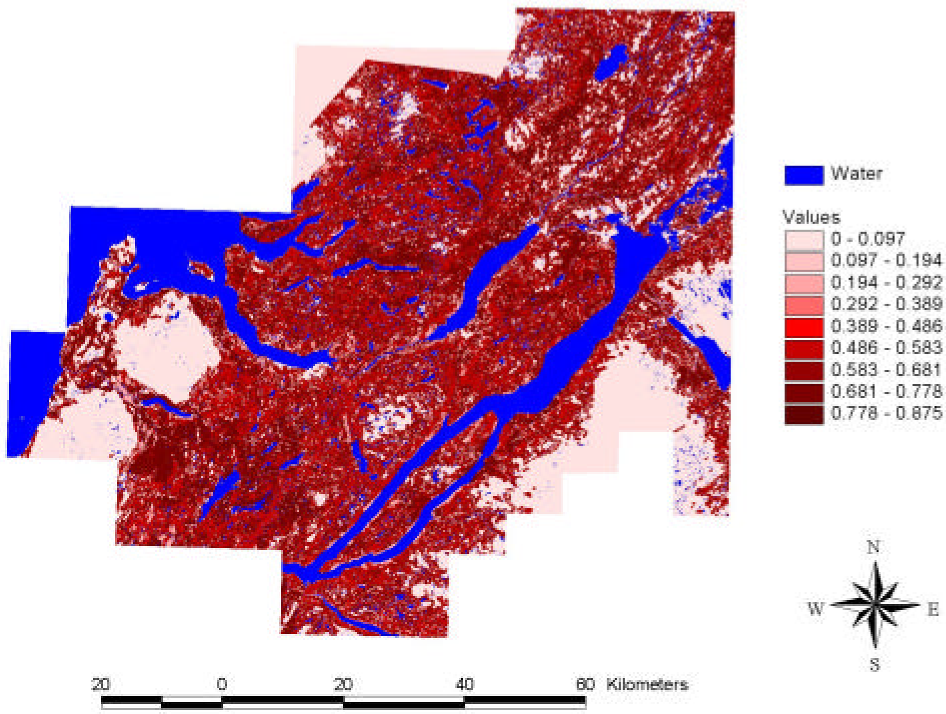
Appendix 5. Map of the forest cover in District 15, western Newfoundland..



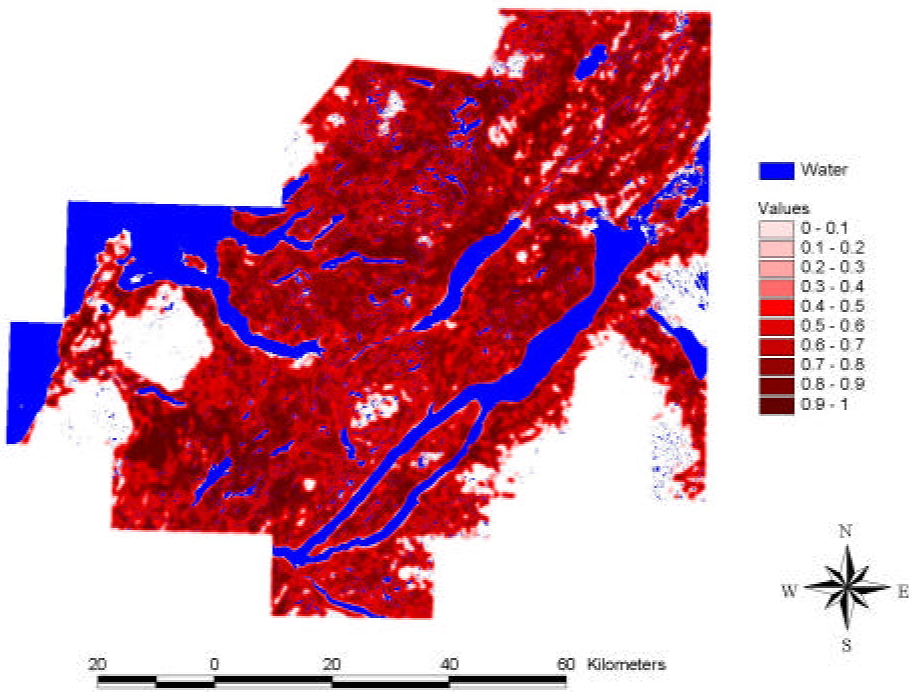
Appendix 6. Map of the DIST values in District 15, western Newfoundland..


Water
Values
0 - 0.097
0.097 - 0.194
0.194 - 0.292
0.292 - 0.389
0.389 - 0.486
0.486 - 0.583
0.583 - 0.681
0.681 - 0.778
0.778 - 0.875
1 0 1 2 3 4 Kilometers
N
W
E
S

Appendix 7. Map of territory adjusted foraging habitat (TAFH) values in District 15, western Newfoundland..



Appendix 8. Map of the FORAGING values in District 15, western Newfoundland..


Water
Values
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1
N
W
E
S
20
0
20
40
60
Kilometers

Appendix 9. Map of the HSI_{local} values in District 15, western Newfoundland..