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Spatially explicit habitat suitability model for the woodland caribou (Rangifer tarandus caribou) in Western Newfoundland

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SUMMARY

We developed a Habitat Suitability Index model for the woodland caribou (*Rangifer tarandus*) dwelling in the Western Newfoundland forest (Corner Brook Lakes herd, CBL herd). In the first place, this document presents a comprehensive literature review on the habitat requirements of the woodland caribou followed by the model *per se*. The literature review presents food, cover, reproduction, movement and habitat area requirements in order to identify critical conditions that relate to habitat selection, population health and productivity, especially for the CBL herd. Based on this information, a model has been developed. The model considers two critical habitats: calving and wintering. Calving habitat suitability is dependant on the availability of good calving habitat and predation risk. Calving habitat get more suitable as the age of a stand increase. Bogs and scrubland are also considered good calving habitat. The predation risk is considered using the amount of predator (bear and lynx) foraging habitat edge. In this model, the wintering habitat reflects the abundance of arboreal lichens of which woodland caribou rely on when the snow pack is too hard to dig through for reaching terrestrial lichens. The wintering habitat suitability index is computed using stand age, composition type and cover density. 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 woodland caribou habitat quality.

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1 DESCRIPTION, DISTRIBUTION AND CONSERVATION STATUS

The woodland caribou (*Rangifer tarandus caribou*), also known as reindeer in Eurasia, is a medium-sized ungulate belonging to the deer family (Cervidae). Female weights vary between 80 and 110 kg whereas male weights range from 118 to 205 kg (Godwin, 1990). Contrary to other deer family members native of Canada, such as moose (*Alces alces*) and white-tailed deer (*Odocoileus virginianeus*), both the male and the female may carry antlers, although male antlers are generally much larger.

As most other cervid species, the woodland caribou is a prey for large predators such as the wolf (*Canis lupus)* (Stuart-Smith *et al*., 1997; Schaefer *et al*., 1999; Courtois *et al*., unpublished data) and the black bear (*Ursus americanus)* (Crête and Desrosiers, 1993; Schaefer *et al*., 1999; Mahoney and Virgl, 2003). It can also be preyed on by a vast array of medium-sized predators. For instance coyote (*Canis latrans)* (Crête and Desrosiers, 1993), Canada lynx (*Lynx canadensis)* (Bergerud, 1971) and golden eagle (*Aquila chrysaetos)* (Crête and Desrosiers, 1993) are known to prey upon the caribou. In insular Newfoundland, wolves have been eradicated since 1911 (Bergerud, 1971) but coyotes have been present since 1985 (Larivière and Crête, 1992 *in* Mahoney *et al*., 2001). In most caribou populations, adult survival is generally high, with a survival rate of 0.84 in Alberta according to Rettie and Messier (1998), 0.88 in Alberta according to Stuart-Smith *et al*. (1997), 0.81-0.87 in Quebec (Courtois *et al*., unpublished data) and 0.87 in the Corner Brook Lakes (CBL) population (Mahoney and Virgl, 2003). Predation by medium-sized predators (such as black bear, coyote and lynx) is probably much more effective on calf survival (Crête and Desrosiers, 1993; Rettie and Messier, 1998; Mahoney and Virgl, 2003), particularly during their first month of life (Bergerud, 1971; Mahoney *et al*., 1990 *in* Mahoney and Virgl, 2003; Stuart-Smith *et al*., 1997). Indeed, in Newfoundland, black bear and lynx are major predators for caribou calves less than one-month-old (Mahoney *et al*., 1990).

In the absence of wolf, adult mortality results mostly from fighting during the rut for males and from aberrant births for females (Bergerud, 1971). Although predation is a major cause

of natural mortality, parasites can also cause caribou population to decline. *Elaphostrongylus rangiferi* (Protostrongylidae) was introduced in Newfoundland from infected reindeers in the early 1900's. The parasite was introduced to the Northern Peninsula in the early 1900's and crossed the island since then. *E. rangiferi* is present in all caribou herdson the island, including the Corner Brook Lakes herd, except for 2 small, isolated herds on the Avalon peninsula. This parasite, which causes a debilitating neurological disease (cerebrospinal elaphostrongylosis), has been known as responsible for a marked decline in the recently infected Avalon herd (Mahoney, 2000). Ball *et al*. (2001) suggested that the quick decline of the Avalon herd might result from the relatively recent arrival of this parasite on the peninsula, which is associated with a low immunity of caribou against it. Another lethal parasite for caribou, *Parelaphostrongylus tenuis*, has not yet been reported in Newfoundland but is suspected to have cause the caribou reintroduction in Nova Scotia to fail (Dauphiné, 1975).

Hunting is also a major cause of caribou mortality in some populations (Stuart-Smith *et al.*, 1997; Courtois *et al.*, unpublished data). Besides, other human-related causes of mortality (poaching, road accident) could be important in some regions (De Bellefeuille, 2001).

Woodland caribou are found from the Yukon to Newfoundland. They inhabit various types of habitats across their range distribution. The caribou is classified into four ecotypes according to its use of habitats: the mountain caribou inhabits mountainous regions of the boreal zone; the migratory barren-ground caribou inhabits the tundra where it generally accomplishes vast seasonal migrations; the insular caribou is restricted to arctic islands; and the more or less sedentary boreal woodland caribou is present across the boreal biome of Canada and lives in small herds (Mallory and Hillis, 1998 *in* De Bellefeuille, 2001). Both the boreal woodland and the migratory barren-ground ecotypes are found in Newfoundland (Bergerud, 1971). The Corner Brook Lakes herd is known as a non-migratory boreal woodland caribou population that is demographically isolated (Mahoney and Virgl, 2003). Other typical non-migratory boreal woodland caribou populations are found in Saskatchewan (Rettie and Messier, 1998), Alberta (Stuart-Smith *et al*. 1997) and Quebec (Courtois *et al.*, unpublished data). Group size among the herd varies according to the season: individuals generally travel alone (males) or with their calf (females) in spring and

summer, then form groups during the rutting period in autumn and remain in groups of fewer than 18 individuals until the end of winter (Stuart-Smith *et al*., 1997; Rettie and Messier, 1998; Courtois *et al*., unpublished data). In the CBL herd, females were observed to isolate themselves for calving and to form groups of 2-3 adults with calves for the remaining of the summer (Mahoney and Virgl, 2003), which appears typical of the spacing out strategy during calving (Rettie and Messier, 1998).

The woodland caribou has experienced a marked decline in the 1800's and early 1900's in most of its range distribution (Bergerud, 1974). Some suspected causes of decline are increased mortality from hunting and higher natural predation (Bergerud, 1971, 1974). However, although hunting has been limited in many areas, some populations still appear to be declining (Rettie and Messier, 1998). Therefore, according to many authors predation might still be an important limiting factor for woodland caribou populations (Bergerud, 1971; Crête and Desrosiers, 1993; Rettie and Messier, 1998; Stevenson, 2001, Mahoney and Virgl 2003). The Western population of mountain caribou in Southeastern British Columbia and the scattered boreal populations across Canada are currently considered as "threatened", whereas the relic herd of the Gaspé peninsula in Quebec is considered as "endangered" by the Committee on the status of endangered wildlife in Canada (COSEWIC, 2003). In Newfoundland, caribou populations have also declined in the 1900's (Bergerud, 1971), but the actual population is considered to be "not at Risk" (COSEWIC, 2003). Moreover, in Western Newfoundland, the CBL herd appears to be stable (Mahoney and Virgl, 2003). On account of the numerous precarious populations of woodland caribou across Canada, prudent and flexible management strategies (following the guidelines of adaptative management) should be implemented where timber harvesting is being planned in woodland caribou habitat (De Bellefeuille, 2001). The CBL herd is estimated to contain around 600 animals according to aerial surveys conducted between 1994 and 1997 (Mahoney and Virgl, 2003), whereas according to Bergerud (1971) the same herd is thought to have amounted to 1000 animals in the early 1900s.

2 HABITAT USE

2.1 Food requirements

The woodland caribou is known to rely in general mainly on terrestrial lichens (reindeer lichens, *Cladina* spp.), particularly during the winter period as it digs craters to reach lichens covered by the snow pack. In a study conducted in Newfoundland, Bergerud (1972) concluded that caribou do not have specialized food habits and are quite adaptable. The author found that caribou spring diet was composed mostly of sedges (*Scirpus cespitosus* and *Carex*) and growing green plants and that few lichens were consumed. The summer season diet was characterized by the variety of plant consumed; fungi, reindeer lichens and deciduous shrubs were the main items consumed. During the autumn, reindeer lichens and evergreen shrubs constitued the major part of the diet. The winter diet was composed primarily of evergreen shrubs and of arboreal lichens when foraging was limited by a deep or a crusted snow pack. Terrestrial and arboreal lichens appear to be consumed to an extent depending on their availability in the habitat (Bergerud, 1972). Recent data have shown that the CBL herd mainly feeds on terrestrial lichens (*Cladina*), but also consumes graminoids and herbs (*Carex*, *Rubus*, *Cornus*), deciduous shrubs (*Betula*, *Salix*), ericads (*Ledum*), conifers and evergreen plants (*Abies*, *Diapensia*) as well as arboreal lichens, particularly during winter (Mahoney, 2000). The quantity of quality forage does not appear to be a limiting factor for the CBL herd (Mahoney and Virgl, 2003).

2.2 Cover requirements and habitat selection

It is difficult to identify general habitat requirements as each local population has its specific needs (De Bellefeuille, 2001). Habitat requirements for woodland caribou seem to be mainly driven by the avoidance of predators and their alternative prey (Bergerud, 1985). Timber harvesting can lead to reduced foraging habitat, but the most pernicious effect appears to be the enhancement of alternative preys' and predators' habitats (Schwartz and Frantzmann, 1991). Caribou generally make seasonal habitat selection in order to avoid predators, deep snow or insect harassment and to find forage (*in* De Bellefeuille, 2001).

The CBL woodland caribou herd use a "spacing out" strategy to reduce predator encounter probability. According to Bergerud (1985), this strategy aims at reducing the prey density in order to make the territory less attractive to predator. To do so the woodland caribou scatter in marginal habitats where alternative preys are in low density (Bergerud, 1985).

Caribou of the CBL herd used rock and heath barrens and virgin and mature forest stands (over 80 years) more than expected during all seasons (Mahoney and Virgl, 2003). Even if those two habitats were preferred all year-round, rock and heath barrens were avoided twice as much during winter when compared to other seasons (Mahoney and Virgl, 2003). Alternatively, the selection for virgin forest stands appeared to be twice as high during winter as compared to other seasons (Mahoney and Virgl, 2003). Early climax stands (61-80 years old) were also used primarily during autumn and winter, whereas bog habitats were used during summer and autumn. On the other hand, recently clear-cut (0-20 years old), young (21-40 years-old) and secondary growth (41-60 years old) stands, dead trees and habitats with frequent human disturbances (agricultural fields, residential lands, roads) were avoided (Mahoney and Virgl, 2003). The woodland caribou herd of CBL also used ponds and lakes. Caribou in Alberta avoided harvested areas as winter habitat (Smith *et al.*, 2000). These authors suggested avoiding standard two-pass logging, which results in a highly fragmented landscape favourable to alternative prey and their predators. In the case where timber harvesting in the winter range of caribou could not be avoided, they recommended larger blocks in order to minimize edge effect and mimic large-scale natural disturbances (common in this region) that would provide future caribou habitat. In Quebec, caribou selected mature coniferous stands, lichen-rich sites and bogs (Courtois *et al.*, unpublished data). Although caribou seems to favour mature stands and avoid regenerating stands, little is known regarding its use of mid-seral stages (Fall *et al*., 2000).

2.3 Reproduction requirements

The reproductive rate of caribou is low compared to other cervids in North America. Females rarely give birth to twins and age at first reproduction is generally 28 months. The mortality rate of calves is high (Bergerud, 1971). Calf mortality usually occurs in the first few weeks of life (Rettie and Messier, 1998; Mahoney and Virgl, 2003). Rettie and Messier (1998) suggested that calf mortality from black bear predation could result from a spring

foraging habitat shared by the two species during a high vulnerability period for caribou calves (Schwartz and Franzmann, 1991; Bergerud, 1971).

Individuals generally form small groups and select open habitats during the rut. However, Stuart-Smith *et al*. (1997) found no aggregation fidelity to areas for calving, rutting or wintering, and Rettie and Messier (2001) did not observe precise calving site fidelity. Habitats used for calving by CBL females of caribou consisted mostly of early climax and mature forest stands (41-80 years; 75-80 % of calving). A few days after parturition, female-calf pairs reach the barren ground areas (Mahoney and Virgl, 2003).

2.4 Movement requirements

Linear developments such as roads, seismic lines and pipelines may act as barriers to the movements of caribou. In Northeastern Alberta, seismic lines were not barriers to caribou movements, whereas roads were avoided, particularly during the late winter period when daily traffic reached its maximum (Dyer *et al*., 2002). In a long term study (1981-1996) of the effect of timber harvesting on woodland caribou habitat use, Smith *et al*. (2000) found that daily movements of individuals and winter range sizes decreased as the amount of cutovers increased in the landscape. Recently fragmented areas were also avoided (Smith *et al*., 2000).

2.5 Habitat area requirements

The average home range size of an individual caribou in Corner Brook Lakes area is between 84.0 and 89.8 km^2, while the entire herd home range size covers about 1016 km^2 (Mahoney and Virgl, 2003). In other isolated woodland caribou populations, the individual annual home range sizes vary between 92 and 1834 km^2 (Rettie and Messier, 2001), whereas the herd annual home range sizes vary between 858 and 985 km^2 according to Smith *et al*. (2000) and could reach 10 000 to 15 000 km^2 according to Courtois *et al*. (unpublished data). Autumn and winter home ranges are larger than calving and summer ranges : approximately 110-460 km^2 versus 100-195 km^2 according to Stuart-Smith *et al*. (1997), about 105-425 km^2 vs. 30-95 km^2 (Rettie and Messier, 2001), about 40-43 km^2 vs. 17 km^2 (Mahoney and Virgl, 2003). In a study conducted in central Quebec, Courtois *et al*.

(unpublished data) showed that caribou modify their space use pattern in order to avoid fragmented areas. In the presence of a fragmented landscape, caribou increased their movements and their home ranges and decreased site fidelity to their home range. In East-central Newfoundland, woodland caribou are generally displaced by clear-cutting and use more frequently mature black-spruce forest stands during summer harvesting (Chubbs *et al*., 1993).

3 HABITAT SUITABILITY INDEX (HSI) MODELS

3.1 Model assumptions

The following HSI models were developed specifically for Management District 15 in Western Newfoundland. The HSI was based on the best scientific literature available (see sections 1 and 2 of the present report) and to reflect as most as possible the conditions that relates to the CBL woodland caribou herd. Existing woodland caribou HSI models were also consulted (Palidwor and Schindler 1995, Higgelke and Macleod 2000).

Two independent models were developed for the woodland caribou: $HSI_{calving}$ and $HSI_{wintering}$. The models are based on the assumption that calving and wintering habitats are the most important limiting factors for the woodland caribou and that these two factors do not spatially interact. This hypothesis of no spatial interaction between calving and wintering habitats was suggested by the relatively small area occupied by the CBL herd and by the ability of the woodland caribou to travel easily between its different seasonal habitats. All components are equally important and non-compensatory for $HSI_{calving}$, while components are compensatory for $HSI_{wintering}$ (see Van Horne and Wiens 1991 for complete explanations on HSI functions).

This Habitat Suitability Index (HSI) models for the woodland caribou assessed the calving and the wintering habitats using spatially explicit relationships. They are raster-based models that have 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 from 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.

3.2 Model equations

3.2.1 $HSI_{calving}$

The calving habitat model is based on 1) calving area selection and 2) predator avoidance during the calving period. Owing to the high susceptibility of caribou calves to predation during their first weeks of life (Bergerud, 1971), the amount of foraging habitat for predators in the vicinity of the calving habitat has been spatially linked to the quality of the calving habitat.

For each pixel, the value of $HSI_{calving}$ is calculated using 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 3241 m, which corresponds to a "neighborhood window" of 3300 ha. This value is based on home range requirements during the calving season (Mahoney and Virgl, 2003). For each pixel, the HSI model is formulated as follows:

Equation 1: $$\mathbf{HSI_{calving} = Window\ (HSI_{calving\_local})_{Mean\ 3241\ m}}$$

For each pixel, $HSI_{calving\_local}$ is calculated as follows:

Equation 2: $$\mathbf{HSI_{calving\_local} = [CALVING * EDGE\_PRED\_FOR]}$$

where CALVING is the calving habitat component and EDGE_PRED_FOR is the predator foraging habitat component. There is no compensation between these two habitat elements. Therefore, it means whatever good calving habitat a female woodland caribou is in, its quality will be linearly reduced by the cumulated risks of predation.

3.2.1.1 Calving

Calving habitat quality increases with stand age. The highest habitat quality is found in mature (over 80-year-old) forest stands as well as in specific habitats such as bogs and scrubs (Mahoney and Virgl, 2003) (Figure 1). Non-forested stands were assumed to have a null CALVING value, except for the bog- and scrub-types, which received the maximum CALVING value. See Appendix 1 for a map of CALVING values.

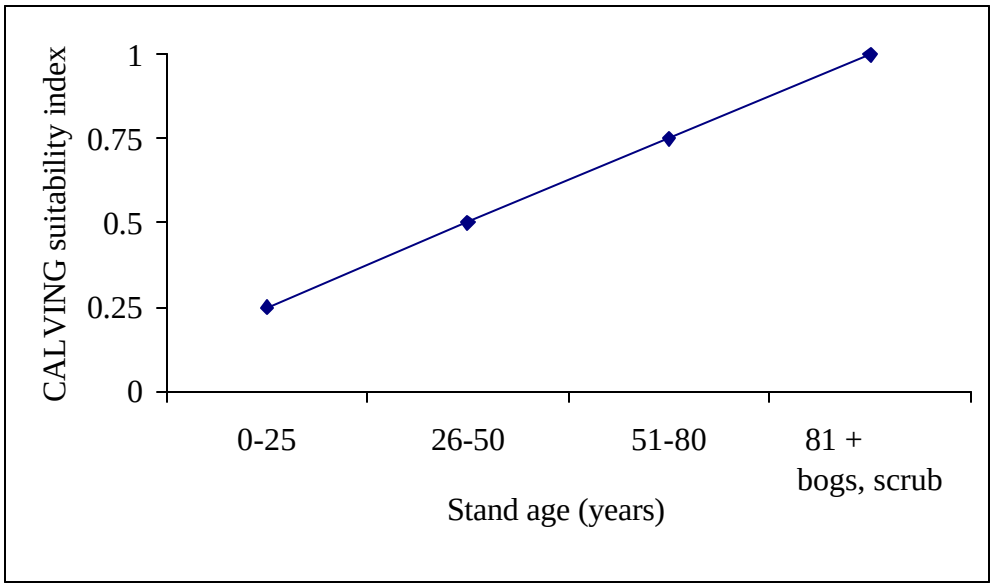

Figure 1. CALVING suitability index value as a function of stand age.

3.2.1.2 EDGE

The predator foraging habitat depends on the age of the cutovers and their vicinity to the calving habitat. In order to calculate such effect, the model first identifies habitats favourable to the predators of the caribou. Here we considered two major predators : the bear and the lynx. Young stands and recently disturbed areas are favourable to black bears because they provide abundant food sources (berries), and therefore the risk of being preyed upon is higher for caribou calves in this type of habitat (Schwartz and Franzmann, 1991). We assumed that, in Western Newfoundland, forest stands younger than 15-years-old were good foraging habitat for the black bear. Dense juvenile stands are favorable habitats for the lynx because they are rich in snowshoe hare, which constitutes its main prey (Canadian Wildlife Service, 2003). Thus we assumed that forest stands between 16 and 30 years-old and with a density of 2 or 3 were good foraging habitat for the lynx. Open stands, such as softwood scrub and hardwood scrub, were also considered as good predator foraging habitats.

The second step was to position 25 m-wide edges (one-pixel wide) around all habitats favourable to predator foraging habitat (EDGES in Equation 3). In a third step, the sum of pixels located within a 1500 m-radius from the centre of each pixel and being a predator

foraging habitat edge was determined. This number is the value of EDGE_PRED_FOR (Equation 3).

Equation 3: $\mathbf{EDGE\_PRED\_FOR = Window\ (EDGES)_{Sum\ 1500\ m}}$

where EDGES is the amount of edge around the predator foraging habitat.

In order to have the EDGE value to be comprised between 0 and 1, we then standardize the EDGE_PRED_FOR using the following standardization equation :

Equation 4: **EDGE = 1-(EDGE_PRED_FOR- EDGE_PRED_FOR Min) / (EDGE_PRED_FOR Max- EDGE_PRED_FOR Min)**

In District 15, once apply to the actual forest, the maximum value of EDGE_PRED_FOR is 3663 and the minimum was 0. Therefore, the standardization equation is then :

Equation 5: **EDGE = 1 – (EDGE_PRED_FOR / 3663)**

A high amount of edges corresponds to a fragmented landscape, which is detrimental for the woodland caribou (Courtois *et al*., unpublished data). Thus the EDGE value decreases with the amount of edges (Figure 2).

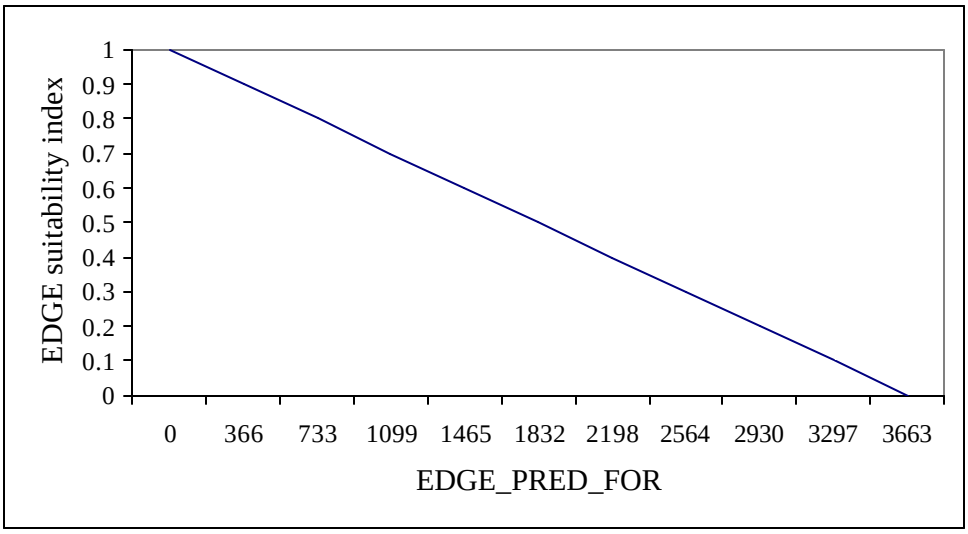

Figure 2. EDGE suitability index values as a function of EDGE_PRED_FOR values.

See the maps of edges (Appendix 2), EDGE values (Appendix 3), EDGE_PRED_FOR values (Appendix 4), HSI_{local} (Appendix 5). The map of the $HSI_{calving}$ is shown in Figure 3.

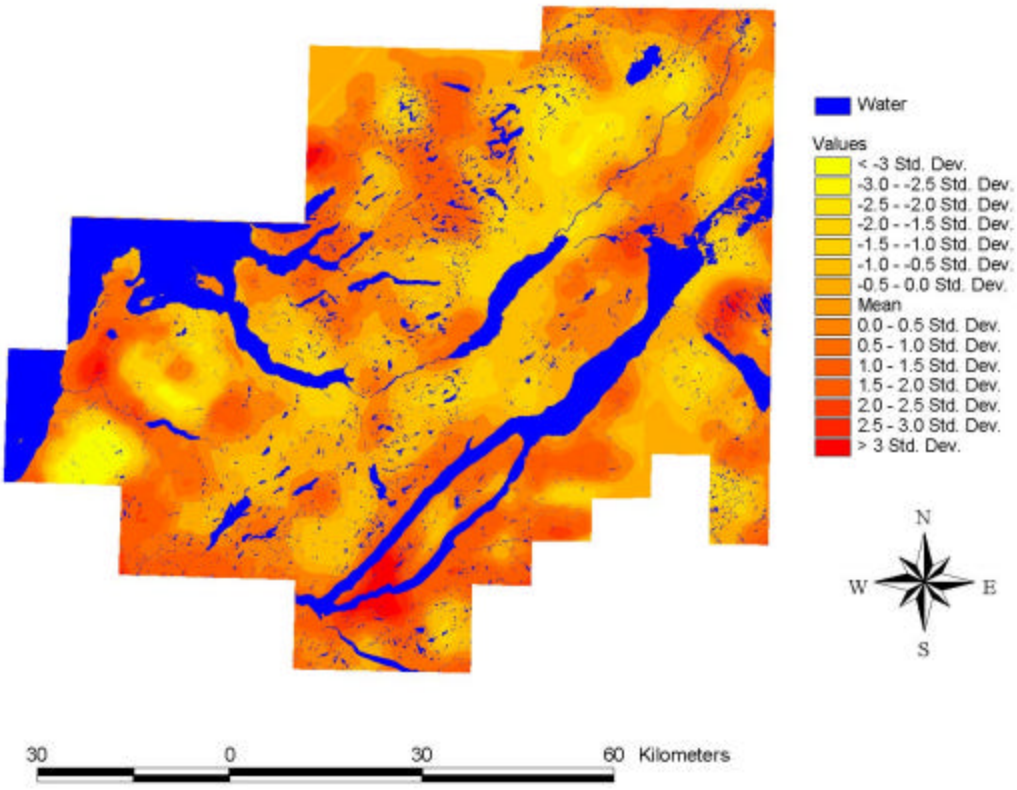

Figure 3. Map of the $HSI_{calving}$ in District 15, Nfld, where 0.0 means least suitable and 1.0 most suitable.

3.2.2 $HSI_{wintering}$

The winter habitat model is based on winter habitat selection by the caribou in order to satisfy its feeding requirements during a period of low food availability. In the period from January to March, when the snow pack is too thick or crusty to dig feeding crater and reach terrestrial lichens and plants, the woodland caribou seeks for mature forest cover with abundant arboreal lichens (Bergerud, 1972).

For each pixel, the value of $HSI_{wintering}$ is calculated using the mean of the information comprised in all pixels within a 3613 m-radius around the center of this pixel. This radius corresponds to a "neighborhood window" of 4100 ha and is based on home range

requirements during the winter season (Mahoney and Virgl, 2003). For each pixel, the HSI model is formulated as follows:

Equation 6: $\mathbf{HSI_{wintering} = Window\ (HSI_{wintering\_local})_{3613\,m}}$

For each pixel, $HSI_{wintering\_local}$ is calculated as follows:

Equation 7: $\mathbf{HSI_{wintering\_local} = AGE * COVER\_TYPE * COVER\_DENS}$

where:

- AGE is the age of the stand.;
- COVER_TYPE is the stand composition type (coniferous, mixed or deciduous);
- COVER_DENS is the cover density of the stand.

3.2.2.1 Age

Older stands support greater arboreal lichen biomass than young and regenerating stands. Lichen biomass accumulates over time and reaches a substantial amount in 60 year-old balsam fir stands (Arseneau *et al.*, 1998). Therefore, the value of the AGE component increases with stand age (Figure 4). See Appendix 6 for a map of AGE values.

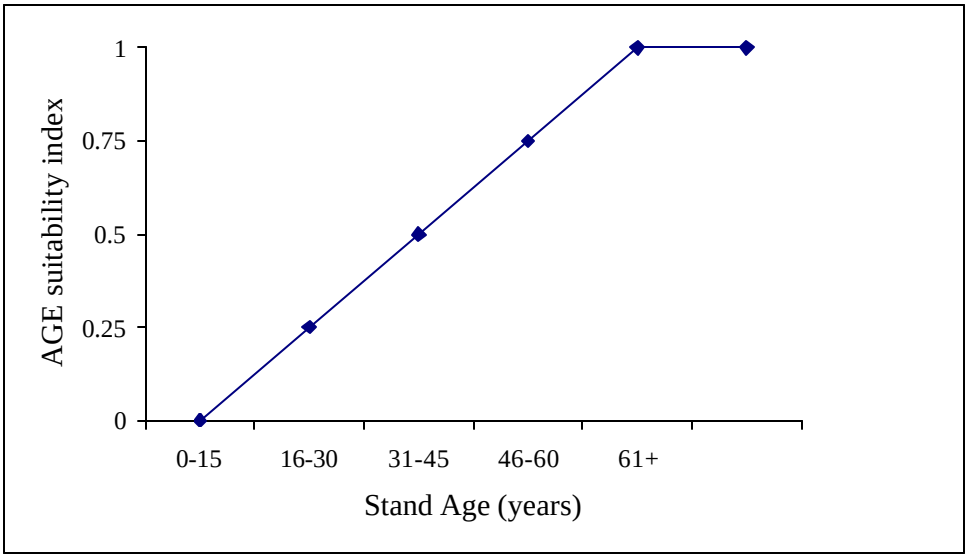

Figure 4. AGE suitability index values as a function of stand age classes.

3.2.2.2 Cover type

We assumed that coniferous stands support greater lichen biomass than deciduous stands because conifers provide a better substrate for colonization (less microclimatic fluctuations, more branches) (Figure 5). See Appendix 7 for a map of COVER_TYPE values.

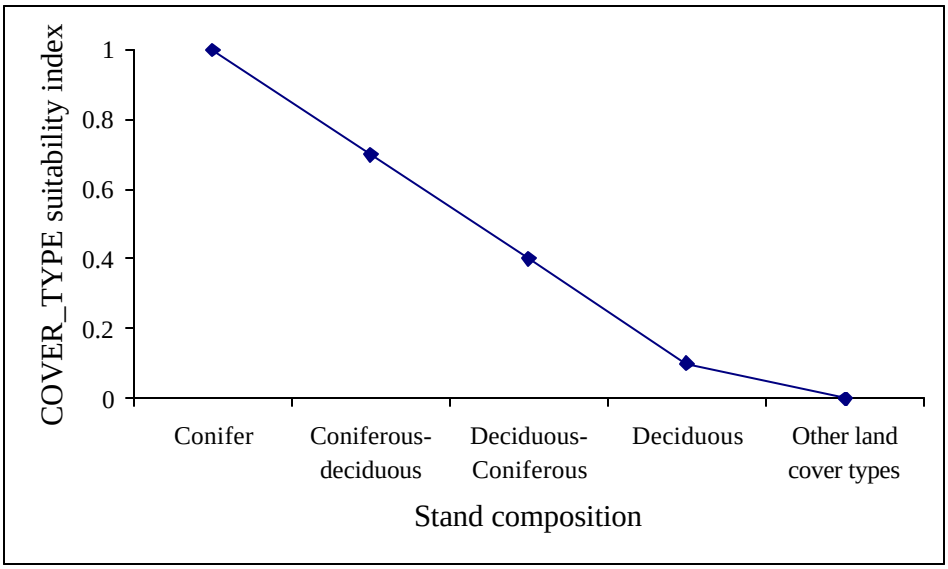

Figure 5. COVER_TYPE suitability index values as a function of stand composition types.

3.2.2.3 Cover density

We assumed that lichen biomass is more abundant in intermediate cover densities, where shade tolerant and intolerant lichen species are relatively abundant and where the occurrence of windthrows provides additional lichen supply (Dansereau, 1999) (Figure 6). See Appendix 8 for a map of COVER_DENS values.

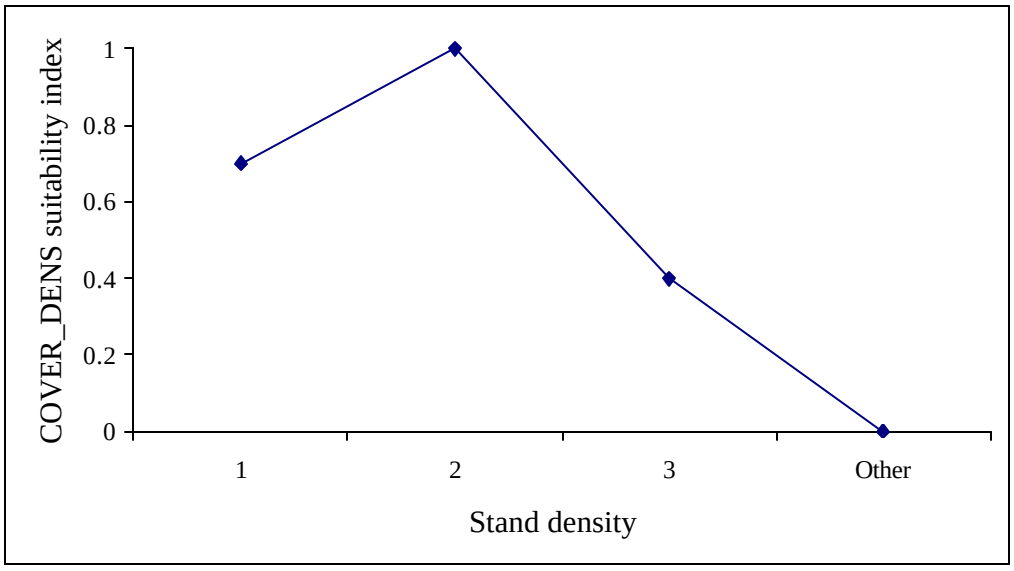

Figure 6. **COVER_DENS suitability index values as a function of stand density classes.**

See Appendix 9 for the map of HSI_{local} values. The map of the $HSI_{wintering}$ is shown in Figure 7.

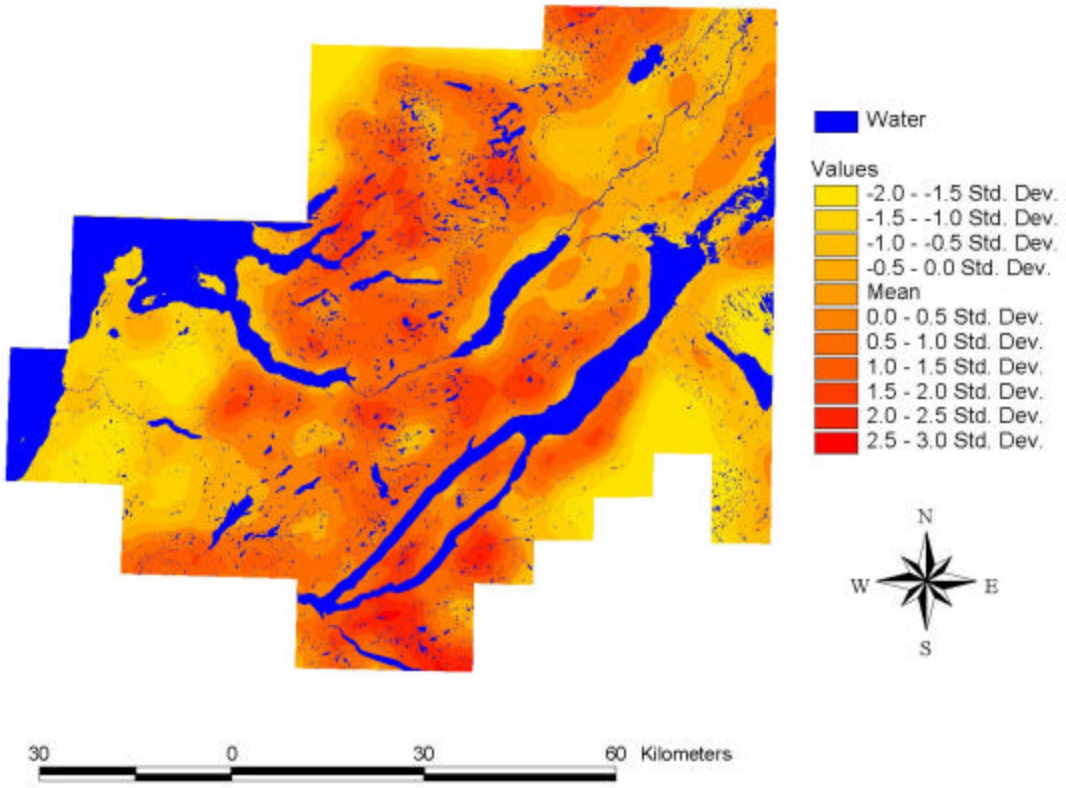

Figure 7. **Map of the $HSI_{wintering}$ in District 15, Nfld, where 0.0 means least suitable and 1.0 most suitable.**

3.3 Examples of forest management recommendations

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

1) At the stand level, as arboreal lichen biomass tend to start to increase at a certain age (40-50 years), increasing the rotation age would considerably increase the abundance of the arboreal lichen in the landscape. In fact, if we assume that the relationships between the arboreal lichen abundance and stand age follows a curve like showed in Figure 8, the abundance of the arboreal lichen in the landscape under a normalized forest will follow the distribution showed in Figure 9, according to the rotation age used when normalizing the forest.

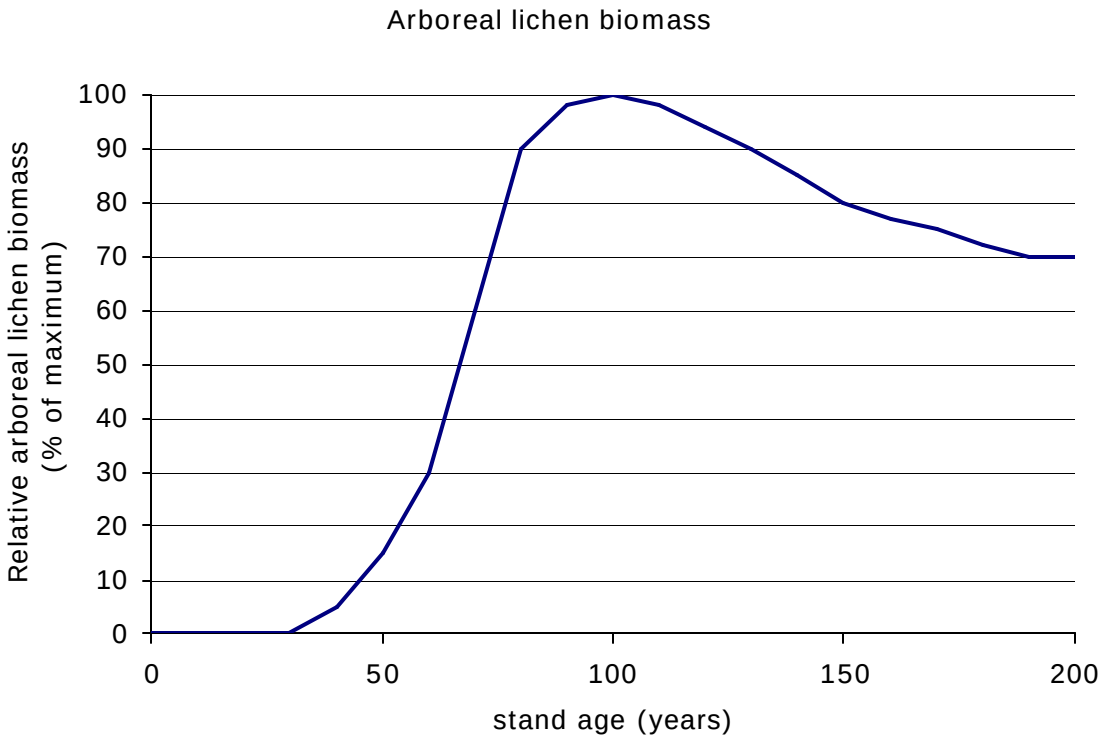

Figure 8. Theoretical relationship between arboreal lichen abundance and age at the stand level.

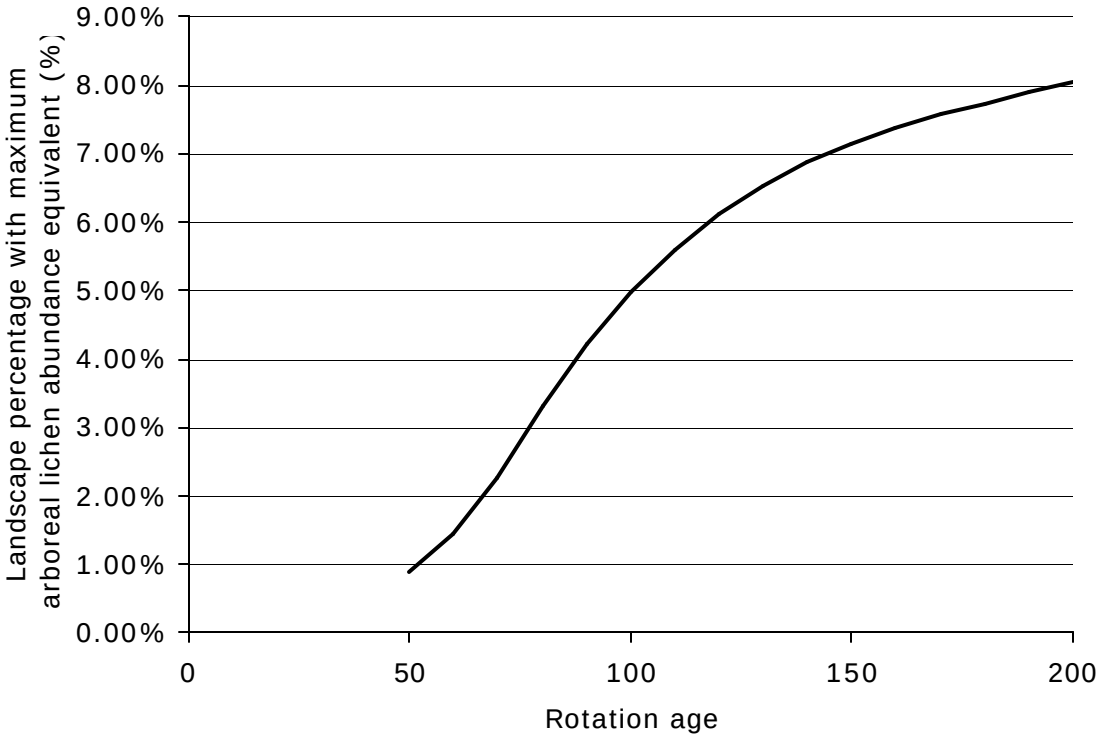

Figure 9. Abundance of arboreal lichen at the landscape level according to rotation age under a normalized forest

It appears clear that the arboreal lichen abundance in the landscape can easily be doubled even tripled with proportion of the landscape with longer rotation. For example, the abundance passes from 1.43% at rotation age 60 to 4.98% at rotation age 100.

2) At the landscape level, our model tells that the caribou will be highly sensitive to forest fragmentation because it allows predators to find there alternative food. Fragmentation provides stepping-stones into the interior woodland caribou good habitat for alternative preys and predators. At one threshold point of fragmentation, one can suppose that there is so much of these "stepping-stones" that all the woodland caribou good habitat is becoming reachable by the predators. This phenomenon in landscape ecology is called percolation threshold. A caribou-friendly forest management scenario would try to reduce the chance of getting beyond such percolation threshold of alternative predation and would maintain large area without fragmentation.

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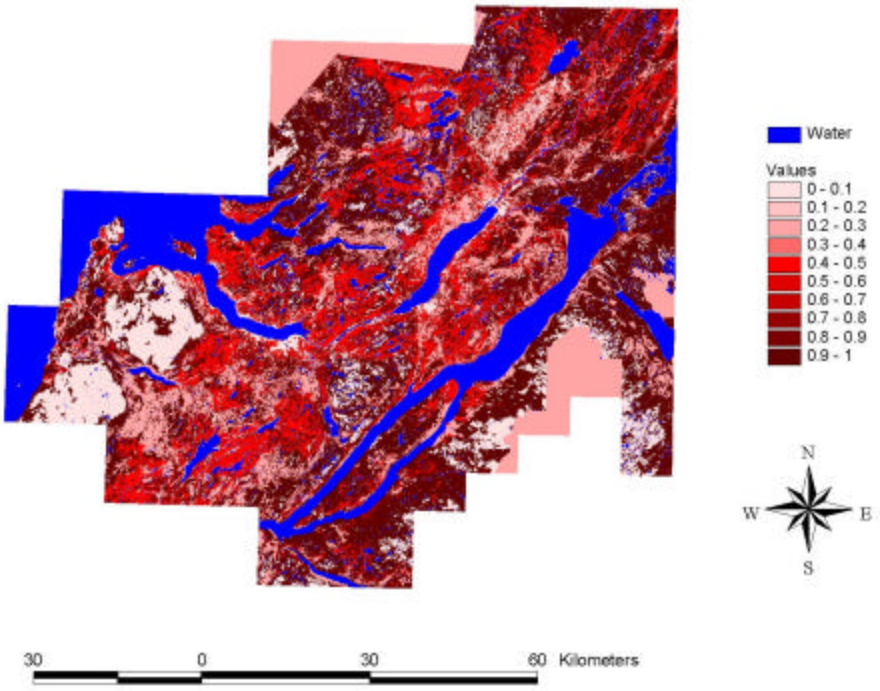
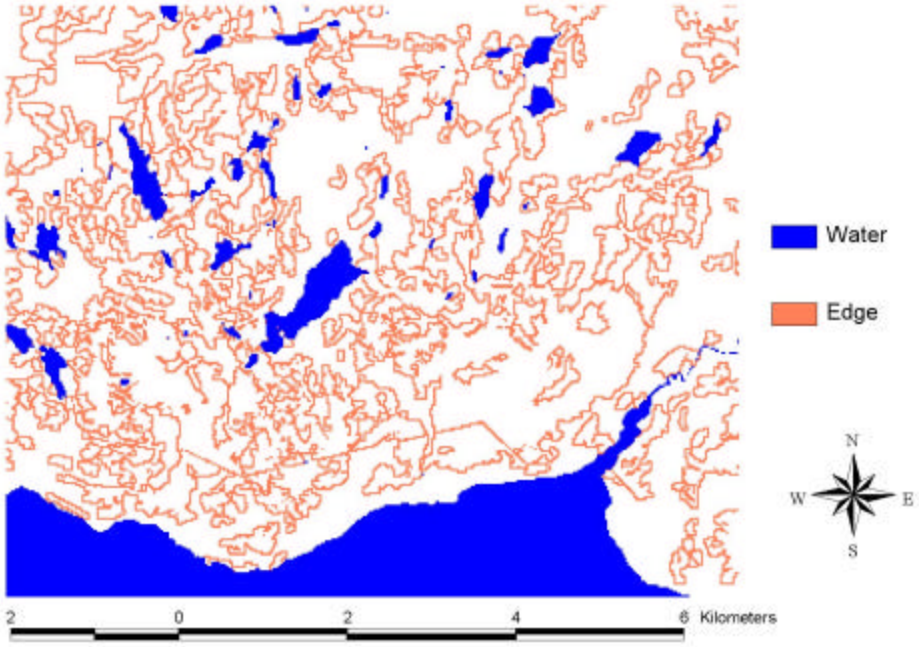
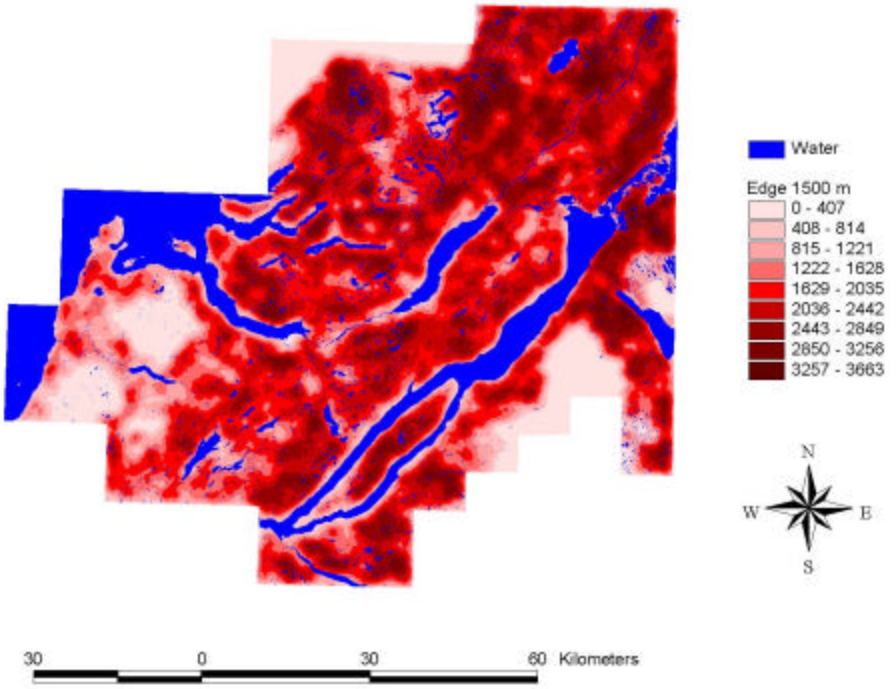
Appendix 1. Map of CALVING values in District 15, western Newfoundland.



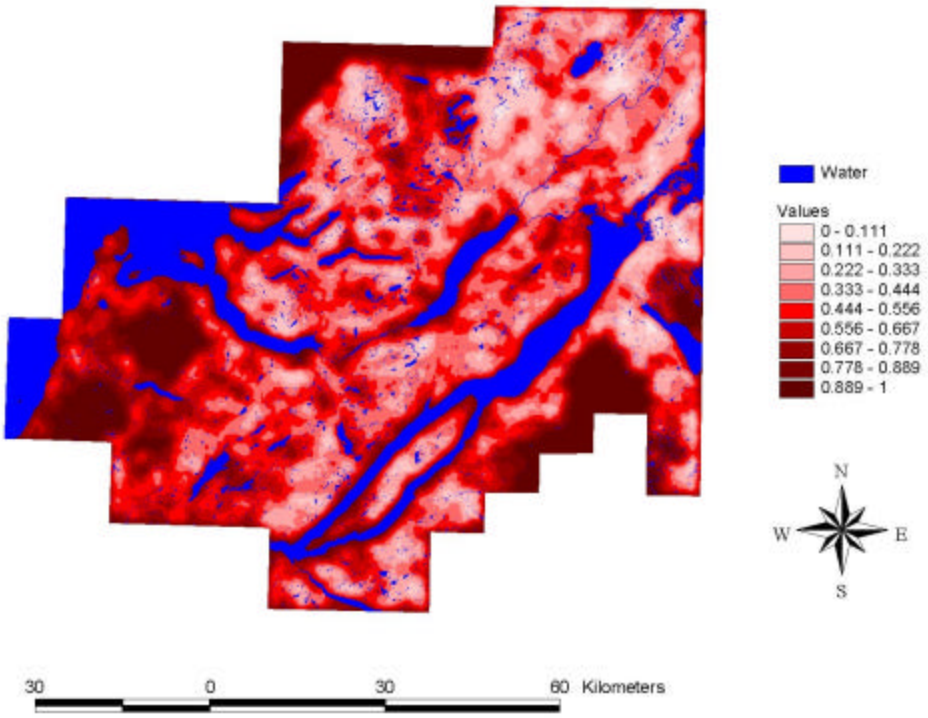
Appendix 2. Map of edges in a sector of District 15, western Newfoundland.



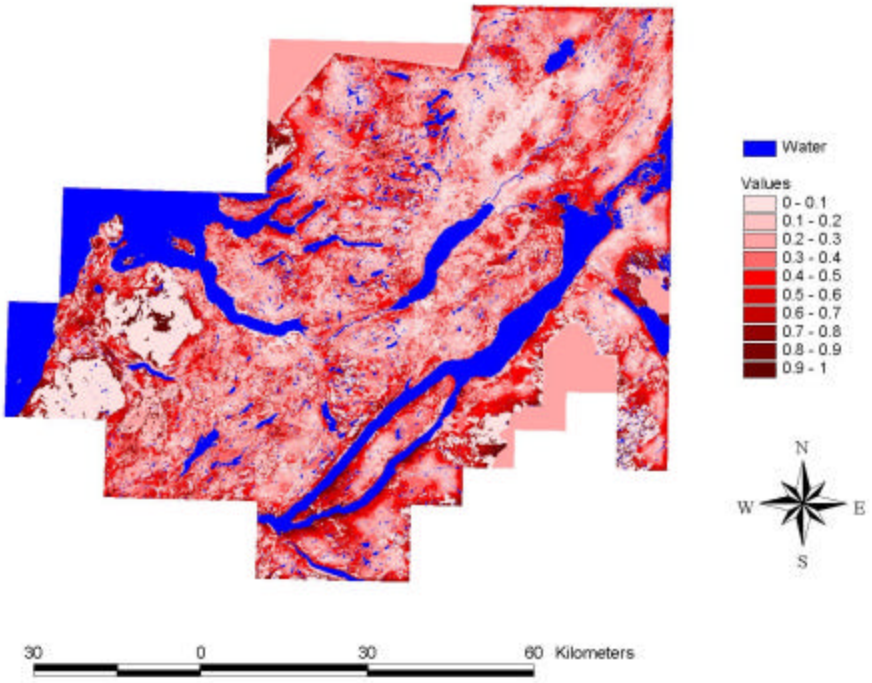
Appendix 3. Map of EDGE_PRED_FOR values in District 15, western Newfoundland.



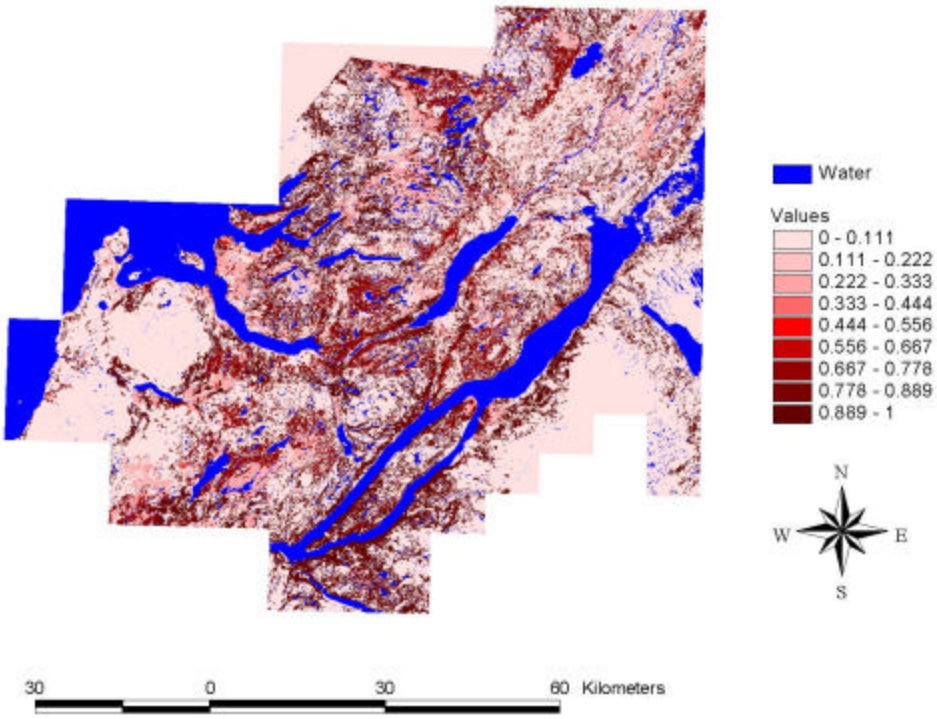
Appendix 4. Map of EDGE values in District 15, western Newfoundland.



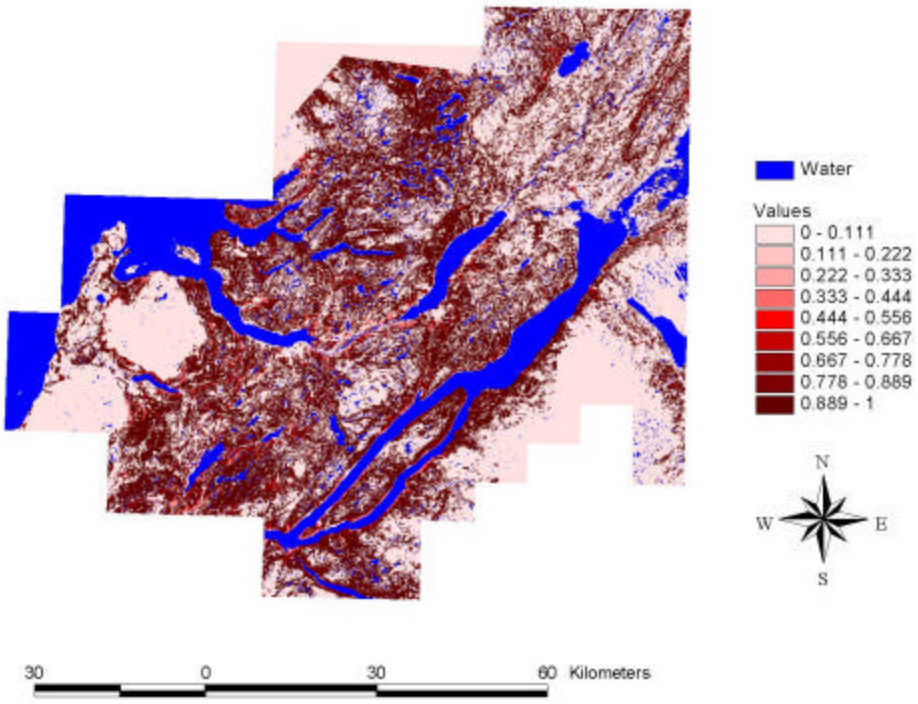
Appendix 5. Map of HSI_{local} (calving) values in District 15, western Newfoundland.



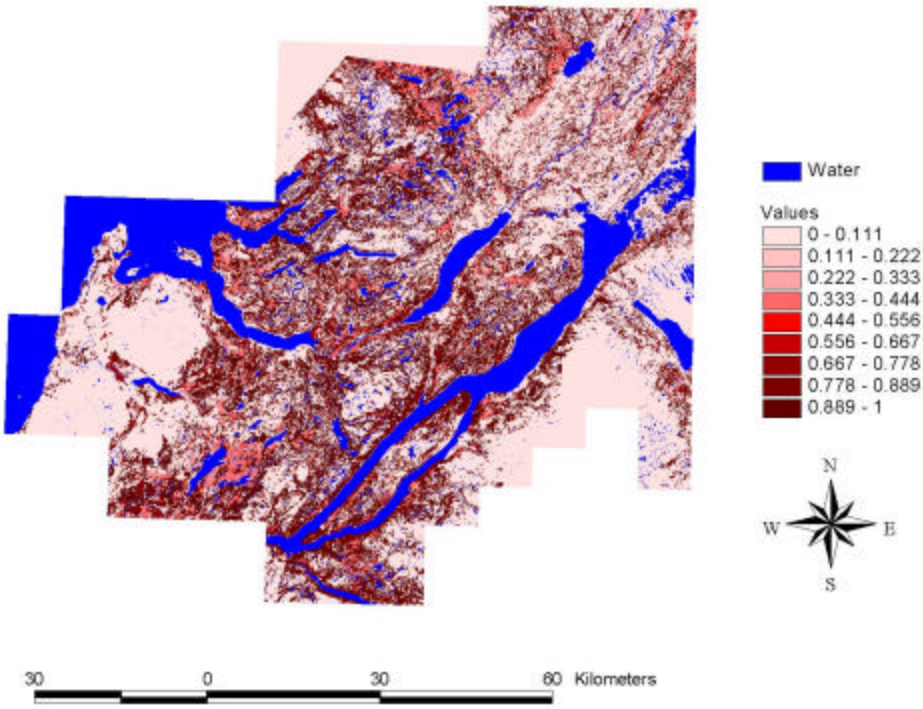
Appendix 6. Map of AGE values in District 15, western Newfoundland.



Appendix 7. Map of COVER_TYPE values in District 15, western Newfoundland.



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



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