Marten Winter – Habitat Suitability Model

Moric and Lakes Forest Districts Innovative Forest Practices Agreement

Prepared for:
ML - IFPA

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Executive Summary

Species – Habitat models are used to evaluate the potential in the Morice and the Lakes forest districts to provide suitable habitat for wildlife species selected by the Ecosystem group of the Morice and Lakes Innovative Forest Practices Agreement (ML-IFPA). The models generally define habitat suitability based on the provision of certain habitat attributes required for living and reproduction.

Unchanging environmental conditions (such as Biogeoclimatic subzone), location of infrastructure and development, and projected forest conditions (from the rules defined in individual scenarios), supply much of the basic information that can be used in the habitat supply models. There are other habitat attributes that are not directly provided by the available data layers that describe forest cover in terms of species composition and age. These habitat attributes are derived from information provided in the forest cover dataset and from data provided in the Predictive Ecosystem Mapping (PEM) using mathematical models and/or beliefs expressed in the Netica conditional probability tables (Habitat Modeling report #1, in prep). Empirical relationships, scientific literature, and professional judgment are incorporated into these equations and/or tables to describe the changes in the state (e.g. abundance, density) of these habitat attributes through changes in forest succession and disturbance.

This report describes the development of the marten winter habitat suitability model.
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INTRODUCTION

This report describes the marten winter habitat suitability model used to evaluate the landscape for the Morice and Lakes IFPA. The following document: 1) provides a species account for marten, 2) outlines the logic used and assumptions made in the preparation of the winter habitat suitability model, 3) describes the model and the relationships used to build the model, and 4) outlines testing of model sensitivity to input variables, level of validation, review, and verification.

AMERICAN MARTEN

Common Name: American Marten
Scientific Name: Martes americana
Species Code: M-MAAM
Status: The marten is a provincially Yellow (Ym) listed species because it is managed for trapping purposes in British Columbia (Ministry of Environment, Lands and Parks 1994).

SPECIES ACCOUNT AND HABITAT USE INFORMATION

Distribution

Provincial Range
The geographic range of the marten is throughout North America from northern New Mexico to the northern limit of tree line in arctic Alaska and Canada and from California east to Newfoundland (Hall 1981 In Buskirk and Ruggiero 1994). Distribution in British Columbia occurs throughout the province and includes Vancouver Island and the Queen Charlotte Islands (Buskirk and Ruggiero 1994, Stevens 1995).

Elevational Range
The marten may inhabit talus fields above tree line (Grinnell et al. 1937 In Buskirk and Ruggiero 1994), but are seldom or never found below the lower elevation limit of trees (Buskirk and Ruggiero 1994). In British Columbia, the marten is likely to occur in forested habitats from sea level to subalpine elevations (Stevens 1995).

Provincial Context
The distribution of the marten in British Columbia is widespread throughout forested biogeoclimatic zones, but is not homogeneous (Pojar and Meidinger 1991 In Lofroth 1993, Buskirk and Ruggiero 1994). The marten is generally separated into interior and coastal ecotypes (Lofroth and Steventon 1990) and the habitat requirements may differ between the two (Nagorsen et al. 1989).

Ecology and Key Habitat Requirements

General
The marten is a medium sized member of the family Mustelidae, which also includes wolverines, weasels, otters, skunks and the fisher (Martes pennanti), to which the marten is closely related. In comparison to the fisher, the marten spends more time in arboreal and subnivean activity, generally preys upon smaller mammals, and is more strongly associated with coniferous forests. Martens are highly selective of habitats that provide thermal and security cover and access to subnivean feeding sites (Buskirk and Ruggiero 1994).
Highly suitable marten winter habitats are mesic to hydric mature and old-growth coniferous forests that have high levels of coarse woody debris (CWD), 20% to 60% canopy closure, little deciduous canopy and little to intermediate high and low shrub cover. Forests located in the SBS biogeoclimatic zone of the Central Interior Ecoprovince provide suitable marten winter habitat when the mature forest reaches the mature seral stage (Lofroth 1993). Mesic habitats support the greatest number of small rodent prey and the greatest variety of understory plant species (Koehler and Hornocker 1977).

Due to its smaller body size, the marten has a greater ability to travel across deep, soft snow than the fisher (Raine 1981 In Buskirk and Ruggiero 1994). Martens tend to climb trees more than the fisher, but like the fisher, most travel and hunting occurs on the surface of the ground (Grinnell et al. 1937 and Francis and Stephenson 1972 In Buskirk and Ruggiero 1994). Martens are flexible in their activity patterns and may be active during the day or night (Hauptman 1979 In Buskirk and Ruggiero 1994). Clark and Campbell (1977) observed that marten activity was affected by weather conditions, with reduced activity occurring during continuous rainfall and snowfall.

The diet of martens varies by season, year and geographic area. Such differences are largely explained by food availability. The general diet of martens includes voles, squirrels, mice, ungulates (as carrion) and soft mast, especially the berries of Vaccinium spp. and Rubus spp. Several studies found that red-backed voles were the primary prey during all seasons (Koehler et al. 1975, Clark and Campbell 1977, Soutiere 1979) while deer mice and shrews are a low preference food (Koehler et al. 1975, Soutiere 1979, Buskirk and Ruggiero 1994), except on Vancouver Island where red-backed voles are absent and deer mice are a staple (Buskirk and Ruggiero 1994). The general diet of martens overlaps considerably with that of the fisher, and it is possible that competition between the two species may result (de Vos 1952). During the critical season of winter, the abundance and availability of small mammals are important determinants of health in martens (Buskirk and Ruggiero 1994).

Predators of the marten include fishers, coyotes, red fox, lynx, golden eagles and great horned owls (Seton 1929 and Grinnell 1937 In de Vos 1952, Ruggiero unpubl. data and Baker 1992 In Buskirk and Ruggiero 1994). In trapped marten populations, trapping is the leading cause of mortality and can be responsible for up to 90% of deaths (Hodgeman et al. 1993 In Buskirk and Ruggiero 1994). Due to wide ranging movements, adult males and juveniles are more susceptible to trapping than adult females (Buskirk and Lindstedt 1989 In Buskirk and Ruggiero 1994).

Most adult martens are non-migratory and make use of relatively constant home ranges in order to satisfy feeding, security and reproducing life requisites. Animals that have not yet established home ranges include dispersing juveniles and non-resident adults (Buskirk and Ruggiero 1994). Soutiere (1979) found that active logging did not cause a shift in home ranges within partially cut forest and that transient martens moved indiscriminately between undisturbed and partially cut forest. In Wyoming, Clark and Campbell (1977) reported that shifts in home ranges might have occurred as a result of logging. Buskirk and Ruggiero (1994) state that seasonal shifts in marten home range do not occur, but marten may migrate during a rare case of unpredictable environmental change.

The home range of males is larger than that of females, but the mean home range size of individual martens in a population varies by geographic location, prey abundance and available habitat types (Buskirk and McDonald 1984 In Buskirk and Ruggiero 1994). In Maine, Soutiere (1979) found that the minimum home range size of male martens varied from 0.1 km² to 7.6 km², and for females, home range varied from 0.1 km² to 2.3 km². Also in Maine, Steventon (1982) found that the mean home range for three males was 8.2 km² and the home range of one female was 2.25 km². In Newfoundland, Bateman (1986) recorded home range sizes of 27.5 km² for one male and 17.7 km² for one female. In the Central Interior Ecoprovince of British Columbia, Lofroth (1993) reported an average male home range size of 5.25 km² and an average female home range size of 3.16 km². The home range of male martens may be larger than that of females so that males can gain access to multiple mates (Powell 1994 In Buskirk and Ruggiero 1994). Home range size is usually much larger in areas with clearcuts than in areas where forests are undisturbed or selective harvest has been practiced (Soutiere 1979, Thompson and Colgan 1987 In Buskirk and Ruggiero 1944). In Ontario, Taylor and Abrey (1982) found that the size and shape of home ranges differed between homogeneous and heterogeneous habitats.

In Wyoming, Clark and Campbell (1977) found that male marten home ranges did not overlap, but that male-female and female-female home range boundaries did overlap. It was felt that non-overlapping...
male home ranges were due to territorial behaviour. Juveniles and transients of both sexes do not occupy home ranges and do not display territorial behaviour (Strickland and Douglas 1987 In Buskirk and Ruggiero 1994). In Ontario, Taylor and Abrey (1982) observed that over short periods individual home ranges may overlap; however, the use of the same area was separated temporally and mutual physical avoidance was practiced.

Younger seral stages generally have lower population densities and larger individual home ranges than older seral stages (Soutiere 1979). In Idaho, Koehler et al. (1977) reported that the highest activity by martens within home ranges was in or near mature mesic spruce/fir stands with greater than 30% canopy cover. Lofroth (1993) found that marten home ranges contained mainly mesic to hygric habitats ranging in successional stage from young forest to old-growth forest. He felt that by establishing home ranges, martens included preferred habitat types and avoided or infrequently used habitats that had little value. Lofroth (1993) also found that large male martens included substantial areas of mid-seral stages within home ranges, which was likely due to the abundance of snowshoe hare found in these habitat types. Ain comparison to unused areas, areas of high use by marten in northeastern US were best described by the following overstory features of a stand: higher live-tree basal areas, taller trees, greater snag volumes (Payer and Harrison 2002 in press), and larger downed logs.

Winter is considered to be the critical season for martens. During this time feeding, opportunities are the most limited, mobility is restricted by deep snow and energy demands for thermoregulation and travel are the highest (Ministry of Environment, Lands and Parks 1992). The distribution and abundance of small mammals during winter provides a measure of the value of foraging habitats. It is during winter that martens are limited to the narrowest range of habitats within individual home ranges (Buskirk and Ruggiero 1994).

**Winter Habitat Use – Life Requisites**

**Feeding Habitat**

During winter, the diet of martens is dominated by voles, mice, hares and squirrels (Buskirk and Ruggiero 1994). During late winter, the importance of mice and voles in marten winter diet may decrease as increasing snow depths make it easier for these species to escape predation. At this time, species that can be caught more easily, such as red squirrels and snowshoe hare, may increase in importance (Martin 1994 and Zielinski et al. 1983 In Buskirk and Ruggiero 1994).

Of particular importance to marten winter feeding habitat is coarse woody debris (CWD) and other large structures on the forest floor. Small mammals living beneath the surface of snow are preyed upon by martens using subnivean access points created by CWD, logs, and the bases of stumps, trees and snags (Corn and Raphael 1992, Koehler et al. 1975 In Buskirk and Ruggiero 1994). In Wyoming, Clark and Campbell (1977) found that, although martens traveled on the snow surface, most hunting occurred below the snow surface. Most hunting sites investigated by martens were associated with fallen trees protruding out of the snow, which were followed to subnivean snow levels with the individual marten surfacing either at the point of entry or at a distance of up to 31 m away.

In Wyoming, Sherbourne and Bissonette (1994) also observed the importance of CWD for martens hunting in winter, but stated that prey biomass was more important to differential access point use than CWD. They also felt that the level of CWD found only in old-growth forest provides the necessary forest floor structure for effective foraging by martens in winter.

During the winter in Idaho, Koehler et al. (1975) found that martens would cross natural forest openings, but would not linger to hunt in them. In Maine, Soutiere (1979) observed that martens would cross clearcuts in winter, stopping to investigate windfall and slash that protruded through the snow surface.

**Denning Habitat**

Martens have a relatively small body size and experience difficulty in retaining body heat during colder temperatures. Mature coniferous forests provide the greatest winter cover and old-growth trees and dead trees for dens and resting sites (Clark and Campbell 1977). In Wyoming, Buskirk et al. (1989) found that 84% of resting sites were in coniferous dominated forests and that spruce-fir stands were preferred due to
the high abundance of CWD. Winter resting sites are mainly selected based upon thermal value, and the high use of subnivean resting sites associated with CWD is due to the insulating property of trapped air spaces and the low thermal conductivity of wood compared to soil and rock (Buskirk et al. 1989).

In British Columbia, Lofroth (1993) found that martens preferred winter resting sites in forested areas, in forest/edge ecotones and near frozen streams. In Wyoming, Buskirk et al. (1989) found that winter resting sites were closely associated with upper level riparian areas. Such habitats commonly had high amounts of CWD due to windthrow.

During winter, resting sites are usually located beneath the surface of the snow and are often associated with squirrel middens, stumps and the root masses of large trees (Ministry of Environment, Lands and Parks 1992). Although martens use red squirrel and Douglas’ squirrel middens for thermal cover in winter, it appears that the squirrels are of limited importance in the marten diet (Buskirk 1983 and Clark and Stromberg 1987 In Buskirk and Ruggiero 1994).

In Wyoming, Hargis and McCullough (1984) found that logs and rocks appeared to be important components of denning sites by allowing access to areas below the snow surface. In northern Maine, Steventon (1982) observed that almost all resting sites in winter were below the snow surface and that 63% of resting sites occurred in natural cavities formed by large, decaying stumps. Also in Wyoming, Buskirk et al. (1989) found that in winter, 49% of resting sites and 63.1% of observed resting activity occurred in subnivean sites associated with CWD, due to their thermal value.

**Reproducing (Birthing)**

Marten breed from late June to early August, with most mating occurring in July (Markley and Bassett 1942 In Buskirk and Ruggiero 1994). Delayed implantation results in a total gestation period of 260 to 275 days (Ashbrook and Hansen 1927 and Markley and Bassett 1942 In Buskirk and Ruggiero 1994), but active gestation occurs only during the last 27 days (Jonkel and Weckworth 1963 In Buskirk and Ruggiero 1994). Parturition occurs in March and April of the year following breeding (Strickland et al. 1982 In Buskirk and Ruggiero 1994) and mean litter size is 2.85 kits with a range of 1 to 5 kits per litter (Strickland and Douglas 1987 In Buskirk and Ruggiero 1994).

Female martens have sole responsibility for the care of young, which consists of finding a suitable natal den, collecting nesting material, moving kits to other dens (Henry and Ruggerio n.d. and Wynn and Sherburne 1984 In Buskirk and Ruggiero 1994), post-partum grooming and nursing (Brassard and Bernard 1939 and Henry and Ruggerio n.d. In Buskirk and Ruggiero 1994) and providing food for young (Buskirk and Ruggiero 1994). Marten kits are weaned after 42 days (Mead 1994 In Buskirk and Ruggiero 1994) and emerge from dens after 50 days, but litters may be moved earlier between maternal dens (Hauptman 1979 and Henry and Ruggerio n.d In Buskirk and Ruggiero 1994).

Young martens leave their mother in the late summer and female martens first mate at 15 months, having their first litters at 24 months (Strickland et al. 1982 In Buskirk and Ruggiero 1994). During years of environmental stress, females may not ovulate and pregnancy rates less than 50% may result (Thompson and Colgan 1987 In Buskirk and Ruggiero 1994). The life span of martens is approximately fifteen years, but is less in trapped populations, especially for adult males and juveniles (Strickland and Douglas 1987 In Buskirk and Ruggiero 1994).

Little information is available on the natal and maternal denning requirements of martens in British Columbia; therefore, most information on this subject comes from other areas in North America. Female martens initially use natal dens, for parturition, then occupy several maternal dens for raising young. Female martens prefer natal and maternal den sites that are above the ground surface to protect kits from wet conditions during whelping (March through August) and for greater security from predators. Cavities located within large snags are often used (Ministry of Environment, Lands and Parks 1992). The availability of natal den sites may limit marten populations in some areas (Bergerud 1969, Wynne and Sherburne 1984).

In Wyoming, Ruggiero (n.d. In Buskirk and Ruggerio 1994) found that natal den sites were located in areas with significantly more developed old-growth characteristics than maternal den sites. It was also found that natal and maternal den sites were often in active red squirrel and Douglas’ squirrel middens.
Female activity patterns are significantly different from male activity patterns. Females tend to be more active than male marten. This difference may be due to greater food requirements of female marten as a result of production and care of young and the higher metabolic rate of a smaller female body size (Clark and Campbell 1977).

**MARTEN MODEL**

The output of the marten winter habitat suitability model is a five-class rating evaluating foraging and denning potential for each habitat. See Figure 1 for a flowchart outlining data use and information exchange when running the model and mapping the output.

**Figure 1.** Flowchart illustrating potential process for running the marten winter habitat suitability model.

This model emphasizes quantitative relationships between key environmental variables and habitat suitability. Habitat information is synthesized into explicit habitat models useful in quantitative assessments. Documentation provides the insights necessary to modify the model when these
judgements are inconsistent with local or new knowledge. Finally, documentation should facilitate reformulation of the model to meet individual study constraints.

Variables that are considered to influence the selection of habitat for marten include conditions that enable escape from predators, the capacity of the environment to shelter it from the cold, and its ability to successfully reproduce and rear young (BAP Marten HSM 2000). The presence of food items is also essential to the survival of marten. Marten are considered opportunistic generalists, consuming many different food items from various habitat types. The marten model consists of rating winter habitat suitability as an outcome of the denning value and the winter foraging value of the habitat.

**Application of Model**

**Geographic Area:** This model has been developed for application in the Morice and Lakes Forest Districts in west-central British Columbia, Canada.

**Season:** Winter Habitat (denning and foraging). The winter requirements are more restrictive than during other seasons of the year.

**Habitat Areas:** All landscape units in the Morice and the Lakes forest districts in central British Columbia.

**Model Output:** The model will produce a suitability value for marten winter habitat.

**Validation:** Validation involved testing the belief net to ensure that the output corresponds with our expected output.

**Review:** Review of the model assumptions was completed internally and with review from Doug Steventon (Ministry of Forests, Smithers).

**Verification Level:** The model has not been verified.

**Assumptions/beliefs**

The following section describes the logic and assumptions used to translate habitat variable information for the marten to the variables and equations used in the model.

1. Marten can obtain water and mineral resources in areas that supply food and denning habitat.

2. The life requisite of food during winter is acquired in the habitat types that supply good cover.

3. Structural stage 7 (old growth) is assumed to provide the most suitable winter habitat for marten, but forests of structural stage 5 (young forest) and 6 (mature forest) that possess the structural attributes of old growth, including large dead and damaged trees, high canopy closure and abundant large diameter CWD (greater than 20 cm diameter), are considered to be equally suitable winter habitat.

4. Structural stages 1 to 3 (non-vegetated/sparse to tall shrub) are considered to be of limited winter value to martens for resting and denning sites due to the lack of canopy closure, the absence of a multi-layered canopy and low CWD, but are considered to have some value for feeding habitat.

5. Structural stage 4 (pole sapling) is assumed to be sufficiently lacking in specific habitat attributes required by marten for satisfying security and thermal life requisites. It is considered of significantly lesser value than higher structural stages.

6. Desirable structural attributes, such as large pieces of coarse woody debris, large live trees and large snags and high forest crown closure are correlated with higher structural stage in natural stands versus managed stands.

7. Ecosystems with mean volumes of large coarse woody debris of 0-50m3/ha are considered to be Low value; 50-150m3/ha is Moderate value; and 150+m3/ha is High value.
8. Non-forested, non-vegetated, alpine tundra, and avalanche ecosystems are not used in the winter due to the lack of food sources and forest cover.

9. Any tree species present within a forest stand will have some value as winter cover, therefore; the lowest value that may be obtained is 0.1 for forest type.

10. This model does not consider the effects of other factors on marten habitat use, such as proximity to human settlements, roads, development, trapping, forest harvesting activities, or spatial configuration of the habitat.

11. In managed versus natural stands, there will be less volume of large CWD, shorter CWD pieces, and fewer snags and large live trees. Therefore, structural stages 5, 6, and 7 stands for managed forests will have a lower value for marten winter habitat than natural stands because of lower value structural attributes.

**Structure**

Figure 2 illustrates the habitat variable layers that were used to build the Bayesian belief model in the Netica© program. The upper layer is the first input and it is assumed that these variables are sufficient to describe marten winter habitat suitability.

**Description of Network Nodes**

**Winter Habitat Suitability**

The winter habitat suitability is the final output node of the marten BBN model. The value of a particular habitat to marten during the winter is a function of the value of the denning potential (including security cover) and the value of the foraging habitat (including structure to access prey and support prey populations). The influence of the value of foraging habitat and the value of denning habitat are defined.
in an equation which weights the importance of foraging 2.5 times more than the influence of denning habitat on the evaluation of the habitat type to marten in winter.

Example Relationship: \( MWHS = \frac{(2.5 \times FH) + DHV}{3.5} \)

Where:
- \( MWHS \) = Marten winter habitat suitability
- \( DHV \) = Denning habitat value
- \( FH \) = Foraging habitat value

**Foraging Habitat Value**

The foraging habitat value node is evaluated by the abundance/biomass of prey and the access to the prey (defined by FHA and SHV). Marten eat a variety of prey items, the proportions depending on abundance and availability. Availability in the winter is largely determined by access to foraging habitat in the winter. Marten will forage below the snow when conditions (snow depth and available entry routes) permit. If snow is shallow, there is often little to no subnivean layer and marten can forage exclusively above the snow. When snow conditions are deeper and there is a developed subnivean layer, marten will access this area via coarse woody debris or small trees and hunt the small mammals that inhabit this layer. The availability of small mammal prey during this time is largely determined by the amount and quality of access routes, which is often defined by coarse woody debris characteristics. Even during deep snow conditions, other above ground prey, such as snowshoe hare, may be available; therefore, the value of foraging habitat does not automatically go to zero for areas with very low coarse woody debris. As well, the value of the foraging habitat is influenced by the level of risk of predation marten are exposed to while hunting. The security value of the habitat is therefore considered to influence foraging habitat value.

Example Relationship: \( FH = \text{If FHA is Nil, then } FH \text{ is Nil, otherwise, } \frac{PREY \times (FHA + SHV)}{2} \)

Where:
- \( FH \) = Foraging habitat value
- \( FHA \) = Foraging habitat access
- \( PREY \) = Rating of prey abundance and type by site series productivity group and structural stage
- \( SHV \) = Security habitat value

**Denning Habitat Value**

Denning habitat was determined to be a function of the amount of snags, large trees, large coarse woody debris, and the security habitat value. Denning habitat value is a function of the variables large snags, large live trees, large CWD, and security forest. CWD, large live trees, and large snags essentially fulfill the same requirement of providing denning structure; therefore, if one of these three is present, even in the absence of the others, there is some possibility of denning structure.

Example Relationship: \( DHV = \frac{(LG_{SG} + LG_{TR} + LG_{CWD} + SHV)}{4} \)

Where:
- \( DHV \) = Denning habitat value
- \( LG_{CWD} \) = Large coarse woody debris (CWD)
- \( LG_{SG} \) = Large snags
- \( LG_{TR} \) = Large live trees
- \( SHV \) = Security habitat value
Security Habitat Value

Marten require security habitat from predators. Security habitat is evaluated based on 1) the type of forest, 2) the canopy closure class, and/or 3) large coarse woody debris. Coniferous forest with high cover provides the best cover for marten in the winter. It is assumed that good foraging opportunities are available in the same habitat that provides good security habitat. This relationship is defined in a probabilistic equation that has a normal distribution with a standard deviation of 0.5.

Example Relationship: \[ p(\text{SHV}) = FT \times \left( \frac{\text{LG}_\text{CWD} + (3 \times \text{CC})}{4} \right) \]
Where:
- \( \text{SHV} \) = Security habitat value
- \( FT \) = Forest type
- \( \text{CC} \) = Crown closure class (HSI rating)
- \( \text{LG}_\text{CWD} \) = Large coarse woody debris

Foraging Habitat Access

Access to foraging habitat, or prey is a consideration in winter during snow conditions that are deep enough that small mammals are living in the subnivean layer. Foraging also occurs above the snow for all conditions; however, for shallow snow conditions, the subnivean layer is generally absent or poorly developed. This node describes the level of access for average snow conditions (based on BEC subzone) in combination with the volume of large CWD (by site series and structural stage). The expected probability of the foraging habitat access value for marten during winter is dependent on the habitat variables large CWD and snow depth (See Figure 3).

Example Relationship: 

\[ \text{Conditional Probability Table} \]
Where:
- \( \text{FHA} \) = Foraging habitat access
- \( \text{LG}_\text{CWD} \) = Large coarse woody debris
- \( \text{SD} \) = Average snow depth rating (BEC subzone)

![Figure 3](image_url)

Figure 3. Conditional probabilities used within Netica© to configure the relationship between the volume of large coarse woody debris and the average snow depth in late winter in describing foraging habitat access in winter by marten.
Crown Closure Class

Crown closure affects security cover by proving a visual barrier from avian and often to terrestrial predators. High crown closure can be provided by mature and old growth forests that have large trees with deep, spreading crowns and a multi-layered canopy and by dense stands of pole/sapling stage forest. See Table 1 for a description of how the crown closure classes were rated within the model.

Variable: \( CC = \) Crown closure class

<table>
<thead>
<tr>
<th>Crown Closure Class</th>
<th>Crown Closure Value</th>
<th>Crown Closure Class</th>
<th>Crown Closure Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Very Low</td>
<td>3</td>
<td>Moderate</td>
</tr>
<tr>
<td>1, 2</td>
<td>Low</td>
<td>4+</td>
<td>High</td>
</tr>
</tbody>
</table>

Forest Type

Forest type affects security cover in the winter mainly as a difference between coniferous and deciduous stands. Coniferous stands maintain their value for security habitat year round, whereas forests that have deciduous trees lose some of their value as a result of shedding leaves in the fall. Forested stands, regardless of whether they are coniferous or deciduous, will provide some cover value; therefore, the values should never go to zero as long as the stand is forested. Possible states for this node are: coniferous (greater than 80% stand coniferous), mixed forest (20-80% deciduous), deciduous (greater than 80% deciduous), non-forested, and non-vegetated. This variable is assessed in the Access database based on the species composition in the forest cover dataset (using species 1 through 5).

Variable: \( FT = \) Forest Type

Large Snag Abundance

The abundance of large snags affects the value of the stand for denning habitat due to the potential to be used as natal or maternal dens, or as resting sites. Snags 37.5cm and greater diameter at breast height are considered to be large. This value was selected partly due to the type and form of data available and because snags this large should be able to provide some structural use to marten for denning. Ratings are (number per hectare): Low: 0-5, Moderate: 5-15, and High: 15+.

Variable: \( LG\_SNAG = \) Large trees

Large Trees

The abundance of large trees affects the value of the stand for denning habitat due to the potential to be used as natal or maternal dens, or as resting sites. Trees 37.5cm and greater diameter at breast height are considered to be large. Even though not all tree species are equally capable of providing good structures for marten dens, we were not able to distinguish this in the data available. Therefore, the ratings are for any type of tree species within the site series group. The ratings are (number per hectare): Low: 0-10, Moderate: 10-60, and High: 60+.

Variable: \( LG\_TREES = \) Large trees

Large CWD

Large coarse woody debris (greater than 20cm diameter) is a factor in determining the denning habitat value because marten can utilize large coarse woody debris as denning sites due to their potential for...
good thermal cover. Large coarse woody debris allows marten to access routes into subnivean hunting areas during the winter months in areas with moderate to high snow depths.

Variable: \( \text{LG\_CWD} = \) Large coarse woody debris

**Snow Depth**

This node is a rating of the mean winter snow depth by biogeoclimatic subzone. The rating is based on the average snow load and ranked for how the snow load impacts the access for marten to the subnivean layer. The effect of snow loads on access is fairly subjective at this point. Division for snow depths with respect to influence on marten winter habitat are: Shallow: 0-51cm, Moderate: 51-199cm, and Deep: 199+cm.

Variable: \( \text{SD} = \) Snow depth

**Total Prey Biomass (Abundance/Biomass)**

This node is a read-in value from a look-up table in an Access database. The occurrence, abundance, and weight of major prey species is predicted based on site series and structural stage. Mean weights per prey item were extracted from literature for North America, and habitats that support prey were evaluated from information summarized from literature. The following is a list of assumptions and information that was used to create the ratings of total prey biomass (based on abundance of prey \( \times \) biomass per prey item varying with site series and structural stage) for the study area:

1. The major prey items for marten in the study area are small mammals, red squirrel, snowshoe hare, and grouse (ruffed, spruce, blue).
2. The mean biomass value of these prey items from other parts of North America, with higher consideration for western studies, adequately describes the animals in our study area.
3. Ratings were made for sites series groupings by productivity (poor, moderate, good) by BEC subzone and structural stage groups (herb\_shrub, pole\_young, mature\_old).
4. Mean biomass values (kcal/item) were used to assess the input of items to the diet. Approximate values that were used were: 5-30kcal/small mammal, 470kcal/red squirrel, 600kcal/grouse, and 1350kcal/snowshoe hare.
5. Red squirrels are most abundant in mature to old, seed producing, especially spruce, and secondly pine, coniferous forests.
6. The SBSmc2 is better habitat for red squirrels than is the ESSFmc.
7. Snowshoe hare are most abundant in young forests with dense cover (either from shrubs or regen.) that is 1-3 metres in height of structural stages 3b, 4, and 5.
8. Snowshoe hare tend to prefer valley bottom and flat habitat to high elevation and steep habitat. They tend to concentrate near openings that support willow, alder, hazel, etc. (such as near swamps and thickets).
9. Small mammals (mostly voles and shrews) are most abundant in mesic mature\_old coniferous forests. Sites that have a high closure of low growing shrubs, 30 to 80% canopy closure, and abundant CWD support more small mammals.
10. Grouse species (ruffed, spruce, and blue) use a range of habitat types. Ruffed grouse prefer aspen dominated pole\_young stands. In winter, spruce grouse prefer dense pole\_young pine stands, or stands with spruce. Blue grouse use a variety of mature\_old coniferous high elevation forests.
11. Relative “catchability” of prey and prey cycles were not quantified because of lack of local data. The importance of prey in the diet was extrapolated from marten studies in British Columbia and this ranking was used as a relative weighting for each prey item.
**Model Description**

The winter habitat suitability model for marten is largely dependent on the ability of the habitat to provide foraging and denning requisites. Foraging and denning habitat are described using a set of variables from various map layers. The following section outlines the components of the winter habitat suitability model for marten in the Morice and Lakes Forest Districts and describes the relationships and beliefs that were used to create the model.

**Winter Habitat**

**Foraging**

Key foods that are used by marten in the winter include small mammals, red squirrel, snowshoe hare, and grouse. Marten forage both on top of the snow and in the subnivean layer between the snow and the ground. It is assumed that access to the subnivean layer is predominantly influenced by the depth of the snow and the amount of structure available to create travel routes into the subnivean layer. We assumed that relatively large coarse woody debris is the main habitat feature for marten to access the subnivean layer. There are other habitat features, such as regenerating trees and stumps, which can be utilized as travel routes, but we considered these secondary to large CWD.

**Denning**

Sites that have structure to provide natal and maternal dens with good security and thermal cover characterize preferred habitat by marten. The attributes that comprise security cover also provide good thermal cover for denning. Sites with a large live trees, large snags, and/or large coarse woody debris and good security habitat value provide the attributes for good denning habitat value.

**Habitat Variables**

Suitability curves were developed for some of the input variables for the marten winter model. These curves were based on data from the study area, data from other areas, and beliefs about how the habitat attributes influence the value of the habitat for marten use and denning success. Forest type was not defined in the model with a suitability index, but with the conditional probability table for its value as security cover. The following figures are graphical representations of the believed suitability value of the input variables to marten winter habitat. The marks along each graph represent lower and upper limits of model ratings (Low, Moderate, or High).

![Figure 4. Canopy closure class, habitat suitability index for marten winter habitat, and model rating (High, Moderate, or Low).](image-url)
Figure 5. Snow depth (m), suitability index, and model ratings for marten winter habitat based on accessibility to the subnivean layer. Optimal (high value) snow depth for accessing the subnivean layer is between 50-199cm.

Figure 6. CWD volume (greater than 20cm diameter) and suitability index based on access to the subnivean layer for foraging and resting sites.

Figure 7. Snag density (greater than 37.5cm DBH), suitability index, and model ratings (High, Moderate, or Low) based on denning opportunities for marten.
Computing Output for Habitat Value

Non-spatial marten winter habitat suitability will be the output from the model. An analysis of the spatial pattern, or configuration, of the habitat needs to be completed to be able to appropriately interpret habitat value for marten in winter. When examining the interaction of landscape composition and pattern on marten, there are a few key points that need to be considered. Marten are territorial and the size and shape of territories are dependent on habitat quality. Use of an area may also be dependent on “patch” size, contiguity, opening size and quality between patches, and/or demographics. There are a number of data gaps in the literature with respect to how landscape configuration and pattern affect habitat value for marten.

Sensitivity Analysis

The marten winter habitat suitability belief model was examined to assess the sensitivity of findings of dependent nodes on input (parent) nodes. This test of sensitivity is conducted within Netica© and is a relative indication of the influence of parent nodes on the findings in the child or output node. The results of this testing allow us to evaluate whether the BBN is working how we expect it to and/or gives insight into relative weighting of variables. Depending on the type of nodes that are involved in each test, the sensitivity is either given as the value ‘mutual info’ or as ‘variance reduction’. In both cases, the node with the largest value has the greatest influence on the output node that is being tested. The sensitivity values for the input nodes can be directly compared to assess the magnitude of their effect on the output node in comparison to the tested parent (input) nodes.

It was expected that the marten winter habitat suitability would be highly influenced by the ecosystem type (biogeoclimatic subzone and site series). Ecosystem type is not directly read into the model, but is used as a strata variable in the look-up tables for all of our variables except for forest type. Of the habitat variables directly reading into the model, the volume of large coarse woody debris is the most influential on the rating of the habitat for marten. Considering that the volume of large coarse woody debris is directly defined by site series and then by structural stage within that series, ecosystem type is contributing the most influential weighting to the rating of the polygon to marten winter habitat suitability.
Testing, Validation and Review

The models should be viewed as hypotheses of species-habitat relationships rather than statements of proven cause and effect relationships. Their value is to serve as a basis for improved decision making and increased understanding of habitat relationships because they specify hypotheses of habitat relationships that can be tested and improved. There are several levels at which the models should be validated. The first is an ongoing process during model development during which we have tested the model to ensure that it is acting in a manner that we want it to. The second level is to test the model assumptions and output through field-testing.

Testing of the model relationships and output is an ongoing iterative process concurrent with the development of the BBN. Development of the marten winter habitat suitability model occurred within Ardea and with several working reviews that occurred with the Ministry of Forests wildlife habitat ecologist (Smithers, BC). These reviews entailed testing the model for various scenarios, evaluating the relationships and ratings, testing the sensitivity of the model to habitat variables and adjusting the equations and tables to reflect fine-tuning. A working review of the model and the model document was done in the winter of 2002-03 and suggested changes were incorporated into the model to create an explicit and transparent flow of information.

The model has been run on a test set of data consisting of approximately 57,500 polygons in the Morice Forest District. The most expected probabilistic value for the marten winter habitat suitability, the denning habitat suitability value and the foraging habitat suitability value were output and the values mapped in Arcview 3.2. The values were examined on the maps and with tables.

Research Needs for Model Verification

What are potential implications to forest management given the output of the model? Habitat variables that can be used as management levers can be evaluated to assess the impact of forest management on habitat suitability for marten. These levers include: large coarse woody debris volume in a managed stand (including number, length, and vertical structure), and number and type of large live trees and snags.

The availability of mature to old coniferous dominated core areas could be threatened by forest management activities, especially in lower to middle elevation forests. Effects of stand and landscape pattern on survival and reproductive success in areas of uncut coniferous versus harvested areas should be evaluated within the study area.

The performance of a model should be tested against population data, preferably estimates of density or reproductive success, to translate the perception of habitat quality into differential use of habitat (Brooks 1997). The spatial configuration of habitat quality will affect the spatial spread and use of a population in a heterogeneous environment (Söndgerath and Schröder 2002). The output of this model provides a habitat suitability value; however, the connectivity of the habitat with respect to marten use is not evaluated. The importance of the landscape structure varies according to the demographic characteristics of the population (Söndgerath and Schröder 2002, With and King 1999).

The following are proposed initiatives and research needs to verify portions of the winter marten habitat suitability model. Various levels of verification can occur to strengthen our confidence in the model output. The input data, ratings, relationships, and output can all be validated. Model output would be most strengthened by verification of the following:

- Coarse filter validation by site series and disturbance type of average values and range of:
  - Large CWD volumes by site series and structural stage
  - Large live tree species by site series and structural stage
  - Large snags by site series and structural stage
- Refine the relationship between how snow depth affects the ability of marten to access the subnivean layer (as well as how subnivean layer development is affected by varying snow depths).
• Quantify the impact of beetle-killed stands on the variables in the marten model, and evaluate how stand structure from beetle kill affect marten populations. As an example, the structure and abundance of potential marten prey species in beetle killed stands versus stands under typical stand rotation or forest management should be measured, evaluated and the results incorporated into the habitat suitability model.

• The relative preference and/or use of forest types are extrapolated from a small portion of the study area and from literature. The assumptions around use of forest types (into broad categories of coniferous, mixed, deciduous, non-forested, and non-vegetated) should be tested.

Habitat quality is defined in terms of the fitness of animal occupants (Fretwell 1972). In the case of martens, fitness or components thereof, are difficult to estimate. Therefore, other attributes are used as indicators of habitat quality, even though the validity of this substitution is largely untested. The two most common attributes from which habitat quality is inferred are behavioural choices for individual marten and population density (including some measure of population structure where possible). Marten appear to meet the criteria set out by Van Horne (1983) for species in which population density is directly related to habitat quality. These criteria are that marten are a habitat specialist, they have a low reproductive rate, and they lack patterns of social dominance in stable populations in high quality habitat.
MARTEN MODEL REFERENCES


