Moose Habitat Model

Morice and Lakes Forest Districts IFPA

Prepared for:

Morice and Lakes 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 that were 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/or 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 expertise 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 moose winter habitat and summer habitat suitability models.

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INTRODUCTION

This report describes the moose winter and summer habitat models developed for the Morice and Lakes Innovative Forest Practices Agreement (IFPA) eco-subgroup. The following report 1) documents a species account for moose in the study area, 2) outlines the logic used and assumptions made in the preparation of the models, 3) describes the model and the relationships used to build the model, and 4) outlines testing of model sensitivity and the level of validation.

SPECIES ACCOUNT AND HABITAT USE INFORMATION

Common Name: Moose

Scientific Name: *Alces alces andersonni*

Species Code: M-ALAL

Status: The moose is classified as a **Yellow** (**Ym)** listed species by the Provincial Tracking Lists of the British Columbia Conservation Data Centre, and is managed for hunting purposes in the province of British Columbia (Ministry of Environment, Lands and Parks 1994).

Distribution

Provincial Range

The moose is found throughout British Columbia excluding coastal islands (Cowan and Guiget 1978). Moose are found in a wide variety of biogeoclimatic subzones in the province although the species is not usually found in non-forested or very open forest types (e.g. Alpine Tundra, Bunchgrass and Ponderosa Pine) or the south coast (Coastal Douglas Fir) (Stevens 1995).

Elevation Range

Moose occur in forested habitats from sea level to sub-alpine elevations, and limited use of alpine areas may occur in summer (Cowan and Guiget 1978, Stevens 1995).

Provincial Context

Moose occur commonly throughout the forested areas of the province. They have been expanding their range in North America since the retreat of the last ice-age (c. 10,000 B.P.), moving north with the retreat of the ice-sheets and the expansion of the boreal forest (Kelsall and Telfer 1974). Moose populations in British Columbia were likely low or non-existent prior to the late 1800's and have increased significantly since then, moving from northeastern BC and Alaska southwards in the last 100 years (Peterson 1955 *In* Kelsall and Telfer 1974, Cowan and Guiget 1978). Moose were not observed in the Houston area until 1922 (Hatler 1988). Provincial population estimates for moose were approximately 170,000 in 1996 and the population was considered stable at that time (R. Marshall pers. comm.). Within the province, the Morice and Lakes Forest Districts provide areas of high value moose habitat in both winter and summer seasons.

Ecology and Key Habitat Requirements

General

The moose is the largest cervid in North America and lives mostly within forested, shrubland and wetland habitat types. Moose seasonal habitat use varies depending on the area studied, sex, age, social status and reproductive status of the animal. General seasonal use patterns are difficult to predict and quantify due to the differences in migratory patterns (LeResche 1974) and food preferences (Peek 1974). Kelsall and Telfer (1974) attribute climate as the most likely limiting factor to moose expansion, with high winter snowfalls and high summer temperatures determining the extents of moose range. Moose are adapted for high snowfall areas, having long legs and low foot loads (Kelsall and Telfer 1974, Coady 1974), and can usually use areas where snow depths are up to but less than 70 cm (Kelsall and Prescott 1971, Kelsall and Telfer 1974, Coady 1974). Moose have a small surface area to body volume ratio which results in reduced transfer of body heat to the environment (Demarchi and Bunnell 1995). As a result, moose are easily heat stressed and temperature has been shown by a number of researchers to affect moose behaviour and habitat use (Kelsall and Telfer 1974, Schwab 1985, Renecker and Hudson 1986, Demarchi and Bunnell 1993 and 1995). Moose browse on a wide variety of plant species over their range in North America. Peek (1974) cautioned against generalizations in food habits due to these wide variations and suggested that local information be used wherever possible.

Seasonal home ranges for moose are generally small, with the maximum size usually ranging from 5 to 10 km^2 (LeResche 1974). Winter home range sizes are usually smaller than other seasonal home ranges and vary substantially due to snow conditions from 0.01 to 2 km^2 (Coady 1974 and LeResche 1974). Home ranges during the summer are larger than winter home ranges but are variable and dependent on the sex, age and reproductive status of the moose. Male moose tend to have larger home ranges than females in all seasons with the largest differences occurring in the fall during the rut (LeResche 1974, Cederland and Sand 1994). Although seasonal home ranges can be relatively small, the distances between the seasonal ranges can be quite large, depending on the population migration type as outlined by LeResche (1974) (see below).

Moose migration patterns are variable over their range in North America. LeResche (1974) reviews these variations, and suggested three migration patterns based on numerous studies of moose populations. He classified moose migrations patterns into Type A: short distance movements between two seasonal ranges with little elevation change; Type B: medium to long distance movements between two seasonal ranges with large elevation differences; and Type C: medium to long distance movements between three seasonal ranges with large elevation differences between the winter/spring and summer/fall habitats. All of these patterns can be expressed within the same general area by different segments of the same population, and may be dependent on factors such as age, sex, social status and reproductive status (LeResche 1974). In his review of numerous moose studies, LeResche (1974) found that Type A populations were found in areas of low elevational relief and high habitat diversity so that movements between winter and growing season habitats were relatively small (0 to 10 km). His review of other work suggested that Type B populations have a low elevation winter range and a higher elevation spring/summer/fall range separated by 500 to 1000 m vertically and 2 to 60 km horizontally. Type C populations were identified where migrations occur from winter areas at low elevations to other low elevation spring areas approximately 20 km away followed by a movement to higher elevation (+ 500 m) summer/fall areas 30 to 50 km from the spring areas. Therefore, annual home ranges can be highly variable and have been reported in the literature as ranging from 15 to 150 km^2 (LeResche 1974).

Habitat Use – Life Requisites

Feeding and thermal cover are modelled for winter and summer seasons.

Feeding Habitat – Winter

During the winter, moose feed primarily on forage plants found in open areas and in the boreal forests of British Columbia early winter foods include willows (*Salix* spp.), red-osier dogwood (*Cornus stolonifera*), and paper birch (*Betula papyrifera*) while late winter diets include willows, paper birch and subalpine fir (*Abies lasiocarpa*) (Eastman 1977). Other winter foods described in the literature for north-central British Columbia include falsebox (*Pachistima* spp.) (Ritcey 1965 *In* Peek 1974), highbush-cranberry (*Viburnum edule*), saskatoon (*Amelanchier alnifolia)*, aspen (*Populus tremuloides*), and sitka mountain ash (*Sorbus sitchensis*) (Westworth *et al.* 1989). Bark stripping in late winter by moose has been reported by various authors (e.g. Miquelle and van Bullenburghe 1989, MacCracken *et al.* 1997) and occurs primarily on deciduous trees such as willow and cottonwood. Aspen (*Populus* spp.) may also be used (Kelsall and Telfer 1974).

Various researchers have looked at winter habitat use by moose in North America and have found that moose use a number of habitat types such as coniferous forests (Peek *et al.* 1976, Forbes and Theberge 1993), riparian areas (LeResche *et al.* 1974, Doerr 1983, MacCracken *et al.* 1997), shrublands (LeResche *et al.* 1974), burns and harvested areas (Eastman 1974, Forbes and Theberge 1993), and mixed forests (Hundertmark *et al.* 1990). The reason for such differences in findings appears to be related to the region studied (e.g. Alaska, Ontario, Minnesota, British Columbia, etc.), sampling methods used (e.g. track counts, pellet counts, radio-telemetry, aerial surveys, etc.), sampling period (i.e. early

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winter vs. late winter), snow characteristics (e.g. depth, density, layers, etc.), life requisite function (foraging vs. bedding) and the delineation of the habitats (i.e. map scale, classification method).

One factor that could be influencing the delineation of winter habitat types could be the scale of the measurements. For example, a study by Forbes and Theberge (1993) in Ontario found that moose selected closed canopy forest habitats at the stand level but mosaics of 33% harvested areas at the landscape level. Another factor that could influence winter habitat selection is moose density, as moose in northern Ontario were found to feed within 80 m of cutblock edges when moose densities were low and up to 260 m from edges when moose densities were higher (Hamilton *et al.* 1980).

Most researchers agree, however, that snow characteristics and canopy closure have the greatest influence on moose winter habitat use (Kelsall and Prescott 1971, Coady 1974, Peek *et al.* 1976, McNichol and Gilbert 1980, Thompson and Vukelich 1981, Hundertmark *et al.* 1990, MacCracken *et al.* 1997). When snow levels are low (less than 60 cm), in early winter or during mild winters, moose are able to forage in open habitat types such as shrublands, burns and cutblocks (Eastman 1974, LeResche *et al.* 1974, Peek *et al.* 1976, Schwab 1985, MacCracken *et al.* 1997). As snow levels increase (> 60 cm), foraging in open habitat types decreased and use of closed canopy forests and edge habitats between open and closed canopy areas increased (Eastman 1974, Peek *et al.* 1976, McNicol and Gilbert 1980, Doerr 1983, Schwab 1985, Hundertmark *et al.* 1990). Use of open areas is limited to distances ranging from 30 to 80 m from forested edges when snow levels are more than 60 cm (Hamilton and Drysdale 1975, Hamilton *et al.* 1980, Thompson and Vukelich 1981).

Thermal/Snow Interception Cover Habitat – Winter

Moose are severely restricted in their movements when snow levels are greater than 90 cm, are relatively mobile if the snow levels are less than 60 cm, and prefer areas where snow depths are less than 40 cm (Coady 1974). Snow density and crusting has an effect on the depth of snow that moose can use, with higher density snow allowing for deeper snow use (Kelsall and Prescott 1971, Coady 1974). Snow depth and duration were found to be the highest natural mortality factors for moose in Alaska over an eleven-year period (Modafferi and Becker 1997).

Although during very extreme winter weather moose may experience cold stress, heat stress may be a more important factor of moose habitat selection during moderate winter temperatures (Schwab 1985). However, Schwab (1985) also found moose using forests with high canopy closures when temperatures were less than -20^{o}C. Mature closed canopy forests provide shelter from wind, with even residual stands of trees providing important wind shelter (McNichol and Gilbert 1978).

Thermal/snow interception cover habitats for moose in winter consist of closed-canopy coniferous forests, which intercept snow, provide shelter and minimize radiation of heat to the open sky (Coady 1974, Eastman 1974, Peek *et al.* 1976, McNicol and Gilbert 1980, Thompson and Vukelich 1981, Schwab 1985, Hundertmark *et al.* 1990). Open habitats such as burns, shrublands and cutblocks are used during early winter or during low snow winters and closed canopy coniferous forests are used during heavy snow winters or in late winter when snow levels increase (Coady 1974, Eastman 1974 and 1977, LeResche *et al.* 1974, Peek *et al.* 1976, MacCracken *et al.* 1997). In British Columbia, Schwab (1985) found moose using forests with high canopy closures when snow levels were greater than 90 cm. Also in British Columbia, Eastman (1974) found that forested habitats were used by moose for cover in winter rather than for feeding and that partially logged stands were the preferred habitat type due to the presence of forage and cover. In Alaska, Hundertmark *et al*. (1990) observed that coniferous stands lacked sufficient browse and were selectively used by moose with greatest use occurring in severe winters.

Feeding Habitat – Spring

Peek *et al.* (1976) and MacCracken *et al.* (1997) provide plant protein analysis data that show spring forage provides the highest value food for moose and suggest that spring feeding is critical for moose replenishment of fat reserves. Moose spring foraging areas consists primarily of open areas that provide early green forage such herbs and new leaf buds of woody plants. Spring foods in north-central British Columbia include deciduous shrubs such as Sitka alder (*Alnus viridis* spp*. sinuata*), Douglas maple (*Acer glabrum*), willows and paper birch (Eastman 1977). Important herbaceous plants eaten in spring in Alaska include horsetails *(Equisitem* spp*.*), buckbean (*Menyanthes trifoliata*), and marsh cinquefoil

(*Potentilla palustris*) (MacCracken *et al.* 1997), which are all common within the wetlands in the study area (Turney and Houwers 1998). Moose have also been reported to strip bark from willow and cottonwood trees during spring (Miquelle and Van Ballenberghe 1989, MacCracken *et al.* 1997). Bark stripping may be related to mineral requirements, as willow and cottonwood bark have high levels of calcium and are easily digested (Miquelle and Van Ballenberghe 1989, MacCracken *et al.* 1997). MacCracken *et al.* (1997) suggests that bark stripping may be an important, spring diet component for a short period of time, prior to full green-up.

Movement from winter areas to spring feeding areas occurs as soon as snow levels allow and green-up of plants starts (LeResche 1974). Spring habitat types used for foraging include wetlands, shrublands, riparian areas, recent burns and cutblocks (Eastman 1977, Schwab 1985, Simpson *et al.* 1988). Moose that exhibit type B and C migration patterns (LeResche 1974), will follow the receding snow levels to upper elevation wetlands, meadows and sub-alpine forest parklands during the latter part of the spring (Edwards and Ritcey 1956, Simpson *et al.* 1988).

Feeding Habitat – Summer

During the summer moose continue to feed on willow and herbaceous plants, such as grasses, ferns, sedges and horsetails, as well as aquatic plants in the early part of the summer (Peek 1974, Peek *et al.* 1976, MacCracken *et al.* 1997). Sedges (*Carex* spp.), grasses and reedgrasses (*Calamagrostis* spp.) are reported as forage species for moose but usually make up very low percentages (1 to 5%) of their summer diet (Peek 1974, MacCracken *et al.* 1997). Aquatic plants used by moose include bur-reed (*Sparganium* spp.), pondweed *(Potamogeton* spp.), horsetails, (Ritcey and Verbeek 1969 *In* Peek *et al.* 1974, Peek *et al.* 1976), buckbean (MacCracken *et al.* 1997), water arum *(Calla palustris)*, yellow water lily (*Nuphar lutea)*, and sedges (Peek *et al.* 1976). The use of aquatic plants has been hypothesized to be a response to the increased amounts of minerals, especially sodium in these plants (Belovsky and Jordan 1981), making them an important food source in the early summer.

Habitats selected during the summer are varied, with open areas such as burns, cutblocks, sub-alpine parklands, avalanche tracks, wetlands and shrublands used for foraging (LeReche *et al.* 1974, Peek *et al.* 1976, Tomm *et al.* 1981, Schwab 1985, MacCracken *et al.* 1997). Use of these open areas is dependent on factors such as temperature and distance from cover, with moose avoiding open areas during hot days (> 20^{o} C) (Schwab 1985) unless sufficient cover (e.g. alder > 5m tall) or water is present to reduce heat stress (Demarchi and Bunnell 1995). Use of open habitats during the summer is also related to the proximity of forested habitat edges. Work in Alberta by Tomm *et al.* (1981) found that moose used edges extensively to provide forage and cover and seldom moved more than 60 m from the edges into open areas when disturbed by road traffic. In central Alaska, moose preferred browsing on diamondleaf willows (*Salix planifolia pulchra*) in shaded areas on an edge to those in sunlight, possibly due to the higher protein content of the willows in the shade (Molvar *et al.* 1993). Wetland habitats are used if they provide the optimum feeding conditions, which are usually found in small lakes (1 to 5 ha) with organic bottoms, slow streams and beaver ponds (Adair *et al.* 1991, Fraser *et al.* 1984).

Thermal Habitat – Summer

During the summer, thermal cover has been reported by many researchers to be an important habitat feature selected for by moose (Schwab 1985, Renecker and Hudson 1986, Demarchi and Bunnell 1995). Demarchi and Bunnell (1995) found that moose generally used habitats in proportion to their availability but modified habitat use in response to warmer temperatures, displaying increased use of forested habitats with greater than 55% crown closure. In north central BC, Schwab (1985) found that summer habitat use was directly related to avoidance of heat stress.

Moose have been found to select habitats such as lakes, rivers and ponds (Kelsall and Telfer 1974, Peek *et al.* 1976), closed-canopy tall shrublands (Demarchi and Bunnell 1995, MacCracken *et al.* 1997), and closed-canopy forests (Schwab 1985, Demarchi and Bunnell 1993 and 1995) during high temperature days (> 20-25^{o} C). Demarchi and Bunnell (1993) also provide a range of crown closure classes required for moose based on summer ambient temperatures. They suggest that moose will select forests with crown closures greater than 66% when temperatures are greater than 25^{o} C.

MOOSE HABITAT MODELS

Moose habitat suitability is a function of feeding habitat requirements and thermal cover habitat requirements. Feeding habitat and thermal cover requirements vary significantly from winter to summer, which resulted in different habitat variables and ratings for each seasonal model. Winter and summer foraging and thermal suitability ratings were mapped into ArcView 3.2 GIS and analysed spatially for winter and summer habitat suitability.

Although the specific diets of moose vary by season, the suitability of feeding habitat in all seasons is dependent upon shrub and herb layer composition, cover, and phenological state. Similarly, the forest characteristics that provide thermal cover (and by extension, winter snow interception cover) are similar for all seasons, with the exception of the specific use of water bodies in summer. Thermal/snow interception cover is best provided by mature to old-growth forests consisting of a multi-layered canopy and trees with deep, spreading crowns, which produce high canopy closure. Feeding habitat is more valuable to moose if it is coincident or in close proximity with cover habitat and vice-verse.

The use of herbs in the diet of moose commences with the appearance of new growth in the spring, when newly sprouted plants such as gasses, ferns and horsetails are consumed. The component of herbaceous matter in the diet increases through the summer, and begins to decline in late summer and early fall as herbs die off and leaves are shed. It is beneficial for moose to consume highly digestible herbaceous plants for as long a period as possible.

As summer passes and herbaceous plants die off, the diet of moose shifts to primarily woody browse. In winter conditions where leaves are no longer available and snow depths preclude foraging from the forest floor, the diet of moose becomes almost strictly woody material. Woody browse is not highly digestible and so food selection by moose becomes particularly important in fall and winter.

Thermal cover is an important component of habitat use by moose throughout the year. Moose are easily heat stressed, which is an obvious factor governing habitat selection in summer, but is also an important component of winter habitat use. Habitat selection that is governed by thermal cover attributes during low temperature is only an issue in a severe winter.

Both winter and summer habitat models predict foraging habitat suitability and thermal habitat suitability. The values for each season are then used in a spatial analysis of habitat suitability (See Figure 1). The model does not currently include variables that modify the effectiveness of the habitat. Suitability ratings have not been calibrated to moose density estimates in either season.

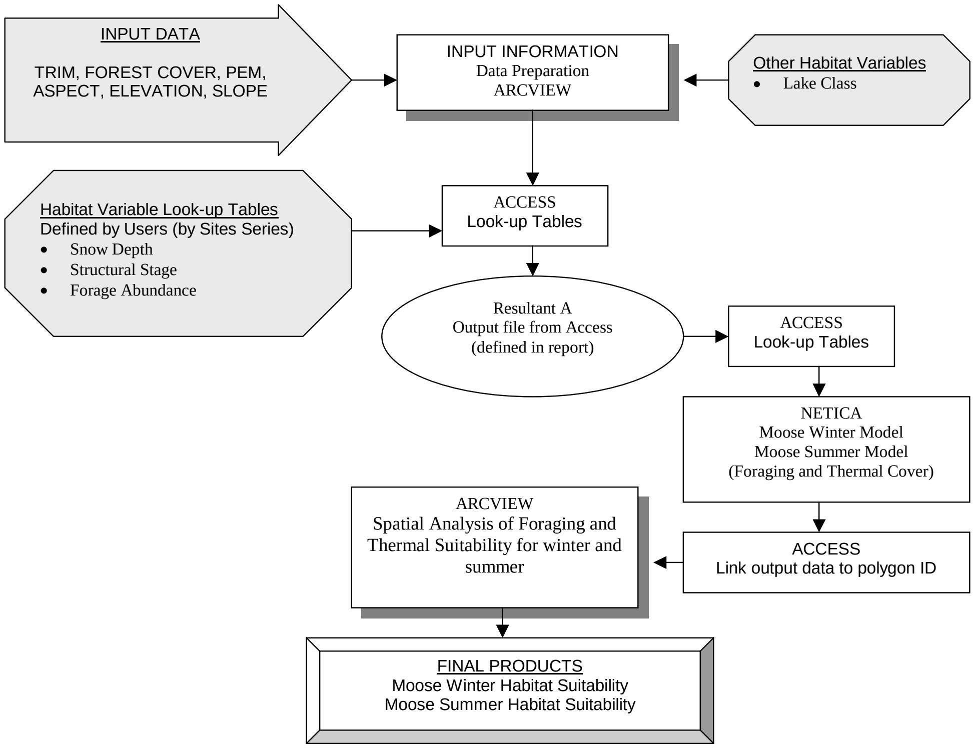

Figure 1. Flowchart illustrating process for running the moose winter and summer habitat suitability models and mapping the output.

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 (thermal and feeding), Summer (thermal and feeding)

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

Model Output: Each BBN model will produce a habitat suitability value of feeding and thermal cover suitability of moose winter and summer habitat. The final spatial model will result in a habitat suitability rating for winter and for summer.

Verification Level: Verification of the model involved testing the belief net to ensure that the output is consistent with our expected output. The winter model was reviewed internally as well and George Schultze and Rick Marshall (WLAP) did a working review. The winter model was also verified using the output of the stratified winter moose surveys by WLAP in 1992, 1997 and 2002.

Assumptions

The following section describes the logic and assumptions used to translate habitat element information for moose to the variables and equations used in the models.

General Assumptions

1. Moose can obtain water and mineral resources in areas that supply foraging and/or thermal habitat.
2. In mountainous areas, moose are often migratory, moving between high elevation summer ranges and low elevation winter ranges. Migrations are related to snow depths and persistence, with moose moving out of areas after prolonged periods of deep snow (MacCracken et al. 1997). Some moose have distinct summer and winter home ranges (< 50% overlap) (MacCracken et al. 1997). The areas of overlap are transitional zones between summer and winter ranges that are occupied only briefly during migration (MacCracken et al. 1997).
3. Areas of relatively low canopy closure are assumed to support higher production of shrubs and herbaceous vegetation during spring greenup and the growing season, and hence produce the largest forage mass for moose.
4. Desirable structural attributes required for thermal cover, such as high forest canopy cover and large trees with deep spreading crowns, are often correlated with higher structural stage.
5. High quality forage habitat should occur within 100 m of cover (thermal/security) habitat.

Moose Winter Habitat Suitability

The following section describes the winter habitat suitability model (See Figure 2) and the assumptions used to define the relationships used in the model. The winter habitat suitability rating is should be interpreted at the landscape level and not used as a stand management interpretation.

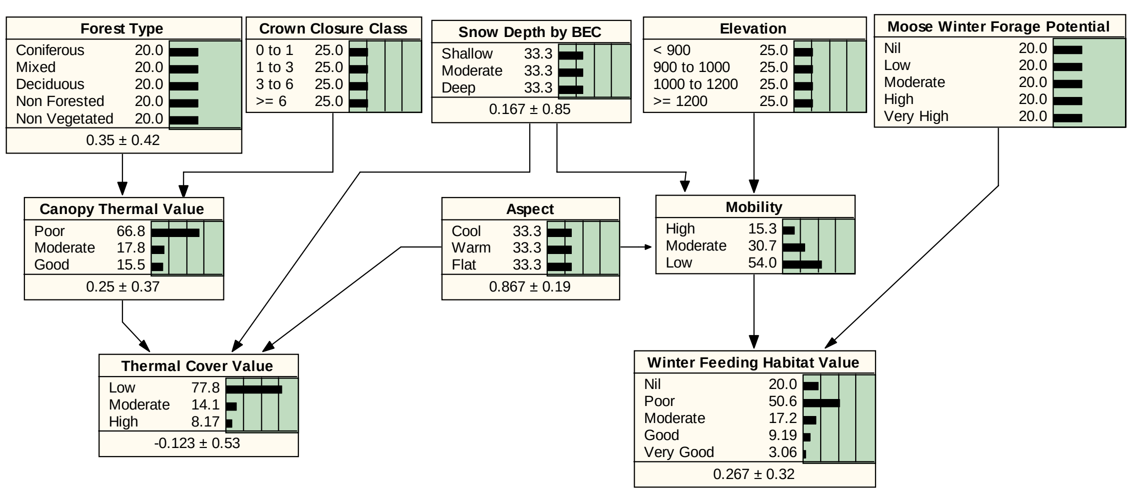

Figure 2. Habitat variables and ecological relationships used to build the moose winter foraging and thermal habitat suitability Bayesian belief model in the Netica© program.

Model Description

The winter habitat suitability model for moose is largely dependent on the ability of the habitat to provide foraging opportunities within a certain proximity to security and/or thermal habitat. Foraging and thermal/security habitat are described using a set of elements from various map layers. The following section outlines the components of the winter habitat suitability model for moose in the Morice and Lakes Forest Districts and describes the relationships that were used to create the model.

Winter Habitat Suitability Model Assumptions

1. At the landscape level, moose select zones of lower snow depth (<70 cm) in winter.
2. The ESSF, ESSF parkland, MH, MH parkland and AT zones are assumed to have no value to moose as winter habitat in the study area due to deep (>60 cm) and persistent (for more than two weeks) snow levels.
3. Cool aspects tend to maintain a relatively higher snow depth than do warm aspects. Warm aspects are relatively better habitat for moose than cool aspects because of higher snow melt.
4. In winter, the mobility of moose is largely dependent on snow depth. In general, moose have low mobility in deep snow and high mobility in shallow snow. Snow depth on the landscape is estimated using a combination of biogeoclimatic subzone lines, elevation, and aspect. As well, forests with high canopy closures result in greater snow interception and snow load retention than those with lower canopy closures.
5. The relative cover of preferred shrub species largely determines winter forage abundance. The only herbaceous cover considered is *Carex* spp.
6. Forage potential can be linked to site series and structural stage. Rich and moist sites in the earlier structural stages support relatively high masses of shrubs.
7. Productive floodplains and their associated benches, riparian habitat, and regenerating burns are rated as either moderate to high moose winter habitat depending on available forage species and cover.
8. In winter, Structural stage 3a and 3b sites in areas with low to moderate snow fall regimes and high willow abundance are rated as high feeding habitat. Thermal habitat is a function of canopy closure (e.g., stands with canopy closure >65% are rated class 1 thermal habitat) and snowfall regimes (e.g., lower elevation sites which receive less snowfall, and are typically warmer have less stringent requirements for winter thermal habitat). Additional features affecting thermal habitat ratings for moose in the winter season include topography, aspect, slope and elevation.
9. Habitats with high shrub cover (structural stages 3a and 3b on willow) are rated high winter feeding habitat, and class “moderate” to “high” security habitat depending on percent cover in the understory.

Description of Network Nodes

Winter Feeding Habitat Suitability

Moose eat a variety of shrubs and herbs, the proportions of which depend on plant phenology and availability due to snow levels and on the ability of moose to move to and about in a habitat. Herb and shrub abundance and availability vary with season, biogeoclimatic subzone and site series. Abundance is a function of moisture and nutrient regimes as reflected by site series. Availability is a function of snow depth as reflected by biogeoclimatic subzone and elevation. Snow depth also provides an indication of moose mobility. Time of year or season affects plant phenology (see Figure 3). During winter, moose forage mostly on woody shrubs, especially willow.

Example Relationship: ***Conditional Probability Table***

Where: WFHV **=** Winter feeding habitat suitability

ALAL_W_Forg = Moose winter forage potential

SMobility = Mobility (based on snow depth)

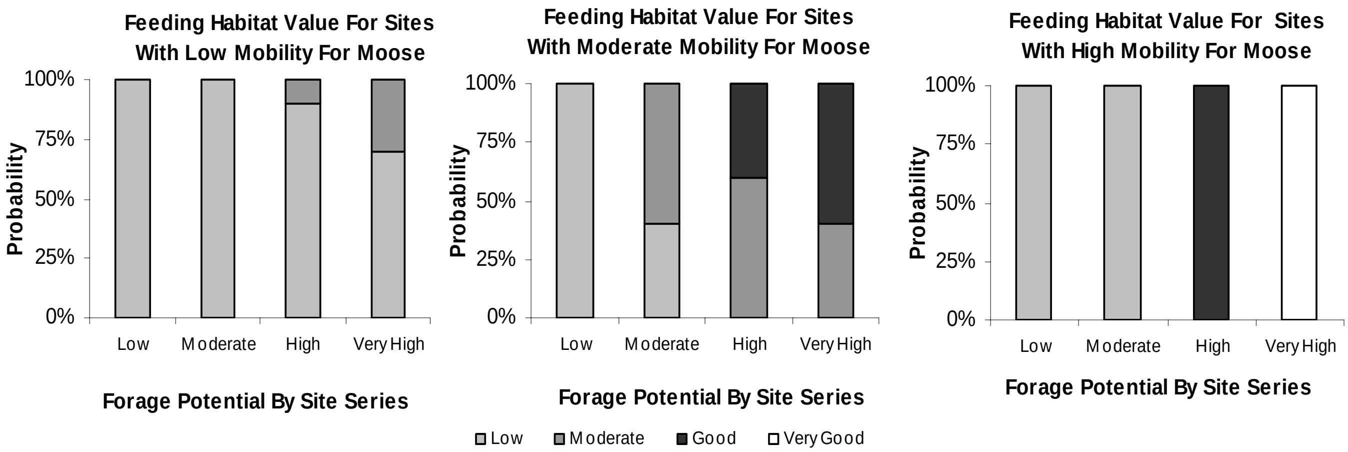

Figure 3. Feeding habitat value for moose in winter based on the forage potential in a site and the ability of moose to access and move about in that site. For sites with “nil” potential (not shown in these graphs), the feeding habitat value is nil, regardless of mobility.

Winter Thermal Cover

The thermal cover node provides a rating, from “poor” to “good”, of a habitats’ ability to provide thermal cover, and by inference, security cover and snow interception during the winter. The thermal cover rating is based on a given forest’s canopy thermal value (discussed in next section) modified by snow depth and aspect (see Figure 4). Moose are able to withstand cold temperatures; however, moose will use protected sites to bed down out of the wind and blowing snow.

Example Relationship: ***Conditional Probability Table***

Where: MTCV = Moose winter thermal cover value

CCV = Canopy thermal cover value

ASPECT = Aspect: warm, cool, flat (for slope<10degrees)

SNOW = Snow depth by biogeoclimatic subzone

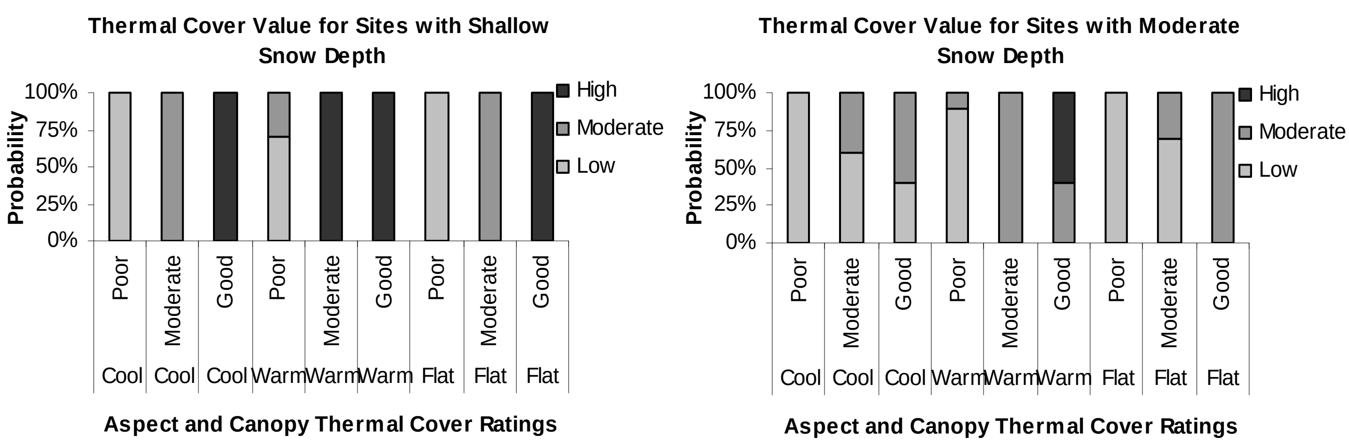

Figure 4. Thermal cover value for moose in winter based on the forested canopy thermal cover, snow depth and aspect. Note that for sites with deep snow, the value for moose is always low.

Canopy Thermal Value

The canopy thermal value is dependent on the type of forest and the crown closure class from forest cover. Higher crown closure generally provides better thermal cover value; however, this is dependent on forest type (See Figure 5).

Example Relationship: ***Conditional Probability Table***

Where: CCV = Canopy thermal value

CRNCL_CL = Crown Closure Class

FT = Forest Type

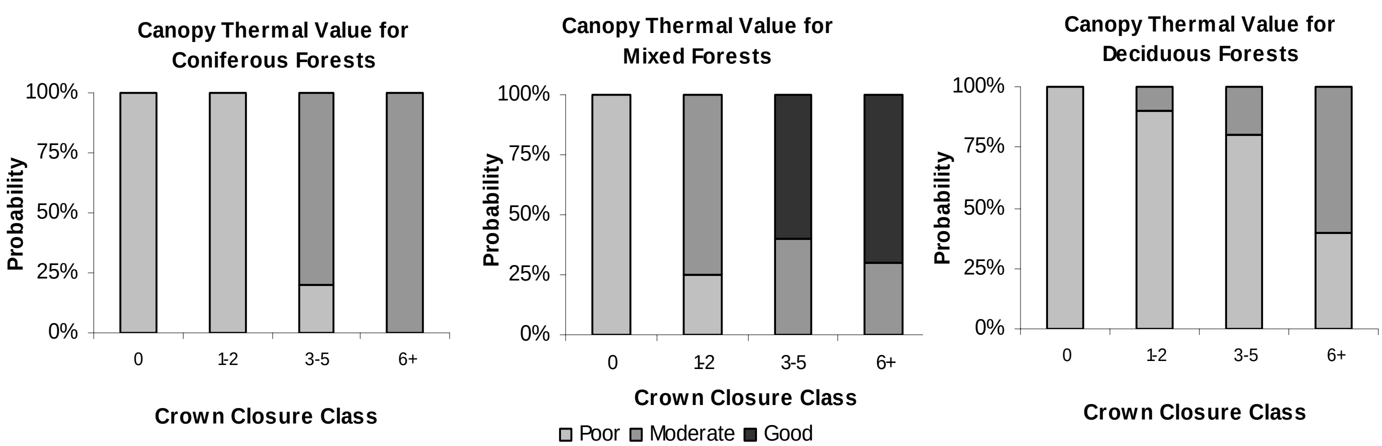

Figure 5. Canopy thermal value for moose in winter based on the crown closure class and forest type. Note that for non-forested and for non-vegetated sites, canopy thermal value is always poor in winter.

Moose Winter Forage Potential

Moose winter forage potential is a parent node that is used to rate overall winter forage potential for a site. Terrestrial forage potential is rated based on the site series, site type, and structural stage. Plot data of species composition and cover by site series and structural stage, and silviculture potential (Banner *et al.* 1993) was used to develop the ratings. In winter, moose typically forage on woody shrub species and small trees (See Table 1 for a list of shrub species considered important forage to moose in winter).

Table 1. Winter food sources used by moose.

Type of Food	Plant Species		
Trees	*Abies lasiocarpa* *Betula papyrifera* *Populus trichocarpa*	*Populus tremuloides* *Thuja plicata* *Picea glauca*	*Pinus contorta* *Pseudotsuga menziesii*
Shrubs	*Salix* spp. *Ribes* spp. *Cornus stolonifera* *Acer glabrum* *Vaccinium* spp.	*Alnus tenufolia* *Shepherdia Canadensis* *Betula glandulosa* *Lonicera involucrata* *Menziesia ferruginea*	*Amelanchier alnifolia* *Sorbus* spp. *Alnus viridis* spp. *sinuata* *Prunus pensylvanica* *Sambucus racemosa*
Herbs	*Carex* spp.	grasses	

The most preferred winter food species reported in the literature include *Salix* spp., *Sorbus* spp., *Populus tremuloides, Prunus pensylvanica and Betula papyrifera.* Most researchers have also observed an increase in the use of *Abies lasiocarpa* in late winter when snow levels are at highest and other foods may not be available.

Variable: ALAL_W_Forg = Moose Winter Forage Potential

Winter Mobility

The ability of moose to move about the landscape is termed "mobility" in this model. The mobility of moose in winter is dependent on snow depth. In this model, coarse scale snow depth values based on biogeoclimatic subzone are modified by aspect and elevation to predict moose mobility. In a normal winter, moose do not typically use elevations above 900m above sea level. In a low snow year, moose movements are not necessarily restricted by snow depth and therefore elevation is not a factor. Note that this model predicts habitat suitability and value for normal conditions and not for severe or gentle winter conditions.

Example Relationship: ***Conditional Probability Table***

Where: SMobility = Moose Mobility in winter

ELE = Elevation (meters above sea level)

ASPECT = Aspect: warm, cool, or flat (slopes <10°).)

SNOW = Snow depth by biogeoclimatic subzone

Elevation

Elevation bands of <900m, 900-1000, 1000-1200 and >1200m are included in the evaluation of snow depth because biogeoclimatic subzones alone are too coarse of a delineation to fully describe the relationship of snow depth and the mobility of moose. Elevations greater than 1200m are considered to have too great a snow load for moose in a normal winter in the study area. In this area, this elevation band tends to be located in the lower ESSF zone.

Variables: ELE = Elevation

Aspect

Aspect is simplified into: warm (136° to 270°), cool (271° to 135°), and "flat" (sites that have slope less than 10°). A flat aspect is presumed to have no impact on snow depth or conditions. Cool aspects are assumed to maintain higher snow depths relative to warm aspects, which experience higher melt due to warming.

Variables: ASPECT = Aspect classes

Snow Depth

Snow depth is separated into three categories, shallow, moderate, and deep, which are linked to biogeoclimatic subzones in a lookup table. These categories were delineated according to moose response to snow loads. Subzones that have snow depths greater than 70cm persisting for more than 2 weeks are considered to be not suitable. Snow depth is a parent node that influences both the mobility of moose and the value of a site as thermal cover.

Variables: SNOW = Snow Depth by biogeoclimatic zone

Crown Closure Class

Canopy closure affects thermal cover value by shading the forest floor from the heat of the sun during warmer temperatures and by reducing wind chill by minimizing air movement and reducing radiation to the open sky during low temperatures in winter. High canopy 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. The crown closure also affects how much snow interception there is. The higher the crown closure, the better the snow interception. Better snow interception results in reduced snow depth under the canopy. As well, when snow accumulates on the canopy and then falls to the ground, the snow tends to pack, which can make travel relatively easier than in open areas. Crown closure classes are summarized in this node as: class 0 (no canopy), class 1 and 2 (low canopy), class 3 to 5 (moderate canopy), and class 6+ (high canopy).

Variable: CRNCL_CL = Crown Closure Class

Forest Type

Forest composition influences how effective the canopy and the understory can be in providing thermal cover (from the wind and blowing snow and from overheating on warm days). The classes are: coniferous, mixed, deciduous, non-forested, and non-vegetated. In the winter, stands with more coniferous and mixed canopy provide better thermal cover habitat.

Variable: FT = Forest Type

Moose Winter Habitat Suitability

Moose winter habitat suitability is evaluated spatially in ArcView GIS 3.2. This analysis spatially evaluates feeding habitat and thermal cover value. Some habitats offer both thermal cover value and feeding value; however, many habitats do not supply both valuable foraging and thermal cover. In a normal winter, moose use foraging habitats that are within a certain proximity to thermal cover. This distance has been reported differently for other study areas (See Table 2), however, after review and consultation with the Ministry of Water, Land and Air Protection (Smithers, BC), a distance of 100m was agreed upon as the maximum distance between foraging habitat and thermal cover in winter. Feeding habitat is not considered as valuable to moose if it is more than 100 m from thermal/snow interception cover habitat. Habitat providing moderate to high value thermal cover is considered more valuable if it also provides high value feeding habitat (e.g. riparian forest, edge habitats). Additionally, habitats providing only thermal cover are not considered as valuable to moose if they are more than 100 m from feeding habitat.

Table 2. Proximity distances reported between feeding and cover habitats from a review of the literature.

Distance (m)	Season	Details	Study Area Location	Citation
530	All	Maximum distance to cover in boreal forest	Alberta	Eastman 1974
40	Winter	Beyond 40 m from cover, frequency of use decreased and became zero at approximately 100 m from cover	Ontario	Hamilton and Drysdale 1975
200	All	< 75 m is considered optimal	Alberta	Tomm *et al.* (1981)
80	Winter	95% of browse activity within 80 m of cover	Ontario	Hamilton *et al.* (1980)

Distance (m)	Season	Details	Study Area Location	Citation
60	Winter	Cow/calf groups ranged 3-60 m from cover (mean of 27 m) in early winter and 0-30 (mean12 m) in late winter, distance decreased with increasing snow depth	Ontario	Thompson and Vukelich (1981)
N/A	Summer	No difference in browsing at varying distances from edge; authors note that no predators exist in study area	Sweden	Andren and Anglestam 1993
100	Spring	Female moose with calves	Alberta	Penner (1997) *in* Higgelke and Macleod 2000
100	Winter	Maximum distance from cover habitat	Alberta	Higgelke and Macleod 2000

The general process followed in the spatial evaluation of winter habitat suitability is depicted in Figure 6. Thermal cover value and foraging habitat value from Netica© were linked back to the polygons in ArcView 3.2. Three spatial layers were generated on a 25m grid for: high thermal cover, moderate thermal cover and feeding habitat value. The descriptive feeding habitat values of “nil” to “very good” were translated into habitat suitability index (HSI) values which could be used in the GIS as described in Table 3. For each thermal cover layer, the number of same value cells within a 100m radius neighbouring each cell was summed. The two grid layers for moderate and high cover values were then summarized into a total thermal cover layer as described by the equation below. These values were also reported as HSI values (ranging 0 to 1).

Thermal total is a weighting and sum of high and moderate value thermal cells within 100m radius of each cell. The total value of thermal cover within 100m of each cell was calculated:

Equation:

$$\text{Thermal Total} = ((H/49) + (0.7*(M/49))$$

There are a total possible 49 cells (within 100m radius) that can be summed and the High value: Moderate value is weighted 10:7 ratio.

Table 3. Feeding habitat ratings from Netica and habitat suitability index (HSI) values.

Feeding Habitat Rating	**HSI**	**Feeding Habitat Rating**	**HSI**
Very Good	1.0	Good	0.9
Moderate	0.5	Poor	0.1
Nil	0		

The total thermal cover layer and the feeding habitat value layer (both reported as HIS values) were then linked in the GIS to calculate a single them for moose winter habitat suitability using the following equation:

Equation:

$$\text{Winter Suitability} = ((F*1.5) + (T*0.6))/2$$

Where: F = Forage HSI value

T = total thermal cover value

Foraging habitat was weighted 2.5 times more than the total thermal cover in the 100m radius surrounding each cell. In a normal winter, moose mostly focus on attaining forage, and only secondly for thermal cover in areas surrounding foraging habitat.

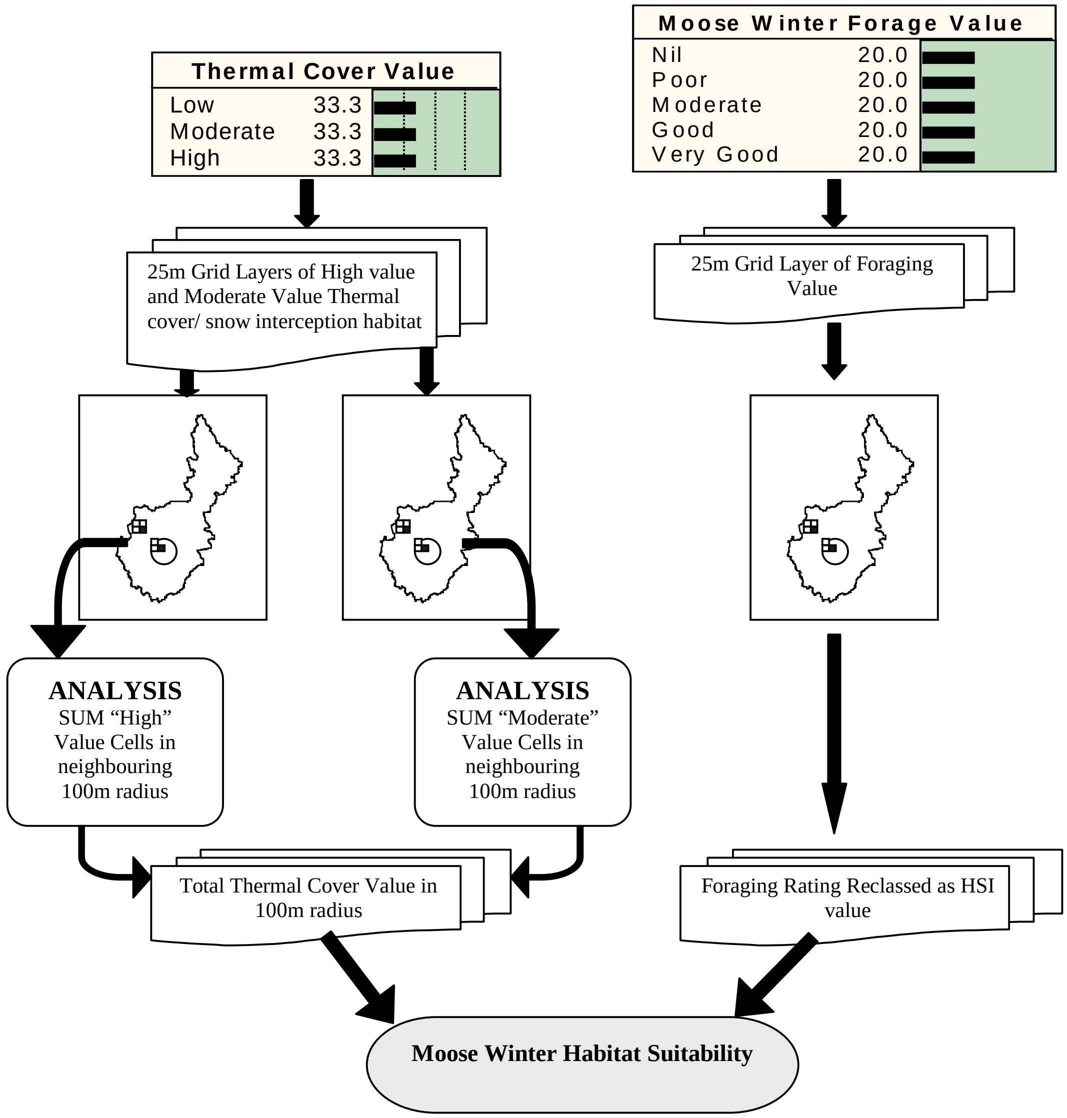

Figure 6. Procedure for spatial analysis of winter habitat suitability in ArcView GIS 3.2 using the aspatial output of winter thermal cover and foraging habitat values from Netica© .

Moose Summer Habitat Suitability

The following section describes the summer habitat suitability model (See Figure 7) and the assumptions used to define the relationships used in the model. The summer habitat suitability rating is meant to be interpreted at the landscape level and not used as a stand management interpretation.

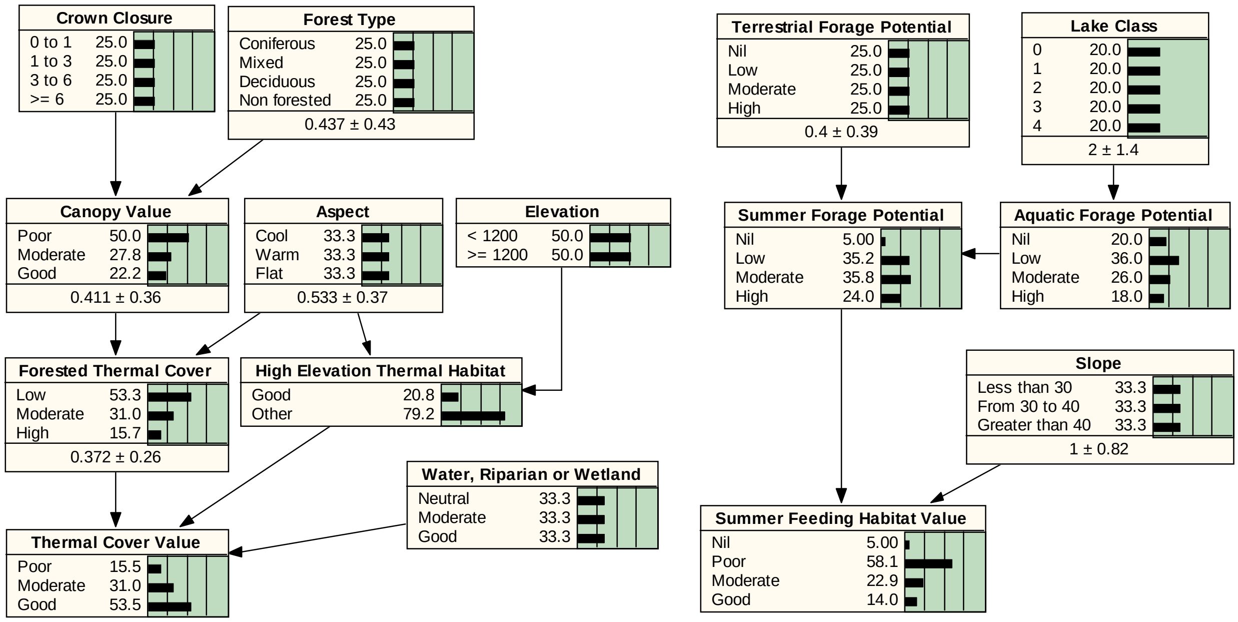

Figure 7. Habitat variables and ecological relationships used to build the moose summer foraging and thermal habitat suitability Bayesian belief model in the Netica© program.

Model Description

The summer habitat suitability model for moose is largely dependent on the ability of the habitat to provide foraging opportunities within a certain proximity to thermal habitat. Foraging and thermal habitat are described using a set of elements from various map layers. The following section outlines the components of the summer foraging habitat and thermal cover models in Netica© and the spatial evaluation of these values as summer habitat suitability.

Summer Habitat Suitability Model Assumptions

1. In summer, moose browse on a variety of shrubs and herbs. Moose primarily use shrubs and aquatic vegetation.
2. Wetland complexes, with suitable aquatic forage, are rated high for feeding habitat during the growing season.
3. As moose disperse from winter ranges, food habits shift from browse and bark stripping to newly growing herbs and new shoots and leaves on shrubs, especially willow and an assortment of aquatic plants which grow in lakes, ponds, and other small water holes (Edie, Morice LRMP Biodiversity Report 2003 draft).
4. In summer, it is very important to moose to have access to thermal shelter (to avoid overheating). Access to shade and/or water is a very important component of effective summer range. Moose may select cooler topographic locations such as high elevation, north-facing valleys
5. During the growing season, thermal habitat is a function of canopy closure (e.g., stands with 25%-50% canopy closure offering shade are rated as class 2 or better thermal habitat). Additional features that affect thermal habitat ratings for moose in the growing season include topography, aspect, slope and elevation.
6. In summer, early seral habitats and very steep slopes are not used.

Description of Network Nodes

Summer Feeding Habitat Value

The summer feeding habitat value is based on an evaluation of the potential of the site to supply summer forage (species composition and cover) and on the slope of the site (See Figure 8). The evaluation of abundance (supply) of summer forage is based on the site series, site type, and structural stage and this relationship to species and cover. Slope affects feeding value as an issue of access.

Example Relationship: ***Conditional Probability Table***

Where: MFHV = Moose summer feeding value

Forage = Summer Forage Potential

Slope = Canopy thermal cover value

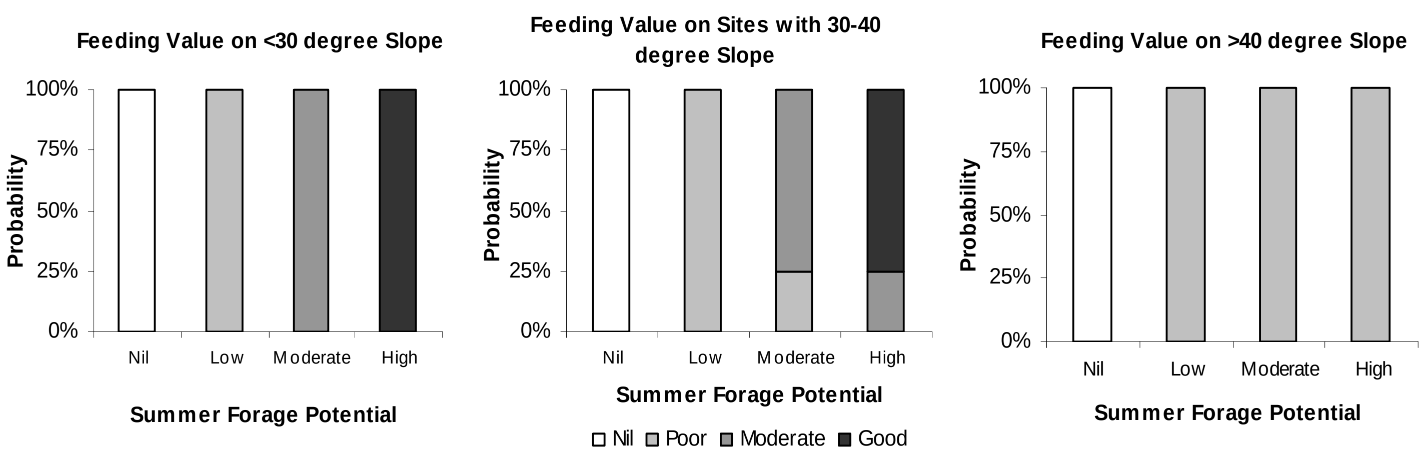

Figure 8. Feeding habitat value based on the potential of the habitat to supply summer forage (based on site series, site type, and structural stage) and on the slope of the site.

Summer Forage Potential

Summer forage potential is an evaluation of the habitats' potential to supply, in its current structural stage, forage species and cover (See Table 4). In summer, moose use both terrestrial vascular vegetation and aquatic vegetation. Because there are no inventories of aquatic vegetative cover available in the Morice or Lakes data set, a surrogate measure of lake class (size) was used and an assumption that a proportion of a lake (along the edges in the littoral zone) support forage vegetation.

Example Relationship: ***Conditional Probability Table***

Where: Forage = Summer forage potential

ALAL_S_Forg = Terrestrial forage potential

AFP = Aquatic forage potential

Table 4. Conditional Probabilities predicting summer forage potential based on terrestrial and aquatic forage abundance.

Terrestrial Forage Potential	Aquatic Forage Potential	Summer Forage Potential			
		Nil	Low	Moderate	High
Nil	Nil	100	0	0	0
Nil	Low	0	100	0	0
Nil	Moderate	0	0	100	0
Nil	High	0	0	0	100
Low	Nil	0	100	0	0
Low	Low	0	100	0	0
Low	Moderate	0	50	50	0
Low	High	0	33	34	33
Moderate	Nil	0	0	100	0
Moderate	Low	0	50	50	0
Moderate	Moderate	0	0	100	0
Moderate	High	0	0	50	50
High	Nil	0	0	0	100
High	Low	0	33	34	33
High	Moderate	0	0	50	50
High	High	0	0	0	100

Aquatic Forage Potential

Aquatic vegetation is an important source of forage to moose in the summer. It is assumed that larger lakes had proportionately less littoral zone and smaller lakes tend to be more eutrophic (more productive) and therefore may support more aquatic vegetation (See Figure 9).

Example Relationship: ***Conditional Probability Table***

Where: AFP = Aquatic forage potential

Lake_Area = Lake Class

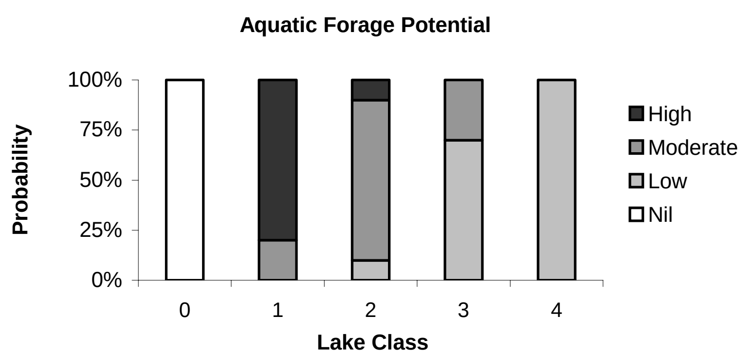

Figure 9. Prediction of aquatic vegetation forage potential based on lake class.

Lake Class

Lake class is a derived variable based on lake size (See Table 5) and is used to predict aquatic forage abundance.

Variable: Lake_Area = Lake Class

Table 5. Lake Class and size (hectares).

Lake Class	Size (Hectares)	Lake Class	Size (Hectares)
1	>0 - 10	3	25 – 100
2	10 - 25	4	100+

Terrestrial Forage Potential

Terrestrial forage potential is a parent node that is used to rate overall summer forage potential for a site. Terrestrial forage potential is rated based on the site series, site type, structural stage, plot data by site series (species composition and percent cover), and silviculture potential (Banner *et al.* 1993).

Variable: ALAL_S_Forg = Terrestrial forage potential

Foods that are used by moose during spring and summer are summarized in Table 6 (Peek 1974, Peek *et al*. 1976, Eastman 1977, Belovsky 1981, Blower 1982, Simpson *et al*. 1988, Westworth *et al.* 1989, MacCracken *et al.* 1997). The most preferred summer food species reported in the literature include *Salix* spp., grasses and aquatic plants.

Table 6. Spring/Summer food sources used by moose.

Type of Food	Plant Species		
Trees	*Populus balsamifera*		
Shrubs	*Salix* spp. *Rubus chamaemorus* *Paxistima myrsinites* *Cornus stolonifera*	*Rosa* spp. *Rubus idaeus* *Sorbus* spp. *Prunus pensylvanica*	*Viburnum edule* *Sambucus racemosa* *Betula papyrifera*
Herbs	*Equisetum* spp. *Carex* spp.	*Epilobium angustifolium* grasses	*Lupinus arcticus*
Aquatics	*Potamogeton* spp. *Menyanthes trifoliata*	*Sparganium* spp. *Potentilla palustris*	*Nuphar polysephalum* *Calla palustris*

Thermal Cover Value

Thermal cover is important to moose throughout the year. Thermal cover habitats consist mainly of closed canopy mature forests; aquatic environments such as lakes, rivers and ponds may also be used. North to east aspects may also provide cooler temperatures. Therefore, the thermal cover value of a habitat is a measure of canopy closure, aspect, and, if applicable, water type. Other criteria related to biogeoclimatic subzone also influence thermal cover value, such as elevation. Thermal cover in summer is supplied by one of three main habitats: forested, water feature, or suitable high elevation types. High elevation sites that are classed as “good” for thermal cover will result in “good” summer thermal cover.

Example Relationship: ***Conditional Probability Table***

Where: MTCV = Moose summer thermal cover value

FTCV = Forested thermal cover

HEC = High elevation thermal habitat

ALAL_WRW = Water, riparian, or wetland

Table 7. Moose summer thermal cover value.

High Elevation Thermal Habitat	Water, Riparian, or Wetland	Forested Thermal Cover	Summer Thermal Cover Value
Good	Any	Any	Good
Other	Good	Any	Good
	Moderate	High	Good
		Moderate, Low	Moderate
	Neutral	High	Good
		Moderate	Moderate
		Low	Low

Water, Riparian, or Wetland

This node describes habitats that provide thermal cover in the summer through water or riparian habitats (and some wetland types). Water, riparian and wetland types are either: good, moderate, or neutral. Neutral means the habitat is not actually water, riparian, or wetland (i.e. it is forested)(See Table 8).

Variable: ALAL_WRW = Water, riparian, or wetland

Table 8. Water, riparian, or wetland types as thermal cover for moose in the summer.

Site Series, Site Type	Rating
Lakes (LA), Rivers (RI)	Good
Slide Avalanche (SA), Alder/Willow (AW), Riparian Shrub (RS), Cow-Parsnip (CP), Wet Meadow (WM), Wetland (WL)	Moderate
All Other	Neutral

High Elevation Thermal Habitat

High elevation thermal habitat is described as habitats that are above 1200m above sea level and located on “cool” aspects. “Other” refers to all other habitats (See Table 9).

Example Relationship: ***Conditional Probability Table***

Where: HEC = High elevation thermal habitat

ASPECT = Aspect class (cool, warm, flat)

ELE= Elevation (metres above sea level)

Table 9. High elevation thermal habitat value based on elevation and aspect.

Elevation	Aspect	High Elevation Thermal Habitat	
		Good	Other
<1200	Any	0	100
>=1200	Cool	100	0
>=1200	Warm	0	100
>=1200	Flat	25	75

Elevation

Elevations of <1200m and >=1200m are used in the evaluation of high elevation thermal cover in the summer because biogeoclimatic subzones alone are too coarse of a delineation to fully describe the relationship of thermal cover.

Variables: ELE = Elevation

Aspect

Aspect is simplified into three states: warm (136° to 270°), cool (271° to 135°), and "flat" (sites that have slope less than 10°).

Variables: ASPECT = Aspect classes

Forested Thermal Cover

Moose use closed canopy forests in mature, multi-layered stands in the summer to avoid thermal stress (overheating). The value of the forested stand as thermal cover for moose is dependent on the canopy value (based on forest type and crown closure) and aspect of the site (See Figure 10).

Example Relationship: ***Conditional Probability Table***

Where: FTCV = Forested thermal cover value

ASPECT = Aspect class (cool, warm, flat)

CCV = Canopy value

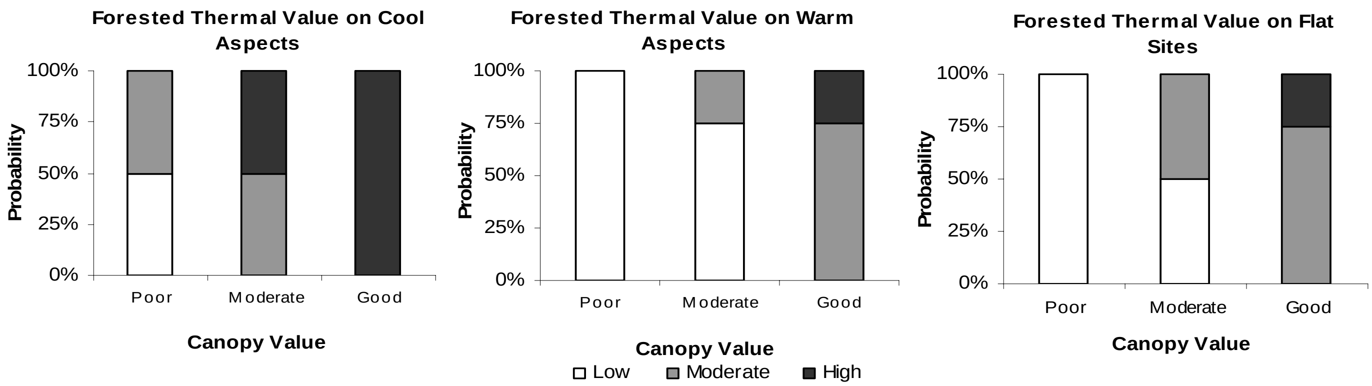

Figure 10. Forested thermal cover ratings based on canopy value and aspect.

Canopy Value

Canopy value is a measure of a habitats' ability to provide forested thermal cover in summer. A value, from poor to good, is assigned based on the canopy closure class and forest type as indicated in Figure 11). Non-forested sites and sites with crown closure class 0 have "nil" value for canopy value.

Example Relationship: ***Conditional Probability Table***

Where: CCV = Canopy Value

CRNCL_CL = Crown closure class

FT = Forest type

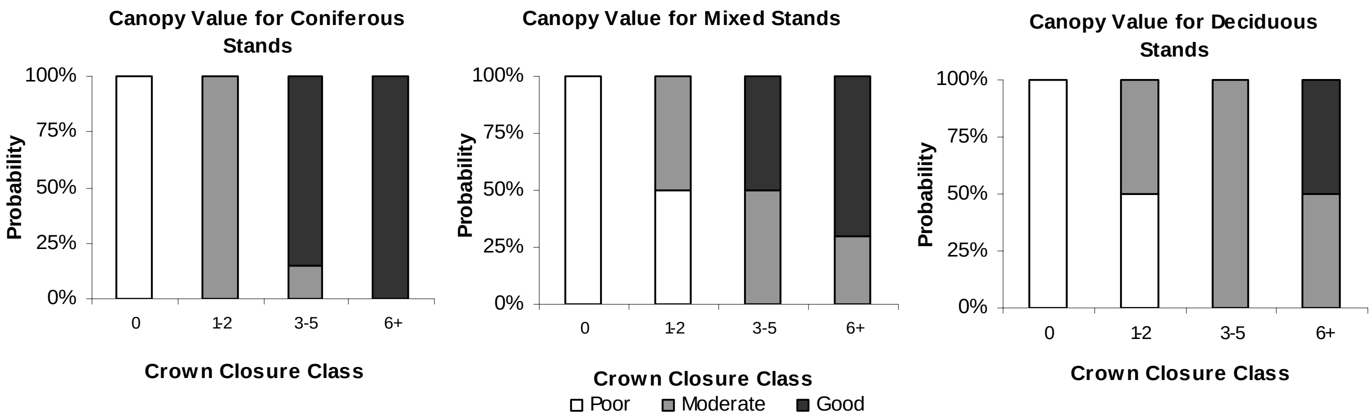

Figure 11. Canopy value for providing thermal cover based on crown closure class and forest type.

Crown Closure

Crown closure is summarized into a series of classes, from 0 to 6, from the forest cover dataset. Crown closure provides a barrier from the sun, which results in cooler air under the crown than the ambient air.

Variables: CRNCL_CL = Crown closure class

Forest Type

Forest type affects thermal cover in the summer. 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. However, it is assumed that coniferous stands tend to be better types for thermal cooling than are deciduous stands. Possible states for this node are: Coniferous (greater than 80% stand coniferous), mixed forest (20-80% deciduous), deciduous (greater than 80% deciduous), and non-forested.

Variables: FT = Forest Type

Moose Summer Habitat Suitability

Moose summer habitat suitability is evaluated spatially in ArcView GIS 3.2 based on the Netica© model results for thermal cover and feeding habitat, as described previously for moose winter habitat suitability. It is likely that thermal cover is not a limiting feature for moose in the summer; habitats are mainly selected for forage within proximity of thermal types. The distance between feeding habitat and thermal cover is not as restricted as it is in winter, as there is no snow to travel through. There was not much direction in the literature for defining an optimal distance in summer (See Table 2). Therefore, two distances were chosen for comparison: 100m and 400m radius neighbouring a cell. The results of this comparison will inform the selection of a radius to use in future land base scenarios.

The general process used to conduct the spatial analysis is illustrated in Figure 12. Thermal cover value and feeding habitat value from Netica© were linked back to the polygons in ArcView 3.2. Spatial layers in 25m grids were generated for high and moderate thermal covers and for foraging value. For the evaluation of thermal cover within a 100m radius: The number of cells within a 100m radius of each cell was summed for both high and moderate thermal cover. Total thermal cover was calculated and values reported as HSI values (ranging 0 to 1) using the equation below.

Thermal total is a weighting and sum of high and moderate value thermal cells within 100m radius of each cell. The total value of thermal cover within 100m of each cell was calculated:

Equation:

$$\text{Thermal Total} = ((H/49) + (0.5*(M/49))$$

There are a total possible 49 cells (within 100m radius) that can be summed and the High value: Moderate value is weighted 2:1 ratio.

The evaluation of thermal cover within a 400m radius had more steps because of the capacity of ArcView to intersect such large datasets. Before the sum of high, sum of moderate, and forage layers could be intersected, both the high and moderate were reclassified into HSI values (twenty categories from 0 to 1, in 0.05 increments) before these layers were joined.

The moose summer feeding habitat values from Netica© were reported as categorical descriptive values. These were reclassified into HSI values (See Table 10) to be used in the GIS.

Table 10. Summer feeding habitat ratings from Netica and habitat suitability index (HSI) values.

Feeding Habitat Rating	HSI	Feeding Habitat Rating	HSI
Good	1.0	Poor	0.1
Moderate	0.6	Nil	0

Moose summer habitat suitability is calculated with the following equation:

Equation:

$$\text{Summer Suitability} = ((F) + (T*0.7))/2$$

Where: F = Forage HSI value

T = total thermal cover value

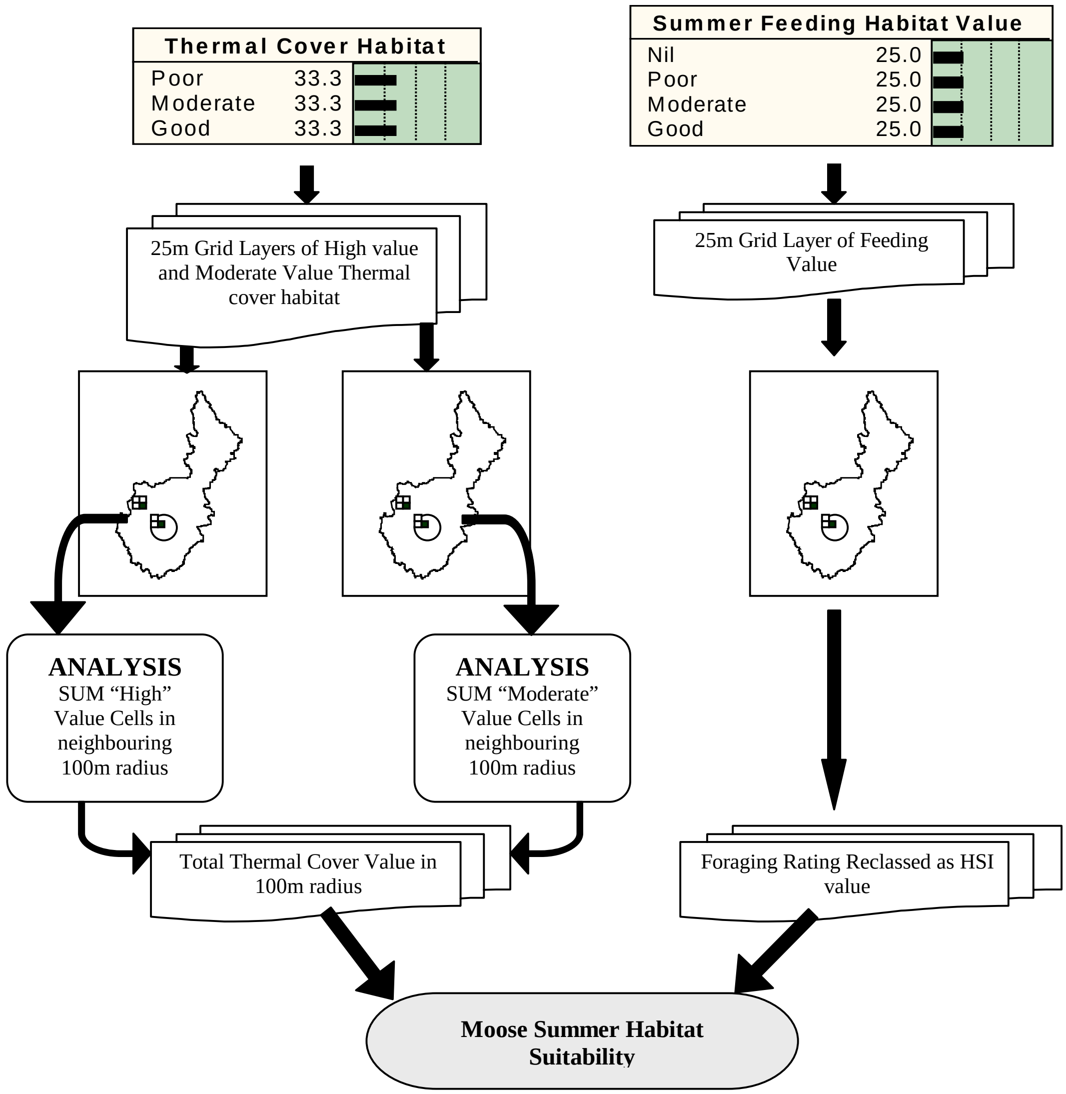

Figure 12. Procedure for a spatial analysis of summer habitat suitability in ArcView GIS 3.2using the aspatial output of summer thermal cover and foraging habitat value from Netica©

Sensitivity Analysis

Testing and Validation

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.

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 Water, Land, and Air Protection (MWLAP) wildlife ecologists (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. The moose winter model also involved comparing the suitability ratings (during the spatial analysis) against known and mapped survey data in a portion of the Morice forest district. Winter moose survey conducted by the MWLAP in 1992, 1997, and 2002 were mapped and the rating strata were used to compare our output against.

Research Needs for Model Verification

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 Schröeder 2002). The importance of the landscape structure varies according to the demographic characteristics of the population (Söndgerath and Schröder 2002, With and King 1999).

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