A Habitat Supply Model for Moose Within the Manitoba Model Forest Region

Introduction

The management of wildlife habitat through forest management planning activities is becoming increasingly sophisticated. Geographic information systems (GIS) have allowed forest managers to efficiently assess large landscapes for their potential to support various wildlife species through the use of spatial habitat supply models (HSM). These models can examine the effects of different forest management strategies through time. These tools can provide easily understood map-based products to help both professionals and the general public in making informed decisions from amongst forest management alternatives.

This project's objective was to create a habitat supply model that could assess forests in and around the Manitoba Model Forest for their potential to support moose (Alces alces sp.). The basis for the model is the habitat suitability index (HSI) developed for moose in this area (Palidwor et. al. 1995) and later adapted to the new forest inventory for the Duck and Porcupine Mountains (V.Crichton pers. comm.). This moose HSM is designed to be part of the overall indicator modeling strategy in forest management planning on the model forest (see Manitoba Model Forest Indicator Modeling Design Document Template - prepared by KBM Forestry Consultants: 23/03/2005)

The model we have developed is theoretical in nature as the relationships between habitat quality and environmental parameters have been assumed at the outset rather than derived from reverse fitting to actual field observations (Morrison *et. al.* 1998). Habitat models such as this should be considered a formalization of our knowledge about the system (Hall and Day 1977) or, more accurately, as a current working hypothesis of species-habitat relationships as opposed to a statement of definitive cause and effect (Van Horne and Wiens 1991, Morrison *et. al.* 1998). This model was developed through a detailed literature review; however the lack of studies in northern Manitoba required information to be used from other boreal forest regions and drew upon the senior author's experience in northern Ontario.

The Habitat Supply Model Building Process

The process of developing a habitat supply model for moose in the Manitoba Model Forest region involved several key stages:

1. Literature review to identify the forest characteristics of key habitat features for moose in Boreal shield conditions.
2. Examine the 1995 and 2003 HSI's developed for the Manitoba Model Forest.
3. Create HSI curves for seasonal habitat elements using the 1995 HSI as a base.
4. Create HSI equations for seasonal habitat components and overall seasonal habitat.
5. Incorporate proximity analysis elements to address distance dependant relationships between important habitat components.

6. Develop a year-round moose habitat suitability index derived by integrating the values of seasonal moose habitats at the scale of an average moose home range.

Development of Habitat Suitability Indices (HSI)

Site and Stand Characteristics of Moose Forage and Cover

Moose seek food and cover based on the age, species composition and crown closure of forest stands. Well-drained, productive sites (e.g. loamy soils) produce the best habitat for moose. Sites that tend to be dry and unproductive (e.g. sandy soils) do not support high moose densities.
Since most important woody browse species are shade intolerant, stands that are open canopied, young (or very old) and have a good deciduous species component, have a higher HSI for food (see Figures 1 & 2 and Appendix 2) than stands that are closed canopied and have a high conifer component. The latter stands tend to be used by moose as cover for relief from deep snow conditions, predators or temperature extremes (see Figures 5 to 8). Aquatic sites and sites which are sparsely, or not forested can provide some food and cover value for moose (see Figures 4, 9 and 10).

General Habitat Requirements for Moose

Moose, the largest member of the deer family, are particularly well adapted to the Boreal forest type and climatic conditions. Northern Boreal forests are disturbance – driven ecosystems and it is this characteristic more than any other that makes these forests suitable for moose populations. Wildfires, insects and wind events kill "patches" (<1 to >100, 000 ha) of forest to produce the conditions necessary for the establishment of large quantities of successional , deciduous tree and shrub species. Young deciduous tree and shrub species provide the primary food source for this species (McNicol 1990).

In the best habitats for moose, shelter or cover necessary to supply protection from predators, reduce snow depths and ameliorate temperature extremes, is interspersed with or proximate to forage resources. This juxtaposition of forage and cover and other forest components (conifer/mixedwood, riparian/upland, old forest/young forest etc.) produces "edge". The best moose habitats have a lot of "edge". Special habitats (e.g. mineral lick sites), summer aquatic feeding sites and forest habitats conducive to calving (i.e. enable predator avoidance) add other important habitat components for moose.

Summer and Winter Forage Requirements
Deciduous Forage

Most summer and winter food required by moose is supplied by the leaves, twigs and stems of deciduous shrub and tree species. Large quantities of trembling aspen (*Populus tremuloides*), white birch (*Betula papyrifera*), willow (*Salix* sp.), beaked hazel (*Corylus cornuta*), mountain ash (*Sorbus americana*) and pin cherry (*Prunus pensylvanica*), amongst others, are necessary to sustain these ruminants. Most of these deciduous trees and shrubs are shade intolerant and grow best when they are exposed completely to sunlight. These trees and shrubs have evolved to quickly establish in areas where mature overhead cover has been removed. Clearcutting, the primary forest harvesting approach in the boreal forest, is designed to remove the mature forest canopy, as happens with natural disturbances such as wildfires. Once the forest canopy is removed, shade intolerant deciduous and coniferous regeneration quickly establish producing browse in comparable amounts and quality as wildfire (Lautenschlager et al.1997, Collins and Schwartz 1998). The higher the quality of the forage, the greater is the fitness of the animals through improved condition before winter (Regelin et al. 1987) and at the end of winter (Saether and Andersen 1990).

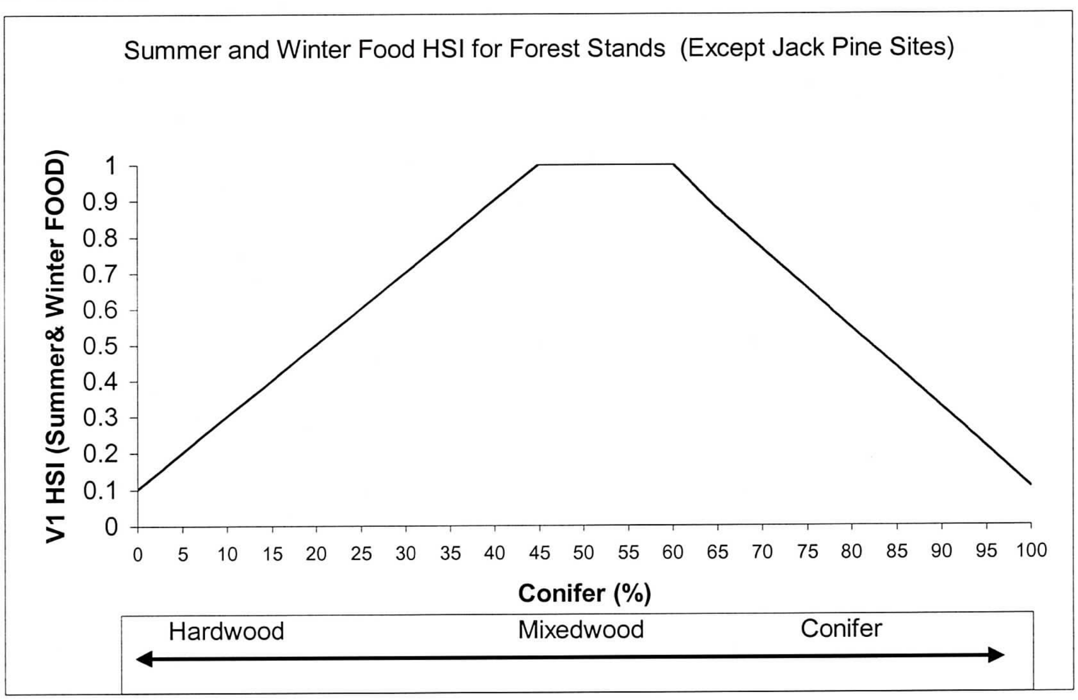


Figure1: Habitat suitability indices (HSI) for moose summer and winter browse (Variable 1) on hardwood, mixedwood and conifer sites except where jackpine is the dominant conifer species.

The mature forest border around or within a recent disturbance (e.g. a wildfire, a clearcut etc.) has been shown to receive preferential use by moose. Shoreline reserves adjacent to

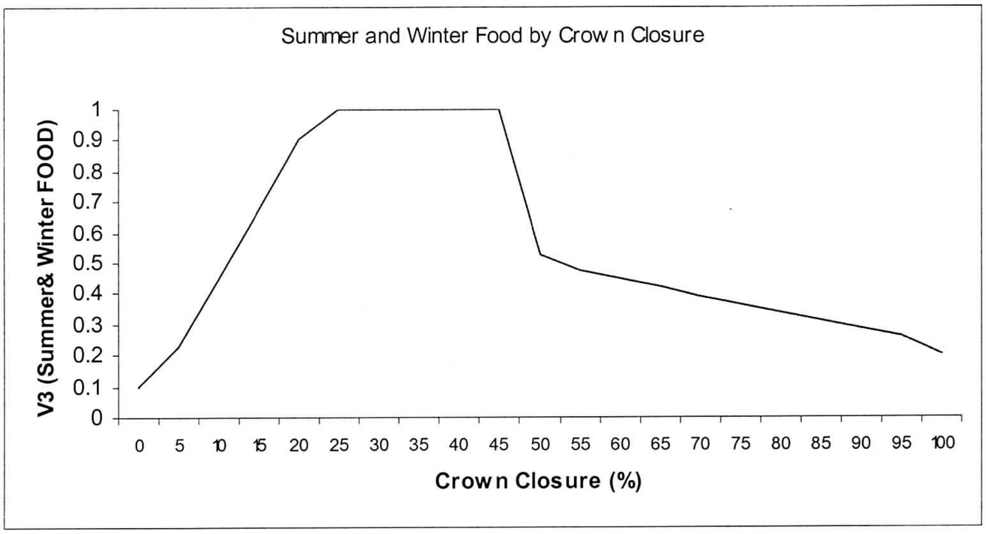


Figure 2: The relationship between forest crown closure and the availability of summer and winter food (Variable 3). See also crown closure affect on cover values (V6) in Appendix 1.

clearcuts were preferred winter habitats for moose in a study in northeastern Ontario (Brusnyk and Gilbert 1983). The authors believed the conifer/forage edge to be important. Mastenbrook and Cumming (1989) found that strips of residual conifer (approximately 120m in width) used to separate larger clearcuts were preferred use areas for moose in early winter. McNicol and Gilbert (1980) and Hamilton et al. (1980) also documented preferred use of border edge around clearcuts by moose in winter.

These findings indicate there is a relationship between forage acquisition by moose and proximity to cover. These studies indicate that although a recent disturbance area might produce large quantities of browse, not all of that food resource was likely to be available to moose since it was too far from cover able to provide predator escape or moderation of environmental conditions (e.g. warm temperatures or deep snow). While this relationship is discussed further in following sections dealing with cover requirements, it is important to understand this connection between residual and peripheral cover and how it affects moose access to food.

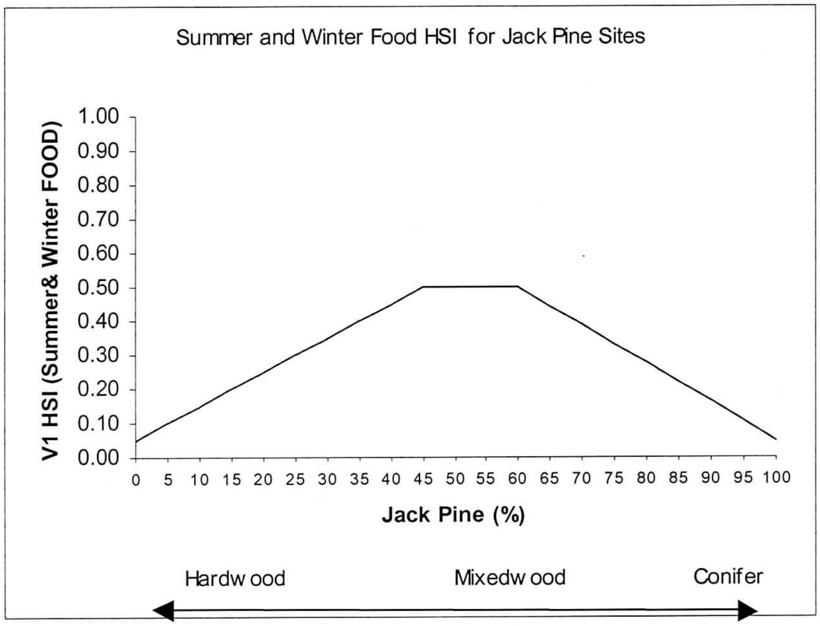


Figure 3: Habitat suitability indices (HSI) for summer and winter food (Variable 1) on dry, relatively unproductive sites where jackpine is the dominant conifer species.

Aquatic Forage

Forest cover adjacent to aquatic feeding sites may serve to provide moose with resting cover between feeding bouts, thermoregulatory cover, security cover for calves when cows are feeding, travel corridors to and from feeding sites etc. In Ontario for example, forest management guidelines suggest that usually a 120 m no cut reserve (shape and extent determined by surrounding habitat conditions) should be left around these sites. Little research exists however concerning whether shoreline reserves left to maintain or encourage use of aquatic feeding sites actually achieve that objective.

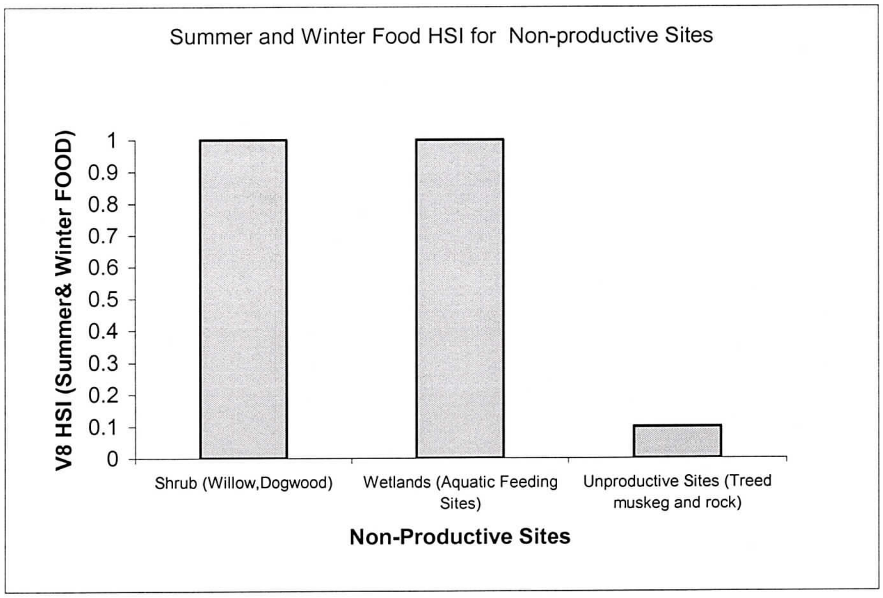


Figure 4: Habitat suitability indices (HSI) for summer and winter food (Variable 8) from non-productive sites. These sites include willow riparian areas and aquatic feeding sites.

Summer and Winter Cover Requirements

Moose appear to use vegetative cover during all seasons and in reaction to various stimuli. Shelter is sought to ameliorate environmental extremes of heat, cold, wind, deep snow and to provide security from predators including man.

Different types of vegetative cover are used by moose to facilitate movement in deep or crusted snow conditions (usually mature dense conifer- Thompson and Vukelich 1981; Crete and Jordon 1982), to provide protection from winds or escape cover when bedding or feeding (can be mature or immature conifer but close to plentiful forage-McNicol and Gilbert 1980; Hamilton et al 1980; conifer or deciduous but at least 2.5 m in height and dense enough to be able to obscure 50% of a moose at 15m-Courtois et al. 1998) or to provide thermoregulatory cover (a variety of vegetative types and characteristics depending on time of year).

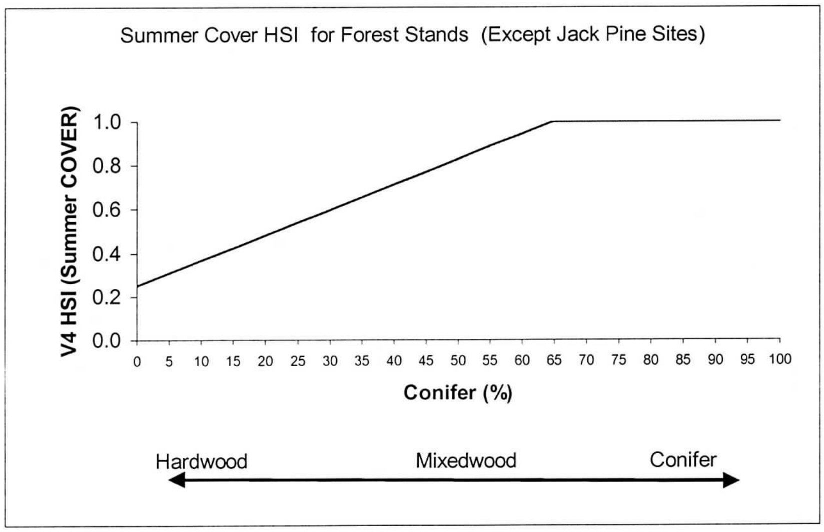


Figure 5: Habitat suitability indices (HSI) for summer cover (Variable 4) on all sites except those dominated by jack pine.

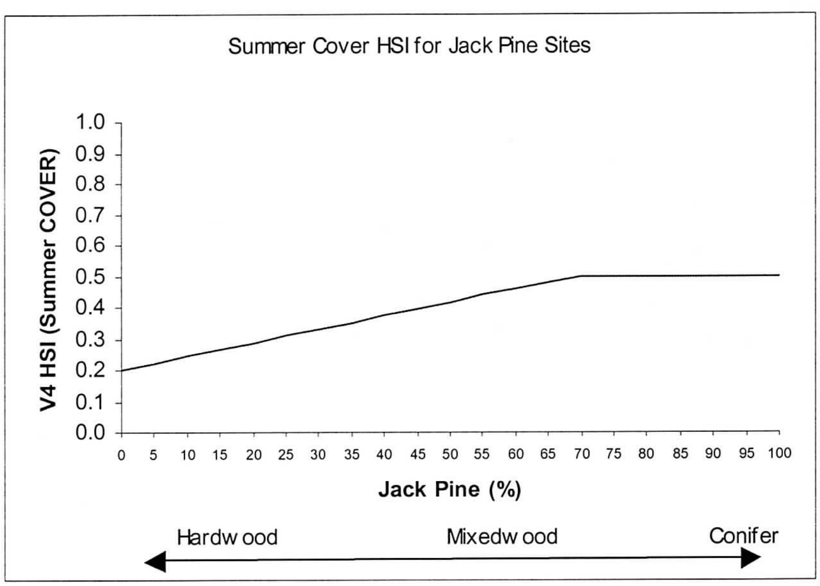


Figure 6: Habitat suitability indices (HSI) for summer cover (Variable 4) on sites that have jack pine as the climax coniferous species.

After the concentrated browsing by moose that occurs in early winter in areas supporting abundant forage, and particularly when snow begins to impede movement, moose move into closed canopy coniferous areas. These areas are generally poor in forage but offer ease of movement (energy savings), perhaps thermoregulatory advantages and adjacent or interspersed browse that can be accessed along the edges of overhead cover. The assumption is that if moose concentrated in forage-rich, open canopied habitats in early winter, they would probably not move far once snow conditions forced them into closed canopy conditions if the appropriate forest types were nearby.

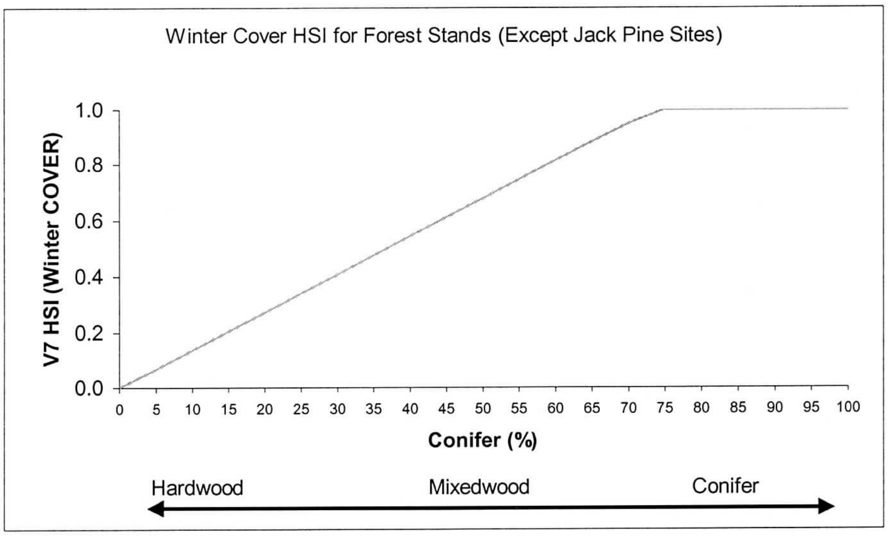


Figure 7: Habitat suitability indices (HSI) for winter cover (Variable 7) on all sites except those dominated by jack pine.

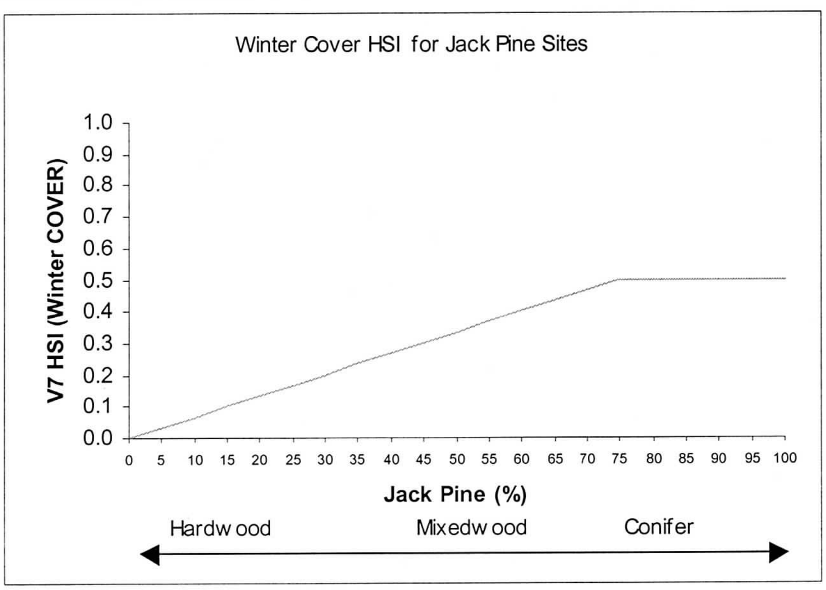


Figure 8: Habitat suitability indices (HSI) for winter cover (Variable 7) on sites that have jack pine as the dominant coniferous species.

Special Habitat Components

Mineral Licks

Mineral licks are relatively rare occurrences, at least in Ontario (see Jackson et al. 1991). In Manitoba mineral licks receive frequent usage in all regions during spring and summer (Cameron, Whaley,Collins, Soprovich pers. comm. in Palidwor et. al. 1995). Many of the waterbodies in eastern Manitoba are typical "shield lakes with rock shorelines and poor aquatic macrophyte production, therefore, mineral licks may be an important local source of minerals for moose (Schindler unpubl. in Palidwor et. al. 1995).

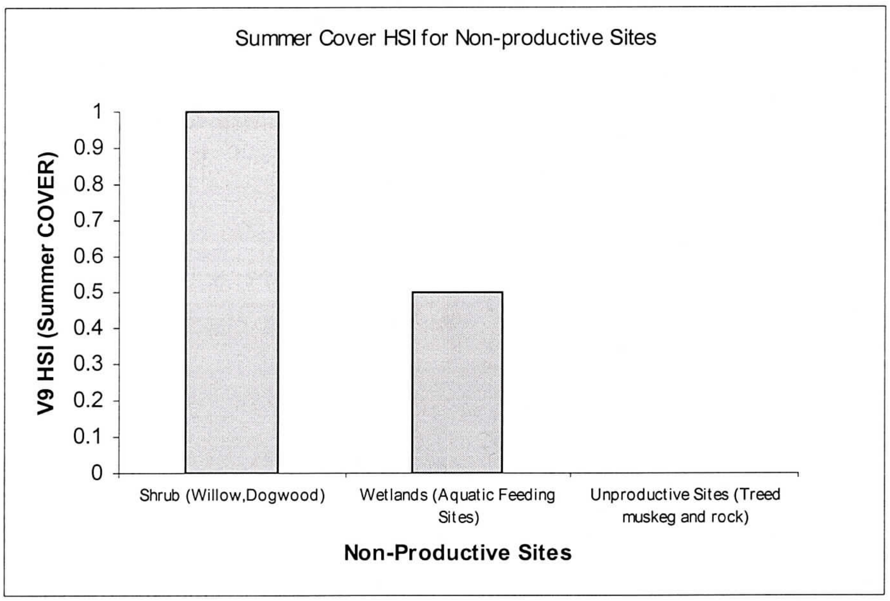


Figure 9: Habitat suitability indices (HSI) for summer cover (Variable 9) from non-productive sites. These sites include willow riparian areas and aquatic feeding sites.

Despite their probable importance, actual calving sites are seldom identified and those that are appear not to possess unique identifiers or even many common physical characteristics that have been identified in the literature for which surveyors could look (see Jackson et. al.1991; Welch et al. 2000). Predator avoidance and nearness to water seem to be common characteristics of many known sites located on islands and peninsulas.

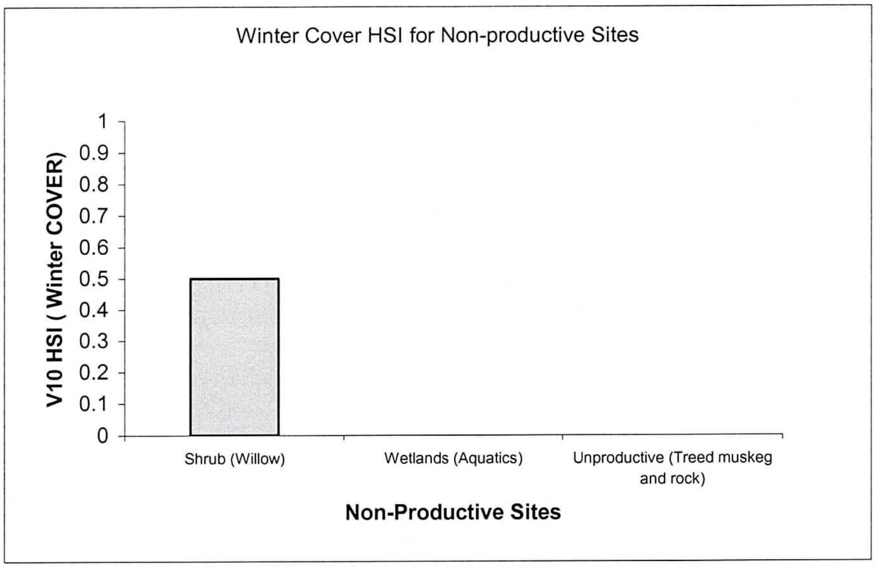


Figure 10: Habitat suitability indices (HSI) for winter cover (Variable 10) from non-productive sites. These sites include willow riparian areas and treed muskeg and rock.

General Moose Habitat Assumptions

(i) Moose acquire most of the nutritional resources that sustain them throughout the year during the summer growing season.

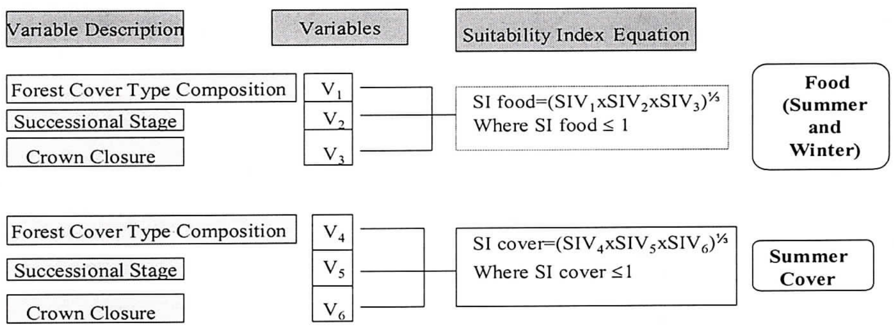
(ii) Feeding on aquatic vegetation, where it is available, seems to be important for moose in the early summer.

(iii) Most of the attributes of good summer habitat (juxtaposition of thermal cover, water and browse) are also important in the fall and early winter.

(iv) Habitat used by moose in late winter tends to be closed canopied, conifer dominated stands poor in food resources.

Seasonal Moose Habitat Equations

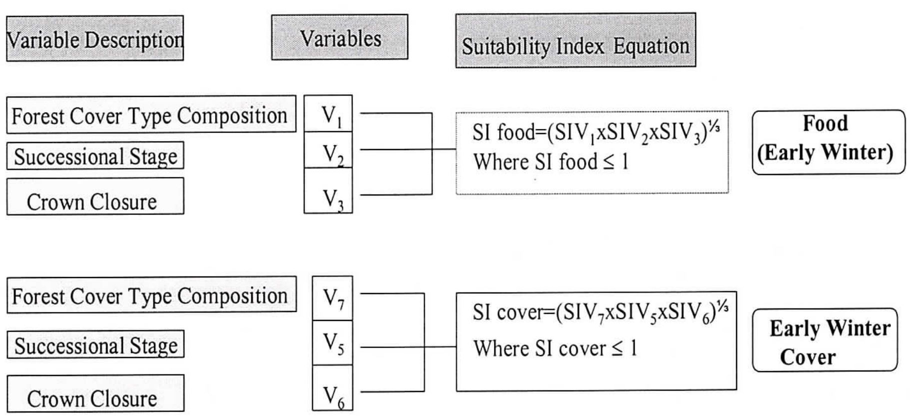
Suitability index (SI) values for seasonal moose habitats were developed by combining the forest parameter variables affecting the quality of the seasonal habitat into an equation (see Figures 11-13). Food and cover were given different arbitrary weightings in the equations with food being heavily weighted in summer and early winter (Fig.11&12) while cover was heavily weighted in late winter (see Fig.13).



Moose Summer Habitat SI $_{\text{Productive Sites}} = [(V_1xV_2xV_3)^{1/3}{}_{\text{FOOD}}\ x\ (.75)] + [(V_4xV_5xV_6)^{1/3}{}_{\text{COVER}}\ x\ (.25)]$

Each 25m² forest cover pixel is assessed for summer food and cover attributes and assigned a value.The assigned value can be modified based on a spatial assessment (100m buffer) around the pixel for other important habitat attributes i.e. water, cover, food.The SI value for one habitat attribute is increased if another habitat attribute is found near by. In the summer, habitats rich in food are higher value if they are close to water and thermoregulatory cover.

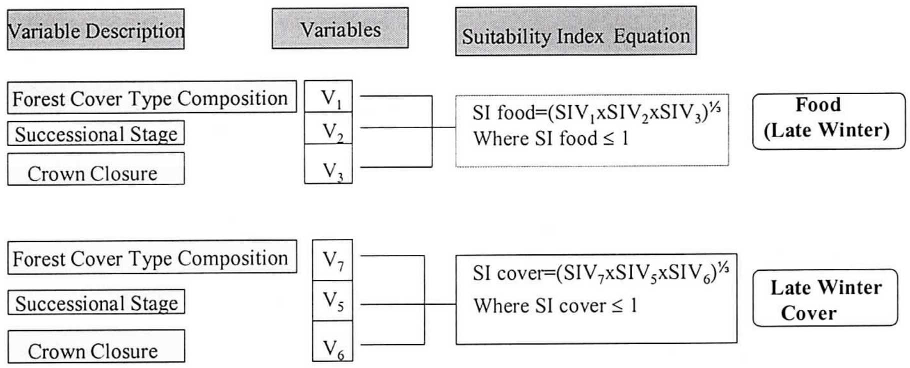
Figure 11: HSM structure for moose summer habitat on the Manitoba Model Forest



Moose Early Winter Habitat SI $_{\text{Productive Sites}} = [(V_1xV_2xV_3)^{1/3}{}_{\text{FOOD}}\ x\ (.75)] + [(V_7xV_5xV_6)^{1/3}{}_{\text{COVER}}\ x\ (.25)]$

Each 25m² forest cover pixel is assessed for early winter food and cover attributes and assigned a value.The assigned value can be modified based on a spatial assessment (100m buffer) around the pixel for other important habitat attributes i.e. water, cover, food.The SI value for one habitat attribute is increased if another habitat attribute is found near by.In early winter, habitats rich in food are higher value if close to escape/thermoregulatory cover.

Figure 12:HSM structure for moose early winter habitat on the Manitoba Model Forest



Moose Late Winter Habitat $SI_{\text{Productive Sites}} = [(V_1 x V_2 x V_3)^{1/3}_{FOOD} \times (.35)] + [(V_7 x V_5 x V_6)^{1/3}_{COVER} \times (.65)]$

Each $25m^2$ forest cover pixel is assessed for late winter food and cover attributes and assigned a value.The assigned value can be modified based on a spatial assessment (100m buffer) around the pixel for other important habitat attributes i.e. cover, food.The SI value for one habitat attribute is increased if another habitat attribute is found near by.In late winter, habitats rich in mature ,coniferous cover which can ameliorate adverse snow and weather conditions are higher value if there is a food source near by.

Figure 13: HSM structure for moose late winter habitat on the Manitoba Model Forest

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Adjustment of SIs Based on Proximity between Foraging and Cover Habitats

Foraging habitat is not as useful to moose if it is further than 100 m from thermal cover during summer and late winter and from hiding cover during early winter. Similarly, both types of cover habitats are not as valuable unless they are within this distance from food. Habitat that contains both foraging and cover opportunities within close proximity to each other should receive a suitability rating higher than those in which one of these resources is lacking. To take this into account, SI food values are adjusted based on each pixel's proximity to thermal or hiding cover. To adjust the summer SI values, a circle of radius 100 m moves over the grid with each pixel, in turn, acting as its centre. The final SIs are calculated as follows:

Adjusted SI food (summer) = [SIfood (summer) xWindow (Max(SIsummer cover))100m]$^{1/2}$

Additionally, thermal cover is not as valuable unless it is within 100 m of good foraging habitat. This requirement is incorporated into the following equation:

Adjusted SI cover (summer) = [SIcover (summer) x Window (Max (Si summer food))100m] $^{1/2}$

The winter SIs (early and late winter) for cover and food are adjusted in the same manner as the summer SIs.

For example: **Adjusted SI food (early winter) = [SI food (early winter) x Window (Max (Si cover (early winter))) 100m]$^{1/2}$**

In addition to the cover/food SI proximity adjustment in the summer, the summer food and cover SI's were enhanced if they were found within 100m of specific water types as given by the equation:

$$\textbf{Adjusted SI (summer}_{\text{food or cover}}\textbf{)} = \textbf{SI}_{\text{(summer food or cover)}} + .1$$

If an assessed pixel had both food and cover values and was found within 100 m of water, the equation was:

$$\textbf{Adjusted SI (summer}_{\text{food and cover}}\textbf{)} = \textbf{SI}_{\text{(summer food and cover)}} + .2$$

Overall Moose Habitat Quality

Once seasonal habitat SI's are adjusted for proximity to other valuable habitat components the overall moose habitat quality can be assessed using a moving "window" which assesses the seasonal habitats at the scale of an average moose home range. The moving "window" assesses the seasonal HSI's for food and cover and integrates them spatially to determine the ability of that portion of the forested landscape to provide good year-round habitat (see The Illustrated Moose Habitat Supply Model for the Manitoba Model Forest document for illustrations of the assessment methodology).

The overall moose habitat HSI equation, assessing pixel values for food and cover within a moving "window" approximating an average moose home range, is given by:

$$HSI_{\text{overall}} = (HSI_s)(.5) + \{(HSI_{ew})(.35) + (HSI_{lw})(.15)\}$$

Computation Methodology

1. Each 25 m^2-forested pixel is first assessed for its seasonal food or cover SI value.
2. Each pixel is then reassessed by searching in a 100m radius for an additional but different habitat attribute. If one is found, the original SI value of the pixel is increased.
3. For summer habitat, all rivers, small lakes (< 260 ha) and small bays on large lakes are given a 100m buffer and pixels with a summer food or cover (or both) SI value found within the 100 m buffer have their SI values increased.
4. Overall moose habitat quality is assessed using an assessment "window" approximating the size of a moose home range that moves across the landscape in a grid pattern assessing overall moose habitat seasonal components for all seasons at the scale of a moose home range.

Analysis Products

1. Digital layers and paper maps depicting:
   a. High, medium and low potential seasonal moose habitat areas for the Manitoba Model Forest.

b. High, medium and low potential year-round moose habitat areas for the Manitoba Model Forest assessed at the scale of an average moose home range.

Home Range Smoothing

Moose have the capability to select certain sections of their home range in which to forage or take cover. The overlapping "moving window" approach of assessing the landscape at the scale of a moose home range in essence integrates the seasonal HSI's to determine the ability of portions of the forest to support moose on a year-round basis. This approach masks the precise locations of suitable seasonal foraging and/or cover habitats. If the locations of these components need to be determined this is easily done from the digital layers showing the HSI values for seasonal food and cover attributes.

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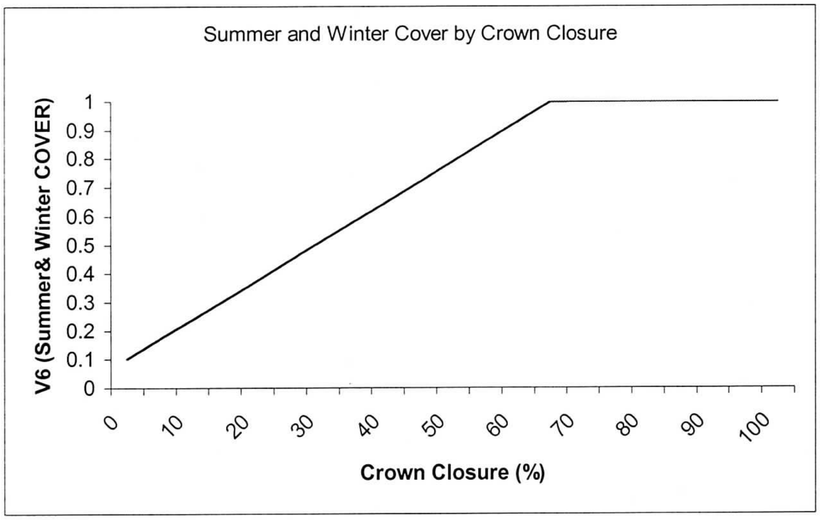
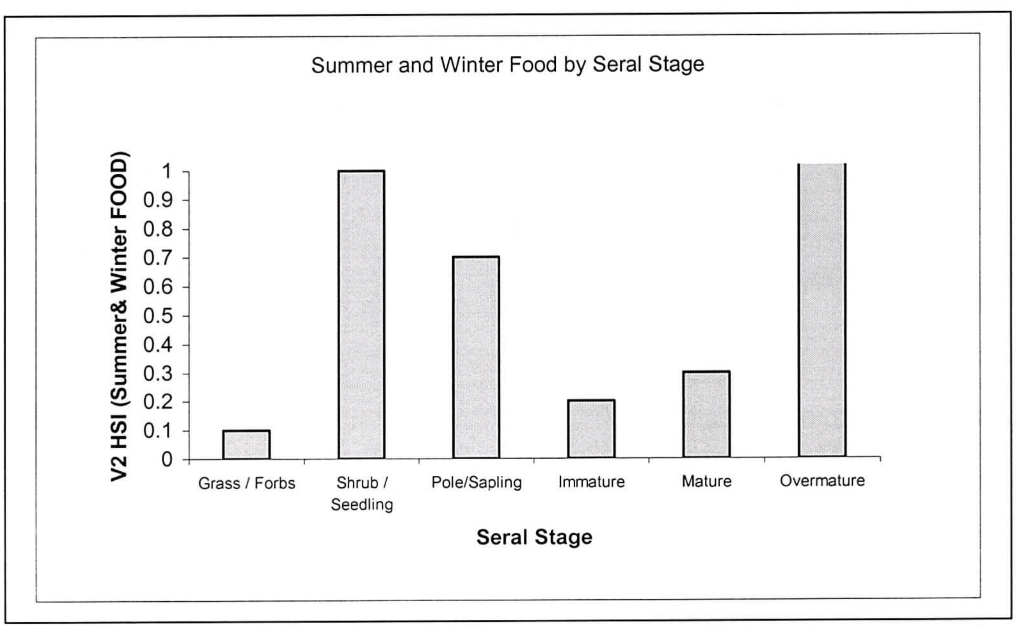
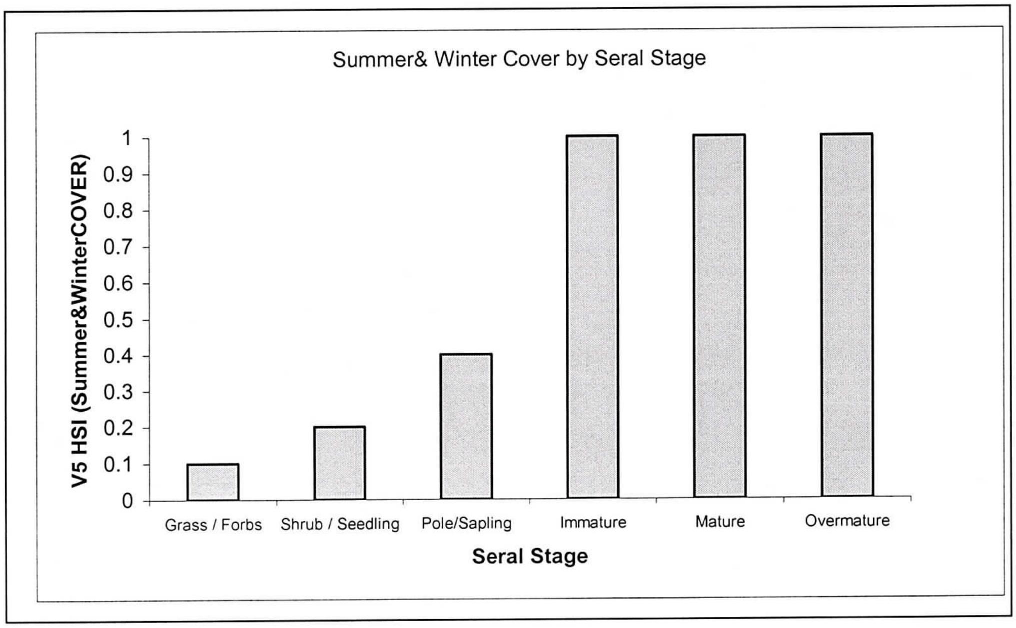
Appendix 1: Crown closure as it affects winter cover values (Variable 6)



Appendix 2: Habitat suitability indices (HSI) for moose summer and winter food and cover as these habitat attributes are affected by seral stage of stand development and a table to allow for the conversion of seral stage to age class by stand type.





Appendix 2 (continued): Table showing the age class conversion for seral stages used to determine HSI values for the 1995 HSI Models within the Manitoba Model Forest Region. Manitoba Conservation forest inventory strata are used here; a different inventory could have different age class relationships with these seral stages.

MC Strata Age Class Template (Open and Closed Density Classes)

Strata	Composition	Seral Stage					
		Grass/ Forbs	Shrub/Seedling	Pole/Sapling	Immature	Mature	Overmature
PTA	80-100% TA, 0-20%softwood	0 - 3	4 - 6	7 - 20	21 - 50	51 - 70	71+
MDE	80-100%TA,BP,WB, 0-20% softwood	0 - 5	6 - 10	11 - 25	26 - 55	56 - 75	76+
NWS	51-79%hardwood,21-49%softwood,Wsor BF or JP leading	0 - 5	6 - 10	11 - 25	26 - 55	56 - 75	76+
NBS	51-79%hardwood,21-49%softwood,BS and TL leading	0 - 5	6 - 10	11 - 25	26 - 55	56 - 75	76+
MWS	51-79%softwood,21-49%hardwood,WS orBForJP leading	0 - 5	6 - 15	16 - 35	36 - 70	71 - 100	101+
MBS	51-79%softwood,21-49%hardwood,BS and TL leading	0 - 5	6 - 15	16 - 35	36 - 70	71 - 100	101+
PJP	80-100% softwood, JP leading	0 - 5	6 - 15	16 - 30	31 - 65	66 - 80	81+
PWS	80-100%white spruce,WS or BF leading	0 - 5	6 - 15	16 - 35	36 - 70	71 - 100	101+
UBS	80-100% softwood, BS and TL leading,moisture classD,F,M,V	0 - 5	6 - 15	16 - 35	36 - 70	71 - 100	101+
LBS	80-100% softwood,BS and TL leading,moisture classW	0 - 7	8 - 20	21 - 50	51-89	90 - 120	121+