MOOSE

(Alces alces)

Source: Savage and Savage (1981)

Prepared for Millar Western Forest Products' Biodiversity Assessment Project

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1.1 Introduction

The Moose (*Alces alces*) is distributed across most of Canada and parts of the northern United States (Figure 1). Of the four subspecies that exist across this range, *A. a. andersoni* is the natural resident of central Alberta (Peterson 1955; Telfer 1984). The range of this subspecies follows the boreal forest ecosystem and extends from the central Yukon Territory in the northwest to Thunder Bay, Ontario in the east (Peterson 1955). Although Moose range and population size have experienced declines in Europe, the animal continues to inhabit its historical range in North America (Telfer 1984; Kufeld and Bowden 1996).

1.2 Effects of Forest Management Activities

Forest management can contribute to the production of necessary Moose habitat elements if appropriate practices are implemented. The young growth that sprouts after timber harvest can provide browse for Moose. If adequate shelter is maintained in proximity to these developing stands, suitable Moose habitat is provided (OMNR 1996).

The use of herbicides, such as glyphosate, on cutblocks is prescribed as a component of the stand tending process to ensure that regeneration standards are met. According to several authors, herbicide use discourages the development of browse cover for at least a few years (Connor and McMillan 1990; Santillo 1994). Research by Penner (1997) has shown that the presence of unsprayed strips within the cutblock greatly increases ungulate use of the area. Similarly, Mastenbrook and Cumming (1989) found that Moose will use the area within 90 m of residual timber corridors that remain following clearcut harvesting.

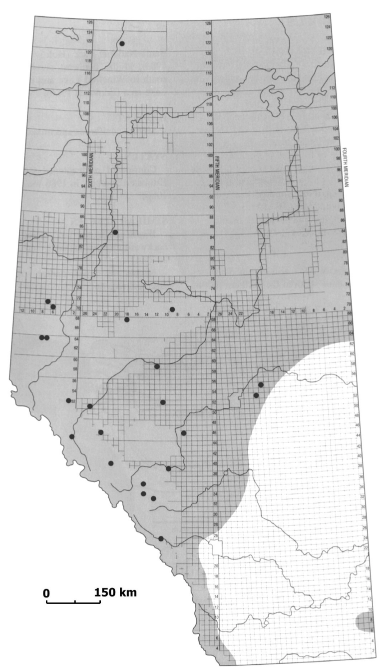

Figure 1. Estimated distributionof the Moose in Alberta (Smith 1993).

2.0 HABITAT USE INFORMATION

2.1 Food Requirements

The Moose is a browsing ruminant and its dietary requirements vary with the seasons (Robbins 1993). While woody browse and new leafy growth are the main food resources in spring, both woody and herbaceous new growth are preferentially consumed during summer. Gradually, as summer passes and leaves are shed, Moose begin to change from a leafy diet to one comprised primarily of woody browse. It is beneficial for them to consume highly digestible leaf material for as long as possible. Therefore, Moose tend to forage for willow along stream sides and for leaf litter on the forest floor of mature aspen stands in early winter. Once snow precludes the Moose from foraging on the forest floor and leaves are no longer available, the diet becomes almost strictly woody material (Aho and Jordan 1976; Renecker and Hudson 1986; Histol and Hjeljord 1993; Stelfox 1993). At various times throughout the year, the Moose has also been known to ingest birch bark, lichens, moss, and ground plants such as *Equisetum* spp. and *Ledum* spp. (Thomas 1990).

Important factors in the selection of foods by the Moose are its need for salts, particularly sodium compounds (Belovsky and Jordan 1981; Telfer 1984) and its need for highly digestible foods (Renecker and Hudson 1986; Stelfox 1993). The search for sodium attracts the species to natural salt licks and if available, aquatic vegetation, which has a greater salt component than terrestrial plants (Belovsky and Jordan 1981; Telfer 1984). In addition, Moose are drawn to the available salt resources on and around highways during winter (Miller and Litvaitis 1992). In the experience of Lynch (pers. comm. 1999), however, Moose' use of salt licks is greatest from mid- May until late July. While most summer food is quite digestible, woody browse is not, thus digestibility becomes a factor in food choice during fall and winter (Renecker and Hudson 1986; Stelfox 1993). The Moose appears able to identify the most nutritious browse by smell and preferentially consumes these species (Aho and Jordan 1976; McNicol 1990; Histol and Hjeljord 1993; Stelfox 1993).

Following the rut in early winter, Moose (particularly males) seek plentiful food supplies. It is essential that they replenish body mass lost during the rut period and build sufficient fat reserves to prepare for the winter season during which it is common for an individual to lose 20% of its weight (McNicol 1990). Lynch (pers. comm. 1999) has pointed out that Moose commonly seek open muskeg or riparian habitat with abundant willow growth in early winter. They are thought to seek willow because it is able to withstand substantially more browsing pressure than aspen. In addition, willow branches remain in reach of Moose as the tree grows whereas aspen quickly grows out of the animal's reach. Moose tend to use willow particularly when it is proximate to the mature aspen stands from which they receive early winter cover and leaf litter as forage (Renecker and Schwartz 1998).

Clearings, such as recent clearcuts, seismic lines, and utility lines, provide plentiful herbaceous vegetation and shrubs (Higgelke 1994) and make excellent foraging habitat. In particular, both aspen and willow are known to grow in these clearings (Lynch pers. comm. 1999). Therefore, habitat located proximate to these landscape features could be considered good foraging habitat.

2.2 Cover Requirements

While clearings are valuable as foraging habitat, it is vital that Moose also have access to forest cover that moderates climatic extremes, intercepts a portion of the incoming snow, and offers protection from predators (McNicol 1990). Both lateral and vertical cover are required for these purposes and the type and degree of cover required changes seasonally (McNicol 1990).

Shelter from Environmental Extremes (Snowfall and Temperature)

Summer

Moose become physically stressed during periods of temperature extremes. Summer temperatures over 14° C and winter temperatures over 0° C are sufficient to cause heat stress (Renecker and Hudson 1990). During summer, Moose select dense upland coniferous stands, muskeg environments, or riparian sites for their shady, cool conditions (Smith pers. comm. 1999). In particular, habitats associated with wetlands are beneficial in relieving heat stress (Renecker and Hudson 1990). North-facing aspects are also appreciated during warm summers (Telfer 1988).

Mild Winter

Research results of Schwab and Pitt (1990) suggest that Moose select mild winter habitat based on the quality and quantity of food available. In addition, the chosen stand generally contains a range of microclimatic conditions, allowing the Moose to position itself in the area that will best suit its immediate needs (Peek *et al.* 1976; Hauge and Keith 1981; Telfer 1988).

Severe Winter

Though the Moose' heavy coat and long legs allow it to withstand low temperatures and to move through relatively deep snow, the presence of habitat able to moderate temperatures and to intercept some snowfall may also be critical during severe winters (McNicol 1990). During mild winters, however, Moose tend to remain within mild winter habitat for the entirety of the season as foraging conditions are superior in areas where canopy closure is less dense (Hundertmark *et al.* 1990; Todd pers. comm. 1999). It is possible that Moose in west-central Alberta do not often utilise severe winter cover (which consists of relatively pure coniferous stands with significant canopy closure) because conditions are generally not sufficiently severe to prompt them to move away from the ample food resources of mild winter habitat.

Hiding Cover

The primary predators of the Moose are Humans, Wolves, Cougars, Grizzly Bears, and Black Bears (Franzmann *et al.* 1980; Gasaway *et al.* 1983; Boerje *et al.* 1988; Ballard *et al.* 1991). Both the Moose' choice of habitat and its movement pattern will affect its vulnerability to predators. Lateral cover, provided by trees and tall shrubs of less than 3 m height, can be used as hiding cover. Additionally, the ability of this vegetation to act as a windbreak reduces the risk that predators will be made aware of the Moose' presence by odours carried with the wind (McNicol 1990). Where harassment by human activity is high, Tomm *et al.* (1981) have determined that Moose prefer to remain within 60 to 80 m of hiding cover though they will move up to 200 m outside of hiding cover where access is controlled. In addition, it is beneficial for the Moose to locate itself in proximity to water, open muskeg, or swamps as predator avoidance is maximised in these areas. Moose are in greatest need of hiding cover during early winter. For the rest of the year, habitat selection does not appear to be associated with provision of hiding cover.

2.3 Reproduction Requirements

In spring, many cow Moose bearing young spend time in open muskeg habitats (Smith pers. comm. 1999). Islands in both lakes and larger rivers are also known to be important calving areas (Addison *et al.* 1990). According to the unpublished data of Lynch (pers. comm. 1999), Moose are known to select wet areas such as swamps and muskegs to calve within Millar Western's FMA area. It is thought that since the Moose have better manoeuvrability than their predators in this environment, they are able to avoid predators.

Moose calves are born in late May or early June (Peterson 1955; LeResche *et al.* 1974) and may remain with the mother for a period of up to 14 months (Ballard *et al.* 1991). Lynch (pers. comm. 1999) has stated, however, that it is unlikely that a calf will remain with the female for more than one year following birth. Even once on their own, the young do not stray far from their mother's home range until they are sexually mature (Peterson 1955; Rolley and Keith 1980; Stelfox 1993).

2.4 Habitat Area Requirements

The home range of a Moose consists of spring-summer-fall, mild winter, and severe winter habitat of suitable size. Though some Moose populations must migrate to fulfil habitat requirements (Rolley and Keith 1980; Telfer 1984; Ballard *et al.* 1991), it is thought that Moose in west-central Alberta do not (Lynch pers. comm. 1999).

There is controversy over the relative sizes of seasonal ranges. Some authors claim that the home range of the Moose is largest in summer because plentiful energy-rich foods increase the ability to travel. It has also been suggested that in winter, the animals remain relatively sedentary within mature coniferous forests where temperatures and snow accumulations are moderate (Phillips *et al.* 1973; Telfer 1984; Cederlund and Okarma 1988; McNicol 1990; Ballard *et al.* 1991). Conversely, the study of Lynch and Morgantini (1980) in the Swan Hills of Alberta concluded that winter ranges are nearly double the size of and completely engulf the other seasonal ranges.

Studies in North America have shown that ranges can be extremely variable (300 to 25,900 ha areas have been recorded through telemetry work, Hundertmark 1998). In the Swan Hills study site near Millar Western's FMA area, seasonal ranges were found to range from 2,200 to 5,200 ha for males and 1,500 to 4,700 ha for females. The size of the winter ranges greatly exceeded that of the other seasonal ranges (Lynch and Morgantini 1980). Since the measurements taken from Swan Hills come from forests similar to those within the Millar Western FMA area, optimal home range size is set at 5,200 ha for this model. This area will encompass all seasonal ranges of male Moose.

2.5 Landscape Configuration Requirements

Based on a review of the literature and discussion with local experts, we have determined the maximum suitable distances between food and cover that will be used for HSM purposes. Moose remain within a maximum of 400 m of cover while foraging in Ontario (Higgelke 1994). Though unaware of a similar figure for west-central Alberta, Lynch (pers. comm. 1999) suggested that the maximum separation of food and cover of 400 m may also work in Millar Western's FMA area. It has been the experience of Higgelke (pers. comm. 1999) in Ontario to see Moose venturing further from forest cover during summer than winter. Due to the controversy over the relative sizes of seasonal ranges, it is not known whether Moose in Alberta move further in winter or summer. Therefore, until additional information becomes available, we will use a maximum suitable distance between foraging habitat and forest cover of 400 m year-round.

Since proximity to human access is correlated with hunting pressure, the distance between foraging and hiding cover habitats should also be considered. Calving Moose in Alberta have stringent requirements with respect to proximity of hiding cover to foraging habitat. They prefer to remain within 100 m of hiding cover at all times (Penner 1997). At other times of the year, it is best if the animals can remain within 200 m of hiding cover though < 75 m is always optimal (Tomm *et al.* 1981).

To ensure that all of the proximity requirements of Moose are met by this HSM, habitat suitability is maximised where habitat types are located within 100 m of each other.

2.6 Sensitivity to Human Disturbance

As a predator of Moose, humans can significantly influence their populations through hunting pressure. In addition, although seismic and utility lines may provide Moose with desirable foraging conditions, in some areas they are so dense (positioned approximately 50 m apart) and devoid of cover that Moose populations are easily depleted by hunters using these narrow clearings.

3.0 MODEL

3.1 Envirogram

Three models have been developed to predict Moose habitat suitability. The first takes into account the specific habitat requirements of the Moose during summer. The second considers its needs in mild winter and the third looks at habitat requirements during rare, severe winters. Habitat quality influences the Moose' ability to obtain food, escape from predators, and find cover that will protect it from environmental extremes. The forest attributes that determine the suitability of the habitat for Moose vary with season and are shown in the envirograms below (Figures 2, 3, and 4).

Spring, Summer and Fall Habitat

Appropriate foraging habitat will have a dense layer of shrubs, small trees, and/or herbaceous vegetation on the ground. The area is even more desirable as a feeding zone if it is coincident with a narrow clearing such as a seismic or utility line, where shrubs and herbs are plentiful. Additionally, the food resource is most valuable to Moose if it is located proximate to suitable cover. Dense coniferous stands, muskeg habitats, or riparian environments provide the best summer thermal cover. In addition, north-facing slopes have enhanced utility for this purpose (Figure 2).

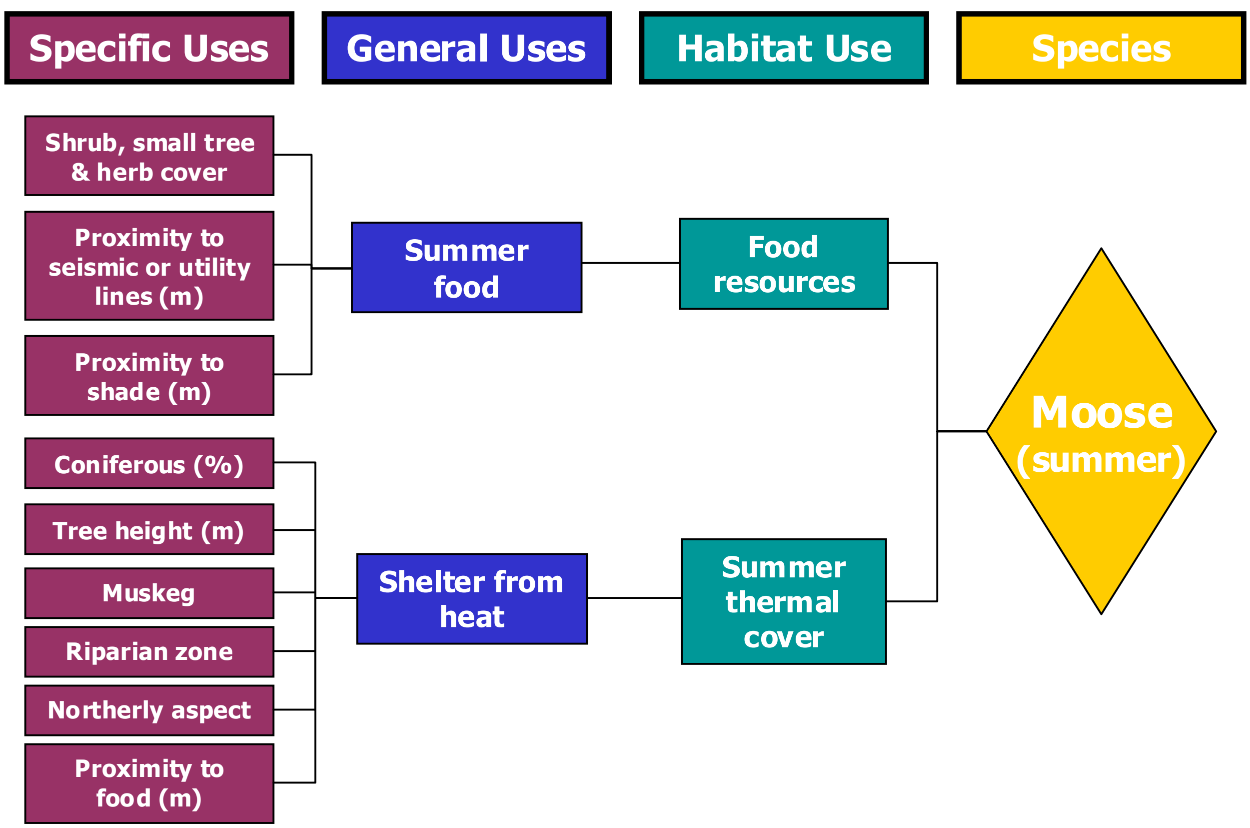

Figure 2. Envirogram of the summer habitat of the Moose based on available information for HSM development.

Mild Winter Habitat

As herbaceous vegetation is not as readily available in winter, the food variables indicate the density of shrub and small tree cover, particularly aspen and willow. Proximity to seismic or utility lines and hiding cover are important attributes of foraging habitat. Moose find suitable hiding cover in stands with relatively dense shrub cover and trees with low height to crown. Habitat close to water bodies, muskeg, or swamps has enhanced utility as hiding cover (Figure 3).

Severe Winter Habitat

Moose use shrubs and small trees as forage during severe winters. As cover during severe winters, they may require dense coniferous stands with significant canopy closure and trees of suitable height to provide some shelter from cold temperatures and incoming snow (Figure 4).

3.2 Application Boundaries

Season: Three separate models have been created: spring/summer, mild winter, and late winter.

Habitat Area: Home range size is thought to be 5,200 ha. No home range smoothing is required in this HSM, however.

Model Output: The model assigns a SI value for summer foraging, mild winter foraging, severe winter foraging, summer cover, severe winter cover, and hiding cover habitat suitability to each 25 m pixel of forested habitat.

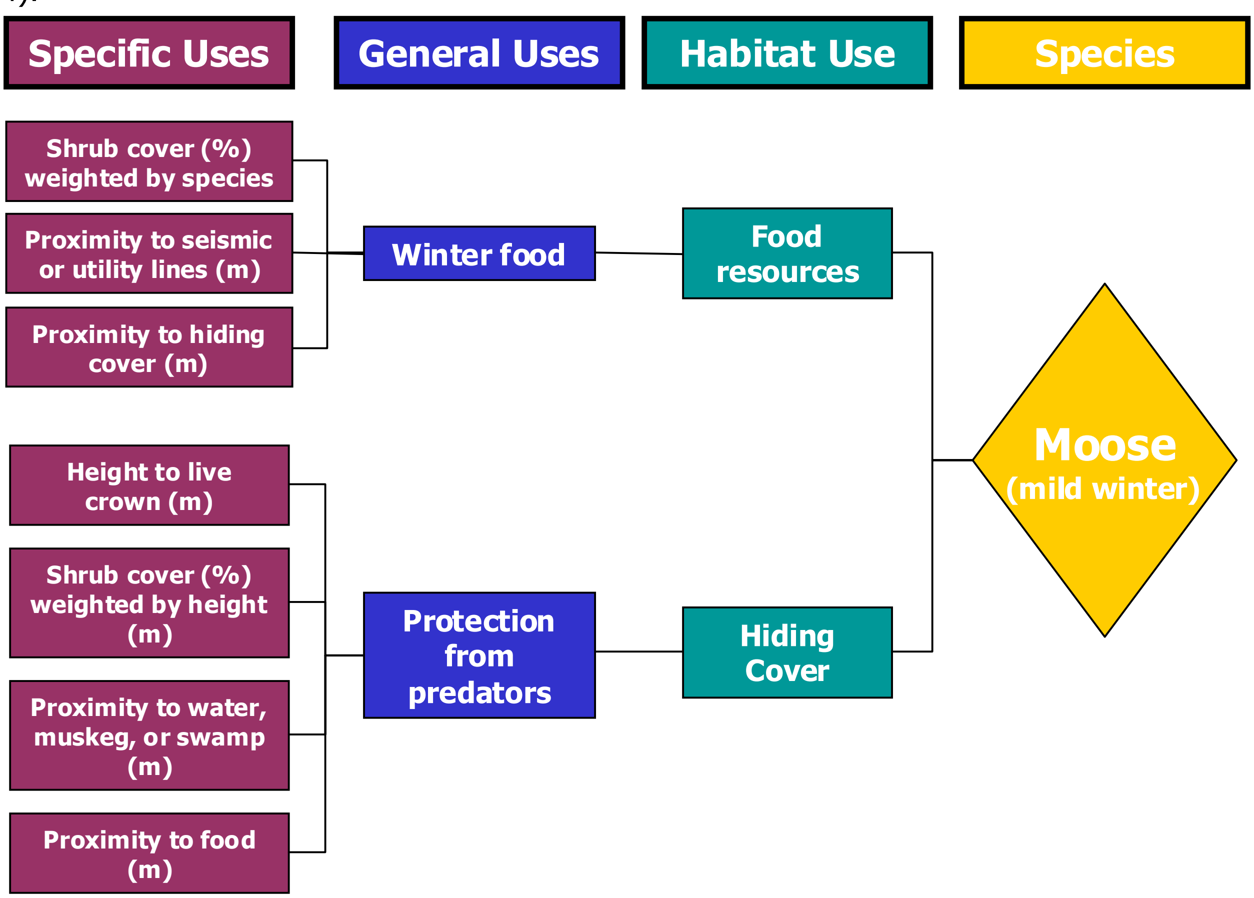

Figure 3. Envirogram of the mild winter habitat of the Moose based on available information for HSM development.

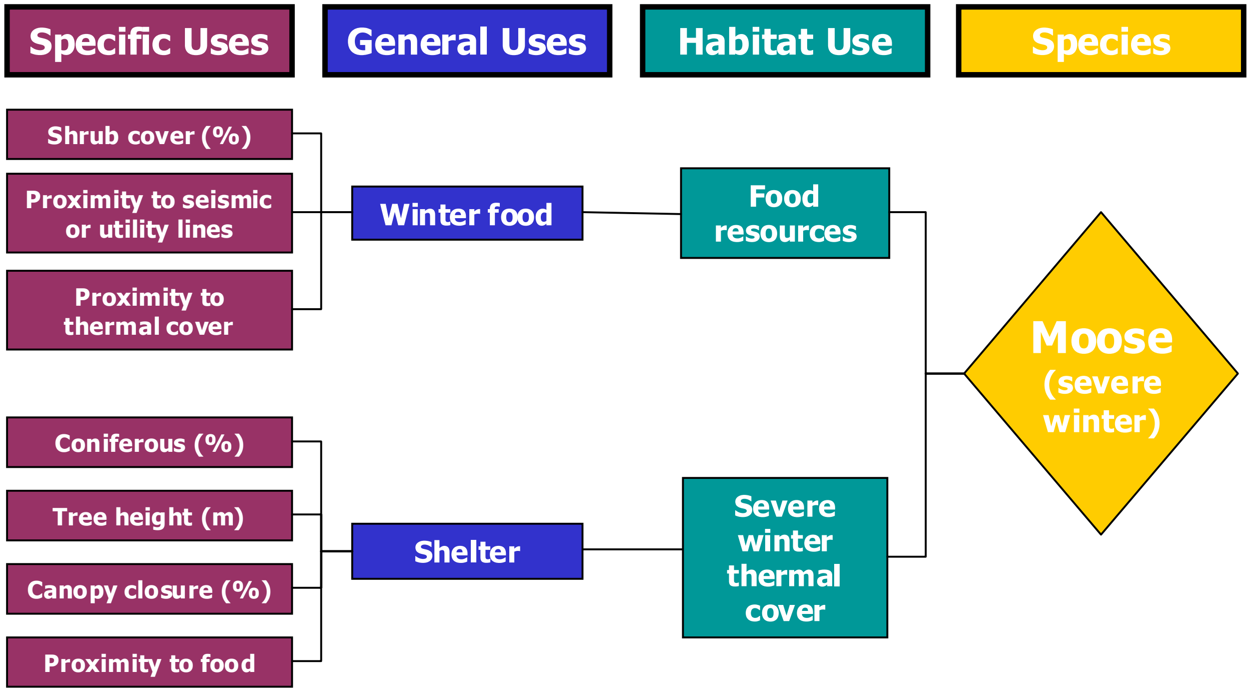

Figure 4. Envirogram of the severe winter habitat of the Moose based on available information for HSM development.

3.3 Model Description

The HSMs for Moose habitat follow the structures described in the envirograms (Figure 5, 6, and 7). As all habitat elements are critical and needed at the same time, no compensation is allowed between them.

All seasonal food SIs take into account proximity to seismic and utility lines. We consider either of these features to supply optimal foraging conditions. The SI_{food} for summer also includes herbaceous vegetation, shrub cover, and density of small nutritious hardwood trees. The mild winter food SI considers the density of shrub cover, particularly willow and aspen cover. In severe winters, the Moose may not have access to willow and aspen and may forage on any species of shrub or small tree, selecting the most nutritious plants available, by smell.

The SI_{cover} also differs with season. In summer, the variables included are the percentage of coniferous trees in a mature stand and proximity to muskeg or riparian areas. As any of these three habitat types can be used as summer thermal cover, the habitat type providing the highest suitability rating is used in the equation. A bonus of 0.1 is applied to habitats with north-facing aspect. Thermal cover is not an important component of mild winter habitat. During severe winters, Moose may elect to remain within coniferous-dominated stands with significant canopy closure and trees of at least 10 m height. Since a stand must meet all of these three requirements to be considered suitable severe winter thermal cover habitat, the variables are non-compensatory.

The SI_{hiding} is used only in the mild winter HSM. It is composed of variables indicating the percent cover of shrubs weighted by height and height to live crown of trees. As both shrubs of appropriate height and trees with a low height to crown contribute to hiding cover, these variables are fully compensatory. In addition, since locating itself close to water, muskeg, or swamps is a predator avoidance strategy of Moose, a bonus of 0.5 is applied to all pixels in proximity to these habitat types. The proximity of food and cover habitats is considered in the Computation Section (3.5).

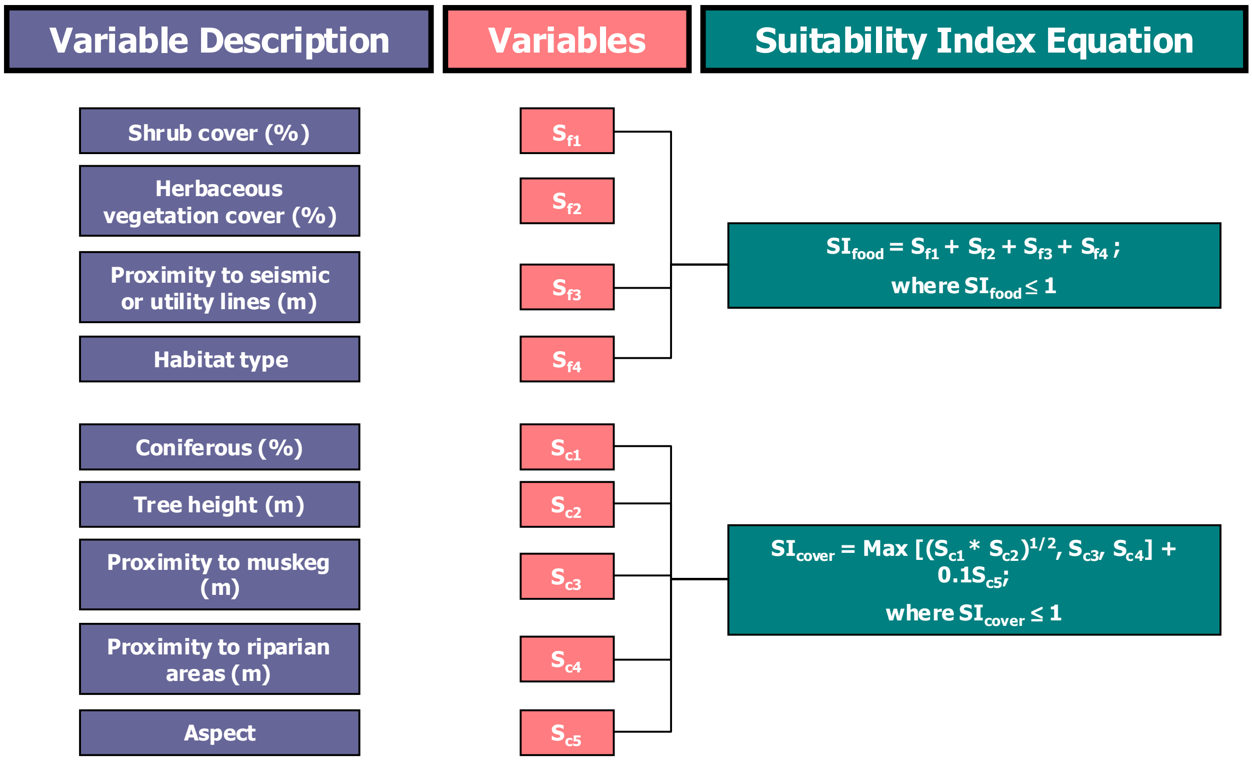

Figure 5. HSM structure for summer habitat of Moose within Millar Western's FMA area.

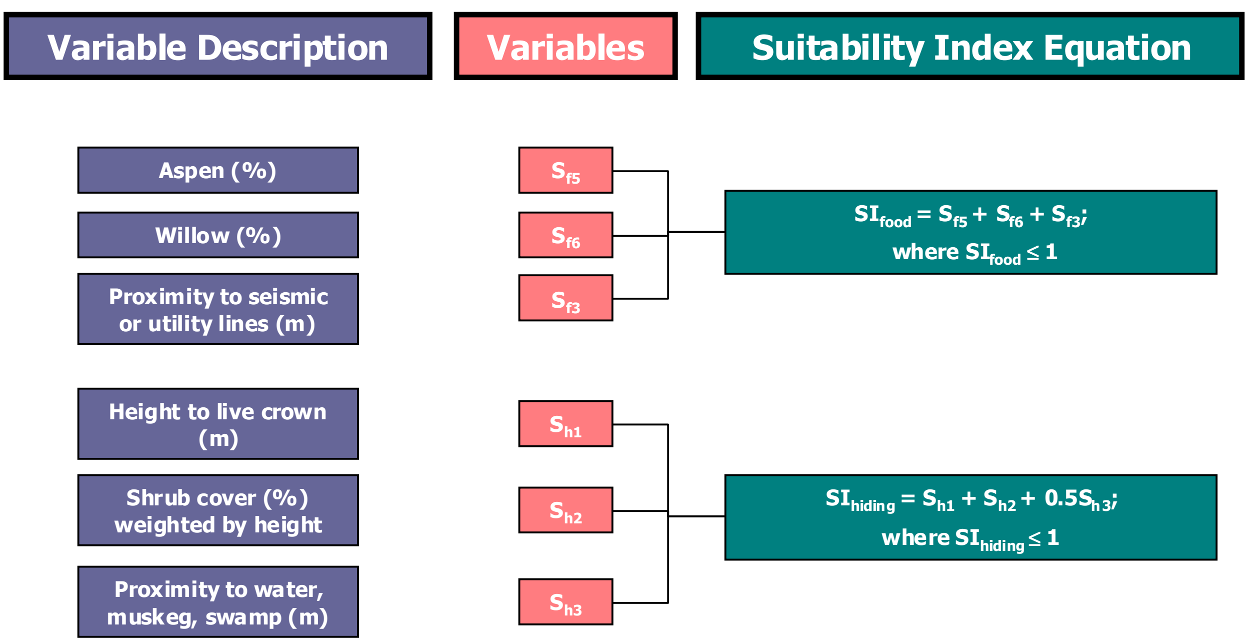

Figure 6. HSM structure for mild winter habitat of Moose within Millar Western's FMA area.

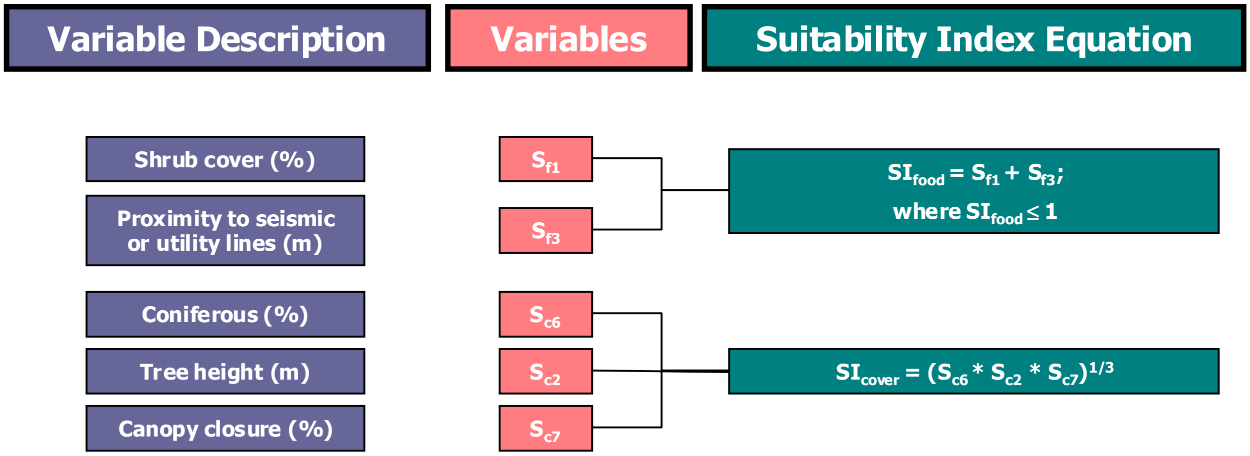

Figure 7. HSM structure for severe winter habitat of Moose within Millar Western's FMA area.

3.4 Habitat Variable SIs

Food

The SI_{food} equations include variables indicating the percentage of the forest floor covered with different types of vegetation. Summer food is provided by shrub cover (S_{f1}), herbaceous vegetation cover (S_{f2}), and habitat types expected to support abundant small deciduous trees (S_{f4}). In mild winter, aspen (S_{f5}), and willow (S_{f6}) are preferable. Proximity of the area to a seismic or utility line (S_{f3}) is also considered. In severe winter, shrubs are consumed (S_{f1}). As shown in Figures 8 to 11, habitat suitability increases with coverage of these preferred vegetation types. Suitability is maximised with > 25% coverage of shrubs, 40% coverage of herbaceous vegetation, and > 15% coverage of willow. In addition, pure (at least 70%) aspen stands and pixels with narrow clearings are suitable for foraging. The habitat types considered suitable for foraging moose are shown in Table 1.

Cover

The summer SI_{cover} consists of five variables: % coniferous (S_{c1}), tree height (S_{c2}), proximity to muskeg (S_{c3}), proximity to riparian areas (S_{c4}), and aspect (S_{c5}). Figure 12 shows that a stand's suitability as summer thermal cover increases linearly with coniferous cover up to 50%. A hardwood stand has the ability to supply summer shade to Moose and is given a suitability rating of 0.25. Coniferous-dominated mixedwoods and pure coniferous forests are optimal, however, and are rated 1. Figure 13 displays the relationship between tree height and cover habitat suitability. The average height of the trees must be at least 4 m to be used but should optimally be > 10 m. If a pixel could be described either as muskeg or as a riparian zone, it is given a rating of 1 for suitability as summer thermal cover. Winter thermal and snow interception cover is best provided by pure coniferous stands. Therefore, habitat suitability increases linearly with coniferous representation to a maximum at 70% coniferous cover (Figure 14). Canopy closure of at least 75% is considered optimal (Figure 15).

Hiding

Hiding cover is provided either by trees with low height to live crown (S_{h1}) or by thick shrub cover (S_{h2}). As shown in Figure 16, stands with average height to live crown of 1 to 3 m supplies suitable hiding cover. Similarly, the opportunity for Moose to hide from predators is optimal in stands with at least 50% shrub cover of height between 1 to 3 m though those > 3 m may also be valuable for this purpose (Figure 17). In addition, stands proximate to water, muskeg, or swamp provide an enhanced predator avoidance opportunity.

Table 1. Preferred habitat types of the foraging Moose.

		Opening	Developing		Forest		Old
Broad	**Specific**	**Clearcut**	**Regenerating**	**Young**	**Immature**	**Mature**	**Old**
Hardwoods	Aspen		1	1			
	Poplar		.75	.25			
	White birch		1	1			
Hardwood Mixed	Aspen-Pine		1	1			
	Aspen-White spruce		1	1			
	Aspen-Black spruce		1	1			
	Poplar-Pine		.5				
	Poplar-White spruce		.5	.25			
	Poplar-Black spruce		.25				
Softwood Mixed	Pine-Poplar		.75	.25			
	Pine-Aspen		.75	.75			
	White spruce-Poplar		.75	.25			
	White spruce-Aspen		.75	.75			
	Black spruce-Poplar		.25				
	Black spruce-Aspen		.75	.25			
Conifers	Pine		.5	.25			
	White spruce		.75	.25			
	Black spruce		.25				
	Larch		.25				

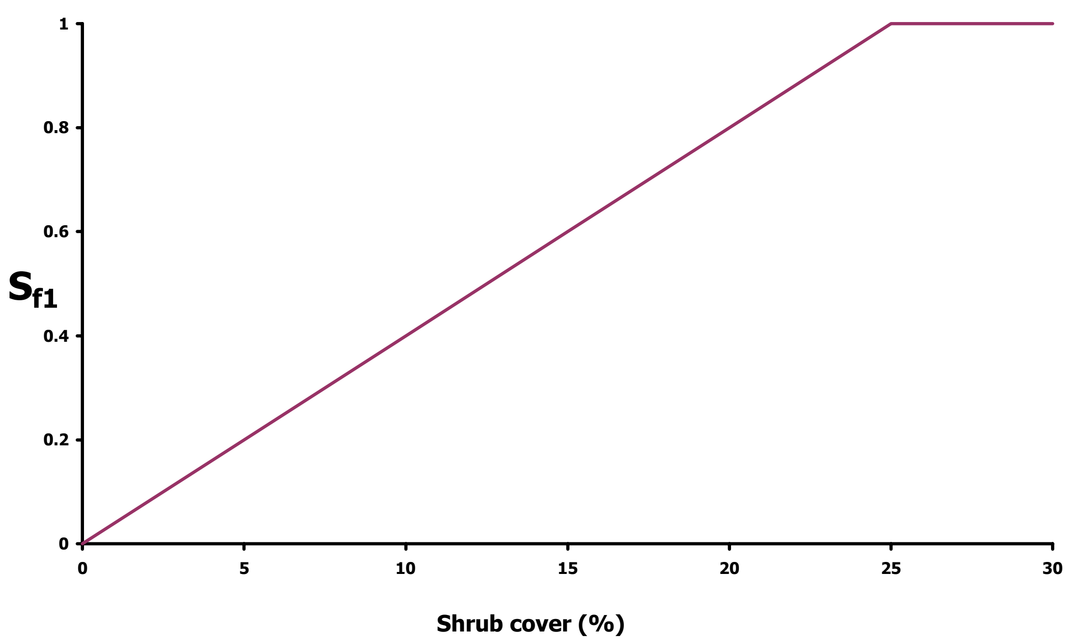

Figure 8. Moose foraging habitat suitability in relation to shrub cover within Millar Western's FMA area. Weighting: 0 - 50 cm = 0, 50 cm - 1 m = 0.25, 1 - 2 m = 1, > 2 m = 0.5.

Figure 9. Moose foraging habitat suitability in relation to herbaceous vegetation cover within Millar Western's FMA area.

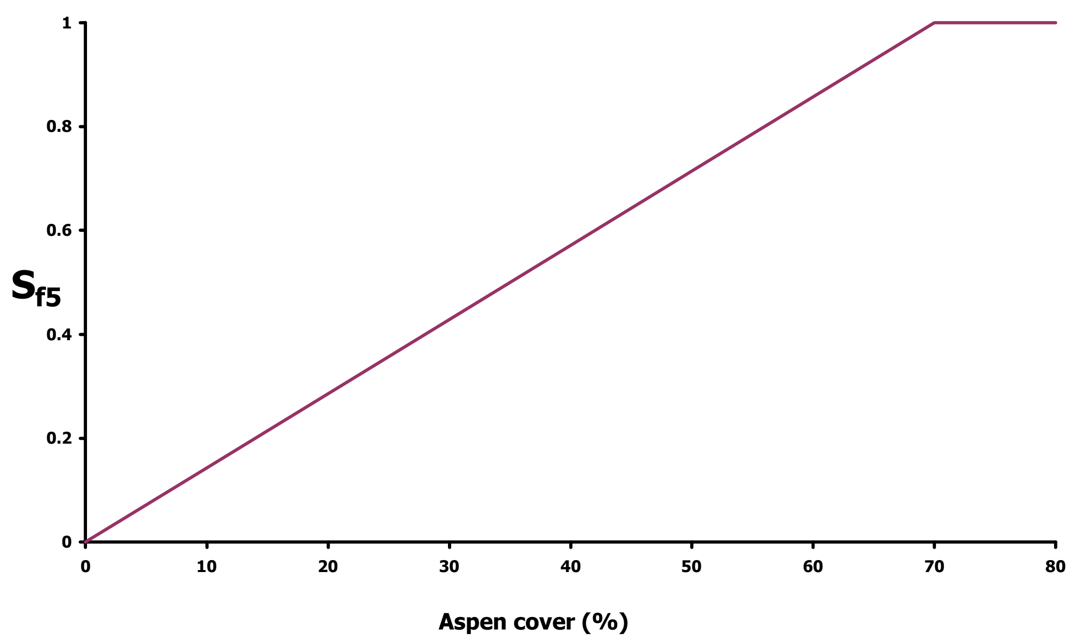

Figure 10. Moose foraging habitat suitability in relation to aspen cover within Millar Western's FMA area.

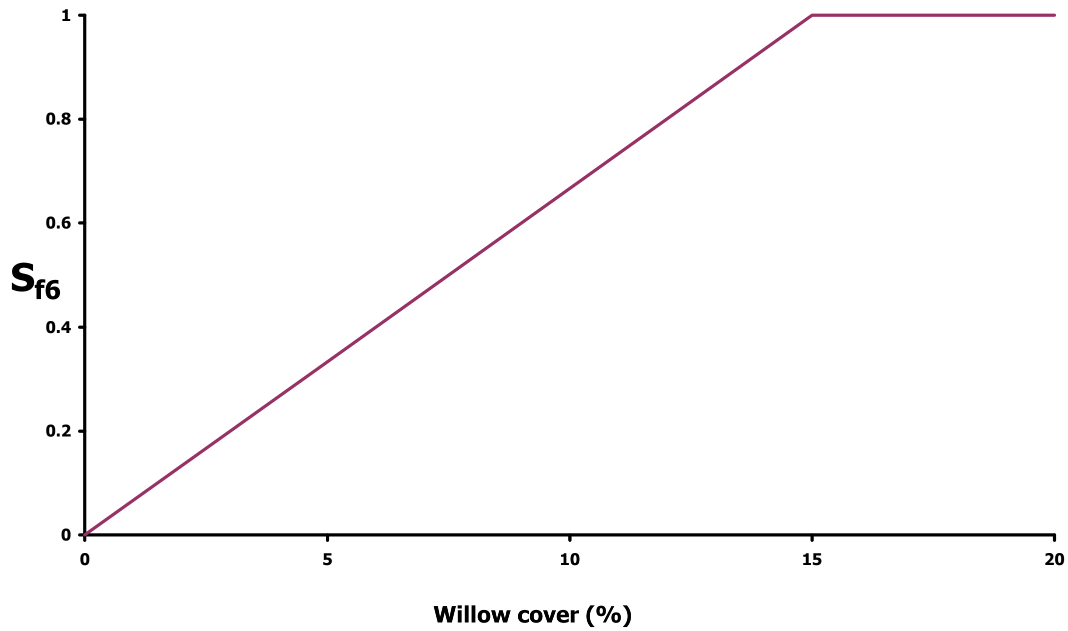

Figure 11. **Moose foraging habitat suitability in relation to willow cover within Millar Western's FMA area.**

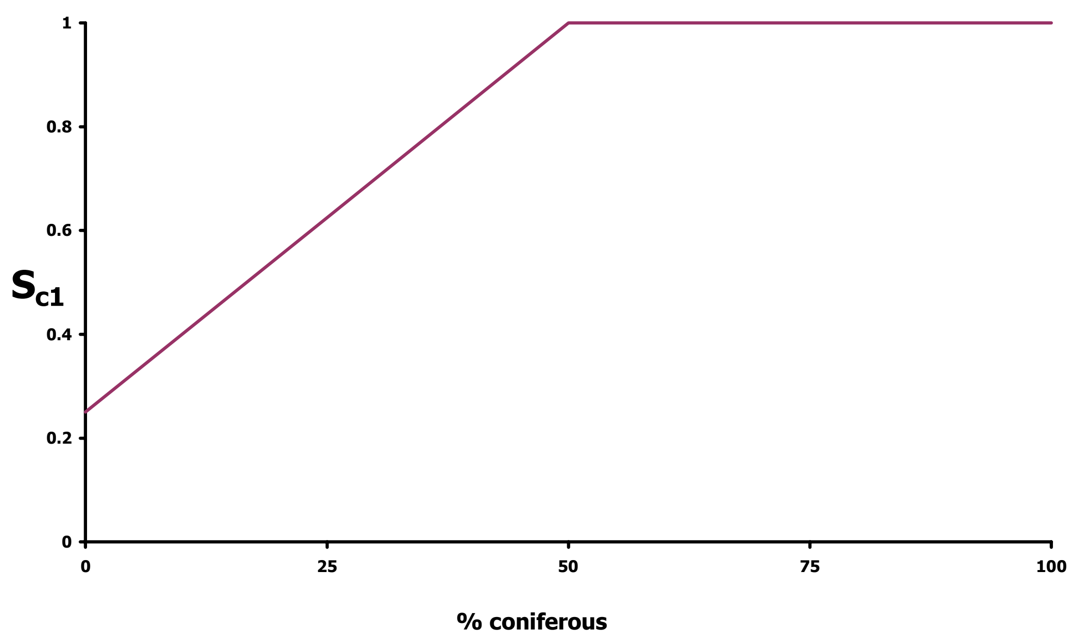

Figure 12. **Moose cover habitat suitability for summer in relation to the percentage of coniferous trees present within Millar Western's FMA area.**

Figure 13. **Moose cover habitat suitability in relation to tree height within Millar Western's FMA area.**

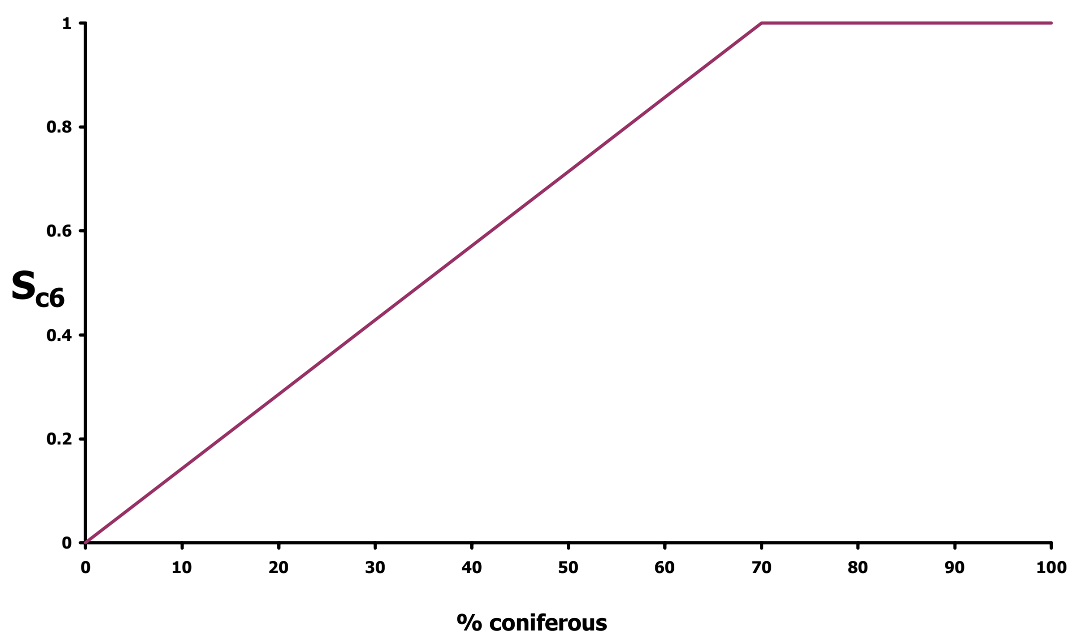

Figure 14. **Moose cover habitat suitability for severe winter in relation to the percentage of coniferous trees present within Millar Western's FMA area.**

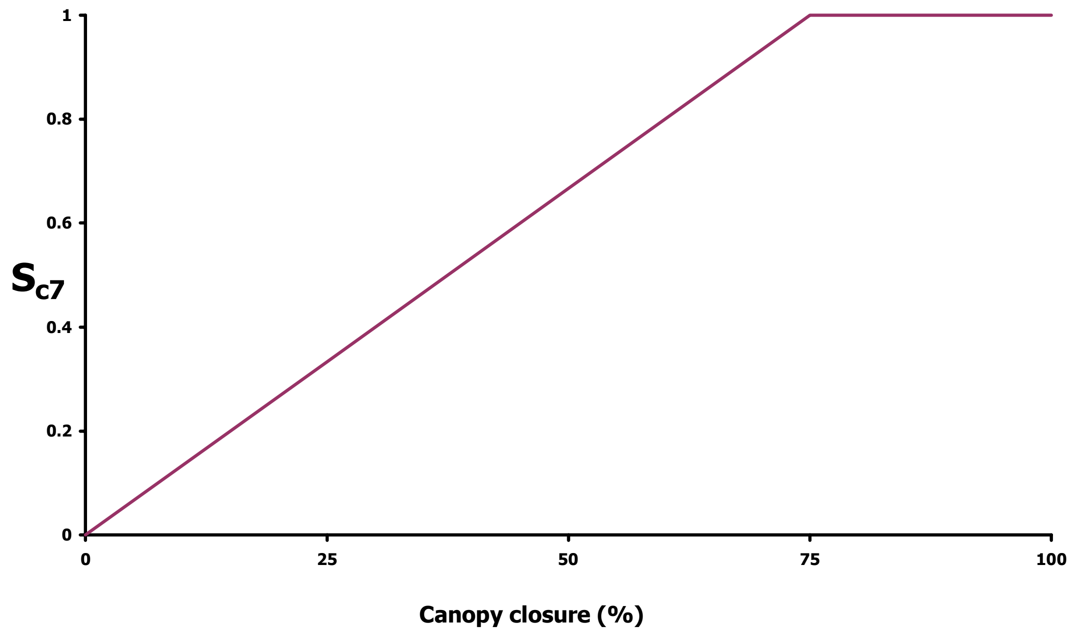

Figure 15. Moose cover habitat suitability for severe winter in relation to canopy closure within Millar Western's FMA area.

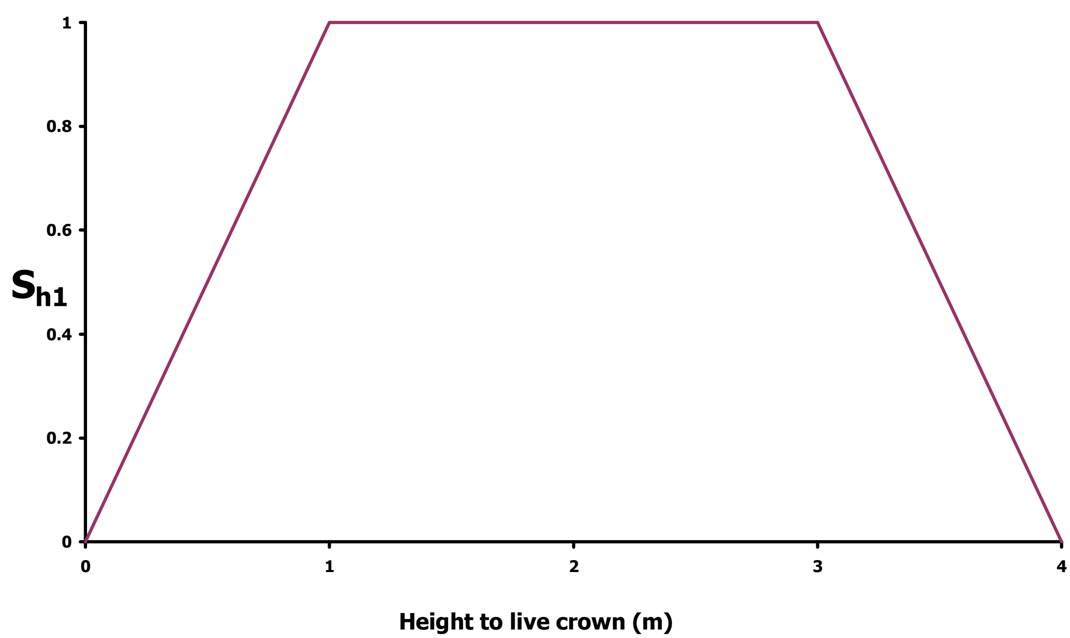

Figure 16. Moose cover habitat suitability in relation to height to live crown within Millar Western's FMA area.

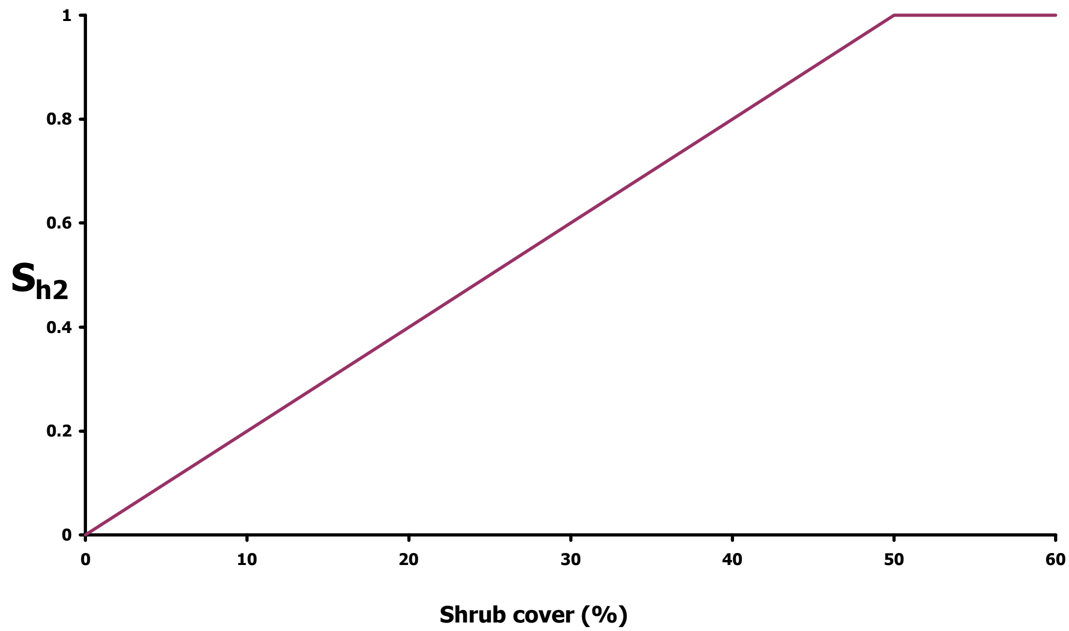

Figure 17. Moose hiding cover suitability in relation to shrub cover within Millar Western's FMA area. Weighting: Height 1 to 3 = 1, > 3 = 0.75, < 1 m = 0.

3.5 Computation

Our goal is to create HSMs that enable the user to identify the potential impacts of proposed forest management strategies on foraging, hiding cover, and thermal cover habitats. Therefore, the outputs of the SI_{food}, $SI_{cover,}$ and SI_{hiding} calculations are considered individually by season to display trends in habitat availability.

The Moose is an edge-using species that requires foraging habitat in proximity to thermal or hiding cover. Since the Moose consumes different food items in winter than in summer and because of their variable cover requirements throughout the seasons, three HSMs have been created. The first model predicts the quality of the habitat as summer range while the second and third look at the requirements of the Moose in mild and severe winters, respectively.

Foraging Habitat Index

The quality of each pixel as seasonal foraging habitat is first evaluated. The value of foraging habitat in all seasons is enhanced by proximity to seismic or utility lines. All pixels that contain a seismic or utility line will receive a suitability rating of 1 for variable S_{f3}, used in all seasonal foraging equations. All other pixels receive a rating of 0 for this variable.

To assess the quality of each pixel as foraging habitat, the following calculations are performed:

$$SI_{food\ (summer)} = S_{f1} + S_{f2} + S_{f3} + S_{f4};$$

$$SI_{food\ (mild\ winter)} = S_{f3} + S_{f5} + S_{f6};$$

$$SI_{food\ (severe\ winter)} = S_{f1} + S_{f3};$$

where all SI_{food} equations ≤ 1.

Cover Habitat Index

The quality of each pixel as summer cover is assessed. As summer shade, Moose may select forested, muskeg, or riparian habitat. Each forested pixel is given a rating according to the relationships shown in Figures 12 and 13 for stand composition and tree height. These variables are combined as follows:

$$(S_{c1} * S_{c2})^{1/2}$$

All pixels representing muskeg habitat are given a suitability value of 1 for variable S_{c3}. The rivers in Millar Western's FMA are buffered a distance of 25 m and all habitat existing within the buffer is given a suitability rating of 1 for variable S_{c4}. Pixels with a northerly aspect are given a rating of 1 for variable S_{c5}. Each pixel receives an $SI_{cover(summer)}$ value as these variables are brought together in the following equation:

$$SI_{cover(summer)} = Max\ [(S_{c1} * S_{c2})^{1/2}, S_{c3}, S_{c4}] + 0.1\ S_{c5};$$

where $SI_{cover(summer)}$ ≤ 1.

Similarly, the quality of each pixel of forested habitat as severe winter thermal and snow interception cover is calculated as follows:

$$SI_{cover(severe\ winter)} = (S_{c6} * S_{c2} * S_{c7})^{1/3}$$

Hiding Cover Habitat Index

The hiding cover equation is used only in the mild winter HSM. Habitat proximate to lakes, rivers, muskeg, or swamps is preferable since Moose have a better opportunity to escape from predators in this sort of environment. A buffer of 100 m is placed around all of these wet areas. Pixels existing within this buffer are given a suitability rating of 1 for variable S_{h3}. Those outside the buffers receive a value of 0 for this variable. Each pixel of forested habitat receives a suitability rating based on the following equation:

$$SI_{hiding} = S_{h1} + S_{h2} + 0.5S_{h3};$$

where SI_{hiding} ≤ 1.

Adjustment of SIs Based on Proximity between Foraging and Cover Habitats

Foraging habitat is not as useful to the Moose if it is further than 100 m from thermal cover during summer and severe winter and from hiding cover during mild 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:

$$\text{Adjusted } SI_{food(summer)} = [SI_{food(summer)} * \text{Window } (Max(SI_{cover\ (summer)}))_{100m}]^{1/2}$$

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

$$\text{Adjusted } SI_{cover\ (summer)} = [SI_{cover\ (summer)} * \text{Window } (Max\ (SI_{food\ (summer)}))_{100m}]^{1/2}$$

The winter SIs are adjusted in a manner similar to the summer SIs:

$$\text{Adjusted } SI_{food\ (mild\ winter)} = [SI_{food\ (mild\ winter)} * \text{Window } (Max\ (SI_{hiding}))_{100m}]^{1/2}$$

$$\text{Adjusted } SI_{hiding} = [SI_{hiding} * \text{Window } (Max\ (SI_{food\ (mild\ winter)}))_{100m}]^{1/2}$$

$$\text{Adjusted } SI_{food\ (severe\ winter)} = [SI_{food\ (severe\ winter)} * \text{Window } (Max\ (SI_{cover\ (severe\ winter)}))_{100m}]^{1/2}$$

$$\text{Adjusted } SI_{(cover\ (severe\ winter)} = [SI_{(cover\ (severe\ winter)} * \text{Window } (Max\ (SI_{food\ (severe\ winter)}))_{100m}]^{1/2}$$

Home Range Smoothing

We have chosen not to smooth the foraging and cover habitats for Moose since the animals have the capability to select certain sections of their home range in which to forage or take cover. To smooth the values within a large home range area would cause the precise locations of potentially suitable foraging and cover zones to be masked.

4.0 EXTERNAL REVISION

Arlen Todd, wildlife biologist with Alberta Environment, Fisheries and Wildlife Management Division in Whitecourt Alberta provided comments on an early version of the Moose model on June 4, 1999. The following changes have been made from the original document, based on his advice.

1) Todd felt that the effects of such herbicides as glyphosate on ungulate foraging habitat suitability should have been discussed. This information was included in the literature review.

2) The fact that Moose are attracted to highway salt was not included in the original document.

3) Todd mentioned that both Black Bears and Cougars are important predators of Moose.

4) It was suggested that the benefit of seismic lines to foraging was overstated and that the negative impact of these on animal security from hunters was understated.

5) The potential for Moose to calve on islands in lakes and large rivers was mentioned by Todd. This was included in the literature review.

6) The original document stated that the suitability of cover habitat would be enhanced if further than 100 m from roads. Todd pointed out that Moose use roadsides to forage and that habitat should only be considered unsuitable if hiding cover bordering the road is not functional.

7) In mild winters, Moose may choose not to enter late winter habitat at all and may remain, instead, in early winter habitat where browse is more readily available.

8) Summer thermal cover suitability is enhanced on north-facing slopes. This was included in both the literature review and the model.

9) The rate at which suitability decreases with distance from hiding cover was reduced on Todd's advice.

Kirby Smith, Area Wildlife Biologist with the Natural Resources Service in Edson, Alberta, provided comments on a draft of the Moose model on June 22, 1999. The following changes were made based on his advice:

1) Smith felt that the original weighting scheme used to make shrubs < 3 m more suitable as hiding cover was inappropriate. He suggested that shrubs less than 1 m tall would not be valuable as hiding cover while those greater than 3 m tall would be more useful than we had indicated. Therefore, the weighting scheme was changed according to Smith.

2) Smith provided us with a reference that provided details on the movement of Moose from hiding cover with respect to human access and activity. It was helpful in creating the maximum suitable distance between food and hiding cover relationship.

Gerry Lynch, a biologist with over 30 years of experience with Moose in west-central Alberta, has provided comments on the Moose HSM, received on June 30, 1999. The document was altered in response to his comments:

1) Lynch suggested that the importance of aquatic vegetation be reduced since it is not as accessible in Alberta as it is in more eastern provinces. In addition, he mentioned that salt licks are used most commonly in spring and early summer.

2) He mentioned that though he doesn't have any figures on maximum suitable separation of food and cover for Alberta Moose, he felt that the use of 400 m will probably work for western Alberta. He doesn't believe, however, that distances greater than 400 m will 'make the food and cover habitats both useless to Moose'. The literature

review and discussion with experts has not revealed a suitable value for Alberta, however. Therefore, it is necessary, at this time, to use the maximum distance known for Ontario. As more detailed Alberta-specific information becomes available, this portion of the model should be updated. At the present time, we will be conservative in using a smaller distance.

3) He suggested that the importance of thermal cover to the model was over-rated since Moose should be able to find a microclimate within most stands to warm or cool itself as necessary. We have chosen to retain these variables in the model since they will give an indication of the Moose' capability to find shade or snow interception cover if weather conditions deem this necessary.

4) Moose often locate themselves near wet areas as a predator avoidance strategy. Therefore, Lynch suggested that a variable of hiding cover suitability be proximity to water.

5) Lynch recommended that the importance of willow be emphasized in the model. The food and cover suitability relationships for early winter were changed to take this into account. He also suggested that the importance of thermal cover was over-stated for early winter since Moose are more attracted to foraging opportunities than cover at that time. He stated that Moose use mature aspen stands when they are in proximity to willow stands. Once snow depth drives them out of willow stands, they use mature aspen until snow depth encourages them to enter mature coniferous stands.

6) The controversy over seasonal home range size was introduced by Lynch who provided alternate references.

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