# Habitat Suitability Models for the Suncor Study Area

May, 1996

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**This report is one of a series of reports prepared for Suncor Inc. Oil Sands Group for the Environmental Impact Assessment for the development and operation of the Steepbank Mine, north of Fort McMurray, Alberta. These reports provided information and analysis in support of Suncor's application to the Alberta Energy Utilities Board and Alberta Environmental Protection to develop and operate the Steepbank Mine, and associated reclamation of the current mine (Lease 86/17) with Consolidated Tailings technology.**

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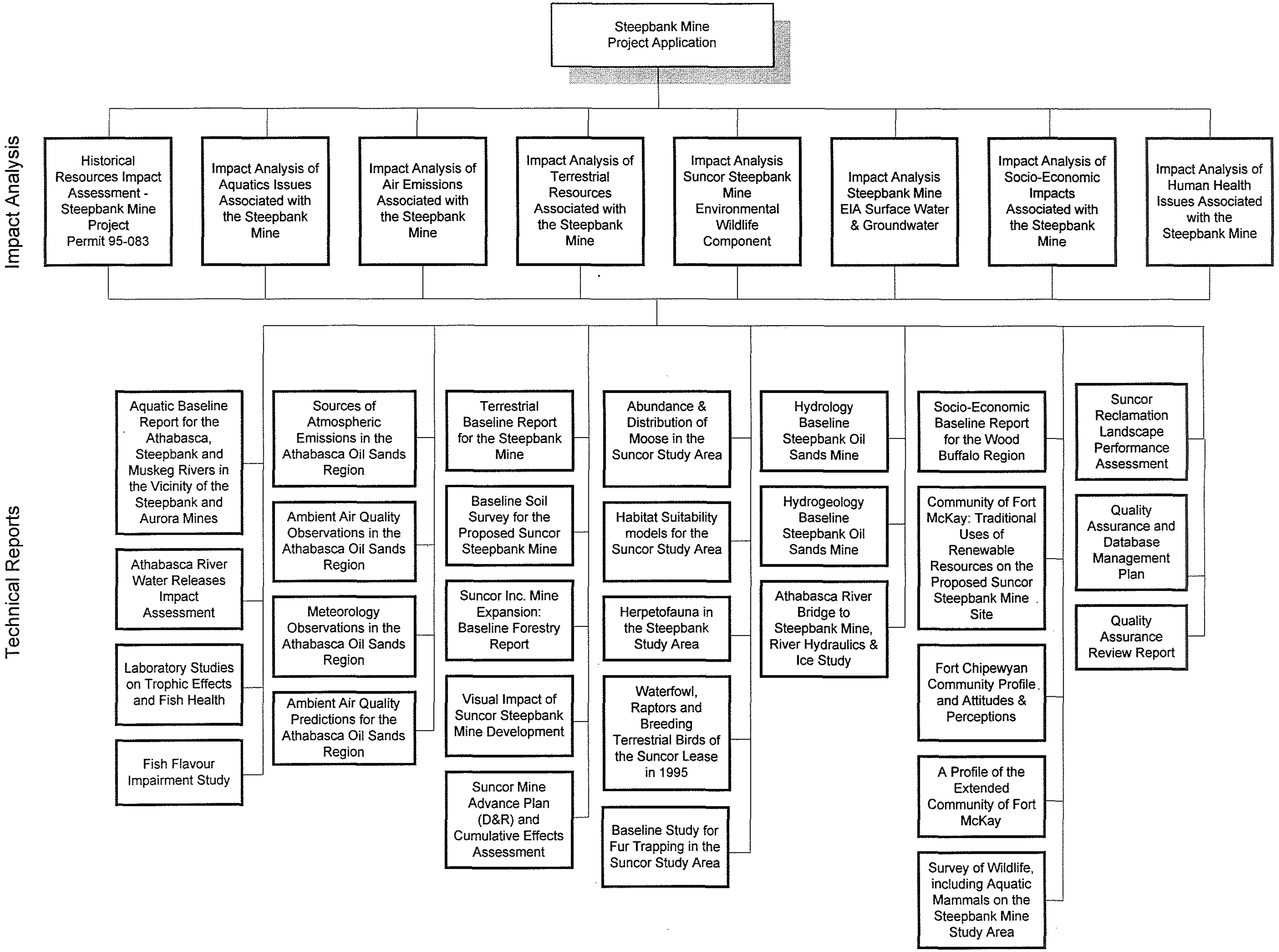

**Reports Prepared for the Steepbank Mine Environmental Assessment**

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# HABITAT SUITABILITY MODELS
# FOR SELECTED WILDLIFE SPECIES
# IN THE SUNCOR STUDY AREA

May 1996

**Prepared for:**

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**Fort McMurray, Alberta**

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## EXECUTIVE SUMMARY

Habitat Evaluation Procedures (HEP) models were developed for six wildlife species in the Suncor study area. The red-backed vole, beaver, moose and dabbling duck models were produced by modifying existing models, whereas the woodland caribou and Cape May warbler models were developed specifically for the Suncor study area.

Five habitat variables, ground cover, shrub cover, cover of deadfall, canopy cover and forest maturity, are used in the red-backed vole model. However, forest cover characteristics as indicated by the percent canopy cover and forest maturity are assumed to be the most important components of habitat suitability for this species.

The beaver model is based on the type of woody forage available and the characteristics of aquatic habitat, both of which are considered critical components of suitable habitat for this species. Four variables, woody vegetation cover, the species composition of woody vegetation, bank slope and distance from water to forage, are included in the forage submodel. In contrast, variables in the submodel for aquatic habitat differ between riverine and lacustrine habitat. Streams with low gradients and wetlands that are less than 8 ha in area are assumed to provide optimal beaver habitat. However, the suitability of wetlands that cover an area of more than 8 ha is assumed to increase with increasing shoreline development.

The moose model assumes that woody forage production is the most important component of habitat suitability for this species, although forest cover and proximity to roads are also included in the model. The forage production submodel is based on the biomass and species diversity of woody browse produced in each habitat type but is modified by the distance from the habitat unit being evaluated to forest cover. Optimal habitat is assumed to be capable of supporting two or more moose per km$^2$. The model also assumes that the presence of nearby roads substantially reduces habitat suitability. Forest cover, particularly that dominated by conifers, also contributes to habitat suitability, although its contribution is comparatively small.

The woodland caribou model is based largely on woodland caribou habitat utilization studies conducted in the Fort McMurray region by Bradshaw et al. (1995). These studies indicated that certain types of

peatland complexes were preferred over other habitat types. However, because caribou move seasonally between lowland and upland coniferous habitat types, this model assumes that the suitability of peatland habitat is modified slightly by the availability of upland coniferous forest. Human disturbance, as indicated by the amount of access provided by roads and cutlines, is also assumed to have a major impact on caribou habitat suitability.

The dabbling duck model assumes that the suitable breeding, nesting and brood rearing habitat are all critical for reproductive waterfowl. The submodels for breeding pairs and brood rearing both assume that habitat suitability depends on the types of wetlands available, and the surface area and length of shoreline available in each wetland type in the evaluation area. In contrast, the submodel for nesting habitat assumes that the suitability of upland nesting habitat increases as the amount of cover provided by residual vegetation increases and distance from water decreases.

The model for the Cape May warbler includes four variables, percent tree cover, percent conifer cover, dominant tree species and the height of coniferous trees. The model assumes habitat for this species is optimal where canopy cover is 15 to 25%, more than 80% of the canopy is composed of white spruce and where mean tree height is greater than 15 m. It is also assumed that the variable with the lowest value determines habitat suitability for the Cape May warbler.

## ACKNOWLEDGMENTS

This baseline report was prepared for Suncor Inc., Oil Sands Group (Suncor) by Westworth, Brusnyk & Associates Ltd. as part of the Suncor Steepbank Mine Environmental Impact Assessment (EIA). Mr. Don Klym was the Suncor project manager and Ms. Sue Lowell was the Suncor project coordinator. Mr. Steve Tuttle was Suncor's task leader for the wildlife resources component. Mr. Hal Hamilton of Golder was the EIA project manager.

The component leader for the wildlife resources impact assessment was Mr. Lawrence Brusnyk. Mr. Doug Skinner served as the principal author of the modelling report. Ms. Kari Donnelly and Ms. Carol Brittain were responsible for word processing and report formatting.

Mr. Lawrence Brusnyk, Mr. John Gulley (Suncor), and Ms. Bette Beswick reviewed the draft of the report.

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## 1.0 INTRODUCTION

Habitat Evaluation Procedures (HEP) models are frequently used to quantify potential habitat losses and gains for wildlife species as a result of various land use activities. HEP, which uses mathematical models to assess habitat capability, was initially developed by the U.S. Fish and Wildlife Service (1980) for use in impact assessment and project planning.

These procedures evaluate the *potential* of an area to support a wildlife species, based on a number of assumptions about how various habitat components interact to determine habitat suitability. However, because they are not capable of providing information about abundance and other demographic characteristics of wildlife populations, HEP procedures are not a substitute for population data. The U.S. Fish and Wildlife Service (1980) indicates that HEP is appropriate for two types of comparisons: (1) comparisons of different areas at the same time, and (2) comparisons of the same area at different times; however, in practice these types of comparison are frequently combined to quantify the impact of habitat alteration on its carrying capacity for wildlife.

The application of HEP for a wildlife species includes both a mapping component and the selection of variables for measurement in the field. After important variables are identified, they are measured and combined mathematically into Habitat Suitability Index (HSI) models. Values generated by these models may range from 0, which indicates habitat of no value, to 1.0, which indicates optimal habitat. Usually, HSI values for each habitat type are multiplied by the area (ha) of the habitat type or area under consideration to determine the number of habitat units (HUs) for each wildlife species.

The development of suitable models requires an understanding of the ecology and habitat requirements of the species under consideration. However, because these requirements may vary among geographic areas, models developed for one area may not be suitable for another. HSI models were developed for six representative wildlife species in the Suncor study area, the red-backed vole (*Clethrionomys gapperi*), beaver (*Castor canadensis*), moose (*Alces alces*), woodland caribou (*Rangifer tarandus*), dabbling ducks (*Anas* spp.) and the Cape May warbler (*Dendroica tigrina*). The red-backed vole, beaver, moose and dabbling duck models were produced by modifying existing models, whereas the remaining models were developed specifically for the Suncor study area.

The efficacy of HSI models is often tested by means of sensitivity and verification analyses. A verification analysis usually involves comparing the values generated by a model with population data collected from the area being evaluated. However, the models developed for this study were not subjected to this type of analysis, sometimes because the structure of the model precluded such analysis, and sometimes because low population densities or insufficient data did not allow it. It is therefore recommended that sufficient population data be collected to perform verification analyses prior to any extensive use of the following models.

# 2.0 RED-BACKED VOLE

## 2.1 Background

Two existing models provided the basis for the red-backed vole model for the Suncor study area. One of these models was designed to assess habitat suitability for the red-backed vole in the western United States (Allen 1983), whereas the other was used to assess red-backed vole habitat near Canmore, Alberta (Van Egmond et al. 1991). The model developed for the Suncor study area assumes that forest cover is the principal factor in determining red-backed vole habitat suitability but that appropriate ground cover is also necessary.

## 2.2 Key Habitat Factors

### 2.2.1 Forage

Red-backed voles exhibit seasonal changes in food habits and thus, consume a variety of plant materials during the year. A number of researchers (Whitaker 1962, Williams and Finney 1964, Dyke 1971, Martell 1981) have indicated that fungi are a dietary staple during the summer; however, studies conducted in northern Ontario, Manitoba and the Northwest Territories indicate that there is a seasonal shift in diet (Dyke 1971, Perrin 1979, Martell 1981). Lichens dominate the diet of red backed voles in May, green plants are important between mid-May and mid-July, and seeds are frequently consumed in June and July (Martell 1981). Mushrooms become an important food item in early summer and consumption of them increases throughout August and September.

During winter, red-backed voles consume petioles, small twigs, and buds (Criddle 1932, Hamilton 1941, Dyke 1971, Zemanek 1972), as well as the fruits of plants such as bog cranberry (*Vaccinium vitis-idaea*), buffaloberry (*Sherpherdia canadensis*), bearberry (*Arctostaphylos uva-ursi*) and rose (*Rosa* spp.) (Ure and Maser 1982). This model assumes that the food requirements of red-backed voles will be met in any habitat type in which shrubs and forbs are abundant.

### 2.2.2 Cover

The red-backed vole is usually associated with forested habitats, (Clough 1964, Grant 1969, Morris 1969, Grant 1970, Iverson and Turner 1973, Miller and Getz 1973, Crowell and Pimm 1976) and some studies have indicated that coniferous forest supports the highest red-backed vole populations (Rickard 1960, Armstrong 1977, Merrit 1981, Millar et al. 1985). Consequently, the model developed by Allen (1983) assumes that coniferous forests with more than 60% canopy cover and 20% ground cover of woody debris provide the highest quality red-backed vole habitat. In contrast, red-backed voles near Slave Lake, Alberta were most abundant in deciduous forest (Bondrup-Nielsen 1984). This species is also occasionally found in open habitats in late fall, apparently in response to the reduced aggressiveness of grassland rodents after breeding seasons ends (Iverson and Turner 1973).

Studies of site selection within forested habitats indicate that understory characteristics are important in determining red-backed vole habitat suitability, although the availability of free water may also affect their distribution (Miller and Getz 1973). Miller and Getz (1977) reported that red-backed vole abundance was associated with the amount of herbaceous cover and Iverson and Turner (1973) found that red-backed voles were captured most frequently in areas with high forb diversity. Other studies have indicated that red-backed vole densities are higher in areas with a well developed shrub understory than in more open areas (Iverson and Turner 1973, Miller and Getz 1973).

Habitat suitability for the red-backed vole may also be affected by the amount of deadfall present. Powell (1972) found that voles were three times as abundant in areas with high amounts of blow-down and deadfall as elsewhere, and similar results have been reported in numerous other studies (Williams 1955, Gunderson 1959, Miller and Getz 1973, Lovejoy 1975, Miller and Getz 1977, Merrit 1981). Nordyke and Buskirk (1991) reported a positive correlation between the state of decay of deadfalls and red-backed vole abundance.

### 2.2.3 Overall Habitat Suitability

This habitat suitability model assumes that forest cover is the most important component of red-backed vole habitat suitability and that forest maturity, as indicated by the percentage of trees more than 10 cm in diameter, increases habitat suitability by contributing to the amount of debris and deadfall. Within forested habitat types, understory characteristics, as indicated by the amount and type of vegetation, and debris are assumed to be the most important factors contributing to habitat suitability. The model assumes that forage requirements will be met where the amount of ground cover is high (Table 1):

$$HSI_{overall} = (0.4\ SIV1 + 0.3\ SIV2 + 0.3\ SIV3) \times (SIV4 \times SIV5)$$

where:

SIV1 = the suitability index for the ground cover of vascular plants and litter,
SIV2 = the suitability index for shrub cover,
SIV3 = the suitability index for the cover of deadfall,
SIV4 = the suitability index for forest canopy cover, and
SIV5 = the suitability index for tree maturity.

## 2.3 Model Equations

$$HSI_{overall} = (0.4\ SIV1 + 0.3\ SIV2 + 0.3\ SIV3) \times (SIV4 \times SIV5)$$

## 3.0 BEAVER

### 3.1 Background

A number of models have been used to assess habitat suitability for the beaver. Predictive models that use statistical procedures to assess habitat capability have been developed for the interior of British Columbia (Slough and Sadlier 1977) and Massachusetts (Howard and Larson 1985); however, the following model is based largely on the HSI model developed by Allen (1982). The model assumes suitable habitat for beavers must include both a suitable water regime and woody vegetation, which is used both for winter forage and as a construction material.

### 3.2 Key Habitat Factors

#### 3.2.1 Forage

The bark of trees and shrubs usually provides the bulk of the winter diet for beavers residing at northern latitudes (Aldous 1938, Brenner 1962, Novakowski 1967, Slough 1978, Jenkins 1981), although herbaceous forage is often consumed during the growing season. As a result, the availability of woody forage in proximity to water forms the basis for the forage submodel. The model assumes that habitat suitability (SIV1) increases with increasing woody vegetation cover (V1) until the amount of cover exceeds 70% (Table 2). Suitability decreases for higher cover values because, in high density stands, trees cut by beavers often become entangled in neighbouring trees and thus, are not available as food.

The species composition of woody vegetation (V2) is also important in determining habitat suitability for beavers. Several studies have indicated that, where trembling aspen (*Populus tremuloides*) is available, beavers prefer it to other shrub and tree species (Hall 1960, Northcott 1971, Slough and Sadlier 1977, Pinkowksi 1983); however, studies conducted in central Alberta indicate that balsam poplar (*Populus balsamifera*) is also a preferred forage species (Schwanke and Baker 1977, Skinner 1984). Willows (*Salix* spp.) are also reported to be important in the ecology of beavers, particularly where aspen and balsam poplar are sparsely distributed or absent (Hall 1960, Aleksiuk 1970). Because willow is more able to withstand repeated cutting than most other woody plant species (Kindschy 1985, 1989), it likely provides a more stable source of food than most other woody plant species. The model therefore assumes that forests composed of more than 50% trembling aspen, balsam poplar or willow provide the most important foraging opportunities for beavers. Because other deciduous species, such as birch (*Betula papyrifera*) and alder (*Alnus tenuifolia*), are consumed less frequently (Skinner 1984), the suitability (SIV2) of stands dominated by these species is slightly lower. In contrast, the suitability of areas dominated by coniferous trees is considered very low.

The height and slope of the banks adjacent to steams or other waterbodies is also an important factor in determining beaver habitat quality. Yeager and Rutherford (1957) indicated that beavers were uncommon in streams in V-shaped valleys because floods in such streams were associated with high water velocities, which resulted in the destruction of beaver dams. In addition, beavers must be capable of scaling banks to obtain woody forage. Thus, bank slope (V3) is used as a component of the forage submodel. In the Suncor study area, no beaver colonies were present along the Steepbank River or along deeply incised stream sections near the Athabasca River escarpment even though these sections were often associated with stands of trembling aspen, a preferred forage species. Average bank slope along these unoccupied stream sections was approximately 14°. The model therefore assumes that beavers in the Suncor study area will not usually establish colonies where bank slope exceeds 12° (SIV3=0) and that bank slopes of less than 8° are optimal (SIV3=1.0) (Table 2).

The distance that beavers must travel over land to obtain forage (V4) is also an important component of habitat suitability. Studies conducted in the United States indicate that most foraging occurs within 30 m of the water (Hall 1960, Jenkins 1980); however, at Elk Island National Park, Alberta, most foraging takes place within about 20 m of the water (Schwanke and Baker 1977, Skinner 1984). In contrast, Jenkins (1980) reported that foraging occasionally extended 100 m from the water's edge and Skinner (1984) reported that foraging occurred approximately 200 m from the water's edge at a site where an elaborate system of canals had been constructed by beavers. Thus, the value of percent cover and species composition of woody vegetation is modified by distance from water (SIV4). Forage availability is therefore calculated for each of the following three distance intervals: (1) <30 m from the water, (2) 30 to 100 m from the water, and (3) 100 to 200 m from water. The highest value obtained from these three distance intervals is the value used to assess habitat suitability.

The final food submodel assumes that suitable cover of forage plants, the presence of forage species near water and banks that are not steep are necessary to provide suitable foraging habitat for beavers:

$$HSI_{food} = SIV1 \times SIV2 \times SIV3 \times SIV4$$

where:

SIV1 = the suitability index for the cover of woody vegetation,
SIV2 = the suitability index for the species composition of woody vegetation,
SIV3 = the suitability index for bank slope, and
SIV4 = the suitability index for the distance from water to forage.

### 3.2.2 Water

In this model, suitability indices for water were derived directly from the model developed by Allen (1982). Because Allen's (1982) model assumes that factors affecting the suitability of riverine and lacustrine habitats differ, different variables are used to assess the suitability of water for these two types of aquatic habitat.

**Riverine Habitats**

Several studies have indicated that the suitability of riverine habitats for beavers is determined largely by stream gradient (V5), which affects water velocity (Yeager and Rutherford 1957, Slough and Sadlier 1977, Howard and Larson 1985, Beier and Barrett 1987). In streams with high gradients, beavers may be unable to construct lodges or food caches, and may also find swimming difficult. In this model, the suitability of riverine habitats (SIV5) is assumed to be high where stream gradients are less than 6°, whereas stream sections with gradients greater than 15° are assumed to be unsuitable for beaver (Table 2).

The second factor affecting habitat suitability in riverine habitats is the degree of annual water fluctuation (V6); the model assumes that suitability (SIV6) declines as the amount of annual water fluctuation increases. Three classes are recognized by Allen (1982):

(1) Small - fluctuations that do not affect the entrances of lodges or bank burrows,
(2) Moderate - fluctuations that affect the entrances of lodges or bank burrows, and
(3) Extreme - high fluctuations or no water present during part of the year.

For the purposes of this model, it was assumed that a water fluctuation of less than 1 m was small, a fluctuation of 1 to 1.5 m was moderate and a fluctuation of more than 1.5 m was extreme. These values are based roughly on information collected at Elk Island National Park, which indicated that most beaver lodges are established in less than 1 m of water (Skinner 1984).

The suitability of water in riverine habitat is assumed to be a function of both stream gradient and the degree of annual water fluctuation as indicated by the equation:

$$HSI_{water} = SIV5 \times SIV6$$

where:

SIV5 = the suitability index for stream gradient, and
SIV6 = the suitability index for water fluctuation.

**Lacustrine Habitats**

The suitability of lacustrine habitats for beavers (SIV7) is assumed to be related to the size of the waterbody and the amount of shoreline development. The model assumes that waterbodies occupying an area of less than 8 ha provide optimum habitat regardless of the extent of shoreline development:

$$HSI_{water} = 1.0\ (for\ lacustrine\ habitats\ <8\ ha\ area)$$

In contrast, the suitability of larger waterbodies is assumed to be a function of shoreline development (V7), which is an indication of the number of coves and inlets present. Because beavers can reduce the effects of wind and wave action by establishing colonies in sheltered areas, waterbodies that have a high shoreline development index are assumed to have high habitat suitability. Shoreline development, which is calculated as the ratio of actual shoreline length to the minimum length required for circular waterbody of the same area, is determined by the formula (Allen 1982):

$$DI = \frac{L}{2\sqrt{A \times \Pi}}$$

where:

DI = the shoreline development index,
L = the actual shoreline length (m), and
A = the area of the waterbody ($m^2$).

The shoreline development index is compared to the values in Table 2 to determine the suitability (SIV7) of water bodies larger than 8 ha in area:

$$HSI_{water} = SIV7 \text{ (for lacustrine habitats >8 ha area)}$$

where:

SIV7 = the suitability index for shoreline development.

### 3.2.3 Overall Habitat Suitability

The final habitat suitability model for beavers assumes that the presence of adequate forage and a suitable water regime are both essential for beavers to occupy an area. The model also assumes that the potential of an area to support beavers will be determined by either food or water, whichever variable has the smaller HSI. Thus, overall habitat suitability is calculated as:

$$HSI_{overall} = minimum\,(HSI_{food},\ HSI_{water})$$

## 3.3 Model Equations

$$HSI_{food} = SIV1 \times SIV2 \times SIV3 \times SIV4$$

$$HSI_{water} = SIV5 \times SIV6$$

$$HSI_{water} = SIV7 \, (for\ lacustrine\ habitats > 8\ ha\ area)$$

$$HSI_{water} = 1.0 \, (for\ lacustrine\ habitats < 8\ ha\ area)$$

$$HSI_{overall} = minimum\,(HSI_{food},\ HSI_{water})$$

## 4.0 MOOSE

### 4.1 Background

The habitat suitability model for moose in the Suncor study area incorporates many of the features of an HSI model developed for moose in the Lake Superior region (Allen et al. 1987). That model includes both a summer and winter component; however, because winter is the critical period for wildlife in northern Alberta, the model developed for the Suncor study area is based on the capability of habitat to support moose during winter. The model developed by Allen et al. (1987) assumes that the primary factors that govern the ability of an area to support moose include forage availability and forest cover. However, in addition to those assumptions, the following model also includes human disturbance as indicated by road development as a key habitat factor.

### 4.2 Key Habitat Factors

#### 4.2.1 Forage

**Forage Production**

Moose are considered more dependent on woody forage than any other North American cervid (Telfer 1978a, 1978b, Peek and Eastman 1983). Irwin (1985) indicated that browse is important to moose throughout the year and Allen et al. (1987) concluded that, although grasses and forbs are consumed during the growing season, these plants are not a critical habitat factor. Thus, this model assumes that woody browse production is the most important factor in determining habitat suitability for moose. In Alberta, woody plants consumed by moose include trembling aspen, balsam poplar, willow, red osier dogwood (*Cornus stolonifera*), saskatoon (*Amelanchier alnifolia*), cranberry (*Viburnum edule*), paper birch, chokecherry (*Prunus virginiana*) and pincherry (*P. pensylvanica*) (Westworth et al. 1983; Brusnyk and Westworth 1985, 1988). Consequently, the dry weight of forage produced by these nine species forms the basis of the moose suitability model.

Because severe browsing can damage plants and reduce browse production in subsequent years, the model assumes that 20% of current annual growth can be consumed each year without reducing production (Allen et al. 1987).

Woody forage is assumed to be available to moose if twigs are present between 0.4 and 2.5 m above ground level. The lower limit is based on a mean maximum annual snow depth of 38 cm and a maximum snow depth of 66 cm reported for the Fort McMurray region from 1944 to 1972 (Hauge and Keith 1981), whereas the upper limit is based on the height of browse available to moose through stem breakage (Telfer and Cairns 1978).

Gasaway and Coady (1974) reported that moose require 4.5 to 5.5 kg/day dry weight of forage in winter, and between 10 and 12 kg/day in summer, whereas Nystrom (1980) indicated that calf moose required from 2.43 to 3.97 kg/day of forage. In contrast, Renecker and Hudson (1985) reported that the dry matter intake requirement for a moose, expressed as a function of body weight (BW), ranged from 37.8 g/kg $BW^{0.75}$ to 128.5 g/kg $BW^{0.75}$ annually; based on these figures, forage requirements for an adult moose would be about 7 kg/day. This model therefore assumes that the average browse requirement for a moose during the winter period is 2660 kg of browse/year, based on a consumption rate of 7 kg of woody forage/day.

### Forage Diversity

Forage species diversity (V1) may also be an important factor in determining habitat suitability for moose. Feeding trials have indicated that, although moose may prefer certain species, a variety of woody plants is usually consumed (Miquelle and Jordan 1979). Similarly, a study conducted in Alaska indicated that, because nutrient regimes in various plant species differ, a diversity of browse species is required to meet the nutritional needs of moose (Oldemeyer et al. 1977). In that study, habitats containing five browse species were found to be superior to those with only one species. This model therefore assumes that habitat suitability (SIV1) increases with forage species diversity (Table 3). Forage diversity is considered optimum where more than five browse species are available.

### Distance to Cover

Several studies in Ontario have indicated that moose using open habitat types usually remain near the forest's edge. Hamilton et al. (1980) reported that most moose activity in clearcuts was within 80 m of the forest's edge, although moose were sometimes observed as far as 260 m away from forest cover. Similarly, Hamilton and Drysdale (1975) reported that few moose were recorded more than 100 m away from the forest's edge, and Thompson and Vukelich (1981) reported that moose were usually found less than 60 m from cover. In this model, the suitability of an area for forage is modified by the distance from forest cover (V2). The suitability (SIV2) of foraging sites within 100 m of forest cover is considered optimal and suitability declines as distance from cover increases (Table 3).

### Overall Suitability for Forage

Although aerial surveys have indicated that moose densities in the Fort McMurray region usually range from 0.10 to 0.31/km$^2$ (Bibaud and Archer 1973, Skinner and Westworth 1981), these low densities likely reflect, at least in part, the prevalence of coniferous forests, which usually produce little forage for moose. In the late 1970s, moose density in the Rochester, Alberta area, which includes a higher proportion of deciduous forest, was estimated at 1.4 moose/km$^2$ (Mytton and Keith 1981). Thus, it appears likely that moose densities in Alberta may be somewhat higher in areas comprised of entirely of optimal habitat. As a result, this model assumes that optimal habitat produces enough forage to support a density of 2.0 moose/km$^2$ (Allen et al. 1987).

The final forage submodel therefore assumes that optimal foraging habitats are those that provide sufficient woody browse to feed two or more moose per km$^2$ throughout the winter. As a result, the submodel is based primarily on forage production but is modified by plant species diversity and distance to cover. The output for the forage submodel may not exceed 1.0:

$$HSI_{food} = minimum\ 1,\ \left(\frac{100 \times 0.2 \times FP}{2660}\right) \times SIV1 \times SIV2$$

where:

100 = the conversion factor from kg/ha to kg/km$^2$,
0.2 = the reduction factor assuming 20% cropping,
FP = the dry weight of browse produced (kg/ha),
2660 = the biomass of browse required to support two moose for one winter,
SIV1 = the suitability index for species diversity, and
SIV2 = the suitability index for distance from forest cover.

### 4.2.2 Cover

Several studies conducted in eastern North America have indicated that forest cover is an important component of habitat suitability for moose. Moose in that region frequently move into habitats dominated by conifers in response to severe weather or high snow accumulations (Telfer 1970, Peek et al. 1976, Addison et al. 1980, Doerr 1983, Peek and Eastman 1983). However, because snow accumulations in northeastern Alberta seldom approach the 70 cm depth required to impede movements by moose (Kelsall 1969, Coady 1974), thermal cover is considered less important to moose in this region. Moreover, extreme cold appears to have little effect on moose, providing that shelter from the wind is available (Kelsall and Telfer 1974).

The model therefore assumes that moose in northeastern Alberta use cover primarily for security and that the value of hiding cover is principally a function total forest cover (V3). However, the suitability of cover is enhanced by the presence of coniferous trees (V4), which provide better hiding and thermal cover than deciduous trees. The model also assumes that the suitability of cover is modified by mean tree height (V5) because large trees provide better cover and also facilitate movements under the canopy (Table 3):

$$HSI_{cover} = (0.6\ SIV3 + 0.4\ SIV4) \times SIV5$$

where:

SIV3 = the suitability index for total forest cover,
SIV4 = the suitability index for total conifer cover, and
SIV5 = the suitability index for mean tree height.

### 4.2.3 Disturbance

Human disturbance may have a pronounced effect on moose distribution. Aerial surveys flown in the Suncor study area in February 1995 indicate that the population density of moose differs between areas east and west of the Athabasca River, likely in response to the amount of human activity (Skinner and Brusnyk 1996). The area west of the river contains borrow pits, regenerating clear cuts and numerous roads. A density of 0.20 moose/km$^2$ were recorded in this area as compared to 0.24 moose/km$^2$ east of the river, which is more remote. Similarly, Hancock (1976) reported 0.82 moose/km$^2$ in an area with little human disturbance as opposed to 0.25 moose/km$^2$ in a more highly disturbed area. At least two studies have indicated that moose distribution near Rochester, Alberta is affected by the presence of roads. Rolley and Keith (1980) reported that, between November and January, moose were located significantly farther than expected from roads. Skinner (unpubl. data) similarly found that moose near Rochester avoided well-travelled roads; in that study, the track frequency near well-travelled roads was approximately one-third of that recorded in the vicinity of little-travelled roads. The presence of roads often results in increased hunting pressure. Lynch (1973) indicated that, near Swan Hills, Alberta, 80% of hunting took place within 1.5 km of a road and Boer (1990) reported that 92% of the moose killed by hunters in New Brunswick were taken within 1 km of a road.

The model therefore assumes that habitat suitability is modified by the presence of roads (V6). Habitat suitability (SIV6) is reduced by the presence of an all-weather road (Table 3):

$$HSI_{disturbance} = SIV6$$

where:

SIV6 = the suitability index for distance from an all-weather road.

### 4.2.4 Overall Habitat Suitability

The final model for moose assumes that the availability of forage is the most important factor affecting habitat suitability but that the presence of nearby forest cover enhances suitability. However, suitability is reduced if a habitat unit occurs near an all-weather road:

$$HSI_{overall} = (0.75\ HSI_{food} + 0.25\ HSI_{cover}) \times HSI_{disturbance}$$

## 4.3 Model Equations

$$HSI_{food} = minimum\ 1, \left(\frac{100 \times 0.2 \times FP}{2660}\right) \times SIV1 \times SIV2$$

$$HSI_{cover} = (0.6\ SIV3 + 0.4\ SIV4) \times SIV5$$

$$HSI_{disturbance} = SIV6$$

$$HSI_{overall} = (0.75\ HSI_{food} + 0.25\ HSI_{cover}) \times HSI_{disturbance}$$

## 5.0 WOODLAND CARIBOU

### 5.1 Background

The following model to assess habitat suitability for the woodland caribou has been developed specifically for the Fort McMurray region. Consequently, the model relies heavily on the caribou habitat relationships reported by Bradshaw et al. (1995), who recently conducted studies of radio-collared caribou in the Fort McMurray-Calling Lake-Winifred Lake region of northeastern Alberta. Based on their data, this model assumes that the key habitat feature for caribou is the availability of relatively undisturbed peatlands, although the presence of nearby upland coniferous forest is assumed to contribute slightly to overall habitat suitability.

### 5.2 Key Habitat Factors

### 5.2.1 Food and Cover

**Forage**

Although some workers have suggested that lichens are not necessary for the survival of caribou (Bergerud 1972, Euler et al. 1976), caribou are unique among cervids because lichens comprise much of their diet and are eaten throughout the year (see review in Thompson et al. 1980). Studies conducted in west-central Alberta indicate that lichens provide approximately 66% of the winter diet (Edmonds and Bloomfield 1988) and about 20% of the summer diet of caribou (J. Edmonds, pers. comm.). Holleman et al. (1979) reported that captive caribou consumed from 1.3 to 4.9 kg of lichens per day in winter; however, they believed that the energy requirements and therefore lichen consumption by free-ranging caribou would be much higher because of the energy expenditures associated with climatic extremes and the avoidance of predators.

Several studies indicate that caribou prefer terrestrial lichens, which are located by using holes in the snow created by tall shrubs as air vents (Bergerud 1976), to arboreal lichens. Terrestrial lichens of the genus *Cladina* were the most common forage species found in caribou feeding craters in northeastern Alberta (Bradshaw et. al. 1995). Similarly, terrestrial lichens (*Cladina* spp.) were eaten much more frequently than other potential food items in southeastern Manitoba (Schaefer and Pruitt 1991).

However, arboreal lichens are also consumed, especially when terrestrial lichens are not available (Cumming 1992). Arboreal lichens (*Usnea hirta, Bryoria trichodes, Evernia mesomorpha*) are common forage species in southeastern Manitoba (Schaefer and Pruitt 1991).

Although lichens appear to be the most important food item for caribou, other types of vegetation are also consumed. In spring and summer, caribou feed on forbs, leaves, fungi, grasses and sedges in addition to lichens, whereas the autumn and winter diet is composed primarily of lichens, ericaceous vegetation and sedges (Simkin 1965, Bergerud 1972).

In southeastern Manitoba, caribou feed on terrestrial lichens (*Cladonia* spp.) and lichens growing among rocks (*Parmelia* spp.) in spring (Darby and Pruitt 1984), but also consume the growing twigs of alder and willow. In late spring and summer, the diet shifts to forbs, deciduous foliage, and arboreal and terrestrial lichens, whereas in autumn, terrestrial and arboreal lichens, sedges, and ericaceous plants, such as bog rosemary (*Andromeda glaucophylla*), leatherleaf (*Chamaedaphne calyculata*), pale laurel (*Kalmia polifolia*), and Labrador tea (*Ledum groenlandicum*) are eaten. In mid-February, caribou feed primarily on terrestrial lichens and blueberries (*Vaccinium myrtilloides*).

Because of the close association between caribou and lichens, forests of sufficient age to produce enough lichens for forage are considered important caribou habitat. Miller (1976) reported that good lichen-producing forests in northwestern Manitoba are typically 30 to 40 years old; however, in Alberta, such forests are usually 60 to 80 years old (J. Edmonds, pers. comm.). In northeastern Alberta, caribou selectively forage in forested ombrotrophic bogs or oligotrophic peatlands dominated by black spruce (*Picea mariana*). Because relatively dry sites are present in these habitat types, they produce a greater biomass of terrestrial lichens than other lowland habitat types (Bradshaw et al. 1995).

### Cover

Studies conducted in the Birch Mountains of northeastern Alberta indicate that caribou prefer lowland habitat for much of the year (Fuller and Keith 1981). In that area, black spruce muskegs, in which 44% of all caribou observations were made, were used at all times of the year. In comparison, black spruce forest and jack pine (*Pinus banksiana*)-spruce (*Picea* spp.) forest, the second and third most frequently used habitat types, contained only 13 and 12% of all caribou observations, respectively. Deciduous and mixedwood forests were rarely used by caribou. The use of black spruce muskeg peaked in December when 61% of all caribou observations were recorded in that habitat type. In contrast, only 21% of the caribou were observed in black spruce muskeg in August.

Fuller and Keith (1981) indicated that habitat use by caribou varied seasonally. The use of lowland habitats increased in early spring and then declined in summer, when caribou moved into upland coniferous forests to take advantage of the greater abundance of vascular vegetation. After the autumn rut, caribou aggregated in open lowlands and then later moved into upland habitats as winter progressed.

Similar seasonal habitat use was reported for caribou in southeastern Manitoba (Darby and Pruitt 1984). Caribou in that area also aggregated in bogs during and after the rut. These bogs were used until February, when access to forage was limited by deep, hard snow and caribou moved into jack pine forest.

Bradshaw et al. (1995) used the peatland classification of Vitt et al. (1992) to assess caribou habitat use near Fort McMurray. Their study indicated that, during winter, caribou in that region preferred complexes consisting of more than 50% peatland. These preferred peatlands have greater than 25% forest cover and 25% open areas (Type C, Table 4); however, ombrotrophic peatlands dominated by black spruce (Type D) are also a preferred habitat type and contained most of the feeding craters recorded during the study. In contrast, nonpatterned, open peatlands composed of less than 50% peatland (Type E) are avoided by caribou.

### Food and Cover Submodel

The food and cover submodel assumes that habitat quality is based primarily on the peatland types identified by Vitt et al. (1992) and used by Bradshaw et al. (1995) to evaluate caribou habitat in northeastern Alberta. Two habitat types, Type C (Table 4), which contained the greatest proportion of caribou observations, and Type D, which contained most of the feeding sites (Bradshaw et al. 1995), are assumed to provide the highest quality habitat (SIV1=1.00 and 0.80, respectively). Because woodland caribou may move seasonally between peatland and upland coniferous habitat (Fuller and Keith 1981, Darby and Pruitt 1984), the model assumes that the quality of peatland habitat increases slightly if large blocks of upland coniferous forest are nearby (Table 4). However, the effect of distance is considered minor because, although most caribou movements in the Birch Mountains were less than 10 km, seasonal movements of up to 71 km were recorded (Fuller and Keith 1981). Similarly, the suitability of upland habitats is increased by the presence of nearby peatlands. Thus, the formula for the food and cover component of the model is:

$$HSI_{food/cover} = SIV1 \times SIV2$$

where:

SIV1 = the suitability index for the habitat type being evaluated, and
SIV2 = the suitability index for distance to upland coniferous forest (or peatland).

### 5.2.2 Disturbance

Because caribou have a low reproductive rate, there is a fine balance between levels of reproduction and natural mortality (Bergerud 1974). Thus, caribou populations often decline when predation pressure increases (Edmonds, 1986, 1988). As a result, caribou, which are more vulnerable to predators than most other cervids (Bergerud 1974, Bergerud and Elliot 1986), inhabit large tracts of undisturbed forest probably primarily as a strategy to avoid predation (Bergerud 1985, Bergerud and Page 1987). Bergerud (1980) suggested that, to maintain a stable caribou population when wolves (*Canis lupus*) were present, each caribou required about 2 $km^2$ of habitat and postulated that, space was therefore more important than food in limiting caribou populations. Some studies have indicated that caribou also try to minimize their encounters with predators by avoiding habitats occupied by other ungulates and their predators. Studies conducted in British Columbia indicate that habitat use by caribou is both spatially and temporally separated from that of moose and wolves (Bergerud and Page 1987, Seip 1990).

Human activities that alter caribou habitat and increase predator abundance may also have an adverse effect on caribou. Darby and Duquette (1986) documented several occasions in which logging resulted in the disappearance of woodland caribou from localities in Ontario. The removal of forest cover often results in the creation of early successional habitats, which can increase the availability of forage used by other ungulate species. Consequently, populations of deer (*Odocoileus* spp.) and moose may increase in response to timber harvesting and cause concomitant increases in the number of predators, such as wolves and black bears (*Ursus americanus*), which also prey on caribou. Caribou numbers may also decline when remote areas are opened by roads (Bergerud 1974), because roads and cutlines allow predators to search for prey more efficiently. Caribou populations have also been reported to decline in response to cottage building (Cumming and Beange 1987).

Caribou are also highly susceptible to overhunting because they form large groups and appear unable to perceive danger at a distance (Bergerud 1974). Thus, the presence of roads and cutlines may result in direct human-caused mortality by providing access for hunters and poachers. The results of a study conducted by Edmonds (1988) suggested that access was directly responsible for much of the caribou mortality in west-central Alberta. Of 31 caribou found dead during that study, 83% were located within 50 m of a frequently-travelled road. Fifty-five percent of the dead caribou were illegally shot, 23% were struck by vehicles, 10% were shot by native hunters and 3% were killed by wolves.

Although few actual studies have been conducted to determine the effect of cutline and road access on woodland caribou, this model assumes that human disturbance, as indicated by the amount of access, is an important factor in determining habitat suitability for caribou. B. Rippen (pers. comm.) indicated that caribou calf:cow ratios near Red Earth, Alberta, an area with extensive oil exploration, were approximately one-half of those near Wabasca, where development is more limited. The suitability indices for access (SIV3) are therefore based on an examination of airphotos of these two areas, which indicated that there are over 500 km of access/100 $km^2$ near Red Earth as compared to about 100 km of access/100 $km^2$ near Wabasca (Table 4):

$$HSI_{disturbance} = SIV3$$

where:

SIV3 = the suitability index for disturbance.

### 5.2.3 Overall Habitat Suitability

The model for overall habitat suitability assumes that the availability of suitable peatland habitat is the principal factor affecting habitat suitability for woodland caribou in the Fort McMurray region, although the suitability of peatlands is modified to some extent by the availability of upland coniferous forests. Human disturbance, as indicated by the presence of roads and cutlines is also assumed have a significant impact on habitat suitability for caribou:

$$HSI_{overall} = HSI_{food/cover} \times HSI_{disturbance}$$

## 5.3 Model Equations

$$HSI_{food/cover} = SIV1 \times SIV2$$

$$HSI_{disturbance} = SIV3$$

$$HSI_{overall} = HSI_{food/cover} \times HSI_{disturbance}$$

# 6.0 DABBLING DUCKS

## 6.1 Background

The habitat evaluation model used for waterfowl in the Suncor study area is based on a model developed for blue-winged teals (*Anas dicors*) in the prairie pothole region of the United States (Sousa 1985). That model, which evaluates the potential of wetlands to support populations of breeding, nesting and brood-rearing blue-winged teals, was selected as a basis for the following model because the habitat requirements of blue-winged teals and most other species of upland nesting waterfowl are similar during the breeding season. However, the model was altered by using data from the Buffalo Lake Moraine, which is considered to be some of the best waterfowl habitat in Alberta (D. Hofman, pers. comm.), to develop suitability indices. These values were substituted for suitability indices in Sousa's (1985) model, which are based on data obtained from the pothole region of the Dakotas, because breeding habitat in Alberta is less productive than that in the Dakotas, which contain some of the most productive waterfowl habitat in North America. Although rivers are frequently used as staging habitat by migrating waterfowl, this model is not appropriate for the assessment of riverine habitats because they usually do not provide suitable habitat for breeding ducks.

## 6.2 Key Habitat Factors

### 6.2.1 Breeding Pairs

Preferred breeding habitat for dabbling duck pairs includes a variety of wetland types depending on the species; however, an interspersion of open water, and emergent and submergent vegetation generally provides the most productive breeding habitat (Kaminski and Prince 1981, Murkin et al. 1982). Shallow, eutrophic, seasonal and semipermanent wetlands are considered the best habitats for breeding waterfowl because they usually support large populations of invertebrates, which are a principal food item for waterfowl during the breeding season. Egg-laying females require high levels of protein and these types of wetlands reliably recycle the nutrients required to produce forage that is high in protein (Krapu 1974, Swanson et al. 1974, Joyner 1980).

### Length of the Wetland Shoreline

The presence of suitable wetlands is the most important habitat requirement for breeding waterfowl. Consequently, Sousa (1985) used the number of wetlands per section of land (259 ha) to describe habitat suitability for breeding pairs; however, the model developed for the Suncor study area uses the length of the wetland shoreline. This variable is used instead of wetland density because the amount of shoreline is more closely correlated with breeding pair density (J.T. Lokemoen, pers. comm.).

For modelling purposes, the total length of the wetland shoreline in an evaluation area (V1) is converted to an equivalent shoreline length for optimum wetlands by multiplying V1 in each wetland class by the preference index for pairs (Table 5). The preference index, which is based on data from Kantrud and Stewart (1977), follows Sousa (1985). Thus:

$$EOS_{wp} = \frac{259}{s} \cdot \sum_{i=1}^{n} (V1_i \times P_i)$$

where:

$EOS_{wp}$ = the equivalent optimum shoreline length (weighted by preference indices)/259 ha,
259 = the number of ha per section (1 $mi^2$) of land,
$s$ = the area of the evaluation area (ha),
$n$ = the number of wetland classes,
$V1_i$ = the length of shoreline in wetland class i, and
$P_i$ = the preference index for wetland class i.

The suitability index for shoreline length (SIV1), which is based on data from Buffalo Lake Moraine, Alberta (D. Hofman, pers. comm.), is obtained by comparing the value of $EOS_{wp}$ to the values in Table 6.

### Area of Wetlands

Another component of wetland suitability is the surface area of water in each wetland class. Like shoreline length, the area of wetlands in an evaluation area (V2) is converted to an equivalent area of optimum wetlands by multiplying V2 in each class by the preference index for pairs (Table 5):

$$EOA_{wp} = \frac{259}{S} \cdot \sum_{i=1}^{n} (V2_i \times P_i)$$

where:

$EOA_{wp}$ = the equivalent optimum area of wetlands/259 ha for pairs, and
$V2_i$ = the area of wetlands in class i.

The suitability index for wetland area (SIV2) is obtained by comparing the value for $EOA_{wp}$ to the values in Table 6.

**Suitability of Breeding Habitat**

Shoreline length and wetland area are assumed to be equally important in determining habitat suitability for dabbling duck pairs. However, it is assumed that the variable with the lowest suitability index (SI) has the greatest influence on the suitability of an area. Thus:

$$HSI_{pairs} = \sqrt{(SIV1 \times SIV2)}$$

### 6.2.2 Nesting

Nesting success is the most important factor affecting the recruitment of new individuals into waterfowl populations. Nesting habitat for dabbling ducks may consist of grasslands, grassland-low shrub complexes, hayfields, rights-of-way, vegetated islands, or wetland margins. Most dabbling ducks nest primarily in upland habitat, but some, such as the mallard (*Anas platyrhynchos*), will also select sites in dense cattails (*Typha* spp.) and bulrushes (*Scirpus* spp.) at the edges of wetlands (Cowardin et al. 1985).

Ducks that nest in habitats with tall, dense cover usually have greater nesting success than those that nest where cover is sparse (Kirsch et al. 1978, Livezey 1981, Cowardin et al. 1985). The presence of residual herbaceous vegetation, which consists of dead standing vegetation, also appears to be an important factor in nest site selection, particularly for species, such as the pintail (*Anas acuta*) and mallard, that nest early in the season (Duebbert and Lokemoen 1976).

### Residual Vegetation

Upland nesting ducks typically select the tallest and most dense herbaceous vegetation available for nest sites (Lokemoen et al. 1990). Before the growing season, residual herbaceous cover (V3) provides especially important nesting cover. The suitability of residual cover depends on both its height and density (Shaffer et al. 1985, Kirsch, unpubl. data cited in Sousa 1985), both of which can be incorporated into a single visual obstruction measurement (Robel et al. 1970). Visual obstruction is measured as the height to which a pole 3 cm in diameter is completely hidden by vegetation when observed from a distance of 4 m. The model assumes that the suitability of nesting cover (SIV3) is directly related to the height and density of residual herbaceous vegetation and, hence, to visual obstruction (Table 6).

### Distance to Wetlands

The distance from nesting cover to a suitable wetland (V4) also influences the suitability of potential nesting cover. Optimum nesting cover (SIV4=1.0) usually occurs less than 250 m from any wetland unless it is ephemeral, in which case the wetland is considered unsuitable (Duebbert and Lokemoen 1976). Nesting cover located more than 1000 m from a wetland is seldom used by nesting waterfowl and is therefore also considered unsuitable for nesting dabbling ducks (Table 6).

### Suitability of Nesting Habitat

A suitability index for nesting in each cover type ($SIN_i$) is obtained by calculating the product of the suitability for residual vegetation (SIV3) and distance to water (SIV4):

$$SIN_i = SIV3_i \times SIV4_i$$

where:

$SIN_i$ = the suitability of cover type i for nesting,
$SIV3_i$ = the suitability index for residual vegetation in cover type i, and
$SIV4_i$ = the suitability index for distance from a wetland for habitat type i.

The sum of the products of $SIN_i$ and area across all cover types provides an estimate of the equivalent optimum area of nesting habitat (V5) available to dabbling ducks:

$$V5 = \frac{259}{s} \cdot \sum_{i=1}^{n} (A_i \times SIN_i)$$

where:

s = the size of the study area (ha),
m = the number of habitats with potential nesting cover, and
$A_i$ = the area of cover type i.

Habitat suitability (SIV5) for nesting dabbling ducks is obtained by comparing V5 to the values in Table 6:

$$HSI_{nesting} = SIV5$$

where:

SIV5 = the suitability index for area of optimum nesting habitat/259 ha.

### 6.2.3 Brood Rearing

Relatively permanent water, such as that provided by semipermanent and permanent wetlands, and the presence of emergent vegetation, which provides hiding cover from predators and thermal cover during periods of severe weather (Smith et al. 1964, Hudson 1983), are important for the successful rearing of duck broods. Shallow water is selected by brood-rearing hens because it contains an abundance of invertebrates, which provide important forage for broods (Sugden 1973, Talent et al. 1982).

**Length of the Wetland Shoreline**

Because there are no data available with which to quantify optimum brood habitat in Alberta, information for blue-winged teal broods in the Dakotas was used in this portion of the model. Optimum habitat for waterfowl broods is assumed to exist where there are at least six equivalent wetlands with a total area of 20.2 ha per section (259 ha) of land (J.T. Lokemoen, pers. comm. cited in Sousa 1985). For the purposes of this model, the area of wetlands was converted to an optimum shoreline length by assuming that the average shoreline development index for these wetlands was 1.5.

The length of shoreline in each wetland class is converted to an equivalent shoreline length for optimum wetlands by multiplying shoreline length in each wetland class by the preference index for broods (Table 5), which was derived from the opinion of experts (Sousa 1985). Thus:

$$EOS_{wb} = \frac{259}{S} \sum_{i=1}^{n} (V6_i \times B_i)$$

where:

EOS$_{wb}$ = the equivalent optimum shoreline length (weighted by preference indices)/259 ha,
n = the number of wetland classes,
V6$_i$ = the length of shoreline in wetland class i, and
B$_i$ = the preference index for broods for wetland class i.

The suitability index for shoreline (SIV6) is obtained by comparing the value of EOS$_{wb}$ to the values in Table 6.

### Area of Wetlands

Another important component of habitat suitability for broods is the surface area of water available in each wetland class. To assess the importance of this variable, the area of wetlands in the study area (V7) is converted to an equivalent area of optimum wetlands by multiplying the area in each wetland class by its preference index for broods:

$$EOA_{wb} = \frac{259}{S} \sum_{i=1}^{n} (V7_i \times B_i)$$

where:

$EOA_{wb}$ = the equivalent optimum area of wetlands (weighted by preference indices)/259 ha, and
$V7_i$ = the area of wetlands in class i.

The value of $EOA_{wb}$ is compared with Table 6 to obtain a suitability index for wetland area (SIV7).

**Suitability of Brood Rearing Habitat**

The assessment of brood-rearing habitat is similar to that for pairs in that the variable with the lowest suitability is assumed to have the greatest influence in determining the suitability of brood rearing habitat:

$$HSI_{broods} = \sqrt{(SIV6 \times SIV7)}$$

### 6.2.4 Overall Habitat Suitability

The model for overall habitat suitability assumes that the presence of breeding, nesting and brood-rearing habitat are all essential for waterfowl to reproduce successfully. Thus, the component with the lowest potential to support reproductive waterfowl is assumed to determine overall habitat suitability:

$$HSI_{overall} = minimum(HSI_{pairs}, HSI_{nestings}, HSI_{broods})$$

## 6.3 Model Equations

### 6.3.1 Breeding Pairs

$$EOS_{wp} = \frac{259}{S} \sum_{i=1}^{n} (V1_i \times P_i)$$

$$EOS_{wp} = \frac{259}{S} \sum_{i=1}^{n} (V1_i \times P_i)$$

$$EOA_{wp} = \frac{259}{S} \sum_{i=1}^{n} (V2_i \times P_i)$$

$$HSI_{pairs} = \sqrt{(SIV1 \times SIV2)}$$

### 6.3.2 Nesting

$$SIN_i = SIV3_i \times SIV4_i$$

$$V5 = \frac{259}{S} \sum_{i=1}^{n} (A_i \times SIN_i)$$

$$HSI_{nesting} = SIV5$$

### 6.3.3 Brood Rearing

$$EOS_{wb} = \frac{259}{S} \sum_{i=1}^{n} (V6_i \times B_i)$$

$$EOA_{wb} = \frac{259}{S} \sum_{i=1}^{n} (V7_i \times B_i)$$

$$HSI_{broods} = \sqrt{(SIV6 \times SIV7)}$$

### 6.3.4 Overall Habitat Suitability

$$HSI_{overall} = minimum(HSI_{pairs}, HSI_{nestings}, HSI_{broods})$$

## 7.0 CAPE MAY WARBLER

### 7.1 Background

The following model was developed to assess habitat suitability for the Cape May warbler in the Suncor study area. However, because the Cape May warbler is uncommon throughout its range in the boreal forest region of Alberta (Semenchuk 1992), little specific information about its breeding requirements in this area is available.

### 7.2 Key Habitat Factors

### 7.2.1 Forage

The Cape May warbler is primarily an insectivore (DesGranges 1980), although it may feed on a variety of invertebrates and other materials. Beetles, dragonflies, moths, caterpillars, flies, ants, wasps, bees and spiders are eaten, and the species may also feed on sap from woodpecker holes (Terres 1980). The Cape May warbler usually forages near, but not at, the terminal ends of branches near the tops of trees (Morse 1978). MacArthur (1958) reported that 70% of foraging by Cape May warblers occurred near the periphery of trees, primarily in the upper branches of conifers. Ninety-two percent of their feeding activity was concentrated above 12 m and 63% was above 15 m; however, during cold, rainy, or windy weather, they often foraged in low shrubs where they fed among the flowers.

### 7.2.2 Nesting Habitat

Cape May warblers breed and nest in open stands of mature coniferous forest, particularly those dominated by white spruce (*Picea glauca*) (Godfrey 1966, Harrison 1978, Terres 1980, Semenchuk 1992). During the breeding season, male Cape May warblers select tall conifers that rise above the rest of the forest for singing perches (Godfrey 1966, Salt and Salt 1976, Harrison 1978, Terres 1980, Semenchuk 1992). In Quebec, Cape May warbler density in a white spruce plantation was at least six times that recorded in any other habitat type (DesGranges 1980). In Maine, this species bred almost exclusively in tall spruce and fir (*Abies* spp.) stands. The density of breeding Cape May warblers in these habitat types was 12 times that of mixedwood stands (Morse 1978). A study recently conducted in New Brunswick indicated that Cape May warblers nested only in mature conifer stands over 60 years old, in which forest cover was about 20% (Parker et al. 1994). Three breeding pairs/ha were recorded in that habitat type, whereas none were found in younger forest stands.

Cape May warblers also frequently nest near forest openings (Godfrey 1966, Semenchuk 1992). In a study to determine the effects of various forest harvesting regimes on songbirds, Darveau et al. (1995) found that this species was most abundant in unharvested strips of conifers at least 60 m wide adjacent to either forest that had been harvested approximately one year earlier or else an uncut control area.

Nests are usually constructed within 2 m of the tops of coniferous trees that are 10 to 20 m tall (Godfrey 1966, Harrison 1978, Terres 1980, Semenchuk 1992). In MacArthur's (1958) study, 95% of the nests were 12 to 15 m above the ground. The majority of these nests were located near the trunk in the uppermost dense cluster of branches of a spruce tree.

### 7.2.3 Overall Habitat Suitability

This model assumes that coniferous and mixedwood forests dominated by white spruce have the potential to provide both forage, and breeding and nesting opportunities for Cape May warblers. Based on a literature review, the model assumes that habitat suitability for the Cape May warbler is greatest in forests that have 15 to 25% canopy cover (SIV1) and where most of the canopy consists of conifers (SIV2) (Table 7). In this model, suitability (SIV3) is highest where white spruce is the dominant tree and trees are taller than 15 m (SIV4). The model assumes that overall habitat suitability is determined by the variable with the lowest suitability:

$$HSI_{overall} = minimum(SIV1, SIV2, SIV3, SIV4)$$

where:

SIV1 = the suitability index for percent cover of trees,
SIV2 = the suitability index for percent of cover provided by conifers,
SIV3 = the suitability index for the dominant tree species, and
SIV4 = the suitability index for the mean height of coniferous trees.

## 7.3 Model Equations

$$HSI_{overall} = minimum(SIV1, SIV2, SIV3, SIV4)$$

## 8.0 SENSITIVITY OF THE MODELS

The sensitivity of habitat suitability models to changes in the values of each of the input variables is often tested by systematically increasing each variable by 10% increments while holding all other variables constant and calculating the change in the final HSI relative to the change in the input variable (Hays 1987). This type of analysis is often used to determine if models produce reasonable HSI values through a range of input data (Schroeder and Haire 1993) but may also be used to identify effective methods of improving habitat (Hays 1987).

This approach was used for the HEP models developed for the Suncor study area. In most cases, these models were tested by increasing the value of each variable by 10% increments while holding the remaining variables at levels that allowed the manipulated variable to exert the greatest effect on model output. However, for categorical variables, the effect of a one category change was examined.

### 8.1 Red-backed Vole

Forest cover characteristics, particularly tree cover, have the greatest effect on the output of the red-backed vole habitat suitability model (Table 8). If other variables are held at optimal values, percent tree cover has the potential to alter the overall HSI of the model by 0.96. An increase in tree cover from 0 to 10% causes the overall HSI to increase by 0.16. The output of the model then increases by 0.20 for each 10% increase until forest cover exceeds 50%. Model output remains stable when cover values are increased above 50%. Forest maturity, as indicated by the percentage of trees greater than 10 cm in diameter, has the second greatest impact on model output; this variable has the potential to change the final HSI by 0.50. Model output does not vary when less than 50% of the trees are greater than 10 cm in diameter; however, when more than 50% of the trees are greater than 10 cm in diameter, each 10% increase in this variable increases the final output of the model by 0.10.

Considered together, understory characteristics have the potential to change the output of the red-backed vole model by 1.0; however, individually, none of the three variables included in this portion of the model can change the final HSI by more than 0.40. Percent cover of vascular plants and litter, which has the potential to contribute 0.40 to the final HSI, has the greatest impact on model output; each 10% change in this variable can change the final HSI by 0.06. In contrast, percent cover of shrubs can change model output by only 0.30. In this case, each 10% increase in shrub cover causes the final HSI to increase by 0.04 when values are below 80%; however, when shrub cover exceeds 80%, each 10% increase results in a decrease of 0.03 in the overall HSI. The percent cover of deadfall also has the potential to alter the overall HSI by 0.30. Each 10% increase in this variable results in a 0.15 increase in the final output of the model when cover values are lower than 20%; however, increasing values above 20% does not result in an incremental increase in the final HSI.

## 8.2 Beaver

The sensitivity analysis conducted for the beaver model indicated that the characteristics of both forage and water are capable of varying the model output from 0 to 1.0. Within the forage submodel, percent cover of woody vegetation, distance of forage from water, and bank height are all capable of changing the final HSI through the full range of possible values (Table 8). In contrast, the species composition of woody forage has the potential to alter model output by 0.70.

The contribution of percent cover to the overall HSI varies with the distance from the water's edge to potential foraging sites. Within 30 m of water, percent cover of woody forage has the potential to alter model output by 1.0, providing that no forage is available at other distance intervals. However, this function is nonlinear; when cover values within 30 m of the water are below 40%, each 10% increase causes the output to increase by 0.25. In contrast, the output of the model remains stable when percent cover varies in the 40 to 70% range; however, when percent cover is greater than 70%, each 10% increase results in a 10% decrease in habitat suitability. Although this pattern is similar at other distance intervals, the potential contribution of cover and the incremental change in model output are reduced substantially.

The effect of species composition also differs with distance interval. However, the contribution of this variable is less than that of percent cover. In the <30 m distance interval, a change in species composition can alter the output of the model about by 0.70, whereas a similar change in the 100 to 200 m interval can change the output by only 0.21.

For riverine habitats, both components of the water submodel are capable of altering the final output over the full range of values. A change of one category for either stream gradient or water fluctuation can alter the final HSI by 0.50.

The shoreline development index used in the assessment of lacustrine habitat is also capable of changing model output by 1.0. In this case, a 0.2 change in the index results in a 0.07 change in the overall HSI.

## 8.3 Moose

Forage production, which has the potential to alter the final HSI by 0.75 (Table 8), is the most important component of the moose habitat suitability model. The sensitivity analysis indicated that each 10 kg/ha increase in woody browse production changes overall habitat suitability by 0.06. Browse species diversity, which is capable of changing the final HSI by 0.60, also has a significant effect on model output. Each additional browse species alters the overall HSI by 0.12 until six or more species are included in the model. In contrast, distance to forest cover has the potential to alter model output by only 0.30. The overall HSI remains constant when distances to cover are below 100 m or above 300 m; however, for distances in the 100 to 300 m range, each 30 m increase causes the final output of the model to decline by 0.03.

Forest cover characteristics have the potential to alter the final HSI by 0.25. Total forest cover, which by itself can alter overall habitat suitability by 0.25, is the largest contributor to the cover submodel. However, the contribution of this variable depends largely on the amount of coniferous cover. Each 10% increase in total canopy cover in conifer-dominated forest results in a 0.05 increase in model output. If coniferous cover is not present, total forest cover can contribute only 0.15 to the final HSI. In this case, a change of 10% in total forest cover results in only a 0.03 change in the final HSI.

Because the cover of conifers cannot exceed total canopy cover, the potential of coniferous cover to change the final HSI is limited by amount of total forest cover. However, percent conifer cover is capable of contributing 0.10 to the overall HSI, when total forest cover exceeds 50%. In this case, each 10% increase in conifer cover increases the final output of the model by 0.02. Tree height can contribute 0.15 to the overall HSI; when trees are between 5 and 15 m tall, the final HSI increases by 0.01 for each 1 m increase in height. The final HSI is also strongly affected by distance to an all-weather road, which has the potential to alter model output by 0.50.

### 8.4 Woodland Caribou

Both habitat type and disturbance, as indicated by the linear amount of road and cutline per 100 km$^2$ of habitat, have a significant impact on the overall HSI generated by the caribou model. However, habitat type, which is capable of altering the final HSI by 0.90, has the greatest impact on model output.

Disturbance, which is capable of altering the output of the model by 0.60, has the second greatest impact on the overall HSI. When the amount of access is less than 400 km/100 km$^2$, each 40 km increase in access per 100 km$^2$ reduces the final HSI by 0.06; however, model output does not respond to increasing access when it exceeds 400 km/100 km$^2$ of habitat.

In contrast, distance to another seasonal habitat type has the potential to change the final HSI by only 0.15. When distance is between 10 and 25 km, the output of the model is reduced by 0.02 for each 2.5 km increase in distance; however, when distance is less than 10 km or greater than 25 km, the final HSI does not respond to changes in this variable.

### 8.5 Dabbling Ducks

Because the overall model for dabbling ducks assumes that habitat will be unsuitable for waterfowl if breeding, nesting or brood-rearing habitat are unsuitable, each of these three components has the ability to change the overall HSI from 0 to 1.0 (Table 8). Wetland class, which is used in both the pairs and brood-rearing submodels, also has the potential to change the final output of the model by 1.0. However, for the purposes of the sensitivity analysis, it was assumed that only one wetland class was present in an evaluation area, although it is recognized that waterfowl breeding habitat usually consists of an interspersion of wetland types.

Because preference indices for pairs and brood-rearing differs among wetland classes (Table 5), the preference index with the lowest value controls the final HSI. Thus, the overall HSI is controlled by suitability for broods when wetlands are class I, II, or III and by suitability for pairs when wetlands are class V or VI.

For all remaining variables, the sensitivity analysis assumed that only class IV wetlands, which provide both optimal breeding and brood-rearing habitat, were available to waterfowl. The potential change in the overall HSI resulting from a change of shoreline length is restricted by area of wetlands available. For example, the minimum length of shoreline for a single 48 ha wetland is about 2500 m (shoreline development index = 1.0). Thus, shoreline length has the potential to alter the overall HSI by only 0.57 when the area of wetlands is held at its optimal value of 48 ha and only class IV wetlands are assumed to exist (Table 8); each 10% increase in shoreline length results in a 0.04 to 0.08 change in the final HSI. In contrast, wetland area has the potential to alter the final output of the model by 1.0; in this case, each 5 ha increase in wetland area alters the final HSI by 0.10.

Both components of the nesting habitat submodel have the potential to change the final HSI by 1.0. Each increase of 0.5 dm in the visual obstruction measurement changes the overall HSI by 0.12. However, the pattern for distance to water is different. For distances of less than 300 m, a 100 m change does not alter the final HSI, whereas, for distances greater than 300 m, each 100 m increase causes the final HSI to decrease by 0.12.

## 8.6 Cape May Warbler

Because each of the four variables in the Cape May warbler model is considered a critical component of Cape May warbler habitat, each has the potential to change the final HSI from 0 to 1.0 (Table 8). However, the change in the final HSI resulting from an incremental change in these variables is not always linear. For example, changing the percent cover of trees from 0 to 10% causes the final HSI to increase by 0.68 and a further increase from 10% to 15% causes an increase of 0.32. The final HSI then remains stable as the percent cover of trees varies between 15 and 25%. Between 25 and 50% cover, the final HSI declines by 0.30 for each 10% increase in tree cover. Similarly, the effect of forest height on the overall HSI is not linear. The final HSI remains at 0.20 when forest height is varied between 0 and 10 m, remains at 0.75 when it varies between 10 and 15 m, and is 1.00 for heights greater than 15 m.

In contrast, each 10% increase in the percent cover of conifers causes the final output of the model to increase by 0.17 when the percent cover composed of conifers is between 20 and 80%. A change in the dominant tree species results in a 0.25 to 1.00 change in the final HSI.

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# TABLES

## 10.0 TABLES

**Table 1.** Habitat suitability indices for the red-backed vole.

| Model | Important Habitat Factor | Measurable Habitat Factor | Variable Category (%) | Suitability Index (SI) |
|---|---|---|---|---|
| Food and Cover | Ground cover | V1 - % cover of vascular plants and litter | 0 | 0.00 |
| | | | 15 | 0.20 |
| | | | 30 | 0.40 |
| | | | 45 | 0.60 |
| | | | 60 | 0.80 |
| | | | >75 | 1.00 |
| | Shrub cover | V2 - % cover of shrubs | 0 | 0.00 |
| | | | 15 | 0.20 |
| | | | 30 | 0.40 |
| | | | 45 | 0.60 |
| | | | 60 | 0.80 |
| | | | 80 | 1.00 |
| | | | 90 | 0.80 |
| | | | 100 | 0.70 |
| | Cover of deadfall | V3 - % cover of deadfall | 0 | 0.00 |
| | | | 5 | 0.25 |
| | | | 10 | 0.50 |
| | | | 15 | 0.75 |
| | | | >20 | 1.00 |
| | Forest cover | V4 - % canopy cover of trees | <10 | 0.20 |
| | | | 20 | 0.40 |
| | | | 30 | 0.60 |
| | | | 40 | 0.80 |
| | | | >50 | 1.00 |
| | Forest maturity | V5 - % trees < 10cm DBH | <50 | 0.50 |
| | | | 60 | 0.60 |
| | | | 70 | 0.70 |
| | | | 80 | 0.80 |
| | | | 90 | 0.90 |
| | | | 100 | 1.00 |

Table 2. Habitat suitability indices for the beaver.

| Submodel | Important Habitat Factor | Measurable Habitat Factor | Variable Category | Suitability Index (SI) |
|---|---|---|---|---|
| Food | Forage availability | V1 - cover of woody vegetation | 0% | 0.00 |
| | | | 10% | 0.25 |
| | | | 20% | 0.50 |
| | | | 30% | 0.75 |
| | | | 40-70% | 1.00 |
| | | | 80% | 0.90 |
| | | | 90% | 0.80 |
| | | | 100% | 0.70 |
| | | V2 - species composition | >50% poplar/willow | 1.00 |
| | | | >50% other deciduous | 0.60 |
| | | | >50% coniferous | 0.30 |
| | | V3 - bank slope | <8 degrees | 1.00 |
| | | | 8-12 degrees | 0.50 |
| | | | >12 degrees | 0.00 |
| | | V4 - distance from water | <30 m | 1.00 |
| | | | 30-100 m | 0.70 |
| | | | 100-200m | 0.30 |
| | | | >200 m | 0.00 |
| Water | Water characteristics | V5 - stream gradient | <6 degrees | 1.00 |
| | | | 6-15 degrees | 0.50 |
| | | | >15 degrees | 0.00 |
| | | V6 - water fluctuation | small (<1 m) | 1.00 |
| | | | Moderate (1-1.5 m) | 0.50 |
| | | | Extreme (>1.5 m) | 0.00 |
| | | V7 - shoreline development | 1.0 | 0.20 |
| | | | 1.5 | 0.40 |
| | | | 2.0 | 0.60 |
| | | | 2.5 | 0.80 |
| | | | >3.0 | 1.00 |

**Table 3.** Habitat suitability indices for the moose.

| Submodel | Important Habitat Factor | Measurable Habitat Factor | Variable Category | Suitability Index (SI) |
|---|---|---|---|---|
| Food | Forage availability | V1 - diversity of wood browse | 1 species | 0.20 |
| | | | 2 species | 0.36 |
| | | | 3 species | 0.52 |
| | | | 4 species | 0.68 |
| | | | 5 species | 0.84 |
| | | | >5 species | 1.00 |
| | | V2 - distance to forest cover | >300 m | 0.60 |
| | | | 200 m | 0.80 |
| | | | <100 m | 1.00 |
| Cover | Cover characteristics | V3 - total canopy cover | 0% | 0.00 |
| | | | 10% | 0.20 |
| | | | 20% | 0.40 |
| | | | 30% | 0.60 |
| | | | 40% | 0.80 |
| | | | >50% | 1.00 |
| | | V4 - coniferous canopy cover | 0% | 0.00 |
| | | | 10% | 0.20 |
| | | | 20% | 0.40 |
| | | | 30% | 0.60 |
| | | | 40% | 0.80 |
| | | | >50% | 1.00 |
| | | V5 - mean tree height | <5 m | 0.40 |
| | | | 10 m | 0.70 |
| | | | >15 m | 1.00 |
| Disturbance | Presence of all-weather roads | V6 - distance to all-weather road | <1 km | 0.50 |
| | | | 1-2 km | 0.75 |
| | | | >2 km | 1.00 |

Table 4. Habitat suitability indices for the woodland caribou.

| Submodel | Important Habitat Factor | Measurable Habitat Factor | Variable Category [a] | Suitability Index (SI) |
|---|---|---|---|---|
| Food and cover | Habitat type | V1 - habitat type | C. Complex with >50% peatland; forested fen with tamarack, black spruce, willow, or birch, or complex with >25% forest and >25% open area; largely minerotrophic | 1.00 |
| | | | D. Habitat with >85% peatland; forested ombrotrophic bog or peatland dominated by black spruce | 0.80 |
| | | | F. As type A but 15 to 50% peatland | 0.20 |
| | | | A. Complex of >50% peatland; nonpatterned open peatland, mainly minerotrophic, dominated by sedges, willow, birch, and ericacious shrubs | 0.10 |
| | | | G. Upland coniferous forest | 0.20 |
| | | | B. Complex with >50% peatland; patterned, open minerotrophic fens; strings and margins with any combination of tamarack, birch, and black spruce | 0.10 |
| | | | E. As type D but 15 to 50% peatland | 0.10 |
| | | | H. Deciduous or mixedwood forest | 0.10 |
| | Seasonal habitat availability | V2 - distance to upland coniferous habitat (for lowlands) or distance to peatlands (for upland habitats) | <10 km | 1.00 |
| | | | 15 km | 0.95 |
| | | | 20 km | 0.90 |
| | | | >25 km | 0.85 |
| Disturbance | Amount of access | V3 - km of roads and cutlines/100 km$^2$ | 0 | 1.00 |
| | | | 100 | 0.85 |
| | | | 200 | 0.70 |
| | | | 300 | 0.55 |
| | | | >400 | 0.40 |

[a] Habitat classifications follow Bradshaw et al. (1995).

Table 5. Wetland classification and preference indices for breeding ducks.

| Wetland[a] |  | Preference Index |  |
|---|---|---|---|
| **Class** | **Description** | **Pairs[b]** | **Broods[c]** |
| I | Ephemeral ponds | 0.03 | 0.00 |
| II | Temporary ponds | 0.52 | 0.00 |
| III | Seasonal ponds | 0.98 | 0.50 |
| IV | Semipermanant ponds/lakes | 1.00 | 1.00 |
| V | Permanent ponds/lakes | 0.48 | 0.50 |
| VI | Alkali ponds/lakes | 0.03 | 0.15 |

[a] Based on the classification system of Stewart and Kantrud (1971).
[b] Based on data for blue-winged teal in North Dakota (Kantrud and Stewart 1977).
[c] Based on expert opinion about blue-winged teal brood requirements (Sousa 1985).

Table 6. Habitat suitability indices for waterfowl.

| Submodel | Important Habitat Factor | Measurable Habitat Factor | Variable Category | Suitability Index (SI) |
|---|---|---|---|---|
| Pairs | Equivalent optimum shoreline length of wetlands ($EOS_{wp}$) | V1 - length of wetland shoreline per 259 ha by wetland class | 0 m | 0.00 |
| | | | 2,740 m | 0.20 |
| | | | 5,480 m | 0.40 |
| | | | 8,220 m | 0.60 |
| | | | 10,960 m | 0.80 |
| | | | >13,700 m | 1.00 |
| | Equivalent optimum area of wetlands ($EOA_{wp}$) | V2 - area by wetlands per 259 ha by wetland class | 0 ha | 0.00 |
| | | | 9.6 ha | 0.20 |
| | | | 19.2 ha | 0.40 |
| | | | 28.8 ha | 0.60 |
| | | | 38.4 ha | 0.80 |
| | | | >48.0 ha | 1.00 |
| Nesting | Equivalent optimum area of nesting area | V3 - mean visual obstruction measurement by cover type | 0 dm | 0.00 |
| | | | 1.0 dm | 0.20 |
| | | | 2.0 dm | 0.40 |
| | | | 3.0 dm | 0.60 |
| | | | 4.0 dm | 0.80 |
| | | | >5.0 dm | 1.00 |
| | | V4 - mean distance to a wetland by cover type | >1000 m | 0.00 |
| | | | 750 m | 0.35 |
| | | | 500 m | 0.65 |
| | | | <250 m | 1.00 |
| | | V5 - area of optimum nesting habitat/159 ha | 0 ha | 0.00 |
| | | | 42 ha | 0.20 |
| | | | 84 ha | 0.40 |
| | | | 127 ha | 0.60 |
| | | | 169 ha | 0.80 |
| | | | >211 ha | 1.00 |
| Brood rearing | Equivalent optimum shoreline length of wetlands ($EOS_{wb}$) | V6 - length of wetland shoreline per 259 ha by wetland class | 0 m | 0.00 |
| | | | 1,180 m | 0.20 |
| | | | 2,360 m | 0.40 |
| | | | 3,540 m | 0.60 |
| | | | 4,730 m | 0.80 |
| | | | >5,900 m | 1.00 |
| | Equivalent optimum area of wetlands ($EOA_{wb}$) | V7 - area of wetlands per 259 ha by wetland class | 0 ha | 0.00 |
| | | | 4.0 ha | 0.20 |
| | | | 8.0 ha | 0.40 |
| | | | 12.0 ha | 0.60 |
| | | | 16.0 ha | 0.80 |
| | | | >20.0 ha | 1.00 |

**Table 7.** Habitat suitability indices for the Cape May warbler.

| Model | Important Habitat Factor | Measurable Habitat Factor | Variable Category | Suitability Index (SI) |
|---|---|---|---|---|
| Food and cover | Forest cover | V1 - % cover of trees | 0% | 0.00 |
| | | | 5% | 0.35 |
| | | | 10% | 0.70 |
| | | | 15-25% | 1.00 |
| | | | >50% | 0.40 |
| | Conifer cover | V2 - % of forest cover composed of conifers | <20% | 0.00 |
| | | | 40% | 0.35 |
| | | | 60% | 0.65 |
| | | | >80% | 1.00 |
| | Availability of singing sites | V3 - dominant tree species in the upper 1/3 of the canopy | Deciduous | 0.00 |
| | | | Other conifer | 0.25 |
| | | | Balsam fir | 0.50 |
| | | | White spruce | 1.00 |
| | Height of the coniferous canopy | V4 - mean height of coniferous trees | <10 m | 0.20 |
| | | | 10-15 m | 0.75 |
| | | | >15 m | 1.00 |

Table 8. Sensitivity of habitat suitability models to changes in habitat variables.

| Species | Manipulated Input Variable | Potential Contribution to Overall HSI | Incremental Increase in Input Variable | % Change in Input Variable | Incremental Change in Overall HSI |
|---|---|---|---|---|---|
| Red-backed vole | Cover of vascular plants and litter (%) | 0.40 | 10% | 10 | 0.06 |
| | Cover of shrubs (%) | 0.30 | 10% | 10 | 0.04 to -0.03 |
| | Cover of downfall (%) | 0.30 | 10% | 10 | 0.15 |
| | Canopy of cover of trees (%) | 0.96 | 10% | 10 | 0.20 |
| | Trees > 10 cm DBH (%) | 0.50 | 10% | 10 | 0.10 |
| Beaver | % cover of woody vegetation | | | | |
| | <30 m from water | 1.00 | 10% | 10 | 0.25 to -0.10 |
| | 30-100 m from water | 0.70 | 10% | 10 | 0.17 to -0.07 |
| | 100-200 m from water | 0.30 | 10% | 10 | 0.08 to -0.03 |
| | Species composition | | | | |
| | <30 m from water | 0.70 | 1 category | N/A | 0.30 to 0.70 |
| | 30-100 m from water | 0.49 | 1 category | N/A | 0.21 to 0.49 |
| | 100-200 m from water | 0.21 | 1 category | N/A | 0.09 to 0.21 |
| | Bank slope | 1.00 | 1 category | N/A | 0.50 |
| | Stream gradient | 1.00 | 5 degrees | 33 | 0.50 |
| | Water fluctuation | 1.00 | 1 category | N/A | 0.50 |
| | Shoreline development | 0.80 | 0.2 | 13 | 0.07 |
| Moose | Forage Production (kg/ha) | 0.75 | 10 kg/ha | N/A | 0.06 |
| | No. of browse species | 0.60 | 1 species | 17 | 0.12 |
| | Distance to forest cover (m) | 0.30 | 30 m | 10 | 0.03 |
| | Total Canopy Cover (%) | | | | |
| | coniferous dominated | 0.25 | 10% | 10 | 0.05 |
| | no conifers | 0.15 | 10% | 10 | 0.03 |
| | Coniferous canopy cover (%) | 0.10 | 10% | 10 | 0.02 |
| | Mean tree height (m) | 0.15 | 1 m | N/A | 0.01 |
| | Distance to all-weather roads (km) | 0.50 | 1 km | N/A | 0.25 |
| Woodland caribou | Habitat type | 0.90 | 1 category | N/A | 0 to 0.90 |
| | Distance to seasonal habitat (km) | 0.15 | 2.5 km | 10 | 0.02 |
| | Cutline per 100 km$^2$ | 0.60 | 40 km | 10 | 0.06 |
| Dabbling ducks | Wetland class | 1.00 | 1 class | N/A | 0 to 1.00 |
| | Length of shoreline (m) | 0.57 | 1125 m | 10 | 0.04 to 0.08 |
| | Area of wetlands (ha) | 1.00 | 5 ha | 10 | 0.10 |
| | Visual obstruction (dm) | 1.00 | 0.5 dm | 10 | 0.12 |
| | Distance to wetland (m) | 1.00 | 100 m | 10 | 0.14 |
| Cape May warbler | Cover of trees (%) | 1.00 | 10% | 10 | 0 to 0.68 |
| | Conifer cover (%) | 1.00 | 10% | 10 | 0.17 |
| | Dominant trees species | 1.00 | N/A | 1 category | 0.25 to 0.50 |
| | Height coniferous canopy (m) | 1.00 | 1.5 m | 10 | 0 to 0.55 |