
RED SQUIRREL

WINTER FOOD AND COVER

HABITAT SUITABILITY INDEX MODEL

VERSION 5

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1. INTRODUCTION

Habitat Suitability Index (HSI) models predict the suitability of habitat for a species based on an assessment of habitat attributes such as habitat structure, habitat type and spatial arrangements between habitat features. This HSI model for the red squirrel (*Tamiasciurus hudsonicus*) applies to habitats of the Foothills Model Forest (FMF) in west-central Alberta. The intended use is to predict habitat suitability at landscape scales and over long-time periods. The model will be used to determine potential changes in red squirrel habitat area and carrying capacity throughout an entire forest management cycle (200 years). The model was primarily developed using literature review.

2. SPECIES DESCRIPTION AND DISTRIBUTION

The red squirrel is the most widely distributed and versatile squirrel in North America and ranges from Alaska to Newfoundland, south to South Carolina and west to the Rocky Mountains of New Mexico (Banfield 1974). Red squirrels are generally associated with coniferous forest but also use mixedwood and deciduous forests (Kemp and Keith 1970, Obbard 1987). Red squirrels are solitary and normally active during the day (C.C. Smith 1968). They are year-round residents and do not hibernate during the winter (C.C. Smith 1968). Densities of red squirrels tend to vary among years and occasionally increase to very high densities (Rusch and Reeder 1978). In 'high' years, squirrels can cause significant damage to leaders and upper branches of white spruce (*Picea glauca*) that are used as emergency winter food (M.C. Smith 1968).

Adults average 31 cm in length (tail 12.5 cm) and have a mass of 188 g (females) or 193 g (males; Banfield 1974). The summer coat is olive-brown with pale buff or grey underparts (Obbard 1987). The winter coat is thicker and redder (Obbard 1987). The tail is usually reddish above and grey below with a dark tip (Gadd 1995). Red squirrels are permanent residents in all forest types in the FMF and have moderate to high densities in coniferous forests (Farr 1995). They are more common in montane coniferous forests than subalpine forests throughout mountainous regions (Gadd 1995). Red squirrels are not at risk in Alberta and their habitat is secure (Wildlife Management Division 1996).

Red squirrels are important prey to many animals such as marten (*Martes americana*), hawks, owls, coyotes (*Canis latrans*), wolves (*C. lupus*), weasels, and lynx (*Felis lynx*) (Rusch and Reeder 1978, Soutiere 1979). Predation can have a significant impact on red squirrel populations (Rusch and Reeder 1978).

3. FOOD

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The availability of food regulates red squirrel populations, both through its effect on reproduction (Kemp and Keith 1970, Rusch and Reeder 1978) and population densities (C.C. Smith 1968, M.C. Smith 1968, Rusch and Reeder 1978).

The omnivorous red squirrel eats a variety of seeds, nuts, berries, fungi, insects, bird eggs, juvenile animals (birds, rodents and hares), mice, carrion, and tree bark. (Klugh 1927). Winter survival is dependent on whether enough food has been collected and stored to last the winter (C.C. Smith 1968). Coniferous seeds are staple winter food for red squirrels (Klugh 1927, M.C. Smith 1970). During late summer and fall, red squirrels store cones in caches or middens located under ground or in shady, moist areas such as around the base of large spruce trees (M.C. Smith 1968), under old windfall (M.C. Smith 1968), inside hollow logs (Thomas 1979) or in large standing snags (Vahle and Patton 1983). In winter, squirrels maintain tunnels to their seed caches under snow (M.C. Smith 1968). Spruce seeds are preferred to pine (*Pinus* spp.) seeds and white spruce seeds are preferred to black spruce (*P. mariana*) seeds (Brink and Dean 1966). This may be due to nutritive values (Brink and Dean 1966), or the costs of obtaining seeds since pine cones are much harder. Douglas-fir (*Pseudotsuga menziesii*) and subalpine fir (*Abies lasiocarpa*) are generally not consumed (Gadd 1995). Engelmann spruce (*P. engelmannii*) is the preferred seed of the upper subalpine forest.

4. COVER

Optimum cover occurs in mature, dense coniferous forests (Vahle and Patton 1983, Sullivan and Moses 1986, Allen 1987). Dense coniferous stands provide winter food, nest sites, cover, moisture, and shade for food storage (Vahle and Patton 1983, Allen 1987). Dense stands also give maximum protection from wind, permitting the accumulation of low density, insulating snow cover (Zirul and Fuller 1970).

Densities of red squirrels were similar in second growth (20 yrs) and mature (> 100 yrs) lodgepole pine forest in British Columbia (Sullivan and Moses 1986). However, second growth stands had lower survival and reproductive rates, and higher recruitment rates which suggests that young stands act as a dispersal sink (Sullivan and Moses 1986). Red squirrel populations in young (20-28 yr) and mature (>120 yr) lodgepole pine forests in British Columbia had similar densities and body mass, recruitment, survival rates, and proportion of breeding squirrels were not significantly different between the two seral stages (Ransome and Sullivan 1997).

In the FMF, densities of red squirrels were highest in stands that were over 60% spruce (M. Wheatley, An empirical evaluation of a habitat suitability index model for the North American red squirrel in west-central Alberta, unpublished report for the Foothills Model Forest, 1997). Stands examined were 14-35 m in height. There was a poor relationship between squirrel densities and stand height, but it was suggested that stand height remain in the model as a stronger relationship may exist at lower canopy heights. Highest densities of red squirrels in the FMF were in stands with at least a 70% spruce component and were 120 years old (Farr 1995).

Highest densities of red squirrels in central Alberta were in white spruce stands (Rusch and Reeder 1978). Pine support lower densities than white spruce and aspen supported the lowest densities of primarily juvenile red squirrels (Rusch and Reeder 1978). Of those squirrels found in aspen stands, few survived the winter.

5. REPRODUCTION

Females produce their first litter at the age of 1 (Millar 1970). Breeding season for red squirrels in Alberta starts in March or April and lasts 3-4 months (Rusch and Reeder 1978). Courtship begins when patches of snowfree ground appears (Rusch and Reeder 1978). Females are receptive for one day (C.C. Smith 1968). Litter size ranges from 3-5 naked and helpless young (Banfield 1974, Rusch and Reeder 1978). Squirrels stay with their mother for up to 18 weeks before dispersing to new territories (Banfield 1974).

Depending upon geographic area and habitat, nests are in tree cavities, outside the tree in branch nests composed of grass, moss, or leaves, or under ground (Klugh 1927, Fancy 1980, Vahle and Patton 1983, Allen 1987). Tree cavities, commonly used in eastern hardwood forests and north-western U.S. are generally replaced by underground nests (sometimes within their midden) and outside branch nests in boreal coniferous forests (Klugh 1927, Fancy 1980, Allen 1987). Where available, spruce trees are used for branch nests because they have more dense branches and a higher canopy coverage than pines (Fancy 1980).

6. HABITAT AREA

Red squirrels in coniferous forests inhabit single occupant territories defended from neighbours of either sex (Price et al. 1986). Each territory generally contains one midden (M.C. Smith 1968, Vahle and Patton 1983). Territory size is highly variable depending on food abundance (M.C. Smith 1968), and appears to approximate the area that would produce sufficient cones during a poor cone crop to support a squirrel for one year.

Territory sizes were 0.24-0.35 ha in spruce stands in central Alberta (Rusch and Reeder 1978), 0.28-0.46 ha in the Yukon (Price et al. 1986), 0.62-1.18 ha in southern British Columbia (C.C. Smith 1968) and an average of 0.4 ha in New Brunswick (Klugh 1927). There is no data on territory size for red squirrels in the FMF.

7. HSI MODEL

7.1 MODEL APPLICABILITY

Species: Red Squirrel (*Tamiasciurus hudsonicus*).

Habitat Evaluated: Winter Food and Cover.

Geographic area: This model is applicable to the Foothills Model Forest in west-central Alberta.

Seasonal Applicability: This model produces HSI values for critical winter habitat.

Cover types: This model applies to all forest and non-forest habitat areas of the Lower and Upper Foothills, Montane and Subalpine Natural Subregions (Beckingham et al. 1996) since suitability is determined from structural characteristics within stands rather than classified forest stands directly. The model should also be broadly applicable to other habitat areas dominated by vegetation similar to that in this region, including pure deciduous, mixedwood and pure coniferous forest types, as well as wetland and riparian forests, meadows, shrublands, and areas regenerating after forest harvesting.

Minimum Habitat Area: Minimum habitat area is defined as the minimum amount of contiguous habitat to which the model will be applied. It is assumed that red squirrels can use any habitat area which has sufficient cover and food.

Model Output: The model will produce Habitat Units (HU) of winter habitat for each habitat area based on HSI value and area. HU are calculated by multiplying the HSI score with the area in hectares. The performance measure for the model is carrying capacity (red squirrels per ha). Model output (HU) should be correlated to estimates of carrying capacity to verify model performance.

Carrying Capacity (Red Squirrels per ha where HSI = 1.0): The current estimate of the maximum number of animals per fully suitable hectare is 3 red squirrels (M. Wheatley, 1997, An empirical evaluation of a habitat suitability index model for the north american red squirrel in west-central Alberta, unpublished report for the Foothills Model Forest, 1997).

Verification Level: The reliability of this model has not been evaluated against local data. The verification is 4: local data has been used to develop model but model predictions have not been tested.

Application: This HSI model is designed to assess habitat suitability for relatively large forest landscapes using generalized species-habitat relationships and stand-level vegetation inventory. Its purpose is to predict relative changes in red-squirrel habitat supply at the landscape level over long time periods (200 years), for integration with forest management planning. The model is not designed to provide accurate prediction of suitability or use at the stand level. Approximate population size can be calculated by assuming linear habitat-population relationships, but the model is not designed to provide accurate population density estimates. Any attempt to use the model in a different geographic area or for other than the intended purpose should be accompanied by model testing procedures, verification analysis, and other modifications to meet specific objectives.

7.2 MODEL DESCRIPTION

The HSI model for red squirrel winter habitat assumes life requisites of food and cover to be limiting. It is assumed the needs for nesting habitat are met by the same parameters that provide the essential winter food and cover.

7.2.1 Habitat Variables and HSI Components

The red squirrel model is determined from three elements of habitat structure within forest stands: tree canopy closure, coniferous canopy height, and tree species composition (Table 1). The red squirrels' need for thermal and hiding cover is determined by the tree canopy closure and is used to predict HSI component S_1 . Dense canopy closure provides security from avian predators, and allows easy tree to tree movement to escape arboreal predators. Dense tree cover also protects against wind chill and moderates the snow cover on the forest floor. Canopy closure also affects food (along with the next variables) since more canopy closure means more cone producing volume.

Winter food is determined from a combination of coniferous canopy height and the composition of tree species. The importance of canopy height is in the ability of older trees to provide good seed crops. It is assumed that conifers start to produce adequate cone crops at 5 m height and this increases as the trees grow taller. Tall trees also provide more cover than small trees.

Winter food availability is determined from the composition of conifers in the forest stand. This is done using percent composition of all conifers, and the composition of just spruce species. The spruce component is included in the model because red squirrels prefer spruce seeds. Conifers, especially spruce, provide greater hiding and thermal cover for squirrels compared to deciduous trees and pines. Peak squirrel densities are found in white spruce forests. However, white spruce cone production is highly variable. Black spruce produces reliable seed crops which can compensate the lack of white spruce seeds in low production years. Spruce in the tree canopy is included as a compensatory variable because spruce are not essential for squirrel survival but do add to the quality of the area. A small S_4 value can be compensated by a large S_2 value and has been weighted accordingly in the HSI equation.

Table 1. Relationship between habitat variables and life requisites for red squirrel winter habitat HSI model.

HSI Component	Life Requisite	Habitat Variable	Habitat Variable Definition
S_1	Cover and Food	Tree Canopy Closure (%)	Percent of area covered by a vertical projection of tree crown areas onto the ground. Includes trees ≥ 8 cm diameter at breast height (dbh at 1.3 m).
S_2	Cover and Food	Coniferous Canopy Height (m)	Average top height of 100 coniferous trees/ha with the largest dbh.
S_3	Cover and Food	Pine, Spruce and Fir in Tree Canopy (%)	Percent composition of pine, spruce and fir species in the tree canopy.
S_4	Cover and Food	Spruce in Tree Canopy (%)	Percent composition of all spruce species (white, black and Engelmann) in the tree canopy.

7.2.2 Graphical HSI Component Relationships

- S_1 Canopy closure is unsuitable only when there is no coverage, and increases over the range 0-50%. Values $\geq 50\%$ are optimal (Figure 1a)
- S_2 Heights ≥ 15 m is considered optimal habitat. Habitat decreases to 0 when the stand is disturbed and remains unsuitable until mean coniferous height surpasses 5 m. From 5-15 m suitability is restored (Figure 1b).
- S_3 A forest stand with no conifers is unsuitable ($S_3 = 0$). Suitability increases directly with coniferous composition until 50% is reached. All values $\geq 50\%$ are optimal (Figure 1c)
- S_4 This component modifies the previous one to account for white, black or Engelmann spruce. When there is no spruce in a coniferous forest, the composition is generally pine and the component value is 0.3. This rises to optimum at all values $\geq 60\%$ spruce. (Figure 1d).

7.3 MODEL ASSUMPTIONS

1. Red squirrel winter food is obtained only from within their immediate territory, thus composition and height of trees at the stand scale is important in determining habitat suitability.
2. Winter nesting needs are provided by the same habitat features needed for winter food and cover.
3. Spring, summer and fall habitat is provided in areas with suitable winter habitat. Winter habitat is critical for survival and is the main determinant on squirrel habitat area and carrying capacity.
4. Red squirrel habitat is not affected by proximity to human disturbances.

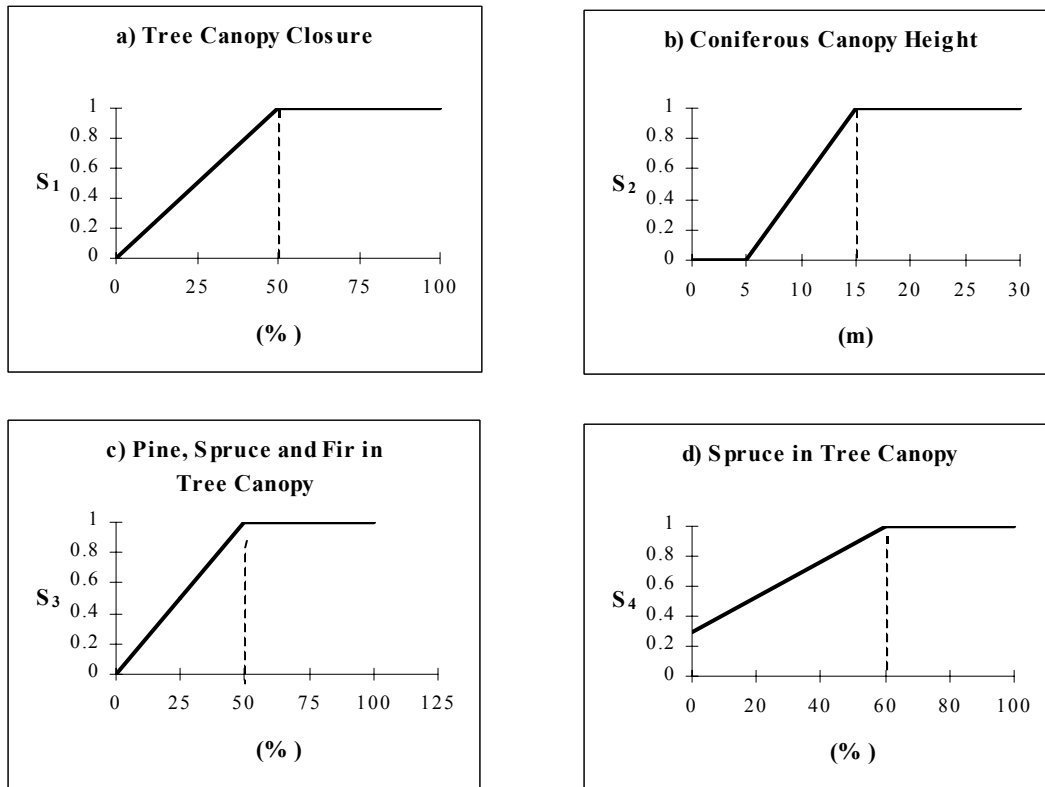


Figure 1. Graphical relationships between habitat variables and HSI components in the red squirrel model.

7.4 EQUATION

The equation assumes tree canopy closure, percent coniferous in the tree canopy and percent spruce in the tree canopy are compensatory in that lower values of one can be compensated by high values in any of the other two components. Low values in S₂ (coniferous canopy height) can not be compensated and has the greatest impact on the overall suitability score.

$$HSI = S_2 \times (S_1 \times S_3 \times S_4)^{1/2}$$

8. SOURCES OF OTHER MODELS

A red squirrel habitat model was developed for the OSLO project in northern Alberta (Jalkotzy et al. 1990).

Model History

All of the HSI models for the Weldwood Forest Management Area have undergone several revisions, and they will be revised again as new information becomes available. Contact Rick Bonar for information about the most current version.

- Version 1 (1989) was developed by the Weldwood of Canada Integrated Resource Management Steering Committee (IRMSC).
- Version 2 (1994) was revised by Barb Beck and Melissa Todd.

- Version 3 (1995) was written by Tara Banks for a special topics course in habitat modelling at the University of Alberta.
- Version 4 (1996) was edited and reformatted by Wayne Bessie and sent to species experts for critical comment.
- Version 5 (1999) was revised by Karen Graham, Rick Bonar, Barb Beck, and Jim Beck to incorporate reviewer comments and information from recent literature.

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