NORTHERN FLYING SQUIRREL
YEAR ROUND HABITAT

HABITAT SUITABILITY INDEX MODEL
VERSION 3

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Lisa Takats, 3535 105A Street, Edmonton, Alberta. T6J 2M6.
Barbara Beck, Department of Renewable Resources, University of Alberta, Edmonton, Alberta. T6G 2H1.
James Beck, Department of Renewable Resources, University of Alberta, Edmonton, Alberta. T6G 2H1.
Melissa Todd[1], Foothills Model Forest, Box 6330, Hinton, Alberta. T7V 1X6.
Richard Bonar[2], Weldwood of Canada Ltd., 760 Switzer Drive, Hinton, Alberta. T7V 1V7.

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 northern flying squirrel (*Glaucomys sabrinus*) 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 northern flying 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 northern flying squirrel is a member of the family Sciuridae in the order Rodentia. Total length of this squirrel ranges from 24-37 cm and mass ranges from 75-139 grams (Banfield 1974). The gray cheeks and under-parts are blotched with pinkish cinnamon, and the lower belly fur is lead gray (Banfield 1974). There is a web or fold of skin that extends laterally to the level of the ankle and wrist (Smith 1993). This fold can be flattened to create 'wings' on which the squirrel glides (Smith 1993). The 10-18 cm dorso-ventrally flattened tail is gray above and pale buffy-gray beneath and is used as a rudder during the glide (Banfield 1974, Smith 1993). The feet are gray above and well furred in winter (Banfield 1974).

Northern flying squirrels inhabit the northern coniferous forest that runs from the arctic treeline in Alaska to Labrador, and south through the Cascade Range of Washington and Oregon and the Sierra Nevada mountains almost to Mexico. The range continues through the Rocky Mountains to Utah and North Carolina, and along the Appalachian Mountains to Tennessee (Pattie and Hoffman 1990). Northern flying squirrels are considered a sensitive species in Alberta because they are associated with old seral staged forests (Wildlife Management Branch 1996). The northern flying squirrel is found throughout the FMF, but likely occurs at highest densities in coniferous stands (M. Todd 1994, personal communication).

The northern flying squirrel is nocturnal and seldom appears until at least a half hour following sundown (Banfield 1974). They are sociable animals and up to nine adults may communally nest in the winter (Banfield 1974). Flying squirrels are preyed upon by owls and hawks (Banfield 1974).

3. FOOD

Northern flying squirrels are omnivores and will feed on flowers, forbs, lichens, fungi, mosses, leaves, seeds, fleshy fruits, nuts, insects, nestling birds, and birds' eggs (Banfield 1974, Holroyd and Van Tighem 1983, Benyus 1989). These mammals will scavenge on carcasses found in the forest (Banfield 1974). They are also fond of tree sap, and

[1] Current Address: Houston Forest Products, Box 5000, Houston , B.C. V0J 1Z0
[2] Contact Address

have been observed chewing away the bark between sapsucker holes to increase the flow of sap (Foster and Tate 1966, Banfield 1974). In the spring, the buds of aspen (*Populus tremuloides*), alder (*Alnus crispa*), and pussy willow (*Salix discolor*) are preferred. In the fall, conifer seeds, cones, and nuts of various species are cached in hollow trees for the winter (Banfield 1974, Benyus 1989). They will choose staminate cones, as they tend to be rich in protein (Pattie and Hoffman 1990). Food storing behavior is poorly documented (Ingles 1965). Northern flying squirrels forage in trees and on the ground (Banfield 1974, Stevens and Lofts 1988).

Fungi and lichens predominate or are the only foods eaten at certain times of the year (Cowan 1936, Maser et al. 1978, Waters and Zabel 1995). In Oregon, greater than 90% of ingested materials were fungi and lichen (Maser et al. 1985) but this may vary seasonally (McKeever 1960). Flying squirrel densities were correlated with the abundance of fungi, and were not correlated to cavity density, which suggests that food may be more limiting for flying squirrels than cavities (Waters and Zabel 1995).

4. COVER

Areas inhabited by flying squirrels are typically dominated by conifers, but may also be mixedwood forest and occasionally pure deciduous forest (Weigl and Osgood 1974, Holroyd and Van Tighem 1983). Mature and old seral stages appear to be preferred habitat, (Holroyd and Van Tighem 1983, Stevens and Lofts 1988) likely due to food availability (Ransome and Sullivan 1997) and nesting/protective cover. However, some second growth forests (20-28 yr) can provide suitable habitat for flying squirrels (Ransome and Sullivan 1997). The northern flying squirrel's arboreal habitat and use of tree cavities may be negatively impacted by intensive forest management (Mahon and Steventon, in prep.).

Coniferous and mixedwood forests with suitable cavities are important requirements for this species (Smith 1993). In summer, cavities are used for nesting and in winter provide thermal and protective cover. As well, conifer trees are an important food source.

In mixedwood forests in central Alberta, flying squirrels were found in young (20-30 yr) and mature stands (50-65 yr) but were most often in old (120+ yr) stands (McDonald 1995). Abundance was positively associated with density of spruce and shrubs. Dens were found in live and dead aspen, balsam poplar, spruce, birch and willow. However, live spruce and birch trees and dead aspen trees were used more often than expected. Den trees had tree diameters that ranged from 5-55 cm and tree heights ranged from 7-35 m. Trees greater than 25 cm diameter at breast height (dbh at 1.3 m) and greater than 7 m tall appeared to be favoured. Dens were found in excavated cavities, knotholes, cracks, old nests and broken tops of trees. Knotholes, nests and broken tops were used more than expected. Excavated cavities were the most common den site (McDonald 1995). In Jasper and Banff National Parks, northern flying squirrels preferred mature forest in montane and lower subalpine regions (Holroyd and Van Tighem 1983). Squirrels were found in white spruce (Picea glauca), lodgepole pine (*Pinus contorta*), aspen, Douglas fir (*Pseudotsuga menziesii*), and mixedwood forests throughout the foothills region (Holroyd and Van Tighem 1983). In the FMF, northern flying squirrels were found in older aspen and spruce dominated stands with medium crown closures (Table 1). All sites had a spruce component.

5. REPRODUCTION

Northern flying squirrels mate between late March and early April (Banfield 1974). Gestation ranges from 40-42 days and litter size is 2-6 (Soper 1970, Pattie and Hoffman 1990). In British Columbia and Alberta, one litter is born per year (Cowan 1936). The date of birth may vary with latitude and altitude (Cowan 1936). The altricial young have a mass of 6 g and are 70 mm in length (Banfield 1974). At 18 days the young are well furred (Banfield 1974). They open their eyes at 32 days and walk freely at 41 days (Banfield 1974). Weaning occurs after 65 days, and young will take their first glide at 3 months (Banfield 1974). After 4 months they are proficient climbers, runners and glider (Banfield 1974). They do not reach sexual maturity until their second winter (Pattie and Hoffman 1990).

Nests are found in tree cavities, leaf or stick nests, or inside witch's broom near the trunks of conifers (Table 1). Nests are lined with grass, moss, lichens, feathers, pine needles, fur and other available material and have leaves, moss, twigs and strips of bark around the outside **(**Cowan 1936, Weigl and Osgood 1974, Stevens and Lofts 1988, Benyus 1989, Pattie and Hoffman 1990, Hayward and Rosentreter 1994, Carey et al. 1997).

Individual squirrels use many nest sites: one for eating, another for raising young and another for resting (Weigl 1978, Benyus 1989). Heights of nests range from 1-18 m (Cowan 1936, Jackson 1961, Weigl and Osgood 1974). In sub-

boreal spruce in north-western British Columbia, northern flying squirrels were mainly in hybrid white spruce with a lesser number found in lodgepole pine, subalpine fir, cottonwood and trembling aspen (L. Cotton, personal communication). Trees that were used were larger and taller than what was randomly available. Most nests were found in cavities in live trees, few nests were found in snags and witches broom (L. Cotton, personal communication).

Table 1. Flying squirrel roost sites in the FMF (L. Takats, J. Herbers, and J. Watson, personal observation)

Roost site	Roost Tree Species	Canopy Closure (%)	Canopy Height (m)	Canopy Composition.	Subcanopy Composition
YBSA * nest	Aw[1]	32	29.4	Aw / Pl	Sw
YBSA nest	Aw	15	27.4	Aw	Sw
YBSA nest	Aw	40	23.3	Aw/ Sw / Pl	Sw
YBSA nest	Aw	23	22.7	Aw	Aw
YBSA nest	Aw	60	17.3	Aw/ Sw	Sw
NOFL ** nest	Aw	51	28.2	Aw	Pl / Pb / Sw
TTWO*** nest	Fa (stub)	70	28.0	Sw / Aw	Sw / Pb / Aw
Witches' broom	Sw	80	27.0	Sw	Sw / Aw
YBSA* nest	Aw	60	27.0	Aw	Sw

* Yellow-bellied Sapsucker (*Sphyrapicus varius)*; ** Northern Flicker (*Cloaptes auratus)*;

*** Three-toed Woodpecker (*Picoides tridactylus*)

[1] Tree Species: Aw = Aspen, Fa = Subalpine Fir, Sw = White Spruce, Pl = Lodgepole Pine, Pb = Balsam Poplar

6. HABITAT AREA

Flying squirrels are not territorial (Banfield 1974). Home range size varies with habitat type and geographic location. A home range size of 2 ha was found in large, dense forests in the southern interior of British Columbia (Stevens and Lofts 1988). Squirrels in Pennsylvania and North Carolina had a home range radius of 100-200 m or 3-12 ha (Weigl and Osgood 1974). In north-western British Columbia, average core nesting area (the area where all nest sites for individual squirrels occurred) for 16 animals was 2.5 ha (males averaged 3.5 ha and females averaged 1.3 ha; L. Cotton, personal communication).

Flying squirrels typically den together. Sexes will den together except before parturition and while females rear young. While females care for young, they often move to a different nest (Carey et al. 1997). Home ranges overlap and densities can be quite variable. Population densities of northern flying squirrels range from 0.3-10 animals/ha in favorable habitat (Jackson 1961, Mowrey and Zasada 1982).

7. HSI MODEL

7.1 MODEL APPLICABILITY

Species: Northern Flying Squirrel (*Glaucomys sabrinus*).

Habitat Evaluated: Nesting Sites, Thermal and Protective Cover.

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

Seasonal Applicability: This model is applicable to year round 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. The smallest home range size found in the literature was 2 ha, so it is assumed that this is the minimum habitat area.

Model Output: The model will produce Habitat Units (HU) for nesting and cover (thermal and hiding) for each classified plant community based on HSI value and stand area. Habitat units are calculated by multiplying the HSI score with the area in hectares. The performance measure for the model is potential carrying capacity (adult flying squirrels per ha). Model output (HU) should be correlated to estimates of carrying capacity to verify model performance.

Carrying Capacity (Adult Flying Squirrels per ha where HSI = 1.0): The population density of northern flying squirrels range from 1 squirrel/3 ha to 10 squirrels/ha under favorable habitat. This averages to about 3 squirrels per optimal hectare.

Verification Level: The reliability of this model has not been evaluated against local data. The verification level is 4: local data 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 northern flying 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 northern flying squirrel requires nesting sites, and thermal and protective cover. Protective cover is important because they are preyed upon by many different forest predators. These squirrels do not hibernate despite the cold winters in the foothills region. Nesting sites must be safe from predation and environmental factors. It is assumed that the same locations that provide nesting and cover also supply adequate food throughout the year.

7.2.1 Habitat Variables and HSI Components

Tree canopy closure is important for both thermal and protective cover. However, tree canopy closure is also related to canopy density and at some sites canopy closure may become too high to allow gliding maneuverability. Canopy closure is used to define HSI component S_1 (Table 2).

Conifer trees are important for flying squirrel habitat suitability because they provide thermal cover. Flying squirrels in the FMF used deciduous trees for roosting, but there was always a conifer component in the forest canopy. Cones and seeds from conifer trees are an important food source for the winter months. HSI component S_2 is defined based on the percentage of conifers in the canopy.

Tree height is an indication of the developmental state of the forest. Flying squirrels appear to prefer fully developed stands which typically are associated with large-diameter/tall trees and numerous cavities in snags and trees. HSI component S_3, defined as tree canopy height is used as an index of these conditions. Flying squirrels also rely on the height of trees to glide about the forest.

The final variable is the number of deciduous trees with a dbh $\geq$ 35 cm which is used to predict HSI component S_4 and determines the value of an area for nesting habitat. Since nest sites are also found in coniferous trees or snags, and in some smaller deciduous trees, this component does not have as large an influence on the habitat suitability as the other 3 components.

Table 2. Relationship between habitat variables and life requisites for the northern flying squirrel HSI model.

HSI Component	Life Requisite	Habitat Variable	Habitat Variable Definition

Component			
S_1	Thermal & Protective Cover	Tree Canopy Closure (%)	Percent of ground covered by a vertical projection of tree crown areas onto the ground. Includes trees ≥ 8 cm dbh.
S_2	Thermal & Protective Cover	Pine, Spruce and Fir in Tree Canopy (%)	Composition of pine, spruce and fir species in the tree canopy.
S_3	Nest Site, Protective & Thermal Cover	Tree Canopy Height (m)	Mean top height of 100 trees/ha with the largest dbh.
S_4	Nest Site	Large Deciduous Trees ≥ 35 cm dbh	Number of deciduous trees ≥ 35 cm at 1.3 m height per hectare.

7.2.2 Graphical HSI Component Relationships

S_1 Until a tree canopy closure of 15% is reached, a forest area is unsuitable habitat ($S_1 = 0$). Fifteen percent was chosen because this was the lowest density that a northern flying squirrel was found in the FMF. The suitability increases to 1 at 50% closure. A canopy closure of 50-85% is considered optimal for the northern flying squirrel. A density higher than 85% reduces the squirrels ability to glide through the trees, thus the component drops to 0 over the range 85-100%.

S_2 This component starts at 0 when there are < 10% conifers in the stand. The component value rises to 1 over the range 10-30%. This remains at the optimum value until conifer composition is ≥ 80%. The suitability then decreases, since there is a need for deciduous trees for nesting locations. At 100% conifers the stand is again unsuitable.

S_3 Over the range 0-15 m canopy height, $S_3 = 0$. The component value increases linearly until it is equal to 1 at 21 m in height. The suitability is considered optimal at all heights ≥ 21 m. The height of 15 m was chosen because 15 m is close to the lowest height at which a roost was found in the FMF.

S_4 This variable is only a habitat modifier, as S_4 never can drive a stand to being completely unsuitable. However, over the range 0-2 deciduous trees ≥ 35 cm dbh per hectare, the suitability increases from 0.5 to 1. Suitability remains at 1 for all greater densities.

7.3 MODEL ASSUMPTIONS

1. Flying squirrel nest sites, and thermal and protective cover are all equally limiting in determining habitat suitability. Predation cover and thermal cover are provided by the same elements of habitat structure.
2. Food, water, and other nutrients are available at sites that have adequate cover and nesting sites.
3. There is no seasonality to the suitability of habitat based on the 4 variables in this model.
4. Flying squirrel habitat is not affected by human activities except in the manner in which habitat structure may be altered. Thus the distance to roads, settlements, or industrial work-sites have no influence on habitat use.

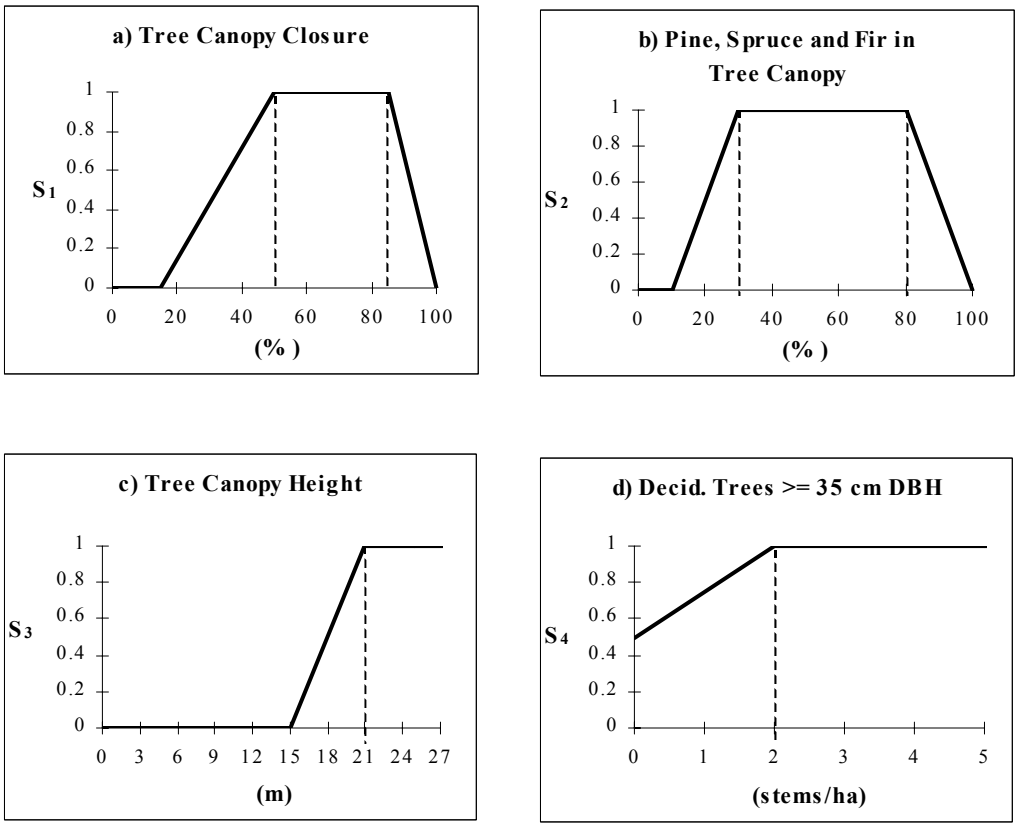

Figure 1. Graphical relationship between habitat variables and HSI components in the northern flying squirrel model.

7.4 HSI EQUATION

The HSI equation is the product of the 4 components, all of which are considered equal and non-compensatory. However, S_4 has less influence on the overall HSI since it only varies from 0.5 to 1. All other components can drive the HSI score to 0.

$$HSI = S_1 \times S_2 \times S_3 \times S_4$$

8. OTHER SOURCES OF MODELS

No other HSI models for the northern flying squirrel were found.

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 (1995) was written by Lisa Takats for a special topics course in habitat modelling at the University of Alberta.
- Version 2 (1996) was edited and reformatted by Wayne Bessie and sent to species experts for critical comment.
- Version 3 (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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