BAP REPORT #6:
HABITAT SUPPLY MODELS

Prepared for Millar Western Forest Products' Biodiversity Assessment Project

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6.1 INTRODUCTION

In BAP, there are three levels at which biodiversity is assessed: ecosystem, landscape, and species. As mentioned in BAP Report #1: Background and Structure (Duinker *et al*. 2000), the ecosystem diversity and landscape configuration analyses form the "coarse-filter" portion of the analysis and the species-specific habitat supply analysis represents the "fine-filter" portion (Noss 1983; Hunter 1990). The ecosystem diversity and landscape configuration analyses are described in detail in BAP Report #7: Ecosystem Diversity and Landscape Configuration Models (Doyon 2000). The species-specific habitat supply analysis is the focus of this report.

It is essential to the success of BAP that the fine-filter analysis complements the coarse-filter analyses. To accomplish this, the BAP team selected species according to a set of criteria which described their status, specificity to habitat and landscape conditions, and socio-economic values (Doyon and Duinker 2000). Although all species selected are terrestrial vertebrates, an effort was made to choose species that covered a wide range of taxonomic and body-size classes.

As described in BAP Report #2: Species Selection Procedure (Doyon and Duinker 2000), each terrestrial vertebrate on a preliminary list of 76 species was given a ranking describing its suitability as a bioindicator. This process allowed the BAP team to select a group of 22 species for which habitat models would be created (Table 6.1).

Table 6.1. Species selected for habitat supply modelling under BAP.

Common Name	Scientific Name
Barred Owl	*Strix varia*
Beaver	*Castor canadensis*
Brown Creeper	*Certhia americana*
Canada Lynx	*Lynx canadensis*
Elk	*Cervus elaphus*
Least Flycatcher	*Empidonax minimus*
Little Brown Bat	*Myotis lucifugus*
Marten	*Martes americana*
Moose	*Alces alces*
Mountain Bluebird	*Sialia currucoides*
Northern Flying Squirrel	*Glaucomys sabrinus*
Northern Goshawk	*Accipiter gentilis atricapillus*
Pileated Woodpecker	*Dryocopus pileatus*
Ruffed Grouse	*Bonasa umbellus*
Snowshoe Hare	*Lepus americanus*
Southern Red-backed Vole	*Clethrionomys gapperi*
Spruce Grouse	*Dendragapus canadensis franklinii*
Three-toed Woodpecker	*Picoides tridactylus*
Varied Thrush	*Ixoreus naevius*
White-tailed Deer	*Odocoileus virginianus*
Wood Frog	*Rana sylvatica*
Woodland Caribou	*Rangifer tarandus caribou*

6.2 HABITAT SUPPLY MODELS (HSMS)

Models are representations of real-world situations (Holister 1984; Starfield and Bleloch 1986; Morrison *et al*. 1992; Patton 1992) that help the user describe reality (Duinker 1985). According to Starfield and Bleloch (1986), models are tools which "help us to (1) define our problems, (2) organise our thoughts, (3) understand our data, (4) communicate and test that understanding, and (5) make predictions." Therefore, models are learning tools that can help determine the impacts of any external perturbation on the entire system (Higgelke 1994).

"A habitat model is a tool for assessing an area's ability to support a wildlife species..." (Fish and Wildlife Branch, New Brunswick Department of Natural Resources 1989). Since their beginning in 1979 (Thomas 1979), wildlife habitat models have evolved remarkably. In the early 1980s, Habitat Suitability Index (HSI) models (e.g. Allen 1982; Allen 1983; Short 1984) provided an idea of the current suitability of an area as wildlife habitat. Habitat Supply Analyses (HSA) or Habitat Supply Models (HSMs) "measure ... the quantity and quality of habitat features to be produced by a management prescription and ... project future habitat quality for wildlife..." (Greig *et al*. 1991). Therefore, HSMs diverge from HSIs in that they incorporate a temporal dimension to the process (Higgelke 1994).

HSMs have been used extensively in Canada to identify the potential impacts of timber management activities on wildlife habitat through time (e.g. Duinker 1986; Bonar *et al*. 1990; Eng and McNay 1990; Greig *et al*. 1991; Duinker *et al*. 1993; Bonar and Beck 1994; Higgelke 1994; McCallum *et al*. 1994; Naylor *et al*. 1994; Knox 1995; Sullivan 1995). Through these models, one can assess the impact of forest management activities on the spatial and temporal distribution of habitats.

Practicality to forest management planning

HSMs were created for the wildlife species chosen for study within the FMA area with the purpose of preparing practical tools to assist in forest management planning. Often, a species will require quite different habitat characteristics for different habitat uses (e.g. dense shrubby vegetation as hiding cover and open meadows for foraging). In such a situation, a habitat patch may rate extremely high for one aspect of habitat use and extremely low for another. Combining these values together into a single suitability rating (a practice which is commonplace in modelling) will, in effect, mask these high and low values that are biologically significant. It would be impossible for the forest manager to predict the forest features with which he or she should be concerned. Therefore, it was decided that the format would be altered to allow output of the habitat's suitability rating for each forest use separately (*i.e.,* a model prepared for a species that requires habitat for foraging, hiding, and nesting will output three separate suitability values, one for each of these habitat uses). It is believed that this approach more effectively provides information on habitat suitability within the FMA area. In this way, forest managers are easily able to target the habitat elements in need of attention in forest management planning.

The HSM process

The development of the HSMs followed the steps shown in the flowchart (Figure 6.1). The first steps in model development included the collection and synthesis of relevant literature. This information assisted in identifying the potential effects of forest management activities on the species of interest, along with their food, cover, reproduction, habitat area, and landscape configuration requirements, and sensitivity to human disturbance. Using this information, the models were then conceptualised, developed, reviewed, and revised. The following subsections describe this process in detail.

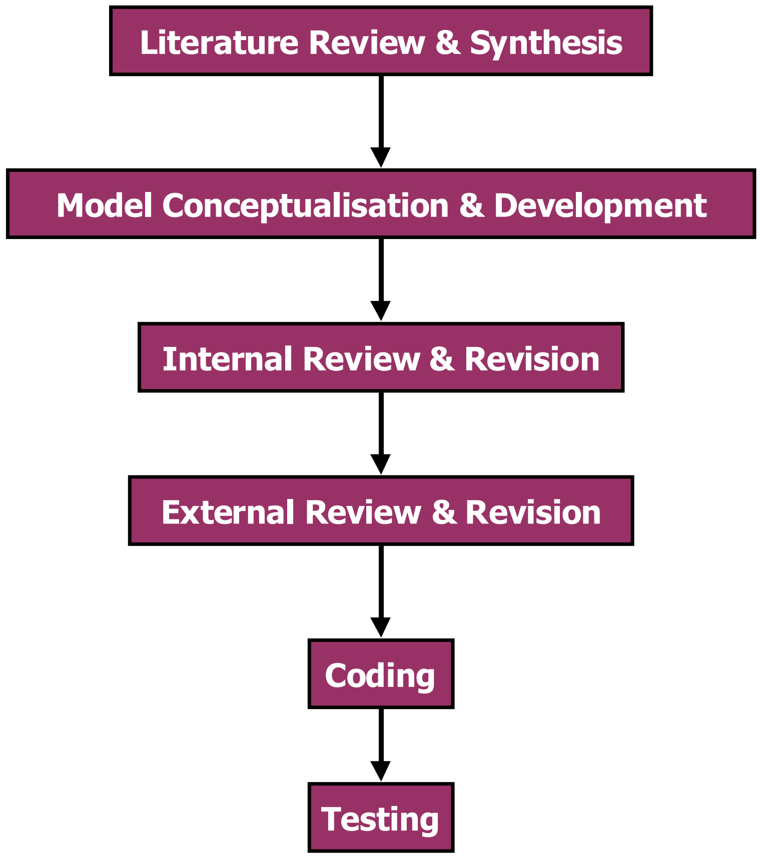

Figure 6.1. Flowchart displaying the HSM development procedure.

Forest uses

As recommended in the critique of HSI modelling written by Van Horne and Wiens (1991), the "theory of environment", developed by Andrewartha and Birch (1984), was used as a framework for the creation of the HSMs. According to this theory, "…the environment of an animal consists of everything that might influence its chance to survive and reproduce…". These environmental elements have been summarised as four habitat uses central to an animal's survival. These include availability of food resources, protection from predators, protection from inclement environmental conditions, and the opportunity to produce young. For a species' needs to be fulfilled, the forest must supply certain features, referred to as general and specific forest features. For example, a general forest feature under the habitat use of reproduction for the Northern Goshawk is the existence of nesting sites. The corresponding specific forest feature is the presence of an appropriate number of large deciduous trees per ha.

The envirogram technique

The relationships that link forest characteristics to habitat uses and to the species can be expressed in the form of an envirogram. An envirogram is a graphic hierarchical representation of pathways of causal relationships that aids in identifying habitat variables vital to each habitat use. It "…offers a way to develop a logical foundation for specifying and relating variables in the models…" (Van Horne and Wiens 1991). The foraging portion of the envirogram built for the Northern Goshawk, referred to above, is shown in Figure 6.2. It shows, from right to left, the progression from habitat use to general forest feature to specific forest feature.

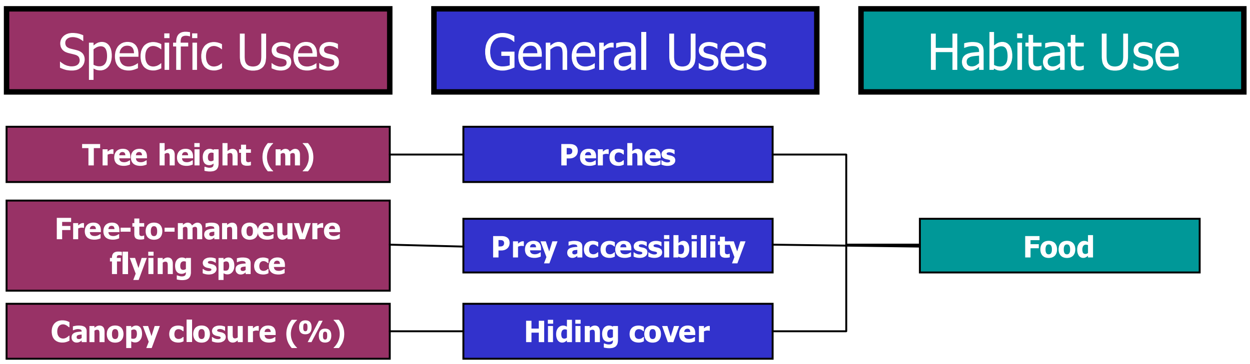

Figure 6.2. The foraging portion of the envirogram for the Northern Goshawk.

Suitability Index (SI) curves

Suitability Index (SI) curves were developed for each habitat feature considered important to each animal. These curves show how the SI value of the habitat changes as a function of a particular forest feature. For example, as shown in Figure 6.3, the goshawk requires trees of significant height as perches while hunting. While trees less than 8 m tall are thought to be too small to be used as perches, those of 16 m height may suffice and those of height > 24 m are of optimal size.

In many cases, data were available in the literature that suggested the optimal condition of the necessary habitat features (e.g. the percentage of the forest floor that should be covered with downed woody debris before the SI curve peaks). For other variables, these data were not available. In these cases, it was necessary to make assumptions regarding the shape of the curves. It is well understood that animals behave variably depending on their geographic location. Therefore, it is essential that all suitability curves are verified in the field within Millar Western's FMA area.

Some of the selected habitat variables are directly linked to inventory variables that are provided by the forest projections. Others need to be estimated indirectly using the Special Habitat Element (SHE) models described in BAP Report #5: Special Habitat Element Model Development (Doyon and MacLeod 2000).

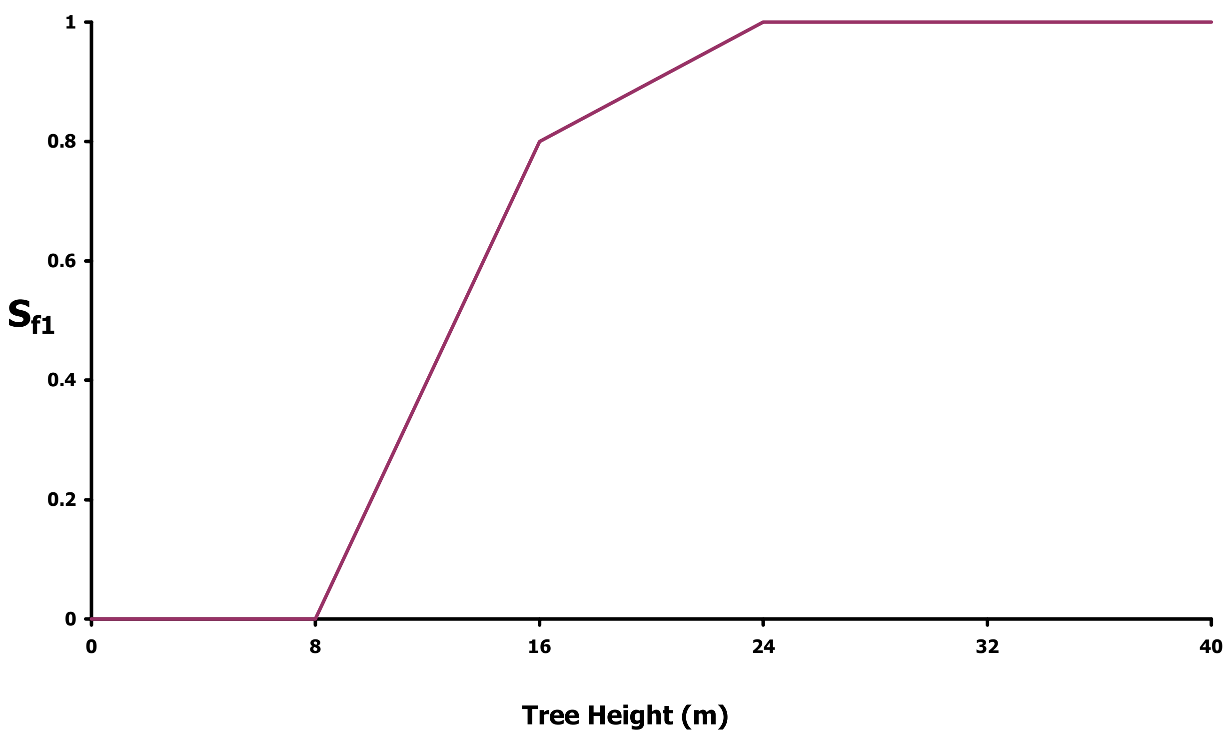

Figure 6.3. An example of a SI curve. The relationship between Northern Goshawk foraging habitat suitability and tree height.

Suitability Index (SI) equations

All habitat variables thought to be required by a species were grouped according to habitat use (e.g. shrub cover, density of trees with low height to crown, and downed woody debris cover may be grouped as contributors to hiding cover habitat). These variables were combined together in SI equations. Most of the equation forms used are standard (*i.e.*, used regularly in Habitat Suitability Index modelling). These are listed in Table 6.2.

Home range smoothing

The spatial arrangement and scale of suitable habitat patches is an important consideration in model interpretation. To give an indication of the potential value of each pixel as part of a home range, we carry out a process referred to as home range smoothing. Home range smoothing is based on a system that was developed by Daust and Sutherland (1997). Maps of suitable habitat are 'smoothed' by averaging the SI values inside a circular area comparable to the home range size of the species (e.g. all SI_{food} results are averaged to reveal the average SI_{food}). The average values are applied to the pixel at the centre of the circle to indicate the value of a home range centred at that pixel. Depending on the home range size of the species in question, the habitat supply maps will appear more or less 'blocky'. Figure 6.4 shows the habitat supply map for the Pileated Woodpecker, a species with a relatively large home range. Figure 6.5 shows the habitat supply map for the Least Flycatcher, a bird with a very small home range.

Originally, it was the BAP team's plan to classify each pixel as suitable or unsuitable, by comparing its smoothed value to an arbitrarily defined threshold value, depending on the frequency distribution of SI values in all projections. It was decided, however, that it would be misleading to create arbitrary thresholds to identify suitable habitat. Though a species will prefer to use high quality habitat, it may use habitat of lesser quality if optimal habitat is unavailable. Therefore, a habitat patch that may be considered unsuitable if located adjacent to excellent quality habitat, may still be useful if surrounded by habitat of even lesser quality.

Table 6.2. Equation forms used in HSM development.

Effect Desired	Equation Form	Purpose	Example
Full compensation	Addition	Used when more than one habitat element can contribute simultaneously to the same habitat use.	$SI_1 + SI_2$ (Maximum of 1)
No compensation	Multiplication	Used when two different habitat elements are both vital to species survival and must be present at the same time in the same location.	$(SI_1 * SI_2)^{1/2}$
Bonus	Limited addition	Used when the presence of a habitat element is beneficial to a species but not vital to survival.	$1/A\ (SI_1)$ The value of A is variable and is set by the model author. Lower values of A reflect more significant benefits from the habitat element.
Alternative resource	Maximum	Used when two different habitat elements are equally suitable in their ability to contribute to a particular habitat use but when only one may be used at a time.	$Max\ (SI_1, SI_2)$
Emphasising	Power	Used to emphasise the importance of one habitat variable over another in the SI equation.	$SI_1^{\ 2}$
Diminishing	Root	Used to diminish the importance of one habitat variable over another in the SI equation.	$SI_1^{\ 1/2}$
Spatial link	Distance function	Used to adjust the value of a habitat type based on its proximity to another required resource.	$[SI_{food} * (Window\ (Max\ SI_{cover})_{300m})]^{1/2}$; Within a circular window of radius 300 m, the pixel that has been rated highest as cover habitat is found. This value is multiplied by the value of the pixel at the centre of the circle as foraging habitat. The resulting adjusted food value is applied to the centre pixel.

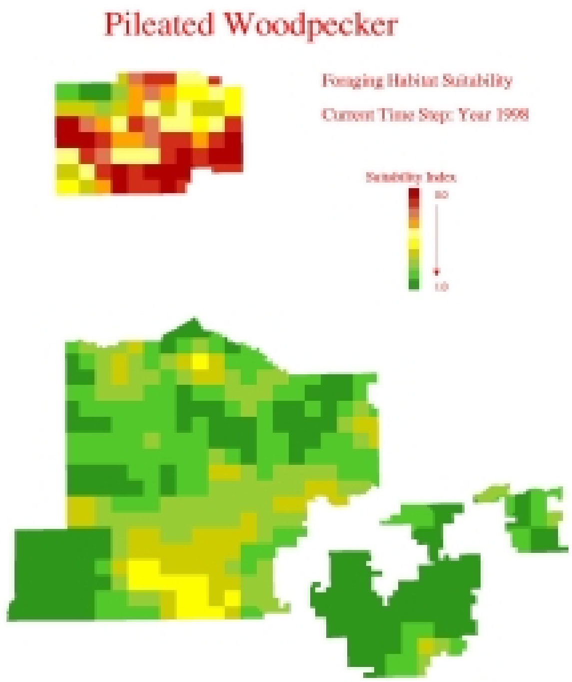

Figure 6.4. Current foraging habitat supply for the Pileated Woodpecker.

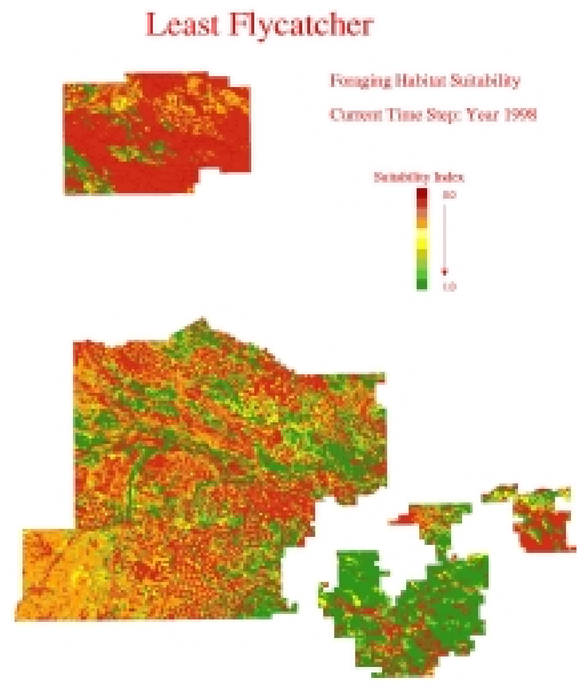

Figure 6.5. Current foraging habitat supply for the Least Flycatcher.

Adjustments to the list of species to be modelled

Once the BAP team began development of the HSMs, it was suggested by Jonathan Russell, planning forester for Millar Western, that the Gray Wolf should be included as a species to be modelled. However, this species, along with the Beaver, Little Brown Bat, Mountain Bluebird, and Wood Frog were subsequently removed from the list for reasons explained in BAP Report #2: Species Selection Procedure (Doyon and Duinker 2000).

The review process

Completed models were reviewed internally at KBM Forestry Consultants Inc. and were then sent to one or more external experts to ensure that they were biologically sound and locally applicable. Models were revised after each review and records were kept of the changes made. Finally, the models were coded by the GIS analyst, using the section of the HSM reports entitled Computation as a guide.

Once coding was complete and each model was run, they were tested for internal adequacy and consistency. On occasion, the maps of suitable habitat that were prepared following execution of the model did not show expected results. These problems were generally found to be caused by improper variable selection or coding errors. The HSMs were revised and the model output was analysed and interpreted.

Analysis and interpretation

Only preliminary analyses have been conducted on the HSM results to date. The BAP team considered maps displaying supply of habitat for each use for each indicator species. By comparing the habitat supply maps both within and between scenarios, we were able to determine which habitat elements had the greatest influence on habitat supply. From this, best management practices intended to minimise the negative impact of timber harvesting on wildlife habitat were devised.

HSM testing

Though the HSMs are based, as much as possible, on field data collected by experts on the habitat requirements of each species, some of the assumptions made in the models may be invalid. Therefore, there should be great importance attached to testing the validity of the assumptions (Berry 1986). The proposed approach of Schamberger and O'Neil (1986) and Laymon and Barrett (1986) was used as a framework for development of a HSM testing procedure. Internal discrepancies in the models can be expected to be identified with repeated execution. A sensitivity analysis on the different parameters of each HSM will allow us to remove variables with little importance while identifying critical variables. It is hoped that a research program directed towards HSM validation will be established in the future under which different aspects of the HSMs will be tested in the field. The results from these field studies may lead us to model modification.

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