

**Northern Goshawk (*Accipiter gentilis*) Habitat Model  
for the Mist Mountain Project**

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## EXECUTIVE SUMMARY

The purpose of this project was to assess the amount, quality and distribution of habitat for the Northern Goshawk (*Accipiter gentilis*; hereafter goshawk) within the Mist Mountain study area in southeastern British Columbia, as part of environmental baseline work being conducted for BP Canada Energy Company. The approach used here follows a model framework that WildFor Consultants Ltd. Helped develop for the Habitat Recovery Implementation Group of the BC Coastal Northern Goshawk Recovery Team. The overall model consists of three components: a goshawk nesting habitat model, a foraging habitat model, and a “territory” model. The “territory” model was used primarily for analysis purposes to assess the amount and distribution of nesting and foraging habitat relative to average goshawk territory size in the region. The structures of the nesting habitat and foraging habitat models are consistent with the Habitat Suitability Index (HSI) methodology and have ratings ranging 0-1. This report provides details of the model structures, the information used to parameterize them, and the model outputs for the study area.

The proportion of nesting habitat predicted from the model for the overall Wildlife Study Area (WSA) was 1.4% High, 5.3% Moderate, 16.4% Low and 76.9% Nil. The foraging model indicated substantially more suitable foraging habitat existed with 11.8% High, 26.8% Moderate, 35.3% Low and 26.1% Nil. The proportions of nesting and foraging habitat in the Project Area were very similar and amounts differed by less than 2% from the WSA values, above. Based on the amount, quality and distribution of nesting and foraging habitat, the territory model predicted an average of 18 territories within the WSA (including the Project Area) and 10 within the Project Area. The relatively limited extent of suitable nesting habitat was the primary factor limiting the number of territories the model predicts under current conditions.

Field verification indicated that the nesting model had an average error (difference between field and model rating) of 0.21 HSI units and the foraging model had an average error of 0.13 HSI units. Both the nesting and foraging models underestimated true habitat quality on average: nesting by 0.12 HSI units, foraging by 0.07 units. The primary source of error associated with the model predictions were errors in the forest cover, which precluded model revision to improve accuracy (conditions differed between the field data and GIS forest cover data at 44% of the plots).

Surveys to locate new goshawk nest areas were also conducted in the 2008 breeding season. Four adult goshawks were detected during the 2008 surveys, but the birds did not appear to be breeding and no nests were found.

Potential impacts to goshawks associated with gas development are discussed and mitigation strategies are provided.

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# Northern Goshawk Habitat in the Mist Mountain Study Area

## INTRODUCTION

BP Canada Energy Company (BP Canada) has proposed a three to five year technical appraisal program to assess the feasibility of coalbed gas (CBG) development in southeast British Columbia. The proposed project is located south of the Municipal District of Sparwood and east of the City of Fernie. WildFor Consultants Ltd. (WildFor) has been retained by Matrix Solutions Inc. (Matrix) on behalf of BP Canada to assess the amount, quality and distribution of Northern Goshawk (*Accipiter gentilis*; hereafter goshawk) habitat using habitat models and conduct field surveys to verify the models and search for nest areas.

The approach used here follows a model framework that WildFor helped develop for the Habitat Recovery Implementation Group of the BC Coastal Northern Goshawk Recovery Team (Mahon *et al.* 2008). The overall model consists of three components: a goshawk nesting habitat model, a foraging habitat model, and a “territory” model. The “territory” model was used primarily for analysis purposes to assess the amount and distribution of nesting and foraging habitat relative to average goshawk territory size in the region. The structures of the nesting habitat and foraging habitat models are consistent with the Habitat Suitability Index (HSI) methodology (US Fish and Wildlife Service 1981). The variables used in the models and ratings assigned for each variable were developed based on observed habitat characteristics at goshawk nest areas in the East Kootenays and similar habitats in British Columbia, relevant literature, and the expert opinion of the authors.

The intended use of these habitat models is to assess the relative quality, amount, and distribution of goshawk breeding habitat within the study area. Habitat ratings that result from these models represent relative values suitable for comparisons across the study area and for comparing relative habitat supply over time or under different management scenarios. Ratings do not predict, or correspond to, absolute measures of habitat quality or absolute numbers of goshawk territories. The models were developed specifically for the Interior Cedar-Hemlock (ICH), Interior Douglas Fir (IDF), Montane Spruce (MS), and Engelmann Spruce-Subalpine Fir (ESSF) biogeoclimatic variants (Pojar *et al.* 1987; Braumandl and Curran 2002) found in the Mist Mountain Study Area using forest inventory and Terrain Resource Inventory Management (TRIM; elevation) databases.

## **Objectives**

The specific objectives of this project were to:

1. Provide a baseline assessment of the amount, quality, and distribution of goshawk habitat within the Mist Mountain Wildlife study area.
2. Conduct field verification activities to assess the accuracy of the model and to gather local field data to refine the nesting and foraging habitat models.
3. Conduct goshawk inventory surveys to locate new nest areas to validate the suitability mapping and to identify specific sites for management purposes.

## **SPECIES ACCOUNT**

Several documents provide compressive accounts of the ecology, management and conservation of the Northern Goshawk internationally (Squires and Reynolds 1997), provincially (Cooper and Stevens 2000) and regionally (Iverson *et al.* 1996; Mahon and Doyle 2003; McClaren 2003). For detailed background information readers should refer to these documents. Below is a brief synopsis of that information with emphasis on information that is most relevant to goshawk habitat selection and management in the East Kootenays.

### ***Species Overview: Description, Distribution, and Ecology***

The Northern Goshawk is a raven-sized forest raptor with a circumpolar distribution inhabiting coniferous and mixed forest dominated landscapes (Brown and Amadon 1989). Across its range there are several morphologically different sub-species. Within British Columbia the larger *A. g. atricapillus* is found throughout the interior of the province and the smaller Threatened *A. g. laingi* is found on Vancouver Island, Haida Gwaii (Queen Charlotte Islands) and along the mainland coast (Campbell *et al.* 1990; Cooper and Stevens 2000).

The goshawk is primarily adapted to forest habitats where its short, rounded wings, long tail, and powerful flying action make it an effective direct pursuit hunter, capable of quick acceleration and excellent manoeuvrability through the forest. Across their broad range goshawks take a variety of mid-sized forest prey ranging from small mammals and passerines to hares (Squires and Reynolds 1997). In Interior British Columbia the main prey of goshawks are red squirrels, ground squirrels, grouse, snowshoe hares and forest passerines (typically thrushes, woodpeckers and jays) (Mahon and Doyle 2003; W. Harrower, pers. comm.).

Goshawks typically nest in mature and old-growth coniferous stands that have a closed canopy and open understory (Cooper and Stevens 2000, Penteriani 2002, McGrath *et al.* 2003). Across landscapes with suitable habitat goshawks are relatively evenly distributed (Reynolds and Joy 1998; Reich *et al.* 2004) with the distance between

territories being primarily driven by prey and habitat availability within landscapes (Doyle and Smith 1994, 2001; Reich *et al.* 2004). In Interior British Columbia nest area spacing distances are typically 4 to 6 km, corresponding to breeding territory sizes of approximately 2400 ha (Mahon and Doyle 2003 [west central British Columbia]; W. Harrower unpub data [East Kootenays]).

The Northern Goshawk is probably a year-round resident in most years throughout most of its range (Squires and Reynolds 1997). This is an important factor for management because breeding success is linked to the over winter body condition of the female, which is dependent on the foraging quality of the territory surrounding the nest area. In west-central British Columbia 82% of 32 radio-tagged adult goshawks were resident year-round (Mahon 2008). In the East Kootenays, all of 26 radio-tagged adults remained in the study area through the winter following the breeding season they were radio-tagged in (W. Harrower, pers. comm.).

### ***Taxonomy and Status***

It is recognized that it is the *A. g. atricapillus* subspecies that occupies Interior British Columbia (COSEWIC 2000). *A. g. atricapillus* is considered not at risk (Yellow-listed) provincially and widespread and secure globally (G5, NatureServe Conservation Status) (BC Conservation Data Centre 2008). Although the goshawk is not at risk of extinction, is often recognized as a species of management concern with respect to resource development activities, especially forestry, in forested landscapes (Reynolds *et al.* 1992; Widen 1997).

Due to its strong selection of mature forest for nesting and foraging activities, large territory size requirements, and role as a predator, the goshawk is also often considered a mature forest indicator species (e.g. Betts *et al.* 2003). An indicator species is one that is associated with particular ecological conditions and processes and, following the tenants of indicator species management, by conserving the requirements of goshawks, the requirements for a suite of other species will be met as well. Species that share similar requirements and ecological traits as goshawks include marten, Great Grey Owl, and Barred Owl. Effective conservation of goshawk habitat will also help conserve prey species associated with mature forest, such as woodpeckers.

Goshawks are also a keystone species and ecosystem engineer by providing surplus nests that owls, such as Great Grey Owl and Barred Owl, depend on because they do not build their own nests.

### **Threats**

Loss of mature forest (as nesting and foraging habitat) from resource development, notably logging, is probably the most significant factor threatening goshawks in British Columbia (Cooper and Stevens 2000, COSEWIC 2000). In parts of

Europe populations of goshawks have declined 50-60% in response to broad-scale forest harvesting (Widen 1997). Monitoring in most of British Columbia has been inadequate to determine population trends, but Doyle (2004) estimated that timber harvesting over the last 40 years on Haida Gwaii has reduced the number of suitable territories from >50 to approximately 20.

### **Existing Local Information**

Before the mid 1990s very few goshawk nest areas were known in the East Kootenays, or the broader Interior British Columbia. In 1995 both subspecies of the Northern Goshawk were listed as “Identified Wildlife Species” under the Forest Practices Code, resulting in a combination of several intensive inventory and research programs and education and training to forest workers in goshawk identification and reporting requirements. As a result of these initiatives several hundred goshawk nest areas have been located in Interior British Columbia in the last 12 years, including approximately 48 nest areas in the East Kootenays, and two within the overall Mist Mountain Wildlife Study Area (including one within the nested Project Area) (Harrower *et al* 2007). The general location of known nest areas within and adjacent to the Wildlife Study Area are provided on Figures 2 and 3. Due to conservation concerns, nest site locations should be treated as sensitive information and not presented on maps at a finer resolution than 1:500,000.

### **Territory Components**

Goshawks exhibit strong territoriality and that affects population density, distribution, and habitat use. A goshawk territory is traditionally described as having several hierarchically arranged components (Figure 1; after Reynolds *et al.* 1992). At the largest scale is the overall home range, which includes the total area used by a pair throughout the year. At the home range scale there is considerable overlap among adjacent goshawk pairs. During the breeding season, space use contracts to a smaller breeding territory with reduced overlap among neighbouring pairs (Squires and Reynolds 1997). The nest area/post-fledging area (PFA) is the smallest territory component and is the centre of breeding activities throughout the reproductive season – mid-February to early September. The nest area usually includes multiple nest sites. Goshawks exhibit very strong fidelity to nest areas once established, often using them intermittently for periods of years or decades (Squires and Reynolds 1997). The estimated size of nest areas ranges from 8 ha (Reynolds 1983) to 50 ha (McCarthy *et al.* 1989). From a sample of >80 nests in the ICH and SBS biogeoclimatic zones in the Northern Interior Forest Region nest area size was estimated to be 24 ha (Mahon and Doyle 2005).

The post-fledging area (PFA) is an area of concentrated use by the juveniles after they leave the nest but before they disperse from their natal area. Originally, the PFA

was considered by researchers as a separate territory component, however, recent studies in British Columbia have indicated there is substantial overlap in the size and extent between the nest area and PFA. The first PFA study estimated the size to be 170 ha (southwestern USA, Kennedy *et al.* 1994), however, more recent studies with larger sample sizes have found the PFA is much closer in size and extent to the nest area. In west central British Columbia PFA size averaged 20 ha (Mahon *et al.* 2003); in the East Kootenays the PFA size averaged 37 ha (Harrower *et al.* 2007); on Vancouver Island PFA size average 59 ha (McClaren *et al.* 2005). During the post-fledgling period juvenile goshawks preferentially use mature forest similar to habitat around the nest trees and avoid herb, shrub and pole-sapling stage habitats (Harrower *et al.* 2007; Mahon *et al.* 2003; McClaren *et al.* 2005). Ultimately, the biological role of a nest area and post-fledgling area appear to be inseparable (McClaren *et al.* 2005).

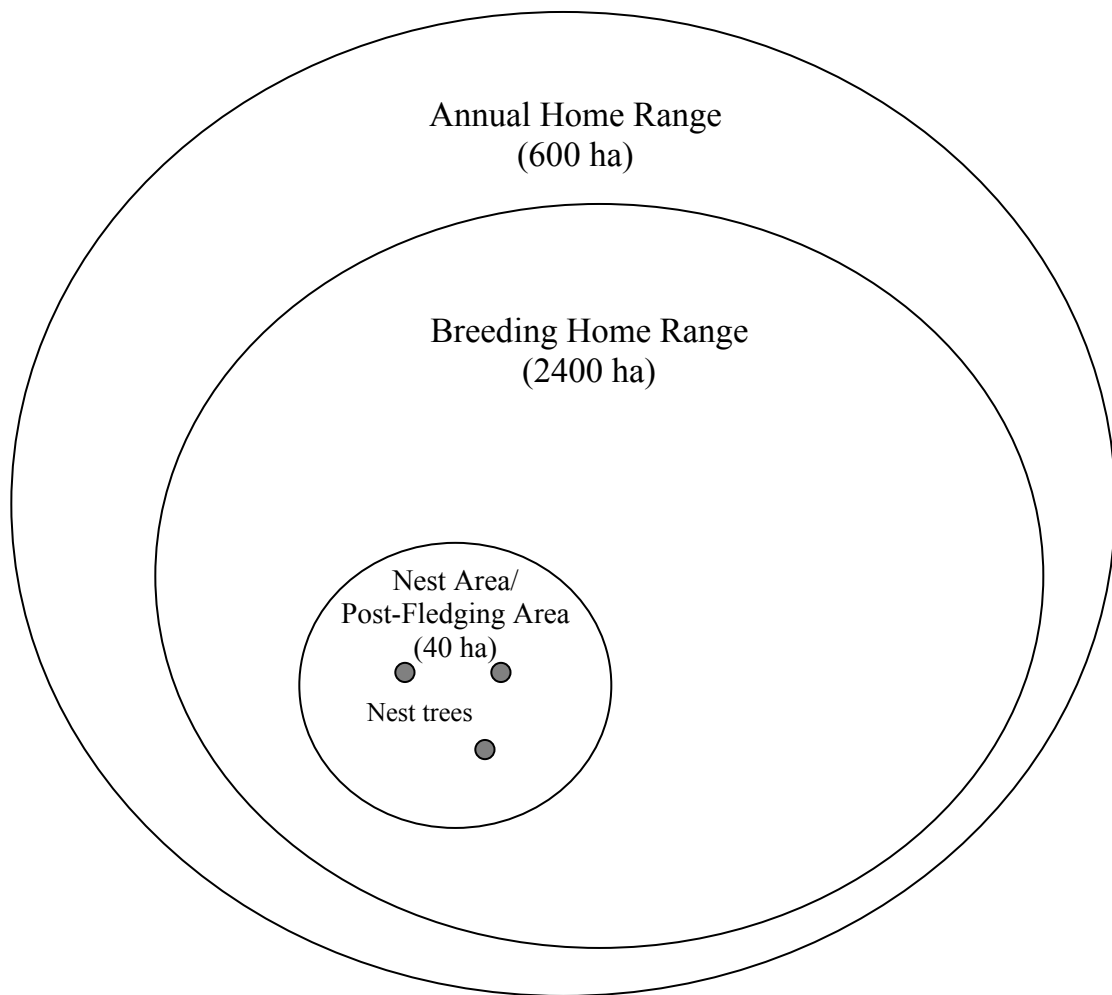


Figure 1. Conceptual arrangement of hierarchical components of a goshawk territory.

## ***Nesting Habitat***

Despite significant variation in forest types used for nesting across their geographic range, goshawks consistently select key structural attributes for nesting habitat. These attributes include mature/old-growth stand structure that offer 1) branch platforms large enough to support nests and self-thinned enough to offer access to the bole, and 2) stands are also tall enough and have relatively closed canopies with corresponding open sub-canopy flyways (Cooper and Stevens 2000, Penteriani 2002, McGrath *et al.* 2003). At the regional level, selection of forest species composition is also evident (Mahon and Doyle 2003; Schaffer *et al.* 1999). Nest stands in southeast British Columbia are typically dominated or co-dominated by Douglas fir, Western larch and lodgepole pine, are typically  $\geq 100$  years,  $\geq 28$  m in height, and have  $\geq 50\%$  canopy closure (Harrower 2007). These characteristics are generally associated with mesic, average sites. Dry, poor and wet, rich sites are typically less suitable. Photographs of high quality and low quality nest area stands are provided in Photos 1 and 2, respectively.



Photo 1. An example of High value goshawk nesting habitat in the Montane Spruce BEC zone. This mature stand offers good subcanopy flyways and individual trees have branches large enough to support a goshawk nest.



Photo 2. An example of Low value goshawk nesting habitat in the Interior Cedar Hemlock BEC zone. Although individual mature trees offer nest platforms, the multilayered stand impedes subcanopy flyways.

### ***Foraging Habitat***

Foraging habitat can occur throughout the home range. Habitats used by goshawks for foraging are generally similar to those used for nesting, although foraging habitat is more variable, depending on fluctuating prey populations, and generally broader (i.e., a broader range of levels for a given variable are suitable for foraging than they are for nesting). In addition to foraging habitat being more general and more variable than nesting habitat, the level of knowledge of foraging habitat selection by goshawks is lower than it is for nesting habitat.

Notwithstanding regional and temporal variation, goshawks primarily forage in mature forest across their range (Squires and Reynolds 1997). In a recent review of goshawk habitat selection outside of the nest stand, Greenwald *et al* (2005) identified 12 studies that compared used habitat types to those available. All 12 studies showed selection for mature (including old-growth) habitats compared to non-forested or seral habitats. Nine of the 12 studies demonstrated selection for stands with higher canopy closures and larger trees than found in random stands. It has also been shown that goshawks preferentially use forest stands where the structure makes prey more accessible than habitats where prey is most abundant (Beier and Drennan 1997, Good 1998, and

Drennan and Beier 2003). This favours hunting primarily in mature/old growth forest areas with high canopy closure, and a relatively clear understory, a habitat that allows goshawks to move freely under the canopy, allows good visibility of its prey and also provides ample perches from which it hunts (Squires and Reynolds 1997). Five studies have demonstrated a positive relationship between amount of mature forest within the territory (defined at various scales) and nest area occupancy (Crocker-Bedford 1990, 1995; Ward *et al.* 1992; Patla 1997; Finn *et al.* 2002).

In west-central British Columbia, a foraging study of 28 goshawks over five years found that goshawks used mature forest 50% more than its proportional availability and all other structural stages were used less than their availability (Mahon 2008).

## **STUDY AREAS**

The study area for this project has been named Mist Mountain and occurs in the Rocky Mountains of southeast British Columbia between the town of Fernie and the Alberta border. There are two nested study areas of interest in this project (Figure 2). The larger, Mist Mountain Wildlife Study Area (WSA) consists of 131,444 ha and is bounded by the Elk River on the west, the Elk Valley Coal mine on the north, the Alberta border on the east and Lodgepole Creek on the south. The smaller, Mist Mountain Coalbed Gas Project Area (hereafter Project Area) is 65334 ha in extent and is nested approximately 5 km inside the WSA boundary. The smaller Project Area is the area being considered for resource development. Baseline environmental studies were expanded to the larger WSA to account for wildlife movement across the Project Area boundary and to provide a more ecologically based study area (the WSA boundaries were based on wildlife management areas, topographic features, watershed boundaries, and land planning zones).

The WSA occurs predominantly within the Elk Valley Ecoregion of the Northern Continental Divide Ecoregion. The area is mountainous, ranging from 950-2400 m above sea level in elevation with one broad, low elevation valley, the Elk Valley, along the west side of the WSA. The climate is continental with warm, moist-dry summers and cold winters with heavy snowfall (Braumandl and Curran 2002). Four Biogeoclimatic Ecosystem Classification (BEC) zones occur in the study area (Braumandl and Curran 2002). Lower elevations on the west side of the WSA are dominated by the Interior Cedar Hemlock zone (ICHmk1). Mid elevations, mostly in the northern portion of the study area, consist primarily of the Montane Spruce zone (MSdk), with a small area of Interior Douglas Fir (IDF un). The Engelmann Spruce-Subalpine Fir zone occurs at upper elevations (ESSFwv above the ICH and ESSFdk above the MS).

Although the WSA is relatively sparsely populated, there has been a high degree of human influence on the area over the last century. The majority of forest stands in the

area are second growth, resulting from logging or fires, or have been selectively harvested as a result of several decades of logging (initially related to mining; mostly traditional forestry over the last 30 years). Forestry road networks are developed throughout the study area with the exception of portions of the Upper Flathead watershed. The Elk Valley contains the City of Fernie and the Municipal District of Sparwood and much of the valley bottom has been converted to farms and acreages. As well, the Elk Valley is a major transportation corridor with a major highway, railway, transmission lines and pipelines.

Goshawks range throughout the Mist Mountain WSA and regularly use all BEC zones. Primary prey for goshawks in the area, based on occurrence and limited prey remain and pellets collected from nests, are red squirrels, Columbian ground squirrels, grouse, medium sized birds (jays, thrushes, woodpeckers) and snowshoe hares. Other large raptors that goshawks may interact with include Red-tailed Hawks, which may be competitors in fragmented landscapes, Great Horned Owls, which occasionally prey on goshawks, and Great Grey and Barred Owls, which occasionally use goshawk nest sites.

## **METHODS**

### ***Goshawk Habitat Model***

The model framework used here is adapted from one the author played a lead role in developing for BC Northern Goshawk Recovery Team (Mahon *et al.* 2008). The overall goshawk model consists of three main components:

1. A nesting habitat suitability model
2. A foraging habitat suitability model, and
3. A territory analysis model

The way the overall model works is that nesting and foraging habitat suitability ratings are first generated across the entire study area and then the territory model generates potential goshawk territories across portions of the study area that have adequate amounts and configuration of suitable nesting and foraging habitat.

The primary outputs associated with the model are the numbers and general distribution of potential territories that meet a 35% foraging habitat threshold. In addition to the number of potential territories, the nesting and foraging habitat layers can be used as stand-alone products to assess the amount, quality and distribution those habitats across the Mist Mountain Study Area. It is important to emphasize that both suitability layers and the territory outputs represent relative estimates of goshawk habitat amount and quality.

The nesting habitat and foraging habitat models were based on the Habitat Suitability Index (HSI) methodology (US Fish and Wildlife Service 1981). This methodology is commonly used in habitat assessment and has been successfully used in several goshawk habitat mapping and supply analyses in British Columbia (e.g. BC

Coastal Northern Goshawk Recovery Team (Mahon *et al.* 2008), North Coast LRMP (Mahon *et al.* 2003), Morice LRMP (A. Edie and Associates 2004), see review of others by Mahon (2005)).

HSI methodology involves three key steps:

1. Selection of relevant habitat variables to include in the model.
2. Development of rating curves or scores for each habitat variable.
3. Building a mathematical relationship among habitat variables to produce overall habitat suitability scores.

The variables used in the models and ratings assigned for each variable were developed based on relationships from the literature, the authors experience and knowledge having assessed nearly 200 goshawk nest areas in western Canada, and tailored using habitat characteristics from approximately 40 goshawk nest areas in the East Kootenay area (Stuart-Smith, unpub. data).

Details about each of the goshawk habitat model components, including variables used and the model equations are provided in Appendix 1.

### ***Model Verification and Validation***

Habitat model verification involves independent surveys that rate the suitability of sites in the field and compare the field results to the variable ratings and map output from the model (Brooks 1997). Field assessment for this project consisted of two components:

1. Field rating of goshawk habitat suitability (nesting and foraging), and
2. Collection of basic habitat attribute information that was used to
  - a. verify underlying data between the field and model ratings,
  - b. quantify errors and biases in forest cover information, and
  - c. provide a basis for adjusting attribute rating curves in the model

Due to the subjective nature of habitat rating, the assessments were conducted by goshawk experts to minimize bias and variance associated with field interpretations. To further minimize any bias and variance associated with having multiple observers, three formal calibration exercises were conducted by field personnel: 1) a thorough review of the model and discussion of its assumptions, local data, and broader goshawk habitat literature, 2) explicit definition of typical habitat conditions found across the range of habitat suitability, and 3) calibration surveys by all personnel at the same sites to ensure ratings were similar among observers. Since the model predictions were in a continuous range from 0 to 1, a similar rating scheme was used in the field. The approach we used when deciding on a rating in the field was to first decide on the appropriate quartile (e.g. 0.75-1), then decide on a more precise rating based on whether suitability was on the low, middle or high end of that quartile. Separate ratings were provided for nesting and foraging habitat. The accuracy of the model predictions were examined by simply taking 1 minus the absolute difference of the model and field ratings.

Field surveys were conducted in September 2007 and July 2008 by Todd Mahon and Bill Harrower, both of whom have studied goshawk habitat selection for at least five years. Broad survey areas were first stratified to provide general representation of the different BEC variants across the WSA. Within each broad survey area actual field sites were selected using a targeted approach to cover a range of leading tree species and stand heights from forest cover maps, which were expected to correspond to a range of goshawk nesting and foraging habitat conditions. Non-forested habitats and herb and shrub stage habitats were not sampled because it is known that those areas have nil nesting habitat value for goshawks, and that they are generally classified correctly on the forest cover maps.

Validation of habitat suitability models involves testing the performance of the model with respect to actual use by the species of interest (Brooks 1997). In this case validation of the nesting habitat model would require locating a new, independent sample of goshawk nest areas and evaluating the rating of the suitability mapping for those areas. Surveys to locate breeding goshawks (call playback surveys) were conducted in conjunction with habitat model verification in July 2008. However, based on normal goshawk densities, goshawk detection rates, and project resources available in 2008, we did not expect to find enough new nest areas to constitute a validation sample.

### **Systematic Call Playback Surveys**

The standard survey method used to locate breeding goshawks is to broadcast recorded goshawk calls using a loud speaker in an attempt to elicit a defensive response from real goshawks on nest areas. Standardized inventory methods for this technique, adapted from Kennedy and Stahlecker (1993) for the Resource Inventory Standards Committee (RISC 2001), were used for all goshawk surveys. Crews broadcast recorded goshawk calls from stations at 400 m intervals along transects. At each station surveyors first listened for two minutes for spontaneously calling goshawks. After the brief listening period, surveyors broadcast recorded goshawk call sequences consisting of three call bouts, with 60 second intervals between bouts in which to detect responses. Each of the three bouts was played in a different direction, with the megaphone rotated 120° between calls. At the end of the three broadcasts, an additional five minutes were spent listening and visually searching for birds at each station. Broadcast calls were played at a volume that was audible to observers at a minimum of 200 m. Call surveys were discontinued during rain or winds exceeding 30 km/h because these conditions would diminish broadcast distance or minimize response detections. The location of playback stations was recorded from hand held geographic positioning system (GPS) units. Call playback transects were usually only surveyed once. Two exceptions were made where goshawks were detected and crews went back a second time to resurvey the area.

All survey crews were trained to distinguish goshawks and their calls from other raptors and from goshawk mimics (jays and sapsuckers). Crews recorded any responses to a broadcast including those from other hawks and mimics, in addition to the time, species, sex, age and type of response (visual/aural). Crews also estimated the initial distance and compass bearing to any hawk, as well as the direction of departure (where appropriate), as these provide clues to the proximity and direction of a nest. When a call playback elicited a response from a goshawk, crews conducted an intense search for goshawk nests and sign (white wash, pellets, prey remains, plucking perches) within a 500 m radius of the detection.

Surveys were conducted during the fledgling period (late July) when response rates are typically highest (Mahon and Doyle 2003). Juvenile food begging calls were used (as opposed to adult alarm calls), because they were more appropriate at the fledgling stage of development (Joy *et al.* 1994).

As a variation to the standard call playback survey conducted on foot, similar methods were used while traveling on bicycle along logging roads as the primary survey technique. Experimentation with this technique early in another project (Mahon and Doyle 2003) found that crews could complete approximately three times more playback stations per day than along traditional walking surveys. These surveys followed the methodology described above except that crews used roads as their transect routes and travelled between stations via mountain bikes. Bike surveys were only conducted when there was no timber hauling underway.

Call playback surveys were conducted at eight areas between July 24 - 30 2008. Survey areas were selected to provide geographic distribution and habitat representation across the study area. Survey information was recorded on modified RISC Raptor Call Playback Forms (RISC 2001).

## **RESULTS**

### ***Goshawk Habitat Model***

Overview maps showing the current distribution of goshawk nesting and foraging habitat in the Mist Mountain study area are provided in Figures 2 and 3, respectively. The thick black boundary lines on each map indicate the larger WSA and smaller Project Area. The amounts of nesting and foraging habitats in each study area classified into four rating classes (Nil, Low, Moderate, and High) are provided in Tables 1 and 2 respectively. Generally, useable conditions for goshawks (i.e. suitable habitats) include both Moderate and High classes, with better habitat quality occurring in High than Moderate on average. Both Nil and Low classes generally offer unsuitable habitat for goshawks, although the Low class represents a transitional range from completely nil value habitats to the low end of suitable. The proportions of nesting and foraging habitat

in each class are very similar between the WSA and Project Area, with amounts differing by less than 2% between study areas, so further information and discussion is only presented for the WSA.

Suitable nesting habitat is quite limited with only 1.4% of the WSA in High and 5.3% in Moderate. These habitats are generally mature and old growth, coniferous leading stands, at lower to mid elevations. The distribution of High and Moderate habitats is strongly associated with low and mid elevation valleys and large, higher elevation portions in the centre of the study areas are devoid of goshawk nesting habitat.

Suitable foraging habitat is much more extensive and wide spread than nesting habitat (Figure 3), with 11.8% of the study area classed as High and 26.9% as Moderate. High and Moderate value foraging habitat is also primarily in mature forest but consists of a broader range of stand conditions and elevation ranges than nesting habitat. Nil value areas are dominated by urban areas, mine pits and tailings, non-vegetated alpine, and water.

Table 1. Amounts of nesting and foraging habitat for northern goshawks in the overall Wildlife Study Area for the Mist Mountain area as predicted using habitat suitability index models.

Habitat Class	HSI Values	Nesting Habitat		Foraging Habitat	
		Ha	%	Ha	%
Nil	0-0.25	101143	76.9%	34331	26.1%
Low	0.25-0.50	21506	16.4%	46337	35.3%
Moderate	0.50-0.75	6973	5.3%	35297	26.9%
High	0.75-1.00	1822	1.4%	15479	11.8%
<b>Total</b>		<b>131444</b>	<b>100.0%</b>	<b>131444</b>	<b>100.0%</b>

Table 2. Amounts of nesting and foraging habitat for northern goshawks in the overall Local Study Area for the Mist Mountain area as predicted using habitat suitability index models.

Habitat Class	HSI Values	Nesting Habitat		Foraging Habitat	
		Ha	%	Ha	%
Nil	0-0.25	50180	76.8%	16359	25.0%
Low	0.25-0.50	10945	16.8%	23432	35.9%
Moderate	0.50-0.75	3314	5.1%	18152	27.8%
High	0.75-1.00	896	1.4%	7391	11.3%
<b>Total</b>		<b>65334</b>	<b>100.0%</b>	<b>65334</b>	<b>100.0%</b>

Based on the amount, quality, and distribution of nesting and foraging habitat the territory model predicts an average of 18 goshawk territories could occur in the WSA and 10 in the Project Area. An example of the theoretical territory model output for one

model run is shown in Figure 4. Under current conditions the number of territories predicted by the model is limited by the amount and distribution of suitable nesting habitat. The distribution of theoretical territories follows the broad pattern of nesting habitat distribution, with territories centred on low and mid elevation valleys and with a lack of territories in the higher elevation, central portions of the study areas.

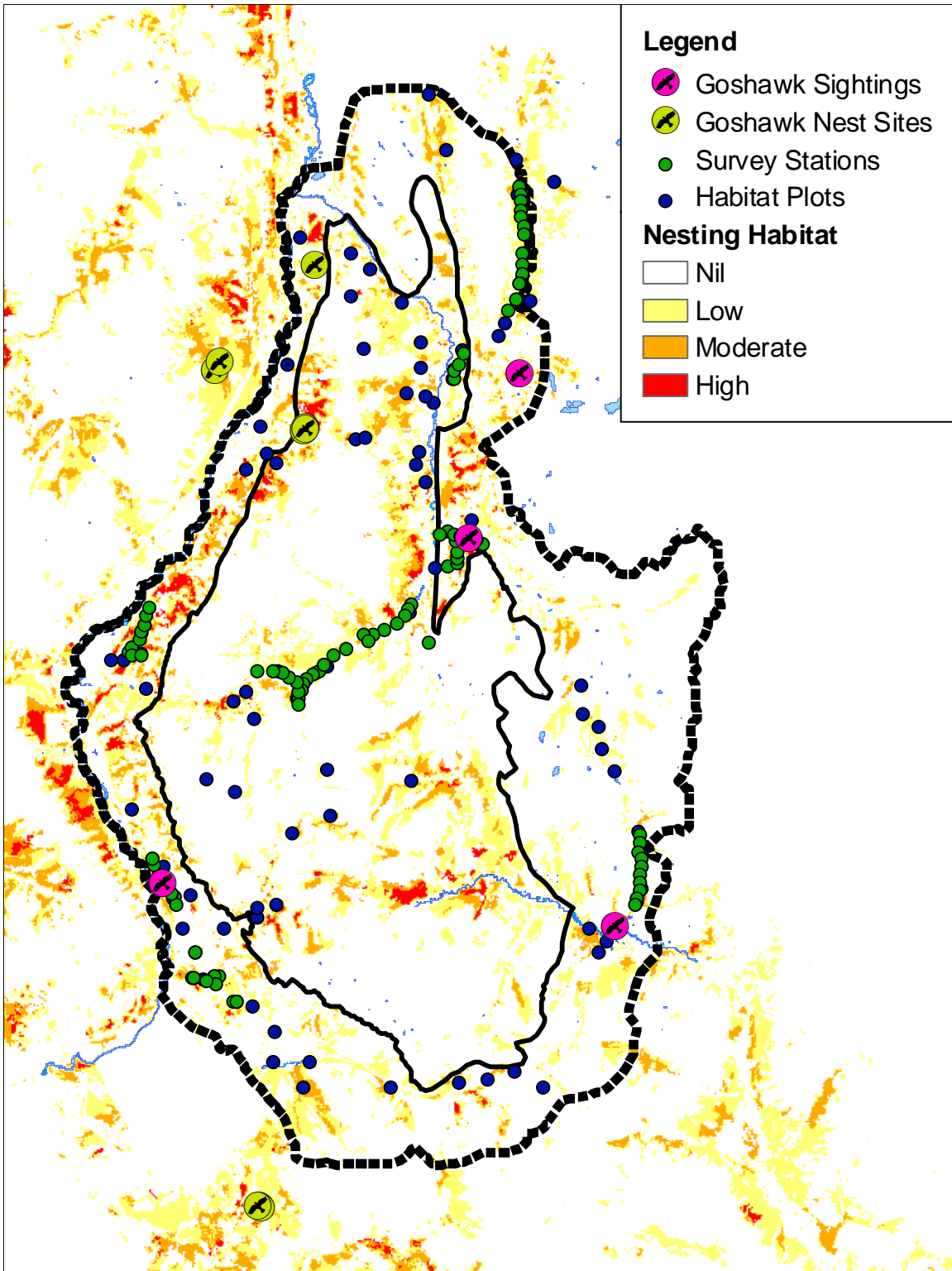


Figure 2. Distribution of nesting habitat for Northern Goshawk within the Mist Mountain study areas. Scale  $\approx 1:350,000$ . The thick, dashed outer boundary indicates the Wildlife Study Area; the thinner, solid line is the Project Area.

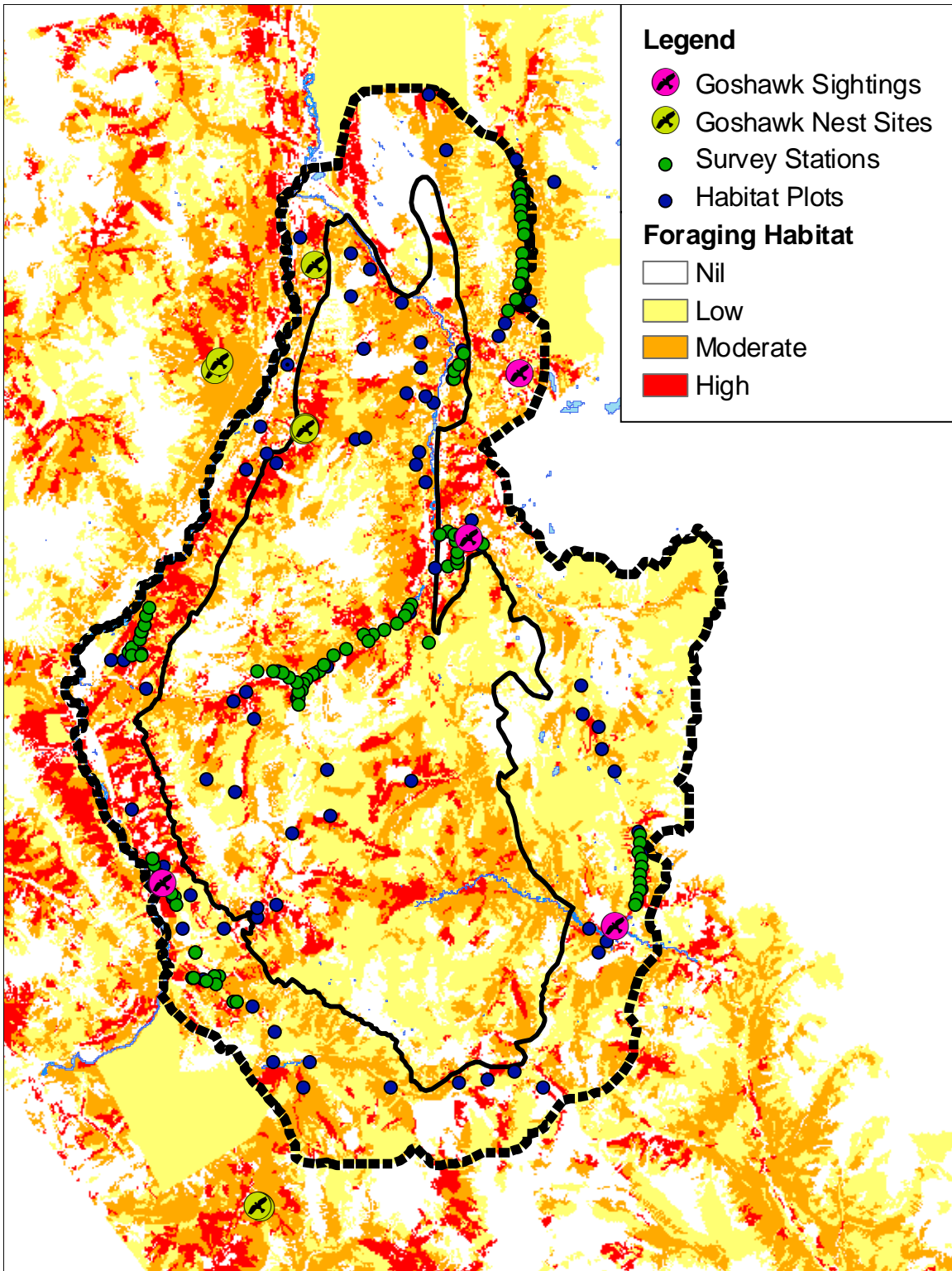


Figure 3. Distribution of foraging habitat for Northern Goshawk within the Mist Mountain study areas. Scale  $\approx 1:350,000$ . The thick, dashed outer boundary indicates the Wildlife Study Area; the thinner, solid line is the Project Area.

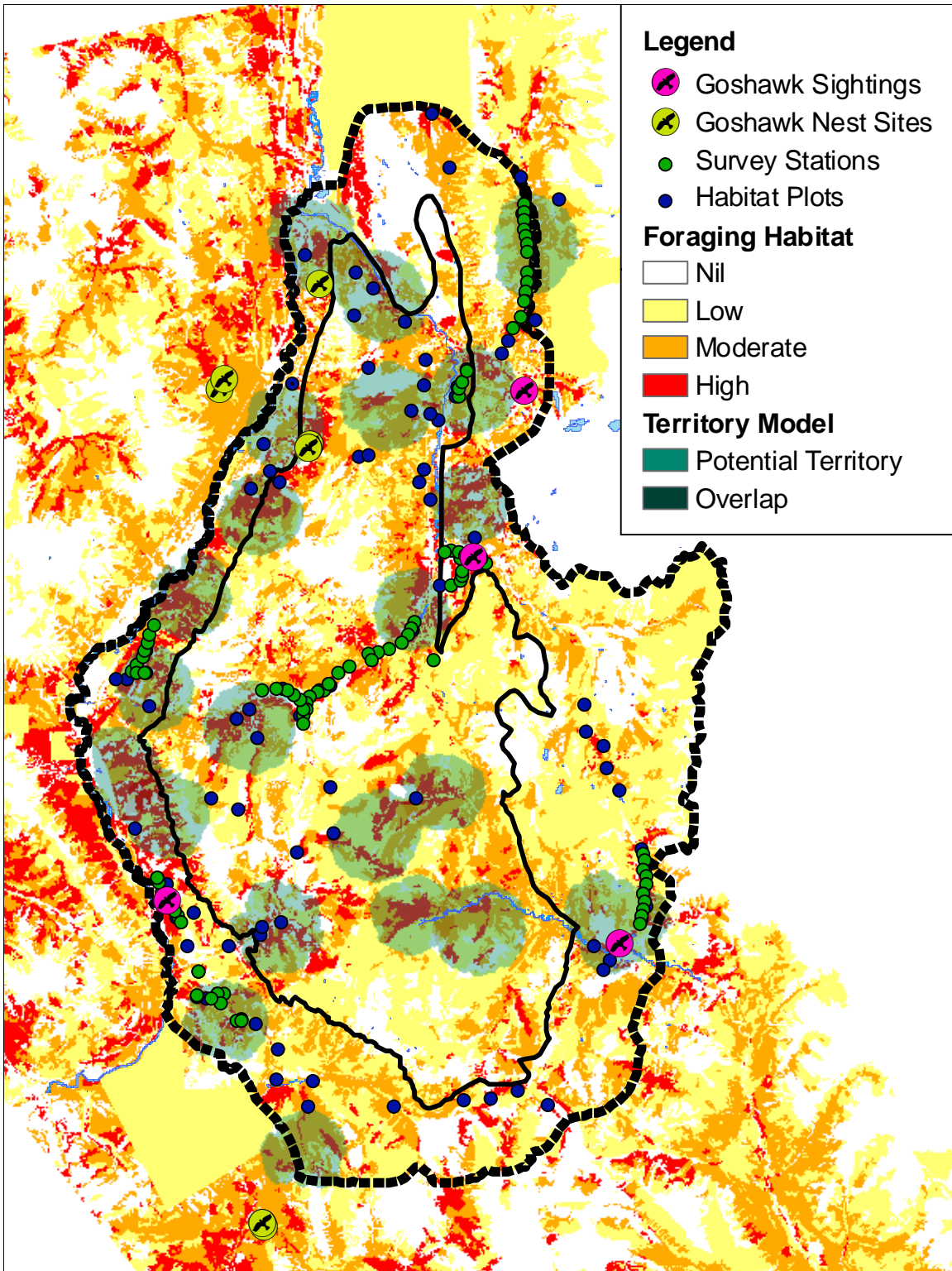


Figure 4. Example of theoretical territory model outputs for the Northern Goshawk in the Mist Mountain study areas. The thick, dashed outer boundary indicates the Wildlife Study Area; the thinner, solid line is the Project Area.

## ***Model Verification***

A total of 104 field habitat verification plots were assessed in 2007 and 2008. For nesting habitat the average absolute difference between model predictions and field observations was 0.21 units corresponding to an accuracy score of 79%. The average difference (not absolute difference) was -0.12 indicating that the nesting model is, on average, underestimating true habitat quality. For foraging habitat the average absolute difference between model predictions and field observations was 0.13 corresponding to an accuracy score of 87%. The average difference (not absolute difference) was -0.07 indicating that, on average, the foraging model is also underestimating true habitat quality.

The greatest source of error associated with the model predictions appears to be errors in the forest cover. Another source of error was positional error. In several cases the environmental conditions did not correspond between the map and the field at the exact coordinates, but corresponding conditions did occur nearby. An example of this was a plot in a mature pine stand 50 m in from a recent clearcut, but where either our GPS unit or the cutblock boundary location were wrong, resulting in the plot being located in the clearcut on the map.

High variation in the relationships between field ratings and individual variable rating curves coupled with the frequent discrepancies between the field and forest cover conditions generally did not provide useful patterns to facilitate revising the model. One revision that was made was to drop BEC variant as a variable in the nesting model. Initially BEC variant was included in the model to facilitate downgrading of the ESSF variants, however, field observations indicated that good nesting conditions could occur in the lower portion of the ESSF (especially the ESSFdk). Elevation and forest composition, already in the nesting model, were adequate for capturing the pattern of decreasing nesting habitat suitability with increasing elevation through the ESSF.

## ***Goshawk Survey Results***

A total of 131 playback stations were surveyed in 2008, including 35 stations conducted at habitat verification plots and 96 along playback survey transects. Four adult goshawks were detected during the 2008 surveys, but the birds did not appear to be breeding and no nests were found. The locations of the detections are noted on Figures 2 and 3 and details associated with each detection are provided in Table 3.

Table 3. Details associated with four goshawk detections in the Mist Mountain study area during July 2008.

Location	Comments
Gas Plant Road	Adult female responded with alarm call to broadcast of juvenile beg. Goshawk hung out in general area for ~20 minutes and was observed two more times while nest searching in area. Moderate to high value nesting suitability. High priority for follow-up survey in future years.
Leach Branch A	Adult goshawk observed flying through stand. No response to multiple playbacks while nest searching in area. No sign or subsequent observations. Moderate nesting suitability. Historic record of goshawk in general area reported by Tembec layout crew. Moderate priority for follow-up survey in future years.
River Road	Adult goshawk observed flying 100m over stand towards river. No response to playback and no sign detected. Several mature forest stands between River Road and the river offer Moderate to High nesting suitability. General area is a high priority for follow-up survey in future years.
North Flathead FSR	Adult goshawk was flushed off right-of-way while driving through shrub stage regenerating pine cutblock. Very limited suitable nesting habitat within 1 km. Goshawk was likely just foraging in area. Low priority for follow-up survey in future years

## DISCUSSION

### *Model Accuracy*

The results of the field verification work indicated that both habitat models tend to underestimate habitat suitability – the nesting model by 0.12 HSI units and the foraging model by 0.07 HSI units. Since the model errors and biases appear to be primarily related to forest cover errors they cannot be corrected through model revisions. Model bias and error has at least two implications for management using the models. First, is simply the recognition that there is likely more suitable nesting and foraging habitat and theoretical territories in reality than predicted by the model. Unfortunately, the current field data are insufficient to quantify how much more suitable habitat may occur and whether there are specific forest cover conditions where model bias or error are more likely to occur.

The second issue is that model error limits the confidence managers can have in using the model outputs. For strategic, large scale planning exercises, such as assessing how long term development might affect the relative number of theoretical territories that can exist in the study area, the model outputs should be relatively robust. But for operational planning, such as the layout of roads and well sites, the stand scale accuracy

of the nesting and foraging models is probably low enough that field verification is recommended.

### ***Habitat Amount, Quality and Distribution***

The proportion of the study area in suitable nesting habitat is quite low with only 1.4% High and 5.3% Moderate. Even though the nesting model tends to underestimate suitability the amount of suitable nesting habitat that truly occurs is still low. Even if the true amounts were twice the predicted (and likely the amount is more in the order of 25%) suitable habitat would still be a small proportion of the study area. The limited amount of suitable nesting habitat is currently the limiting factor in the number of theoretical territories the model can generate. Based on this, it is a reasonable hypothesis that the amount of true nesting habitat may be limiting the real number of breeding territories in the WSA. Under this scenario, mitigation strategies to minimize impacts to nesting habitat are key to minimizing overall impacts to goshawks.

### **Alternative Modeling Approach**

While expert-opinion models, like the one used here, are widely used, data-driven approaches, such as resource selection functions (RSF; Manly *et al.* 2002) are generally considered preferable. Although too few nest areas were known in the Mist Mountain area to use a data-driven model, Tembec, a local timber company, is currently developing a goshawk nesting habitat RSF as part of their long-term goshawk inventory, monitoring and research program for the larger East Kootenay area (Harrower *et al.* 2007). As part of this project the potential appropriateness of applying the Tembec model to the Mist Mountain area was assessed. Key issues associated with the Tembec model are:

1. The Tembec model (Harrower *et al.* 2007) remains under development and a 'final' version has not been formally released (Harrower, pers. comm.). Concerns about model availability and ownership issues were a significant factor in moving forward with this expert-opinion model to ensure a product was available within the time constraints of the Mist Mountain Baseline Inventory Program. When the final Tembec model is released the potential appropriateness of incorporating it into future goshawk habitat assessments for the Mist Mountain area should be examined.
2. Most of the data for the Tembec model come from outside of the Mist Mountain area and the appropriateness of the model to Mist Mountain (with respect to different BEC variants, harvest pattern and history, etc) is unknown.
3. The first version of the model (Harrower *et al.* 2007) did not include key stand-level habitat variables known to relate to goshawk nesting habitat suitability, such as stand age or height (Penteriani 2002). Rather, the model was driven primarily by landscape pattern variables, such as distance to roads and cutblocks, patch size, and amount of edge habitat, which do not have well understood relationships with goshawk habitat selection. This results in serious concerns about the appropriateness of the model for assessing habitat supply over

time or for comparing different management scenarios. Although the RSF model may have good fit for the current sample of nest areas under the current landscape pattern, it is unknown whether the model will provide good prediction under different patterns. For example, since the model did not include age or height, it is possible that recent cutblocks, which are unsuitable nesting habitats in reality, could be predicted as suitable habitat by the model. That limits the appropriateness of the model for habitat supply analysis, which is often conducted as part of environmental impact assessments.

## **Goshawk Survey Results**

Compared to other studies, our goshawk detection rate of 0.03 (4 sightings / 132 playback stations) was quite high. Detection rates in other areas have been 0.0018 in the Kispiox Timber Supply Area (Doyle and Mahon 2001), 0.0048 in the Nadina Forest District (Mahon and Doyle 2002), 0.0010 on the Queen Charlottes Islands (Chytyk 1996) and between 0.000 - 0.0015 for five studies in southeast Alaska (Iverson *et al.* 1996).

Low response rates for goshawks are primarily a function of their low density. Given an average goshawk breeding territory size of 2400 ha and an effective call playback station size of 12.5 ha, the expected detection rate would be 0.005, assuming 100% detection probability. Accounting for the behaviour that goshawks only breed (and hence are available to be detected) about 50% of the years and only respond about 50% of the time when present (pers. data), a more realistic detection rate is 0.00125. In 2008 average breeding rates for the larger Tembec goshawk study were 13% (Harrower, pers. comm.) so average detection rates during 2008 could even be lower. Our observations of four goshawks in the three main BEC zones (ICH, MS, ESSF) verifies the species presence across the study area. The apparent lack of breeding activities associated with the observations was also consistent with the low breeding rates observed in the Tembec study.

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Bill Harrower recently conducted a Master of Science degree at Thompson River University studying goshawk nesting habitat selection as part of the broader, Tembec led, East Kootenay goshawk study. Bill made major contributions to this project by applying his local expertise and broader knowledge of goshawk habitat requirement to model review, field verification, and goshawk call playback survey components of this project.

Cait Good and Aaron Phillips provided additional assistance with fieldwork.

Kari Stuart-Smith, with Tembec, provided results from their ongoing resource selection function model of goshawk nesting habitat across the broader East Kootenay area, as well as the locations of known goshawk nest site within the Mist Mountain area.

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## **APPENDIX 1. MIST MOUNTAIN NORTHERN GOSHAWK HABITAT MODEL**

This appendix provides detailed information about the model framework, equations, and variable ratings used in this project as well as the rationales behind them, including supporting information from the literature and provincial goshawk studies. This document is adapted from a report authored by Todd Mahon using a similar modelling approach for the threatened Queen Charlotte Goshawk (*A. g. laingii*) for the Coast Northern Goshawk Recovery Team (Mahon *et al.* 2008).

### **Overview**

The overall goshawk model consists of three main components:

1. A nesting habitat suitability model
2. A foraging habitat suitability model, and
3. A territory analysis model

The way the overall model works is that nesting and foraging habitat suitability ratings are first generated across the entire study area and then the territory model generates potential goshawk territories across portions of the study area that have adequate amounts and suitable configuration of nesting and foraging habitat.

The primary outputs associated with the overall model are the numbers and general distribution of potential territories that meet a 40% foraging habitat threshold levels. In addition to the number of potential territories, the nesting and foraging habitat layers can be used as stand-alone products to assess the amount and distribution of different qualities of goshawk habitat across the study area. It is important to emphasize that both suitability layers and the territory outputs represent relative estimates of goshawk habitat amount and quality.

The following summary information outlines key components and criteria of this project and is consistent with the type and format of information required by the RISC Wildlife Habitat Rating Standards (RISC 1999).

### **Project Purpose**

The purpose of this project was to assess the amount, distribution and quality of goshawk habitat under current conditions, as well as to provide a framework that could be used to assess changes in habitat supply over time or under different management scenarios.

### **Focal Species, Life Requisites, and Season**

Suitability ratings were developed solely for the Northern Goshawk. Separate habitat models were developed for nesting habitat (life requisite: reproduction, season: breeding) and foraging habitat (life requisite: hunting/feeding, season: year-round). In

addition to these habitat models a territory model was also developed to facilitate analysis of habitat distribution relative to observed territory spacing of the species.

## **Study Areas**

The study area for this project has been named Mist Mountain and occurs in the Rocky Mountains of southeast British Columbia between the town of Fernie and the Alberta border. The study area occurs predominantly within the Elk Valley Ecosection of the Northern Continental Divide Ecoregion. The models were developed specifically for the Interior Cedar-Hemlock (ICH), Interior Douglas Fir (IDF), Montane Spruce (MS), and Engelmann Spruce-Subalpine Fir (ESSF) biogeoclimatic variants (Braumandl and Curran 2002) found in the Mist Mountain study area using forest inventory data and TRIM map databases.

## **Project Scale**

The project scale is 1:20,000. All mapping queries were conducted using 1:20,000 scale Forest Cover data converted to 50 m grids and 50 m slope and elevation digital elevation models (DEMs) from TRIM.

## **Rating Scheme**

Output from the habitat models produced a continuous range of rating scores from 0-1. These ratings were summarized in quartiles corresponding to the 4-class rating scheme in the *RISC Wildlife Habitat Rating Standards* (Table 1, RISC 1999).

## **HABITAT SUITABILITY RATING METHODOLOGY**

The nesting habitat and foraging habitat models were based on the HSI methodology (US Fish and Wildlife Service 1981). This methodology is commonly used in habitat assessment and has been successfully used in several goshawk habitat mapping and supply analyses in British Columbia (e.g. BC Coastal Northern Goshawk Recovery Team (Mahon *et al.* 2008), North Coast LRMP (Mahon *et al.* 2003), Morice LRMP (A. Edie and Associates 2004), see review of others by Mahon (2005)).

HSI methodology involves three key steps:

1. Selection of relevant habitat variables to include in the model.
2. Development of rating scores for each habitat variable.
3. Building a mathematical relationship among habitat variables to produce overall habitat suitability scores.

The variables used in the models and ratings assigned for each variable were developed based on habitat characteristics at 48 goshawk nest areas within the East

Kootenays (Harrower *et al.* 2007), relevant literature, and the expert opinion of the authors.

### **Rating Definitions**

Numeric ratings from 0-1 were used at two levels within the HSI models: 1) to rate individual variables included in each model, and 2) as final scores for each model. At each level the ratings can be broken down into ranges for biological interpretation. Interpretations for final scores for nesting and foraging habitat are provided at the end of their respective sections.

For individual habitat variables, two rating approaches were used, depending on the strength of the relationship between habitat variables and use by goshawks. Variables were defined as either ‘strong’ or ‘weak’. Strong variables were ones that appeared to play a primary role in determining habitat suitability for goshawks **and** for which there was good information (from provincial data and the literature) to base ratings on. Weak variables were ones that appeared to be secondary in determining suitability or ones where there was limited information to base ratings on. For strong variables ratings were generally applied across the full range from 0-1 using biological criteria outlined in Table A1. Ratings for weak variables were generally applied within a narrow range (e.g. 0.7 – 1) and were meant to downgrade the final rating by a certain amount (often by 0.25, which represents one suitability class).

Table A4. HSI rating criteria for individual habitat variables

<b>HSI Ratings</b>	<b>Class</b>	<b>Interpretation</b>
0 - 0.249	Nil	Unsuitable. Condition fails to provide minimum requirements.
0.250 - 0.499	Low	Suitability Unknown. Condition of variable provides theoretical minimum requirements, but use by goshawks is unknown or rarely observed. Goshawks are not normally expected to use attributes in these conditions, but may do so if that is all that is available.
0.500 - 0.749	Moderate	Suitable. Suitability is lower than optimal conditions but exceeds minimum requirements. A small proportion of use by goshawks is expected to occur in areas with variables in this condition.
0.750 – 1.000	High	Suitable. Conditions at or near optimal (optimal = 1). Majority of use by goshawks is expected to occur in areas with variables in this condition.

## **NESTING HABITAT SUITABILITY MODEL**

### ***Selection of Relevant Nesting Habitat Variables***

Potentially relevant nesting habitat variables were identified from the published literature, regional studies and my personal experience. A list of 14 habitat variables were identified as being potentially important for describing goshawk nesting habitat (Table A2). The appropriateness of each variable in this model was then evaluated based on: 1) the strength and consistency of its relationships in other studies, 2) its general relevancy to local ecosystems, 3) its specific relationships to known nest areas in the East Kootenays, and 4) the availability of the variable in GIS databases. Based on this review, stand age, stand height, forest composition, slope, elevation and distance from edge were included.

Table A5. A summary of habitat variables commonly associated with goshawk nesting habitat from published literature and regional studies. A list of the studies reviewed and their key findings is provided in Appendix 2.

Habitat Variable	Included in Model?	Comments
Stand Age	Yes	Frequently used to assess structural maturity of a stand.
Stand Height	Yes	Frequently used to assess structural maturity of a stand.
Forest Composition	Yes	Suitability of branching platforms for nests and subcanopy flyways are related to the form of different tree species.
Canopy Closure	Yes	Mid-high canopy closures were consistently identified as a common characteristic of used nesting areas (relates to subcanopy flyways), but variable not available for projection analysis
Average Stand Diameter/ No. Large Trees	No	These two variables were commonly associated with goshawk nesting studies in the USA. Not available in FC database; correlated to height and age
Distance from Forest Edge	Yes	Data from Vancouver Island and interior BC show strong avoidance of edges for nest sites.
Patch Size	No	Issue more appropriately captured by edge.
Slope	Yes	Nest sites often on low-moderate slopes. Local data indicates no nests on slopes >60%.
Aspect	No	Identified as a significant variable in dry SW USA. No selection noted for any study in BC.
Elevation	Yes	Local data indicates strong avoidance of higher elevation in the ESSF.
Mesoslope Position	No	Weak selection noted in a couple of studies but no consistent relationship; no relationship in BC studies. Effect observed likely related to slope.
Site Index	No	Considered as a local variable. Few nests in poorest or richest sites, but forest composition and height more directly capture structure.
Distance to Water	No	Significant variable only in dry SW USA; no relationship in BC studies. Water sources unlikely limiting in study area.
Biogeoclimatic Variant	No	Few goshawk nest areas have been located in the ESSF zone. Initially included in model but later dropped because lower portions of the EESFdk offered suitable conditions. Reduced suitability in other higher parts of zone captured by elevation and forest composition.

## Stand Age and Height

(*Strong Variables*) The structural maturity of a stand, and trees within a stand, form the fundamental basis for nesting suitability for goshawks (Squires and Reynolds 1997). Individual trees must have large enough branches to support the nest structure. Suitable stands will have progressed through the self-thinning stage and be tall enough to provide open flyways below the main canopy layer (Penteriani 2002). “Structural Stage” (as classified in: BC Ministry of Environment, Lands and Parks and BC Ministry of Forests 1998) would probably provide the best scheme for categorizing this characteristic, however it was not available in the existing inventory information. As a surrogate to structural stage stand age and height were used as criteria. Because the two variables are so strongly correlated, an average of the ratings for the two variables was used to avoid overweighting the model by these factors. The ratings estimates applied to stand age and height are provided in Figures A1 and A2, respectively. The ratings were derived primarily based on observed age and height values from known nest areas across the East Kootenays (Harrower *et al.* 2007) and in west-central BC (Mahon and Doyle 2003).

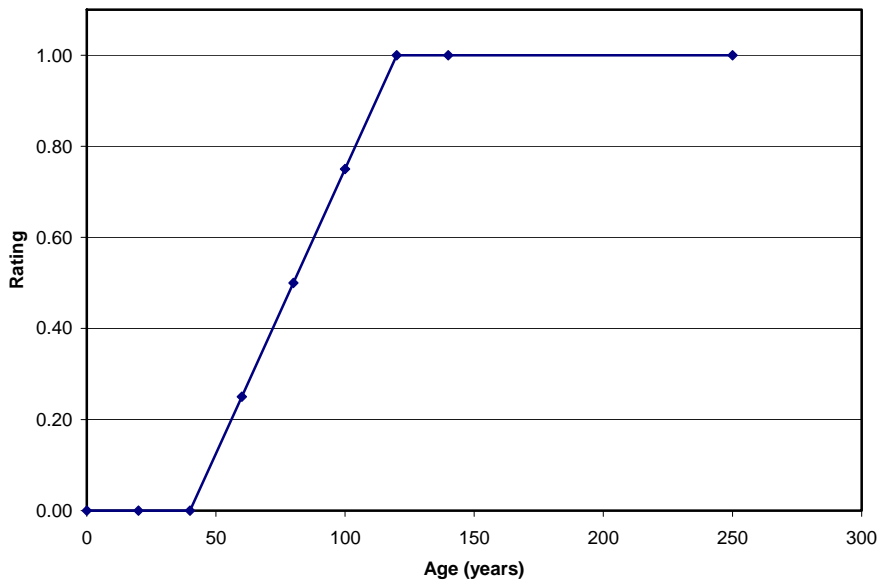


Figure A1. Northern Goshawk nesting habitat suitability rating curve for stand age.

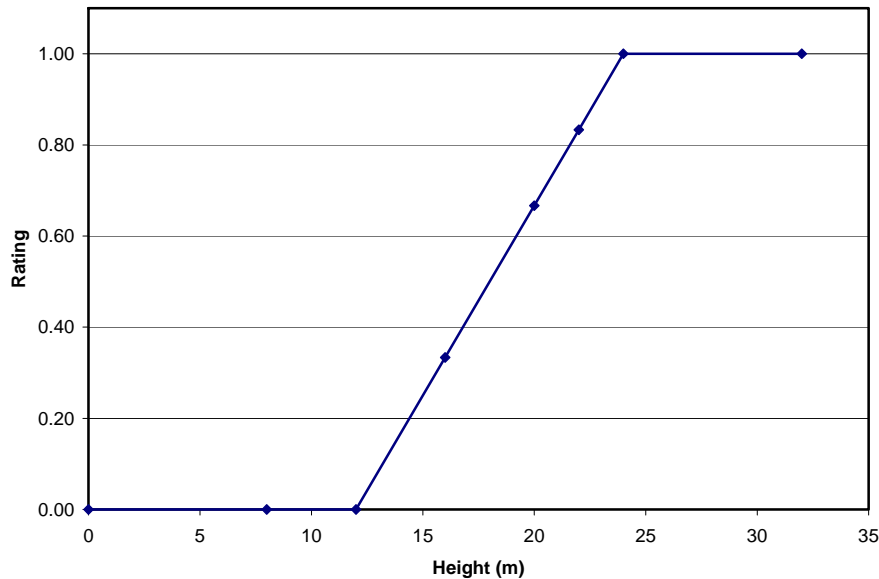


Figure A2. Northern Goshawk nesting habitat suitability rating curve for stand height.

### Canopy Closure

(*Strong Variable*) After the fundamental requirement of a ‘mature’ forest stage, canopy closure is probably the single most important structural variable relating to nest area suitability. Virtually every study examining goshawk nesting habitat identifies canopy closure as a key attribute (e.g. Bosakowski *et al.* 1999; Daw and DeStefano 2001; Penteriani 2002; see others in Appendix 2 of Mahon *et al.* 2008). Stands <30% canopy closure are generally too open for nesting. Optimal values, as indicated from nearly 150 nest areas in interior BC are 45 -70% (Harrower 2007; Mahon and Doyle 2003; Gyug 2001). Corresponding suitability ratings for the canopy closure classes available in the forest cover database are provided below (Table A3).

Table A3. Northern Goshawk nesting habitat ratings for canopy closure.

Canopy Closure Class	Canopy Closure %	Rating
0-1	0-15	0.2
2	16-25	0.3
3	26-35	0.4
4	36-45	0.7
5-7	46-75	1
8-9	>75	0.7

## Distance from Edge

(*Strong Variable*) Data from both coastal and interior studies in BC indicates that goshawks tend to avoid locating nests near edges (E.L. McClaren, unpublished data; Mahon and Doyle 2003). In addition, goshawks on the coast appear to abandon existing nests when a new cutblock edge is created near them (E.L. McClaren, pers. obs.). This pattern of selection was noted for abrupt or 'hard' edges, which occur where mature forest meets non-forested or early seral habitats and the difference in height is >10 m. A stronger edge effect is applied for 0 - 50 m compared to 50 - 100 m as noted below (Table A4).

Table A4. Northern Goshawk nesting habitat ratings for distance from hard edges.

Edge Distance (m)	Rating
0-50	0.4
50-100	0.7

## Forest Composition

(*Strong Variable*) Some of the key structural requirements goshawks have for nesting (e.g. branch platforms, subcanopy flyways) are strongly related to tree species composition. Favourable structural forms, and relative use for the known East Kootenay goshawk nest sites, are most common in Douglas Fir, Western Larch, and Lodgepole Pine dominated stands. Stands that are dominated by Western-Red Cedar or Subalpine Fir tend to have more broken canopies, greater vertical stand structure (with poorer subcanopy flyways) and poorer branch structures for nests. A list of nesting habitat suitability ratings for each tree species occurring in the Mist Mountain study area is provided in the table below (Table A5).

Table A5. Northern Goshawk nesting habitat ratings for forest composition.

Tree Species	Condition	Rating
Cottonwood (Ac)		0.6
Aspen (At)	>20%	0.6
Aspen (At)	<20%	1.0
Birch (Ep, Es)		0.5
Douglas Fir (Fd)		0.8
Pine (Pl, P, Pw)		1.0
Ponderosa Pine (Py)		1.0
Whitebark pine (Pa)		0.6
Spruce (Se, Sw, Sx)		0.7
Sub-alpine Fir (Bl, B)		0.6
Western Larch (Lw, L)		1.0
Mountain Larch (La)		1.0
Western-red Cedar (Cw)		0.6
Black Spruce (Sb)		0.5

Suitability ratings for stands with multiple species were calculated by multiplying the species percentages by their rating from the above table and summing the products.

$$\text{E.g.: } P_{70}S_{20}A_{T10} = 0.7(1.0) + 0.2(0.7) + 0.1(1.0) = 0.96$$

## Elevation

*(Weak Variable)* The observed pattern of goshawk nest sites across British Columbia suggests they avoid higher elevation areas, however, this pattern is relative to the range of elevations in each region rather than to absolute elevations (Mahon and Doyle 2003; McClaren 2003; Harrower 2007). This likely at least partly relates to correlations between elevation and tree species, such as subalpine fir, and BEC variants, such as ESSF, which generally offer suboptimal nesting habitat. Another possible reason is greater energy expenditures required to carry prey upslope to higher elevation nests (Finn 2000). Elevation is treated as a weak variable to avoid overweighting the model with factors correlated to elevation, such as forest composition, but it is still included as a variable because forest composition does not appear to adequately account for the observed pattern of nest area selection. The ratings curve below is intended to cover the elevation range generally associated with ESSF, where nesting habitat can be good at the lower range but decreases with increasing elevation (Figure A3).

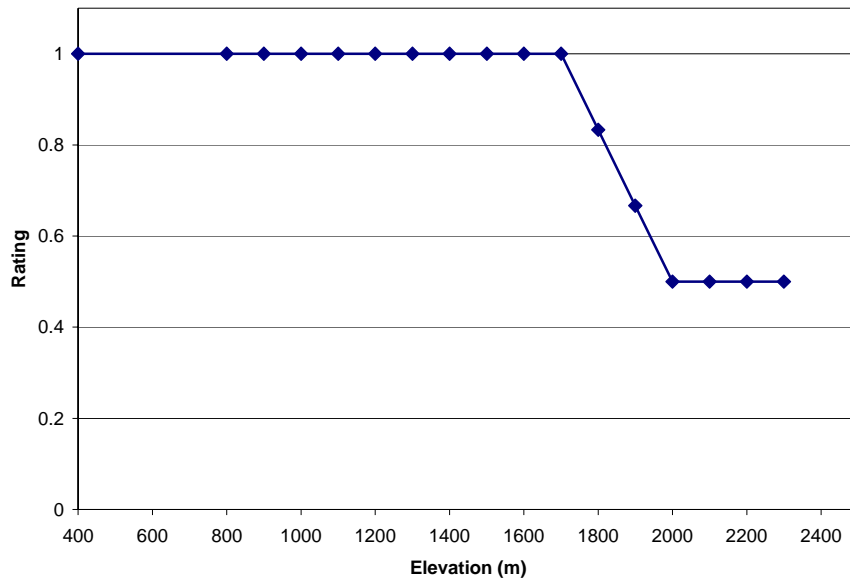


Figure A3. Northern Goshawk nesting habitat suitability rating curve for elevation.

### Slope

(*Weak Variable*) All known goshawk nest sites in British Columbia occur on slopes <100% and the vast majority are on slopes <60% (Mahon and Doyle 2003; McClaren 2003; Harrower 2007). The rating curve in the figure below applies weak downgrades to areas steeper than 60% (Figure A4).

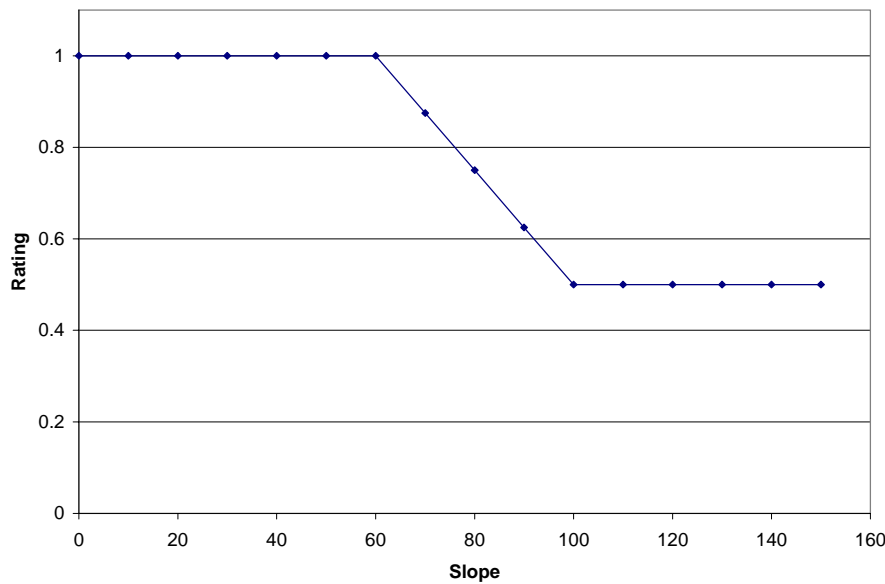


Figure A4. Northern Goshawk nesting habitat suitability rating curve for slope.

### ***Nesting Habitat Model Equation***

The nest area model uses a limiting factor, non-compensatory structure. From an ecological perspective this means that when the suitability rating of one variable falls below its optimal range it decreases the overall suitability by that amount. Further, suboptimal ratings in two or more variables are combined, through a multiplicative function, to decrease the overall value. The function is non-compensatory in that the value of one variable cannot compensate for a deficiency in another. The equation used to calculate the nesting suitability ratings is:

$$\text{Nesting HSI} = \text{mean}(\text{Age}_r, \text{Height}_r) * \text{CanCl}_r * \text{Edge}_r * \text{FC}_r * \text{Elev}_r * \text{Slope}_r$$

*r*=rating

### ***Nesting Habitat Score Interpretations***

For interpretation purposes the final HSI scores can be categorized into a 4-class rating scheme (Table A6).

Table A6. Interpretation of final HSI scores for goshawk nesting habitat.

<b>HSI Ratings</b>	<b>Class</b>	<b>Interpretation</b>
0 - 0.250	Nil	Unsuitable. Habitat fails to provide minimum requirements.
0.251 - 0.500	Low	Suitability Unknown. Habitat provides theoretical minimum requirements for supporting a nest, but use by goshawks is rarely observed. Suitability of two or more habitat variables is suboptimal, substantially reducing the overall suitability of the stand. Goshawks are not normally expected to use Low class habitats, but may do so if that is all that available.
0.501 - 0.750	Moderate	Suitable. Suitability of one or two habitat variables is slightly lower than optimal conditions but minimum requirements still exceeded. Minority of nest sites expected to occur in Moderate class habitat.
0.751 - 1.000	High	Suitable. All habitat variables meet optimal conditions. Majority of nest sites are expected to occur in High class habitat.

## FORAGING HABITAT SUITABILITY MODEL

### ***Selection of Relevant Foraging Habitat Variables***

Habitats used by goshawks for foraging are generally similar to those used for nesting, although foraging habitat is more variable, depends on fluctuating prey populations, and is generally broader (i.e. a broader range of levels within a variable are often more suitable for foraging than they are for nesting). In addition to foraging habitat being more general and more variable than nesting habitat, our level of knowledge of foraging habitat selection by goshawks is lower than it is for nesting habitat. Further, from the relatively few studies, patterns of selection for some variables appear to be contradictory, possibly reflecting high regional or temporal variation. For example in Alaska Iverson *et al.* (1996) found selection for habitats within 300 m of shoreline and a negative relationship between habitat use and elevation. On Vancouver Island McClaren (2003) saw no selection for shoreline areas, and some goshawks actually moved into moderate to high elevation areas over the winter.

Variables for the foraging habitat model were selected using the same approach as was used for the nesting habitat model. Potentially relevant foraging habitat variables were selected from the published literature, regional studies and personal experience. A summary of the literature that was reviewed, with their key findings, is provided in Appendix 3. Eight habitat variables were identified as being potentially important for describing goshawk foraging habitat (Table A7). The appropriateness of including each variable in the model was evaluated based on: 1) the strength and consistency of its relationships in other studies, 2) its general relevancy to coastal ecosystems, 3) specific relationships that were identified for coastal habitats, and 4) the availability of the variable in our GIS databases. Based on this review, stand age, stand height, forest composition, and BEC variant were included in the model. In addition, ratings for all of the non-forest types (e.g. alpine, swamp, meadow) included in the Forest Cover database were developed.

Table A7. A summary of habitat variables considered for the goshawk foraging habitat model based on published literature and regional studies. A list of the studies reviewed and their key findings is provided in Appendix 3.

Habitat Variable	Included in Model?	Comments
Stand Age	Yes	All studies we reviewed indicated that goshawks selected mature forest.
Stand Height	Yes	Several studies observed that goshawks selected stands with larger diameter trees. Tree diameter is not available in our GIS databases but diameter is strongly correlated to height, which was available.
Forest Composition	Yes	Local data is available quantifying relative abundance of prey in different forest types (Doyle 2004; Mahon 2008).
Canopy Closure	Yes	Several studies indicated that goshawks selected stands with higher canopy closure than random areas, although range of use was quite broad.
Site Index	No	Considered as a local variable that may influence prey. Doyle (2004) indicates forest type is better predictor.
Slope	No	No data to support this variable.
Elevation	No	Few studies examined elevation, and those that did showed different patterns.
Biogeoclimatic Variant	Yes	Modest downgrades applied to ESSF. Strong downgrade to AT.

### Stand Age and Height

(*Strong Variables*) Similar to the nesting habitat model, though to a lesser extent, mature forest habitats are the primary habitats that goshawks use for foraging. In the Mist Mountain study area mature forest structure typically offers the highest availability and of prey (red squirrels, jays, thrushes, woodpeckers), and the type of structure that makes those prey accessible to goshawks (semi-concealed hunting perches, appropriate sightlines and flyways for detecting and pursuing prey; Greenwald *et al.* 2005). Similar to nesting habitat, stand height and stand age were used as surrogates for structural stage to estimate the suitability of stands for goshawk foraging. The ratings curves for age and height are shown below in Figures A5 and A6. The biggest difference in these ratings from the nesting ratings is that foraging ratings do not start at 0 and rise quickly to 0.4, and maintain that value through the shrub stage, before beginning a linear rise. This reflects the fact that early seral habitats can offer some limited foraging potential (Bloxtton 2002), whereas they have no value as nesting habitat.

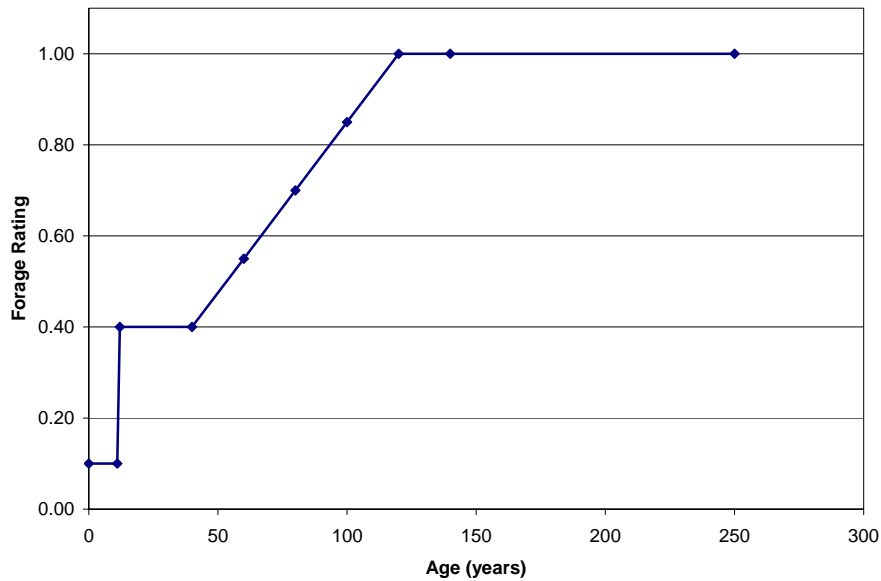


Figure A5. Northern Goshawk foraging habitat suitability rating curve for stand age.

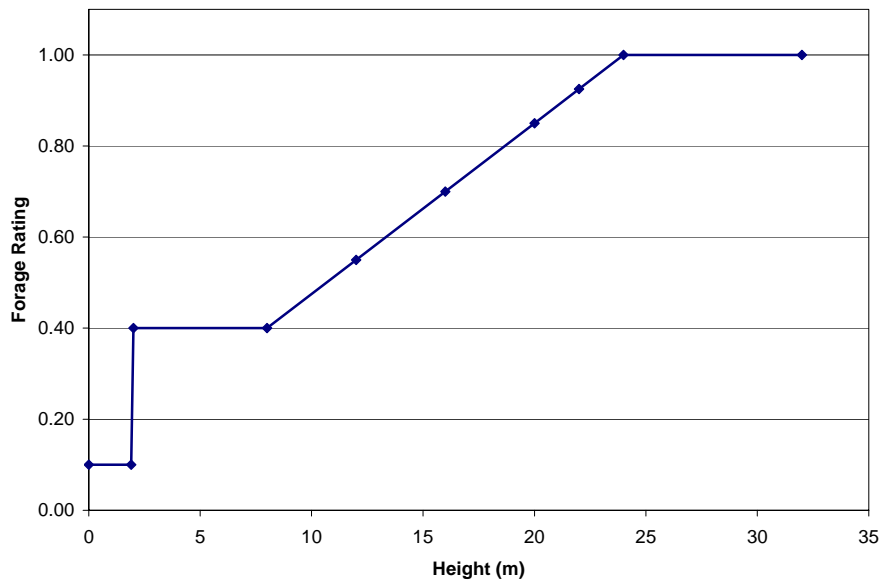


Figure A6. Northern Goshawk foraging habitat suitability rating curve for stand height.

### Canopy Closure

*(Weak Variable)* Several studies indicated that goshawks selected stands with higher canopy closure than random areas, although range of use was quite broad (Appendix 3). Ratings below represent a broader range of suitability than was applied in the nesting model (Table A8).

Table A8. Northern Goshawk foraging habitat ratings for canopy closure.

Canopy Closure Class	Canopy Closure %	Rating
0-1	0-15	0.5
2	16-25	0.6
3	26-35	0.7
4	36-45	1
5-7	46-75	1
8-9	>75	0.8

### Forest Composition

(*Weak Variable*) Forest composition affects both prey abundance and prey accessibility. Douglas Fir and spruce stands are especially productive because they produce high quality cones for red squirrels, as well as offering good flyways. Western-Red Cedar stands are probably offer the lowest value foraging habitat because of lower prey and impeded flyways. Forest composition is treated as a weak variable because goshawks will forage in a wide range of stand types and adjust selection with variations in prey availability. Tree species rating for goshawk foraging habitat are provided below (Table A9).

Table A9. Northern Goshawk foraging habitat ratings for forest composition.

Tree Species	Condition	Rating
Cottonwood (AC)		0.7
Aspen (At)		0.7
Birch (Ep, Es)		0.7
Sub-alpine Fir (Bl, B,)		0.7
Douglas Fir (Fd)		1.0
Pine (Pl, P, Pw)		0.9
Whitebark pine (Pa)		0.7
Ponderosa Pine (Py)		0.9
Spruce (Se, Sw, Sx)		1.0
Larch (Lw, La)		1.0
Western-red Cedar (Cw)		0.6
Black Spruce (Sb)		0.6

Suitability ratings for stands with multiple species were calculated by multiplying the species percentages by their rating from the above table and summing the products.

$$\text{E.g.: } FD_{70}PL_{20}SX_{10}=0.7(1.0)+0.2(0.9)+0.1(1.0)=0.98$$

## BEC Variant

(*Weak Variable*) Very few goshawk nests in British Columbia occur in the ESSF zone. Although this does not preclude foraging in those areas, year-round foraging is often relatively near the nest area (Mahon 2008), so use of the ESSF is expected to be lower than BEC variants where goshawks commonly nest. Other factors that potentially reduce the suitability of the ESSF and AT zones include higher energetic costs associated with flying in areas of higher elevations and steeper slopes (Bloxtton 2002), thick snow in winter that offers prey subnivean cover, and fewer red squirrels associated with the dominance of sub-alpine fir. Foraging ratings for the BEC variants in the Mist Mountain Study Area are below (Table A10).

Table A10. Northern goshawk foraging habitat ratings for BEC variant.

<b>BEC Variants</b>	<b>Rating</b>
Alpine Tundra (all except parkland)	0.4
Alpine parkland	0.7
ESSF (all [dk, wm])	0.9
ESSF woodland (dkw, wmw)	0.8
ESSF parkland (all [dkp, wmp])	0.7
ICH (all [mk1, dm])	1
IDF (all [dm2, dm2a, undiff])	1
MSdk	1
PPdh2	1

## Non-Productive & Non-Forested Habitats

Although goshawks often prefer to forage in forest, several non-forested habitats occur in the Mist Mountain Study Area that may be used to some degree by goshawks. Examples of these include wetlands, meadows, non-productive brush patches and alpine. While these habitat types may offer some prey for goshawks, it is unlikely that enough prey occurs in these habitat types, or that they provide suitable foraging structure for goshawks, to warrant a rating higher than Low. Therefore, all polygons with a non-productive (NP) or non-forest (NF) descriptor in the Forest Cover database were rated according to the categories in the table below. For all NP and NF types and any other possible types that could overlap with the forested criteria above, the highest rating of either the multiplicative model below or the rating of 0.4 from the following table was applied (Table A11).

Table A11. Northern goshawk foraging habitat ratings for non-forested habitats.

Code	Non-Forest Descriptor	Rating
A	Alpine	0.4
AC	Poplar	0.7
AF	Alpine forest	0.4
BR	Brush	0.4
CP	Cultivated fields	0.2
GB	Gravel bar	0.0
GC	Golf course	0.2
GP	Gravel pit	0.0
L	Lake	0.0
M	Mixed deciduous/coniferous	1.0
MI	Mine	0.0
MZ	Rubbly mine	0.0
NCBR	Non commercial brush	0.4
NP	Non productive	0.4
NPBR	Non productive brush	0.4
NPBU	Non productive burn	0.4
NSR	Not satisfactory restocked	0.4
OR	Open range	0.2
PD	Pond	0.0
PN	Permanent snow	0.0
R	Rock	0.0
RIV	River	0.0
RN	Railway	0.0
RW	Rural	0.0
RY	Reclaimed mine	0.2
RZ	Road	0.2
SF	Sedge fen	0.2
TA	Talus	0.0
TZ	Tailings pond	0.0
UR	Urban/suburban	0.0

### ***Foraging Habitat Model Variables and Equation***

The foraging model also uses a limiting factor, non-compensatory structure. From an ecological perspective this means that when the suitability rating of one variable decreases below its optimal range it decreases the overall suitability by that amount. Further, suboptimal ratings in two or more variables are combined, through a multiplicative function, to decrease the overall value. The function is non-compensatory in that the value of one variable cannot compensate for a deficiency in another. The equation used to calculate the foraging suitability ratings is:

$$HSI_f = \text{mean}(\text{Age}_r, \text{Height}_r) * \text{CanCl}_r * \text{FC}_r * \text{BECvar}_r \text{ or Non-Forest rating, whichever is greater.}$$

## ***Foraging Habitat Score Interpretations***

For interpretation purposes the final HSI scores can be categorized into a 4-class rating scheme (Table 12).

Table 6. Interpretation of final HSI scores for foraging habitat.

<b>HSI Ratings</b>	<b>Class</b>	<b>Interpretation</b>
0 - 0.250	Nil	Unsuitable. Habitat fails to provide even minimum requirements for prey (e.g. non-vegetated areas such as lakes, gravel bars, urban areas).
0.251 - 0.500	Low	Suitable. Habitat believed to contain some prey, but prey is often at low density and structure of habitat offers low accessibility of prey to goshawks (e.g. alpine, pole-sapling stage forests).
0.501 - 0.750	Moderate	Suitable. Either density or accessibility of prey lower than optimal conditions but minimum requirements still exceeded. (e.g. young forest, mature forest but with less productive tree species, such as Bl).
0.751 - 1.000	High	Suitable. Density and availability of prey both good. Includes a broad range of forest types in mature and old growth structural stages. Due to high annual and regional variation in prey and only modest knowledge of goshawk foraging habitat selection, this rating class is intentionally broad.

## TERRITORY MODEL

The primary purpose of the territory model is to assess the amount and distribution of nesting and foraging habitat relative to observed spacing patterns of goshawks, namely their territories. The territory model incorporates several aspects of goshawk ecology as criteria or constraints. These include territory spacing pattern, territory size, territory overlap, habitat suitability, relationships between nesting and foraging habitat, and territory-level habitat threshold requirements.

The primary output of the territory model is a prediction of the number and distribution of potential goshawk territories across a study area. The model uses an iterative optimization procedure to find a configuration of territories that maximizes the number of territories that are realized given certain constraints such as territory spacing and habitat threshold requirements. Although the model produces theoretical territories that can be mapped, they probably are not a good prediction of real territories on the landscape. Also, each run of the model will produce different territory sets.

The way the territory model works is as follows:

1. Territory centroids, which represent nest areas, are first located across the conservation region. Locations are random except that they must meet two criteria:
  1. Occur in a  $\geq 50$  ha patch with nesting habitat suitability of high or moderate.
  2. Meet observed territory spacing distances (5000m, Harrower *et al.* 2007; Mahon and Doyle 2003). Spacing distances are stochastic, drawn from a normal distribution around the means, above.
2. Territories then spread out from all of the centroids simultaneously in an attempt to acquire enough suitable foraging habitat (see next section – Habitat Thresholds). Territories that acquire enough habitat are realized and fixed on the map. As a territory spreads out from a centroid it is subject to three constraints that are represented by a cost surface. It is important to note that costs are relative, and should be viewed in terms of order and magnitude of differences among types. A base cost of 1 represents no constraint on movement.
  - a. *Distance from centroid.* This cost was used to represent the energetic costs of carrying prey back to the nest (Bloxtton 2002) and of overlap into core areas of neighbouring territories, which is likely to be increasingly defended as individuals approach the nest area of their neighbours. For 0-3 km from the centroid the cost was 1 (no constraint); from 3-5 km the cost is linearly increasing from 1 to 2; from 5-10 km the cost is linearly increasing from 2 to 4; and distances  $> 10$  km received a cost of 4.
  - b. *Spreading across different habitat types.* A travel costs was also applied based on the foraging HSI scores. Areas with foraging HSI scores of 0.5 - 1 (Moderate and High) generally indicate mature forest stands and were assigned a cost of 2

(Initially high and moderate foraging habitat were assigned a cost of 1, but in order to weight the relative influence of habitat vs distance from centroid in the spreading model the habitat costs were all doubled). Areas with foraging HSI scores of 0.25 - 0.5 (Low) were generally non-forest habitats or early seral regenerating forest and were assigned a cost of 3. Areas with scores of 0.01 - 0.25 were typically recent clearcuts and were given a cost of 4. Non-vegetated areas such as ocean, mountain, and urban areas had foraging HSI scores of 0 and were assigned cost scores of 10.

- c. *Territory overlap*. In addition to the spreading costs, a constraint of a maximum 5% overlap between any two territories and 20% total overlap for any individual territory was applied. These overlaps may underestimate actual territory overlap, because territory defence is believed to be relatively weak in outer portions of territories, but allowing too much territory overlap over the same area reduced the sensitivity of the analyses.

Whether or not a territory was realized depended on whether enough suitable habitat could be acquired within a given maximum territory size (see habitat thresholds, next section). Territory size was constrained with both a maximum and minimum size. The maximum size represents the distance and area over which a breeding pair of goshawks could realistically travel to obtain enough suitable habitat. This establishes a spatial constraint on the distribution of foraging habitat from nests for it to be useful to a breeding pair. For example, it is unrealistic that a pair of goshawks could be successful if they had to travel in a 20 km radius out from a nest to meet their foraging habitat requirements. The minimum territory size represents the degree to which territory size can shrink under favourable conditions (i.e. when the amount of suitable habitat is higher). Behavioural spacing limits the degree to which territories are compressible (Reich *et al.* 2004). Maximum and minimum territories sizes were based on +/- 20% the estimated average territory size of 2400 ha.

3. Territory Packing. In order to ensure the territory configurations generated by the model approximated the observed pattern of goshawk territories in reality, three optimization loops were incorporated into the model:
  1. First, the nest placement sub-model was run multiple times and a set of configurations with the highest number of nest areas are selected.
  2. Second, territories are simultaneously formed around each nest area for each configuration from step 1. At some nest areas territories are successful (acquire enough habitat) and are realized, at others the territory attempt fails.
  3. Third, for the territory formation output with the greatest number of successful territories from step 2, the model then attempts to locate additional nest areas

among the successful territories (still subject to the initial spacing constraints, above) and territories are attempted for the new nest areas.

### **Habitat Thresholds**

There is relatively little information quantifying the minimum amount of suitable habitat required within a territory to support a breeding pair of goshawks. Minimum requirements, or thresholds, likely vary widely regionally and temporally in response to prey abundance and availability. For example Bloxton (2002) observed that foraging areas of goshawks doubled following a strong La Niña event and declines in the relative abundance of prey. Five studies have demonstrated a positive relationship between amount of mature forest within territories and nest area occupancy (Crocker-Bedford 1990, 1995; Ward *et al.* 1992; Patla 1997; Finn *et al.* 2002). Minimum threshold requirements were generally not evident in these studies, although Finn *et al.* (2002) noted “Late-seral forest was consistently >40 % of the landscape (unspecified scale) surrounding occupied nest sites”. In a management paper Reynolds *et al.* (1992) recommends that 60 % of the foraging area be in mid-aged to old forest and that 40 % be in mature to old.

Goshawk researchers in BC have explored potential threshold relationships between habitat amount and occupancy at the territory level. Mahon (2003) found no relationship between occupancy and amount of mature forest in territories at 2400 ha, 4000 ha and 6500 ha scales for 80 territories in west-central BC. Similarly, there was no relationship between occupancy and amount of habitat in early, mid, or mature seral stages at 201 ha, 707 ha, 3848 ha scales for 66 territories on Vancouver Island (McClaren and Pendergast 2003), although nest areas within fragmented landscapes (patches <50 ha surrounded by unsuitable habitat) had significantly lower occupancy rates than nest areas in contiguous mature and old forests (McClaren 2003). Doyle (2005) noted weak evidence for a threshold response to occupancy at 60 % mature forest and stronger evidence at 40 % for nest areas in Haida Gwaii.

Based on this limited information, goshawk biologists on the BC Northern Goshawk Recovery Team identified and used three potential habitat thresholds in the coastal territory model: 60 %, 40 %, and 20 % suitable habitat. These correspond to high, moderate, and low probabilities of territory occupancy. For the Mist Mountain project a somewhat less conservative range of thresholds of 50%, 35% and 20% was used, based on ongoing studies by the author of goshawk-habitat relationships in west-central BC. In this report only territory numbers resulting from the moderate threshold run are reported. Foraging habitat HSI >0.50 was considered potentially suitable habitat, and areas were weighted by the HSI score to account for the differences in quality (e.g. 10 ha of foraging

HSI = 0.75 equals 7.5 ha of suitable habitat). Incorporating these three habitat thresholds required that the model was run once for each threshold.

### ***Model Implementation***

All components of the goshawk model were implemented in SELES (Fall and Fall 2001) by Cortex Consultants.

## APPENDIX 2. SUMMARY OF SELECTED GOSHAWK NESTING STUDIES

Study	Location	Forest Type	Canopy Closure	Tree diameter/ height	Basal Area/ Tree Density	Other Variables	Comments
Bosakowski 1997	British Columbia  (Williams Lk.)	Lodgepole Pine, Douglas Fir	Range 33.3 – 70%	Dbh = 35.5cm Ht = 20.9m	BA range 21.9 – 68.3 m <sup>2</sup> /ha	<u>Tree spp</u> - Lodgepole Pine	Lodgepole Pine preferentially chosen as nest sites over other tree species
Bosakowski <i>et al.</i> 1999.	Washington	Western Hemlock	86.7% (SD 5.77)	55.7cm (SD 16.17) Ht = 30.3m (SD 9.10)	Trees/ha = 764 (SD 329.4)	<u>Slope</u> – 36 % <u>Aspect</u> - N-NE <u>Tree Species</u> : Hw, Fd, Psf <u>Elevation</u> – 773m (SD189.1)	Nests in 40-60 year old stands. Mean 45.7 (SD7.37).
Daw and DesStefano . 2001.	Oregon	Ponderosa Pine- Doug Fir- Lodgepole Pine.	>50%	Dbh = >53cm			Nests with greater dense forest canopy and late forest structure than random sites.
Doyle and Mahon 2001	British Columbia  (Kispiox)	Hemlock	Mean 75.4% (Range 35-85%)	Dbh = 58.8cm (39-72) Height = 27.6m (range 15.3 – 37.8m)	N/A	<u>Slope</u> – Avg. 12.1% <u>Aspect</u> – no relationship <u>Tree spp</u> – Hw, (Ba 6%)	
Finn 2000 and Finn <i>et al.</i> 2002.	Olympic Peninsula	Coastal rainforest	Mean 85%	Dbh = 60.9cm Ht = 45.9m		<u>Tree spp</u> – Douglas Fir, Western Hemlock, Alder	Nest sites with a deep overstory canopy depth. Low % shrub cover. Occupied nest sites had a higher proportion of late seral forest.
Gyug 2001	British Columbia  (Merritt)	Douglas Fir, Lodgepole Pine, Engleman Spruce	=>50%	Dbh range 34 – 90 cm Ht =>34m		<u>Slope range</u> 12 – 32% <u>Elevation range</u> 1250 – 1600m <u>Tree spp</u> - Doug Fir, spruce, aspen	Nests mid-slope Lodgepole Pine form the largest portion of the canopy around nests
Hall 1984	California	Douglas Fir	Mean 88% (60 – 98%)	Dbh = 58cm (43 – 119cm) Ht =21m (SE 2.0)	BA=90 m <sup>2</sup> /ha 279 trees/ha	<u>Slope</u> – 42% (11 – 80%) <u>Aspect</u> – NE <u>Elevation</u> – 824m (494 – 1036m) <u>Tree spp</u> – Douglas Fir	Nests were typically in dense single storied stands of Douglas Fir, scattered hardwoods, park-like understory. Tree density and canopy closure less in nest sites in surrounding nest stand.

Study	Location	Forest Type	Canopy Closure	Tree diameter/ height	Basal Area/ Tree Density	Other Variables	Comments
Hargis <i>et al.</i> 1994.	California	Jeffrey Pine- Lodgepole Pine	31% (SD 13)	Dbh = 87.2 cm(SD 27.2) Ht = Nest only 11.6m (SD 2.33)		<u>Slope</u> – 12% (SD 11)	Nests significantly closer to water than random.
Hayward and Escano 1989	Montana and Idaho	Hemlock-cedar and Douglas fir- lodgepole pine	80%	Hw-Cw >50, Fd- Pl 35-50	BA= 40 1125/ha	<u>Aspect</u> – 315-45 used more <u>Slope</u> – all ensts <50% lower slope positions preferred	Nest site char. vary widely across the goshawk range. However, within any region nest-site selection is predictable and depends on available habitat and local climate
Iverson <i>et al.</i> 1996.	SE Alaska	Costal Rainforest	49.6%				Areas within 30 acres of the nest had greater forest cover and greater productive old-growth than compared to random plots.
Machmer and Dulisse. 2000.	British Columbia  (Invermere)	Interior Douglas Fir-Montane Spruce	Mean 54% (SD2.4)	Dbh = 52.7cm (SD 2.67) Ht = 29.4 m (SD 0.66)		<u>Slope</u> - 19.6% (SE 4.2) <u>Aspect</u> – Most west-south west <u>Tree Spp</u> - Doug Fir and Western Larch <u>Elevation</u> 849-1,072m	Nests predominately in mature-old forest stands. Mid to lower slope positions.
Mahon and Doyle 2003.	British Columbia  (Lakes Forest District)	Interior Sub- boreal Spruce.	>40% (100%)	Dbh = 29.7cm (SD 9.0). Ht = 23.9 (range 8.1-23.2)		<u>Slope</u> <30%, <u>Aspect</u> - Not significant <u>Tree spp</u> – 50% Pine, 36% Aspen, 14% Fir.	Nests in open uderstory locations. 34-1080m to clearcut edges. Average 2.0 nests per nest areas (range 1-6).
Manning, Cooper and Associates 2000	British Columbia  (Chetwynd)	Lodgepole Pine	Mean 32 %	Dbh = 31.5cm Ht = 22.5m		<u>Slope</u> - 15% <u>Tree spp</u> - Lodgepole Pine	Nests mid-slope
McClaren 2003. . Ethier 1999.	British Columbia  (Vancouver Island)	Coastal Rainforest	Mean 49% (29- 69%)	Dbh = 70.7cm (SD 2.9) Ht = 39.0m (SD 1.6)	No. Trees/0.04 ha = 31 (SD 2)	<u>Slope</u> – 34%(0-61) <u>Aspect</u> – 358 (SD 41) <u>Tree spp</u> – Douglas Fir and Western Hemlock <u>Elevation</u> – 80-816m (Mean 358m).	Nests in contiguous old growth, second growth and Fragmented Landscapes. 97% of nests in live trees. Nests sites further from clearcuts than random. Nests centred is larger areas of contiguous forest >120 years at 800m scale, but not significant.

Study	Location	Forest Type	Canopy Closure	Tree diameter/ height	Basal Area/ Tree Density	Other Variables	Comments
Patla and Trost 1995	Idaho	Douglas Fir, pine, spruce	Mean 86% Range 64 -96%	Dbh = 48cm (range21-84cm) Ht = 26m (range 12-38m)	Tree density = 382 trees/ha (range 134 – 717trees/ha)	<u>Slope</u> – 24% (0 – 43%) <u>Elevation</u> – 2136m	Mean distance to water 152m Study found that nest sites were close to water – significant.
Schaffer <i>et al.</i> 1999.	Alberta (Hinton)	Lodgepole Pine- Aspen-Fir	Mean 77.4% (SE 1.68)	Dbh = 30.0cm (SE 1.32) Ht = 21.9 m (SE 0.63)		<u>Slope</u> - N/A <u>Aspect</u> – all except W and SW <u>Tree Spp</u> – 90% in At	Nest sites and contrasting sites not significantly different.
Siders and Kennedy. 1996.	New Mexico	Ponderosa Pine- Doug Fir-White Fir	Mean 66.3% (SD 7.5)	Dbh = 50cm (SD 6.7) Ht = 28.4 m (SD 2.6)			Comparison in attributes selected by sympatric accipiters. Correlation between nest tree selection and tree size. Goshawks selecting largest trees.
Squires and Ruggiero 1996	Wyoming	Lodgepole Pine	66% sign. > random plots	Dbh = 32cm Ht = 19m both sign. > random plots	BA=50m <sup>2</sup> sign. > random plots	<u>Slope</u> – gentler at NAs (12%) <u>Aspect</u> – no relationship <u>Tree spp</u> – At and Pl used prop to abound.	Nest stands were not old-growth in the classic sense of being multi-storied stands with large diameter trees, high canopy closure, and abundant woody debris. Rather, nest stands were in even-aged, single-storied, mature forest stands with high canopy closure and clear forest floors.

### APPENDIX 3. SUMMARY OF GOSHAWK FORAGING STUDIES

Study	Location	Forest Type	Key Findings
Beier and Drennan 1997	Arizona	Ponderosa pine	n=20 individuals. Goshawks used mature and old-growth forest almost exclusively for foraging. Goshawks selected foraging sites that had higher canopy closure, greater tree density and more large trees (>40cm). Goshawks selected areas based on forest structure rather than prey abundance.
Bloxton 2002	Olympic and Cascade Mtns, Washington	Douglas fir and western hemlock	For a sample of 17 goshawks kill sites had higher canopy closure, greater basal area, larger diameter trees, and avoided areas with pole/sapling.
Bright-Smith and Mannan 1994	Northeast Arizona		Examined selection for 11 goshawks using LANDSAT coverages. Most birds showed no selection. 3 selected for higher canopy cover, 3 avoided open canopy areas, 4 used core woodland more than its availability
Drennan and Beier 2003	Arizona	Ponderosa pine	Assessed winter habitat selection for 13 goshawks. Most males moved to lower elevation pinyon-juniper areas. Foraging sites had more medium-sized trees and higher canopy closure than random sites.
Good 1998	Southcentral Wyoming	Lodgepole pine and aspen	Goshawks returned most often to sites with more mature forests, gentler slopes, lower ground coverage of woody plants, and greater densities of large conifers
Hargis <i>et al.</i> 1994	Eastern California		Home range locations of goshawks were similar to nest sites and both had greater canopy cover, greater basal area, and more trees per ha than a random sample from the study area.

Study	Location	Forest Type	Key Findings
Iverson <i>et al.</i> 1996	Southeast Alaska	Coastal temperate forest; 1° western hemlock	Obtained 2333 locations on 67 goshawks. Strong selection for old growth, avoidance of non-forest, clearcut and alpine. Goshawks predominantly used gentle slopes, lower elevations and showed preference within old-growth for riparian areas and areas within 350m of shoreline.
Mahon 2008	West-central BC	Lodgepole pine; SBSmc2	Obtained 455 locations of 12 goshawks and examined habitat selection based on structural stage. Mature and old-growth were used 55% more than available. All other structural stages were used less than available despite higher prey biomass in shrub stage areas.
McClaren 2003	Vancouver Island	Coastal temperate forest; 1° western hemlock	259 locations were obtained from 63 goshawks over 5 years. 74% were in old growth, 20% were in second growth, 5% in mixed OG/SG. On average birds were located ca. 13km from nest sites.
Stephens 2001	Northeast Utah	spruce, subalpine fir, lodgepole pine	Studied 18 goshawks during the winters of 98/99 and 99/00. 73% were migratory with a trend to lower elevations where they fed on cottontails. (compared to tahu's at higher elevation). Used a wide variety of habitats but showed selection for high canopy closure.