Parameterization of the Northern Goshawk (*Accipiter gentilis laingi*) Habitat Model for Coastal British Columbia.

Nesting and Foraging Habitat Suitability Models and Territory Analysis Model

NOTE: This report is a working DRAFT and should be cited and regarded as such. It has undergone an internal review by the Northern Goshawk Recovery Team and Habitat Recovery Implementation Groups. It has not undergone an external peer-review and may contain errors and outdated information.

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Abstract

The purpose of this project was to develop a standardized habitat model for the Northern Goshawk (*Accipiter gentilis laingi*; hereafter goshawk) across this subspecies' range in coastal British Columbia. 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 based on the Habitat Suitability Index (HSI) methodology. This report summarizes the variables used in the models and the ratings assigned for each variable, which were developed, based on observed habitat use by goshawks in Coastal BC, relevant literature, and the expert opinion of the authors. Separate reports detailing the results and outputs of the model has been prepared by Cortex Consultants (Smith et al. 2006, 2007, 2008), who implemented the model. As of March 2008 the model has now been applied to all four goshawk conservation regions: Haida Gwaii, North Coast, South Coast and Vancouver Island. Field verification of the model has been conducted on Haida Gwaii and a sensitivity analysis was conducted 2007 to assess the relative influence of variables within the models. Additional verification work is planned for 2008/09 in other Conservation Regions. Based on the results of the verification work and sensitivity analysis one final revision of the models across all regions is planned for the future.

This document updates and supersedes earlier version of this report produced in 2006 for modelling conducted on Haida Gwaii and in 2007 for the North Coast Conservation Region and the South Coast Conservation Region.

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Northern Goshawk (*Accipiter gentilis laingi*) Habitat in Coastal British Columbia.

Nesting Habitat and Foraging Habitat Suitability Models and Territory Analysis Model

Last modified May 12, 2008 (v2008-1)

Introduction

This document describes habitat suitability models developed for the Northern Goshawk (*Accipiter gentilis laingi*; hereafter goshawk) in Coastal British Columbia. We developed models for goshawk nesting and foraging habitat as well as a "territory" model that was used primarily for analysis purposes to assess the amount and distribution of nesting and foraging habitat relative to average goshawk territory sizes across the region. The structures of the nesting habitat and foraging habitat models are based on 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 Coastal BC, relevant literature, and the expert opinion of the authors.

The study area for this project encompassed the entire Coast Forest Region (hereafter Coastal BC) and reflected the estimated range of *A. g. laingi* in BC. Due to differences in habitat characteristics, harvest histories and future harvest projections and data availability across this large region, the area was stratified into four conservation regions and model parameters for the three models were tailored for each conservation area. The four conservation areas are Haida Gwaii, North Coast, South Coast, and Vancouver Island. Generally, model parameters were very similar among areas, reflecting similar patterns of habitat use by goshawks across the area, however, in some circumstances model parameters were varied to account for differences in goshawk biology (e.g. differences in nesting density), habitat structure and ecology (e.g. different distribution of forest composition among biogeoclimatic variants), and data availability (e.g. stand age was not available in some TFL data bases). As of March 2008 the model will have been implemented across all four Conservation Regions. It is anticipated that one final run of the model will be conducted for all Conservation Regions in 2009 to standardize minor differences in model structure and to incorporate any recommended revisions that arise from additional field verification that is planned for 2008 and 2009.

The intended use of these habitat models is to assess the relative amount and distribution of goshawk breeding habitat in Coastal BC. Habitat ratings that result from these models represent relative values suitable for comparisons across the study area and for comparing habitat supply 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 Coastal Western Hemlock (CWH), Coastal Douglas Fir (CDF), Mountain Hemlock (MH) and Alpine

Tundra (AT) biogeoclimatic variants (Pojar et al. 1987) found in the Coast Forest Region using forest inventory data from the Ministry of Forests and forest licensees and TRIM map databases. Application of these models to different biogeoclimatic variants or using other data inventories should be done cautiously.

Outputs from this model should generally be restricted to large, scale strategic purposes. This is primarily due to the relatively poor stand level accuracy of at least some of the forest cover data. In addition, some variables that are known to affect goshawk habitat suitability (notably canopy closure), and which we would recommend should be included in models used for stand level purposes, such as operational management, could not be included in these models because they were not available in all forest cover databases across the study area.

Five goshawk habitat mapping projects have previously been conducted in Coastal BC (see review by Mahon 2005). The purpose of this project was to standardize model structure, model variables, variable ratings, input data, and analysis methods to facilitate region-wide evaluation of goshawk habitat. This was not possible using the outputs from the previous projects due to differences in several factors among those projects. The intent of this project was not to redo habitat mapping for any specific area on the basis that the previous output was of poor quality, or that this product would be superior; it was simply to provide a standardized set of outputs across the region, using the collaborative expertise of three provincial goshawk experts.

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 we provide a brief synopsis of key information. The following sections provide more detailed information specific to the ecology of goshawks in Coastal BC (*Accipiter gentilis laingi*) and the application of this information in the development of habitat models.

Species Overview: Description, Distribution, and Ecology

The Northern Goshawk (*Accipiter gentilis*) is a raven-sized forest raptor with a circumpolar distribution, and is found in both temperate and boreal forests (Brown and Amadon 1989). Across its range there are several morphologically different sub-species. Within BC 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 maneuverability 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 coastal BC its main prey during the breeding season are red squirrels, forest passerines (typically thrushes, woodpeckers and jays) and grouse (Roberts 1997; Ethier 1999; Mahon and Doyle 2003). In southeast Alaska, Lewis (2001) also reported Northwestern Crows and Marbled Murrelets to be important components of goshawk's breeding diet (Lewis 2001).

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. 2005). Within homogenous mature forest 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 Coastal BC nest area spacing ranges from approximately 7 km on Vancouver Island (McClaren 2003) to approximately 11 km on Haida Gwaii (Doyle 2005). These spacing distances correspond to territory sizes of 3800 ha – 9200 ha, respectively, which are substantially larger than territories in interior BC (2300 ha; Mahon and Doyle 2003) and in the southwestern United States (1200 ha; Reynolds et al. 2005). The Northern Goshawk is probably a year-round resident in most years throughout most of its range (Squires and Reynolds 1997). This is supported by McClaren (2003) who tracked 68 birds on Vancouver Island over seven years using telemetry, and found that all birds remained resident (on Vancouver Island or on adjacent coastal mainland) over the winter, although some moved off of their breeding territories (McClaren 2003).

Taxonomy and Status

It is generally accepted that it is the *A. g. laingi* subspecies that occupies Coastal BC (Taverner 1940, Johnson 1989, COSEWIC 2002). The original subspecies designation was based on morphological analysis by Taverner (1940), who first noted that *A. g. laingi* was darker and smaller than *A. g. atricapillus*. More recently, Whaley and White (1994), Flatten et al (1998) and Flatten and McClaren (in prep.) have conducted more detailed morphometric studies that support *A. g. laingi* subspecies delineation. Genetic studies are ongoing to help define the range boundary between *A. g. laingi* and *A. g. atricapillus* in BC and adjacent portions of Alaska and Washington (Talbot et al. 2005).

A. g. laingi is designated Threatened (COSEWIC 2002) nationally and Red-listed (Threatened or Endangered (S2B)) provincially (BC Conservation Data Centre 2005). This sub-species is also listed as a Category of Species at Risk under the Forest and Range Practices Act (FRPA; BC Ministry of Water, Land and Air Protection 2004), due to its strong association with mature coniferous forests for foraging and nesting, and the possible impact to this habitat resulting from forest development.

Before the mid 1990s very few Northern Goshawk nest areas were known in Coastal BC. Since the mid 1990s approximately 100 nest areas have been discovered through a combination of intensive inventory programs and education and training of forest workers. Most known nest areas occur on Vancouver Island (*n* = 66, McClaren 2003), Haida Gwaii (*n* = 11, Doyle 2004), North Coast (*n* = 1, Hetherington, pers. Comm.) and South Coast (*n* = 20, Marquis et al. 2005).

Loss of mature forest breeding habitat (nesting and foraging) from logging is probably the most significant factor threatening goshawks in Coastal BC (Cooper and Stevens 2000, COSEWIC 2002). In parts of Europe populations of goshawks have declined 50-60% in response to broad-scale forest harvesting (Widen 1997). Monitoring in most of Coastal BC 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. Further, nest productivity at the known nest areas over the last five years has been inadequate to sustain the population (Doyle 2004).

Territory Components

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 is the smallest territory component and is the centre of breeding activities throughout the reproductive season – mid-February to the 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). On Vancouver Island nest area size was not estimated but >90% of the alternative nest sites were within 500 m of each other and 95% are within 800 m of each other (McClaren 2003).

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. Only one study on *A. g. laingi* in BC has been conducted and this estimated the average PFA size around one nest tree to be 59 ha (McClaren et al. 2005). Because goshawks use multiple nest sites, post-fledging areas around an average of three nest sites would be approximately 100 ha (McClaren et al. 2005). Other studies on A. g. atricapillus have estimated PFAs to range from 20 ha (interior BC, Mahon and Doyle 2003) to 170 ha (southwestern USA, Kennedy et al. 1994). Minimally, goshawks require one nest tree within one post fledging area to breed and so our model assumed at least 50 ha was required to establish a nest area/post-fledging area. Ultimately, the biological role of a nest area and post-fledging area appear to be inseparable (McClaren et al. 2005).

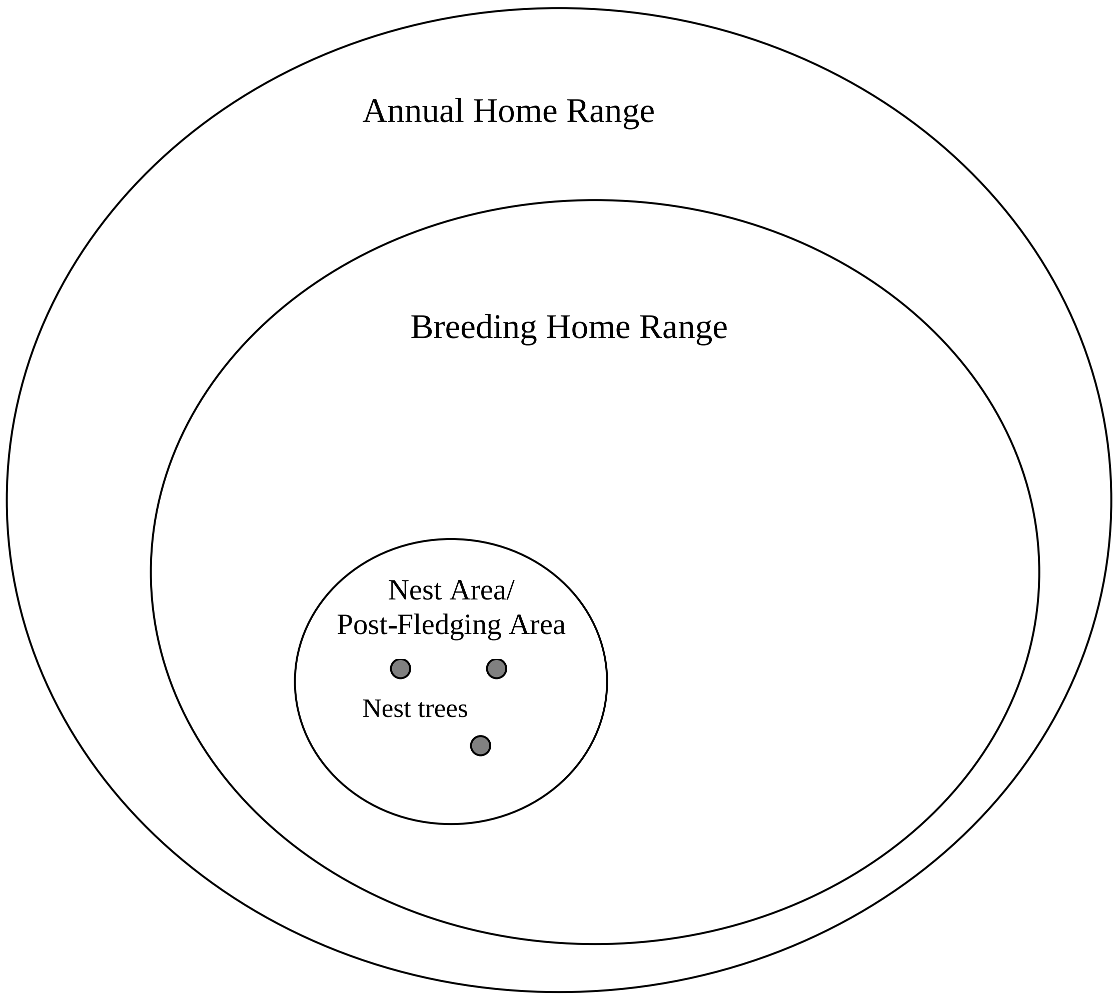

Figure 1. Conceptual arrangement of hierarchical components of a goshawk's territory. The nest area and post fledging area have historically been considered separate territory components but two recent studies in BC indicate that the PFA is similar in size and extent to the nest area (McClaren et al 2005, Mahon and Doyle 2003).

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 and relatively closed canopies with corresponding open sub-canopy flyways (Cooper and Stevens 2000, Penteriani 2002, McGrath et al. 2005). At the regional level, selection of forest species composition is also evident (Mahon and Doyle 2003; Schaffer et al. 1999). A summary of stand characteristics for 16 known goshawk nest areas in the CWH biogeoclimatic zone on Haida Gwaii and in northwestern BC is provided in Appendix 1. Nest stands are dominated by western hemlock or co-dominated by western red-cedar and western hemlock and are typically ≥ 140 years (age class 8), ≥ 28 m in height (height class 4), and have ≥ 50% canopy closure (canopy closure class 5). Photographs of high quality and low quality nest area stands are provided in Figures 2 and 3, respectively. These characteristics are generally associated with the more productive site series (especially in the maritime and hypermaritime CWH variants) in mid to toe slope positions. These habitats are generally constrained by climatic and geographic factors that limit their extent and result in patchy, constrained distributions of suitable habitat. For example, fjordland geography dominates much of coastal BC and suitable habitat is often limited to narrow bands of forest in toe and lower slope positions along these fjords (Figure 3).

Figure 2. Example of a high quality goshawk nest area, with high canopy closure and open sub-canopy fly-ways.

Figure 3. Example of a poor quality goshawk nest area, with low canopy closure and diverse vertical stand structure within all canopy and shrub layers.

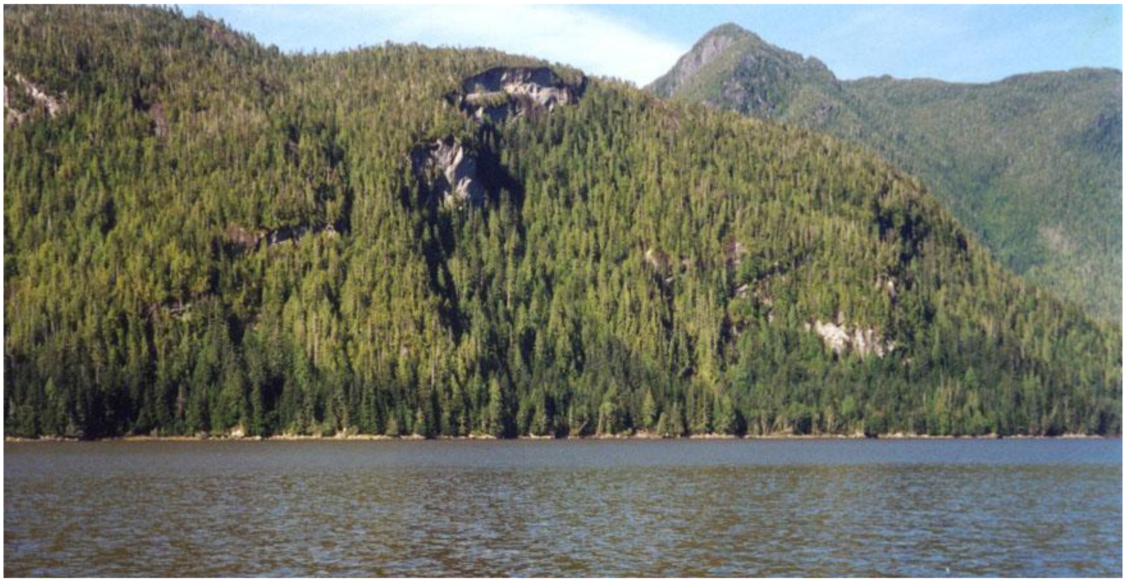

Figure 4. High quality nesting and foraging habitat for goshawks, identifiable here as the darker stands in the lower slope positions, is limited in extent and frequently constrained in linear distributions within Coastal BC.

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, our level of knowledge of foraging habitat selection by goshawks is lower than it is for nesting habitat (especially in coastal habitats). Furthermore, patterns of selection for some variables, from relatively few studies, appear to be contradictory, possible 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.

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 available 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 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).

Two radio telemetry studies of *A. g. laingi* (southeast Alaska, Iverson *et al*. 1996; Vancouver Island, McClaren 2003) both showed that goshawks selected mature forest habitat preferential to its availability in coastal landscapes. This is also supported by prey remains and pellets observed at nest sites on Vancouver Island (Ethier 1999), Haida Gwaii (Doyle 2005), and in southeast Alaska (Iverson et al. 1996; Lewis 2001) that showed that the goshawk diet was dominated by prey associated with mature forest (red squirrels, forest grouse and forest passerines).

Northern Goshawk Habitat Model for Coastal BC

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 model are the numbers and general distribution of potential territories that meet three foraging habitat threshold levels (20%, 40% and 60% of total territory). 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 Coastal BC 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 is to parameterize habitat models for *A. g. laingi* across their range in BC. These models will be used as part of a larger project being conducted by the Habitat Recovery Implementation Group (RIG) of the Northern Goshawk Recovery Team to assess the amount, distribution and quality of goshawk habitat under historic, current future forest management scenarios.

Focal Species, Life Requisites, and Season

Suitability ratings were developed solely for the Northern Goshawk (*A. g. laingi*). 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, to determine how many goshawk pairs may potentially be supported by the landbase, and for future population modelling.

Project Area

Our project area encompasses the entire Coast Forest Region, which corresponds to the BC range of *A. g. laingi*. This overall area has been divided into four conservation regions based on differences in habitat characteristics, harvest histories and future harvest projections: Haida Gwaii (Queen Charlotte Islands), North Coast, South Coast, and Vancouver Island Conservation Regions. Habitat variable ratings were developed for each of these areas based on differences in habitats that occur across these areas and differences in the types of data available. The primary biogeoclimatic zones within these areas are Coastal Western Hemlock (CWH), Coastal Douglas Fir (CDF), Mountain Hemlock (MH), and Alpine Tundra (AT) (Banner et al. 1993; Green and Klinka 1994).

Project Scale

The project scale is 1:20,000. All mapping queries were conducted using 1:20,000 scale Forest Cover data and 50 x 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 rating 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 BC (e.g. 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 observed habitat characteristics at approximately 100 goshawk nest areas across Coastal BC (stratified by Conservation Region where appropriate), relevant literature, and the expert opinion of the authors.

Rating Definitions

We used numeric ratings from 0-1 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 we used two rating approaches depending on the strength of the relationship between habitat variables and use by goshawks. We defined variables 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 we had good information (from local data and the literature) to base ratings on. Weak variables were ones that appeared to be secondary in determining suitability or ones that we did not have good information to base ratings on. For strong variables we generally applied ratings across the full range from 0-1 using biological criteria outlined in Table 2. 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 1. HSI rating criteria for individual habitat variables

HSI Ratings	**Class**	**Interpretation**
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

We identified potentially relevant nesting habitat variables from the published literature, regional studies and our personal experience. We provide a summary of the literature we reviewed, along with key findings, in Appendix 2. We identified 14 habitat variables as being potentially important for describing goshawk nesting habitat (Table 1). We evaluated the appropriateness of each variable in this model based on: 1) the strength and consistency of its relationships in other studies, 2) its general relevancy to coastal ecosystems, 3) its specific relationships to known nest areas in Coastal BC, 4) the current availability of the variable in our GIS databases, and 5) our ability to project variables into the future for time sequence analysis. Based on this review, we included stand age, stand height, forest composition, slope, elevation and BEC Variant.

Table 2. A summary of habitat variables commonly associated with goshawk nesting habitat from published literature and regional studies. A list of the studies we 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	No	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 >50%.
Aspect	No	Identified as a significant variable in dry SW USA. No selection noted for any study in BC.
Elevation	Yes	Local data indicates weak avoidance of higher elevations.
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. No 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 Coastal BC.
Biogeoclimatic Variant	Yes	Apparent avoidance of the higher elevation Mountain Hemlock and hypermaritime Coastal Western Hemlock zone; none of the ca. 100 nest areas occur in these variants.

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 is not available in the existing inventory information. As a surrogate to structural stage we used stand age and height. Because the two variables are so strongly correlated, we used an average of the ratings for two variables to avoid overweighting the model by these factors. The ratings were derived primarily based on observed age and height values from the known nest areas on Haida Gwaii and North Coast (Appendix 1) and Vancouver Island (McClaren 2003). Figures 5 and 6 show our estimates of habitat suitability for goshawks increasing linearly from starting point of 0 to a maximum rating of 1 that plateaus at 150 years for age and 30 m for height (Doyle 2005).

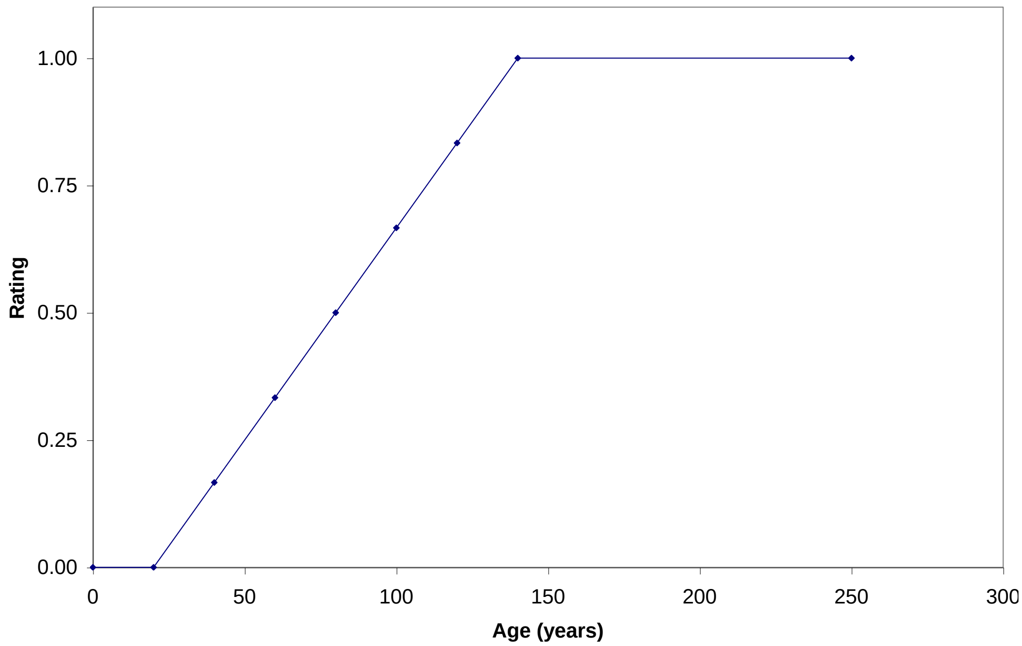

Figure 5. Northern Goshawk nesting habitat suitability rating curve for stand age.

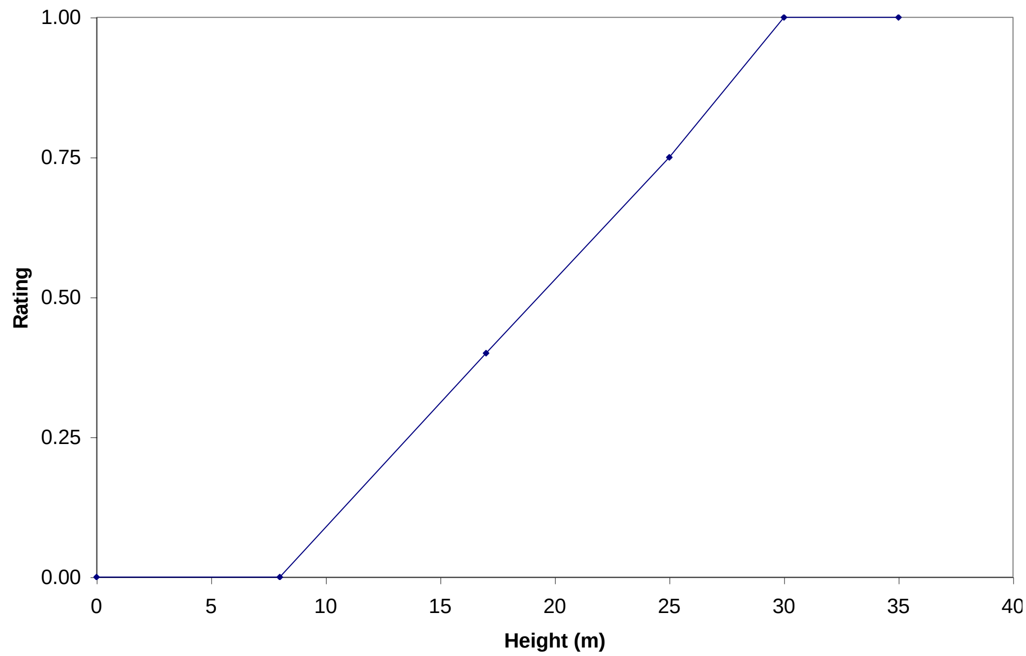

Figure 6. Northern Goshawk nesting habitat suitability rating curve for stand height.

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). A summary of the distance from edge for 148 goshawk nests on Vancouver Island is provided in Appendix 3. 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 what we defined as 'hard' edges. Hard edges occur where mature forest meets non-forested or early seral habitats and the difference in height is >15 m. Edges were separated into two types because our data suggested goshawk responded differently to: 1) anthropogenic edges resulting primarily from cutblocks (roads were not included), and 2) natural edges such as those adjacent to lakes, swamps, etc. Ratings for each edge distance and type are provided below (Table 3). A stronger edge effect is applied for 0 - 100 m compared to 100 – 200 m and the ratings represent a downgrade of two classes for anthropogenic edges and one class for natural edges.

Table 3. Nesting habitat model edge ratings.

	Edge Type	
Edge Distance (m)	**Anthropogenic**	**Natural**
0-100	0.4	0.6
100-200	0.8	0.9

Forest Composition – Inventory Type Group

(*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. These structural attributes (and relative use (Appendix 1)) seem to be most common in Western Hemlock (Hw) dominated stands. Stands that are dominated by Cw and Subalpine Fir (Bl) or Balsam Fir (Ba) tend to have more broken canopies, greater vertical stand structure (with poorer sub-canopy flyways) and poorer branch structures for nests. Yellow cedar (Yc) and Lodgepole pine (Pl) stands tend to have the lowest suitability due to both tree form and stand-level heterogeneity (multi-storied canopy low canopy closure; Figure 3). We evaluated several ways of incorporating tree species composition into the model (mostly to account for the highly variable forms this data was recorded in different data sets). In the end we decided Inventory Type Group (ITG) from the provincial Forest Cover database provided the best base categorization to work from but we needed to modify some categories to factor Yellow cedar more prominently in the classes. A list of the main forest composition groups and their ratings is provided in the table below (Table 4).

Table 4. Nesting habitat ratings for forest composition.

Name	**First Sp**	**Second Sp**	**Rating**
Hw dominant	Hw	any except Yc or Pl	1
Cw pure	Cw >80%	any <20%	0.45
Cw dominant	Cw <80%	any except Yc or Pl	0.65
B dominant	B	any except Yc or Pl	0.8
S dominant	S	any except Yc or Pl	1
Fd dominant	Fd	any except Yc or Pl	1
Yc dominant	Yc	any	0.4
Yc secondary	any	Yc	0.6
Pl dominant	Pl	any	0.5
Pl secondary	any	Pl	0.7
Deciduous	Dr, Ac, At	any deciduous	0.7
Mixed forest	Dr, Ac, At	any coniferous	0.9

Elevation

(*Weak Variable*) The observed pattern of goshawk nest sites suggest they are avoiding higher elevation areas, however, this pattern is relative to the range of elevations in each conservation Region rather that to absolute elevations. This likely at least partly relates to correlations between elevation and tree species, such as subalpine fir, and BEC variants, such as MH, which generally offer suboptimal nesting habitat. Another possible reason is greater energy expenditures required to carry prey upslope to higher elevation nests. We treat elevation as a weak variable to avoid overweighting the model with factors correlated to elevation (forest composition and BEC variant), but still include it as a variable because forest composition and BEC variant do not adequately account for the observed pattern of nest area selection. The ratings curves used apply weak downgrades to areas above 400 m for Haida Gwaii, 600 m for North Coast (Figure 7), and 800 m for South Coast and Vancouver Island. Irrespective of the lower elevation where suitability is first impacted, rating decrease linearly to 0.5 at 1300 m.

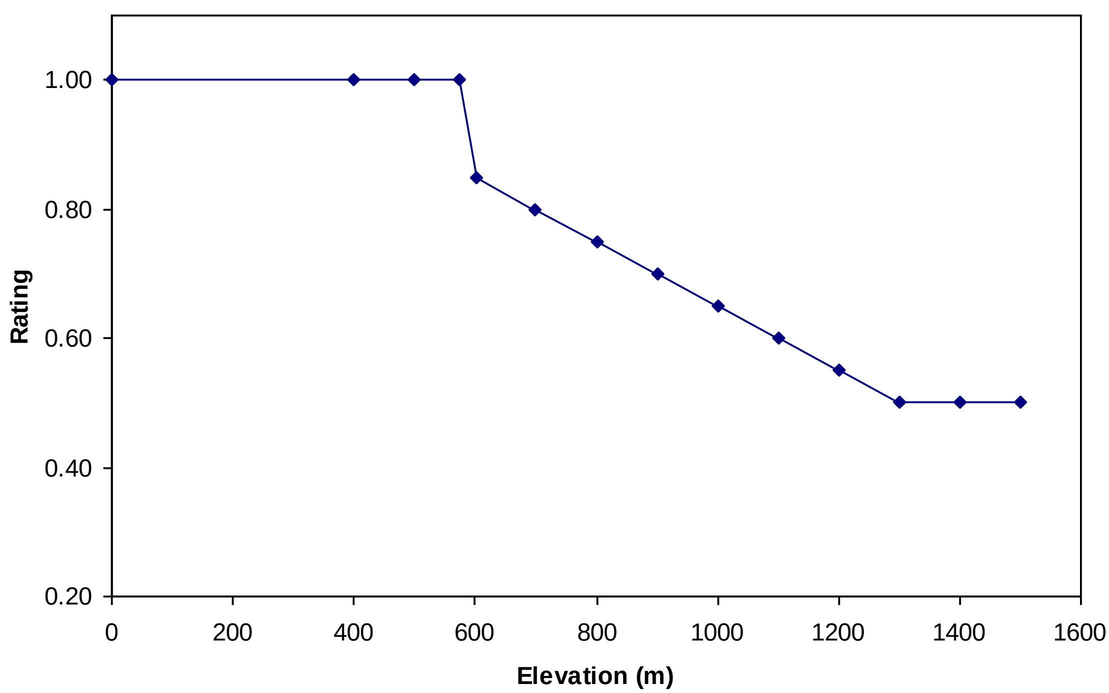

Figure 7. Northern Goshawk nesting habitat suitability rating curve for elevation.

Slope

(*Weak Variable*) All known goshawk nest sites in Coastal BC occur on slopes <100% and the vast majority are on slopes <60%. The ratings in the table below apply weak downgrades to areas above 60%.

Table 5. Northern goshawk nesting habitat rating for slope.

Slope (%)	Rating
0-60	1
60-100	0.7
>100	0.5

BEC Variant

(*Weak Variable*) Of the approximate 100 known goshawk nest areas in Coastal BC none are within the hypermaritime CWH or MH BEC variants (although a few nest areas occur in transitional areas to these variants). The lack of known goshawk nests in the hypermaritime CWH and the MH makes it appear that these BEC variants are avoided even where otherwise suitable nesting stands occur. The mechanisms behind the lack of use, or at least reduced use of, these areas for breeding are not known. It is possible that other factors in our model that are linked to BEC variants such as tree species and elevation, have accounted for the patterns we observe. For example, hypermaritime forests tend to have significant components of yellow cedar with low canopy closure and dense understory vegetation. As well, within mountain hemlock stands, canopy closure appears to be reduced and dense understory vegetation prevails. However, canopy closure and understorey vegetation density, which affects access to prey, are not available. Our ratings for BEC variant (below) reflect a compromise between the relatively strong pattern of low use by goshawks and our poor understanding of why that occurs. These ratings are designed to downgrade the final suitability score by one class for hypermaritime CWH, MH and ESSF if the ratings for any other variable are <1, which will usually occur for elevation or forest composition, and two classes for alpine.

Table 6. Northern goshawk nesting habitat ratings for BEC variant.

BEC Variants	Rating
Alpine Tundra (all except parkland)	0.4
Alpine parkland	0.4
CDF (all)	1
CWH (all except vh)	1
CWH vh1 + vh2	0.8
ESSF (all except parkland)	0.7
ESSF parkland (all)	0.4
ICH (all)	1
IDF (all)	1
MH (all)	0.8

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:

$$HSI_n = \text{mean}(Age_r, Height_r) * CanCl_r * Edge_r * ITG_r * Elev_r * Slope_r * BECvar_r$$

n=nesting, r=rating

Nesting Habitat Score Interpretations

For interpretation purposes the final HSI scores can be categorized into a 4-class rating scheme (Table 7).

Table 7. Interpretation of final HSI scores for nesting habitat.

HSI Ratings	**Class**	**Interpretation**
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 (especially in coastal habitats). 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.

We selected variables for the foraging habitat model using the same approach as we used for the nesting habitat model. We identified potentially relevant nesting habitat variables from the published literature, regional studies and our personal experience. A summary of the literature we reviewed, with their key findings, is provided in Appendix 4. We identified 8 habitat variables as being potentially important for describing goshawk foraging habitat (Table 8). We evaluated the appropriateness of each variable in this model 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, we included stand age, stand height, forest composition, and BEC variant in the model. In addition, we developed ratings for all of the non-forest types (e.g. alpine, swamp, meadow) included in the Forest Cover database.

Table 8. A summary of habitat variables we considered for the foraging habitat model based on published literature and regional studies. A list of the studies we reviewed and their key findings is provided in Appendix 4.

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).
Canopy Closure	No	Several studies indicated that goshawks selected stands with higher canopy closure than random areas, although range of use was quite broad. Variable not available.
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	Apparent avoidance of the Mountain Hemlock and hypermaritime Coastal Western Hemlock zones.

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 coastal ecosystems mature forest structure typically offers the highest abundance and diversity of prey (red squirrels, jays, thrushes, woodpeckers; Doyle 2004), 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 we used a combination of stand height and stand age 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 8 and 9. The biggest difference in these ratings from the nesting ratings is that foraging ratings start at 0.3 compared to 0 for nesting. This reflects the fact that early seral habitats can offer some limited foraging potential (Bloxton 2002), whereas they have no value as nesting habitat. For the foraging model stand height and age ratings are also conditional on forest composition, with spruce leading stands exhibiting higher suitability at shorter heights and younger ages.

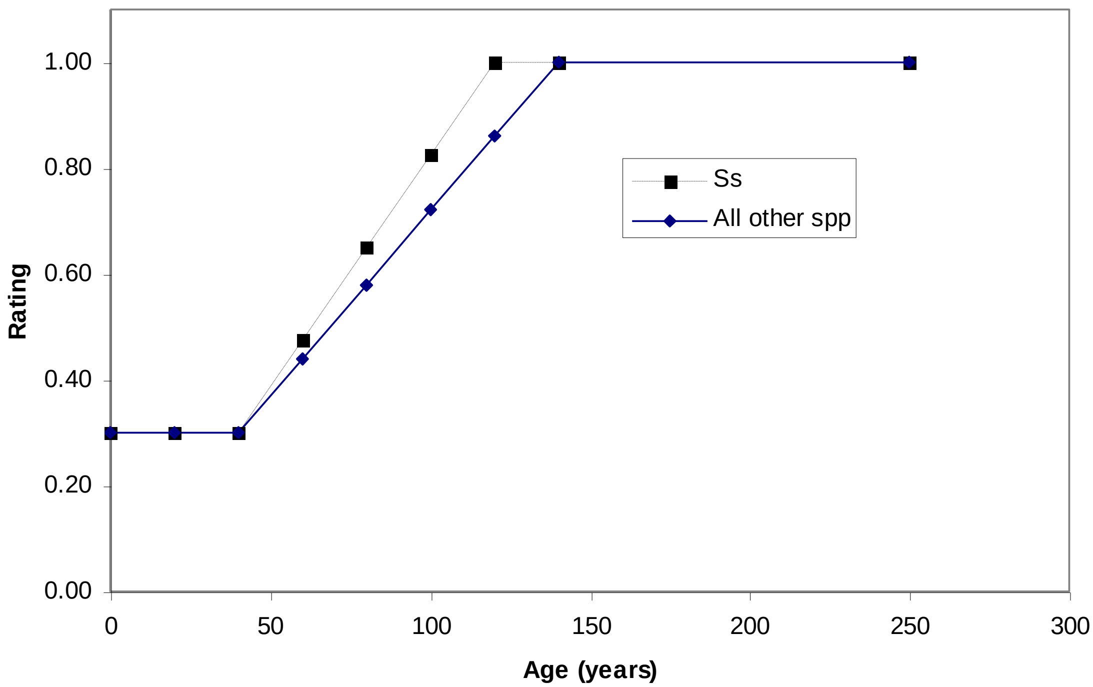

Figure 8. Northern Goshawk foraging habitat suitability rating curve for stand age (Ss = Stika Spruce).

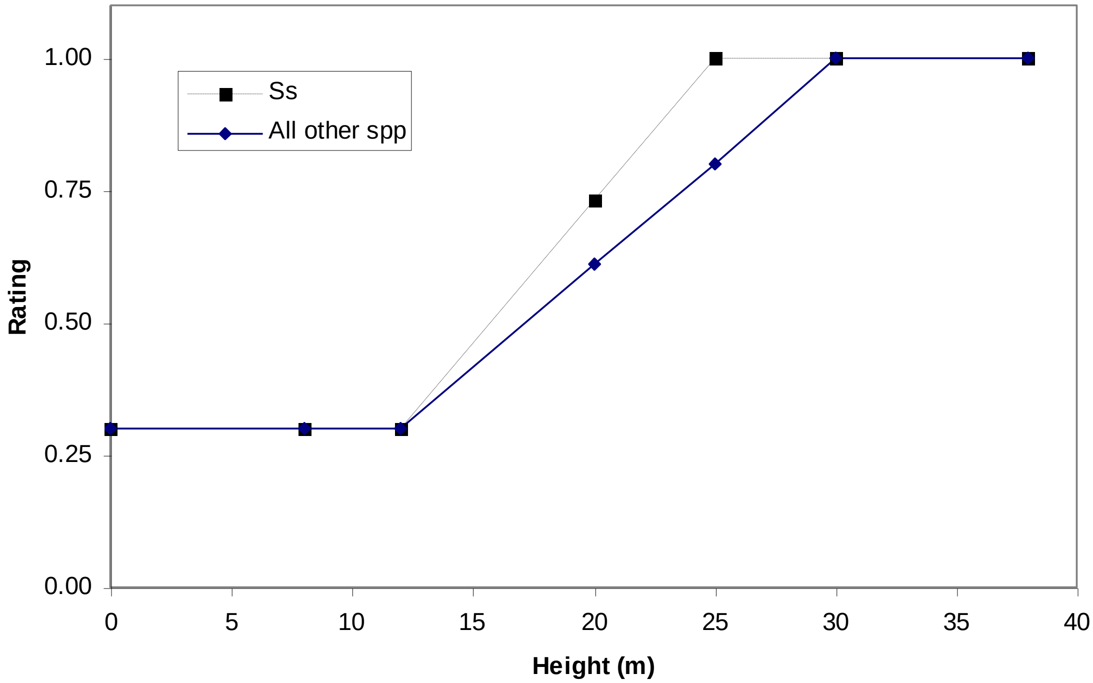

Figure 9. Northern Goshawk foraging habitat suitability rating curve for stand height (Ss = Stika Spruce).

Forest Composition – Inventory Type Group

(*Weak Variable*) We applied a range of foraging habitat suitability ratings from 0.6 – 1.0 to forest composition (Table 9). This means that even the least preferred forest types could have a rating of moderate if stand age and height are in optimal conditions. The relative ratings here are based primarily on prey surveys conducted on Haida Gwaii (Doyle 2004). That study indicated that overall prey abundance was highest in stands with spruce (largely due to higher relative abundance of red squirrels) and lowest in yellow-cedar.

Table 9. Northern goshawk foraging habitat ratings stand composition.

Name	**First Sp**	**Second Sp**	**Rating**
S 1^{o} or 2^{o}	any except Yc or Pl	any except Yc or Pl	1
H dominant	H	any except S, Yc, or Pl	0.95
Cw	Cw >80%	any <20% expect Yc or Pl	0.7
B dominant	B	any except S, Yc, or Pl	0.95
Fd dominant	Fd	any except S, Yc, or Pl	1
Yc dominant	Yc	any	0.6
Yc secondary	any	Yc	0.7
Pl dominant	Pl	any	0.7
Deciduous	Dr, Ac, At	any deciduous	0.8
Mixed forest	Dr, Ac, At	any coniferous	0.95

BEC Variant

(*Weak Variable*) As mentioned previously, none of the 100 known goshawk nest areas in Coastal BC are within the hypermaritime CWH or MH BEC variants. Hypermaritime forests tend to have low canopy closure (F. Doyle and E. McClaren, pers. obs.), stands dominated by western redcedar and yellow cedar and dense understorey vegetation, which likely limits goshawk access to prey. However, canopy closure and understorey vegetation density, are not available in the forest cover databases and therefore, we used BEC as the closest surrogate. Our ratings for BEC variant (Table 10) reflect a compromise between the relatively strong pattern of low use by goshawks and our poor understand of why that is occurring. These ratings are designed to downgrade the final suitability score by one class for hypermaritime CWH, MH, and ESSF and two classes for alpine.

Table 10. Northern goshawk foraging habitat ratings for BEC variant.

BEC Variants	**Rating**
Alpine Tundra (all except parkland)	0.4
Alpine parkland	0.7
CDF mm	1
CWH (all except vh)	1
CWH vh1 + vh2	0.7
ESSF (all except parkland)	0.7
ESSF parkland (all)	0.7
ICH (all)	1
IDF (all)	1
MH (all)	0.7

Non-Productive & Non-Forested Habitats

Several non-forested habitats occur in Coastal BC that may be used to some degree by goshawks for foraging. Examples of these include wetlands and bogs, non-productive brush patches and alpine. While these habitat types may offer some prey for goshawks, we are not aware of any situations in Coastal BC where enough prey occurs in these habitat types 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 Table 11 was applied.

Table 11. Northern goshawk foraging habitat ratings for non-forested habitats.

Non-Forest Type	Rating
A (Alpine), AF (Alpine Forest), Swamp, NPBR (Non-productive Brush), C (Clearing), M (Meadow), OR (Open Range), NPBU (Non-productive Burn) NCBR (Non-commercial Brush)	0.4 (Low)
R (Rock), GR (Gravel), SAND, CL (Clay Bank), L (Lake), G (Gravel Bar), RIV (River), U (Human Development)	0 (Nil)

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 = mean(Age_r, $Height_r$) * ITG_r * $BECvar_r$ **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 12. Interpretation of final HSI scores for foraging habitat.

HSI Ratings	Class	Interpretation
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 availability of prey to goshawks (e.g. alpine, pole-sapling stage forests).
0.501 - 0.750	Moderate	Suitable. Either density or availability 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 Yc).
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 way the territory model works for the NCCR and the SCCR is outlined below and described in detail in the model implementation report (Smith et al. 2007). This version of the territory model is modified from the one applied to Haida Gwaii in 2006. These revisions were implemented to account for some unintended behaviours of the 2006 model and conceptual inconsistencies. Differences in the territory model used on Haida Gwaii in 2006 are outlined in Appendix 6 and described in detail in the model implementation report (Smith et al. 2007). It is anticipated that the current version of the territory model will be applied to Haida Gwaii in 2007.

The primary output of the territory model is a prediction of the number and distribution of potential goshawk territories across a conservation region. 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.

The way the territory model works is as follows:

1. <u>Nest areas, which serve as territory centroids, are first located across the conservation region</u>. Locations are random except that they must meet two criteria:
    a. Occur in a ≥50ha patch with nesting habitat suitability of high or moderate.
    b. Meet observed territory spacing distances (HG and NCCR=10.8km, SCCR and VI=6.9km). Spacing distances are stochastic, drawn from a normal distribution around the means, above.
2. <u>Territories then spread out from all of the centroids simultaneously</u> 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 (Bloxton 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 0-5 km from the centroid we applied a cost of 1 (no constraint); from 5-10 km we applied a linearly increasing

cost from 1 to 2; from 10-15 km we applied a linearly increasing cost from to 4; and distances >15 km received a cost of 4.

b. *Spreading across different habitat types*. We also applied travel costs 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 we assigned high and moderate foraging habitat a cost of 1 but in order to weight the relative influence of habitat vs distance from centroid in the spreading model we doubled all of the habitat costs). 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, we applied a constraint of a maximum 5 % overlap between any two territories and 20 % total overlap for any individual territory. 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 our analyses.

Whether or not a territory was realized around a nest area depended on whether enough suitable habitat could be acquired within a given maximum territory size (see habitat thresholds, next section). We constrained territory size 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). We based the maximum and minimum territories sizes on +/- 20% the estimated average size of territories on HGCR/NCCR=9150 ha and SCCR/VICR=3740ha.

3. <u>Territory Packing</u>. 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:
   a. First, the nest placement sub-model was run multiple times and a set of configurations with the highest number of nest areas are selected.
   b. Second, territories are simultaneously formed around each nest area. At some nest areas territories are successful (acquire enough habitat) and are realized, at others

the territory attempt fails. Territory formation is attempted for the subset of nest placement trials generated from the first step.

c. Third, for the territory formation output with the greatest number of successful territories from the last step the model then attempts to locate additional nest areas among the successful territories (still subject to the initial constraints in 1, above) and territories are attempted for the new nest areas.

Habitat Thresholds

There is 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 Nina 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.

We 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, we identified and used three potential habitat thresholds in the territory model: 60 %, 40 %, and 20 % suitable habitat. These correspond to high, moderate, and low probabilities of territory occupancy. We considered areas with a foraging habitat HSI >0.50 as potentially suitable habitat, and weighted those areas 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). To incorporate 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. Cortex has prepared a separate report that provides more information about programming details and the results from all of the model runs (Smith et al 2006, 2007, 2008). Model development and implementation was an iterative process between the authors of this report, Cortex, and the Northern Goshawk Habitat RIG.

Model Review

Model implementation involved two formal review components. One was conducted by Cortex and involved assessing the underlying data at 10,000 random points in each Conservation Region and recalculating the nesting and foraging HSI scores in an Excel worksheet to verify that the outputs from the model were correct. The second component was more biologically based and consisted of an evaluation of the behaviour and outputs of each of the three components of the model relative to the initial variable ratings, model structures and expectations of results. This second review was conducted for each Conservation Region primarily by Todd Mahon, with involvement from Erica McClaren and Frank Doyle. Also, during initial model development for the first Conservation Region, Haida Gwaii, interim output was reviewed by all Habitat RIG members during three model review workshops in 2006 and 2007. This review process resulted in several minor revisions to the variable ratings and model structure of the HSI model. As well, the RIG identified three issues with the territory model that were investigated by performing sensitivity analysis for specific territory model parameters.

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). 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. Validation of the foraging habitat model would require a telemetry study that compared relative habitat use of goshawks to the foraging HSI ratings.

We strongly recommend that, at a minimum, some level of verification be conducted for each conservation region. Verification is critical for providing an estimate of the accuracy of the model and the underlying GIS data. Field verification activities often identify biases between field and GIS data that can be quantified and used to refine variable ratings and improve the accuracy of the model (Brooks 1997). To date, limited habitat verification has been conducted for the Haida Gwaii Conservation Region

(McClaren and Doyle 2007). Thirty-three sites have been assessed to date, which represent approximately half of the target number to be verified. Results from the 33 sites found project level accuracy of 82% and 84% for nesting and foraging habitat, respectively. Stand-level accuracy was much lower at 48% for nesting and 33% for foraging. These scale-dependent results emphasize the limitations of attempting to use the model outputs for stand-level purposes. We reiterate that the primary purpose of this work is to facilitate large-scale strategic planning. At that level model accuracy appears robust.

In addition to model verification, validation projects, such as systematic call playback surveys to locate new nest areas for the nesting habitat model and telemetry based habitat use studies for the foraging model, would be highly desirable. However, due to the multiple years and relatively high costs required to collect this information, validation may be impractical.

Sensitivity Analysis

Summary information to be added from Cortex Report when available.

Model Uncertainty and Limitations

With any model the outputs are only as good as the data and knowledge that go into them and there is always uncertainty and limitations of both. In this model Forest Cover information is the primary data source and both the accuracy and precision of these data has long been recognized as a concern. In all Conservation Regions except North Coast these data quality problems were confounded by having different data sources (i.e. Ministry of Forests (TSAs) and forest companies (TFLs)). Generally speaking, the accuracy of the forest cover data is believed to be relatively good at the TSA or District-level, but poor to moderate at the polygon level. This is supported by the limited field verification conducted on Haida Gwaii. Based on poor accuracy at the polygon-level we caution against using the resulting maps stand-level purposes with assessing the accuracy for the area of interest.

Aside from these data quality issues, not having canopy closure data for the nesting model limits its specificity. Without canopy closure the model will overestimate the amount of moderate and high quality nesting habitat, unless we have captured this through inventory type group.

Again, we emphasize the outputs of these models are relative in nature and meant for comparisons across Coastal BC and for comparing habitat supply within a given area under different management scenarios. Even thought the model identifies potential territories we caution their use with respect to any type of population estimate. At this time the model territories have been designed primarily as analysis units to assess the amount and distribution of suitable nesting and foraging habitat with respect to spatial constraints of goshawks.

This goshawk model was designed for circumstances specific to Coastal BC (e.g. goshawk ecology and available types of data) and we strongly caution against its application to areas outside of this study area without thoughtful adaptation.

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Appendix 1. Stand-level habitat characteristics of known goshawk nest sites from Haida Gwaii, North Coast and inland portions of the CWH. Information is primarily derived from Forest Cover and TRIM coverages, although some data for Haida Gwaii was updated based on field information.

Nest Area	**Location**	**BEC Zone**	**Hw**	**B**	**S**	**Cw**	**Yc**	**Age Cl,**	**Ht. Cl.**	**CanCl**	**Slope (%)**	**Elev (m)**
Ain	Haida Gwaii	CWHwh1	55	5		40		9	4	5	14	50
Bonanza 1	Haida Gwaii	CWHwh2/vh2	1^o		2^o	3^o		9	5	6	30	98
Bonanza 2	Haida Gwaii	CWHwh2/vh2	1^o		2^o	3^o		9	5	6	21	135
Ian SW (315)	Haida Gwaii	CWHwh1	1^o			2^o		9	5	6	41	201
Datlamen 1	Haida Gwaii	CWHwh1	1^o			2^o		9	5	6	14	62
Datlamen 2	Haida Gwaii	CWHwh1	1^o			2^o		9			4	42
Demon 1	Haida Gwaii	CWHwh1	2^o		3^o	1^o		9	4	5	20	281
Demon 2	Haida Gwaii	CWHwh1	2^o		3^o	1^o		9	4	5	13	299
Demon 3	Haida Gwaii	CWHwh1	2^o		3^o	1^o		9			25	262
Survey 1	Haida Gwaii	CWHwh1	1^o			2^o		9	4	6	12	127
Survey 2	Haida Gwaii	CWHwh1	1^o			2^o		9	n/a	3	38	81
Survey 3	Haida Gwaii	CWHwh1	1^o			2^o		9	n/a	9	21	96
Ian 990 (Ian NE)	Haida Gwaii	CWHwh1	1^o		3^o	2^o		9	3	2	34	262
Three Mile	Haida Gwaii	CWHwh1	1^o					9	5	7	18	258
Black Bear 1	Haida Gwaii	CWHwh1	1^o			2^o		9	4	7	8	60
Black Bear 2	Haida Gwaii	CWHwh1	1^o		3^o	2^o		9	n/a	5	20	55
Black Bear 3	Haida Gwaii	CWHwh1	1^o		3^o	2^o		7	n/a	7	29	88
Skowkona	Haida Gwaii	CWHwh1	2^o		3^o	1^o		9	3	5	5	320
Upper Hancock	Haida Gwaii	CWHwh1	2^o		3^o	1^o		9			15	106
Lyell Is.	Haida Gwaii	CWHwh1	1^o		2^o	3^o	4^o	9	5	6	12	67
Lyell Is. 2nd nest	Haida Gwaii	CWHwh1	2^o		1^o			9	5	5	28	96
Yakoun 1	Haida Gwaii	CWHwh2	1^o		4^o	2^o	3^o	9	4	5	34	247
Yakoun 2	Haida Gwaii	CWHwh2	1^o		4^o	2^o	3^o	9	n/a	5	52	238
Alder Creek	North Coast	CWHvm1	90	10				9	5	7		
Marron	Kalum	CWHws2	95	5				9	4	7		

Nest Area	Location	BEC Zone	Hw	B	S	Cw	Yc	Age Cl,	Ht. Cl.	CanCl	Slope (%)	Elev (m)
Big Cedar	Kalum	CWHws2	1^{o}	2^{o}				9	4	7		
Newton Creek	Kalum	CWHws2	1^{o}	3^{o}		2^{o}		9	4	4		
Deep Creek	Kalum	CWHws2	1^{o}					8	4	5		
Cranberry	Kispiox	CWHws2	90		10			8	4	7		
Kitsun's	Kispiox	CWHws2	70	30				9	3	5		
Mill Creek	Kispiox	CWHws2	75	20		5		8	4	7		
Ten Link	Kispiox	CWHws2	95	5				8	4	4		
Upper Cranberry	Kispiox	CWHws2	85			15		9	5	6		
Weber Creek	Kispiox	CWHws2	85	15				9	4	6		

*For some nest stands the exact percent forest cover is not known and leading species status has been substituted (primary, secondary, etc.).

Appendix 2. A summary of studies that have examined goshawk nesting habitat.

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^2 /ha	<u>Tree spp</u> - Lodgepole Pine	Lodgepole Pine preferentially chosen as nest sites over other tree species
Bosakowski et al. 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 2000	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 et al. 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^2 /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.
Hargis et al. 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.

Study	Location	Forest Type	Canopy Closure	Tree diameter/ height	Basal Area/ Tree Density	Other Variables	Comments
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 prefered	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 et al. 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.
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.

Study	Location	Forest Type	Canopy Closure	Tree diameter/ height	Basal Area/ Tree Density	Other Variables	Comments
Schaffer 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)		Slope - N/A Aspect – all except W and SW Tree Spp – 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^2 sign. > random plots	Slope – gentler at NAs (12%) Aspect – no relationship Tree spp – 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. Edge distances for 148 goshawk nests on Vancouver Island.

Edge Distance	No. Nests	% of nests
0-50	4	2.7%
50-100	6	4.1%
100-150	9	6.1%
150-200	12	8.1%
>200	117	79.1%
Total	148	100.0%

Appendix 4. A summary of studies that have examined goshawk foraging habitat.

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 et al. 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.
Iverson et al. 1996	Southeast Alaska	Coastal temperate forest; 1^{o} 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.

Study	Location	Forest Type	Key Findings
Mahon and Doyle 2005	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^{o} 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.

Appendix 5. Differences in the Northern Goshawk Habitat Model applied to Haida Gwaii in 2006.

Several modifications were made to the Northern Goshawk Habitat Model in 2007. The main types of changes fell into three categories:

1. Revision of habitat variable ratings and parameter values to account for differences among Conservation Regions.
2. Revision of habitat variable ratings to the overall model based on field verifications activities conducted on Haida Gwaii in 2006.
3. Modification of the territory model to address a potential over-packing problem.

The most significant parameter differences among Conservation Regions were the territory spacing distances (and associated territory sizes) used in the territory model – 10.8km HGCR and NCCR, 6.9km SCCR and VICR. All habitat variable ratings were the same between the NCCR and SCCR, although some values of specific variables, such as BEC variant, were unique to one Conservation Region. One difference in ratings between the HGCR and the NCCR and SCCR was with respect to elevation. Different elevation bands were used on the mainland to account for the greater range in elevation that occurs there.

Several minor revisions were made to habitat variable ratings based on field verification activities conducted by E. McClaren and F. Doyle on Haida Gwaii in the fall of 2006. These revisions were exclusively to forest composition ratings and included downgrading of Cw ratings for nesting suitability and upgrading of Ss stands for foraging through modification of stand age and height rating curves.

The modification resulting in the largest change to overall model outputs was modification of the territory model. For example, a comparison of the 2006 and 2007 territory models was conducted for the 40% habitat threshold on Haida Gwaii (Cortex Consultants 2007); the 2006 model predicted an average of 65 suitable territories and the 2007 model predicted an average of 56 territories (16% difference).

As indicated in the body of the report, it is a priority to rerun the HGCR using the revised 2007 model to ensure standardized results across all Conservation Regions.

The following table summarizes differences between the 2006 and 2007 models. For a complete list of habitat variable ratings and other model parameters refer to last years' project reports (Mahon et al 2006, Cortex Consultants 2006).

Table A5-1. Summary of difference between the current 2007 model and the 2006 model applied to Haida Gwaii.

Habitat Variable / Parameter	**Change in 2007 NCCR/SCCR model**
Nesting Habitat Model	
Stand Age	No change
Stand Height	No change
Distance from Edge	No change
Forest Composition	Cw rating was downgraded for exclusive and dominant conditions
Elevation	Elevation rating bands were modified for NCCR and SCCR to account for broader elevation range
Slope	No change
BEC Variant	No change but ratings developed for several additional variants in the NCCR and SCCR
Foraging Habitat Model	
Stand Age	Separate rating curve developed for Ss
Stand Height	Separate rating curve developed for Ss
Forest Composition	Slight downgrade to Cw ratings
Non-Productive and Non-Forest Habitats	NCBR, NSR, and NC added from NF_Desc field in the FC database
BEC Variant	No change but ratings developed for several additional variants in the NCCR and SCCR
Territory Model	
Territory spacing	No change for HGCR and NCCR (10.8km), but 6.9km spacing applied to SCCR

Appendix 6. Potential revisions to incorporate in the final model run for all Conservation Regions.

- Upgrade foraging ratings for Fd leading ITGs to 1 (equivalent to Ss)
- Include coast and water as a hard edge type
- Change slope classes to account for nests on steeper slopes in Mid Coast
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