



Northern Goshawk (*Accipiter gentilis laingi*) Habitat and Territory Models

Modelling Methodology and Implementation

&

Scenario Results for Coastal British Columbia

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, but many requested revisions have not yet been incorporated into the document. It has not undergone an external peer-review and may contain errors and outdated information.

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Executive Summary

Spatially explicit habitat and territory models were developed for assessing patterns and trends in Northern Goshawk (*Accipiter gentilis laingi*; hereafter referred to as NOGO) habitat over the coastal B.C. range of this threatened subspecies, under past present and potential future conditions. The ecological background, conceptual models, and estimates of parameters for NOGO habitat use and territory dynamics have been developed and documented by the NOGO Habitat Recovery Implementation Group (RIG).

The spatially-explicit simulation model described in this report implements those conceptual models and parameters using spatial landbase inventory data assembled for ongoing large-scale coastal landscape planning processes (e.g., timber supply projections and analyses to support LRMP processes). This raster-based model, developed in SELES (Spatially Explicit Landscape Event Simulator), is designed to integrate with other SELES-based landscape projection models and tools to enable assessment of NOGO habitat supply and comparison of potential impacts to habitat that may result from different landscape management policies.

The resulting model framework contains four main components: (i) a pre-processing step for inferring additional Inventory Types Groups (ITGs) tree species combinations not represented in standard ITG classification; (ii) a landscape projection model for projecting vegetation growth and disturbances; (iii) a habitat model for classifying the suitability of each raster cell for NOGO foraging and nesting; and (iv) a territory model for dynamically placing and growing “core” territories on the landscape. The primary indicators from the models are: (1) area of foraging and nesting habitat (classed into four suitability classes ranging from nil to high); and (2) numbers of projected territories along with attributes summaries for each territory. These indicators are output as maps and data summaries.

We ran the models for the Haida Gwaii (HGCR), North Coast (NCCR), South Coast (SCCR), and Vancouver Island Conservation Regions, which together cover the entire range of this subspecies. Using alternative landscape conditions we tested the effects of differing amounts and configurations of habitat on the indicators. The models were run under the following scenarios: (i) current conditions (HGCR, NCCR, SCCR, VICR), (ii) current or *status quo* land management (HGCR), (iii) historical conditions (HGCR), and (iv) capable habitat (HGCR, NCCR, SCCR, VICR). In addition, to address the considerable uncertainty in how much habitat a NOGO requires in its territory, we ran the model under three different habitat thresholds.

NOGO habitat distribution is generally driven by stand composition (including height, age, and stand density) elevation, and regional climate. When comparing the area of current habitat relative to capable habitat, the greatest differences among the landscape conditions we tested were apparent in the SCCR and VICR, which have the longest and most extensive forest harvesting history of the four conservation regions we examined (e.g., current nesting habitat in the SCCR is 52% less than capable nesting habitat). We also found that the number of territories that can be supported in the landscape was closely related to forage habitat availability. However, in some cases the spatial distribution of foraging habitat also influenced the number of territories. For example, at higher thresholds for the minimum amount of habitat required in a successful territory, the difference in territory numbers between current conditions and capable habitat scenarios was greater than the difference in suitable habitat.

For the projection scenarios on Haida Gwaii, changes in amounts of habitat (foraging and nesting) are generally consistent with changes in harvest flows and growing stock levels as projected by the outputs of the landscape projection models used to generate future conditions. The future distribution of territories appears consistent with harvesting assumptions. This implies that the current version of the model is useful for comparing future impacts of alternative



land management scenarios on numbers and distribution of habitat and territories. Furthermore, much of the impact of forest harvesting on habitat and territories has either already occurred, or is projected to occur within the next 50 years under the present model assumptions.

1. Introduction

1.1. Background

Northern Goshawks (*Accipiter gentilis*) are a widely distributed, medium-sized species of raptor that breeds primarily in mature and old-growth temperate and boreal forests (Squires and Reynolds 1997). One subspecies, *Accipiter gentilis laingi*, is red-listed in coastal British Columbia and listed as threatened nationally (COSEWIC 2000). The distribution of this subspecies is limited to Haida Gwaii/Queen Charlotte Islands, Vancouver Island, and the coast of the adjacent mainland (Cooper and Stevens 2000). Because NOGO nest areas are typically in relatively even-aged mature/old coniferous stands with large trees, they are potentially adversely impacted by forest harvesting activities.

Due to their specific habitat requirements, life history characteristics, and low overall density in coastal landscapes, this subspecies has become a focal environmental indicator species in analyses of land-use management plans across the coast region of B.C. (e.g., Haida Gwaii: see Holt 2005; North Coast: see Mahon 2003). To date, most of the analysis work using NOGO as an indicator species has focused on assessing the ability of different habitats to meet various life requisites (nesting, foraging and generalized territory spacing). These analyses have been partially or completely independent from projections of the future landscape under different land-use and environmental change scenarios. In order to infer potential consequences of landscape change on the dynamics of populations over the species' range, a more complete spatially-explicit modelling approach was required.

The focus of this study is on the development of that approach and its preliminary application across the four Conservation Regions established by the NOGO Recovery Team for this subspecies (Haida Gwaii, North Coast, South Coast, and Vancouver Island).

1.2. Model Overview

The NOGO habitat and territory models were implemented based on conceptual models developed by Mahon *et al.* (2007). The intent of this implementation was to assess the potential impacts of management actions on amounts and spatial distribution of habitat and territories for the coastal subspecies of the Northern Goshawk *Accipiter gentilis laingi*. The model was parameterized for the Haida Gwaii, North Coast, and South Coast Conservation Regions within the subspecies' range. Selected land management scenarios were used to verify the models and to produce indicators to help the RIG assess the potential of different forest management options to alter the status of this subspecies.

The NOGO habitat/territory models classify habitat types for NOGO according to vegetation structure, and topographic factors, and simulate the shape and spatial arrangement of core annual territories under different assumptions of NOGO habitat requirements. The NOGO models are spatially-explicit simulation models that represent uncertainty about the ecological factors defining habitat use and territory dynamics for this subspecies. The models are designed to easily incorporate data on different landscape conditions. For example, on Haida Gwaii the habitat and territory models were integrated with a landscape projection model that simulates forest growth and anthropogenic disturbances (forest harvesting) forward in time.

Indicators from the models include: area of foraging and nesting habitat (classed into four suitability classes ranging from nil to high); and projected number of territories along with range of supporting attributes describing each territory. Habitat conditions and territory locations are spatially explicit, and can be output as maps and data summaries. However, the modeled results

are intended to be used as a high-level, strategic planning tool. The model is not intended to map habitat conditions at local scales, or to predict the locations of specific territories.

The results in this report are derived from two different versions of the models. In 2006, we developed an initial implementation of the model using parameters and data available for Haida Gwaii. Accordingly, we tested the model and used it to compare land management options for the Haida Gwaii Conservation Region. In 2007 and 2008, we made minor refinements to the habitat models and more significant changes to the territory model, and ran this implementation on the North Coast, South Coast, and Vancouver Island Conservation Regions. These changes incorporate both new parameter estimates specific to these regions and an improved implementation of NOGO territory dynamics that better reflects our current understanding. Therefore, the model description and analysis results for each Conservation Region are based on the model version appropriate to the region. In addition, we provide a technical comparison of the 2006 and 2007 implementations in Appendix A of this report.

1.3. Study Area Boundaries

Our current study area (Figure 1) approximates the known range of the coastal subspecies of Northern Goshawk *Accipiter gentilis laingi*. Although thorough genetic inventories of coastal NOGO populations have not been conducted, there is general agreement among members of the NOGO Recovery Team that the eastern boundary of the coastal subspecies' range coincides with the transition from maritime to sub-maritime variants of the Biogeoclimatic Ecosystem Classification system (BEC). However, there is likely a zone of transition in sub-maritime variants from *Accipiter gentilis laingi* to *Accipiter gentilis atricapillus*, the interior subspecies. Therefore, our analysis will restrict territory initiation to maritime BEC variants, although territories will be allowed to spread into adjacent variants.

The southern boundary of our study area is the international border with the United States of America. While the border is not ecologically relevant, it reflects the extent of the NOGO Recovery Team's jurisdiction. The northern boundary of our study area is the northernmost edge of the North Coast Forest District. Although there is suitable habitat within maritime variants of the Cassiar Forest District, the total area is minimal relative to the effort required to apply the model to these northern patches of habitat.

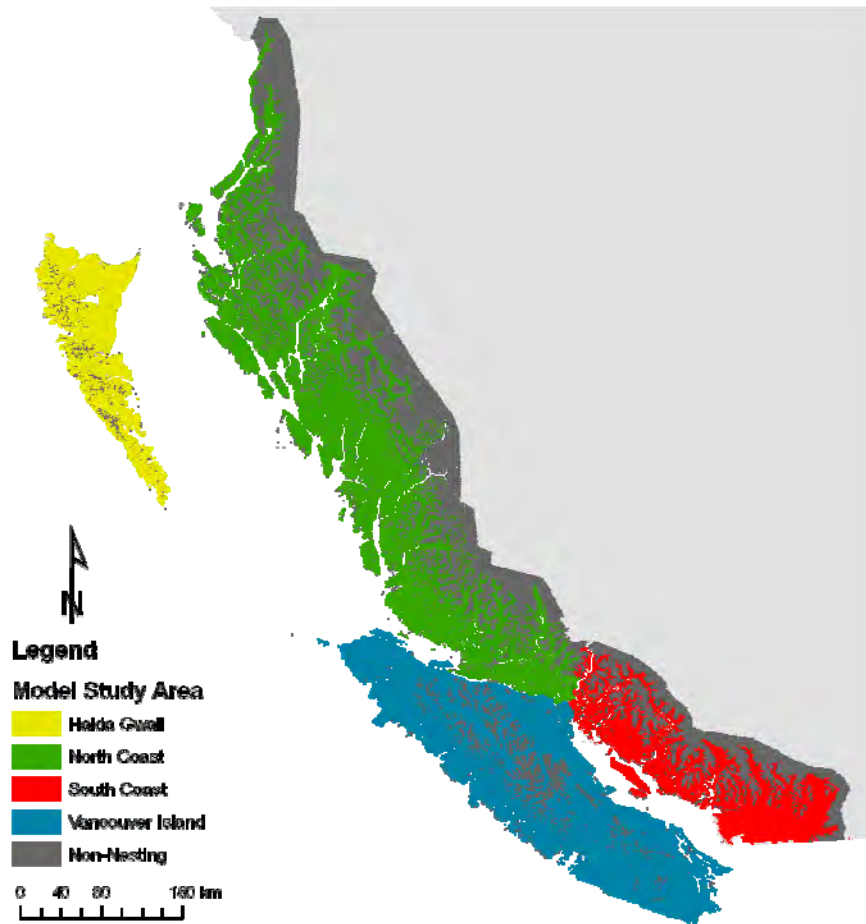


Figure 1: Study area over which habitat and territory models were applied

Coloured regions indicate variants of the biogeoclimatic zone within each conservation region that were considered suitable for nesting. Grey regions are subalpine and transition zone habitat into which modeled territories can extend, but nest placement and territory initiation are not permitted.

2. Model Implementation

2.1. Overview

The Northern Goshawk model is comprised of several separate models (Figure 2): (i) a pre-processing Inventory Type Group (ITG) model; (ii) a Landscape projection model; (iii) a Habitat classification model; and (iv) a Territory model that establishes and projects potential territories. The pre-processing ITG model generates a modified Inventory Type Group (ITG) layer used as part of habitat quality calculations. This model is further discussed in Appendix B. The Landscape Projection models implement management according to policy specifications. Haida Gwaii is the only conservation region for which a landscape projection model currently exists (Haida Gwaii land use model; Williams *et al.* 2004). Therefore, we were unable to conduct landscape projection scenarios for the North and South Coast Conservation Regions.

Implementation of the NOGO habitat and territory conceptual models developed by Mahon *et al.* (2007) was the main focus of the project described in this report. The habitat models use up to eight (8) biophysical attributes to generate spatially explicit estimates of habitat suitability for both nesting and foraging habitat. The territory model uses this habitat information to generate potential territories across the landscape based on known and assumed habitat requirements of the NOGO. The territory model also calculates a large number (up to 19) of summary attributes for each of these territories (e.g., area of suitable habitat per territory; territory area within the timber harvesting land base) to aid in understanding model behaviour. The full list of attributes is given in Appendix D.

A large number of parameters are used to specify how the model functions. Throughout this document the names of these parameters will be written in italics, followed by the default value. A complete list of parameters as well as region-specific values for each parameter can be found in Appendix C.

The model structure is generally intended to permit future landscape time series to be analyzed. At the time of this writing, the landscape state time series incorporating current, agreed upon management policies has not yet been generated for the NCCR, SCCR, or VICR.

Implementation of the Northern Goshawk model was initiated in 2005/2006 for Haida Gwaii and the North Coast Forest District (FD). In 2006/2007 we expanded application of the model to include the North and South Coast Conservation Regions (NCCR and SCCR), which comprise the entire mainland coast of British Columbia. We learned several lessons from the model's initial implementation in 2005/2006, which in turn have been applied in the 2007 version of the model. The conceptual differences in implementation of the two model versions are significant enough that the analyses for the North Coast FD and Haida Gwaii are not directly comparable to the results for the NCCR and SCCR. Therefore, we will first present the current version (2007) of the model as implemented in the NCCR, SCCR, and VICR, and then discuss how this version of the model differs from that implemented on Haida Gwaii (2006).

For details on the biological and ecological rationale behind the habitat and territory models, please refer to Mahon *et al.* (2007).

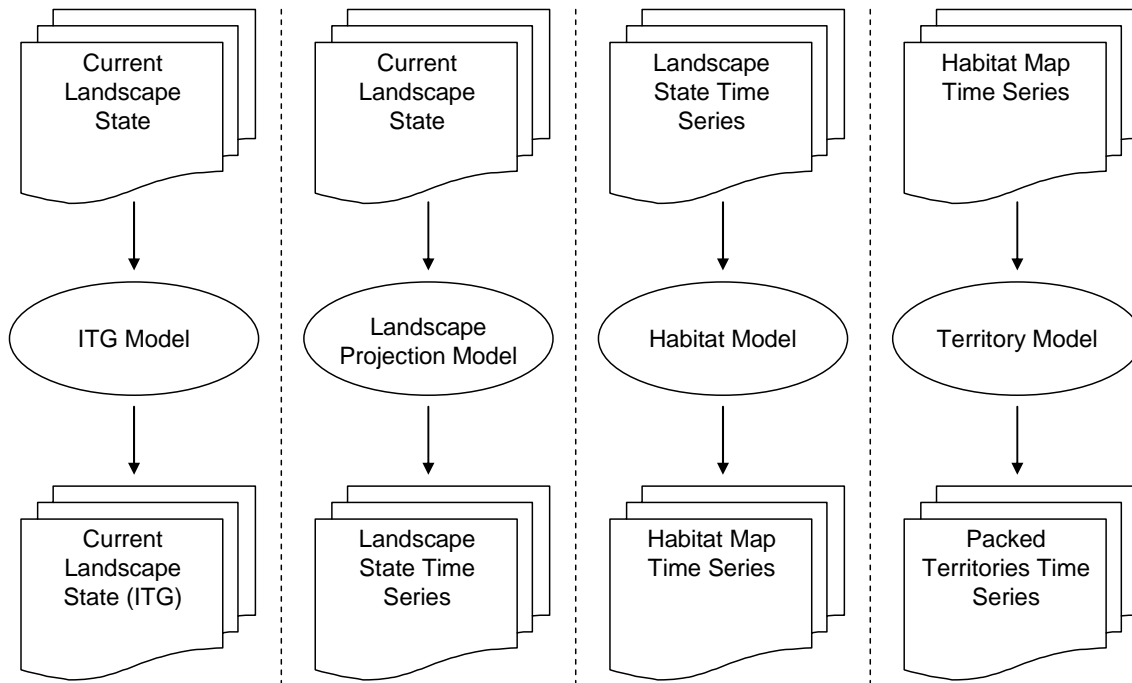


Figure 2: Overview of modelling framework as a “pipeline”

2.2. North Coast, South Coast and Vancouver Island Conservation Regions

2.2.1. Habitat Model

Overview

The habitat model is composed of two sub-models, the edge sub-model and the habitat sub-model (Figure 3). In general, for each set of landscape maps (i.e., for time period and/or scenario), the edge sub-model is run first to define where anthropogenic and natural edges occur in the landscape, with edges defined by height differences between adjacent stands. Then the habitat model calculates nesting and foraging habitat based on output from the edge model, as well as on the basis of other ecological and topographic attributes. We describe the implementation of these two models in more detail below.

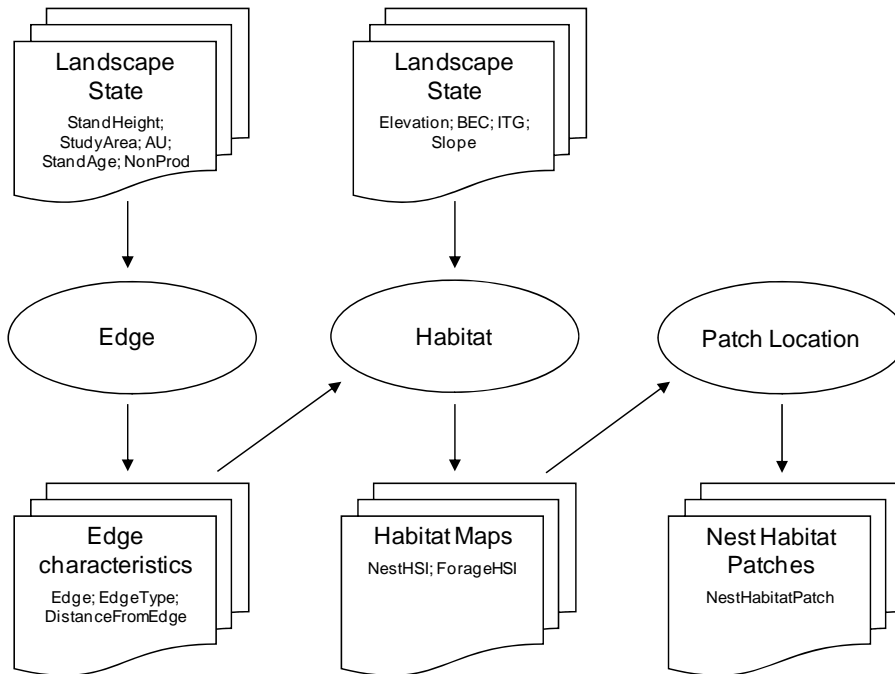


Figure 3: Flowchart of the NOGO habitat model, indicating input layers, output layers and sub-model components

Edge Definition Sub-Model

Edge Calculations

The edge-model identifies places in the landscape where habitat quality within an older stand is affected by the edge influence of an adjacent younger and shorter stand. Therefore, the edge sub-model identifies habitat edges by calculating height differences between adjacent cells. A particular cell is considered to occur on an edge when this difference exceeds a specified threshold ($edgeHeightDifference = 15\text{ m}$), and the shorter stand is less than a maximum height ($edgeHeightThreshold = 15\text{ m}$). The maximum depth of the edge influence into the taller stand can be specified within the model ($edgeBuffer = 200\text{ m}$). The distance from edge less than this maximum is used to determine the habitat suitability of a particular cell.

Each edge cell is specified as either anthropogenic or natural, depending on the underlying source of the edge. The ecological rationale for this distinction is that anthropogenic edges are generally more abrupt with the transition between stands occurring over a very short distance, whereas natural edges are more gradual (the model does not account for edges associated roads, or reduced edge effects associated with partial cutting). If an edge occurs adjacent to non-productive forest, the edge type is determined from the non-productive forest type attribute, with gravel pits, clearings and urban areas considered anthropogenic and all other land cover types considered natural. Edges adjacent to harvest blocks were also classified as anthropogenic. Because we lacked information on harvest history, edges adjacent to cells that were not classified as non-productive were assumed to be caused by forest harvesting. We differentiated harvested stands from cases where cells were simply missing data (e.g., due to rasterization artefacts), by further restricting our inference of forest harvesting to cells with data on either analysis unit or leading species.

Ideally clearcut edges would be defined as edges adjacent to known harvested areas, but data limitations prevented us from taking this approach. The sources of these limitations are primarily

dataset dependent. For example, in Haida Gwaii, our harvest history layer only contains areas cut through the year 2000, while our stand height and stand age layer is current to 2004. Therefore, in this dataset, any areas cut between 2000 and 2004 would not be identified as edges by the model. For the NCCR and the SCCR, our harvest history information is incomplete, and seldom extends further than ~40 years into the past. No effort has been made to assess the extent of harvest history information in the VICR. Our working definition of harvested edges may result in non-edges being defined as anthropogenic where leading species and analysis unit data are missing.

Stand Height Estimation

The edge sub-model provides the option to calculate stand height using growth and yield tables based on analysis unit and stand age, rather than using stand height values derived from forest cover (*updateHtAndCC* = FALSE). This behaviour ensures consistent estimates of stand height across the study area, and standardizes methods for specifying heights among current and forecast scenarios. This standardisation ensures that any influence of height differences on model outputs among time periods is due to actual changes in height and not just different calculation methods. Stand heights calculated using this option would also be used in the habitat models.

A drawback to calculating stand height is that forest cover values of stand height, interpreted from aerial photos, are generally more accurate for the current landscape than height values predicted from growth and yield tables. We used forest cover stand heights where available (primarily TSA lands), and used VDYP (MOF 1998) to predict stand heights where forest cover estimates was not available. We considered using TIPSYP for managed stands but the increased effort, and difficulty in identifying managed stands were considered worthwhile for the incremental gain in accuracy. However, it may be worthwhile testing the implication of this assumption.

Nesting and Foraging Habitat Suitability Sub-Models

The model uses information about edge location and edge type, in combination with seven other landscape attributes to calculate nesting (Equation 1) and foraging (Equation 2) habitat suitability indices (HSIs). The model first calculates a partial HSI for each landscape attribute, and then uses these partial HSIs to calculate aggregate HSIs for each of nesting and foraging habitat. This process is repeated for every cell in the landscape. These calculations are deterministic and assume that habitat suitability can be described by a multiplicative relationship among landscape attributes. Ecological rationales for these relationships are provided in Mahon *et al.* (2007).

Equation 1: Nesting Habitat Suitability Index (nHSI) is calculated as the product of HSIs for individual landscape attributes.

$$\text{nHSI} = \text{average}(\text{StandAge}, \text{StandHeight}) * \text{ITG} * \text{BEC} * \text{Elevation} * \text{Slope} * \text{Edge}$$

Equation 2: Foraging Habitat Suitability Index (fHSI) is calculated as the product of HSIs for individual landscape attributes.

fHSI is the greater of:

- 1) $\text{average}(\text{StandAge}, \text{StandHeight}) * \text{ITG} * \text{BEC}$
- 2) NonForest

Once nHSI and fHSI values are calculated for each cell, their values are classified into four classes, nil, low, moderate and high using the ranking thresholds (*HSIForageRankCutoffs.txt*; *HSINestRankCutoffs.txt*).

Patch Location Sub-Model

The Patch Location Sub-Model finds patches of suitable nesting habitat in the landscape, defined by contiguous groups of cells that are at least moderate quality nesting habitat (as specified in *HSINestRankCutoffs*), and that exceed a minimum size (*MinHabPatchSize* = 50 ha) under a given management scenario or time frame. Note that the model does not specify a maximum patch size. Therefore, in homogenous portions of the landscape with suitable nesting habitat, patches can be very large.

2.2.2. Territory Model

Overview

The objective of the territory model is to predict how many feasible territories could potentially be supported by a particular configuration of nesting and foraging habitat. The model is run after nesting and foraging habitat suitability has been determined for a given land management scenario. The model uses a simple iterative optimization approach to test different configurations of nest area placement in the landscape to find the configuration that produces the greatest number of successful territories. Some of the parameters used to specify territory spacing and size are stochastically determined. Therefore, the model does not fully optimize territory-packing because this would result in a bias towards the far left tails of the sampling distributions used to derive spacing and territory size parameters. Instead, the model is intended to balance the competing influences of stochastic and optimization elements (see Appendix A for details).

The territory model consists of two sub-models: (1) nest placement; and (2) territory growth. The nest placement sub-model places nests in the landscape according to habitat quality and nest spacing criteria, and the territory growth sub-model attempts to create territories around each nest area according to habitat quality, distance from the nest and restrictions on overlap of adjacent territories. The general flow of the territory model is described below. Details of each sub-model follow in subsequent sections of this report.

The territory model (including both sub-models) iteratively places nests and forms territories via three nested loops (Figure 4). In the first loop (nest-placement), nest areas are consecutively placed in the landscape using spacing criteria intended to match observed spacing patterns of actual goshawk nests within the Conservation Region (see Table C-1). Within the bounds of the spacing criteria and habitat quality requirements, nest locations are randomly determined. The model stops attempting to place new nest areas after a specified number of nest placement failures (*numNestFailures* = 2)

Once the landscape is saturated with nests, territories are simultaneously formed around each nest area (territory growth). Each territory is evaluated to determine whether it contains sufficient density and quality of habitat to support a NOGO. At the end of this loop the number of suitable territories for the current configuration of nest areas is recorded. The second loop tests different configurations of nest areas to determine which supports the greatest number of successful territories. The model requires specification of how many nest area configurations should be attempted (*numConfigAttempts* = 5) before advancing to the third loop.

The third loop involves iterative adjustment of the spatial arrangement of nests to find the configuration of nest areas that will support the greatest number of territories. After the first

iteration of this loop, the loop starts with the configuration of successful nest areas from the second loop that produced the greatest number of territories and uses this configuration as the seed for a second round of configuration attempts. Similarly, the best configuration from the second round is used to seed a third round. This loop continues until a prescribed number of iterations have been made ($numIterations = 5$).

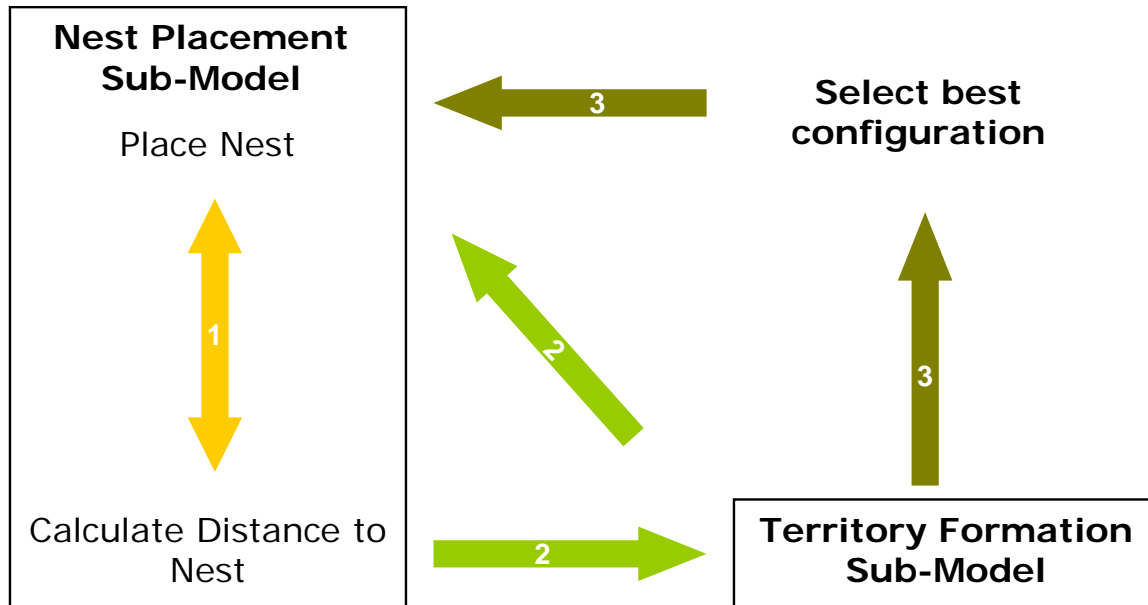


Figure 4: Flowchart of iterative packing approach used by the territory model in the North Coast and South Coast CRs.

The three nested loops described in the text are indicated by numbering and colour.

Nest Placement Sub-Model

A primary aim of the Nest Placement Sub-Model is to maintain a spacing pattern among territories that is similar to the spacing pattern observed among known nest areas within each conservation region (Mahon *et al.* 2007). In addition, the model also ensures that nests occur in areas with sufficient quality and quantity of nesting habitat. Within these spacing and habitat quality restrictions, the nest placement sub-model attempts will continue to initiate new nest areas until the landscape is saturated.

The cell chosen for a new nest area is based on several criteria:

1. The nest must fall within a patch of suitable nesting habitat, as defined by the Patch Location sub-model.
2. A nest area is more likely to initiate in a cell of high nesting habitat, than in a cell of moderate nesting habitat. The probabilities of initiating in each habitat type are weighted by model parameters ($HighHabMod = 4$; $MedHabMod = 1$).
3. The distance of the prospective nest from existing nests affects the probability of initiation. For a particular territory attempt, the distance of the initiation cell from an existing nest area is sampled from a normal distribution (for the VICR, $NestProbMod = 6900$ m, $NestProdSD = 1400$ m). Only cells along the perimeter of this spacing distance are available for initiation.
4. The prospective nest cannot occur within the spacing distance of adjacent territories (Figure 5).

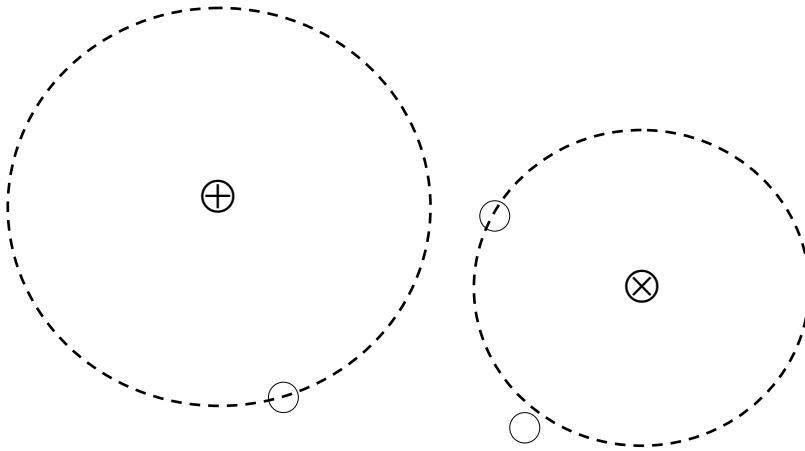


Figure 5: Spatial restrictions on the placement of new nest areas, relative to existing nest areas.

Small circles indicate nest area centroid (○ : existing, ⊕: new nest permitted, ⊗: new nest not permitted). Spacing distances associated with each nest are indicated by shaded circles for existing nests, and dotted lines for potential new nests.

The probability of a territory initiating in a particular cell is calculated as the probability of initiation based on habitat quality (see point 2 of initiation cell criteria above) multiplied by the probability of initiation based on distance from the nearest nest. For each nest area initiated, the model stores the stochastically determined minimum and maximum area for the associated territory. These stored parameters are used for establishing territory boundaries around the nest area over successive iterations of the model.

The nest placement sub-model continues to place new nests until there are no cells with suitable habitat at the sampled nest spacing distance. At this point the sub-model attempts to place a nest at random location that is at least the mean sampling distance (as specified by *NestProbMode*) from an existing nest area. The purpose of this behaviour is to identify patches of nesting habitat that may be isolated from existing nest areas. If no suitable nesting habitat exists at distances greater than the mean sampling distance, the model proceeds to the territory growth sub-model. If a nest is successfully placed, the nest placement sub-model continues trying to place additional nests using the nest spacing criteria.

Optionally, the nest placement sub-model can be seeded with known nest areas (*useInitialNestSites* = FALSE). Except for the HGCR which was the first region considered, we did not use this option for at least three reasons. First, the model is not intended to predict actual nest areas, but rather predict the overall capacity of the landscape for NOGO territories. Second, known nest areas may be legacies of pre-existing landscape conditions, and may be currently unsuitable. Third, for the NCCR very few current nest area locations are available for initialization of the model.

Territory Formation Sub-Model

Once a territory initiates at a nest area, it grows outward by adding new cells to the territory from the pool of cells immediately adjacent to cells currently within the territory. The rate at which

cells are added determines how quickly the territory grows in a particular direction. This rate is determined by two characteristics of the cell to be added: the distance of the new cell from the nest area, and the foraging HSI of the cell. The *fHSISpreadingCost* and the *distanceSpreadingCost* are added together to determine the relative rate at which the territory expands into a particular cell.

Because spreading is an important concept in the territory model we emphasize two key concepts in more detail. First, the absolute magnitude of this spreading rate is not relevant to the model. Rather, it is the relative differences in spread rate at points along the territory's spreading front that determines how the territory expands. For example, the territory will add four cells with a spreading cost of one in the same amount of calculation time it takes to add one cell with a cost of four. Second, "time" is also relative and is only used to implement the assumed preferences for different landscape features ascribed to NOGOs when expanding territories. Therefore the absolute amount of time taken to spread out a territory is not important. Since all cells adjacent to cells currently within a territory are eligible for addition, the territory will eventually spread into cells with very high costs. The result is that territories will generally have a fairly even spreading front, with the overall shape of territories being determined by landscape conditions averaged over a large number of adjacent cells, rather than the values of single cells or small groups of cells.

Territory expansion is also restricted by the amount of overlap between a new territory and adjacent territory. Specifically, the proportion of overlap between adjacent two territories (*maxOverlap* = 0.05), and the proportion of total overlap between a territory and all other territories (*maxTotalOverlap* = 0.2) are restricted. The model prevents new territories from expanding into any cells where the expansion would cause either of these overlap restrictions to be violated for either the newly forming territory, or an existing territory. To simplify calculations and increase model efficiency we used the area of a typical territory (circle with $r = \text{NestProbMode}$) for calculating proportional, area-based limits on overlap, rather than the actual area of overlapping territories.

The model will continue adding new cells to a territory until one of two stopping conditions is met:

1. The model accumulates a minimum amount of total area and a minimum area of suitable habitat. When these conditions are met the new territory is considered successful and is kept. A list of territory attributes (D-1) and a list of the distance from each territory to the nearest adjacent territory are recorded for all successful territories.
2. The territory reaches its maximum area without satisfying condition one. When this occurs the territory is considered unsuccessful and is rejected.

The maximum and minimum territory areas are stochastically determined for each attempted territory. The maximum area is drawn from a skewed normal distribution (for the VICR *ModeMaxTerritoryRadius* = 6000 m, *LeftSDMaxTerritoryRadius* = 375 m, *RightSDMaxTerritoryRadius* = 75 m) with the left tail truncated (for the NCCR *LeftCutoffMaxTerritoryRadius* = 4886 m), while the minimum territory area is drawn from a symmetrical normal distribution for the VICR (*MeanMinTerritoryArea* = 7500 ha, *SDMinTerritoryArea* = 500 ha) with the left tail truncated (*MinTerritoryCutoff* = 6500 ha). Suitable habitat is calculated as the area of all cells with a foraging HSI greater than a minimum threshold (*SuitHabCutoff* = 0.5), with the area of each cell weighted by its foraging HSI score. By way of illustration, consider the following example. For one hectare cells, if a cell has a foraging HSI of 0.8, its area of suitable habitat is calculated as $1 * 0.8 = 0.8$ ha.

The stochastic elements of the territory model will cause it to output different results over multiple runs using the same inputs. This behaviour is intended to reflect both the influence on

territory formation of factors not included in the model, and the variability of these parameters in the real world. Due to this stochasticity, we recommend running the model multiple times for each scenario and using the distribution of outputs for further analyses or interpretation, rather than output from a single model run. For the results presented in this report, we ran five replicates of each scenario.

2.2.3. Analysis Scenarios

Current Conditions

This scenario is intended to capture the current configuration of habitat in the landscape, and estimate the maximum number of territories that could be supported by this configuration. Most attributes used for this scenario, including stand age, stand height, non-productive type, species cover, non-forest descriptor, and site index are directly derived from standard forest cover mapping based on aerial photography. Inventory type group is calculated from forest cover attributes. Elevation and slope are calculated from the standard provincial digital elevation model (25 metre pixels), and biogeoclimatic variants are derived from Version 6 Biogeoclimatic Maps¹.

Capable Habitat

The original objective for this scenario is to show the distribution of habitat prior to industrial logging and to estimate how many territories could have been supported in this historical landscape. However, we were unable to produce such a backcast scenario because we had neither accurate information on harvest history, nor a natural disturbance model. Therefore, we chose to estimate the maximum potential of the landscape for both habitat and territories by aging the entire landscape to old-growth (251 years).

As a forest ages, three of the landscape attributes used in our model may be affected: stand age, stand height, and Inventory Type Group. For stand age, we used a value of 251 years across the entire landscape. We used the Variable Density Yield Prediction (VDYP) model (MOF 1998) to predict stand height, based on site index and tree species composition. Where species information and/or site index were not available we used the forest cover value for stand height. We do not use a stand succession model, so we were unable to project Inventory Type Group. Therefore, we simply used the ITG calculated from forest cover attributes of the current landscape.

2.3. Haida Gwaii Conservation Region

2.3.1. Habitat Model

Overview

The habitat model used on Haida Gwaii is virtually identical to the model used in the other conservation regions, except for the way the model determines stand height. On the Haida Gwaii the model calculates stand height using growth and yield tables, rather than using the forest cover values for stand height. This calculation is done to ensure stand heights used in the current conditions scenario are consistent with heights used in the forecasting scenarios. Thus, any changes in habitat are due to temporal effects, rather than methodological artefacts. For the backcast scenario, we were unable to calculate stand height due to lack of information on the historic distribution of analysis units. Therefore, we used stand height values output from the

¹ <http://www.for.gov.bc.ca/hre/becweb/index.html>. Accessed March 30th, 2007.

Haida Gwaii Land Use Plan backcast analysis (Holt 2004). Further details on the backcast methodology can be found in the scenario description later in this document.

2.3.2. Territory Model

Overview

The Haida Gwaii version of the model employs a sequential packing algorithm to place nest areas, rather than the simultaneous iterative approach used in the more recent version implemented on the North and South Coasts.

There are three key differences between the 2006 version of the territory model as applied on Haida Gwaii (Figure 6), and the 2007 version of the model applied on the other conservation regions (Figure 4). The first difference is that the 2006 version forms territories after each nest placement, rather than forming territories after all potential nest locations have been identified. Thus, the placement of subsequent nests is restricted to locations in the landscape that are not within the territory of a previously established nest area. The second difference between the two versions is that in the 2006 version packing is achieved by repeatedly trying to fit new territories within a single configuration of existing territories, whereas the newer version of the model repeatedly tries completely different territory configurations and selects the arrangement that maximizes territory density. The third difference is that territories are first initiated at known, occupied nests sites in the landscape. These territories then form the basis for spacing of new territories. Once nest locations are chosen, territory formation in the 2006 version is very similar to the 2007 version, with minor differences.

Following, we will present the sequential nest placement algorithm used on Haida Gwaii, and briefly summarize the differences in how territories are formed in the two models. Since many aspects of the two model versions are similar, we have endeavoured to minimize repetition with the previous section by focussing only on the differences between the two versions.

Nest Placement Sub-Model

Following the establishment of territories at known nest areas, the model calculates the distance from every point in the study area to the nearest nest. New nests sites are then placed according to the same criteria used in the recent version of the model, and the territory formation sub-model attempts to form a territory following each nest. Upon successful establishment of a new territory, the model recalculates distance to the nearest nest across the landscape. The model stops trying to place additional territories following a specified number of consecutive failures to establish a territory (*MaxNumTerminations* = 50).

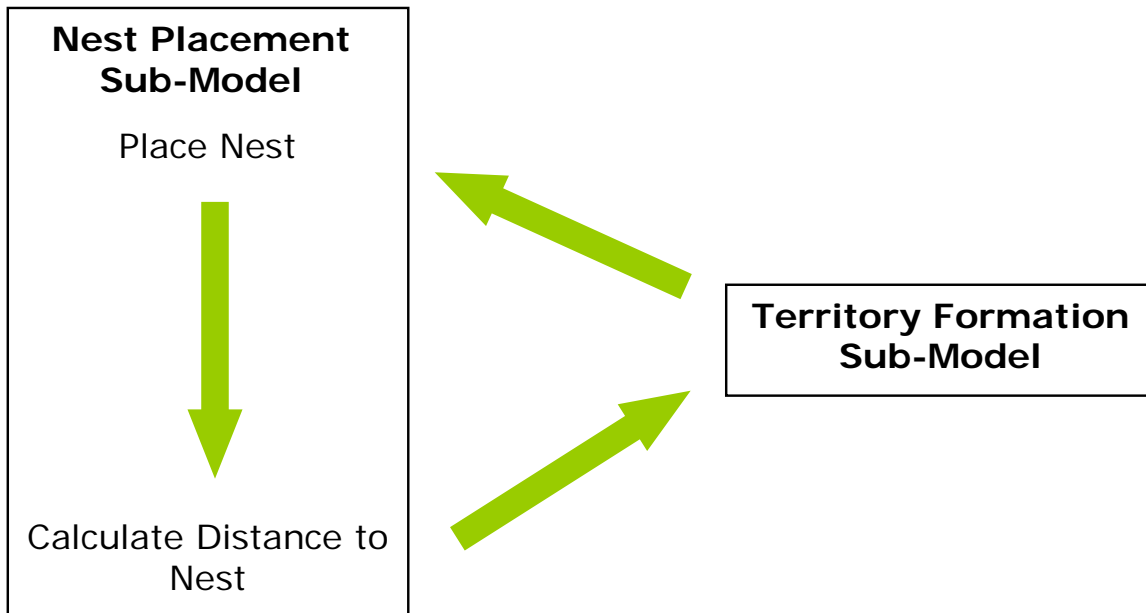


Figure 6: Flowchart of sequential packing approach used Haida Gwaii version of the territory model

A primary aim of the Territory Growth Sub-Model is to maintain spacing among territories that is similar to the spacing observed for existing territories on Haida Gwaii. In addition, the model also ensures that territories occur in areas with sufficient quality, quantity, and configuration of nesting and foraging habitat. Therefore, the model is designed to initiate territories under a fairly narrow range of circumstances.

The first territories to initiate in the model are located at known nest areas within the landscape. If territories fail to establish at all known nest areas, stochastic initiation locations are attempted until a territory is successfully established. These stochastic locations are chosen using the same criteria as the current model version, except nest initiation is prevented within the actual extent of existing territories rather than within the spacing distances used during nest placement.

Although the distance of each new nest from existing nest areas is sampled from a normal distribution, the final distribution of the distance from each nest area to the nearest adjacent nest may not match the original sampling distribution. For example, if territories initiated closer to existing nests fail more often than those initiated farther away, final nest spacing will be greater than specified in the original sampling distribution. Since this outcome does not fit with the ecological rationale as specified by the NOGO RIG, we devised a method of adjusting the sampling distribution to reduce biases caused by a non-random relationship between distance to the nearest nest area, and the probability of a territory failing. Specifically, if the actual distribution of distances from each existing nest to the next nearest nest is right-shifted, we sampled from a distribution that was left-shifted by the same amount. However, to maintain the absolute range of distances sampled we anchored the nearest tail of the shifted distribution at the third standard deviation of the target distribution. Furthermore, we did not allow the mode of the shifted distribution to deviate by more than one standard deviation from the mean of the target distribution (Figure 7).

In some landscapes, potentially large areas of suitable habitat could occur outside the portion of the landscape that falls within the maximum possible distance that new nests are allowed to establish from existing nests, resulting in no territories being established in these areas. This behaviour is undesirable, as it is reasonable to assume that NOGOs would eventually colonize these widely dispersed areas. Also, it is likely that inventories of existing nest areas are not

complete and some nests can and do occur in these apparently remote regions. This problem of excluding regions of suitable habitat for territory initiation will be exacerbated in scenarios or landscapes where there are a small number of known nests, or where a small proportion of the known nests successfully establish territories. In order to deal with this problem, once territories consecutively fail to establish a specified number of times (*terminationThreshold* = 25), the model eliminates the restriction on the upper end of the nest distance distribution by increasing the right standard deviation to a very large value².

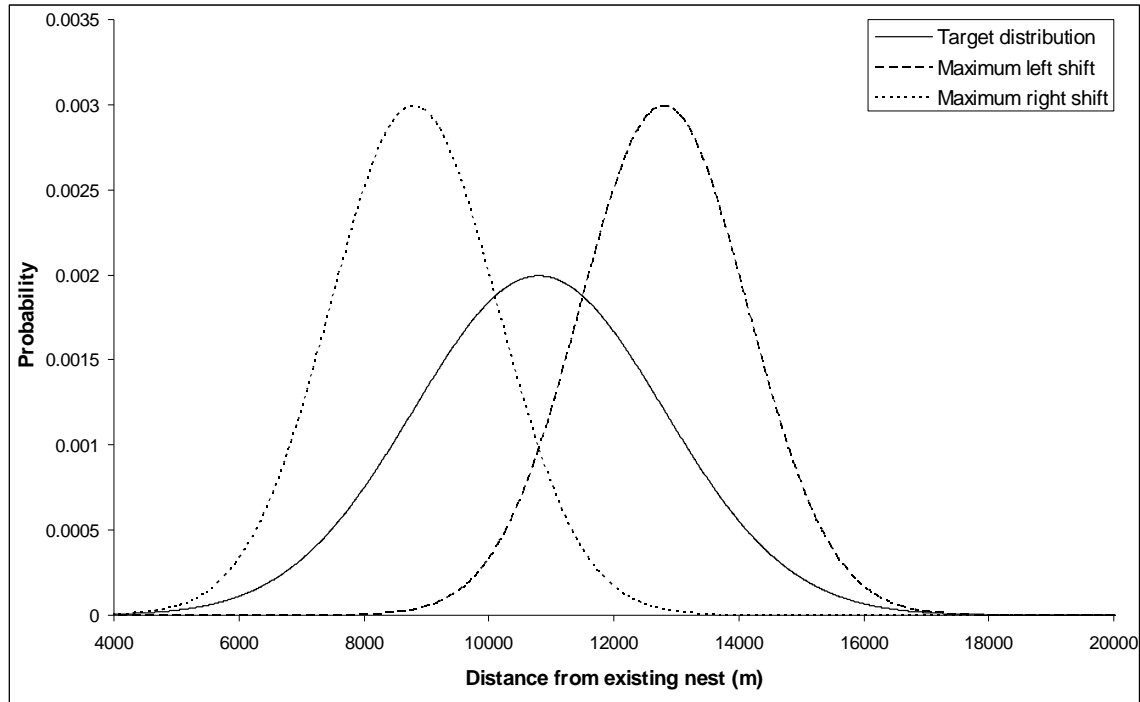


Figure 7: Distributions describing the probability that a new nest area will initiate a given distance away from an existing nest area

The solid line indicates the target distribution for the distance of each nest to the nearest adjacent nest. The dashed lines indicate the maximum amount the sampling distribution can shift to compensate for an equal shift of the population distribution in the opposite direction. Probabilities are based on distance increments of ten metres.

Territory Formation Sub-Model

The only difference between the Haida Gwaii and current territory formation sub-models is that the former uses the actual area of adjacent territories when calculating overlap restrictions, while the latter uses the area of a typical territory.

2.3.3. Analysis Scenarios

Current Conditions

The current conditions scenario for the Haida Gwaii Conservation Region is the same as the current conditions scenario for the other Conservation Regions.

² The right standard deviation is increased to the maximum distance between any two points in the landscape. A smaller standard deviation may result in too strong a bias for cells close to existing nests, while a larger standard deviation would result in the model frequently selecting cells for territory initiation that are outside the landscape.

Backcast

This scenario is intended to reflect the condition of the landscape prior to industrial forest harvesting. Specifically, the landscape attributes relevant to our analysis have been projected back in time to reflect conditions as they were in 1800 AD. The objective of the scenario is to provide a baseline for model outputs under natural conditions. This baseline can then be used to compare relative impact on habitat and territories under other scenarios, relative to the natural state of the landscape.

We used stand age and stand height layers developed as part of the Historic Condition modelling for the Haida Gwaii Land Use Management Plan (HGLUP; Fall *et al.* 2005). All harvested forest was converted to old-growth forest (age class 9), and assigned a stand height of at least 36.5 m. Because the NOGO Habitat model is insensitive to stand heights taller 27 m, any distinction in height beyond 36.5 m will have no effect on model outputs. For all non-harvested areas of the landscape, stand age and height from current forest cover data were used. Therefore, this backcast scenario does not account for natural disturbance in harvested areas.

Aging Only

The aging only scenario is intended to estimate the habitat potential of the landscape, barring any natural disturbances. In this manner, it performs the same function as the capable habitat scenario on the North and South Coasts. All cells with a stand age attribute were aged forward in time using the landscape projection model, until landscape composition reached equilibrium. The resulting landscape was used for subsequent model runs and analyses.

Management Projection

The management projection scenario develops a time series of landscape conditions for 20, 50, 100 and 250 years into the future, based on the 'Base Case 2' (BC2) scenario from the HGLUP (Fall *et al.* 2005). This scenario provides perspective on how current forest harvesting methods and patterns will influence NOGO habitat and potential territories in the future.

The landscape time series used by the habitat and territory models was generated using the landscape projection model. Management actions were based on assumptions from Timber Supply Review 2, updated to reflect current management. These updates included: (1) spatial representation of management units in Queen Charlotte Islands TSA; (2) 2588 ha of low-site cedar stands designated as heli-operable; and (3) in TFL 47, low volume (<200 m³/ha), old (>250 years), cedar-dominated stands were included in the THLB to reflect current harvesting.

2.4. Model verification

For the habitat model we sampled the attributes of 10 000 randomly chosen cells within the selected landscape to verify the calculations made by the model. We exported the values of all input attribute layers into an Excel spreadsheet which independently calculated the HSI scores from the input layers. We then compared the values calculated in Excel with the values calculated in the model to ensure they were consistent. Following some minor modifications, we were able to ensure that our code was correctly implementing the parameters and formulas provided to us by RIG for the habitat models.

While we did not conduct a similar formal verification of the territory model, both the modelling team and members of the NOGO RIG checked the model output for any obvious errors or

discrepancies. In addition, the NOGO RIG is currently working to ground-truth and verify output from the territory models on Haida Gwaii and North Coast.

3. Analysis Results

3.1. North Coast Conservation Region

3.1.1. Nest and Foraging Habitat

For the current conditions scenario, the spatial distribution of nesting (Figure 8) and foraging (Figure 9) habitat was similar across the NCCR. Most of the outer coast is low quality habitat, interspersed with patches of moderate habitat. Most of the moderate to high quality habitat occurs along a North-South band on the western slope of the Coast Mountain Range, with the highest concentrations occurring around Kitimat. Within these broad regions, spatial distribution of habitat quality closely follows the linear-tending, deeply-incised valley complexes of this conservation region, with higher quality habitat generally occurring at lower elevations.

For nesting habitat, the majority of the area in the conservation region is presently nil-quality habitat (65%), while a very small proportion of the landscape is considered suitable habitat (8% moderate; 5% high; Figure 10). While foraging habitat was similarly distributed spatially to nesting habitat, it was generally higher quality for a given location. Only 12% of the landscape was classified as nil-quality foraging habitat, mostly due to missing data rather than intrinsic characteristics of the landscape. Slightly less than a third of the landscape was classified as suitable foraging habitat (15% moderate; 11% high).

For much of the NCCR, occurrence of capable habitat showed a similar spatial pattern to that of current habitat (Figures 8 and 9). However, the south portion of the conservation region, adjacent to the northern tip of Vancouver Island, showed markedly more suitable nesting and foraging habitat than is present in the current landscape. At the landscape scale, the largest differences in foraging habitat quality between the two scenarios are in the high and low classes. For nesting habitat, the largest shifts are in the high and nil classes. Overall, the area of suitable habitat in the current landscape versus capable habitat is 20% lower for foraging habitat and 35% lower for nesting habitat.

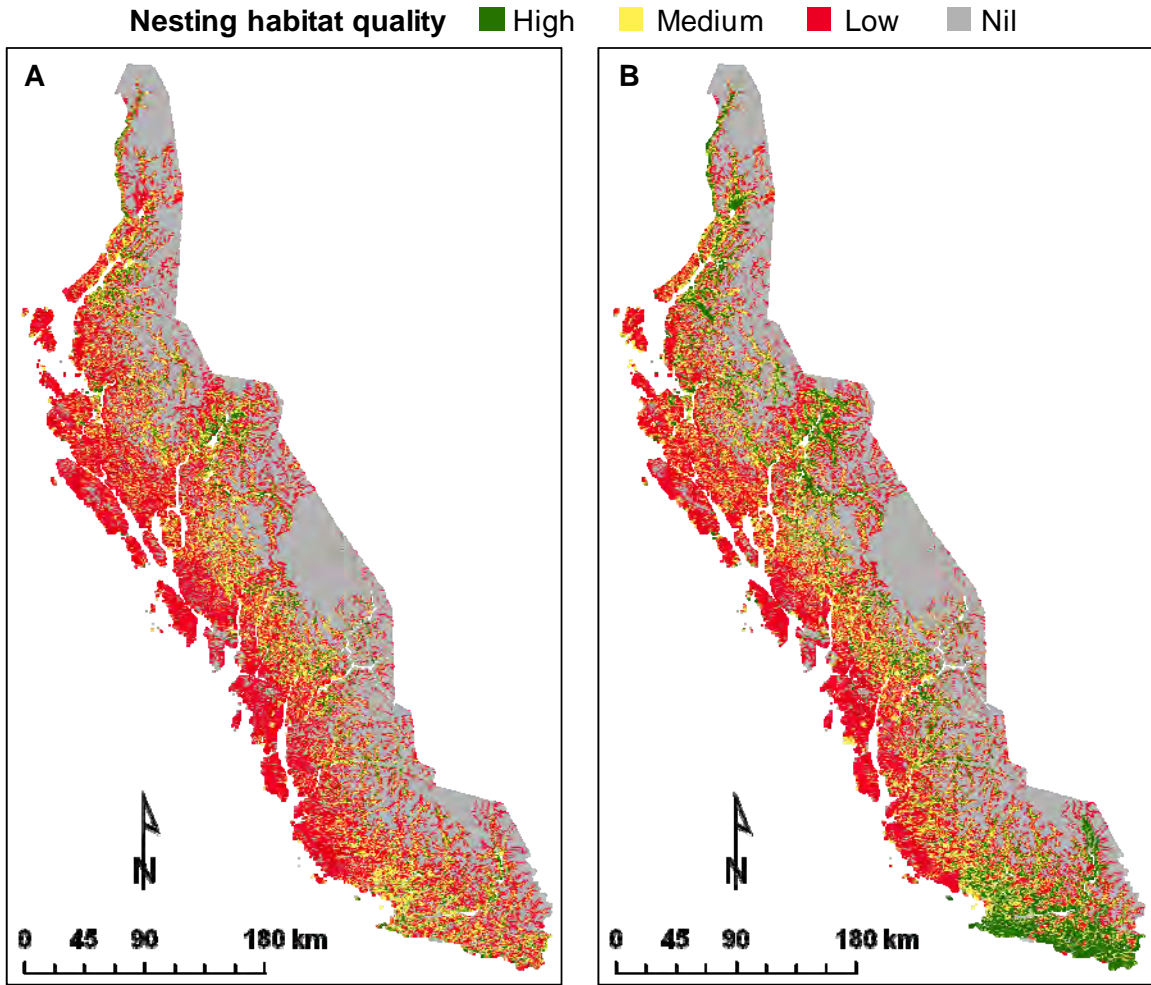


Figure 8: Distribution of nesting habitat in the NCCR for the current landscape (A) and capable habitat (B) scenarios.

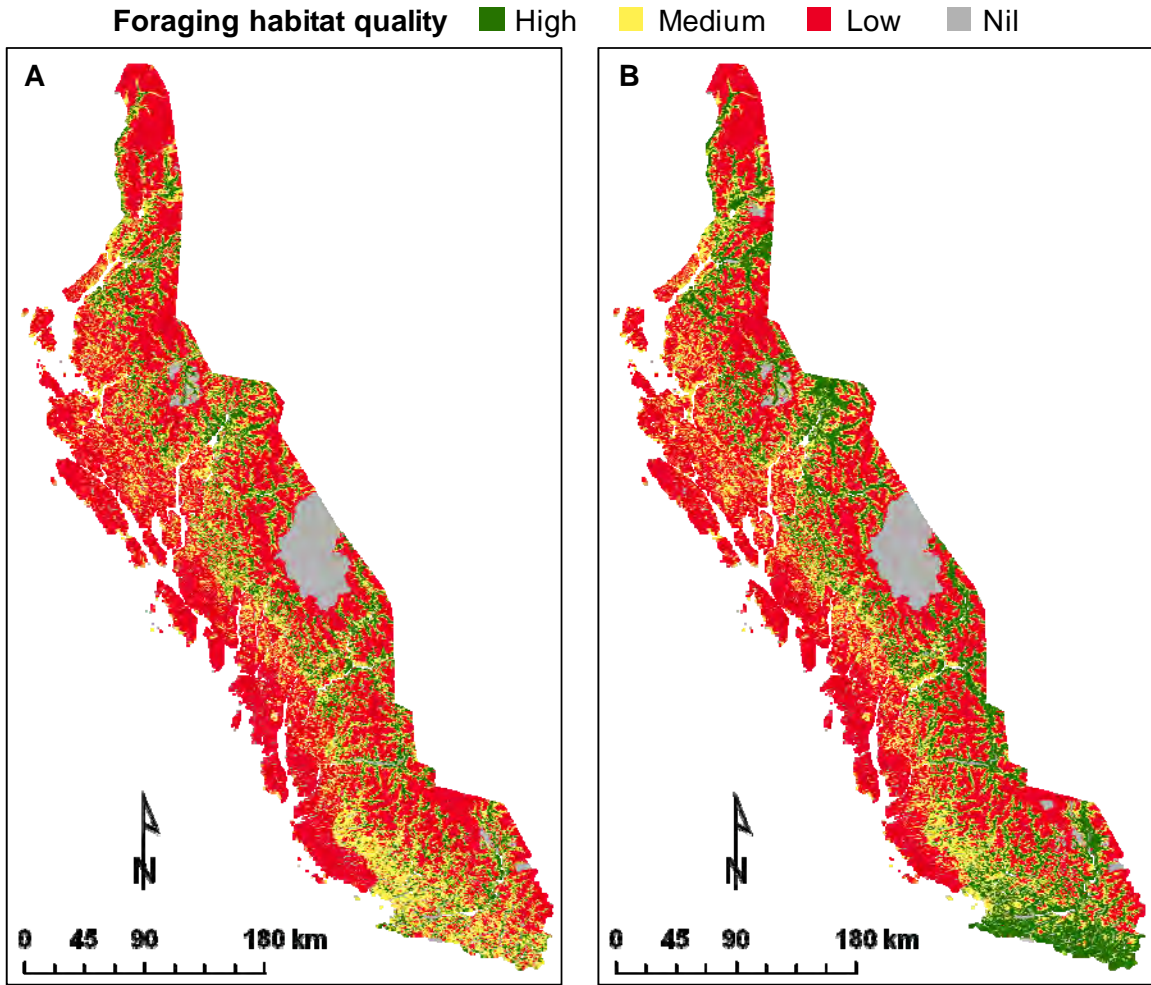


Figure 9: Distribution of foraging habitat in the NCR for the current landscape (A) and capable habitat (B) scenarios.

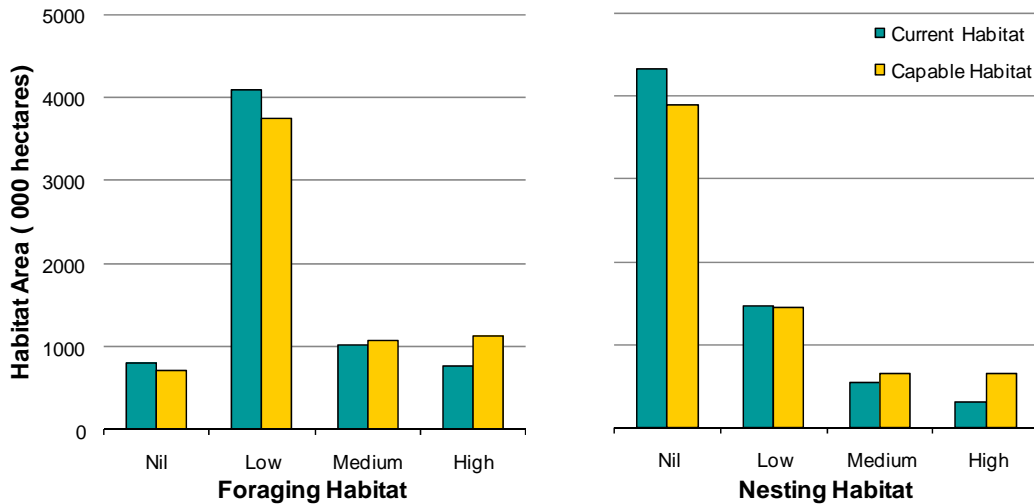


Figure 10: Area of foraging and nesting habitat classes for the current landscape and capable habitat scenarios in the North Coast Conservation Region

3.1.2. Territories

For both the current landscape and capable habitat scenarios, the habitat threshold used for evaluating the feasibility of territory had a very large effect on the number of territories that could be supported in the landscape (Figure 11). In addition, the variability between replicates was small relative to the differences between habitat thresholds. For the high and moderate habitat thresholds, territories seemed to clump around larger pockets of suitable foraging habitat; for the low threshold, territories were tightly packed along the entire western slope of the Coast Mountains (Figure 12).

While the differences between scenarios were less marked than the effect of habitat threshold, there were considerably more territories in the capable habitat scenario for high and medium habitat thresholds (Figure 11). This difference was largely driven by a large increase in the number of territories at the south end of the conservation region (12). At the low habitat threshold, the landscape appeared to be saturated with territories under current conditions, because accounting for capable habitat had virtually no effect on the number of territories.

Overall, the model placed territories as expected in relation to nesting and foraging habitat (Figures 13 and 14). Higher density patches of habitat are typically associated with a territory, and the shape of the territories show an appropriate correspondence to the underlying pattern of foraging habitat. However, there are some patches of habitat that appear sufficient to support a territory, but are not associated with a modeled territory.

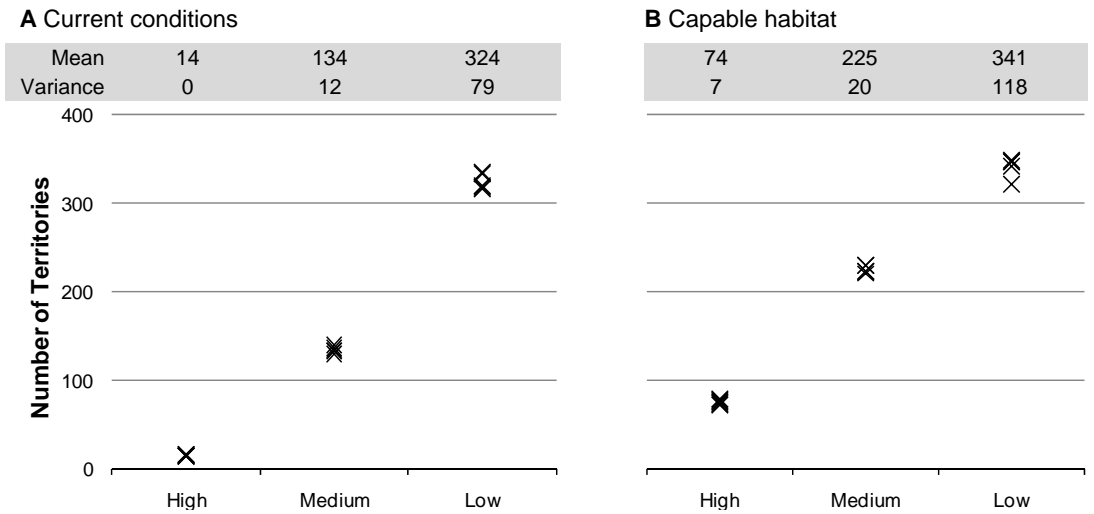


Figure 11: Effect of habitat threshold on the number of territories supported in the NCCR for the current conditions and capable habitat scenarios (N= 5).

Mean number of territories and associated variance for each scenario are indicated at the top of the figure. Additional replicates greater than one that produce the same number of territories have been shifted on the y-axis by increments of 0.05 to facilitate interpretation.

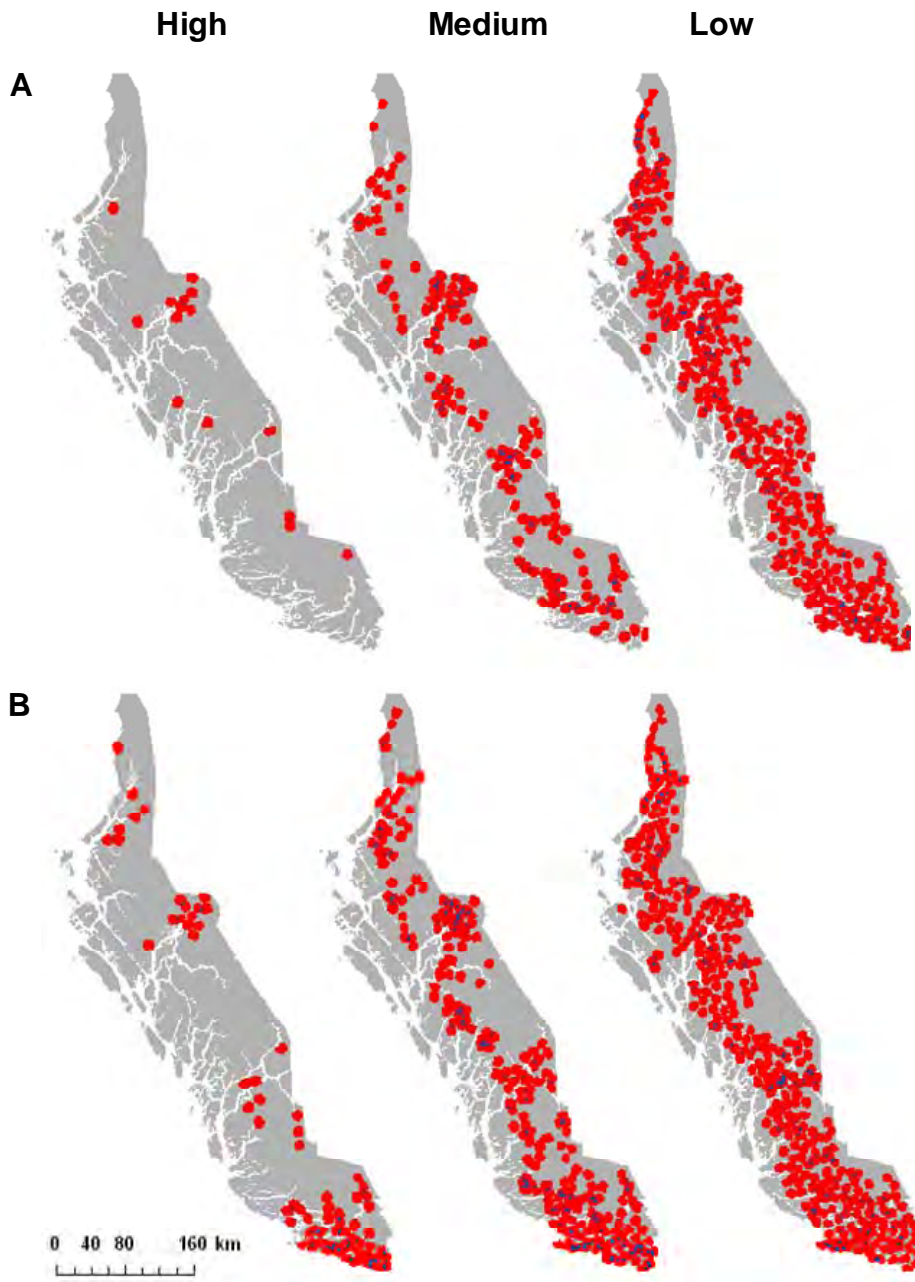


Figure 12: Spatial arrangement of territories in the North Coast Conservation Region for one iteration of the model for the current conditions (A) and capable habitat (B) scenarios, for three habitat thresholds.

Red indicates presence of a single territory, while blue indicates cases where one or more territories overlap. Grey indicates the extent of the study area.

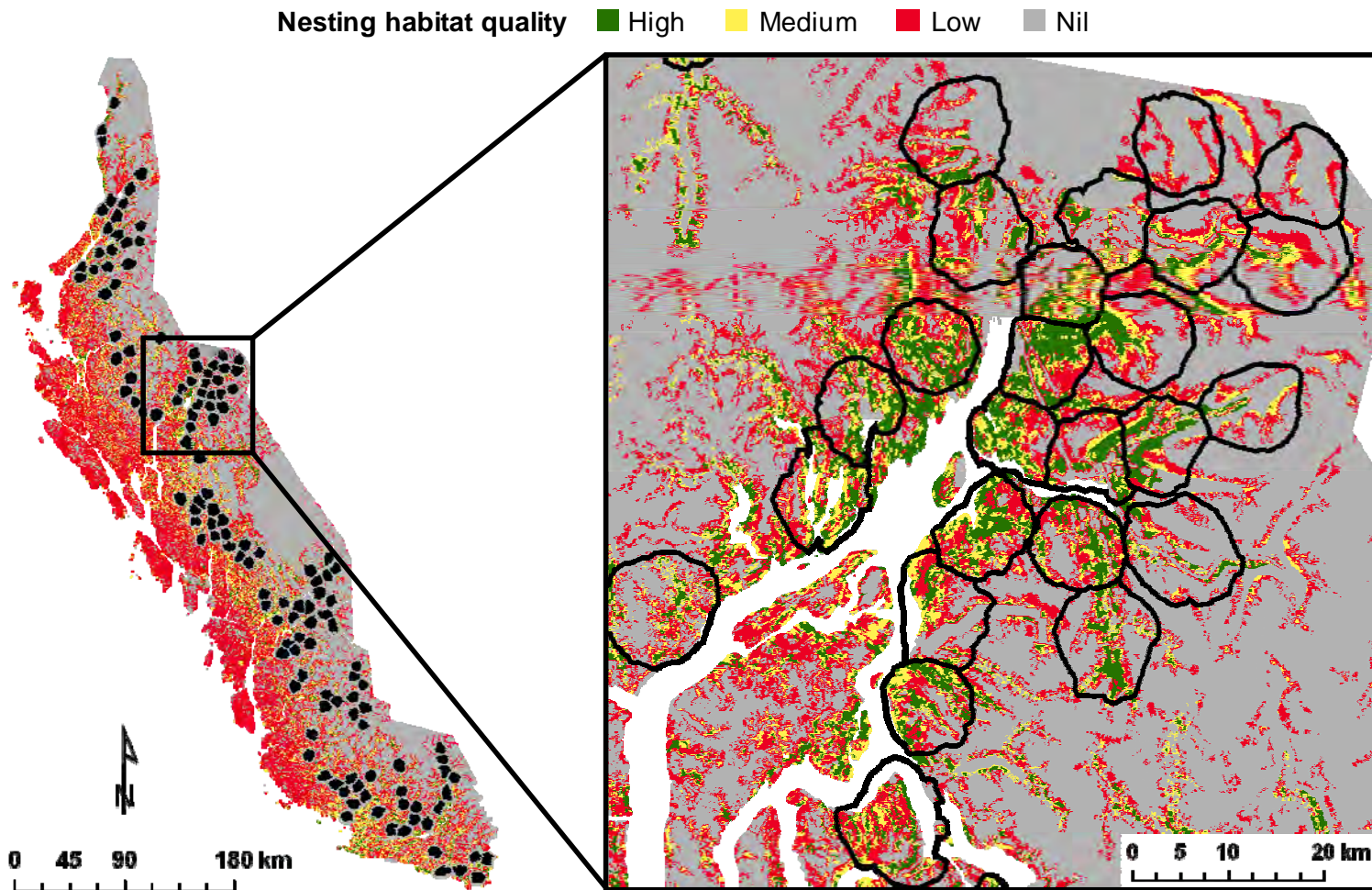


Figure 13: Close up of territory shape and arrangement in relation to the distribution of nesting habitat.

Red polygons indicate individual territories, with overlap between adjacent territories not shown.

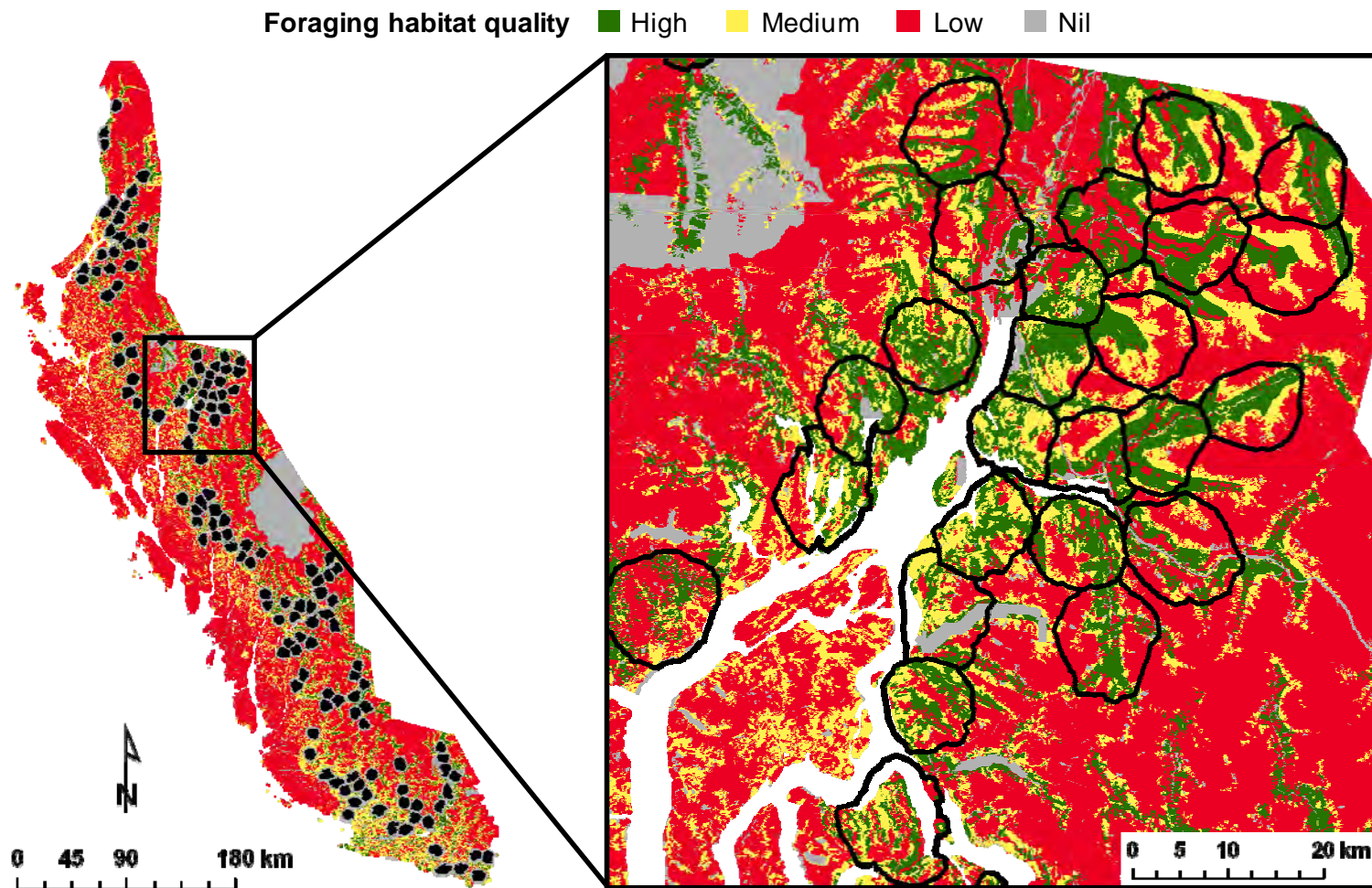


Figure 14: Close up of territory shape and arrangement in relation to the distribution of nesting habitat.

Black polygons indicate individual territories, with overlap between adjacent territories not shown.

3.2. South Coast Conservation Region

3.2.1. Nesting and Foraging Habitat

In the current landscape, nesting (Figure 15) and foraging (Figure 16) habitat form a fine-scale mosaic of habitat classes at low- to mid-elevations. At higher elevations, nesting habitat is generally non-existent and foraging habitat is of low quality. The trend in areas of the landscape in each habitat class (Figure 17) is similar to that observed on the North Coast. For foraging habitat, low is the most common class, followed by medium, then high. For nesting habitat, the area in each habitat decreases across the continuum from low to high quality habitat. Forty-two percent of the landscape is classified as suitable foraging habitat and 44% of the landscape is suitable nesting habitat.

For habitat capability scenario, almost the entire coast line of the conservation region, extending up into adjacent valleys is classified as high quality nesting and foraging habitat. This is a marked difference from current habitat conditions, where much of this area as comprised of a patchwork of low and moderate quality habitat. Overall, the area of suitable habitat in the current landscape versus capable habitat is 31% lower for foraging habitat and 52% lower for nesting habitat.

Foraging habitat quality ■ High ■ Medium ■ Low ■ Nil

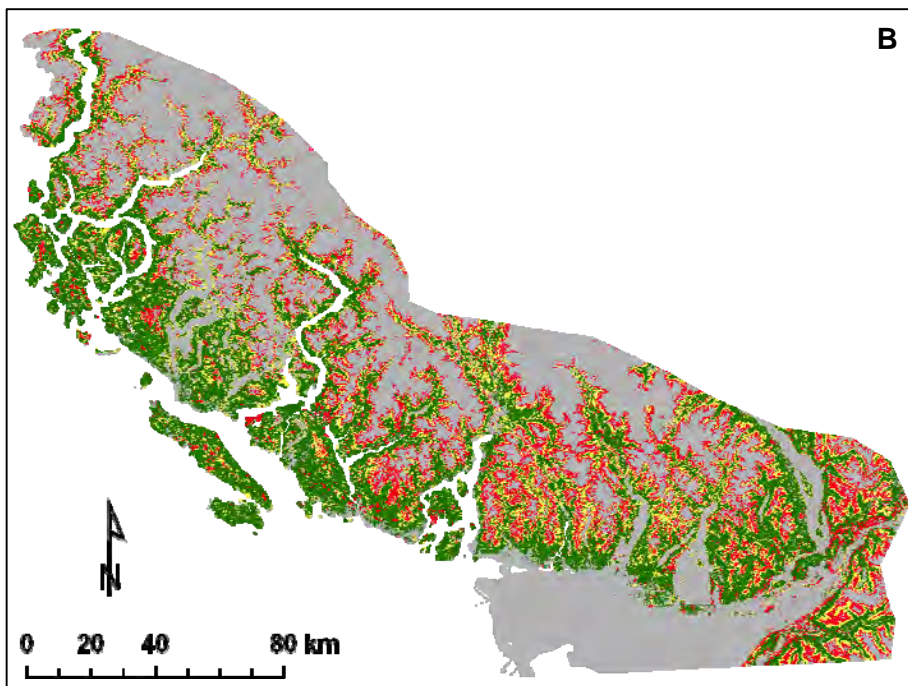
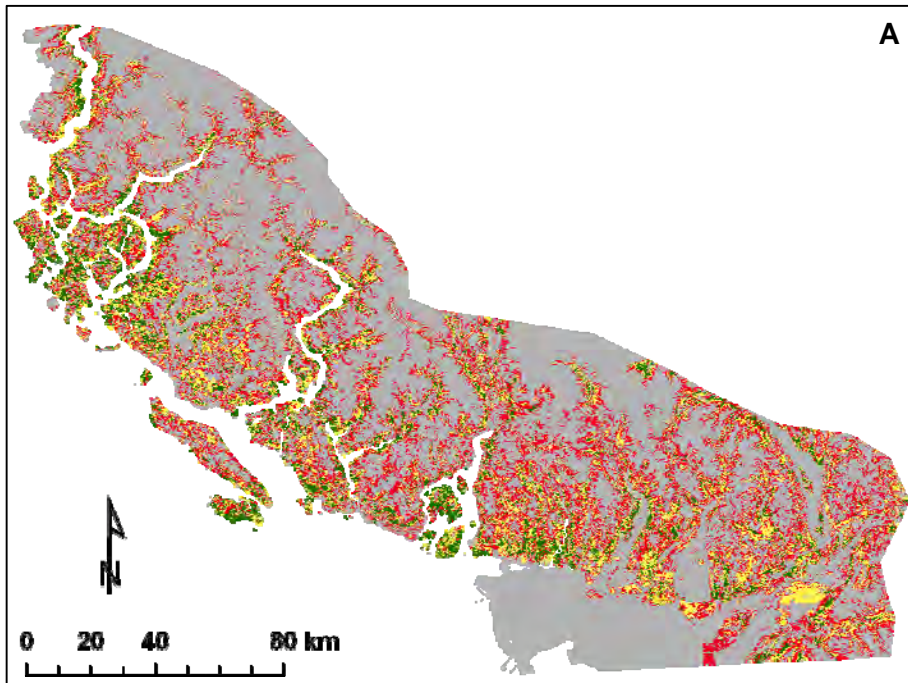


Figure 15: Distribution of nesting habitat in the SCCR for the current landscape (A) and capable habitat (B) scenarios.

Foraging habitat quality ■ High ■ Medium ■ Low ■ Nil

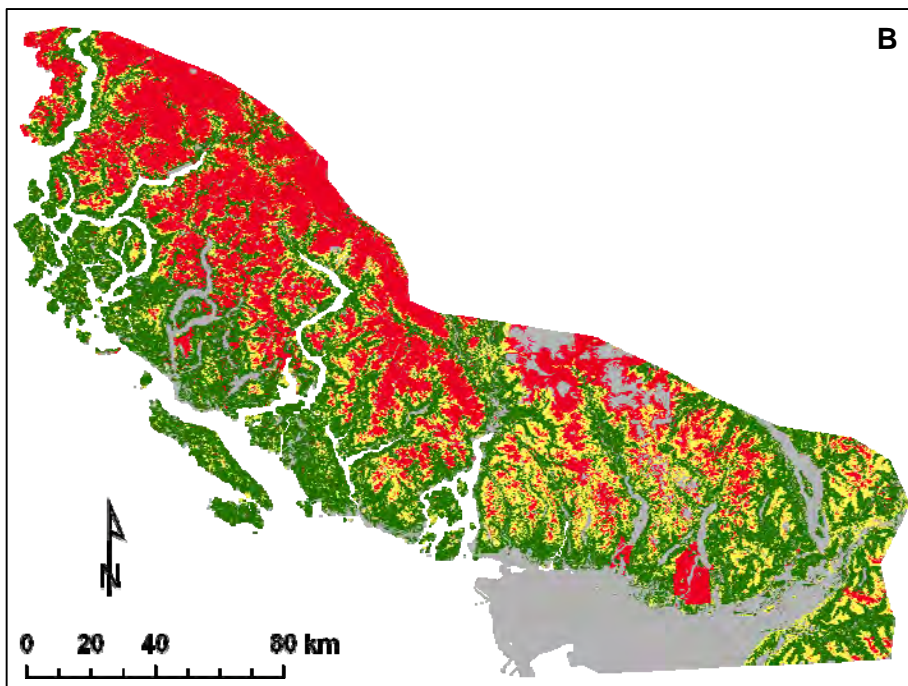
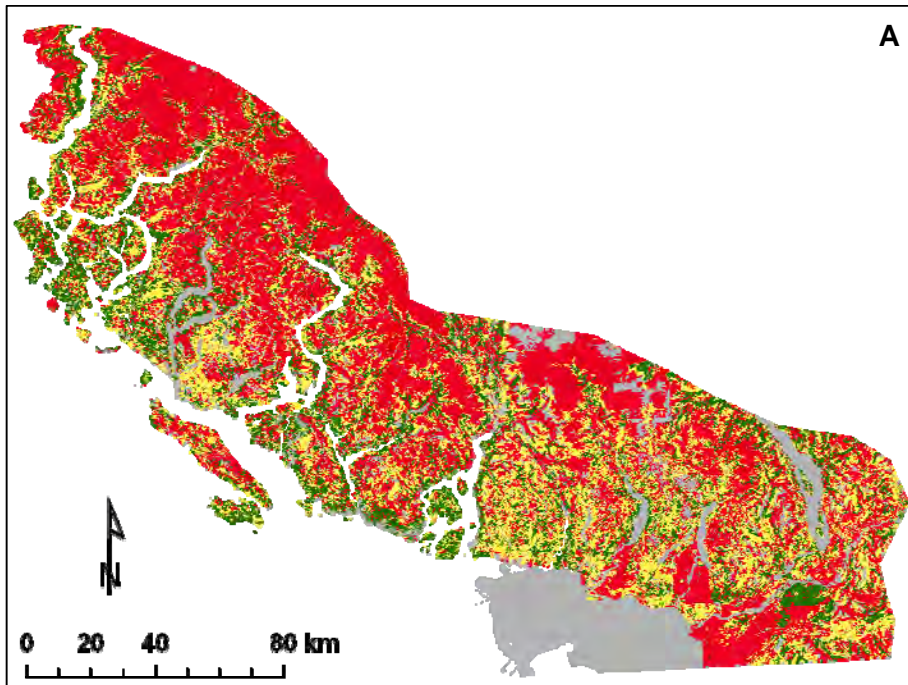


Figure 16: Distribution of foraging habitat in the SCCR for the current landscape (A) and capable habitat (B) scenarios.

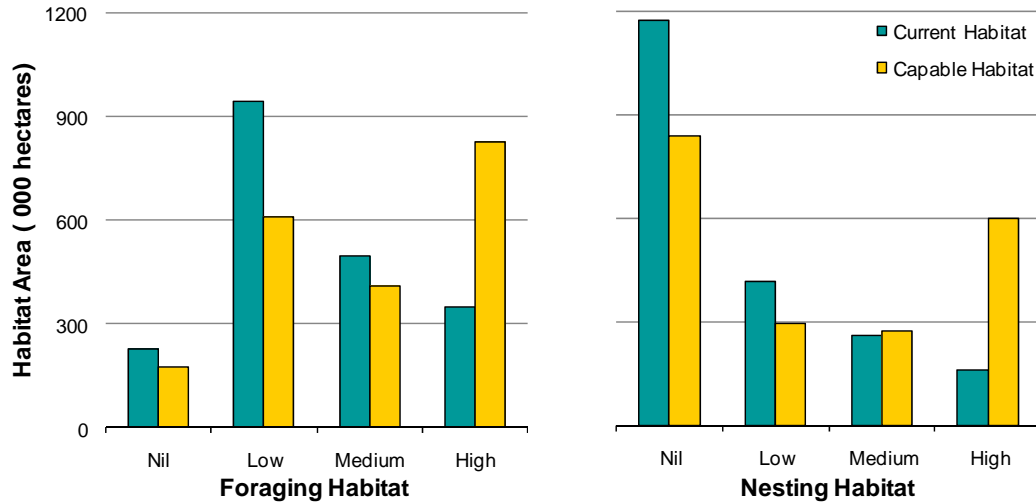


Figure 17: Area of foraging and nesting habitat classes for the current landscape and capable habitat scenarios in the South Coast Conservation Region.

3.2.2. Territories

For the current conditions scenario, the habitat threshold had a large effect on the number of territories that could be supported by the landscape, with the greatest difference occurring between the low and medium thresholds (Figure 18). For the high threshold, the most concentrated clump of territories occurs in the GVRD watersheds on the east side of Howe Sound; territories are more evenly distributed throughout the landscape for the medium and low thresholds (Figure 19).

When placing territories based on capable habitat, the effect of habitat threshold was much smaller. While there were few territories under the high threshold the difference was minor relative to the other two thresholds. In contrast to the current conditions scenario, territories under the high threshold were dispersed throughout the conservation region. The difference between the medium and high thresholds in territory numbers and distribution was negligible.

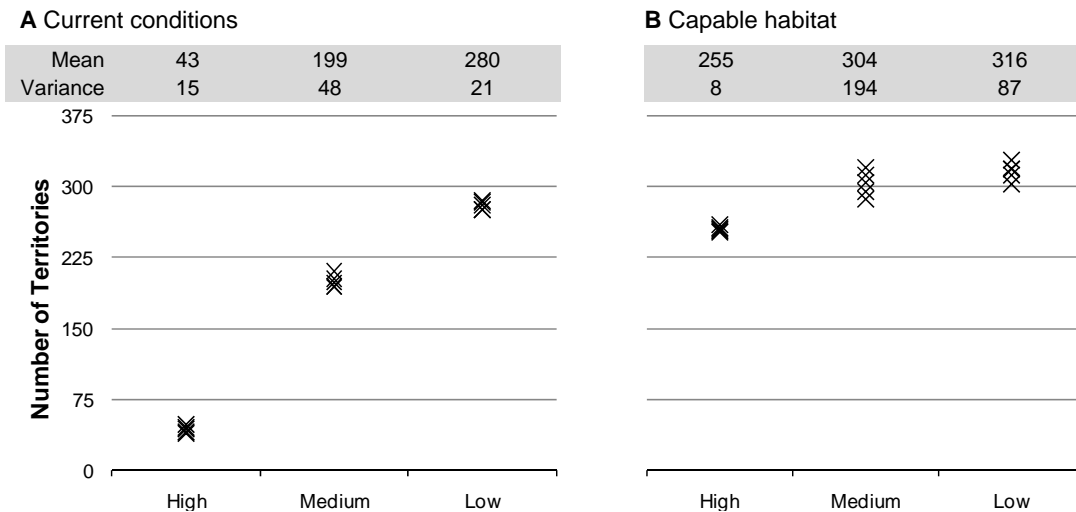


Figure 18: Effect of habitat threshold on the number of territories supported in the SCCR for the current conditions and capable habitat scenarios (N= 5).

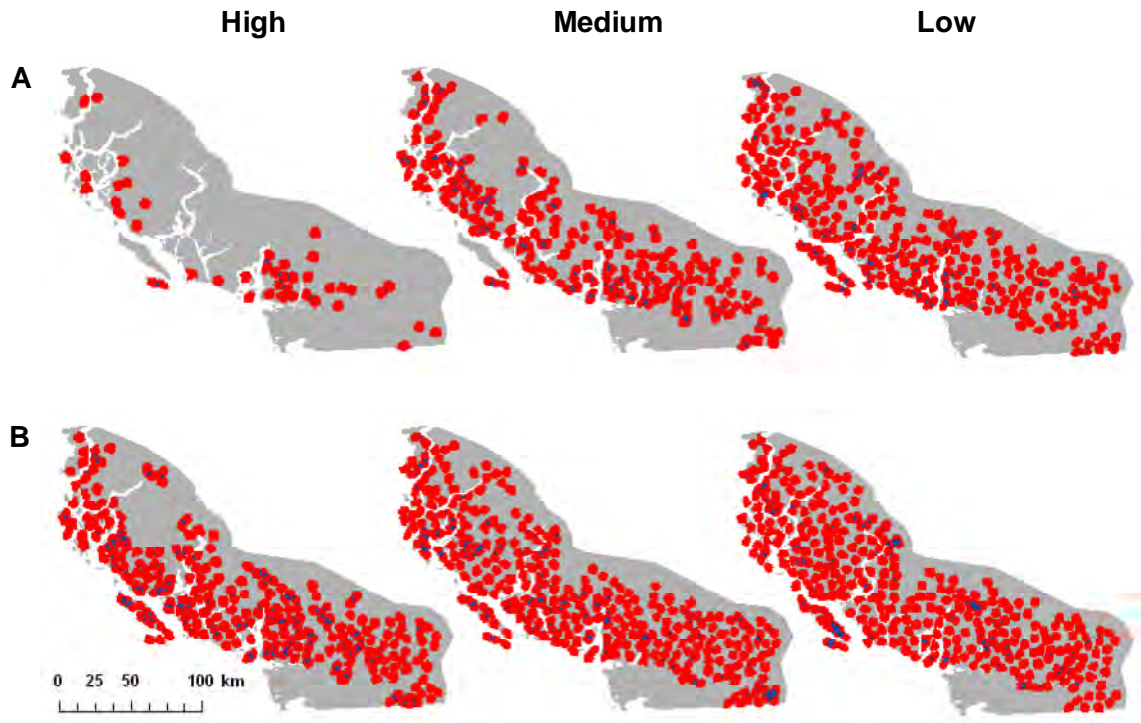


Figure 19: Spatial arrangement of territories in the South Coast Conservation Region for one iteration of the model for the current case (A) and capable habitat (B) scenarios, for three habitat thresholds.

Red indicates presence of a single territory, while blue indicates cases where one or more territories overlap. Grey indicates the extent of the study area.

3.3. Vancouver Island Conservation Region

3.3.1. Nesting and Foraging Habitat

In the current landscape, suitable nesting and habitat are distributed throughout Vancouver Island with the highest quality habitat occurring in small to moderate sized patches of unlogged forest (Figure 20). The southwestern coast of the island is primarily low and nil quality habitat; however, much of this region is private land for which forest cover data is not available. In the central Island, much of Strathcona Park is nil habitat due to the classification of much of the land cover as rock. Patterns in the amount of nesting and foraging habitat among habitat classes are similar to those observed in the North and South Coast Conservation regions (Figure 22), with total proportions of suitable habitat greater than the NCCR and less in the SCCR; 17% of the landscape is suitable nesting habitat and 35% is suitable foraging habitat.

For the capable habitat scenario, high quality nesting and foraging habitat occurs in large patches throughout most of the study area (Figure 21). As previously, the southwest corner is an exception due to lack of data for private lands. Another exception is Clayoquot Sound in the middle of the west coast; in this sub-region, high quality nesting and foraging habitat occur in smaller and more fragmented patches due to a high proportion of cedar leading stands which provide sub-optimal habitat. Similar to the current landscape, proportions of suitable habitat in the region are greater than the NCCR and less than the SCCR (Figure 22). For the capable habitat scenario, 51% of the landscape is suitable foraging habitat and 38% is capable nesting habitat.

Nesting habitat quality ■ High ■ Medium ■ Low ■ Nil

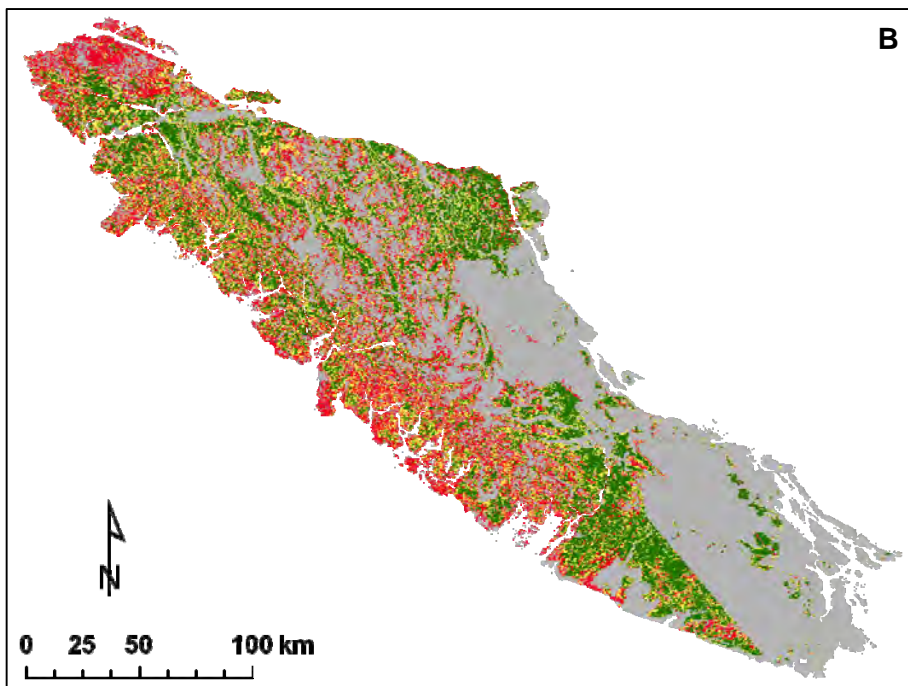
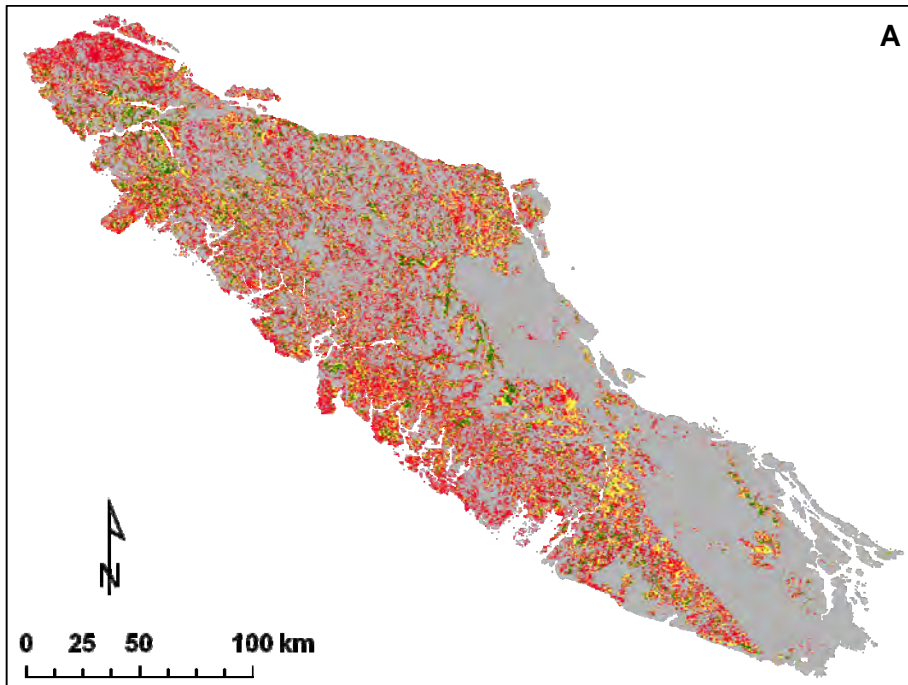


Figure 20: Distribution of nesting habitat in the VICR for the current landscape (A) and capable habitat (B) scenarios.

Foraging habitat quality ■ High ■ Medium ■ Low ■ Nil

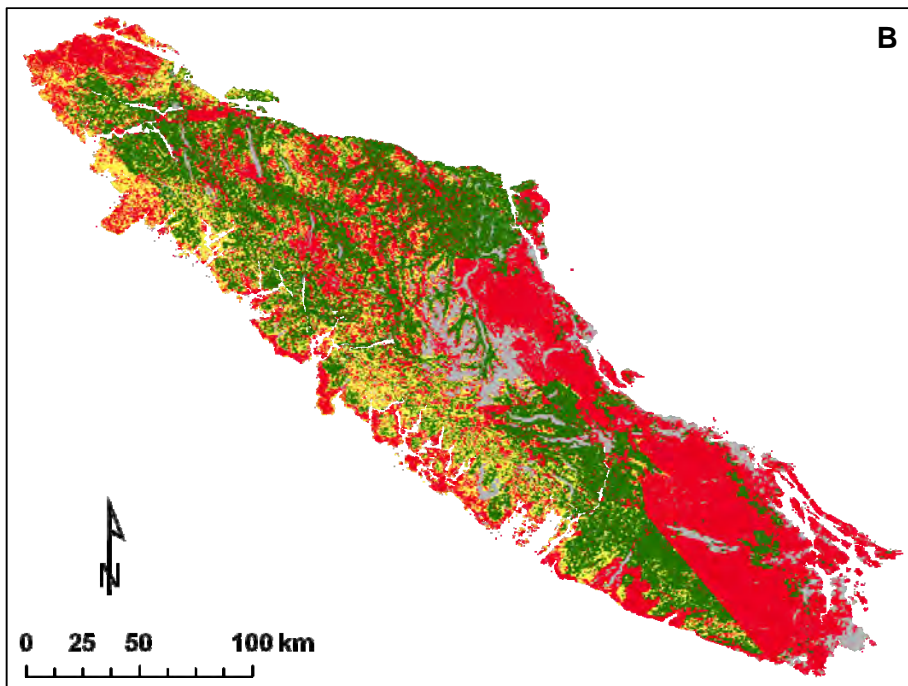
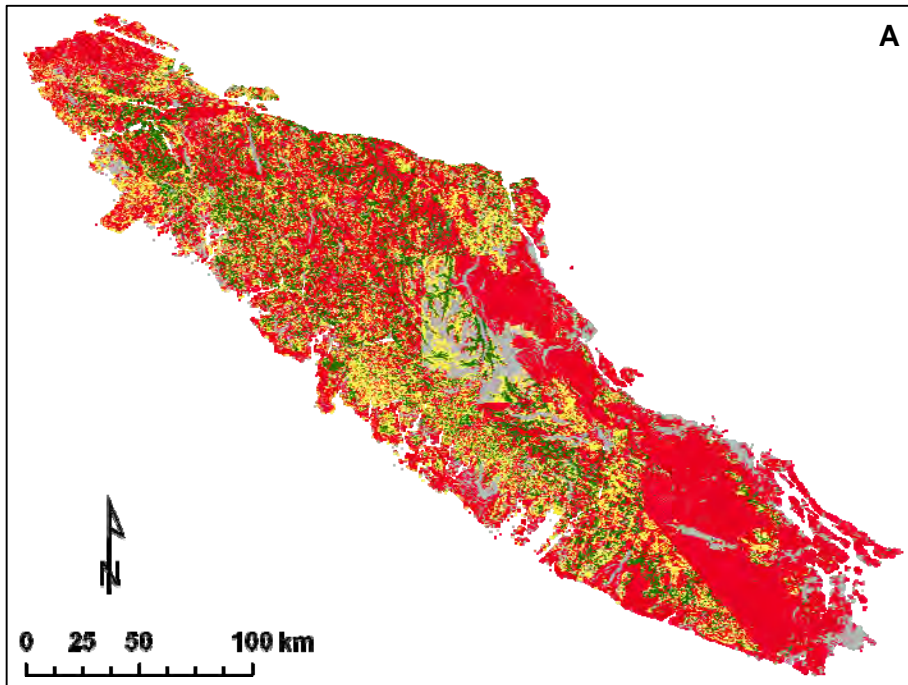


Figure 21: Distribution of foraging habitat in the VICR for the current landscape (A) and capable habitat (B) scenarios.

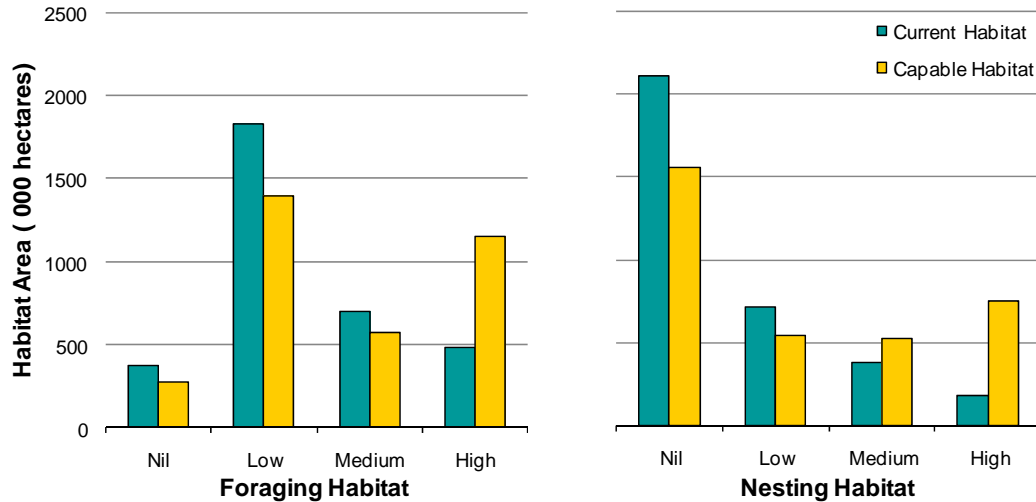


Figure 22: Area of foraging and nesting habitat classes for the current landscape and capable habitat scenarios in the Vancouver Island Conservation Region.

3.3.2. Territories

In the current landscape, the threshold area of suitable habitat used to specify viable territories had a large influence on the number of potential territories that were predicted in the VICR. Under the high threshold less than 100 territories were predicted, while using the low threshold produced greater than 400 territories. With the exception of the southwestern corner of the region, territories were broadly distributed throughout the study area for the low and moderate thresholds. For the high threshold, territories were distributed throughout the study area, but were primarily restricted to patches of old forest.

For the capable habitat scenario, there was no discernable difference in the mean number of territories predicted between the medium and low habitat thresholds (Figure 23). Using the high habitat threshold, 20 - 25% fewer territories were predicted relative to the other two thresholds, primarily due to a lack of territories at higher elevations and in hyper-maritime ecosystems (Figure 24).

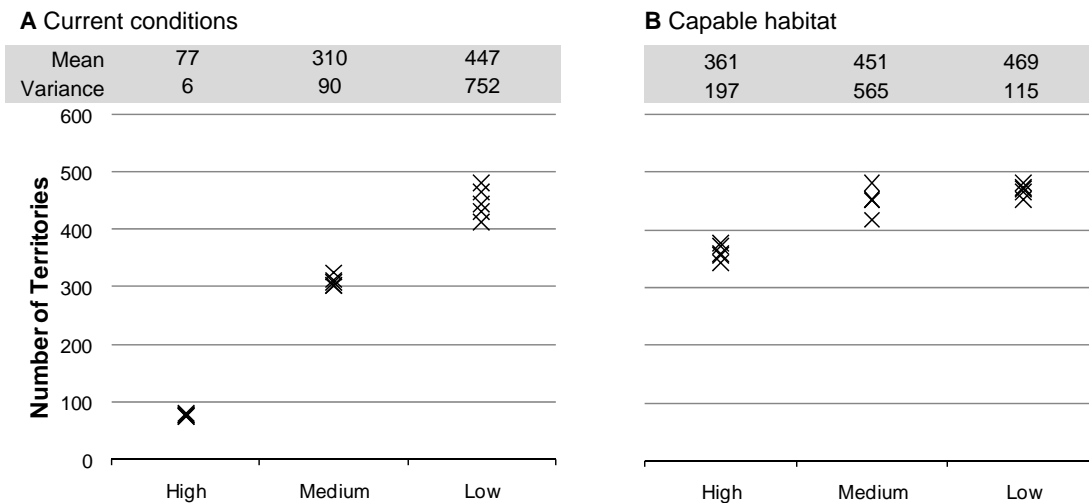


Figure 23: Effect of habitat threshold on the number of territories supported in the VICR for the current conditions (A) and capable habitat (B) scenarios (N= 5).

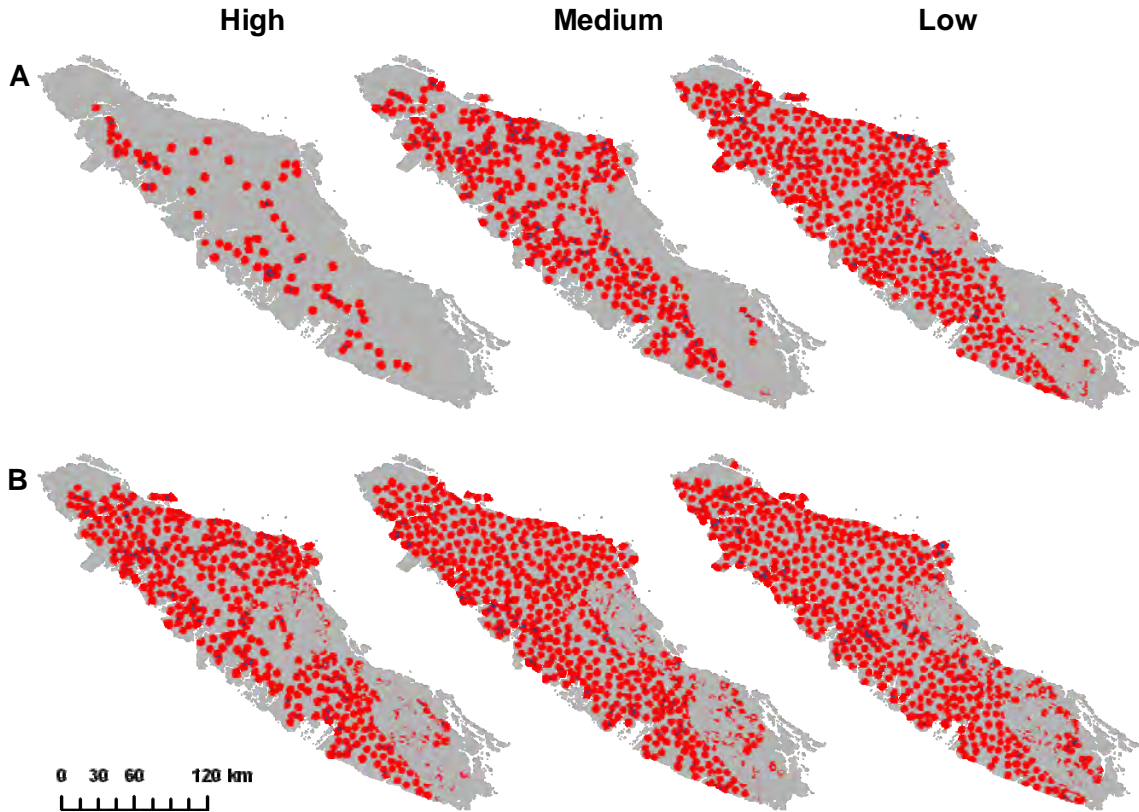


Figure 24: Spatial arrangement of territories in the Vancouver Island Conservation Region for one iteration of the model for the current case (A) and capable habitat (B) scenarios, for three habitat thresholds.

Red indicates presence of a single territory, while blue indicates cases where one or more territories overlap. Grey indicates the extent of the study area. Note in SE corner of the study area some territories are only partially visible because results on private lands have been masked.

3.4. Haida Gwaii Conservation Region

3.4.1. Nesting and Foraging Habitat

Historically, the best quality foraging and nesting habitat is concentrated in the central portion of Graham Island, extending south on to the east coast of Moresby (25). Nesting habitat is historically more concentrated on Graham Island, east of the Coast Ranges, with the exception of the Naikoon peninsula, and on the very north-east corner of Moresby Island (26).

For both nesting and foraging habitat under Current management (Base Case 2), across a time series from 200 years in the past to 250 years into the future, the greatest changes in habitat occurs in the period leading up to the present (25 and 26). The amount of foraging habitat in the landscape reaches equilibrium about 20 years into the future, and nesting habitat reaches equilibrium in about 50 years.

As expected, under the Aging Only scenario higher quality nesting and foraging habitat begin to recover immediately, and reach equilibrium in around 100 years (27 and 28). At this equilibrium, the distribution of the landscape among different habitat types is very similar to the Backcast scenario, for both foraging (25) and nesting habitat (26). For both habitat types, the primary

change is conversion of low or nil quality habitat to high quality habitat – a straightforward consequence of stands growing older and taller.

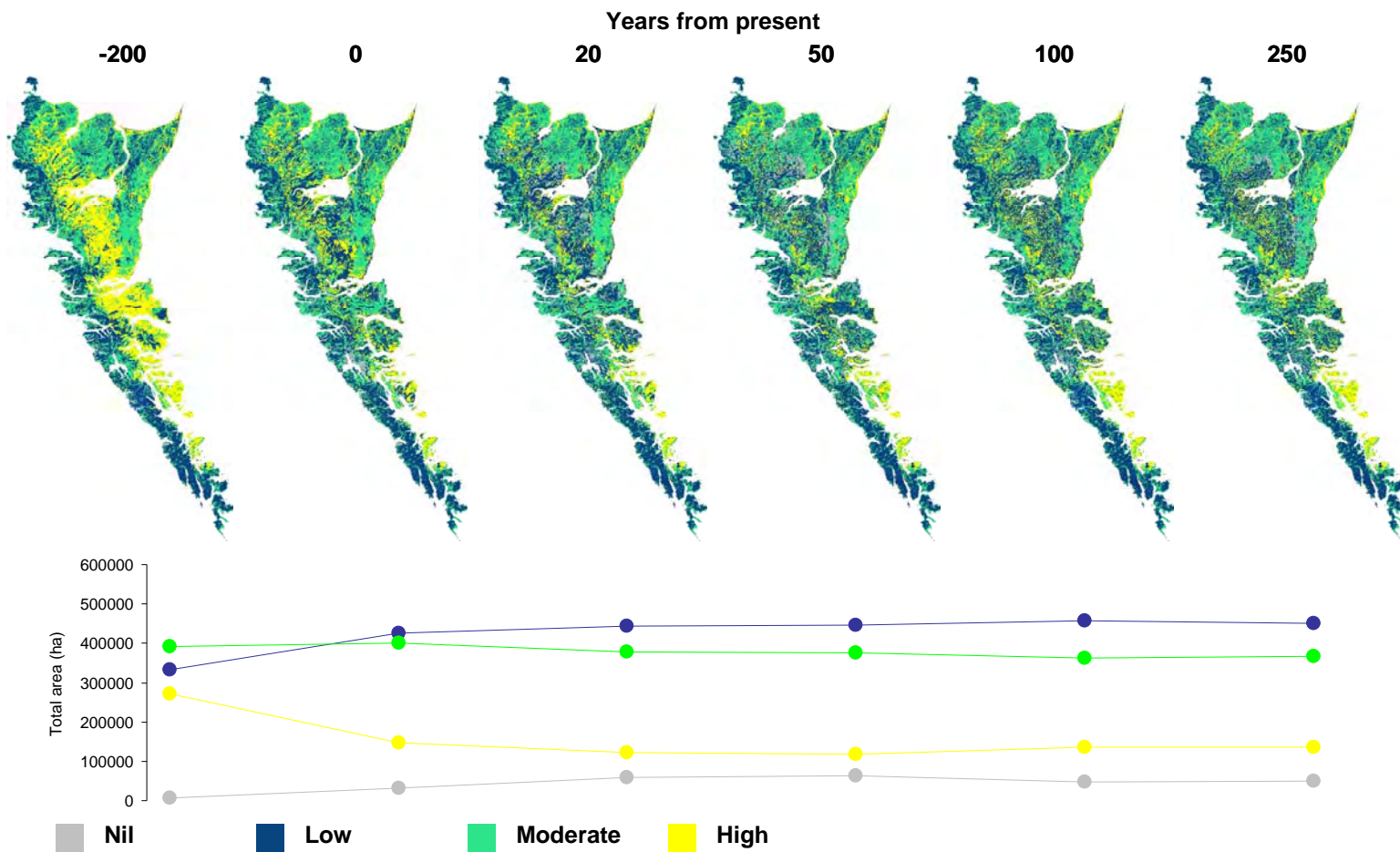


Figure 25: Projected changes in foraging habitat on the Haida Gwaii landbase under the Base Case 2 (BC2) land management scenario.

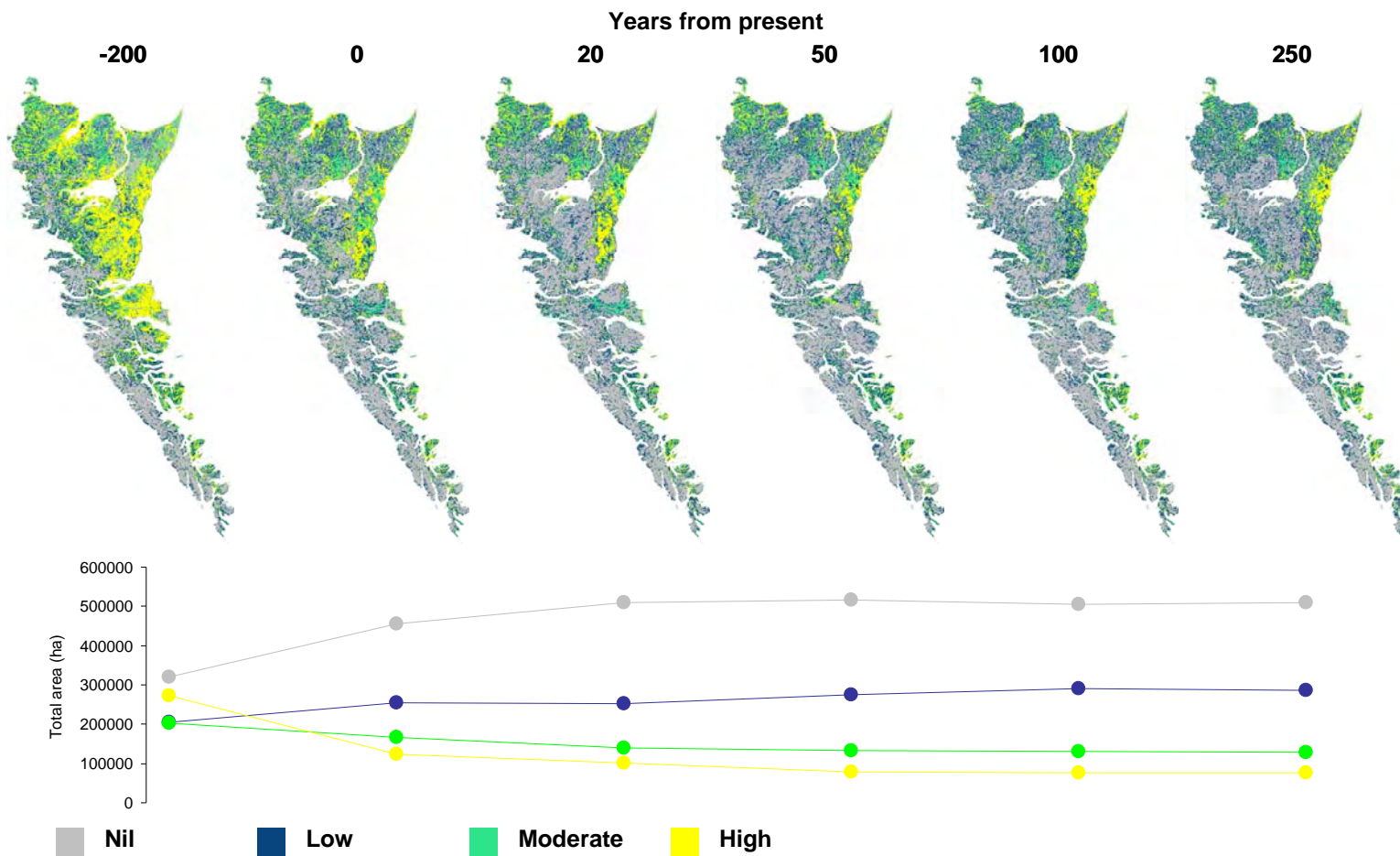


Figure 26: Projected changes in nesting habitat on the Haida Gwaii landbase under the Base Case 2 (BC2) land management scenario.

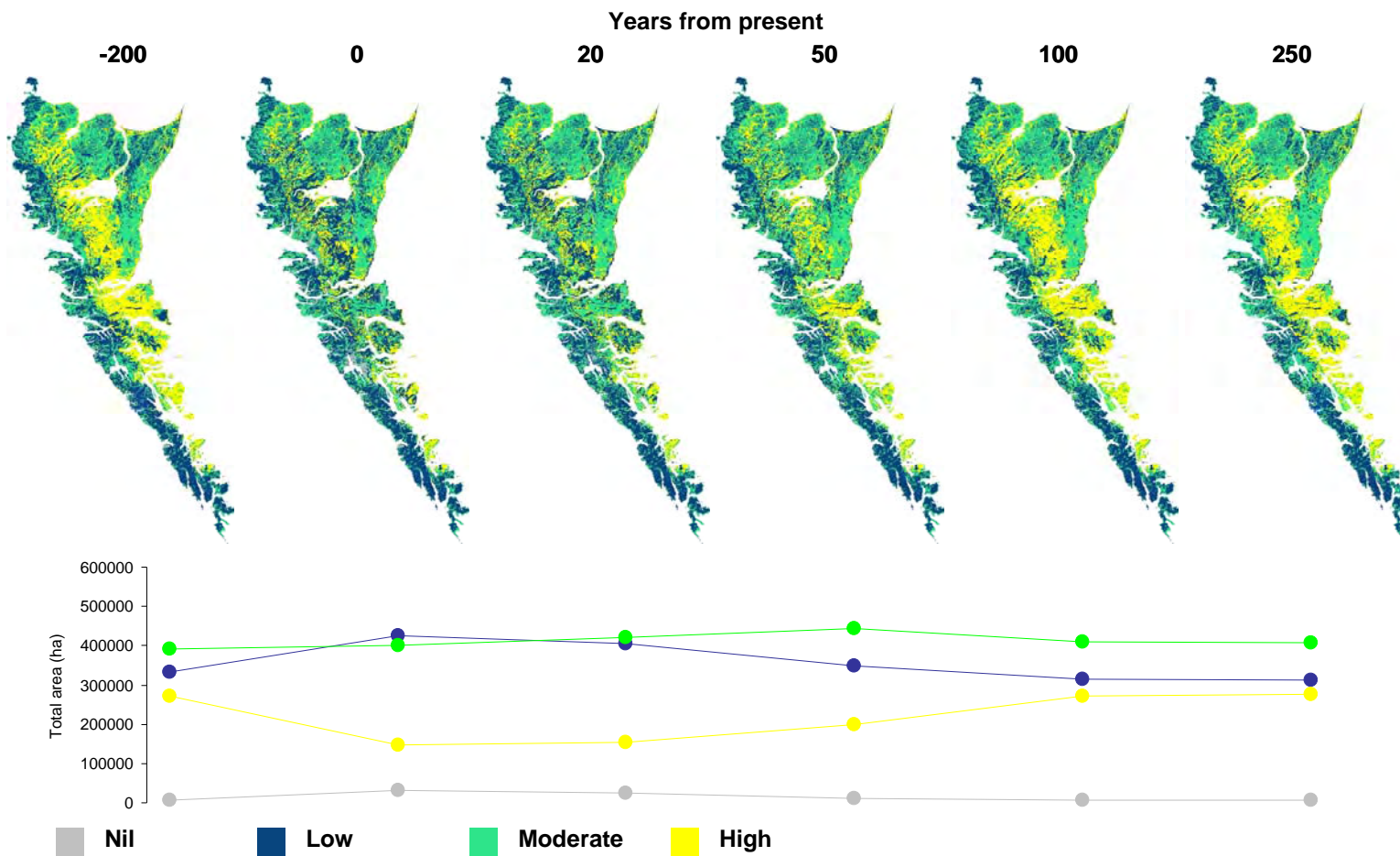


Figure 27: Projected changes in foraging habitat on the Haida Gwaii landbase under the Aging Only land management scenario.

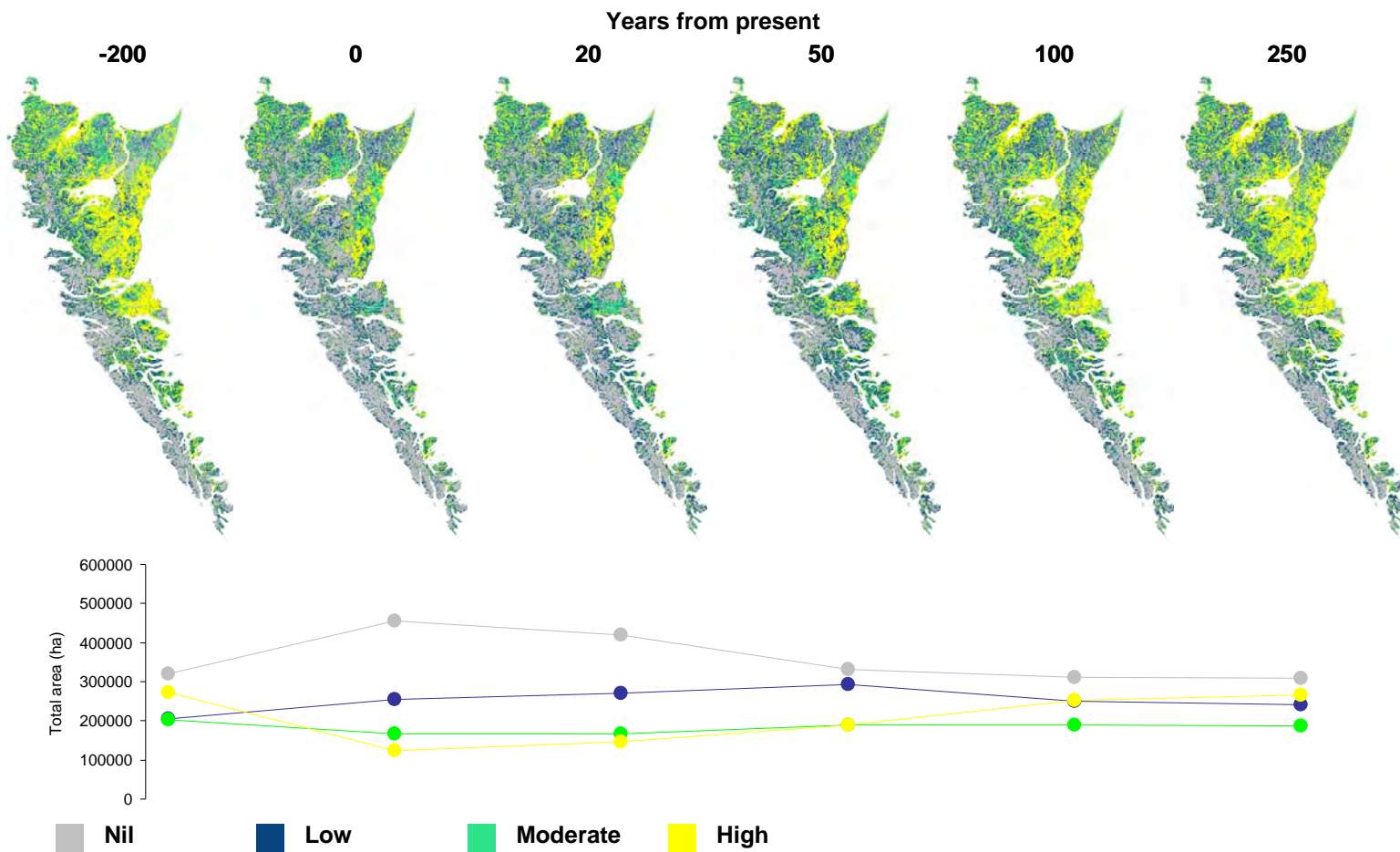


Figure 28: Projected changes in nesting habitat on the Haida Gwaii landbase under the Aging Only land management scenario.

3.4.2. Territories

We found that in the Aging Only scenario, the number of projected territories in the landscape shows similar patterns to the amount of higher quality foraging habitat, with a decline leading up to the present followed a consistent recovery into the future (29). In contrast, for the current management (Base Case 2) scenario, the area occupied by territories declines 45% by 50 years in the future, with a slight increase (16%) over the next 50 years. This pattern generally matches the projected pattern of high quality foraging habitat (25).

Appendix E contains maps detailing the distribution and number of territories across a time series. We illustrate these indicators for the Backcast and Current conditions (Figure E-1), and projections for both the Base Case 2 (Figure E-2) and Aging Only (Figure E-3) scenarios.

Details on the amount of different habitat classes within projected territories can be found in Appendix E, for both foraging (Figure E-4 and E-5) and nesting (Figure E-6 and E-7) habitat.

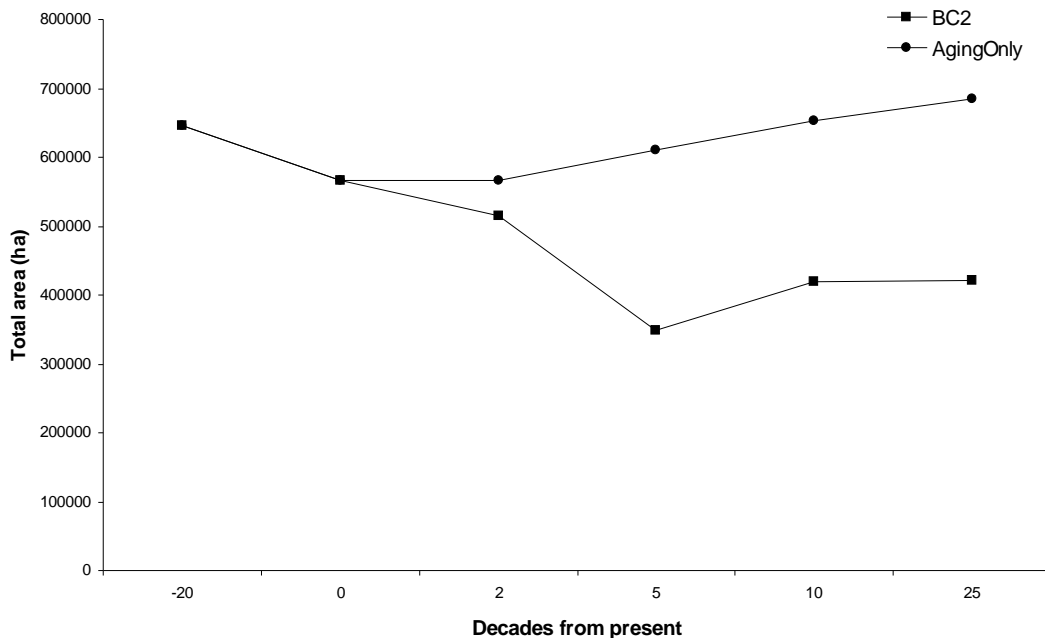


Figure 29: Projected changes in area in territories for both the Aging Only and the Base Case 2 (BC2) scenario for Haida Gwaii.

3.4.3. Effects of stochasticity on results

While we did not produce multiple replicates of model output for each scenario, we tested the effects of stochasticity in the model parameters by running replicates of the current conditions scenarios (medium habitat threshold). We focussed our examination on the territory model, because the habitat model is deterministic not stochastic.

In 23 replicated runs of the model, we found that coefficients of variation ranged between 2.6 – 6.9%, depending on the particular territory attribute examined (1). When considering the precision of model outputs (especially when comparing across scenarios), this level of variation should be taken into account.

Table 1: Means and coefficients of variation for territory attributes, estimated from iterative runs (N = 23) of the current conditions scenario on Haida Gwaii using the moderate habitat threshold.

	Mean	Coefficient of variation
Overall Attributes		
Total Area (ha)	572800	2.9%
Number of Territories	65	2.6%
Area of Forage Habitat (ha)		
Nil	62300	6.9%
Low	169800	4.1%
Moderate	241000	3.4%
High	99800	3.3%
Area of Nest Habitat (ha)		
Nil	239700	4.0%
Low	137900	3.6%
Moderate	108400	3.3%
High	86800	3.3%

4. Discussion

4.1. Analysis Results

The primary objective of this document is to describe the Northern Goshawk habitat and territory models developed for the NOGO Habitat Recovery Implementation Group, and to present model results for the Haida Gwaii, North Coast and South Coast Conservation Regions. Detailed interpretation of results is not a primary objective of this document. However, due to the complexity of the models, we provide preliminary interpretations of results to illustrate the appropriate use of model output and to further explain model behaviour.

Over all three conservation regions, patterns of habitat quality appear to be strongly influenced by forest harvesting history (i.e. stand-replacing disturbances). In general, we found a correlative relationship between both time-since disturbance and extent of disturbance within a region, and habitat quality for NOGOs. The more recent and extensive the disturbance, the lower the region's habitat quality was relative to that region's capable habitat. The differences between current and capable habitat were greatest on the South Coast with its extensive harvest history, and smallest on the North Coast with a relatively localized harvest history. These patterns of habitat impacts could have implications for recovery planning.

The objective of using the territory model is to explore the effect of changes in *spatial distribution* of habitat that may not be reflected in the *magnitude* of changes in habitat area reported by the habitat model. For example, removing all habitat from one part of the study area is expected to create a different potential impact on the NOGO population than removing the same amount of habitat in small patches throughout the study area. The outputs from the model conformed to this expectation, with territory densities responding differently than measures of habitat areas to the various land management scenarios. In addition, the influence of the spatial distribution of habitat increased with the threshold level of suitable habitat required for territory success. For example, in the North Coast's current landscape a 20% reduction in suitable foraging habitat relative to the capable habitat resulted in a 40% reduction in the number of territories at the medium habitat threshold, and an 81% reduction at the high threshold. For the low habitat threshold, the 20% difference in suitable foraging habitat resulted in only a 5% reduction in territories. Sensitivity analyses found that the territory model is more sensitive to changes in spatial distribution of nesting habitat, than changes in amount of nesting habitat (Smith 2008).

The Base Case 2 (BC2) land management scenario for Haida Gwaii projects a decline of 60% (relative to current levels) in total growing stock over the next 120 years, under a harvest flow regime that declines by 16% over the next 100 years (Williams *et al.* 2004). The majority of this change occurs within the next 50 years, and our projected changes in amounts of habitat (particularly high quality habitat) and numbers of territories are consistent with these trends. The future distribution of territories (Figure E-2) appears consistent with the harvest flow assumptions by forest tenure type (Williams *et al.* 2004) leading us to suggest that this version of the model appears useful in comparing future impacts of alternative land management scenarios on numbers and distribution of habitat and territories.

4.2. Model design and applicability

The habitat model calculates a habitat suitability index (HSI) ranging from 0 to 100 to describe nesting and foraging habitat quality. However, for many aspects of the model this HSI is simplified to a four class rating system (Nil: 0-25, Low: 26-50, Medium: 51-75, and High: 76-100). This simplification could be problematic if the breakpoints used for classification coincide with

natural breakpoints in the data. For example, if a large portion of the study area has a foraging HSI of 0.75, the model output would be significantly different if we chose 0.75 as the minimum value for the high quality class rather than 0.76. Upon examining the distribution of area by HSI score, we conclude that the model output is relatively insensitive to the choice of boundary values for habitat quality classes (Figures 30 and 31). The distribution for nesting HSI shows no natural breakpoints for the NCCR and a breakpoint at 1 for SCCR that appears associated with the maximum HSI for spruce-leading and cedar-spruce stands. For foraging HSI, there is a spike in habitat area at 0.4, which corresponds to the default HSI for non-productive habitat, and another spike at 0.95 which is the maximum HSI possible for fir-, hemlock-, and balsam-leading stands. However, none of these breakpoints in the HSI distributions is associated with a habitat-class boundary. For the VICR, we considered the response of the territory model for reducing the number of breakpoints for classifying habitat from four to two. This change produced a small increase in the mean number of predicted territories, from 194 to 208 territories (Smith 2008).

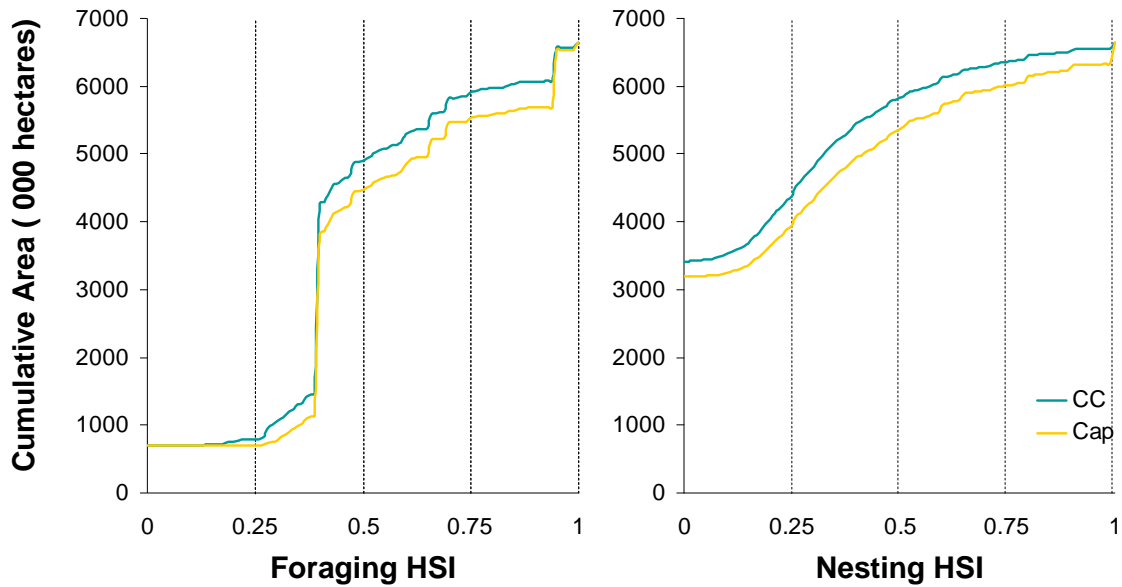


Figure 30: Cumulative area of the NCCR landscape with increasing value of foraging and nesting habitat suitability indices (HSI), in relation to breakpoints used for habitat classes (dotted lines)

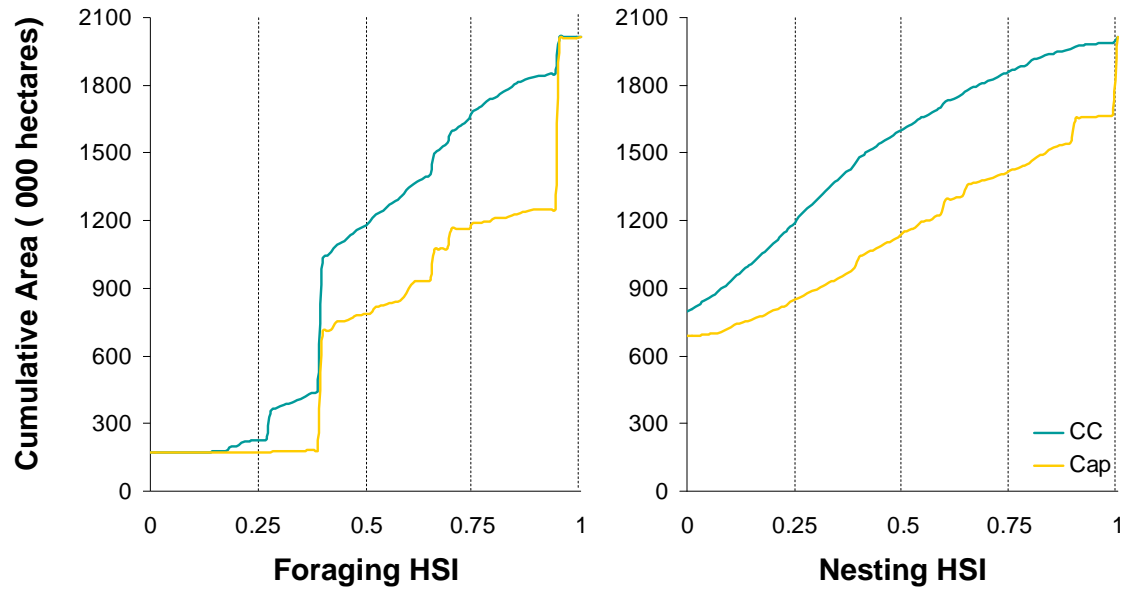


Figure 31: Cumulative area of the SCCR landscape with increasing value of foraging and nesting habitat suitability indices (HSI), in relation to boundaries used for habitat classes (dotted lines)

Sharp increases indicate natural breakpoints in the dataset. The current conditions (blue) and capable habitat (orange) scenarios are both presented.

A significant conceptual and technical challenge with developing the territory model and interpreting its output is the problem of how to spatially initiate and “pack” territories. This is required in order to estimate the number of territories that could be supported by a particular habitat configuration, while maintaining the spacing between nest areas that is observed in actual NOGO populations. To address this challenge, we modified the algorithm for territory formation in the 2007 version of the model from a sequential to simultaneous establishment process (see Appendix A for details). However, this change invoked additional challenges. For example, two territories may fail when forming together, even though at least one would have been successful if formed in isolation. To address this problem, we explored several approaches, such as reinitiating territory in cells along the border between adjacent territories once one of the territories failed. We finally settled on using iterative loops to fill in gaps where territories previously failed to form, either due to simultaneous formation, or sub-optimal nest area placement.

A second challenge of the territory model was to balance the stochastic behaviour of the model with its intended optimization behaviour (i.e. “packing”). Emphasis on the optimization process would cause biased sampling of the underlying probability distributions associated with stochastic parameters, leading to over-packing of territories. Conversely, domination of stochastic behaviour would lead to sub-optimal packing of territories and an underestimation of territory density. Furthermore, the influence of optimization parameters (i.e., values specifying the number of iterations in each loop of the territory model) on model behaviour varies with landscape context. The parameter values required to saturate small, isolated patches of foraging habitat with territories leads to over-packing of territories in larger, contiguous patches of foraging habitat. Therefore, the parameter values currently used in the model may slightly underestimate the number of potential territories, due to the potential omission of a few territories. However, the magnitude of this bias is likely small, and relatively consistent among replicates and scenarios (although it will be larger in more fragmented landscapes). Therefore, relative interpretations between scenarios and thresholds are still meaningful.

Output from the territory model is intended as a prediction of the landscape *capacity* for NOGO territories, rather than the *actual number* of territories that would be present under a particular set of landscape conditions. This output could be combined with information on the occupancy rate of potential nest areas to guide estimation of the probable number of territories in a particular landscape. However, we offer two cautions when interpreting the results of such an analysis. First, the territory model does not account for the effects of lags in demographic response to landscape change on inventories of territory locations. For example, a particular NOGO may persist in a territory following logging, even though the quality of the territory falls below the level necessary for mating and reproduction. Second, the models implement our best understanding of the relationships between the different attributes that affect habitat quality and territory formation. However, there is still significant ecological uncertainty in the actual values of underlying parameters. Therefore, the model results are more reliable for making comparisons among different scenarios than for predicting absolute amounts of habitat and numbers of territories.

4.3. Future Work

A major conceptual challenge in developing this model has been to appropriately weight the influences of ‘bottom-up’ (fine-scale process behaviour known from field samples) and ‘top-down’ (structural assumptions that constrain possible behaviours in novel situations) controls on the outcomes of the model. Specifically, the requirement that nests maintain a particular spacing in the landscape (even if specified by a probability distribution) directly or indirectly influences much of the model’s behaviour. Future developments of the model could focus on identifying ecologically meaningful mechanisms for the observed or hypothesized spacing pattern and implementing that behaviour in the model. Such a modification would allow the model to react to changes in the landscape configuration that drive spatial patterning, and would also eliminate many of the artefact behaviours caused by the current implementation. However, development of a more process-based model would have to be accompanied by further field studies of NOGO ecology, to provide the required understanding of the mechanisms and parameters that drive territory development and spacing. We anticipate that the present model will still provide useful guidance for planning while further research is undertaken.

An advantage of the simulation approach taken in this model is the ability to represent poorly understood processes that influence model outcomes by including stochastic elements in the model. At present, our model only includes the stochastic components of territory formation. The habitat model is completely deterministic, based on current empirical and projected estimates derived from forest cover inventory data. Given the known uncertainties of forest cover data to accurately represent wildlife habitat attributes at the polygon scale (let alone at the pixel scale) our analyses to date likely underestimate the uncertainty in the model’s predictions. Future versions of the model could include mechanisms to account for this uncertainty in the state of the landscape. Data from the ongoing field verification program could be used to parameterize the magnitude of this uncertainty.

The Edge Sub-Model of the Habitat Model currently infers the location of anthropogenic edges adjacent to cut blocks based on a range of layers including Non-Productive Forest type, and THLB. While this method works in most cases, it can result in misclassifying natural edges as anthropogenic edges where data are missing from one of the input layers. An obvious solution to this problem is to use spatial coverage of harvest history to ensure cut block edges are only placed adjacent to known cut blocks. However, we were not able to obtain harvest history information beyond the year 2000 for Haida Gwaii and were only able to obtain a partial harvest history for the North and South Coast. In the future, it may be worth making further efforts to

obtain up-to-date harvest history information in order to improve the estimations of cut block edges.

Further work on verifying and refining parameter values would increase the reliability of model outputs. While all aspects of the model could benefit from this type of work accurate information is especially important for parameters related to nest spacing, given their large influence on territory model outputs. In the current model, there is a sharp change in territory spacing and size parameters from the North to South Coast Conservation Regions, which likely causes either an underestimation of territories supported in the northern portion of the SCCR or an overestimation of territories supported in the southern portion of the NCCR. For example, sensitivity analyses found that using SCCR spacing on the North Coast produces a 186% increase in the number of predicted territories (Smith 2008). Creating a north-south gradient of these parameter values would likely reduce the magnitude of potential bias. Additional field data on nest spacing parameters would further enhance model performance.

This model implements a relatively detailed set of ecological assumptions (see Mahon *et al.* 2007) and there are 24 parameters and 12 input files containing parameterization data (Appendix C). Clearly there is need for additional sensitivity analyses to be undertaken as part of model development and testing.

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Appendix A - Comparison of Approaches to Modelling Territories

A.1. Simulation versus simple circles

We compared the outputs of this simulation model with the results obtained using a previous approach that applied circular buffers over the landscape, using a similar method for characterizing habitat suitability (F. Doyle, pers comm.). Using Haida Gwaii as our test landscape, that approach, termed the “circular buffers” territory model, produced a similar number of territories as did our model parameterized for the medium habitat threshold for the Current conditions scenario (Figure A-). In addition, the total area of each habitat category within territories was most similar for the circular buffers territory model and our model at the medium habitat threshold for Current conditions (Figure A-2).

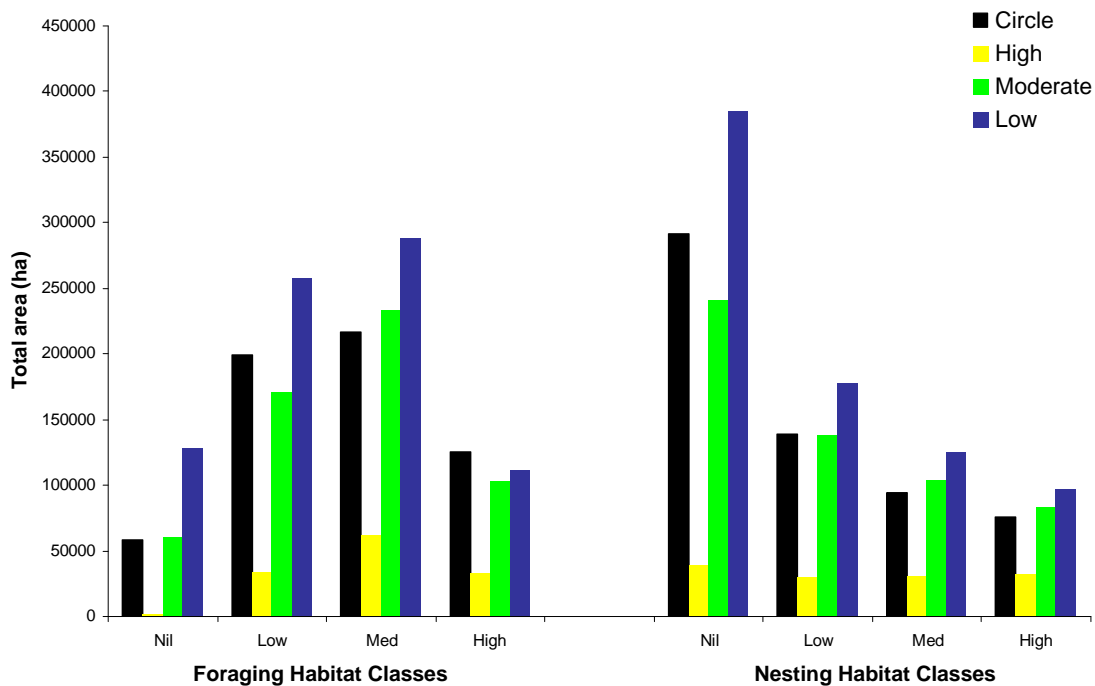


Figure A-1: Projected changes in the area included in territories between the circular buffers model and this model for current conditions on Haida Gwaii.

Black bars show the results for the circular buffers model, while coloured bars indicate different habitat thresholds.

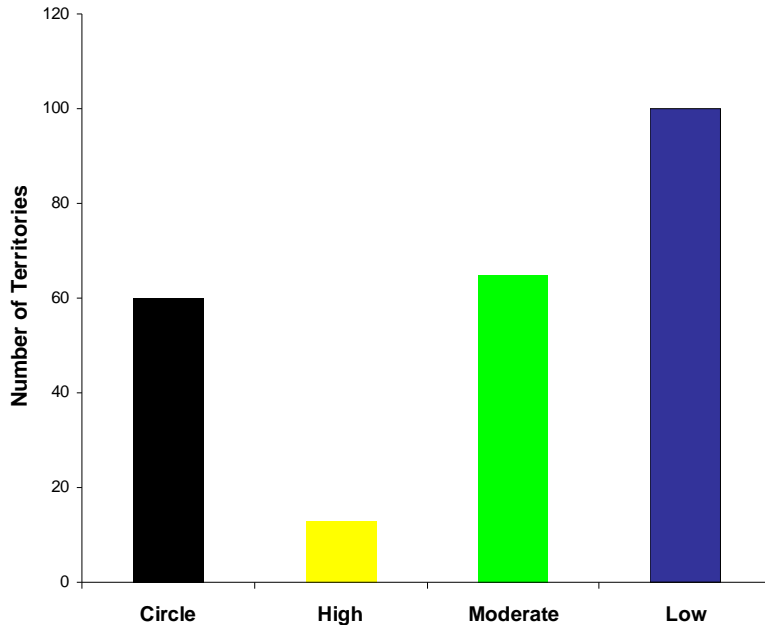


Figure A-2: Numbers of territories estimated by the circular buffers model and this model under current conditions and three habitat thresholds on the Haida Gwaii landscape (Current conditions).

A.2. Current territory model versus 2006 version

A.2.1. Overview

The first version of the territory model was produced in 2006, and was implemented and tested on Haida Gwaii and the North Coast Forest District. The NOGO Habitat RIG reviewed results of this round of modelling, and was generally satisfied with the performance of the model. However, the modelling team, in consultation with the RIG, identified some unintended behaviours of the model, as well as some conceptual inconsistencies. We will describe these challenges and the potential implications for interpreting model output, present possible solutions to the problems, and outline how these problems were addressed in the current version of the territory model. We will primarily use Haida Gwaii as a sample landscape for comparing the two versions of the model, although occasionally we will draw examples from other conservation regions. See also Section 4.2 for related discussions of the effects of these differences on interpretations.

A.2.2. Modelling Challenges

A key objective of the territory model is to re-create via simulation the spacing patterns of nests observed in the actual NOGO populations within each study area. Both versions of the model use a normal distribution derived from these empirical observations of nest spacing to specify the distance to place each new nests apart from existing nests. However, the final distribution of nest area spacing indicates territories were more tightly packed than specified by the source distribution (mean = 9.6 km, s.e. = 20 m, N = 23; Figure A-3).

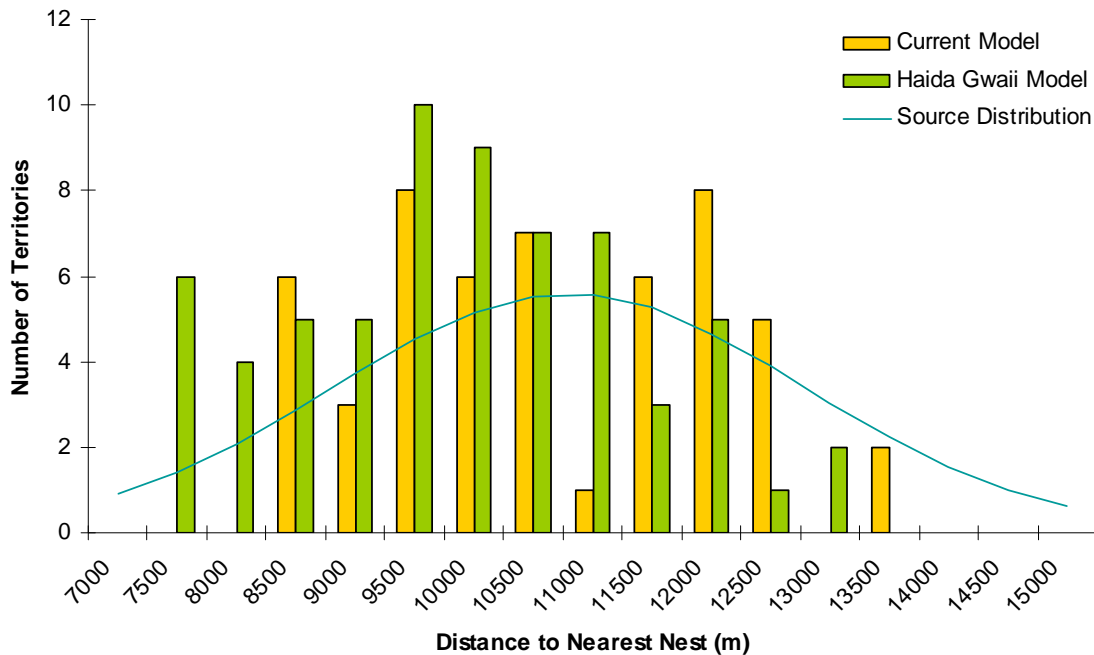


Figure A-3: Actual distribution of nest spacing on Haida Gwaii compared to source distribution

The bars indicate the actual distribution of nest area spacing on Haida Gwaii for the 2006 (green) and 2007 (orange) versions of the territory model. The orange bars indicate the actual distribution of nest area spacing on the North Coast. The results shown are from a single run of each version of the model. Outliers beyond three standard deviations were excluded from this figure. The blue line indicates the source distribution for nest spacing, with a mean of 10.8 km and standard deviation of 2 km.

This over-packing behaviour in the 2006 version was caused by at least two factors. First, as the landscape begins to fill with territories, most of the opportunities for establishing new territories occur at the edge of large habitat patches (e.g., valley complexes). Since the success of a territory is based on containing a sufficient proportion of suitable habitat, these edge territories are more likely to fail, relative to territories attempted at the centre of a habitat patch – the territory cannot encompass habitat towards the centre of the patch because it is already occupied, and habitat quality at the edge of the patch is poor. Therefore, although the model chooses new sites according to the appropriate spacing distribution, nests placed at more far flung distances will fail because of this edge effect, while nests placed closer to existing nests will succeed because they are more likely to be near the centre of a large habitat patch (Figure A-4). This introduces a bias into the spacing behaviour, creating a less-dispersed distribution of territories.

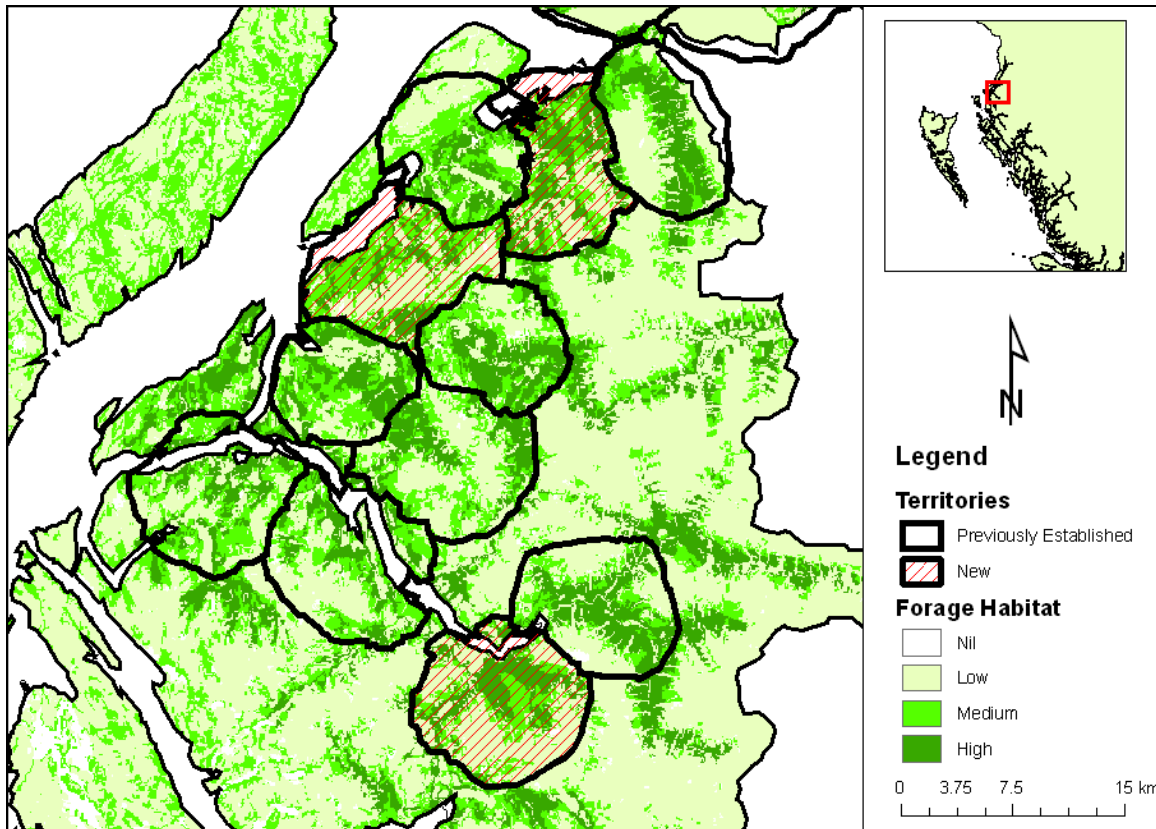


Figure A-4: Establishment bias of new territories towards centre of large habitat patches

New territories (red-hatched polygons) are biased to succeed close to existing territories (hollow polygons) relative to farther away from existing territories.

A second cause of over-packing results from the stochastic determination of parameters describing the minimum size of a territory. Towards the end of a model run, territories with an average to large minimum size will be unable to incorporate sufficient habitat for viability due to a lack of large patches of suitable habitat. However, through repeated sampling of the territory size distribution upon each territory attempt, eventually a suitably small minimum size will be produced to allow the territory to squeeze in among the previously established territories.

These two causes of over-packing both derive from the same conceptual limitation within the model. The model is attempting to maximize the number of territories in the landscape, while at the same time stochastically determining parameters that are directly related to packing density. Following this approach, a model designed to produce a fully optimized solution would continue to reconfigure nest configuration and resample the distributions for spacing and territory size parameters, until the density of territories reached a limit based on the deterministic territory overlap limits. The final optimized solution would be completely independent of the characteristics of the probability distributions used to produce stochastic model parameters.

In the 2006 version of the model, territories form sequentially, and once a territory is successfully established it remains unaltered for the duration of the model. One implication of this behaviour is that the establishment order of adjacent territories can have a significant impact on how surrounding habitat is incorporated into the territory; territories formed earlier in the model progression can exclude habitat from subsequent adjacent territories, even when that habitat may be closer in terms of the territory growth cost surface to the newly forming territory (Figure A-5).

This behaviour does not meet the biological expectation that adjacent territories should meet roughly equidistant from associated nest areas along the foraging cost surface.

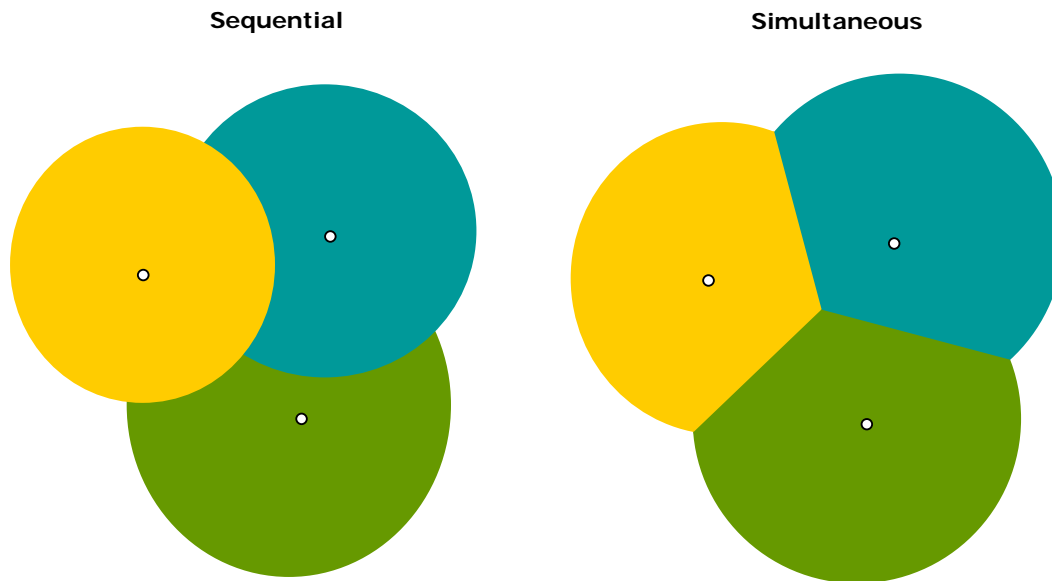


Figure A-5: Difference in territory formation between sequential and simultaneous territory formation from the same configuration of nest areas.

Coloured circles indicate individual territories, and the small white circles indicate the associated nest areas from which territory formation initiates.

A.2.3. Approaches to address modelling challenges

There are at least three possible approaches for dealing with overestimation of territory density by the territory model. First, uncertainty and variability in model parameters could be addressed through scenario analysis rather than with stochastic parameters. Each scenario would specify a unique combination of territory size and spacing parameters, for which the model would calculate the maximum density of territories that could be supported by this combination of parameters. An advantage to this approach is that detailed post-hoc analyses could be conducted to determine the influence of parameter on model outcomes (e.g., using a Bayesian Belief Network). These analyses could help guide researchers and decision makers on the implications of model- and data-related uncertainties, and on the benefits of acquiring additional information. The NOGO RIG decided not to take this approach because they felt it was important to explicitly include real-world variability in the model behaviour. In addition, this scenario-based approach would be computationally intensive and time-consuming.

The second approach to deal with over-packing is to redesign the model to simulate actual density of NOGOs, allowing NOGO density and nest spacing to be an emergent property of the model. A key advantage of this approach is that observed patterns of NOGO occupancy could be used to verify the model behaviour. Furthermore, such an approach would better suit the objectives of the NOGO RIG. For example, the model could be used to simulate the real time response of NOGO populations to changes in habitat configuration. The potential of the landscape to support Northern Goshawks could be assessed using an aging-only scenario, and allowing the model to run to equilibrium. Furthermore, the impact of phenomena such as legacy nests could be evaluated (i.e., where birds will maintain fidelity to a nest even though the surrounding habitat has been destroyed). However, the NOGO RIG concluded that there was insufficient data on the biology of the species to design such a bottom-up NOGO territory model.

Given the computational limitations of a scenario-based approach, and the data limitations for using a bottom-up behavioural model, the modelling team together with the NOGO RIG decided to modify the existing model to minimize the number of times that territory failure is assessed in the model. The intent of this third approach is to reduce the bias of the samples selected from probability distributions describing nest spacing and territory size parameters. With this approach we acknowledge that we are not able to determine the *maximum* number of territories that can be supported by a particular landscape. Rather, our estimates of territory configuration will underestimate territory density, but are intended to be consistent enough to explore the relative differences in territory density and configuration among different scenarios and landscapes. For a complete description of this approach, please refer to the model description for the North and South Coast Conservation Regions.

The new territory modelling approach addressed the concerns identified with the 2006 version, but with varying degrees of success. First, the current version of the model mitigated the bias towards tightly packed nests (mean = 10.0 km, s.e. = 212 m, N = 5), although the spacing was still closer than specified by the source distribution. This mitigation primarily occurred through reduced over-representation in the left tail of the nest spacing distribution (Figure A-3). The effect of this increase in nest spacing can be seen in the reduced number of territories placed by the 2007 territory model versus the 2006 model. Second, we successfully implemented simultaneous spreading of territories from nest areas, which leads to the incorporation of habitat into each territory to form a more biologically realistic pattern (e.g., nest areas roughly at the centre of the territory).

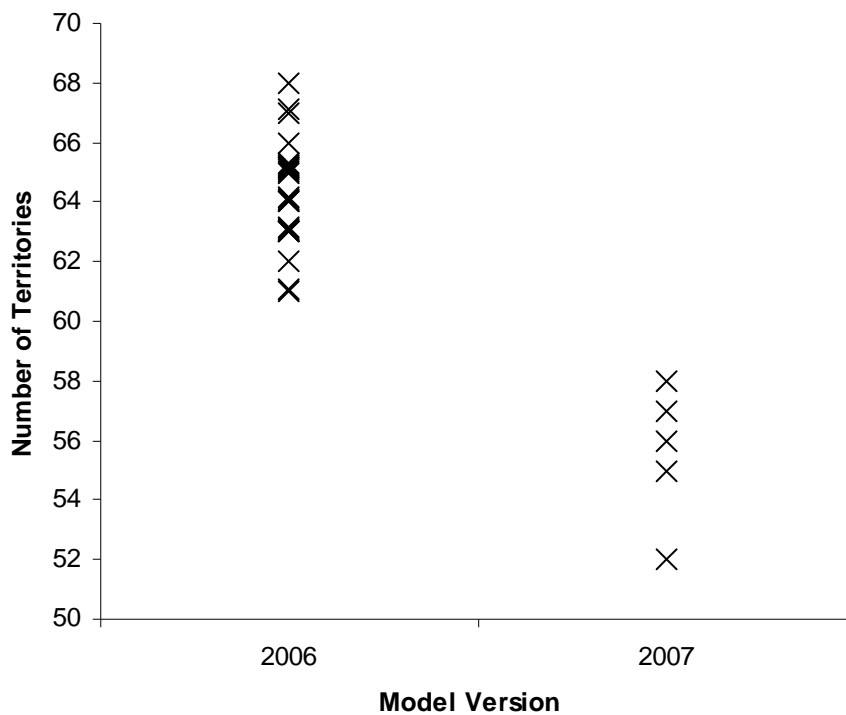


Figure A-6: Comparison of number of territories placed by the 2006 and 2007 versions of the NOGO territory model (2006: N = 23; 2007: N = 5).

Additional replicates greater than one that produce the same number of territories have been shifted on the y-axis by increments of 0.05 to facilitate interpretation of the figure.

Appendix B – Data Assembly

The spatial data required for the model is primarily available as vector data, with polygons delineating different land cover types. Our model is raster-based, which means the landscape is not viewed as a collection of polygons, but rather as a grid of square cells. Thus, before we could use the data it had to be converted from vector to raster format. On Haida Gwaii, much of this conversion had already been done when the HG Land Use Plan model was developed (Williams *et al.* 2004). However, we did have to convert some additional layers required to generate an updated Inventory Type Group layer. For the other conservation regions, rasters were generated from a mosaic of vector forest cover data obtained from licensees and government sources. For projecting predictions into the future on Haida Gwaii, stand age and stand height were updated using the landscape models developed for the Haida Gwaii Land Use Plans.

In addition to rasterising existing data layers, we also developed a simple pre-processing sub-model to generate an Inventory Type Group (ITG) layer from species and species cover layers derived from forest cover layers (Figure A-1). While ITG is available from standard forest cover mapping, our model included additional ITGs not accounted for in forest cover. These new ITGs were primarily intended to differentiate between Yellow Cedar and Western Red Cedar stands, and were specified by RIG. We used three layers to define ITG classes: leading species, percent cover of leading species, and second species. If leading species was missing ITG was set to zero, with the exception that when the cell was “not sufficiently stocked” (NSR) we considered the leading species to be hemlock.

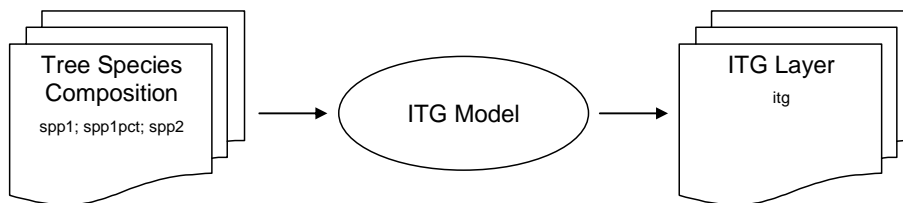


Figure B-1: Flowchart of ITG model, indicating input layers and output layers

On Haida Gwaii we were able to obtain forest cover data for the entire study area. However, on North and South Coasts, we were missing data for regions. On the South Coast, stand height was missing for all the TFLs, so we used VDYP (MOF 1998) to calculate stand height for these management units, based on species composition and stand age. Other data missing on the South Coast included all forest cover for TFL 26, non-productive codes for TFL 10 and TFL 38. For these situations we assumed a default nesting HSI of 0, and a foraging HSI of 0.4. TFL 38 data was missing second species which is necessary for calculating our custom ITGs, so for TFL 38 we were restricted to using standard ITGs and not distinguishing additional stand types. The southwestern corner of the SCCR is comprised of mostly urban areas, and was excluded from all analyses.

On the North Coast, we were missing data for Kitlope Heritage Conservancy Provincial Park and part of Gitnadoiks River Provincial Park. In addition, we were missing data for a couple of other small patches of landscape. For these regions, we assumed default values of zero for the missing layers. The assumption manifests itself in habitat model output as regular shaped regions of low to nil quality habitat. It is hoped that in future versions of the model we can acquire the data necessary to fill these holes.

On Vancouver Island, we were missing data for Woss Lake Park, Carmanah-Walbran Park and Nimpkish Lake Park. In addition, for Strathcona Park the scale of forest cover data was coarse, and much of the Park was classified as rock even though immediately adjacent areas were

classified as alpine or alpine forest. In addition, much of the south-western corner of the study area is private land. We were able to obtain forest cover for approximately half of the private lands in this sub-region (~320 000 ha). The territory model was run using habitat layers that incorporated this private land data. However, data-sharing restrictions require us to treat these areas as missing data for presentation of habitat predictions in this report. Furthermore, presentations of territory model results in this report have these private lands masked out. For the VICR, missing data was assigned a default foraging habitat rating of 0.4 and a nesting habitat rating of 0. For consistency, we may apply this approach to dealing with missing data in other conservation regions for future runs of the model. Stand height was missing for all the TFLs except TFL 36, so we used VDYP (MOF 1998) to calculate stand height for these management units.

Appendix C – Definition of Model Parameters

Table C-1: Parameters used in habitat and territory models.

Parameter	HGCR	NCCR	SCCR	VICR	Description
CellWidth	50	100	100	100	Cell size of input rasters (m)
InitialNestsPlaced	FALSE	FALSE	FALSE	FALSE	Seed territory model with known nest areas
EdgeHeightThreshold	15	15	15	15	Maximum age of younger forest along an edge (m)
EdgeHeightDifference	15	15	15	15	Minimum height difference along an edge (m)
EdgeBuffer	200	200	200	200	Total width of an edge (m)
MinNestPatchSize	50	50	50	50	Minimum sized patch for territory initiation (ha)
NestProbMode	10800	10800	6900	6900	Mean of normal distribution describing distance from the nearest nest used to calculate probability of territory initiation (m)
NestProbSD	2000	2000	1400	1400	SD of NestProbMode distribution (m)
HighHabMod	4	4	4	4	Weighting applied to NestProbMode distribution in cells of high quality nesting habitat
MedHabMod	1	1	1	1	Weighting applied to NestProbMode distribution in cells of moderate quality nesting habitat
MaxOverlap	0.05	0.05	0.05	0.05	Maximum proportion of overlap between two adjacent territories
MaxTotalOverlap	0.2	0.2	0.2	0.2	Maximum proportion of overlap between a territory and all adjacent territories
SuitHabCut-off	0.5	0.5	0.5	0.5	Minimum foraging HSI for suitable habitat
MinSuitableHabitatHigh	5496	5496	2244	2244	Minimum area of suitable habitat for successful territory (High threshold; ha)
MinSuitableHabitatMod	3664	3664	1496	1496	Minimum area of suitable habitat for successful territory (Moderate threshold; ha)
MinSuitableHabitatLow	1832	1832	748	748	Minimum area of suitable habitat for successful territory (Low threshold; ha)
ModeMaxTerritoryRadius	6000	6000	3833	3833	Mode of skewed normal distribution used to determine the radius of a circle whose area equals the maximum area of a territory (m)
LeftSDMaxTerritoryRadius	375	375	239	239	Left SD of ModeMaxTerritoryRadius distribution (m)
RightSDMaxTerritoryRadius	75	75	48	48	Right SD of ModeMaxTerritoryRadius distribution (m)
MinMaxTerritoryRadius	4886	4886	3122	3122	Left cut-off of ModeMaxTerritoryRadius distribution (m)
MeanMinTerritoryArea ³	7500	7500	3061	3061	Mean of normal distribution used to calculate the minimum area of a territory (ha)
SDMinTerritoryArea	500	500	204	204	SD of SDMinTerritoryArea distribution (ha)
MinTerritoryCut-off	6500	6500	2653	2653	Left cut-off for MeanMinTerritoryArea distribution (ha)

³ The minimum territory area is constrained such that it is always less than the maximum territory area.

Parameter	HGCR	NCCR	SCCR	VICR	Description
MaxIterations	5	5	5	5	Number of iterations filling in holes in previous best territory configuration
MaxConfigAttempts	5	5	5	5	Number of iterations attempting new configurations of territories
MaxNestFailures	2	2	2	2	Number of consecutive failures to place a nest area before terminating inner loop of territory model, the nest placement sub-model

Table C-2: List of input files used in the habitat and territory models. The specific values used for each Conservation Region and the rationale for choosing these values can be found in Mahon *et al.* (2007).

Filename	Description
BECClasses.txt	HSI scores for BEC variants.
EdgeClasses.txt	HSI scores for edge distances.
ElevationClasses.txt	HSI scores for elevation classes.
ITGClasses.txt	HSI scores for Inventory Type Groups.
NonProdClasses.txt	HSI scores for non-productive forest types.
SlopeClasses.txt	HSI scores for slope classes.
Heights.txt	Growth and yield table for predicting stand height from analysis unit and stand age.
HSIForageRankCutoffs.txt	Cut off values of foraging HSI used to define foraging habitat classes.
HSINestRankCutoffs.txt	Cut off values of nesting HSI used to define nesting habitat classes.
distanceSpreadingCosts.txt	Cost of territory spreading into cells different distances from initiation point. Used as inflection points of continuous function describing distance spreading costs.
fHSISpreadingCosts.txt	Cost of territory spreading into each class of foraging habitat.
NoGoNestLoc.txt (HGCR)	Locations of known nest areas used to initialize territory model.

Appendix D – Detailed Territory Attributes

Table D-1. List of fields in the territory summaries output file. Not all fields are available for all conservation regions.

Field	Description
Decade	Used for forecast and backcast scenarios to specify the which time period was used for landscape conditions
SiteID	The territory number, in order of when a territory was placed for a particular time step.
Col	The column position of the nest area within the landscape rasters.
Row	The row position of the nest area within the landscape rasters
area	The area of the territory (ha).
aSuitHab	The area of the territory in suitable foraging habitat, where cells of high habitat count for their full area and cells of moderate habitat count for half their area (ha).
pSuitHab	Proportion of the territory's area in suitable habitat.
overlap	Proportion of territory's area that overlaps with adjacent territories.
aNilForage	Area of nil quality foraging habitat.
aLowForage	Area of low quality foraging habitat.
aMedForage	Area of moderate quality foraging habitat.
aHighForage	Area of high quality foraging habitat.
aNilNest	Area of nil quality nesting habitat.
aLowNest	Area of low quality nesting habitat.
aMedNest	Area of moderate quality nesting habitat.
aHighNest	Area of high quality nesting habitat.
aTHLB	Area of the territory in the THLB.
aAge30	Area of the territory with a stand age less than or equal to 30 years.
avgNestHSI	Average nesting HSI for the entire territory.
avgForageHSI	Average foraging HSI for the entire territory.
avgElevation	Average elevation for the entire territory.
predomLU	Predominant landscape unit within the territory.
predomBEC	Predominant biogeoclimatic unit within the territory.

Appendix E – Supplementary Graphical Results from the Model

In this appendix we present further results from the models that support and provide background to the findings presented in the main body of the report. These figures are referenced in the main body for the respective landscape and scenario.

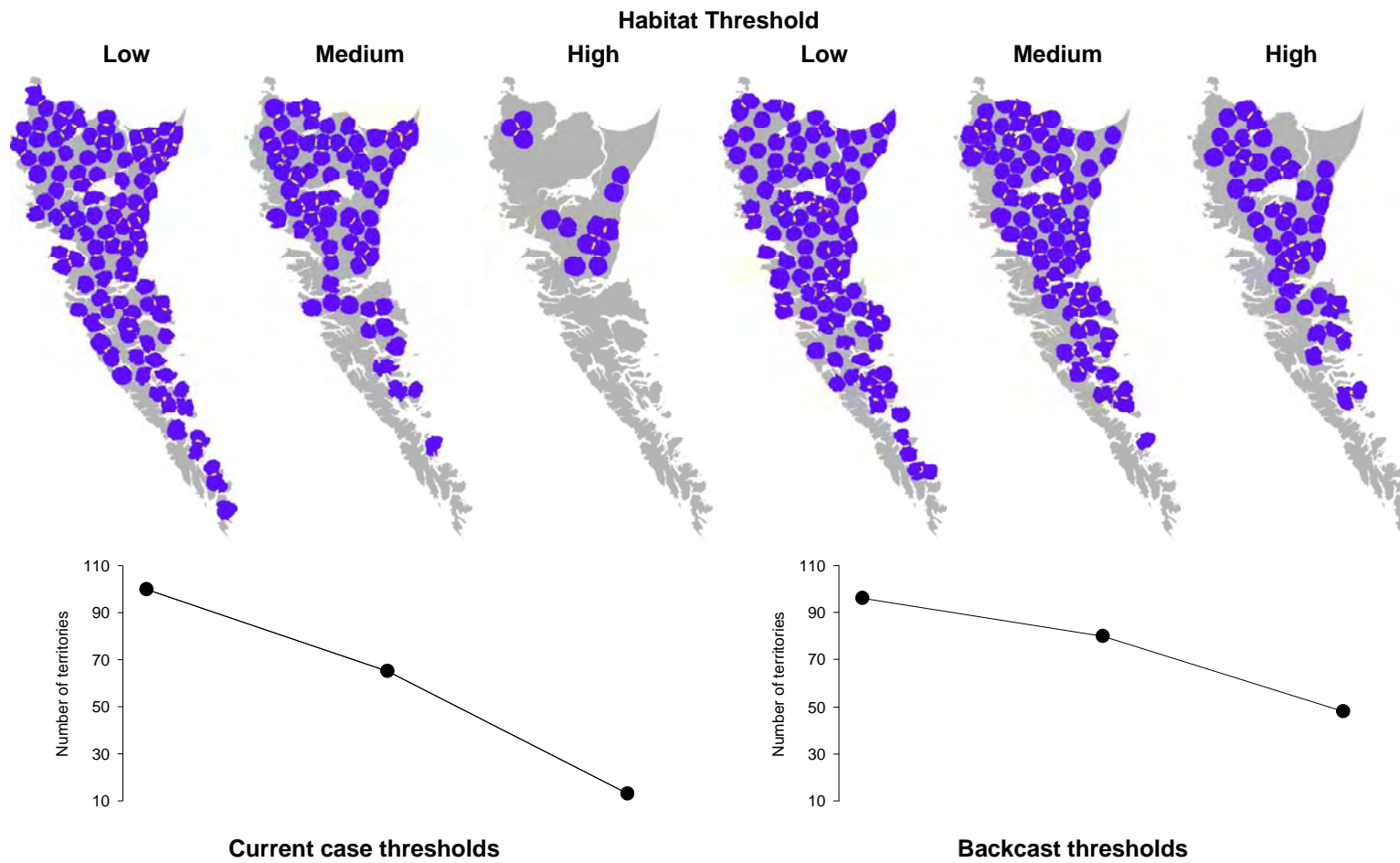


Figure E-1: Projected changes in numbers of territories under all occupancy thresholds on the Haida Gwaii landbase under Current conditions (left) and the Backcast (right) land management scenarios.

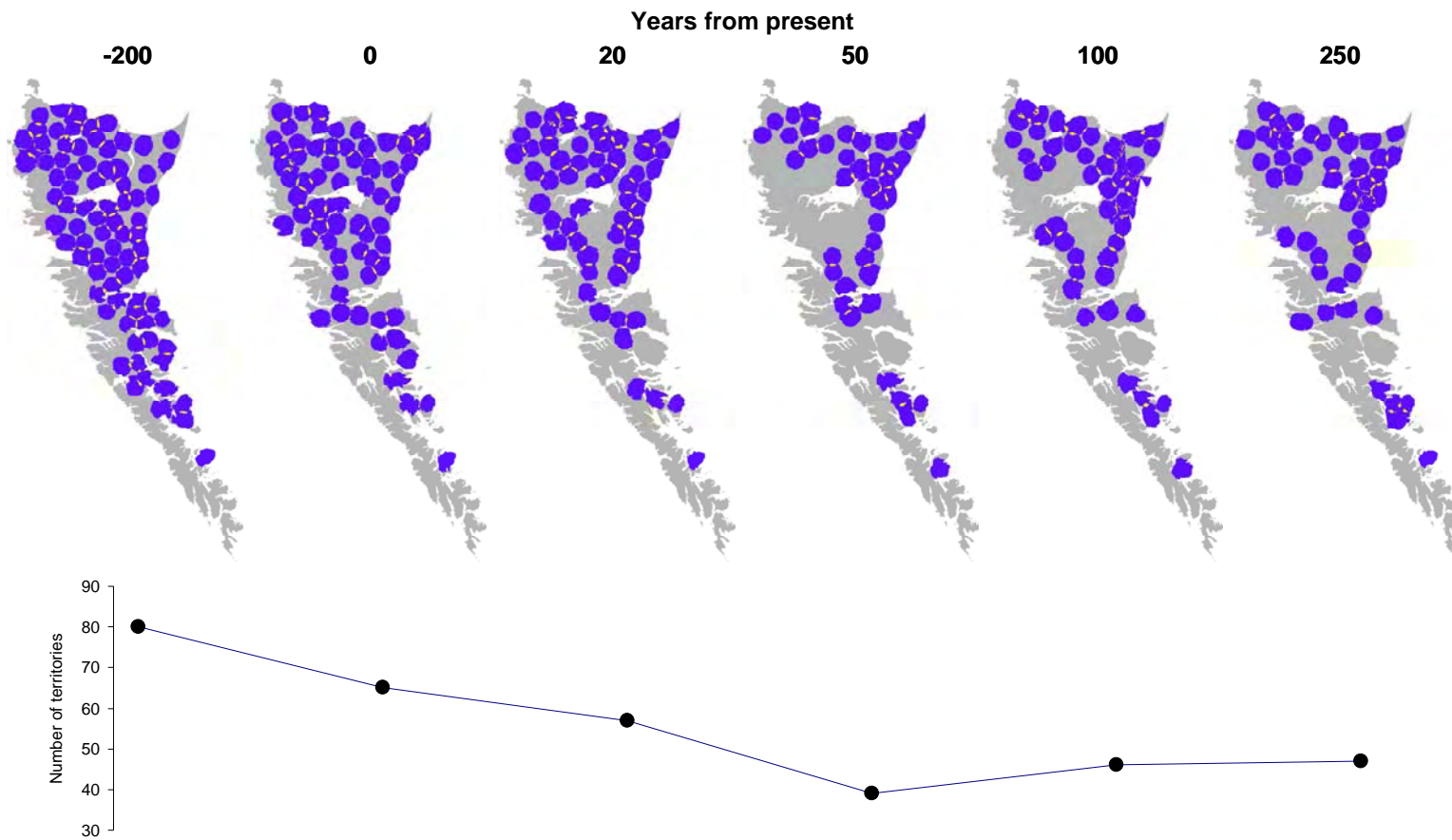


Figure E-2: Projected changes in numbers of territories under the medium occupancy threshold on the Haida Gwaii landbase under the Base Case 2 management scenario.

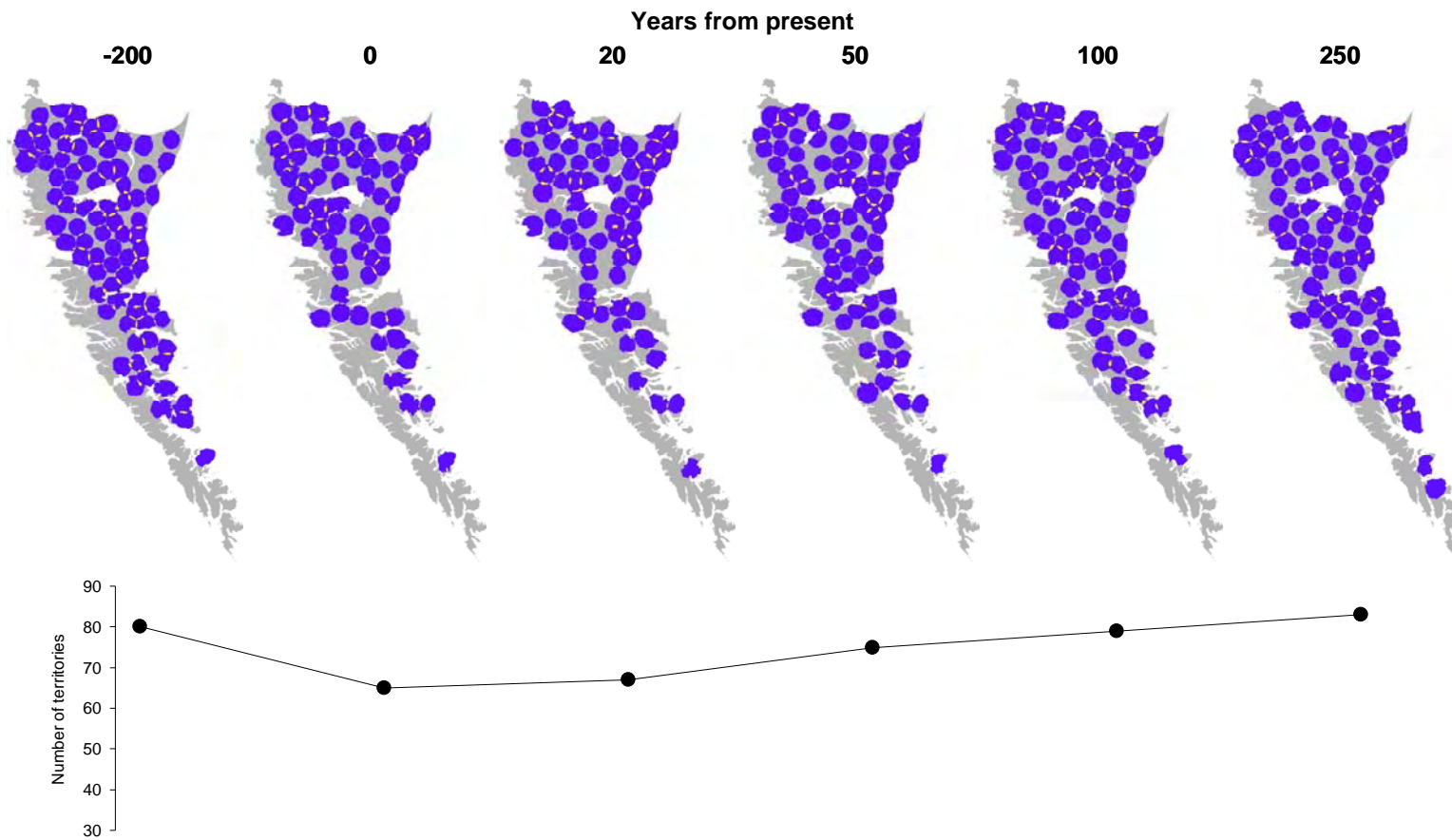


Figure E-3: Projected changes in numbers of territories under the medium occupancy threshold on the Haida Gwaii landbase under the Aging Only land management scenario.

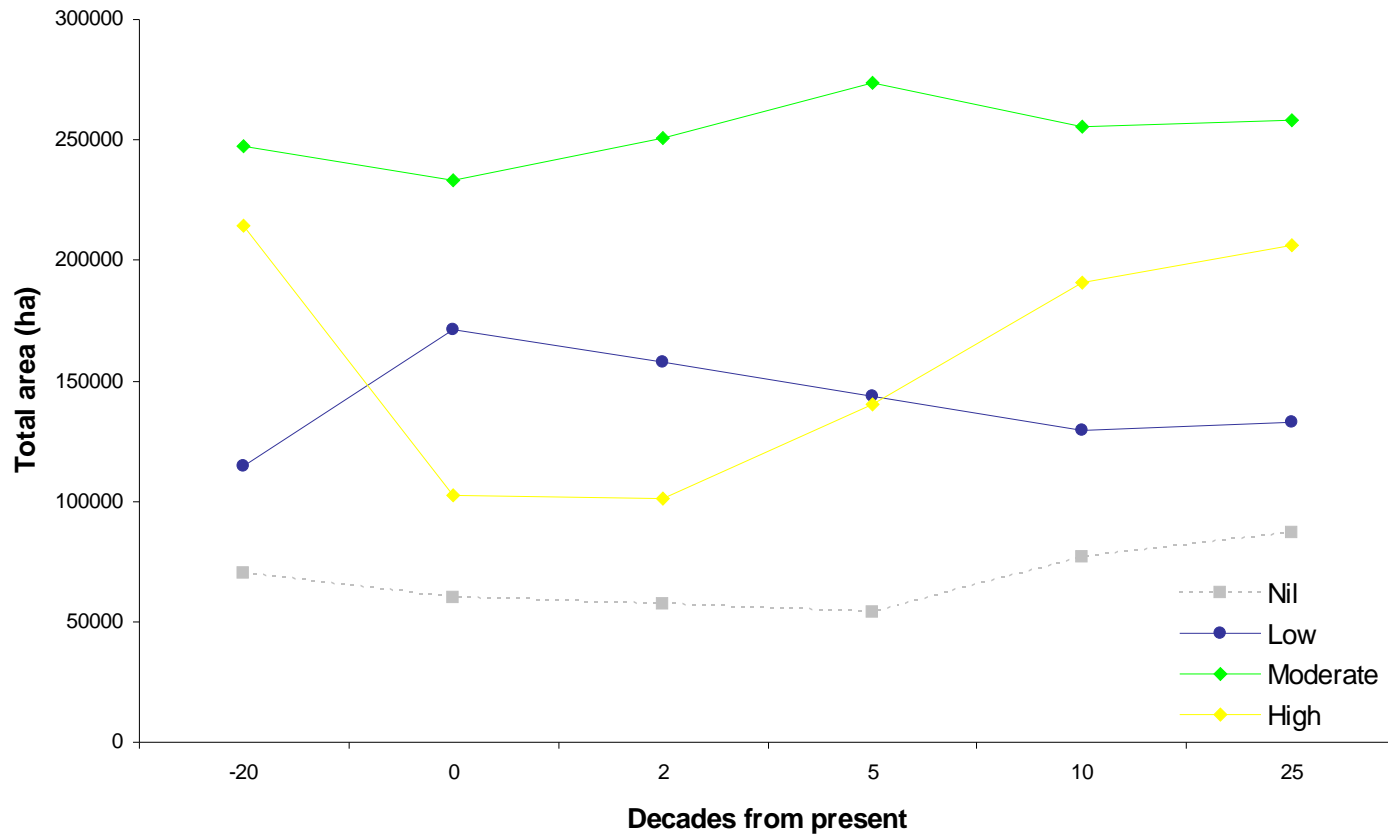


Figure E-4: Projected changes in foraging habitat within territories for the Aging Only scenario for Haida Gwaii.

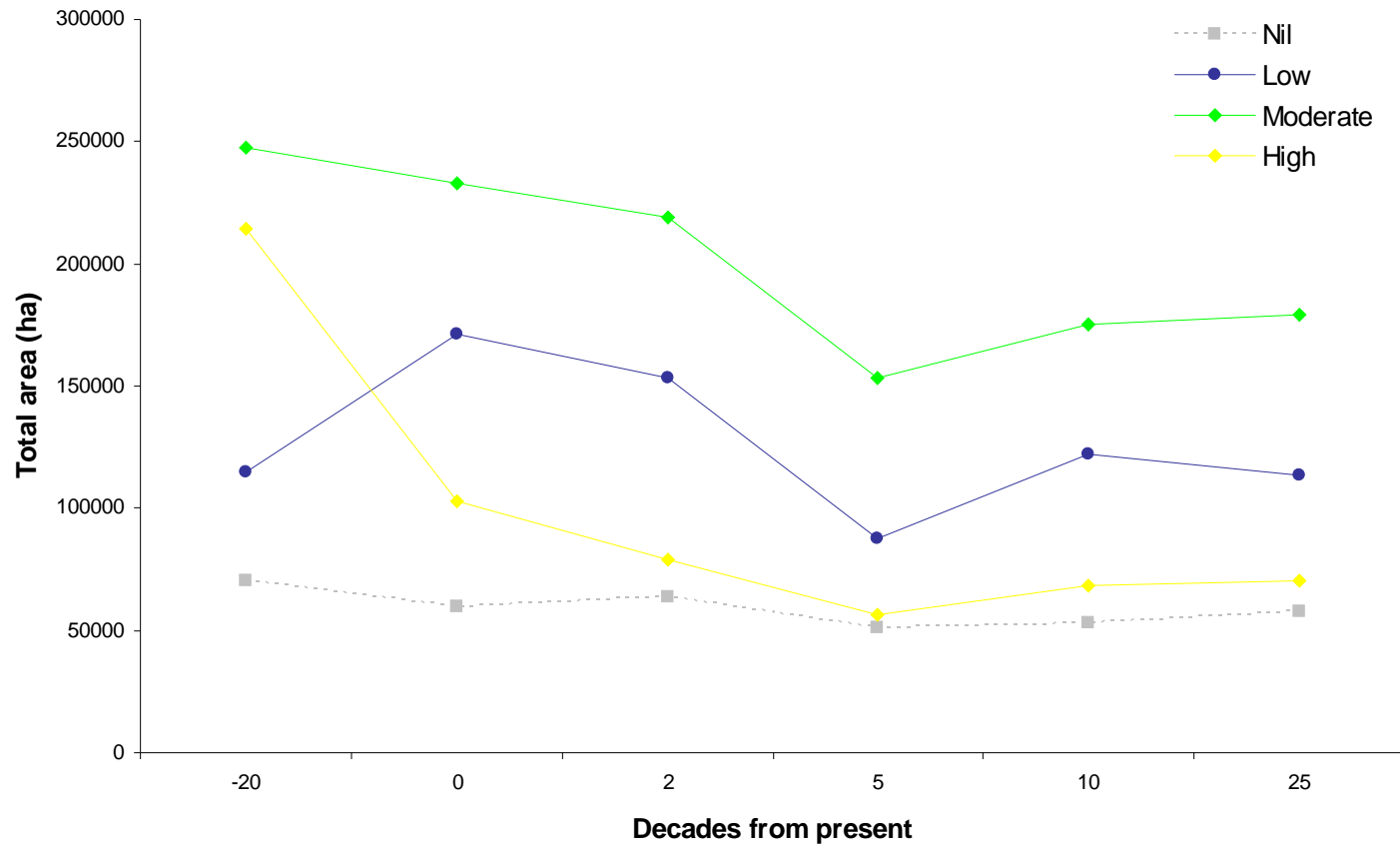


Figure E-5: Projected changes in foraging habitat within territories for the Base Case 2 scenario in Haida Gwaii.

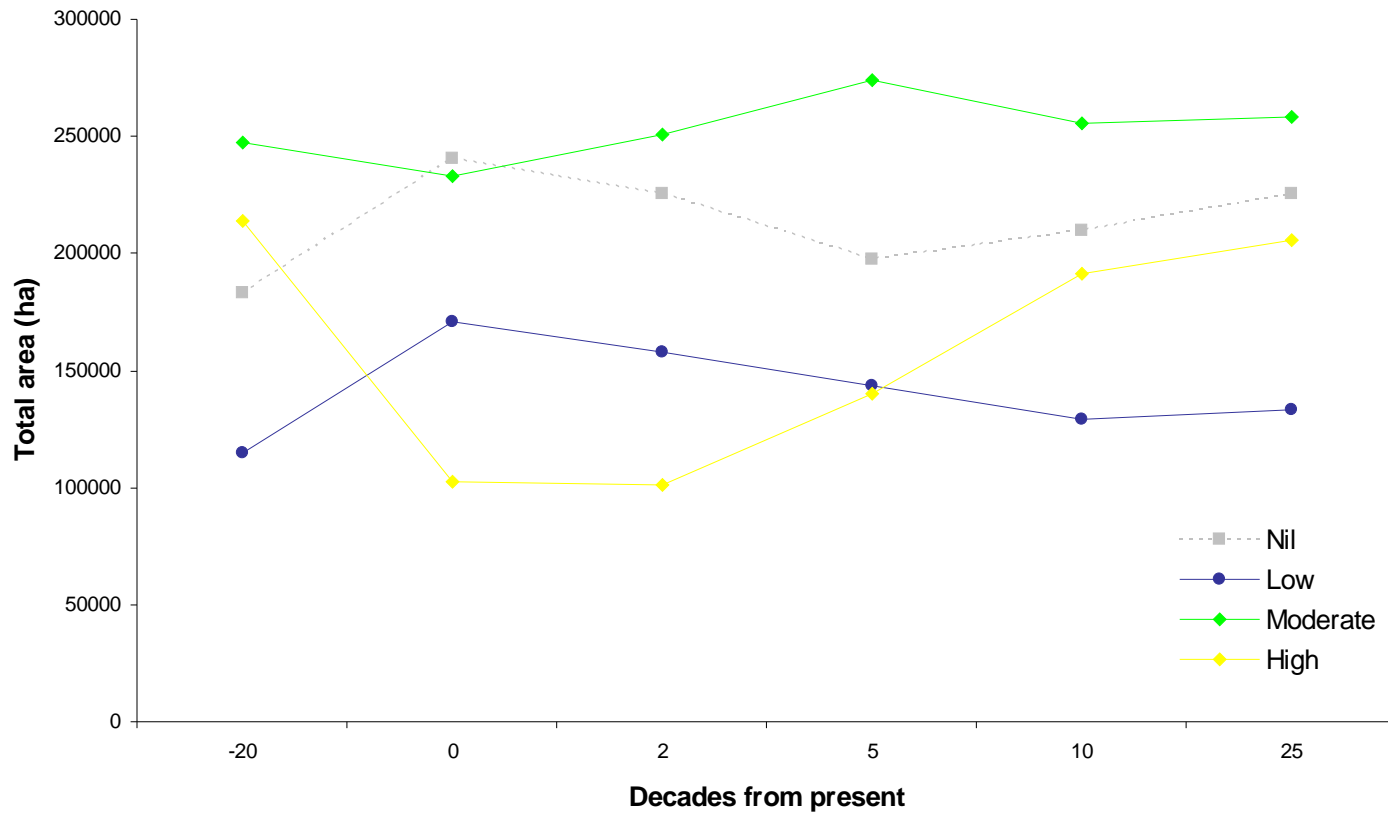


Figure E-6: Projected changes in nesting habitat within territories for Aging Only scenario for Haida Gwaii.

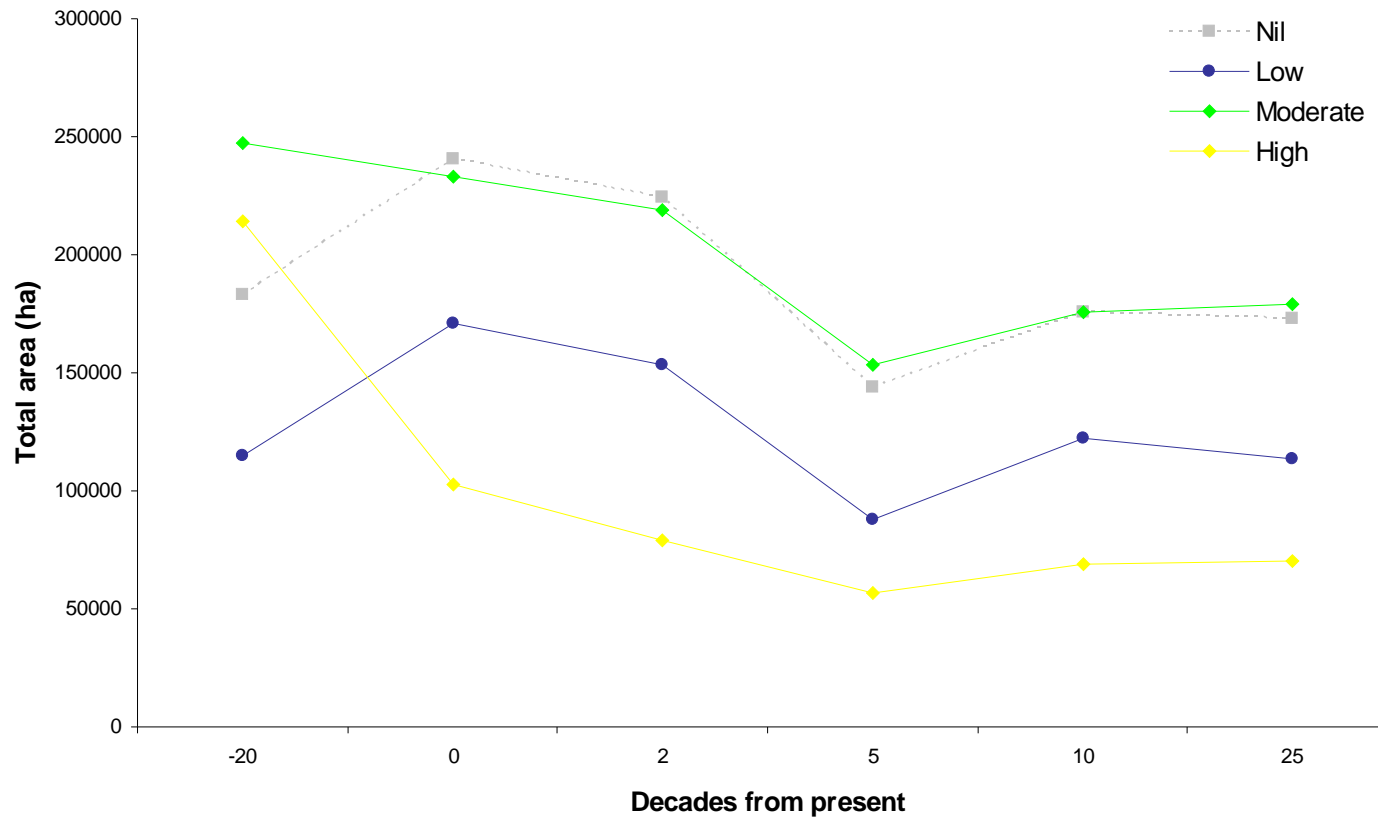


Figure E-7: Projected changes in nesting habitat within territories for Base Case 2 (BC2) scenario for Haida Gwaii.