

# Marbled Murrelet Nesting Habitat Suitability Model for the British Columbia Coast

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## Abstract

The Marbled Murrelet (*Brachyramphus marmoratus*) is legally listed as a threatened species in Canada primarily due to loss of nesting habitat. The Marbled Murrelet Nesting Habitat Suitability Model for the British Columbia Coast (referred to here as the “BC Model”) predicts the amount and distribution of Marbled Murrelet nesting habitat. The BC Model is an aggregate of predicted suitable habitat from a wide-scale algorithm using elevation, distance inland, and mapped forest cover attributes—tree height and age—that are important for nesting habitat as well as regional models in Haida Gwaii and Clayoquot Sound. It will monitor the progress of the Canadian Marbled Murrelet Recovery Team’s goal to maintain at least 70% of the suitable nesting habitat that existed in 2002. The BC Model predicted approximately 2 million ha of potential Marbled Murrelet nesting habitat. Twenty-six percent of the total habitat was in protected areas, which is equivalent to 37% of the habitat required to meet the recovery goal. The amount of nesting habitat predicted from the model algorithm was compared with aerial survey habitat predictions. There was no significant difference between the predictions from the two methods of identifying potential nesting habitat. The BC Model is recommended for broad-scale, strategic accounting of habitat, status assessments, and to aid in recovery and action planning.

**KEYWORDS:** *Brachyramphus marmoratus*; British Columbia; habitat suitability modelling; Marbled Murrelets; recovery planning.

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## Introduction

The Marbled Murrelet (*Brachyramphus marmoratus*) is listed as threatened under the Canadian *Species at Risk Act*, based primarily on the assessment by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (2008) that the rate of nesting habitat loss was excessive. The Marbled Murrelet nests on large mossy pads in the canopy of large old conifers. The old conifer forests have been harvested extensively in the murrelet's Pacific Northwest range. Trees with nest sites are usually greater than 200 years old and attain a height of greater than 28.5 m (Hamer and Nelson 1995; Burger 2002). Most nests have been found within 30 km of the sea and very few farther than 50 km inland (Hamer and Nelson 1995; Canadian Marbled Murrelet Recovery Team 2003). The majority of nests are found at elevations less than 900 m above sea level and less than 600 m at higher latitudes such as the central and north coast regions of British Columbia (Burger 2002; Canadian Marbled Murrelet Recovery Team 2003).

Linear relationships between Marbled Murrelet population size and area of suitable nesting habitat have been demonstrated for a wide range of areas in British Columbia and Washington state (Burger 2002; Raphael et al. 2002; Burger et al. 2004; Burger and Waterhouse 2009). When a forest patch is harvested murrelets do not pack into adjacent habitat (Burger and Waterhouse 2009). Nesting habitat loss is considered one of the major threats to populations (Burger 2002). Therefore protecting nesting habitat is a priority for species recovery. The Canadian Marbled Murrelet Recovery Team (CMMRT) is a diverse scientific team assembled to develop a recovery strategy and to advise the government about improvements for the status of the species. The team recommends down-listing the Marbled Murrelet from its threatened status by limiting the decline of the British Columbia population to less than 30% over three generations from 2002 to 2032 (Canadian Marbled Murrelet Recovery Team 2003). The team proposes that this will be accomplished by maintaining at least 70% of the nesting habitat that existed in 2002.

Since some regions of the province have had greater historic losses of nesting habitat than others, the Canadian Marbled Murrelet Recovery Team divided the British Columbia coast into six Marbled Murrelet conservation regions (Figure 1) where recovery efforts could be adjusted to local conditions (Canadian Marbled Murrelet Recovery Team 2003). Each conservation region

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has a different history, population status, and recovery goal (Burger 2002). Although the Canadian Marbled Murrelet Recovery Team recommends maintaining an average of 70% of the habitat in the province, each conservation region has a regional goal varying from maintaining as much as 90% of the remaining habitat on the highly developed East Vancouver Island region and 85% on the Southern Mainland Coast compared to 69% in the more remote West and North Vancouver Island, Haida Gwaii, and Central and North Mainland Coast regions (Canadian Marbled Murrelet Recovery Team 2003). A major objective of the recovery team is to map the amount and distribution of nesting habitat in each of the six conservation regions.

The Marbled Murrelet Nesting Habitat Suitability Model for the British Columbia Coast (referred to here as the "BC Model") includes a combination of habitat predicted from a wide-scale algorithm using elevation, distance inland, and mapped forest cover attributes of tree height and age that are important for nesting habitat as well as separate regional models in Haida Gwaii and Clayoquot Sound. The BC Model predicts suitable nesting habitat for the year 2002, providing a benchmark to measure the rate of habitat loss and success in achieving the 70% habitat maintenance goal. The BC Model is useful at the regional and landscape-level scale for mapping and analyzing potentially suitable habitat in coastal British Columbia and provides a rigorous basis for making high-level management decisions regarding nesting habitat conservation.

The primary objective of this article is to present the BC Model and provide predictions of distribution and amount of suitable nesting habitat in the province in 2002. The secondary objective is to compare the predictions of the BC Model's nesting habitat algorithm against those of low-level aerial surveys, an alternative, nesting habitat evaluation method. The BC Model's limitations, accuracy, and potential applications are also discussed.

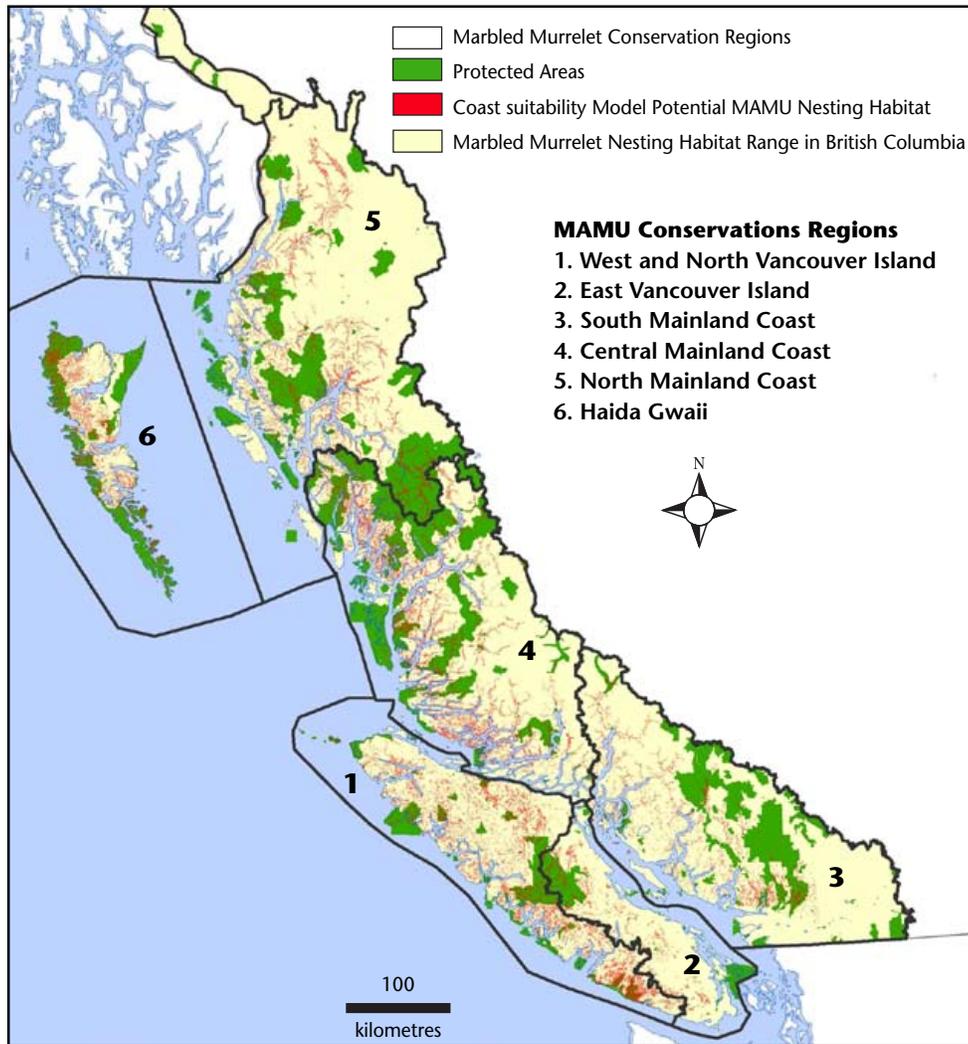
**Methods**

The BC Model was developed to predict nesting habitat using a variety of sources, including a habitat algorithm for most of the range, as well as two regional habitat models, and information on habitat use on the southern Gulf Islands.

**Habitat algorithm used to predict 2002 nesting habitat for most of the British Columbia coast**

The nesting habitat algorithm used to predict murrelet habitat suitability was derived from a selection of critical nesting habitat parameters described in the Canadian Marbled Murrelet Recovery Teams Conservation

Assessment Part B (Canadian Marbled Murrelet Recovery Team 2003), and expert opinion from members of the recovery team’s Habitat Recovery Implementation Group (scientific advisory group specifically assigned to develop a nesting habitat recovery plan for murrelets). The full list of parameters described as important for Marbled Murrelet nesting habitat includes distance from saltwater, biogeoclimatic subzones, variants, site series, site index (Meidinger and Pojar [editors] 1991) and productivity, elevation, slope, stand age, tree-height class, canopy closure and vertical complexity, topographic variability, aspect, exposure, moisture regimes, and other criteria such as platform density (Burger 2002). The BC Model is a bivariate model, using a suitable/not suitable classification system. It uses a combination of tree age,



**FIGURE 1.** Predictions of suitable nesting habitat (red) from the Marbled Murrelet Nesting Habitat Suitability Model for the British Columbia Coast in the six Marbled Murrelet conservation regions and the protected areas.

tree height, elevation, and distance from saltwater to evaluate habitat suitability. These data were available in forest inventories throughout British Columbia, and are the best predictors of nesting habitat (Canadian Marbled Murrelet Recovery Team 2003; Burger et al. 2009). Tree-age classes 8 (141–250 years) and 9 (250+ years) with height classes 4–7 (28.5 m or greater) were included. On Vancouver Island and the South Mainland Coast the elevation threshold was 900 m and in the North and Central Coast conservation regions the threshold was 600 m (Burger 2002). The distance from the coast to 50 km inland was used as the extent of the potential nesting habitat. Other combinations of habitat parameters were considered for the BC Model algorithm, but were eliminated if data was not available throughout the species range or if they would greatly over- or underestimate the majority of the potential nesting habitat.

### Data sources for habitat algorithm

The primary data source for the algorithm was the British Columbia Seamless Forest Cover Inventory,<sup>1</sup> a large spatial database with detailed information on British Columbia's forests. This inventory was assembled in 2002–2003 from four spatial databases described below. The databases were interpreted from air photos, calibrated with ground samples, and mapped at 1:20 000 scale. Although the data sources represent a range of years, the algorithm predicts the amount of habitat available in approximately 2002.

The Timber Supply Area Inventory covers more than 88% of the province at a scale of 1:20 000 and provides information on forest stand attributes (species, age, height, volume, and non-forest areas such as lakes, urban areas, etc). Most of these data were collected in 1995 for the Timber Supply Review 2. Inventory data were updated for disturbances (burns, harvesting, and insect infestations) in the late 1990s and in 2000 for all areas including Tree Farm Licences and parks.

The Tree Farm Licence Inventory, consisting of mapped data maintained by forest companies holding Tree Farm Licences, was used for about 6% of the provincial forested land base. Information is similar to the Timber Supply Area Inventory, however the quantity and quality of data, such as updating for harvesting or burns is variable among Tree Farm Licences.

The Park Forest Cover Inventory covers 2% of the province (11 of British Columbia's coastal provincial and federal parks), and is similar, but more generalized, than the other inventories. The forest cover inventory in the long established parks was based on aerial photography and field work from the 1950s. Therefore, tree ages in these parks were projected to January 1999.

Baseline Thematic Mapping is a database that was used for the 2% of the province not covered by the other forest cover inventories. The areas mapped are comprised largely of private lands and municipal parks. The database was compiled from Landsat satellite imagery from the early 1990s at a scale of 1:250 000. Old growth forests are identified as forests 140 years old and above, but there is no estimate or threshold for height. Therefore some of the forests classified as suitable nesting habitat will not have tall trees with structural components required for nest sites.

### Additional regional habitat models and geographic data used in the BC Model

For some parts of British Columbia, more accurate habitat models or information on the location of nesting habitat for the baseline year of 2002 replaced the algorithm in the BC Model.

In Haida Gwaii, the BC Model algorithm was replaced with a photo-interpreted model of the suitable nesting habitat (Waterhouse et al. 2007).<sup>2</sup> The forest cover inventory in Haida Gwaii was unavailable in the large area of the Tree Farm Licence or considered inaccurate due to overestimates of tree height used in the Timber Supply Review (A. Cober, B. C. Ministry of Environment, pers comm., February 2010). The air photo-interpreted method uses air photos to classify forest stand attributes based on a six-level ranking system as described in Burger (2004). Ranks are associated with structures that murrelets need for nesting such as stand access and protection provided by the canopy around the nest site (Burger et al. 2009). Also included are calculations of stand age, height, canopy closure, and vertical and canopy complexity. Air photo habitat classes 1, 2, and 3 (very high to moderate) were combined and classified as suitable in the BC Model. Waterhouse et al. (2010) reported that 97% of their study sites where the BC Model algorithm predicted suitable habitat fell into the top three air photo ranks.

<sup>1</sup> B.C. Ministry of Forests and Range. 2000. Seamless Forest Cover Inventory of British Columbia. Forest Practices Branch, Victoria, B.C. Unpublished data.

<sup>2</sup> Cober, A., F.L. Waterhouse, A.E. Burger, A. Donaldson, B. Smart, and P. Ott. Haida Gwaii/Queen Charlotte Islands Marbled Murrelet Habitat Mapping Project. In preparation.

In the Clayoquot Sound Planning Area on western Vancouver Island, we used the Bahn-Newsom algorithm based on Vegetation Resource Inventory maps specially made for Clayoquot Sound (Bahn and Newsom 2002). This algorithm included tree height, tree age, basal area, vertical canopy complexity, canopy closure, average distance from sea of the polygon, and average elevation to provide a four class rank of each polygon. The polygons ranked as Important Excellent and Important Good habitat were included as predicted suitable habitat in the BC Model.

Burger et al.<sup>3</sup> found that there was no evidence of Marbled Murrelet nesting in the southern Gulf Islands based on audio-visual detection surveys. Therefore, the small amount of habitat predicted from the algorithm on the southern Gulf Islands was eliminated from the BC Model.

### **Additional geographic data**

The distance of the potential nesting habitat from saltwater was identified and divided into three zones based on the Marbled Murrelet Conservation Assessments ratings of the relative value of the habitat (Burger 2002). The zone extending from the ocean edge at exposed coastlines to about 400 m is not generally used by Marbled Murrelets due to increased numbers of corvid predators or lack of appropriate forest structure (Burger et al. 2000; Rodway and Regehr 2002). However, steep fjords or sloping hillsides with little exposure to beaches or winds may contain high value nest sites, thus we maintain this zone in our estimates of habitat as in some areas it may maintain suitable habitat.

The zone from 400 m to 30 km is considered to be the most important habitat, whereas the zone between 30 and 50 km is generally less important to murrelets because it is so far from marine foraging habitats (Burger et al. 2000; Burger 2002; Waterhouse et al. 2004; Malt and Lank 2007). A breakdown of the relative amounts of habitat in each of these zones will also provide information on the distribution of the habitat relevant for conservation and habitat management planning.

Protected areas legally established by 2008 were identified to determine their overlap with suitable

nesting habitat. Protected areas include legally established provincial and national parks, ecological reserves, wildlands on the south coast, conservancies, and biodiversity, mining and tourism areas within the North and Central Coast Resource Planning Areas (see Glossary at end of article).

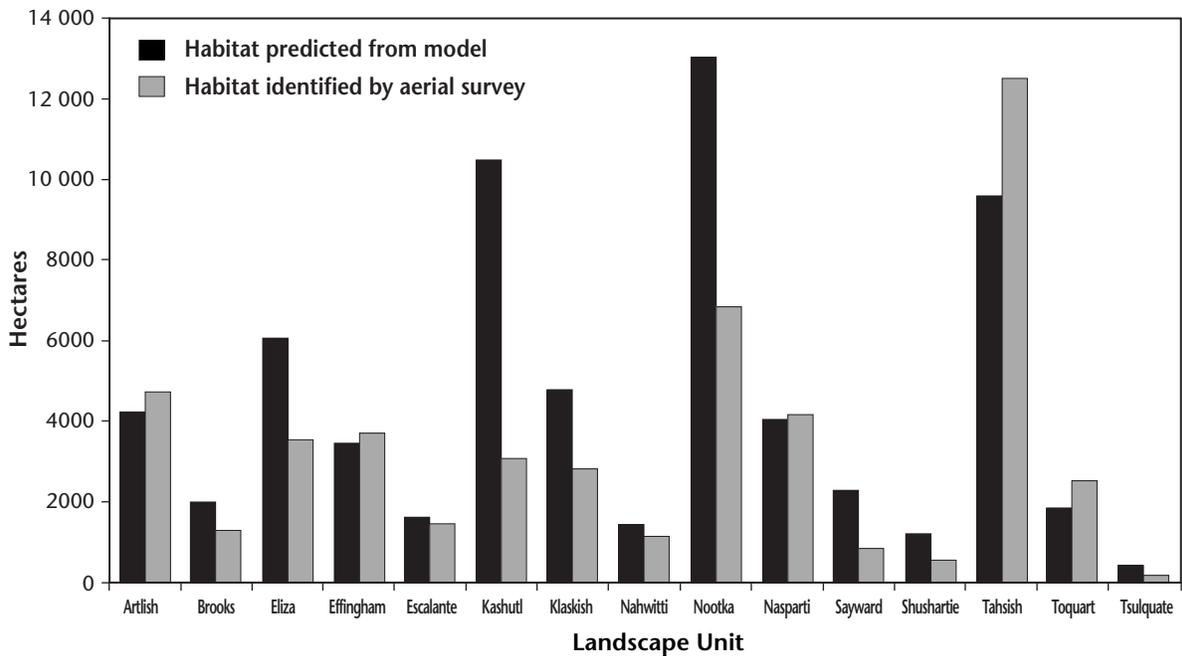
### **Test of the BC Model nesting habitat suitability algorithm**

To assess the reliability of the BC Model algorithm at predicting the amount of habitat, we compared the amounts of suitable habitat predicted by the algorithm to the amounts of habitat ranked Moderate to Very High by low level aerial surveys in 15 landscape units on Vancouver Island (Figure 2). Landscape units are planning areas, generally up to about 100 000 ha in size, delineated according to topographic or geographic features such as a watershed or series of watersheds (B.C. Ministry of Forests and Ministry of Environment, Lands and Parks 1999). Low-level aerial surveys rank the potential nesting habitat suitability based on Burger's (2004) six-class system. The field ranking is assigned by observers in helicopters based on the presence and relative abundance of potential nest platforms, the cover and thickness of epiphytes, and the canopy complexity and structure. The highest quality of forest structure is considered class 1, whereas areas of forest with no suitable structures are considered a 6 or nil habitat. Aerial surveys were done at the landscape unit scale or greater using modified methods as described by McDonald and Leigh-Spencer (2009). Ranks 1–3 (combined) of the six-rank system are considered comparable to the suitable habitat predicted in the algorithm for the BC Model (Burger and Waterhouse 2009; Waterhouse et al. 2010).

The 15 landscape units were chosen in areas where the majority of land was in the timber supply areas and where aerial surveys had been completed. We used the statistical analysis package, R (R Development Core Team 2008), to run a paired non-parametric Wilcoxon signed-rank test (Corder and Foreman 2009) in each of the 15 landscape units to determine if there was a significant difference in the amount of habitat predicted by both methods ( $\alpha = 0.05$ ).

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<sup>3</sup> Burger, A.E., V. Bahn, and A. Young. 2000. Assessment of nesting habitat for Marbled Murrelets in the coastal Douglas-fir forest of SE Vancouver Island in 1998 and 1999. Unpublished report.



**FIGURE 2.** Comparison of Marbled Murrelet habitat identified by the BC Model algorithm (black) compared with low-level aerial surveys (grey) for 15 landscape units on Vancouver Island. The two habitat estimates in each landscape unit are not significantly different (Wilcoxon signed-rank,  $p = 0.107$ ).

## Results

The area of suitable habitat as of 2002 identified by the BC Model was 1 980 846 ha. Of that habitat, 515 411 ha (or 26%) is located in protected areas (Figure 1). The amounts of suitable habitat were calculated by conservation region and geographic zones based on the distance from the ocean. The total potentially suitable nesting habitat is the sum of all three zones. The majority (82%) of the predicted suitable habitat in British Columbia is in the zone between 400 m and 30 km from the coast.

The suitable habitat in protected areas includes all parks, ecological reserves, conservancies, and biodiversity, mining, and tourism areas established by 2008. The recovery goals are from the Canadian Marbled Murrelet Recovery Team's recommendations of how much of the remaining habitat is needed to meet the 70% habitat retention goal (Canadian Marbled Murrelet Recovery Team 2003).

A GIS data file of the predicted suitable habitat is available for download from <ftp://littlearth.ca/pub/downloads/mamu/bc>.

## Testing the model: Comparing predicted amounts of habitat from the BC Model algorithm and aerial surveys

In the selected 15 Vancouver Island landscape units, the BC Model algorithm predicted a total of 66 135 ha of suitable habitat, compared to 48 981 ha by aerial surveys (ranks 1–3 combined). A non-parametric pairwise test (Wilcoxon signed-rank) compared the amounts predicted in each landscape unit. There was no significant difference in amounts of nesting habitat predicted by the model algorithm and the aerial surveys ( $p = 0.107$ , Figure 2).

## Discussion

The BC Model predicted approximately 2 million ha of potential Marbled Murrelet nesting habitat that existed in 2002. This amount sets the benchmark for the CMMRT recovery goal of maintaining at least 1 386 592 ha (70%) of this habitat. As of 2009, 515 411 ha (26%) is protected in legally established parks, conservancies, ecological reserves, wildlands, and biodiversity, mining, and tourism areas. The percentage of protected habitat varies by conservation region. Haida Gwaii has the highest percentage (51%), whereas the South Mainland Coast has protected only 18% (Table 1).

MARbled MURRELET NESTING HABITAT SUITABILITY MODEL

TABLE 1. Predicted suitable Marbled Murrelet nesting habitat in British Columbia in 2002

Marbled Murrelet conservation region	0–400 m zone	> 400 m to 30 km zone	> 30 km to 50 km zone	Total suitable nesting habitat 0–50 km inland (ha)	Total protected suitable nesting habitat 0–50 km inland (ha)	Protected (%)	Recovery goal (%)	Additional habitat needed to meet recovery goal (ha)
Northern Mainland Coast	38 241	327 251	70 460	435 952	110 361	25	69	191 818
Haida Gwaii	34 788	193 595	0	228 383	116 859	51	69	41 109
Central Mainland Coast	90 672	459 195	18 864	568 731	146 395	26	69	244 554
South Mainland Coast	10 943	164 110	32 680	207 733	36 600	18	85	139 181
West and North Vancouver Island	23 404	409 976	18 890	452 270	87 848	19	69	226 135
East Vancouver Island	461	74 192	13 124	87 777	17 348	20	90	65 833
<b>Totals</b>	<b>198 509</b>	<b>1 628 319</b>	<b>154 018</b>	<b>1 980 846</b>	<b>515 411</b>	<b>26</b>	<b>70</b>	<b>908 630</b>

Twenty-six percent of the murrelet habitat in protected areas in the province is equivalent to 37% of the habitat needed to meet the recovery goal. The additional habitat required outside of the protected areas is 908 630 ha (just under 46% of the total habitat).

**New and ongoing protected habitat designations**

Suitable nesting habitat outside of the identified protected areas should be considered and quantified as other new protected or partially protected designations proceed in current land planning processes. These designations include Wildlife Habitat Areas and Ungulate Winter Ranges established under the *Forest and Range Practices Act*, old-growth management areas (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1999), riparian reserve zones, and non-contributing and excluded forested land base (see Glossary at end of article). On the central and north coast of British Columbia, there will be additional protected designations through the ecosystem-based management (see Glossary at end of article) land use

planning process (Integrated Land Management Bureau 2007). Legal direction under Section 14 of the Central and North, and South Central Coastal Orders directs co-location of focal species habitats—including that of Marbled Murrelet—within old growth retention areas (B.C. Ministry of Agriculture and Lands 2009).

As a result of the Strategic Land Use Agreement ([http://archive.ilmb.gov.bc.ca/slrp/docs/Haida\\_SLUPA\\_Dec\\_07.pdf](http://archive.ilmb.gov.bc.ca/slrp/docs/Haida_SLUPA_Dec_07.pdf)), the Haida Gwaii Conservation Region has the highest proportion of potential habitat protected (51%). The process of identifying reserved habitat is also not finished. Objective 19 of the draft Haida Gwaii Land Use Objectives Order of 2009 ([http://archive.ilmb.gov.bc.ca/slrp/legalobjectives/pdf/HG\\_proposed\\_LUOs.pdf](http://archive.ilmb.gov.bc.ca/slrp/legalobjectives/pdf/HG_proposed_LUOs.pdf)) specifies further protection of air photo Class 1 and 2 Marbled Murrelet nesting habitat that will result in approximately 32 000 ha of suitable nesting habitat in reserves (Integrated Land Management Bureau 2009). Haida Gwaii would then easily meet the recovery goal of maintaining 69% of the nesting habitat: an estimated 65% in protected areas and easily more than 4% remaining in riparian reserve zones and the operable forest.

Preliminary analysis of 13 landscape units on Vancouver Island where ungulate winter ranges were established and wildlife habitat areas and old growth management areas (draft and legal) have been identified, shows that an additional 15% of the habitat was maintained under these designations above the 28% protected in parks (unpublished data). Therefore, a total of 43% of the habitat was maintained in reserved areas within the 13 landscape units.

The habitat protected from various ongoing planning processes should increase the amount of nesting habitat sustained throughout the range of Marbled Murrelets in the province. The BC Model could be updated to include recent protected habitat designations and used to track progress in meeting the regional habitat goals. It is also important to recognize that not all nesting habitat outside of protected areas will be harvested. Some portion of the habitat can be maintained in unprotected forest. As our knowledge of what is sustained in protected areas improves, the amount required in the operable forest can be predicted and managed to help meet habitat recovery requirements.

### **Reliability of the model algorithm in predicting amount of suitable habitat**

Results showed that there was no significant difference between the amount of habitat predicted by the BC Model algorithm and that predicted by low level aerial surveys in landscape units on Vancouver Island. This result confirms that the BC Model algorithm can provide reliable estimates of nesting habitat, comparable to the more direct habitat assessments done by aerial surveys.

Waterhouse et al. (2010) compared the habitat predicted by the BC Model algorithm and low-level aerial surveys to actual nest locations. Seventy-three percent of the nest sites fell within the habitat predicted by the BC Model algorithm, while over 97% fell within the top three aerial survey habitat classes. Low level aerial surveys are considered a more accurate method of evaluating potential nesting habitat (Burger 2004; Burger et al. 2009; Waterhouse et al. 2009) as they can identify microhabitat features such as the presence of platforms and epiphyte cover suitable for nests. However, researchers have noted that large-scale habitat mapping by aerial surveys (such as that done at the landscape unit or multiple watershed scale) does not always identify small patches and may rank larger polygons as an average rank, thus masking the small high quality patches (McDonald and Leigh-Spencer 2009; Waterhouse et al. 2010).

### **Limitations**

Understanding the limitations of the accuracy of this BC Model is important as it provides strategic estimates of available habitat to guide the implementation of recovery planning. The accuracy of the model is limited to that of the forest cover data, obtained in the Timber Supply Review 2 in the mid 1990s. Timber Supply 2 data is outdated and does not contain key features of nesting habitat such as the presence of mossy platforms (Burger 2004; Burger et al. 2009; Waterhouse et al. 2009).

Accuracy is also limited because of its bivariate ranking system (classifying habitat as suitable or not), compared to the six-rank systems of aerial surveys and air photo interpretation.

Harvesting data has only been updated to 1999 in the Tree Farm Licences and to 2000 in the Timber Supply Areas. Although harvesting from 2004 to 2007 was accounted for in comparisons between the model algorithm and aerial surveys, there is still a gap in the harvesting data from 2000 to 2004. This could account for the considerably higher habitat predictions of the model algorithm in the Kashutl and Nootka landscape units (Figure 2). Donald (2005) and Burger et al. (2005) compared aerial survey habitat ranks to the BC Model predictions of habitat. They found that the BC Model algorithm was less successful at correctly classifying the absence of habitat on both Vancouver Island and in the north coast of British Columbia. Differences in the date of the forest inventory data, the dates of harvesting, and the dates of aerial surveys, preclude simple comparisons.

Despite these discrepancies, the landscape or regional scale predictions of the amount of habitat from the BC Model algorithm, were not significantly different from those of the aerial survey habitat assessments.

### **Potential uses**

The BC Model is suited to broad-scale estimation of Marbled Murrelet nesting habitat area, but not its precise location. It was designed to help managers decide where to put emphasis on meeting the nesting habitat goals on a large (landscape, regional, and provincial) scale. It is not suitable for site-level purposes such as locating individual Wildlife Habitat Areas. Since the cost of aerial surveys are often prohibitive (Waterhouse et al. 2010), it is important to have an alternative, less expensive, and less time consuming method of estimating habitat area. Potential uses of the BC Model include the following:

- To predict the benchmark (2002) amount of Marbled Murrelet suitable nesting habitat.

- To predict and track protected habitat by conservation region, landscape units and forest development units.
- To evaluate and track various forest conservation and management options considered in land use planning and how they meet recovery plan objectives for Marbled Murrelets. For example, when evaluating or identifying possible reserve areas for murrelets, ensure that the reserves contain habitat primarily in the safest zone from predators, between 400 m and 30 km from the ocean.
- To evaluate habitat loss from the 2002 baseline by overlaying modelled habitat polygons with up-to-date satellite imagery indicating forest removals. Satellite imagery, available on an annual basis, can be overlaid on the model to show where habitat is lost through harvesting or other forest removals at a provincial scale.
- To evaluate Marbled Murrelet nesting habitat conservation status at a regional or landscape scale.

## Conclusion

The BC Model predicts the entire area of suitable Marbled Murrelet nesting habitat in the range of the species in British Columbia as of 2002. Its component models, created for Haida Gwaii and Clayoquot Sound, improve the accuracy of the predictions from the main habitat algorithm as they are based on more direct evaluation of habitat suitability for nesting. The BC Model is useful for land use planning and quantifying protected habitat as required for Marbled Murrelet recovery.

Updated versions of the BC Model could provide more accurate estimates of current habitat by incorporating suitability data from other more direct habitat assessments such as low-level aerial surveys done on Vancouver Island and portions of the central coast, and recently completed air-photo interpretation for the Central Mainland Coast and portions of the North Mainland Coast Conservation Regions. Any updates will provide more accurate current information on the amount and possible change in potential habitat, but not on the baseline amount predicted by the BC Model presented here. If the suitability of protected habitat changes over time, potentially in response to climate change, fire, or other disturbances, these areas could be removed from the model and the habitat amounts recalculated. The predictions provided by the BC Model are sufficient to show that, provincially, current nesting habitat protection falls short of meeting the goals set out by the Canadian Marbled Murrelet Recovery Team.

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## Acknowledgements

Support for this research was provided by the B.C. Ministry of Environment and the B.C. Forest Investment Account (FIA). Advice and direction in the early development of the BC Model was provided by the Marbled Murrelet Habitat Recovery Implementation Group including Alan Burger, Greg George, Toby Jones, Dave Lindsay, Wayne Wall, Louise Waterhouse, and Liz Williams. Alvin Cober also supplied data and information on Haida Gwaii inventory and planning processes. Thanks also to Stephanie Hazlitt, Louise Waterhouse, and Dave Donald for advice and reviews. Jamie Duncan, Byron Woods, and Dan Hirner provided essential GIS data compilation and analysis. Jamie Popkin revised and updated the GIS data and summarized the aerial survey information. Thank you, Ruth Joy, for providing much needed statistical advice and analysis. Aerial survey data was also provided by funding through FIA and Western Forest Products Inc.

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ARTICLE RECEIVED: January 5, 2010

ARTICLE ACCEPTED: September 10, 2010



Production of this article was funded, in part, by the British Columbia Ministry of Forests and Range through the Forest Investment Account–Forest Science Program.

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## Glossary

**Biodiversity, mining, and tourism areas** – These are designated areas that contribute to the conservation of species, ecosystems, and seral stage diversity by being located adjacent to existing conservancies and other types of protected areas, and by limiting the land uses within the zones. Commercial timber harvesting and commercial hydro-electric power projects are prohibited within these areas. Other resource activities and land uses will continue, subject to existing regulations and legislation ([http://www.ilmb.gov.bc.ca/slrp/lrmp/nanaimo/central\\_north\\_coast/biodiversity.html](http://www.ilmb.gov.bc.ca/slrp/lrmp/nanaimo/central_north_coast/biodiversity.html)).

**Conservancies** – Conservancies are established through the *Park (Conservancy Enabling) Amendment Act* and are maintained under protected areas legislation. Conservancies are areas where industrial resource development activities are prohibited in order to protect the high values of these areas to First Nations and the public. Commercial logging, mining, hydroelectric development, new roads, and commercial development are not permitted within conservancies. Some development activities may be considered acceptable where all collaborative management planning parties are in agreement ([http://www.ilmb.gov.bc.ca/slrp/lrmp/nanaimo/central\\_north\\_coast/cons\\_area\\_docs.html](http://www.ilmb.gov.bc.ca/slrp/lrmp/nanaimo/central_north_coast/cons_area_docs.html)).

**Ecosystem-based management in British Columbia** – This is an adaptive approach to manage human activities to ensure the co-existence of healthy, fully functioning ecosystems and human communities (<http://www.ilmb.gov.bc.ca/slrp/lrmp/nanaimo/cenocast/plan/ebm.html>).

**Ecological reserves** – Ecological reserves are permanent sanctuaries located throughout British Columbia that have been selected to preserve representative and special natural ecosystems, plant and animal species, features, and phenomena (<http://www.ecoreserves.bc.ca/erwhen.html>).

**Excluded forest (X)** – Portion of the land that is not managed by the Forest Service for timber supply. It is excluded from contributing to old growth and wildlife tree biodiversity targets (non-Crown, non-forest, non-productive forest).

**Identified wildlife** – Wildlife species and plant communities that are at risk in British Columbia, and receive special consideration if their habitat would be affected by forest or range activities on public land. Wildlife Habitat Areas are designated for Identified Wildlife under British Columbia's Identified Wildlife Management Strategy (<http://www.env.gov.bc.ca/wld/frpa/iwms/index.html>).

**Inoperable forest** – Lands unsuited for timber production now and in the foreseeable future by virtue of their elevation, topography, inaccessible location, low value of timber, steep or unstable soils, or other designations.

**Non-contributing land base** – The crown forested land base that does not contribute to annual allowable cuts (AAC) but does contribute to biodiversity objectives and targets. It includes riparian reserves, inoperable forest and any other 100% netdown areas, and partial netdowns, such as environmentally sensitive areas as defined by the Timber Supply Review.

**Old growth management areas** – Defined in the *Forest Practices Code of British Columbia Act Operational Planning Regulation* as an area established under a higher level plan that contains or is managed to replace structural old growth attributes.

**Operable forest** – The portion of the productive forest that, under the current market conditions, can be logged economically.

**Riparian reserve zones** – Defined in the *Forest Practices Code of British Columbia Act Operational Planning Regulation* as that portion, if any, of the riparian management area or lakeshore management area located adjacent to a stream, wetland, or lake of a width determined in accordance with Part 10 of the regulation.

**Ungulate winter ranges** – A designated area that contains habitat that is necessary to meet the winter habitat requirements of an ungulate species (<http://www.env.gov.bc.ca/wld/frpa/uwr>).

**Wildlands** – Wildland (Mining/Tourism Permitted) zones have been identified in recognition of their First Nations cultural values, high wildlife habitat values, backcountry recreation values, and remote, natural, wilderness characteristics. Wildland zones are intended to permit tourism and subsurface resource development while maintaining these values. Commercial timber harvesting is not allowed, nor is the infrastructure of independent power projects, including but not limited to commercial run-of-river hydroelectric power generation ([http://www.ilmb.gov.bc.ca/slrp/lrmp/surrey/s2s/docs/S2S\\_LRMP\\_Final/S2SLRMP\\_Final\\_April2008.pdf](http://www.ilmb.gov.bc.ca/slrp/lrmp/surrey/s2s/docs/S2S_LRMP_Final/S2SLRMP_Final_April2008.pdf)).

**Wildlife Habitat Areas** – A mapped area of land that is designated to meet the habitat requirements of one or more species of identified wildlife (<http://www.env.gov.bc.ca/wld/frpa/iwms/wha.html>).

## Test Your Knowledge . . .

### *Marbled Murrelet Nesting Habitat Suitability Model for the British Columbia Coast*

How well can you recall some of the main messages in the preceding Research Report?

Test your knowledge by answering the following questions. Answers are at the bottom of the page.

1. The Marbled Murrelet Nesting Habitat Suitability Model for the British Columbia Coast (BC Model) is an aggregate model including an algorithm using elevation, distance inland, and mapped forest cover attributes of tree height and age as well as two separate regional nesting habitat models in Haida Gwaii (from airphoto interpretation) and Clayoquot Sound (aerial habitat assessments and vegetation).
  - A) True
  - B) False
  
2. The BC Model is most useful for:
  - A) Fine scale habitat evaluation to identify suitable nesting habitat
  - B) Broader regional estimates of suitable nesting habitat
  - C) Both (A) and (B)
  
3. The BC Model predicts the amount of suitable Marbled Murrelet nesting habitat for what benchmark year?
  - A) 2000
  - B) 2002
  - C) 2010
  - D) 2006

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**ANSWERS**

1. A 2. B 3. B