Testing models of habitat suitability for nesting Marbled Murrelets, using low-level aerial surveys on the North Coast, British Columbia

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EXECUTIVE SUMMARY

We used low-level aerial surveys to assess nesting habitat attributes for Marbled Murrelet (*Brachyramphus marmoratus*) at 100 sites on the North Coast, British Columbia in October 2004. We had four objectives:

- To test the reliability of two models in predicting the occurrence of microhabitat attributes important to nesting murrelets;
- To contribute North Coast data to the growing database from standardized aerial surveys across the murrelet's range in BC;
- To provide information on likely habitat suitability for murrelets and thereby assist management within the North Coast region;
- To compare the forest cover and topographic data within the GIS database (data which would be used for management and habitat modeling) with similar measures made from the helicopter during the aerial surveys.

The aerial surveys followed the standard helicopter protocol (Burger et al. 2004). Site quality and the availability of habitat features were ranked on a six-step scale (1 Very High, 2 High, 3 Moderate, 4 Low, 5 Very Low, and 6 Nil). Two habitat models were tested. The first (MMRT Model) was a general algorithm provided by the Marbled Murrelet Recovery Team for determining the forest and topographic parameters most or moderately likely to provide suitable nesting habitat. The MMRT model was derived from stand age, height class, crown closure and elevation, and predicted only Habitat or Not Habitat. The second (Regional Model) was a more detailed algorithm, derived from a similar study on the Central Coast. This model used stand age, height class, crown closure, elevation, slope, and dominant tree species, and produced a 4-level rank of habitat quality (Superior, Good, Fair and Nil).

Two sites which had been partially logged by heli-select logging showed reduced suitability for murrelets and were excluded from the analysis. We also excluded two sites which fell on sharp stand boundaries. Data were therefore analysed for 96 sites (94 with GIS forest cover data).

In comparing data for each site from the GIS forest cover database with the aerial survey assessments, we found good agreement for stand age and tree height. Estimates of crown closure were generally similar, but with a slight tendency for higher ranks in the aerial surveys. High vertical complexity usually occurred within the range of crown closure recommended by the recovery team (98% of the sites with vertical complexity rated Moderate to Very High fell within crown closure 3-7 (rated Most or Moderately Likely in the MMRT algorithm). These results confirm the need for a relatively wide range of crown closure within habitat algorithms. The GIS forest cover and aerial surveys showed similar trends for the dominance of western red-cedar and western hemlock, but some marked differences for amabilis fir, Sitka spruce and yellow cedar. Differences in species dominance were in part due to differences in spatial scale between the GIS polygons and the aerial survey sites. These differences caution against strong reliance on tree species dominance within regional algorithms for murrelet nesting habitat.

We examined which of the parameters or combination of parameters available within the GIS forest cover data could best predict the availability of trees with platforms and moss development (essential features for nesting murrelets but not available in forest cover or air photo data). Platform availability, moss development and vertical canopy complexity were all significantly positively correlated with forest age class, height class, and site index, and negatively correlated with crown closure, slope and elevation. Platform and moss availability were not affected by aspect. Both showed a significant positive association with dominance by Sitka spruce and negative association with western red cedar, with western hemlock and amabilis fir intermediate. A combination of elevation (negative effect) and tree height class (positive effect) had the strongest effects, but explained only 29-30% of the variability in platform and moss availability.

Both the MMRT and Regional models performed well in predicting the occurrence of suitable nesting habitat but were less successful in predicting when habitat was not suitable or Nil. These models can therefore be applied with some confidence to identify stands likely to provide the canopy attributes known to be important for nesting Marbled Murrelets. The models should, however, be applied with great caution, and supplemented by aerial surveys, if used to determine areas with no habitat attributes which therefore might be excluded from management for murrelets.

For the Regional Model, 92% and 83% of the sites predicted to be Superior or Good were in fact good habitat as identified from the helicopter. Most (70%) of the sites modeled as Fair were in fact good habitat and the rest were marginal. Only 60% of the sites predicted to be Nil by the model were rated as Nil from the helicopter. Many of the sites erroneously rated as Nil by the Regional Model had been downrated because they lacked Sitka spruce and had height class 4 (28.5-37.4 m) rather than larger trees. The Regional model could therefore be improved by reducing the weighting given to spruce and by slightly lowering the threshold for marginal suitable habitat.

For the MMRT Model, out of 85 sites predicted to be suitable murrelet habitat, all except one (99%) had some habitat attributes; 79% were ranked as Likely Habitat (rank 1-3) and 20% were ranked as Marginal Habitat (rank 4-5). Out of 11 sites rated as Not Habitat 55% were assessed to be Nil from the helicopter, 36% had at least Marginal Habitat status (rank 4-5) and 9% were assessed to be Likely Habitat (rank 1-3).

Our aerial survey data provide insights into the habitat parameters most strongly associated with good or poor habitat on the North Coast. Large trees and many canopy trees with platforms were consistently found within the upper ranks of the sites assessed, because these were the parameters given greatest weight by the observers. Moss development tracked platform availability almost identically, because in the North Coast nearly all of the platforms were provided by mossy mats. Vertical canopy complexity declined with decreasing habitat rank but was sometimes high in poor sites and by itself it was not a reliable indicator of highly ranked sites. Canopy cover and topographic complexity showed no consistent trend across the habitat ranks and were not important indicators of habitat quality. Although age class by itself was not a reliable indicator of habitat quality (many poor sites were in mature or old forest), age class has to be included in all models and aerial assessments, because suitable habitat was found only in sites that were old-growth (age 9 >250 y), mature (age 8, 140-250 y) or a mix of 8 and 9. The five sites that were in age 8 were all ranked Low, Very Low or Nil. It is therefore risky to assume that suitable murrelet habitat might occur in stands that are not old (age 9).

Sites dominated by Sitka spruce were strongly skewed towards the high end of the aerial ranks, as predicted by the Regional Model (but see caution above about the risk of putting undue weight on spruce). Yellow cedar (given a positive weighting in the Regional model) and lodgepole pine (given a negative weighting), were uncommon and their importance as predictors could not be adequately tested. Hemlock trees frequently provided suitable platforms but were too ubiquitous to be predictors of good habitat. Similarly, western red-cedar and amabilis fir were found in all habitat ranks and cannot be used as indicators of suitable murrelet habitat on the North Coast.

In our aerial survey sample, sites within valley bottoms or on lower slopes tended to have high ranked habitat, but we found no statistical significance in ranking due to slope position or gradient. Our results confirm that slope should be treated as a neutral variable in identifying suitable habitat. The negative weighting given to slope grade in the present Regional model should be removed in future models, although it did not appear to create any obvious misclassifications. Most of the murrelet habitat on the North Coast appears to be in valley bottoms and lower elevations, but our sample of high elevation sites (>600 m) was inadequate to test where the upper habitat threshold might occur.

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Appendices 1 to 3 are available as an Excel file – contact Alan Burger aburger@uvic.ca

1 INTRODUCTION

This report covers low altitude aerial surveys conducted to assess nesting habitat available to the threatened Marbled Murrelet (*Brachyramphus marmoratus*) in the North Coast conservation region (as defined by the Marbled Murrelet Recovery Team; MMRT 2003). The intent of the survey was to assess randomly selected sites using a standard protocol (Burger et al. 2004), which ranks forest and topographic attributes believed to be important for nesting Marbled Murrelets, based on reviews of nest sites and habitats known to be used by murrelets in BC. The study had four primary objectives.

The first objective was to test the reliability of two algorithms designed to identify and map potentially suitable nesting habitat for the murrelet in the North Coast. One algorithm was a general model (MMRT model) suggested by the Marbled Murrelet Recovery Team to identify likely nesting habitat across the BC coast range of the murrelet (details below). The other model (Regional model) was a modification of the regional habitat algorithm developed for the Central Coast conservation region, and tested there using aerial surveys (Leigh-Spencer et al. 2002, Hobbs 2003). This model was adapted by Jared Hobbs for the North Coast region (details below). Testing habitat algorithms using aerial surveys provides some indication of the reliability of the models in identifying stands with suitable trees, platforms and canopy gaps necessary for murrelets to nest.

A second objective of the study was to refine the aerial survey protocol and contribute to the growing database of sites assessed using this protocol in British Columbia. Other studies have applied the protocol on Vancouver Island (e.g., Clayoquot Sound, Zeballos Landscape Unit), the Sunshine Coast, Central Coast and Haida Gwaii (QCI; Eden Lake Landscape Unit). These data will ultimately be combined in a BC-wide analysis of the aerial survey method and can also be used to assess BC-wide models and habitat algorithms.

The third, and important objective was to provide information on the likely suitability of watersheds and habitat types within the North Coast region. This information will be applied in guiding landscape-level and stand-level land-use decisions which affect Marbled Murrelets. At the landscape level important decisions will soon be made on the value of existing and future protected areas (e.g. those areas set aside by the North Coast LRMP table). At the stand level the information will assist the correct selection of Wildlife Habitat Areas (WHAs), Old Growth Management Areas (OGMAs) and other areas of maintained nesting habitat for murrelets.

The fourth objective was to compare the forest cover and topographic data within the GIS database (data which would be used for management and habitat modeling) with similar measures made from the helicopter during the aerial surveys. This would show the consistency between the methods for important variables such as stand age class, tree height, crown closure etc. This comparison also allowed us to determine which of the data within the GIS database could most reliably predict the availability of platform limbs and moss development on these limbs. Platforms and epiphytic moss are not included in forest cover or similar forest databases and cannot be assessed from air photos. It is therefore important to identify which of the features in the GIS databases can best predict the availability of platforms and moss which are critical for nesting murrelets.

Our aerial survey study complements previous and ongoing studies made in this region using radar to count murrelets using selected watersheds (Steventon and Holmes 2002), and modeling of habitat suitability and risks of land-use decisions (Steventon 2003, Steventon et al. 2003).

2 METHODS

***The MMRT Model* –** The MMRT model is based on the parameters identified by the Marbled Murrelet Recovery Team (MMRT 2003) which are generally found in forest habitat used by nesting Marbled Murrelets within BC. The recovery team ranked the variations within each parameter on the basis of “most likely”, “moderately likely” and "least likely" to provide suitable nesting habitat for murrelets. The current MMRT model tested here is a mix of "most" and "moderately" likely features, and essentially identifies older forests (age class 8 [141-250 y] or 9 [>250 y]), with larger trees (height class 4 and above [>28.4 m tall], and intermediate canopy cover (cover 40-80% inclusive). For the North Coast the MMRT algorithm selected all suitable habitat below 600 m. Forest within 500 m of saltwater were included in the MMRT model. Details of the parameters selected in the MMRT model are given in Table 1 The model ranks forest polygons as either Habitat (H) or Not Habitat (Nil N). It does not provide information on the quality or probability of suitability within the Habitat category.

The Regional Model **–** This is an adaptation of a model developed and refined in the Central Coast region (Hobbs 2003). The model parameters are given in Table 1. Unlike the bimodal MMRT model, the Regional model provides a range of suitability ratings, with greatest weighting given to age class and height class, less weighting given to crown closure and leading tree species, and least weighting given to elevation and slope. For the purposes of this project this model excluded forests within 500 m of saltwater. The model ranks habitat into four classes (1 Superior, 2 Good, 3 Fair and 4 Nil) based on the scores derived from the weighted habitat attributes (Table 1).

Mapping of model predictions and selection of survey sites **–** A set of maps, for both the MMRT model and the Regional Model, were created for evaluation in the field. The suitability predictions that resulted from each model were mapped as colored polygons, reconciled against 1:20K TRIM topographic data for the entire North Coast region. . Within these areas, 128 sites were selected for aerial assessment. The geographic location of each site was mapped using North American Datum 1983 (NAD 83) Universal Transverse Mercators (UTM) to enable efficient navigation in the field. The sites were selected using a stratified random selection process: 32 sites were randomly selected within each of the four habitat categories predicted by the Regional model. Points were placed in the approximate center of the polygon intended for evaluation to reduce errors resulting from evaluation of adjacent dis-similar habitats. To reduce the amount of helicopter flying time between sites, the random selections were clustered into groups of

3-8 sample points within watersheds. Points were selected to sample all three Biogeoclimatic Ecosystem Classification (BEC) sub-zones (maritime, hyper-maritime and sub-maritime) within the study area (Banner et al. 1993).

Aerial survey protocol – Methods followed the standard protocol for aerial assessment of potential murrelet habitat in BC (Burger et al. 2004). The standard data sheet was modified to include a 4-class ranking (in addition to the standard 6-rank system) to compare with the 4-rank Regional model. All the data shown on the data sheet (Appendix 1) were recorded, except for the % of polygon within each class (this attribute was not applicable to the project objectives).

The surveys were conducted on 4, 5 and 7 October 2004. An A-Star helicopter, based in Terrace, BC was used to maximize fuel carrying capacity, speed and lift power. The navigator (JH on 4 and 5 Oct; AH on 7 Oct) sat in the front seat, next to the pilot and directed the flight path and choice of survey points using the GIS maps and a GPS. Two observers (AB on all flights; S Guy on 4 Oct; AH on 5 Oct; F. Doyle on 7 Oct) viewed the habitat on either side of the aircraft, recorded the information on data sheets, and took still photographs and videos. Assessments were made blind (i.e., the observers in the rear of the helicopter did not know the model ranking of the points being assessed and did not have access to maps showing the survey points). Using the helicopter's audio system, the observers discussed each attribute being ranked at each site and reached a consensus on each rating assigned in the field (field rating). Habitat was assessed within an approximated 100 m radius around each UTM position. Data used in the analysis are given in Appendix 2.

Changes had to be made to several of the pre-selected sites. Sites 7, 10, 37, 45, and 99 had been recently clearcut, but the sites were re-located to the nearest matching sites by the navigator; the UTMs shown for these 5 sites were the new locations and these data were included in the analysis. Sites 22 and 53 had been logged and there were no replacement sites available; no data were therefore collected. Sites 6 and 12 had been partially logged with heli-select logging; these sites were assessed from the helicopter (see results) but not included in the subsequent analysis.

In a few cases, the navigator had problems matching the habitat found at the UTM position with the habitat predicted on the map. Usually this involved small patches of boggy or estuarine forest/scrub mixed in with more suitable stands of larger trees. In these cases the navigator directed the observers to restrict the area being assessed and identified an alternative point at which to centre the assessment. Site 60 was omitted because the UTM location bordered poor (bog) and good (riverine) habitat with rapid transition, making it difficult to assess any reasonable area (observers reported widely diverging scores here). Site 30 also fell on a sharp habitat boundary between forest and avalanche chute. Two assessments were done (30a and b) but only 30a was used because it more closely matched the originally selected habitat type.

The still photographic prints taken at each site area were all scanned into digital format and are available on a CD (archived with Anne Hetherington, MWLAP, Smithers).

GIS habitat data – Forest cover and topographic measures for the UTM location of each survey site were extracted from the GIS database used for forest management. These data were extracted by the Prince George Contact Centre, Land Information BC, MSRM, at the request of Doug Steventon (Research Wildlife Habitat Ecologist, Ministry of Forests, Regional Service Centre, Smithers, B.C.). The sites fell within TFL 25 and 41 and within TSA areas (Appendix 3). Forest cover data for the TFLs originated from Forest Cover Layer 1 (polygon lines) and the Forest Inventory Planning database (contains the various attributes associated with the polygons). Forest cover data for the TSAs was derived from Vegetation Resource Inventory (VRI) data. Stand ages were projected to 1 Jan 2001 (TFL 25), 1 Jan 2002 (TFL 41) and 1 Jan 2004 (TSA). Sites 10 and 93 were not included in the comparison with the GIS data, because the GIS data erroneously indicated a non-vegetated area for site 10 and there were no GIS data for site 93 (rated nil by all models) because it fell into a non-contributing land-base.

Data analysis – The aerial survey data were entered into an Excel spreadsheet for archiving and preliminary analysis (Appendices 2). Two people independently compared the spreadsheet with the paper data sheets and corrected errors. Statistical analysis was done using SPSS 11.5.

To increase sample sizes for statistical tests and to show trends more strongly it was sometimes necessary to pool categories. In the aerial assessments, we sometimes combined the 6 ranks into three: Likely Habitat (ranks 1-3), Marginal Habitat (ranks 4-5) and Nil (rank 6). The grouping of the upper three categories is consistent with the application of other 6-rank classifications of murrelet habitats (e.g., in a recent analysis of habitat in the Eden Landscape Unit on Haida Gwaii involving air photo interpretation and aerial helicopter surveys, likely habitat was considered to be the top 3 ranks).

3 RESULTS

3.1 Database and exclusions from analysis

The complete aerial survey database is shown in Appendix 2. An Excel digital version is available from the authors. Data were collected at 100 sites, but four were subsequently excluded. Sites 6 and 12 which had been partially logged were excluded after testing the effects of heli-select logging (see below). Sites 60 and 31 were excluded because the UTM point fell on a sharp habitat boundary (see above).

3.2 Effects of partial heli-select logging

Two sites had been partially cut by heli-select logging, but were assessed from the helicopter (Appendix 2). Site 6 had been quite heavily cut (about half of the canopy trees removed); the site had been rated Superior by the regional model and as Habitat by the MMRT model, but was assessed as Fair in the aerial survey. Site 12 had evidently lost about 10-12% of the canopy trees; the site was rated Good by the regional model and

Habitat by the MMRT model, and Good by the aerial survey. Given the likelihood that the partial logging had significantly changed habitat quality, these two sites were subsequently omitted from further analyses.

3.3 Comparison of aerial survey assessment with GIS forest cover data

There were two goals here:

1) To compare the GIS forest cover data (Appendix 3) with the same or similar measures made from the helicopter (Appendix 2). These comparisons indicated the consistency between the data sources, and also helped to identify problem sites to be excluded from tests of the habitat models.
2) Compare overall site habitat rank from the aerial survey with the GIS forest cover data identified by the recovery team as key indicators of Most Likely and Moderately Likely habitat (MMRT 2003).

Two sites had incomplete forest cover data and hence the sample size for these comparisons was 94 sites. Some of the differences between the GIS forest cover and aerial survey data shown below undoubtedly were due to differences of scale: the GIS forest cover data were derived as averages for polygons (mean area 41 ha, range 5-266 ha; Appendix 3) whereas the aerial surveys were restricted to 100 m radii (3.1 ha).

Stand age – The aerial surveys did not classify young stands in detail but only as less than age class 8 (<140 y). There was 93% agreement in the age classes from the two methods (98% if age classes 8 and 9 were pooled; Table 2A). Only one site showed major discrepancies. Site 124 (aged 130 y, class 7, in GIS) was ranked age 9 from the helicopter, but the GIS data were probably correct. This site was dominated by Sitka Spruce and had large trees, likely due to rapid growth of this species. Field notes mentioned big trees with relatively little moss and dense canopy, and field photo shows some tall snags but not strong old-growth attributes. The GIS age (130 y) is probably correct and age was overestimated from the helicopter.

When GIS age class was compared with the overall aerial site rank, 97.1% of the 68 sites ranked as 1-3 (Moderate to Very High) fell in GIS age class 9, one site (1.4%) was in class 8, and the remaining site (Site 31) was the problem site identified above (Table 2B).

Height class – We did not assess height class from the helicopter. In general there was good agreement between the GIS height classes and the aerial ranking of the percentage of large trees at the site (Table 3A). All 79 sites ranked as 1 and 2 for large trees, and four of five sites in rank 3, fell within GIS height class 4 or higher (i.e., 99% of all sites ranked 1-3 were in height class 4). Four sites showed fewer large trees in the aerial surveys than expected from the GIS tree height classes:

- site 30 (GIS height class 4) was assessed as having no large trees;
- site 61 (GIS height class 4) was assessed as having ~1% large trees (rank 5);
- site 32 (GIS height class 5) was assessed as having 1-5% large trees (rank 4);
- site 105 (GIS class 6) was assessed as having 6-25% large trees (rank 3).

One site was assessed higher than the GIS height class would predict:

- site 58 (GIS class 3) was assessed as having 6-25% large trees (rank 3) – the field notes say "Few big trees but good moss".

Comparing overall habitat ranking, all sites ranked 1-2 (High and Very High) and all but one (i.e., 98.6%) of the 69 sites that were ranked 1-3 (Moderate to Very High) in the aerial surveys fell within height class 4. Site 58 (see above) was the exception, and this result was explained by relatively high moss development in comparatively small trees.

Crown Closure – The aerial surveys showed a slight tendency to overestimate crown closure relative to the closure in the GIS forest cover data (Table 4A). About a third (33.7%) of the sites showed a match within 5%, and about two-thirds (63.2%) were within 10% of each other. Major differences were seen in three sites:

- Site 30 (GIS closure 65%) was an avalanche chute assessed as <20% closure from the helicopter (problem site with other variables – see above).

- Sites 116 (GIS closure 20%) was assessed from the air as 80% closure (overall site ranking 3) - field notes mention some big trees with few platforms and a very dense canopy. The GIS data were evidently wrong.
- Site 122 (GIS closure 20%) was assessed from the air as 70% closure (overall site ranking 4). This site had a high proportion of younger trees (recorded as age class <8), with a few veterans (age class 9), and evidence of avalanche disturbance. The GIS crown closure evidently focused only on the mature trees.

Comparing overall habitat rankings of the sites, 73.9% of the 69 sites ranked 1-3 (Moderate to Very High) fell within GIS crown closure classes 4-6 (36-65% cover; rated as Most Likely by the Recovery team) and 98.6% fell within GIS classes 3-7 (rated as Most or Moderately Likely). These results suggest that a broad range of crown closure (classes 3-7) should be used in algorithms and that crown closure by itself is not a good predictor of murrelet habitat attributes.

Vertical canopy complexity – This measure taken from the helicopter was not available in the GIS forest cover data. Vertical canopy complexity was compared with crown closure in the GIS data, but the two measures did not show any clear patterns (Table 5). Overall 88% of the sites with vertical complexity rated 1-3 (Moderate to Very High) fell within crown closure 4-6 (rated Most Likely in the MMRT algorithm), and 98% fell within crown closure 3-7 (rated Moderately Likely). Two sites rated with High or Very High canopy complexity had very low canopy closure (20%), while conversely two sites with canopy complexity rated Low or Nil fell within the canopy closure range recommended by the MMRT. These data suggest that although most sites with canopy complexity likely to suit nesting murrelets fell within the recommended canopy closure range, canopy closure itself was not a good substitute for vertical canopy complexity.

Slope gradient – It was impossible to make a tight comparison of slope gradient in the GIS forest cover data (relevant to the entire polygon) and the assessment from the helicopter (covering a 100 m radius), but there was good general agreement between the two measures (Table 6). Four sites assessed as “moderate” from the helicopter had GIS slopes of 60% of more, generally considered fairly steep, suggesting that in a few cases slope was underestimated from the helicopter, but this might have been due to the differences in spatial scale between the GIS and aerial data.

Dominant tree species – We compared the top three ranks of dominant tree species given in the GIS forest cover data with the dominant species recorded in the aerial surveys (Table 7). In each comparison of the five dominant tree species, we show the number of sites in the GIS and aerial survey ranks and the percentage of sites which correctly match each other in various rank groupings. For example the GIS data showed 39 sites (13+26) with amabilis fir as dominant or co-dominant (ranks 1 & 2), whereas the aerial surveys showed 60 sites (20+40) with these ranks (Table 7). Considering ranks 1 and 2, the aerial surveys showed a higher number of sites with these ranks than the GIS data for amabilis fir (60 vs 39 sites), and western red-cedar (32 vs. 15), but the two methods showed very similar results for yellow cedar (5 vs. 7 sites), western hemlock (91 vs. 89), and Sitka spruce (36 vs. 35). The right columns in Table 7 show the similarity in ranking of each species between the two methods, beginning with rank 1 alone, then ranks 1+2 pooled and finally ranks 1-3 pooled.

The GIS and aerial survey data showed very similar rankings in dominance for western red-cedar and western hemlock, but relatively modest agreement for amabilis fir and Sitka spruce. In the case of Sitka spruce, although both methods had similar numbers of sites ranked 1 and 2 (36 and 35 sites), these were not consistently the same sites for both methods; 14 sites ranked 1 or 2 in the aerial surveys had spruce as rank 3 or absent in the GIS data and conversely 13 sites ranked 1 or 2 in the GIS data showed spruce as rank 3 or absent in the aerial surveys. The aerial surveys showed yellow cedar as ranked 1 or 2 in five sites, but the GIS data never showed this species in the top three ranks in the 14 sites in which it was reported. Many of these differences in species dominance were probably due to differences in scale (see above), but the differences do caution against strong reliance on tree species dominance in habitat algorithms for Marbled Murrelets on the North Coast.

3.4 Predictors of platforms and epiphyte development

A common problem in management of nesting habitat for murrelets is to decide which parameters available in forest cover or air photo data can reliably predict the occurrence of potential nest platforms and epiphyte (mainly moss) development on the canopy limbs. Neither platforms nor moss availability are available in forest cover data or any other standard databases, and cannot be detected from air photos. Determining reliable proxies or predictors for these critical features of murrelet nest sites is therefore important.

The rank scores of platform availability and trees with moss development were converted into percentages (mid-point for each score) to allow statistical testing, and to get more intuitive results when testing correlations (using ranked data with 1 as high and 6 as low gives negative correlations when there are actually positive effects). Scores for platform availability and moss development were almost perfectly correlated with each other (Table 8), and consequently gave almost identical results when compared with forest cover data. Aspect and dominant tree species, which were non-numerical data, were analysed separately.

Forest cover and topographic measures – Platform availability, moss development and vertical canopy complexity were all significantly positively correlated with forest age class, height class, and site index, and negatively correlated with crown closure, slope and elevation (Table 8). Among the forest cover variables, age class was negatively correlated with crown closure, but not correlated with any other measure (surprisingly age and height class were not significantly correlated). Height class and site index were highly intercorrelated (as expected) and both were negatively correlated with elevation and slope. Slope and elevation were positively intercorrelated.

Using a multiple regression model we investigated which combination of these forest cover variables might best predict platform and moss availability (Table 9). Elevation (negative effect) and tree height class (positive effect) had the strongest effects, but explained only 29-30% of the variability in platform and moss availability. The addition of site index, while statistically significant, explained only an additional 7% of the variability (the apparent negative effect of site index is an artefact of its high correlation with tree height, see Table 8).

Using another approach, we tested the ability of the forest cover and topographic data to discriminate between sites with Moderate to Very High scores for platform and moss availability (ranks 1-3) and those with Nil to Low scores (ranks 0-4). We used a binary logistic regression model in SPSS to do the test. The model gave identical results for platform and moss availability; in both cases tree height class and elevation were the best predictors, but the models were not statistically significant (P = 0.052). These variables were able to distinguish sites with Moderate to Very High scores (94% correctly predicted; N = 67 sites), but were not able to distinguish Nil to Low scores (50% correctly predicted; N = 26 sites).

Aspect – Sites were grouped into quadrants based on the GIS forest cover data (North-facing: 19 sites; East: 21; South: 23; and West: 32). Two sites on flat ground were excluded. Both platform and moss availability showed no significant effect of aspect (identical results for both variables; GLM ANOVA, $F_{3, 94} = 0.944$, P = 0.423).

Dominant tree species – We compared platform availability and moss development among sites with four different dominant tree species, as indicated in the GIS forest cover data (Table 10). Two sites dominated by yellow cedar and mountain hemlock were excluded. We found a significant difference among the tree species dominants for both platform availability and moss development (Table 10; GLM ANOVA P<0.05 in both cases). These results were largely due to the significant differences between sites dominated by western red-cedar (low scores) and those dominated by Sitka spruce (high scores; Tukey post-hoc test; Table 10). These results support the inclusion of Sitka spruce as a positive predictor of suitable habitat in the regional algorithm.

3.5 Comparing the MMRT and Regional models

After deleting sites which had obvious problems (see above and Methods), 96 sites remained in the database. These 96 sites were approximately evenly distributed among the four categories predicted by the Regional model (Table 11). The MMRT model classified forest as Habitat (85 sites) or Nil (11 sites).

Of the 73 sites classified by the Regional model as potential habitat (Fair, Good or Superior), only 1 was classified by the MMRT as Nil (not habitat; Table 11). This site (No. 106) was excluded because of elevation (it was the only site above 600 m; Appendix 3) and was assessed as Low (rank 4) in the aerial survey. Elevation was not applied in the Regional model and should probably be excluded in the MMRT model too.

Of the 23 sites classified by the Regional model as Nil (not habitat), 10 were also classified by the MMRT model as Nil, but 13 were classified as potential habitat (Table 11). Out of these 13 sites, four (sites 26, 61, 94 & 128) were ranked nil because of their proximity to the ocean (see Table 1). Reference to the raw data from the GIS forest cover data (Appendix 3) showed that a further six sites (59, 62, 89, 91, 122 & 123) were rated as Nil, but had scores very close to the threshold of Fair habitat (their scores were 49-52; compare Table 1) and they had slightly lower scores because they all lacked Sitka spruce and were in height class 4. The aerial surveys found that one of these six sites was not habitat (site 123) but the other five ranked 3-4 (Moderate to Low). These results suggest that the threshold between Nil and Fair was perhaps a little high and excluded some sites with moderate to low quality habitat. No obvious reasons could be found for the exclusion of the remaining three sites (27, 28 & 29), and a re-calculation of the Regional model scores using the GIS data in Appendix 3 gave a different result (all were ranked as Fair in the re-calculation) and all three were ranked High or Very High in the aerial survey. Evidently there was an error in the Regional model here.

Out of the 13 sites showing differences between the models, 12 were classified by the aerial survey as potential habitat (2 sites rated Very High, 2 High, 4 Moderate, 2 Low, and 2 Very Low) and one was ranked as Nil. We also investigated whether these 13 sites might have been affected by their Biogeoclimatic Ecosystem Classification (BEC): 2

sites were in CWHvh2, 7 in CWHvm1, 1 in CWHvm2, 2 in CWHwm, and 1 in CWHws2. These proportions did not differ from the overall proportions of these variants in the 96 sites (see Table 18 and text below), but the samples were insufficient for statistical testing.

In subsequent analyses we included tests using only the 10 sites ranked as Nil by both models (labelled "True Nil") and excluding the 13 sites which differed between models. These tests give a better indication of the ability of the Regional model to identify forest with no murrelet habitat attributes.

3.6 Comparing the Regional Model with the Aerial Assessments

The habitat ranks predicted by the Regional model were first compared with the standard 6-rank aerial assessment (Table 12). It is difficult to compare a 4-rank model product with a 6-rank aerial assessment, but a general comparison is possible. Out of 96 sites, 39 (43%) were exactly as expected (shown in bold in Table 12) and a further 30 were within one rank (above or below) of the expected aerial assessment. Hence 69 sites (72%) had similar ranks between the Regional model and the aerial survey. When the 13 sites which were ranked nil by the Regional but not the MMRT model were omitted, 80% of the sites (N = 83) fell within one rank above or below what the Regional model predicted (Table 12). In general the model matched the aerial surveys well for higher ranked habitat, but the model was more likely to underestimate habitat quality than overestimate it (there were more sites above the predicted ranks than below them in Table 12). This was most obvious when the aerial assessments were grouped into Likely Habitat (rank 1-3), Marginal Habitat (rank 4-5) and Not Habitat (rank 6). In this case 92% and 83% of the sites predicted by the model to be Superior or Good were in fact good habitat as identified from the helicopter (Table 12). Most (70%) of the sites modeled as Fair were in fact good habitat and the rest were marginal. Only 60% of the sites predicted to be Nil by the model (i.e. the "true nil" column in Table 12) were rated as Nil from the helicopter.

The results were broadly similar when the 4-rank model predictions were compared with a 4-rank aerial assessment (Table 13). Out of 96 sites 49 (51%) had the same model and aerial ranking, and 84 (88%) were within one rank (above or below) of the expected aerial rank. With the 13 problematic nil sites excluded (using only the 10 “True nil” sites), 55% of sites had the same model and aerial survey rank, and 93% were within one rank of the expected aerial rank. Again the aerial rankings suggested that the model was more likely to underestimate habitat quality than overestimate it (there were more sites above the predicted model ranks than below them in Table 13).

3.7 Comparing the MMRT Model with the Aerial Assessment

Out of 85 sites predicted to be suitable murrelet habitat by the MMRT model, all except one (99%) had some habitat attributes; 79% were ranked as Likely Habitat (rank 1-3) and 20% were ranked as Marginal Habitat (rank 4-5; Table 14). The one site incorrectly identified as Habitat by the model (site 123) had large trees, but had very little moss development and no evidence of suitable platforms. This discrepancy would not have been evident from air photos.

The MMRT model was less successful in correctly identifying Nil or Not Habitat; 55% of the 11 sites rated as Not Habitat by the model were assessed to be Nil from the helicopter, 36% had at least Marginal Habitat status (rank 4-5) and 9% were assessed to be Likely Habitat (rank 1-3).

3.8 Comparing Habitat Attributes with Aerial Ranking

Table 15 summarises the habitat attributes assessed from the helicopter with the resultant rank. Tree size, platform and moss availability, and to a lesser extent vertical canopy complexity appeared to be the main features discriminating the habitat ranks. Habitat ranked 1 (Very High) or 2 (High) almost invariably had a large percentage of large trees and trees with platforms and moss development, whereas all of the habitats ranked Nil lacked both platforms and obvious development of mossy mats. All of the Very High or High sites had Moderate to Very High canopy complexity (providing access to the murrelets to potential nest sites within the canopy), but high canopy complexity in the absence of platforms led to Low, Very Low or Nil rankings.

Canopy cover and topographic complexity did not seem to vary greatly across the habitat ranks and did not appear to be reliable indicators of suitable habitat (Table 15). All of the sites ranked 1-3 were assessed to be in age class 9 or in mixed age 8 and 9, but most of the sites at the low end or ranked Nil were also in such stands. Although age class is an essential attribute, by itself age class does not guarantee suitable habitat.

The dominant tree species in the patches assessed were western hemlock, amabilis fir, western red-cedar and Sitka spruce (Table 16). Although western hemlock was found in over 80% of the sites within the top three ranks, it was equally or more common in the poor stands and was therefore not likely to be a reliable indicator of high quality habitats. Amabilis fir and western red-cedar were less frequently a dominant species and, like hemlock, were also found in both good and poor or Nil stands and were therefore unlikely to be good indicators of good murrelet habitat. Yellow cedar was rare in our samples and occurred in both good and poor habitats.

Sitka spruce was the only species to have a distribution skewed towards the high end of murrelet habitat. Although not invariably present in the better habitat it was the dominant or sub-dominant species in the top two habitat ranks more often than in lower or Nil ranks. This was not unexpected since spruce was used in the Regional model as an indicator of high quality habitat. The aerial assessments did, however, confirm that sites where spruce was dominant or subdominant were highly likely to have attributes useful for nesting murrelets, which justifies a positive weighting of this species in models applied to the North Coast.

At the other extreme, lodgepole pines, although rare, were found only in Very Low or Nil habitats, usually coastal bog forests or ridge-top scrubby forests. Future models might therefore consider including pines as an indicator of poor habitat, although larger samples are needed to confirm this trend.

Most of the sites tested were on the valley bottom or lower and mid slopes (Table 17). Most of the higher ranked sites were in the valley bottom or lower slope categories, but sites on the mid slopes showed no trend relative to habitat ranking. The upper slope and ridge-top sites were too sparse to show any trends.

Slope grade had no effect on habitat rank (Table 17). To get sufficient data for statistical testing we pooled a) flat and gentle grades; and b) moderate and steep slopes, and also combined aerial assessment ranks 1-3 (Likely Habitat), 4-6 (Marginal Habitat and Nil Habitat). With these pooled data there was no significant effect of slope grade on rank (Table 17; $\chi^2 = 1.742$, df = 1, P>0.05).

Common combinations of slope position and slope grade are shown in Table 17. Most of the sites were either: a) valley bottom or lower slope sites with flat or gentle grades (29 sites); lower slopes with moderate to steep grades (33 sites); or mid- or upper slopes with moderate to steep grades (32 sites). To get sufficient numbers for statistical testing it was necessary to pool ranks as 1-3 (Likely Habitat) and 4-6 (Marginal or Nil Habitat). With data pooled in this way we found no significant difference in rank among the three common combinations of slope position and grade (Table 17; $\chi^2 = 5.755$, df = 2, P>0.05).

The sites assessed fell within seven Biogeoclimatic Ecosystem Classification (BEC; Banner et al. 1993) subzone variants (Table 18). Sites in CWHvm1 and vm2 tended to be on the high end of the habitat ranks but there were no other trends in habitat ranking in the other subzone variants. With the data pooled, we found a significant difference between sites in CWHvm and all other variants; the vm sites were strongly clustered in the top three habitat ranks whereas the other subzone variants were evenly distributed between rank groups (Table 18). Unexpectedly, sites within the hypermaritime variant (CWHvh2) did not show any tendency for low ranks; six sites were in the top three ranks and four in the lowest three ranks.

4 DISCUSSION

4.1 Selection of sites

The selection of survey sites in the study was designed to provide similar numbers of sites for all ranks of habitat quality, i.e., within the four ranks used in the Regional model. One should not expect that a truly random selection of forested sites on the North Coast would yield a similar distribution of habitat ranks and habitat attributes (age and size classes, tree species etc.). It was clear, for example, that our sampling was biased towards valley bottom and lower slope sites, but this was not a serious problem. Our informal observations from the helicopter and the data (Table 17) confirmed that there was relatively little suitable murrelet habitat in the higher elevations, upper slopes and ridge tops within most of the watersheds that we visited.

One of the problems revealed in our analysis was in the classification and sampling of Nil habitat (not suitable for murrelet nesting). Following the Marbled Murrelet Recovery Team recommendations (MMRT 2003), the Regional model treated sites within 0.5 km of saltwater as unsuitable. Unfortunately, some of these sites proved to have large trees with platforms and were hence not Nil habitat. To rigorously test the selection of Nil sites these shoreline sites had to be omitted leaving 10 sites ("True Nil" sites) which were modeled as Nil by both models. As discussed below, both models had good success in identifying higher ranked habitat, but were less successful at separating marginal (rank 4-5) from Nil (rank 6) habitats. We also identified six sites which were ranked as Nil by the Regional model but not the MMRT model, which fell close to the Regional model's threshold for Fair habitat. Additional modeling and aerial surveys in the North Coast therefore need to focus greater attention on the low end and establish a more reliable threshold for the Nil rating of the habitat ranks.

4.2 Comparison of the GIS forest cover and aerial survey measures

Our aerial surveys provided an opportunity to test the reliability of the forest cover data within the GIS database at 96 sites on the North Coast. Many of the features important to murrelets (stand age, tree height, vertical canopy complexity) were strongly intercorrelated and also showed significant correlations with features such as site index, elevation and slope. In general there was strong agreement between the GIS forest cover and aerial survey measures for stand age and tree height. Estimates of crown closure were generally similar, but with a slight tendency for higher ranks in the aerial surveys. Crown closure in the GIS database was not a reliable proxy for vertical canopy complexity (Table 5), although high vertical complexity usually occurred within the range of crown closure recommended by the recovery team (e.g., 98% of the sites with vertical complexity rated 1-3 [Moderate to Very High] fell within crown closure 3-7 (rated Most or Moderately Likely in the MMRT algorithm). These results confirm the need for a relatively wide range of crown closure within habitat algorithms.

The GIS forest cover and aerial surveys showed similar trends for the dominance of western red-cedar and western hemlock, but some marked differences for amabilis fir, Sitka spruce and yellow cedar. As mentioned in the results, these differences in species dominance were probably due to differences in spatial scale between the GIS polygons and the aerial survey sites. The differences found in the dominance patterns of Sitka spruce do caution against strong reliance on this species in habitat algorithms for Marbled Murrelets on the North Coast.

4.3 Predicting platforms and moss development from GIS forest cover data

No single forest cover or topographic variable readily available in forest databases for the North Coast was a failsafe predictor of the availability of platform limbs or moss development. Combinations of variables also did not predict availability with high confidence. Overall, the best predictors were elevation (negative effect), tree height class or site index (positive effect), and to a lesser extent dominance by Sitka spruce (positive) or western red-cedar (negative). Combinations of GIS variables explained less than a third of the variability in the ranking of % trees with platforms or moss development.

The forest cover and topographic variables were generally better at predicting the availability of platforms and moss than they were in predicting when these attributes might be missing. A similar trend was found when testing the Regional and MMRT models (discussed below). There is therefore likely to be little risk in misidentifying sites which have high availability of platforms and moss, but there is a higher risk of incorrectly identifying sites as lacking these attributes. This might not be a problem in managing murrelet habitat if WHAs and other areas to be maintained are placed in sites ranked high in regional models, but will be a problem if most habitat to be maintained ranks as low or marginal.

4.4 Predictions of the Regional Model

The Regional model performed well in correctly identifying habitat at the high end of the ranks, and could be confidently applied to select forest likely to have essential attributes for murrelet nesting (e.g., for candidate core areas or candidate WHAs). For example, the data suggest that if such candidate areas were selected from the Superior and Good categories in the Regional model, then 88% (44 out of 50 sites; Table 12) would fall within Likely Habitat (ranks 1-3 in the aerial assessment), the remainder (12%) would fall in marginal (rank 4-5) sites, and none would be in sites assessed as Nil in the aerial surveys. If selection included sites ranked Fair in the Regional Model (73 sites; Table 12), there would still be 82% which fell within likely habitat (ranks 1-3 in the aerial assessment), the remainder would be in marginal habitat (ranks 4-5), but none would be in Nil habitat. We caution that our sample is relatively small within each model ranking and larger samples of the model Fair rank might well include Nil habitat as assessed from a helicopter. Furthermore, we caution that our survey sites are not in the same proportions of habitat quality as found in the region as a whole, and so the proportions falling into

Likely Habitat might not be applicable to a purely random sample across the North Coast forests.

The Regional model was less successful at correctly identifying Nil habitat (lacking attributes for nesting murrelets). Even omitting the 13 problematic sites possibly erroneously ranked Nil (i.e., within the "True Nil" sample), only 60% of the Nil sites were ranked as Nil in the aerial survey, and 30% were ranked as marginal (ranks 4-5 in the aerial assessment; see Table 12). Application of the Regional Model might therefore underestimate the true availability and area of apparently suitable murrelet habitat, although most of the habitat missed by the model would likely fall within the Low and Very Low ranks and therefore have marginal value for murrelets.

4.5 Predictions of the MMRT Model

The MMRT model was less detailed than the Regional model and only identified Habitat or Not Habitat. Out of the 85 sites identified by the model as Habitat, 80% were ranked Likely Habitat (habitat ranks 1-3), 19% were Marginal (ranks 4-5), and only one (1%) was ranked Nil in the aerial surveys. The data therefore provide some confidence on the North Coast that nearly all the forest predicted to be nesting habitat by the MMRT model would in fact contain some essential attributes for nesting murrelets. If the distribution of sites being considered had a similar distribution of rankings than our samples, then our data also suggest that a large proportion of the habitat selected by the MMRT model would contain high ranking habitat. These conclusions would have stronger support if the sampling had included a larger number of low or Nil sites. If, as tends to happen in forests managed for timber extraction, candidate WHAs and OGMAs are sought in the higher elevation, more patchy forests, then one cannot assume that 80% of sites identified by the MMRT would be ranked 1-3. Our samples were biased towards lower elevation, valley bottom and lower slopes as discussed above.

As with the Regional model, the MMRT model was less successful at identifying Nil habitat, but again the samples here were small and our conclusions therefore tentative.

About half (55%) of the sites predicted to be Nil by the model were also ranked Nil in the aerial surveys (Table 5), but 36% were ranked marginal (4-5) and 9% were ranked as likely habitat (ranks 1-3). As shown in the Results, one of the erroneously modeled sites was excluded because of elevation and the MMRT might be improved with a less rigid elevational cut-off. Overall, the MMRT model is therefore also likely to underestimate the availability and extent of suitable habitat on the North Coast, but as with the Regional model, most of the mis-identified sites proved to be either Low or Very Low as assessed from the helicopter.

The MMRT model also proved to be reliable in correctly identifying stands with suitable attributes in the Zeballos Landscape Unit on Vancouver Island (approx. 84% correct; Donald 2005). As on the North Coast, however, the MMRT model was less successful at correctly classifying the absence of habitat (Nil habitat) in Zeballos. The MMRT model was less successful in correctly predicting suitable habitat attributes in the drier forests of north-eastern Vancouver Island (Deal and Smart 2004).

4.6 Habitat Parameters Affecting Aerial Assessments

Our data provide some insights into the habitat parameters most strongly associated with good or poor habitat on the North Coast, as assessed in the aerial surveys. In part this merely reflects the weighting given to each parameter by the observers. Large trees and the presence of many trees with platforms were consistently found within the upper ranks of the sites assessed (Table 15), because these were the parameters given greatest weight by the observers. Moss development tracked platform availability almost identically, because in the North Coast nearly all of the platforms were provided by mossy mats. In some drier areas of BC (e.g., Sunshine Coast, AEB pers. obs.) large platform limbs with relatively little moss development provide potential nesting platforms, but there was no evidence for this in the North Coast surveys. Some of the sites, possibly affected by hypermaritime conditions or local microclimates, had large trees and complex canopies but lacked development of mossy mats and were therefore ranked as Low, Very Low or Nil (e.g., sites 102, 107, 108, and 123).

Vertical canopy complexity declined with decreasing habitat rank (Table 15) but this trend was less striking than that with large trees and platforms, and many of the Nil sites had high canopy complexity. Although vertical canopy complexity is an important habitat attribute, allowing access to the inner canopy by flying murrelets, by itself vertical canopy complexity was not a reliable indicator of highly ranked sites.

Canopy cover and topographic complexity showed no consistent trend across the habitat ranks (Table 15) and do not appear to be important indicators of habitat quality on the North Coast. Similarly age class by itself was not a reliable indicator, since most of the sites at the low end of the ranking and about half of the Nil sites were mature or old-growth. Nevertheless, age class has to be included in all models and aerial assessments, because suitable habitat was found only in sites that were old-growth (age 9, >250 y), mature (age 8, 140-250 y) or a mix of 8 and 9. The five sites that were in age 8 were all ranked Low, Very Low or Nil (Table 15). This suggests that there is some risk of including unsuitable habitat on the North Coast in stands that are not classified as old (age 9).

Tree species composition has proved to be a difficult issue in identifying suitable murrelet habitat in BC. Murrelets are known to nest in virtually all of the larger conifer species and even in moss-laden red alders, and there are regional differences in the species of trees most often dominant in habitat suitable for nesting murrelets (Burger 2002). On the basis of the results from the Central Coast modeling and aerial surveys (Hobbs 2003), tree species were included in the North Coast Regional model. When they occurred as leading species, Sitka spruce and, to a lesser extent, yellow cedar were given a positive weighting, lodgepole pine was given a negative weighting, and all other species were treated as neutral (see Table 1). Our aerial survey results suggest that the bias towards Sitka spruce was partly justified; sites where this species was dominant were strongly skewed towards the high end of the aerial ranks (Table 16). Only one site dominated by spruce was ranked below Moderate. Sites where spruce was subdominant or merely present were however less likely to be consistently highly ranked and spruce was present (but not dominant) in at least three of the seven sites rated as Nil in the aerial surveys. Although Sitka spruce as a dominant or co-dominant species is a useful indicator of likely nesting habitat on the North Coast, suitable habitat does occur in stands dominated by other species, and spruce was probably given undue weight in the Regional Model.

Yellow cedar, given a positive weighting in the Regional model, proved to be relatively rare (5 of the 100 sites), and did not show any tendency to occur in high ranking sites (Table 16). Future models should re-assess the inclusion of yellow cedar as a positive feature on the North Coast. Our sites did, however, sample relatively few high elevation sites where yellow cedar might be more common and might provide nest sites in otherwise marginal habitat – this needs further field research.

Western hemlock, although a dominant or subdominant in most of the highly ranked sites, was also dominant in all the sites ranked Low or Very Low, and dominant in 57% of sites ranked Nil (Table 16). Dominance of the ubiquitous hemlock is therefore not a reliable indicator of habitat quality, even though hemlock trees often provide suitable platforms and are known to be used by nesting murrelets in BC (Burger 2002). Similarly, for the North Coast, western red-cedar and amabilis fir did not show any trends towards dominance at either end of the habitat ranks (Table 16) and cannot be used as indicators of suitable murrelet habitat on the North Coast.

As predicted by the Regional Model, lodgepole pine was associated only with Very Low or Nil sites, but it occurred in only one of each of these sites, and our sample is therefore not a reliable test of the value of including pines in habitat models. A large sample of sites ranked Low or Nil, in coastal bog forests and high scrubby forests would provide a stronger test of the predictive ability of pines.

Our samples covered a wide range of slope positions and slope grades, although we included relatively few high elevation upper slopes and ridge tops. Both models tended to predict more areas of suitable habitat in lower elevations and valley-bottoms, and this is generally supported by the distribution of known nests for most of BC (Burger 2002). In our North Coast sample, sites within valley bottoms or on lower slopes had a tendency to have high ranked habitat, but the data show no statistical significance in ranking due to slope position or gradient (Table 17). Out of 69 sites ranked as likely habitat (aerial ranks 1-3), 36% were on flat or gentle slopes and the rest (64%) were on moderate or steep slopes (Table 17). Similarly, marginal (rank 4-5) and Nil sites included these slope categories too. With slope position and slope grades combined into commonly occurring categories, we again found no significant effect of these features on habitat ranking (Table 17).

Our results confirm the conclusion reached by the Marbled Murrelet Recovery Team (MMRT 2003) that slope should be treated as a neutral variable in identifying suitable habitat in BC. The results also show that the negative weighting given to slope grade in the present Regional model was not justified and should be removed in future models. It is unlikely that this weighting had a strong effect on the model predictions, and we did not notice any sites which were obviously misclassified because of the slope weighting.

Most of the murrelet habitat on the North Coast is likely to be found in valley bottoms and lower elevations (our informal observations while transiting large tracts of the North Coast area in the helicopter confirmed this).

5 CONCLUSIONS

In general both the Regional and MMRT models were reliable in that the habitat predicted to be suitable almost always contained attributes believed to be important for nesting murrelets, and usually ranked as Likely Habitat (Very Good, Good, or Moderate) in the aerial assessments. Both models were less successful in correctly identifying Nil (totally unsuitable) habitat, but the misidentified sites usually had marginal value (ranked as Low or Very Low). Including such marginal sites in critical areas for murrelets (such as core areas, WHAs, OGMAs or other maintained areas for nesting) would be highly risky. We therefore recommend that maintained habitat for Marbled Murrelets in the North Coast area could be identified with some confidence by either model, provided that habitat known to be marginal (or found to be marginal in aerial or ground surveys) was excluded. The Regional model provided some additional information on habitat quality which is reliable at the high end of the ranking scale. We have identified problems with both models and recommend that these models be modified slightly to provide more reliable predictions on the North Coast. Finally, we remind readers that we were not able to compare the models with real nest sites, but only with aerial assessments of the canopy features known to be important for nesting murrelets.

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Table 1. Parameters used in the two habitat models for the North Coast region in 2004. The MMRT model is based on the parameters identified by the Marbled Murrelet Recovery Team as likely to predict suitable habitat on the North Coast. The Regional model contains more detail and is modified from an earlier model developed for the Central Coast by Hobbs (2003).

MMRT Model		**Regional Model**	
Age Class	**Weight**	**Age Class**	**Weight**
Age class 8,9	1	Age Class 9	20
Age class 1-7	0	Age Class 8	15
		Age Class 1-7	1
Height Class	**Weight**	**Height Class**	**Weight**
Height Class 4,5, 6, 7, 8	1	Height class 5,6,7 and 8	20
Height Class other	0	Height Class 4	18
		Height Class 1, 2 and 3	1
Canopy Closure (CC)	**Weight**	**Crown Closure (CC)**	**Weight**
CC classes 4, 5, and 6	1	CC classes 4 and 5	10
		CC class 6	8
CC classes 1-3	0	CC classes 3 and 7	5
		CC classes 2 and 8	1
Elevation Range	**Weight**	**Elevation**	**Weight**
N. Mainland Coast 0-600m	1	0-300m	5
All other elevations	0	301-500m	3
		501->1,000m	1
Slope Range	**Weight**	**Slope**	**Weight**
Not Included		<45%	5
		46 – 70%	3
		> 71%	1
Tree Species		**Tree Species in Polygon**	**Weight**
Not Included		SS, S, SW (Sps 1, 2 & 3)	10
		SS, S, SW (Sps 4)	7
		SS, S, SW (Sps 5 & 6)	5
		YC (Sps 1 & 2)	6
		YC (Sps 3)	2
		YC (Sps 4, 5 & 6)	0
		H, B, CW, DR, FD	0
		PL	-10
Distance from Saltwater		**Distance from Saltwater**	**Weight**
≥500m	include	≥500m	include
0-499m	include	0-499m	exclude
Habitat Suitability Class	**Index Range**	**Habitat Suitability Class**	**Index Range**
Habitat	5	Nil	0 – 52
Nil	4	Fair	53 – 64
Nil	3	Good	65 - 69
Nil	2	Superior	> 70
Nil	1		
Nil	0		

Table 2. Comparison between the GIS forest cover data and the aerial survey data for stand age.

A) Comparing GIS age class with aerial assessment of age class

GIS age class	Aerial survey age class <8	Mixed <8 & 8	8	9	Mixed 8 & 9	Total sites
6	1					1
7	1	1		1		3
8			1	1		2
9			4	76	8	88
Total sites	2	1	5	78	8	94

B) Comparing GIS age class with overall site rank

GIS age class	Overall aerial ranking of the site 6 Nil	5 Very Low	4 Low	3 Moderate	2 High	1 Very High	Total sites
6	1						1
7	2	1					3
8			1			1	2
9	3	7	11	17	22	28	88
Total sites	6	8	12	17	22	29	94

Table 3. Comparison between the GIS forest cover data and the aerial survey data for tree height.

A) Comparing GIS height class with aerial assessment of large trees

GIS height class		Aerial rank of % large trees						
		6	5	4	3	2	1	Total
Code	Height (m)	(Nil)	(~1%)	(1-5%)	(6-25%)	(26-50%)	(51-100%)	sites
2	10.5-19.4	3		1				4
3	19.5-28.4			2	1			3
4	28.5-37.4	1	2	1	2	15	15	36
5	37.5-46.4			1	1	6	21	29
6	46.5-55.4				1	3	9	13
7	55.5-64.4						7	7
8	64.5+						2	2
Total no. of sites		4	2	5	5	24	54	94

B) Comparing GIS height class with overall site rank

GIS height class		Overall aerial ranking of the site						
		6	5	4	3	2	1	Total
Code	Height (m)	Nil	Very Low	Low	Moderate	High	Very High	sites
2	10.5-19.4	1	3					4
3	19.5-28.4	1	1		1			3
4	28.5-37.4	3	3	7	8	9	6	36
5	37.5-46.4	1	1	3	6	5	13	29
6	46.5-55.4			1	1	4	7	13
7	55.5-64.4				1	3	3	7
8	64.5+			1		1		2
Total no. of sites		6	8	12	17	22	29	94

Table 4. Comparison of crown closure (%) as recorded in the GIS forest cover data and as assessed in the aerial surveys. Sites enclosed in boxes show agreement within 5% closure.

A) Comparing GIS crown closure with aerial assessment of crown closure

GIS Crown Closure	Crown closure in aerial survey								Total sites
	<20	20	30	40	50	60	70	80	
20							1	1	2
30					1	1			2
40		1				7	1		9
50		1	2	1	6	15	13		38
55						6	4		10
60				1	3	8	4	3	19
65	1					1	4		6
70				1		1	5		7
80								1	1
Total sites	1	2	2	3	10	39	32	5	94

B) Comparing GIS crown closure with overall site rank

GIS Crown Closure	Overall aerial ranking of the site						Total sites
	6 Nil	5 Very Low	4 Low	3 Moderate	2 High	1 Very High	
20			1	1			2
30						2	2
40	1	1				5	9
50		4	4	5	2	16	38
55		1		2	9	2	10
60	3		6	5	4		19
65	2			1	6	2	6
70		1	1	3	1	2	7
80		1					1
Total sites	6	8	12	17	22	29	94

Table 5. Comparison of crown closure (%) as recorded in the GIS forest cover data with vertical canopy complexity recorded during aerial surveys.

GIS Crown Closure	Vertical canopy complexity in aerial survey						Total sites
	6 Nil	5 Very low	4 Low	3 Moderate	2 High	1 Very High	
20					1	1	2
30						2	2
40					3	6	9
50				5	19	14	38
55					6	4	10
60			1	5	10	3	19
65	1			2	2	1	6
70				3	3	1	7
80			1				1
Total sites	1	0	2	15	44	32	94

Table 6. Comparison of slope gradient in the GIS forest cover data and as assessed in the aerial survey.

	Slope assessed in the aerial survey						
GIS Slope (%)	Flat	Flat & Gentle	Gentle	Moderate	Moderate & Steep	Steep	Total sites
0-9	4		6	1		0	11
10-19	3	2	6	4		0	15
20-29	1	1	4	11		0	17
30-39			1	15	1	1	18
40-49			3	5		3	11
50-59				5	1	4	10
60-69				3		2	5
70+				1		8	9
Total sites	8	3	20	45	2	18	96

Table 7. Comparison of dominant tree species ranking in the GIS forest cover data and in aerial surveys. Each comparison shows the number of sites falling within the GIS and aerial ranks.

A) Amabilis Fir (BA)

GIS data		Aerial survey rank Amabilis Fir 1	2	3	NR	Total
BA	rank1	8	3	1	1	13
BA	rank2	5	12	6	2	25
BA	rank3	4	9	2	4	19
BA	None	3	16	6	12	37
		20	40	15	19	94

Match between GIS & aerial ranking

GIS rank	Observed	Expected from GIS	% correct
Rank 1	8	13	61.5
Rank 1+2	28	38	73.7
Rank 1-3	50	57	87.7

B) Western Red-cedar (CW)

GIS data		Aerial survey rank W Red-cedar 1	2	3	NR	Total
CW	rank1	6	0	0	1	7
CW	rank2	5	1	0	2	8
CW	rank3	6	5	4	3	18
CW	None	2	7	8	44	61
		19	13	12	50	94

GIS rank	Observed	Expected from GIS	% correct
Rank 1	6	7	85.7
Rank 1+2	12	15	80.0
Rank 1-3	27	33	81.8

C) Yellow Cedar

GIS data		Aerial survey rank Yellow Cedar 1	2	3	NR	Total
YC	rank1	0	0	0	1	1
YC	rank2	0	0	0	6	6
YC	rank3	0	0	0	7	7
YC	None	4	1	0	75	80
		4	1	0	89	94

GIS rank	Observed	Expected from GIS	% correct
Rank 1	0	1	0.0
Rank 1+2	0	7	0.0
Rank 1-3	14	14	100.0

D) Western Hemlock (HW)

GIS data		Aerial survey rank Western Hemlock 1	2	3	NR	Total
HW	rank1	58	3	0	0	61
HW	rank2	23	4	1	0	28
HW	rank3	1	1	1	0	3
HW	None	0	0	0	2	2
		82	8	2	2	94

GIS rank	Observed	Expected from GIS	% correct
Rank 1	58	61	95.1
Rank 1+2	88	89	98.9
Rank 1-3	92	92	100.0

E) Sitka Spruce (SS)

GIS data		Aerial survey rank Sitka Spruce 1	2	3	NR	Total
SS	rank1	9	1	0	2	12
SS	rank2	9	2	1	10	22
SS	rank3	5	7	1	13	26
SS	None	1	1	5	27	34
		24	11	7	52	94

GIS rank	Observed	Expected from GIS	% correct
Rank 1	9	12	75.0
Rank 1+2	21	34	61.8
Rank 1-3	35	60	58.3

Table 8. Spearman rank correlations between platform, moss and vertical canopy complexity recorded in aerial surveys, and forest cover parameters from the GIS database. Because ranked data go from 1 (very high) to 6 (zero), giving reversed correlations, to get more intuitive results we used actual mid-point % for platform and moss categories and inverted the VCC correlations.

	Aerial survey measures (n = 96)			GIS forest cover measures (n = 94)				
	% canopy trees with platforms	% canopy trees with moss develop-ment	Vertical canopy complex ity	Age class	Height class	Crown closure	Site index	Elevation
	PLATPC	MOSSPC	VCC	GISAGECL	GIS_HTCL	GIS_CC	S_INDEX	ELEV
MOSSPC	0.990**	1.000						
VCC	0.546**	0.549**	1.000					
GISAGECL	0.249**	0.248*	0.411**	1.000				
GIS_HTCL	0.469**	0.454**	0.264*	0.174	1.000			
GIS_CC	-0.233*	-0.247*	-0.431**	-0.303**	-0.161	1.000		
S_INDEX	0.347**	0.332**	0.150	-0.057	0.920**	-0.094	1.000	
ELEV	-0.485**	-0.477**	-0.376**	0.047	-0.401**	0.182	-0.389**	1.000
SLOPE	-0.430**	-0.429**	-0.298**	0.096	-0.411**	0.094	-0.444**	0.546**

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

Table 9. Multiple regression models for predicting platform availability (A) and moss development (B). See text for details.

A) Models to predict % canopy trees with platforms (PlatPC)

				Change Statistics				
Steps	Predictors added	Effect	Adjusted R Square	R Square Change	F Change	df1	df2	P
1	(Constant), ELEV	-ve	0.214	0.214	26.865	1	91	0.000
2	GIS_HT	+ve	0.302	0.094	12.705	1	90	0.001
3	S_INDEX	-ve	0.373	0.072	10.716	1	89	0.001
	Predictive equation:	PlatPC = 8.241 - 0.094 ELEV + 3.102 GIS_HT – 4.554 S_INDEX						

B) Models to predict moss development (% trees with obvious mossy pads; MossPC).

				Change Statistics				
Steps	Predictors added	Effect	Adjusted R Square	R Square Change	F Change	df1	df2	P
1	(Constant), ELEV	-ve	0.207	0.215	24.986	1	91	0.000
2	GIS_HT	+ve	0.287	0.087	11.240	1	90	0.001
3	S_INDEX	-ve	0.361	0.079	11.439	1	89	0.001
	Predictive equation:	MossPC = 9.337 - 0.095 ELEV + 3.140 GIS_HT – 4.699 S_INDEX						

Table 10. Effects of dominant tree species (from GIS forest cover data) on availability of potential platforms (A) and moss development (B). Two sites dominated by mountain hemlock and yellow cedar were excluded. Different letters (a or b) indicate significant differences among the tree dominants (Tukey post-hoc test). Platform and moss ranking scores made in aerial surveys were converted to mid-point % for this test.

(A)	**% canopy trees with platforms**		
Tree species	Mean	SD	N
Western red-cedar (CW)	17.9 a	15.4	7
Western hemlock (HW)	37.9 ab	31.0	60
Amabilis fir (BA)	46.8 ab	34.1	13
Sitka spruce (SS)	60.2 b	30.1	12
All species	40.5	31.6	92
GLM ANOVA	F(3,88) = 3.282, P = 0.025		
	Power = 0.733		

(B)	**% canopy trees with moss development**		
Tree species	Mean	SD	N
Western red-cedar (CW)	17.9 a	15.4	7
Western hemlock (HW)	38.2 ab	31.4	60
Amabilis fir (BA)	46.6 ab	34.3	13
Sitka spruce (SS)	60.2 b	30.1	12
All species	40.6	31.8	92
GLM ANOVA	F(3,88) = 3.164, P = 0.028		
	Power = 0.715		

Table 11. Comparison of the Regional and MMRT models. The numbers of sites classified by each model are compared.

	Regional Model Ranking				
MMRT Model	1 Superior	2 Good	3 Fair	4 Nil	Total
1 Habitat	26	23	23	13	85
4 Nil	0	1*	0	10	11
Total	26	24	23	23	96

*This is Site 106 ranked Good by the Regional Model but Nil by the MMRT model. The site was ranked 4 (Low) in the aerial survey

Table 12. Habitat ranking predicted by the Regional Model compared with the standard 6-scale rankings made in the aerial surveys. The "True Nil" column excludes the 13 sites which were rated Nil by the Regional model but not the MMRT model (coastal proximity exclusion etc.). Bold numbers show the number of sites for which there was the closest match between model and aerial assessment.

	Regional Model Ranking					
Aerial survey rank	1 Superior	2 Good	3 Fair	4 Nil	Total	"True Nil"
a) 6-rank protocol						
1 Very High	**16**	9	3	2	30	0
2 High	6	**7**	7	2	22	0
3 Moderate	2	**4**	6	5	17	1
4 Low	2	2	**6**	2	12	0
5 Very Low	0	2	**1**	5	8	3
6 Nil	0	0	0	**7**	7	**6**
Total	26	24	23	23	96	10
b) Approximate % correctly ranked						
% correctly ranked	61.5	45.8	30.4	30.4	42.7	60.0
% which the model overestimated by 1 rank	23.1	8.3	0.0	-	8.3	-
% which the model overestimated by >1 rank	15.4	8.3	-	-	6.3	-
% which the model underestimated by 1 rank	-	37.5	26.1	21.7	20.8	30.0
% which the model underestimated by >1 rank	-	-	43.5	47.8	21.9	10.0
% correct or within one rank	84.6	91.7	56.5	52.2	71.9	90.0
Total	100	100	100	100		100
c) 6-rank grouped into 3 categories						
Ranked 1-3 Likely Habitat	**24**	**20**	16	9		1
Ranked 4-5 Marginal Habitat	2	4	**7**	7		3
Ranked 6 Not Habitat	0	0	0	**7**		**6**
% ranked 1-3	**92.3**	**83.3**	69.6	39.1		10.0
% ranked 4-5	7.7	16.7	**30.4**	30.4		30.0
% ranked 6	0.0	0.0	0.0	**30.4**		**60.0**

Table 13. Habitat ranking predicted by the Regional Model compared with a 4-scale rankings for aerial surveys. Some sites were rated Nil by the model because they were within 0.5 km of the coast. These were omitted in the "True Nil" column. Bold numbers sh

	Regional Model Ranking					
Aerial survey rank	1 Superior	2 Good	3 Fair	4 Nil	Total	"True Nil"
a) 4-rank scale						
1 Superior	**20**	10	4	2	36	0
2 Good	4	**9**	10	4	27	0
3 Fair	2	5	**9**	6	22	2
4 Nil	0	0	0	**11**	11	**8**
Total	26	24	23	23	96	10
b) Approximate % correctly ranked						
% correctly ranked	76.9	37.5	39.1	47.8	51.0	80.0
% model overestimated by one rank	15.4	20.8	0.0	-	9.4	-
% model overestimated by >1 rank	7.7	0.0	-	-	2.1	-
% model underestimated by one rank	-	41.7	43.5	26.1	27.1	20.0
% model underestimated by >1 rank	-	-	17.4	26.1	10.4	0.0
% correct or within one rank	92.3	100.0	82.6	73.9	87.5	100.0
Total	100	100	100	100	100	100

Table 14. Comparison of habitat ranking as predicted by the MMRT model and assessed using the standard 6-scale aerial assessment on the North Coast.

	MMRT model rank		
Aerial survey rank	1 Habitat	4 Not habitat	Total
a) 6-rank protocol			
1 Very High	30	0	30
2 High	22	0	22
3 Moderate	16	1	17
4 Low	11	1	12
5 Very Low	5	3	8
6 Nil	1*	6	7
Total	85	11	96
b) % breakdown of rankings			
% modeled as habitat and ranked as Likely Habitat (rank 1-3) in aerial surveys	80.0		
% modeled as habitat and ranked as Marginal Habitat (rank 4-5) in aerial surveys	18.8		
% modeled as habitat and ranked as Nil in aerial surveys	1.2		
% correctly modeled as Not Habitat		54.5	
% modeled as Nil but ranked Marginal (rank 4-5)		36.4	
% incorrectly modeled as Nil but ranked Likely Habitat (rank 1-3)		9.1	
Total	100	100	

*This is site 123 which had many large trees but no apparent platforms

Table 15. Habitat parameters relative to habitat ranking in the aerial surveys on the North Coast.

Habitat parameter	Aerial habitat assessment: 1 Very High	2 High	3 Moderate	4 Low	5 Very Low	6 Nil
Large trees - mean rank	1.0	1.6	1.6	1.6	4.4	4.3
Large trees - range in ranks	1-2	1-2	1-3	1-4	2-6	2-6
Platforms - mean rank	1.0	1.7	2.8	4.0	4.6	6.0
Platforms - range in ranks	1	1-3	2-3	4.0	4-5	6.0
Moss development - mean rank	1.0	1.7	2.8	4.1	4.5	6.0
Moss development - range	1.0	1-3	1-3	4-5	4-5	6.0
Canopy cover - mean %	59.3	63.6	65.3	65.8	48.8	58.0
Canopy cover - range in %	50-70	40-70	50-80	50-80	20-80	20-80
Vertical canopy complexity - mean rank	1.3	1.8	2.2	2.4	2.3	3.3
Vertical canopy complexity - range	1-3	1-3	1-3	1-4	1-4	1-6
Topographic complexity - mean rank	2.9	3.0	2.8	2.8	3.1	2.9
Topographic complexity - range	1-4	2-4	2-4	2-4	1-4	1-6
Number of sites within each age class						
Age class 9 (>250 y)	30	19	16	7	5	2
Age class 8 (140-250 y)	0	0	0	3	1	1
Mixed age class 8 and 9	0	3	1	0	1	1
Less than age class 8 (<140 y)	0	0	0	0	0	3
Mixed mostly <8 but some 8 or 9	0	0	0	2	1	0
Total no. of sites	30	22	17	12	8	7

Table 16. Tree species composition in sites assessed by aerial surveys on the North Coast. The number of sites in each category is shown on the left and the % of sites on the right. The % is calculated as the % of sites in each habitat rank.

		A) Number of sites in each category							B) % of sites in each category						
		Aerial habitat assessment							Aerial habitat assessment						
Tree species		1 Very High	2 High	3 Moderate	4 Low	5 Very Low	6 Nil	Total	1 Very High	2 High	3 Moderate	4 Low	5 Very Low	6 Nil	Total
W. Hemlock	1 Dominant	25	19	16	12	8	4	84	83.3	86.4	94.1	100.0	100.0	57.1	87.5
	2 Subdominant	4	3	1	0	0	0	8	13.3	13.6	5.9	0.0	0.0	0.0	8.3
	3 Present	1	0	0	0	0	1	2	3.3	0.0	0.0	0.0	0.0	14.3	2.1
Amabilis Fir	1 Dominant	11	3	2	3	1	2	22	36.7	13.6	11.8	25.0	12.5	28.6	22.9
(Balsam)	2 Subdominant	11	12	8	4	3	1	39	36.7	54.5	47.1	33.3	37.5	14.3	40.6
	3 Present	5	2	3	2	1	2	15	16.7	9.1	17.6	16.7	12.5	28.6	15.6
W. Red-cedar	1 Dominant	3	5	8	0	3	0	19	10.0	22.7	47.1	0.0	37.5	0.0	19.8
	2 Subdominant	1	5	2	3	1	1	13	3.3	22.7	11.8	25.0	12.5	14.3	13.5
	3 Present	4	2	2	2	2	0	12	13.3	9.1	11.8	16.7	25.0	0.0	12.5
Yellow Cedar	1 Dominant	0	3	0	0	1	0	4	0.0	13.6	0.0	0.0	12.5	0.0	4.2
	2 Subdominant	0	0	0	0	0	1	1	0.0	0.0	0.0	0.0	0.0	14.3	1.0
	3 Present	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sitka Spruce	1 Dominant	16	6	1	0	1	0	24	53.3	27.3	5.9	0.0	12.5	0.0	25.0
	2 Subdominant	6	3	0	1	0	2	12	20.0	13.6	0.0	8.3	0.0	28.6	12.5
	3 Present	1	2	3	0	0	1	7	3.3	9.1	17.6	0.0	0.0	14.3	7.3
Alder	1 Dominant	0	0	0	0	0	2	2	0.0	0.0	0.0	0.0	0.0	28.6	2.1
	2 Subdominant	1	1	0	0	0	0	2	3.3	4.5	0.0	0.0	0.0	0.0	2.1
	3 Present	5	3	1	2	0	1	12	16.7	13.6	5.9	16.7	0.0	14.3	12.5
Pines	1 Dominant	0	0	0	0	1	1	2	0.0	0.0	0.0	0.0	12.5	14.3	2.1
	2 Subdominant	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	3 Present	0	0	0	0	2	0	2	0.0	0.0	0.0	0.0	25.0	0.0	2.1
Total number of sites		30	22	17	12	8	7	96	30	22	17	12	8	7	96

Table 17. Slope position and slope grade for the sites assessed in aerial surveys on the North Coast.

Slope attribute	1 Very High	2 High	3 Moderate	4 Low	5 Very Low	6 Nil	Total
	Aerial habitat assessment						
Total sites	30	22	17	12	8	7	96
a) Slope position							
Valley Bottom (VB)	10	3	2	0	1	2	18
Lower Slope (LS)	11	13	2	7	0	2	35
VB and LS	6	1	2	0	0	0	9
Mid Slope (MS)	2	4	9	4	2	2	23
MS Bench	0	0	0	0	3	0	3
Upper Slope (US)	0	1	1	1	1	0	4
US Bench	0	0	0	0	1	0	1
Ridge Top (RT)	1	0	0	0	0	1	2
US and RT	0	0	1	0	0	0	1
b) Slope grade							
Flat	5	2	0	0	0	1	8
Mixed Flat and Gentle	3	0	0	0	0	0	3
Gentle	8	4	3	0	2	3	20
Moderate	11	12	6	11	3	2	45
Mixed Moderate and Steep	0	0	2	0	0	0	2
Steep	3	4	6	1	3	1	18

Slope grade data pooled to allow statistical testing

	Combined ranks: Ranks 1-3	Ranks 4-6	Total
Flat or gentle slopes	25	6	31
Moderate or steep slopes	44	21	65
Chi-square	1.742	df = 1, P>0.05	

d) Common combinations of slope position and grade							
VB, LS with Flat or Gentle slope	16	6	3	0	1	3	29
MS Bench or RT with Gentle slopes	0	0	0	0	1	1	2
MS, US with Mode or Steep slopes	3	5	11	5	6	2	32
LS with Mod or Steep slopes	11	11	3	7	0	1	33

Common combinations pooled to allow statistical testing

	Combined ranks: Ranks 1-3	Ranks 4-6	Total
VB, LS with Flat or Gentle slope	25	4	29
MS, US with Mode or Steep slopes	19	13	32
LS with Mod or Steep slopes	25	8	33
Chi-square	5.755	df = 2, P>0.05	

Table 18. Biogeoclimatic Ecosystem Classification (BEC) Subzone Variants for the sites assessed in aerial surveys on the North Coast. Most sites were in the Coastal Western Hemlock (CWH) zone, except for two in the Mountain Hemlock (MH) zone.

BEC Subzone Variant		Aerial habitat assessment: 1 Very High	2 High	3 Moderate	4 Low	5 Very Low	6 Nil	Total
CWH vh 2	Very Wet Hypermaritime - Central Variant	3	2	1	1	2	1	10
CWH vm 1	Very Wet Maritime - Submontane variant	21	12	10	2	2	1	48
CWH vm 2	Very Wet Maritime - Montane variant	4	3		1		2	10
CWH wm	Wet Maritime Subzone	1	4	4	5	2	2	18
CWH ws 1	Wet Submaritime - Submontane variant	1		1	2	1		5
CWH ws 2	Wet Submaritime - Montane variant		1		1		1	3
MH mm 1	Mountain Hemlock Moist Maritime - Windward variant			1		1		2
Total		30	22	17	12	8	7	96

BEC subzone variants pooled to allow statistical testing

Pooled subzone variants	Very High to Moderate Ranks 1-3	Low to Nil Ranks 4-6
All CWH vm	50	8
All other variants	19	19
Chi-square	14.889, df = 1, P < 0.001	

Appendices 1 to 3 are available as an Excel file – contact Alan Burger aburger@uvic.ca