STANDARD METHODS FOR IDENTIFYING AND RANKING NESTING HABITAT OF MARBLED MURRELETS (*BRACHYRAMPHUS MARMORATUS*) IN BRITISH COLUMBIA USING AIR PHOTO INTERPRETATION AND LOW-LEVEL AERIAL SURVEYS

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PREFACE

This manual brings together methods for air photo interpretation and low-level aerial surveys dedicated to identifying, assessing and ranking forest features important to nesting Marbled Murrelets. This represents the first attempt to establish standard methods for this purpose in British Columbia. These two methods have, of course, been used for many other purposes in forestry and wildlife management, but their application for identifying murrelet habitats is relatively new. This manual is based on increased efforts over the past 2 years to develop and improve these methods. Under the auspices of the Marbled Murrelet Recovery Team, and with funding and support from the B.C. Ministry of Water, Land and Air Protection, the Ministry of Forests, the Forest Investment Account (FIA), and several forest companies, these methods have been tested by numerous people and widely discussed in several workshops. The authors of this manual welcome suggestions for improving the methods and the presentation of the methods in this manual. Please send comments to:

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PART ONE: GENERAL INTRODUCTION

Marbled Murrelets (*Brachyramphus marmoratus*) are listed as Threatened by the Committee on Status of Endangered Wildlife in Canada (COSEWIC) and are on the provincial Red List (legally designated or being considered for legal designation as Endangered or Threatened within the Province of British Columbia). Loss of nesting habitat in old seral forest is the main threat to this species (MMRT 2003). Identifying and mapping suitable nesting habitat is therefore one of the key elements in the management and conservation of Marbled Murrelets in BC.

Various methods are used to identify nesting or stand occupancy in this species in BC (Burger 2002). These include: location and description of nests using radio-telemetry and tree-climbing (Bradley 2002; Conroy *et al*. 2002); ground-based audio-visual surveys to determine presence of murrelets, level of activity and occupancy of stands (RIC 2001); ground-based transects or plots used to quantify the forest structure and presence of canopy features important to murrelets, such as the availability of platforms for nest sites (RIC 2001); algorithms which combine topographic, forest-cover and biogeoclimatic features to identify and rank suitable habitat (Tripp 2001, Burger 2002).

Recently, air photo interpretation and low-level aerial surveys using helicopters (hereafter referred to as aerial surveys) have been increasingly used for identifying and mapping potentially suitable habitat. This manual is the first attempt to summarize and standardize these two methods for use in BC.

Following this general introduction (Part 1), which deals with issues common to both protocols, the manual has two main parts:

- Part 2 deals with air photo interpretation;
- Part 3 deals with low-level aerial surveys using helicopters.

Key features of Marbled Murrelet nesting habitat

The following section outlines the key features of forest habitat used by nesting murrelets, and explains how air photo interpretation and aerial surveys fit into the process of identifying, mapping, ranking and maintaining nesting habitat for the murrelets.

At the microhabitat level, five key features have been identified which are typically found at murrelet nest sites in BC (Table 1.1). Most of these microhabitat features are not included in forest-cover or biogeoclimatic mapping and Geographic Information System (GIS) databases. Larger features which correlate with these microhabitat features are therefore used for landscape and stand-level mapping and in the initial stages of planning Wildlife Habitat Areas (WHAs) and other maintained habitat for Marbled Murrelets.

Table 1.1. Key microhabitat characteristics for Marbled Murrelets nest sites in British Columbia (for more details see: Hamer and Nelson 1995; Nelson 1997; Burger 2002).

Murrelet requirements	Key habitat attributes
Sufficient height to allow stall-landings and jump-off departures	Nest trees are typically >40 m tall (range 15–80 m), and nest heights are typically >30 m (range 11–54 m); nest trees are often larger than the stand average.
Openings in the canopy for unobstructed flight access	Small gaps in the canopy are typically found next to nest trees, and vertical complexity of the canopy is higher in stands with nests than in other nearby stands.
Sufficient platform diameter to provide a nest site and landing pad	Nests are typically on large branches or branches with deformities, usually with added moss cover; nest limbs range from 15-74 cm in diameter; nests typically located within 1 m of the vertical tree trunk.
Soft substrate to provide a nest cup	Moss and other epiphytes provide thick pads at most nest sites, but duff and leaf litter are used in drier areas.
Overhead cover to provide shelter and reduce detection by predators	Most nests are overhung by branches.

The Marbled Murrelet Recovery Team (MMRT 2003) has outlined the stand- and landscape-level habitat features which are important for nesting murrelets in BC. The team also recommended a stratified, strategic approach for selecting habitat which is consistent across BC and which gives all areas under consideration equal probability of being selected (MMRT 2003). The recommended sequence is:

1. the use of GIS and/or habitat maps to identify and map habitat polygons under consideration;
2. the use of habitat algorithms and/or recognized habitat indicators (e.g., vertically complex canopy combined with age and size of trees) to assess and rank the suitability of the habitat for nesting murrelets;
3. air photo interpretation to assess the evidence of suitable habitat using standardized criteria, including vertical complexity, tree height, stand age and other regionally relevant parameters;
4. selection of potential polygons to be protected or maintained as murrelet nesting habitat;
5. confirmation that the selected polygons are suitable habitat, using one or more of the following:
    - evidence of nesting (nests found, eggshells found);
    - evidence of occupancy by murrelets (using the standard protocol; RIC 2001);
    - evidence of suitable nesting microhabitat (acceptable evidence of potential platform limbs, adequate epiphyte cover, and canopy complexity), established using standard ground plots or transects (RIC 2001);
    - evidence of suitable nesting microhabitat (as above) established using low-level helicopter reconnaissance.

Several algorithms have been developed for identifying suitable habitat based on parameters available on forest cover maps and other GIS sources (Tripp 2001, Burger 2002). These have proved useful in preliminary identification of habitat, especially at large spatial scales (e.g., 1:250,000), but ground-truthing has shown that even the best algorithms are likely to identify suitable nesting habitat only about 40-70% of the time (McLennan *et al*. 2000; Tripp 2001; Leigh-Spencer *et al*. 2002; Hobbs 2003). There are several reasons for this inaccuracy, notably:

- inaccuracies in the mapping data;
- failure of large-scale polygon-level habitat categories to show small patches of suitable habitat which might be used by murrelets;

- poor match between the canopy microstructure features important for murrelets and the forest macrostructure features used for mapping;
- unexpected effects of local climate on moss development, either resulting in fewer platforms (e.g., seasonally dry microclimates, or cold outflow winds), or more platforms (e.g., moist, mild microclimates) than expected;
- inconsistent levels in the quality of updated and original inventory data among forest districts.

Air photo interpretation allows a more refined analysis of the structure and complexity of the forest canopy, tree size, micro-topography, and other features not always accurately shown in forest cover and similar data (this manual Part 2). Some critical features of the canopy microstructure are, however, still not visible on air photos. Air photo interpretation is therefore used as a means of refining the selection and ranking of polygons to be considered as maintained murrelet habitat. This process is also important for determining the amount (area) of suitable habitat within a watershed or Landscape Unit (LU). Air photo interpretation following the methods in this manual focuses on identifying the age class, height class, canopy structure and presence of canopy gaps which are important to murrelets. This method is more likely to correctly identify suitable habitat than coarser-scale processes using forest-cover and biogeoclimatic mapping and GIS, or the use of satellite imagery.

Low-level aerial surveys are used to check the presence and relative abundance of the micro-habitat features important for nesting murrelets (Table 1.1). In particular, the surveys provide information on the presence and abundance of potential nest platforms (defined as limbs or deformities 15 cm or more in diameter, including any moss cover), and epiphyte cover, which are not detectable from air photos, maps or GIS databases. Aerial surveys also allow confirmation and re-assessment of important stand features, such as height class, age class and canopy complexity, which can also be assessed from air photos, forest cover maps and some GIS data.

Habitat ranking methods used in these protocols

At present, the relationships between habitat quality (as assessed from field studies, forest cover data, air photos or aerial surveys), and the likely density of nesting Marbled Murrelets (nests per ha of forest) or nesting success (fledged chicks per nest) are poorly understood. Similarly, there are no clear indications of any habitat quality threshold that might separate habitat used for nesting from that which is never used. Habitats with high proportions of apparently important attributes are more likely than habitats with fewer of these attributes to a) contain nests, b) have higher densities of murrelets as assessed using radar counts, and c) show stand occupancy based on audio-visual surveys (reviewed by Burger 2002). The exact relationships between habitat quality and the probability or density of nesting, however, remain unknown. The following habitat ranks are therefore based on incomplete knowledge and are likely to be adjusted as information accumulates.

Both air photo interpretation and aerial survey protocols use a 6-level ranking system to assess the suitability of forests as murrelet nesting habitat. This is loosely based on the 6-level rating system used in the B.C. Wildlife Habitat Rating Standards (RIC 1999), with one modification. This was to adjust the range of values (e.g., % of suitable habitat) used for each habitat category. This was done to provide greater sensitivity at the low end of habitat suitability so that there was a better chance of separating habitat which was not likely to be suitable at all from habitat which was assessed to be low quality but might have supported murrelets in small, suitable patches. A rating system with a wide range of categories will be more adaptable to deal with the uncertainty of present knowledge, and the changes likely to come with improved knowledge.

We chose to use ranks instead of scores. This **ranking** system gives 1 to the highest rank and 2-6 for lower ranked habitats (RIC 1999). **Scores** are the opposite, and give 0 to no value, 1 to a low value and 2, 3, 4, 5, 6 to increasingly better habitat. Working groups involved in the production of this manual concluded that this manual should use **ranks** rather than scores because a) ranking reflects an intuitive approach to evaluating habitat (i.e., the best habitat is ranked number 1); b) this approach is consistent with other provincial habitat ranking protocols; and c) some GIS programs treat zero values as missing data. Scores have been included in Table 1.2 for comparison with earlier surveys which have used this scoring system.

Table 1.2. General description of the ranking system used in the protocols for air photo interpretation and aerial surveys of Marbled Murrelet habitat. See Parts 2 and 3 for further details within each protocol.

Rank[1]	(Score)	Habitat value	General description of habitat quality and availability of key habitat features	Percentage of polygon area with habitat feature present[2]
1	(5)	Very High	Key habitat features present in abundance; nesting highly likely	50-100%
2	(4)	High	Key habitat features common and widespread; nesting likely	25-50%
3	(3)	Moderate	Key habitat features present but uncommon and patchy; nesting likely but at moderate to low densities.	6-25%
4	(2)	Low	Key habitat features all evident but patchy and sparse; nesting possible but unlikely or at very low density	2-5%
5	(1)	Very Low	Key habitat features sparse and might not all be present; nesting highly unlikely	about 1%
6	(0)	Nil	All key habitat features absent; nesting impossible (e.g., bogs, bare rock).	0%

[1]Ranking is to be used to assess polygons. The associated score is included here to facilitate converting data where a scoring system has already been used.
[2]This column shows how the ranking system is applied when assessing the relative abundance of a particular feature, such as large trees or trees with platforms.

This ranking system was adopted after field trials which tested several possible levels of rating the habitat (e.g., 4-, 5- and 6-level systems), analysis of the availability of key habitat features in areas where murrelets were known to nest, and consultation with biologists experienced in murrelet habitat assessment in BC.

Dealing with regional variations across the province

In BC, there are latitudinal and elevational variations in the type of habitat used by nesting Marbled Murrelets (Burger 2002). Some of these have been recognized in regional algorithms (Tripp 2001) and in the forest attributes associated with nesting (MMRT 2003). The intention in this manual is to provide a single province-wide habitat standard for assessing nesting habitat of murrelets. Some minor regional adjustments might be needed before applying these protocols. For example, in northern regions where trees are generally smaller, the standard for large trees in aerial surveys might be adjusted to include height class 3 (19.5-28.4 m). Any local adjustments to the standards used must be clearly stated on the data forms, data files and reports.

Local adjustments might be needed in the *interpretation* of the air photo and aerial survey data in selecting WHAs and other maintained habitat areas. For example, in Landscape Units in which there has been intensive logging, there might not be sufficient high quality habitat remaining to meet the demands for WHAs, and in such a case, WHAs might have to be placed in habitat ranked somewhat lower than that used for WHAs elsewhere. These decisions need to be made by regional working groups and the statutory decision makers.

Important note on the selection of WHAs and other maintained habitat areas

Although air photo interpretation and aerial surveys are important procedures in assessing habitat suitability of a proposed WHA or other maintained area for murrelets, they are not necessarily the final steps in selecting the most suitable area for the maintained habitat. Other criteria, in addition to those assessed from forest cover maps, air photos or aerial surveys need to be considered. These include:

- the size (area), integrity, and location of the area, relative to other areas of suitable habitat that are being considered;
- distance to known or likely foraging areas at sea (patches of suitable habitat that are a long way from foraging sites are less likely to be used by nesting murrelets);
- other evidence of the use of the proposed area, such as radar counts, distribution of known nest sites in the area, and audio-visual survey results;
- the role of the proposed WHA or maintained area within the entire murrelet conservation region (e.g., maintaining the spatial distribution of breeding murrelets across the region, or contributing to a proposed core area; see MMRT 2003);
- the likely future of surrounding areas which might affect the suitability of the proposed area to be maintained as nesting habitat;
- the contribution that the proposed area might make to maintaining other wildlife or biodiversity attributes;
- economic and social implications of selecting the area as a WHA.

Dealing with these topics is beyond the scope of this manual. Refer to the revised species account in the Identified Wildlife Management Strategy (IWMS), and consult with the local statutory decision maker for further details.

PART TWO: AIR PHOTO INTERPRETATION

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INTRODUCTION TO PART TWO

This section covers the interim standard protocol for air photo interpretation to identify and rank potential Marbled Murrelet habitat in British Columbia. Habitat criteria are consistent with the Marbled Murrelet Conservation Assessment (MMRT 2003), and the revised Identified Wildlife Management Strategy (IWMS) species account for the Marbled Murrelets (IWMS, in prep.) Air photo interpretation is one of the tools used to delineate potential murrelet habitat areas, and to prioritize areas for further habitat assessment. It is a recommended step in identifying suitable nesting habitat using the specified attributes recommended by the Marbled Murrelet Recovery Team (MMRT 2003). See the general introduction to this manual for further information in the use of air photo interpretation in identifying and managing habitat for nesting murrelets.

The following sections describe forest cover inventory information and photo interpreted attributes for identifying and ranking potential murrelet nesting habitat. Appendices provide further information regarding forest cover labels, and methods for forest cover photo interpretation.

BACKGROUND TO AIR PHOTO INTERPRETATION

Forest cover mapping provides a preliminary basis on which potential murrelet habitat can be identified using existing algorithms, GIS-themed mapping, or by simply looking at the forest cover labels. There are two Ministry of Sustainable Resource Management (MSRM) styles of forest cover inventory in BC. The current standard, Vegetation Resources Inventory (VRI), was initiated in 1996 and includes the important stand structure attribute of vertical complexity. The more prevalent older forest classification does not include vertical complexity. In addition, areas in Tree Farm Licences (TFLs) may have licensee-specific inventory styles. Inventories provide forest cover labels derived mainly from photo interpretation of mid-scale aerial photography (1:15,000 to 1:20,000), combined with data collected from ground sample points and low level helicopter observations. Appendix 1 provides examples of forest cover labels and keys to the codes found on forest cover maps.

Although the forest inventory provides useful information for determining potential murrelet habitat, air photo interpretation specifically focused on this goal provides additional information that will improve the efficiency and accuracy of identifying potential habitat identification, and help prioritize specific areas for further assessment.

Air photo interpretation does not provide assessment of the presence and abundance of potential nest platforms, or of epiphyte cover. In some areas, local knowledge may be available regarding these features and their relationships to photo-interpreted attributes such as species, height, and location. Where this knowledge is available, it may be used to increase the accuracy of the habitat ratings based on air photo interpretation. The presence of platforms and epiphyte cover is assessed and confirmed at a further stage of habitat assessment, either by ground-based transects or plots (RIC 2001), or low-level aerial surveys (Part 3 of this manual).

Research on the Sunshine Coast has shown the usefulness of air photo interpretation for identifying potential murrelet habitat. Waterhouse *et al*. (2002) described stand level habitat associations of murrelets and showed that important parameters associated with murrelet nesting habitat, interpretable on mid-scale air photos included: stand age, stand crown closure, stand vertical complexity, stand basal area, and tree height. The report discusses the significance of these attributes, and their evaluation on air photos.

Other research on air photo interpretation of murrelet habitat is in progress to produce reference materials and supporting information, as well as to identify potential knowledge gaps and uncertainties (Waterhouse *et al*. 2003). This study describes the range of photo-interpreted habitat features found at murrelet nesting habitat which was identified from nests located by radio telemetry and occupied stands identified from audio-visual observations. The study illustrates the wide range of habitat being used by murrelets, and in general, supports the information given in these guidelines. A note of caution, however: a portion of the habitats identified in this study as being used by murrelets, would be classified as "least likely habitat" based on air photo interpretation. This indicates that air photo interpretation may not effectively identify all potential nesting habitat. Reference photos showing examples of the range of habitats used by nesting Marbled Murrelets BC are available on loan from Louise Waterhouse at Ministry of Forests (Louise.Waterhouse@gems1.gov.bc.ca).

PHOTO INTERPRETATION OF FOREST COVER ATTRIBUTES

The MMRT (2003) identified features likely to provide suitable nesting habitat for murrelet within the defined conservation regions. A selection of the features suitable for photo interpretation is shown in Table 2.1. The features are then described with guidelines for photo interpretation. Appendix 2 provides more details and photo interpretation guidelines for these attributes.

Potential habitat for murrelets should be delineated sufficiently to identify areas with significant differences in the interpreted attributes, or with distinct ranking differences, without creating an unmanageable number of polygons that require further assessment and management decisions. The intent is to contribute to the efficiency of further assessment such as helicopter or ground-based checks. If air photo interpretation is being carried out as a prelude to these more detailed assessments (helicopter or ground surveys), habitat may simply be initially ranked as being suitable or unsuitable for murrelets, so that further assessment efforts are not biased by air photo ranks.

Table 2.1. Selected features for identifying suitable habitats for Marbled Murrelets in British Columbia, ranked on the likelihood that polygons with these features will contain a large proportion of suitable nesting habitat (from MMRT 2003).

Feature	Most likely	Moderately likely	Least likely
Stand age class	9	8	<8
Tree height class	4 - 7	3	<3
Canopy closure class	4 - 7	3	2 & 8
Vertical canopy complexity	moderately uniform, non-uniform, very non-uniform	uniform	very uniform

Mid-scale (1:15:000 to 1:20,000) or larger scale aerial photographs, available for most managed forest land in BC, are appropriate for interpretation of these key attributes. Larger scale photographs provide more detail, particularly with respect to canopy structure. However, the larger the scale, the more photographs required, resulting in increased time and costs associated with the interpretation. Smaller scale photographs (>1:20,000) are not recommended for potential habitat assessment, other than for a general overview.

A small minority of mature coastal stands are defined as multi-layer stands. Stand descriptions and attribute interpretation for these stands are for the top (tallest) layer of the stand.

Age Class

Age class is included in standard forest cover labels. Age class 9 (>250 years) is most likely to provide suitable nesting habitat, and age class 8 (141-250 years) is moderately likely (Table 2.1). Photo indicators are useful for determining stand age, and the accuracy of the estimated age is also strongly related to ground sampling information in the area.

The forest cover stand age identifies the average age of the dominant, codominant, and high intermediate trees (see Appendix 2 for details). Scattered veteran trees or older trees likely to provide suitable platforms may not be reflected in the stand age label. For example, stands of age class 8 may have scattered older trees that, in conjunction with the stand structure, may provide suitable nesting habitat. Photo interpretation specifically to determine murrelet habitat confirms the given age class, and also identifies the variation within the stand and the presence of potentially suitable older trees

Important age indicators include:

- Height - look for heights that are among the maximum expected for the site, using known species-age-height-site relationships, and comparison with adjacent stands.
- Height variation - older stands tend to have a wider variation in height that is observable on air photos for stands in the CDF, CWH, and MH biogeoclimatic zones. Height variation may also indicate the presence of suitable older trees in a stand with a lower average age. Look for height variation of 5 to 10 m, which is common in older stands within the same forest cover polygon.
- Large crown size - look for large, varied crown size, in comparison with stands in the same general area. These are often associated with canopy gaps and large branches. Branching can sometimes be seen on good quality photos where trees and crowns are large.

- Crown openings - look for openings that could range from half a tree length to several tree lengths in width, often associated with older stands.
- Snags - snag frequency tends to increase with the age of the stand; however snags are not always visible on mid-scale photographs.

Height Class

Height class is included in standard forest cover labels. In general, height class ≥ 4 (≥ 28.5 m) is most likely to provide suitable nesting habitat, and height class 3 (19.5-28.4 m) is moderately likely to provide suitable habitat (Table 2.1). The accuracy of estimated stand height is strongly related to ground sampling information in the area. The same trees used for age estimation (i.e. the dominant, codominant and high intermediate), are used for height estimation.

Knowledge of species-age-height-site relationships in conjunction with ground measured information provides the basis for height estimation. It is useful to first observe on the air photos the areas where the tallest stands are likely to occur (either using local knowledge or forest cover information) to calibrate your eyes and provide reference heights for comparing other trees being assessed.

The variation in height within a stand can be significant when determining potential habitat. For example, stands of height class 4 range from 28.5 to 37.4 m, a variation of up to 8 m. The forest cover label alone does not describe where the stand fits within the height class range, and the older (pre-VRI) inventory labels do not describe the variation of height within the stand. Photo interpretation specifically to determine potential murrelet nesting habitat therefore confirms the given height class label, and identifies stands with relatively tall trees within the height class and stands with a wide height variation.

Photo interpretation for height attributes is described under Age Class (above). Locations of ground-measured heights used for the forest cover label are identified on forest cover maps, and can be used as an indication of how much ground measurement was available for height estimation in the forest cover labels. In addition, where softcopy software is used for forest inventory work, heights may be more accurate because this software has a feature for measuring heights directly from the photos.

Canopy Closure

Canopy closure, also called crown closure, is included in the forest cover label. It is defined as the percentage of ground area covered by the vertically projected crowns of the tree cover for the tree layer. Canopy closure classes 4 to 7 are most likely to provide murrelet habitat requirements, and class 3 is moderately likely to provide habitat requirements (Table 2.1). Comparison charts for crown closure estimation are useful for providing consistency among interpreters (Appendix 2).

Vertical Complexity

Vertical complexity is an attribute of VRI that describes the relative uniformity of the forest canopy for each tree layer. The five-class VRI vertical complexity codes describe stands ranging from very uniform, to very non-uniform. The classification is based on the difference in height between the leading tree species and the tree height range for all stand species, and also indicates expected presence of canopy gaps and stocking (tree establishment) patterns.

General descriptions of vertical complexity in the stands as it appears on mid-scale photographs are:

- Very uniform: less than 11% height difference, generally no visible canopy gaps or recent disturbance;

- Uniform: 11-20% height difference, a few canopy gaps may be visible, generally no evidence of recent disturbance;
- Moderately uniform: 21-30% height difference, some canopy gaps may be visible, stocking may be somewhat patchy or irregular;
- Non-uniform: 31-40% height difference, canopy gaps often visible, stocking is typically patchy or irregular;
- Very non-uniform: >40% height difference, stocking is typically very patchy or irregular.

In general moderately uniform, non-uniform, and very non-uniform complexity classes are most likely to provide murrelet nesting habitat (Table 2.1). Vertical complexity features corresponding with these classes are:

- Specified percent difference in tree height of dominant, codominant and high intermediate trees compared with average height. See sample calculations in Appendix 2.
- Presence of dominant and emergent trees. For age class 8 and 9 stands, these dominants of some species will typically have large crowns on good sites.
- Presence of canopy gaps. Look for gaps ranging in size from half a tree length to several tree lengths. These should be visible throughout much of the stand, particularly for non-uniform and very non-uniform classes.
- Patchy, irregular stocking. Look for variation in stocking with canopy gaps and openings from half a tree length to 1 hectare in size. This will often correspond with variation in crown closure throughout the stand of 10-20%, or more.

Topographic Complexity

Topographic complexity might enhance the suitability of forest stands for nesting by breaking up the continuity of the forest canopy and perhaps improve access to the canopy for nesting murrelets (MMRT 2003). It is a subjective assessment of small irregularities in the stand topography that create small gaps and variability in the canopy structure. Features such as small rock outcrops, avalanche chutes, and gullies contribute to canopy complexity and do not necessarily affect the vertical complexity classification. Slope also contributes to the canopy height variation and gaps. Slopes or areas with irregularities would generally be rated higher than less steep slopes or areas without irregularities, but topographic complexity should not over-rule canopy structure in rating habitat. Topographic complexity is recommended as a consideration in the overall habitat rating by potentially increasing or decreasing the stand rating by a class, particularly for relatively uniform stands where vertical complexity is low.

Tree Species Composition

The MMRT (2003) made no distinction of tree species for providing suitable nesting habitat. However, there may be local knowledge that identifies regional, elevational, or site-specific species relationships with nest platforms and epiphyte cover. For example, Sitka spruce (*Picea sitchensis*) often provides good platforms in many areas whereas bog forests dominated by lodgepole pine (*Pinus contorta*) seldom do. If known, these local factors can be taken into account for the overall habitat rating by potentially increasing or decreasing the stand rating by a class. Species composition is identified in standard forest cover labels and can be estimated from the air photos. Accuracy is strongly correlated with local knowledge of the geographic and ecological limits of the species, species associations, and sample information. Appendix 2 provides further information regarding species identification on aerial photographs.

HABITAT RANKING

Habitat ranking based on photo-interpreted attributes is intended to be consistent with or adaptable to other habitat rating schemes used for murrelets. Ranking habitat using air photos is usually part of a larger process in identifying and selecting suitable habitat for nesting murrelets (see the general introduction to this manual and MMRT 2003). If air photo interpretation of murrelet habitat is being conducted as part of this larger process, ranking habitat polygons as per Table 2.2 is optional; habitat may simply be rated as "likely" (i.e., equivalent to habitat ranks 1-4) or "unlikely" (ranks 5-6). As the reliability and accuracy of ranking potential habitat from air photos requires further testing, pre-ranking habitat prior to ground or aerial surveys may bias ground-truthing efforts.

A habitat rank is applied as an overall measure of a stand's current potential for providing suitable nesting habitat, based on the described photo interpreted attributes, and their classification as most likely, moderately likely, or least likely to provide suitable nesting habitat per Table 1.1 (check this reference is correct). In addition, variation of stands within the Table 1.1 (check this) criteria, consideration of topographic complexity, and local knowledge is considered in the air photo ranking.

Because habitat features vary regionally, habitat within a specified geographic area (e.g., landscape unit or group of landscape units) is assessed relative to all potential habitat in that area. The best habitat would be defined by a stand that meets all 'most likely' criteria, and is most expected to provide significant numbers of platforms and epiphyte cover. All habitat is assessed with respect to this benchmark stand. Table 2.2 describes the 6 class ranking scheme.

Table 2.2. Ranking scheme for potential Marbled Murrelet nest habitat based on air photo interpreted attributes (see also Table 1.2 in the General Introduction to this manual).

Rank	Characteristics
1: Very High	Key habitat features present in abundance; meets all 'most likely' attribute criteria and includes the best habitat in the specified geographic area.
2: High	Key habitat features common and widespread; generally meets all 'most likely' attribute criteria but does not have the best canopy structure as shown by the benchmark stands.
3: Moderate	Key habitat features present but patchy; generally meets all 'moderately likely' attribute criteria, and may marginally meet some 'most likely' criteria.
4: Low	Forested, key habitat features evident but patchy and sparse; generally minimum age class 8 or height class 3. Poor site not expected to provide significant numbers of platforms.
5: Very Low	Forested, key habitat features sparse and might not all be present; generally age class <8 and height class <3. Stand will probably require further assessment to show nesting potential. Nesting unlikely based on IWMS criteria.
6: Nil	Non-forested. All key habitat features absent. Nesting highly unlikely.

Habitat with a rank of 6, 5, or 4 would generally fit into the MMRT (2003) "least likely" habitat category; a rank of 3 into the "moderately likely" category, and ranks of 1 and 2 into the "most likely" category. Some of the known nest sites, however, have shown a mixture from all three categories (Waterhouse *et al*. 2003).

PART TWO - APPENDIX 1. STANDARD FOREST COVER LABELS AND CODES

Forest cover labels for forested land on standard Ministry of Forests forest cover maps provide information regarding tree species composition, stand age, stand height, stocking class, crown closure, and site index at breast height age 50. See Appendix 2 for more discussion of these attributes.

An example of a forest cover label is:

HC(B) 9416-15

Species Composition: HC(B)
Species are listed in their order of predominance. Major species are listed first, followed by minor species in brackets. The example shows that species composition is hemlock and cedar, with a minor component of balsam.

Age class: 9
The example shows that average stand age of dominant, codominant, and high intermediate trees is greater than 250 years.

Height class: 4
The example shows that average height of dominant, codominant, and high intermediate trees is between 28.5 and 37.4 m.

Stocking class: 1
This stocking class indicates that the stand is mature and contains at least 76 stems per hectare at least 27.5 cm diameter. In general, stocking class 1 refers to a well-stocked mature stand.

Crown closure: 6
The example shows that crown closure is between 56 and 65%.

Site Index: 15
The example indicates that this stand at age 50 (age measured at breast height, 1.3m from base of tree) is 15 m tall. This is an indication of site productivity

FOREST COVER LABEL CODES

Species Symbols

- F - Douglas-fir
- C - Western redcedar
- H - Hemlock
- B - Balsam (true fir)
- S - Spruce
- Y - Yellow cedar
- Pl - Lodgepole Pine
- Ac - Cottonwood
- D - Red alder
- Mb - Broadleaf maple
- Pw - Western white pine

Age Class Codes

Code	Limits (years)
1	1-20
2	21-40
3	41-60
4	61-80
5	81-100
6	101-120
7	121-140
8	141-250
9	251+

Height Class Codes

Code	Limits (metres)
1	0-10.4
2	10.5-19.4
3	19.5-28.4
4	28.5-37.4
5	37.5-46.4
6	46.5-55.4
7	55.5-64.4
8	64.5+

Stocking Class Codes

Code		Applies to	Limits No. of trees / hectare, dbh limits
0		all immature	NA
1		all mature	≥76/ha, 27.5+cm dbh
2		all mature	<76/ha, 27.5+cm dbh
Subdivision of 2	3	mature, with leading species *Pl*	
	4		
R		immature, mature	stands disturbed 26 – 75% by area or volume

Crown Closure Class Codes

Code	Limits (%)
0	0-5
1	6-15
2	16-25
3	26-35
4	36-45
5	46-55
6	56-65
7	66-75
8	76-85
9	86-95
10	96-100

PART TWO - APPENDIX 2. SELECTED EXCERPTS FROM PHOTO INTERPRETATION GUIDELINES

The following guidelines are selections from the publications listed below:

- Ministry of Forests Inventory Manual (1992);
- Vegetation Resources Inventory (VRI) Photo Interpretation Procedures (VRI 2002); and,
- Ministry of Forests Air Photo Interpretation Training Manual (1996).

Selected photo interpretation guidelines are provided for standard forest inventory attributes. These describe the methods used for existing forest cover labels, and provide guidelines for use in air photo interpretation to identify potential habitat for nesting Marbled Murrelets. Stereogram examples illustrating some of these attributes are available in the Ministry of Forests publications: *Black and White Stereogram Handbook*, and *Colour Stereogram Handbook*, available at the Ministry of Forests library.

Overview:

1. Delineation / Stratification

These guidelines show how the polygon boundaries are determined for forest cover mapping based on air photo interpretation. For example, for stands greater than 140 years, or height greater than 30 m, stands should be separated only if the age difference between adjacent stands is at least 50 years, and the height difference is at least 5 m. Other delineation criteria are species composition and crown closure. An understanding of the forest cover map delineation is important for understanding the variation that can be expected within a polygon for each of the interpreted attributes. Note that vertical complexity is not considered for delineation of separate stands.

2. Tree Layer

Defines tree layers and criteria for multi-layered stands.

3. Species Composition

Describes the procedure for estimating species composition. A table identifies some of the common photo characteristics of main tree species.

Accuracy of species identification is strongly correlated with local knowledge of the geographic limits of the species, ecological limits (e.g., slope, aspect, elevation, moisture and nutrients), species associations and history. Data sources such as low level air assessments and ground measurements, near or within the stand, are also used to determine species composition. Air and ground assessment locations are identified on forest cover maps.

4. Stand Age

Describes the age determination of the leading species. A table identifies common photo characteristics used to help estimate age. Accuracy is strongly related to ground sampling information in the area. The interpreter also uses known species-age-height-site relationships.

5. Stand Height

Describes procedure for height estimation. Note height correction for change of elevation on the photos. As with age, accuracy is related to ground sampling information in the area and knowledge of species-age-height-site relationships.

6. Crown Closure
Describes procedure for estimating crown closure. A comparison chart shows examples of crown closure from 1% to 50% with examples showing differences in spatial distribution of the trees.

7. Vertical Complexity
Describes this attribute, which is a component of VRI inventories only. A table describes the five vertical complexity codes ranging from very uniform to very non-uniform.

1. DELINEATION / STRATIFICATION

The following guidelines are suggested for forest inventory purposes. These guidelines may vary depending on each user's needs and the complexity of the project area.

Delineation Guidelines for Treed Polygons

<table>
<tr><th>Polygon Attribute Classification</th><th>Age</th><th>Height</th><th>Crown Closure</th><th>Species Composition</th></tr>
<tr><td>Age < 50 yrs
or
Height < 20 m</td><td>Difference between adjacent stands should be at least 10 yrs.</td><td>Difference between adjacent stands should be at least 3 m.</td><td>Difference between adjacent stands should be at least 20%.</td><td rowspan="3">When to delineate polygons:

1. if there is >20% difference in leading species composition; or

2. if there is a switch in the leading species;

or
3. if there is a different 2nd species present;

or
4. if the species composition changes from a mixed species stand to a pure stand.</td></tr>
<tr><td>50≤ Age < 140
or
20 m≤ Ht <30 m</td><td>Difference between adjacent stands should be at least 20 yrs.</td><td>Difference between adjacent stands should be at least 3-5 m.</td><td>Difference between adjacent stands should be at least 20%.</td></tr>
<tr><td>Age ≥ 140 yrs
or
Height ≥ 30 m</td><td>Difference between adjacent stands should be at least 50 yrs.</td><td>Difference between adjacent stands should be at least 5-10 m.</td><td>Difference between adjacent stands should be at least 20%.</td></tr>
</table>

Adapted from Forest Inventory Manual, Forest Classification / Sampling and Environmentally Sensitive Areas, Vol.2 (Ministry of Forests 1992).

2. TREE LAYER

Tree layers are distinguished according to recognized height differences which are, in many cases, associated with distinct age differences. Identification guidelines may vary, depending on each user's needs and the complexity of the project area. An example of this is a regenerated lodgepole pine stand growing under an older Douglas-fir layer after a fire.

To be classified as multi-layered, a stand should meet the following criteria:

- Each layer must be distinct and relatively homogenous throughout the type.
- Each layer should consist of different tree species except when the layer separation is distinct.
- Differences in age and height between layers should be identifiable on the aerial photograph and on the ground.
- The bottom layer is usually established following a major disturbance such as fire or logging.
- The age of the younger of the two layers should be 120 years or less. If both layers are 121 years or older, the polygon should be treated as one layer.

3. SPECIES COMPOSITION

Species composition describes the tree species present, and provides an estimate of the percentage of each species within the polygon based on the proportion of basal area or density of live trees. Tree species are listed in descending order of abundance.

Note:

- Dominant trees have well developed crowns that extend above the general level of the trees around them.
- Codominant trees have crowns forming the general level of trees around them.
- High intermediate trees have smaller crowns slightly below but extending into the general level of trees around them.

Stereograms, ground calibration points, ecological site descriptions, and local knowledge are all used to estimate species composition. The following table identifies air photo characteristics and common associates of common coastal tree species.

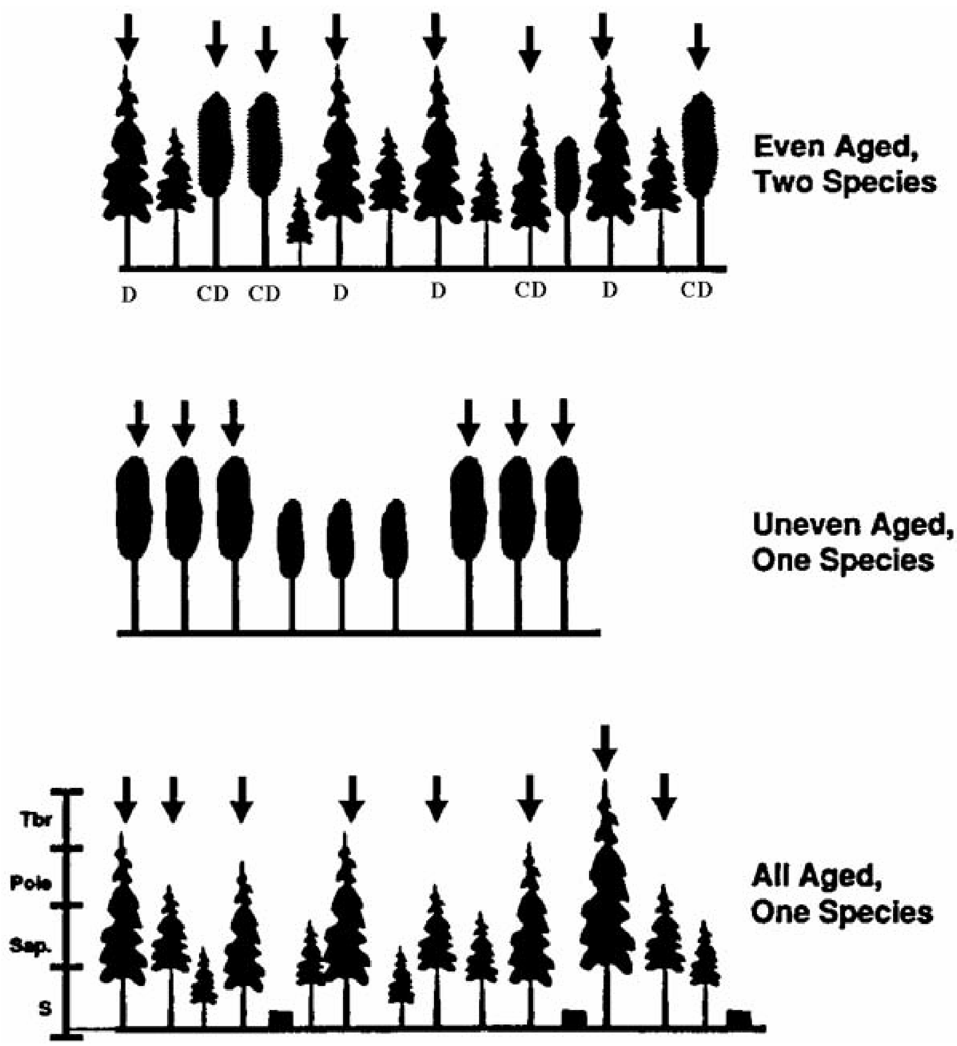
Species	Tone	Texture	Shape	Density	Site	Association	Remarks
Cottonwood	dark to medium gray	fine to coarse	tufted	open	alluvial	S	common on alluvial soils
Bigleaf maple	dark	dense	widespread	open	better	alder	coastal
Red alder	medium gray	fine	rounded, short	moderately dense	better	F, H	pioneer species
Lodgepole pine	medium gray	fine, peppery	rounded to conical	open	variable	F	pioneer species, even aged stands
Sitka spruce	medium to dark	coarse	cylindrical	moderately open	better	H,C	coastal, small patches
Subalpine fir	dark	coarse	narrowly conical	dense	poor to medium	S, H	higher elevation
Grand fir	dark	coarse	cylindrical	dense	valley bottom	H	small patches
Amabilis fir	dark	moderately coarse	conical	dense	1000m+	H,C	very shade tolerant
Douglas-fir	medium gray	coarse	broadly conical	open to moderately dense	dry sites/ south facing slopes	H,C,Pl	pioneer species
Red cedar	light	fine	broadly conical	open	better	F,H	low to mid elevation
Yellow cedar	light to medium	fine	conical to cylindrical	open	poor	H,B	
Western hemlock	light to medium	fine	broadly conical	open	moist	C,B,F	

Source: Air Photo Interpretation Training, 1996.

4. AGE

Age is an average age, weighted by basal area, of the dominant, codominant and high intermediate trees for the leading and second species of each tree layer identified. (See definitions of dominant, codominant and high intermediate earlier in this appendix).

Selection of Dominant and Codominant Trees for Age and Height Estimations



Arrows indicate trees included for age (and height) estimation.

The following data can be collected and used to aid in the photographic interpretation of tree age within a polygon:

- history of origin (previous surveys, silviculture);
- field measurements (for calibration, verification);
- species-age-height-site relationships; and,
- age patterns.

Aids to Photo Interpretation of Age

Photo Characteristics	Immature	Mature
Stand texture	even	coarse-often crown openings are present
Crown size on species	narrow	wide-varies dependent on species
Height variation	minor	variable
Height	less than maximum	equals maximum per site
Snag frequency	few	increasing
Presence and height of successional species	none	common
Presence of short-lived pioneer species	present	reduced occurrence around 120 years

5. HEIGHT

Height is an average height, weighted by basal area, of the dominant, codominant and high intermediate trees for the leading and second species of each tree layer identified. (See definitions of dominant, codominant and high intermediate earlier in this appendix).

Consider making height adjustments for the following situations:

1. For species with narrow crowns, as the crowns do not resolve on the photograph where the crown width is less than 1 m (e.g., narrow crowned alpine fir or rapidly growing coniferous). Adjust height upwards by 1-6 m.

2. For high-elevation stands, heights appear taller than they actually are. For example, for a tree of the same height, differential parallax increases with elevation at the rate of 7m/1000 m.

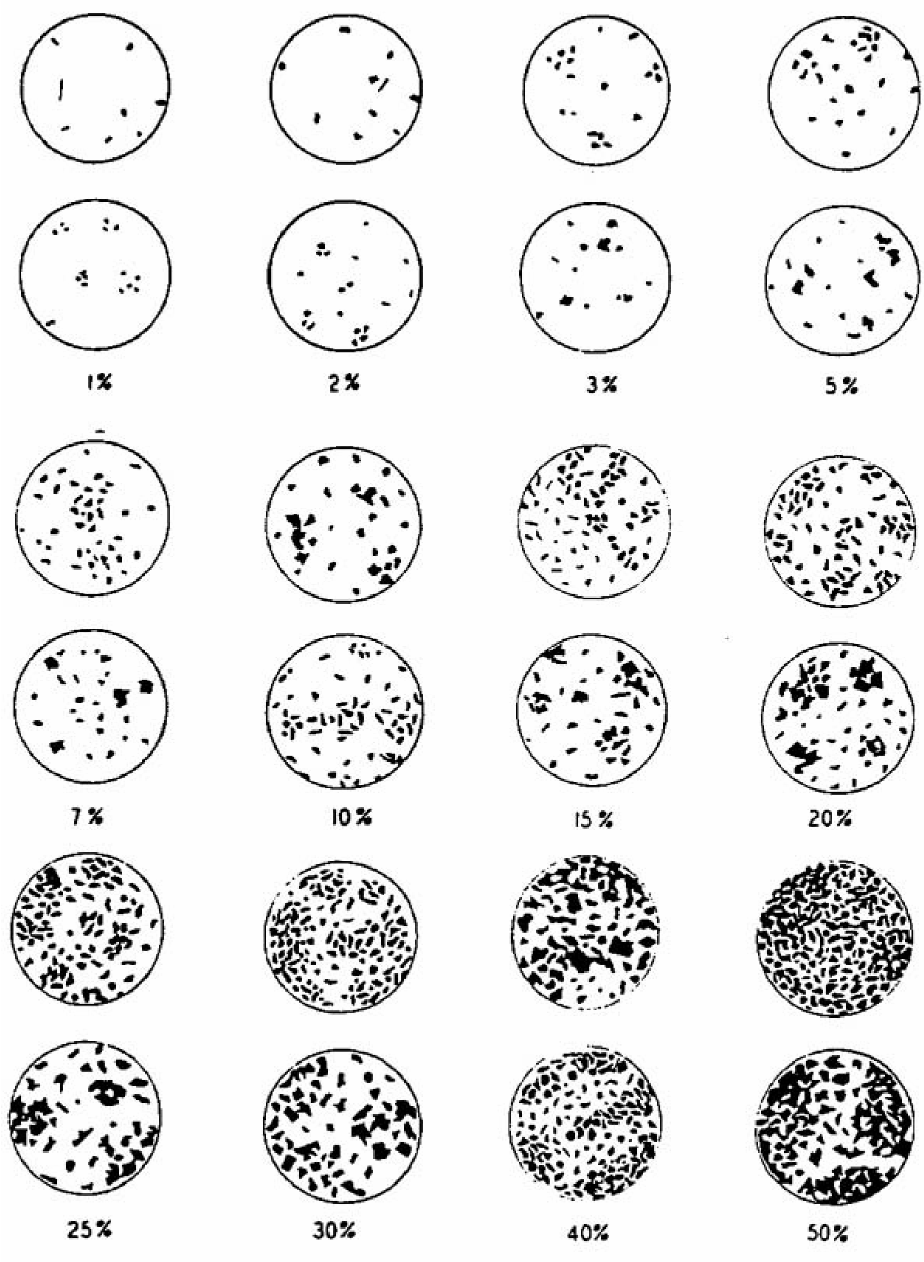
6. TREE CROWN CLOSURE

Tree crown closure is the percentage of ground area covered by the vertically projected crowns of the tree cover for each tree layer within the polygon. Tree crown closure is very difficult to measure on the ground.

Where vegetation is overlapping (such as a two-layer stand), only the visible portion of each layer is estimated for crown closure. Crown closure is estimated for each tree layer in the polygon.

The following comparison chart is useful for providing consistency among interpreters, and provides examples of crown closure for various spatial distributions.

Comparison Chart for Visual Estimation of Crown Closure



Developed by Richard D. Terry and George V. Chillinger. Published by the Society of Economic Paleontologist and Minerologist in its journal of Sedimentary Petrology 25(3): 229 - 234, September 1955.

7. VERTICAL COMPLEXITY

Vertical complexity is a subjective classification that describes the form of each tree layer as indicated by the relative uniformity of the forest canopy as it appears on mid-scale aerial photographs. It is used to identify and describe even-aged and uneven-aged stands for further analysis in forest stand management and wildlife habitat assessment.

Vertical complexity is influenced by stand age, species (succession as it relates to shade tolerance) and degree and age of past disturbance. The tree height range is calculated as the total difference in height between the tallest and shortest visible dominant, codominant, and high intermediate trees. To adequately represent the tree layer of interest, occasional occurrences of either very tall or very short trees should be ignored so that the vertical complexity indicated is for the majority of stems in the dominant, codominant, and high intermediate portion of each tree layer.

Coding for Vertical Complexity

Code	Description
1	Very uniform. A very uniform canopy with less than 11% difference between the height of the leading species and the average tree layer height. Holes (or canopy gaps) are generally not visible in the canopy and there is usually no evidence on the photograph of recent disturbances affecting the form of the stand. Examples include plantations and young, immature stands of shade intolerant species.
2	Uniform. A uniform canopy with 11-20% difference between the height of the leading species and the average tree layer height. A few holes (or canopy gaps) may be visible in the canopy and there is usually little or no evidence on the photograph of recent disturbance affecting the form of the stand.
3	Moderately uniform. A moderately uniform canopy with 21-30% difference between the height of the leading species and the average tree layer height. Some holes (or canopy gaps) may be visible in the canopy and there may be evidence of past disturbance affecting the form of the stand. Stocking may be somewhat patchy or irregular. Examples include older spruce-balsam stands.
4	Non-uniform. A relatively non-uniform canopy with 31-40% difference between the height of the leading species and the average tree layer height. Holes (or canopy gaps) are often visible in the canopy (due to past disturbance) and stocking is typically patchy or irregular.
5	Very non-uniform. A very non-uniform canopy with more than a 40% difference between the height of the leading species and the average tree layer height. Stocking is typically very patchy or irregular. Examples include disturbed dry belt Douglas-fir stands and “decadent”, coastal stands.

Example: the following table shows the height variation within a stand that corresponds to the vertical complexity codes for stands with average heights of 10 to 50 metres.

Average Tree Layer Height (m)	Tree Height Range (m) by Vertical Complexity Code				
	1	2	3	4	5
10	0 - 1.0	1.1 - 2.0	2.1 - 3.0	3.1 - 4.0	>4.0
20	0 - 2.0	2.1 - 4.0	4.1 - 6.0	6.1 - 8.0	>8.0
30	0 - 3.0	3.1 - 6.0	6.1 - 9.0	9.1 - 12.0	>12.0
40	0 - 4.0	4.1 - 8.0	8.1 - 12.0	12.1 - 16.0	>16.0
50	0 - 5.0	5.1 - 10.0	10.1 - 15.0	15.1 - 20.0	>20.0

Example Calculation:

To determine the percent difference in tree height for the assignment of the tree vertical complexity code: The leading species height (dominant, codominant, and high intermediate trees) is 23 m and the tree heights range from 20 to 26 m (all species in the dominant, codominant, and high intermediate crown positions) for a total tree height range of 6 m:

$$\text{Percent difference} = \frac{\text{Tree height range}}{\text{Height of leading species}} \times 100$$

$$= \frac{6}{23} \times 100$$

$$= 26\%$$

A difference of 26% correlates to a vertical complexity code 3 for the tree layer.

PART THREE: LOW-LEVEL AERIAL SURVEY METHODS

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INTRODUCTION TO PART THREE

This part of the manual deals with low level helicopter surveys (hereafter called aerial surveys) for assessing the suitability of forest habitat for nesting Marbled Murrelets in British Columbia. **Please read the introduction to the complete manual before using this section. The manual introduction explains the background to the use of aerial surveys and the ranking system used for these surveys.**

Aerial surveys can provide details on the canopy structure and suitability not possible with the use of algorithms, air photo interpretation, or other large-scale methods. In particular, aerial surveys can provide a rapid, cost-effective assessment of important canopy features, including:

- the presence and relative abundance of potential nest platforms (defined as limbs or deformities >15 cm in diameter providing a nest site and landing platform for murrelets);
- the cover and thickness of epiphytes (moss, lichens, and ferns) which usually provide the substrate for murrelet nests;
- canopy structure and complexity allowing access by flying murrelets to and from potential nest sites.

In addition, aerial surveys provide confirmation and correction of features which might be available from forest cover maps, air photos or other large-scale sources. These include:

- tree species composition;
- tree size;
- stand age class;
- assessing the availability of gaps in the forest and topographical micro-structures (e.g., boulder-fields, slopes, avalanche chutes), which facilitate access by murrelets to the canopy nest sites; and,
- recent changes in forests not captured in the maps or air photos caused by logging, avalanches, blow-downs, fires, or disease.

In effect, aerial surveys provide a "murrelet's eye view" of the forest canopy. Human observers in a slow-moving helicopter might be able to detect and recognize many of the canopy features that murrelets themselves use when selecting a nest site, although we do not know what the proximate features are that trigger nest-site selection in this bird. The Marbled Murrelet Recovery Team has recognized the value of low-level aerial surveys in refining the identification and selection of murrelet nesting habitat (MMRT 2003).

This section and the data form (Appendix 3) are meant to provide guidance for aerial surveys covering a wide range of purposes and situations. Carefully review the purpose, methods, data required, and personnel, time and funds available when planning the survey. In Part 3 of this manual the term **site** is used to include the polygon, forest patch, or point on the ground being evaluated.

WHEN TO USE AERIAL SURVEYS

Low-level helicopter surveys are useful in the following situations (which is not an exhaustive list of their application):

1. Identification and confirmation of the suitability of proposed Wildlife Habitat Areas (WHAs). Proposed WHAs must contain the essential requirements for murrelet nesting and ideally include a large proportion of habitat which is confirmed to be Most Likely or Moderately Likely (MMRT 2003; IWMS in prep.) to contain suitable nesting habitat. Aerial surveys allow rapid assessment and ranking of potential WHAs based on platform availability and other critical features.

2. Confirming the suitability of habitat to be maintained outside WHAs. Not all habitat to be maintained as suitable for murrelet nesting will be within WHAs. Habitat will also be within parks and other protected areas, non-merchantable and non-contributing forest areas, and riparian corridors and other areas with constrained logging. Confirmation that such areas do in fact contain suitable nesting habitat is important.

3. Testing habitat definitions, algorithms, and other procedures for identifying nesting habitat. Habitat definitions and algorithms developed for identifying suitable nesting habitat for murrelets are generally tested with ground-based transects or plots (e.g., Bahn and Newsom 2002; McLennan *et al.* 2000) or comparisons with nest sites found with telemetry (e.g., Waterhouse *et al*. 2002). Aerial surveys are also an effective way to rapidly assess a large number of widely-spaced points or polygons which were identified as potential murrelet habitat based on algorithms (Leigh-Spencer *et al*. 2002; Hobbs 2003) or air photo interpretation and biogeoclimatic data (Deal and Smart 2003).

Important notes: Although an aerial survey is often the last step in assessing habitat suitability for proposed WHAs and other maintained habitat, it is usually not the last step in actually selecting the WHA. Other criteria need to be considered, and these are outlined in the general introduction to this manual.

The effects of low-level helicopter flights on nesting Marbled Murrelets are not known. To avoid possible disturbance and breeding failure, helicopter surveys are best done outside the breeding season, which runs from mid-April through August in most areas in BC (Burger 2002).

PERSONNEL AND TRAINING

Aerial surveys can be conducted by a single experienced observer, but the optimal crew size is three observers (in addition to the pilot).

Pilot – An experienced pilot makes a significant difference to the success and cost effectiveness of this procedure. A pilot who has done a lot of low-level surveys and can fly the aircraft in a manner which maximizes the observers' views (e.g., by flying next to and not directly above the patch being assessed) is essential. Much time may be spent giving directions to inexperienced pilots to fly in a manner that provides the correct view of attributes. Experienced pilots, especially those familiar with the survey area, assist in navigating, which saves time. This experience requirement should be stated when booking the helicopter. Having a pilot who is genuinely interested in the work being performed is a great asset, because the pilot can report on what is visible from the right side of the aircraft, and guide the helicopter to maximise the observers' views.

Observer-Navigator – This person, seated in front next to the pilot, is responsible for assisting the pilot with navigation and location of the sites to be surveyed (using maps and air photos with the locations of the sites and the pre-planned flight route clearly marked). This person will participate in the site evaluation, and make adjustments, if necessary to the proposed layout of the WHA or other area being assessed. Ideally, this person will be very familiar with the layout of the area being surveyed, will have worked extensively with the air photos and maps being used in the evaluation, and will have previous experience with aerial surveys.

Observer-Biologist – This person, seated behind the Observer-Navigator on the left of the aircraft, participates in the site evaluation and is also responsible for recording the data, either on the data form (Appendix 3), or on a tape recorder. This person must have some previous experience with identification of murrelet habitat. This person should also take photos of the site and/or operate the video camera. Ideally, the observer uses the video camera's mini-screen for viewing rather than the viewfinder, so that he/she can visually scan the forest at the same time as videotaping. The left rear observer should operate the camera because the helicopter usually flies so that the two observers on the left are optimally placed for observing.

Observer-Recorder – Having a third observer, seated on the right (pilot's) side of the aircraft is useful, but only if the helicopter has sufficient power to fly slowly and hover with four people on board. This observer will participate in the site evaluation, and report on the habitat visible on the right of the aircraft. If the survey is covering many sites in rapid succession, it is advisable to have the Observer-Recorder do all the recording, while the Observer-Biologist on the rear-left of the aircraft focuses entirely on observing and videotaping, and calls out the habitat ranks for the recorder. The third observer position can be used for training new personnel.

Crew communication and training – All observers and the pilot should be in communication throughout the flight, and should discuss their evaluations at the time of the survey, to reach a consensus on the suitability and ranking of the site before starting the evaluation of the next site. If possible, the crew's comments during the site evaluation should be recorded on the audio-recording of the video taken during the site evaluation, to provide a permanent record of the evaluation process (see below).

The observers should be trained in the methods given in this manual, should thoroughly discuss all the attributes before the survey, and should be consistent in their evaluation and ranking of habitat features. In particular, the evaluation of platform availability should be thoroughly discussed. Rapid and accurate identification of tree species from the air is sometimes difficult, and the crew must review the key features of the locally common species before the flight.

EQUIPMENT

Helicopter – The critical requirements are that the helicopter has sufficient power to fly slowly or hover close to the forest canopy, climb fairly rapidly, and provide a safe and comfortable working environment for the crew. Selection of helicopter type will take into account speed, ability to climb and hover, visibility (window configuration), crew capacity, cost, and availability. The Bell 206 is generally well suited for this work. The A-Star is more expensive but can carry a larger crew and is faster and might be economical if the sites to be evaluated are far apart. Window configurations vary among similar helicopters. Small, piston-driven helicopters are generally not powerful enough for this work.

Video recording – Continuous video recording of the site during the evaluation, ideally combined with simultaneous audio recording of the crew's comments, is recommended. The video provides a permanent visual and audio record of the evaluation. It is an effective tool for showing suitability or lack of suitability to those unable to be on flight, such as the officials approving WHAs or other management plans. Before the survey, discuss the use of video with these officials to determine what they will require to be confident in the results of the habitat evaluation. The video camera must be of professional quality; standard home-quality video recorders do not have fine enough resolution or picture quality to be useful. Ideally, the helicopter should have a video/photo window that can open. An ideal set-up is a video camera which can also continuously record the comments and assessments of the crew as they view the passing habitat. This can be achieved by linking the video-camera's audio-intake with the helicopter's communication system (e. g., R. McGregor, Goldwing Helicopters, Sechelt). Details on how to effectively video-tape forest habitat are given below.

Audio tape – In some situations it might be useful to record details of the survey on a tape recorder rather than on the data form. This might apply to surveys where there is a single observer who does not have enough time to navigate, evaluate and use a data form. People prone to air sickness might prefer to keep their eyes on the outside world, and record on a tape, rather than look down to record on a data form. The disadvantages of audio-tape are that helicopter noise results in a poor quality recording, the observer will have to transcribe the tape at a later time, and the observer might forget to record all the necessary attributes if he/she is not referring to the data form.

PRE-TRIP ORGANIZATION

Review the purpose of the survey – It is of utmost importance to be clear on the purpose of the survey flight. The primary purpose of most aerial surveys is to determine the availability and ranking of required attributes for murrelet nesting habitat that cannot be determined from air photos or maps. Assessing potential nest platforms and canopy microstructure is most important. Confirming the availability of attributes that are given on air photos, maps, GIS, existing inventory database and other pre-existing data is a secondary goal, especially in situations where there are no high-quality air photos.

Prepare air photos and maps – In most cases aerial surveys will assess polygons or patches of forest following air photo interpretation. Prior to the aerial survey, number the polygons on the air photos for reference in data collection and future mapping. Within polygons which contain large areas of potential nesting habitat, it might be useful to subdivide and stratify the area into distinct forest types. Do this during the air photo interpretation phase, using natural boundaries within the polygon where significant changes in attributes are visible. This has to be done within reason - do not create a cumbersome number of polygons.

The Observer-Navigator should carry the air photos and maps, and make changes and notes on them. If possible, a second set of the air photos or habitat maps should be prepared, with the polygons marked and labelled, to allow the two people in the back seat to quickly view and evaluate them.

Plan the flight route – In consultation with the pilot, plan a flight route to minimize flight time and enhance viewing opportunities. Send a copy of this manual to the pilot several days before the aerial surveys so that the pilot can read up on what is expected.

Prior to the flight, draw the proposed flight path onto the air photos or maps used for navigation. Show where the helicopter will enter the photo/map area, the sequence in which the polygons will be evaluated, and the exit route to the next photo/map area. Consider altitude and proximity of polygons, maintaining altitude whenever possible to save time and fuel. The main observers will be on the left side of the aircraft, so it is advantageous to plan the route with that in mind. For example, plan a route to circumnavigate a watershed in a clockwise direction to keep the hillside view on the left side. Many small areas will be surveyed in one pass, and this will avoid having to fly past the polygon and turn around to fly it again with the observer on the correct side. Before leaving an area that is geographically distant from the next area to be visited, review the photos to ensure that no polygons were missed. Land at pre-planned rest stops if more time is required to do this.

Have one detailed overview map for navigational purposes with the entire flight route on it for general reference between air photos or fine-scaled maps. Unless you are very familiar with the survey area, do not use forest cover maps for navigation between polygons. The boundaries of forest cover polygons are often not readily visible from the air, and small details such as rock outcrops which are excellent reference points are not usually shown on the maps. If unfamiliar with the area it helps to check the date of air photos and draw recently harvested areas and new roads onto the air photos for navigation purposes. A lot of time can be wasted looking for timber boundary landmarks that no longer exist.

To locate specific survey points and small polygons, it is useful to determine their UTM co-ordinates or latitude and longitude, and program these into the helicopter's GPS. Number the points or polygons so that the number in the GPS matches that on the map or air photo. To locate specific points precisely be careful to include sufficient decimal points of the co-ordinates (i.e., to within 1 or 10 m resolution).

Plan for contingencies and route flexibility – Weather conditions should be considered prior to the flight. Patchy conditions or elevation-limiting cloud may result in some areas being missed during the survey. Additional flights to pick up missed areas significantly increases the overall cost of the project. Areas that cannot be revisited later, while en-route to another part of the project area, should be saved for days when the weather will not be a limiting factor. Be prepared to alter the route during the flight in the event that weather or some other factor prevents you from following the prepared route.

Arrange to have extra fuel cached along the flight route to avoid travelling back to base to refuel. When booking helicopter time request that a fuel pump be brought along; it is not always standard equipment. Plan rest stops to break up the flight, reduce observer fatigue, and minimize the chance of air sickness. Most companies do not charge for breaks when the helicopter is not flying.

SITE ASSESSMENTS

Habitat attributes to record at each survey site (polygon, stand and/or sample point) are identified here. These factors are known to be found at most Marbled Murrelet nests in BC, and probably provide essential requirements for nesting murrelets or are strongly associated with essential habitat requirements. The following fields are included on the Site Assessment Data form (Appendix 3). Have the data form in hand while reviewing these attributes.

If there are obvious differences in the habitat attributes of valley bottom and slope portions of the site, identify these separately on the data form. Where necessary, circle the attributes separately for valley bottom and slope, and label them: VB for valley bottom; SL for slope. It might be advisable to sub-divide large, complex polygons and fill in a separate data form for each subdivision. Be sure to label each form carefully and indicate the subdivision boundaries on the air photo or map.

Location Attributes

Name, number or other identification of the polygon, stand or point being assessed.
UTM coordinates (zone, easting and northing), or alternatively latitude and longitude.

Documentation of the survey and habitat attributes

General points – Still or video images greatly add to the documentation of the site being surveyed, provide archival information for future reference, and should be part of each aerial survey. Record on the data form whether video and/or still photos were taken, and indicate the number of each image for future reference. Alternatively, write the photo number directly on the map or air photo being used for navigation, indicating with an arrow the direction in which the photo was taken.

Video – Video recordings of the site being assessed, ideally with a hook-up to the helicopter's internal communication system, are very valuable. See above for details on equipment. When video-taping a forest stand, it is most effective to focus on individual trees rather than holding the camera still and capturing moving images of the forest passing by. It is very difficult to see stand attributes, especially potential platforms, from a video of continuously moving forest images. Use wide angle to capture the overall layout of the habitat, but zoom in a little when documenting the canopy structure and evidence of platforms.

Take a video image of the air photo or detailed map of the site immediately before filming the site itself. This is a useful way to label or bookmark the video and to record the size, shape and special features of the polygon being evaluated. The Observer-Navigator can hold up the air photo or map in the aircraft for the Observer-Recorder to film (zoom in to capture the details). With audio hook-up to the video, the Observer-Navigator can simultaneously comment on the specific site about to be evaluated, while using the photo/map to delineated the polygon boundaries, reference numbers, and other features of the site. Without this type of reference it is difficult for later video reviewers to know which polygon is being shown.

Still images – Photographs of the polygon are a useful form of documentation. Use high-speed film (200 or 400 ISO) and fast shutter speeds (1/100 sec or faster). A 35-80 mm zoom lens, or similar, allows photos of the general habitat plus some detail of the canopy. Ideally the helicopter should be fitted with an opening window to allow photography. Use a polarizing filter to reduce reflections if shooting through the helicopter window. To reduce vibrations, avoid touching the helicopter with the camera or your elbows.

Digital still photography is increasingly being used for documenting habitat. Some newer digital cameras can be linked with GPS units and can automatically document the coordinates as the photograph is taken.

It is critically important to record the number of each photo or digital image in the space provided on the data form. This will allow you to later match the image with the correct polygon or point being assessed. When using several rolls of film, number each roll with a permanent marker before the flight and number the photos using both the roll number and image number (e.g., 2-03 = roll 2, image number 3).

Description of the site

Space is provided on the data form for a brief description of the site, if needed. Make a note if some part of the polygon is not assessed, and whether the survey was a detailed habitat evaluation or a rapid confirmation of the habitat ranking.

Habitat attributes

The habitat attributes shown on the data form (Appendix 3) are those considered important in aerial surveys done to date in many parts of BC. The data form is also available in an Excel spreadsheet format, which can be modified to add additional data fields or re-shuffle the sequence of data fields. The most critical attributes to assess are those which are not identified on forest cover maps, air photos or other sources, but which can be readily assessed from a helicopter: the % of trees with platforms; moss development; vertical canopy complexity; overall field ranking.

Most of the habitat attributes on the data form can be ranked according to their perceived value and availability to nesting Marbled Murrelets. Some habitat features can be assessed on a numerical or percentage scale. For most attributes a six-scale ranking system is used (1 = Very High, 2 = High, 3 = Moderate, 4 = Low, 5 = Very Low, and 6 = Nil). See the general introduction to this manual for a discussion on this ranking system.

The form is designed to minimize the amount of writing that is needed during a site evaluation. In most cases the observer need only circle the appropriate ranking category on the form.

Large Trees *(% of canopy trees)***:** The percentage of all trees that are large, i.e. height class = 4+ (>28.4 m). This is classified as 1 – 6, where 1 = Very High (51-100%), 2 = High (26-50%), 3 = Moderate (6-25%), 4 = Low (1-5%), 5 = Very Low (around 1%), and 6 = Nil (0%). It is impossible to judge tree height accurately from a helicopter. The intention is to identify the % of trees capable of providing a nest site for murrelets within the canopy or emergent layers. In areas where there are many platforms on relatively small trees (e.g., older trees at higher elevations), a more liberal definition of large trees might be appropriate (e.g., height class 3+, or >19.5 m). Make a note on the assessment form if such a modified height ranking is being used.

% Trees with Platforms: The percentage of canopy and emergent trees with one or more platforms (defined as limbs or deformities >15 cm in diameter providing a nest site and landing platform for murrelets). This is classified as 1 – 6 where 1 = Very High (51-100%), 2 = High (26-50%), 3 = Moderate (6-25%), 4 = Low (1-5%), 5 = Very Low (around 1%), and 6 = Nil (0%). Some important points to note when assessing platform availability:

- Most platforms are provided by mossy mats on the limbs of trees (see next category), but in drier areas (e.g., southern aspects in the Georgia Depression), large branches with little or no moss might also be suitable. Look for large limbs in addition to moss cover.
- Focus the assessment on the limbs *within* the canopy, not on the outer or upper extremities. Murrelets generally nest in the mid- to lower-third of the canopy. Mossy limbs on the upper canopy and emergent crowns are generally most obvious. Although these might not be used by murrelets, they are often indicators of similar mossy platforms within the canopy itself. Be aware, however, that the absence of mossy platforms on the outer extremities need not mean the absence within the canopy itself. Look carefully *within* the canopy at all times.
- It is easier to assess platforms within the canopy by looking horizontally into the canopy than by looking down from above. Fly the helicopter as close to the canopy along slopes, and as low as possible over flat areas, taking into account all safety concerns.

Moss Development: In addition to reporting the availability of platforms it is valuable to report the development of moss. This is reported as the percentage of canopy and emergent trees with obvious mossy pads on the limbs, classified as 1 – 6 where 1 = Very High (51-100%), 2 = High (26-50%), 3 = Moderate (6-25%), 4 = Low (1-5%), 5 = Very Low (around 1%), and 6 = Nil (0%). In moist habitats where mossy pads provide most of the platforms this ranking should be similar to the one above (% trees with platforms), but several surveys in southern and northern BC have reported situations where relatively few platforms were mossy or where moss development was insufficient to provide platforms. Do not confuse mossy pads on the limbs with obvious growths of lichen ("old man's beard") which are very common in some environments, but generally do not provide nest platforms. Report lichen development separately if desired.

Canopy Closure: The projected canopy closure (or canopy cover) is equal to the percentage of the ground that would be covered by canopy vegetation. This is classified as 1 – 6 where 1 & 2 = High & Very High (40, 50 or 60%), 3 = Moderate (30% or 70%), 4 = Low (20% or 80%), and 5 & 6 = Nil & Very Low (>20% or <80%). The effects of variation in canopy on habitat generally follow those recommended by the Marbled Murrelet Recovery Team (MMRT 2003), and are too coarse to allow a full six-level ranking. Note that both Nil and Very Low share the same canopy cover values, as do both High and Very High. Note also that the ranking is not linear: habitats are given a low rank if the canopy is too sparse ***or*** if it is too dense. For this reason, circle the most appropriate % on the data form (e.g., if the rating is Very Low because canopy cover is too sparse, circle <20% on the form).

***Vertical Canopy Complexity*:** Vertical complexity and "gappiness" is subjectively ranked from least to highest, approximately matching the criteria used in air photo assessments of murrelet habitat (see Part 2 of this manual, and Waterhouse *et al*. 2002). This is classified as 1 – 5, where 1 = Very High, 2 = High, 3 = Moderate, 4 = Low, and 5 = Very Low. Nil is not considered here. Specifically:

- Very High: very non-uniform (>40% difference leading trees and average canopy, very irregular canopy created by emergent trees, gaps, fallen trees).
- High: non-uniform (31-40% height difference, canopy gaps often visible due to past disturbance, irregular canopy created by emergent trees, gaps, fallen trees).
- Moderate: moderately uniform (21-30% height difference, some canopy gaps visible, evidence of past disturbance, a few emergent trees and obvious gaps).
- Low: uniform (11-20% height difference, few canopy gaps visible, little or no evidence of disturbance, no emergent trees).
- Very Low: very uniform (<11% height difference between leading trees and average canopy, no evidence of canopy gaps or recent disturbance, no emergent trees).

Topographic Complexity: A subjective assessment based on the effect of stand-level topography in creating small gaps and creating a complex canopy structure. Stand-level complexity can be created by slope, small rocky outcrops, avalanche chutes, large boulders, etc. This is classified as 1 – 6 where 1 = Very High, 2 = High, 3 = Moderate, 4 = Low, 5 = Very Low, and 6 = Nil.

Age Class*:* The estimated age of the forest stand. This is classified as <8 (<140 y), 8 (141-250 y), 9 (>250 y). If necessary give the actual age class of those parts of the area being assessed that are immature as a result of past disturbance or logging. If desired, the % area within each age class can be recorded.

Leading Tree Species*:* Identify or rank the dominant (rank = 1), secondary (rank = 2) or tertiary (rank 3) tree species in the area. Note that more than one species can be included in each ranking (e.g., both western hemlock and western red-cedar can be rated 1 if they are co-dominants). Ignore rare species which do not contribute significantly to the canopy and emergent layers. In many areas the leading species in the valley bottom differ from those on the adjacent slopes. The data form allows these to be assessed separately, where necessary. Write in the names or codes of less common species, such as alders and maples. Identifying tree species from the air requires some skill and practice. Videos and still photos of aerial surveys can be used to train inexperienced observers in the features needed to identify common tree species in the survey area.

Overall Field Ranking: This is an important assessment and can be done in two ways. For a rapid assessment or when assessing a single point, simply circle the most appropriate category (Very High, High, Moderate, Low, Very Low, or Nil). A more detailed assessment can be made by estimating the % of the total polygon area which falls within each category (%Very High, %High, %Moderate, %Low, %Very Low, or %Nil). If necessary, these % can then be applied to the relevant ranking (1, 2, 3, 4, 5, or 6) to provide a single weighted numerical rank for the polygon. For example, if a polygon area was assessed as 10% Very High (rank 1), 40% High (rank 2), 20% Moderate (rank 3), 5% Low (rank 4), 5% Very Low (rank 5), and 20% Nil (rank 6), then the overall weighted rank for the polygon would be 3.15 (calculated as: 0.10*1 + 0.40*2 + 0.20*3 + 0.05*4 + 005*5 + 0.20*6). These weighted values might be useful in comparing and ranking polygons.

Slope: The following two measures of slope attributes are considered neutral in assessing habitat suitability (MMRT 2003), i.e., murrelets are likely to nest on slopes or valley bottoms if the habitat is suitable. Slope is therefore not part of the overall habitat ranking, except that it contributes to topographic complexity providing improved access for murrelets to canopy platforms (see above).

Slope Position**:** A visual assessment of the meso-slope position. This is classified as valley bottom, lower slope, mid slope, upper slope, ridge top. In large polygons you might need to circle two or more categories. If possible estimate the % of the polygon which falls within each slope category, but it is usually not worth spending helicopter time on this detailed assessment, because the assessment can also be made from maps and air photos.

Slope Grade*:* A visual assessment of the slope grade (steepness). This is classified as flat (0°), gentle (1-29°), moderate (30-45°) and steep (> 45°).

Notes: Space is provided for brief notes. Important things to record include:

- evidence of recent logging, avalanches, landslides, fires, wind-throw, or other disturbance which might alter the amount of habitat and that might not be seen in air photos or forest cover maps;
- factors that might have limited your ability to accurately assess the polygon, such as weather or insufficient flight time;
- the tree species or parts of the polygon which provide the most likely nesting sites for murrelets;
- the tree species or parts of the polygon which show no evidence of suitability for nesting murrelets (explain why not); and,
- uncertainties in any of the data recorded, e.g., identification of the leading tree species.

PART THREE - APPENDIX 3. DATA SHEET FOR AERIAL ASSESSMENT OF MARBLED MURRELET NESTING HABITATS

The data sheet is designed to cover most situations in which aerial surveys will be undertaken. An Excel version is available that can be modified for more specific uses. For example, additional fields can be added for testing algorithms which do not follow a 6-scale ranking system. In most cases the habitat feature can be assessed by circling the appropriate ranking category. Read the manual for details on how to assess and rank each feature.

Observers	Date
Polygon or site name/number	Video taken Yes / No
Air Photo No.	Still Photo Nos.
Description	UTM zone
	Easting
	Northing

Rank (shaded parameters are most important)

	6	5	4	3	2	1
	Nil	**Very low**	**Low**	**Moderate**	**High**	**Very High**
Large trees (% of canopy trees)	**0**	**~1%**	**1-5%**	**6-25%**	**26-50%**	**51-100%**
% canopy & emergent trees with platforms	**0**	**~1%**	**1-5%**	**6-25%**	**26-50%**	**51-100%**
Moss development (% canopy trees with obvious mossy pads)	**0**	**~1%**	**1-5%**	**6-25%**	**26-50%**	**51-100%**
Canopy cover (circle nearest 10%)	-	<20% or >80%	20% or 80%	30% or 70%	40%, 50%, or 60%	
Vertical canopy complexity	**Nil**	**Very low**	**Low**	**Moderate**	**High**	**Very High**
Topographic complexity	Nil	Very low	Low	Moderate	High	Very High
Age class	**<8 (<140 y)**		**8 (140-250 y)**		**9 (>250 y)**	

Leading tree species a) slopes	W. hemlock **Hw**	Amabilis fir **Ba**	W. redcedar **Cw**	Yellow cedar **Yc**	Sitka spruce **Ss**	Douglas-fir **Fd**	Other:
b) valley bottom							

Overall field ranking **(give % of polygon area in each class)**	**6** **% Nil**	**5** **% Very low**	**4** **% Low**	**3** **%Moderate**	**2** **%High**	**1** **%Very High**
Slope position	Valley bottom	Lower slope	Mid slope	Upper slope	Ridge top	Not included in ranking
Slope grade	Flat	Gentle	Moderate	Steep		

Notes:

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