Extension Note

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New methods for assessing Marbled Murrelet nesting habitat: Air photo interpretation and low-level aerial surveys

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Abstract

This extension note summarizes the application of two new methods that were developed to assess the quality of forest habit that Marbled Murrelets (*Brachyramphus marmoratus*) use for nesting in British Columbia: air photo interpretation and low-level aerial surveys. Both methods use comparable six-level ranking systems that are based on the availability of forest attributes deemed important for nesting murrelets. The methods were developed and refined through preliminary work done in many varied coastal regions in British Columbia; they were designed to complement each other and be applicable to either small patches (1–2 ha) or to larger polygons used in mapping for forest management. Both methods were tested in comparisons with known murrelet nest sites and both are currently being applied by government and forest industry biologists. This note provides practitioners who are proposing to use one or both of these methods a concise guide to their suitability and limitations, and also provides links to relevant reports that offer greater detail on testing and applicability.

KEYWORDS: *air photo interpretation,* Brachyramphus marmoratus*, habitat mapping, habitat suitability, low-level aerial surveys, Marbled Murrelet.*

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Introduction

The Marbled Murrelet (*Brachyramphus marmoratus*) is a small seabird that forages in nearshore seas and nests in the canopies of old seral forests, usually within 30 km of the coast (Nelson 1997; Burger 2002). The species is listed as Threatened in Canada, is on the British Columbia "Red List" (legally designated or being considered for legal designation as Endangered or Threatened), and is a Species at Risk under the Identified Wildlife Strategy of the *British Columbia Forest and Range Practices Act* (Province of British Columbia 2004). It is also listed as Threatened in Washington, Oregon, and California. Loss of forest nesting habitat is identified as one of the main threats for this species (CMMRT 2003).

Marbled Murrelets require a very specific set of nest site features to breed successfully (Table 1). This combination of features is typical of trees > 200 years old on the coast and explains the overwhelming use of old seral forests for nesting. Nevertheless, not all forest stands meeting the age criterion provide the required canopy structure and mossy platforms for nests, and identifying likely nesting habitat is a key step in managing the murrelet's nesting habitat.

Understanding habitat relationships and managing for habitat is difficult because nesting murrelets are secretive and well-camouflaged, and nests are extremely hard to find. Currently, murrelet nesting habitat in British Columbia is described from data that is obtained at nest sites or in stands where occupancy by breeding murrelets is likely, as identified from audio-visual surveys (CMMRT 2003). From these data, habitat suitability models (algorithms) are developed to predict, rank, and map potential murrelet habitat using a combination of forest cover (i.e., Vegetation Resources Inventory [VRI]; Resources Inventory Committee 2002), topographic, and biogeoclimatic data. Models built from this information are usually applied broadly using Geographic Information Systems (GIS) to landscapes covering hundreds or thousands of hectares, and are not always good predictors of whether or not the forest has the attributes necessary for murrelets to nest (Tripp 2001; Burger 2002).

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In recent years, new techniques based on air photo interpretation and low-level aerial surveys from helicopters have been developed in British Columbia

TABLE 1. Key microhabitat characteristics for Marbled Murrelets nest sites in British Columbia (for more details see Nelson 1997 and 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 to 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.

TABLE 2. General description of the six-level ranking system used in the protocols for air photo interpretation and aerial surveys of Marbled Murrelet habitat (see Burger 2004 for details).

Rank	Habitat value	General description of habitat quality and availability of key habitat features	Percentage of surveyed area or proportion of canopy trees with habitat feature present[a]
1	Very High	The key habitat feature is present in abundance; nesting highly likely.	51–100%
2	High	The key habitat feature is common and widespread; nesting likely.	26–50%
3	Moderate	The key habitat feature is present but uncommon and patchy; nesting likely but at moderate to low densities.	6–25%
4	Low	The key habitat feature is evident but patchy and sparse; nesting possible but unlikely or at very low density.	2–5%
5	Very Low	The key habitat feature is very sparse and might be absent; nesting highly unlikely.	about 1%
6	Nil	The key habitat feature is absent; nesting impossible (e.g., bogs, bare rock).	0%

[a] This column shows how the ranking system is applied in aerial surveys when assessing the relative abundance of a particular feature, such as large trees or trees with platforms.

to add finer-scale detail to GIS-based methods. The air photo interpretation focuses on murrelet habitat criteria related to forest canopy structure (Donaldson 2004). The low-level air surveys focus on canopy microhabitat features such as epiphyte cover and availability of potential nest platforms (Burger et al. 2004).

The purpose of this extension note is to review the application and value of these two methods in managing the murrelet's nesting habitat, to describe situations in which the methods might be applied, to discuss tips that improve their use (based on input from biologists who have used the methods), and to provide links to studies which have used these methods. In short, we aim to provide practitioners who are planning to use either or both methods with a decision tool to help select and implement either method. This note is not a substitute for the full protocols, which are explained in detail elsewhere (Burger 2004). We emphasize that classifying forest structure for habitat potential does not account for external factors such as predators or microclimate that may affect habitat quality and the success of a nesting site.

Goals and criteria

Both air photo interpretation and low-level aerial survey methods can be applied to either strategic (long-range planning and management covering large spatial areas such as landscape units or conservation regions) or operational situations (short-term decision making usually applied to smaller areas such as proposed cutblocks or Wildlife Habitat Areas [WHAs]).

Both air photo interpretation and aerial survey protocols use a six-level ranking system to assess the suitability of forests as murrelet nesting habitat (Table 2; Burger 2004); this is loosely based on the six-level British Columbia Wildlife Habitat Rating Standards (Resources Inventory Committee 1999). For both methods, each habitat attribute is ranked independently and an overall habitat suitability rank is then assessed based on the collective ranks of all the other habitat attributes. Both methods can be applied to either small forest patches (e.g., generally 2–5 ha with air photos and < 1 ha with aerial surveys) and larger areas such as polygons typically used in VRI mapping.

Air photo interpretation

In general, air photo interpretation quantifies the structure and complexity of the forest canopy, tree size, micro-topography, and other features important for murrelets, and is intended for application to an entire landscape (Donaldson 2004). Attributes are associated with structures that murrelets need for nesting, stand

TABLE 3. Summary of key attributes interpreted on air photos[a] (Resources Inventory Committee 2002; Donaldson 2004).

Variable	Variable classes and definitions of classes
Air Photo Habitat Quality	Qualitative ranking using the six-class system with habitat rated Nil to Very High based on CMMRT (2003) recommendations.
Stand Age	Average age (year) weighted by basal area of the dominant, co-dominant, and high intermediate of the leading species for each tree layer identified.
Tree Height	Average estimated height (m) of the dominant, co-dominant, and high intermediate trees for the upper tree layer.
Crown Closure	Percent estimate of the vertical projection of tree crowns (upper layer) upon the ground.
Canopy Complexity	Estimate of overall variability of canopy structure and the distribution and abundance of large crowns and canopy gaps created by local topography (e.g., slope, hummock, and streams), vertical complexity, and/or past stand disturbance (standing dead or down trees). Further details in Waterhouse et al. (2004, 2008).
Vertical Complexity	Describes uniformity of the forest canopy by considering estimates of the total difference in height of leading species and average tree layer height.

[a] Reference photos are available illustrating the classification (contact F. L. Waterhouse, BC Ministry of Forests and Range)

TABLE 4. Summary of features assessed during low-level aerial surveys (Burger et al. 2004).

Feature	Description
Overall Field Ranking	Qualitative six-class system with habitat ranking Nil to Very High based on a cumulative assessment of the other features in this table. See Figure 1.
Large trees	The percentage of canopy or emergent trees > 28.5 m in height (i.e., height class = 4+).
Trees with Platforms	The percentage of canopy and emergent trees with one or more platforms (limbs or deformities >15 cm in diameter).
Moss Development	The percent of canopy or emergent trees with obvious mossy mats.
Canopy Cover	The estimated percentage of the ground that would be covered by canopy vegetation.
Vertical Canopy Complexity	Vertical complexity is subjectively ranked from least (most uniform canopy) to highest (very non-uniform).
Topographic Complexity	An assessment of the effect of slope, rocky outcrops, avalanche chutes, large boulders, creeks, etc. in creating small gaps subjectively ranked from Nil to Very High.
Age Class	The estimated age of the forest stand classified as < 8 (< 140 yrs), 8 (140–250 yrs), or 9 (> 250 yrs).
Leading Tree Species	The dominant, secondary, tertiary tree species.
Slope Position	Macro-slope position.
Slope Grade	Steepness based on slope segment.

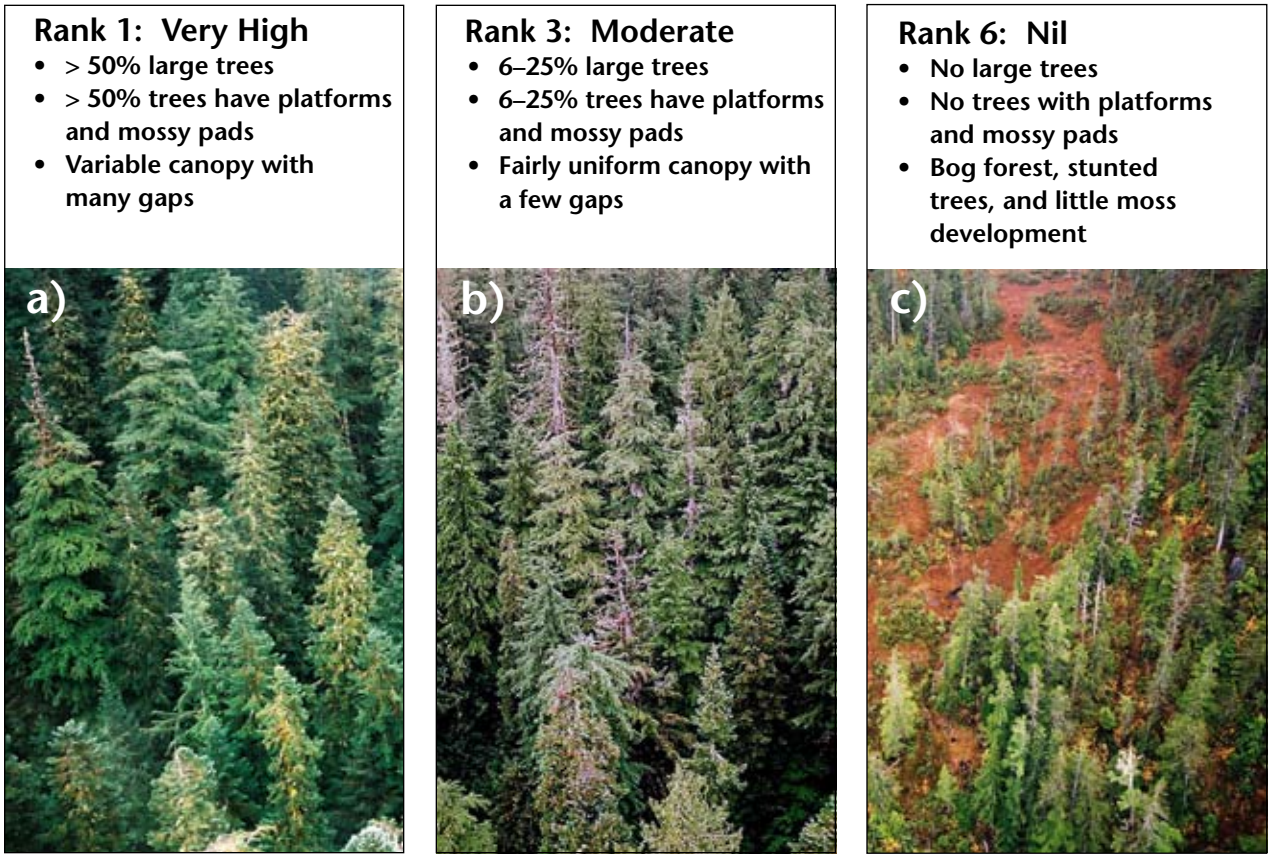

FIGURE 1. Examples of sites with the overall habitat quality ranked as 1, Very High (a); 3, Moderate (b); and 6, Nil (c) from low-level aerial surveys.

access, and the protection provided by the canopy around the nest site against weather and predation risk (Table 3). Following the standards requires the use of accredited interpretation techniques by an experienced interpreter (Resources Inventory Committee 2002).

Low-level aerial surveys

Aerial surveys use low-flying helicopters to provide a "murrelet's eye view" of the forest canopy to check the presence and relative abundance of the microhabitat features important for nesting murrelets (Table 4, Figure 1). Details of the protocol are given in Burger et al. (2004). In particular, the surveys provide information on the presence and abundance of potential nest platforms (defined as branches or deformities > 15 cm in diameter, including any epiphyte growth) and epiphyte cover (moss, lichens, and ferns), 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, vertical complexity, crown closure, and topographic features. Aerial surveys should be used once potential habitat has been identified to confirm the presence of microhabitat features that are important to nesting murrelets.

Testing with actual nest sites

Both methods have been applied in research that compares actual nest sites with randomly selected points in the same watersheds. These studies used nests located with radio-telemetry in Desolation Sound (62 nests) and Toba Inlet (24) on the southern mainland, Clayoquot Sound (32) on west Vancouver Island, and Haida Gwaii/Queen Charlotte Islands (QCI) (7). The results of this research are summarized in Table 5.

Application and limitations

Using comparable six-rank classification and several shared parameters, the air photo interpretation and aerial-survey methods were meant to complement each other or be used independently. The shared and

TABLE 5. Key research findings using air photo interpretation and low-level aerial surveys applied to actual murrelet nest sites in British Columbia (Waterhouse et al. 2002, 2004, 2007, 2008).

Air photo interpretation	Low-level aerial surveys
Stand age improves the probability of murrelets nesting in a stand, but at a decreasing rate for stands > 200 years old.	Murrelets use a range of habitats rated Very Low to Very High in overall habitat quality—most nests occurred in the Moderate to Very High classes. Selectivity was indicated for the Very High class, avoidance for the pooled Moderate, Low, and Very Low classes, and the High class was used in proportion to availability.
A mixture of forest characteristics interpreted from air photos best describes nesting habitat; and different combinations of characteristics may similarly predict potential murrelet habitat.	Trees with mossy pads providing potential nest platforms are a key feature for identifying habitat used by murrelets for nesting.
Murrelets use a range of habitats ranked Very Low to Very High in Air photo Habitat Quality—most nests occurred in the Moderate to Very High classes. The data indicated preferential selection of High and Very High classes and avoidance of the Low and Very Low classes. Moderate habitat was used in proportion to its availability.	Aerial assessments of macro slope suggest that murrelets avoid upper slopes and ridge tops; they are more likely to use mid-slopes, which tend to be steeper slopes at this scale.
Occurrence of large dominant trees, relative to the main canopy, may be as important as tree height itself as an indicator of nesting habitat. Complex canopies created by large trees and lower meso slopes associated with large trees both describe selected habitats.	When mapping habitat using the aerial method, ensure that the mapping resolution is fine enough that smaller patches of high quality habitat are not missed within larger stands of lower quality habitat. Patches 100 m in diameter (~3 ha) were assessed around each nest in this research, and patches of high-quality habitat were sometimes used for nesting that were surrounded by larger areas rated lower in overall quality.
Evaluating stand access by assessing gappy openings and natural edges can help identify nesting habitat; but the benefit of openings for murrelet access must be balanced against protection from weather and predator detection that canopy cover provides.	
When interpreting habitat quality, consideration must be given to the landscape, its disturbance history, and potential threats (e.g., predators).	

unique features of the methods and their limitations are summarized in Table 6.

Decisions on which habitat quality ranks to include as "suitable nesting habitat" will depend on the management objectives, spatial scales of the mapping, regional habitat differences, and local amounts of existing habitat. Generally ranks 1–3 (Table 2), or 1–4 in some situations, are considered more likely to include suitable habitat than lower ranks and, hence, are valuable for management planning (Burger and Waterhouse 2008). When both methods have been applied to the same forest patches (100-m radius around nest sites or randomly selected points) the rankings given by air photo interpretation tended to be slightly lower than those from the aerial surveys (Waterhouse et al. 2007; Burger and Waterhouse submitted; L. Waterhouse unpublished data). The differences, generally less than one rank, were probably due to the inability to assess platforms and moss development in the canopy from air photos. These differences need to be taken into account when using air photos for large strategic mapping; surveyors must recognize that some polygons might be ranked slightly higher with aerial surveys.

Based on published reports, workshops, and informal input from several biologists experienced with these methods (see Acknowledgements), we present suggestions for the efficient application of these methods (Sidebars 1 and 2) and reiterate the need for practitioners to thoroughly review the published protocols (Burger 2004).

Air photo interpretation tips

- Digital photography using three-dimensional software has been used extensively on the British Columbia coast and is more efficient than handling hardcopy photographs. Viewing at 1:10 000 to 1:20 000 scale provides similar results as mid-scale hardcopy photography, while the software also allows for zooming in to larger scales for viewing stands of particular interest.
- Mid-scale (1:15 000 to 1:20 000) hardcopy air photos are most appropriate. Larger scales (e.g., 1:10 000) give good views of the canopy but require numerous photos. Smaller-scale photos provide insufficient detail.
- A stereoscope with a minimum two-power magnification works well on midscale photos. Field stereoscopes with no magnification are usually not suitable.
- Be aware of distortions towards the edges of photos, and height distortion on higher-elevation sites.
- Use knowledge of local species-age-height-elevation-site relationships to provide a check of the interpreted attributes.
- In evaluating vertical complexity, give consideration to the stand gappiness as well as tree height differences because canopy gaps contribute to stand accessibility for murrelets.
- Recent forest cover or vegetation maps are useful for the following:
  - To update logging information.
  - To calibrate photo scale, especially when several flight lines are used for a project. Air photos are not an exact or consistent scale as labelled. For example, trees look significantly larger on 1:14 000 scale photos than on 1:16 000 photos, and, unless taken into account, this difference could lead to inconsistent habitat ranking. Digital photography software identifies exact scale which eliminates potential error from scale inconsistencies.
  - To provide forest cover information, be aware that the quality of forest inventories varies; the newer Vegetation Resources Inventories (VRI) generally provide more reliable information. Ground-based forest cover data are particularly valuable for interpreting and calibrating age and height classes.
- Find out from a local biologist/planner if there are "known" rank 1 and 2 habitats in the study area, and use photos of these areas to calibrate your eyes to the study area (see Waterhouse et al. 2004 regarding availability of coastal reference sets).
- The most difficult break is between ranks 3 (Moderate) and 4 (Low). Review and keep notes and photo examples of the attributes for these two ranks handy for reference.
- If the project covers a large area (landscapes), review previous work periodically to ensure consistency.

Current management applications

Air photo interpretation

This method is being used for region-wide assessment and mapping of murrelet habitat; maps of Haida Gwaii/QCI are complete (A. Cober, BC Ministry of Environment, pers. comm, December, 2008), while those of the central and north coast regions are nearing completion (D. Donald, BC Ministry of Environment, pers. comm, December, 2008). Maps derived from air photo interpretation are a key element in strategic planning of the central and north coast regions, which is currently being undertaken by the multi-stakeholder Ecosystem-based Working Group. Air photos were also used in conjunction with a habitat suitability model and aerial surveys to map management units in Clayoquot Sound (Chatwin et al. 2006). The air photo method is also routinely used in many parts of coastal British Columbia for mapping prior to aerial surveying, especially in the selection of WHAs.

Tips for aerial surveys

- Having two observers, plus the pilot and navigator, helps to ensure that each observer evaluates a slightly different perspective of the forest from both sides of the helicopter.
- A turbine-powered helicopter capable of carrying this crew, while flying safely and slowly just above the treetops, is essential.
- Slow figure-8 flight by the helicopter usually gives the best views into the canopy.
- Pre-plan a flight route in consultation with the pilot to minimize flight time between survey sites, taking into account fuel depots, rest stops, and options for weather.
- Be sure to use the appropriate map datum on the GPS (usually NAD 83)—some helicopter GPS units are set in older datums.
- Pre-program the survey sites into the GPS and, if you are using the helicopter's GPS, fax or email the co-ordinates to the pilot well in advance of your flight.
- A hand-held GPS usually works well in the front of the cockpit but might take a minute or two to locate satellites—get it going before takeoff.
- Be aware that air photos and forest cover maps are sometimes out of date and you might spend flight time looking for forest features that no longer exist
- Training using videos before any flights and doing a few surveys with an experienced observer is essential to achieve consistency.
- Review the key features of the locally common tree species before the flight.
- Photos and videos of each site are essential to permanently document each survey. Report where these are archived for future reference.
- It is useful to think of the % categories in Table 2 as proportions of the trees having the required feature; e.g. 5% is 1 in 20 trees, 25% is 1 in 4 trees, so between 1/20 and 1/4 of the trees having platforms would be rank 3 (Moderate).
- Observers should discuss their evaluations to reach a consensus on the suitability and ranking of the site before moving to the next site.

Mapping methods for aerial surveys

- Static maps and photos: Use a combination of GPS, topographic maps, satellite imagery, 1:20 000 air photos, plus a detailed overview map. Pre-stratify for potential habitat using air photos or satellite imagery (e.g., SPOT5). Map polygons and rank habitat directly on the maps during flight. Focus on potential suitable habitat areas, but investigate areas designated as non-habitat before eliminating as Nil. Post-trip, produce shape files in GIS by editing original GIS database.
- Real-time, moving-map technique: Uses a program running on a laptop computer with a GPS feed (e.g., OziExplorer). Pre-stratify landscape using model-generated habitat polygons on satellite imagery (e.g., SPOT5) and base map data. During the flight locate waypoints and rate habitat quality in polygons and/or at polygon transition boundaries. Post-flight processing is required to link waypoints with the same rating, taking into account underlying satellite imagery and other land information, to produce polygons.

TABLE 6. Summary of the shared features and different capabilities and limitations of air photo interpretation and low-level aerial survey methods.

Air photo interpretation	Low-level aerial surveys	Both methods
Can be used to narrow down areas that require more expensive aerial surveys.	Can confirm the suitability (presence of platforms and other canopy features) of potential habitat for management (e.g., proposed WHAs).	Produce maps rating forest structure relative to potential habitat use by nesting murrelets.
Cannot ensure the availability of suitable platform structures.	Are more costly than GIS and air photo mapping, therefore practitioners may need to weigh the additional value of aerial survey information relative to cost.	Provide reliable habitat maps for either strategic (long-range planning over large areas such as watersheds or landscape units) or operational implementation (shorter-term plans for proposed cut blocks or WHAs).
Does not usually identify individual trees and is generally done for larger scale overview (i.e., areas > 2 ha).	Might be less costly if air photo interpretation is used to pre-stratify areas and hence focus efforts on stands having some potential as murrelet habitat.	Can map or refine murrelet habitat polygons that need not rely on existing forest cover polygons (e.g., in VRI mapping).
	Can be undertaken on the same flights as other activities such as evaluations for operability.	Provide seamless and consistent measures of habitat suitability over the area of interest, in contrast to forest cover data, which often have spatial gaps (e.g., parks and other non-timber lands) and are often recorded in slightly different ways by different management agencies or companies.
	Should not be reduced in intensity for broad-scale assessments as habitat evaluations may be scale-sensitive (i.e., smaller patches of high quality habitat can be missed if minimum map unit is too large) and observers might miss small patches of suitable habitat.	Can refine or replace the results of a local GIS-based algorithm, thereby providing a higher-resolution overview of potential habitat in a large study area or landscape unit.
	Allow interpretation of small patches (~ 1 hectare) or even individual trees.	

Low-level aerial surveys

The high cost of helicopters may limit the application of this method to verification of habitat suitability following the application of either habitat suitability algorithms or air photo interpretation. Examples include the verification of habitat algorithms (central coast: Hobbs 2003; north coast: Burger et al. 2005; Vancouver Island: Donald 2005, D. Donald unpublished data), verification of mapping based on air photo interpretation in Haida Gwaii/QCI (Cober et al. in prep.), and operational mapping confirming management areas on Vancouver Island and the southern mainland (Deal and Smart 2004, Chatwin et al. 2006; T. Chatwin and I. McDougall, BC Ministry of Environment). In addition, aerial surveys covering multiple landscape units have also been used for strategic habitat mapping of large areas of Vancouver Island, and the southern and central mainland (W. Wall, International Forest Products and S. MacDonald, Western Forest Products, pers. comm., January, 2008).

Conclusions and the way ahead

The air photo and aerial survey methods summarized here provide flexible and complementary approaches to assessing habitat suitability for nesting Marbled Murrelets. They can also be used in combination with other methods such as habitat suitability models, which are based on forest cover and topographic data. Both methods will continue to be refined as they are more widely applied across coastal British Columbia. Future work will also focus on reconciling the differences in rank between these methods. We do not anticipate having a much larger sample of actual nest sites to test, due to the high costs of telemetry studies needed to find large numbers of nests. LiDAR (Light Detection and Ranging) is being tested in British Columbia for forestry use (BC-CARMS 2006) and might provide detailed three-dimensional measures of canopy structure that could be extremely valuable for large-scale assessments of Marbled Murrelet nesting habitats.

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Test Your Knowledge . . .

New methods for assessing Marbled Murrelet nesting habitat: Air photo interpretation and low-level aerial surveys.

How well can you recall some of the main messages in the preceding Extension Note?
Test your knowledge by answering the following questions. Answers are at the bottom of the page.

1. Which of the following features important to Marbled Murrelets can be assessed by low-level aerial surveys, but not with air photo interpretation?
   A) Tree height
   B) Canopy complexity
   C) Potential nest platforms
   D) Overall habitat quality

2. Most murrelet nests have been found in habitat patches ranked by air photo interpretation as:
   A) Low to Very High
   B) Moderate to High
   C) Moderate to Very High
   D) High to Very High

3. Because of the high cost of helicopter flights low-level aerial surveys are well-suited for:
   A) Research on actual nest sites found with telemetry
   B) Confirming habitat suitability after application of habitat algorithms
   C) Confirming the suitability of Wildlife Habitat Areas for murrelets
   D) All of the above apply

Answers

1. C (see Tables 3 and 4)

2. C (see Table 5)

3. D