Inventory Methods for Marbled Murrelets in Marine and Terrestrial Habitats

Standards for Components of British Columbia's Biodiversity. No. 10.

Prepared by
Ministry of Environment, Lands and Parks
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Preface

This manual, version 2.0, is a revised and improved manual describing standard methods for inventory of Marbled Murrelets in British Columbia. This manual includes methods for inventory to evaluate presence, relative abundance and absolute abundance. Version 2.0 attempts to incorporate new knowledge of the province's Marbled Murrelets from surveys completed after the publication of version 1.1. This version also includes a more detailed section on sample design. Like its predecessor, this manual was compiled by the Elements Working Group of the Terrestrial Ecosystems Task Force, under the auspices of the Resources Inventory Committee (RIC). The objectives of the working group are to develop inventory methods that will lead to the collection of comparable, defensible, and useful inventory and monitoring data for the species component of biodiversity.

This manual is one of the Standards for Components of British Columbia's Biodiversity (CBCB) series that present standard protocols designed specifically for groups of species with similar inventory requirements. The series includes an introductory manual (*Species Inventory Fundamentals No. 1*) which describes the history and objectives of RIC, and outlines the general process of conducting a species inventory according to RIC standards, including selection of inventory intensity, sampling design, sampling techniques, and statistical analysis. The *Species Inventory Fundamentals* manual provides important background information and should be thoroughly reviewed before commencing with a RIC wildlife inventory. RIC standards are also available for vertebrate taxonomy (No. 2), animal capture and handling (No. 3), voucher collection (No.4), and radio-telemetry (No. 5). Field personnel should be thoroughly familiar with these standards before engaging in field inventories which may involve any of these activities.

Standard dataforms are required for all RIC species inventory. Survey-specific dataforms accompany most manuals while general wildlife inventory forms are available in *Species Inventory Fundamentals No. 1 [Forms].* This is important to ensure compatibility with provincial data systems, as all information must eventually be included in the Species Inventory (SPI) Datasystem (visit the website at http://www.elp.gov.bc.ca/rib/wis/spi/).

It is recognized that development of standard methods is necessarily an ongoing process. The CBCB manuals are expected to evolve and improve very quickly over their initial years of use. Field-testing is a vital component of this process and feedback is essential. Comments and suggestions can be forwarded to the Elements Working Group by contacting:

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The Resources Inventory Committee consists of representatives from various ministries and agencies of the Canadian and the British Columbia governments as well as from First Nations peoples. RIC objectives are to develop a common set of standards and procedures for the provincial resources inventories, as recommended by the Forest Resources Commission in its report “The Future of our Forests”.

For further information about the Resources Inventory Committee and its various Task Forces, please access the Resources Inventory Committee Website at: http://www.for.gov.bc.ca/ric.

Terrestrial Ecosystems Task Force

All decisions regarding protocols are the responsibility of the Resources Inventory Committee.

The current version of this manual (2.0) is the result of the hard work of Irene Manley. Review of the document was provided by Alan Burger, and statistical review comments were provided by John Boulanger (Integrated Ecological Research). Figures 3 and 4 are original artwork by I. Manley. Contributors to earlier versions of this manual include Alan Burger, with helpful comments and reviews from Sharon Dechesne, Tony Gaston, Tom Hamer, Andrea Lawrence, Irene Manley, Stan Orchard, Mike Rodway, Andy Derocher, and Paul Jones.

The Components of British Columbia’s Biodiversity series is currently edited by Leah Westereng and James Quayle.

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1. INTRODUCTION

Marbled Murrelets (*Brachyramphus marmoratus*) are unique among North American seabirds in that most nest on large boughs high in old-growth conifers (Nelson 1997). A very small proportion of the population nests on the ground in southeastern Alaska (3%, Piatt and Ford 1993) and British Columbia (1 confirmed ground nest, Bradley and Cooke in press). Census methods normally applied at nest sites to colonial or solitary-nesting seabirds cannot be used for this species. Its patchy near shore distribution also necessitates special census techniques at sea. This manual presents and recommends census methods to determine the presence, relative abundance and absolute abundance of Marbled Murrelets in BC in their forest and marine habitats.

Marbled Murrelets were listed as a Threatened species in Canada by COSEWIC (Committee on the Status of Endangered Wildlife in Canada), following reviews by Rodway (1990) and Hull (1999). They are currently Red-listed in British Columbia (B.C. Conservation Data Centre 2000). The primary threats identified were the loss of nesting habitat through logging of old-growth forests, and mortality caused by gillnetting and oil spills. The species was also declared a federally threatened species in California, Oregon, and Washington (US Fish and Wildlife Service 1997).

The perceived risks to the species and conflicts with logging operations prompted a great increase in inventory and research efforts on this bird across its North American range. The Marbled Murrelet Technical Committee of the Pacific Seabird Group (PSG) has taken a lead in coordinating research methods resulting in protocols on forest surveys (Ralph *et al.* 1994; Evans *et al.* 2000), and locating and describing nest sites (Varoujean and Carter 1989; Hamer 1993; Naslund and Hamer 1994). Protocols for at-sea surveys have been developed by researchers in California (Miller and Ralph 1993; Bekker *et al.* 1997). The Marbled Murrelet Technical Committee meets annually to discuss inventory techniques and recent research results.

There is a rapidly growing body of literature on the biology and management of Marbled Murrelets in North America. Useful reviews and research papers can be found in Carter and Morrison (1992), Nelson and Sealy (1995), and Ralph *et al.* (1995). Hooper (2001) and Burger (2001) review and summarize recent work on Marbled Murrelets in BC.

2. Inventory Species: Marbled Murrelet

2.1 Range, Marine Habitat, and Foraging

The Marbled Murrelet belongs to the family Alcidae (alcids or auks) which are wing-propelled diving seabirds common in northern temperate and arctic oceans. Many familiar alcids (murres, puffins, and guillemots) are among the most abundant northern seabirds.

Marbled Murrelets have been recorded in most inshore marine areas of British Columbia, usually within 0.5 km of the shore (Sealy 1975a; Carter 1984; Sealy and Carter 1984; Burger 1995a). High densities of Marbled Murrelets have been found, on the east coast of Moresby Island, Queen Charlotte Islands (French 1993), certain inlets on the mainland coast (Kaiser and Keddie 1999; Schroeder *et al.* 1999), and off Vancouver Island from Clayoquot Sound to Port San Juan (Burger 1994, 1995a; Mason and Hansen 1997). The BC population was estimated to be about 45,000-50,000 breeding birds (Rodway *et al*. 1992), but there have not been adequate censuses through most of its range and this is a very rough estimate, largely based on surveys made in the 1970s and early 1980s. A more recent estimate based on radar counts and at-sea surveys estimated the BC population at about 60,000 birds (Burger 2001).

In BC, Marbled Murrelets are commonly found in relatively sheltered inshore waters (usually <40 m in depth), where their principal prey are sand lance (*Ammodytes hexapterus*), juvenile herring (*Clupea harengus*), anchovies (*Engraulis mordax*) and other small schooling fish. Other prey include epipelagic crustaceans, mainly larger euphausiids (*Thysanoessa*, *Euphausia*) and mysids, juvenile rockfish (Scorpaenidae), juvenile salmon (*Onchorynchus*), and small seaperch (*Cymatogaster*) (Sealy 1975a; Carter 1984; Vermeer *et al*. 1987; Burkett 1995).

2.2 Life History and Breeding Chronology

Marbled Murrelets occur year-round in British Columbia, but local numbers fluctuate seasonally due to movements and migrations, which are poorly understood. Many birds appear to leave breeding sites on the Queen Charlotte Islands and SW Vancouver Island in August or September after breeding, and return in early spring from March - April (Sealy 1974; Rodway *et al*. 1992; Burger 1995a). Sheltered waters in the Strait of Georgia and Puget Sound support high densities of Marbled Murrelets during the winter (Rodway *et al*. 1992; Speich *et al*. 1992; Burger 1995a). A Marbled Murrelet banded in Desolation Sound was found wintering in the San Juan Islands and then returned to Desolation Sound the following summer (Beauchamp *et al*. 1999). Other marked birds in Desolation Sound did not migrate but remained in Desolation Sound throughout the winter (Beauchamp *et al*. 1999).

Paired birds and courtship displays are seen in early spring, but pairs of adults are often seen in fall and winter too. Birds arrived in late April at Langara Island already paired (Sealy 1974). The breeding season is protracted, extending from mid-April through September (Rodway *et al*. 1992). Eggs are laid from mid-May through early July at Langara Island (Sealy 1974). During a 3 year study in Desolation Sound, Lougheed (2000) documented the core incubation period as 19 May to 8 July, the core nestling period as 18 June to 4 August, and the duration of the breeding season as 137 days from 21 April to 5 September. Breeding seasons vary with latitude.

Chicks hatch after an estimated 30-day incubation period and remain in the nest for 26-36 days (Sealy 1974; Nelson and Hamer 1995). Both members of the pair incubate and deliver food to the chick at the nest. Radio tagged Marbled Murrelets move up into inlets to forage closer to their nest sites during the chick rearing stage (Hull *et al.* in press). Fledged chicks have been reported on the water from 28 May (unusually early) through 5 October, but were most common in July (Sealy 1974; Rodway *et al*. 1992; Hamer and Nelson 1995; Lougheed 2000).

2.3 Identification of Age and Plumage Categories

2.3.1 Age Categories

For purposes of inventories we can recognize two age classes:

- **After-hatching year** (AHY) birds which includes adults and immatures older than one year; and
- **Juveniles** (less than one year old).

During the breeding season, a significant portion of the AHY birds do not breed (15% at Langara Island, Sealy 1975b; 31% in Desolation Sound, Cooke 1999). Breeders and non-breeders cannot be identified on the water.

2.3.2 AHY Plumage Categories

The AHY birds may be divided into two seasonally varying plumage types:

- **Basic plumage** (also known as non-breeding and winter plumage), which has dark grey-brown to black upper parts, and white underparts with species diagnostic white scapulars; and
- **Alternate plumage** (also known as summer and breeding plumage although not all birds in this plumage are active breeders) which is dark brown all over, "marbled" with rusty-buff margins of the upper body feathers.

For a complete description of the plumages and moult of Marbled Murrelets see Kozlova (1957) and Carter and Stein (1995). Sexes are alike in coloration and size (Sealy 1975b), although subtle differences in plumage have been reported among pairs seen at nests. The AHY birds have a pre-alternate moult (from basic to alternate plumage) in spring (early April to late May; later birds appear to be immature), and a post-breeding pre-basic moult, which includes moult of the wing and tail feathers, in late summer or fall (generally mid-August through October).

The white scapular feathers in basic and juvenile plumages form a distinctive shoulder line, which is diagnostic for this species.

2.3.3 Juveniles vs. AHY Birds

Separation of juveniles and AHY birds is important in the field because counts of newly fledged juveniles provide the only known measure of productivity for this species. The juvenile plumage is attained at the nest and becomes visible when the nestling plucks the overlying natal down off a day or two before fledging. It resembles the AHY basic plumage, with dark brown to black upperparts and white scapulars. The underparts and sides of the head are white, lightly speckled with blackish brown.

Criteria for identifying newly-fledged juveniles from AHY birds on the water (see also Carter and Stein 1995):

1. Presence of an egg tooth. Egg tooth may persist for a week or more after fledging, but is difficult to see in the field.
2. Relative size. Fledged juveniles tend to be smaller than adults (70% body mass; 85% beak and wing length; Sealy 1975b).
3. Overall percentage of dark vs. light coloration. Juveniles are paler overall than AHY birds in alternate plumage.
4. Ventral coloration and patterning. Juveniles appear lightly speckled on the throat, breast and abdomen giving a "salt and pepper" appearance. Breeding birds are much darker, and moulting AHY birds have crescent-shaped blotches of dark feather tips or pure white breasts rather than faintly specked ones.
5. Dorsal coloration. Juveniles are uniformly dark brown to black, and lack the rusty-tipped dorsal plumage of the AHY alternate plumage.
6. Wing moult and shape. Juveniles do not moult their wing feathers in their first fall, and so can be distinguished from similar-looking AHY birds moulting into basic plumage in fall. Birds in early stages of wing moult show mid-wing gaps, and in late stages, show stubby rounded rather than longer pointed wings. Check this when birds on the water raise their wings.

Some AHY birds (e.g., failed breeders) begin their pre-basic moult during the period that newly-fledged birds appear, and thus the criteria used to separate them will vary. In June-July, criteria nos. 2-5 all apply because most AHY birds are in the "marbled" alternate plumage, but in August-September when AHY birds begin their pre-basic moult, the size of marks on the white breast and evidence of wing moult should be examined more closely. Juvenile birds have also been described as being more solitary and more often associated with kelp beds in shallow water than AHY birds. Juveniles also tend to be more wary and are less approachable by boat.

2.3.4 Other Species

In BC, several other alcids are likely to be confused with Marbled Murrelets. Cassin's Auklets (*Ptychoramphus aleuticus*) are more uniformly grey and are usually found further offshore (>1 km off). Ancient Murrelets (*Synthliboramphus antiquus*) are most likely to be confused with Marbled Murrelets in winter, but lack the white scapulars. Newly-fledged juvenile Rhinoceros Auklets (*Cerorhinca monocerata*) may be confused at a distance, but are larger, more chunky, have a heavier beak, and lack white scapulars. Juvenile and winter-plumaged Pigeon Guillemots (*Cepphus columba*) could also be mistaken for Marbled Murrelets, but are larger and have distinctive red feet. Check recent field guides for identification features.

3. PROTOCOLS

3.1 Inventory Surveys

The table below outlines the type of surveys that are used for inventorying Marbled Murrelets for the various survey intensities. These survey methods have been recommended by wildlife biologists and approved by the Resources Inventory Committee.

Table 1. Types of inventory surveys, the dataforms needed, and the level of intensity of the survey.

Survey Type	Forms Needed	Intensity
Vessel Line Transects	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form • Animal Observations Form – Marbled Murrelet Vessel Line Transects	• PN • RA
Forest Surveys	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form • Animal Observation Form- Marbled Murrelet Forest Surveys • Habitat Observation Form -Marbled Murrelet Habitat Analysis • Ecosystem Field Form (or an equivalent customized form)	• PN • (RA)
Radar Surveys	• Wildlife Inventory Project Description Form • Wildlife Inventory Survey Description Form Animal Observations Form- Marbled Murrelet Radar Surveys	• PN • RA • (AA)

* PN = presence/not detected (possible); RA = relative abundance; AA = absolute abundance

3.1.2 Survey Design Hierarchy

Marbled Murrelet surveys follow a survey design hierarchy, which is structured similarly to all RIC standards for species inventory. Figure 1 clarifies certain terminology used within this manual (also found in the glossary), and illustrates the appropriate conceptual framework for a forest survey. A survey set up following this design will lend itself well to standard methods and RIC dataforms.

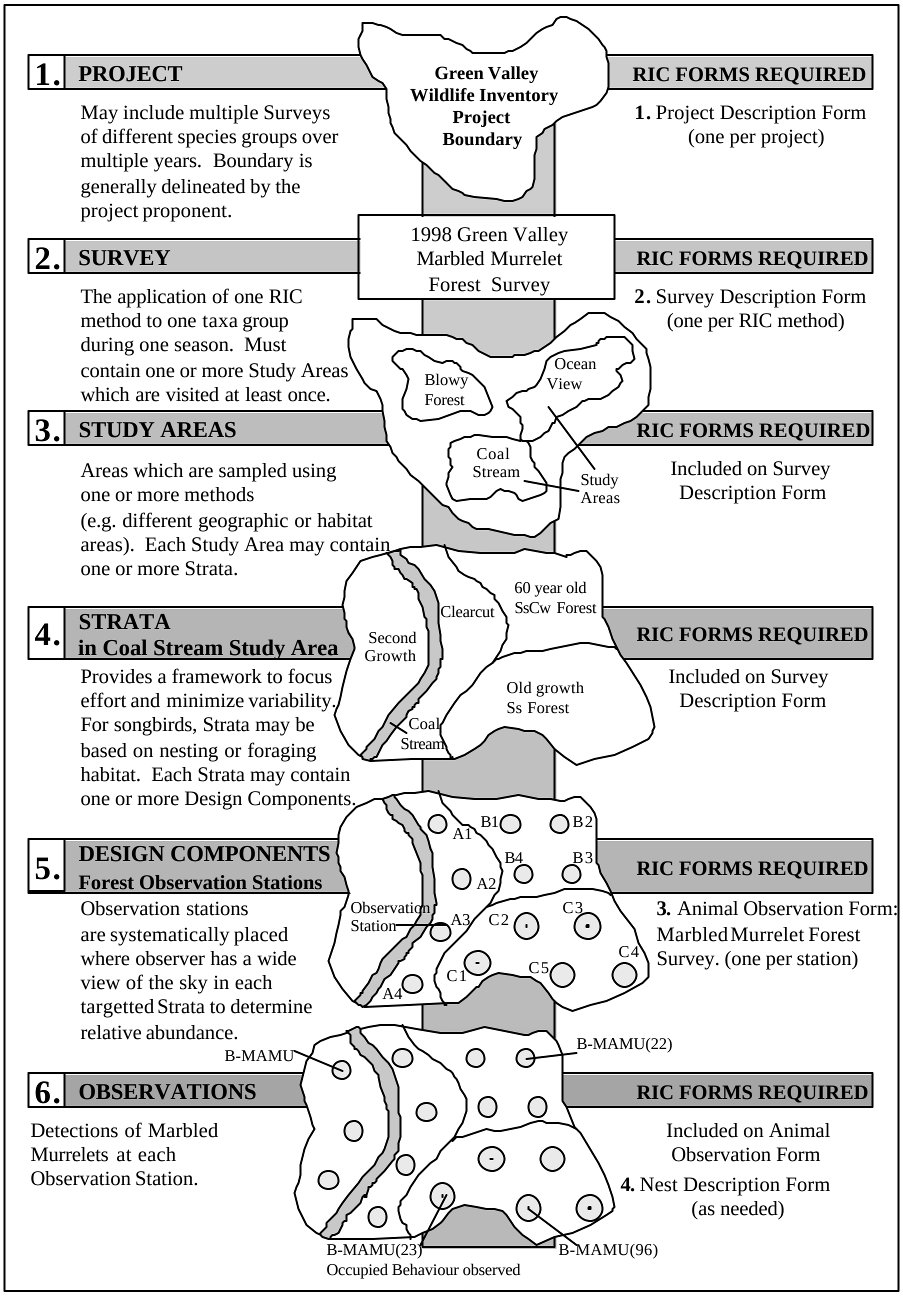

Figure 1. RIC species inventory survey design hierarchy with examples.

3.2 Protocol for Marine Surveys

Some important goals of marine censuses are:

- To establish the marine distribution of Marbled Murrelets over wide geographic ranges
- To compare relative abundance between marine areas
- To estimate trends in relative abundance over time
- To estimate populations within specified coastal areas
- To establish marine habitat use
- To determine seasonal patterns of population estimates for comparison with the chronology of activity in nearby forests
- To establish breeding chronology and productivity through counts of newly-fledged juveniles

Marbled Murrelets spend most of their lives in inshore coastal seas. Surveys in this zone are therefore the most reliable way to describe their distribution across a wide geographic range. Because the birds cannot be easily censused at nest sites, detailed censuses at sea and radar surveys (section 3.4) are the most practical means of estimating population densities.

Counts of newly-fledged juveniles on the water are an important measure of breeding success and productivity. Capture-recapture methods to establish population estimates and demographics have been used with Marbled Murrelets in Desolation sound for the past 7 years (Cooke 1999). At the present time these methods are useful for long-term (10-15 years) studies but are probably not suitable for most inventory efforts.

Marine census methods may be conducted in an aircraft, on a boat, or on shore. In general, aerial surveys provide information on wide-scale distribution, boat surveys provide accurate relative abundance estimates, fine-scale habitat use and chronology, while shore-based counts provide a cheap method for monitoring numbers and movements close to shore. Boat based surveys are by far the most common marine survey method for Marbled Murrelets. To date no aerial surveys and very few shore-based surveys have been used for inventory of Marbled Murrelets in BC (Hooper 2001). This manual will only focus on the marine vessel line transect surveys. Details on aerial and shore-based surveys can be found in *Inventory Methods for Seabirds* (RIC 1997).

3.2.1 Sampling Standards

Time of day

In general most marine surveys should be conducted between one hour after sunrise and three hours before sunset. Most surveys are conducted during the earlier morning to take advantage of favorable weather conditions. Daily activity patterns of Marbled Murrelets vary throughout the breeding season and in different locations (see review in Hooper 2001). Surveys in Desolation Sound in May and June 1995 found higher densities of sitting birds after 1400 hours (Derocher *et al*. 1996), whereas this was not the case in Trevor Channel (Carter 1984). Preliminary studies of local behaviour should be done to select a suitable standard time, and repeated surveys should start at the same time each day. Densities can change through the day, and surveys made near dusk can give either lower (Carter and Sealy 1990) or higher (Rodway *et al*. 1995) estimates.

Environmental conditions

Marbled Murrelet counts and density estimates can be affected by environmental conditions. Depending on the size of boat used, Marbled Murrelet sightings decreased at Beaufort sea state 2 and above (Bekker *et al.* 1997) or Beaufort state 3 and above (Ralph and Miller 1995). Surveys should be conducted in Beaufort sea states 0 to 2 whenever possible (Appendix A) to obtain the best survey data.

3.2.2 Aerial Transect Survey

Goals: To establish presence/not detected (possible), and coarse-scale distribution and habitat use.

Aerial surveys are recommended only for coarse-scale reconnaissance or habitat assessment and are not as reliable as boat surveys for assessing relative abundance and fine-scale habitat use. Aerial surveys should be undertaken only with experienced observers, when sea conditions are Beaufort scale 2 or less and when sun glare can be avoided. Savard (1982) found large differences in results produced in aerial censuses of waterfowl between experienced aerial and inexperienced observers. Test flights over known numbers of dummy birds can be used to gauge observer efficiency and determine probability of detection in various sea and light conditions (Varoujean and Williams 1995). Aerial surveys can also be improved by applying distance sampling procedures (Buckland *et al*. 1993), although this will not be possible when Marbled Murrelet densities are high. Details on aerial transect methods can be found in the Seabird manual (RIC 1997).

3.2.3 Vessel Line Transects

Goals: To estimate relative abundance (birds per square km), spatial and temporal distribution, habitat use and breeding chronology. May be used to determine presence/not detected.

The use of line transects over fixed-width (strip) transects is recommended as it can provide more reliable and precise results with minimal additional effort (Bekker *et al*. 1997). Fixed-width transects assume that all birds are detected within the strip, when often this assumption is not met (Buckland *et al*. 1993). Line transects incorporate the probability of detecting birds at different distances (the detection curve) into population estimates.

Fixed-width transects were the previously recommended standard for Marbled Murrelet at-sea surveys and has been used extensively for many other species (RIC 1997). To ensure continuity between previously collected fixed-width transects and the present standard of line transects the following should be considered (from Hamer 1997):

1) Surveys may combine line transects with a narrow fixed-width transect (50 m on each side). This allows for a comparison between line transect and fixed-width sampling for Marbled Murrelets. Combining transect types also allows for multi-species inventory when this is an important objective (i.e., the collection of data on other species using the fixed-width transect, combined with line transect sampling for Marbled Murrelets only).

2) Statistical techniques may allow data collected with fixed-width transects to be re-analyzed using distance sampling software or by using a smaller fixed width distance.

3) High densities of Marbled Murrelets may present a challenge to the collection of distance sampling information. However, in such cases it is not necessary to record every bird visible. Observers should focus on detecting all birds that are on or near the transect line. The distance curve you construct with these data will determine detection probabilities and ensure that densities are calculated for the correct area.

Office procedures

- Review the introductory manual No. 1 *Species Inventory Fundamentals.*
- Select dates and times of surveys as discussed in Sampling Standards (Section 3.2.1.)
- Obtain maps and charts for Project and Study Area(s) (*e.g.,* Marine charts 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps). Any map, which is used to record data, should be referenced to NAD83.
- Outline the Project Area on a small to large scale map (1:250,000 – 1:20,000).
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the project area from maps. Determine BC Marine Ecological Classification Ecosection and Ecounit(s) from maps (Howes, Zacharias and Cannessa in press) or from the LUCO website (www.luco.gov.bc.ca).
- Select Project (census) area - If the goal is to census all the Marbled Murrelets in an extensive area, divide the area into coastal segments of equal size bounded by conspicuous landmarks. If the area is to be routinely censused to monitor seasonal and interannual variations, select an area with a consistently high density of Marbled Murrelets (see Bekker *et al.* 1997), and a transect route long enough to cover most of the local movements among foraging patches (e.g. >30 km).

Sampling design

- Systematic using fixed transect routes. [The Design Components for this survey are transects and transect segments.]
- **Determine the distance from shore and number of transects needed** - The protocol recommends using two shoreline transects within 1 km of shore (at 200 m and 600 m). Murrelet density in relation to distance from shore may not be consistent in different locations. If transects are being conducted in areas that have not been surveyed previously, preliminary surveys should be conducted to determine the Marbled Murrelets distribution from shore. Transects can then be run at the appropriate distance from shore.
- **Plot survey routes on a chart**. Inner transects should be run 150-200 m off the surf line, and follow the coastline for at least 5-10 km. Outer transects should be 500-600 m offshore (and 1.2, 2, 3 and 4 km offshore if more are needed) and for ease of navigation should run in straight lines between pre-determined points (off pronounced landmarks) which can be readily detected on a chart or with GPS (NAD 83). Waypoints for the survey route can be used with a GPS to replicate the surveys accurately. An example is given in Figure 2.
  A single shoreline transect may suffice in narrow channels and among islands or in fjords (cover both shores) where Marbled Murrelets tend to avoid deeper water.
  Divide transects into smaller segments (e.g., 0.5-1 km) to track fine-scale movements and habitat preferences of birds.

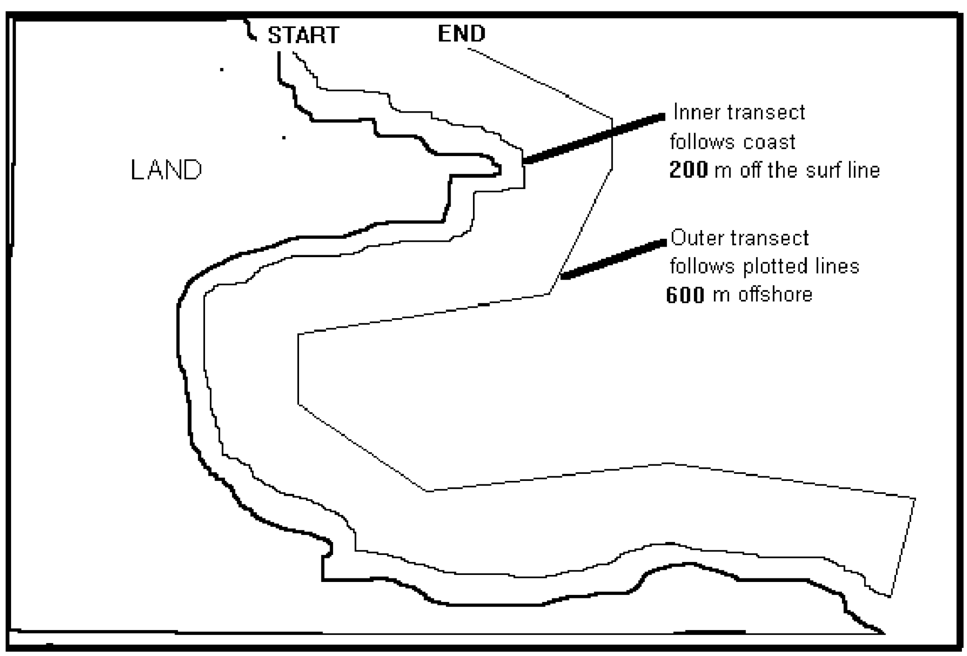

Figure 2. Schematic of how inner and outer transect routes can be laid out along a hypothetical coastline.

Sampling effort

Sampling effort will depend on the goals of the survey. If the survey intends to monitor population trends or make comparisons of relative abundance, a power analysis should be done following preliminary surveys to determine the sampling effort required. Bekker *et al.* (1997) found that 10 surveys /season were needed to detect a 10% decline in population density. With higher Marbled Murrelet densities in Prince William Sound, Alaska, K. Kuletz (unpubl. data) found that five surveys were sufficient to track annual changes, if carefully planned to coincide with peak densities. A minimum of four to five replicate counts should be done during the breeding season if the goals are to document distribution or habitat use. Repeated surveys dedicated to counting fledged juveniles should be planned from mid-June through August (see Lougheed 2000 for additional information).

Year-round marine surveys are needed in BC to understand migratory movements, moulting and winter distribution. Survey dates should be standardized from year to year to minimize effects due to seasonal variation. If large-scale surveys are planned, it is preferable to use many boats to cover the project area in an instantaneous manner.

Equipment

- Motorized boat capable of 8-12 knots
- Marine charts
- Binoculars
- Tape recorder
- Watch
- Dataforms for marine vessel line transects
- GPS (NAD 83)
- Buoy trailing at a measured distance (50 m, 100 m)
- Range finder to assist in distance estimation
- Angle board (large protractor) to aid in angle estimation

Optional equipment

- Salinity meter
- Paper chart echosounder (if possible)
- Thermometer

Field procedures

Before you begin:

- **Vessel operation** - A team of two observers and one driver-navigator is ideal. Alternatively, one observer may drive the boat, the other tape-record all sightings.
- **Observer scanning -** Have at least two observers (one for each side of the boat). Observers should scan the sea ahead of the boat over a 90^{o} arc from the bow to the beam. In distance sampling it is important that observers focus on the area ahead of and close to the boat. Distance sampling assumes that all birds on the transect line are detected, and that detectability is high near the transect line. Hamer (1997) discusses some methods to improve this. Report the observer's eye level height above sea level. Distance calibration should take place at the beginning of and consistently throughout each survey using either buoys at measured distances or a range finder. A range finder can be used to measure the distance to shore or to larger birds (gulls are reflective targets) to calibrate distance throughout the survey.
- **Vessel speed -** 8-12 knots (15-22 km h^{-1}). Maintain constant speed but stop to confirm plumage classes of birds if necessary.

- **Navigation -** Use a GPS (NAD 83) if possible. Navigation with reference to conspicuous landmarks is suitable for inner transects, but would be difficult for outer transects.

Record general information:

- **Record time** - Note the beginning and end of each segment.
- **Record weather and sea conditions** - Record the following at the start of a survey and again if conditions change: cloud cover (percentage sky covered) and cloud type (e.g., stratocumulus, stratus, cumulus, altocumulus); precipitation; wind direction; wind and sea conditions (use Beaufort scale; see Appendix A); height of wavelets to nearest 5 cm as a measure of choppiness; and visibility (glare). At any time in the survey, note whether sun glare is affecting visibility. Miller and Ralph (1993) list other variables that might affect the detection of birds at-sea.
- **Physical parameters and prey densities -** If possible, record sea surface temperature (SST), tides, and salinity (SSS), and run a recording echosounder (e.g., paper chart sounder) continuously while underway to determine sea depth and prey densities. While underway; record the beginning and end of each segment, and the position of Marbled Murrelet aggregations on the paper chart. A simple method for analyzing densities of fish schools from paper sounder traces is given by Piatt (1990).

Record Marbled Murrelet sightings:

- Record all observations into a tape recorder. Check frequently that the recorder is working properly, and keep it inside a thin plastic bag to keep spray and rain out.
- Binoculars should be used to confirm plumage classes of Marbled Murrelets, but not to locate new birds.
- Record birds on the water and flying separately. A bird seen landing or taking off should be counted as being on the water. Make notes on any birds seen holding fish.

For each sighting record:

1) Time

2) Number of Marbled Murrelets in the group - (birds within 2 m of each other)

- Record flock size: flocks are birds <2 m apart; use commas to separate adjacent flocks. Put brackets around records of mixed groups, (e.g., (4B+1J+2M), (6B+1J)).

3) Plumage class of each bird:

- B = AHY in alternate (breeding) plumage
- W = AHY in basic (winter) plumage
- J = juvenile plumage
- M = moulting AHY

4) Distance from the boat – estimate the direct distance from the observer to the bird's initial location in metres. Do not estimate the horizontal distance from the transect line to the bird. This will be calculated using the direct distance and angle (Figure 3).

5) Angle from the transect line - estimate the angle from the bow of the boat to the bird's initial location to the nearest 5 degrees.

- Angles can be estimated using an angle board mounted on the boat (essentially a large protractor), or a digital compass.
- It is important that the distance and angle to bird sightings is recorded for where the birds are first observed. Observers are trying to scan ahead of the boat to record sightings before they move away from the boat.

- Flying birds are recorded only when they cross the beam of the boat. The distance is measured at that point. If birds fly in and land, the location where they land is recorded if it is within the 90 degree scanning area. Flying birds are recorded in a column separate from birds on the water.

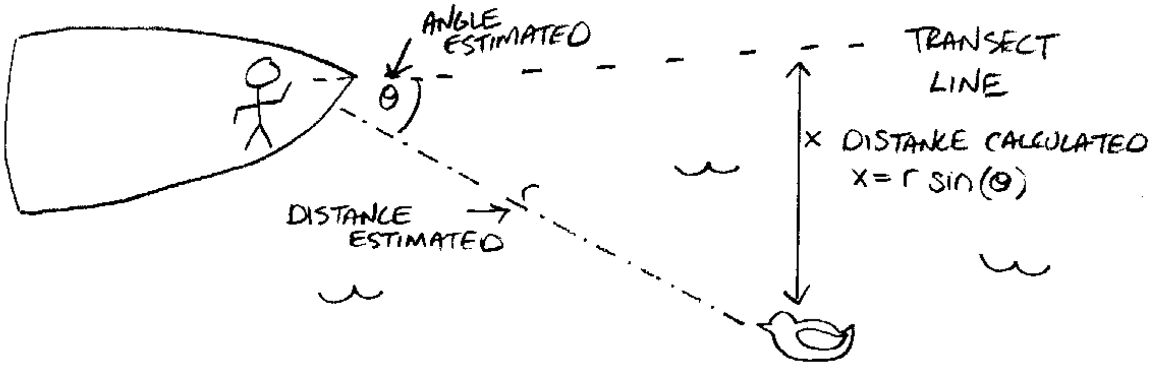

Figure 3. Calculating distance (x) the bird is from the transect line by estimating the distance from the observer and the angle from the bow of the boat to the bird.

6) Count other bird species and marine mammals:

- Sampling a large number of other species during a survey for Marbled Murrelets can lead to bias in Marbled Murrelet density estimates (Hamer 1997). How many other species you choose to sample will depend on the species and numbers you are likely to encounter in your study area. To ensure that other species do not distract observers from Marbled Murrelet observations, it is recommended that other species are only sampled for a small fixed width transect (50 m) so that distances and angles are not collected for other species (Hamer 1997).
- Information on other species may be useful to other researchers and to interpret Marbled Murrelet activities (Mahon *et al.* 1992). Make notes on interactions between Marbled Murrelets and other species (e.g., murre chasing a Marbled Murrelet; a gull feeding in association with a diving Marbled Murrelet).

Transcribing data

- After the survey, transcribe the observations on to the dataform, and then into a computer database. Always make duplicate copies and store them separately.
- Record other species encountered per survey segment on a separate sheet.

Data entry

The Design Component for this survey is transects. When digitally entering your survey data, choose ‘Transect’ from the ‘Design Component Type’ picklist and enter the relevant data.

Data analysis

Calculate the distance from the transect line (D) using the function D = (d) cos θ where d is the estimated distance from the boat and θ is the angle from the bow of the boat.

Estimate Marbled Murrelet density using the program DISTANCE for line transect sampling (See Appendix G *Species Inventory Fundamentals* (RIC 1998a) for details). Examples and discussion of distance sampling analysis can be found in Hamer (1997) and Bekker *et al*. (1997).

Table 2. RIC objectives and analysis methods for relative abundance using line transects.

Objective	**Analysis method**[1]	**Programs**[2]
• Trends in abundance over time	• Line transect • Regression techniques[1] • Power analysis	• DISTANCE • Generic statistical packages • MONITOR
• Comparison in abundance between areas	• Line transect • ANOVA and related methods[1] • Power analysis	• DISTANCE • Generic statistical packages • Power analysis software

[1]See RIC 1998a (Section 2) for more details on analysis

[2]See RIC 1998a (Section 3) for more detail on software packages

3.3 Protocol for Terrestrial Surveys

Methods used in terrestrial surveys of Marbled Murrelets have become standardized in North America, through the efforts of the Pacific Seabird Group (PSG) Technical Committee on Marbled Murrelets (Ralph *et al.* 1994; Evans *et al.* 2000). Terrestrial surveys of Marbled Murrelets as described in this protocol are to establish:

1. presence or probable absence in a forest stand or other site;
2. occupancy or non-occupancy of the site by probable breeding birds;
3. temporal variations in activity including diurnal, seasonal and interannual patterns;
4. likely areas in which to search for nest sites;
5. habitat associations which might indicate preferred habitat

Intensive forest surveys provide the only reliable method of establishing presence or probable absence of Marbled Murrelets when repeated several times per season over two or more years. Intensive Surveys have been routinely used in BC in many studies (See Burger 1995b and review in Hooper 2001) and many more in the United States (Ralph *et al.* 1995).

The PSG protocol (Evans *et al.* 2000) recommends a minimum of four visits per year at each study area (40-50 ha) for two years, in order to establish presence or probable absence. If there are two or more observation stations within the defined study area, then the four surveys can be divided among them (see Evans *et al*. 2000 for details on locating stations within study areas). Additional visits (5-10) might be needed to establish occupancy, especially when Marbled Murrelets occur at low densities. Additional years should be sampled if there is evidence that the survey years were abnormal (i.e. low levels of activity due to unusual ocean conditions such as El Nino; Burger 2000).

Terrestrial surveys may also be used to evaluate Marbled Murrelet habitat use and associations. However, for this use the study must be carefully designed to control sources of variability in Marbled Murrelet activity. Sources of variation that should be considered in such a study include: date, weather, canopy opening, canopy height, location relative to flight paths and any other factor that may affect detectability. Even with careful control of external factors Marbled Murrelet activity can be highly variable at all temporal and spatial scales (Jodice and Collopy 2000). Studies that aim to evaluate Marbled Murrelet habitat use or describe patterns in activity must be specifically designed to deal with this variability, and will likely involve multi-year, high-intensity forest surveys. The number of surveys required will depend on the goals of the project and can be determined using a power analysis. Paired survey designs with pairs surveyed on the same day can control for daily and weather related variation (see Rodway *et al.* 1993a,b; Rodway and Regehr 1999; Burger *et al.* 2000; Bahn and Newsom 1999) for examples. Researchers should be familiar with the most recent PSG protocol and Marbled Murrelet literature when planning studies.

3.3.1 Definitions and Field Codes

Detections - These are the units to measure levels of activity.
A detection is defined as the sighting or hearing of one or more Marbled Murrelets acting in a similar manner (Ralph *et al.* 1994; Evans *et al.* 2000).

- A series of calls coming from the same bird(s) should be classified as a single detection. If the bird was out of sight and stopped calling for more than five seconds (this time is variable, and could be longer at sites with poor visibility), then renewed calling or sightings should be treated as a new detection.
- Two birds seen at the same time flying well apart from each other or behaving differently comprise two detections, but a bird circling overhead and calling for three minutes would constitute a single detection.
- A flock, which splits into two groups, is a single detection.
- If two flocks coalesce, they should be counted as two detections.
- When several birds are visible or multiple calls are heard, observers need to listen and watch until birds have disappeared or stopped calling to determine the number of detections.

Definition of "occupied" stands - Certain detections signify behaviour associated with nest sites or stands with evidence of nesting. These are classified as "occupied" behaviours and identify "occupied" stands (Ralph *et al.* 1994; Paton 1995; Evans *et al.* 2000). These conditions or behaviours include:

- discovery of an active nest;
- discovery of a nest with signs of recent occupancy (e.g., fecal rings);
- discovery of a chick or egg shells on the forest floor;
- birds seen perching, landing or attempting to land on branches;
- birds flying below, through, into or out of the forest canopy; and
- birds calling from a stationary location (at least three successive calls)

Any sub-canopy activities indicate occupancy.

Circling behaviour above the canopy needs to be assessed carefully since Marbled Murrelets are known to circle over habitat in which they are unlikely to nest (Ralph *et al.* 1994). If this is the only evidence of occupancy, further surveys are recommended to establish occupancy (Evans *et al.* 2000). Note that circling above canopy was previously considered an occupied activity. If circling above canopy is observed at a site and further surveys are not possible this should be noted.

Project Area - An area, usually politically or economically determined, for which an inventory project is initiated. A project boundary may be shared by multiple types of resource and/or species inventories. Sampling for species generally takes place within smaller, representative study areas so that results can be extrapolated to the entire project area.

Study Area - an area containing $\geq$ 1 observation station. A discrete area within a project area in which sampling actually takes place. Study areas should be delineated to logically group samples together, generally based on habitat or population stratification and/or logistical concerns.

Forest stand - a group of trees forming a contiguous potential habitat with no gaps wider than 100 m.

Observation Station - the exact location where the observer stands/sits.

Visit - a single morning's visit to an observation station.

3.3.2 Sampling Standards

Habitat standards

A minimum amount of habitat data must be collected for each forest survey. The type and amount of data collected will depend on the scale of the survey, the nature of the focal species, and the objectives of the inventory. For a generic but useful description of approaches to habitat data collection in association with wildlife inventory, and a list of habitat attributes that must be collected for Marbled Murrelet studies consult the introductory manual, *Species Inventory Fundamentals* (RIC 1998a Appendix D & E).

As this wildlife inventory projects deals with terrestrially based wildlife, fields from the terrestrial Ecosystem Field Form (FS 882) (Ministry of Environment Lands and Parks and Ministry of Forests 1998) can be used. Habitat sampling is described in section 3.3.5 Analysis of Terrestrial Habitats.

Time of year

In BC, the most consistent results are obtained from surveys made between 1 May and 31 July. Evans *et al*. (2000) give 5 August as the recommended end point in BC, but in southwestern Vancouver Island, rates of detection decline rapidly after mid-July (Burger 1994). The extent of the breeding season may vary in the northern parts of the BC coast and in years with unusual weather conditions. There is some consensus among researchers that the peak of activity in July is partially due to an influx of non-breeding or prospecting birds. Year-round surveys can be undertaken to determine seasonal patterns of site occupancy, which is still unknown for BC.

Time of day

In southern BC, morning surveys should be started 60 minutes before local sunrise, and continue to 60 minutes after sunrise or 15 minutes after the last detection, for a minimum survey time of two hours. In northern BC, including the Queen Charlotte Islands, where twilight is longer, surveys should start 75 minutes before sunrise and continue to 45 minutes after sunrise (Rodway *et al*. 1993b). Murrelet activity is often prolonged on misty, overcast days.

Evening surveys are not routinely used in behavioural or habitat studies but can provide additional opportunities to observe Marbled Murrelets and locate possible nesting areas. Evening surveys should start one hour before local sunset and continue for one hour after sunset (45 minutes before to 75 minutes after sunrise in northern BC) or until it is too dark to observe flying birds.

Local sunrise and sunset times can be obtained from the Dominion Astrophysical Observatory in Saanich (phone 363-0001) see webpage http://www.hia.nrc.ca/services/sunmoon/sunmoon.html, or from Atmospheric Environment Service, Environment Canada. Do not rely on sunrise times published in newspapers.

Weather

Surveys can be undertaken in light rain but not when heavy rain is likely to obscure the birds or mask their calls. High winds can impair a surveyor's ability to hear Marbled Murrelets. Any weather conditions that affect visibility or audibility should be noted, and if possible additional surveys should be scheduled.

Personnel

Adequate training is essential to minimize potential bias between observers. Guidelines for training and testing observers of Marbled Murrelets and interpreting hearing tests are given in Evans *et al*. (2000).

A hearing test is recommended for all observers at the start of each season.

Any person wishing to be eligible to conduct Marbled Murrelets forest surveys must successful complete the RIC Marbled Murrelet Inventory training course.

Training includes:

- detailed reviews of the biology and flight patterns of Marbled Murrelets, and other species likely to be encountered;
- repeated reference to field guides, videos and tapes of the various sounds (calls and wing beats); and
- at least four mornings of observation at a site frequented by many Marbled Murrelets (ideally >50 detections per morning).
    - On the first two mornings, the instructor will record Marbled Murrelet detections in the standard manner while explaining each step to trainees. Trainees can observe Marbled Murrelets with binoculars to familiarize themselves with the flight characteristics, although binoculars are not used in standard surveys. The trainees then participate in transferring the data from tapes to dataforms.
    - On day three, the trainees each do a survey, assisted by the instructor. The results and any problems are discussed afterwards. On day four, the instructor tests the trainees by making simultaneous surveys at the same station and comparing results afterwards.

Experienced observers should hone their skills at the start of each season by doing surveys together at the same station and comparing and discussing their results. This should be done every year before a new survey begins and periodically throughout the summer if required.

3.3.3 Forest Surveys

Goals: To determine presence/not detected or occupancy within forest stands; monitor diurnal, seasonal or inter-annual variations in detections; determine relative importance of various terrestrial habitats.

It is important to remember that while presence of Marbled Murrelets in a stand can be documented fairly easily, absence is more difficult to ascertain and could be incorrectly deduced from inadequate sampling. If the stand is occupied, biologists could determine the spatial and temporal patterns of use by Marbled Murrelets, and if possible verify nesting through nest searches.

Studies to assess habitat suitability and prioritize potential breeding areas must be carefully designed. There is still no clear understanding of the relationship between detection frequency and nesting density, and all studies in BC have shown a high degree of short- and long-term variability in detection frequencies.

Office procedures

- Review the introductory manual No. 1 *Species Inventory Fundamentals* (RIC 1998a).
- Obtain maps for Project and Study Area(s) (*e.g.,* 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps). Typically 1:50 0000 are used, but a larger scale such as 1:20 000 are ideal for identifying transects on to map sheets. Any map, which is used to record data, should be referenced to NAD83.
- Outline the Project Area on a small to large scale map (1:250,000 – 1:20,000).
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the project area from maps (Min. Environ., Lands and Parks and Min. For. 1998).
- Based on the maps and other knowledge of the project area (previous reports, local resource specialists), identify strata which are of most interest.
- Delineate one to many Study Areas within this Project Area.

Sampling design

In general, a stratification scheme based on habitat will be used in conjunction with either randomly or systematically placed observation stations. Study areas should be representative of the Project Area if conclusions are to be made about the Project Area. A typical example, would be where the project area is a watershed and the study aims to determine the extent of Marbled Murrelet presence and occupancy in the watershed. Stratification of the watershed can be done using mappable features that coincide with the species habitat requirements (age class, height class, timber volume). Once the strata have been identified you can then select study areas to represent all of the strata. Forest observation stations can be located randomly or systematically within the strata (see survey effort). Another example would occur where you wish to determine the extent of presence and occupancy in several potential Wildlife Habitat Areas (WHAs). The project area could be the Landscape Unit containing these WHAs, but the study results will not be extrapolated to the entire project area, only to the WHAs. Each WHA would be a study area and habitat strata would be delineated within these and used as a basis to locate forest observation stations.

Sampling effort

Number of stations needed

If the study aims to determine the presence, probable absence, or "occupied" behaviour of Marbled Murrelets, then several stations may be needed per stratum (usually a forest stand). In forests, observers usually see birds only within 100 m and hear birds within 200 m so that under ideal conditions 12.6 ha can be surveyed from one observation station (Ralph *et al.* 1994). Additional stations will be needed if the stand is long and narrow, or if the stations are positioned along the edges of the stand (e.g., on clearcuts), because the area of habitat sampled per station will be much reduced (see figures in Evans *et al*. 2000). In studies covering large areas, with constraints on personnel and time, there should be at least one station per 40 hectares (a common cutblock size used in forest planning), although this reduces the probability of detecting presence or occupancy. Other considerations are the homogeneity of the habitat and the goals of the sampling. If the surveys are meant to map out areas of potential Marbled Murrelet habitat in forests being considered for logging, then the sampling area should ideally be closer to the 12.6 ha optimal size, and not less than one station per 20 ha. Additional suggestions and examples on how to position stations are given in Evans *et al.* (2000).

Equipment

- Maps
- Tape recorder and extra tapes and batteries
- Plastic bag and waterproof container for tape recorder
- Watch- preferable digital and with a light or glowing face.
- Flashlight or preferably a headlamp as it allows hand free operation
- Compass
- Waterproof Notebook and pencil
- Dataforms
- Insect repellent
- Binoculars – preferably waterproof
- Foam pad or camp chair to sit on
- Thermometer
- Flagging tape

Field procedures

Select observation stations

Stations should be positioned where the observer has a wide view of the sky, since visual detections are essential for establishing site occupancy. Forest clearings, windfall openings, roadways, and edges of clearcuts could be considered. Open sites along streambeds are often used although the noise of the stream may mask some of the more distant calls. Rodway and Regehr (2000) suggested that observations along valley bottoms should be placed where canopy opening and visibility did not bias observations.

If stations are being located using random or systematic points within a strata then select the closest canopy opening to the random or systematic location for the observation station. The size of canopy opening may differ with forest types and should be recorded on the dataform as it may affect Marbled Murrelet detectability.

Stations should be no further than 50 m from the edge of the habitat being sampled, and ideally placed within the stand for the best chance to detect subcanopy behaviour. Stations, which are relatively low in relation to the surrounding hills, are good, because birds will be more readily seen as dark silhouettes against a paler sky than against a dark background when looking down from a hilltop or ridge.

Observers must visit and flag the observation station during daylight so that stations can be positioned optimally and so that they will be easier to find in the darkness on the survey morning. Reflective tape is useful for locating stations by flashlight. Observers may have to camp some distance from the station and flag a clear trail to it. Information on station placement can be recorded the evening before the survey or immediately after the survey, but should be done in daylight conditions.

Observers should be randomized or changed between survey stations to minimize bias in any one part of the survey, unless the goal is to study seasonal variations at a particular station in which case keeping the same observer at each station is desirable.

Making observations

- Be at the station at least 5 minutes before the recommended starting time (60 minutes before dawn in southern BC, 75 minutes in northern BC) to position yourself.
- Stand where you have the best view of the open sky. In some instances, it might be more appropriate to sit or lie semi-prone to get a better view of a clearing or to reduce the noise from nearby streams, but at all times keep your head raised to hear better. A semi-prone person will be able to scan the sky more efficiently than a standing person, but is less likely to hear and orient to distant calls.
- Use the compass to orient yourself and memorize landmarks that correspond to the primary compass bearings (N, S, E and W).
- Avoid using the flashlight if possible (read time from a lighted watch).
- Use the tape recorder to dictate all notes, but remain silent between detections. You will likely miss birds if you write down observations. Check the tape recorder frequently to ensure it is working properly.

Record environmental conditions

At the beginning and end of each survey period, and at any significant change in weather during the survey, record: cloud cover, ceiling, cloud type, precipitation, wind speed, and temperature. See the dataform for categories.

For each detection record the following:

1) **Time**: Record the detection time using the 24hr clock
2) **Initial Detection Location:** Relative to your location, record the direction in which you first detected the Marbled Murrelet(s). Record the direction using cardinal points in 45 degree increments (N, NW etc.).

3) **Type**
   - **Visual detections (V)** - birds are seen but not heard.
   - **Audio detections (A)** - birds are heard but not seen.
   - **Audio and Visual detections (A+V)** - birds are both seen and heard.

For audio (A) detections record:

4) **Number and type of calls:** or other sounds heard (estimate, to the nearest five calls, multiple calls **(M)**, which cannot be counted); For details on Marbled Murrelet vocalizations see Nelson (1997) and Dechesne (1998). Classify sounds as:

   - **Keer Call: (K)** a two-syllable, high-pitched call often given in series. (Over 90% of vocalizations heard over land are this call);
   - **Quack Call (Q)** (also known as the Groan or Alternate Call): a low, guttural call, almost duck-like, possibly associated with nesting;
   - **Keer-Quack series: (K-Q)** series of Keer Calls sometimes blend into Quack Calls;
   - **Stationary Calls:** at least three calls of the above types given from the same site indicating that the bird is not flying (Classified as **S** under Behaviour type);
   - **Wing beats (W):** tremulous fluttering sounds. These are often heard when birds fly from nest branches; and
   - **Jet Sounds (J):** a rare whooshing sound apparently made by the wing-tips of diving Marbled Murrelets.

For visual detections (V or AV) record:

5) **Group Size:** the number of birds visually observed during the detection
6) **Behaviour:** which is usually restricted to an estimate of flight path and includes one or more of the following:
   - DA = Direct flight above canopy;
   - DB = Direct flight at or below canopy height
   - CA = Circle above canopy
   - CB = Circle at or below canopy height

     Circling behaviours include full quarter and half circles; the degree of circling should be noted in the notes section
   - L = Land on or depart from a tree
   - S = call from a stationary point; birds emitting at least 3 calls from a fixed point within 100m of the observer. This is a rare event.
   - U = Unknown
   - Notes should be made on other behaviours or modifications of the above categories that occur. For example entering or exiting the canopy at various points, aerial dives, following another bird.
7) **Initial flight direction:** This is the direction that the Marbled Murrelet(s) is travelling towards when it is first detected.

8) **Bird Height:** Estimate bird height based on the lowest location of the bird relative to the height of the forest canopy (i.e. the tallest trees observable from the observation station. The height of the tallest observable tree is equivalent to 1.0 canopy heights. For example if a bird flies at 1/3 the canopy height it is recorded as 0.3. A group of birds flying very high at 200 m where the canopy height is 50 m would be recorded as 4.0. Height is not determined for Auditory (A) detections.

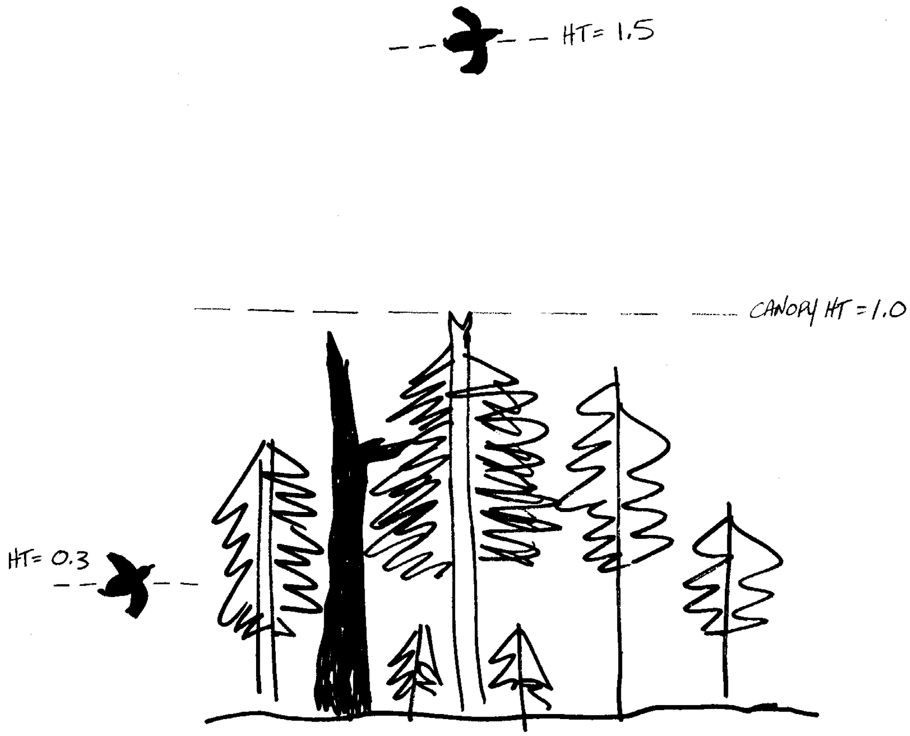

Figure 4. Bird height codes.

9) **Closest distance to birds (seen):** record the closest horizontal distance from the observer to the bird(s). This distance is 0 m if birds fly directly overhead.

10) **Final Fight Direction:** This is the direction that the Marbled Murrelet(s) is travelling towards when it is last detected.

5) **Final Detection Location:** Relative to your location, record the direction in which you last detected the Marbled Murrelet(s). Record the direction using cardinal points in 45 degree increments (N, NW etc.).

Additional notes: record anything else that will help interpret the detection (e.g., "3 birds circling + 12 keer calls, 1 split away to the north, 2 continue circling silently"). In addition, notes should be kept of any other behaviours (e.g., flock formation, apparent chasing) and the associated Marbled Murrelet vocalizations.

The bird and detection direction information is important for mapping detections (see page 57 in Evans *et al.* 2000). During a very busy survey it may not be possible to collect all four directions.

Be conservative in counting detections, especially when the same birds are repeatedly circling overhead. Thoroughly review the criteria for detections.

Predators: Report the presence of potential predators of adult Marbled Murrelets their eggs or chicks observed during the survey. In most cases it will only be possible to record the presence of predators and not their abundance. Predator species can be listed at the bottom of the last survey page. See page 44 of Evans *et al.* 2000 for a list of predators. Species codes for predators can be found in RIC (2000).

Data entry

Transcribe observations to the dataforms as soon as possible after each survey. The Design Component for this survey is stations. When digitally entering your survey data, choose 'Station' from the 'Design Component Type' picklist and enter the relevant data.

Data analysis

The status of each survey station: Not Detected, Present or Occupied can be determined using the survey data if the required number of surveys have been completed. If only one year of surveys has been done then record the status for that specific year (i.e. present in 2001) until further surveys are completed.

Means and standard errors of total detections, occupied detections and detections close to the observation station (50 m or 100 m), can be calculated. However these averages are not likely to be useful unless the sample size is large and sources of variation have been controlled for in the study design or analysis methods. Important sources of variation include date, weather and view or opening size. If activity levels are to be associated with habitat types then averages of occupied or detections within 100 m should be used as they better reflect local habitat. For examples of data analyses using activity surveys see Rodway *et al.* (1993a,b) Jodice and Collopy (2000) and Rodway and Regehr (1999a).

3.3.4 Techniques for Finding Tree Nests

The number of Marbled Murrelet nest sites and nesting locations has increased substantially in the last 5 years. At least 170 nest sites and nesting locations have been documented in BC, largely in the last 5 years (Hooper 2001). Nest sites are very important for providing information on the habitat requirements and nesting success of this species. Despite the increased number of nest locations in BC relatively few nests have complete habitat descriptions together with nesting success information (<30 nests). Descriptions of nest sites are rare or lacking for several parts of the province including northwestern and eastern Vancouver Island, the Queen Charlotte Islands, the North and Central mainland coast and the lower mainland. Any additional nests with complete descriptions would provide important information on the habitat needs of this species. Researchers should refer to the PSG Marbled Murrelet Nest Structure Form for describing nest sites. Hamer and Nelson (1995) and Manley (1999) provide examples of describing the habitat around nests. Four methods have been used to locate nests. These are described briefly here. Researchers should review the relevant references for additional information.

Monitoring nesting behaviours from the ground

This is also known as the "ground search" technique and was responsible for locating several nests in BC (Manley *et al.* 1992; Jones 1993; Manley 1999a). The methodology as described in Naslund and Hamer (1994) involves tracking Marbled Murrelets making dawn visits to nests. Murrelets approaching a nest appear to follow preferred flight paths, which can be detected by observers on the ground who progressively narrow down the search until finding the nest site. The Marbled Murrelets' wingbeats are often louder as it slows for landing or takes off. Recommended procedures involve (see Naslund and Hamer 1994 for details):

- focus the search in areas with apparently suitable habitat or known to have high levels of occupied behaviour;
- focus observations during the peak periods of Marbled Murrelet activity (dawn, and to a lesser extent dusk) using the same procedures as in Forest Surveys, but concentrating on detections within a 100 m radius of the observer;
- through observations of flight paths, progressively narrow the area searched until the possible nest location is found;
- observe the suspected nest site for several days ("stake-out" the site) using several observers strategically placed;
- confirm the nest using a spotting scope to search the tree limbs; and
- climb the tree only if you are certain that this will not disrupt the Marbled Murrelet's nesting (i.e., once the chick has fledged) and if you have the necessary experience.

Searching the forest floor

Systematic searches of the forest floor in areas of high Marbled Murrelet concentrations can yield discarded eggshells, which indicate nests. One nest in BC and several in the U.S. have been found in this way. It is most effective where the undergrowth is relatively sparse. Searches for eggshells are usually done in conjunction with the ground search technique, or during habitat plots or transect. The observer searches the undergrowth beneath potential nest trees for eggshell fragments. Fragments of eggs have been found directly beneath nests to >25 m from nest trees depending on the slope of the area. This method has not been used systematically in any studies. However, most researchers scan below trees with platforms for eggshells during vegetation plots or transects. Harrison (1984) and Appendix A of Evans *et* *al.* (2000) describe the size, shape and coloration of Marbled Murrelet eggs and others likely to be found.

Radio-telemetry

Techniques to capture Marbled Murrelets at-sea and track them using radio transmitters have been used to successfully locate Marbled Murrelet nests in several areas of the province. Details on the methodology can be found in Kaiser *et al.* (1995), Lougheed *et al.* (1998) and Cooke (1999). RIC (1998b) provides general standards for Animal Capture and Handling and RIC (1998c) provides general guidelines for Radio-telemetry. In some cases tree-climbing and ground search methods are used in addition to telemetry to locate the nest tree once the signal has been found in the forest.

Tree-climbing

Tree-climbing has been used both to document nests found using other methods (Jordan *et al.* 1997) and to search forests using random or systematic climbing plots (Rodway and Regehr 1999b). During nest searches every potential nest tree within a plot is climbed and searched for nests. This is the only method that can measure the density of Marbled Murrelet nests in forested habitats. Avoid bias by stratifying randomly located tree-climbing plots across all available habitat and elevation ranges within the project area.

3.3.5 Analysis of Terrestrial Habitats

Quantitative data on the vegetation at each observation station will greatly help the interpretation of terrestrial survey results through documentation of habitat preferences. Such analyses have been done in several studies in BC (Rodway *et al.* 1993b; Rodway and Regehr 1999a; Bahn 1998; Bahn and Newsom 1999). The following is a brief outline of the recommended methods, but researchers can collect additional data.

Three forms will be required:

- Marbled Murrelet Habitat Analysis
- Site Description (FS882 (1))
- Vegetation Description (FS882 (3))

The latter two are from the Ecosystem Field Form and are available to purchase through Crown Publications (phone 250 386-4636). You may also create your own form containing these fields.

Types of habitat data & plot types

The general purpose of plots is to obtain a sample of the habitat structure in the vicinity of the observation station. Observation stations are usually located in canopy openings that provide a view of the canopy. For this reason habitat plots are not located directly at the observation station but are randomly or systematically located in the habitat surrounding the observation station.

A variety of forest plot sizes have been used for Marbled Murrelet surveys. There are two main reasons for laying out plots:

1. To collect the site and vegetation description portion of the habitat analysis. Plots of 400 m^2 are standard in British Columbia for these surveys. This information is used for Biogeoclimatic Ecosystem Classification of the habitat.
   Note that these plots are placed within the Habitat Analysis plots.
2. To collect the required information for Marbled Murrelet Habitat Analysis. Larger plots are needed for Marbled Murrelet Habitat Analysis because the structures important for Marbled Murrelets are large and often patchily distributed. Murrelet habitat is most commonly documented using:
   - 30 x 30m quadrats (0.09 ha), see Rodway and Regehr (1999a);
   - 25 m radius circular plots (0.19 ha); or
   - fixed-width transects (0.6 ha, 200m long by 30m wide; however, other lengths and widths can be used).

   The type and size of plot used depends on the goal of the study. To facilitate analysis the plot size and type should be consistent for each survey. Plots may need to be buffered from natural or artificial edges to avoid edge effects (i.e., the plot perimeter should be >10 m from the forest edge).

Choosing a plot type and sampling design

To sample habitat at observation stations or nest trees, use either:

- circular plots centered on the nest tree;
- circular or square plots randomly or systematically located in the forest adjacent to the observation station.

For broader scale recording of habitat and ground-truthing habitat maps use transects.

Plots

Smaller plots (0.09 ha) have been used to systematically describe habitat surrounding the observation station. In patchy habitats or forests with few or well spaced large trees these plots may not contain enough trees with platforms to evaluate structural features. In this situation a larger area of habitat will need to be sampled by using 2 small plots per observation station, such as one on each side of a creekbed (Burger 1994), or one larger plot.

Larger plots are suited to random or systematic samples of the habitat strata being surveyed. Studies describing relationships between activity levels and habitat characteristics generally use plots or transects that are randomly located within the habitat strata or type. For example Manley (1999) used 25 m radius circular plots located randomly within 100 m of the observation station and within the habitat polygon being sampled. Ideally plots are randomly located (using a random distance and direction) to avoid bias in their location but are also close enough to the observation station (<100 m) to reflect the forest survey results.

Transects

Habitat transects are commonly used in studies mapping the availability of Marbled Murrelets habitat features, or documenting the relationship between Marbled Murrelet habitat features and habitat classification schemes (McLennan *et al.* 2000). As transects are larger they are usually used to measure Marbled Murrelet habitat structures only (trees with platforms only, or trees over a certain size only). Trees without platforms are not sampled. The length of transect sampled can be adjusted depending on the studies requirements. A 333 m x 30 m transect conveniently samples 1 hectare. Transects should run across the dominant habitat gradients, such as elevation contours, if the goal is to get a generalized summary of what is available. Transects should run along habitat isoclines if the goal is to compare different habitats across the gradient, e.g., run along contour lines to compare the effects of elevation.

Consistency in collecting habitat data

In general only one size of plot will be used throughout a project, but plot size and placement will vary between projects. It is important that the basic data collected (site and vegetation description and Marbled Murrelet habitat features) is recorded consistently between projects. This will provide data on the relationships between habitat types and Marbled Murrelet habitat features and assist in mapping Marbled Murrelet habitat. Data on Marbled Murrelet habitat features can be converted to densities per hectare to allow comparison between projects.

Data collection

Step 1. General site and vegetation description

At each habitat sample certain site characteristics should be described through examination of maps or site work. Use Chapters 1 (site description) and 3 (vegetation description) from the Field Manual for Describing Terrestrial Ecosystems handbook (Ministry of Environment, Lands and Parks and Ministry of Forests 1998) to describe the surrounding area. The data can be entered on the matching Site Description (FS882 (1) and Vegetation Description (FS882 (3) forms or on your own form containing these fields.

Complete the Site Description fields:

- Date
- Surveyor
- Plot number
- Location (Latitude/Longitude)
- Ecoregion/Ecosection
- Broad Habitat Units (RIC 1998d)
- Biogeoclimatic zone, Subzone, Variant and Site Series
- Elevation
- Slope
- Aspect
- Meso Slope Position
- Moisture Regime
- Nutrient Regime
- Structural Stage

Complete the Vegetation Description fields:

On the vegetation description form, record the percent cover of major tree species, major shrub species, major herb species and major bryophyte and lichen species. Record percent canopy closure for the plot. This is the percentage of the plot, which would be covered if the canopy foliage were projected down

Step 2. Marbled Murrelet Habitat Analysis

The following tree characteristics are to be recorded on the Marbled Murrelet Habitat Analysis form.

From examination of maps record parameters likely to affect Marbled Murrelets:

- distance to the ocean, lake or stream
- stand age
- stand forest cover polygon classification if available
- distance to nearest natural or artificial forest edge, and the type of edge (e.g., road, clearcut, river)

In your plot out in the field record the characteristics of trees listed below.

In plots record characteristics of all trees with diameter at breast height (DBH) >10 cm using the dataform. Ignore dead snags less than 5 m tall.

In transects record the characteristics of every tree having at least one potential nest platform.

For each tree record the following:

1. **Species**
2. **Layer** - Record which layer the tree reaches (see Min. Forests and Min. Environment, Lands and Parks 1998);
3. **DBH (cm)** - diameter at breast height
4. **Tree height (m)** - Use a clinometer to measure a few trees and use them as a guide to estimate the rest. Practice estimating tree height using the clinometer to check actual heights, so that all members of the survey team give similar, accurate estimates.
5. **Number of potential nest platforms -** Potential platforms are limbs or other structures large enough to provide a nesting surface for Marbled Murrelets. Platforms are recorded in two categories those >18cm diameter and >15m in height and those 12-18cm in diameter and >10m in height. Platforms were originally defined as the number of limbs (or other structures) greater than 15 m above ground and thicker than 18 cm in diameter (including moss). More recently nests have been found on smaller limbs especially in high elevation forests (Nelson 1997; Manley 1999a; R. Bradley pers. comm.). A second platform size category 12-18 cm in diameter has been added to account for these nests. Platforms in both size categories should be counted from one location that provides the best view of the tree canopy. Do not make any judgements about suitability as nest sites, and do not count more than one platform per limb.
6. **Epiphyte cover -** Estimate the cover of epiphytes (moss, lichen, ferns etc.). See dataform for codes of cover. Also estimate whether the epiphyte coverage is generally sparse (thin) or is in the form of thick mats, or intermediate.
7. **Mistletoe infestation -** Mistletoe can provide suitable nest sites for Marbled Murrelets. Use the 6-point rating system of Hawksworth (1977). Divide the live crown into vertical thirds. For each third report mistletoe as:
   - 0 = no visible infections;
   - 1 = light infections (half or less of branches infected); or
   - 2 = heavy infections (more than half-infected).

   The total score is then added to give a range of scores from 0 to 6 per tree.

9. **Comments -** Note other features of the tree, use by other wildlife, nests or roosts of predators, etc.

   Refer to Pojar *et al.* (1987) and Green and Klinka (1994) for site identification in the biogeoclimatic zone system, RIC (2000) and Min. Environment, Lands and Parks and Min. of Forests (1998) for sampling methods used to describe ecosystems in the vicinity of points. Pojar and MacKinnon (1994) should help with plant species identification.

Habitat data analysis

Site associations and vegetation groupings can be made using established methods such as Braun-Blanquet or VTAB analysis (Pojar *et al*. 1987; Kayahara 1992). However, at this point the main interest of the Resources Inventory Branch is the receipt of the data in untabulated (uncondensed) form.

Important summary variables to produce from plot or transect data include; density of platforms per hectare, density of platform trees per hectare, average tree height, average tree dbh, average moss cover and average lichen cover. Some measure of variability (e.g., standard deviation, standard error) of each measure within the sample is also needed.

3.3.6 Incidental Data

Incidental records of Marbled Murrelet activities on land are useful in locating new sites in which to survey. Detections of Marbled Murrelets during other surveys such as multi-species forest bird surveys or roadside breeding bird surveys are also valuable and could identify sites for further observation. Incidental records should be recorded on the Wildlife Sighting Form.

Any opportunistic information on predation of Marbled Murrelets or predation risk is extremely valuable and should be recorded in detail, such as sighting a hawk chasing or killing a Marbled Murrelet. Record the species of predator, location, time of day and weather conditions, along with a detailed description of what was seen. Likewise record and collect any other evidence of predation, such as a pellet or other Marbled Murrelet remains left by a predator.

Any vouchers collected (e.g. photos of fledged chicks, grounded chicks and the surrounding habitat or eggshells found on the ground) should be submitted to the Royal British Columbia Museum (see RIC 1999, manual No. 4a). These records should include: date; time of day found; name, address and phone number of finder; detailed description of the location (UTM coordinates, or grid reference on 1:50,000 topographic map); and a description of the surrounding topography (slope, aspect) and vegetation.

3.4 Protocol for Radar Surveys

High-frequency marine radar has recently been developed as a census technique for Marbled Murrelets (Cooper 1993; Hamer *et al.* 1995; Burger 1997). An official protocol has not been established but most surveys have employed consistent methodology as described in Cooper and Hamer (2000). Researchers should check the most recent references and consult with murrelet biologists to ensure that they are following the most recent recommendations. Uses of radar surveys include the following (Cooper and Hamer 2000):

1. To measure the abundance of Marbled Murrelets in a drainage or watershed
2. To monitor changes in Marbled Murrelet populations at the watershed level
3. To measure the abundance of Marbled Murrelets flying along inlets channels or other marine areas (Drever and Kaiser 1999)
4. To compare counts of Marbled Murrelets with watershed habitat characteristics and to determine the effects of logging (Burger 1999a; Manley 1999b).

Radar surveys provide the only reliable method of estimating Marbled Murrelet numbers at specific watersheds (Burger 1997). Observers conducting forest surveys detect only 7-15% of Marbled Murrelets visible with radar within 200 m. As radar surveys are not affected by light levels they detect more Marbled Murrelets and detect them earlier in the morning than observers are able to (Burger 1997). Radar surveys have been used in at least six studies in BC to measure Marbled Murrelet numbers in watersheds on Vancouver Island, the central coast and the Sunshine Coast (Burger 1997, 1999a; Drever and Kaiser 1999; Manley 1999b; Schroeder *et al.* 1999). These studies could form a baseline for future population monitoring efforts.

Radar has also been used inland to determine the presence or probable absence of Marbled Murrelets in forest stands (Hamer *et al.* 1995; Cooper and Blaha 1998). Radar surveys may be a more efficient method to determine Marbled Murrelets presence/ probable absence, especially when they occur at low densities (Cooper and Hamer 2000). The advantages and limitations of using radar in this fashion are discussed in Cooper and Hamer (2000). The use of radar for inland surveys may be formalized in future PSG protocols but will not be addressed as an inventory method here.

Radar survey methods have remained consistent with those described by Burger (1997, 1999a) in BC. These methods are summarized here for measuring abundance at the watershed scale and for population monitoring in BC. Researchers should consult with the Chair of the Marbled Murrelet Technical Committee and those using radar surveys in BC for updates in this methodology.

3.4.1 Sampling Standards

Habitat standards

The position of the radar unit during the survey should be accurately measured and plotted on topographic maps and/or marine charts. This will allow the survey to be duplicated exactly in long term monitoring efforts. A circle equal in radius to the scanning radius should be plotted around this point to show exactly what areas were covered with the radar survey. Any ground clutter or shadow zones where birds cannot be detected due to blocking of the radar beam by trees or other obstructions should be sketched on the map or documented by taking a photo or video image of the radar screen during the survey. The major flight paths taken by Marbled Murrelets can also be sketched on the map.

Radar counts at a watershed are often compared to landscape level habitat variables for the watershed (Burger 1999a; Manley 1999b; Raphael *et al.* submitted). These will usually be derived from the most recent GIS databases or satellite photography.

Time of year

In Clayoquot Sound, Burger (1999a) recommended 15 May to 15 July as the survey period, and counts were found to drop off rapidly after 15 July. Adjustments to the seasonal period may need to be made in Northern BC or in years with unusually early or late breeding.

Year-round surveys could be conducted to determine seasonal patterns of inland visitation.

Time of day

Sunrise

Radar surveys conducted to date in BC have started 120 minutes before sunrise and continued to 60 min past sunrise or 15 min after the last Marbled Murrelet detection. Radar surveys have not been conducted on the North Coast or Queen Charlotte Islands yet. In these areas it may be necessary to adjust the daily time of surveys for earlier arrivals. As with forest surveys Marbled Murrelet activity is often prolonged on misty, overcast days.

Evening

Evening surveys are not routinely used to census Marbled Murrelets within a watershed. Burger (1999a) found that activity was lower and more variable during evening radar surveys. Evening surveys should start 30 minutes before local sunset and continue for a total of 3 hours. Evening surveys can be used to test out a new survey location to determine if the survey location is effective for detecting Marbled Murrelets flightpath, and might be useful if dawn surveys are rained out.

Weather

Surveys can be undertaken in light mist or fog. Rain will obscure the detection of Marbled Murrelets on the radar screen. Surveys are considered incomplete if the flight path is obscured by rain clutter for more than 10 minutes during a survey. Wind speed and direction should be measured during radar surveys, as it will affect the flight speed of targets on the radar screen. Surveys should only be conducted during light winds to avoid mis-identification of species (Cooper and Hamer 2000). The height of the cloud ceiling relative to the surrounding ridges should be recorded as this may affect the flight routes taken by Marbled Murrelets.

Personnel

Personnel conducting radar surveys should be experienced in Forest surveys and should successfully complete the RIC Marbled Murrelet Inventory training course. Additional training on radar surveys should take place for at least 3 days, as this is not part of the inventory training course.

3.4.2 Radar Surveys

Goals: To determine relative abundance within watersheds or along marine flight paths. Monitor trends in abundance at the watershed or landscape scale.

Office procedures

- Review the introductory manual No. 1 *Species Inventory Fundamentals* (RIC 1998a).
- Obtain maps for Project and Study Area(s) (*e.g.,* 1:50 000 air photo maps, 1:20 000 forest cover maps, 1:20 000 TRIM maps, 1:50 000 NTS topographic maps). Typically 1:50 0000 are used, but a larger scale such as 1:20 000. Any map that is used to record data should be referenced to NAD83. Topographic maps are important for selecting radar survey locations that funnel the birds into distinct flightpaths.
- Outline the Project Area on a small to large-scale map (1:250,000 – 1:20,000).
- Determine Biogeoclimatic zones and subzones, Ecoregion, Ecosection, and Broad Ecosystem Units for the project area from maps.
- Based on the maps and other knowledge of the project area (previous reports, local resource specialists), identify strata which are of most interest.
- Delineate one to many Study Areas within this Project Area. Study areas should be representative of the Project Area if conclusions are to be made about the Project Area. For example, this means if a system of stratification is used in the Sampling Design then strata within the Study Areas should represent relevant strata in the larger Project Area.

Sampling design

The selection of sites for radar surveys is the most important consideration for an inventory study. Ideal locations have the topography to funnel birds into narrow, discrete flight paths (Cooper and Hamer 2000). Radar stations will normally be located at watershed entrances of well-defined valleys. Sites will be located where the radar has unobstructed scanning of the flight path and will not be randomly located. Watersheds along steep fiords or channels are particularly suitable, but surveys can also be conducted at river entrances on lakes or at accessible locations along rivers. The selection of study areas within a project area will largely be a factor of how many watersheds are suitable for radar surveys. Because of these limitations it may not be possible to select study areas that are representative of the project area. In general each watershed will be considered a study area. More than one radar survey site may be needed to cover a complex watershed with multiple entrances. Examples of sampling designs for inventory purposes include Burger (1999a), Schroeder *et al.* (1999), and Manley (2000). In most cases radar surveys will have to be completed in order to evaluate the suitability of a survey location. At the start of a project extra days should be allowed for evaluating the suitability of new sites, and moving to more suitable locations if necessary.

Sampling effort

For long-term monitoring of population change precision (low variability in sampling) is more important than counting every bird in the landscape. For monitoring purposes the most important consideration is the selection of sites with low among day variation in radar counts (Cooper *et al.* in press). To determine the sampling effort required for long term monitoring, an initial year of surveys should be done to assess the sites and the variability in radar counts. At least 4-6 surveys should be conducted at each site to measure variation. These data can then be used in a power analysis to determine the monitoring effort needed to detect various trends. Power analysis using radar data and the software TRENDS and MONITOR is shown in Cooper *et al.* (in press), (see also RIC 1998a, Appendix G). Cooper and Hamer (2000) discuss other considerations in selecting monitoring sites.

Concurrent 'forest' survey

A standard forest survey should always be done concurrently with any radar survey, even though the radar survey will likely be conducted in a marine location. Note that the forest survey should be done far enough from the radar beam to avoid the radiation in its vicinity. The survey is done concurrently to determine if any other bird species are flying at a similar speed and flight-path as Marbled Murrelets. The surveyor stays in contact with the radar surveyor by radio and informs them of any fast flying species they see during the survey (see Burger 1997, 1999a; Cooper *et al*. in press). The forest survey is conducted at the times described in section 3.3.2 and therefore begins later in the morning than the radar survey. It is generally too dark at the beginning of the radar survey to observe any birds.

Equipment

- Radar Unit X –band marine radar 10 KW (as described in Burger 1997, 1999a; Cooper and Hamer 2000)
- Power supply (sufficient batteries if operating in remote areas)
- Radios for communicating between surveyors
- Maps topographic and marine charts
- Tape recorder and extra batteries
- Tapes
- Watch
- Flashlight
- Compass
- Notebook and pencil
- Dataforms
- Video camera if the survey will be recorded (some radar units allow internal connections with a VCR)

Field procedures

Select observation stations

Radar surveys can be conducted using boat based (Schroeder *et al*. 1999), land based (Burger 1999a), and vehicle based (Cooper *et al.* in press) radar units. The type of survey used will depend on the access to estuaries in the Project Area. Boat based surveys are the most expensive but are the only option on remote coastlines. Topography is the most important consideration when selecting sites. Sites at the mouths of well defined valleys or the ends of inlets and fiords will produce the most consistent flight paths. The best way to evaluate a survey location is to conduct one to a few initial radar surveys. Evening surveys can be used to test survey locations.

Before the survey begins

- Turn the radar unit on and allow it to warm up (refer to the User's Manual for the radar model being used).
- When setting up the radar scanner, or positioning the vessel or vehicle carrying the scanner, determine the compass bearing that the scanner is oriented towards (i.e., figure out which direction the top of the screen will show).
- The operation of the radar unit will depend on the specific model being used (see Cooper and Hamer 2000 for recommended radar equipment). In general the unit should be operated with the rain and sea scatter suppressors turned off and the gain set to ¾ to full strength. The scanning range for the radar should be between 1.0 and 1.4 km (0.5 to 0.75 NM).
- Use the compass to orient yourself. Use tape or other markers to mark N, S, E and W on the radar screen.
- Take a photograph of the screen from as close up as possible to record the field of view of the radar and the areas blanked by back-scatter.

Record environmental conditions

At the beginning and end of each survey period, and at any significant change in weather during the survey, record the percentage cover and altitude of clouds (e.g., stratocumulus 50%), precipitation, and wind speed and direction. See the dataform for categories.

Record the amount and duration of any weather related obstruction on the radar screen.

Making observations

Use the tape recorder to dictate all notes. You will likely miss birds if you write down observations. Check the tape recorder frequently to ensure it is working properly. Some studies have used video cameras to record the radar screen and then transcribed these tapes. If this method is used the tapes should be viewed and transcribed soon after the survey.

For each detection record the following (see codes and the dataform):

- Time
- Flight path recorded as: incoming (going from sea inland), outgoing (going from land towards the sea), or circling
- Flock size, recorded as accurately as possible but if the flock size is not clear record as 2 or more birds
- Speed: measured as mm between successive echoes on the radar screen. To convert this to speed first determine the fixed time interval between plotted echoes on your radar unit. Then determine the scale used on the screen (depending on the scanning radius) to convert the mm between echoes to an actual distance. Speed is then calculated as distance/time.
- Distance of the target from the radar antenna along a line perpendicular to the general flight path
- Flight directions
- Note if the target is confirmed as a Marbled Murrelet by the outside observer

During peak flight times it may not be possible to collect all the above data for each target. During busy periods record the time, flightpath and flock size at a minimum.

Data entry and analysis

- Transcribe observations to the dataform or computer as soon as possible after each survey.
- Burger (1999a) recommends using the number of incoming birds before local sunrise as an index of the population at that site to eliminate Marbled Murrelets making more than one visit to a nest at dawn.
- Cooper and Hamer (2000) recommend that incoming, outgoing and total counts are determined and the count with the lowest variation is used for monitoring purposes.
- Examine data for evidence of a second peak of landward flights after sunrise that may reflect second feeding trips made by adults (Burger 1999a; Cooper and Hamer 2000).
- See Burger (1999a) and Raphael *et al*. (submitted) for examples comparing radar counts to landscape habitat variables (determined from GIS or satellite photography) for watersheds.

GLOSSARY

ABSOLUTE ABUNDANCE: The total number of organisms in an area. Usually reported as absolute density: the number of organisms per unit area or volume.

ACCURACY: A measure of how close a measurement is to the true value.

BIODIVERSITY: Jargon for biological diversity: “the variety of life forms, the ecological roles they perform, and the genetic diversity they contain” (Wilcox, B.A. 1984 cited in Murphy, D.D. 1988. Challenges to biological diversity in urban areas. Pages 71 - 76 in Wilson, E.O. and F.M. Peter, Eds. 1988. Biodiversity. National Academy Press, Washington, D.C. 519 pp.).

BLUE LIST: Taxa listed as BLUE are sensitive or vulnerable; indigenous (native) species that are not immediately threatened but are particularly at risk for reasons including low or declining numbers, a restricted distribution, or occurrence at the fringe of their global range. Population viability is a concern as shown by significant current or predicted downward trends in abundance or habitat suitability.

CBCB (Components of B.C.’s Biodiversity) Manuals: Wildlife species inventory manuals that have been/are under development for approximately 36 different taxonomic groups in British Columbia; in addition, six supporting manuals.

COSEWIC: Committee on the Status of Endangered Wildlife in Canada.

CREPUSCULAR: Active at twilight, at dawn or dusk

DESIGN COMPONENTS: Georeferenced units which are used as the basis for sampling, and may include geometric units, such as transects, quadrats or points, as well as ecological units, such as caves or colonies.

EWG (Elements Working Group): A group of individuals that are part of the Terrestrial Ecosystems Task Force (one of 7 under the auspices of RIC) which is specifically concerned with inventory of the province’s wildlife species. The EWG is mandated to provide standard inventory methods to deliver reliable, comparable data on the living “elements” of BC’s ecosystems. To meet this objective, the EWG is developing the CBCB series, a suite of manuals containing standard methods for wildlife inventory that will lead to the collection of comparable, defensible, and useful inventory and monitoring data for the species populations.

INVENTORY: The process of gathering field data on wildlife distribution, numbers and/or composition. This includes traditional wildlife range determination and habitat association inventories. It also encompasses population monitoring which is the process of detecting a demographic (e.g. growth rate, recruitment and mortality rates) or distribution changes in a population from repeated inventories and relating these changes to either natural processes (e.g. winter severity, predation) or human-related activities (e.g. animal harvesting, mining, forestry, hydro-development, urban development, etc.). Population monitoring may include the development and use of population models that integrate existing demographic information (including harvest) on a species. Within the species manuals, inventory also includes, species statusing which is the process of compiling general (overview) information on the historical and current abundance and distribution of a species, its habitat requirements, rate of population change, and limiting factors. Species statusing enables prioritization of animal inventories and population monitoring. All of these activities are included under the term inventory.

MONITOR: To follow a population (usually numbers of individuals) through time.

OBSERVATION: The detection of a species or sign of a species during an inventory survey. Observations are collected on visits to a design component on a specific date at a specific time. Each observation must be georeferenced, either in itself or simply by association with a specific, georeferenced design component. Each observation will also include numerous types of information, such as species, sex, age class, activity, and morphometric information.

POPULATION: A group of organisms of the same species occupying a particular space at a particular time.

PRECISION: A measurement of how close repeated measures are to one another. High precision requires low variability in the sampling measure.

PRESENCE/NOT DETECTED (POSSIBLE): A survey intensity that verifies that a species is present in an area or states that it was not detected (thus not likely to be in the area, but still a possibility).

PROJECT AREA: An area, usually politically or economically determined, for which an inventory project is initiated. A project boundary may be shared by multiple types of resource and/or species inventory. Sampling for species generally takes place within smaller, representative study areas so that results can be extrapolated to the entire project area.

PROJECT: A species inventory project is the inventory of one or more species over one or more years. It has a georeferenced boundary location, to which other data, such as a project team, funding source, and start/end date are linked. Each project may also be composed of a number of surveys.

RANDOM SAMPLE: A sample that has been selected by a random process, generally by reference to a table of random numbers.

RED LIST: Taxa listed as RED are candidates for designation as Endangered or Threatened. Endangered species are any indigenous (native) species threatened with imminent extinction or extirpation throughout all or a significant portion of their range in British Columbia. Threatened species are any indigenous taxa that are likely to become endangered in British Columbia, if factors affecting their vulnerability are not reversed.

RELATIVE ABUNDANCE: The number of organisms at one location or time relative to the number of organisms at another location or time. Generally reported as an index of abundance.

RIC (Resources Inventory Committee): RIC was established in 1991, with the primary task of establishing data collection standards for effective land management. This process involves evaluating data collection methods at different levels of detail and making recommendations for standardized protocols based on cost-effectiveness, co-operative data collection, broad application of results and long term relevance. RIC is comprised of seven task forces: Terrestrial, Aquatic, Coastal/Marine, Land Use, Atmospheric, Earth Sciences, and Cultural. Each task force consists of representatives from various ministries and agencies of the Federal and BC governments and First Nations. The objective of RIC is to develop a common set of standards and procedures for the provincial resources inventories. [See http://www.for.gov.bc.ca/ric/]

PSG: Pacific Seabird Group.

SPI: Abbreviation for 'Species Inventory'; generally used in reference to the Species Inventory Datasystem and its components.

STRATIFICATION: The separation of a sample population into non-overlapping groups based on a habitat or population characteristic that can be divided into multiple levels. Groups are homogeneous within, but distinct from, other strata.

STUDY AREA: A discrete area within a project boundary in which sampling actually takes place. Study areas should be delineated to logically group samples together, generally based on habitat or population stratification and/or logistical concerns.

SURVEY: The application of one RIC method to one taxonomic group for one season.

SURVIVORSHIP: The probability of a new-born individual surviving to a specified age.

SYSTEMATIC SAMPLE: A sample obtained by randomly selecting a point to start, and then repeating sampling at a set distance or time thereafter.

TERRESTRIAL ECOSYSTEMS TASK FORCE: One of the 7 tasks forces under the auspices of the Resources Inventory Committee (RIC). Their goal is to develop a set of standards for inventory for the entire range of terrestrial species and ecosystems in British Columbia.

YELLOW-LIST: Includes any native species which is not red- or blue-listed.

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Appendix A. Beaufort Scale.

Beaufort scale for estimating wind and sea conditions.

Beaufort	Mariner's description	Wind Speed		Effect of Wind at Sea
		knots	m/s	
0	calm	0-1	0-0.5	like a mirror
1	light air	1-3	0.5-1.5	ripples form with the appearance of scales, but without foam crests
2	light breeze	4-6	2.1-3.1	small wavelets, crests appear glassy, no breaking
3	gentle breeze	7-10	3.5-5.2	larger wavelets begin to break, glassy foam, perhaps some scattered white horses
4	moderate breeze	11-16	5.7-8.2	small waves predomiant but fairly frequent white horses
5	fresh breeze	17-2`	8.7-10.8	moderate waves, distinctly elongated, many white horses, chance of spray
6	strong breeze	22-27	11.3-13.9	long waves with extensive white foam breaking crests begin to form, spray likely
7	moderate gale	28-33	14.4-17.0	sea heaps up, white foam breaking waves start to be blown in streaks, beginning of spindrift
8	fresh gale	34-40	17.5-20.6	moderately high waves with extensive crests, tops of crests break into sprindrift; foam blown into well-marked streaks, spray blown off crests
9	strong gale	41-47	21.1-24.2	high wave , rolling sea, dense streaks of foam, spray may affect visitility
10	white gale	48-55	24.7-28.3	very high waves with long overhanging crests, foam in great patches blown in dense white streaks downwind; heavy rolling sea causes ships to slam, visibility reduced by spray, sea surface takes on whitish appearance
11	storm	56-66	28.8-34.0	exceptionally high waves, sea covered with long white patches of foam blown downwind, everywhere wave crests blown into froth, visibility impeded by spray
12	hurricane	above 66	above 34	air filled with foam and spray, sea entirely white, visibility seriously impaired