Assessment of nesting habitat for Marbled Murrelets in the Coastal Douglas-fir forests of SE Vancouver Island in 1998 and 1999

Final report: July 2000

by

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Report submitted to:

- **Habitat Conservation Trust Fund**
- **Forest Renewal B.C. (Research)**
- **Endangered Species Recovery Fund**
- **World Wildlife Fund Canada**
- **Canadian Wildlife Service**
- **Capital Region District Water and Parks divisions**
- **B.C. Parks**
- **B.C. Ministry of Environment Lands and Parks (Wildlife Branch)**
- **B.C. Ministry of Forests**
- **Weyerhaeuser Ltd.**
- **Department of National Defence**

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1. SUMMARY

We report on a two year study (1998-1999) on the occurrence, distribution, relative abundance and habitat use of Marbled Murrelets *Brachyramphus marmoratus* in the dry Douglas-fir forests of southeastern Vancouver Island. Our study covered the Coastal Douglas-fir (CDFmm) and Coastal Western Hemlock very dry maritime (CWHxm1) biogeoclimatic subzones, between Sooke and Parksville. The Marbled Murrelet is a Threatened and Red-listed species dependent on old-growth coniferous forests for nesting.

Using Sensitive Ecosystem Inventory (SEI) maps along with forest cover maps and aerial photographs, where available, we identified possible mature stands and visited these to check their suitability for nesting. Of 218 stands, 67 were considered suitable for nesting. We discuss the risks of uncritically applying SEI forest data for identifying and mapping potential nesting areas for Marbled Murrelets.

Most of the suitable stands were found in the Greater Victoria Water Supply Area (GVWSA) and adjacent Sooke Hills Wilderness Regional Park. Suitable stands were also located in private lands owned by Weyerhaeuser (formerly MacMillan Bloedel) and in Englishman River Falls Provincial Park.

Observations of murrelets were made in standardised dawn surveys following the RIC (1997) protocol at 49 stations located at suitable stands. Most (34) stations were sampled twice each year during the breeding season to meet the RIC (1997) standards, and a further five stations had evidence of occupancy within the first two surveys in 1998 and were not re-sampled in 1999. Murrelets were detected in 59% of all stations and occupied detections (indicating near-nest behaviour) were recorded at 31% of stations. Occupied detections were found in the GVWSA, Sooke Hills Park and in two of the Weyerhaeuser stands.

Habitat plots were sampled at each station. We found few significant differences in forest characteristics between the CDFmm and CWHxm1 subzones. Plots in the CWHxm1 zone were at higher altitude and had higher densities of Western Hemlock. The levels of human disturbance and predator numbers were significantly higher in the CDFmm subzone.

Frequencies of detections and/or occupied detections were positively associated with altitude, distance from sea, productivity, average diameter at breast height (DBH) of large trees (DBH >60cm), epiphyte thickness, stem density of trees, and density of Western Hemlock. Most of these results are

consistent with those found in other studies, i.e., nesting habitat for murrelets requires large old-growth trees providing suitable nest platforms with epiphyte cover and variable canopy structure. This study does not show nesting and habitat preferences as clearly as do other studies conducted in a wider range of habitats, and where murrelets have a wide choice and are not forced to nest in small remnant stands.

Potential predators of Marbled Murrelets (adults, eggs or chicks) were reported at 98% of the 49 stations, and at 91% of the 168 dawn surveys. Corvids (Common Raven, Northwestern-Crow, and Steller's Jay) and red squirrels were the most common. The occurrence and relative densities of potential predators were considerably higher than in comparable studies from the Carmanah-Walbran forests on SW Vancouver Island. Corvids, in particular, are attracted to human activities and garbage, and unnatural forest edges created by logging or road construction. Their high density in the extremely disturbed and fragmented forests near Victoria indicates that high levels of predation on Marbled Murrelet eggs and chicks are likely. Land management for murrelets should aim to reduce predator abundance near suitable habitat.

Over 90% of trees with suitable nest platforms were Douglas-fir. A total of 32 Douglas-fir trees were climbed in 1998 and 1999 and three nests were found, the first on southeastern Vancouver Island. All nests were in the GVWSA, confirming the importance of these lands for Marbled Murrelets. Nest trees were all larger and structurally more complex than surrounding trees and were partly damaged, with evidence of senescence. Details of the nests are provided.

Forest cover maps, habitat analysis, detections of murrelets and the discovery of three nests all confirm the importance of the GVWSA and Sooke Hills Wilderness Regional Park as the prime remaining habitat for murrelets on southeastern Vancouver Island. Although small, this remnant population of murrelets is important for maintaining the geographical distribution of the B.C. population, and was singled out for attention in the Marbled Murrelet Recovery Plan (Kaiser et al. 1994).

Marbled Murrelets are almost certainly nesting in two forest stands on Weyerhaeuser land, one on the west-facing slope of Koksilah Ridge near Shawnigan Lake and one close to South Nanaimo River near the Nanaimo Lakes. These stands support relatively few murrelets, but given the scarcity of nesting habitat on southeastern Vancouver Island, they are important habitat.

General management guidelines to maintain and restore the remnant murrelet populations on southeastern Vancouver Island include:

- preservation of all remaining stands of old-growth identified as suitable for murrelet nesting;
- establishing adequate buffers of maturing second growth around such old-growth stands;
- establishing larger tracts of older second-growth that will mature into suitable habitat in the next 50-100 years;
- minimising logging, road-building or any other human activities within 500 m of suitable stands;
- minimising human activities (such as camping and picnicking) likely to attract corvids within 1 km of suitable habitat.

The planned raising of the Sooke Lake reservoir with its associated logging will have an impact on habitat suitable for nesting murrelets. We provide specific guidelines for minimising the impacts and disturbance likely to come from this process.

Future work on southeastern Vancouver Island should include:

- completing the two-year survey schedule for the stations established in 1999;
- continued tree-climbing to find and describe more nests in order to get an adequate sample of habitat requirements and nest distribution;
- radar surveys to estimate the actual numbers of murrelets using the GVWSA, Sooke Hills Park and Weyerhaeuser lands;
- continued liaison with land managers (such as CRD Water and Parks Divisions) to assist with incorporation of our management recommendations into long-term management plans for the GVWSA and Sooke Hills Park;
- continued investigation, using forest cover maps, aerial photographs and ground-truthing, to locate and map additional stands of suitable habitat;
- completion of GIS mapping of the suitable stands located in 1998, 1999 and in future years.

2. INTRODUCTION

We report on two years of research (1998 and 1999) covering the presence, distribution, relative densities and habitat use of the Marbled Murrelet *Brachyramphus marmoratus* in the dry Douglas-fir forests of southeastern Vancouver Island. This is the first study of the murrelet, a seabird with threatened status, in this part of its range. Our study covered the remnant old-growth and mature forest up to 20 km inland from Sooke to Parksville. Our work was carried out in the Coastal Douglas-fir (CDFmm) and the associated Coastal Western Hemlock very dry maritime (CWHxm1) biogeoclimatic subzones. Preliminary results from the 1998 season were reported in Burger et al. (1999).

2.1 Background

Marbled Murrelets occur in North America from central California to the Bering Sea, though the bulk of the population is found in B.C. and Alaska (Ralph et al. 1995, Nelson 1997). Murrelets spend most of their time at sea, diving for small schooling fish in nearshore waters. They are unique among temperate seabirds in that they nest in trees, generally on broad, mossy limbs in the canopy of large old-growth coniferous trees, up to 70 km inland from the ocean. A single chick is raised during the breeding season and fed several times a day by both parents. When visiting their nest, murrelets are generally very secretive, making nests hard to find and the birds difficult to observe. The breeding biology of the Marbled Murrelet has in large part been shaped by the risk of nest predation, still the major cause of nest failure (Nelson 1997). This is also the reason for the secrecy surrounding their nesting attempts.

The numbers of Marbled Murrelets in British Columbia have declined over the last 25 years (Ralph et al. 1995). The murrelet is a Red-listed Species in British Columbia (i.e., a species that is a candidate for designation as endangered or threatened), and is listed as nationally threatened in Canada by COSEWIC (Rodway et al. 1992, Kaiser et al. 1994). Loss of nesting habitat due to logging is the main threat facing the bird in B.C., but other threats include increased nest predation due to forest fragmentation, and mortality at sea from oil spills and gill nets. There have been several studies of the Marbled Murrelet in B.C., but none has focused on the dry forests of the Georgia Depression, typified by the CDF zone and CWHxm1 subzone. Although these zones represent a small portion of the bird's potential breeding range, they are likely to support remnants of the dwindling Georgia Depression breeding population, which was identified as a priority for research in the Marbled Murrelet Recovery Plan (Kaiser et al. 1994).

The old-growth forest on the southeast coast of Vancouver Island, within the CDF zone and CWHxm1 subzone, is greatly reduced and highly fragmented as a result of urbanisation, logging, agriculture, roads and other human activities. Old-growth stands often showed evidence of selective logging. Nevertheless, nearshore waters between Sooke and Parksville routinely have moderate densities of at-sea murrelets in summer, and adults carrying fish for nestlings (Burger 1995a, A.E. Burger and J. Clowater, unpubl. data, B. Cousens and G. Monty, pers. comm.), indicating that they breed in the area.

2.2 Project goals

The primary goals of the project, begun in 1998, were to establish the presence, relative densities, and spatial distribution of Marbled Murrelets in southeastern Vancouver Island, map and sample the remnant old-growth nesting habitat, and sample trees for nests.

The main goals of the project in 1999 were:

- to re-sample the stations used in 1998 in order to provide the two years of sampling required by the RIC (1997) standards;
- to establish additional observation stations and habitat plots in the area between Victoria and Nanaimo;
- to produce GIS maps of the distribution of suitable habitat remaining for Marbled Murrelets in the CDFmm and CWHxm1 subzones, and of the distribution of occupied stands where murrelet behaviour indicates nesting. These maps will assist management of remnant old-growth forests in the CDF and CWHxm1 zones;
- to locate nest trees through tree-climbing and describe macro- and micro-habitat features of nest stands, trees and sites.

2.3 Study area

In 1998 the study area was confined to the CDFmm and CWHxm1 subzones in the eastern part of the Capital Regional District (CRD), but in 1999 was expanded northwards to Parksville (see Maps 1 - 3). This area comprises the southern Gulf Islands, the Saanich Peninsula, and a strip of land approximately 20 km wide running from the extreme southern end of Vancouver Island to Parksville (though the CDFmm and CWHxm1 subzones continue further north). The initial focus of the study was the CDFmm subzone but we found that the largest areas of mature forest in the study area were located in the associated CWHxm1 zone. Many mature stands showed characteristics of both subzones, with a substantial transition zone, and we therefore included both in our study. Marbled Murrelets had not been studied in either subzone before. Selective logging and other human influence in many of the forest stands have also influenced the vegetation composition.

3. METHODS

3.1 Site selection and habitat assessment

With limited time and resources for the project we focused our attention on the most likely areas to support nesting murrelets. Areas of forest potentially suitable as murrelet habitat were identified from several sources. For the study area within CRD these included the Ministry of Environment's Sensitive Ecosystem Inventory (SEI) maps and database, also forest cover maps of the Greater Victoria Water Supply Area (GVWSA), Sooke Hills Wilderness Regional Park and the Department of National Defence (DND) sites. We also consulted with staff from CRD Water and CRD Parks, and other people with local knowledge of old-growth stands. For the study area between Victoria and Parksville we used SEI maps and air photos from a 1998 survey by the Ministry of Environment, Lands and Parks (MoELP).

The SEI database was used to produce working maps of forest stands over 100 years old and greater than 10 ha, and was principally used to locate stands outside the GVWSA. Within the GVWSA, Sooke Hills Wilderness Regional Park and DND lands, detailed forest cover maps were used to locate stands, which could be smaller than 10 ha. On the forest cover maps, all stands of age class 7 or higher (120 years and older) and height class 5 or higher (37.5 m and over) were marked for assessment. Stands of height class 4 (28.5 - 37.5 m) were also located if the age class was given as 9 (250 years and older). In the GVWSA, a large fire in the 19th century meant there were no stands of age class 7, so effectively all stands of age class 8 (141 - 250 years) and higher were identified.

During 1998, once forest stands had been identified, they were visited to assess their suitability for murrelet occupation (Burger et al. 1999). To include as many stands as possible, we used very liberal minimal requirements: stands considered to be potentially suitable for nesting were at least 1 ha in size, and included at least 1 potential nest tree per ha. Potential nest trees met the requirements generally found at Marbled Murrelet nests (Hamer and Nelson 1995), and included:

- diameter at breast height (DBH) greater than 60 cm;
- tree height greater than 30 m;

- branches at least 18 cm in diameter to provide suitable nesting platforms at least 10 m above ground level, and/or deformations and mistletoe growths suitable for nesting platforms;
- epiphyte cover on branches.

In 1999 it was possible to correlate SEI maps with air photos from a 1998 MoELP survey which covered the majority of the study area. The air photos were used to assess the quality of habitat within the forest stands identified by the SEI database together with their suitability for murrelet occupation. A stereoscope was used to view the photos, which were taken from 17,000 feet. The canopy variability of the stand, size of the trees within the stand and some limb sizes could be clearly seen. High canopy variability is a good indicator of a forest structure suitable for murrelets, with older trees emergent, canopy openings and trees of many different sizes present. The SEI maps were used as a starting point for habitat location, but examination of the air photos revealed potentially suitable areas of habitat not present on the SEI maps. These were also included in the study.

Once identified as potential murrelet habitat, the forest stands were visited to confirm suitability. Approximately 170 stands were visited for assessment in 1998. In 1999 a further 48 stands were assessed using air photos and 17 were visited for on-site assessment. Weyerhaeuser (formerly MacMillan Bloedel) kindly provided a helicopter to allow aerial checking of potentially suitable stands. A total of seven stands on Weyerhaeuser lands were visited in this way, and five were considered suitable for survey stations. All the forest stands in the study area were within 16 km of the sea and at medium to low elevations, ranging from 0 – 350 m, well within the normal ranges of Marbled Murrelet nests (Hamer and Nelson 1995). Some stands were not checked due to their more remote locations.

3.2 Survey stations

In 1998 41 survey stations were established in and around forest stands within the CRD which met the minimum selection criteria as possible nesting habitat for murrelets. In 1999 a further eight stations were established between Victoria and Parksville (listed in Appendix 1). The number and position of survey stations per stand were selected to effectively survey the whole stand, assuming that each station could sample a circular area of 12.6 ha centred on the surveyor, who should be able to detect murrelets to a distance of 200 m (Ralph et al. 1994). Stations were at least 500 m apart to prevent double recording of murrelets.

Stations were established according to the RIC (1997) protocol. Most were established within 500 m of a road for accessibility. Criteria for station selection included:

- good visibility of the sky over and adjacent to stand;
- minimal noise which might prevent hearing murrelets (e.g., from roads or streams);
- placement within stand where possible, rather than adjacent to the stand;
- placement low in relation to surrounding hills (seeing murrelets in semi-darkness is much more difficult when looking down into dark foliage than when looking up to the paler sky).

Stations were established in a wide range of forest types. Variables measured at each station included elevation, slope, aspect, distance to ocean, distance to creeks/rivers, stand area and timber volume taken from forest cover maps, canopy closure, and estimated tree height (see Appendix 2 for list of variables). Canopy closure at survey stations was an important factor affecting the visibility of passing murrelets. It was estimated by the observer on each survey visit, though in 1998 was calculated using a photographic technique developed at UVic for murrelet studies (Burger et. al. 1999).

3.3 Audio-visual surveys

Audio-visual surveys were carried out using the standard RIC (1997) protocol for intensive surveys, which is derived from the Pacific Seabird Group protocol (Ralph et al. 1994). Intensive surveys sample one survey station per survey visit and aim to establish the probable presence, absence, occupancy, and relative abundance of Marbled Murrelets in a specific tract of land.

In both seasons, members of the field team were trained in survey techniques and vegetation analysis using the RIC training manual for Marbled Murrelets. Audio and video tapes of murrelet activity were used to familiarise team members with calls and behaviour. Practical training was provided by experienced Marbled Murrelet surveyors over the course of three dawn surveys in the Carmanah Valley on the west coast of Vancouver Island, at stations which generally yielded >30 detections per survey.

In 1998, two dawn surveys were completed for each of the 41 stations established. In 1999 an additional two dawn surveys were completed at most stations except for five where proof of occupancy had already been established (multiple occupied detections had occurred on at least one visit in 1998). This completed the minimum requirement for dawn surveys under the RIC protocol (1997). Two dawn surveys were completed for most of the new stations established in 1999. In 1999 the first series of survey visits were made between 13 May and 10 June, with the second series between 3 June and 16 July. Two of the five sites with established occupancy were surveyed on 16 July, with the intention of providing additional information about murrelet use of the stands for the tree-climber. Dawn surveys ran from one hour before sunrise to one hour after sunrise, or 20 minutes after the last detection, for a minimum of two hours. The observer was in place at the survey station a few minutes before the start of a survey to allow preparation time. No dusk surveys were carried out in 1999.

All observations were recorded using a tape recorder. This allowed the observer to continue scanning for murrelets while recording. The measure of murrelet activity was the **detection**, defined as the sighting or hearing of one or more murrelets acting in a similar manner (Paton 1995). A subset of these, called **occupied detections**, included circling flight above or adjacent to a forest stand, any flight below tree-tops (**sub-canopy flights**), and stationary calls coming from a murrelet in the canopy (Paton 1995). Occupied detections were better indicators of near-nest activities than total detections, because they excluded detections in which the birds were not seen (except for the very rare stationary calls), and also excluded direct, high commuting flights of birds probably nesting elsewhere.

For each detection, the following variables were recorded (see Appendix 2 for codes used):

- time of day;
- first and last direction of the bird or its calls;
- number and type of calls;
- number of birds seen (if any);
- behaviour (if birds seen);
- nearest distance (horizontal distance from observer to bird, or if no bird seen, to estimated origin of calling);
- bird height (only when birds seen: measured relative to canopy height at station).

During the survey the observer recorded the weather at the start and finish, and any changes during the survey. The taped observations were transcribed to a data sheet and later entered into an Excel database.

In order to combine the two years of murrelet observation data, an Index of Relative Activity (IRA) for both total detections and occupied detections was derived. This was calculated by:

- first finding the mean detection rates for each station in each year;
- then finding the annual mean rate of detection within each year for the 34 stations which were sampled twice in both years to get a common denominator;
- then finding the IRA for each station within each year. This was the station's annual mean divided by the annual mean for the 34 indicator stations (an index of 1 was equivalent to the overall annual mean of the indicator stations, stations >1 were above average and those <1 were below average);
- the separate indices for 1998 and 1999 were then averaged to produce an overall IRA for each station;
- the process was done separately for total detections (**iradet**) and occupied detections (**iraocc**)..

3.4 Vegetation plots

In 1998 habitat analysis was done at all 41 stations (Burger et al. 1999). In 1999 eight vegetation plots were sampled using the RIC (1997) protocol, one close to each new survey station, within the habitat under observation. At each plot, we completed the Marbled Murrelet Habitat Analysis form (RIC 1997), the Ecosystem Field Form (from B.C. Ministry of Forests) and the Indicator Plant Analysis form used to determine the ecosystem site series (Green and Klinka 1994). The following characteristics were noted within each plot (see Appendix 2 for codes):

- distance to ocean (km);
- canopy closure (estimated percentage averaged at 4-6 points across the plot);
- distance to stream/lake/river (km);
- aspect (NW, SE, etc.);
- slope (in degrees);
- any significant features of the plot (marshy area, fallen trees etc.);
- latitude and longitude (degrees, minutes and seconds);
- biogeoclimatic subzone (CDFmm or CWHxm1; Green and Klinka 1994);
- ecosystem site series determined from moisture and nutrient regimes (Green and Klinka 1994);
- site series pooled into ecosystem productivity units (Green and Klinka 1994: p. 202 for CDFmm and p. 209 for CWHxm1);
- elevation (m);
- site diagram, showing significant features and relation to survey station;

- percentage cover of all plant species present within the plot, plus total percentage coverage of tree, shrub and herb layers (also used in calculation of site series);
- numerical value for a station's location in the valley (valley bottom (B) = 1, lower slopes (L) = 2, upper slopes and ridge tops (U) = 3);
- index value of human disturbance for each station using the following scale:
  - 0 - no trail or road adjacent to station and very limited foot access;
  - 1 - quiet trail or no through road (little used) adjacent to station and limited foot access;
  - 2 - medium-use trail, quiet paved road, limited access dirt road, medium foot access adjacent to station;
  - 3 - continuous and extensive vehicle and foot traffic on roads, trails and other human facilities adjacent to station.

In addition, the following characteristics were recorded for each tree within the plot with a diameter at breast height (DBH) greater than 10 cm:

- tree species;
- DBH (cm);
- stratum reached (emergent, canopy or subcanopy);
- height (m);
- number of limbs providing potential nest platforms (branches, mistletoe growths or limb deformities greater than 18 cm in diameter and higher than 10 m up the tree);
- epiphyte cover on tree branches (where 0 = none, 1 = trace, 2 = 1-33%, 3 = 34-66%, 4 = 67-100%);
- epiphyte thickness on tree branches (where A = sparse, I = intermediate thickness, B = thick mats);
- mistletoe/deformity score (Hawksworth 1977) in which the canopy was divided into three vertical parts; each part was scored separately for mistletoe/deformities (0 = none, 1 = light, 2 = heavy), and the scores totalled to give a range from 0-6.

All characteristics except the first two were estimated as accurately as possible from the ground. In order to focus on large trees, we also analysed data from trees >60 cm DBH separately.

Mistletoe does not occur in Douglas-fir trees in the CDFmm zone (Dr J. Kuijt, UVic, pers. comm.), but many trees showed branch deformities similar to those caused by mistletoe. Mistletoe deformities did occur in western hemlock. Limb deformities were graded in the same way as for mistletoe deformities.

From the field data, we derived a series of measures that described the macrohabitat and topographic features, forest structure attributes, and tree species densities for each station (listed and defined in Appendix 2).

3.5 Analyses and statistical methods

We correlated habitat characteristics with detection frequencies of Marbled Murrelets and the densities of potential predators using Spearman's rank correlation coefficient. We grouped stations by biogeoclimatic sub-zones, location in or out of the GVWSA, presence or absence of Marbled Murrelets, and occurrence or absence of occupied behaviour. Comparisons of habitat characteristics and murrelet activity between groups of stations were tested with two-tailed Student's t-tests for normally distributed variables and two-tailed Mann-Whitney U-tests for non-normal ones. Comparisons among activity levels of this study and west coast studies in pristine areas (Carmanah-Walbran and Ursus watersheds) were based on 1998 surveys and tested with ANOVA's and Tukey multiple comparisons. We used the same tests for comparisons among habitat characteristics from stations below 400m from the three areas. To compare predator activities between southeast and west coast (Carmanah-Walbran) we tested data from 246 surveys in 1998-99 with a Mann-Whitney test. Means are given ± standard deviation unless noted otherwise. Statistical analysis was done using the Excel 97 and SPSS 9.0 statistical packages. Tests were significant if $P < 0.05$. Scatterplots comparing all murrelet and predator measures against the range of habitat measures were plotted, to test for non-linear relationships in the data.

3.6 Potential predators

During the 2-h dawn surveys, the presence, numbers and activities of potential predators (raptors, owls, corvids [ravens, crows and jays], and squirrels) were recorded on tape in the same way as murrelet detections.

3.7 Tree climbing

A specialist tree-climber (Kevin Jordan of Arbonaut Access of Victoria, B.C.) was hired to search selected trees for murrelet nests and make detailed descriptions of the canopy characteristics. All sites chosen for tree climbing in 1999 were within the GVWSA. The climbing was done in October, as access in September (immediately after the breeding season) was not possible due to the high fire hazard. Jordan has extensive experience in locating and describing Marbled Murrelet nests in many parts of B.C. and the U.S.. The areas selected for climbing were all forest stands adjacent to survey stations where occupied detections had been recorded during the 1998 and 1999 seasons. These included stations SL-1A1, SL-SL2, SL-SL3 (located close to the Sooke Lake Reservoir) and stations R-RE1 and R-RW1.

The climber noted the following characteristics for each tree:

- species;
- percentage cover of moss on the upper surfaces of branches, averaged throughout the tree;
- average depth of moss (cm) on branches, averaged throughout the tree;
- percentage cover of lichen on branches, averaged throughout the tree;
- percentage of branches showing mistletoe-like deformities;
- rodent activity (e.g. faeces, chewing, nests), scored as:
    - 0 = no activity;
    - L = low, 1-20% of branches show activity;
    - M = medium, 21-60% of branches show activity;
    - H = high, 61-100% of branches show activity);
- tree height (m), measured by lowering a graduated rope from the top of the tree to the ground;
- number of limbs suitable as potential nesting platforms (as defined in section 3.5.);
- number of suitable nest platforms per limb.

The climber assessed the standard characteristics of the same trees from the ground for comparison, in the same way as for trees in vegetation plots.

4. RESULTS

4.1 Habitat assessment and site selection

A total of 60 stands were assessed as being suitable for murrelet occupancy within the 1998 study area, and 41 survey stations were established. In 1999 an additional seven stands were assessed as suitable habitat. One stand was too remote to access and eight survey stations were established in the remaining six stands. Forty-nine stations were therefore established in both years, of which 27 (55%) lay within the GVWSA and Sooke Hills Wilderness Regional Park. These areas contain the bulk of the remnant older forest in the study area, as identified using the SEI database (see Maps 1 - 3).

When forest stands were assessed as unsuitable, the main reasons were that the identified stands were too small (<1 ha), and/or provided no suitable nesting trees (trees too small and uniform in structure, no suitable nest platforms, and insufficient epiphyte cover). Some forest stands on SEI maps did not have recent air photo coverage or were too remote to access, meaning that no assessment of habitat suitability could be made. These were marked as such on the maps.

Six stands on private land owned by Weyerhaeuser were sampled in 1999. The largest of these lay on the eastern slope of Koksilah Ridge near Shawnigan Lake, with a smaller stand close by. Three survey stations were established here. Close to Nanaimo Lakes were three small stands, each with a survey station. The remaining stand was on the upper slopes of Mount Benson, near Nanaimo. This site was too remote to access, so a survey station was not established there. The last new stand established in 1999, containing two observation stations, formed part of the Englishman River Falls Park. The stand lay on either side of the river, on the slopes of the valley, and formed the largest part of the park.

4.2 Audio-visual surveys

4.2.1 Variation in detection frequencies among stations

Table 1 summarises the results from dawn surveys in 1999, and details of each survey are in Appendix 3. Maps 1 – 3 show mean detection frequencies for 1998 - 99 as black dots, while mean occupied detection frequencies are shown as smaller white dots inside the black dots. The size of the dots indicates the level of detections. A total of 45 stations were surveyed in 1999 and 17 (37.8%)

had detections on at least one visit. Of the 17, eight stations had occupied detections on at least one visit (17.8% of all stations).

Inside the GVWSA, as in 1998, occupied detections indicating likely nesting by murrelets were concentrated in the forest stands along the Goldstream River and Rithet Creek (see Map 3). High frequencies of occupied detections, comparable with those found in prime habitat on SW Vancouver Island (Carmanah and associated areas), were recorded at the Rithet Creek stations (R-RE1 and R-RW1). Eight stations in forest stands adjacent to Sooke Lake reservoir yielded medium levels of detections in at least one season. Occupied detections were recorded at four of these stations (SL-1A1, SL-SL1, SL-SL2 and SL-SL3) in at least one season. The two stations located in the Sooke Hills park in 1998 (N-8N1 and N-8N2) were not resurveyed in 1999 as probable nesting by murrelets had been proved in 1998 with high levels of occupied detections.

Murrelets were recorded at four of the eight new stations established in 1999 (Table 1). Three of the four were on Weyerhaeuser land (stations LL-Clearcut, LL-Forest and NR-Road), while the fourth was in Englishman River Falls Park (station ER-Middle). At stations LL-Clearcut and NR-Road, 27 and seven occupied detections were recorded respectively, indicating likely nesting in the adjacent forest. No behaviour indicating nesting was noted in Englishman River Falls Park or at the remaining Weyerhaeuser station (LL-Forest).

4.2.2 Variation in detection frequencies between years

Murrelet detection rates were lower in 1999 than in 1998, including both total detections (1999: 0.88 ± 2.35, 1998: 1.94 ± 5.11) and occupied detections (1999: 0.07 ± 0.31, 1998: 0.21 ± 1.00). These differences were not statistically significant (total detections Mann-Whitney $U_{134} = 2060$, $P > 0.05$; occupied detections $U_{134} = 2211$, $P > 0.05$), due to the high inherent variation in murrelet activity data. Detections were reported at 50% of the stations sampled in both years in 1998, but only 32% of the same stations in 1999. The same figures for occupied detections were 14.7% in 1998 and 11.8% in 1999. An Index of Relative Activity (IRA) was calculated for total, occupied and subcanopy detections for 1998 and 1999 (see Appendix 4).

4.2.3 Effect of date on detection frequencies

At nearly all of our stations, the frequencies of total, occupied and sub-canopy detections were considerably higher on the second visit (3 June - 16 July) than on the first (13 May - 10 June; see Table 1). This was also the case in 1998 (Burger et al. 1999). These increases probably reflect a combination of factors, including increased activity of adults feeding chicks and increased flights over the forest by non-breeding, prospecting or failed murrelets. The date of survey was not likely to affect comparisons between detection rates and habitat parameters, because nearly all stations were sampled twice and the detection frequencies averaged.

In 1999 the surveys started on 13 May, almost four weeks earlier than in 1998. A cold, wet spring in 1999 meant the start of the breeding season was delayed for many bird species, and likely also Marbled Murrelets. This may have contributed to the lower detection frequencies in the first period of 1999, although the mean detections in the second period were also lower in 1999 than in 1998.

4.2.4 Comparison with activity in optimal habitat on Vancouver Island

In 1998 the numbers of total and occupied detections were significantly higher in the pristine Carmanah-Walbran and Ursus watersheds on the southwest coast of Vancouver Island than in the highly fragmented southeast coast study area (Table 2). Mean total and occupied detections were approximately eight and five times higher in the Ursus valley than on the southeast coast.

4.3 Habitat analysis

4.3.1 Comparison between CDFmm and CWHxm1 vegetation plots

The vegetation surveys gave a mixture of 26 CWHxm1 and 22 CDFmm plots. Although all measures of murrelet activity were generally higher in the CWHxm1 zone, no significant differences were found in the frequencies of total, occupied and subcanopy detections of murrelets in the two sub-zones (Mann-Whitney U-tests, $P > 0.05$ in each case; Table 3). Study areas in the CDFmm subzone showed significantly higher levels of human disturbance and also significantly higher levels of predators, which are often linked to human activity. As expected, the CWHxm1 sites contained more western hemlocks, were further away from the ocean and were found at higher altitudes (differences for the first two were significant, the last one nearly so [$P = 0.065$]). Other interesting but non-significant differences between the two sub-zones were a higher abundance and thickness of epiphyte cover, as well as a higher number of potential nesting platforms in the CDF subzone and a higher mean tree deformity score in the CWHxm1 subzone.

4.3.2 Inter-relationships between habitat characteristics

In the vegetation plots for stations established in 1999, the majority of trees with potential nesting platforms were Douglas-fir (92.3%), as in 1998 (89.9%). Bigleaf maple (5.1% in 1999, 3.4% in 1998) and western hemlock (2.6% in 1999, 0.5% in 1998) also provided potential platforms.

Several significant inter-correlations were found among habitat characteristics known to be important to Marbled Murrelets (Table 4). Interpretation of correlations is risky when so many variables are considered but some consistent patterns emerge. Distance to sea (dissea) was highly significantly correlated with total tree density (densstem) and Western Hemlock density (denwh). These correlations reflect the nature and distribution of the forest stands in the study area. The CDF zone along the coast contains smaller and more fragmented stands than the CWHxm1 subzone further inland, which contains most of the suitable murrelet habitat. Density of trees with platforms (deplattr) was also significantly correlated with ecosystem productivity unit (produnit).

The mean diameter (dbhmean) and height (trheight) of trees were significantly correlated with all measures of platform abundance (poplha, platmn, deplattr), and with epiphyte cover (epimean), though there was no correlation with deformity measurements. Mean height of large trees >60cm DBH (htmeantrees>60) was significantly correlated with mean deformities for trees >60cm DBH (mismn60). These correlations indicate the expected relationships between tree size, platform availability and deformity scores. Large trees provide the most potential nest platforms.

4.3.3 Relationships between detection frequencies and habitat characteristics

Three sets of comparisons were made to investigate possible differences in habitat characteristics:

- stations with some detections against stations with none;
- stations with occupied detections against stations with none;
- stations inside the GVWSA against stations outside.

In the comparison of stations with some detections against stations with none, some differences were found (see Table 5). Stations with detections showed significantly higher mean values for DBH of large trees, epiphyte cover and epiphyte thickness, and also had more mammalian predators than stations without detections.

Stations with occupied detections were at significantly higher altitudes than those with no occupied detections (Table 6). Stations with occupied detections also had a higher density of western hemlocks, were further from the ocean, had higher productivity, higher epiphyte thickness, higher standard deviation in height, and a higher mean deformity index, thought these differences were not significant. In addition fewer bird predators and fewer total predators were found at stations with occupied detections, though mammalian predators were more abundant.

Stations within the GVWSA had significantly higher total detection and occupied detection rates, lower disturbance ratings, and were significantly higher elevations than stations outside the GVWSA (Table 7). Bird predators and all predators combined were higher but did not show significant differences, though mammalian predators did. Large trees (DBH >60cm) in the GVWSA were taller, with higher DBH and DBH variability (standard deviation), together with more and thicker epiphyte cover.

Comparisons between the combined 1998-1999 IRA for total detections (iradet) and occupied detections (iraocc) showed significant positive correlations with several habitat variables (Table 4). The IRAs for total detections were significantly correlated with altitude, DBH of large trees (DBH >60), and epiphyte thickness (epithik). The IRAs for occupied detections were significantly correlated with distance to sea (dissea), productivity (produnit), epiphyte thickness (epithik) and Western Hemlock density (denwh). Of the habitat characteristics linked with high detection and occupied detection rates in other studies, the only one to be so linked in this study was epiphyte thickness. This is likely because of the non-random nature of the sites selected for study, all were selected on the basis of their suitability for murrelet nesting. The positive correlation of occupied detections with Western Hemlock density (denwh) and distance from the sea (dissea) were likely due to the preponderance of suitable forest stands in the CWHxm1 zone, as mentioned previously. We do not recommend that density of Western Hemlock or distance from the sea be used as indicators for locating suitable murrelet nesting habitat.

4.3.4 Comparison of habitat characteristics in our study area and elsewhere

The comparison of habitat characteristics among the southeast coast and the two west coast areas on Vancouver Island yielded surprising results (Table 8). Most of the habitat characteristics known to be important to murrelets were similar in both areas, rather than significantly better in the west coast studies as was expected. The only habitat characteristics significantly lower on the southeast coast were epiphyte cover (epimean) and thickness (epithik), which reflects the drier climate on the southeast coast.

4.4 Potential predators

4.4.1 Occurrence and relative densities of predators and habitat associations

In 1999, as in 1998, the most common predators recorded were Common Raven, North-western Crow, Steller's Jay and Red Squirrel (details in Appendix 5). No significant differences were found between the years in occurrence and numbers of predators, so the data were pooled (Table 9). Ravens were most numerous (mean 1.11 birds per survey), followed by crows (0.95), Red Squirrels (0.51) and Steller's Jays (0.27). These were the only species present in sufficient numbers for statistical analysis.

Total predator frequency averaged at each station was significantly higher in the CDFmm subzone (mean 4.49 ± 3.17 SD) than in the CWHxm1 zone (2.13 ± 1.15; two-tailed t-test: $t_{26} = 3.31$, P = 0.003). Crows showed a highly significant positive correlation with human disturbance, a result of their attraction to human activity (Table 10). Crow numbers also showed a highly significant negative correlation with stand area (starea). This is likely due to the known correlation between increased predator numbers and proximity to stand edges. A smaller forest stand has proportionally more edge than a larger one and will have higher predator numbers as a result.

Potential predators occurred at more stations, in more surveys, and at higher numbers per survey on southeastern Vancouver Island (this study) than in Carmanah-Walbran on the southwest of Vancouver Island (Table 9). Predator numbers per survey showed significant differences between these two areas (two-tailed Mann-Whitney test, $U_{245} = 2534.5$, $P < 0.001$). Clearly murrelets nesting in the fragmented and disturbed forest patches of southeastern Vancouver Island face higher predation risks than those in optimal, less disturbed old-growth forests on the west coast of the island.

4.4.2 Relationships between predator and murrelet detection frequencies

There were no significant differences in mean predator frequencies between stations with and without detections and at stations with (2.64 ± 1.69 predators per survey) and without (3.41 ± 2.85; $t_{47} = 0.98$, P = 0.33) occupied detections, except for higher Red Squirrel numbers at stations with some detections (Table 5). Common Raven and North-western Crow showed significant negative correlations with IRAs for occupied detections (Table 10); i.e., as crow and raven numbers increase, detection levels fall.

4.5 Tree climbing

Tree climbing was carried out for seven days in 1999, during which 17 trees were climbed. Three nests were found, confirming that Marbled Murrelets nest in the GVWSA. These are the first murrelet nests to be found in the CDFmm and CWHxm1 subzones on southeastern Vancouver Island. All trees climbed were Douglas-fir; no other species in the sites used for climbing were regarded as potential nest trees. The stands selected for climbing were in age class 8 (141-250 years) and height classes from 5 (37.5-46.4 m) to 7 (55.5-64.4 m). The mean height of the trees climbed was 54.94 m (SD ± 5.83) and mean DBH was 137.47 cm (SD ± 28.38).

Characteristics of the 15 trees climbed in 1998 and the 17 climbed in 1999 are given in Table 11. Estimates of the tree height made by the ground observer were close to the actual measurements made by the climber, with no significant differences (two-tailed paired t-test, $t_{31} = 0.760$, $P = 0.453$) and a significant correlation (Pearson $r = 0.766$, $N = 32$, $P < 0.001$). Ground observation underestimated the number of limbs as potential platforms compared to those counted by the climber (two-tailed paired t-test, $t_{31} = 2.645$, $P = 0.01$), but the average difference was only one platform limb per tree. The two estimates of potential platforms were significantly correlated ($r = 0.723$, $N = 32$, $P < 0.01$). There was no significant correlation between the ground-based epiphyte score and the estimated moss cover ($r = 0.017$, $N = 32$, $P = 0.926$), lichen cover ($r = 0.264$, $N = 32$, $P = 0.144$) or the mean moss + lichen cover ($r = 0.319$, $N = 32$, $P = 0.076$).

Three nests were found (Table 12). The Douglas-fir trees containing nests appeared older than other trees in the surrounding stands and had more complex structures, with mistletoe deformities and alternative leader growth. Two nests were found in the stand adjacent to station R-RE1 (forest polygon numbers 470 and 800), about 1.5 km up Rithet Creek from its junction with the Sooke Lake reservoir. One nest was found in the stand adjacent to station SL-SL2 (forest polygon number 260), between the Sooke Lake Main road and Begbie Lake at the northern end of the reservoir. Two nests were located on platforms created by large mistletoe-like deformities, while one was on a platform created by the formation of two co-dominant leaders, following the breakage of the original main stem. All three nests were well hidden by overhanging foliage, as is usual for murrelet nests.

From the condition of the nest depression and eggshell fragments found in and around the nest, the two nests at Rithet (R-RE1) were estimated at 1-2 and 2-3 season old, while the nest at SL-SL2 was estimated at one season old. Nesting success was not determined at the two Rithet sites due to the age of the nests. The nest at SL-SL2 was likely not successful, given the small size of the nest depression and large size of eggshell fragments present. Landing pads, where the murrelets alight when visiting the nest, were present at all three nest sites. Samples of nest material and eggshell fragments were collected from all nests, together with detailed descriptions following Pacific Seabird Group (PSG) protocol (updated 1996). These will be archived at the University of Victoria, Department of Biology.

Although small clumps of moss were present on the nest platforms, the nest depressions themselves were located in accumulations of tree debris and needle duff. In forests within our study area, the amount of moss on tree limbs is typically less than that on similar limbs in forests on the wet SW coast of Vancouver Island. In other areas with low epiphyte abundance murrelets tend to nest in alternative substrates such as fallen needles and other loose debris (Hamer and Nelson 1995).

5. DISCUSSION

At the majority of stations we met the minimum number of surveys recommended in the RIC (1997) guidelines, and obtained detailed habitat measures. These data provide a solid basis for our conclusions. For the eight stations first established in 1999, only provisional conclusions can be drawn.

5.1 Nesting in the GVWSA and Sooke Hills Wilderness Regional Park

Marbled Murrelets are nesting in the GVWSA and are almost certainly nesting in the Sooke Hills Wilderness Regional Park, within the CDF and CWHxm1 biogeoclimatic zones. Three murrelet nests were located during tree climbing, all within the GVWSA. Occupied detections indicating nearby nesting were found at 10 stations in the GVWSA and at three stations in the Sooke Hills Park.

The GVWSA and Sooke Hills Park contain the largest and least fragmented remnants of old-growth and mature forest on southeastern Vancouver Island and therefore represent the most important habitat for Marbled Murrelets here. These lands provide multiple stands of old-growth trees suitable for murrelet nesting, combined with restricted human activity which reduces the direct impact of human disturbance (and the indirect impact of increased predator numbers associated with human activity). In addition, large stands of maturing second growth act as buffer zones and as potential future habitat. Murrelet nesting activity was concentrated in slopes immediately adjacent to Goldstream River and Niagara Creek, two forest stands on Rithet Creek, and forest stands adjacent to Sooke Lake Reservoir, though not confined only to these areas (Map 3). These preferred areas containing nesting habitat are critically important for the long-term future of the Marbled Murrelet in the study area.

The relatively small numbers of birds likely to be breeding and the limited extent of suitable habitat suggest that this remnant population requires careful monitoring and management. It represents an important part of the overall distribution of murrelets in B.C. and is part of the Georgia Depression population that was specifically targeted for research and conservation attention by the Marbled Murrelet Recovery Plan (Kaiser et al. 1994). Murrelets were almost certainly far more common and widespread in the CDFmm and CWHxm subzone forests of southeastern Vancouver Island prior to urbanisation and logging, and efforts should be made to restore this population by planning long-term restoration of old-growth forests over the next 100 years. Marbled Murrelets will likely be lost as a breeding species in the GVWSA and Sooke Hills Park unless land management is adapted to accommodate their nesting requirements.

5.2 Likely nesting on Weyerhaeuser lands

Marbled Murrelets are almost certainly nesting in two forest stands on Weyerhaeuser lands. One is on the east-facing slope of Koksilah Ridge near Shawnigan Lake (Map 3) and the other is close to South Nanaimo River near the Nanaimo Lakes (Map 2). These stands support relatively few murrelets, but given the scarcity of nesting habitat on southeastern Vancouver Island, these lands should be considered important for murrelets. Of these two the stand at South Nanaimo River is small and isolated from other stands of suitable habitat in the area. The other, near Shawnigan Lake, is the largest single stand of old-growth in the study area and is close to other stands of suitable habitat outside the study area. Both of these stands are scheduled to be partially logged within the next four years, which would be a significant loss to the overall nesting habitat available to murrelets on the south-east side of Vancouver Island.

5.3 Adverse effects of high predator levels

Potential predators, particularly corvids such as crows, ravens and jays, were found at high levels during our dawn surveys and are likely to adversely affect the nesting success of murrelets in the study area. Levels were much higher than in similar studies in optimal habitat on the southwestern coast of Vancouver Island. Predators, especially corvids, are the main cause of failure for breeding Marbled Murrelets, and were responsible for failure of 43% of 32 nests across the Pacific Northwest (Nelson and Hamer 1995), and 66% of 21 nests in British Columbia (Manley 1999). Management of the GVWSA and Sooke Hills Wilderness Park should therefore prioritise measures to restrict and minimise corvids. They are primarily attracted to discarded food and garbage. No picnic or camping sites, buildings, parking lots or other places where people may discard food should be established within 1 km of suitable murrelet habitat. Hiking trails and other access routes should be more than 500 m from suitable habitat. Research in Carmanah Valley showed that Steller's Jays were primarily concentrated along edges created by clearcut logging and roads (Masselink 1999). Management should ensure that such edges are minimised and do not abut on suitable nesting habitat for murrelets.

5.4 Comparisons with other studies of Marbled Murrelets

Although the GVWSA and Sooke Hills Park contained the best remaining habitat in our study area, frequencies of both detections and occupied detections were considerably lower than in studies made on the west coast of Vancouver Island (Table 2). Even at stations in our study area where murrelets were present, the frequencies of detections were still much lower than on the west coast. This is not surprising since the southwest coast of Vancouver Island supports the highest densities of Marbled Murrelets in B.C. (Rodway et al. 1992, Burger 1995a,b). The extensive stands of old-growth forests there offer large tracts of apparently optimal nesting habitat (Bahn 1998, Bahn et al. 1998, Burger 1994, 1995b, Rodway and Regehr 1998).

There are likely to be many reasons for the differences between the southeast and southwest coasts of the island, including:

- the small total area of remnant old-growth forests remaining in the Douglas-fir forests of southeast Vancouver Island, compared with large tracts on the west coast of the island;
- the small size and isolated nature of old-growth fragments on southeast Vancouver Island, which are less likely to attract murrelets and more likely to attract potential predators;
- the high densities and widespread occurrence of potential predators of murrelets, particularly the corvids which benefit from human activities;
- the drier climate on southeast Vancouver Island which restricts the growth of large trees and epiphyte cover;
- possible differences in the availability of food at sea close to suitable nesting habitats.

Besides epiphyte cover, there were few significant differences between the southeast and west coasts in stand and tree characteristics. Therefore, the small area, high fragmentation and low number of old-growth stands in our study area, combined with high human disturbance and high predator densities were likely the key factors determining the low abundance of breeding Marbled Murrelets.

5.5 Management options and the size of habitat patches

The habitat available to murrelets in our study area is substantially degraded from the optimum. The Identified Wildlife Management Strategy (IWMS) (1998) recommends preserving a minimum of 10-12% of old-growth forest within a Landscape Unit as Wildlife Habitat Areas (WHA's) for Marbled Murrelets. Within the GVWSA and Sooke Hills Park, only about 5.5% of land designated as mature forest >100 years by the SEI database is actually suitable habitat for murrelets. The majority of this is minimally suitable rather than optimal, due to small stand size and removal of potential nest trees by past logging. In addition, the minimum size of WHA recommended for murrelets is 200 ha and >600 m wide. The average size of suitable forest stands within the GVWSA and Sooke Hills Park is approximately 9 ha, ranging from 6 to 35 ha, substantially smaller than the recommended minimum. Although surveys at some of these stands recorded occupied detections, the success of breeding in these stands is probably low and the population viability of the area is unknown. Therefore, breeding activity in these stands should not be taken as a sign that the small stand sizes in the area could replace the minimum stand sizes required by the IWMS. Activity at these stands is more indicative of a lack of larger stands in the area.

Manley (1999) found that murrelet nests in her Sunshine Coast study (with comparable habitat fragmentation and isolation) "appear to be aggregated, are at higher densities and are re-used more frequently than in other locations". All these factors increase levels of predation on murrelet nests, and are also likely to exist in southeastern Vancouver Island. Three nests were found in the 32 trees climbed in our study area, compared with two nests found in 180 trees climbed in optimal murrelet habitat in Carmanah in 1999 (K. Jordan, pers. comm.). This indicates a much higher concentration of nests in our study area, but an increased likelihood that predators would find a nest. Predation risk is likely to be particularly high, given the high relative densities of corvids and squirrels. More dispersed nests would be at lower risk than aggregated nests.

Preserving single wildlife trees, or small wildlife-tree patches is not a viable option for maintaining breeding Marbled Murrelets. Manley (1999) studied a small sample of murrelet nests in wildlife trees and wildlife tree patches retained in harvesting plans on the Sunshine Coast, B.C. These comprised forest retention on a smaller scale than that of Landscape Units (i.e., watershed-level or drainage-level units). Solitary wildlife trees were not re-used by murrelets following logging of the surrounding stand. In some wildlife tree patches, active nests were found close to clearcut edges that were 9 - 10 years old, but several studies have shown that nests in trees close to artificial forest edges are subject to higher rates of predation (Nelson and Hamer 1995, Manley 1999, Manley and Nelson 1999). Manley (1999) concluded that preserving sufficient areas of old-growth forest at a Landscape Unit level was likely to be the most successful strategy for preserving murrelet populations, and that management of single trees and small patches was not sufficient to keep murrelets nesting in an area. Given the present degradation of the habitat on southeast Vancouver Island, the continued existence of Marbled Murrelets as a breeding species in the study area would become more likely with remedial forest management at the Landscape Unit level. We do not recommend management at smaller scales, such as selective logging, wildlife patch/ tree retention because the habitat available in this study area is already substantially degraded from the optimum.

Marbled Murrelets are known to nest at very low densities in optimal habitat (0.18 ± 0.28 nests per hectare per year in Clayoquot Sound; Newsom and Bahn 1999). They do not necessarily return to the same nest tree or forest stand year after year, though re-use of nest trees has been observed to a varying degree in different studies (Manley 1999, Nelson and Peck 1995, Singer et. al. 1995). It is difficult to determine how murrelets disperse in available breeding habitat. Suitable forest stands in our study area, even those without records of occupied detections, should be included in all management plans as buffers and potential future habitat, along with stands where nesting is indicated by occupied detections or nests.

Given that long term plans for the GVWSA and Sooke Hills Wilderness Regional Park do not involve further logging of suitable or potentially suitable habitat, the area of habitat suitable for murrelet nesting is likely to increase in the long-term (50 – 100 years). Human access, however, should be kept to a minimum. This will prevent further increases in the number of predators and the associated risk to murrelet nesting success. Preserving suitable habitat is of little value if predator numbers in the habitat are so high that nesting attempts fail.

5.6 Identifying and mapping optimal nesting habitat within southeastern Vancouver Island

The location of the three nests found confirms that murrelets on southeastern Vancouver Island prefer similar nesting habitat to those elsewhere; i.e., large diameter old-growth / mature conifers with adequate nest platforms. No strong correlations between detection levels and habitat characteristics emerged in this study. This is likely due to two factors. The first was the non-random selection of sites The stations and habitat plots were selectively placed to maximise our chances of finding murrelets, and hence did not cover the full range of habitats available to murrelets in the area. Random selection of sites to ensure a mix of stations in optimal and sub-optimal habitat was not an option in this pilot study; any habitat meeting minimum selection criteria for murrelet occupancy was likely to have a station located in or near it anyway. Multi-year studies in the Carmanah-Walbran (Burger 1994, 1995b, unpubl. data) and the Ursus valley (Bahn 1998, Bahn et al. 1998) on the west coast of Vancouver Island indicate that habitat characteristics important for murrelets do not emerge as significant until both optimal and sub-optimal habitats are analysed. The habitat characteristics known to be important to nesting murrelets (Hamer and Nelson 1995, Nelson 1997, Manley 1999) i.e., old trees, variable canopy structure, large limbs or limb deformities providing nesting platforms, were present at similar levels in this study and in other studies of optimal nesting habitat. It is assumed that such habitat characteristics are similarly important in this study area.

A second factor contributing to the paucity of significant correlations between habitat features and detections was the lack of choice afforded the murrelets in this greatly depleted and fragmented habitat. Given limited choice in nesting habitat, there was unlikely to be a strong relationship between habitat and detection rates when the sample included mostly forest patches assessed as suitable for nesting.

Although the SEI database was used as a starting point for locating forest stands, it was not a reliable or comprehensive source of information on habitat for breeding murrelets. SEI maps were useful for identifying non-suitable habitat (i.e., habitat younger than 100 years) but not useful to identify suitable habitat for several reasons. The forest stands present in SEI maps were often found to be smaller and more fragmented in air photos of the same areas. Conversely, some stands of mature forest identified from forest cover maps and air photos were not present on SEI maps. However, these inaccuracies were less important than the habitat classification used in the SEI database. The maps in this database show forest stands of trees older than 100 years, but of this mature forest, only about 5.5% can be considered old-growth forest and suitable habitat for Marbled Murrelets. Forest stands assessed as suitable habitat are shown on Maps 1 - 3, and the difference in area between these and stands older than 100 years can be clearly seen.

The forest cover maps showing stand age and height class within the GVWSA and Sooke Hills Park were not always reliable indicators of suitable murrelet nesting habitat either. Although all the stands deemed suitable after inspection by the ground crew were included in the initial map selection, the majority of stands selected on the maps did not meet the minimum selection criteria when checked on the ground. Ground-truthing is an essential component in the selection of suitable habitat.

We consider that site series data (Green and Klinka 1994) should be used with caution in the present study area. The process used to identify a site series for a plot assumes that climax vegetation is present. In the greater part of the southeast coast study area, selective logging and other human use have altered the species composition of stands, sometimes greatly, so site series data cannot be relied on.

6. MANAGEMENT RECOMMENDATIONS

Although small, this remnant population of murrelets is important for maintaining the geographical distribution of the B.C. population, and was singled out for attention in the Marbled Murrelet Recovery Plan (Kaiser et al. 1994). Management of the forests to maintain and restore the remnant murrelet populations should include:

- preservation of all remaining stands of old-growth identified as suitable for murrelet nesting;
- establishing adequate buffers of maturing second growth around such old-growth stands (see below);
- establishing larger tracts of older second-growth that will mature into suitable habitat in the next 50-100 years;
- minimising logging, road-building, trail-building or any other human activities within 500 m of suitable stands;
- minimising human activities (such as picnicking and camping) likely to attract corvids within 1 km of suitable habitat.

Within the study area, stands of mature second-growth should be preserved to ensure suitable habitat for murrelets in the long-term and act as buffers for existing old-growth. In time this will raise the total amount of murrelet habitat closer to the minimum 10-12% suitable or originally suitable habitat recommended by the Identified Wildlife Management Strategy as Wildlife Habitat Areas for Marbled Murrelets at Landscape Unit level. These guidelines recommend the preservation of large stands (ideally 200 ha and >600 m wide, but smaller if no large stands are available). Ideally they should be established immediately adjacent to presently suitable habitat or in close proximity (within a 2 km radius).

If logging or road building are necessary near suitable murrelet habitat, we recommend the following guidelines to minimise disturbance:

- restrict logging to areas 200 m outside the boundary of suitable habitat;

- for work involving heavy plant or powered equipment (such as chainsaws, mowing machines, generators), use and store machinery at least 200 m from suitable habitat during the murrelet breeding season. If work closer to habitat is unavoidable during the breeding season, limit work to the afternoon when adult birds are least likely to visit the nest and disturbance is minimised;
- human access to suitable habitat should be outside the breeding season. If access to habitat during the breeding season is unavoidable, activity, and the effects of any activity, should be limited to the afternoon.

Raising the water level in the Sooke Lake reservoir will have an impact on suitable habitat for murrelets. To lessen this impact we recommend:

- compensate for lost habitat by increasing protection and buffer zones for remaining habitat;
- in areas of suitable habitat which will be flooded by the raise, keep felling to a minimum, following the line of the new water level precisely;
- noise such as chainsaw or automobile engines is higher than background noise up to 175 m away and has been shown to disturb nesting murrelets (Hamer and Nelson 1998). In areas to be flooded, fell only during fall and winter to avoid disturbance during the murrelet breeding season (February - August);
- ensure that new access roads are routed at least 100 m from stands of suitable habitat. Carry out road work in fall and winter to avoid disturbance during the breeding season. If work during the breeding season is unavoidable, roads should be routed 200 m from suitable habitat.
- in upgrading or changing existing road-use where roads are 100 m or closer to suitable habitat, carry out work in fall and winter to avoid disturbance during the breeding season
- visual disturbance by humans has a greater effect on nesting murrelets than noise disturbance (Hamer and Nelson 1998), with human activity close to nests most disturbing of all. To minimise human disturbance, continue to restrict human access to the GVWSA and Sooke Hills Park.
- new picnic areas and campsites should be at least 1 km away from suitable murrelet habitat, and new trails should be routed at least 500 m away. This will help to minimise the impact of human-associated predators on nesting murrelets. Any increase in camping, picnicking or other human activities likely to attract crows, ravens or jays would be detrimental to murrelets.

7. CONCLUSIONS AND FUTURE WORK

Our study proved for the first time that Marbled Murrelets nest in the dry Douglas-fir forests on southeastern Vancouver Island, although the present population is clearly a small remnant restricted to fragments of remaining old-growth forests. The GVWSA and Sooke Hills Wilderness Regional Park are clearly the most important areas for the murrelets, but the birds almost certainly nest in some of the Weyerhaeuser lands. Habitat features important to murrelets on southeast Vancouver Island are generally similar to those important elsewhere in their range: large trees, variable canopy structure, presence of suitable nest platforms on large limbs or limb deformities. Such characteristics are most likely in old-growth forests and in our area Douglas-fir trees are the most important species. The occurrence and relative densities of potential murrelet predators are high in our study area, indicating a high risk of nest failure. Forest fragmentation and human activities providing food for crows, ravens and jays are probably a major factor.

Our study over two years, with minimal funding, could not cover all the aspects of research and monitoring needed in this area. Future work should include:

- completing the two-year survey schedule for the stations established in 1999;
- continued tree-climbing to find and describe more nests in order to give an adequate sample of habitat requirements and nest distribution;
- radar surveys (Burger 1997) to get an estimate of the actual numbers of murrelets using the GVWSA, Sooke Hills Park and Weyerhaeuser lands.
- continued liaison with land managers (such as CRD Water and Parks Divisions) to assist with incorporation of our management recommendations into long-term management plans for the GVWSA and Sooke Hills Park;
- continued investigation, using forest cover maps, aerial photographs and ground-truthing, to locate and map further stands of suitable habitat;
- completion of the GIS mapping of the suitable stands located in 1998, 1999 and future years.

8. ACKNOWLEDGEMENTS

This project was supported by grants from Forest Renewal B.C. (Research), the Habitat Conservation Trust Fund, the Endangered Species Recovery Fund (World Wildlife Fund Canada and Canadian Wildlife Service), and the CRD Water division. Additional logistical support was provided by the University of Victoria. We gratefully acknowledge the help and support of the friendly staff of the

Ministry of Environment, Lands and Parks (MoELP) air photo library, Jan Kirkby (MoELP), Jack Hull, Tom Tamboline and Judy Auringer (CRD Water), Joel Ussury and Tracy Flemming (CRD Parks), Ron McLaughlin, Pat Philips and Steve Stupich of Weyerhaeuser (with particular thanks for the helicopter trip), Dave Lindsay of TimberWest, Art Robinson (DND Resource Management), Charles Kellogg, Cathy and Arnie of the Kellogg's Saltspring Island property, Dr J. Kuijt and the UVic Communications Office. Special thanks to Kendra Clare, Jennifer Grant, Angeline Tillmanns, Deanna Newsom and Steve Young for their hard work and assistance in 1999. We also thank Kevin Jordan and Stephanie Hughes for the tree-climbing work, and Bruce Cousens, Charlene Lee and Guy Monty of Lee Associates.

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Table 1. Summary of audio-visual surveys, southeast Vancouver Island, 1999. See Burger et al. (1999) for 1998 data.

		Sample period 1 (13 May-10 June)				Sample period 2 (3 June-16 July)				Mean detections per station		
Watershed	Station code	Date	Total detections	Occupied detections	Subcanopy detections	Date	Total detections	Occupied detections	Subcanopy detections	Total detections	Occupied detections	Subcanopy detections
DND	D-RP1	13 May	0	0	0	03 Jun	0	0	0	0	0	0
	D-RP2	13 May	0	0	0	03 Jun	0	0	0	0	0	0
	D-RR1	14 May	0	0	0	04 Jun	0	0	0	0	0	0
Goldstream	G-1N1	24 May	4	2	1	11 Jun	1	0	0	2.5	1	0.5
	G-3N1	27 May	0	0	0	11 Jun	0	0	0	0	0	0
	G-3N2	28 May	1	0	0	11 Jun	2	0	0	1.5	0	0
	G-44A/B	10 Jun	1	0	0	04 Jul	1	0	0	1	0	0
	G-OG2	26 May	0	0	0	18 Jun	0	0	0	0	0	0
	G-P1	16 May	0	0	0	14 Jun	2	0	0	1	0	0
	G-PT1	02 Jun	0	0	0	05 Jul	0	0	0	0	0	0
Humpback	H-HU1	23 May	0	0	0	16 Jun	0	0	0	0	0	0
	H-K1	22 May	0	0	0	17 Jun	0	0	0	0	0	0
	H-K2	21 May	0	0	0	13 Jul	0	0	0	0	0	0
Niagara	N-4N1	16 May	0	0	0	25 Jun	0	0	0	0	0	0
	N-4N2	16 May	2	0	0	25 Jun	0	0	0	1	0	0
	N-NB	15 May	1	0	0	14 Jul	5	0	0	3	0	0
Rithet	R-RE1					16 Jul	76	23	11	76	23	11
	R-RW1					16 Jul	22	6	0	22	6	0
Saltspring Island	S-MAX1	17 May	0	0	0	01 Jul	0	0	0	0	0	0
	S-MAX2	17 May	0	0	0	01 Jul	0	0	0	0	0	0
	S-MAX3	17 May	0	0	0	01 Jul	0	0	0	0	0	0
	S-KF	18 May	0	0	0	02 Jul	0	0	0	0	0	0
	S-MP1	18 May	0	0	0	02 Jul	0	0	0	0	0	0
	S-MW	18 May	0	0	0					0	0	0
Small Parks	P-FK1	14 May	0	0	0	04 Jun	0	0	0	0	0	0
	P-JD1	14 May	0	0	0	15 Jun	0	0	0	0	0	0
	P-ML1	13 May	0	0	0	03 Jun	0	0	0	0	0	0
Sooke Lake	SL-6S1	1-Jun	1	0	0	09 Jul	0	0	0	0.5	0	0
	SL-LR1	31-May	0	0	0	08 Jul	0	0	0	0	0	0
	SL-PR1	2-Jun	0	0	0	22 Jun	0	0	0	0	0	0
	SL-PR2	2-Jun	0	0	0	21 Jun	1	0	0	0.5	0	0
	SL-SL1	1-Jun	2	0	0	07 Jul	5	1	0	3.5	0.5	0
	SL-SL2	1-Jun	1	0	0	06 Jul	6	1	1	3.5	0.5	0.5
	SL-SL3	01 Jun	10	0	0	19 Jun	14	1	1	12	0.5	0.5
Veitch	V-SH1	15 May	0	0	0	26 Jun	0	0	0	0	0	0
	V-V1	29 May	0	0	0	20 Jun	0	0	0	0	0	0
	V-V2	15-May	0	0	0	26 Jun	0	0	0	0	0	0
Englishman River Falls	ER-Camp	9-Jun	0	0	0	30 Jun	0	0	0	0	0	0
	ER-Middle	9-Jun	0	0	0	30 Jun	1	0	0	0.5	0	0
Lois Lake	LL-Bluff					28 Jun	0	0	0	0	0	0
	LL-Clearcut	07 Jun	0	0	0	28 Jun	28	27	2	14	13.5	1
	LL-Forest	7-Jun	0	0	0	28 Jun	2	0	0	1	0	0
Nanaimo River	NR-Clearcut	8-Jun	0	0	0	29 Jun	0	0	0	0	0	0
	NR-Junction	8-Jun	0	0	0	29 Jun	0	0	0	0	0	0
	NR-Road	8-Jun	0	0	0	29 Jun	11	7	0	5.5	3.5	0
Mean			0.55	0.05	0.02		4.02	1.50	0.34	3.31	1.08	0.30
% stations with detections			21.4	2.4	2.4		34.1	15.9	9.1	37.8	17.8	11.1
Excluding stations surveyed in 1999 only												
Mean			0.66	0.06	0.03		3.75	0.89	0.36			
% stations with detections			25.7	2.9	2.9		30.6	13.9	8.3			
1998 mean			2.17	0.32	0.12		4.29	0.95	0.49			
1998 % stations with detections			31.7	14.6	4.9		56.1	24.4	14.6			
(Sample period dates and stations surveyed will differ between years)												

Table 2. Comparison of habitat and murrelet detection data: SE and SW Vancouver Island compared.

	Habitat characteristics					Murrelet detection data	
	Mean tree DBH dbhmean	Mean tree height trheight	Platform density/ha poplha	Mean epiphyte score epimean	Tree density/ha densstem	Total detections totdet	Occupied detections occdet
SE Vancouver Island (this study)							
Mean	56.9	32.4	239.6	1.96	362.4	3.23	0.63
SD	16.2	6.5	136.2	0.52	162.4	7.05	1.75
SW Vancouver Island							
Carmanah-Walbran (Burger unpubl. Data)							
Mean	58.2	30.3	1074.8	2.39	404.3	21.14	2.55
SD	21.1	6.7	1051.0	0.75	121.1	15.81	3.62
Ursus Valley (Bahn 1998, Bahn et al. 1998)							
Mean	40.1	22.9	159.3	2.77	415.4	25.29	3.11
SD	14.0	4.9	149.0	0.59	153.7	29.12	5.40

Table 3. Comparison of habitat characteristics, predator densities and detections of Marbled Murrelets in the CDFmm and CWHxm1 biogeoclimatic subzones. Student's t-tests used for normally distributed variables, and Mann-Whitney U test used for non-normally distributed variables.

	Mean ± SD				
Variable	CDFmm	CWHxm1	Statistic	P value	N
Macrohabitat/topographical features					
disturbance	1.82 ± 1.05	1.19 ± 0.94	U46 = 192.0	**0.045***	48
starea	20.47 ± 25.86	16.84 ± 21.62	U24 = 80.0	0.850	26
volha	947.9 ± 169.8	1003 ± 203.1	t24 = 0.74	0.464	26
age	7.92 ± 0.28	8.07 ± 0.26	U26 = 84.0	0.516	28
htmap	5.69 ± 0.85	5.93 ± 0.80	t26 = 0.77	0.448	28
altitude	164.1 ± 94.49	212.4 ± 63.72	t36 = 1.90	0.065	39
dissea	2.56 ± 2.42	8.61 ± 4.84	U45 = 73.5	**0.000****	47
disfresh	0.23 ± 0.42	0.12 ± 0.14	U37 = 154.5	0.363	39
slope	12.09 ± 6.49	9.56 ± 7.76	t45 = 1.20	0.235	47
produnit	2.45 ± 0.51	2.42 ± 0.70	U46 = 280.0	0.892	48
Forest structure attributes					
canclsite	23.33 ± 22.13	22.17 ± 20.95	t38 = 0.17	0.867	40
canclveg	72.73 ± 9.09	72.31 ± 11.86	t46 = 0.14	0.893	48
dbhmean	56.76 ± 17.49	52.01 ± 16.02	t46 = 0.98	0.332	48
dbhmean>60	114.4 ± 18.41	111.4 ± 17.58	t46 = 0.57	0.568	48
dbhstdev	44.65 ± 11.73	42.46 ± 12.10	t46 = 0.63	0.531	48
trheight	31.59 ± 5.95	29.38 ± 8.81	t46 = 1.00	0.322	48
htmeantrees>6	47.43 ± 6.45	45.92 ± 10.10	t43 = 0.63	0.534	48
htstdev	14.21 ± 2.30	14.31 ± 3.72	t46 = 0.10	0.920	48
poplha	264.4 ± 135.8	190.8 ± 152.6	t46 = 1.75	0.087	48
platmn	0.87 ± 0.57	0.62 ± 0.61	t46 = 1.44	0.155	48
deplattr	52.98 ± 32.67	50.38 ± 41.44	U46 = 252.5	0.491	48
epimean	2.00 ± 0.51	1.73 ± 0.43	t46 = 2.00	0.052	48
epimean>60	2.01 ± 0.56	2.07 ± 0.46	t46 = 0.39	0.700	48
epithik	1.20 ± 0.36	1.04 ± 0.26	t46 = 1.74	0.088	48
mismn	0.29 ± 0.33	0.53 ± 0.58	t40 = 1.77	0.084	48
mismn>60	0.67 ± 0.76	1.22 ± 1.27	t42 = 1.83	0.074	48
Tree species densities					
densstem	358.7 ± 175.3	391.1 ± 145.7	U46 = 229.5	0.246	48
densbstem	97.88 ± 38.70	98.62 ± 44.77	t46 = 0.06	0.952	48
dendf	191.7 ± 192.3	146.9 ± 110.5	t46 = 1.01	0.318	48
denwh	7.57 ± 12.53	117.4 ± 122.9	U46 = 37.0	**0.000****	48
Predator densities					
allbirds	3.95 ± 3.28	1.70 ± 0.95	U46 = 124.5	**0.001****	48
squirrels	0.54 ± 0.48	0.43 ± 0.45	U46 = 241.0	0.346	48
allpred	4.49 ± 3.17	2.13 ± 1.15	t26 = 3.31	**0.003****	48
Murrelet detections					
iradet	0.96 ± 1.59	3.48 ± 9.55	U46 = 267	0.675	48
iraocc	1.61 ± 3.56	12.82 ± 35.57	U46 = 249	0.334	48

Significant differences: *P<0.05; **P<0.01

Table 4. Pearson correlation coefficient matrix comparing murrelet detection measures and habitat variables, southeast Vancouver Island, 1998 - 1999.

Significant correlations highlighted. *P<0.05; **P<0.01

			Detections		Macrohabitat/topographical features										Forest structure attributes			Forest structure
Variable		Sample	49	37	49	49	26	26	39	47	39	47	48	49	41	48	48	48
type	Variable	size	IRAdet	IRAocc	meancloud	disturbance	starea	volha	altitude	dissea	disfresh	slope	produnit	vallocno	canclsite	canclveg	dbhmean	dbhmean>60
Detections	IRAdet	49	1.000															
	IRAocc	37	0.793**	1.000														
Macrohabitat/	meancloud	49	0.009	0.258	1.000													
topographical	disturbance	49	-0.125	0.021	-0.007	1.000												
features	starea	26	-0.213	-0.085	0.093	-0.338	1.000											
	volha	26	0.082	0.152	-0.191	-0.032	0.044	1.000										
	altitude	39	0.365*	0.301	0.169	-0.300	0.254	0.392*	1.000									
	dissea	47	0.274	0.306*	0.299*	-0.119	-0.062	0.164	0.187	1.000								
	disfresh	39	-0.004	-0.168	-0.136	0.034	-0.005	0.304	0.180	-0.161	1.000							
	slope	47	0.062	0.105	0.171	0.158	-0.116	0.110	0.046	-0.054	-0.205	1.000						
	produnit	48	0.087	0.295*	0.100	0.150	-0.165	-0.089	0.095	0.079	-0.202	0.013	1.000					
	vallocno	49	-0.001	-0.058	0.008	0.050	0.154	0.197	0.347*	-0.138	0.111	-0.057	-0.140	1.000				
Forest	canclsite	41	0.048	-0.135	-0.336*	-0.264	-0.046	0.483*	0.285	0.193	0.294	-0.079	-0.163	0.313*	1.000			
structure	canclveg	48	0.043	-0.055	-0.370**	-0.298*	-0.002	0.272	-0.025	-0.056	0.005	-0.062	-0.167	-0.065	0.172	1.000		
attributes	dbhmean	48	0.013	-0.063	-0.334*	0.187	0.030	0.025	0.292	-0.427**	0.346*	-0.197	-0.092	0.077	0.018	0.095	1.000	
	dbhmean>60	48	0.290*	0.140	-0.433**	-0.071	0.417*	0.223	0.337*	-0.071	0.256	-0.157	-0.164	-0.082	0.159	0.378**	0.472**	1.000
	dbhstdev	48	0.184	0.024	-0.421**	0.079	0.208	0.301	0.176	-0.221	0.350*	-0.154	-0.234	-0.018	0.164	0.312*	0.742**	0.801**
	trheight	48	-0.188	-0.239	-0.450**	0.068	0.099	-0.113	0.008	-0.394**	0.212	-0.340*	-0.060	-0.091	-0.088	0.165	0.780**	0.401**
	htmeantrees>60	48	0.085	0.045	-0.344*	-0.052	0.208	0.054	0.149	-0.004	0.101	-0.362*	0.115	-0.247	-0.039	0.286*	0.260	0.574**
	htstdev	48	0.235	0.214	-0.162	0.076	-0.107	0.303	0.169	-0.041	0.039	-0.133	-0.011	-0.214	-0.063	0.246	0.539**	0.497**
	poplha	48	-0.161	-0.141	-0.204	0.033	0.423*	0.080	0.135	-0.585**	0.065	-0.005	0.140	0.018	0.030	0.145	0.373**	0.314*
	platmn	48	-0.096	-0.118	-0.232	0.108	0.208	-0.047	0.118	-0.608**	0.201	-0.100	0.079	-0.018	0.007	0.030	0.603**	0.367*
	deplattr	48	0.014	0.075	-0.093	0.060	0.002	0.002	0.421**	-0.394**	-0.072	-0.036	0.376**	0.092	0.046	0.076	0.317*	0.147
	epimean	48	0.190	-0.025	-0.399**	-0.045	0.025	-0.099	0.176	-0.330*	0.042	-0.124	-0.261	0.017	0.041	0.251	0.488**	0.344*
	epimean>60	48	0.154	0.045	-0.163	-0.051	0.066	-0.357	0.030	0.021	-0.035	-0.218	0.031	0.055	-0.106	0.092	0.118	0.198
	epithik	48	0.441**	0.307*	-0.256	-0.045	0.110	0.061	0.276	-0.113	0.065	0.069	-0.074	-0.070	0.044	0.093	0.344*	0.254
	mismn	48	0.144	0.154	0.050	-0.029	-0.132	-0.086	0.199	-0.126	-0.067	-0.272	0.277	-0.045	-0.038	-0.318*	0.221	-0.025
	mismn>60	48	0.075	0.156	-0.016	-0.105	-0.063	0.020	0.135	0.051	-0.115	-0.197	0.268	-0.220	0.064	-0.180	0.018	0.133
Tree species	densstem	48	0.030	0.191	0.223	-0.191	0.178	0.059	-0.063	0.400**	-0.344*	0.135	0.168	-0.062	-0.066	0.184	-0.731**	-0.249
densities	denbstem	48	-0.074	0.020	-0.108	0.219	0.014	0.211	0.164	-0.209	0.059	-0.001	0.096	0.062	0.003	0.118	0.570**	0.035
	dengf	48	-0.269	-0.158	-0.107	0.188	-0.198	-0.045	-0.496**	-0.211	-0.105	-0.032	-0.016	-0.272	-0.098	0.093	0.136	-0.052
	dendf	48	-0.240	-0.081	0.264	0.223	0.005	-0.118	0.064	0.062	-0.034	0.284	0.363*	0.000	-0.135	-0.258	-0.321*	-0.298*
	denwh	48	0.276	0.308*	0.173	-0.367*	0.115	0.223	0.156	0.572**	-0.297	-0.264	0.036	0.070	0.021	0.238	-0.304*	0.026
	denrc	48	0.277	0.166	-0.104	0.019	0.155	-0.119	0.006	0.252	0.118	-0.023	-0.105	-0.264	-0.039	0.363*	-0.020	0.309*

Table 4. Pearson correlatio Table 4 (continued).

Significant correlations highlig Significant correlations highlighted. *P<0.05; **P<0.01

Variable type	Variable	Sample size	Detections: IRAdet	IRAocc	dbhstdev	trheight	htmeantrees>60	htstdev	popltha	platmn	deplattr	epimean	epimean>60	epithik	mismn	mismn>60	Tree species densities: densstem	densbstem	dengf	dendf	denwh
			49	37	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
Detections	IRAdet	49	1.000																		
	IRAocc	37	0.793**	1.000																	
Macrohabitat/	meancloud	49	0.009	0.258																	
topographical	disturbance	49	-0.125	0.021																	
features	starea	26	-0.213	-0.085																	
	volha	26	0.082	0.152																	
	altitude	39	0.365*	0.301																	
	dissea	47	0.274	0.306*																	
	disfresh	39	-0.004	-0.168																	
	slope	47	0.062	0.105																	
	produnit	48	0.087	0.295*																	
	vallocno	49	-0.001	-0.058																	
Forest	canclsite	41	0.048	-0.135																	
structure	canclveg	48	0.043	-0.055																	
attributes	dbhmean	48	0.013	-0.063																	
	dbhmean>60	48	0.290*	0.140																	
	dbhstdev	48	0.184	0.024	1.000																
	trheight	48	-0.188	-0.239	0.550**	1.000															
	htmeantrees>60	48	0.085	0.045	0.345*	0.610**	1.000														
	htstdev	48	0.235	0.214	0.565**	0.448**	0.470**	1.000													
	poplha	48	-0.161	-0.141	0.402**	0.419**	0.304*	0.243	1.000												
	platmn	48	-0.096	-0.118	0.555**	0.568**	0.315*	0.337*	0.893**	1.000											
	deplattr	48	0.014	0.075	0.197	0.257	0.248	0.360*	0.683**	0.584**	1.000										
	epimean	48	0.190	-0.025	0.434**	0.403**	0.185	0.202	0.131	0.256	0.151	1.000									
	epimean>60	48	0.154	0.045	0.132	0.264	0.372**	-0.025	0.102	0.206	0.113	0.509**	1.000								
	epithik	48	0.441**	0.307*	0.345*	0.134	0.026	0.101	0.014	0.126	0.059	0.760**	0.375**	1.000							
	mismn	48	0.144	0.154	-0.006	0.301*	0.233	0.250	0.224	0.236	0.442**	-0.072	-0.068	-0.180	1.000						
	mismn>60	48	0.075	0.156	-0.001	0.219	0.459**	0.252	0.211	0.162	0.437**	-0.111	0.077	-0.194	0.827**	1.000					
Tree species	densstem	48	0.030	0.191	-0.577**	-0.483**	0.013	-0.274	-0.222	-0.556**	-0.051	-0.377**	-0.135	-0.311*	-0.051	0.138	1.000				
densities	denbstem	48	-0.074	0.020	0.296*	0.490**	0.187	0.571**	0.260	0.244	0.465**	0.161	-0.158	0.126	0.301*	0.150	-0.101	1.000			
	dengf	48	-0.269	-0.158	0.054	0.220	0.115	0.177	0.293*	0.273	0.132	0.050	-0.039	-0.148	0.045	0.126	-0.123	0.099	1.000		
	dendf	48	-0.240	-0.081	-0.481**	-0.173	-0.050	-0.127	0.001	-0.180	0.175	-0.365*	-0.194	-0.348*	0.138	0.200	0.496**	0.137	-0.125	1.000	
	denwh	48	0.276	0.308*	-0.033	-0.219	0.070	0.060	-0.227	-0.315*	-0.182	-0.185	0.079	-0.063	0.054	0.119	0.273	-0.172	-0.255	-0.268	1.000
	denrc	48	0.277	0.166	0.110	-0.062	0.238	0.095	-0.112	-0.106	-0.107	0.131	0.239	0.111	-0.429**	-0.293*	0.153	-0.157	0.142	-0.264	-0.079

Table 5. Comparison of habitat characteristics and predator densities at stations with and without detections of Marbled Murrelets. Student's t-tests used used for normally distributed variables and Mann-Whitney U test used for non-normally distributed variables.

	Mean ± SD				
	Stations with no detections	Stations with some detections	Statistic	P value	N
Macrohabitat/topographical features					
disturbance	1.70 ± 1.22	1.34 ± 0.86	U47 = 237	0.253	49
starea	16.03 ± 5.43	18.96 ± 25.26	U24 = 30	0.303	26
volha	990.3 ± 180.9	975.4 ± 192.0	t24 = 0.14	0.887	24
age	8.00 ± 0.63	8.00 ± 0	U26 = 66	1.000	28
htmap	5.33 ± 0.82	5.95 ± 0.79	t26 = -1.7	0.100	26
altitude	151.7 ± 99.71	206.0 ± 68.62	t37 = -2.02	0.051	37
dissea	4.29 ± 4.82	6.79 ± 4.81	U45 = 182	0.067	47
disfresh	0.25 ± 0.51	0.13 ± 0.13	U37 = 142	0.531	39
slope	9.63 ± 6.58	11.50 ± 7.66	t45 = -0.87	0.391	45
produnit	2.45 ± 0.69	2.43 ± 0.57	U46 = 267	0.751	48
Forest structure attributes					
canclsite	20.86 ± 18.90	23.35 ± 22.96	t39 = -0.36	0.719	39
canclveg	71.10 ± 11.00	73.50 ± 10.34	t46 = -0.77	0.444	46
dbhmean	54.85 ± 16.96	53.71 ± 16.81	t46 = 0.23	0.818	46
dbhmean>60	106.1 ± 13.99	117.5 ± 18.98	t46 = -2.28	**0.028***	46
dbhstdev	41.41 ± 12.08	44.93 ± 11.69	t46 = -1.01	0.316	46
trheight	31.55 ± 8.10	29.56 ± 7.33	t46 = 0.89	0.381	46
htmeantrees>60	44.70 ± 8.53	47.98 ± 8.48	t46 = -1.32	0.193	46
htstdev	13.38 ± 3.47	14.89 ± 2.74	t46 = -1.68	0.099	46
poplha	249.8 ± 154.8	206.5 ± 143.6	t46 = 0.99	0.325	46
platmn	0.80 ± 0.56	0.69 ± 0.63	t46 = 0.58	0.564	46
deplattr	56.06 ± 43.14	48.36 ± 32.99	U46 = 250	0.519	48
epimean	1.69 ± 0.55	1.96 ± 0.40	t46 = -2	0.052	46
epimean>60	1.97 ± 0.47	2.09 ± 0.53	t46 = -0.83	0.411	46
epithik	0.99 ± 0.32	1.21 ± 0.29	t46 = -2.53	**0.015***	46
mismn	0.40 ± 0.46	0.43 ± 0.51	t46 = -0.23	0.815	46
mismn>60	0.96 ± 1.05	0.98 ± 1.14	t46 = -0.07	0.945	46
Tree species densities					
densstem	365.2 ± 144.4	384.1 ± 170.9	U46 = 273	0.883	48
densbstem	101.6 ± 41.42	95.94 ± 42.43	t46 = 0.46	0.649	46
dendf	199.8 ± 140.7	144.3 ± 160.3	t46 = 1.24	0.220	46
denwh	44.40 ± 76.82	83.25 ± 121.0	U46 = 224	0.233	48
Predator densities					
allbirds	3.45 ± 3.54	2.14 ± 1.44	U47 = 235	0.257	49
squirrels	0.34 ± 0.47	0.61 ± 0.47	U47 = 184	**0.028***	49
allpred	3.79 ± 3.56	2.75 ± 1.46	t23 = 1.23	0.231	47

*P<0.05

Table 6. Comparison of habitat characteristics and predator densities at stations with and without occupied detections of Marbled Murrelets. Student's t-tests used used for normally distributed variables and Mann-Whitney U test used for non-normally distributed variables.

	Mean ± SD				
	Stations with occupied detections	Stations with no occupied detections	Statistic	P value	N
Macrohabitat/topographical features					
disturbance	1.53 ± 0.74	1.47 ± 1.13	U47 = 241.5	0.770	49
starea	18.46 ± 26.02	18.56 ± 21.62	U24 = 73.0	0.586	26
volha	992.1 ± 174.1	965.2 ± 202.8	t24 = 0.36	0.723	26
age	8.00 ± 0.00	8.00 ± 0.37	U26 = 96.0	1.000	28
htmap	6.00 ± 0.74	5.69 ± 0.87	t26 = 1.00	0.327	28
altitude	225.8 ± 70.09	167.0 ± 85.94	t37 = 2.08	**0.045***	39
dissea	8.00 ± 5.28	4.83 ± 4.52	U45 = 147.5	0.052	47
disfresh	0.09 ± 0.10	0.21 ± 0.36	U37 = 148.5	0.445	39
slope	12.64 ± 8.54	9.94 ± 6.58	t45 = 1.18	0.245	47
produnit	2.71 ± 0.47	2.32 ± 0.64	U46 = 160.0	0.064	48
Forest structure attributes					
canclsite	16.20 ± 18.88	25.24 ± 22.00	t39 = 1.28	0.209	41
canclveg	70.86 ± 10.44	73.18 ± 10.70	t46 = 0.69	0.496	48
dbhmean	51.71 ± 15.42	55.20 ± 17.32	t46 = 0.65	0.516	48
dbhmean>60	116.7 ± 16.23	111.1 ± 18.45	t46 = 0.97	0.335	48
dbhstdev	43.58 ± 11.87	43.42 ± 12.03	t46 = 0.04	0.966	48
trheight	27.98 ± 6.15	31.38 ± 8.04	t46 = 1.42	0.163	48
htmeantrees>60	47.53 ± 8.78	46.24 ± 8.59	t46 = 0.47	0.641	48
htstdev	15.20 ± 2.68	13.88 ± 3.24	t46 = 1.35	0.184	48
poplha	210.9 ± 143.5	230.2 ± 152.0	t46 = 0.41	0.687	48
platmn	0.70 ± 0.61	0.75 ± 0.60	t46 = 0.29	0.777	48
deplattr	57.88 ± 41.80	48.97 ± 35.64	U46 = 215.0	0.606	48
epimean	1.91 ± 0.38	1.82 ± 0.53	t46 = 0.57	0.574	48
epimean>60	2.11 ± 0.43	2.01 ± 0.54	t46 = 0.63	0.530	48
epithik	1.24 ± 0.22	1.06 ± 0.33	t46 = 1.86	0.070	48
mismn	0.60 ± 0.67	0.34 ± 0.38	t17 = 1.34	0.197	48
mismn>60	1.33 ± 1.41	0.82 ± 0.91	t18 = 1.26	0.222	48
Tree species densities					
densstem	423.4 ± 196.1	356.8 ± 139.8	U46 = 193.5	0.319	48
densbstem	102.3 ± 53.35	96.64 ± 36.61	t46 = 0.42	0.674	48
dendf	168.1 ± 202.2	167.2 ± 132.0	t46 = 0.02	0.985	48
denwh	123.7 ± 152.8	43.75 ± 69.24	U46 = 155.5	0.057	48
Predator densities					
allbirds	1.93 ± 1.72	3.01 ± 2.82	U47 = 183.0	0.119	49
squirrels	0.71 ± 0.54	0.41 ± 0.43	U47 = 169.5	0.058	49
allpred	2.64 ± 1.69	3.41 ± 2.85	t47 = 0.98	0.335	49

*P<0.05

Table 7. Comparison of habitat characteristics, predator densities and murrelet detections at stations inside and outside the Greater Victoria Water Supply Area (GVWSA). Student's t-tests used used for normally distributed variables and Mann-Whitney U test for non-normally distributed variables.

	Mean ± SD				
	Outside GVWSA	Inside GVWSA	Statistic	P value	N
Macrohabitat/topographical features					
disturbance	1.86 ± 1.13	1.19 ± 0.83	U47 = 193	**0.028***	49
age	8.00 ± 1.41	8.00 ± 0	U26 = 26	1.000	28
htmap	4.5 ± 0.71	5.92 ± 0.74	t26 = -2.61	**0.015***	28
altitude	128.5 ± 100.3	213.5 ± 60.46	t16 = -2.81	**0.012***	39
dissea	5.61 ± 5.67	5.91 ± 4.33	U45 = 223	0.285	47
disfresh	0.22 ± 0.49	0.14 ± 0.14	U37 = 157	0.719	39
slope	11.62 ± 7.07	10.04 ± 7.42	t45 = 0.74	0.462	47
produnit	2.36 ± 0.58	2.50 ± 0.65	U46 = 246	0.346	48
Forest structure attributes					
canclsite	21.66 ± 20.27	22.75 ± 22.12	t39 = -0.15	0.879	41
canclveg	69.41 ± 9.83	75.12 ± 10.65	t46 = -1.92	0.062	48
dbhmean	51.6 ± 16.07	56.37 ± 17.22	t46 = -0.99	0.329	48
dbhmean>60	103.9 ± 12.71	120.2 ± 18.33	t46 = -3.51	**0.001****	48
dbhstdev	39.8 ± 11.09	46.57 ± 11.79	t46 = -2.04	**0.048***	48
trheight	27.74 ± 7.78	32.63 ± 6.89	t46 = -2.31	**0.026***	48
htmeantrees>60	41.55 ± 8.74	50.9 ± 5.66	t35 = -4.31	**0.000****	48
htstdev	13.26 ± 3.87	15.11 ± 2.03	t31 = -2.02	0.052	48
poplha	205.4 ± 157.8	240.8 ± 140.9	t46 = -0.82	0.415	48
platmn	0.68 ± 0.58	0.79 ± 0.61	t46 = -0.64	0.526	48
deplattr	45.91 ± 40.43	56.35 ± 34.52	U46 = 220	0.165	48
epimean	1.67 ± 0.46	2.00 ± 0.46	t46 = -2.44	**0.019***	48
epimean>60	1.89 ± 0.54	2.17 ± 0.45	t46 = -1.97	0.055	48
epithik	0.99 ± 0.26	1.22 ± 0.33	t46 = -2.67	**0.010****	48
mismn	0.43 ± 0.57	0.4 ± 0.42	t46 = 0.19	0.847	48
mismn>60	0.73 ± 0.92	1.17 ± 1.2	t46 = -1.43	0.160	48
Tree species densities					
densstem	372.9 ± 148.7	379.1 ± 170.2	U46 = 283	0.950	48
densbstem	96.87 ± 42.26	99.47 ± 41.94	t46 = -0.21	0.832	48
dendf	186.2 ± 137.4	151.6 ± 166.8	t46 = 0.78	0.442	48
denwh	56.00 ± 95.08	76.42 ± 114.9	U46 = 234	0.269	48
Predator densities					
allbirds	3.16 ± 3.46	2.28 ± 1.47	U47 = 291	0.904	49
squirrels	0.22 ± 0.36	0.73 ± 0.45	U47 = 100	**0.000****	49
allpred	3.38 ± 3.49	3.01 ± 1.47	t27 = 0.46	0.652	49
Detections					
iradet	0.54 ± 1.67	3.69 ± 9.27	U47 = 115	**0.000****	49
iraocc	4.95 ± 18.81	9.67 ± 31.46	U47 = 191	**0.009****	49

*P<0.05, **P<0.01

Table 8. Comparison of habitat variables on SE Vancouver Island (this study) and those at selected stations (<400 m elevation) on SW Vancouver Island in Carmanah/Walbran (Burger unpubl.) and Ursus Valley (Bahn 1998, Bahn et al. 1998).

ANOVA used to compare data and Tukey multiple comparison test used to show which areas varied. Areas with different letters (a,b etc.) had significant differences, underlined ones were similar.

	SE Vancouver Island (n = 31 stations)		Carmanah/Walbran (n = 22 stations)		Ursus Valley (n = 36 stations)			
	Mean	SD	Mean	SD	Mean	SD	F	P value
Macrohabitat/topographical features								
altitude	195.48 a	75.62	196.36 a	92.66	152.78 a	108.25	2.24	0.112
dissea	5.35 b	4.16	10.74 a	5.97	6.24 b	2.34	12.14	**0.000**
Forest structure attributes								
dbhmean	56.9 a	16.16	58.17 a	21.11	40.07 b	14.00	11.58	**0.000**
dbhstdev	47.10 a	11.38	45.73 a	15.81	29.51 b	13.37	17.41	**0.000**
trheight	32.42 a	6.54	30.25 a	6.72	22.92 b	4.87	23.14	**0.000**
htstdev	14.95 a	2.04	16.28 a	3.21	11.18 b	2.58	31.70	**0.000**
poplha	239.55 b	136.15	1074.75 a	1051.03	159.26 b	149.02	22.58	**0.000**
deplattr	53.35 b	33.23	94.7 a	62.77	48.15 b	31.31	9.37	**0.000**
epimean	1.96 b	0.52	2.39 a	0.75	2.77 a	0.59	14.65	**0.000**
epithik	1.19 c	0.35	1.82 a	0.46	1.57 b	0.37	18.40	**0.000**
mismn	0.38 a	0.42	0.21 a	0.28	0.24 a	0.26	2.12	0.126
Tree species densities								
densstem	362.36 a	162.44	404.29 a	121.06	415.43 a	153.67	1.11	0.333
densbstem	97.75 a	39.86	91.67 a	31.18	31.79 b	16.62	47.98	**0.000**

Table 9. Occurrence of Marbled Murrelet predators per station and per survey on SE Vancouver Island in 1998 & 1999 (168 surveys at 49 stations), with comparative data from murrelet surveys in Carmanah-Walbran in 1994-1997 (392 surveys at 26 stations; A. E. Burger, unpubl. data).

	% occurrence per station		% occurrence per survey		Predator numbers per survey			
	SE Vancouver	Carmanah-	SE Vancouver	Carmanah-	SE Vancouver Is		Carmanah-Walbran	
Predator species	Island	Walbran	Island	Walbran	Mean	SD	Mean	SD
Bald Eagle (*Haliaeetus leucocephalus*)	9.4	7.7	5.4	5	0.08	0.42	0.07	0.28
Cooper's Hawk (*Accipiter cooperii*)	4.7	1.9	2.4	0.2	0.02	0.15	0.01	0.03
Sharp-shinned Hawk (*Accipiter striatus*)	2.0	0	0.6	0	0.01	0.08	0	-
Falcon species	0.0	4.8	0.0	0.8	0	-	0.02	0.08
Western Screech-Owl (*Otus kennicottii*)	6.9	9.6	3.6	5.5	0.04	0.19	0.03	0.09
Northern Pygmy-Owl (*Glaucidium gnoma*)	16.7	12.5	8.9	8.5	0.11	0.36	0.06	0.14
Barred Owl (*Strix varia*)	9.4	0	4.8	0	0.06	0.28	0	-
Great Horned Owl (*Bubo virginianus*)	0.0	8.7	0.0	0.9	0	-	0.05	0.17
Northern Saw-whet Owl (*Aegolius acadicus*)	0.0	1.9	0.0	0.04	0	-	0.01	0.05
Long-eared Owl *(Asio otus)*	2.0	0.0	0.6	0.0	0.01	0.08	0	-
All owls	29.3	28.8	16.7	17.2	0.21	0.50	0.14	0.27
Common Raven (*Corvus corax*)	73.6	20.2	57.7	8.1	1.11	1.30	0.15	0.31
North-western Crow (*Corvus caurinus*)	41.9	5.8	26.8	5	0.95	3.09	0.23	1.07
Steller's Jay (*Cyanocitta stelleri*)	38.9	56.7	22.0	39.5	0.27	0.57	0.72	0.64
Grey Jay *(Perisoreus canadensis)*	4.1	0	1.2	0	0.04	0.39	0	-
All bird predators	95.3	62.5	82.7	62.9	2.69	2.57	1.37	1.55
Red squirrel (*Tamasciurus hudsonicus*)	53.6	41.3	36.3	22.6	0.51	0.77	0.25	0.32
All predators	97.8	67.3	91.1	70.7	3.20	3.64	1.62	1.55

Table 10. Correlation coefficients (Spearman) of predator densities (numbers per survey) compared with murrelet detections and habitat variables on southeast Vancouver Island, 1998-1999.

Variable		No. of stations	Common Raven CORA	NW Crow NWCR	Steller's Jay STJA	All birds allbird	Red Squirrels squirrels	All predators allpred
Detections	IRA totdet	49	-0.175	-0.141	0.230	-0.163	0.258	-0.090
	IRA occdet	49	**-0.286***	**-0.287***	0.025	-0.222	0.229	-0.143
Macrohabitat/ topographical features	meancloud	49	**-0.288***	**-0.314***	-0.202	-0.243	-0.281	**-0.304***
	disturbance	49	-0.109	**0.434****	-0.190	0.030	-0.259	-0.009
	starea	26	0.188	**-0.519****	-0.238	-0.054	0.108	-0.066
	volha	26	-0.052	-0.226	-0.315	-0.185	0.311	-0.119
	altitude	39	-0.014	**-0.436****	-0.018	-0.314	**0.348***	-0.258
	dissea	47	-0.280	**-0.452****	-0.029	**-0.576****	-0.149	**-0.559****
	disfresh	39	0.177	0.045	-0.018	0.077	0.023	0.107
	slope	47	0.009	0.067	0.023	0.062	0.054	0.048
	produnit	48	**-0.366***	-0.093	-0.052	**-0.347***	0.001	**-0.326***
	vallocno	49	0.245	-0.196	**-0.367****	0.032	-0.049	0.009
Forest structure features	canclsite	41	-0.020	-0.097	0.002	-0.121	0.137	-0.113
	canclveg	48	0.227	0.145	**0.375****	0.278	0.148	**0.287***
	dbhmean	48	0.219	**0.319***	0.098	**0.315***	0.202	**0.343***
	dbh60	48	0.057	0.135	0.220	0.027	0.282	0.107
	dbhstdev	48	0.154	**0.295***	0.210	0.219	0.271	**0.286***
	trheight	48	0.260	**0.389****	0.234	**0.344***	0.264	**0.405****
	htmn60	48	0.001	0.236	0.273	0.003	**0.348***	0.110
	htstdev	48	-0.171	0.210	0.190	-0.010	**0.322***	0.065
	poplha	48	0.204	0.221	0.244	**0.299***	**0.346***	**0.354***
	platmn	48	0.173	**0.360***	0.232	**0.365***	**0.353***	**0.420****
	deplattr	48	-0.083	0.034	**0.308***	-0.039	**0.367***	0.018
	epimean	48	0.218	0.191	0.245	0.219	**0.307***	0.260
	epimn60	48	0.024	0.058	0.135	-0.008	**0.290***	0.077
	epithik	48	0.067	0.020	0.226	0.046	**0.351***	0.113
	mismn	48	**-0.307***	-0.050	0.139	-0.213	0.142	-0.170
	mismn60	48	**-0.370****	-0.084	0.220	**-0.309***	0.279	-0.211
Tree species densities	densstem	48	-0.130	**-0.402****	0.008	**-0.289***	-0.151	**-0.313***
	denbstem	48	0.025	0.056	0.056	0.044	0.031	0.042
	dengf	48	0.184	**0.305***	0.181	**0.383****	0.143	**0.394****
	dendf	48	-0.163	-0.131	-0.070	-0.273	-0.166	-0.278
	denwh	48	-0.089	**-0.389****	0.008	**-0.333***	-0.105	**-0.326***
	denrc	48	0.122	0.137	0.185	0.174	0.045	0.159

Significant correlations:*P<0.05, **P<0.01

Table 11. Characteristics of Douglas-fir trees climbed on SE Vancouver Island in 1998 and 1999, comparing assessments made by the tree-climber with ground estimates.
Three variables (epiphyte cover, tree height and number of potential nesting platforms were compared using Wilcoxon Signed Rank Tests.

		Assessments made by tree climber										**Ground-level assessments**						
Year	Tree no.	% moss cover	Mean moss depth (cm)	% lichen cover	Deformity total score	Rodent activity score	Tree height (m)	No of limbs as nest platforms	Platform count per limb x 0	x 1	x 2	DBH (cm)	Stratum reached	Height (m)	No. of limbs as nest platforms	Epiphyte cover: Cover	Epiphyte cover: Thick	Deformity total score
1998	1	30	2	65	0	0	49	7	4	3	0	127	Em	50	2	3	I	1
	2	50	3	40	2	L	46	6	1	5	0	128	Em	50	8	3	I	4
	3	20	2	80	2	0	51	6	0	6	0	129	Em	50	7	3	I	3
	4	25	2	75	1	0	39	9	4	5	0	128	Em	55	7	3	I	1
	5	70	3	45	3	L	56	13	2	11	0	189	Em	50	5	3	I	3
	6	45	3	45	2	0	49.5	7	1	6	0	130	Em	55	4	3	A	4
	7	40	2	30	2	L	55	6	0	6	0	149	Em	55	2	2	A	1
	8	75	3	30	3	L	58	16	0	14	1	169	Em	55	17	4	A	5
	9	40	2	55	1	0	46	4	1	3	0	108	Em	55	2	4	I	5
	10	50	3	55	3	0	47.5	8	1	7	0	110	Em	55	8	4	A	3
	11	30	2	70	3	L	46	5	1	4	0	122	Em	45	6	3	A	4
	12	50	2	70	4	L	39.5	7	0	7	0	75	Em	40	6	3	I	3
	13	35	2	85	4	L	46	11	1	10	0	151	Em	50	5	2	A	3
	14	60	2	35	4	L	32	8	1	7	0	121	Em	30	8	2	I	2
	15	45	2	85	4	0	54	8	0	8	0	134	Em	45	8	3	A	1
1999	1	10	1	40	1	0	63	3	0	3	0	99	Can	60	5	2	I	1
	2	25	1.5	70	6	0	50	10	0	10	0	178	Can	55	8	4	I	6
	3	30	2	80	6	L	51	9	0	7	1	175	Can	56	7	4	I	5
	4	25	2	80	2	0	61	10	4	6	0	165	Em	58	10	4	I	4
	5	20	1.5	80	4	L	58	11	2	9	0	158	Can	60	7	4	I	3
	6	40	1.5	40	0	0	46	5	0	5	0	133	Em	48	4	4	I	0
	7	30	1.5	60	0	0	48	2	0	2	0	139	Em	48	3	4	I	0
	8	30	1	70	0	0	51	8	0	8	0	164	Em	50	9	4	I	0
	9	20	1	80	6	M	53	11	1	10	0	192	Em	52	8	4	I	0
	10	45	2	40	1	0	64	3	0	3	0	117	Can	63	3	3	I	1
	11	55	2	30	2	L	59	6	1	5	0	122	Can	57	5	3	I	4
	12	30	1.5	60	2	0	63	2	0	2	0	114	Can	60	3	3	I	2
	13	30	1.5	55	3	0	58	3	0	3	0	115	Can	56	4	3	I	2
	14	25	1.5	45	1	L	57	4	0	4	0	120	Can	53	3	2	I	2
	15	10	1	70	2	0	48	3	0	3	0	112	Can	50	3	3	I	1
	16	20	2	70	3	0	53	4	1	3	0	116	Can	55	5	4	I	4
	17	65	2.5	40	6	0	51	6	2	4	0	119	Can	48	3	4	I	5
Mean		36.7 a	1.94	58.6	2.6	-	51.5 b	6.91 c	0.88	5.91	0.06	134.6	-	52.2 b	5.78 c	3.25 a	-	2.6
SD		16.5	0.59	18.1	1.8	-	7.3	3.35	1.21	2.94	0.25	27.3	-	6.4	3.07	0.72	-	1.7

Notes for the measures

1) Percentage cover of moss and lichen is average cover throughout the canopy on branches only.
2) Rodent activity is measured as;
   0 - no activity.
   L - 1-20% of branches show activity.
   M - 21-60% of branches show activity.
   H - 61-100% of branches show activity.
3) Platform count per limb is defined as;
   x0 - Potential platforms only, not suitable as real nesting platforms.
   x1 - 1 real nesting platform per branch/mistletoe formation.
   x2 - 2 real nesting platforms per branch/mistletoe formation.
4) Stratum reached: Em = emergent above canopy; Can = canopy tree.

Wilcoxon Signed Ranks Test

a $Z_{31} = 4.5; P < 0.001$
b $Z_{31} = 0.3; P > 0.05$
c $Z_{31} = 2.4; P = 0.017$

Table 12. Details of Marbled Murrelet nests found on SE Vancouver Island in 1999.

	Two nests in the same tree		
Station code	R-RE1 Upper	R-RE1 Lower	SL-SL2
Date nest found	10-Oct-99	10-Oct-99	12-Oct-99
Probable Nesting Year	1996/1997	1997/1998	Likely 1998
Site Characteristics			
Location	GVWSA lands	GVWSA lands	GVWSA lands
Latitude	48 34 22	48 34 22	48 35 13
Longitude	123 43 07	123 43 07	123 40 53
Elevation (m)	235	235	190
Distance to Nearest Surface Water (m)	150	150	80
Distance to Ocean (km)	11.3	11.3	12.5
Aspect (degrees)	260	260	140
Slope (degrees)	0	0	2
Nest Tree Characteristics			
Species	Douglas-fir	Douglas-fir	Douglas-fir
Tree Condition	Alive	Alive	Alive
DBH (cm)	119.2	119.2	165
Height (m)	51 (40 with lean)	51 (40 with lean)	61
Canopy Layer	Overstorey	Overstorey	Overstorey
Canopy Lift (m)	10	10	27
Crown Ratio (%)	80	80	55
Nest Height/Crown Height (%)			
Total Number of Platforms	6	6	10
Moss Cover (%, all limbs)	65	65	25
Lichen Cover (%, all limbs)	40	40	80
Trunk Diameter at Nest Limb (cm)	43.2	56.2	84.5
Nest Limb Characteristics			
Limb Condition	Healthy, upturned co-dominant leader	Healthy, turns upwards	Healthy, mistletoe-like deformity
Height at Nest Limb (m)	40 (32 with lean)	32 (29 with lean)	38.75
Limb Diameter at Trunk (cm, including n	57	42	n/a
Limb Diameter at Nest (cm, proximal an	57, 57	42, 42	n/a
Nest Limb Length (m)	8.5	6.4	n/a
Limb Aspect (degrees)	270	90	65
Moss Cover on Nest Limb (%)	1	1	5
Lichen Cover on Nest Limb (%)	99	90	70
Landing Pad Present?	Yes	Yes	Yes
Distance from Nest (cm)	4.50	20	5
Landing Pad Dimensions (cm)	10 x 8	12 x 8	10 x 8
Nest Cup Characteristics			
Nest Cup Materials	Dead needles, small twigs	Mostly needle duff, some moss and lichen	Needle debris
Excrement Present?	No	No	No
Eggshells Present?	Yes	Yes	Yes
Distance from Trunk (cm)	0	0	67
Platform (cm) - length	30	30	30
- width	19	14	20
- depth	6	4	3.6
Access to Platform (degrees)	345	340	160
Inside of Nest Rim (mm) - length	80	70	60
- width	75	65	55
-depth			20
Vertical Cover (%)	95	65	95
Distance Above Nest (m)	0.12	1.5	0.45
Average Depth Materials (mm)	20	18	25
Moss Depth Adjacent to Nest (mm)	38	10	30

Appendix 1. List of survey stations on SE Vancouver Island used in 1998 and 1999.

Station no.	Watershed	Station Code	Lat./Long.	UTM (m E / m N)	Station Description
1	Goldstream	G-1N1	48*28'07" / 123*35'45"	455958 / 5368564	On road 1N
2	Goldstream	G-3N1	48*28'26" / 123*35'50"	455864 / 5369139	On road 3N
3	Goldstream	G-3N2	48*28'12" / 123*35'12"	456636 / 5368707	On road 3N
4	Goldstream	G-44A/B	48*27'45" / 123*34'50"	457086 / 5367870	On log in middle of swamp
5	Goldstream	G-OG2	48*28'20" / 123*36'10"	458106 / 5367547	On Old Government Road
6	Goldstream	G-PI	48*27'35" / 123*34'00"	455443 / 5368957	At Goldstream pipeyard
7	Goldstream	G-PT1	48*27'43" / 123*33'20"	458934 / 5367801	On Prospectors Trail under powerline
8	Humpback	H-HU1	48*26'50" / 123*33'30"	458712 / 5366153	On gravel bed at Humpback Reservoir
9	Humpback	H-K1	48*27'15" / 123*33'53"	458250 / 5366935	On rocky bluff on hillside
10	Humpback	H-K2	48*27'20" / 123*34'11"	457881 / 5367086	Under powerlines on road 5K
11	Niagara	N-4N1	48*28'45" / 123*33'53"	458270 / 5369714	On log in middle of swamp
12	Niagara	N-4N2	48*28'54" / 123*34'05"	458026 / 5369994	In clearing on hillside
13	Niagara	N-8N1	48*29'45" / 123*34'24"	457643 / 5371571	On road 8N
14	Niagara	N-8N2	48*29'30" / 123*34'15"	457825 / 5371107	On road 8N
15	Niagara	N-NB1	48*28'45" / 123*33'27"	458802 / 5370080	On Niagara Trestle Bridge
16	Small Parks	P-FK1	48*29'00" / 123*26'45"	467050 / 5370400	On lawn next to caretakers house, Francis King
17	Small Parks	P-JD1	48*36'47" / 123*27'48"	467050 / 5384600	In John Dean Park parking lot
18	Small Parks	P-ML1	48*21'52" / 123*35'45"	455750 / 5356950	Beach at Matheson Lake
19	Small Parks	P-RR1	48*26'18" / 123*28'50"	464500 / 5365300	In field by tennis courts, Royal Roads University
20	Saltspring	S-Max1	48*47'57" / 123*30'43"	462400 / 5405300	Rocky bluff at cliffs edge, Mt. Maxwell
21	Saltspring	S-Max2	48*47'56" / 123*30'15"	463200 / 5405300	In clearing on Peak Trail, Mt. Maxwell
22	Saltspring	S-Max3	48*47'50" / 123*30'0"	463300 / 5405100	In field at base of Mt. Maxwell
23	Saltspring	S-MW	48*46'39" / 123*32'43"	459900 / 5402850	On Matheson Manor Wharf
24	Saltspring	S-MP1	48*45'23"/123*34'43"	461159/5400505	In clearing in Mill Hill Parks Reserve
25	Saltspring	S-KF	48*45'32"/123*33'10"	459350 / 5400800	In upper field of Kellog's property
26	Veitch	V-V1	48*25'22" / 123*36'10"	455400 / 5363474	On long in middle of swamp
27	Veitch	V-SH1	48*24'50" / 123*36'42"	454739 / 5362484	On log in middle of swamp
28	Veitch	V-SH2	48*24'58" / 123*36'23"	455320/ 5362733	On Rocky bluffs on hillside
29	Rithet	R-RE1	48*34'20" / 123*42'53"	447281 / 5380144	In clearing on hillside
30	Rithet	R-RW1	48*35'13" / 123*43'30"	446535 / 5381800	On gravel bed near Rithet Creek
31	Rithet	R-RB	48*33'45" / 123*42'35"	447640 / 5379066	In clearing near Rithet Bridge
32	Rocky Point	D-RP1	48*18'50" / 123*35'09"	456750 / 5351350	In clearing on rocky bluff, Rocky Point.
33	Rocky Point	D-RP2	48*18'52" / 123*34'00"	457880 / 5351400	At juction of roads, Rocky Point
34	Sooke Lake	SL-1A1	48*32'25" / 123*41'33"	448884 / 5376590	On road 1A1 near Daisy Creek
35	Sooke Lake	SL-6S1	48*34'40" / 123*40'24"	450336 / 5380746	In clear-cut
36	Sooke Lake	SL-LR1	48*34'28" / 123*38'58"	452091 / 5380360	On Landing road
37	Sooke Lake	SL-PR1	48*33'36" / 123*41'20"	449171 / 5378744	End of a rocky point at Sooke lake
38	Sooke Lake	SL-PR2	48*34'32" / 123*39'28"	451477 / 5380477	On log in middle of swamp
39	Sooke Lake	SL-SL1	48*34'55" / 123*41'37"	448840 / 5381223	On Sooke Lake Main near gravel pit
40	Sooke Lake	SL-SL2	48*35'19" / 123*40'53"	449757 / 5381956	On Sooke Lake Main
41	Sooke Lake	SL-SL3	48*34'58" / 123*40'25"	450316 / 5381302	On gravel bed near Judges Creek
Stations first established in 1999					
42	Englishman	ER-Camp	49*15'06" / 124*21'00"		In small blow-down clearing adjacent to Site 15
43	River Falls Pk	ER-Middle	49*14'52" / 124*20'06"		Adjacent to stand in clearcut clearing
44	Lois Lake	LL-Bluff	48*42'57" / 123*45'00"		On one of rocky bluffs on edge of stand
45	Lois Lake	LL-Clearcut	48*42'43" / 123*45'00"		In SE corner of small clearcut at road end
46	Lois Lake	LL-Forest	48*42'27" / 123*45'07"		In small clearing in stand close to top edge
47	Nanaimo River	NR-Clearcut	49*05'25" / 124*07'54"		On clearcut road close to stand
48	Nanaimo River	NR-Junction	49*04'34" / 124*04'45"		In clearing adjacent to stand
49	Nanaimo River	NR-Road	49*04'02" / 124*05'14"		On road adjacent to stand

Appendix 2. Codes used in main habitat analysis database, southeast Vancouver Island. See Methods section for further explanations.

Code	Explanation
Macrohabitat/topographical features	
watershed	Watershed name
site	Site code
meancloud	Mean cloud cover during surveys (%)
disturbance	Disturbance code for stations (0=none, 1=low, 2=medium, 3=high)
starea	Area of the sampled stand (ha)
volha	Timber volume per ha from logging maps
age	Tree age class from logging maps
htmap	Tree height class from logging maps
altitude	Altitude (m)
dissea	Distance to sea (km) - direct to nearest ocean
disfresh	Distance to stream/lake/river (km)
slope	Slope in vegetation plot (degrees)
aspect	Aspect (compass bearing)
sseries	Site series
produnit	Productivity unit measurement drawn from site series
valloc	Location in valley (B = valley bottom, L = lower 1/3, U = upper 1/3, R = ridge top)
vallocno	Location in the valley given as numerical code (B=1, L=2, U=3) for analysis
Forest structure attributes	
canclsite	Average canopy closure at observation site (%) - from 5 photos (1998 only)
canclveg	Average canopy closure in the habitat plot (%)
dbhmean	Mean diameter at breast height (DBH) in cm
dbhmean>60	Mean DBH (cm) per plot for trees greater than 60 cm DBH
dbhstdev	Standard deviation of tree dbh
trheight	Mean tree height (m)
htmeantrees>60	Mean tree height (m) in plot for trees over 60 cm DBH
htstdev	Standard deviation of tree height (m)
poplha	Density of platforms per ha
platmn	Mean no. of platforms per tree
deplattr	Density of trees with platforms per ha
epimean	Mean cover code of epiphytes per plot
epimean>60	Mean cover code of epiphytes per plot for trees over 60 cm DBH
epithik	Mean thickness of epiphytes
mismn	Mean mistletoe/deformity score
mismn>60	Mean mistletoe/deformity score for trees over 60 cm DBH
Tree species densities	
densstem	Density per ha of all trees in veg plot
densbstem	Density per ha of all trees >60cm dbh
dengf	Density per ha of Grand Fir
dendf	Density per ha of Douglas-fir
denwh	Density per ha of Western Hemlock
denrc	Density per ha of Western Red-cedar
denblm	Density per ha of Big-leafed Maple
denra	Density per ha of Red Alder
denarb	Density per ha of Arbutus

densp	Density per ha of Shore Pine
denwp	Density per ha of White Pine
densw	Density per ha of Scouler's Willow
Predator densities	
BAEA	Mean number of Bald Eagles recorded per station
COHA	Mean number of Cooper's Hawks recorded per station
SSHA	Mean number of Sharp-shinned Hawks recorded per station
LEOW	Mean number of Long-eared Owls recorded per station
WSOW	Mean number of Western Screech-owls recorded per station
NPOW	Mean number of Northern Pygmy Owls recorded per station
BAOW	Mean number of Barred Owls recorded per station
CORA	Mean number of Common Ravens recorded per station
NWCR	Mean number of North-western Crows recorded per station
STJA	Mean number of Steller's Jays recorded per station
GRJA	Mean number of Grey Jays recorded per station
GWGU	Mean number of Glaucous-winged Gulls recorded per station
allbirds	Mean number of bird predators recorded per station
mammals	Mean number of mammal predators recorded per station
allpred	Mean number of predators recorded per station
Detections	
totdet	Mean number of detections per station
iradet	Index of relative abundance (IRA) for total detection rates
occdet	Mean number of occupied detections per station
iraocc	Index of relative abundance (IRA) for occupied detection rates
occnot	Presence of occupied detections at station (0 = no occupied detections, 1=occupied detections)

For Appendices 3-5 see Excel files or pdf files

Maps are separate too