

Using Multi-Scale Inventory and Research to Conserve Marbled Murrelets in Clayoquot Sound, British Columbia

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ABSTRACT

The marbled murrelet (*Brachyramphus marmoratus*) is a threatened species in Canada and is Red-listed in British Columbia. Clayoquot Sound on Vancouver Island, an area of high profile forest conflicts, supports one of the largest concentrations of breeding marbled murrelets in North America. In 1994, the Province of British Columbia appointed a Scientific Panel to make recommendations regarding forest management in Clayoquot Sound. One of the recommendations from the Clayoquot Scientific Panel was “to ensure that particular species known or suspected to be at risk are monitored and their habitats protected.” Our goal is to provide quantitative information on the importance of Clayoquot Sound and habitats within Clayoquot Sound for marbled murrelets. We gathered data at a full range of spatial scales over 3 years using different inventory techniques. At the regional level over multiple years, we used boat surveys to estimate total numbers and marine distribution of the murrelets, allowing comparisons with other regions and estimations of population trends. At the watershed level, we used high frequency radar to count numbers of murrelets entering each watershed and correlated these numbers with large scale vegetation and topographic parameters such as amount of valley-bottom timber. At the forest stand level, we conducted standard audiovisual surveys to determine site nesting occupancy and to compare relative densities of marbled murrelet detections with a range of macro- and microhabitat parameters. We studied nesting density in an Ursus River valley-bottom site with high numbers of detections. Sea surveys showed a significant variation in year-to-year numbers and distribution of marbled murrelets. Using sea survey and radar data we estimate the population of marbled murrelets in Clayoquot Sound to be 6,000–8,000 birds. High radar detection numbers in a watershed correlated with size of watershed and amount of remaining valley-bottom timber. We found that “occupied” marbled murrelet detections were significantly correlated with large (both tall and large diameter) moss-covered coniferous trees in valley-bottom forest stands. A combination of ecosystem classification and 3 years of detection data was used in a geographic information system (GIS) mapping analysis to rank and map habitats of importance to marbled murrelets in the Ursus watershed. Tree-climbing of random trees with potential platforms demonstrated that in this undisturbed west coast watershed, marbled murrelets nest in very low densities. We continue to use this information in the planning processes that delineate protected habitat and management zones for marbled murrelets in Clayoquot Sound, and other coastal areas of British Columbia.

Key words: at-sea surveys, *Brachyramphus marmoratus*, Clayoquot Sound, conservation, inventory, marbled murrelet, multi-scale.

The marbled murrelet (*Brachyramphus marmoratus*), a seabird of the family Alcidae, is listed as threatened by the Committee on the Status of Endangered Wildlife in Canada

(COSEWIC) and is on the British Columbia Red List of species at risk (i.e., considered for legal designation as either extirpated, endangered, or threatened). Loss of nesting habitat in coastal old-growth forests is recognized as the principal threat to the species in British Columbia (Rodway et al. 1992) and elsewhere (Ralph et al. 1995). Clayoquot Sound has long been recognized as supporting large populations of

breeding marbled murrelets (Sealy and Carter 1984, Rodway et al. 1992, Burger 1995). Minimum estimates from sea surveys during the breeding season have ranged from 2,600 to 4,500 birds (Sealy and Carter 1984, Kelson et al. 1995). There is evidence that the Clayoquot population is declining, and loss of nesting habitat in old growth is suggested as a cause of decline (Kelson et al. 1995).

Little was known about the inland distribution and habitat requirements of the murrelets within Clayoquot Sound when we began work in 1996. However, it was recognized that Clayoquot Sound's intact old-growth forests and abundance of near-shore feeding habitats were important to North American populations of marbled murrelets (Rodway et al. 1992).

Our 3-year inventory and research program began in May 1996 as part of the government's commitment to implement recommendations of the Scientific Panel for Sustainable Forest Practices in Clayoquot Sound (1995) for sustainable ecosystem management. The marbled murrelet inventory primarily addressed Recommendation 8.3.2: to "ensure that particular species known or suspected to be at-risk are monitored and their habitats protected" and Recommendation 7.16 which states: "at the watershed level map and designate reserves in which no harvesting will occur to protect red- and blue-listed species [and] late successional forest with forest interior conditions." In addition, we worked to address silvicultural recommendations 3.6 and 3.8: to assist in identifying retention areas with significant wildlife resource values and assist in selecting specific structures and patches to meet ecological objectives.

The program was designed to provide empirical data for ongoing monitoring of murrelets, both inland and at sea, and for assessing the effects of changes occurring in Clayoquot Sound. As well, our study provides tested methodologies which can be applied to conservation of marbled murrelet nesting habitat in coastal temperate rain forests throughout its range.

The objectives of our work were to:

1. estimate the total number of marbled murrelets found in Clayoquot Sound in summer;
2. estimate the numbers entering Clayoquot Sound watersheds during the breeding season, and assess the relative importance of each watershed as nesting habitat;
3. determine which parts of selected watersheds are most important to nesting murrelets;
4. identify critical macro- and microhabitat features and mapped ecosystem or forest vegetation units that provide high quality marbled murrelet nesting habitat;
5. determine nesting density of various ecological units, and describe nest stand, and nest tree characteristics;
6. assess the risks of predation to nesting marbled murrelets in a wide range of habitats;
7. assess how clearcut logging and forest fragmentation affect population densities, nest site selection, and predation

risk in marbled murrelets;

8. monitor distribution and densities of marbled murrelets at sea including juvenile recruitment; and
9. assess seasonal and annual variations in all measurements, the factors causing these variations, and the effects of the variations on inventories and management decisions.

STUDY AREA

The study area (Fig. 1) is located in Clayoquot Sound on the west coast of Vancouver Island, British Columbia (latitude: 45°00'–49°30'N; longitude: 125°20'–126°30'W). The area is a maze of islands, inlets, and coastal temperate rain forest watersheds which are classified predominantly within the Coastal Western Hemlock (CWH) biogeoclimatic zone (Green and Klinka 1994) and the Windward Island Mountains Ecoregion (Campbell et al. 1990). This is the rainiest zone in British Columbia and climate is characterized by cool summers and mild winters (Meidinger and Pojar 1991). The area we sampled ranged in elevation from 0 to 730 m, but mountains in the area range up to 1800 m. The vegetation of Clayoquot Sound is comprised of dense coniferous forest with trees ≤ 70 m in height and ≤ 2.5 m in diameter. The understory of these forests is characterized by a dense tangle of shrubs, deadfall trees, and moss. Clayoquot Sound contains several watersheds which have not been accessed for forest harvesting or other industrial development (Moore 1991). These intact watersheds form a substantial proportion of intact watersheds remaining on the west coast of North America.

METHODS

To meet objectives, we conducted several multi-scale inventories over each of the 3 years of the study. Each sub-study had a leader providing scientific direction. Detailed discussion of methodology can be found in Clayoquot Sound Marbled Murrelet Inventory for 1996 (Burger et al. 1997), 1997 (Chatwin et al. 1999), and 1998 (Bahn and Newsom in press).

SEA SURVEYS

In 1996, a quadrat survey of the entire Clayoquot Sound was conducted in a similar manner to sea surveys conducted in 1982 (Sealy and Carter 1984), 1992 and 1993 (Kelson and Mather in press) to compare distribution and abundance of marbled murrelets from year to year.

Standard sea surveys (Resources Inventory Committee 1995) were conducted in small boats from mid-May, every 2 weeks until at least mid-August. Fixed-width transects were used to estimate relative and absolute abundance (birds/km²), spatial and temporal distribution, habitat use, and breeding chronology. The southern (Tofino) route (1996, 1997, and 1998) went from Tofino, south to Portland Point, around

Vargas Island, and back to Tofino. The second set of surveys (1997 and 1998) circumnavigated Flores Island. Both routes covered exposed coastal waters and sheltered channels.

RADAR INVENTORY

Mobile high frequency marine surveillance radar units were used to sample up to 19 watersheds units in 1996, 1997, and 1998. As we were using a relatively new method for estimating populations of murrelets entering a watershed, we investigated the most appropriate sampling times, effects of weather, and various measures for estimating numbers. The scanner was generally set on a platform above the ground at the mouth of an inlet to provide a clear view across the expected flight path of murrelets to the watershed. We

surveyed 2 hours before dawn and 1 hour afterwards and also at dusk. Only pre-sunrise counts were used to estimate mean and maximum counts per watershed. Comparisons among years and within seasons were done with paired *t*-tests. Maximum and mean counts of murrelets were compared with areas of logged, immature, mature/old growth, total forest, freshwater, other habitat (alpine, rock, ice), and total area of watershed.

INLAND AUDIOVISUAL SURVEYS

Inland audiovisual surveys (Resources Inventory Committee 1995) were conducted at 177 stations throughout Clayoquot Sound over 3 years, during the breeding season (15 May to 15 July). In 1997, the most extensive and intensive year of

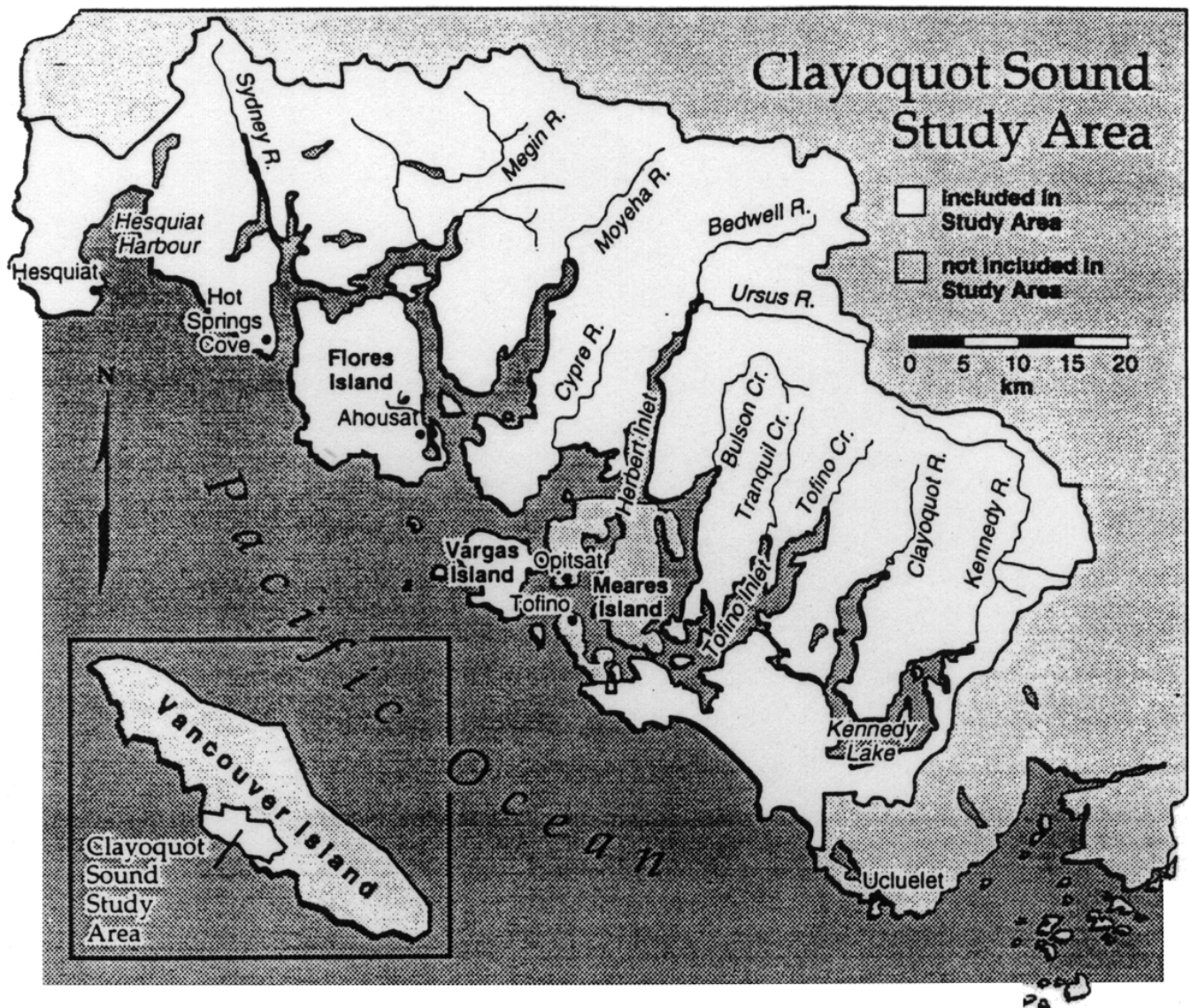


Figure 1. Clayoquot Sound study area.

sampling, stations were sampled 3 times over the season to control for variation in activity due to date. Surveys were conducted from 1 hour before to 1 hour after sunrise by trained observers. Murrelet behaviour and distance from observer, weather, number and species of potential predators, and standard landscape parameters were measured. Vegetation characteristics were measured in 30 X 30 m plots adjacent to each survey station. Ecosystem units were determined through examination of species composition, soils, and moisture regime. An in-depth statistical analysis of the relationship of occupied detections (detections indicative of nesting including landing in a tree, flights below canopy, and circling above a stand) to a suite of habitat characteristics was done using hierarchical regression models. Forest structural characteristics were compared with location in valley and subzone variants using 1-way analysis of variance (ANOVA).

NESTING DENSITY STUDY

Twenty random plots were selected in valley-bottom and lower slope habitat (10 in each habitat type) in the Ursus Valley Special Management Area. The 12 coniferous trees with platforms closest to the plot centre were climbed and inspected for marbled murrelet nests. In 1998, 4 lower slope and 4 valley-bottom slope plots were climbed before weather closed in on climbers. An initial nesting density was calculated based on nests found over areas sampled in 1998, and observer bias in estimating platforms was calculated by comparing actual platform counts by climbers to platform estimates from the ground.

INTENSIVE MONITORING OF MARBLED MURRELETS IN THE URSUS VALLEY SPECIAL MANAGEMENT AREA

During breeding season from 1995 (see Burger et al. 1995) through 1997, audiovisual surveys were conducted in combination with vegetation plots at 51 stations in a wide range of elevations, slopes, and ecosystems types across the Ursus Valley. We correlated murrelet activity with habitat at stations. Using the mapped ecosystem unit polygons (Clement 1995) and the murrelet activity data, we mapped and ranked polygons to indicate the most important areas for nesting murrelets. As well, we compared annual variation in murrelet activity at 12 survey stations that were surveyed every year between 1995 and 1998.

TESTING PREDICTIONS ON NESTING HABITAT QUALITY

In 1998, we tested our ability to predict murrelet activity and habitat quality based on a single mapped forest characteristic. This analysis was based on polygons and habitat variables found on the Vegetation Resource Inventory maps (B.C. Ministry of Forests 1998). We chose to use the height of the dominant tree species as our predictive characteristic, as an analysis of 118 Ursus River vegetation plots showed that this mapped characteristic was most strongly correlated with

habitat features thought to be important to murrelets, such as the amount of epiphyte cover, number of potential platforms, standard deviation of tree height (a measure of canopy complexity), and timber volume. We tested our predictions by simultaneously surveying murrelet activity in polygons in Bulson Creek and Flores Creek 6 that appeared to have good habitat and poor habitat (i.e., fell into different tree height categories). As well, we surveyed the vegetation characteristics associated with murrelet nesting (platforms, tree diameter, epiphyte cover, tree height, and species) in various mapped polygons considered to be good, moderate, or poor habitat (again based on tree height categories) in the Ursus watershed and looked for differences among the categories. Each mapped polygon in the Ursus watershed was evaluated using an index created from spatial and mapped attributes thought to be associated with nesting. (See Bahn [1998] for details of the Habitat Suitability Index.)

RESULTS

AT-SEA SURVEYS

Marbled murrelets are abundant in Clayoquot Sound between mid-May and mid-July, then decline dramatically in the latter part of the summer. The quadrat census of the entire Clayoquot Sound (650 km²) in 1982, 1992, 1993, and 1996 showed declines in total numbers of murrelets in the most populated inshore waters since 1982 (Fig. 2). The 1996 count of 4,036 murrelets was 22% less than the 1982 count of 5,178. Kelson and Mather (1999) attribute this observed decline to loss of nesting habitat from high rates of logging which occurred from 1982 to 1993. Mortality due to sports-

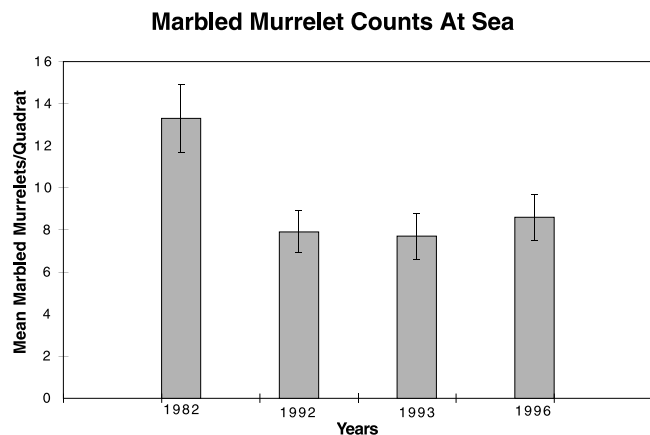


Figure 2. Means and standard errors of marbled murrelets per quadrat of at-sea surveys in the 4 years sampled. Means were significantly different (ANOVA, $df = 3$, $F = 5.22$, $P < 0.05$). Sheffe's pairwise comparisons indicated that numbers in 1982 were greater than in 1993.

Table 1. Means of all counts, means of maximum counts, and percentage of total counts at 19 watersheds in Clayoquot Sound in 1996–1998.

Station	Dawn surveys (Pre-sunrise count)				Dusk surveys			
	Overall mean	%	Mean of maximum	%	Overall mean	%	Mean of maximum	%
Atleo	87	1.9	118	2.1	56	4.5	69	3.9
Bedwell	361	7.8	441	8.0	139	11.2	303	17.2
Boat Basin	206	4.5	331	6.0	83	6.7	89	5.0
Bulson	326	7.1	412	7.4	96	7.8	158	9.0
Clayoquot River	385	8.3	494	8.9	52	4.2	75	4.2
Cow Bay	259	5.6	259	4.7	30	2.4	30	1.7
Cypre	42	0.9	63	1.1	31	2.5	40	2.3
Flores #6	108	2.3	120	2.2	32	2.6	45	2.5
Hesquiat Pt. Cr.	160	3.5	196	3.5	26	2.1	26	1.5
Kennedy	276	6.0	334	6.0	73	5.9	85	4.8
Meares (Lemmen's)	83	1.8	83	1.5	21	1.7	21	1.2
Megin	415	9.0	430	7.8	118	9.5	160	9.1
Moyeha	472	10.2	596	10.8	159	12.8	270	15.3
Pretty Girl	222	4.8	260	4.7	31	2.5	39	2.2
Sydney	180	3.9	225	4.1	44	3.6	52	2.9
Tofino Creek	212	4.6	213	3.8	36	2.9	46	2.6
Tranquil	172	3.7	268	4.8	47	3.8	63	3.6
Watta	628	13.6	650	11.7	155	12.5	182	10.3
Watta SE	30	0.7	45	0.8	9	0.7	12	0.7
Totals	4,624	100	5,537	100	1,238	100	1,765	100

fishing bycatch, the Nestucca oil spill, and an increase in water temperatures, which affects prey availability, are also mentioned as contributing factors to declines.

Season average for the Tofino transect ranges from 6.5 birds/km² in 1996, 8.9 birds/km² in 1997, to 9.1 birds/km² in 1998. Season average for the Flores Island transect ranges from 8.0 birds/km² in 1997 to 9.5 birds/km² in 1998 (Diggon et al. in press). The areas used by marbled murrelets tend to shift periodically through the season. However, the areas around islets off the southwest coasts of Wickaninnish Island, Vargas Island, and Flores Island, as well as Calmus Passage, had high densities of marbled murrelets in all years. In 1997, the juvenile percentage was 2% on the Tofino transect and 3% on the Flores transect. In 1998, the juvenile percentage was 5% for both transects. Further monitoring is required to assess long-term population trends.

WATERSHED RADAR COUNTS

Dawn counts of murrelets were consistently higher than dusk counts, but both counts produced a consistent ranking of watersheds (Table 1). In most dawn surveys there was a unimodal pre-sunrise pulse of incoming murrelets, but a few surveys found a second post-sunrise pulse. We therefore used pre-sunrise counts when making estimates of mean and maximum number of murrelets entering a watershed. We

found no effect of date on dawn counts between 14 May and 16 July and this core period was used to compare watersheds. The radar inventory showed that over 4,600 marbled murrelets (mean of the sum of annual mean counts per station) and perhaps as many as 5,500 (sum of mean of annual maximum counts) were using the 19 watersheds. This count includes nonbreeding murrelets. Considering the areas not sampled with radar, the regional population of Clayoquot Sound is estimated to be at least 6,000–8,000 breeding and nonbreeding marbled murrelets.

About 80% of the marbled murrelets counted were at 7 watersheds: Moyeha, Watta, Megin, Clayoquot, Kennedy, Bedwell-Ursus, and Bulson rivers, as well as Boat Basin, and Flores Island. Numbers of murrelets per watershed were positively correlated with the area of remaining mature and old-growth forest (>140 years old).

Stations sampled over 2 years showed no significant difference between the years in total maximum or mean counts. However, there were some changes among watersheds between years. This indicates that while the total number of marbled murrelets remained constant in Clayoquot Sound between 1996 and 1998, there was movement of murrelets between watersheds in the various years. Therefore, multiyear radar sampling is required to correctly assess the relative importance of watersheds.

INLAND INVENTORY: MARBLED MURRELET ACTIVITY, AND STRUCTURAL CHARACTERISTICS OF OLD-GROWTH FORESTS

Numbers of occupied, within 50 m, and sub-canopy detections, all considered to be indications of marbled murrelet nesting, were positively related to forest structural characteristics known to be important to nesting murrelets (Hamer and Nelson 1995), especially density of trees with platforms (a branch over 18 cm in diameter including branch and moss that could be used by a nesting marbled murrelet), density of trees over 80 cm diameter at breast height (dbh), and mean diameter of all trees (Rodway and Regehr 1999b).

Numbers of occupied, within 50 m, and sub-canopy detections were greater at valley-bottom stations located at stream channels. It could not be determined if this activity was associated with local habitat use or with flight corridors (Rodway and Regehr 1999a) used to access other parts of the valley. However, most structural characteristics associated with known murrelet sites, such as high mean tree diameter, greater epiphyte cover, and high density of large trees (trees >80 cm diameter), were more prevalent in valley-bottom than slope habitats. Density of trees with potential nesting platforms decreased with distance from major streams.

Biogeoclimatic subzone variant CWHvm1 had higher numbers of detections than other subzones (CWHvm2 and CWHmm1). Within this subzone variant the High Bench Floodplain Sitka Spruce/Salmonberry site series rated highest for structural characteristics important to nesting murrelets. Low numbers of detections at stations close to the ocean edge at outer coast CWHvh1 habitat, lower densities of trees with potential nesting platforms at the ocean edge, and elevated predator levels at the ocean edge all suggest that perimeter forest along the ocean would be poorer habitat for murrelets. Vegetation site series with poorer nutrient and moisture regimes generally rated poorer for forest structural characteristics important to nesting murrelets. However, differences in occupied, within 50 m, and sub-canopy detections between vegetation site series were generally not discernible.

Numbers of detections tended to be highest in Bulson, Flores Creek 6, Ursus, Hesquiaht Point, and Sydney watersheds. Forest stands fragmented by logging had significantly lower detection rates than unfragmented forests, and the murrelet predators, Steller's jays and northwestern crows, were more frequent in areas fragmented by logging.

Numbers of detections were highly variable and were influenced by weather, date, opening size, and the placement of survey stations. The general association with forest characteristics and habitat use by marbled murrelets suggests that structural characteristics may be a more useful method than inland surveys for differentiating and prioritizing murrelet breeding habitat at stand scales.

NESTING DENSITY STUDY

Although the nesting density study is not complete, 93 coniferous trees with platforms were climbed in 4 valley-bottom and 4 lower slope plots. The total area of valley-bottom plots and lower slope plots climbed was 130,000 m². In this area, 3 marbled murrelet nests were found; 2 were in large diameter western redcedars in lower slope plots and 1 was in a large diameter Sitka spruce in a valley-bottom plot. We found that actual platform counts made by tree climbers were significantly higher than ground observer platform counts.

The calculated nesting density for lower slope and valley bottom habitat is 0.18 (SE = 1.39) nests/ha/year. Applying this density to the areas of "excellent" habitat derived from the habitat suitability evaluation in the Ursus Valley (Newsom and Bahn 1999) and comparing the 355 nests with the radar estimate of 446 marbled murrelets entering the Ursus watershed (Burger in press), we recognize that the nesting density mean is probably high overall. However, this is the first unbiased estimate of nesting density in an unfragmented forest and it is encouraging that this estimate is not entirely inconsistent with radar estimates. Nesting density estimates are used to correlate the amount of suitable habitat with number of nesting murrelets and make more informed management decisions.

INTENSIVE MONITORING OF MARBLED MURRELETS IN THE URSUS VALLEY SPECIAL MANAGEMENT AREA

Average total, occupied, and sub-canopy activity levels in the Ursus Valley fluctuated between 1995 and 1998. Generally, activity levels were high in 1995 and 1997 and lower in 1996 and 1998. These annual differences were significant ($P < 0.05$) for total detections and log-transformed occupied detections. However, individual station means for all measures of activity were not significantly different for any station. The relative importance of each station and geographical area within the Ursus Valley varied from year to year. For example, survey stations within the Thunderbird Creek tributary accounted for over 50% of total occupied activity in 1997, but less than 15% in 1998. The variability in relative amounts of occupied activity at both individual survey stations and areas may indicate that marbled murrelets shift their breeding focus among years (Bahn and Newsom in press). Shifting nesting areas could be a predator avoidance strategy, but also emphasizes the need for caution in determining critical habitat areas based on 1 season's activity monitoring, and the possibility that marbled murrelets may need large areas to ensure breeding success.

TESTING PREDICTIONS ON NESTING HABITAT QUALITY

The number of occupied and sub-canopy detections were significantly higher in polygons where the Vegetation Resource Inventory maps showed average tree height was >35 m than in those mapped polygons where average tree

height was <26 m. Abundance of habitat variables predicted to be important for marbled murrelet nesting such as the density of trees with platforms and epiphyte abundance correlated with height of dominant trees on the Vegetation Resource Inventory maps. The values for these variables were significantly different among tree height classes; as expected, polygons with leading species over 35 m high had the highest number of platforms and thick epiphytes, followed by polygons with leading trees 26–35 m high, and finally polygons with leading trees <26 m high. In general, the height category 26–35 m contained variable nesting habitat for murrelets. The vegetation structure data from plots was used to construct a habitat suitability model for use with GIS polygon data from the Vegetation Resource Inventory (Bahn and Newsom in press). The model calculates a suitability index for each polygon based on tree age, height, basal area, vertical complexity, canopy closure, distance to the sea, and average altitude of the polygon. Nesting habitat suitability

was then applied as 4 classes (unsuitable, sub-optimal, important-good, important-high) to the Ursus watershed (Fig. 3) and other areas in Clayoquot Sound.

CONCLUSIONS

1. Marbled murrelets are abundant in Clayoquot Sound in May through July. Although numbers of birds at-sea appeared to decline from 1982 to 1992, numbers remained relatively constant from 1996 to 1998.
2. We advanced the use of radar as a method of assessing populations of marbled murrelets at the watershed scale. The population of marbled murrelets in Clayoquot Sound is estimated to be 6,000–8,000 birds. Large and intact watersheds containing mature and old-growth forests support most of this population.
3. Correlation of audiovisual surveys and vegetation plots confirmed the association of marbled murrelet nesting

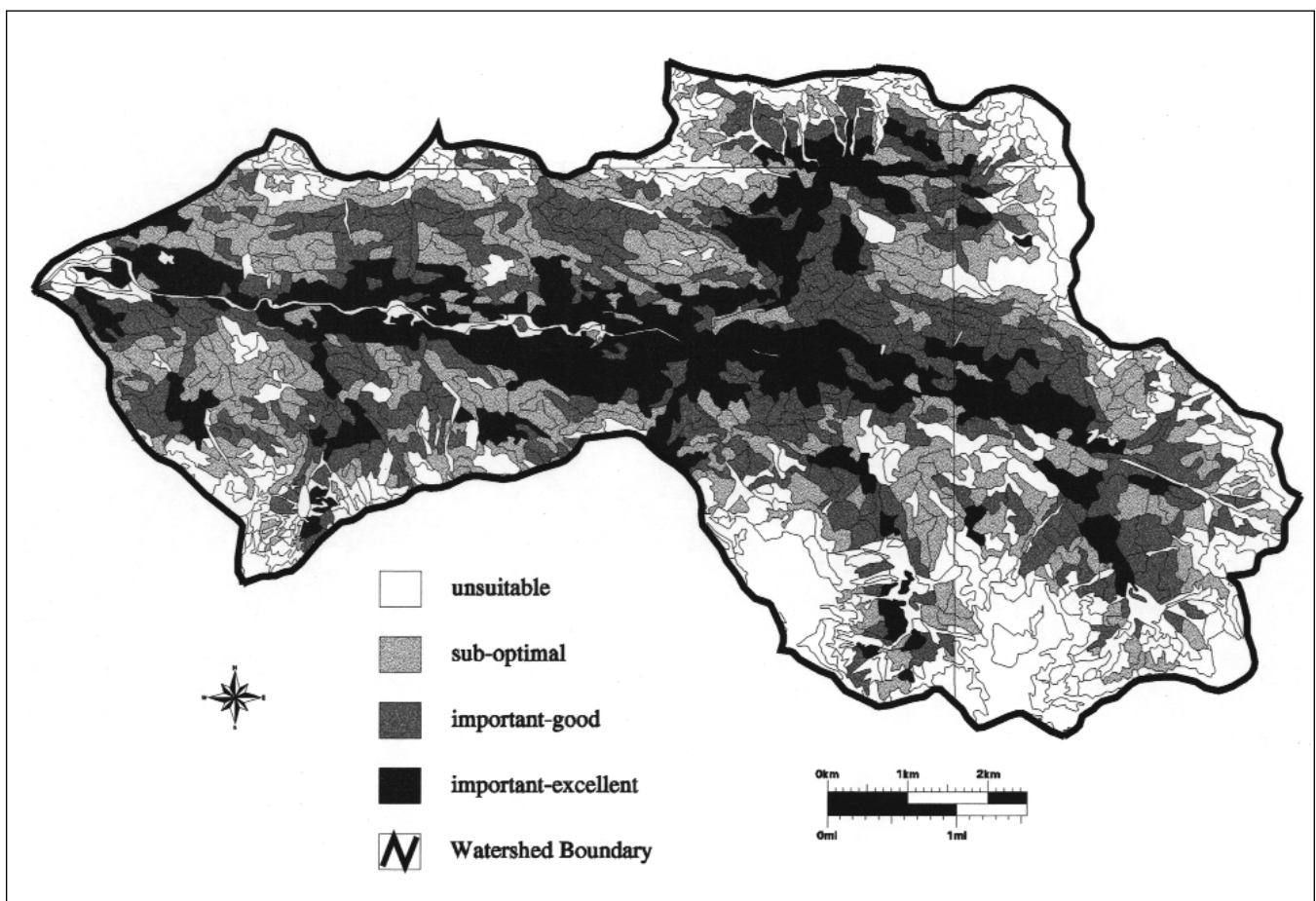


Figure 3. Marbled murrelet habitat suitability evaluation in the Ursus Valley, based on 5 forest characteristics from Vegetation Resource Inventory maps and 2 spatial characteristics. Characteristics considered for each polygon are: tree age, tree height, vertical complexity, canopy closure, distance from ocean, and elevation. Map produced by V. Bahn, D. Newsom, and K. Hodgson.

with tall, large diameter conifers with large mossy boughs. Our research suggests that evaluating a combination of mapped vegetation attributes and structures associated with marbled murrelet nesting may be the most effective and appropriate way of prioritizing forest nesting habitat for marbled murrelets.

4. Although the nesting density study is not finished, we provided the first estimate of nesting density in “excellent” habitat in an unfragmented watershed. Nesting density estimates provide resource managers with vital information for decision-making.
5. Through multiyear and multi-scale inventory we confirmed population estimates and checked the determinations of critical habitat. There is now a well-established baseline inventory of marbled murrelet distribution and abundance against which to measure the effects of future management in Clayoquot Sound.

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