Chapter 16
Inland Habitat Associations of Marbled Murrelets in British Columbia

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Abstract: Most Marbled Murrelets (*Brachyramphus marmoratus*) in British Columbia nest in the Coastal Western Hemlock biogeoclimatic zone. In this zone, detection frequencies were highest in the moister ecosections and in low elevation forests. Nests and moderately high levels of activity were also found in some forest patches in the subalpine Mountain Hemlock zone. There was no evidence of nesting in subalpine scrub forest, lowland bog forest, or alpine tundra. Studies on the Queen Charlotte Islands and Vancouver Island reported consistently higher detection frequencies in old-growth than second growth forests (20-120 years old). Detections in second-growth were usually associated with nearby patches of old-growth. Within low elevation old-growth, detection frequencies were sometimes positively correlated with mean tree diameter, but showed weak or no associations with tree species composition and minor variations in forest structure. Sitka spruce (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla*) were important components of many high-activity sites. High murrelet activities were associated with well-developed epiphytic mosses, but mistletoe seemed less important. A study on Vancouver Island showed higher predation of artificial nests and eggs at forest edges, which suggests problems for Marbled Murrelets in fragmented forests. The use of detection frequencies in the selection and preservation of potential nesting habitat is discussed and the limitations of single-year studies are exposed.

British Columbia supports a significant portion of the North American population of Marbled Murrelets (*Brachyramphus marmoratus*). Over the past century, evidence accumulated that the birds nested in large trees in British Columbia (Campbell and others 1990), and at least one early biologist made the connection between declining numbers of murrelets and the reduction of old-growth forests on eastern Vancouver Island (Pearse 1946). In recent decades the pace of logging of coastal old-growth forests has greatly increased. Between 1954 and 1990 about half of the large-tree old-growth forest on Vancouver Island (75 percent in the southern island) was logged (Husband and Frampton 1991). Out of 354 forested watersheds larger than 5,000 ha in coastal British Columbia, only 20 percent are pristine and 67 percent have been significantly changed by industrial activity, primarily logging (Moore 1991). Concerns over the effects of logging on Marbled Murrelet populations were raised by Sealy and Carter (1984), but there were no intensive inland studies until the species was listed as threatened in Canada in 1990. Loss of nesting habitat by logging was considered the greatest threat (Rodway 1990, Rodway and others 1992). The listing stimulated several inland studies, including reconnaissance surveys in many watersheds of the Queen Charlotte Islands (Rodway and others 1991, 1993a) and Vancouver Island (Savard and Lemon in press) and intensive surveys at several sites.

Identification and mapping of potential nesting habitats was identified as a high priority for research in the National Recovery Plan for the Marbled Murrelet, prepared by the Canadian Marbled Murrelet Recovery Team (Kaiser and others 1994). Detailed 1:50,000 maps of coastal old-growth forests are being prepared (Derocher, pers. comm.). There are still very few data available for either landscape- or stand-level analyses of habitat associations. I review the available data and point out research topics that urgently need to be addressed.

Methods and Sources of Data

The studies reviewed here followed the Pacific Seabird Group survey protocols for general (road) and intensive (fixed station) surveys (Paton and others 1990, Ralph and others 1994), with the exception of Eisenhawer and Reimchen (1990) and Reimchen (1991).

Rodway and others (1991; 1993a,b) did intensive sampling through the 1990 season in Lagins Creek and Phantom Creek on Graham Island, and less frequent general surveys in 12 other watersheds on the Queen Charlotte Islands. Savard and Lemon (in press) analyzed data from 382 surveys at 151 fixed stations and 88 road surveys in 82 watersheds on Vancouver Island in 1991. Relatively few surveys were made at each station (mean 1.6, range 1-5), and large numbers of observers were used with variable degrees of training. Savard and Lemon (in press) warned that their data could not present an accurate picture of murrelet activity in any of the watersheds surveyed. Nevertheless, some significant patterns emerge at the landscape scale.

The remaining studies focussed on fine-scale temporal and spatial variations within single watersheds during one season (Eisenhawer and Reimchen 1990; MacDuffie and others 1993; Manley and others 1992, 1994) or 3-4 seasons (Burger 1994; Jones 1992, 1993). Only three studies combined repeated intensive surveys with detailed habitat analysis at a variety of sites (Burger 1994, Manley and others 1994, Rodway and others 1993a). These data are insufficient for a thorough examination of habitat patterns at stand and landscape scales in British Columbia, but some trends are apparent and are reviewed here. *Figure 1* shows the location of the study sites.

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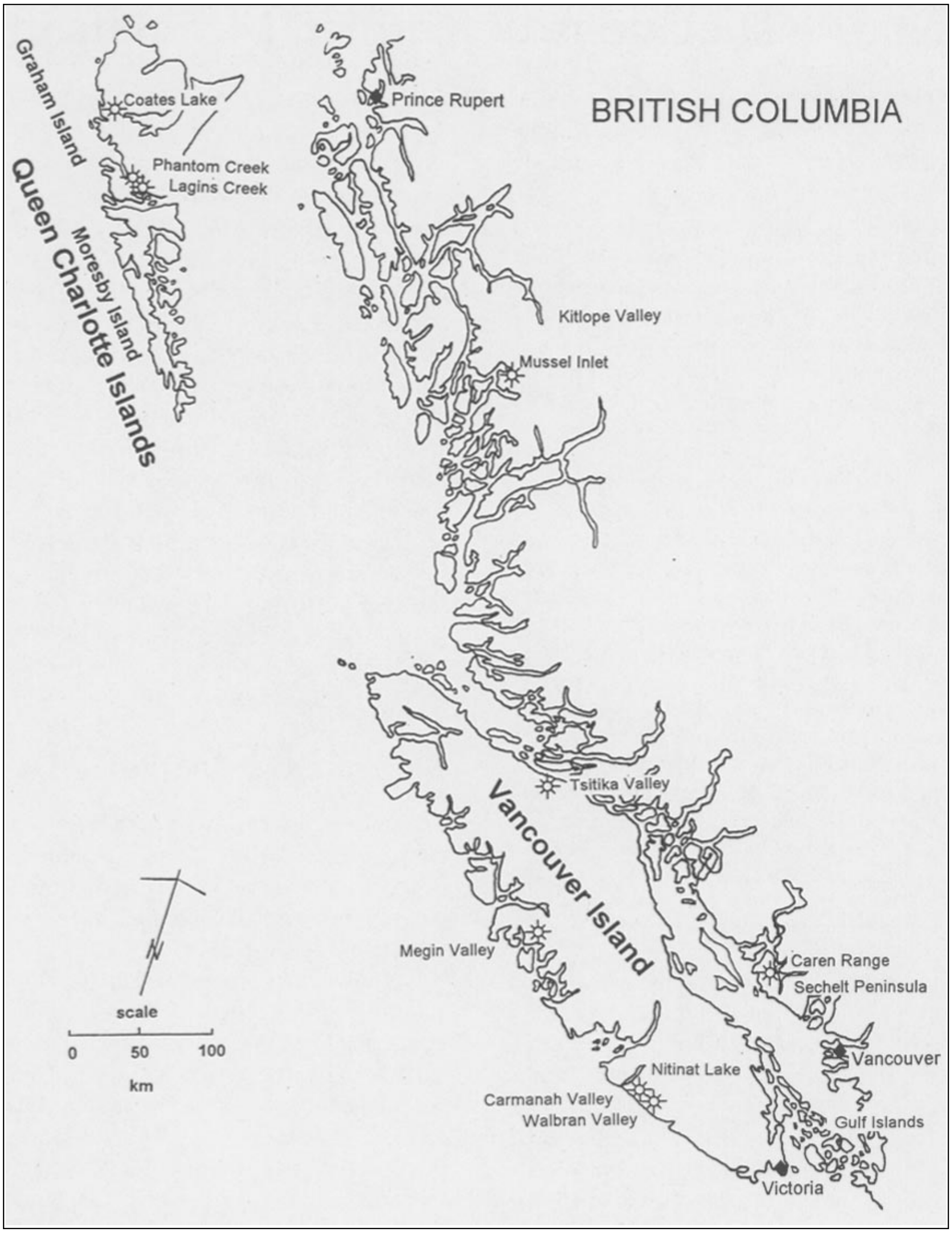

Figure 1—Coastal British Columbia showing the location of inland studies of Marbled Murrelets (open stars).

Biogeoclimatic Zones

Marbled Murrelets have access to four biogeoclimatic zones (Meidinger and Pojar 1991). The Coastal Western Hemlock Zone covers most of coastal British Columbia at low to mid elevations (0-900 m on windward and 0-1050 m on leeward slopes on the south and mid-coast; and 0-300 m on the north coast). Dominant trees are western hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*), and Amabilis fir (*Abies amabilis*), with yellow cedar (*Chaemaecyparis nootkatensis*) in higher elevations and Douglas-fir (*Pseudotsuga menziesii*) in drier habitats. Lodgepole pine (*Pinus contorta*) occurs in dry shoreline areas and bogs. Sitka spruce (*Picea sitchensis*) is an important component on floodplains in the southern forests, and in many older forests in the Queen Charlotte Islands and the northern mainland, and is an important nest site for Marbled Murrelets. Most Marbled Murrelets in British Columbia appear to nest in this zone (see below).

The Coastal Douglas-fir Zone covers a small area on southeastern Vancouver Island, the Gulf Islands, and a narrow strip of the adjacent southern mainland at elevations below

150 m. It characterizes relatively dry forest in the rain shadow of the Vancouver Island and Olympic Mountains. Very little old-growth remains in this heavily populated zone. Douglas-fir is the dominant tree, with other conifers and broad-leaved trees sometimes common. There has been no research on Marbled Murrelets in this zone, but nesting is likely, because the birds are often seen nearby on the ocean.

The Mountain Hemlock Zone occurs at 900-1800 m in southern British Columbia (lower on windward slopes) and 400-1000 m in the north. It is most common above the Coastal Western Hemlock Zone on the mainland Coast Mountains and the insular mountains of Vancouver Island and the Queen Charlotte Islands. Dominant trees are mountain hemlock (*Tsuga mertensiana*), amabilis fir, and yellow cedar. Much of this forest occurs as a mosaic among areas of subalpine heath, meadow, and ferns. Nesting has been recorded in these forests on the southern mainland (see below).

The Alpine Tundra Zone occurs on high coastal mountains, above 1650 m in the south and 1000 m in the north, and is dominated by shrubs (willows and birch), herbs, bryophytes, and lichens. Marbled Murrelets have been reported flying over such habitats (Rodway and others 1993a), but there is no evidence that they nest there in British Columbia.

Landscape Attributes

Old-Growth Compared with Second-Growth

Two studies compared detection frequencies in old-growth and second-growth. Rodway and others (1993a) recorded high densities of activity in intensive surveys in old-growth on the Queen Charlotte Islands (details below), but had only one detection in five intensive surveys in second-growth stands (60-120 years old). In road surveys, detections were reported at 76 percent (n = 25) of old-growth stations, but only at 27 percent (n = 101) of second-growth stations (20-120 years old). In 85 percent of the cases where detections were recorded in second-growth forest, there were stands of old-growth within 500 m. Detection frequencies were significantly higher in old-growth than second-growth, and within second-growth they were significantly higher if there was old-growth nearby (*fig. 2*).

Savard and Lemon (in press) reported significantly fewer detections from stations in watersheds with less than 50 percent remaining old-growth, compared to more intact watersheds (*fig. 3*). At fixed stations in May and July, fewer detections were recorded when the proportion of old-growth fell below 75 percent of the watershed. In addition, stations

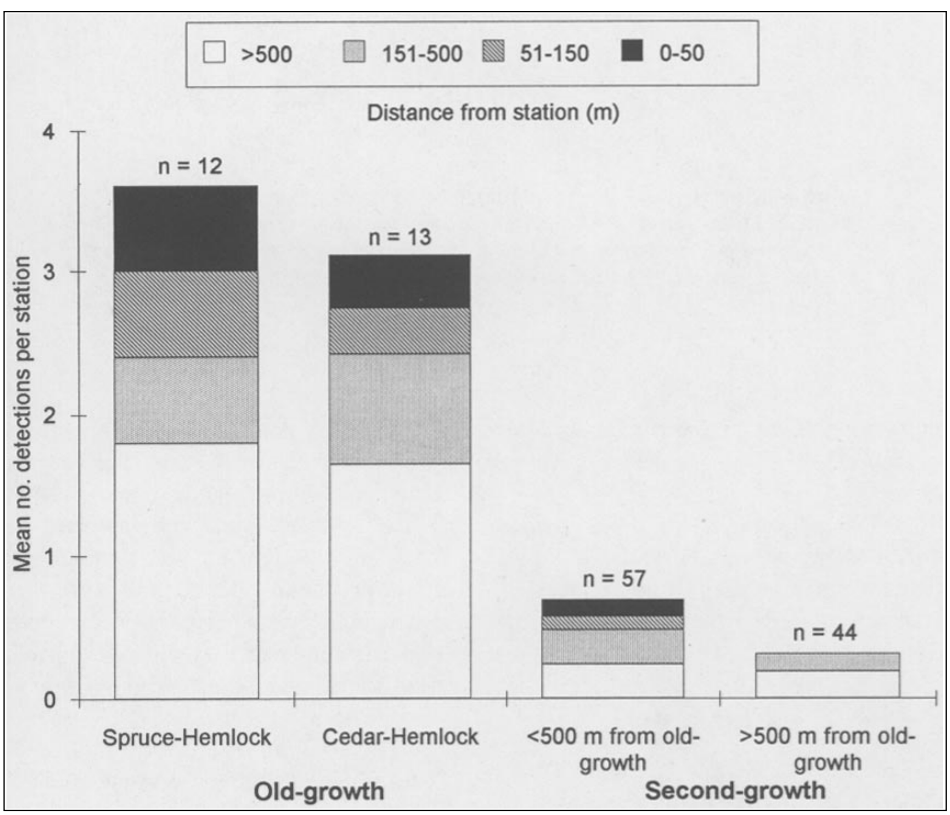

Figure 2—Mean number of Marbled Murrelet detections per road transect station in relation to adjacent habitat type in the Queen Charlotte Islands (from Rodway and others 1993a). The sample size (n) is the number of surveys.

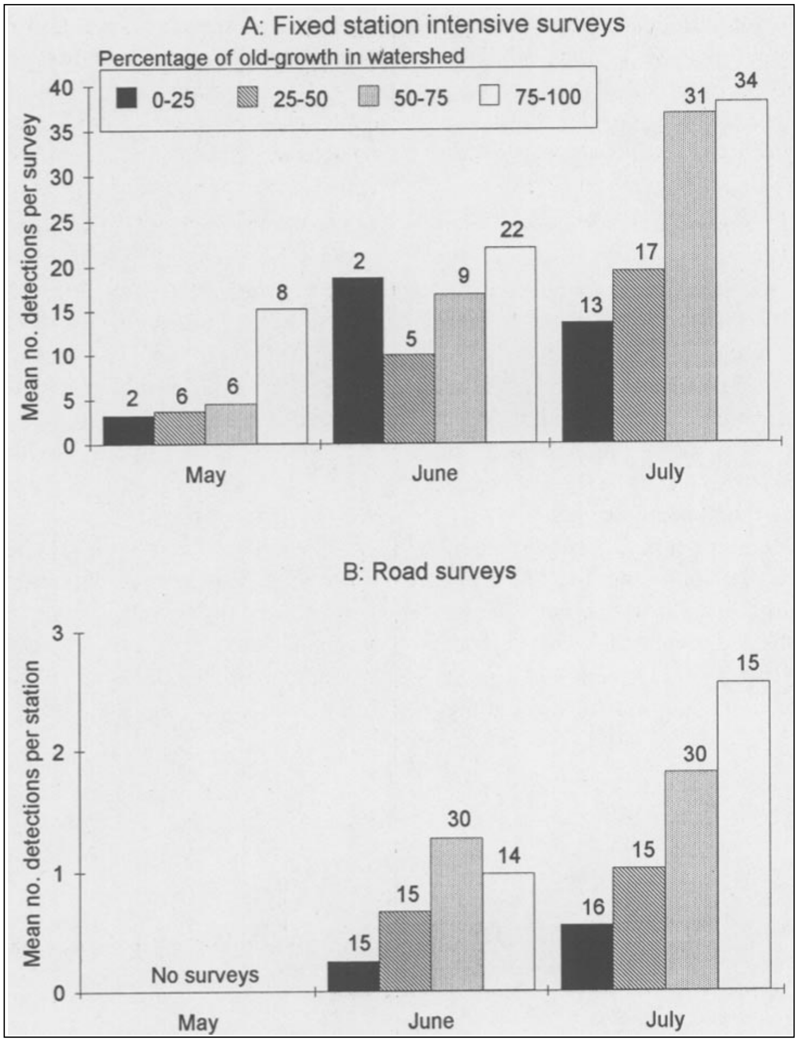

Figure 3—Mean numbers of Marbled Murrelet detections in intensive fixed station (A) and general road surveys (B), in relation to the percentage cover of remaining old-growth forest in the sampled watersheds on Vancouver Island (from Savard and Lemon, in press). Sample sizes (*n*) shown above columns are numbers of surveys.

close to old-growth (within 200 m in fixed stations and within 500 m in road transects) had higher detection rates than those further away.

These studies confirm that murrelets avoid second-growth forests, even those 60-120 years old. Furthermore, the Vancouver Island results tentatively suggest that murrelets do not pack into the remaining old-growth with increased density; reduced habitat leads to reduced populations.

Relationship Between Landscape and Stand

Distance to Salt Water and Location Within the Watershed

Savard and Lemon (in press) found no significant correlation between detection frequency and distance from salt water (using intervals of 0–5, 5–15, and >15 km) at 151 stations on Vancouver Island in May and July, but found a negative correlation in June. They found no effects of distance to open ocean (beyond the inlets) in any month. The location of fixed stations within each watershed did not affect detection rates (each watershed was divided into four zones, from mouth to headwaters), although road surveys showed significantly higher detections in the centers of the watersheds. These data indicate that Marbled Murrelets are able to access all of Vancouver Island, although only a small portion might be suitable nesting habitat.

The effect of distance from the ocean was tested in the Carmanah and Walbran watersheds in which unbroken old-growth forest extends from the ocean almost to the headwaters for 21 and 18 km, respectively. Manley and others (1992) reported a significant negative correlation between detection rates and distance from the ocean at six stations in Carmanah-

Walbran in 1990. A larger data set (11 stations in 1991 and 13 in 1992) produced no significant correlations when occupied detections (Pearson correlation, r = -0.081 and -0.271, respectively) or total detections (r = -0.140 and -0.267, respectively; $P > 0.05$ in all cases) were considered (*fig. 4*; Burger 1994). The highest detection frequencies were found at sites 8–17.5 km inland. All six nests found in Carmanah-Walbran were more than 10 km from the ocean (Burger 1994).

Precipitation Amount and Form

Most of the old-growth forests in which high densities of murrelets have been reported receive high rainfall (most in winter) and relatively little snow. On Vancouver Island, detection frequencies were significantly higher in the two moist ecosections (Western Island Mountains and Northern Island Mountains; Demarchi and others 1990) than in the drier Nahwitti Lowland and Nanaimo Lowland ecosections (Savard and Lemon, in press). Overall, detections were significantly higher on the moister western side of Vancouver Island than on the eastern side, but the latter area has also been far more extensively logged and urbanized, which might contribute to this difference.

Rodway and others (1993a) reported no detections at apparently suitable forest with large Sitka spruce at Gray Bay, Queen Charlotte Islands. The spruce trees there had virtually no moss development on their limbs, apparently as a result of sea spray, which might have made them less attractive to murrelets.

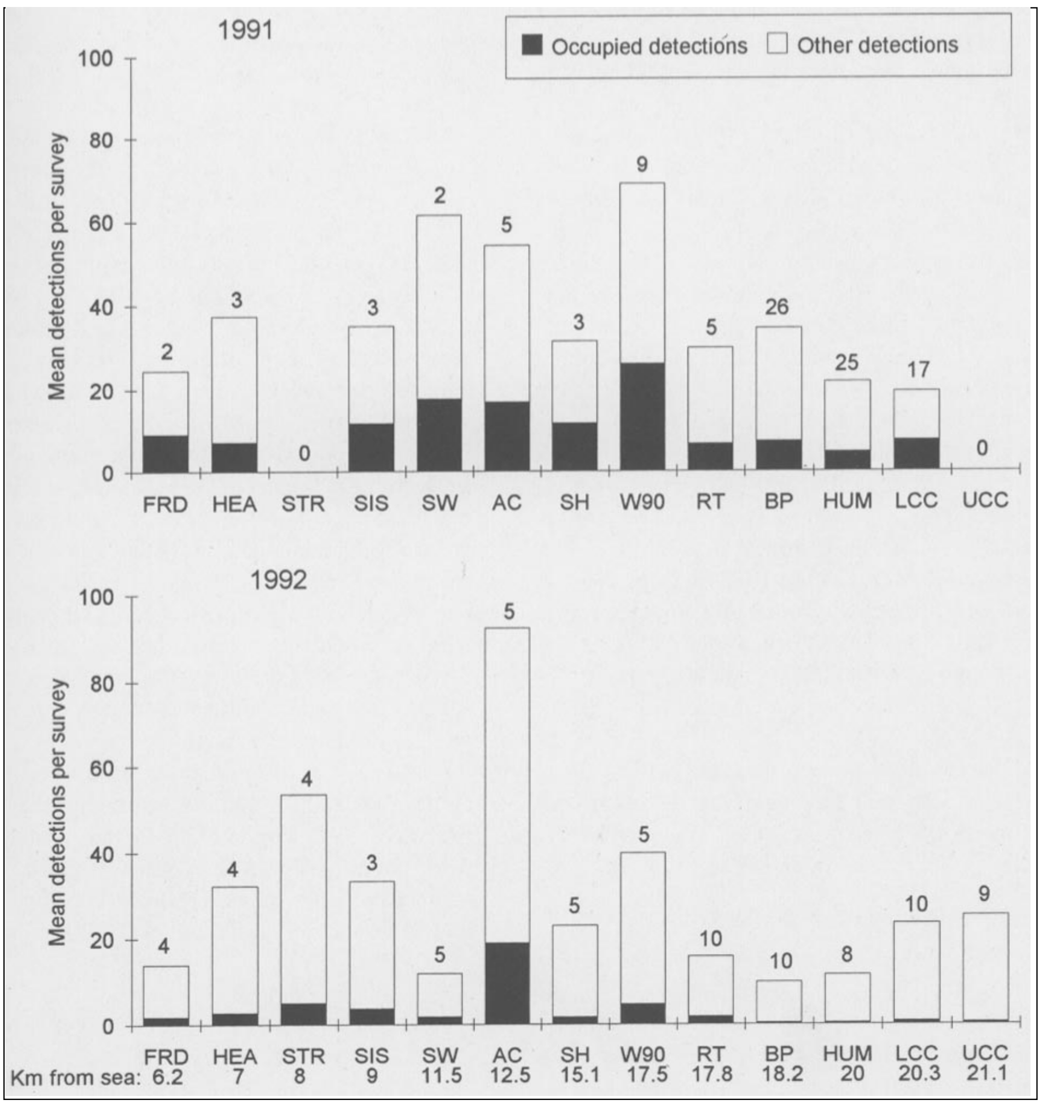

Figure 4—Mean frequencies of occupied and other detections reported from 13 intensive survey stations (arranged in increasing distance from the ocean) in the Carmanah-Walbran watersheds, Vancouver Island, in the period 15 May through 16 July in 1991 and 1992 (from Burger 1994). Sample sizes (n) above columns are numbers of surveys. The x-axis is labelled with the codes for each station. Codes for each station are: FRD = Ford, HEA = Heaven Canp, STR = Stream Site, SIS = Three Sisters, SW = South Walbran Bridge, AC = August Creek, SH = Sleepy Hollow, W90 = West Walbran 1990 Nest Site, RT = Research Tree, BP = Bearpaw Camp, HUM = Hummingbird Camp, LCC = Lower Clearcut, UCC = Upper Clearcut.

Stand Attributes and Relative Murrelet Densities

Elevation

Eisenhawer and Reimchen (1990) found no evidence of Marbled Murrelets in high elevation (to 700 m) subalpine scrub forest of lodgepole pine above Coates Lake, Queen Charlotte Islands. At Lagins Creek, Queen Charlotte Islands, Rodway and others (1991, 1993a) found a significant difference in mean detection rates in May through July between low elevation forests (90-150 m), high forests (230-460 m), and alpine areas (720-1000 m): 32.4 ± 4.1 (*s.e.*), 17.5 ± 3.0, and 3.0 ± 0.7 detections per survey, respectively. About 98 percent of the old-growth forest occurred below 500 m in this area. A few birds passed over alpine ridges in this area, but 84 percent of the detections in high altitude stations were of birds 500-1500 m distant, flying in the valleys below. Ground searches in alpine areas yielded no sign of nesting.

Marbled Murrelets do nest in some high altitude forests above fjords on the mainland coast. Murrelets have been reported flying over the steep slopes, mostly covered in scrubby sub-alpine forest with patches of taller trees, which surround fjords (Burns, pers. comm.; Kaiser, pers. comm.; Prestash, pers. comm.). One radio-tagged bird was tracked to a sub-alpine stand of large conifers above Mussel Inlet (Prestash and others 1992b; see details below). Similar habitat appears to support Marbled Murrelets in the Kitlope drainage on the north-central mainland (Kelson, pers. comm.).

Fairly high rates of activity (details below) were reported from sub-alpine forest at 750-1200 m, dominated by mountain hemlock and yellow cedar in the Caren Range, Sechelt Peninsula (Jones 1992; P. Jones, pers. comm.). An active nest was found here in 1993 at 1088 m (Jones 1993). A fledgling Marbled Murrelet was found alive on the ground by a tree faller at Downing Creek, near Furry Creek on the east side of Howe Sound in 1985. The suspected nest was at the top of a "red cedar" (sic) at an altitude of 1064 m (Morgan 1993).

Marbled Murrelets nest as high as 1000 m, and these somewhat meager data suggest that vegetation development, specifically the absence of large trees at high altitudes, affects Marbled Murrelets more than altitude per se.

Aspect, Slope and Stand Position on Slope

The effects of slope and aspect have not been adequately investigated in British Columbia. High elevation stations on side slopes in two watersheds in the Queen Charlotte Islands (see above for altitudes) had lower detection rates than those in the valley bottoms, but this might be a consequence of elevation, rather than slope or aspect (Rodway and others 1991, 1993a). These authors pointed out that if birds circled over narrow valleys, they would probably pass over observers on the valley floor more often than observers on the side slopes, causing differences in detection frequencies.

Vegetation Classification and Tree Size

Intensive surveys in Lagins Creek, Queen Charlotte Island, by Rodway and others (1993a) yielded the highest densities of detections in stands of large Sitka spruce and western hemlock. These preferred stands included the following site associations: (1) valley bottom, western red cedar/Sitka spruce - foamflower (mean diameter at breast height [d.b.h.] = 162 cm); (2) valley bottom, western red cedar/Sitka spruce - *Conocephalum* (d.b.h. = 104 cm); and (3) slope forest, western hemlock/Sitka spruce - lanky moss (d.b.h. = 93 cm). Within these associations, vegetation groups with the largest trees (mean d.b.h. 141 cm vs. 60 cm for all other plots) had significantly higher rates of murrelet detections. These differences disappeared when only low-altitude sites were considered. Lower detections rates were found in these site associations: (1) valley bottom, western red cedar/Sitka spruce - skunk cabbage (d.b.h. = 40.4 cm); (2) higher altitude, western red cedar/western hemlock - blueberry (d.b.h. not measured); and (3) lodgepole pine/yellow cedar - sphagnum (d.b.h. not measured) found in low-elevation bog-forest.

Reimchen (1991) made informal observations of flight activity of Marbled Murrelets (not following the Pacific Seabird Group protocol) at 49 lakes on Graham and Moresby Islands (Queen Charlotte Islands) between 25 May through 25 July over a 12 year period. The birds were absent or rare (<2 calls per 15 minute survey) at 40 lakes, most of which were surrounded by unforested scrubby vegetation or "poorly forested" terrain. The nine lakes at which there was extensive murrelet activity were distributed primarily in old-growth forest with mossy boughs. Sitka spruce appeared to be an important component of the vegetation at active sites. Intensive observations by Eisenhawer and Reimchen (1990) at Coates Lake, Graham Island from 1 June to 3 August 1986 yielded a mean of 12.9 (range 1-50, n = 42) detections per dawn survey, as well as records of birds carrying fish, landing on trees, and possibly copulating on a branch. The old-growth forests here were mixtures of western hemlock, Sitka spruce, western red cedar, and yellow cedar, with canopies 40-70 m tall. No detailed habitat plots were made.

Murrelet activity was reported over the steep forested slopes overlooking Mussel Inlet, a northern mainland fjord (Prestash and others 1992b; Prestash, pers. comm.; Burns, pers. comm.). The forests were primarily within the Very Moist Coastal Western Hemlock (CWHvm1 and CWHvm2) and Moist Maritime mountain hemlock (MHmm1) biogeoclimatic subzones. Two radio-tagged murrelets were repeatedly tracked to forest stands here (the third radio-tagged bird reported by Prestash and others [1992b] appeared to have lost its transmitter or died in the forest). Vegetation characteristics of these stands were derived from forest inventory maps. One stand was in sub-alpine hemlock/amabilis fir forest (400 m asl) with large mountain hemlock trees (37-46 m tall, estimated age >250 years), and the second in a low altitude (80 m) moss-covered bog-forest dominated by western red cedar (28-37 m, estimated 141-250 years old).

Murrelets were also studied in subalpine forests in the Caren Range, Sechelt Peninsula (Jones 1992). Dominant trees were mountain hemlock and yellow cedar. This is very old forest and one cedar stump was 1717 years old. Detection frequencies from scattered stations in June and July in 1991, 1992 and 1993 averaged 13.9 ± 13.8 (*s.d.*; n = 27; range 1-61), 17.6 ± 16.7 (17; 0-45), and 20.3 ± 13.7 (54; 0-57), respectively (P. Jones, pers. comm.). Vegetation was not analyzed in detail. A nest was found here in a yellow cedar in 1993 (Jones 1993).

High densities of murrelet detections (mean 24.4 ± 20.7 *s.d.*, range 9-85, n = 12) were obtained at Tsitika Creek station between 29 June and 15 July 1991 in the lower Tsitika Valley, northeastern Vancouver Island (MacDuffee and others 1993). A second station nearby, affording less visibility, yielded only 1-4 detections in two surveys in this period. Western hemlock (mean d.b.h. = 73 cm), western redcedar (117 cm), amabilis fir (75 cm) and Sitka spruce (112 cm) made up 60 percent, 18 percent, 16 percent and 7 percent, respectively, of the trees with d.b.h. >7.5 cm in this stand.

Vegetation analysis has been done in Carmanah-Walbran, Vancouver Island in conjunction with murrelet surveys in 1990-1993 (Burger 1994, Manley 1992, Manley and others 1992). This is an area of relatively unfragmented valley-bottom old-growth, dominated by western hemlock (47 percent of all sampled stems >10 cm d.b.h.; 37.7 percent of combined basal area), amabilis fir (41.8 percent; 19.2 percent), Sitka spruce (8.4 percent; 33.3 percent), western red cedar (2.6 percent; 9.7 percent) with a few red alder. Six nests have been found in this area, five in large Sitka spruce (d.b.h. range 1.33–3.7 m) and one in a large western hemlock (d.b.h. 2.1 m). Manley (1992) found that murrelet detections at six stations were positively correlated with combined basal areas of hemlock and spruce, and negatively correlated with combined fir and cedar. Burger (1994) used a larger sample (11 stations in 1991, 12 in 1992) and considered a wider range of habitat variables, including stem densities and basal areas of all species, combinations of species, snags and trees >1 m d.b.h.. He found the same patterns as Manley, but the only significant correlation was a negative relationship between detection rate and stem density of hemlock in 1991 (and not 1992). Burger (1994) concluded that the habitat variables measured were too coarse, and detection rates too variable, to detect subtle variations in suitability in this relatively homogeneous watershed. All of the stations were clearly in suitable nesting habitat, and occupied behaviors had routinely been recorded at all stations (*fig. 4*).

Manley and others (1994) sampled 14 sites in old-growth forest in the Megin Valley, central Vancouver Island. These were grouped into sites dominated by western hemlock (4 sites), western red cedar (4), Sitka spruce (5) and amabilis fir (1), although all sites supported a variety of these large trees. Analysis of detection frequencies in June and July 1993 showed that the spruce sites had significantly lower detection rates than either cedar or hemlock, but cedar and hemlock did not differ significantly (*table 1*). The differences disappeared when only occupied detections were considered, because spruce sites had higher proportions of occupied detections (14 percent) than hemlock (4 percent) and cedar (3 percent). Average tree

Table 1—Mean (*s.d.*) detection frequencies of Marbled Murrelets in three forest types in the Megin Valley, central Vancouver Islands in June and July 1993 (from Manley and others 1994)

	Mixed forests dominated by:			
Parameters	Spruce	Cedar	Hemlock	Significant differences*
Total detections				
June	12.75 (8.75)	38.0 (35.29)	27.56 (13.61)	Cedar>Spruce (Z = 2.28, P < 0.02) Hemlock>Spruce (Z = 2.65, P < 0.01)
July	13.36 (8.3)	27.13 (9.08)	19.56 (10.1)	Cedar>Spruce (Z = 1.96, P < 0.02) Hemlock>Spruce (Z = 3.33, P < 0.01)
Occupied detections				
June	1.44 (2.37)	2.00 (4.50)	1.11 (1.76)	None
July	1.82 (2.74)	0.25 (0.46)	0.56 (1.13)	None
No. of stations	4	4	5	
No. of surveys				
June	16	8	9	
July	10	8	9	

* Multiple Kruskal-Wallace comparisons

diameter and total basal area of trees ranged from 46 to 123 cm, and 5.9 to 25.3 m^2 per 0.9 ha plot, respectively. Frequencies of occupied detections were positively correlated with both mean tree diameter (r = 0.729, n = 15, P < 0.01) and basal area (r = 0.585, n = 15, P < 0.05), but frequencies of all detections showed no significant correlations (Manley and others 1994). These data suggest that the murrelets were more sensitive to tree size than to tree species composition in these old-growth forests.

There have been no analyses of the effects of stand size, edge effects or stand isolation on Marbled Murrelets in British Columbia.

Effects of Epiphytic Mosses and Mistletoe

All nine nests known for British Columbia were on platforms of epiphytic mosses. Dense mosses were associated with the large trees in those vegetation groups in which detection frequencies were highest in the Queen Charlotte Islands (Rodway 1993a). In Carmanah-Walbran watersheds, Burger (1994) found no correlation between murrelet detection frequency and estimated moss cover per site, but the trees in all of the sample plots were well endowed with mosses and this was not a limiting factor for the murrelets here.

None of the nine nests found in British Columbia were associated with mistletoe. Murrelet detection frequencies were not correlated with mistletoe index (Hawksworth 1977) in Carmanah-Walbran in 1991 (11 sites) or 1992 (12 sites), and moss-covered boughs provided many more potential nest sites than mistletoe in these large trees (Burger 1994).

Predator Abundance

I found no records of predation of Marbled Murrelets from British Columbia, but did not review all the raptor literature. Marbled Murrelets were absent from prey remains of Bald Eagles (*Haliaeetus leucocephalus*) found beneath 35 nests (which included 145 bird carcasses) in the Gulf Islands (Vermeer and others 1989a) and 17 nests (33 bird carcasses) in Barkley Sound (Vermeer and Morgan 1989). Jones (1992) reported that murrelets fell silent and disappeared for 10 minutes when a large owl (probably Barred Owl [*Strix varia*]) appeared.

Bryant (1994) tested the effects of egg predators in montane western hemlock-mountain hemlock forest in central Vancouver Island, using 120 artificial nests, each with three quail eggs, placed on the ground or in trees at eye level. He found that 43 percent of nests (52 percent of eggs) were damaged or removed in the first week, and 87 percent (91 percent eggs) after two weeks. The survival of both nests and eggs placed in trees was significantly higher with increasing distance from the forest edge, after both 7 and 14 days (*fig. 5*). Nests of Marbled Murrelets are much higher in trees and better camouflaged than these experimental nests, and so would not necessarily experience the same levels of predation. Nevertheless, these results indicate a strong edge effect of nest predation, suggesting that fragmentation of forests exposes Marbled Murrelet nests to increased predation. Steller's Jays (*Cyanocitta stelleri*), Gray Jays (*Perisoreus canadensis*) and Common Ravens (*Corvus corax*) were likely predators of tree nests in this experiment. These corvids did not appear in Bryant's census transects often enough to determine their distribution (Bryant, pers. comm.).

These results are consistent with the conclusions reached by Paton (1994). In a critical review of 14 studies, he found strong evidence that avian nest success was reduced by predation and parasitism near habitat edges. Increased predation of natural and artificial (experimental) nests was most marked within 50 m of forest edges. In addition, nest success was consistently correlated with habitat patch size. There were apparently no studies in old-growth forest in the Pacific Northwest, nor did any studies consider nests as high in trees as those of the Marbled Murrelet. Studies on the effects of edges and habitat fragmentation on nest success of Marbled Murrelets are clearly a priority in areas with intensive logging.

Assessing Marbled Murrelet Habitat Quality in British Columbia

Conservation and Management Requirements

Marbled Murrelets appear to nest in scattered forest locations over a vast area in coastal British Columbia (Campbell and others 1990, Rodway 1990, Rodway and others 1992). There is a growing need to identify and preserve nesting habitat, particularly in the many areas facing clearcut logging. Unlike the situation to the south in the United States, identification of occupied stands has not guaranteed protection in British Columbia because Canada lacks an Endangered Species Act to enforce strict protection of habitat, and neither federal nor provincial governments are likely to block all commercial logging in occupied stands. Only the most valuable nesting habitat is likely to be preserved outside parks, and measures to identify such habitat are urgently needed. At least two categories of forest need to be considered for immediate preservation: areas supporting many breeding birds which make up a significant proportion of the provincial murrelet population; and forest patches supporting remnant populations in areas severely affected by habitat loss. The first is important for maintaining a large, viable breeding population of murrelets and the second to maintain a wide breeding range and genetic diversity.

Efforts to identify high quality habitat in British Columbia are at a very early stage. The huge areas involved and paucity of resources for surveying murrelets make it unlikely that the intensive multi-year surveys covering 12-30 ha, which are recommended for identifying occupied stands (Ralph and others 1994) will be widely implemented for short term management in British Columbia. As an interim measure, forest and wildlife managers will need general guidelines on the quality of forest stands being considered for logging. Intensive surveys can then be focused on the forest stands with greatest potential as nest sites.

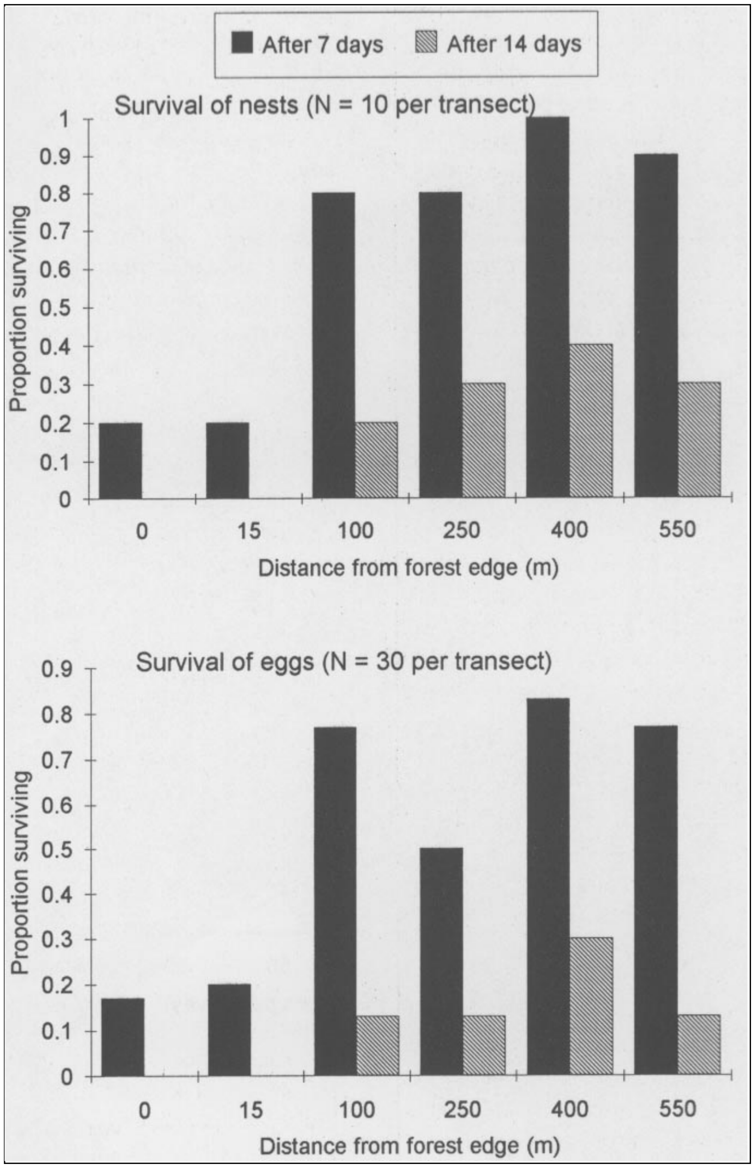

Figure 5—Survival of artificial nests, each containing three quail eggs, placed at eye level in trees in transects laid out at various distances from the forest edge in montane western hemlock-mountain hemlock forest in central Vancouver Island, 1992 (data from Bryant 1994). Nest "survival" meant the nest was in good condition with at least one undamaged egg, egg survival was the count of undamaged eggs.

Use of Detection Frequency to Delineate Marbled Murrelet Habitat

Standardized pre-dawn surveys provide indications of relative nesting density (Ralph and others 1994), although the relationship between the number of detections per survey and the density of nesting pairs has not been established and is likely to vary among sites and through the season (Rodway and others 1993a,b). As a first approach I have compared the frequency of detections among a wide range of survey stations from three sources: (1) the Queen Charlotte Islands (158 surveys at 50 sites in 1990; Rodway and others 1991, 1993a) (2) a large sample of watersheds throughout most of Vancouver Island (471 surveys at 151 sites in 1991; Savard and Lemon in press); and (3) intensive surveys made over four years (1990-1993) at 12 sites in Carmanah Valley, two in the Walbran Valley and one at Nitinat Lake (Burger 1994). At each site (in some of the Queen Charlotte Islands surveys, a site included several stations), the mean frequency of detections per morning survey was calculated for the period 1 May through 31 July. Occupied detections (Ralph and others 1994) could not be analyzed separately since these were not given in all reports.

The percentage of the sampled sites in which the mean frequency of detections exceeded a given threshold was then plotted (*fig. 6*). This should facilitate ranking a particular site, relative to other sites, or guide decisions on how important surveyed sites might be on a provincial or regional basis. The trends in the Queen Charlotte Islands and on Vancouver Island were surprisingly similar. These indicate, for example, that about 18 percent of all sites in these areas had mean densities exceeding 40 detections per survey. If a manager decided to preserve all sites above this threshold, then one would expect about 18 percent of the potential sites to be included. These trends should obviously only be used as guides, since some low-density sites might be important in places where there are few high quality sites.

These data were derived from relatively few surveys (means for Queen Charlotte Islands and Vancouver Island were 3.2 and 1.6 surveys per site, respectively), made in a single year (1990 and 1991, respectively). By contrast, the surveys made in Carmanah-Walbran-Nitinat used fewer sites, but were much more intensive (mean 31.4 surveys per site) and covered four years. Not surprisingly, the threshold pattern

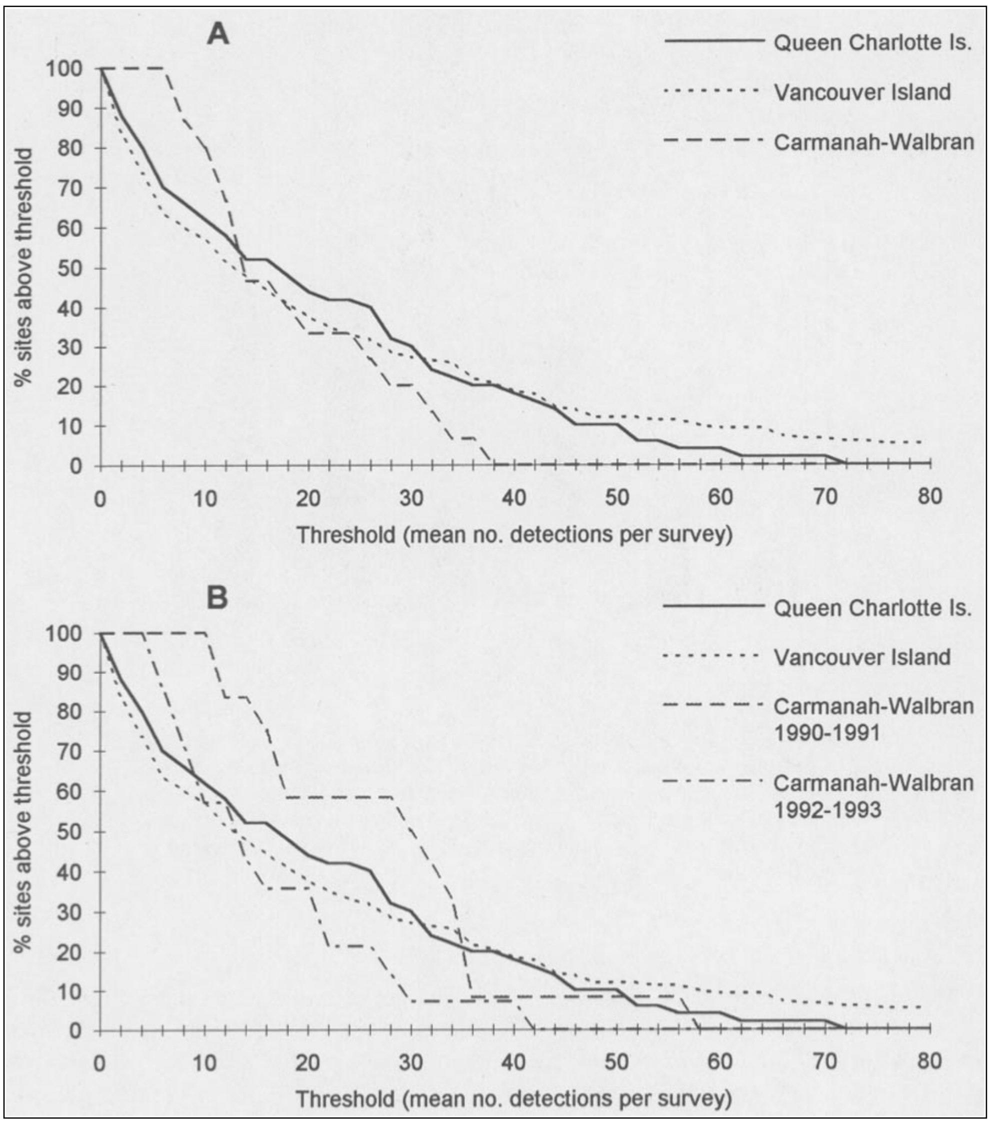

Figure 6—A: plot of the percentage of sites in which the mean frequency of Marbled Murrelet detections exceeded the thresholds on the x-axis. Data from the period 1 May through 31 July in the Queen Charlotte Islands (158 surveys at 50 sites in 1990; Rodway and others 1991), Vancouver Island (209 surveys at 151 sites in 1991; Savard and Lemon in press), and Carmanah-Walbran-Nitinat (471 surveys at 15 sites in 1990-1993; Burger 1994). B: the same plot as A, but with the Carmanah-Walbran-Nitinat data separated into two periods: 1990-1991 (176 surveys at 12 sites) and 1992-1993 (297 surveys at 14 sites).

differed from the previous studies, showing a smaller proportion of sites at each extreme (*fig. 6a*). These results emphasize that the single-year Queen Charlotte Islands and Vancouver Island surveys provide only rough guides to the expected patterns in a specific area.

The effect of year-to-year variability in detection frequency can be clearly seen when the Carmanah-Walbran-Nitinat data are split into two periods (*fig. 6b*). The first (1990-1991) was a period of normal sea temperatures and high murrelet detections in the Carmanah-Walbran-Nitinat forests, whereas the second (1992-1993) covered two years with unusually high inshore sea temperatures and low murrelet activity in parts of the forest (Burger 1994). The resultant threshold patterns are quite different, showing that variable factors affecting murrelets (such as El Niño effects) must be considered when habitats are assessed on the basis of detection frequency. If, for example, forest managers set a threshold of 30 detections per survey to delineate optimal habitat, then this would cover 50 percent of all sites sampled in the good years (1990-1991), but only 7 percent of the same sites in poor years (1992-1993).

In order to avoid such problems, managers would need to be very conservative and use relatively low thresholds (e.g., means of 10 or 20 detections per survey) to delineate high-quality habitat requiring preservation. Comparisons among sites of the mean detection frequencies provides only a crude estimation of the quality of a stand, particularly if only one or two intensive surveys are made in a single season. A more meaningful analysis would use the relative frequency of occupied behaviors recorded over at least two years (Ralph and others 1994), and surveys in British Columbia should be directed towards this goal.

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