Exxon Valdez Oil Spill
State/Federal Natural Resource Damage Assessment Final Report

At-sea Abundance and Distribution of Marbled Murrelets in the Naked Island Area, Prince William Sound, Alaska, in Summer, 1991 and 1992

Restoration Study Number 15-1
Final Report

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December 1994

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Study History: This study of the at-sea abundance of marbled murrelets at Naked Island was part of the Restoration Project R15-2 (Identification of Marbled Murrelet Nesting Habitat in the *Exxon Valdez* Oil Spill Zone), initiated in 1991. Project R15-2 was preceded by a pilot study in 1990 (Restoration Feasibility Study No. 4, Identification of Upland Habitats Used by Wildlife Affected by the EVOS: Marbled Murrelets).

Abstract: We studied the abundance and distribution of marbled murrelets (*Brachyramphus marmoratus*) in the Naked Island area of Prince William Sound, Alaska, in the summers of 1991 and 1992, to supplement inland nesting habitat studies conducted there. We surveyed randomly selected transects by boat in the 'inner zone' (waters <2 km from shore) and 'outer zone' (waters 2-5 km from shore) in early summer (late May or early June) and late summer (late July or early August). The estimated murrelet population <5 km from shore was highest in June 1991 (3049 ± 1197) and lowest in August 1991 (878 ± 376), and murrelets were more concentrated in the inner zone in August. Murrelet density was negatively correlated with distance from shore, and within the inner zone, was higher in shallow areas (<60 m deep) than in deep areas. The lower murrelet densities at sea in late summer occurred when inland detections were highest, suggesting that the increase in inland activity typical in July was not due to more birds using the waters around the island complex. Annual surveys to monitor population trends at sea should be conducted during the same seasonal window, and may need to consider the murrelet's association with nearshore, shallow waters and increased concentration near shore in late summer.

Key Words: *Brachyramphus marmoratus*, abundance, distribution, marbled murrelet, Naked Island, Prince William Sound, seasonality.

Citation: Kuletz, K.J., D.K. Marks, and N.L. Naslund. 1994. At-sea abundance and distribution of marbled murrelets in the Naked Island area, Prince William Sound, Alaska, in summer, 1991 and 1992, *Exxon Valdez* Oil Spill State/Federal Natural Resource Damage Assessment Final Report (Restoration Study Number 15-1), U.S. Fish and Wildlife Service, Anchorage, Alaska.

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ACKNOWLEDGMENTS

We greatly appreciate the field assistance of G. Esslinger, A. Bellman, D. Huntwork, I. Manley, J. Piatt and J. Pitocchel. S. Klosiewski assisted in study design and provided counsel on analysis. T. Jennings, B. Boyle and C. Wilder generated the GIS coverage for site selection and bathymetric coverage and along with S. Kendall and D. Flint, produced the maps. L. Campbell assisted with the tables. Earlier drafts of this report were greatly improved by comments from D. Irons, K. Oakley and two anonymous reviewers.

EXECUTIVE SUMMARY

As a supplement to the marbled murrelet *Exxon Valdez* restoration study, we examined murrelet abundance and distribution in the Naked Island area in Prince William Sound, Alaska, in 1991 and 1992. We used small boats and a stratified-random sampling design to estimate the murrelet population within 5 km of the three islands on three surveys, and within 2 km of the islands on two additional surveys.

Within 5 km of the islands the point estimate for the murrelet population ranged from 878 - 3049. Ninety-five percent confidence intervals were 36 - 64% of the point estimates. There was no significant difference in murrelet abundance between years for surveys conducted during the same period - before (early) or after late July (late). Within a year, total population estimates were lowest after late July.

In June 1991, murrelet density (birds / km^2) in waters <2 km from shore (inner zone; $\bar{x}$ = 11.4, SD = 17.4) was similar to that in waters 2 - 5 km from shore (outer zone; $\bar{x}$ = 7.2, SD = 9.2). However, in both years, late-season murrelet density was significantly higher in the inner zone than the outer zone (in 1991, t = 3.76, df = 29, P = 0.0008; in 1992, t = 2.65, df = 29, P = 0.013).

Murrelet density was negatively correlated with distance from shore, and in the inner zone, transects in shallow areas ($\leq$ 60 m deep) had higher densities than transects with deep water areas (>60 m deep).

In late July and early August, when murrelet inland activity at dawn was highest, murrelet numbers at sea had decreased. These data suggest that increased inland activity typically observed in late July is not due to more birds flying inland or an influx of birds to the waters around the Naked Island area.

We conclude that annual surveys to monitor murrelet abundance should be conducted during the same seasonal window each year. If late summer movement towards shorelines is demonstrated to be consistent, surveys may need to be designed to improve efficiency in this habitat. Surveys after mid-July may not be appropriate for identifying murrelet breeding areas, but may indicate important post-breeding feeding areas.

INTRODUCTION

An estimated 8400 marbled murrelets (*Brachyramphus marmoratus*) were killed directly by oil following the 1989 *Exxon Valdez* oil spill (Kuletz 1994). Murrelets were one of the seabirds most affected by the spill (Piatt et al. 1990, Ecological Consulting, Inc. 1991). The restoration effort for the murrelet has attempted to define murrelet nesting habitat to guide habitat acquisition (Kuletz 1991, Kuletz et al. 1994a). Eventually, the murrelet's use of the marine habitat will need to be incorporated into restoration and monitoring efforts. This pilot study addressed questions of murrelet at-sea abundance and distribution which could assist future survey efforts and the identification of feeding habitat.

Because marbled murrelets do not nest colonially and are secretive nesters, only at-sea surveys can be used to estimate their abundance. During the breeding season (May through August) there are an estimated 100,000 (± 20,000) *Brachyramphus* murrelets scattered widely in Prince William Sound (Klosiewski and Laing 1994). The relationship between the number of murrelets at inland nesting areas and the at-sea population of an area is not well understood, partly because their nests are dispersed and they may fly great distances to forage areas.

The Naked Island group (Fig. 1), in central Prince William Sound (PWS), has been the focus of murrelet studies for the murrelet restoration project. Murrelets nest in the forests on these islands (Naslund et al. 1994), and we have monitored their dawn flights to inland nesting areas there (Kuletz et al. 1994a, b). These inland sites have shown a seasonal trend of increased dawn activity from June to late July (Kuletz et al. 1994a). This pattern is typical of other murrelet nesting areas (Ralph et al. 1993, O'Donnell et al. 1995). However, the relationship between murrelet abundance at sea and dawn activity at adjacent inland sites is not well understood. Our understanding of murrelet inland activity would benefit by knowing the concurrent abundance of the local population at sea.

The main goal of this study was to derive an estimate of the murrelet population on the waters adjacent to the Naked Island area. The number of murrelets counted within 200 m of shore during shoreline censuses of the Naked Island group have ranged from 347 in 1980 to 226 in 1991, with an exceptionally low count of 86 birds in 1989 (Kuletz 1994). However, because murrelets forage further offshore as well, these counts served only as indices of the population, and could not account for possible changes in murrelet distribution in the surrounding waters. A statistically rigorous random-sampling design was developed for PWS (Klosiewski and Laing 1994), and in this study we attempted to apply a similar method to the relatively small area of Naked Island.

In other areas murrelets appear to make seasonal shifts in distribution relative to nearshore or offshore waters (Carter 1984, Sealy and Carter 1984, Rodway et al. 1992). Therefore, we examined seasonal changes in abundance and distribution during the breeding season, relative to distance from shore. This provided data to compare to the inland dawn surveys, and might also indicate what percentage of the local population is censused during shoreline surveys.

OBJECTIVES

1. Test a method to estimate the murrelet population for the Naked Island group.

2. Compare population estimates to complete shoreline surveys.

3. Describe the distribution of murrelet densities relative to distance from shore and water depth.

4. Examine the relationship between murrelet at-sea counts and inland activity.

METHODS

Study Area

The study area included the waters within 5 km of Naked, Peak and Storey islands in central Prince William Sound (PWS), Alaska (Fig. 1). Water depth in this area is shallow relative to most of PWS, <200 m deep, due to the presence of an underwater shelf from which the islands rise. There are two channels in the island group, Liljegren Passage (between Storey and Naked islands) and McPherson Passage (between Peak and Naked islands). Nautical charts show the bottom as primarily rocky, except for McPherson Bay and the outer portions of Bass Harbor and Outside Bay, where the bottom is primarily mud. Tidal range in the study area is 6 m. Surface water temperature during the course of the study ranged from 6^0 - 14^0 C, and air temperature ranged from 4^0 - 14^0 C.

Data Collection

At-Sea Surveys-- We used a stratified random-sampling design with two strata: (1) the 'inner zone' - waters from shoreline to 2 km offshore, and (2) the 'outer zone' - waters between 2 - 5 km offshore (Fig. 2). The inner zone was defined as waters within 2 km of shore because in other locations the highest densities of murrelets have been within this zone (Sealy 1975a, Carter 1984). The inner zone included the channel between the three main islands of the study area. The outer zone included offshore waters that, although low in murrelet density, may support a significant portion of the population (Carter 1984, Carter and Sealy 1990). With the exception of the southwestern portion of the study area, the two zones corresponded roughly to the definitions for inshore and offshore waters used by Kessel (1979). In general, the 100 m underwater contour around the Naked Island group defined the boundary between the inner and outer zones, and the outer boundary of the outer zone followed the 200 m contour.

Transects were selected by overlaying a grid of 0.85 km blocks on a nautical chart of the study area (Fig. 2). We wanted transects of approximately 1 km, so that small-scale patterns could be discerned and a reasonable sample size obtained in a short time frame. The 0.85 km block size resulted from the spacing of 2 second latitude and longitude increments, used to locate transects (see below). Thirty blocks were randomly selected in each of the two strata. Within each selected block, one transect line was randomly selected among five possible lines. All outer zone transects ran north-south. Inner zone transects ran north-south or east-west, the direction most perpendicular to shore, to avoid the possibility of running parallel to a distributional gradient of murrelets relative to shore.

Surveys were conducted following U. S. Fish and Wildlife Service (FWS) protocol (Klosiewski and Laing 1994). Weather, sea conditions, water temperature and wind were recorded prior to each transect. Surveys were discontinued if weather was not favorable (seas >2 ft or heavy rain). A 7.7 m whaler was used for surveys. The crew consisted of a boat operator and two observers. The observers recorded all birds and marine mammals ≤100 m of the vessel onto data sheets and used binoculars to assist identification. Murrelets that could not be positively identified to species were recorded as *Brachyramphus* murrelets. Unidentified murrelets were 26% of all murrelets observed. Kittlitz's murrelets (*B. brevirostris*) were rare in the study area (Kuletz 1994) and only two were identified during these surveys, therefore, we refer to all murrelets as marbled murrelets in this report. Birds flying within 100 m of the boat were included in the counts. The vessel traveled at a relatively constant speed (8 - 10 knots). Average time for each transect was 5 min.

End points of the transects were located using Loran or a Global Positioning System (GPS). We attempted to approach the start point of the transect slowly, and in line with the transect, from at least one hundred meters away to avoid flushing birds from the transect. To minimize possible effects of murrelet diel activity patterns, surveys were conducted between 0600 - 1300 hours. This period of the day had the highest murrelet densities and lowest variation in numbers in British Columbia (Carter and Sealy 1990). Each survey took 2 to 3 days to complete. Time constraints did not always permit us to conduct complete surveys, so the outer zone was surveyed 3 times and the inner zone 5 times (Table 1).

When possible the survey coincided with a complete shoreline census of the Naked Island area (see below). The survey dates also corresponded roughly to stages of marbled murrelet breeding phenology, based on our observations of fish-carrying behavior of adults and the appearance of juveniles at sea. The early season, late May and early June, was early incubation. The mid season, late June, corresponded to the early nestling period. The late season, late July to early August, corresponded to the early fledging period.

<u>Shoreline Census</u>-- A complete shoreline survey was conducted over two mornings between 0600 - 1100 h in early June of 1991 and 1992. Although all birds were counted, these surveys were primarily for the purpose of censusing

pigeon guillemot (*Cepphus columba*) colonies. A 5 m inflatable or 7.7 m whaler was used to circumnavigate Naked, Storey and Peak islands. Two observers counted all birds $\leq$200 m of shore using pre-assigned shoreline segments as transects.

Data Analysis

Murrelet Abundance -- Population estimates were calculated using a simple expansion (Cochran 1977). The population estimate and variance (used to estimate the 95% confidence intervals) were calculated as :

$$T = \frac{X}{\left(\frac{\Sigma x}{n}\right)} \cdot \frac{\Sigma y}{n} \qquad V = \frac{X^2}{\left(\frac{\Sigma x}{n}\right)^2} \cdot v$$

Where T = total population
V = total variance
v = sample variance
X = total area
x = area sampled
y = number of birds counted
n = number of transects

Shoreline Census -- We compared the number of murrelets counted on the complete shoreline census to an estimate of the population in that zone obtained from the random transects. The estimate was derived from the shoreline portion of 14 random transects that abutted the shoreline, and a simple expansion (see above) to calculate the population within 200 m of shore. We also compared the number of murrelets in the shoreline zone to the population estimate of the entire 2 km zone.

Murrelet Densities Within Strata-- We tested for differences between years (1991 and 1992) and seasons (early and late) for the inner zone by two-way analysis of variance (ANOVA), using murrelet density per transect (number of murrelets / transect area) as the sample unit (N=117; in 1992, 3 transects were not sampled). Although murrelet densities tended to be skewed among transects, the sample sizes and variances were similar among surveys, and samples were independent. Under these circumstances, the *F* test is robust against departures from normality (Neter et al. 1990; 623), so we did not transform the original data.

For the 3 surveys which sampled both zones, we tested for differences between inner and outer zones for each survey separately, with Cochran's t-test (Cochran and Cox approximation of the probability level of the t-statistic [SAS Institute Inc. 1988]), with a two-tailed test for significance at $\alpha = 0.05$.

The distribution of murrelets was also examined by graphing the frequency distribution of transects among 6 categories of murrelet density. We tested for differences in the frequency distribution between years and between strata within a survey with the Kolmogorov-Smirnov 2-sample test (SAS Institute, Inc. 1988).

Murrelet Density Relative to Distance From Shore and Water Depth -- To test the effect of distance from shore on murrelet density, we used the nearest distance of each transect from shore, measured to the nearest 0.1 km by a GIS. For each survey we tested the correlation between murrelet density and distance from shore. Because the murrelet densities were sometimes skewed, with a high percentage of empty transects and a few transects with very high densities, we used Kendall's tau-b; this test is distribution free, minimizes the effect of outliers and corrects for ties in the rankings (Hollander and Wolfe 1973, SAS Inc. 1988).

Because of the general trend of deeper water farther from shore, it is difficult to separate the effects of distance from shore and water depth on murrelet distribution. We conducted exploratory analysis on this problem by separating shallower areas from deeper areas within the inner strata, because there were sufficient numbers of blocks with deep water areas; in the outer strata there were few blocks with large portions of shallow water.

The bathymetric coverage of the study area was developed by the Alaska Department of Natural Resources. The FWS (T. Jennings and B. Boyle) used the bathymetric coverage to define underwater contours in 20 m increments to 120 m, then 120 - 200 m and >200m (Fig. 3). The source data for bathymetric coverage were National Oceanographic and Atmospheric Administration (NOAA) point data, supplemented by nautical charts where there were data gaps. The distribution of water depth categories between the two strata followed expected trends of deeper water with distance offshore. The inner zone had a higher proportion of shallow waters, and the outer zone had primarily deep water (Fig. 4).

Based on the estimated diving depths of murrelets (Sealy 1975a, Thoresen 1989), the water depth data were categorized as shallow ($\leq$60 m) or deep (>60 m). For each surveyed block in the inner zone, we calculated the percentage of underwater area within each depth category. For the inner zone, transects were divided into those with $\geq$30% area in deep water (N = 14) and those with <30% in deep water (N = 16). The 30% cut-off point was derived from a frequency distribution on the percentages of each depth category within blocks, to get a roughly equal sample size of blocks with shallow and deep water areas. We tested for differences in murrelet density between the two sets of transects (with deep water and without), with a two-tailed Cochran's t-test (SAS Institute, Inc. 1988).

RESULTS

Total Population of the Naked Island Area

Among the 3 surveys that included outer zone transects, the highest point estimate for the murrelet population in the study area was 3049 (± 1197 CI [95% confidence interval]) in June 1991 (Table 2). The lowest estimate, 878 (± 376 CI), was in August 1991. In late July 1992, we estimated 1057 (± 376 CI) murrelets in the study area. Ninety-five percent confidence intervals ranged from 36-64% of the point estimates. In both 1991 and 1992, point estimates of the population showed a decline by as much as 59%, from early to late season surveys (Table 2).

Comparison of Shoreline Census and Population Estimate

In 1991 the number of murrelets counted on the shoreline census was lower than the estimate obtained from random transects, but in 1992 the two methods yielded similar results. In early 1991, the estimated population of murrelets ≤200 m of shore (based on the 14 transects that abutted the shore) was 530 (± 660 CI), and we counted 226 murrelets on the complete shoreline census. In early 1992, the estimated population from random transects was 336 (± 204 CI) and 322 were counted on the complete shoreline census. The large confidence intervals of the random transects weakened comparisons with the shoreline census.

The murrelet count on the complete shoreline survey ≤200 m from shore represented 14% of the population estimate within 2 km of shore in early 1991, and 17% of the population estimate in early 1992.

Murrelet Densities

There was no significant difference in murrelet densities between years (Table 3; F = 0.10, df = 1, P = 0.76), but there was a seasonal effect, with higher densities early in the season (F = 6.58, df = 1, P = 0.012). There was no interactive effect between year and season (F = 0.14, df = 1, P = 0.71).

Early in 1991, murrelet densities in the inner zone were not significantly different from the outer zone (Table 3; N = 60, t = 1.17, df = 29, P = 0.25). In late 1991, however, densities in the inner zone were significantly higher than in the outer zone (N = 60, t = 3.76, df = 29, P = 0.0008). In late 1992, densities were again higher in the inner zone than the outer zone (N = 60, t = 2.65, df = 29, P = 0.013).

In early 1991 the distribution of densities among transects between the 2 strata was similar (Fig. 5a; Kolmogorov-Smirnov [KSa] = 0.90, P = 0.38), but in late 1991 the distribution of densities was different between strata (Fig. 5b; KSa = 1.42, P = 0.04). In late 1991 the outer zone had a large number of transects without murrelets, and no transect with >5 birds km^2. As a result, the distribution of frequencies for transects in the outer zone was different between early and late surveys that year (Fig. 5a and 5b; KSa = 1.49, P = 0.02). The distribution of densities in the inner zone was not significantly different between early and late surveys (Fig. 5c and 5d; KSa = 0.63, P = 0.82). In late 1992 differences in distribution of densities within transects approached significance between strata (Fig. 5d; KSa = 1.29, P = 0.07).

In general, when the population within a strata was low, such as in the outer zone in late summer, there was a high proportion of transects with no murrelets, and most, if not all of the remaining transects had <5 birds / km^2. When the population was comparatively high, transects had a range of densities, indicating murrelets were not highly clumped. However, a few locations tended to consistently have relatively high densities, such as Cabin and McPherson bays on Naked Island and the shoreline along the east side of Storey Island (Fig. 6a - d and Fig. 7a - b).

Murrelet Density Relative to Distance From Shore and Water Depth

With the exception of early June 1991, murrelet density was negatively correlated with distance of the transect from shore (Fig. 8a - c). In early May and late June 1992, when only the inner zone was sampled, we observed the same trend of lower density farther offshore (tau-b = -0.486, P = 0.001; tau-b = -0.497, P = 0.0005, respectively). The association of murrelets with nearshore marine habitat was evident in all surveys (compare Fig. 6a - d and Fig. 7a-b).

In 4 of the 5 surveys in the inner zone, the blocks with shallow waters had significantly higher murrelet densities than blocks which had ≥30% deep water; the exception was the early 1992 survey (Table 4).

Murrelet Numbers At-Sea v. Inland Activity

The trends between at-sea counts of murrelets and inland numbers of detections were not similar (Fig. 9). Inland detections increased from late June to early August (1991) or late July (1992). In contrast, the at-sea population decreased in early August (1991) and late July (1992) compared to earlier the same year.

DISCUSSION

At-Sea Abundance of Murrelets

We found seasonal effects on murrelet density to be stronger than annual differences between 1991 and 1992. Murrelet density in late July 1992 was also lower than earlier the same year, although late July does not always show a decline in murrelets (see Kuletz 1994, Appendix). A decline in murrelet numbers between June and August was also observed at Naked Island from 1978 - 1980 and 1990 (murrelet numbers were aberrant in June 1989, the year of the *Exxon Valdez* oil spill [Kuletz 1994]). Notable local changes in murrelet abundance in late summer appears to be typical and has implications for the design of murrelet surveys.

Changes in murrelet density in late summer have varied among years at the same site, and among different geographic areas. For example, in the Naked Island area murrelet counts remained high in late July of 1978, 1979 and 1980, but decreased in late July of 1989 and 1990 (Kuletz 1994). In Kachemak Bay, southcentral Alaska (Fig. 1), murrelet density increased 3-fold in late July 1988, and did not decline until late August (Kuletz 1989). Along the Kenai Fjords coastline (Fig. 1), murrelet numbers increased from 2000 in June to 6500 in August 1989 (M. Tetreau, Kenai Fjords National Park, Seward, Alaska, unpubl. data), perhaps an indication of migration south at this time.

The summer seasonal changes in murrelet densities are presumably associated with their breeding phenology and/or prey movements (Sealy 1975b, Carter 1984, Rodway et al. 1992). By mid-June approximately half of the breeding population may be incubating, reducing numbers on the water. At Naked Island, the lower densities in June 1992, compared to late May 1992, probably reflects this change in behavior. July is the peak nestling period in PWS (Kuletz et al. 1994a, Naslund et al. 1994), and both members of breeding pairs would be on the water. However, murrelet densities in July can be highly variable and the examples above show that early July can be significantly different from late July. In other alcid species, birds may leave a breeding area if nest failures are high, or weather affects foraging (review in Nettleship and Birkhead 1985). If murrelets behave similarly, late season movements in Prince William Sound might also reflect environmental perturbations. With appropriate baselines established, late summer surveys might be an indicator of annual murrelet productivity and distribution of their prey base.

Late July may be a period of early migration from murrelet breeding areas in Southcentral Alaska. In Kachemak Bay, Kuletz (1989) noted greater day-to-day variance in murrelet densities and higher peak densities in late July, compared to June and early July. As birds become independent of nest sites, post- and non-breeding birds may aggregate at prey concentrations in late July, causing greater variation in local numbers (Sealy 1975b, Carter 1984, Sealy and Carter 1984).

Effectiveness of Sampling Design

These surveys provided the first statistically rigorous estimate of the murrelet population around the Naked Island area. However, the variances associated with the point estimates were higher than that for the PWS population as a whole (Klosiewski and Laing 1994, Agler et al. 1994). Transect length for the PWS surveys averaged 5.5 km, considerably longer than our 0.85 km transects, which may have contributed to our higher variance. However, to compensate for high variance in the much smaller area of Naked Island, a more consistent monitoring effort might be more desirable than longer transects. Although a larger number of transects per survey might also reduce the variance, our goal was to develop a survey that could be implemented in 2 or 3 days during morning hours, and would fit the scale of a relatively small study area. Possibly, adaptive cluster sampling could improve efficiency (see Thompson 1992).

For an area the size of Naked Island (66 km of shoreline), the complete shoreline census was effective for monitoring waters $\leq$200 m from shore. Alternatively, randomly-selected transects could be surveyed. However, in this case the effort in the field would probably equal that of the complete shoreline census, due to the set-up time per transect.

Our results suggest that in late May and early June, approximately 15% of birds within 2 km of these islands were $\leq$200 m from shore. If the proportion of birds within 200 m of shore, in a given time period, is relatively consistent among years, the shoreline census would be a good indicator of the size of the local murrelet population. However, more surveys that include both nearshore and offshore waters are required to determine if the proportion is consistent. Because of the seasonal changes in abundance and distribution, shoreline surveys in June should not be compared to July surveys for purposes of monitoring population trends. Additionally, the proportion of birds nearshore is probably related to local water depth, and the Naked Island area is not representative of most of western PWS, due to the relatively shallow waters extending 5 km from these islands.

Distribution Relative to Distance From Shore and Water Depth

At Naked Island a large portion of the murrelet population foraged >2 km from shore early in the season. This was consistent with other surveys in PWS that found murrelets, albeit at low densities, in pelagic transects (Klosiewski and Laing 1994, Agler et al. 1994, FWS, unpubl. data). Our results also suggested that those murrelets still present in late summer were concentrated near shore. Carter (1984) found a similar pattern in British Columbia, with murrelets widely distributed early in the breeding season, and more aggregated in nearshore waters in late July, presumably where food was abundant. At Naked Island, the shift towards nearshore in late summer probably reflected changes in the distribution of forage fish. Tracking changes in murrelet distribution could also improve management decisions. For example, nearshore commercial fishing might be managed to minimize encounters with murrelets at important feeding sites during sensitive periods.

The higher density of murrelets in nearshore, shallow waters that we observed supports trends described in other studies (Sealy 1975a, Carter 1984, Mahon et al. 1992). In addition, our data suggest that murrelets forage more frequently in shallow waters than in deeper waters of the same nearshore zone. This hypothesis could be tested by post-stratification and reanalysis of the PWS boat data for murrelets for 1972, 1989-1991 and 1993.

Murrelet Numbers At-Sea v. Inland Activity

Our at-sea survey effort was not adequate to statistically test the relationship between inland and at-sea activity. In addition, the regularly-monitored sites were all in south Cabin Bay, whereas the at-sea surveys included waters surrounding the entire island complex. However, we believe the two measures are comparable. The pattern of inland activity we observed at the monitored sites was consistent with patterns observed throughout Naked Island and PWS (Kuletz et al. 1994a, Marks et al. 1994), the Kenai Fjords and Afognak Islands (Kuletz et al. 1994b), as well as locations farther south (O'Donnell et al. 1995). The increase in inland detections in July is typical, and therefore Cabin Bay should reflect trends in inland activity for the entire area. We also believe the at-sea survey of the larger area is appropriate, because murrelets forage over a wide area during the breeding season (Burns et al. 1994, Kuletz et al. ms).

One explanation for the discrepancy between at-sea and inland observations in late July is that the number of detections does not reflect the number of birds using the local marine habitat, but rather a change in murrelet behavior when they fly inland. Birds may be more vocal and circle nesting areas more frequently after chicks have fledged, and prior to adult migration from breeding grounds. In the vicinity of failed nests on Naked Island, we recorded high frequencies of birds landing on tree branches at dawn (Kuletz et al. 1994a). A more complete analysis of the dawn watches conducted near nests will help determine if post-breeding birds increase their displays and vocalizations, thus contributing to higher detection levels in late July.

CONCLUSIONS

Changes in murrelet abundance and distribution between May and August at Naked Island were significant. For this reason, at-sea surveys to detect annual population trends should be designed such that replicates are conducted during the same seasonal window each year.

Murrelets at Naked Island were most abundant in shallow waters <2 km from shore. However, birds appeared to be more dispersed early in the summer and concentrated nearshore in late summer. This change in distribution likely reflects changes in the distribution of forage fish. To minimize human impacts on murrelets at sea, it would be desirable to identify late summer areas of murrelet concentration, either by locating specific sites or identifying marine habitat types.

Our population estimates for the relatively small area of the Naked Island complex were weakened by large confidence intervals, due to high variance among transects. Additional sampling, or a form of adaptive cluster sampling, should improve the statistical power of surveys for small areas. The shoreline (<200 m zone) alone may be appropriate to serve as an index in early June; however, it would first be necessary to determine if the proportion of birds in an area found within in that zone is consistent year-to-year.

We found no correlation between seasonal changes in murrelet numbers at sea and inland murrelet detection rates, although we had a limited data set. Our data suggest that increased inland detections in late July reflects changes in murrelet behavior near their nesting sites rather than additional birds flying inland. Additionally, at-sea surveys after mid-July may not be appropriate for identifying important murrelet breeding areas, as many birds are already leaving nesting areas. However, late summer surveys could identify post-breeding feeding grounds where protective measures could be explored.

LITERATURE CITED

Agler, B.A., P.E. Seiser, S.J. Kendall, and D.B. Irons. 1994. Marine bird and sea otter population abundance of Prince William Sound, Alaska: Trends following the *T/V Exxon Valdez* Oil Spill, 1989-93. *Exxon Valdez* Oil Spill Restoration Project Final Report, Project 93045. USDI Fish and Wildlife Service, Anchorage, AK.

Burns, R.A., L.M. Prestash and K.J. Kuletz. 1994. Pilot study on the capture and radio tagging of murrelets in Prince William Sound, Alaska, July and August, 1993. *Exxon Valdez* Oil Spill Restoration Project Final Report, Project 93051B. USDI Fish and Wildlife Service, Anchorage, AK.

Carter, H.R. and S.G. Sealy. 1990. Daily foraging behavior of marbled murrelets. Studies in Avian Biology 14: 93-102.

Carter, H.R. 1984. At-sea biology of the Marbled Murrelet (*Brachyramphus marmoratus*) in Barkley Sound, British Columbia. M.Sc. thesis, Univ. Manitoba, Winnipeg.

Cochran, W. G. 1977. Sampling Techniques. John Wiley and Sons, Inc., New York.

Ecological Consulting, Inc. 1991. Assessment of direct seabird mortality in Prince William Sound and the Western Gulf of Alaska resulting from the *Exxon Valdez* oil spill. Ecological Consulting, Inc., Portland, OR. 153 pp.

Hollander, M. and D.A. Wolfe 1973. Non Parametric Statistical Methods. John Wiley and Sons, Inc. New York.

Kessel, B. 1979. Avian habitat classification for Alaska. Murrelet 60: 86-94.

Klosiewski, S. P., and K. K. Laing. 1994. Marine bird populations of Prince William Sound, Alaska, before and after the *Exxon Valdez* Oil Spill. *Exxon Valdez* Oil Spill State/Federal Natural Resources Damage Assessment Final Reports: Bird Study 2. USDI Fish and Wildlife Service, Anchorage, AK.

Kuletz, K. J. 1989. Variability in repeat censusing of marbled murrelets in Kachemak Bay, Alaska; summer 1988. Abstract. Pacific Seabird Group Bull. 15(1).

Kuletz, K. J. 1991. Identification of upland habitats used by wildlife affected by the EVOS: marbled murrelets. *Exxon Valdez* Oil Spill Restoration Project

Final Report, Feasibility Project R4, USDI Fish and Wildlife Service, Anchorage, AK.

Kuletz, K.J. 1994. Marbled Murrelet Abundance and Breeding Activity at Naked Island, Prince William Sound and Kachemak Bay, Alaska, Before and After the *Exxon Valdez* Oil Spill. *Exxon Valdez* Oil Spill State/Federal Natural Resources Damage Assessment Final Reports: Bird Study 6. USDI Fish and Wildlife Service, Anchorage, AK. 46 pp.

Kuletz, K.J., N.L. Naslund and D.K. Marks. 1994a. Identification of marbled murrelet nesting habitat in the *Exxon Valdez* oil spill zone. *Exxon Valdez* Oil Spill Restoration Project Final Report, Project R15. USDI Fish and Wildlife Service, Anchorage, AK. 70 pp.

Kuletz, K.J., D.K. Marks, N.L. Naslund, N.J. Goodson, M.B. Cody. 1994b. Information needs for habitat protection: marbled murrelet habitat identification. *Exxon Valdez* Oil Spill Restoration Project Final Report, Project 93051B. USDI Fish and Wildlife Service, Anchorage, AK.

Kuletz, K. J., D.K. Marks, D.Flint, R. Burns, L. Prestash. MS. Marbled Murrelet Foraging Patterns in Prince William Sound, Alaska. *Exxon Valdez* Oil Spill Restoration Project Final Report (Project 94102), USDI Fish and Wildlife Service, Anchorage, AK.

Marks, D. K., K.J. Kuletz, and N.L. Naslund. 1994. Use of boat-based surveys to determine inland coastal habitat associations of marbled murrelets in Prince William Sound, Alaska. In: Nelson, S.K. and S.G. Sealy (eds). Biology of Marbled Murrelets - Inland and At Sea. Proc. Pacific Seabird Group Symp. Northwestern Naturalist Vol.75 (3).

Mahon, T. E., G. W. Kaiser and A. E. Burger. 1992. The role of Marbled Murrelets in mixed-species feeding flocks in British Columbia. Wilson Bull., 104(4): 743-747.

Naslund, N. L., K. J. Kuletz, M. Cody and D. K. Marks. 1994. Tree and habitat characteristics and reproductive success of marbled murrelet tree nests in Alaska. In: Nelson, S.K. and S.G. Sealy (eds). Biology of Marbled Murrelets: Inland and At Sea. Proc. Pacific Seabird Group Symp. Northwestern Naturalist Vol.75 (3).

Neter, J., W. Wasserman and M.H. Kutner. 1990. Applied linear statistical models: regression, analysis of variance and experimental designs. Irwin, Boston MA.

Nettleship, D.N. and T.R. Birkhead. 1985. The Atlantic Alcidae. Academic Press, Harcourt Brace Jovanovich, Publishers.

O'Donnell, B., N.L. Naslund and C.J. Ralph. 1995. Patterns of seasonal variation of activity of marbled murrelets in forested stands. Pages 117 - 128 In: C.J. Ralph, G.L. Hunt, Jr., M.G. Raphael, and J.F. Piatt (eds). Ecology and Conservation of the Marbled Murrelet. USDA For. Serv. Gen. Tech. Rep. PSW-GTR-152.

Piatt, J. F., C. J. Lensink, W. Butler, M. Kendziorek, and D. K. Nysewander. 1990. Immediate impact of the 'Exxon Valdez' oil spill on marine birds. Auk 107:387-397.

Ralph, C. J., S. K. Nelson, M. M. Shaughnessy, and S. L. Miller. 1993. Methods for surveying marbled murrelets in forests. Pacific Seabird Group, Marbled Murrelet Technical Committee, Technical paper #1. Oregon Cooperative Wildlife Research Unit, Oregon State University, Corvallis, Oregon. 47pp.

Rodway, M.S., H.R. Carter, S.G. Sealy, and R.W. Campbell. 1992. Status of the marbled murrelet in British Columbia. pp. 17-41. In: H.R. Carter and M.L. Morrison. Status and Conservation of the Marbled Murrelet in North America. Proc. West. Found. Vert. Zool. 5(1).

SAS Institute, Inc. 1988. SAS User's Guide, release 6.03 Edition. SAS Institute Inc., Cary, N.C., 1028 pp.

Sealy, S.G. 1975a. Feeding ecology of the ancient and marbled murrelets near Langara Island, British Columbia. Can. J. Zool. 53: 418-433.

Sealy, S. G. 1975b. Aspects of the breeding biology of the marbled murrelet in British Columbia. Bird-Banding 46:141-154.

Sealy, S. G. and H.R. Carter. 1984. At-sea distribution and nesting habitat of the marbled murrelet in British Columbia: Problems in the conservation of a solitarily nesting seabird. In: Croxall, J.P., P.G.H. Evans and R. W. Schrieber, eds. Status and conservation of the world's seabirds. Intl. Committee for Bird Protection Tech. Publ. No.2

Thompson, S.K. 1992. Sampling. John Wiley and Sons, Inc., pp. 263-301.

Thoresen, A. C. 1989. Diving times and behavior of pigeon guillemots and marbled murrelets off Rosario Head, Washington. Western Birds 20: 33-37.

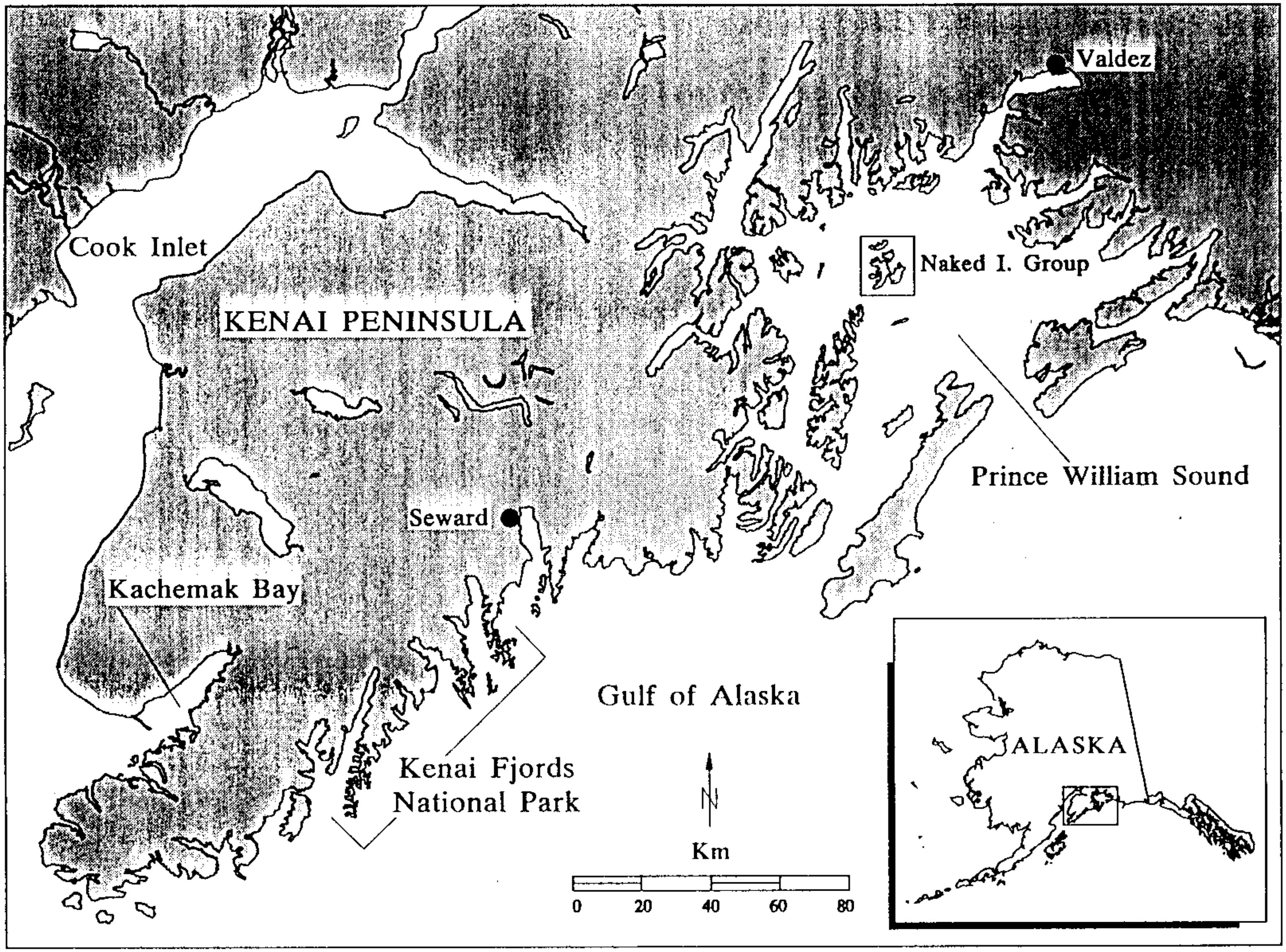


Figure 1. The Naked Island Group in central PWS, Alaska. Also shown are Kachemak Bay and the Kenai Fjords.

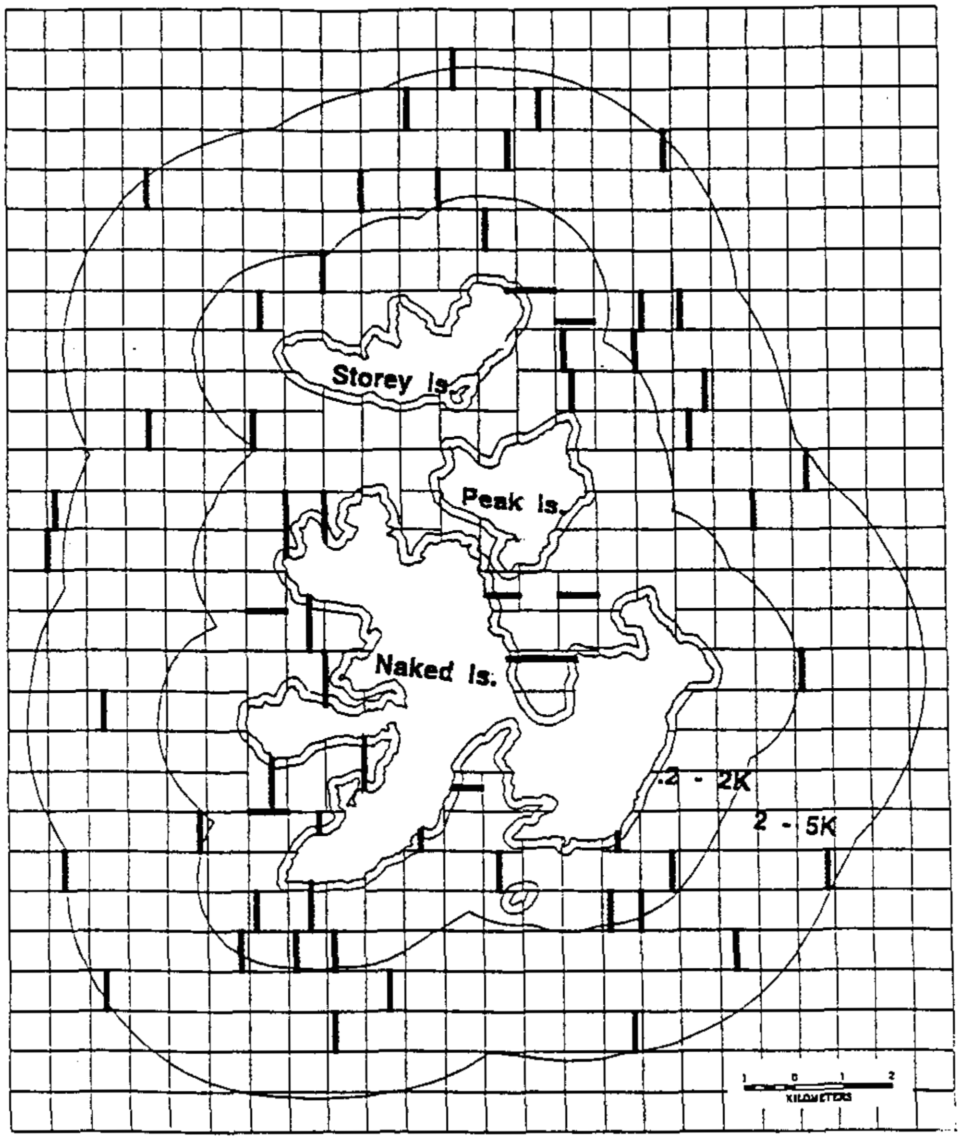
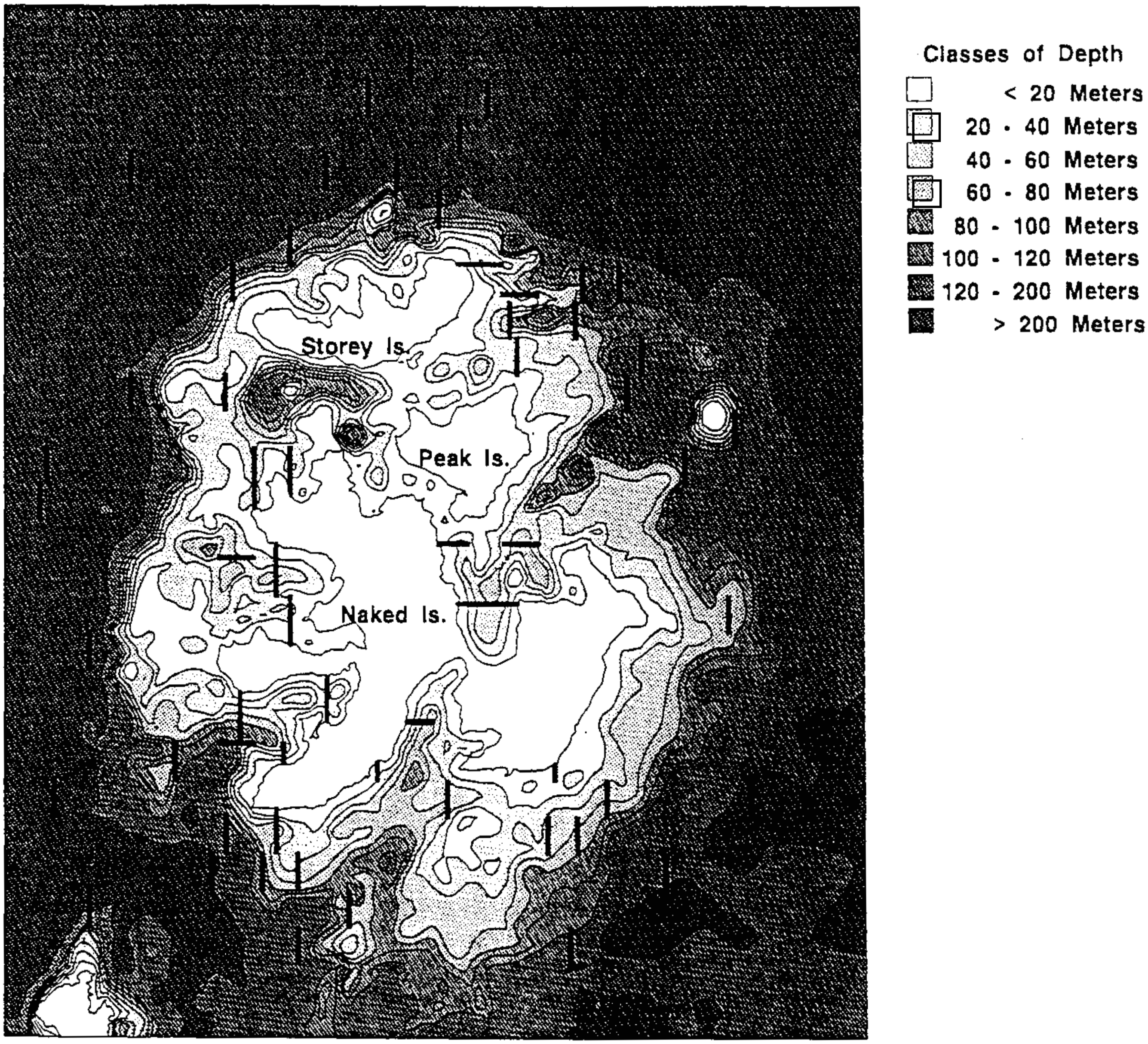


Figure 2. The Naked Island study area, showing the 200 m buffer around the islands, the inner and outer zones, the grid used for transect selection and the randomly-selected transects (black bars) surveyed in 1991 and 1992. The grid follows latitude and longitude lines.



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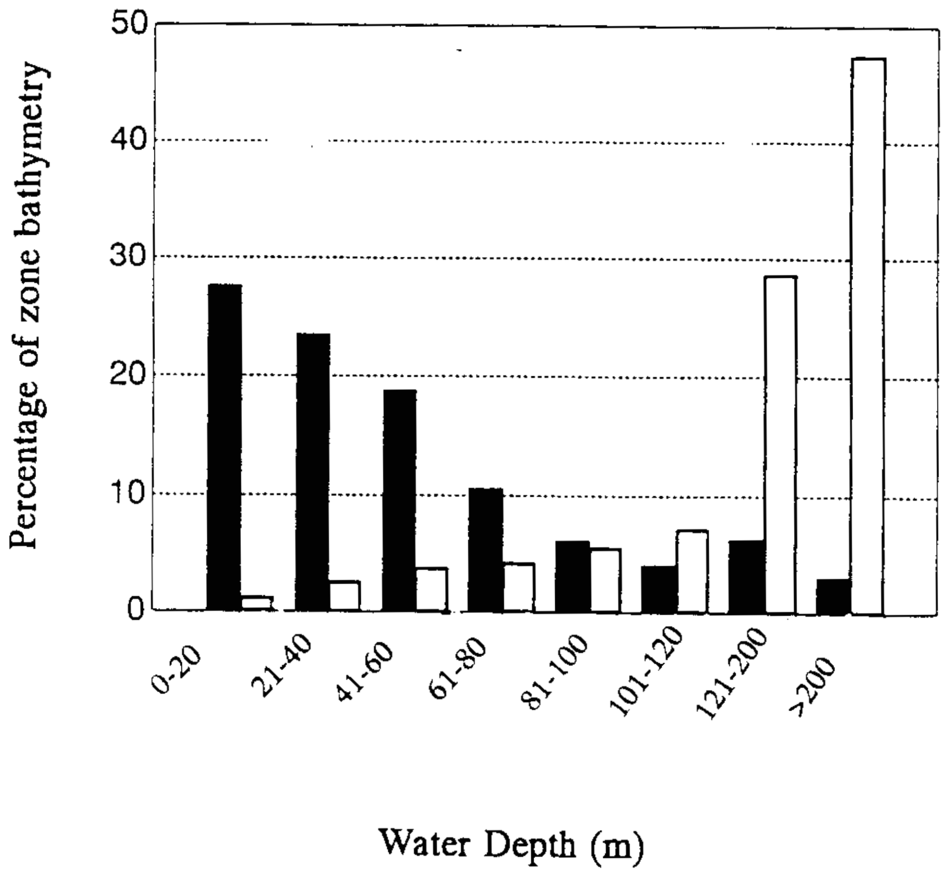

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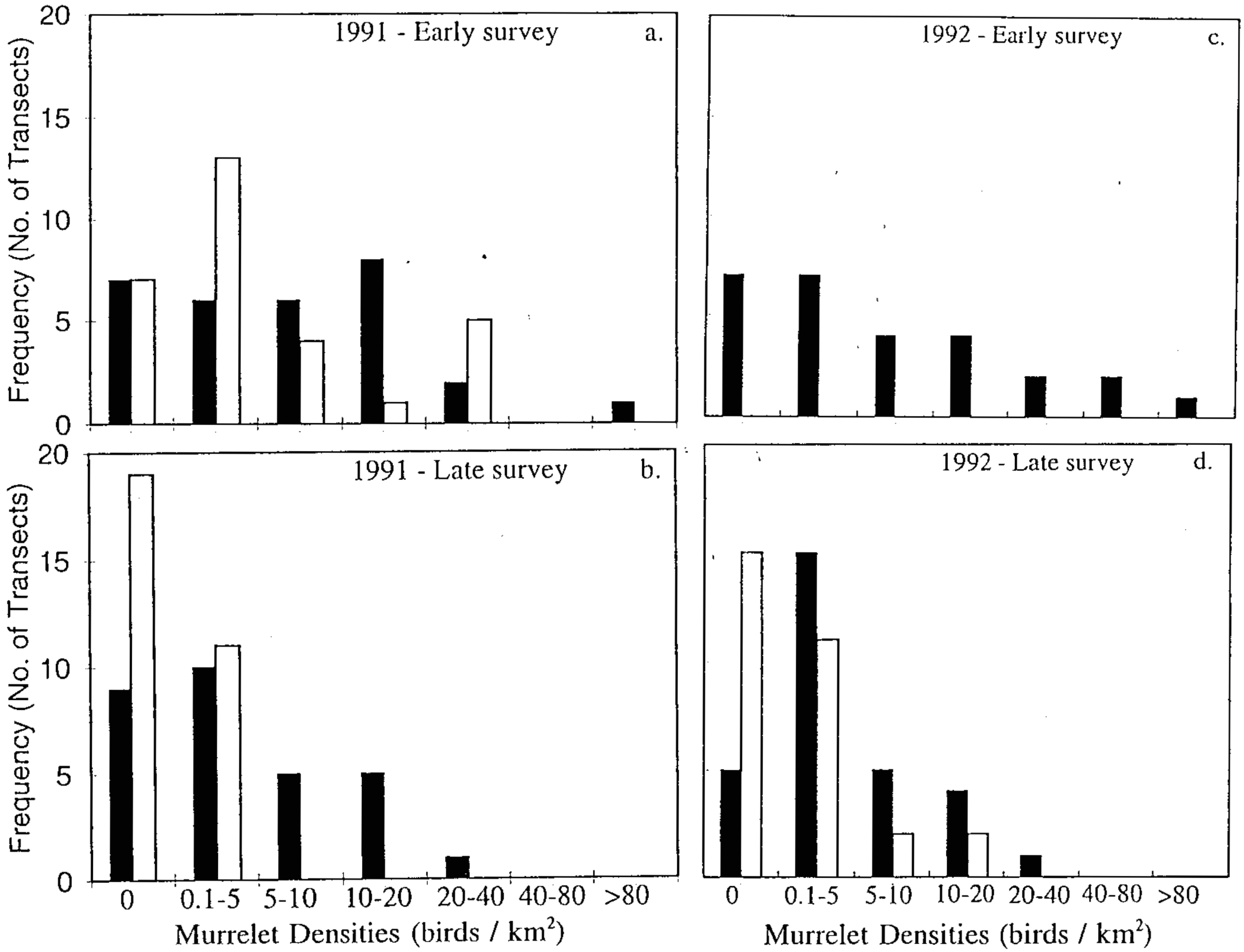

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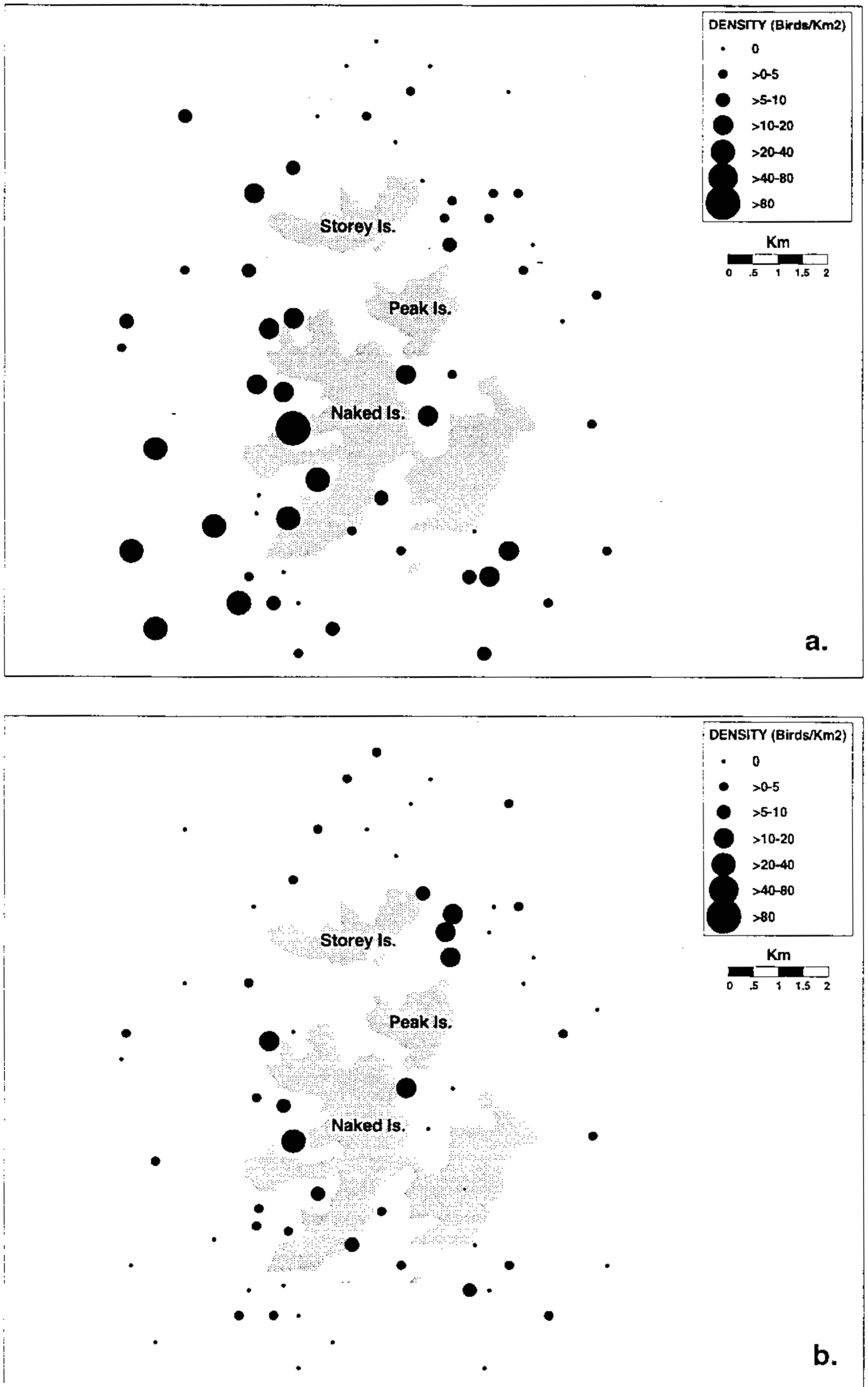

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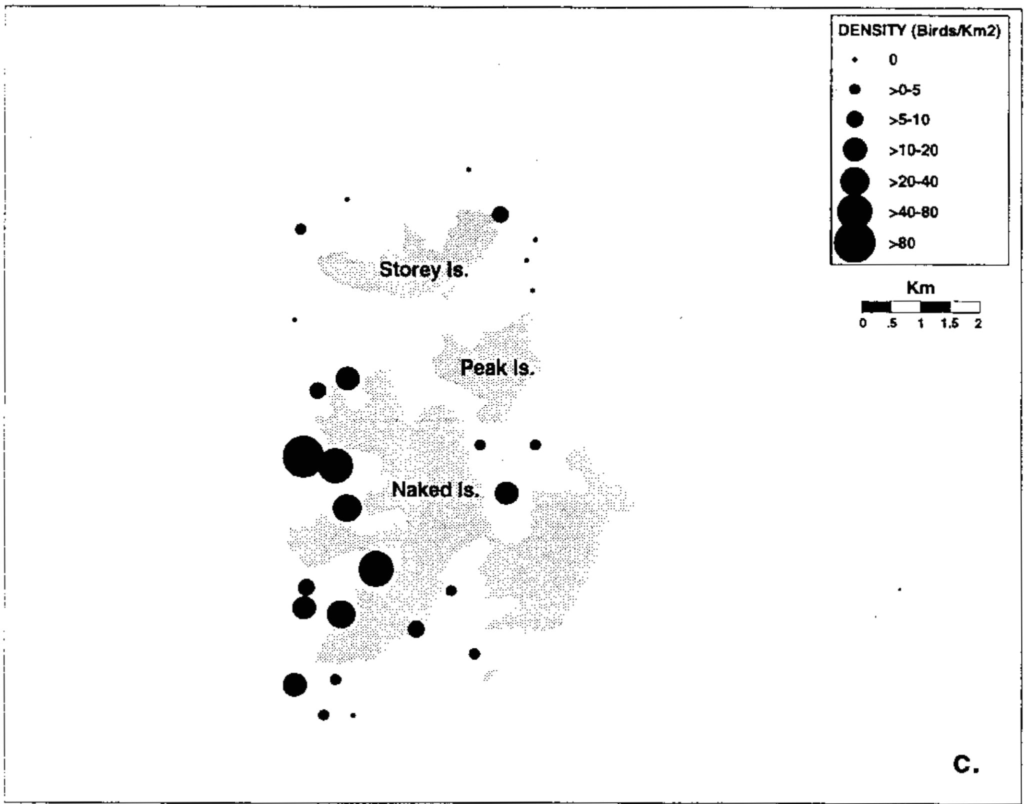


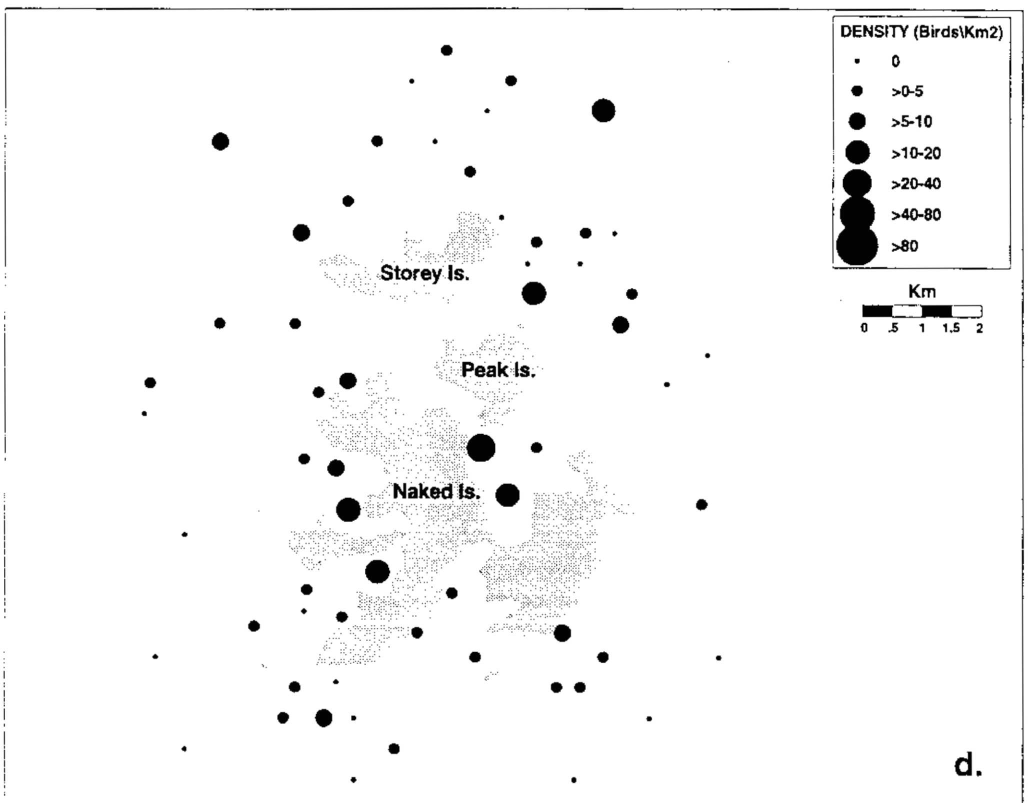
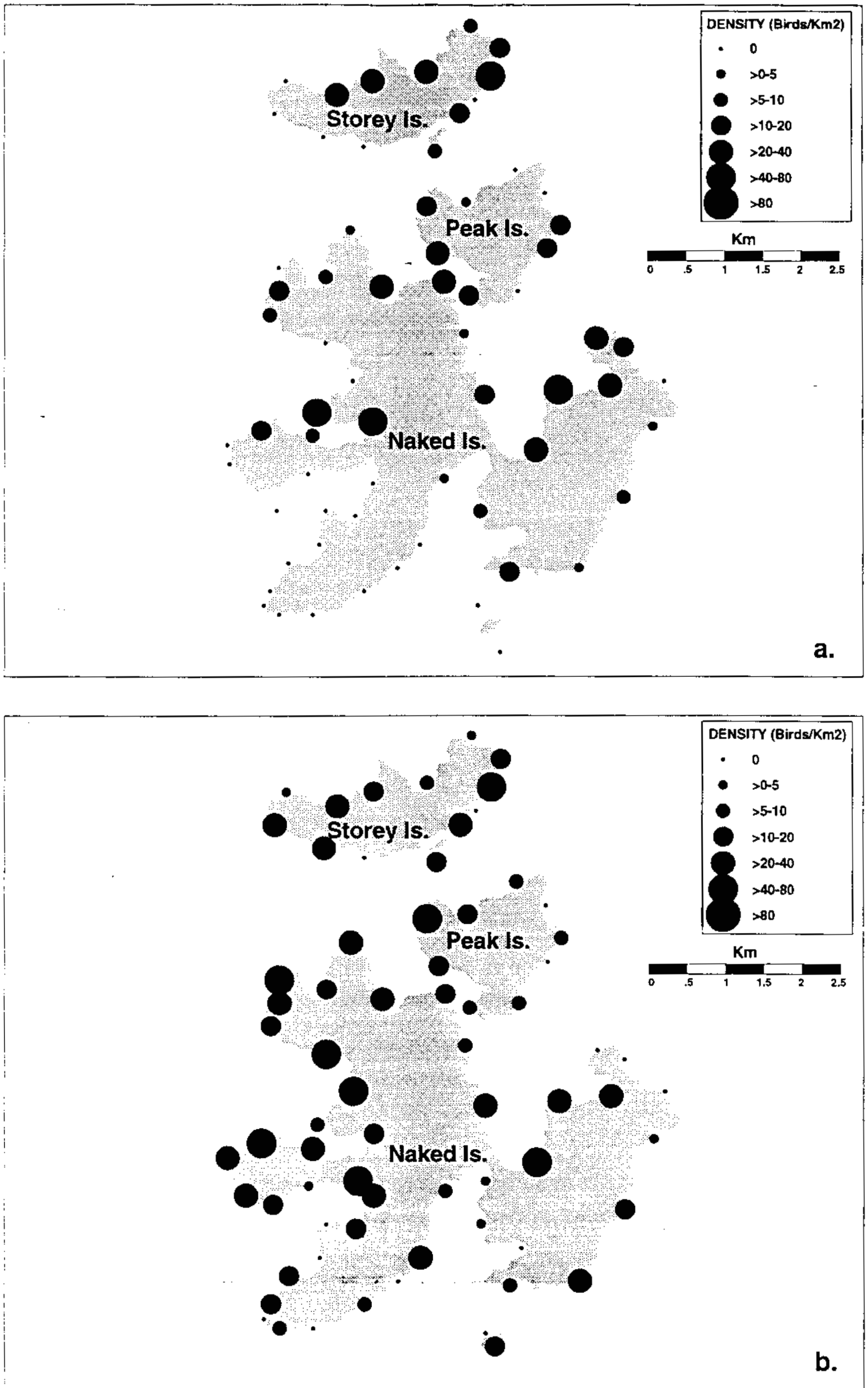


Figure 6c-d. Marbled murrelet density on transects around Naked, Storey and Peak islands for (c) late May 1992, and (d) late July 1992. In May, data were from 30 random transects $\leq$ 2 km from shore. In July, data were from 60 random transects $\leq$ 5 km from shore.



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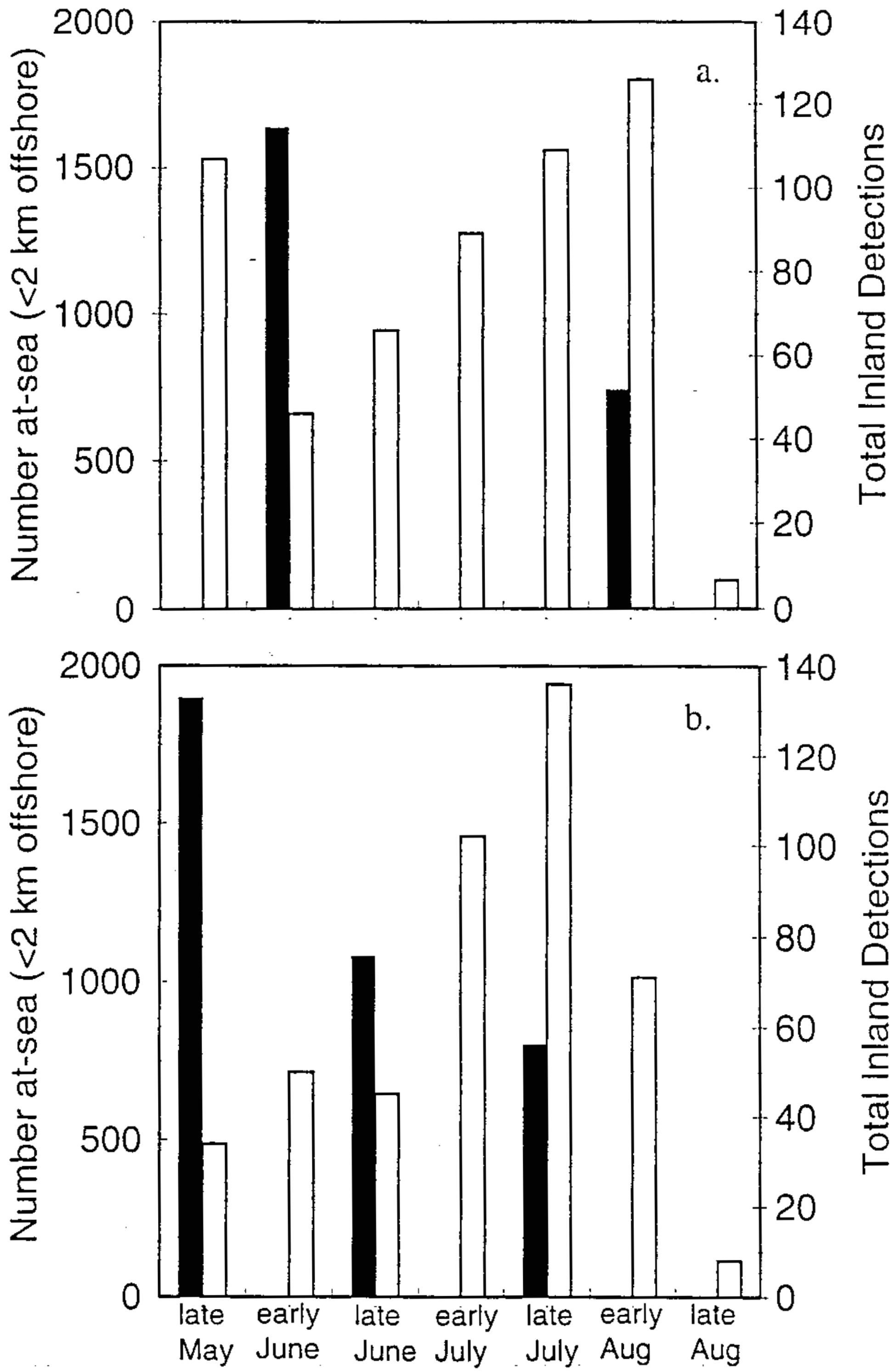

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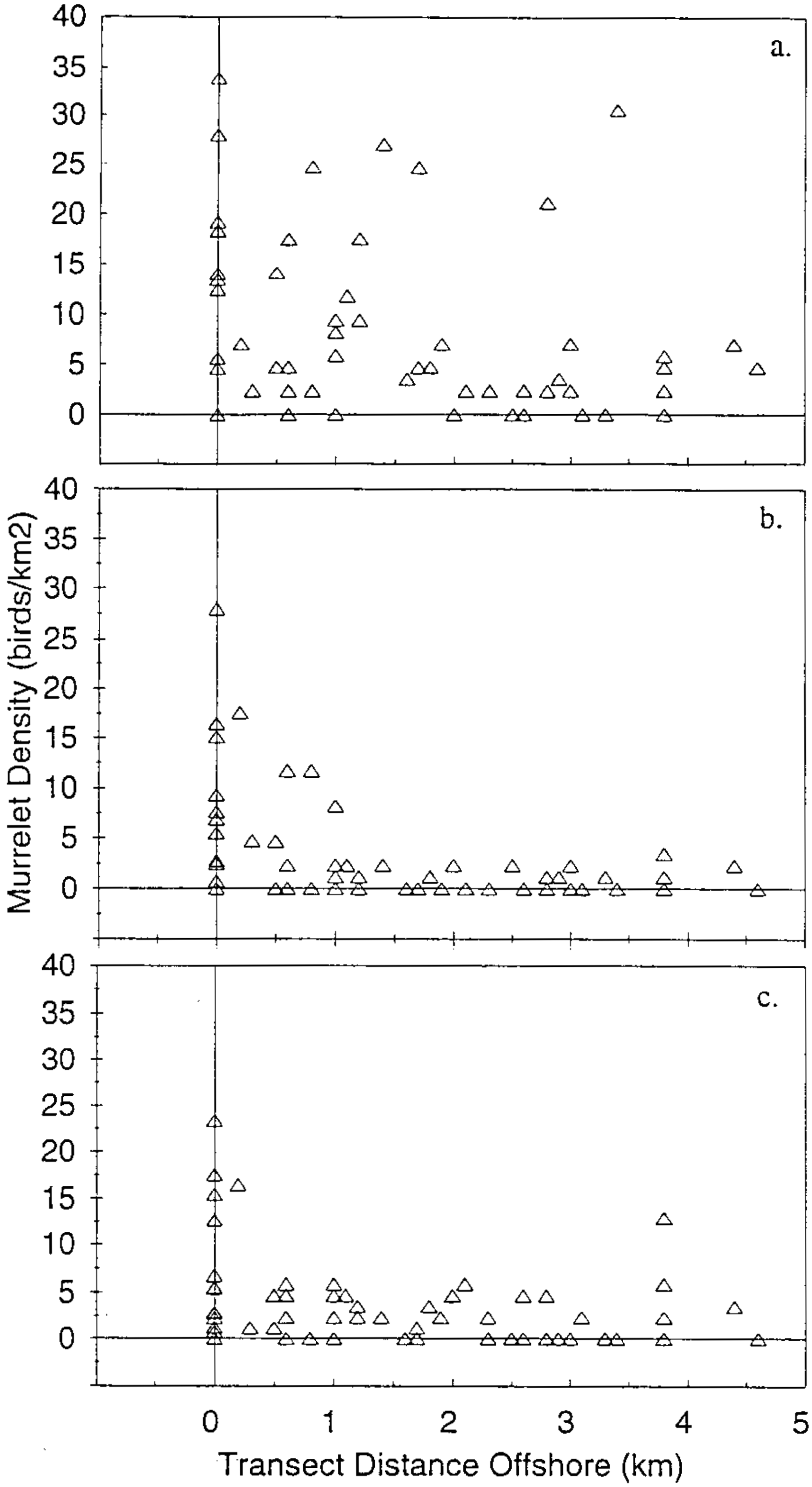

Figure 8. Marbled murrelet density vs. distance of the transect from shore, during surveys on randomly-selected transects within 5 km of Naked, Storey and Peak islands. (a) June 1991, tau-b = -0.18, N = 60, P = 0.059; (b) August 1991, tau-b = -0.30, N = 60, P = 0.002; and (c) July 1992, tau-b = -0.27, N = 60, P = 0.005.

Table 1. Survey effort and dates for at-sea surveys of waters ≤5 km of Naked, Storey and Peak islands in Prince William Sound, Alaska, in 1991 and 1992. The complete shoreline census counted birds ≤200 m from shore. Transects were in the inner zone (0-2 km offshore; N = 30) or outer zone (2-5 km; N = 30).

Year	Strata	Survey Dates		
		Early	Mid	Late
1991	Shoreline census	June 5-7	-	-
	Inner zone	June 7-9	-	Aug 6-8
	Outer Zone	June 7-9	-	Aug 6-8
1992	Shoreline census	June 6-8	-	-
	Inner zone	May 25-27	Jun 26-29	Jul 26-27
	Outer zone	-	-	Jul 26-27

Table 2. Estimated murrelet population ≤5 km of Naked, Storey, and Peak islands, Prince William Sound, Alaska, in early, mid and late summer of 1991 and 1992, based on counts of murrelets on randomly-selected transects in two strata: inner (0-2 km offshore; N=30) and outer (2-5 km offshore; N=30). Dashes indicate no survey was conducted.

		Early Summer		Mid Summer		Late Summer	
Year	Zone	N	(95% CI)	N	(95% CI)	N	(95% CI)
1991	Inner	1633	(± 998)	-		740	(±368)
	Outer	1416	(± 660)	-		138	(± 73)
	Total	3049	(±1197)	-		878	(± 376)
1992	Inner	1897	(±1205)	1083	(± 477)	803	(± 313)
	Outer	-		-		394	(± 207)
	Total	-		-		1057	(±376)

Table 3. Murrelet densities (birds/km^2) on randomly-selected transects $\leq$5 km of Naked, Storey and Peak islands, Prince William Sound, Alaska, early and late summer 1991 and 1992.

		Early Summer			Late Summer		
Year	Strata	N	Mean Density	SD	N	Mean Density	SD
1991	Inner	30	11.4	17.4	30	5.4	6.8
	Outer	30	7.2	9.2	30	0.7	1.0
1992	Inner	27	13.2	20.7	30	5.3	5.7
	Outer	-	-	-	30	2.1	2.4

Table 4. Murrelet densities (birds/km^2) on randomly-selected transects $\leq$2 km of Naked, Storey and Peak islands, Prince William Sound, Alaska, in early and late summer 1991 and 1992, relative to water depth. Text describes water depth categories. A t-test was used to test for differences in density between shallow areas (N = 16) and deep water areas (N = 14). DF = 28 for each test.

Year	Summer Period	Water Depth	Murrelet Density (Birds/km^2) Mean	SD	*t*	P
1991	Early	Shallow	17.2	21.9	-2.21	0.04
		Deep	4.7	5.5		
	Late	Shallow	7.8	7.9	-2.29	0.04
		Deep	2.7	4.1		
1992	Early	Shallow	16.3	18.2	-0.68	0.49
		Deep	10.4	26.1		
	Mid	Shallow	14.7	3.7	-3.36	0.004
		Deep	2.1	0.6		
	Late	Shallow	7.7	7.1	-2.74	0.02
		Deep	2.5	2.3		

Exxon Valdez Oil Spill
State/Federal Natural Resource Damage Assessment Final Report

Identification of Marbled Murrelet Nesting Habitat in the *Exxon Valdez* Oil Spill Zone

Restoration Study Number 15-2
Final Report

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December 1994

Identification of Marbled Murrelet Nesting Habitat
in the *Exxon Valdez* Oil Spill Zone

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Study History: This study was initiated in 1991, and was preceded by a pilot study in 1990 (Restoration Feasibility Study No. 4, Identification of Upland Habitats Used by Wildlife Affected by the EVOS: Marbled Murrelets). Related at-sea studies, under Project R15-1, were reported in: Kuletz, K.J., D.K. Marks and N.L. Naslund. 1994. At-Sea Abundance and Distribution of Marbled Murrelets in the Naked Island Area, Prince William Sound, Alaska, in Summer, 1991 and 1992. Three articles based on the findings of projects R15-1 and -2 were published in S.K. Nelson and S.G. Sealy (eds) 1994. Biology of Marbled Murrelets - Inland and At Sea. Northwestern Naturalist 75(3). They were: (1) Kuletz, K.J., D.K. Marks, N.L. Nasland, and M.B. Cody. Marbled murrelet activity in four forest types at Naked Island, Prince Willam Sound, Alaska. (2) Naslund, N.L., K.J. Kuletz, M.B. Cody, and D.K. Marks. Tree and habitat characteristics and reproductive success at marbled murrelet tree nests in Alaska. (3) Marks, D.K., K.J. Kuletz, and N.L. Naslund. Use of boat-based surveys to determine inland coastal habitat associations of marbled murrelets in Prince William Sound, Alaska.

Abstract: In the summers of 1991 and 1992, we studied dawn activity patterns of marbled murrelets in Prince William Sound (PWS) to develop a protocol for Southcentral Alaska. To describe nesting habitat in PWS, we conducted dawn watch surveys at randomly selected sites and located 10 murrelet nests on Naked Island. Murrelet dawn activity began two hours before dawn, necessitating earlier dawn surveys than at lower latitudes. We also found a more compressed breeding season than at lower latitudes. Murrelet activity on Naked Island was highest in forests of moderate to high volume and high stand size (large trees). Sites near the heads of bays had higher activity levels than others. At 68 sites throughout PWS, activity was highest at bay heads, in high-volume, old-growth forests with more mossy platforms per tree, and sites located in larger stands. All nests were in old-growth coniferous trees on mossy platforms. Nest trees were larger in diameter and had more epiphyte cover and platforms than surrounding trees. Seven of the nests failed due to avian predation, abandonment, or unknown causes.

Key Words: *Brachyramphus marmoratus,* marbled murrelet, Naked Island, Prince William Sound, nesting habitat, nests, dawn surveys, old-growth forests.

Citation: Kuletz, K.J., N.L. Naslund, and D.K. Marks. 1994. Identification of marbled murrelet nesting habitat in the *Exxon Valdez* oil spill zone, *Exxon Valdez* Oil Spill State/Federal Natural Resource Damage Assessment Final Report (Restoration Study Number 15-2), U.S. Fish and Wildlife Service, Anchorage, Alaska.

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ACKNOWLEDGEMENTS

M. Cody and G. Esslinger contributed throughout this project with their excellent field assistance during murrelet surveys. Our thanks also for field assistance by A. Belleman, I. Manley, G. Landua, D. Kaleta, S. Anderson, D. Goley and D. Huntwork. S. Borchers and C. Hubbard provided USFS cooperation and support. Biologists with the U.S. Forest Service which worked in cooperation with us in the field were G. Johnson, C. Wertheim, D. Sigmund, L. Raglund, A. Kirn and C. Hubbard. Z. Cornet and B. Williams (USFS) provided the GIS habitat maps of the study area. S. Klosiewski counseled us on study design and analysis and provided figure 2-6. M. Nixon provided invaluable help with tree climbing and documentation of nests. Assistance from boat operators D. Janka and A. Janka contributed to a successful 1992 season. T. Jennings, B. Boyle and C. Wilder were unfailing in their GIS support (Office of Oil Spill, USFWS). Earlier drafts of this report were improved by comments from K. Oakley, T. Jennings, M. Cody.

EXECUTIVE SUMMARY

The marbled murrelet (*Brachyramphus marmoratus*) was one of the seabirds affected by the *Exxon Valdez* oil spill. This small alcid is listed as threatened in California, Oregon and Washington due to loss of its nesting habitat, which is primarily in old-growth conifers. Protection of nesting habitat of the marbled murrelet has been proposed as a means of enhancing natural recovery in the spill zone. However, little was known about the murrelet's nesting habitat in Alaska. The goal of this project was to identify upland habitat used by murrelets for nesting in the spill zone.

In Prince William Sound, we found upland activity of marbled murrelets began two hours before official dawn, necessitating earlier dawn surveys than at lower latitudes. Activity levels were affected by breeding phenology and weather conditions. On Naked Island, Prince William Sound, murrelets showed a more compressed breeding season than at lower latitudes, and surveys were therefore conducted May, June and July.

Using ground search techniques, we located 10 marbled murrelet nests on Naked Island in 1991 and 1992. These nests were on mossy platforms on branches of old-growth mountain hemlock (*Tsuga mertensiana*) (7 nests), western hemlock (*T. heterophylla*) (2 nests) and Sitka spruce (*Picea sitchensis*) (1 nest). Nest trees tended to be larger in diameter and had more epiphyte cover and potential nest platforms than surrounding trees. Nest trees were located in stands of the highest timber volume and size class found in Prince William Sound, although tree sizes were smaller than nest trees at lower latitudes. At least seven of these nests failed due to avian predation, abandonment, or unknown causes.

Murrelet activity levels among four forest types (N=72 sites) on Naked, Storey and Peak islands were non-random. Murrelet activity, including behavior indicative of nesting, was highest in forests of moderate to high volume and high stand size (i.e., large trees). These same stands tended to be on moderate slopes between 100 - 300 m from the ocean. Sites near the heads of bays had significantly higher activity levels than sites on peninsulas.

In 1992 we surveyed 68 randomly selected sites in western Prince William Sound to test a methodology for documenting murrelet upland activity in large remote areas by boat, and to record activity levels among habitats. Surveys conducted from an anchored vessel were comparable to those done from the shoreline and up to 600 m inland. This method will work for surveying remote areas, although intensive upland work is required to identify specific nesting habitats further inland. As at Naked Island, sites near bay heads had more murrelet activity than other sites. Sites with high murrelet activity levels had larger trees with more mossy platforms than those with low activity levels. Based on preliminary analysis, there was a significant positive correlation between murrelet activity and the amount of forested acreage within 1 km of a site.

The three phases of this project reported here support the conclusion that murrelets use large old-growth conifers for nesting in the spill zone, and also

suggest other habitat features that may be important in identification of murrelet nesting habitat.

PREFACE

The marbled murrelet is an abundant seabird in the coastal waters of southcentral Alaska and was at risk from the 1989 *Exxon Valdez* oil spill. This species is little known because of its secretive habits and because it nests solitarily on tree branches or on the ground, up to 70 km inland (Carter and Morrison 1992). Because of these nesting habits, assessing injury to marbled murrelets from the oil spill was problematic (Kuletz ms.) However, in 1989, murrelets were subject to direct mortality and reproduction may have been disrupted (Piatt et al. 1990, Kuletz, in review).

The Prince William Sound (PWS) murrelet population declined 67% between 1972/73 and 1989 (Klosiewski and Laing ms.). The population of marbled murrelets in PWS has not changed between 1989 and 1991, suggesting little recovery has occurred at the population level. The marbled murrelet is the most abundant seabird in PWS in summer, and PWS is an important breeding area for the species. Protection of nesting habitat of the marbled murrelet has been proposed as a means of enhancing recovery and protecting against loss of breeding birds, because loss of nesting habitat contributed to the decline of marbled murrelets at lower latitudes (Stein and Miller 1992).

The marbled murrelet was listed as threatened under the Endangered Species Act in October, 1992, in California, Oregon and Washington (Stein and Miller 1992). It is also listed as threatened in British Columbia. An estimated 95% of marbled murrelets in U.S. waters breed in Alaska, primarily in southeast and southcentral Alaska (Mendenhall 1992). The primary nesting habitat of the marbled murrelet throughout most of its range is old-growth coniferous forests, where it lays a single egg on a moss-covered branch. In Alaska, although ground nests have been found, the majority of marbled murrelets occur offshore of forested regions, and only a small percentage of the population appears to breed in treeless regions (Piatt and Ford, in press).

In 1989, only one tree nest had been documented in Alaska (Quinlan and Hughes 1990). Several ground nests had been found opportunistically in southcentral Alaska (Simons 1980, Day et al. 1983), but no concentrated effort to locate nests had been made. The protocol for surveying murrelets during their dawn flights inland (Paton et al. 1990) was developed for relatively accessible areas, usually with roads, at lower latitudes. Thus, little information existed on the nesting habitats or activity patterns of the marbled murrelet in the spill zone, and the applicability of the survey protocol to this region was unknown.

The goal of this project was to identify nesting habitat of the marbled murrelet to assist land or timber acquisition, or guide management of public lands, as a method of restoring resources affected by the *Exxon Valdez* oil spill.

The objectives of this study were:

1. Develop protocols for surveying marbled murrelet inland activity, and for finding tree nests in coastal southcentral Alaska.
2. Describe nesting habitat of the murrelet in the spill zone.
3. Use the survey protocol to sample a variety of habitats and areas in the spill zone for murrelet activity.

This project began in 1990 as a feasibility study (Kuletz 1991), during which basic activity patterns of murrelets were documented at Naked Island, Prince William Sound, to develop a survey protocol for Alaska. In addition, locations of murrelet activity indicative of nesting were identified on Naked Island. In 1991, intensive nest searches were concentrated at these sites, and a habitat study was conducted throughout Naked, Storey and Peak islands (Fig. 1). In 1992, nest searches were continued on Naked Island, and a general survey of western Prince William Sound was conducted. The latter was designed to test new techniques of surveying large remote areas for nesting murrelets, and to test for habitat association over a broad range of habitat types found in the spill zone.

This project is ongoing, and this report presents a summary of our progress to date. In Chapter 1, we present the results which led to the development of an Alaskan survey protocol, a review of murrelet nesting phenology and analysis of the nests and associated habitat found on Naked Island. Chapter 2 presents the results of our efforts to describe murrelet activity relative to habitat in the Naked Island area, using U.S. Forest Service timber type maps on a Geographic Information System. Chapter 3 describes a new survey methodology and preliminary results for a murrelet survey conducted in western PWS in 1992. The Appendices include the survey and vegetation protocols we developed for Alaska and used for the surveys reported here. These protocols are being revised and final versions may be slightly altered.

Kathy J. Kuletz
Nancy L. Naslund
Dennis K. Marks

CHAPTER 1

Nests, Nesting Habitat and Inland Activity Patterns of Marbled Murrelets at Naked Island, Prince William Sound, Alaska.

Nancy L. Naslund

INTRODUCTION

Protecting nesting habitat of the marbled murrelet (*Brachyramphus marmoratus*) has been proposed to assist murrelet recovery within the *Exxon Valdez* oil spill zone. Murrelets are thought to nest primarily in trees throughout most of Alaska (Piatt and Ford, in press), as they do in the more southern parts of their breeding range. However, habitat characteristics in Alaska differ substantially from more southern nesting areas, and only one tree nest had been documented in Alaska prior to this study (Quinlan and Hughes 1990). Therefore, information on nesting habitat requirements of marbled murrelets was lacking for the coastal areas of southcentral Alaska affected by the oil spill.

Furthermore, methods for surveying murrelet activity at inland nesting areas or for finding murrelet tree nests had not previously been developed for Alaska. As part of the restoration effort we conducted a study to fulfill the following objectives: (1) develop protocols for surveying marbled murrelet inland activity, and for finding tree nests in coastal southcentral Alaska, and (2) describe nesting habitat of the murrelet in the spill zone. To meet these objectives, we identified the following subobjectives:

a. Evaluate factors affecting murrelet activity patterns inland and use these results for revising guidelines and establishing training protocol for surveying murrelets at inland sites in Alaska.

b. Examine murrelet activity patterns at known nesting areas for comparison with activity patterns observed during the concurrent study of murrelets in western Prince William Sound.

c. Locate as many nests as possible to define suitable habitat for tree nesting murrelets in Alaska and to document nesting phenology, reproductive success, and predation pressures.

d. Determine which behaviors and vocalizations are associated with nesting to develop criteria for documenting occupied nesting habitat within the forested areas of southcentral Alaska.

e. Examine the relationship of nearshore distribution and abundance of murrelets with their inland activity patterns.

f. Test new methodologies for surveying inland activity of murrelets.

We chose Naked Island, Prince William Sound, Alaska, as our study area because probable nesting areas had previously been documented on the island (Kuletz 1991), thereby maximizing our chances of finding nests and fulfilling the subobjectives. In this report, I present preliminary results for subobjectives a, b, c, and d. Additional analysis for subobjective d and results for subobjective e and f will be presented in a later report.

METHODS

Study Area

We studied marbled murrelets during the breeding seasons of 1991 (26 May-14 August) and 1992 (22 May-15 August) on the Naked Island Archipelago in Prince William Sound, Alaska (Fig. 1). The three main islands, Naked, Storey, and Peak, support diverse habitats ranging from muskeg meadows to old-growth coniferous forests. Canopy species include mountain hemlock (*Tsuga mertensiana*), western hemlock (*T. heterophylla*), and Sitka spruce (*Picea sitchensis*). Blueberry (*Vaccinium alaskensis*), salmonberry (*Rubus spectabilis*), rusty mensiesia (*Menziesia ferruginea*), and devil's club (*Oplopanax horridus*) dominate the understory. The islands in the study area are forested to their summits. The highest points on the islands are 400, 460, and 183 m on Naked, Peak, and Storey Island, respectively.

Inland Activity Patterns of Murrelets

We examined murrelet activity patterns using a modified version of the 'intensive inventory' survey (Paton et al. 1990), hereafter referred to as a 'dawn watch'. This survey method was based on previously developed guidelines for surveying murrelets in the southern part of their range, with appropriate modifications for Alaska (see below). Dawn watches focused on the murrelet's pre-dawn activity period, when birds flew from foraging areas to inland nesting areas. The 'detection' was the basic unit of observation and was defined as "the sighting or hearing of a single bird or a flock of birds acting in a similar manner" (Paton et al. 1990:2).

Data collected for each detection included time, number of birds, directions and distances of birds, occurrence of behaviors, numbers and types of vocalizations and wing sounds, bird height, and whether or not birds were seen (see Appendix A). Observers were trained to identify murrelet vocalizations and to estimate murrelet distance. A training area with several flagged landmarks of known distances was established and observers repeatedly practiced distance estimations at the training area throughout the season. During surveys, distances of murrelets that were seen were estimated based on prior practice at the training area. Murrelets that were seen and heard were used for estimating distances to murrelets that were only heard.

Modifications to the dawn watch included: (i) earlier start and finish times relative to sunrise (i.e., beginning 105-120 minutes instead of 45 minutes prior to official sunrise, to compensate for increased light levels in Alaska), (ii) addition of behavior categories not observed further south, reflecting differences in habitat (e.g. muskeg areas, nearshore water directly adjacent to forest stands) used in the two regions, (iii) addition of a more detailed suite of behavior and vocalization categories, and, (iv) additional weather information (see Appendix A).

We counted murrelet detections at three 'monitoring' sites above Cabin Bay on Naked Island, using the dawn watch method describe above. Two of the sites were located in open muskeg forests adjacent to or near documented nest stands (Sites #2 and #5). The third (Site #1) was located in a large muskeg meadow bordered by Cabin Bay and by forested slopes about 200+ m away. Surveys were conducted every two weeks in both years. For each set of biweekly surveys in 1991, each of the three sites was surveyed during a one week period, and observers rotated among sites. In 1992, each site was surveyed simultaneously on one morning and each site was surveyed primarily by the same observer throughout the season. For analysis of variables affecting murrelet activity patterns, weather parameters were grouped into the following categories: (i) temperature (4-7°C, 8-11°C, 12°+ C), (ii) wind (0-5, 6-14, 15+ knots), (iii) cloud cover (0-80%, 81-100%), and (iv) ceiling (clear, above the ridgeline, below the ridgeline). The influence of site location, weather (temperature, wind, cloud cover), and observer variables on activity levels were examined with analysis of variance (ANOVA). Analysis was done separately for 1991, 1992, and for both years combined. Ceiling was included in the model for an additional analysis for 1992, the only year when ceiling was recorded. Dawn watches at the three monitoring sites were also used to refine previously developed murrelet survey protocol for Alaska (Kuletz 1991).

Locating Nests

Our primary method to locate murrelet nests was the ground search technique developed by Naslund et al. (1990). This technique involves focused observations of murrelets in forests during their pre-dawn peak of inland activity. We made the following modifications to the technique to enhance its use in Alaska: (i) dawn nest searches, or 'stake-outs', began 105-120 minutes before official sunrise (instead of 45 minutes), (ii) observers were initially stationed around a group of trees rather than a single tree, and, (iii) additional emphasis was placed on hearing murrelets landing or departing from trees, or vocalizing from branches. We concentrated our search efforts in stands where murrelets were suspected to nest, based on previous studies (Kuletz 1991) and data collected during the concurrent murrelet habitat study in 1991 (see Chapter 2). These areas were located on Naked Island and included Cabin Bay, Outside Bay, Bass Harbor, a small cove on the northwest part of the island, and high elevation stands inland from Cabin Bay.

Potential nest sites were located by identifying trees where murrelets exhibited flight behaviors or calls associated with nesting. Observations were generally made over several days, allowing us to progressively narrow down areas of activity and pinpoint trees on which murrelets landed. Stake-outs were primarily conducted during the pre-dawn activity period, and to a lesser extent, at dusk (see Appendix B). In addition, we used a night-viewing device, video cameras, and audio-recording equipment directed at restricted portions of forest stands to locate areas where behaviors or calls indicated potential nesting. Nests were confirmed by visual observation from the ground, by viewing the nest from an elevated vantage point in a nearby tree, or by climbing the tree and documenting the nest cup after nesting activity had ceased. Nests were also located opportunistically while conducting other field work, and by climbing and searching potential nest trees, based on murrelet behavior or on eggshell fragments found on the forest floor.

Nesting Phenology and Success

Each active nest was checked regularly to ascertain the status of the nest and stage of breeding phenology. Efforts were made to minimize disturbance during these nest checks. In 1992, we periodically checked 1991 nests and failed 1992 nests for signs of nesting or renesting. In 1992, we also climbed one of the 1991 nest trees to inspect the platform for signs of the prior year's nesting effort. To estimate fledging dates and reproductive success for Naked Island, we noted all juvenile murrelets that were seen during shoreline transects.

We also recorded the plumage (i.e., basic, alternate, or juvenile) of murrelets at sea while conducting two sets of shoreline surveys (see Chapters 2 and 4). In 1992, we continued monitoring the numbers and distribution of murrelets in the nearshore waters around Naked, Peak, and Storey islands. We counted all murrelets during a complete survey of the shoreline out to 200 m around the three islands on the mornings of 6 and 7 June. The shoreline survey was repeated on 14 August around Naked Island. In conjunction with the biweekly inland surveys, we counted murrelets in Cabin Bay in 1992. These counts covered 300 m out from the shoreline, across the mouth of Cabin Bay, and diagonally through the center of the bay. Surveys were done following each set of inland dawn watches at monitoring sites.

Nesting Habitat Characteristics

Details of nests, nest and landing trees, and habitat around nest and landing trees were collected using previously developed methods (Varoujean and Carter 1989, Singer et al. 1991) with some modifications (see Appendices C and D). We quantified canopy closure directly above nests by taking a photograph of the view up from the nest cup, then determining the percentage of sky visible in the photograph.

In most cases, a general 50 m circular vegetation plot was done around each nest (n=8) or landing tree (n=7) and at sites where nest searches were conducted but nests were not found (n=17). The following data were collected in these plots: (i) species, diameter at breast height (dbh), vigor, top condition, number of platforms, number of witches brooms (i.e., one branch splits into several smaller branches forming a fan-like platform), and epiphyte cover on branches, for the ten nearest upper canopy trees, (ii) percentage of four size classes (i.e., ≤10, 11-50, 51-100, and >100 cm dbh) of the major tree species and number of snags of each size class, (iii) percentage cover and height of dominant shrubs, (iv) amount of forest cover, (v) canopy closure and canopy height, (vi) elevation, slope, and aspect, (vii) presence and location of fresh water, (viii) distance to salt water, and, (ix) approximate area of contiguous forest. Vigor was classified as live, declining, or dead. Platforms were defined as any flat horizontal surface with a diameter ≥15 cm (including moss) and >10 m above the ground, with witches brooms recorded separately. Epiphyte cover was categorized as none, trace (<1% cover), low (1-33%), moderate (34-66%), or high (>66%). Distance from salt water was determined from aerial photos (see Appendix E). Approximate areas of contiguous forest (i.e., each area contained only forest of stand size and volume classes similar to the nest stand) was provided by the U.S. Forest Service (USFS, Anchorage, Alaska, unpubl. data). We also recorded the presence or absence of epiphyte cover on platforms at 30 of these general vegetation sites and the degree of epiphyte cover on each platform at 22 sites.

Data from general vegetation plots were used for three series of analysis: (i) to determine differences between trees used by murrelets and surrounding trees, (ii) to examine associations among tree characteristics, and, (iii) to evaluate differences in tree characteristics among species. The number of platforms per tree was square root-transformed for analysis because these data were highly skewed.

We also carried out more detailed vegetation plots around eight nest trees (see Appendix D). In these plots, we recorded all trees ≥10 cm dbh in a 25 m radius circle.

Evaluation of Predator Pressures

We conducted 64 avian circular plots at monitoring and stake-out sites (see Appendix F). These 10-minute surveys were carried out during the last hour of, or within one half hour after, dawn watch or stake-out surveys. During each survey we counted each bird that was seen or heard, its behavior, and an estimate of its distance. We also recorded the presence of potential murrelet predators including corvids, raptors, gulls, and small mammals, during all other data collection. We examined murrelet eggshell fragments for signs of predation (e.g., holes pecked by predators, tooth marks), and conducted several hours of observations at nests in an effort to document interactions of nesting murrelets and potential predators.

Murrelet Behavior Around Nests and Landing Platforms

For each stake-out we recorded the time, number of birds, behaviors, and vocalizations for all murrelets within 100 m that were seen or heard (see Appendix B). We recorded murrelet vocalizations during their pre-dawn activity period using a Marantz audio recorder and parabolic reflector. In addition, we installed a video camera connected to a remote sensing device to record activity at one nest (Nest #7). We also made detailed daytime observations for several hours at three nests.

RESULTS

Inland Activity Patterns of Murrelets

Murrelet activity levels peaked in late May in 1991 and from mid- through late July in 1991 and 1992. Activity declined dramatically in early August (Fig. 1-2). During 1991, the seasonal pattern at Site #5 diverged from the general pattern observed at the two other monitoring sites. This may be partly due to other factors influencing murrelets (see below). Annual variation in activity patterns on Naked Island differed among sites (Fig. 1-2). At Sites #2 and #5, activity levels were higher in 1991 than in 1992, while the reverse was true at Site #1.

The observed pattern of murrelet activity was influenced by weather and observer variability (Table 1-1). The total number of detections per dawn watch decreased with increasing wind speeds and decreasing temperatures. In 1992, the only year for which ceiling was recorded, the number of detections increased as the ceiling lowered (i.e., when ceiling, or cloud cover, was closer to the ground). In both years, total numbers of detections tended to be higher with greater cloud cover (i.e., >80%), but this trend was not significant. Observer variability was most pronounced in 1991. The significance of this effect in 1992 was apparently due to a single survey done by a new observer during the last census day, when murrelet activity had nearly ceased.

There was no significant difference between the total number of detections per survey at the three sites. Site #1 had higher detection levels than the other two sites in 1992 (Fig. 1-2). However, Site #1 generally had fewer close (i.e., within 200 m) detections (Fig. 1-3). The total numbers of detections were not correlated between sites in 1991. However, in 1992 when weather and observers were held constant (i.e., by conducting compared surveys on the same day and each site surveyed one observer), total detections between sites were strongly correlated (Table 1-2).

Murrelets were primarily active at inland sites during the 90 minutes prior to and the 30 minutes after official sunrise (Fig. 1-4). The first detections occurred between 29 and 95 minutes before sunrise and varied seasonally (based on 1991 data only; Fig. 1-5).

Nests

We conducted over 100 and 400 person-hours of stake-outs during 1991 and 1992, respectively, in five primary areas (Fig. 1-6). We also climbed 54 trees to search for nests. Our efforts resulted in the discovery and documentation of 10 murrelet tree nests on Naked Island (Fig. 1-6, Table 1-3). Seven of the nests were found using the ground search technique, one was found during a dawn watch, one was spotted in an adjacent tree by a climber collecting data, and one was found by climbing trees in potential nest areas.

Based on behaviors observed at nest cups where nesting status was not known (n=3, see below) and that these nest cups had similar characteristics to known active nests, we considered all nest cups to have been active at some time. We documented an additional nesting area on Storey Island (Nesting Area #5, Fig. 6). At Nesting Area #5, an adult male murrelet with a brood patch was killed by a sharp-shinned hawk (*Accipiter striatus*) following apparent activity at the murrelet's nest (Marks and Naslund, in press). Efforts to locate the nest were unsuccessful, therefore the actual nest tree was not documented.

No 1991 nests were reused in 1992, although nest checks were not made frequently enough to exclude the possibility that birds nested and failed between visits. There was no evidence of renesting at failed 1992 nests. In 1992, there was no sign of a nest cup depression, droppings, or eggshell fragments at Nest #3 (first discovered in 1991). Preliminary analysis of behavioral data indicated that number and location of murrelet pairs active in an area was consistent between years at some sites.

All nests were situated on large moss- or moss and lichen-covered platforms in relatively large, old-growth conifers (Table 1-4). Nest cups contained intact or broken eggs (two nests) or eggshell fragments (three nests), droppings (one nest), and apparently natural accumulations of debris (i.e., pieces of moss and lichen, needles, bark flakes, and decomposing twigs). There was no evidence of murrelets incorporating material into the mossy nest substrate although nesting birds did occasionally rearrange nest material. Nest placement ranged from 0-224 cm from tree boles. Most nests were located on relatively large diameter branches located throughout the live crowns of trees (Table 1-4). The one exception was a nest (Nest #10) that was located at the top of a broken tree bole where several branches had grown upwards, forming a wide platform at their base. Each nest platform supported a moderate to heavy growth of epiphyte (i.e., moss and lichen) cover. Canopy closure above eight nests ranged from 81-95% (Table 1-4). Eggshell fragments were found on the ground below or near five nest trees.

Nesting Phenology and Success

At five nests that were active upon discovery (Nests #1, #2, #3, #6, and #7), murrelets were in the incubation stage of nesting (Table 1-3). At one of these (Nest #6), murrelet behavior suggested that egg-laying may have just occurred. At three sites, pairs of birds were active, but the stage of nesting phenology or status of nests was not determined. At two of these nests (Nests #10 and #11), murrelets landed or displayed on a branch where a nest cup was later documented. At the third site (Nest #9), a nest cup was found where activity at the specific branch was unknown, but where murrelets displayed typical flight behaviors associated with nesting. One nest progressed to the chick stage (Nest #3), although the nestling disappeared when only a few days old. All nests where reproductive success was known (n=7) failed due to nest abandonment, predation, or unknown causes.

In 1992, our first observations of juvenile murrelets on nearshore surveys occurred on 7 August. Incubation dates, the single hatching date in 1991, and the first arrival of juveniles at sea indicated that egg-laying begins in mid- to late May. Of 220 murrelets recorded within a 200 m corridor around Naked Island on 14 August 1992, three were identified as juveniles, one was black and white but age was not determined, and seven were adult birds in basic (i.e., predominately black and white) plumage.

Landing Platforms

We documented nine trees where murrelets landed on branches but where no nests were found. Three of these trees were not climbed. Some of the landing trees had potential nest platforms that were impossible to view or were first climbed the year following their discovery when nest cups may no longer have been visible. Therefore, the status of landing trees as possible nest trees is uncertain. All nine landing trees occurred in known nest tree stands. Areas where murrelets were heard landing but where the exact landing trees were not known, were also documented.

Characteristics of Nest and Landing Trees

Tree characteristics did not differ significantly between nest and landing trees (dbh: t=1.3090, df=11.2, P=0.2167; number of platforms: t=-0.3239, df=16, P=0.7502; epiphyte cover: [Fisher's exact test (2-tail)] x^2=3.600, P=0.300; species: [Fisher's exact test (2-tail)] x^2=0.693, P=1.000). Trees from general vegetation plots were grouped into four categories: nest trees, the nine upper canopy trees around nest trees, landing trees, and the nine upper canopy trees around landing trees. Nest and landing trees tended to be larger than the other upper canopy trees around them although this difference was not significant (t=-1.1968, df=88, P=0.2346 for nest trees, t=-2.1184, df=7.4, P=0.0700 for landing trees) (Fig. 7).

Comparable trends occurred within vegetation plots. Seventy-eight percent (7 of 9) of nest trees were larger in diameter than the mean dbh of the nine closest upper canopy trees in each associated general vegetation plot. Similarly, 75% (6 of 8) of landing trees were larger than their nine closest canopy trees. Seventy-eight (7 of 9) percent and 75% (6 of 8) of nest and landing trees, respectively, had more platforms than their associated nine closest canopy trees. When compared with all trees ≥10 cm dbh measured in detailed vegetation plots around nests (n=8), 50%, 75%, and 100% of nest trees had dbh in the upper 5, 10, and 25 percentiles, respectively.

Core samples at Nests #2 and #4 showed that these nest trees were ca. 424 and 495 years old, respectively. Core samples from other forested areas on Naked Island indicated that most trees ≥30 cm dbh were over 200 years old (USFS, Anchorage, Alaska, unpubl. data).

Nest and landing trees had significantly more platforms than surrounding trees (t=-2.2191, df=88, P=0.0291 for nest trees, t=-2.8665, df=78.0, P=0.0053 for landing trees) (Fig. 1-8). Nest trees and the trees around them had significantly different levels of epiphyte cover (Fischer's exact test [2-tail], x^2=7.193, P=0.0372) (Fig. 1-9). High levels of epiphyte cover occurred more frequently and low levels less frequently than expected on nest trees, accounting for 90% of the chi-square value. Landing trees followed a similar trend but were not significantly different from surrounding trees (x^2=3.048, P=0.379). When compared with nearby upper canopy trees, nest trees were more likely to contain at least one platform with moderate or heavy epiphyte cover (Fisher's exact test [2-tail], x^2=7.619, P=0.00753). This same trend held for landing trees but was not significant (Fisher's exact test [2-tail], x^2=0.741, P=0.671). Of the three conifer species available, mountain hemlocks were more frequently used as nest and landing trees, but this was significantly different only for the latter (Fisher's exact test [2-tail], x^2=2.703, P=0.345 for nest trees, x^2=9.508, P=0.0089 for landing trees).

Characteristics of branches that birds landed on which did not contain nests were recorded for seven landing trees (Table 1-5). The three landing platforms that were measured were similar in size to nest platforms. Some supported moderate or heavy epiphyte cover similar to nest platforms while others had only low epiphyte cover. A depression and worn spot were documented on one landing platform in 1992. Murrelets were active on this branch during both 1991 and 1992, and the depression may indicate a nesting attempt in 1991.

Characteristics of Stands Containing Nest and Landing Trees

All trees used by murrelets were located in high stand size class (3 and 4, i.e., ≥23 cm dbh) and high volume class (3 and 4, i.e., 1883-5649 m^3/ha) hemlock-spruce forests. Stand sizes ranged from approximately 4 to 63 ha and occurred at elevations of 0-330 m (Table 1-6). Slopes varied between approximately 47 and 100%. Nest stands were located at the heads of bays on slopes with aspects that tended to face towards the west. Tree coverage in nest stands (i.e., basal area measured from 25 m radius detailed plots centered on the eight nest trees) ranged from 34 to 89 m^2/ha (Table 1-7). Mountain hemlock was the dominant species around five nests and the one nesting area, whereas western hemlock was the dominant species around three nest sites (Table 1-7). Stands dominated by western hemlock occurred at low to moderate elevations, and mountain hemlock dominant stands occurred at a wide range of elevations (0-330 m). Sitka spruce and snags were important components at all sites (relative coverage of 7-22% and 4-15%, respectively) (Table 1-7). Patches of Sitka alder (*Alnus sinuata*) occurred at three sites.

Association of Tree Characteristics and Differences Among Tree Species

We combined all trees measured in general vegetation plots at 26 forested sites (including those around nine nest trees and eight landing trees, and at nine stake-out sites) (n=260). The number of platforms on trees was positively correlated with dbh (Pearson correlation, r=0.68597, P=0.0001) (Fig. 1-10). The minimum dbh associated with a tree having at least one platform was 29 cm (Fig. 1-10). Mean dbh of trees with moderate (x=59 cm) and high (x=54 cm) epiphyte cover were higher than trees with low or trace (x=42 cm) and no (x=40 cm) epiphyte cover, but these differences were not significant (Tukey-Kramer studentized range test, df=254, P>0.05).

Tree characteristics varied among species, based on the 260 trees in general vegetation plots. Epiphyte cover varied significantly with species (x^2=30.894, P<0.0001). Sitka spruce typically had the highest epiphyte cover, followed by mountain hemlock, then western hemlock. Sitka spruce had significantly more platforms than mountain hemlock and both species had more platforms than western hemlock (Tukey-Kramer studentized range test, df=254, P=0.05). The presence or absence of moss on platforms was recorded for 197 trees (at 30 sites) that had platforms. The mean percentage of platforms with moss per tree was 84%, 90%, and 92% for mountain hemlock, western hemlock, and Sitka spruce, respectively. However, of 122 trees (at 22 sites) for which the degree of epiphyte cover (i.e., none, trace, low, moderate, heavy) was recorded for each platform, the percentage of trees which had one or more platforms with moderate or heavy epiphyte cover was 58, 47, and 93 for these same species (n=52, 43, and 27 for mountain hemlock, western hemlock, and Sitka spruce, respectively). The difference among species was significantly different (x^2=15.419, P<0.0001) with Sitka spruce having more and western hemlock having fewer platforms with moderate or heavy cover than expected, comprising 98% of the x^2 value (Fig. 11). Mean dbh of trees with or without such a platform did not differ significantly for all species combined (t=-0.9747, df=120.0, P=0.3316) or within each species (t=-1.2556, df=50, P=0.2151 for mountain hemlock, t=-0.0783, df=41, P=0.9380 for western hemlock, t=-0.0031, df=25, P=0.9975 for Sitka spruce) (Fig. 1-12). Mean dbh of upper canopy trees was not significantly among between species (Sitka spruce x=51 cm, mountain hemlock x=50 cm, western hemlock x=47 cm; Tukey-Kramer studentized range test, df=254, P>0.05)). However, when including all trees with dbh ≥10 cm (i.e., from detailed vegetation plots), spruce had the largest mean dbh at four of eight nest sites (Table 1-7).

Evaluation of Predation Pressures

Circumstantial evidence (i.e., eggshell fragments with holes made by Steller's Jays, *(Cyanocitta stelleri)* suggested that predation was a factor in nest failure. However, it appeared that in at least some cases, Steller's Jays may have gained access to eggs after nests had already been abandoned. The only observation of predation on a breeding adult murrelet was that by the sharp-shinned hawk at Nesting Area #5 (Marks and Naslund, in press).

Murrelet Behavior Around Nests and Landing Platforms

Preliminary analysis of behavioral data indicated that the number and location of murrelet pairs active in an area was consistent between years at some sites. Activity in and around individual trees during both years was evident. This includes one 1992 nest tree (Nest #6) where murrelets were observed landing during the previous year. At least two landing platforms were used repeatedly, including one that was used in both 1991 and 1992 (Table 1-7). Preliminary analysis of behavioral data also suggested that the frequency of murrelet landings was highest early in the breeding season, during the nestling period, and following nest failure.

DISCUSSION

Inland Activity Patterns

The occurrence of seasonal peaks of inland activity at Naked Island was similar to activity peaks observed in California and elsewhere in the murrelet's range (Nelson 1989, Hamer and Cummins 1990, Manley et al. 1992, Naslund, in review). Most notable was the mid-summer peak of activity (in mid-July) that corresponded with the chick-rearing period. Murrelets also exhibited an apparent pre-breeding peak in late May of 1991 but not 1992. This peak may have occurred prior to our arrival in 1992 or the peak may not have occurred, possibly indicating a reduced nesting effort. Timing of activity peaks on Naked Island were approximately two to four weeks later than activity peaks occurring further south (Nelson 1989, Hamer and Cummins 1990, Manley et al. 1992, Naslund, in review). Similarly, inland activity appeared to cease relatively earlier than elsewhere, including southeast Alaska (S. G. Speckman, University of Alaska, Fairbanks, pers. commun.).

Murrelet activity relative to sunrise was notably earlier at Naked Island than at more southern areas (see Fig. 1-4) (Nelson 1989, Hamer and Cummins 1990, Kuletz 1991, Manley et al. 1992). This difference in activity periods undoubtedly reflects the different light regimes. Pre-dawn light levels are greater and occur earlier, relative to sunrise, in Alaska. At Naked Island, the seasonal variation in the timing of first murrelet detections appeared to track changes in light levels. Murrelets were heard earliest, and occasionally throughout the 'night', around the summer solstice when light levels were greatest. As summer advanced and light levels decreased, murrelet activity occurred increasingly later.

We observed an effect of weather on murrelet activity patterns. Murrelets were most active during periods of complete cloud cover and low ceilings, a pattern that is similar to observations in other areas (Rodway et al. 1991, Manley et al. 1992, Naslund, unpubl. data). Other weather factors, including wind and temperature, influenced murrelet activity and may reflect the more extreme weather conditions that murrelets face in Alaska.

Site characteristics probably influenced the number of murrelet detections that observers were able to detect and may explain some of the variation in activity patterns among monitored sites. Whereas Sites #2 and #5 were closely bordered by forest, effectively muffling incoming sound, Site #1 was located in a large open meadow. Birds could be heard from greater distances at the latter site, and these distant detections accounted for the greater number heard. Kuletz (1991) noted a similar pattern among these sites during the 1990 feasibility study on Naked Island. Further analysis is required to understand how murrelet behavior varies between sites near nest stands and sites at other locations.

Observer variability also played an important role in the number of detections recorded, as others have noted (Naslund, unpubl. data, C. J. Ralph, USFS, pers. commun.). This observer variability has implications for conducting surveys (see below).

Implications of Activity Patterns for Surveying Murrelets in Alaska

Necessary modifications to existing protocol for surveying murrelets at inland sites in Alaska are apparent. Dawn surveys should start at least 105 to 120 minutes prior to sunrise, over one hour earlier than at more southern latitudes. To record the entire activity period, surveys should last for at least 2 and 1/2 hours, instead of the two hours currently recommended. The ideal period to census inland activity of murrelets during the breeding season appears to be between late May and late July. Censuses should be evenly spaced throughout the breeding season to avoid potential biases during seasonal peaks of activity. When possible, efforts should be made to reduce observer variability, thereby increasing the validity of comparing activity levels between sites.

The ground search method for locating nests was highly effective on Naked Island, and this method will likely work well in other parts of Alaska. Habitat characteristics in southcentral Alaska may enhance the ability to locate nests. Because trees are smaller, murrelets are easier to see and hear from the ground. Further, moderately steep hillsides provide ideal vantage points for searching tree branches for nesting murrelets. Similar to other surveys noted above, stake-outs need to be adjusted to earlier light regimes in Alaska. The usefulness of dusk surveys, when adults sometimes fly inland to feed chicks, for locating nesting activity requires further analysis.

Nests and Nesting Habitat

The marbled murrelet tree nests that we found on Naked Island comprise over half of the 17 known tree nests in Alaska. Our ten nests represent the largest sample of murrelet nests in a relatively small geographic area and, for the first time, approach a meaningful sample size for establishing criteria of suitable tree nesting habitat in a part of the *Exxon Valdez* oil spill zone.

Our results show that old-growth forest is an important habitat for marbled murrelets nesting in Alaska. Nest trees on Naked Island were similar in size to the seven other known tree nests in Alaska (Quinlan and Hughes 1990, M. Brown, USFS, pers. commun., M. B. Cody, U. S. Fish and Wildlife, pers. commun., D. Youkey, USFS, pers. commun.). However, nest trees in Alaska were generally smaller than trees used in the southern portion of the species' range, and tree coverage (i.e., basal area) in nest stands was noticeably less. For example, nest trees in British Columbia south through California have ranged from ca. 88-530 cm dbh, and tree coverage around nests may be three to nine times higher than that found in our study area (Hamer and Cummins 1990, 1991; Singer et al. 1991, 1992; Nelson and Hamer 1992; I. Manley, Clayoquot Biosphere Project, pers. commun.). However, Naked Island nests were in the highest volume and stand class forests in the study area, and among the highest in Prince William Sound (USFS, Anchorage, Alaska, unpubl. data).

The relatively small stands of old-growth forest used by murrelets on Naked Island probably reflected the features of the available habitat. On Naked Island, small patchy stands of high stand size and volume class forests are intermixed with areas of open muskeg as well as low stand size and volume class forests.

Characteristics that Naked Island nest trees shared with murrelet nest trees in other regions were evident. Nest trees were relatively large, old conifers which contained broad moss-covered platforms. Further, nearby branches typically afforded cover above nests, thereby providing some degree of protection from inclement weather. These branches may also help murrelets avoid detection by aerial predators. At Naked Island, Sitka spruce trees more frequently possessed certain characteristics that are important for nesting murrelets, including high epiphyte cover and many platforms with thick moss cover. Sitka spruce is the least common conifer on Naked Island and this may partially account for its apparent rareness as a documented nest tree. Other factors that may be important for nesting (e.g., cover around nest) require further analysis.

We did not find nests in thick layers of accumulated debris on tree branches as have been found elsewhere in the murrelet's range. While this may be due to our limited sample size, it may also reflect a difference in murrelet requirements and forest structure in southcentral Alaska. In this area, breeding season weather may include prolonged torrential rain, strong winds (e.g., 20+ knots), and near freezing temperatures. Therefore, protection from inclement weather may be critical for egg and nestling survival. Thick moss cover may provide an important microclimate for eggs and nestlings by providing insulation and allowing only minimal accumulation of standing water. Moss cover may be particularly important to young nestlings, who are typically left alone when only a few days old (Naslund, unpubl. data, S. K. Nelson, Oregon Cooperative Wildlife Research Unit, pers. commun., this study). In addition, nest stands tended to face westward, thus minimizing exposure to prevailing weather systems, further suggesting that weather influences nest site selection. However, an alternative explanation for only finding nests in moss may be that debris cannot accumulate on platforms due to harsh winter weather.

Predation Pressures

Similar to nesting areas documented in other regions (Singer et al. 1991, Nelson and Hamer 1992), predation appeared to be an important factor in the murrelet's reproductive success. However, abandonment by some pairs on Naked Island suggested that the high failure rate that we observed may reflect poor environmental conditions during 1991 and 1992. Nonetheless, it appears that predator populations should be considered when evaluating suitable murrelet nesting habitat.

Nesting Phenology and Success

Nesting phenology of murrelets at Naked Island was similar to phenology of murrelets nesting near Juneau, southeast Alaska (S. Speckman, University of Alaska, Fairbanks, pers. commun.). However, Naked Island nesting began about four to six weeks later than the onset of nesting in the southern part of the murrelet's range (Singer et al. 1991, 1992; Carter and Erickson 1992; S. W. Singer, Santa Cruz City Museum of Natural History, pers. commun.; Naslund, unpubl. data).

Marbled murrelets exhibited low reproductive success at Naked Island. At least 70% of the nests we found failed. This may partly reflect our sample size and may be biased because nests that are easiest to find may not be optimal nest sites. For example, a site with less foliage around the nest may be easier for observers to see and may also have greater exposure to predators or inclement weather. It is also possible that our presence may have contributed to nesting failure.

The high failure rate is corroborated by the few juvenile murrelets observed on the water during nearshore surveys around Naked Island on 14 August 1992. Assuming that 15% of the murrelet population consisted of subadults (see Sealy 1975), and considering that juvenile birds may have been misidentified as adults in basic plumage (i.e., juvenile and basic plumage is difficult to distinguish in the field), murrelets fledged between 0.03-0.12 chicks per pair (in prep.). Kuletz (in prep.) also documented apparent low reproductive success in the Naked Island area from 1989-1992, which was significantly lower than the number of juveniles observed between 1978-1981.

Murrelet Behavior Around Nests and Landing Platforms

Preliminary examination of murrelet behavior around Naked Island nests suggested that murrelet pairs may hold loose territories and nest in small, somewhat dispersed, groups. The possibility that territories are maintained is supported by the consistent numbers and locations of murrelet pairs active around specific branches or groups of trees in 1991 and 1992. Further, at least one 1991 landing tree was used for nesting in 1992, one 1991 landing tree was used again in 1992, and several newly documented nest and landing trees in 1992 were in close proximity to previously used trees. The timing and proximity of Nest #2 to

Nest #4 suggested that the latter may have been a second nesting attempt by the same pair, rather than two pairs nesting in adjacent trees.

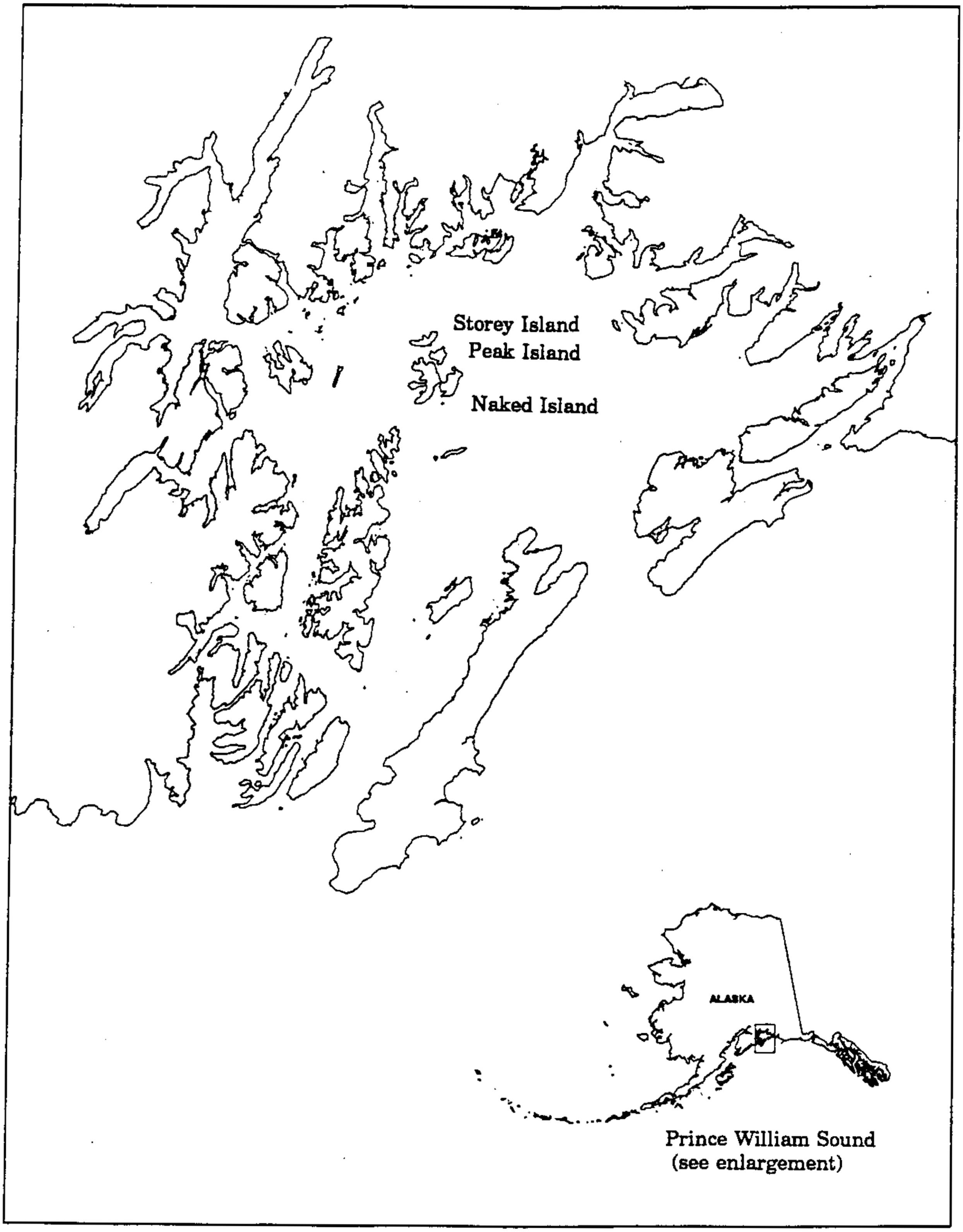

Figure 1-1. Study area for the 1991 and 1992 nesting habitat study at Naked, Storey and Peak islands, Prince William Sound, Alaska.

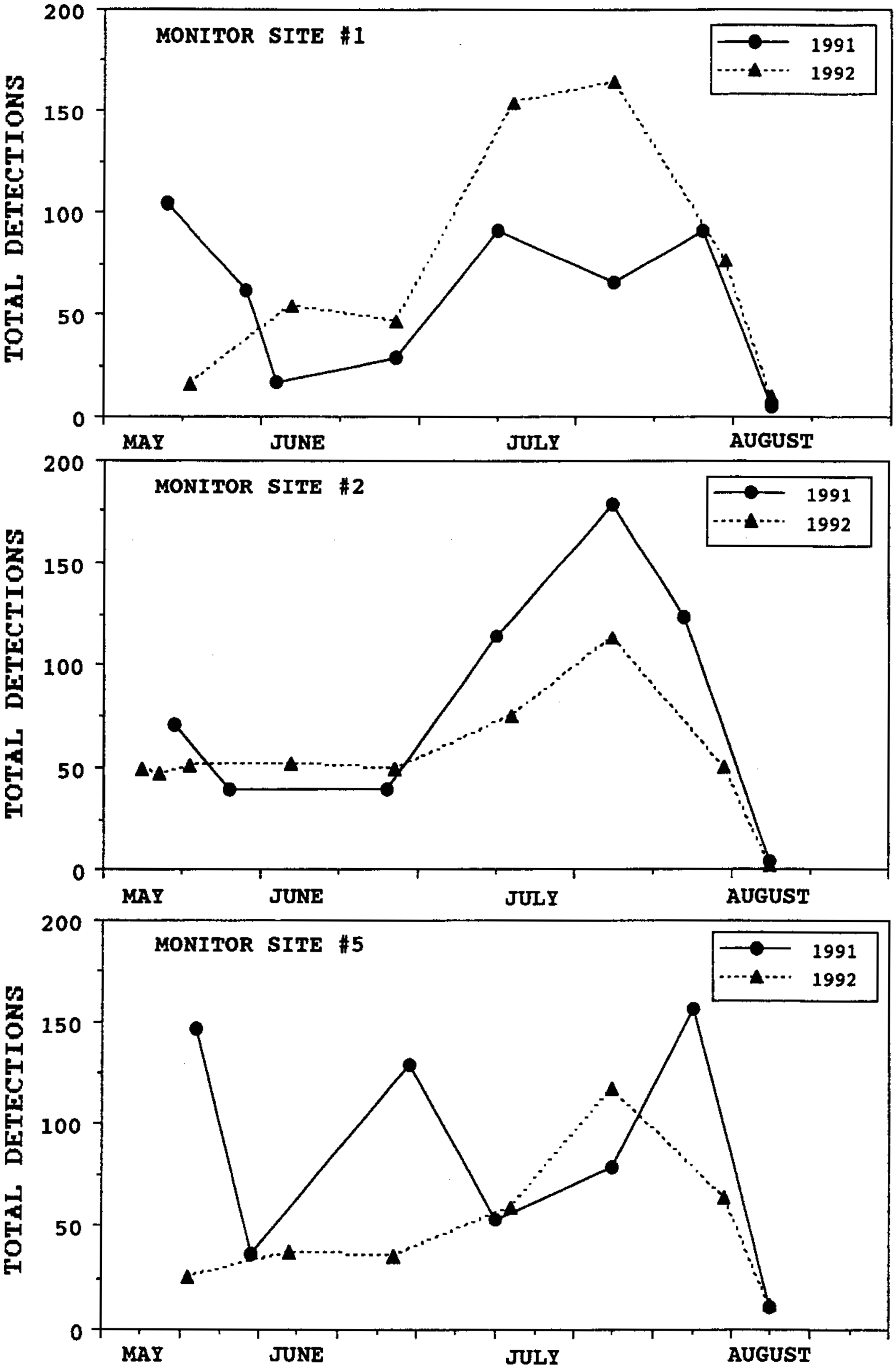

Figure 1-2. Seasonal and annual variation of marbled murrelet activity levels during dawn watches at monitoring sites #1 (top), #2 (center), and #5 (bottom), on Naked Island, Prince William Sound, Alaska, during the breeding seasons of 1991 and 1992.

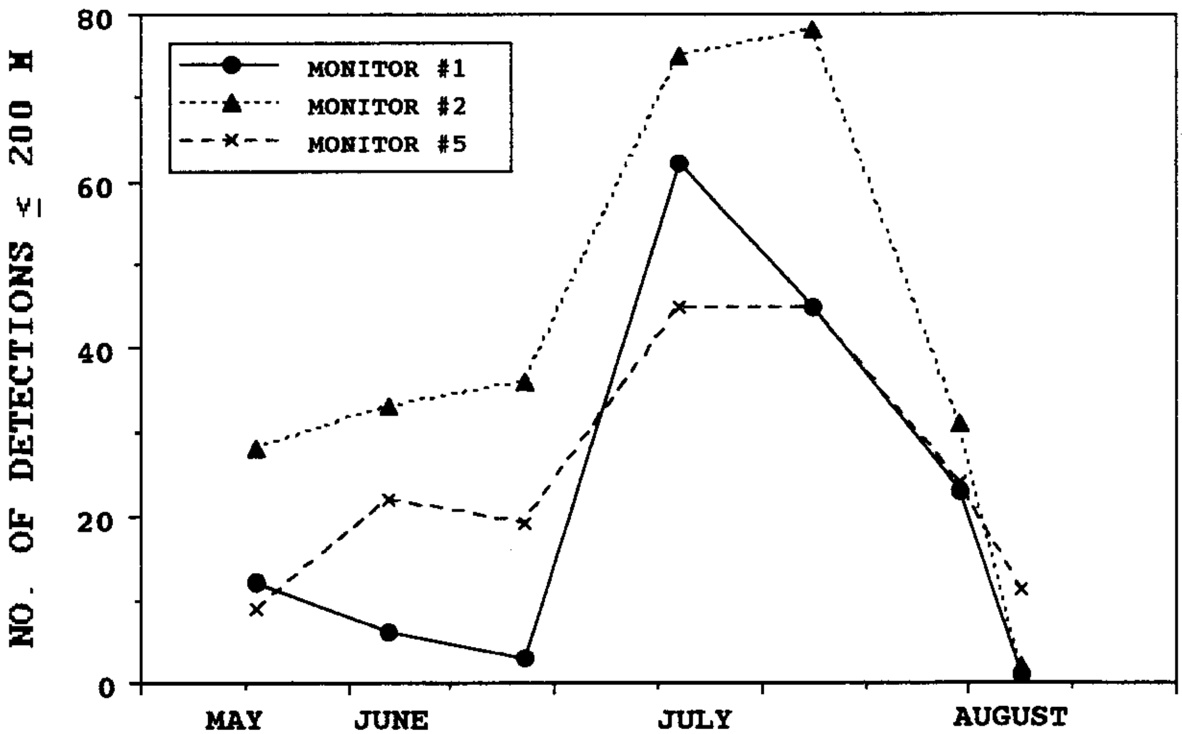

Figure 1-3. Numbers of marbled murrelet detections within 200 m of the observer compared between three monitoring sites on Naked Island, Prince William Sound, Alaska, during dawn watches in 1992.

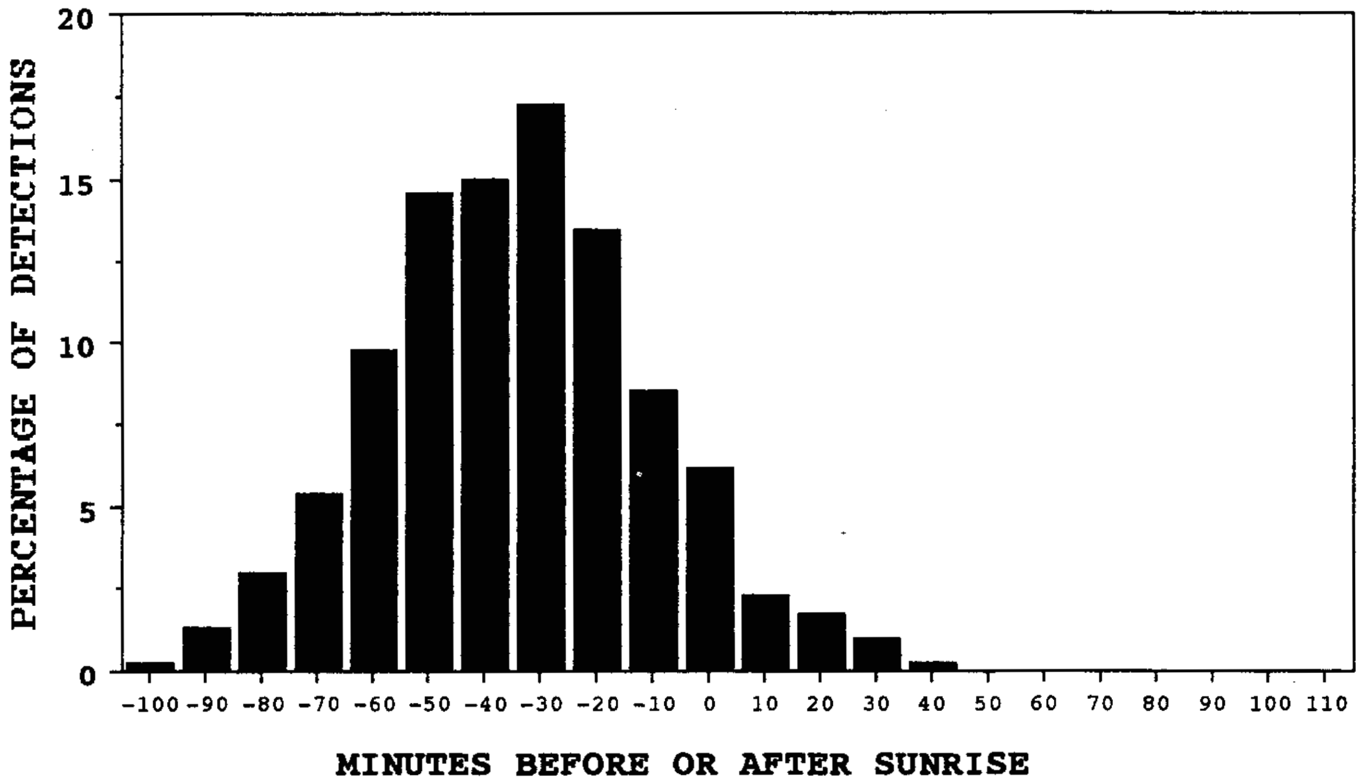

Figure 1-4. Timing of marbled murrelet detections relative to official sunrise on Naked Island, Prince William Sound, Alaska, in May-August 1991.

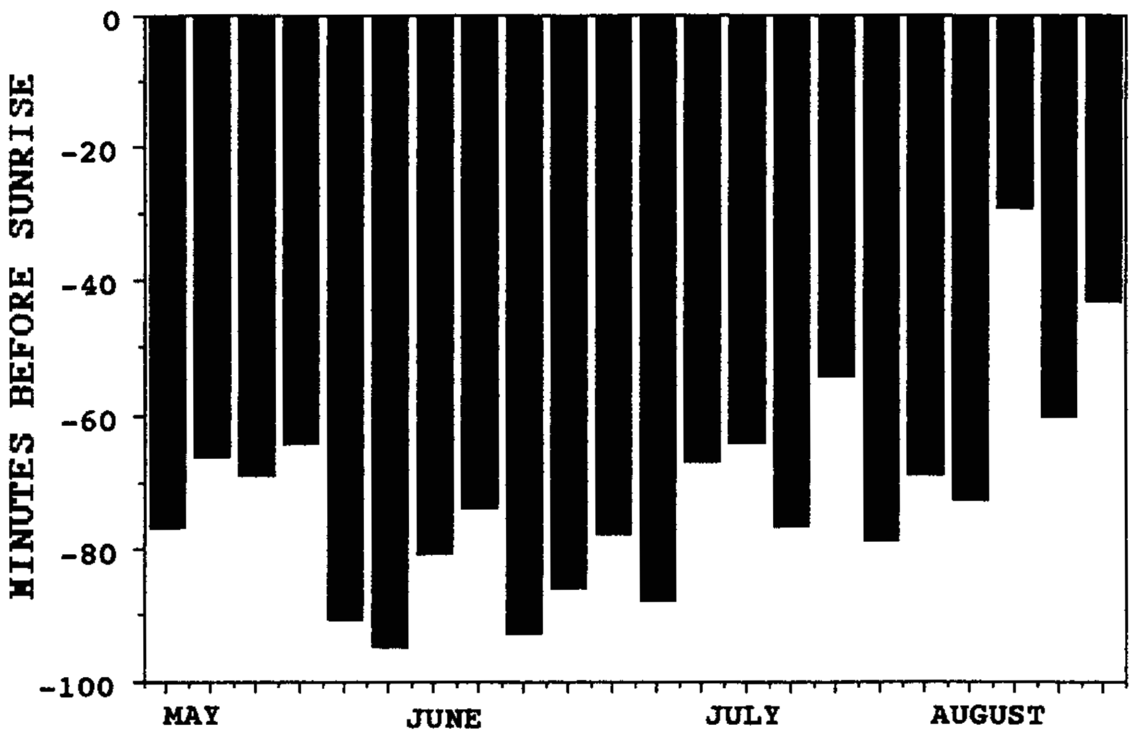

Figure 1-5. Timing of first marbled murrelet detections relative to official sunrise at three monitoring sites on Naked Island, Prince William Sound, Alaska, in May-August 1991.

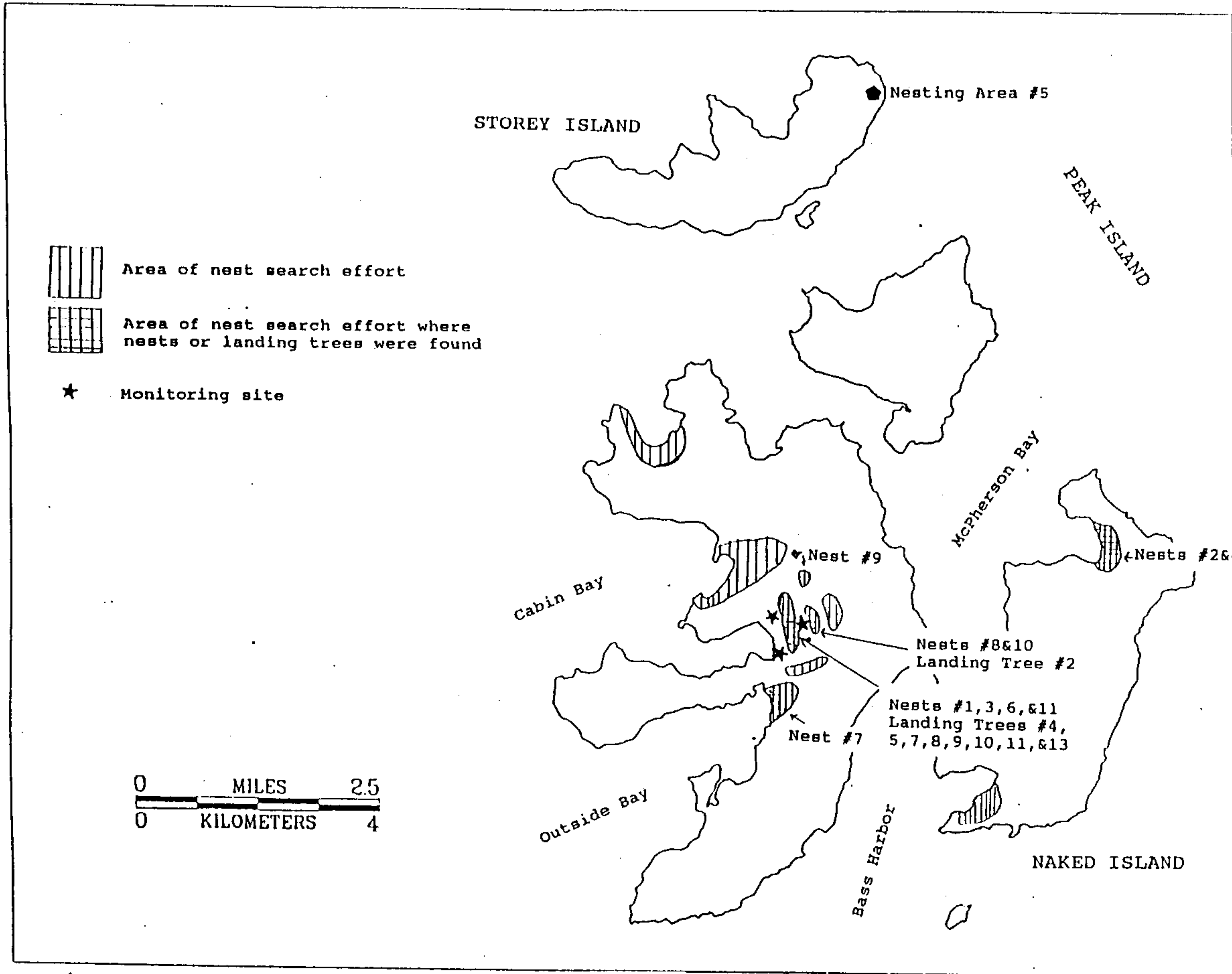

Figure 1-6. Location of marbled murrelet nest search efforts, areas where nests and landing trees were found, and monitoring sites, on Naked Island, Prince William Sound, Alaska, in 1991 and 1992.

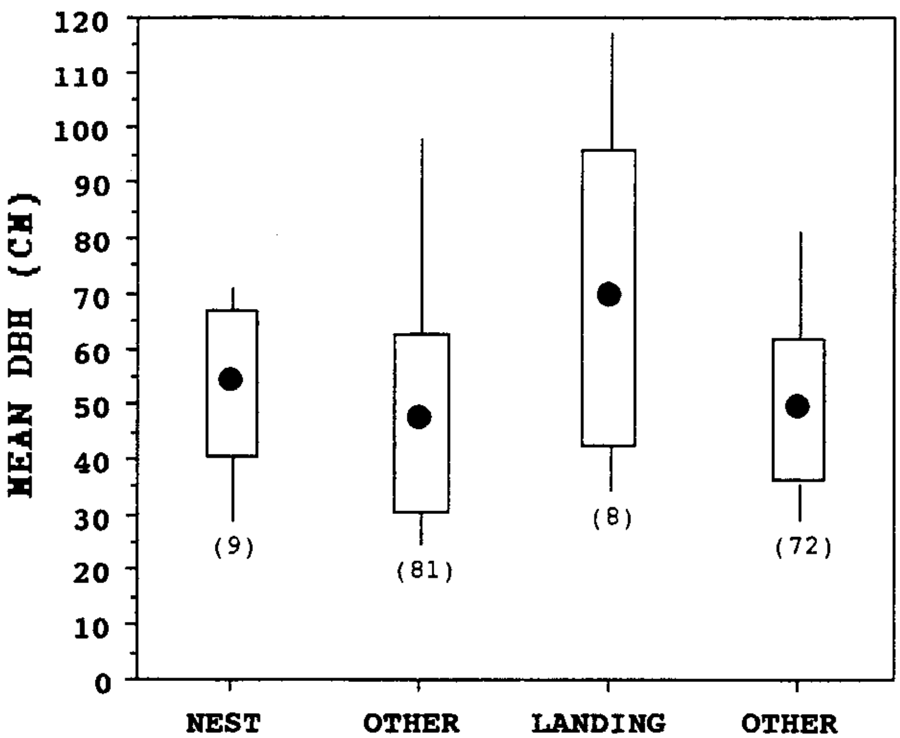

Figure 1-7. Mean diameter at breast height (dbh) of marbled murrelet nest trees found on Naked Island, Prince William Sound, Alaska, in 1991 and 1992, and other associated upper canopy trees and of landing trees and other associated upper canopy trees in general vegetation plots. Means (circles), ± standard deviations (boxes), ranges (vertical lines), and sample sizes (in parentheses) are shown.

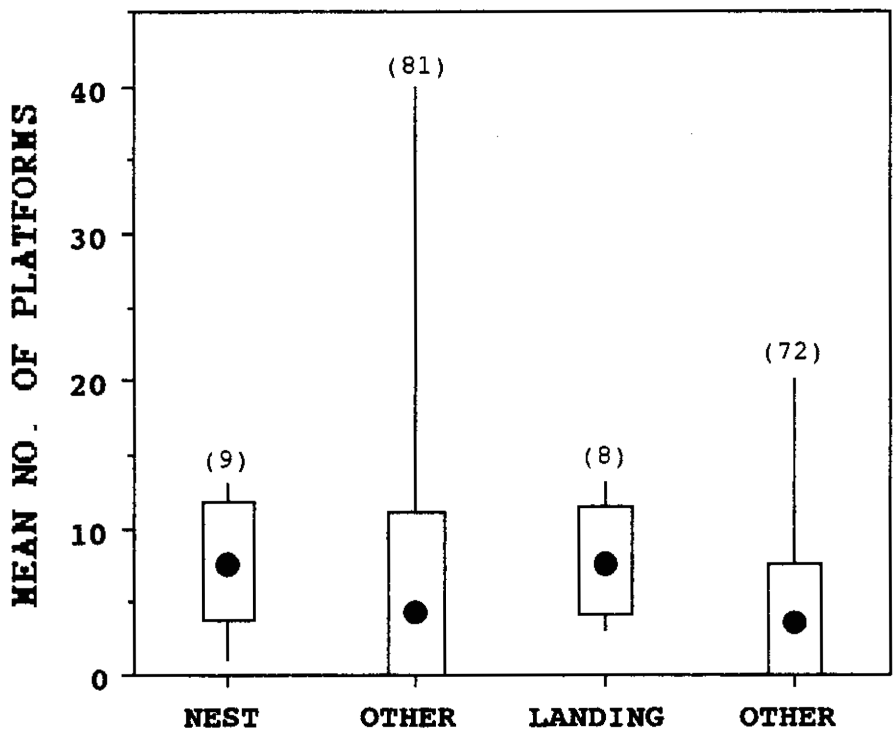

Figure 1-8. Mean number of platforms on marbled murrelet nest trees found on Naked Island, Prince William Sound, Alaska, in 1991 and 1992, and other associated upper canopy trees and on landing trees and other associated upper canopy trees in general vegetation plots. Means (circles), ± standard deviations (boxes), ranges (vertical lines), and sample sizes (in parentheses) are shown.

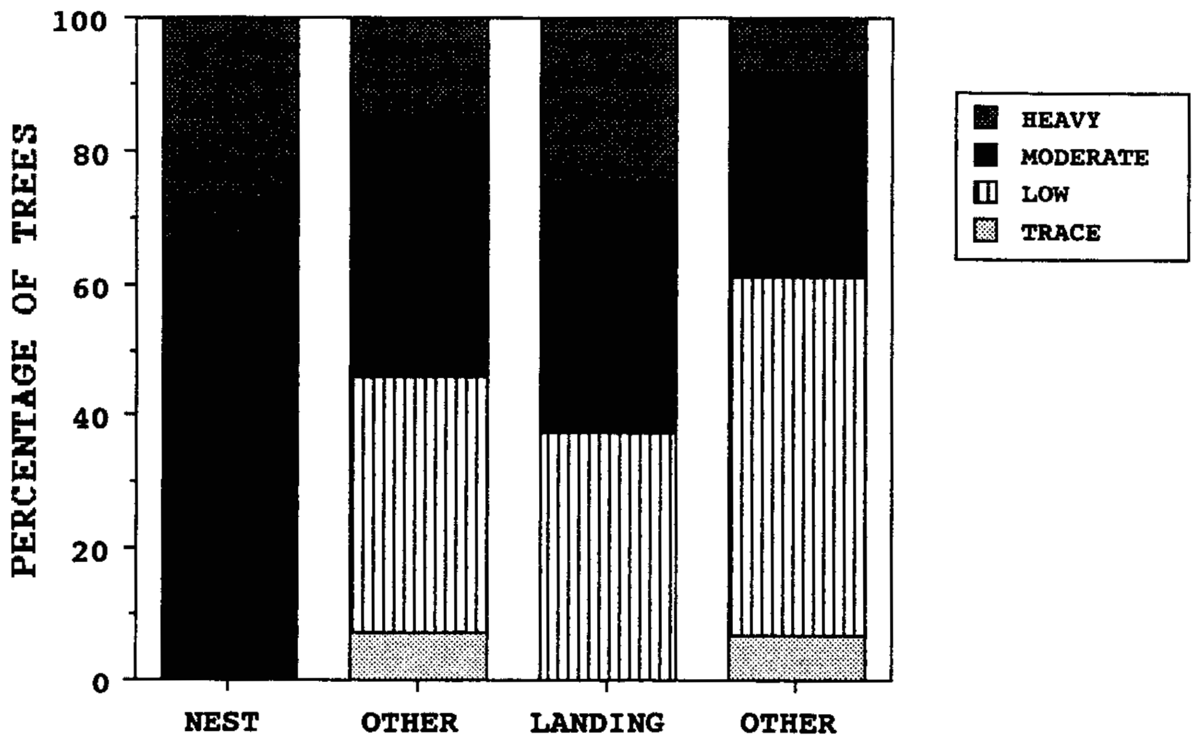

Figure 1-9. Percentage of marbled murrelet nest trees (n=9) and other associated upper canopy trees (n=81) and on landing trees (n=8) and other associated upper canopy trees (n=72) with heavy, moderate, low, and trace amounts of epiphyte cover on Naked Island, Prince William Sound, Alaska, in 1991 and 1992.

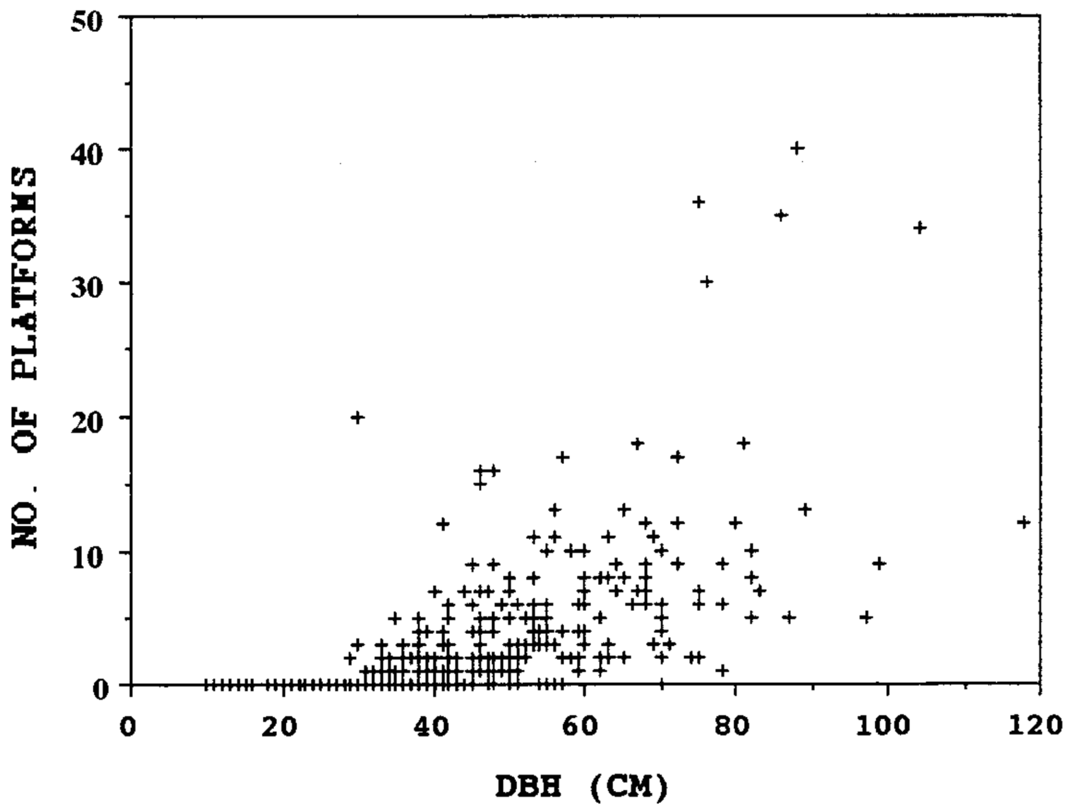

Figure 1-10. Number of platforms vs. diameter at breast height (dbh) of 260 trees measured in 26 general vegetation plots on Naked Island, Prince William Sound, Alaska, in 1992. Pearson's r=0.68597, P=0.0001.

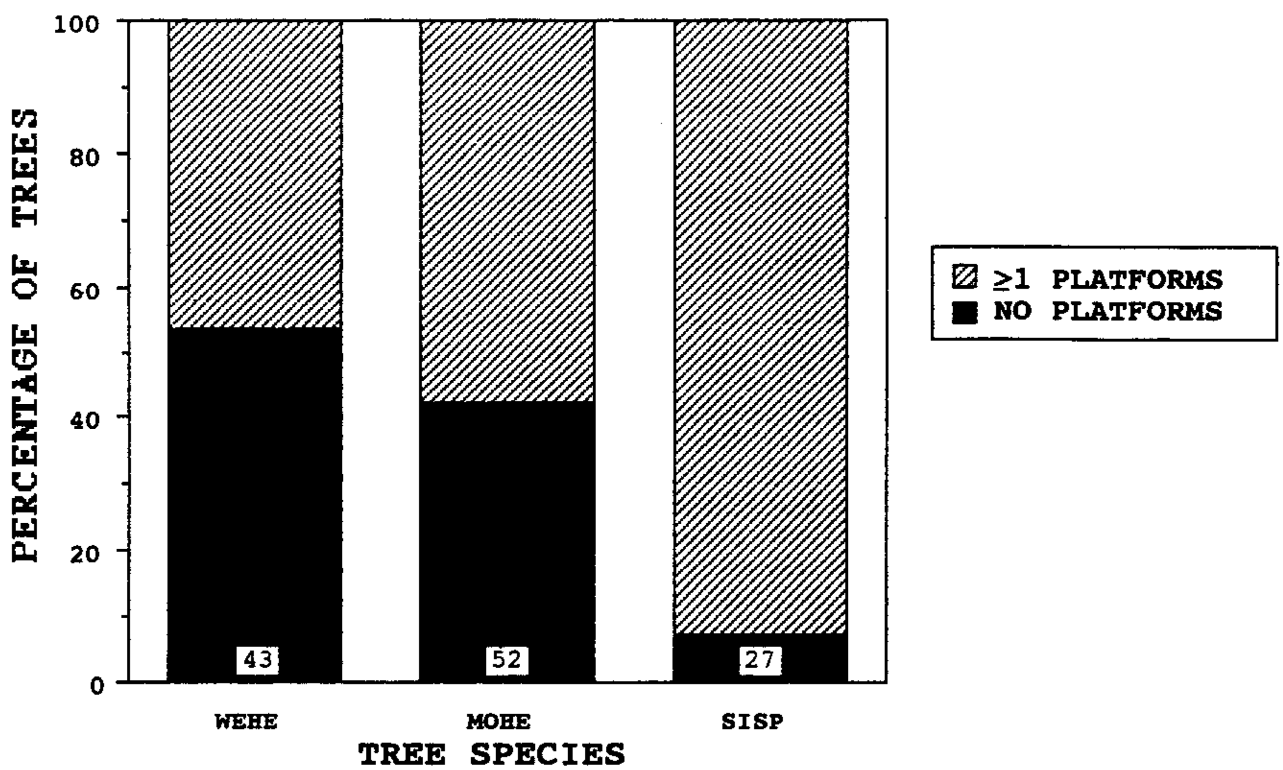

Figure 1-11. Percentage of each species of conifer with or without at least one platform with moderate or heavy epiphyte cover. Data are from general vegetation plots on Naked Island, Prince William Sound, Alaska, in 1992. WEHE = western hemlock, MOHE = mountain hemlock, and SISP = Sitka spruce. Sample sizes are indicated in histogram bars.

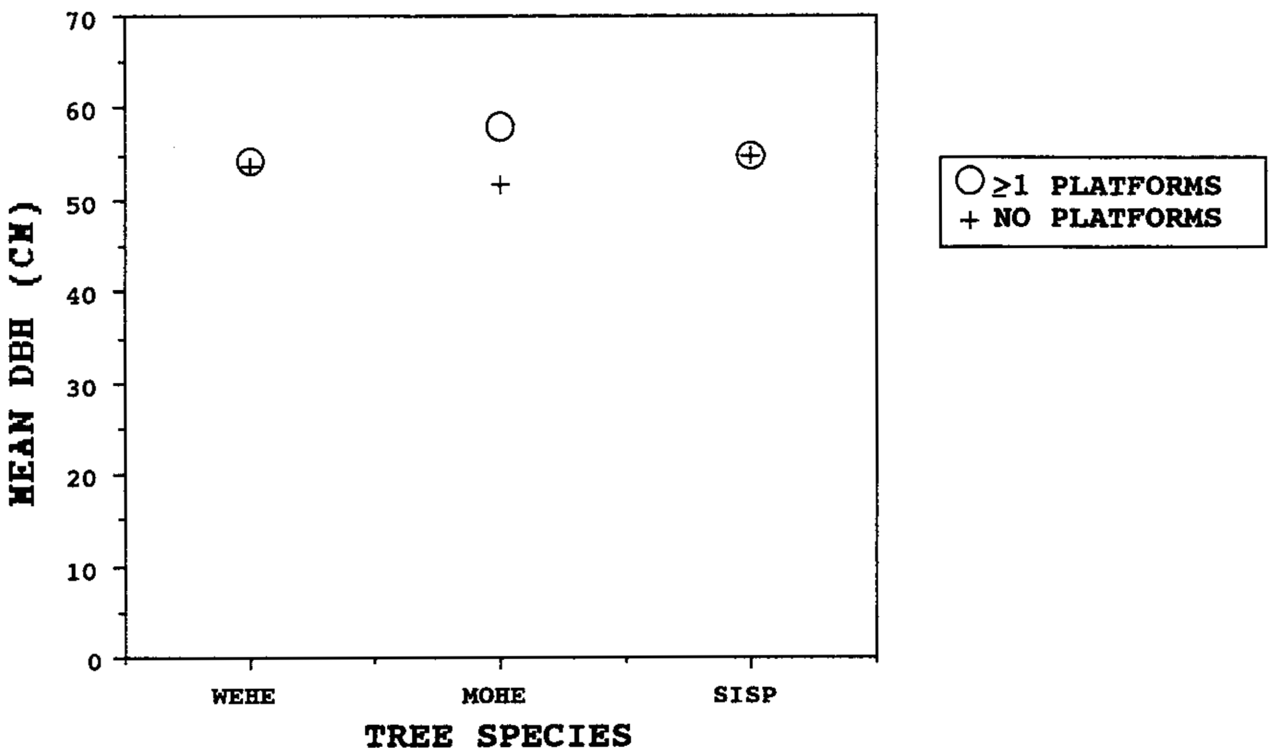

Figure 1-12. Mean diameter at breast height (dbh) of each species of conifer with or without at least one platform with moderate or heavy epiphyte cover. Data are from general vegetion plots on Naked Island, Prince William Sound, Alaska, in 1992. WEHE = western hemlock (n=43), MOHE = mountain hemlock (n=52), and SISP = Sitka spruce (n=27).

Table 1-1. Results of ANOVA tests for variables affecting the total number of marbled murrelet detections per morning survey, on Naked Island, Prince William Sound, Alaska. Results are presented separately for 1991, 1992, and for both years combined. Results with ceiling included in the model are presented for 1992 (indicated by an asterisks), the only year when ceiling was recorded.

	1991			1992			Combined			1992*		
Variable	df	F	P	df	F	P	df	F	P	df	F	P
Year							1	2.73	0.1090			
Site	2	2.50	0.1278	2	3.19	0.0806	2	2.34	0.1140	2	3.52	0.0742
Temperature	2	1.31	0.3082	2	10.14	0.0032	2	0.48	0.6257	2	19.87	0.0005
Wind	2	3.81	0.0552	2	23.15	0.0001	2	5.63	0.0086	2	46.48	0.0001
Clouds	1	0.67	0.4292	1	0.30	0.5935	1	2.37	0.1345	1	0.03	0.8558
Observer	3	5.92	0.0118	4	1.39	0.2999	7	2.20	0.0644	4	4.49	0.0288
Ceiling										2	7.00	0.0146

Table 1-2. Correlations (Pearson's r) of the total numbers of marbled murrelet detections per dawn watch between three sites on Naked Island, Prince William Sound, Alaska. Results are presented separately for 1991 and 1992 and for both years combined.

	1991		1992		Combined	
Site No.	Site No. One	Site No. Two	Site No. One	Site No. Two	Site No. One	Site No. Two
One		0.61028 ns		0.85977*		0.57139*
Two	0.61028 ns		0.85977*		0.57139*	
Five	0.52012 ns	0.32321 ns	0.87793**	0.90219**	0.52019 ns	0.51936 ns

* = $P < 0.05$; ** = $P < 0.01$; ns = not significant.

Table 1-3. Status of marbled murrelet tree nests found on Naked Island, Prince William Sound, Alaska, in 1991 and 1992.

Nest no.	Date found	Date egg laid	Date chick hatched	Fate
1	6/13/91	<6/13/91		failed during incubation (due to predation?)
2	6/25/91	<6/25/91		failed during incubation
3	7/06/91	ca. 6/15/91	ca. 7/15/91	chick died ca. 7/17/91
4	7/26/91	<7/09/91		failed during incubation (abandoned?)
6	5/25/92	ca. 5/25/92		failed during incubation (abandoned?)
7	7/20/92	<7/17/92		abandoned during incubation
8	8/05/92	<6/17/92		failed during incubation
9[i]	8/06/92	unknown		unknown
10[i]	6/09/91	unknown		unknown
11[i]	7/01/91	unknown		unknown

i Tree with nest cup only. Pairs of birds were active at these sites but the stage or status of nests was not determined.

Table 1-4. Characteristics of marbled murrelet nest trees and branches (a) and nests (b), found on Naked Island, Prince William Sound, Alaska, in 1991 and 1992.

(a)

	Tree characteristics				Branch characteristics				
Nest no.	Species	DBH (cm)	Height (m)	Condition	Height (m)	Diameter at bole (cm)	Diameter at nest (cm)	Position in crown	Condition
1	western hemlock	30	21	declining	9.7	16.2	16.2	lower 1/3	both live & dying distally
2	mountain hemlock	49	20	declining	15.6	10.5	22.3	middle	live, healthy
3	western hemlock	76	22	declining	17.4	14.6	16.6	upper 1/4	live, healthy
4	mountain hemlock	71	30	dead	13.3	22.3	20.4	lower 1/4	dead
6	mountain hemlock	48	16	declining	10.5	27.1	27.1	middle 1/3	mostly live
7	Sitka spruce	72	30	healthy	15.0	12.7	nd	lower 1/4	live, split
8	mountain hemlock	60	22	declining	14.8	14.3	14.3	middle	live
9	mountain hemlock	45	20	healthy	9.6	19.4	18.8	lower 1/2	live, healthy
10	mountain hemlock	65	25	declining	13.3			upper 1/4	5 live @ broken top
11	mountain hemlock	49	ca. 20	declining	15.4	11.8	11.8	upper 1/3	live, split

nd Indicates no data available.

Table 1-4 (b).

Nest no.	Distance to bole (cm)	Nest characteristics: Nest cup dimensions (cm)	Nest cup depth (cm)	Depth of moss at: nest (cm)	elsewhere (cm)	Substrate (cm)	Canopy closure above nest (%)
1	14	15 x 15[i]	5[i]	3.3	5.3	moss & lichen covered branch	91
2	32	8 x 9	4	3.5	7.0	moss & lichen covered branch	82
3	135	13 x 7	4	2.0	3.0	moss & lichen covered branch	≥68[ii]
4	138	none	none	5.0	4.0	moss covered branch	ca. 25
6	3	11 x 9	6	3.5	5.0	moss & lichen covered branch	89
7	224	9 x 8	7	2.5	1.5-5.0	moss & lichen covered branch	95
8	6	14 x 10	4	4.0	10.0	moss & lichen covered branch	91
9	3	9 x 8	2	6.0	3.0	moss & lichen covered branch	94
10	0	10 x 10	4	6.0	8.0	moss covered platform	81
11	74	8 x 8	nd	nd	2.5	moss & lichen covered branch	93

i Approximate because nest cup was partially destroyed prior to taking measurements.
ii Measurement taken near nest.
nd Indicates no data available.

Table 1-5. Characteristics and status of trees that marbled murrelets landed in but where nests were not found, on Naked Island, Prince William Sound, Alaska, in 1991 and 1992.

Landing tree no.	Tree Characteristics: Species	DBH (cm)	Height (m)	Condition	Branch Characteristics: Height (m)	Diameter at bole (cm)	Diameter at landing area (cm)	Position in crown	Substrate	Years used	Nearest nest no.	Distance to Nest (m)
2	mountain hemlock	67	21	declining	nd	nd	nd	nd	ND	1991	8	20
4	mountain hemlock	83	27	declining	ca. 20	14	14	upper 1/4	moss & lichen	1991, 1992	1	40
5	Sitka spruce	89	22	declining	nd	nd	nd	lower 1/4	moss (& lichen?)	1991	6	15
7	mountain hemlock	118	nd	declining	nd	nd	nd	nd	ND	1991, 1992?	6	<200
8	mountain hemlock	70	25	healthy	nd	nd	nd	nd	ND	1991, 1992?	6	<150
9	Sitka spruce	42	17	healthy	5.7	36	72	lower 1/4	moss & lichen	1992	6	<100
10	western hemlock	55	15	declining	nd	nd	nd	upper 1/4	moss (& lichen?)	1992	3	150
11	mountain hemlock	35	20	healthy	12.1	37	24	lower 1/4	moss & lichen	1992	3	150
13	mountain hemlock	42	20	healthy	nd	nd	nd	lower 1/4	moss (& lichen?)	1992	3	<100

nd Indicates no data available.

Table 1-6. Habitat characteristics at marbled murrelet nest trees and nest stands, found on Naked Island, Prince William Sound, Alaska, in 1991 and 1992.

	Tree Characteristics				Stand Characteristics							
Nest no. (m)	Nearest saltwater (m) (m)	Nearest creek (m)	Nearest pond (m)	Approx. elevation (m)	Nearest saltwater (m)	Nearest creek (m)	Nearest pond	Approx. elevation (%)	Aspect (%)	Slope (ha)	Canopy closure	Contiguous forest area
1	375	150	100	115	200	0[1]	25	30-180	WNW	65	70	17.5
2	250	200	125	100	10	0[1]	10	1-150	NW	60	75	62.6
3	375	325	300	75	200	0[1]	25	30-180	WNW	70	85	17.5
4	250	200	125	100	10	0[1]	10	1-150	NW	60	75	62.6
6	280	5	150	75	200	0[1]	25	30-200	WNW	70	70	17.5
7	105	75	500	70	0	0[1]	100	0-100	NW	84	75	60.7
8	725	2	80	105	590	0[1]	20	120-150	WSW	47	60	nd
9	1040	10	120	260	920	0[1]	75	230-330	SSW	100	60	4.2
10	620	10	120	100	590	0[1]	20	120-150	WSW	47	60	nd
11	510	nd	300	100	200	0[1]	25	30-200	W	84	50	62.6

i Creek runs through stand.
nd Indicates no data available.

Table 1-7. Density and coverage of trees ≥10 cm diameter at breast height (dbh) in 25 m radius plots centered on eight marbled murrelet nest trees, on Naked Island, and one nesting area, on Storey Island, Prince William Sound, in 1991 and 1992.

Species	Nest 1 Density (no./ha)	Nest 1 Basal area (m^2/ha)	Nest 1 Relative density (%)	Nest 1 Relative basal area (%)	Nest 1 Mean dbh (cm)	Nest 1 *sd*	Nests 2 & 4 Density (no./ha)	Nests 2 & 4 Basal area (m^2/ha)	Nests 2 & 4 Relative density (%)	Nests 2 & 4 Relative basal area (%)	Nests 2 & 4 Mean dbh (cm)	Nests 2 & 4 *sd*
Western hemlock	540	35.6	50.5	47.1	24	16.67	127	8.8	31.2	26.2	27	12.66
Mountain hemlock	306	17.7	28.6	23.4	23	14.29	143	17.7	35.1	52.6	37	14.08
Sitka spruce	132	13.0	12.3	17.2	30	19.06	117	5.9	28.7	17.4	24	8.03
Sitka alder	0	0.0	0.0	0.0			0	0.0	0.0	0.0		
Snag	92	9.3	8.6	12.3	30	21.14	20	1.3	5.0	3.8	28	5.38
Total	1070	75.6	100	100	25	16.84	407	33.6	100	100	30	12.96

Species	Nest 3 Density (no./ha)	Nest 3 Basal area (m^2/ha)	Nest 3 Relative density (%)	Nest 3 Relative basal area (%)	Nest 3 Mean dbh (cm)	Nest 3 *sd*	Nest 6 Density (no./ha)	Nest 6 Basal area (m^2/ha)	Nest 6 Relative density (%)	Nest 6 Relative basal area (%)	Nest 6 Mean dbh (cm)	Nest 6 *sd*
Western hemlock	693	56.5	70.8	63.3	27	17.40	148	8.5	24.3	19.4	25	10.45
Mountain hemlock	87	7.3	8.9	8.2	28	18.59	290	19.2	47.5	43.6	27	12.08
Sitka spruce	138	15.1	14.1	17.0	32	19.28	71	9.5	11.6	21.6	36	21.56
Sitka alder	0	0.0	0.0	0.0			20	0.2	3.3	0.4	10	0.50
Snag	61	10.2	6.2	11.5	42	18.95	81	6.6	13.3	15.0	31	9.10
Total	979	89.1	100	100	29	18.16	610	44.1	100	100	27	13.29

Table 1-7. continued.

Species	Nest 7 Density (no./ha)	Basal area (m^2/ha)	Relative density (%)	Relative basal area (%)	Mean dbh (cm)	*sd*	Nest 8 Density (no./ha)	Basal area (m^2/ha)	Relative density (%)	Relative basal area (%)	Mean dbh (cm)	*sd*
Western hemlock	194	19.0	40.4	35.8	30	19.68	285	22.1	37.8	34.9	27	15.86
Mountain hemlock	204	22.7	42.5	42.9	35	14.26	260	16.1	34.5	25.5	25	13.53
Sitka spruce	46	6.4	9.6	12.1	38	20.59	138	10.7	18.3	16.9	27	16.78
Sitka alder	0	0.0	0.0	0.0			5	7.7	0.7	12.2	14	
Snag	36	4.9	7.5	9.2	39	17.06	66	6.7	8.7	10.6	34	11.40
Total	480	53.0	100	100	33	17.48	754	63.4	100	100	27	14.97

Species	Nest 9 Density (no./ha)	Basal area (m^2/ha)	Relative density (%)	Relative basal area (%)	Mean dbh (cm)	*sd*	Nesting area 5 Density (no./ha)	Basal area (m^2/ha)	Relative density (%)	Relative basal area (%)	Mean dbh (cm)	*sd*
Western hemlock	15	8.7	3.8	14.5	73	54.60	198	28.8	39.6	39.1	35	25.36
Mountain hemlock	239	33.2	61.1	55.4	36	22.57	195	31.6	39.0	43.0	40	22.02
Sitka spruce	41	10.7	10.5	17.9	49	32.47	20	4.8	4.0	6.6	53	17.88
Sitka alder	25	0.3	6.4	0.5	12	1.64	0	0.0	0.0	0.0		
Snag	71	7.0	18.2	11.7	27	24.38	87	8.3	17.4	11.3	29	20.61
Total	391	59.9	100	100	35	26.68	500	73.5	100	100	37	23.34

CHAPTER 2

Differences in Marbled Murrelet Activity Relative to Forest Characteristics in the Naked Island Area, Prince William Sound, Alaska

Katherine J. Kuletz

INTRODUCTION

The marbled murrelet was one of the seabird species affected by the *Exxon Valdez* oil spill which could benefit by protection of nesting habitat. While it was generally recognized that nesting marbled murrelets depend on coastal old-growth coniferous forests throughout the Pacific northwest and southeast Alaska, little was known about murrelet nesting habitat in southcentral Alaska, the area affected by the spill. The goal of this project was to identify marbled murrelet nesting habitat for the restoration effort.

Because marbled murrelet nests are difficult to locate, (in 1990 only four tree nests had been found throughout its range), survey efforts at lower latitudes typically use measures of inland activity by murrelets as an indication of habitat use. By recording the audio or visual observations (detections) of murrelets making dawn flights to their nesting areas, the distribution of probable nesting habitat in California, Oregon and Washington was documented. Invariably, the highest activity levels (i.e., number of detections per survey) were found in coastal old-growth forests. Sites with high murrelet activity levels were typically in large contiguous stands of forests >200 years in age, with large trees averaging >86 cm in diameter in California (Paton and Ralph 1990), >82 cm in Oregon (Nelson 1990), and >134 cm in Washington (Hamer and Cummins 1991). In British Columbia as well, the highest activity levels were found in old-growth forests >140 years in age (Rodway et al. 1992).

Because of differences in available habitat, murrelet nesting habitat criteria derived from lower latitudes could not be applied in the spill zone. Southcentral Alaska is the northern boundary of the north temperate rainforest, and old-growth forests in this region tend to have smaller trees and to be dominated by species typically found in poor soils or at higher elevations in lower latitudes (Viereck and Little 1978, USDA Forest Service, 1992). Prior to 1990, there had been no systematic effort to survey for upland murrelet activity in this region. To assist the restoration effort and identify marbled murrelet habitat, this study sought to develop protocols for surveying marbled murrelet inland activity and to describe nesting habitat of the murrelet in the spill zone. This chapter presents results of our upland surveys of marbled murrelet activity in the Naked Island area. The objectives of this portion of the study were to:

a. Determine if the number of murrelet detections was different among forest types based on tree size and stand volume in the Naked Island area, in Prince William Sound, Alaska.

b. Determine if the number of murrelet detections was correlated with on-site measurements of trees and other habitat features in the Naked Island area.

c. Estimate the population of murrelets in the Naked Island area for comparison with upland murrelet activity and habitat use.

In this chapter we present preliminary results for objectives a and b. Results of objective c, based on randomly selected at-sea transects within a 5 km buffer of the Naked Island area, are presented in Kuletz et al. 1994.

Eventually, our definitions of likely murrelet nesting habitat would have to be applicable to lands throughout Prince William Sound, and thus we wanted to work with a habitat database which would be compatible with a geographic information system (GIS). In 1991 the only comprehensive habitat database for Prince William Sound was the Chugach National Forest timber type database. We used these data to test for differences in murrelet upland activity among forest types. Other studies have found that intact old-growth stands of large trees had higher murrelet activity than stands with smaller, younger trees (Paton and Ralph 1990, Hamer and Cummins 1991, Rodway et al. 1992). Therefore, we used two criteria to define the forests of the Naked Island area: (i) stand size class, a measure of tree diameter and age in a stand, and (ii) stand volume class.

Prior to 1990, there had been no systematic effort to survey for upland murrelet activity in southcentral Alaska. We conducted this study in the Naked Island area in central Prince William Sound because murrelet dawn flights, indicative of nesting, had been observed there in the summer (Oakley and Kuletz 1979, Kuletz, pers. obs.). During a pilot study for the murrelet restoration project in 1990, Kuletz (1991) found that upland murrelet activity on the west side of Naked Island was patchy and that activity was greatest in westerly facing slopes of mixed spruce and hemlock old-growth with 70-80% cover. This study compares marbled murrelet activity among four forest types derived from a timber type database. We also describe murrelet activity relative to on-site measurements of habitat features and the relationships among those habitat features.

METHODS

Study Area

We studied upland activity of marbled murrelets from 10 June - 11 Aug, 1991 on Naked, Storey and Peak islands, Prince William Sound, Alaska (Fig. 2-1). The highest peaks in the study area are 360 m and 400 m on the west and east sides, respectively, of Naked Island, 460 m on Peak Island and 183 m on Storey Island. Naked Island has four large bays, and no point of land is further than 1.2 km from the ocean. The islands support mixed forests of mountain hemlock (*Tsuga mertensiana*), western hemlock (*T. heterophylla*) and Sitka spruce (*Picea sitchensis*), interspersed with muskeg meadows. The Chugach National Forest timber type database (ARC/INFO data files) show the islands as 97% forested (i.e., at least 10% stocked by forest trees), with 27% being productive forest (i.e., capable of producing harvestable wood). The islands are wooded to their summits.

The Naked Island area has not been logged, and core samples taken by USFS in 1991 showed dominant canopy trees to range from about 200 - 495+ years old (USFS, Anchorage, Alaska, unpubl. data). Thus, Naked Island forests are old-growth forests greater than 150 years old.

Definition and Mapping of Forest Types

We used Geographic Information System (GIS) timber type maps produced by the U.S. Forest Service to define and map forest types. These maps were derived from interpreted and ground truthed color aerial photos of 1:15,840 scale, taken in the 1970s. The stereoscopic delineations were transferred to planimetric base maps using standard photogrammetric techniques The transfer met class C Mapping Standards, with a horizontal error of not more than 132 feet ground distance on the base maps. The forest polygons were mapped to a 10 acre minimum size, except for non-commercial and non-forest types, which were mapped at a 5 acre minimum (USDA Forest Service, 1975).

The timber type data for Naked, Storey and Peak islands was digitized to a GIS prior to the 1991 field season by the U.S. Forest Service (Alaska Region, Anchorage, Alaska). The database showed 39 separate habitat types in the study area (Appendix G). Both productive and unproductive forests, which covered 97% of the study area, had stand size class and volume classes assigned. We used these two variables to define four forest types. Muskeg meadows were also included in the maps, but were not included in the sampling scheme.

The forest types were based on stand size class (i.e., predominate tree size), and stand volume class (measured in cubic feet per acre by the Forest Service and converted to cubic meters per hectare in this study) (Table 2-1). We characterized forest types based on these variables because they were the most complete data set by which to describe, *a priori,* forest stands of different tree sizes and structure. In this study area, size class, expressed in tree diameter at breast height (dbh), ranged from 0.25 - 23 + cm dbh in four classes. However, nearly all forests with trees >23 cm dbh were stand size class 4, since class 3 consisted of trees >23 cm dbh but <150 years in age. Tree volume is another means of defining forest structure. In general, although a few large trees can be in a low volume forest, higher volume indicates greater area coverage by large trees. Volume class ranged from 0-5648 m^3/ha, in four classes.

The four forest types range from low volume stands of small trees to high volume stands of large trees (Fig. 2-2). On the basis of this database, the lowest level forest type, FT1, included forests of low volume classes and small trees. Forest type FT2 included forests with low volume and large trees. Forest type FT3 had moderate volume and large trees. Forest type FT4 had the highest volume and large trees. The polygons described by these four forest types matched vegetation patterns we could discern on the aerial photographs.

Murrelet Activity Levels

Murrelet activity was quantified using the intensive inventory (Paton et al. 1990), hereafter referred to as the 'dawn watch', with modifications for Alaska based on the 1990 feasibility study (Kuletz 1991). In a dawn watch, the murrelet's dawn activity period, when birds are flying to and from the nesting area, is monitored from one spot, referred to as the dawn watch 'station'. The basic unit of measure is the 'detection,' which is defined as "the sighting or hearing of a single bird or a flock of birds acting in a similar manner" (Paton et al. 1990:2). The watches usually began 1 hour and 45 minutes before official sunrise and lasted until 15 min. after sunrise, or 15 min. after the last detection. Official sunrise for this study was obtained from the Nautical Almanac Office, U.S. Naval Observatory, Washington, D.C., in the table for Latitude 60^0 34' N, Longitude 151^0 15' W.

Observers were trained to recognize and record murrelet flight patterns and vocalizations at Naked Island by spending up to four days with an experienced observer. Observers were trained to judge distances by practicing with flagged distances and local topographic features. Observers would familiarize themselves with the distances of landmarks prior to a dawn watch, and during the watch, when a bird was observed or heard, used the location of that sound to estimate distance. At a minimum, we attempted to place the detection within three zones relative to the observer: 1) near ($\leq$ 100 m), 2) medium (101-200 m) and 3) far (>200 m). The observers used a tape recorder to note direction and flight pattern of the bird(s), type of vocalization, height above canopy or ground (in unforested areas) and nearest distance to the observer. The same observer transcribed the survey tape onto data sheets for data entry.

For analysis, murrelet detections were grouped according to type of detection, behavior and distance from the station, to reflect the level of association with that site. Because many of our sites were within 500 m or less of the ocean, we had to address the problem of birds calling while flying over the water. We had observed birds circling near shore and passing over both water and land during dawn flights, which may be relevant to nesting behavior. However, birds also called while on the water, and the relationship between this behavior and upland nesting activity was not clear. Therefore, we attempted to separate detections of birds flying over the water from audio detections with unknown behavior or observed to be from birds swimming on the water. In order of increasing association with the survey site, we used the following categories for analysis:

1) Total detections - All detections over land and detections of birds flying over water.

2) Over station - Detections over land and $\leq$ 200 m from observer.
3) Circling - Detections judged to be birds circling the area.
4) Occupied Behaviors - Detections of bird(s) displaying 'occupied behaviors', described below.

Flight patterns and behaviors of the birds are important in separating birds likely to be in transit from those likely nesting nearby. These behaviors, hereafter referred to as 'occupied behaviors', include flying below canopy, emerging from or flying into trees, landing on a branch or stationary calling. We were surveying relatively small stands and wanted our observations of occupied behaviors to be limited to a specific area. Therefore, we did not include circling above canopy as an occupied behavior, although it is considered so for some applications (Ralph and Nelson 1992, Ralph et al. 1993). Circling above the canopy was considered an indicator of closer association with the site than a direct flight through the area. Occupied sites were those with at least one recorded occupied behavior. We used the term 'unknown status' for sites where no occupied behavior was observed, since a single visit was not sufficient to determine if a site was definitely unoccupied.

Selection of Dawn Watch Sites

We wanted to sample murrelet activity in each of the four forest types equally, although they were not equally present on the islands. GIS analysis of the four timber types on the three islands showed coverage of 25% FT1, 37% FT2, 15% FT3, 10% FT4 and 13% unforested or freshwater. Dawn watch sites for assessing inland murrelet activity levels were selected by overlaying a grid (200 m on the side) on a map with the forest types and giving each of the 1500 grid cells a unique number. We then randomly selected numbers until we had 20 sites in each forest type. The forest type at the center of each cell was used to characterize the sample, and the dawn watch station was located 100 m inside that forest type. We ran a GIS buffer analysis of 200 m around each of the 72 selected sites to determine if the forest types were more equally represented by this sampling method. The total area within 200 m of the dawn watch sites did distribute the sampling effort more equally among the forest types; 26% FT1, 31% FT2, 23% FT3 and 20% FT4.

Surveys at Naked Island in 1990 (Kuletz 1991) showed a late July peak in activity and an abrupt decline after mid-August. Therefore, we did not conduct dawn watches after 11 August, at which point we had surveyed 72 sites (Fig. 2-3). To minimize seasonal effects (see Chapter 1), we surveyed in the different forest types equally throughout the season. We conducted one dawn watch at each site, to maximize sample size in each forest type rather than determine within-site variance.

Observers located sites using a map, compass and aerial photograph. In some cases, a hand held Global Positioning System (GPS) was also used. In most cases, the observer arrived the evening prior to the dawn watch and camped on-site.

Observers were stationed in the forest stand, rather than outside the stand in a clearing, because different forest types were often within 200 m of each other, and we wanted murrelet observations to be relevant to the forest type being sampled. Within the stand, the observer would attempt to locate the survey station under an opening in the canopy, to improve visual observations. The location of the dawn watch station was marked on copies of the aerial photograph and finally digitized into the GIS.

Habitat Characteristics of Forest Types

At each dawn watch site a vegetation plot was sampled in a 50 m radius from the site's center. Within the plot we measured the ten nearest upper canopy trees for diameter at breast height (dbh), and we made visual estimates of overall canopy height, percentage canopy closure of the site and percentage of forested area. In 1991, we did not have a basis by which to judge potential nesting sites (i.e., platforms, as described in Chapter 1), but at 63 sites, we recorded the presence or absence of moss clumps on trees in the plot. Slope grade, aspect and elevation were measured on site or taken from topographic maps. Distance from the ocean was measured from aerial photographs. Size of contiguous stands of the same forest type was obtained using the GIS timber coverage. All of these variables, including those taken from topographic maps, are referred to as on-site measurements.

Because 1990 results (Kuletz 1991) suggested that bays had higher activity levels than more exposed coasts, we classified the sites as being near the head of a bay or on a more exposed coast, usually on a peninsula. A bay head site might be near the shoreline, but protected by local topography, or be up to 500 m inland if it was part of the watershed around the bay head. Of the 72 sites surveyed, 21 were categorized as near bay heads, 33 on exposed coasts, and 18 sites could not be readily categorized (Fig. 2-).

Data Analysis

Murrelet activity levels among the four forest types were compared with one-way analysis of variance (ANOVA). Although the numbers of detections were skewed, the sample sizes and variances were similar, and samples were independent. Under these circumstances, the F test is robust against departures from normality (Neter et al. 1990; 623), so we did not transform the original data. Comparison among means was done with the Student-Newman-Keuls test.

We also tested for correlations between murrelet detections and habitat features measured on-site. We used the Kendall *tau-b* correlation to test the relationship between murrelet detections and distance from the ocean, percentage of forested area, canopy closure, canopy height, tree diameter, slope grade and elevation. We used Fisher's exact test for aspect, which was divided into four quadrants (NE (0-90^0), SE (91-180^0), SW (181-225^0) or NW (226-359^0)), and the presence/absence of moss clumps on trees at the site (described below). We used Cochran's t-test on continuous habitat variables to compare sites that were occupied to sites of unknown status. The t-test was also used to compare murrelet activity between sites at bay heads and sites on peninsulas.

We tested for differences among the four forest types (FT1-FT4) for mean tree diameter, canopy height, canopy closure, percentage of forested area, stand size, slope grade, elevation and distance to the ocean, using ANOVA, with the Student-Newman-Keuls test for comparisons among means. The presence/absence of moss on the trees was compared among the four forest types with Fisher's exact test.

Aspect, converted into four directions, was compared among forest types with Fisher's exact test. A t-test was used to compare sites at bay heads and other sites for the following variables: mean tree diameter, slope, elevation, meters from ocean and stand size. We used Kendall's *tau-b* correlation to test for relationships between tree diameter, elevation, slope grade and aspect, stand size and distance from water.

RESULTS

Murrelet Activity Among Four Forest Types

The total number of murrelet detections per dawn watch ranged from 0 to 140 (x=35.9, SE = 3.7). Three dawn watches (4%) had no detections at all. Fourteen of the 72 sites (19%) had no detections within 200m. There was no significant difference in the total number of audio or visual detections among the four forest types (Table 2-2). However, 65% of the detections were at medium or far distances from the observer (> 100 m), including 15% at far distances (> 200m). We recorded murrelets up to 600 m away, and distant detections were common at sites above open bog meadows or overlooking a bay.

The number of detections within 200 m of a given site (over station) ranged from 0 to 71 (x=15.6, SE = 2.2), and was significantly different among forest types (Fig. 2-4; ANOVA; F= 3.19, df = 3, 68, P = 0.0296). FT3 forests had the highest, and FT1 forests the lowest number of detections, both of which accounted for the significant F value. There was no significant difference in the number of circling behaviors observed among the forest types.

The mean number of occupied behaviors observed per dawn watch was also significantly different among forest types, with the greatest number, an average of 1 per site, observed in FT3 forests (Table 2-2). The lowest observation rate for occupied behaviors was observed in the FT1 forest, at 0.06 per site.

Murrelet Activity and Site Characteristics

Among the continuous variables measured on-site (canopy closure, canopy height, forested area, tree dbh, distance from water, elevation, slope grade, stand size), only the percentage of forested area in the vegetation plot was significantly correlated with the number of detections within 200m of the station (Kendall's *tau-b* = 0.260, P = 0.0047). There were no significant correlations between the number of circling behaviors or occupied behaviors and the on-site measurements.

Sites with moss clumps on trees (noted as present or absent in vegetation plots) had significantly higher numbers of detections within 200 m of the site (t=-3.74, df = 53, P = 0.0009). Sites with moss also had higher numbers of occupied behaviors recorded (t = -2.49, df = 49, P = 0.0164).

When the aspects of sites were categorized as NE, SE, SW or NW, there was no significant difference in numbers of detections over station (within 200 m), or in the number of occupied behaviors among the quadrants. However, the mean detection rates were higher in the two northerly quadrants (n = 42) than in the south facing slopes (n = 30). Detections averaged 19.1 per watch at NE facing sites and 16.4 per watch at NW facing sites. Detections averaged 13.3 per watch at SE facing sites and 12.5 per watch at SW facing sites. The highest numbers of occupied behaviors per watch were recorded at sites facing NE, with a mean of 0.72/watch, compared to 0.36-0.38 for the remaining three quadrants.

Compared to sites near more exposed coasts, the sites near the heads of bays had significantly higher numbers of circling behaviors and total detections (Table 2-3). The number of detections within 200 m of the station was not significantly higher at bay heads, but approached significance (t=1.95, df = 52, P = 0.0556). There was no significant difference in the number of occupied behaviors observed between bay and exposed sites.

Occupied Sites v. Sites of Unknown Status

The occupied sites (those with at least one recorded occupied behavior) included two sites where occupied behaviors were observed at the site in the pre-dawn hours before the actual dawn watch began. Occupied behaviors were observed at 22% (16 of 72) of the surveyed sites. Occupied behaviors were 2% of total detections, 4% of detections within 200 m and 5% of detections within 100 m. At this rate, the probability of observing an occupied behavior does not approach 95% until >60 detections per dawn watch (Fig. 2-5). Only one of these 72 sites had no occupied behaviors despite recording >60 detections within 200 m, although three other sites with 53-59 detections had no occupied behaviors.

Occupied sites had significantly higher numbers of detections, on average, than sites of unknown status (Table 2-4; t = -3.18, df=70, P = 0.002), but we did not record significantly higher numbers of circling behaviors at occupied sites. At occupied sites, the mean distance from the observer of all detections was less than at sites of unknown status (t=2.29, df = 67, P = 0.0255).

The occupied sites did not differ significantly from sites of unknown status in slope grade, percentage of forested area, canopy cover, elevation, distance from the ocean or stand size, although stand size tended to be larger for occupied sites (Table 2-5). Occupied sites did have significantly larger trees (t = -2.02, df = 69, P = 0.047), and estimated canopy height approached significantly higher means (t = -1.77, df = 61, P = 0.0809). The presence of moss on tree branches was recorded at 75% of the 16 occupied sites, and 46% of the 56 unknown status sites. However, 16 sites had no data on the presence of moss, and a 2x3 contingency table which included the unknowns was not significant (Fisher's exact test; $x^2 = 4.6$, df = 2, P = 0.108).

Habitat Characteristics of Forest Types

Our on-site visual judgement of forest type usually agreed with the timber type classification. At 15 sites, the observer questioned the timber type classification. In six cases, the observer judged the site to be FT3 rather than FT2. In six cases, the sites were judged FT3 rather than FT4, and in three cases, the sites were judged FT2 rather than FT1. However, within a given forest type, mean tree diameter measured on-site did not show any significant difference between sites of questioned classification and those that were not questioned; both groups had high variances. Therefore, we did not analyze the data based on visual judgement by observers, but relied on the original timber type classifications.

All of the on-site measurements showed significant differences among the four forest types (Table 2-6) and appeared to agree with the basic timber type classification. Sites in FT4 and FT3 forests had the largest mean tree diameters, followed by FT2 and lastly FT1. Based on our on-site measurements, we characterize the forest types as follows: (1) FT1 sites, only 53% forested, had the smallest average tree dbh, lowest canopy height and percentage canopy closure. They had low slope grades, moderate elevation, and were furthest from the ocean. (2) FT2 sites, 75% forested, had intermediate tree sizes, low canopy height and low percentage canopy closure. They had the largest contiguous stand sizes, low slope grade and relatively low elevations. (3) FT3 sites, 97% forested, had large trees, high canopy height, the highest percentage canopy closure. They had the smallest stand sizes, moderately steep slopes, lowest elevation and were closest to the ocean. (4) FT4 sites, 83% forested, had the largest trees, highest canopy height and high percentage canopy closure. They had small stand sizes, the steepest slopes and a large range of elevations.

The differences among the four forest types are reflected in the relationships among the on-site measurements. There was a significant negative correlation between tree diameter and elevation (n = 71, *tau-b* =0.1698, P = 0.042) and a near significant positive relationship between tree diameter and slope grade (*tau-b* = 0.158, P = 0.0544). Steeper slopes tended to have smaller stand sizes (*tau-b* = -0.2007, P = 0.0153). Elevation increased with distance from the ocean (*tau-b* = 0.6389, P = 0.0001).

The aspects of sites differed from expected among the forest types, although the low sample sizes makes the statistical results suspect (Chi-square = 18.6, df = 9, P = 0.029). The FT1 sites faced SE and NW and the FT2 sites faced primarily SE. Most of the FT3 sites faced NE, followed closely by SW and NW. The FT4 sites were primarily facing NW, at 12 of 19 sites.

Among forest types, the percentage of sites with moss on the trees varied significantly, but again, may be suspect due to low sample size (Chi-square = 28.6, df = 6, P = 0.00002). Only 11% of the FT1 sites and 44% of the FT2 sites had moss. The FT3 sites had the highest percentage of sites with moss, 88%, followed by FT4 at 68%.

The sites at heads of bays did not differ significantly from sites along exposed coasts for any on-site measurement except distance from the ocean. Bay sites averaged 302 m from the ocean (n = 21, SE = 49 m), compared to sites on exposed coasts averaging 163 m from the ocean (n = 33, SE = 23 m) (t = 2.6, df = 28, P = 0.0147).

DISCUSSION

The apparent preference of murrelets for nesting in large old-growth conifers has been demonstrated wherever surveys have been done throughout their range. Although some studies have mentioned the importance to murrelets of high volume forests (Marshall 1988, Paton and Ralph 1990), no previous study has used this timber inventory criteria as a sampling strata. Our results suggest that forest stand definitions for Prince William Sound, based on a combination of size class and volume, could provide preliminary identification of potential murrelet habitat.

Murrelet activity levels were higher in stands of high stand size class and high volume class forests than in stands of small stand size class and low volume class forests. Occupied behaviors, indicative of nesting, were more frequently observed in the higher stand size class forests. These results agree with those of other studies done at lower latitudes, showing greater murrelet activity in coastal old-growth forests with larger trees (Eisenhawer and Reimchen 1990, Paton and Ralph 1990, Nelson et al.1992, Hamer and Cummins 1991).

The primary difference between our results and others is the occurrence of murrelet activity around trees which were smaller than at lower latitudes. Because tree size decreases with increasing latitude (Viereck and Little 1978), other old-growth forest features, such as dense canopy closure, high epiphyte accumulation and multilayered structure may be more important to murrelets in Alaska. Nonetheless, as in other areas of its range, murrelet activity at Naked Island was highest in forest stands which had the largest trees in the area, with trees >150 years in age (or 200-495+ based on core samples) and with moss accumulation on the branches.

The structure of old-growth forests can block visual detections and reduce audio detections. At this study site, the relatively low forest canopy may have made it possible to make more low visual detections and detect subtle sounds, such as birds landing in trees or making soft stationary calls. However, it is possible that our results for sites in FT4 forests were affected by reduced murrelet detectability. Our results in the nest search portion of this project (Chapter 1), suggest that our survey of the four timber types underestimated murrelet use of FT4 forests. Although FT4 forests had lower numbers of occupied behaviors per site than FT2, four of the ten murrelets nests found on Naked Island were in FT4 forest types (the remaining six were in FT3 forests).

The problem of reduced detectability in dense forests can be countered by stationing observers outside a stand (Ralph et al. 1993), but we did not want to bias our results among closely adjoining forest types. We attempted to minimize the potential for recording incidental activity from adjacent forest types by stationing observers within the selected forest and using only detections in a 200 m radius. Nonetheless, visual detections were more frequent in the more open canopy of FT2, whereas in FT4 forests we recorded slightly more circling behaviors, which could be heard above trees, but relatively low numbers of visual detections. Thus, the higher total number of occupied behaviors in FT2 forests, compared to FT4 forests, may have been due to reduced detectability in the latter. Countering this argument is the high level of activity we observed in FT3 forests, which also had dense canopy cover and large trees.

The higher detection levels recorded in FT3 forests compared to FT4 forests may be a true reflection of murrelet habitat preference. Our on-site measurements showed FT3 forests to have the highest canopy closure and they were similar to FT4 forests in percentage of forested area and tree sizes. We examined several factors that could have influenced murrelet use.

Murrelet Activity and Site Characteristics

The presence of moss, which is more likely to form nest size platforms on larger trees (Hamer and Cummins 1991, Chapter 1, this report), may influence murrelet nesting patterns. In Washington, Hamer and Cummins (1991) found higher murrelet activity where trees supported mossy platforms >18 cm circumference, and on Naked Island, nest trees had more platforms >15 cm circumference (a size based on nests found at Naked Island) and a higher percentage of epiphyte cover than surrounding trees.

Factors which may influence the accumulation of moss are tree size and tree species (Hamer and Cummins 1991, Chapter 1, this report). Additionally, because moss growth is influenced by moisture, other microhabitat features may be important, such as proximity to the ocean or exposure. Such microhabitat effects may explain the higher activity levels in FT3 forests, which were closest to the ocean.

Because FT3 forests were closer to the water, there is the possibility that either we were recording birds on the water, or that birds circled more near the water and thus increased the detection rate. However, there was no significant correlation between total detections or circling behavior and distance from the ocean. It is unlikely that distance to the ocean in itself influenced murrelet activity levels; none of the forest stands in our study were more than 1.2 km from the ocean, and murrelets are known to nest up to 75 km inland (Nelson 1990).

Similarly, the higher activity we observed at bay heads does not appear to be a result of recording more birds flying over the water, since the bay sites tended to be further from the ocean than more exposed sites. More circling observations were made at bay head sites, but this was at least partially the result of the higher numbers of total detections. The most recent protocol includes circling as indicative of occupation by nesting birds (Ralph et al. 1993), and by this criteria, our observations suggest higher nesting density inland of bay heads.

Although our data were not conclusive, there was a tendency for murrelet activity levels to be higher on northerly facing slopes. The higher activity level we found on slopes with this aspect was corroborated by the 10 nests we found (Chapter 1); six of the 10 Naked Island nests were on slopes facing NW or WNW, and all 10 nests faced westward. The prevailing summer winds in Prince William Sound are from the southeast, and Naked Island, being near the center of the Sound, is fully exposed. Protection from prevailing winds may be a factor in itself, although differences in activity levels could be due to exposure affecting vegetation patterns. Most of the FT3 and FT4 sites (69%) faced NW or NE, while only 47% of the FT1 and FT2 sites were so oriented. The possible effects of slope orientation are likely site-specific, i.e., murrelet preference in a given location may be for slopes away from local prevailing weather patterns. For example, in Oregon, Nelson et al. (1992) found that most sites with murrelet activity faced away from prevailing NW winds. Slope aspect was also a significant factor in Washington, with high activity sites having a mean orientation of 110^0 (southeast) (Hamer and Cummins 1991).

Habitat features are typically correlated (Morrison et al. 1992) and have been found to be so at murrelet study sites (Hamer and Cummins 1991, this study). Therefore, a multivariate approach will be required to determine the degree of influence various habitat features have on murrelet activity. This will be the next step in our analyses.

Determining Occupation by Nesting Murrelets

Although we found higher activity levels at occupied sites, the probability of observing an occupied behavior is so low that its detection is likely to be dependent on the number of total detections at a site. Because of the low frequency of detecting occupied behaviors, and making only a single visit to each site, it is unlikely that we documented every occupied site among those sampled. To determine absence of nesting murrelets with certainty, a site must be surveyed at least eight times over two breeding seasons (Ralph and Nelson 1992). Our data suggest that with a single dawn watch, we could not have a high probability of defining a site as unoccupied unless more than 60 detections had been recorded within 200 m of the site with no occupied behaviors observed. Such a situation might occur in an area used as a flight corridor to the nesting site (Nelson 1989).

Habitat Characteristics of Forest Types

Based on our on-site vegetation plots, especially tree dbh of canopy trees and percentage of forested area in the plot, the classification system provided by the timber type maps was fairly accurate. It is possible that the discrepancies between our visual judgements of timber type made on-site and the timber type shown on the maps were partly due to microhabitat effects. Because the Forest Service has a 10 acre minimum polygon size for photo interpretation, timber types may be averaged over an area and mask microhabitat effects.

When surveying for murrelets over large areas, or with a sufficient number of sample sites, this source of error is probably insignificant. However, we recommend confirmation of GIS timber data for specific areas of interest, particularly murrelet nest sites. For example, on-site measurements at a Naked Island nest site (Chapter 1) indicated that it was located in a stand with higher volume class and stand size class than classified on the timber type map. The U.S. Forest Service's re-analysis confirmed the site as moderate volume and high stand size class. Because the stand of large trees was less than 10 acres, it had been included with the predominately low volume and low size class forest surrounding it. Thus, microhabitat effects limits the application of timber type data on a fine scale and on-site vegetation surveys should be conducted in specific areas of interest.

Our objective was to compare relative activity levels among habitats, and we identified differences between sites where we observed occupied behavior and those of unknown status. Based on results from this study, we characterize potential murrelet nesting habitat in Prince William Sound as mixed hemlock-spruce forests on moderate to steep slopes, with canopy closure of >85 %, trees >23 cm dbh (or >30 cm dbh, based on nest trees on Naked Island), and with moss accumulation. Sites located near the head of a bay may have higher nesting densities than other sites. Occupied sites had larger trees than sites of unknown status, and we observed more occupied behaviors at sites with moss on the trees.

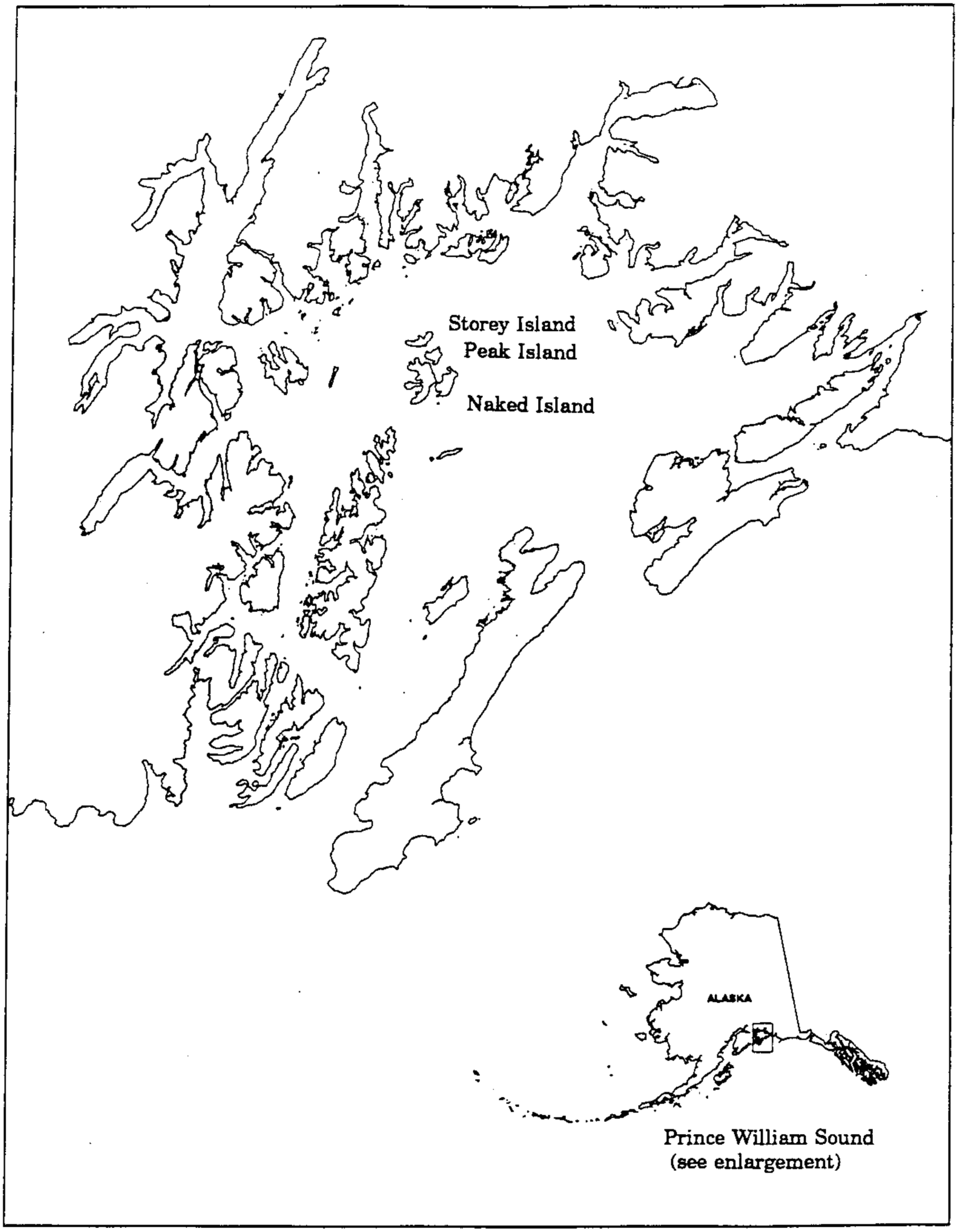

Figure 2-1. Study area for the 1991 habitat study at Naked, Storey and Peak islands, Prince William Sound, Alaska.

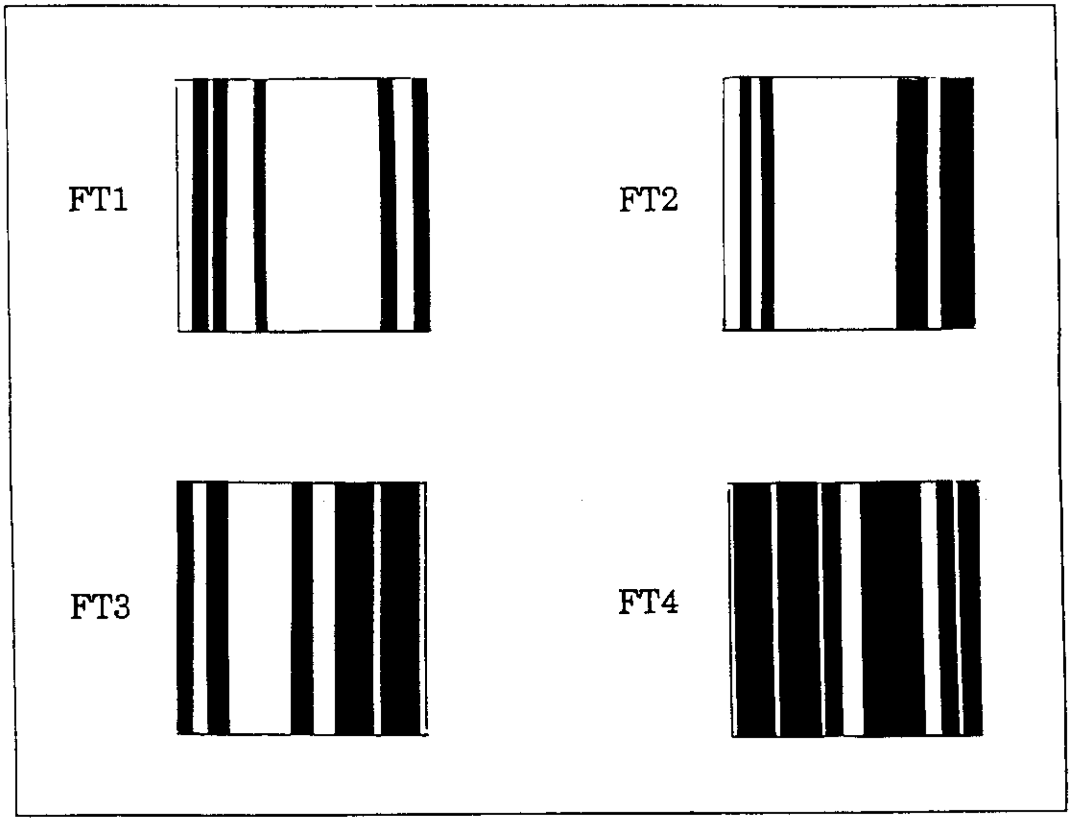

Figure 2-2. Schematic of tree size and distribution for the four forest types (FT1, FT2, FT3, FT4,) used in the 1991 habitat study at Naked, Storey, and Peak islands, Prince William Sound, Alaska in 1991. The criteria for the forest types are described in Table 1-1.

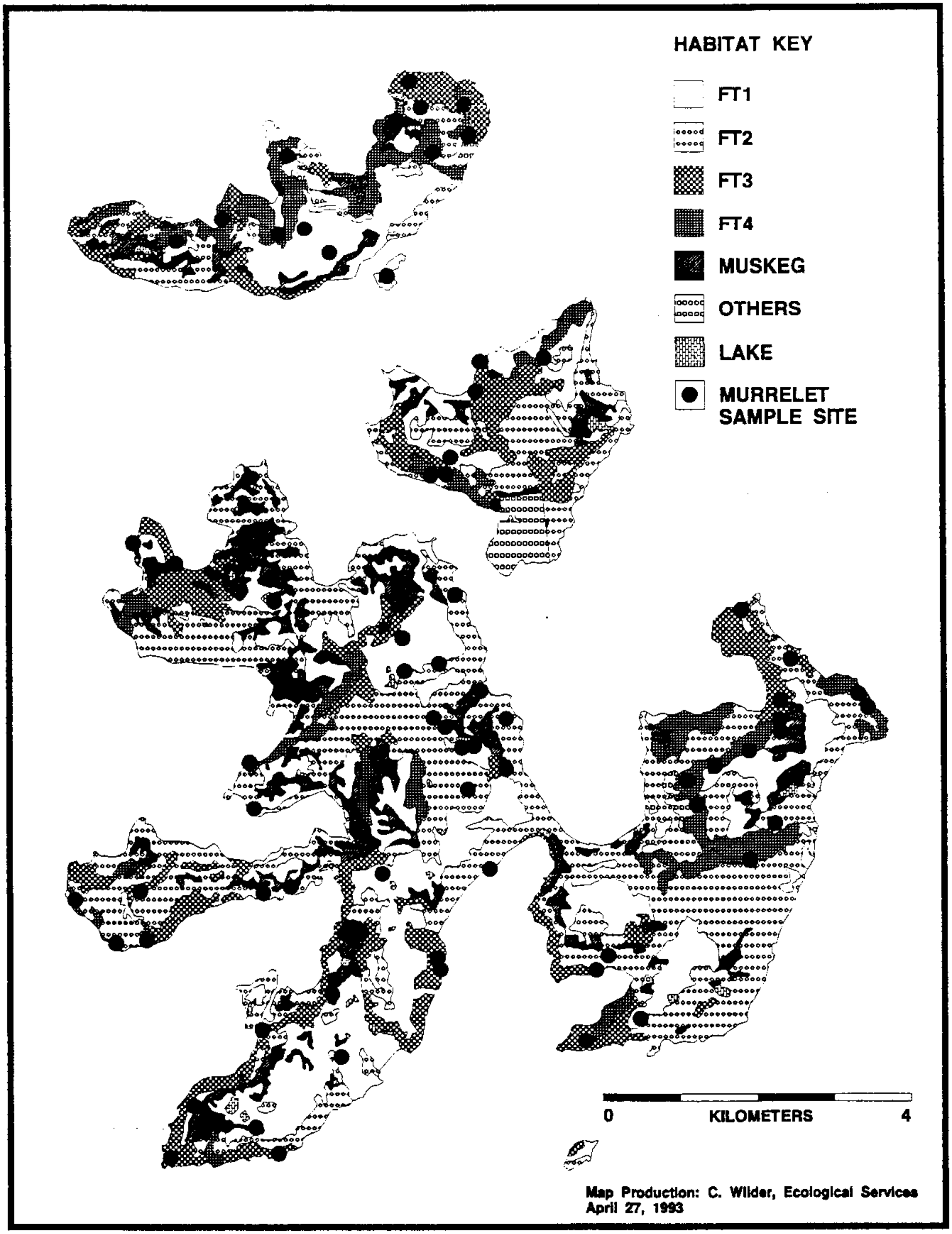

Figure 2-3. Habitat polygons derived from Chugach National Forest timber data at Naked, Storey and Peak islands, Prince William Sound, Alaska. Murrelet activity and forest types were compared at 72 randomly selected sites (black circles) in 1991.

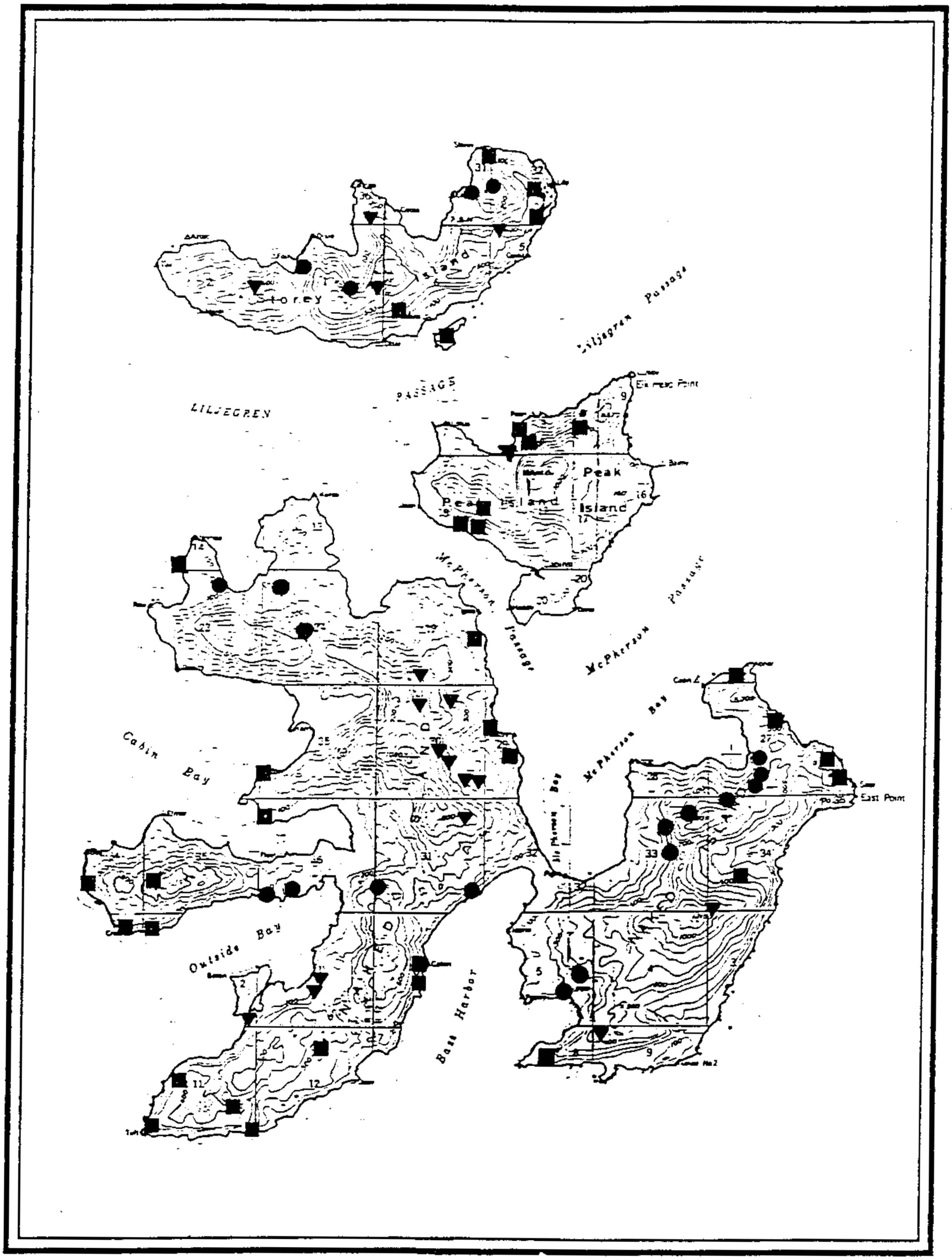

Figure 2-4. Map of the 72 sites surveyed for murrelet activity in 1991, showing their classification as sites at bay heads (circles), peninsula/exposed (squares) or undetermined (triangles).

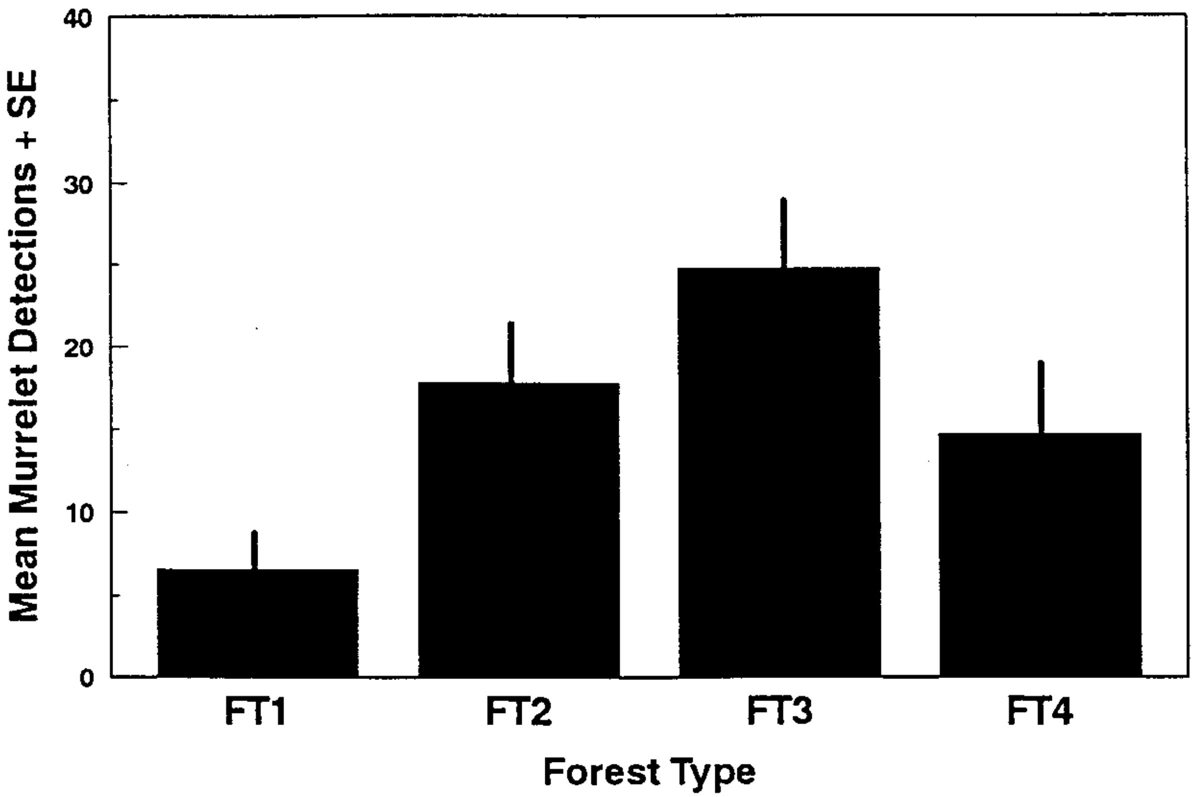

Figure 2-5. Average number of murrelet detections (+ SE) over station, among four forest types on Naked, Storey and Peak islands, Prince William Sound, Alaska in 1991 (n=72 sites). Forest types ranged from low stand size and volume classes (FT1) to high stand size and volume classes (FT4). (ANOVA; $F = 3.19$, $P = 0.03$).

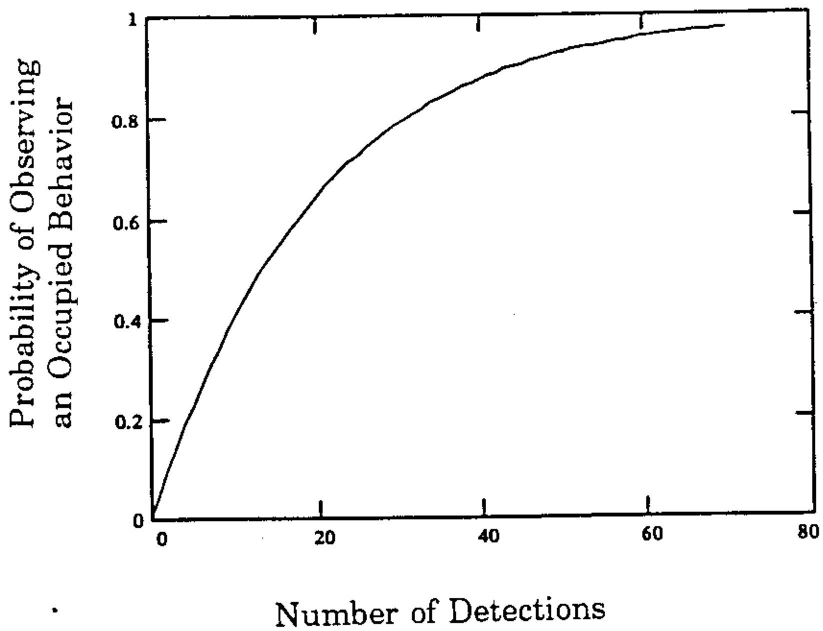

Figure 2-6. The probability of observing an occupied behavior during a dawn watch, when occupied behaviors were 5 % of detections ≤ 100 m from the observer. Based on 72 dawn watches at Naked, Storey and Peak islands, Prince William Sound, Alaska, in 1991.

Table 1-1. Forest types used in 1991 Naked Island habitat study. The timber type codes and criteria for forest volume and size classes are from the Chugach National Forest Data Dictionary.

Forest Type	Stand Class	Tree DBH	Volume Class	Net m^3/ha
FT1	1	0.25- 12 cm	1	0- 752
	2	13 - 23 cm	2	753 - 1882
FT2	3	>24 cm & <150 yr	1	0- 752
	4	>24 cm & >150 yr	2	753 - 1882
FT3	3	>24 cm & <150 yr	3	1883 - 3765
	4	>24 cm & >150 yr		
FT4	3	>24 cm & <150 yr	4	3766 - 5648
	4	>24 cm & >150 yr		

Table 22.Summary of the types of murrelet observations made at the four forest types surveyed in the Naked Island area in Prince William Sound, Alaska in 1991. Detections at all distances from the observer were included.

Forest Type	N Sites	No. Occupied [a*] Behaviors / Site Mean	± SE	No. Circling [b] Behaviors / Site Mean	± SE	No. Visual [c] Detections/ Site Mean	± SE	No. Audio [d] Detections / Site Mean	± SE
F1	18	0.06	(0.06)	5.8	(2.7)	0.51	(0.12)	30.5	(7.3)
F2	18	0.50	(0.22)	5.6	(1.6)	2.69	(0.63)	24.5	(5.8)
F3	17	1.00	(0.34)	7.2	(2.1)	0.77	(0.19)	39.8	(6.7)
F4	19	0.32	(0.22)	8.3	(2.6)	0.93	(0.21)	28.4	(7.7)

[a] ANOVA; F= 2.97, df = 3, 68, P = 0.04. *
[b] ANOVA; F= 0.31, df = 3, 68, P = 0.82.
[c] ANOVA; F= 1.35, df = 3, 68, P = 0.26.
[d] ANOVA; F= 0.84, df = 3, 68, P = 0.48.

Table 2-3. Comparison of the means of murrelet detection categories between sites at bay heads and exposed sites. Data are from the randomly selected sites surveyed on Naked , Storey and Peak Islands, Prince William Sound, Alaska, in 1991. Eighteen sites which could not be readily classified as bay head or exposed were not included in this analysis.

	N	No. of Occupied Behaviors Mean ± SE	Circling Detections Mean ± SE	No. of Detections on Land <200m Mean ± SE	No. of Total Detections Mean ± SE
Bay	21	0.33 (0.14)	11.05 (2.8)	22.1 (4.3)	51.8 (6.3)
Exposed	33	0.51 (0.19)	4.5 (1.5)	11.8 (3.2)	26.9 (5.9)
T-Test	T=	-0.75	2.11	1.96	2.70
	df=	52	31	52	49
	P=	0.45	0.043	0.056	0.009

Table 2-4. Comparison of murrelet detections between sites where occupied behaviors were observed, and sites where they were not observed. Data were from 72 randomly selected sites on Naked, Storey and Peak islands, Prince William Sound, Alaska, in 1991.

Site	N	No. of [a] Circling Observations Mean ±	SE	No. of [b] Detections on Land <200m Mean ±	SE	Distance [c] of Detections (meters) Mean ±	SE
Occupied	16	8.6	(2.2)	26	(4.3)	193	(14)
Unoccupied	56	6.2	(1.3)	13	(2.4)	244	(11)

[a] NS

[b] T-test; T= -3.18, df= 70, P= 0.002

[c] T-test; T= 2.29, df= 67, P= 0.026

Table 2-5. Comparison of habitat characteristics between sites where occupied behaviors were observed (occupied sites) and sites where they were not observed (unocccupied). Data were from 72 randomly selected sites on Naked, Storey and Peak islands, Prince William Sound, Alaska, in 1991. There was no significant difference between occupied and unoccupied sites for slope aspect (Fisher's Exact test), slope grade, elevation, distance to sea, stand size canopy or closure percent pressed area (T-tests). Tree diameter was significantly larger at occupied sites.

Site	N	Slopes (Aspect) No. of Sites NE	SE	SW	NW	Slope Grade (%) Mean ± SE		Elevation (meters) Mean ± SE		Distance to sea (m) Mean ± SE		Stand Size (hectares) Mean ± SE	
Occupied	16	6	3	2	5	34	(5)	94	(9)	284	(68)	247	(81)
Unoccupied	56	12	16	9	19	38	(3)	96	(16)	296	(32)	144	(31)

Site	N	Average[a] Tree DBH (cm)		N	Canopy[b] Height (m)		Canopy Closure (%)		Forested Area of Plot (%)	
Occupied	16	43.5	(3.3)	15	32	(4)	71	(7)	85	(5)
Unoccupied	56	35.8	(1.8)	56	23	(2)	60	(4)	75	(3)

[a] T-test; t= 2.02, df= 69, P= 0.047

Table 2-6. Habitat features of the four forest types surveyed for murrelets in the Naked Island area, Prince William Sound, Alaska, in 1991, based on 72 randomly selected sites.

Forest Type	N	Tree DBH [a] (cm) Mean ±	SE	Stand Size [b] (Hectares) Mean ±	SE	Slope [c] (%) Mean ±	SE	Elevation [d] (Meters) Mean ±	SE	Meters [e] to Sea Mean ±	SE
F1	18	25.4	(1.7)	94	(18)	26	(4)	120	(12)	464	(55)
F2	18	34.2	(2.4)	477	(86)	27	(2)	74	(17)	273	(65)
F3	17	45.3	(3.0)	47	(6)	38	(5)	65	(9)	132	(18)
F4	19	45.7	(3.2)	51	(11)	54	(3)	119	(19)	294	(56)

Forest Type	N	Canopy Height [f] (m) Mean ±	SE	Canopy Closure [g] (%) Mean ±	SE	Forest Area [h] of Plot (%) Mean ±	SE
F1	15	11	(5)	30	(7)	53	(5)
F2	16	24	(3)	60	(6)	75	(5)
F3	15	33	(5)	80	(5)	97	(1)
F4	16	34	93)	76	(3)	83	(3)

[a] ANOVA; F= 14.02, df = 3,67, P = 0.0001. SNK; F3 & F4 not significantly different.
[b] ANOVA; F= 21.98, df = 3,68, P = 0.0001. SNK; only F2 is significantly different.
[c] ANOVA; F= 8.18, df = 3,68, P = 0.0001. SNK; only F4 is significantly different.
[d] ANOVA; F= 3.73, df = 3,68, P = 0.015. SNK; NS
[e] ANOVA; F= 6.46, df = 3,68, P = 0.0007. SNK; only F1 is significantly different.
[f] ANOVA; F= 10.39, df = 3,59, P = 0.0001. SNK; only FT1 is significantly different.
[g] ANOVA; F= 18.87, df = 3,59, P = 0.0001. SNK; FT3 & FT4 not significantly different.
[h] ANOVA; F= 20.15, df = 3,59, P = 0.0001. SNK; FT2 & FT4 not significantly different.

CHAPTER 3

Identification of Marbled Murrelet Nesting and High Activity Areas in Prince William Sound, Alaska, Using Boat-Based Dawn Watches.

Dennis K. Marks

INTRODUCTION

To assist *Exxon Valdez* oil spill restoration efforts, we conducted a pilot study of survey methods designed to identify murrelet nesting areas throughout the spill zone. Unlike most other seabirds, murrelets are secretive and nest solitarily or in small groups (Carter and Sealy 1986, this study) and until recently, their nesting habits have been relatively unknown.

Marbled murrelets fly inland in early morning to visit their nests, and dawn or pre-dawn surveys have been used successfully to determine the overall activity levels as well as the nesting status in an area (Paton et al. 1990). The success of large-scale surveys outside of Alaska is partly due to greater accessibility; observers have easy access through road and trail systems. In contrast, land within the spill zone is rugged, densely vegetated, and difficult to hike in. It is remote and only accessible by boat or aircraft. A large-scale survey of murrelet habitat use had not been previously attempted in Alaska. We examined the usefulness of conducting dawn watches from boats anchored near shore to determine murrelet activity levels in a variety of habitat types throughout western Prince William Sound (PWS), Alaska.

Large tracts of old growth forest constitute the primary habitat for nesting marbled murrelets at lower latitudes (Hamer and Cummins 1990, Nelson 1990, Paton and Ralph, 1990). While our research to date in Prince William Sound supports this conclusion, ground nests in alder thickets and on rocky ground have been found in Alaska (Day et al. 1983, Simons 1980) and it was necessary to investigate a variety of habitats for murrelet activity.

Since the eventual goal of this project was to identify the habitat characteristics of murrelet nesting and high-use areas throughout the Sound, we needed to use a database compatible with a geographic information system (Chapter 2). Although additional criteria were used to define habitat types in this part of the study, the same USFS timber type database employed in the Naked Island analysis was also used here.

Knowledge of murrelet behaviors, daily activity patterns, seasonal trends and habitat use gained from research on Naked Island, PWS, in 1990-91, was used to design this study and evaluate our observations. This chapter describes the application of the dawn watch protocol to survey a variety of habitats in PWS for murrelet activity and to test the validity of conducting dawn surveys from shore. We examine the success of the survey methodology, and report on progress to date investigating the inland activity of murrelets in relation to habitat features. The following subobjectives will be addressed:

a. Test the use of boat-based dawn watches for assessing murrelet inland activity in regions primarily accessible by boat.

b. Investigate murrelet activity in all types of available habitat throughout western PWS to evaluate murrelet habitat associations.

c. Examine the usefulness of U.S. Forest Service (USFS) timber type maps for identifying murrelet nesting habitat.

d. Determine if near-shore (at sea) abundance of murrelets is related to their dawn activity levels at adjacent inland sites.

METHODS

Study Area

We defined the study area as western PWS, since time constraints prohibited adequate coverage of the entire Sound. In addition, western PWS was the oiled portion of the Sound, and previous U.S. Fish and Wildlife Service (USFWS) surveys showed murrelet densities were higher on transects in the western portion (Klosiewski and Laing, unpublished data). The study area included the area west of, and including Columbia Bay in the northeastern corner of the study area, Naked Island in central PWS and Montague Island on the southeastern boundary (Figure 3-1). Western PWS is an area of steep topography, numerous islands, convoluted shorelines and fiords. Old growth forests of mountain hemlock (*Tsuga mertensiana*), western hemlock (*T. heterophylla*), and Sitka spruce (*Picea sitchensis*) occur along the shoreline and many of the steep slopes; smaller trees, muskeg meadows, rock and alpine vegetation predominate at higher elevations. Tidewater glaciers and recently deglaciated valleys are common throughout the study area.

Inland Activity of Murrelets

The basic method used to survey inland activity of murrelets was the 'dawn watch'. Observers recorded the time, and the number and types of murrelet vocalizations and flight patterns. The dawn watches were conducted around dawn, when murrelets fly to their inland nests (Paton et al. 1990). Based on the Naked Island murrelet studies (Chapter 1), we modified the Pacific Seabird Group protocol for inland censusing of murrelets to fit Alaskan conditions. The primary changes were the exclusive use of the intensive inventory, or dawn watch, the earlier timing of the watches relative to dawn, and a more detailed set of behavior and vocalization variables (Appendix A). Conducting dawn watches from a boat or the shoreline required the addition of new variables to the standard protocols to include flight patterns and behaviors of birds sitting, swimming or flying over the ocean.

The range of behaviors, in order of their degree of association with the immediate area, included: (1) landing, leaving or making stationary calls from trees; (2) flying straight through or circling below the canopy; (3) circling above the canopy; (4) flying in a direct line above the canopy; (5) flying or vocalizing at a distance >200 m from the station's center (i.e., the observer). The first two behaviors are 'occupied' behaviors and appear to be indicators of nesting activity (Ralph and Nelson 1992). It is recommended that occupied behaviors be analyzed separately from the total detections (Nelson 1990, Hamer and Cummins 1991).

USFS timber type maps were not available for the Sound prior to the field season, so 80 transects were randomly chosen from a total of 176 shoreline sections in western PWS used previously by USFWS boat surveys. These 80 transects formed the pool of sites to be surveyed. The approximate midpoint of the transect was used as the actual dawn watch site.

The southwest quadrant of the study area is within the spill zone and contains a large range of habitat types, but was poorly represented in the first round of random selections. Because of the potential importance of the southwest quadrant, a secondary random selection was done on a subset of shoreline transects from that region (Figure 3-1). Variance among sites in this subset (n=7) was compared to variance overall to determine if these sites should be included in the overall analysis. No significant difference was found (Cochran t-test, t=-0.662, df= 6.3, P=0.535) so all sites were combined for further analysis.

Three USFWS personnel carried out all surveys, the boat operator did not participate in data collection. All sites were surveyed once between 12 June and 4 August, 1992. A 58' vessel was used for transportation, lodging, and as an observation platform. This reduced the need to hike and camp inland, thereby allowing more days to conduct surveys and enabled us to increase our sample size. The vessel had long-range capabilities and could be completely shut down to provide silence during observations.

In 48 days at sea, we surveyed murrelet activity at 68 sites (Figure 3-1). Sixty-seven boat-based watches were completed--44 from the 58' vessel and 23 from the inflatable (Table 3-1). At some sites, the vessel could not anchor safely, and the watch site had to be adjusted within that transect. At seven sites, the vessel was located 30 m or less from the midpoint. At 12 sites, it was moved between 50-100 m. At one site, the boat was positioned more than 100 m from the midpoint. In all but one case the large vessel anchored within 100 m of shore. Two of the randomly selected sites were not done because of unsafe anchoring conditions.

Each survey day, a 'boat-based' dawn watch was conducted from this vessel which was anchored within 100 m of shore the evening before the survey. On most days, a 14' inflatable boat was used to ferry two people to a site nearby to conduct an additional dawn watch. These watches were done from the beach, if possible, but included four watches from the inflatable boat near shore and three watches from 75 m or less inland.

To evaluate the effectiveness of the boat-based dawn watches in detecting inland murrelet activity, we conducted a companion dawn watch at an adjacent site 100 to 600 m inland from the anchored boat, using protocols identical to the boat-based dawn watch. These 'paired' watches (n=17) were conducted when the boat-based sites were too far apart to sample in one morning. The inland station was directly inland from the vessel and was chosen for its vantage--it was often placed in a clearing or area of small trees, as advised in the Pacific Seabird Group's protocol (Paton et al. 1990).

Habitat Characteristics at Inland Dawn Watch Sites

At 17 inland dawn watch sites a 50 meter radius plot was surveyed. Measurements of slope, elevation, aspect, percentage forest cover, canopy height, percentage canopy closure, and the species, diameter at breast height (dbh) and condition of the 10 nearest overstory trees were recorded at dawn watch sites by USFWS personnel (see Appendix E). In addition, an 'in-stand' vegetation plot was done, using the same protocol, in an adjacent forest stand, if murrelet activity was observed there (n=13). Four more were done in stands at boat-based sites and the USFS recorded similar information in forest stands at 13 of the boat-based survey sites that did not have an inland site paired with it. For preliminary analysis, only the in-stand vegetation plots were used since the dawn watch site itself was selected for its vantage qualities and was often set in a clearing. Vegetation data was collected at a total of 30 of the 67 boat-based watches.

Because surveys on Naked Island suggested that murrelet activity was highest at the heads of bays (Kuletz 1991, Chapter 2 this study), we compared activity levels at 22 sites categorized as bay heads, to 45 sites not at the heads of bays. In this analysis, heads of bays included sites at or near the heads of protected, usually small bays, surrounded by steep topography.

Construction of Habitat Map Using USFS Timber Type Database

A vegetation or land coverage map of western PWS was produced to compare habitat to murrelet activity at each dawn watch site and to compare habitat in unsampled regions of the Sound. Using aerial photographs and 1:63360 U.S. Geologic Survey topographic maps, boat-based and inland dawn watch stations were digitized into a GIS database of PWS. USFS timber type data used for the Chugach National Forest inventory in PWS were derived from interpretations of aerial photographs (Chapter 2) and were made available as ARC/INFO coverages. We used ARC/INFO BUFFER, Clip and Frequency Analysis to determine areas for each timber type that occurred within 1000 m of each dawn watch site. These data included forest stand volumes and tree size, dominant species, and other major habitat types. We chose this size buffer because the boat-based dawn watch station was up to 100 m from land and requires a large area to identify sufficient inland habitat by which to evaluate local habitat types. To prepare a database for preliminary analysis of the GIS maps, a total of 215 different habitat types were identified in PWS, 74 of which occurred within a 1000 m buffer around the dawn watch sites. Three habitat types were defined using the list of habitat characteristics within the 1000 meter buffer: (1) nonforested areas, (2) forested areas, including all productive and unproductive forests, and (3) productive forests of stand classes 3 and 4 (see Appendix G for explanation of timber map hierarchies). 'Nonforest' and 'unproductive forest' categories include rock, alpine, alder and willow. Stand Classes 3 and 4 include productive trees >23 cm (9") dbh and >30 years old. Data from the ARC/INFO frequency analysis were summarized on a Paradox database and analyzed with SAS software.

Relationship Between Murrelet Inland Activity Levels and Nearshore Murrelet Density

To examine the relationship between the number of detections at dawn and the number of murrelets on the water near shore, we conducted at-sea counts of murrelets along a transect 100 m from shore and included an area 100 m on either side of the boat. At-sea surveys were done at each of the boat-based dawn watch sites along the established USFWS transects (Figure 3-2a-d). The transects averaged about 3 km in length, and, in most cases, were conducted within one hour of the dawn watch by two observers in an inflatable boat.

Data Analysis

Since we were interested in the inland activity to and from nesting areas rather than feeding areas, birds on the water were not included in the total number of detections. 'Unknown' birds, or those not known to be flying over or sitting on the water, were also excluded from this total.

A marked seasonality in inland murrelet activity has been documented in Alaska (Kuletz 1991, Chapter 1). We used the seasonal pattern of murrelet activity at inland sites on Naked Island in 1992 to define two periods: the pre-peak period (June 12 to July 10) and the peak period (July 11 to August 3). To compensate for seasonality, murrelet activity at each site was compared to murrelet activity at other sites surveyed in the same period. Within each period, sites were classified as having high, medium, or low activity levels, relative to the mean for that period. For the pre-peak period, low, medium and high levels correspond to detection numbers of 0-15, 16-30 and 31-72 total detections, respectively. For the peak period, low, medium and high levels correspond to detection numbers of 0-50, 51-100 and 101-333, respectively.

For statistical comparisons between groups, Kendall's test of correlation and the Cochran t statistic were used, with significance accepted at $P \leq 0.05$.

RESULTS

Assessment of Murrelet Inland Activity Using Boat-based Dawn Watches

During dawn watches from the boats, murrelets were both heard and seen and detections were similar, in magnitude and behaviors, to those observed at inland sites. Murrelets were observed flying over land and ocean, as well as sitting or swimming on the ocean surface.

Comparing boat-based watches, no significant difference was found between the average number of detections observed during the boat-based surveys from the 58' vessel and those done from the inflatable or the beach ($\bar{x}$= 43 and 41, respectively, t=0.183, df=44.1, P=0.854). These watches were pooled for further analysis and referred to as boat-based watches.

The total number of detections per dawn watch for the boat based surveys ranged from 0 to 223 ($\bar{x}$=42, sd=44). Only two sites had no detections. The number of detections per dawn watch at inland sites ranged from 9 to 333 ($\bar{x}$=69, sd=79). For all dawn watches, adjusted activity levels (dawn watch detection numbers corrected for seasonality) showed 26 sites with a high activity level (20 of these were boat-based), 19 with a medium level (14 boat-based) and 40 with a low level (33 boat-based, Figure 3-4). Eleven of the 17 paired watches inland and boat-based watches had the same activity levels and only two pairs differed by more than one level. Detections from inland sites consisted mainly of detections over land while boat-based surveys had a significantly higher number of detections of murrelets on and over the water. Birds flying over the water were approximately 7% of the total number of detections in both periods. While not included in the total detections, approximately 5% of detections were birds sitting on the water and 18% were of unknown origin.

The mean of the total number of detections observed at inland sites was not significantly different from the mean of the total detections observed for the boat-based surveys (Cochran t-test, t=-1.365, df=19.9, P=0.189). For the paired inland and boat-based surveys, a positive correlation between the number of detections from the boat and the associated inland site was found (Figure 3-3, Kendall's correlation, tau-b=0.370, P=0.039). Inland sites, between 100 and 600 from shore, showed no correlation between the distance the site was from the shore and the number of murrelet detections observed over land (Kendall's correlation; tau-b=-0.009, P=0.934). There was no significant correlation between the number of detections observed over land and the distance the vessel was anchored from shore (Kendall's correlation; tau-b=0.-0.009, P=0.934). The following refer to watches done from the boat.

The total number of detections for each boat-based dawn watch showed a marked seasonality with a distinct increase in murrelet activity around mid-July (Figure 3-5). We observed about a 3-fold increase in the average number of murrelet detections during the peak period ($\bar{x}$=68, sd=53.8) from the earlier pre-peak levels ($\bar{x}$=23, sd=19.6), and these means were significantly different from each other (Cochran t-test; t=4.27, df=33.7, P=0.0001).

Circling behaviors contributed 23% ($\bar{x}$=5 per watch) of the detections to the total number. During the peak period circling behaviors made up a greater proportion of the total detections with 34% ($\bar{x}$=23 per watch; t=3.56, df=31.9, P=0.001). Birds flying over the water were approximately 7% of the total number of detections in both periods. While not included in the total detections, approximately 5% of detections were birds sitting on the water and 18% were of unknown origin.

The number of occupied behaviors per site ranged between 0-8 and were observed at 12 of the 67 boat-based watches (18%) and 5 of the 17 inland sites (29%). Occupied behaviors were not observed from the boat during paired watches where the five inland site surveyors observed occupied behaviors. Furthermore, only one of the 12 boat-based surveys with occupied behaviors had a corresponding inland watch. Inland sites averaged 3.2 occupied detections per watch for thee five sites with occupied behaviors; boat-based sites averaged 1.9 detections per site (n=12). There was no significant relationship between the number of total detections and the presence or absence of occupied behaviors at a site, but there was a significant correlation between the number of total detections and the number of occupied behaviors at each site (Kendall's correlation; tau-b=0.220, P=0.011).

Habitat Characteristics of Dawn Watch Sites with High, Medium and Low Levels of Murrelet Activity

High activity sites were scattered throughout the study area. However, sites on and around Knight Island were some of the most active sites in the study area ($\bar{x}$=96 detections). Although this group was sampled during the peak period, the adjusted values were more frequently high levels of activity, relative to activity levels in other areas (Fisher's Exact [two-tailed], x^2=7.0, P=0.043). A few sites in the northwestern portion of the Sound had very low activity. These sites were in glacial bays and recently deglaciated areas of sparse forests and small trees.

Dawn watch activity levels (H,M,L adjusted for seasonal effects) from boat-based watches at sites near the heads of bays (Figure 3-6) were higher than those sites not near the heads of bays (Chi-square; x^2=11.4, df=2, P=0.002, Table 3-3). The means of the total numbers of detections between the heads of bays and other sites (n=67) were also significantly different ($\bar{x}$=63 and 32, respectively; T=-2.51, df=30, P=0.019). Exceptions to this trend were the heads of bays that were glaciated or recently deglaciated, where we observed very low levels of murrelet activity.

For the 30 sites with on-site vegetation plot data, eight habitat characteristics measured at occupied sites were not significantly different from those at other sites (those of undetermined status) (Table 3-4). Similarly, only one characteristic--canopy height--showed a significant, and positive, correlation with the total number of detections at each site (Table 3-5). When the pre-peak and peak periods were analyzed separately, a correlation between the mean number of platforms and the total number of murrelet detections, approached significance (Kendall's correlation; tau-b=0.301, P=0.068) for the peak period. When adjusted activity level was used, a significant and positive correlation between activity and the average number of platforms at a site was found (Figure 3-8, x^2=9.26, df=2, P=0.0095).

Average tree dbh was positively and significantly correlated to the following habitat features: percentage forest coverage, percent canopy closure, canopy height, slope aspect and mean number of platforms (Table 3-6).

Murrelet Activity and USFS Timber Type Maps

Using GIS, we compared murrelet activity with USFS timber type maps, using the three habitat categories of forested, nonforested and productive forest previously described. Based on timber-type data within a 1000 m buffer of each dawn watch site, we found a significant and positive correlation between the area of forested habitat surrounding the dawn watch station and the total number of detections for the corresponding boat-based dawn watch was found (Kendall's correlation; tau-b=0.344, P=0.0001; Figure 3-9). This 'forested' habitat category included all size classes of trees and accounted for about 85% of the total land area within all buffers. A subset of the forested habitat, productive forest of stand classes 3 and 4, consisted of stands of trees >23 cm dbh. This forest type made up approximately 10% of the land area and also showed a significant and positive correlation with murrelet activity (tau-b=0.302, P=0.0001). The third habitat construct--nonforested land--displayed a negative, but nonsignificant, relationship to the total number of detections within the 1000 m buffers (tau-b=0.002, P=0.983).

Occupied Behaviors and USFS Timber Type Maps

Using the timber-type maps and GIS (to produce polygons of various types of habitat), we examined differences in habitat between sites that were occupied and those that were not. T-tests revealed no significant differences in the amount of forested habitat (F=0.456, P=0.684), productive forests of stand class 3 and 4 (F=0.778, P=.714) or productive and unproductive forest combined (of stand class 3 and 4, F=0.445, P=0.999).

Relationship Between Murrelet Inland Activity Levels and Nearshore Murrelet Density

There was no correlation between the total number of detections and murrelet densities on transects adjacent to dawn watch sites (Kendall's correlation; tau-b=0.034, P=0.802). Anecdotal observations throughout the cruise support this finding; post-dawn at-sea distributions of murrelets did not reflect the level of murrelet activity observed during dawn watches (e.g., large foraging groups were observed in areas where little or no dawn watch activity was observed.

DISCUSSION

Assessment of Murrelet Inland Activity Using Boat-based Dawn Watches

Boat-based surveys allowed for an extensive sampling of habitats throughout PWS. The boat-based surveys appear to be an efficient and dependable method for surveying murrelet activity at sites difficult to access by other means. Using the boat for the actual dawn watch station reduced the need to hike and camp inland, thus allowing more days to conduct surveys and enabling us to increase our sample size. Since the time frame for sampling is short (May through the first week of August), it is important to use a dependable, self sufficient vessel with long-range capabilities to minimize delays from fueling and resupplying. Anchoring near shore was not a significant problem at most sites, although winds and the proximity to rocks and shoreline required lines to shore at a few sites.

While some adjustments to the survey protocol were necessary, such as separating murrelet activity on and over the water, we had close agreement in the types of behaviors observed between our surveys conducted from boats anchored within 100 m of shore and those reported for other surveys previously conducted in PWS. Further, our observations of murrelet inland activity from boat stations were similar in both numbers and behaviors to those recorded by observers stationed inland from boat-based observers. The seasonal trend detected in western PWS, specifically the increase in number of detections in mid-July, is in agreement with murrelet activity patterns on Naked Island (Chapter 1) and elsewhere (Hamer 1990).

At sites with high murrelet activity, the constant calling and visual sightings of several murrelets (and in some cases, more than one group of murrelets), made it difficult to record accurate and detailed behavioral descriptions for all birds. At these high activity sites, recording precise numbers and keeping track of all behaviors is difficult and are more approximate than these records at less active sites.

Aside from locating nests, the presence of murrelets engaged in occupied behaviors is the primary criteria presently used to define nesting habitat (Ralph and Nelson 1992). These behaviors may be restricted to the immediate nesting area and nesting areas located far inland may be impossible to evaluate from offshore. The low number of occupied behaviors occurring at a site make the probability of detecting them during a single watch low. Occupied behaviors were detected by boat-based observers indicating that this methodology could be used to locate nesting areas near shore. However, none of the sites where occupied behaviors were detected inland were paired with occupied sites from the boat and it is likely that boat-based surveys are limited to identifying nesting areas relatively close to the ocean. It has also been suggested that forest immediately adjacent to the coast is less preferred, by murrelets, for nesting. General activity levels and certain behaviors (e.g., circling) may also be helpful in guiding more intensive surveys for nesting sites further inland. While we found a significant correlation between the number of occupied behaviors at a site and the total number of detections, this may be an artifact of seeing more of these behaviors in very busy occupied spots.

Habitat Characteristics of Dawn Watch Sites with High, Medium and Low Levels of Murrelet Activity

There appeared to be a relationship between land form and activity level. We observed relatively low murrelet activity in a majority of the recently deglaciated areas; Rice (1991) made the same observation along the southern Kenai Peninsula. Murrelet activity levels were also higher at dawn watch sites at the heads of bays than at other areas. This was true for the surveys done on Naked Island as well (Kuletz 1991, Chapter 2). The reason for the higher activity at bay heads is unknown but might reflect the vegetation (e.g. the amount of epiphyte found on trees) in these relatively protected areas. Heads of bays might also be preferred flight corridors to sites further inland. Future murrelet and vegetation surveys should focus on potential differences in murrelet activity patterns and vegetation patterns at bay heads. The patchy distribution of high, medium, and low-use sites suggests that there were localized, small-scale differences in habitat which influenced murrelet activity.

Murrelet Activity and USFS Timber Type Maps

We found that murrelet activity was positively correlated with the amount of forest around a site. Productive forests of stand classes 3 and 4, which includes trees >23 cm dbh and >30 years old (stand class 3) and 150 years old (stand class 4), showed a correlation to murrelet activity level as did sites that were considered forested and included all forest types. In Washington State, Hamer and Cummins (1990) found that sites with a high percentage of old growth/mature forest had the highest number of murrelet detections. Sites with <31% old growth/mature forest or >25% clear-cut/meadow/shrub, had consistently low detection levels; high numbers of murrelets were only detected in sites with >31% old growth/mature forests. The high activity levels we observed in forested areas throughout western PWS is also consistent with research done on Naked Island, Alaska (chapter 1 and 2). Occupied behaviors were not useful in the GIS timber type analyses, probably due partly to the low number of sites where occupied behaviors were observed, but there may be several reasons boat-based observations of occupied behaviors do not appear to be accurate indicators of overall nesting in an area. Firstly, a much smaller area is available to a boat-bound observer than when surrounded by forest as in an inland survey. Often a cliff stands between the boat an the forest, placing the tree canopy further away. In addition to limitations in observability, it may be that murrelets have a different nesting distribution and may be more sparse along the coast than further inland.

Relationship Between Murrelet Inland Activity Levels and Nearshore Murrelet Density

We found no relationship between the dawn watch activity level and the numbers of murrelets counted on the water in the adjacent transect. While murrelets were detected on the water during the dawn watch, and birds on the water made up at least 5% of the total detections, they were not observed later, when the post-watch near-shore transects were conducted. Furthermore, large feeding flocks of murrelets were seen in areas of low inland activity. Thus, the presence of murrelets nearshore in early morning did not appear to be an accurate indicator of murrelet inland activity in the immediate area. Following morning flights inland, birds probably travel to forage areas which may be some distance from the nest.

Finally, the results of our habitat analysis supports other findings that the distribution of murrelets (both inland and at-sea) throughout their range is related to the distribution of old growth forests (Carter and Erikson 1992, Piatt and Ford, in press). However, the number of birds observed at sea is not necessarily an indication of activity inland. Given that murrelets fly up to 50 km inland to nests in California and Oregon (Hamer and Cummins 1990), it is not surprising that there is not a relationship between near-shore densities and inland activity at this small scale. On a larger scale, such as island groups, a pattern of high at-sea density and high inland activity may exist.

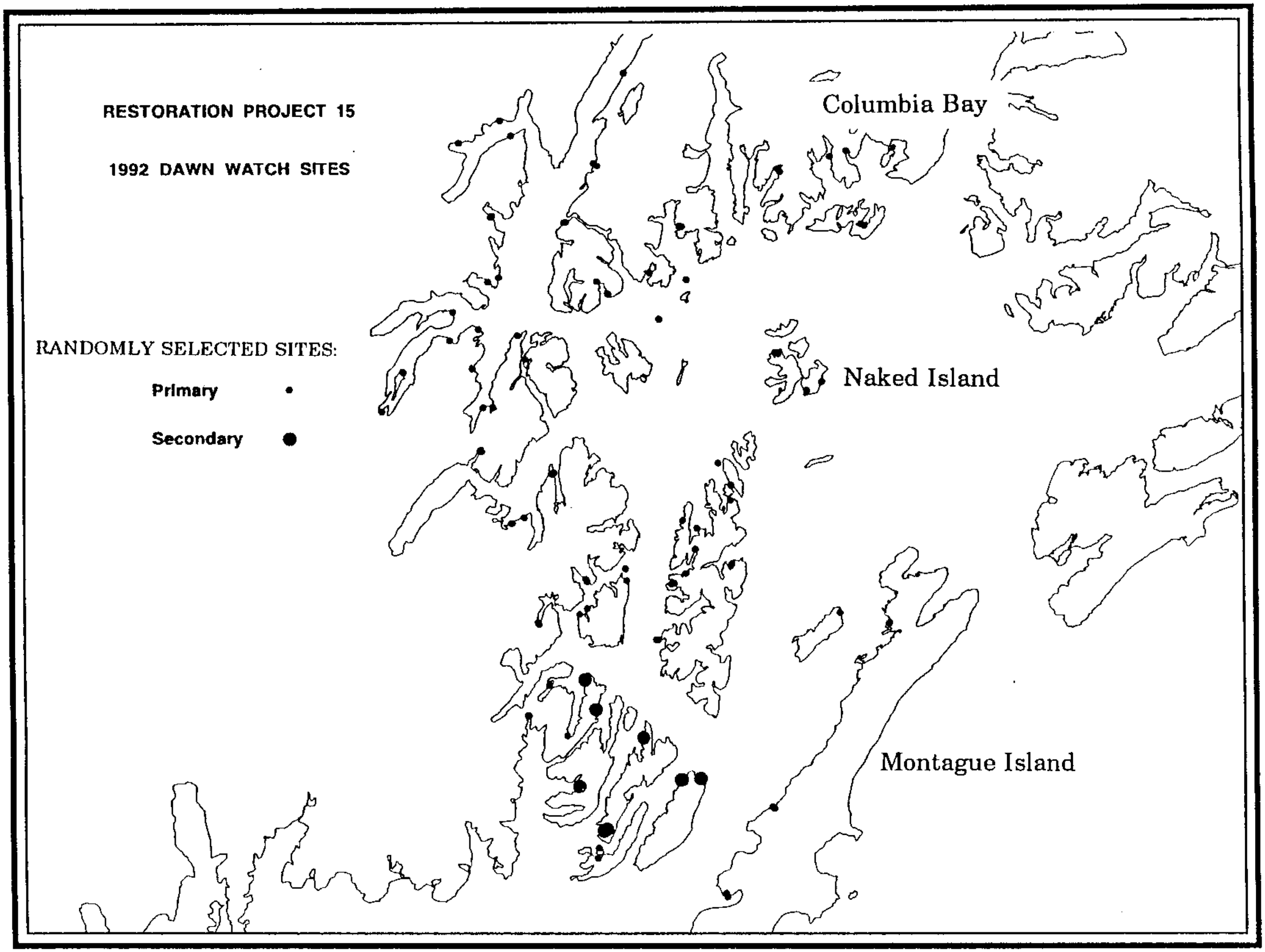

Figure 3-1. 1992 survey study area, Prince William Sound, Alaska. All sites were randomly selected. 'Secondary selections' were drawn from a separate pool of southwest quadrant transects in order to include this potentially important area which was largely missed in the first selection.

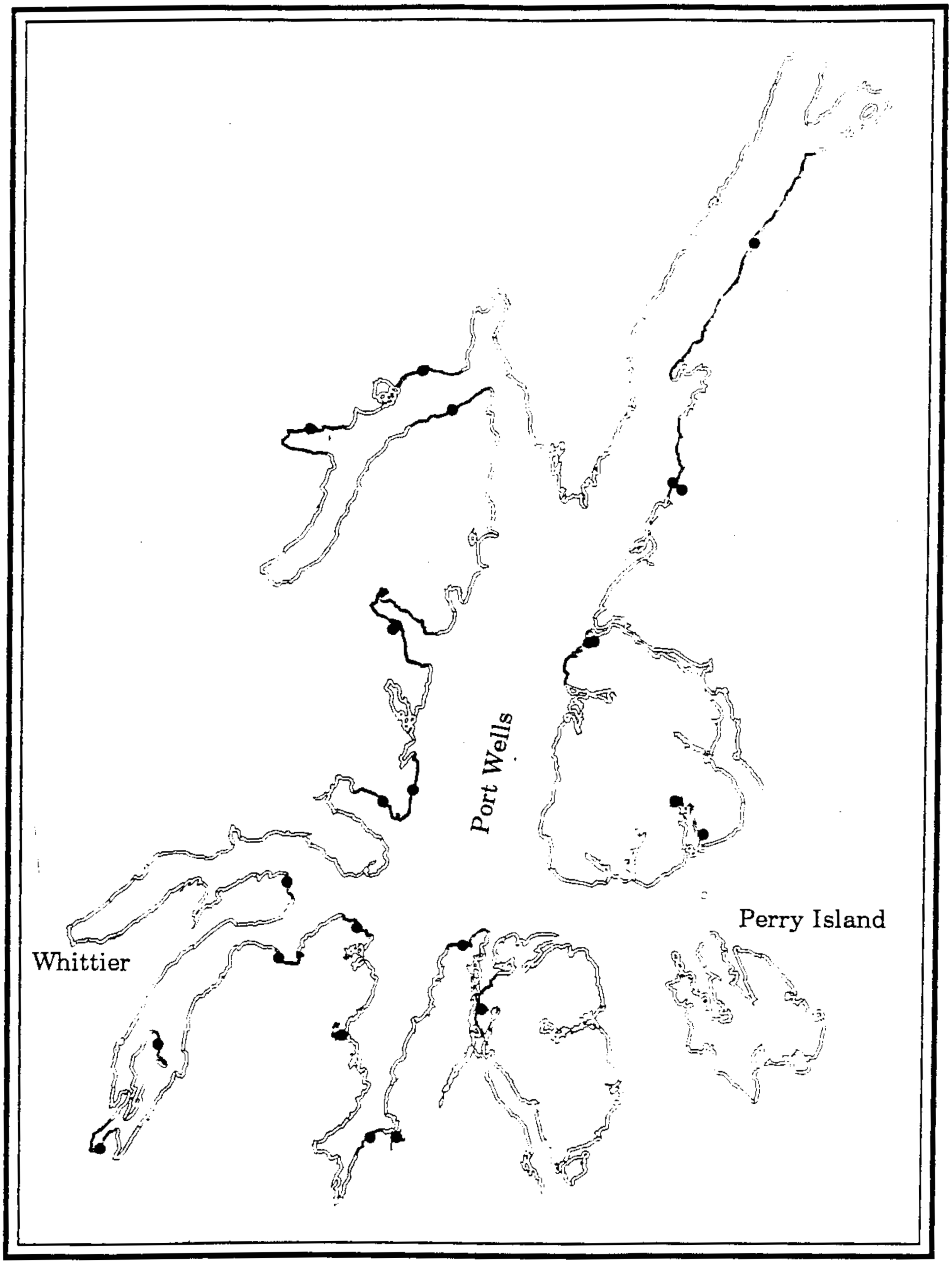

Figure 3-2a. Northwest quadrant. Random dawn watch survey sites and associated at-sea (shoreline) transects. Prince William Sound, Alaska, 1992.

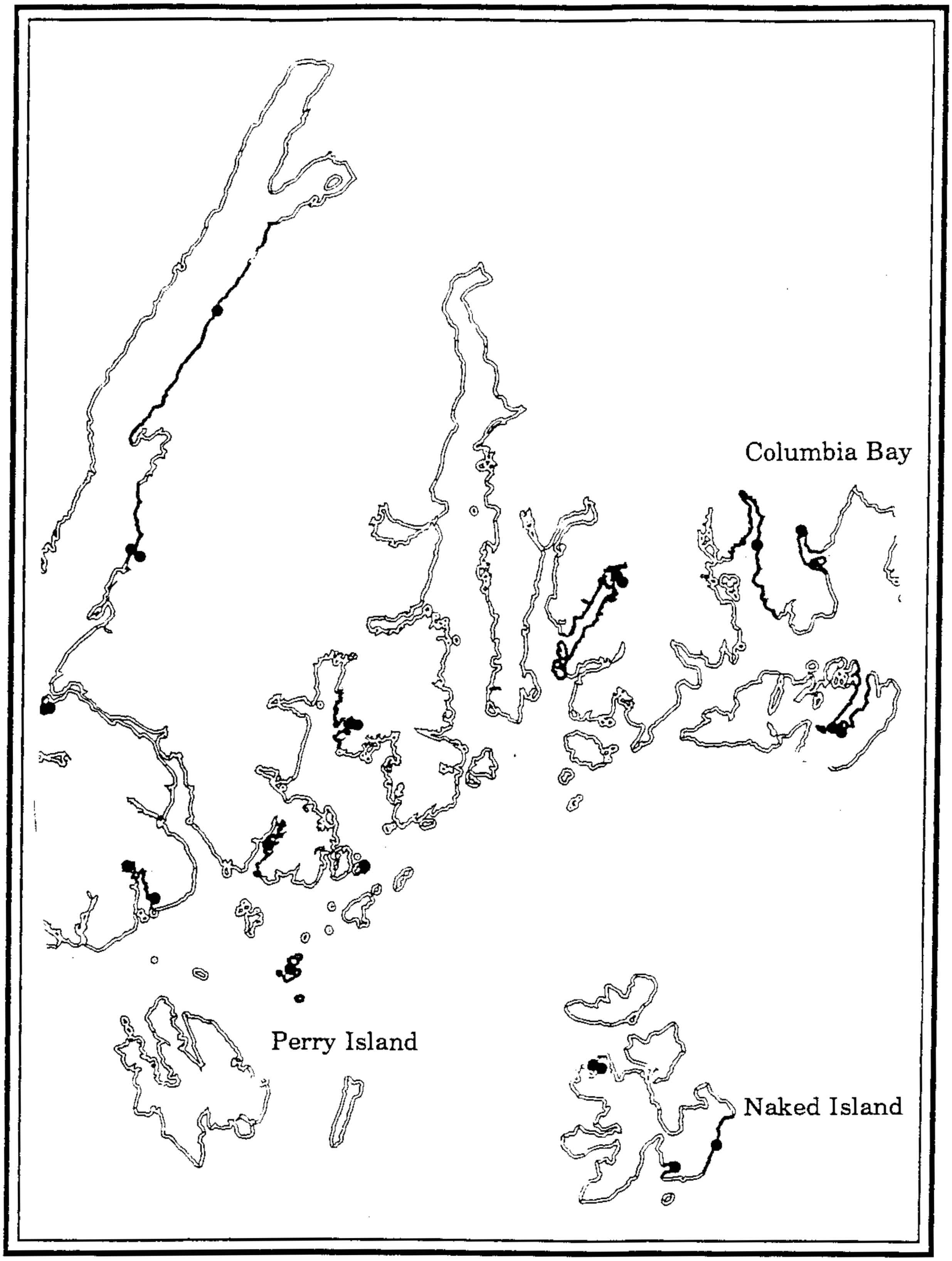

Figure 3-2b. Northeast quadrant. Random dawn watch survey sites and associated shoreline transects. Prince William Sound, Alaska, 1992.

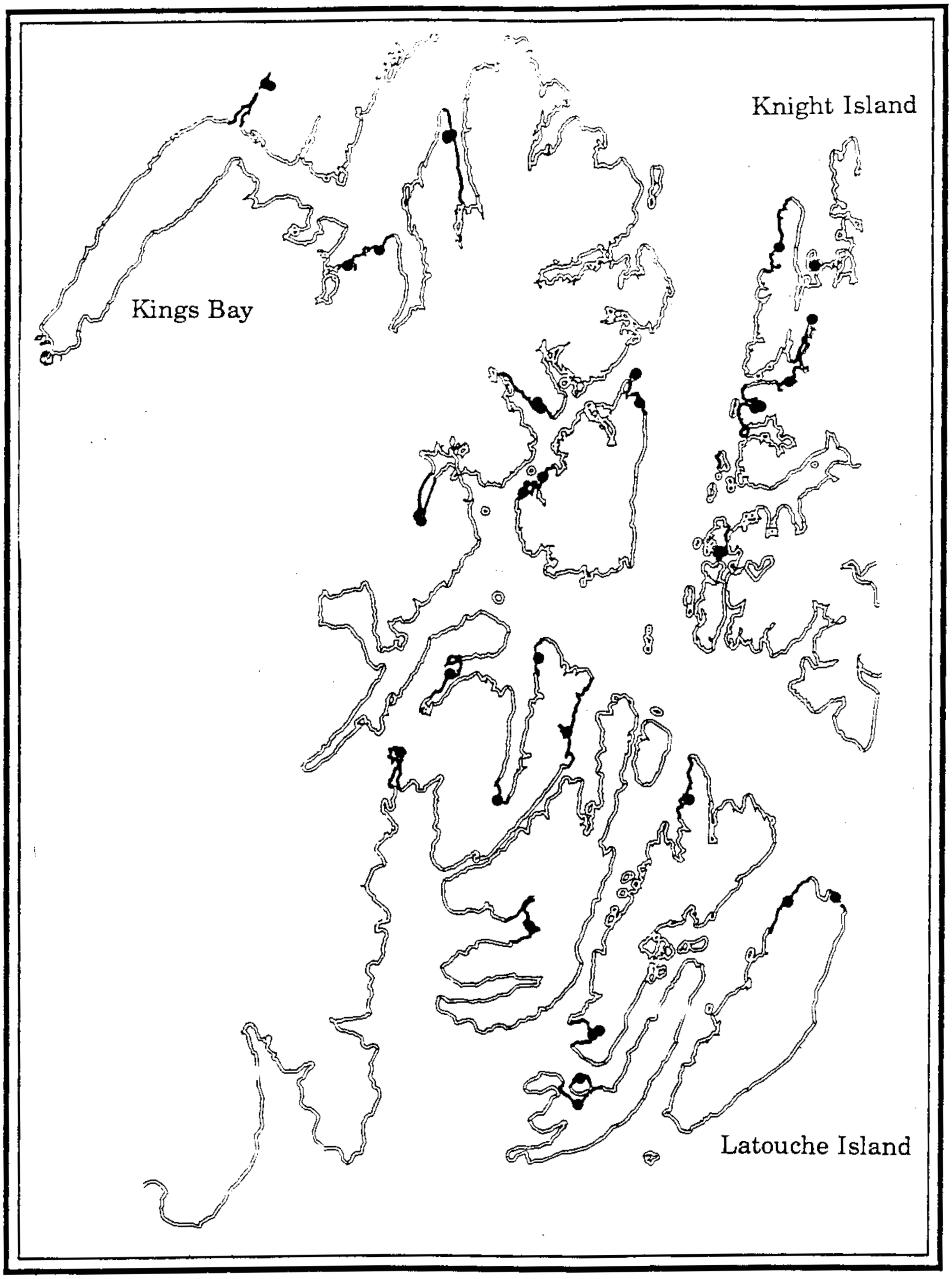

Figure 3-2c. Southwest quadrant. Random dawn watch survey sites and associated shoreline transects. Prince William Sound, Alaska, 1992.

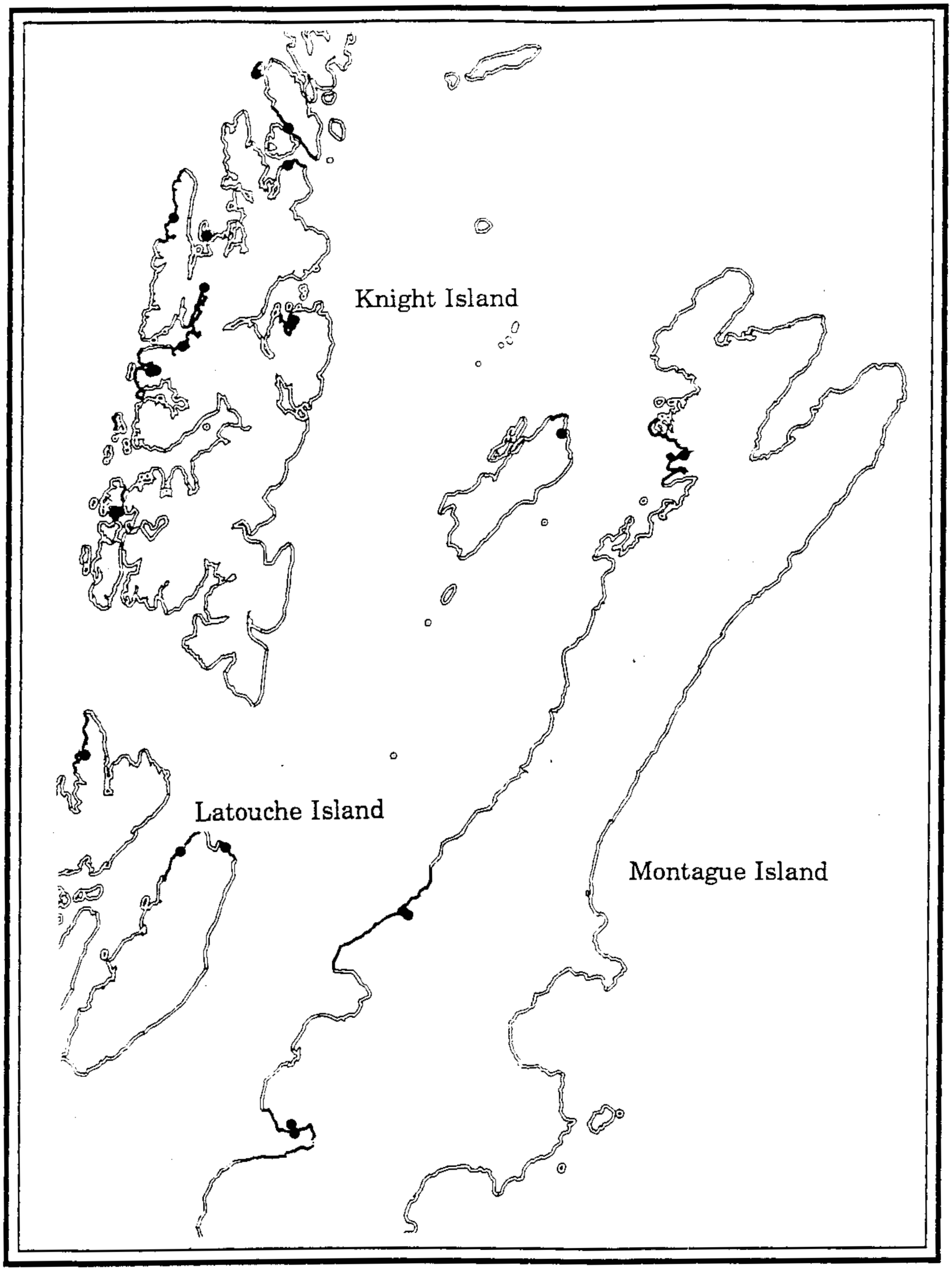

Figure 3-2d. Southeast quadrant. Random dawn watch survey sites and associated shoreline transects. Prince William Sound, Alaska, 1992.

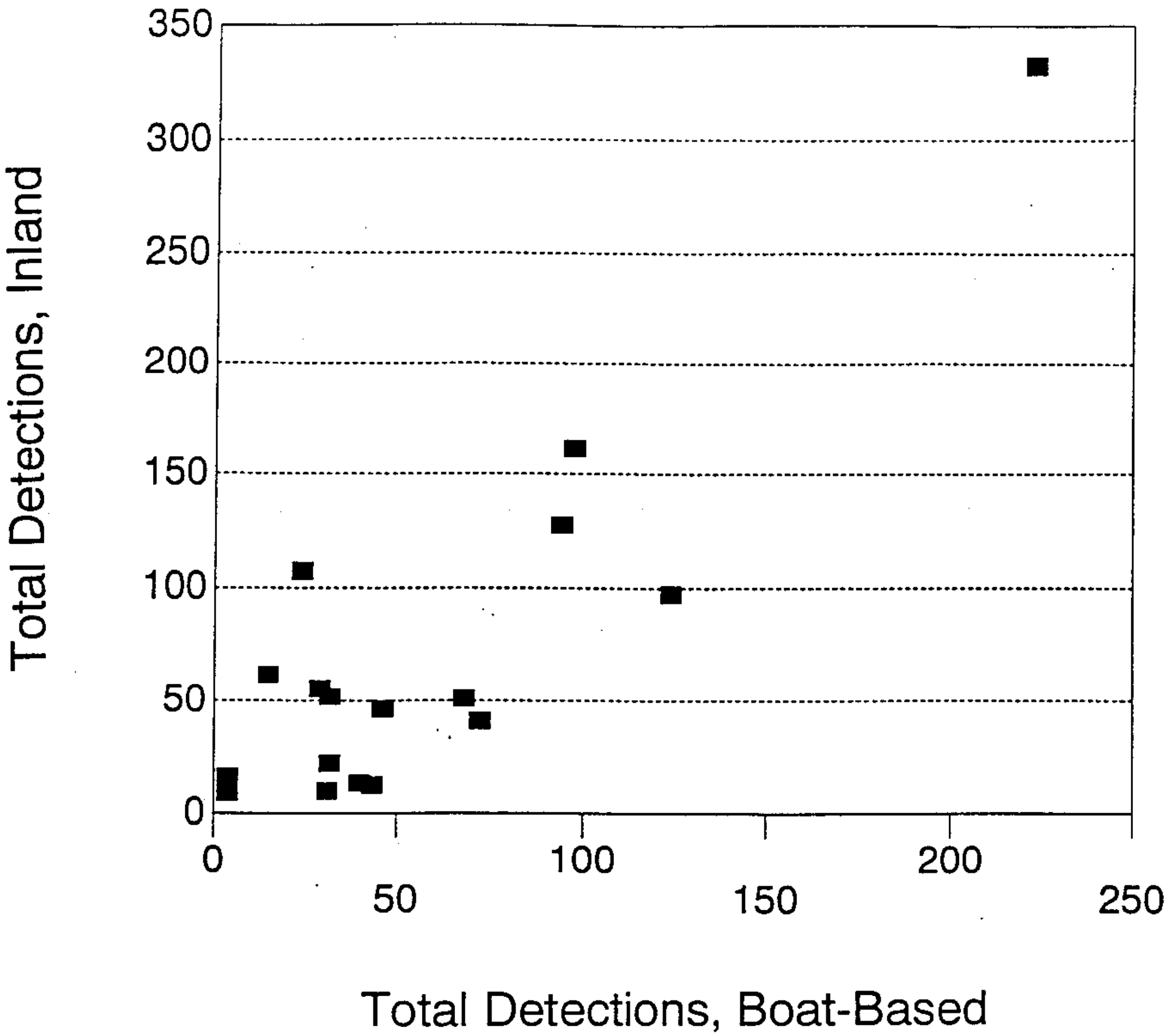

Figure 3-3. Number of total murrelet (dawn watch) detections for paired boat-based and inland survey sites, Prince William Sound, Alaska, 1992. The correlation for all sites (n=17) is significant (Kendall's correlation, tau-b=0.370, P=0.039).

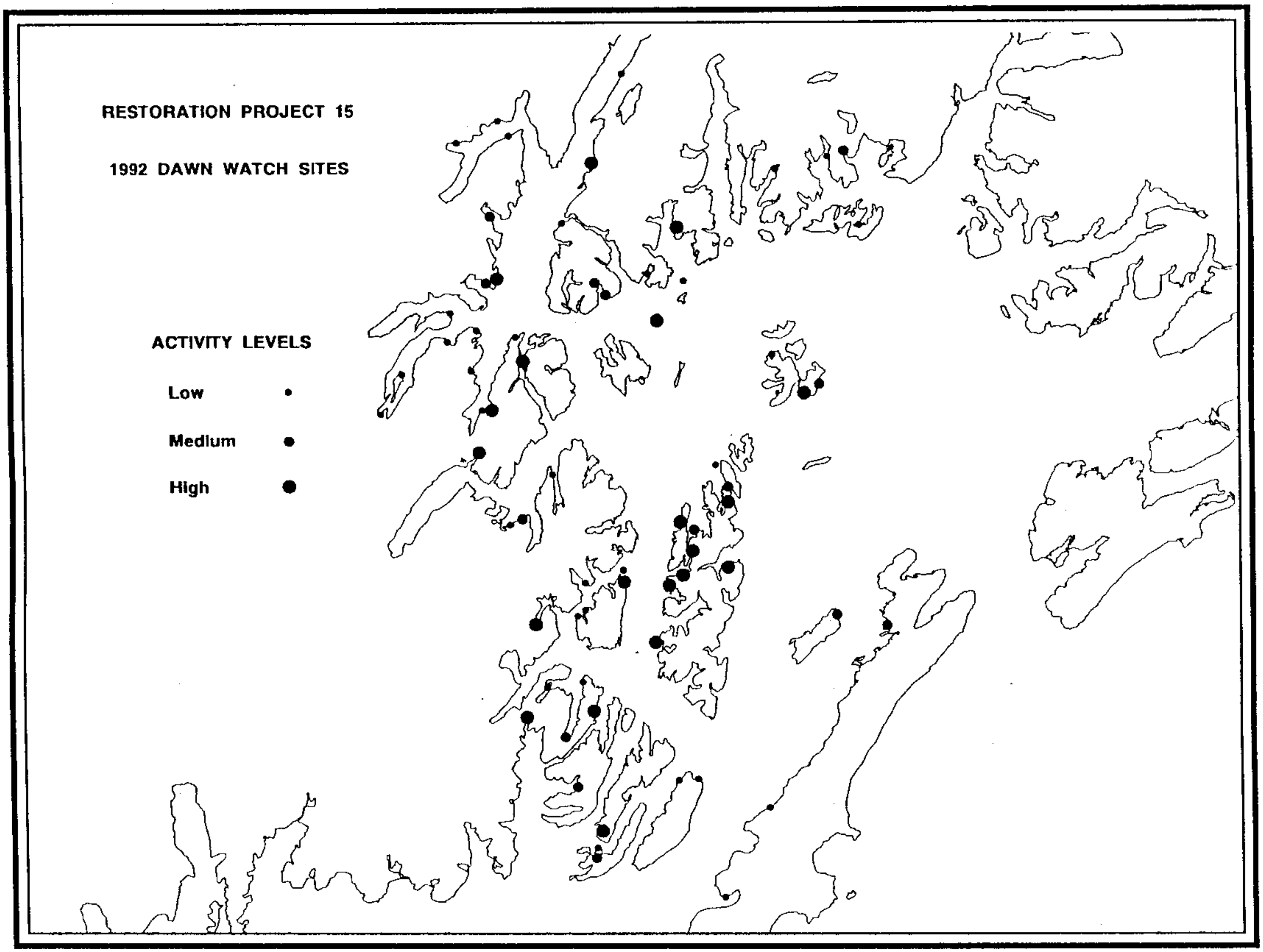

Figure 3-4. Activity levels of marbled murrelets during dawn watches in Prince William Sound, Alaska, in 1992. Data represent the total number of detections for the 67 boat-based sites.

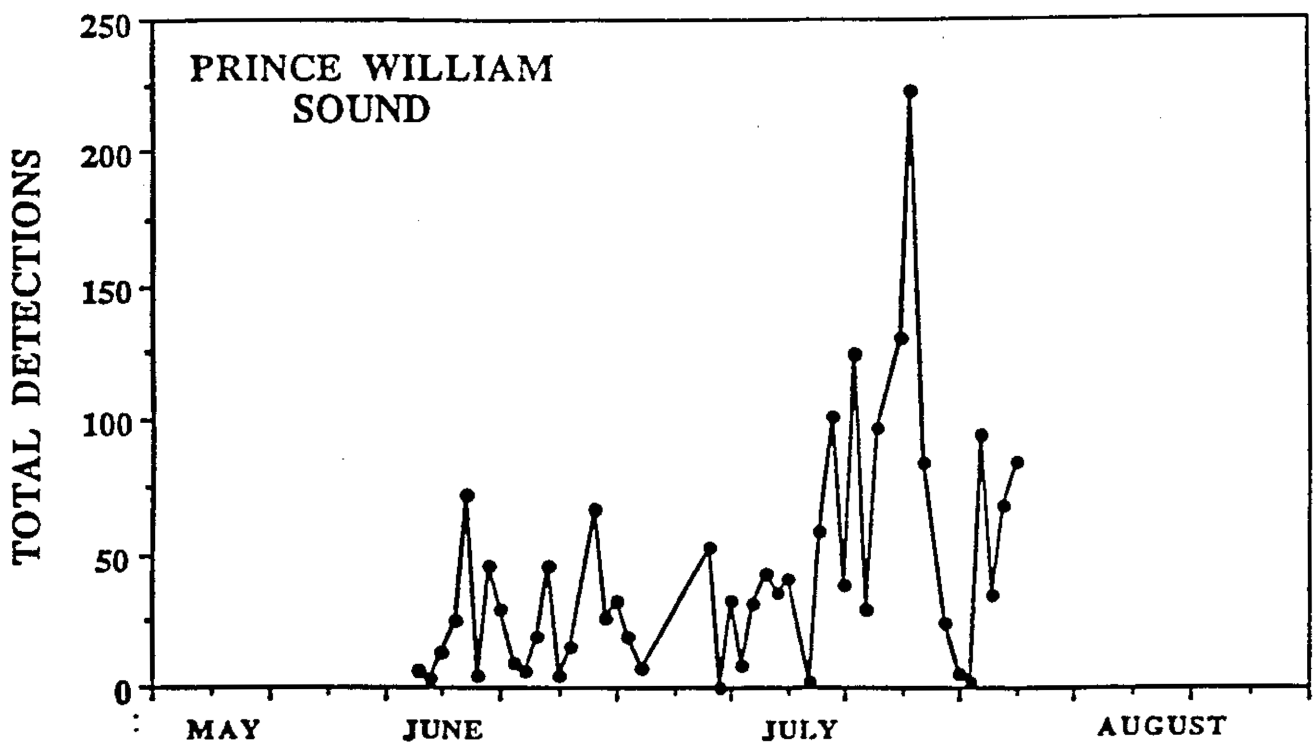

Figure 3-5. Seasonal variation of total marbled murrelet detections throughout western Prince William Sound during the 1992 season, based on the 67 randomly selected (boat-based) sites.

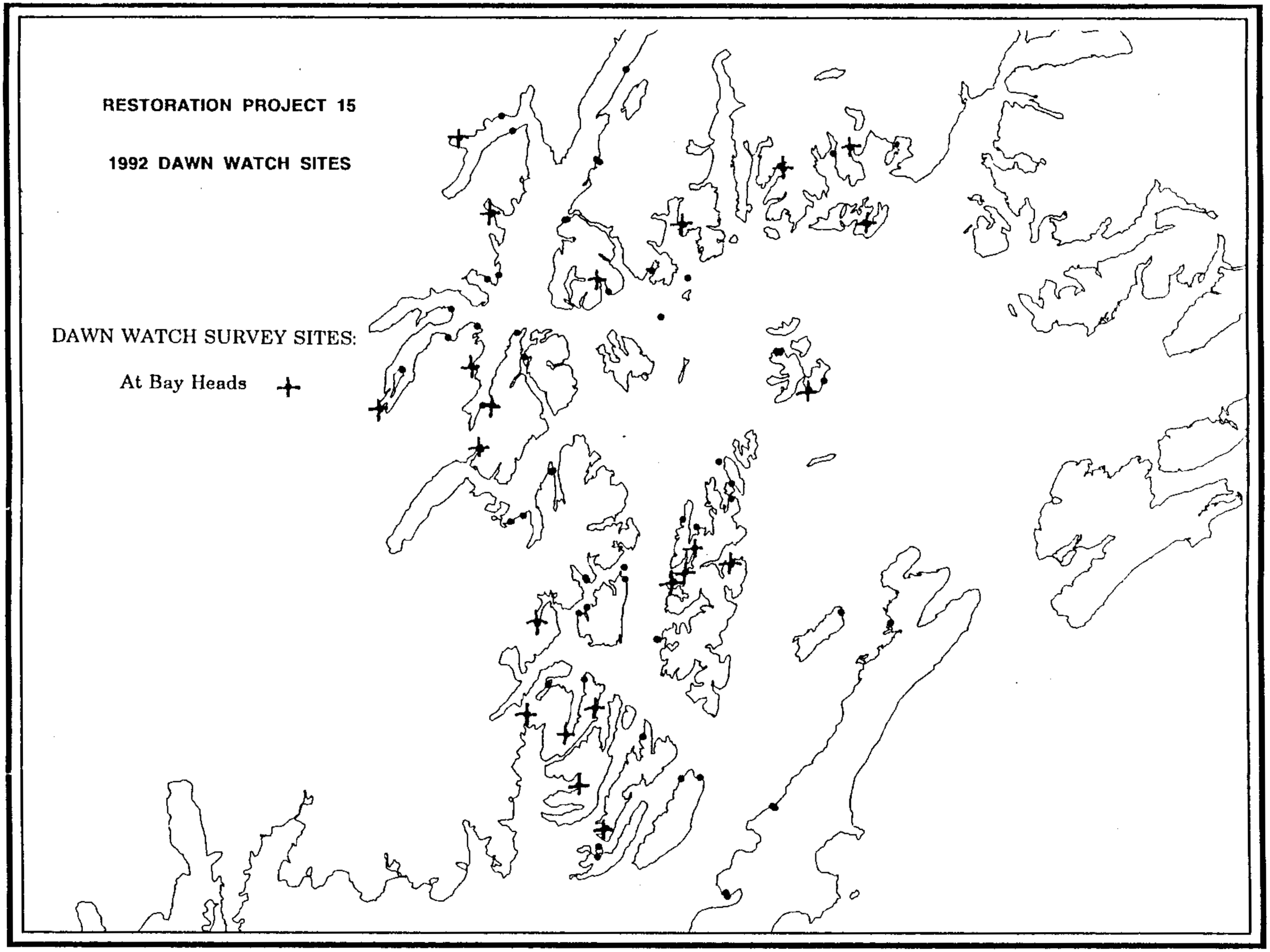

Figure 3-6. Study area showing randomly selected sites located at the heads of bays. Prince William Sound, Alaska, 1992.

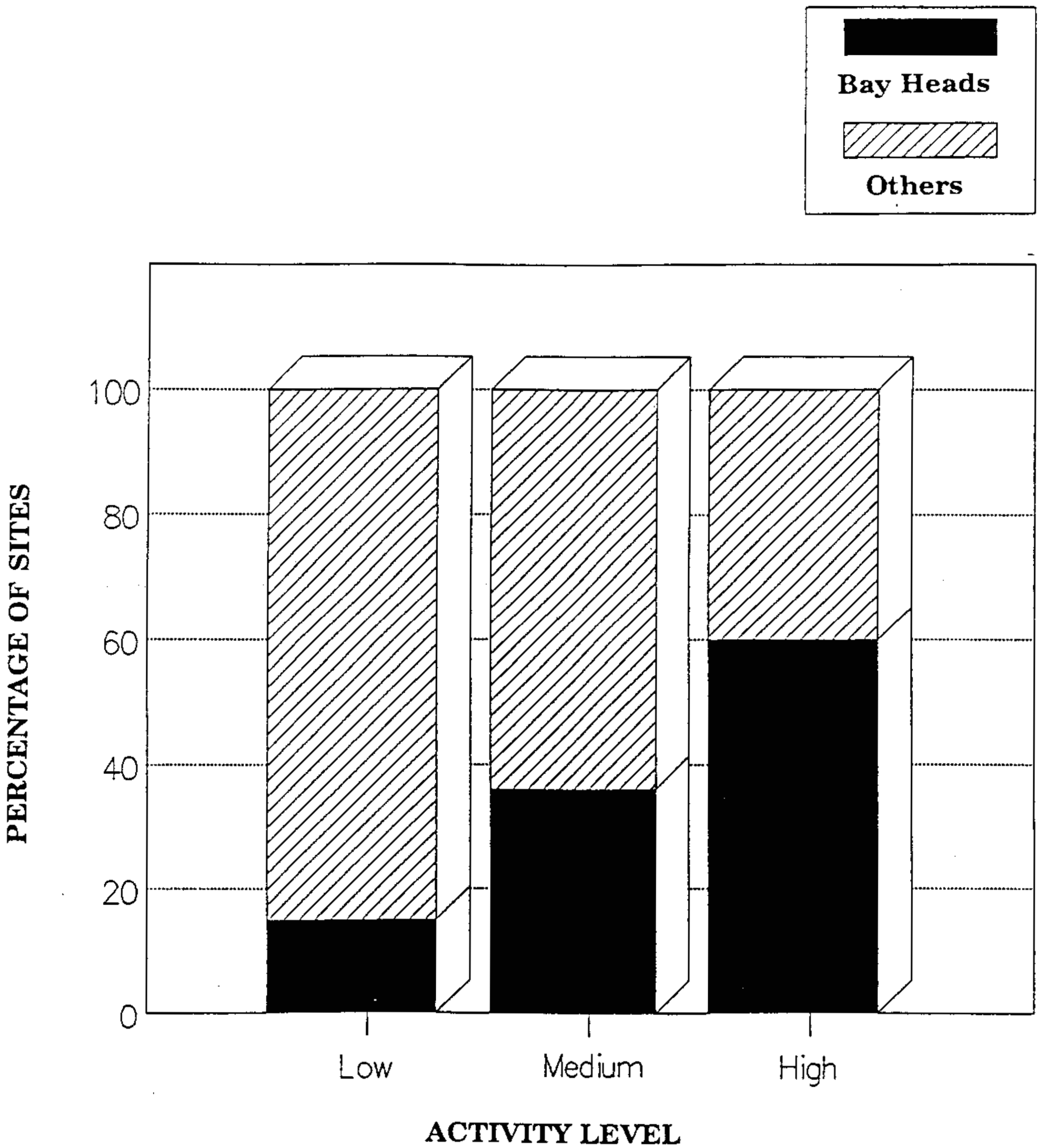

Figure 3-7. Comparison of sites located at the heads of bays and others, in Prince William Sound, Alaska, in 1992. Activity levels of murrelets and the percentage of sites at the head of a bay, for each level.

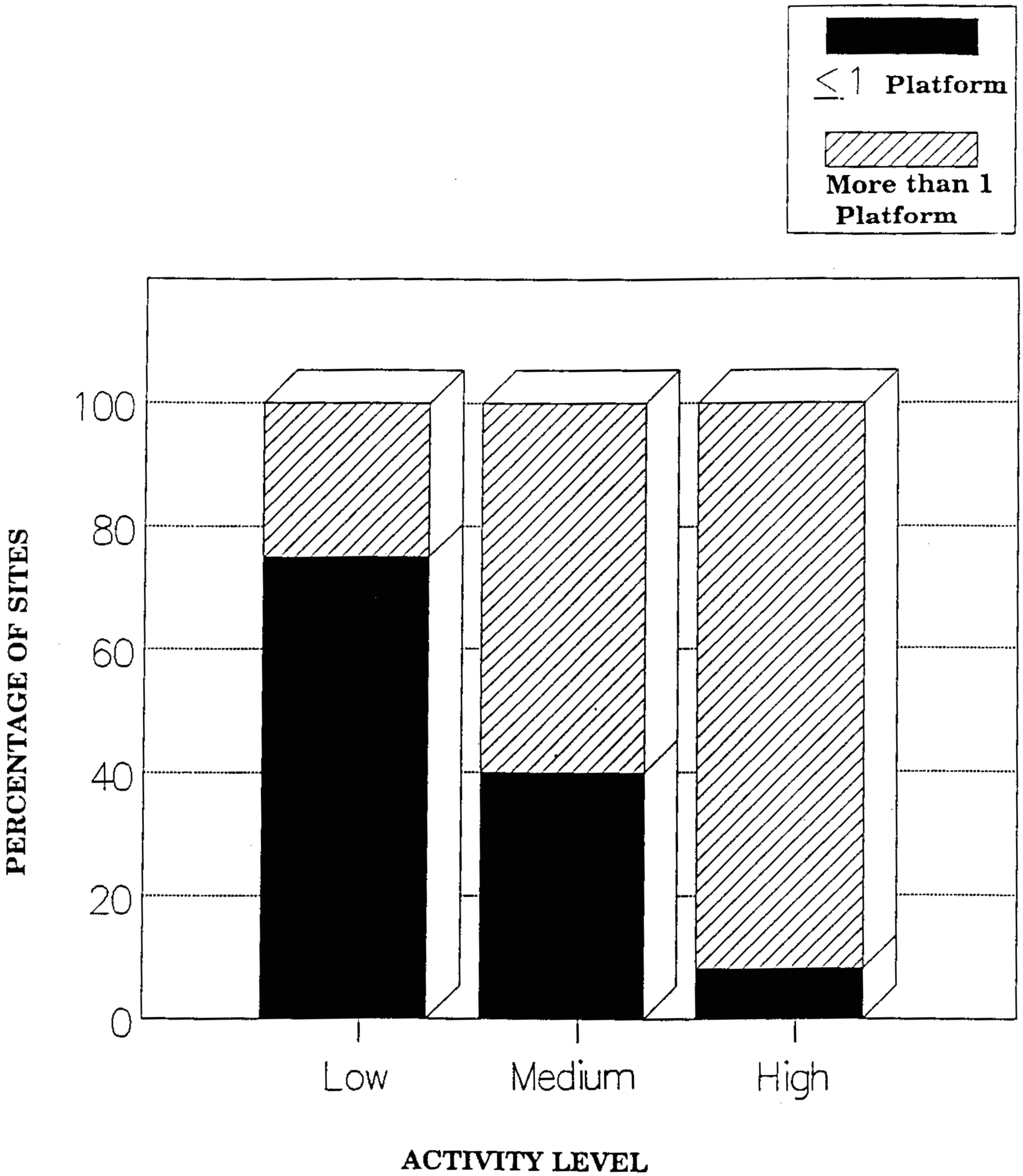

Figure 3-8. Number of dawn watch sites with means of 1 or fewer platforms per tree and those with means of more than 1 platform per tree, compared to marbled murrelet activity levels at those sites. Data from Prince William Sound, AK, in 1992. Activity level is the number of detections adjusted for seasonal effects (see text). Differences are significant [Fishers exact test (two-tail) x^2=9.26, P=0.0095].

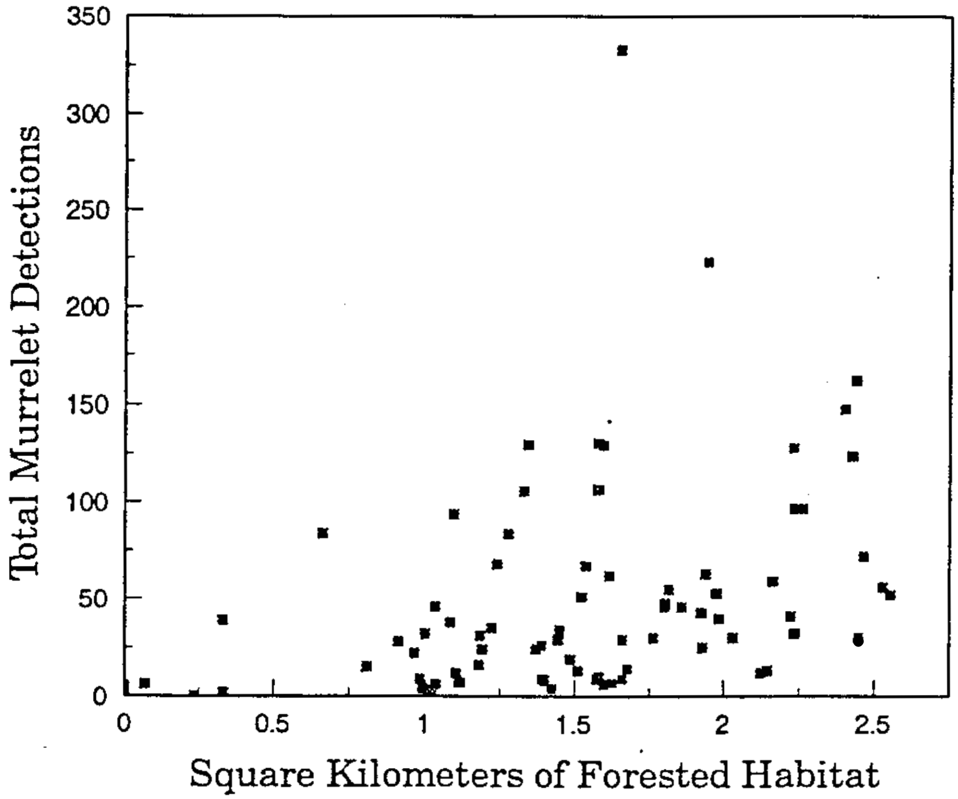

Figure 3-9. Number of marbled murrelet detections during each survey versus the total area of forested habitat within a 1 km buffer at each site. Kendall's Correlation coefficient, tau=0.344, P=0.0001.

Table 3-1. Number of surveys and types of sites surveyed in Prince William Sound, Alaska, in 1992

Dawn Watches for Murrelet Inland Activity	
Boat-based watches, from 58' vessel	43
from inflatable	24
total	67
Inland Sites	18
(Inland sites paired with boat-based)	17
Total number of dawn watch sites	85
Vegetation Plots	
In-stand vegetation plots, USFWS	17
USFS	13
Total number of vegetation plots	30
Shoreline survey transects	68

Table 3-2. Mean numbers of marbled murrelet detections at inland and boat-based dawn watch sites in Prince William Sound, Alaska, 1992. Means and Cochran T-test statistics for 4 categories of observations. Boat-based surveys are those from the 58' vessel.

			Location of Murrelet Detections		
Dawn Watch Site Location	N	Total Detections	On Land	Flying Over Ocean	On Ocean
Inland Sites	17	68.8	68.2	0.5	0.6
Boat-based Sites	44	42.9	36.7	6.2	3.2
T		-1.30	-1.61	3.54	2.48
df		21.4	20.3	49.5	59.2
P		0.209	0.125	0.001	0.019

Table 3-3. Number of sites with corresponding levels of activity for heads of bays and exposed coast in Prince William Sound, Alaska, in 1992. Expected chi-square values are significantly different from observed values (x^2= 11.42, df=2, P= .003).

Dawn Watch Site Location	Number of Sites with Murrelet Activity Level: High	Medium	Low
Head of Bay	12	5	5
Exposed Coast	8	9	28

Table 3-4. Habitat characteristics of dawn watch sites where murrelets exhibited behaviors indicative of nesting (i.e., occupied behaviors) and at sites where murrelets did not exhibit these behaviors. Prince William Sound, Alaska, in 1992. Means (SE in parenthesis) and results of Cochran's t-tests are shown.

	Mean DBH[1]	% Forested	% Canopy Closure	Canopy Height (meters)	Elevation (meters)	Slope (degrees)	Aspect (degrees)	Mean No. Platforms
Occupied Sites	52 (4.0)	83 (11.3)	70 (9.1)	24 (1.6)	137 (76.2)	24 (4.0)	213 (34.7)	1.45 (0.2)
Unknown Status	54 (2.9)	96 (2.4)	72 (3.5)	22 (1.3)	120 (25.6)	24 (1.7)	236 (21.7)	2.2 (0.6)
T	0.037	1.186	0.281	-0.904	-0.203	0.005	0.558	1.29
P	0.766	0.274	0.787	0.392	0.846	0.996	0.591	0.214
df	15.2	7.6	7.8	14.8	6.2	9.6	12.9	25.2
n occupied sites	8	8	7	7	6	8	8	7
n unknown status	22	22	22	19	18	22	22	22

1 of overstory trees

Table 3-5. Correlations between marbled murrelet detections and habitat features at 30 sites in Prince William Sound, Alaska, in 1992.

		DBH	% Forested	% Canopy Closure	Canopy Height	Elevation	Slope	Aspect	Mean No. Platforms
Total No. Murrelet	tau	.096	.106	.057	.253	.085	.067	.106	.164
Detections	P	.417	.435	.645	.041	.484	.586	.377	.175

Table 3-6. Correlations between tree dbh and other habitat features at 35 sites in Prince William Sound, Alaska, in 1992.

		% Forested	% Canopy Closure	Canopy Height	Elevation	Slope	Aspect	Mean No. Platforms
Mean Tree DBH at Site	tau	.498	.451	.447	.164	.57	.315	.570
	P	.0002	.0003	.0003	.175	.202	.009	.0001

Test statistics is the Kendall's coefficient of rank correlation.

Table 3-7. Appendix. Summary of dawn watch detection and weather data for each site, by date, for surveys conducted in Prince William Sound, Alaska, in 1992. Job code refers to location of the dawn watch station: 1=from boat, 2=from shoreline, 3=inland (see methods). Activity levels, adjusted for time of year (two periods), are: high (H), medium (M) and low (L). Dawn watch start and stop times are in Alaska Daylight Time. Weather codes are as follows: 0=<50% clouds, 1=>50% clouds, 2=patchy fog, 3=solid fog, 4=light rain, 5=medium to heavy rain. Cloud ceiling refers to whether the clouds were above the ridge tops (A), or below (B, C=clear). Wind speed is in mph.

D.W. NUMBER	DATE	OBSERVER	JOB CODE	NO.OCCUPIED BEHAVIORS	NUMBER DETECTN	ACTIVITY LEVEL	AK TIME Start	AK TIME Stop	WEATHER CODE	PERCEN CLOUDS	CLOUD CEILING	WIND SPEED	AIR TEMP, C
1	12-Jun-92	ANDERSON	2	0	7	L	238	451	0	0	C	0	
2	12-Jun-92	HUNTWORK	1	1	6	L	239	451	0	0	C	0	3.3
3	13-Jun-92	ANDERSON	1	0	3	L	236	453	0	0	C	1	5.5
4	13-Jun-92	HUNTWORK	2	0	0	L	247	450	0	0	C	1	5.5
5	14-Jun-92	ANDERSON	2	4	63	H	240	456	0	25	C	1	5
6	14-Jun-92	MARKS	1	1	13	L	235	450	0	20	C	0	8.3
7	15-Jun-92	ANDERSON	2	0	12	L	245	443	4	100	A	0	8.5
8	15-Jun-92	HUNTWORK	1	0	25	M	237	450	1	100	B	0	8.5
9	16-Jun-92	KULETZ	1	0	72	H	234	505	5	100	B	1	6.1
10	16-Jun-92	MARKS	3	0	41	H	230	450	4	100	B	0	
11	17-Jun-92	ANDERSON	3	0	9	L	236	449	5	100	C	1	7.2
12	17-Jun-92	HUNTWORK	1	0	4	L	236	445	5	100	F	1	6.3
13	18-Jun-92	ANDERSON	1	1	46	H	236	526	4	100	A	1	6.1
14	18-Jun-92	KULETZ	2	0	9	L	240	450	5	100	A	0	
15	19-Jun-92	MARKS	1	0	29	M	236	455	1	95	A	0	
16	19-Jun-92	SHARED	2	0	30	M	245	449	1	95	A	0	9.5
17	20-Jun-92	HUNTWORK	1	0	9	L	234	449	0	0	C	0	4.4
18	20-Jun-92	SHARED	2	0	30	M	234	454	0	5	A	1	2
19	21-Jun-92	ANDERSON	1	0	6	L	237	449	4	100	B	1	10.5
20	21-Jun-92	SHARED	2	0	12	L	239	447	4	100	A	0	12
21	22-Jun-92	ANDERSON	2	0	2	L	237	449	1	60	A	0	8
22	22-Jun-92	MARKS	1	0	19	M	230	450	1	80	B	1	
23	23-Jun-92	HUNTWORK	1	0	46	H	236	449	0	20	A	1	6.5
24	23-Jun-92	SHARED	3	1	46	H	233	450	0	40	A	1	6.7
25	24-Jun-92	ANDERSON	1	0	4	L	236	501	4	100	A	1	10.6

D.W. NUMBER	DATE	OBSERVER	JOB CODE	NO.OCCUPIED BEHAVIORS	NUMBER DETECTN	ACTIVITY LEVEL	AK TIME Start	Stop	WEATHER CODE	PERCEN CLOUDS	CLOUD CEILING	WIND SPEED	AIR TEMP, C
26	24-Jun-92	SHARED	3	0	16	M	230	500	4	100	A	0	9.5
27	25-Jun-92	MARKS	1	0	15	L	230						5
28	25-Jun-92	SHARED	3	0	62	H	229	502	1	85	A	0	
29	26-Jun-92	SHARED	3	0	22	M	230	500	4	100	A	1	10.6
30	27-Jun-92	ANDERSON	1	0	67	H	233	500	1	100	F	1	8.9
31	27-Jun-92	SHARED	2	0	14	L	237	530	4	100	B	1	
32	28-Jun-92	MARKS	1	0	26	M	230	450	0	35			
33	28-Jun-92	SHARED	2	0	48	H	237	456	0	25		1	
34	29-Jun-92	ANDERSON	1	0	32	H	240	455	1	95	B	1	13.3
35	29-Jun-92	MARKS	3	0	22	L	245	450	1	100	A	1	
36	30-Jun-92	CODY	2	2	30	M	239	509	0	80	A	2	
37	30-Jun-92	HUNTWORK	1	0	19	M	244	457	0	45	A	1	10.5
38	01-Jul-92	MARKS	1	0	7	L	240	445	0	10		1	
39	01-Jul-92	SHARED	2	0	6	L	246	453	0	10	A	1	11.7
40	07-Jul-92	ANDERSON	2	0	24	M	305	500	4	100	A	2	10.5
41	07-Jul-92	HUNTWORK	1	0	53	H	252	511	4	100	A	4	10.5
42	08-Jul-92	ANDERSON	1	0	0	L	255	505	1	100	A	5	11.5
43	09-Jul-92	HUNTWORK	3	0	52	H	253	520	4	100	A	0	12
44	09-Jul-92	MARKS	1	0	32	H	245	515	4	100	A	0	12
45	10-Jul-92	HUNTWORK	1	0	8	L	254	530	2	100	B	2	12
46	10-Jul-92	MARKS	2	0	39	H	250	535	4	100	B	3	13
47	11-Jul-92	ANDERSON	1	1	31	L	305	526	4	100	B	8	12
48	11-Jul-92	MARKS	3	0	10	L	250	515	4	100	B	4	11.5
49	12-Jul-92	ESLINGER	1	0	43	L	258	515	4	100	A	0	10
50	12-Jul-92	MARKS	3	0	12	L	305	510	1	95	B	0	10
51	13-Jul-92	ESSLINGER	2	0	56	M	308	515	1	100	A	0	8
52	13-Jul-92	MANLEY	1	1	35	L	235	530	1	95	A	1	11
53	14-Jul-92	MANLEY	3	0	13	L	300	540	5	100	T	2	9
54	14-Jul-92	MARKS	1	0	40	L	300	545	4	100	B		10
55	16-Jul-92	ANDERSON	2	0	106	H	301	551	1	100	B	0	12

D.W.			JOB	NO.OCCUPIED	NUMBER	ACTIVITY	AK TIME		WEATHER	PERCEN	CLOUD	WIND	AIR
NUMBER	DATE	OBSERVER	CODE	BEHAVIORS	DETECTN	LEVEL	Start	Stop	CODE	CLOUDS	CEILING	SPEED	TEMP, C
56	16-Jul-92	MARKS	1	0	2	L	300	520	1	100	A	3	12
57	17-Jul-92	HUNTWORK	1	0	59	M	305	526	1	95	A	0	11.5
58	18-Jul-92	ANDERSON	1	4	101	H	308	540	1	100	B	3	11.5
59	18-Jul-92	MARKS	2	2	6	L	310	525	1	100	A	0	11.5
60	19-Jul-92	HUNTWORK	2	0	28	L	315	536	3	100	B	2	12
61	19-Jul-92	MARKS	1	0	38	L	315	645	4	100	B	3	12
62	20-Jul-92	ANDERSON	3	0	97	M	310	530	0	45	A	3	10.5
63	20-Jul-92	HUNTWORK	1	0	124	H	316	530	1	60	A	3	10
64	21-Jul-92	ANDERSON	1	0	29	L	315	530	1	100	A	0	11
65	21-Jul-92	MARKS	3	3	55	L	315	550	1	90	A	2	11
66	22-Jul-92	HUNTWORK	3	8	162	H	317	626	1	100	B	0	11
67	22-Jul-92	MARKS	1	0	97	H	315	615	4	100	A	2	11
68	24-Jul-92	HUNTWORK	1	2	131	H	325	557	4	100	A	0	11
69	24-Jul-92	MARKS	2	0	148	H	330	610	1	100	A	3	
70	25-Jul-92	ANDERSON	1	0	223	H	324	705	4	100	B	0	13
71	25-Jul-92	HUNTWORK	3	1	333	H	320	800	1	100	B	0	
72	26-Jul-92	HUNTWORK	1	0	84	M	329	600	1	100	B	0	12
73	26-Jul-92	MARKS	2	0	130	H	330	545	1	100	A	3	
74	28-Jul-92	ANDERSON	1	0	24	L	335	547	5	100	B	8	10.5
75	28-Jul-92	HUNTWORK	3	3	107	M	340	704	4	100	B	2	
76	29-Jul-92	ANDERSON	1	0	5	L	335	555	4	100	B	2	6
77	30-Jul-92	ANDERSON	2	0	9	L	337	551	1	100	B	0	8
78	30-Jul-92	HUNTWORK	1	0	2	L	332	551	1	90	A	0	7
79	31-Jul-92	ANDERSON	3	0	128	M	337	615	1	100	A	1	9.5
80	31-Jul-92	MARKS	1	0	94	H	340	635	1	90	A	3	9
81	01-Aug-92	HUNTWORK	1	2	34	L	345	556	1	100	A	0	8
82	02-Aug-92	HUNTWORK	1	0	68	M	352	608	1	100	B	1	10
83	02-Aug-92	MARKS	3	0	51	L	345	645	1	95	A	0	9
84	03-Aug-92	ANDERSON	1	0	84	M	348	626	4	100	B	3	
85	03-Aug-92	HUNTWORK	2	2	130	H	400	655	3	100	B		

LITERATURE CITED

Carter, H. R., and R. A. Erickson. 1992. Status and conservation of the marbled murrelet in California, 1892-1987. pages 92-108 in Status and conservation of the marbled murrelet. H. R. Carter and M. L. Morrison, eds. Proc. of the West. Found. of Vertebr. Zool., Vol. 5.

____ and M. L. Morrison, eds. 1992. Status and conservation of the marbled murrelet. Proc. of the West. Found. of Vertebr. Zool., Vol. 5.

Day, R. H., K. L. Oakley, and D. R. Barnard. 1983. Nest sites and eggs of Kittlitz's and marbled murrelets. Condor 85:265-273.

Eisenhawer, A.E., and T.E. Reimchen. 1990. Inland flight patterns of marbled murrelets, Brachyramphus marmoratus, on the Queen Charlotte Islands, British Columbia. Canadian Field-Naturalist 104(3): 439-444.

Hamer, T. E., and E. B. Cummins. 1990. Forest habitat relationships of marbled murrelets in northwestern Washington. Final rep., Wash. Dep. of Wildl., Olympia, Wash. 57pp.

____ and E. B. Cummins. 1991. Relationships between forest characteristics and use of inland sites by marbled murrelets in northwestern Washington. Final rep., Wash. Dep. of Wildl., Olympia, Wash. 47pp.

Klosiewski, S. P. and K. K. Laing. MS. Marine bird populations of Prince William Sound, Alaska, before and after the *Exxon Valdez* oil spill. NRDA Bird Study No. 2. U.S. Fish and Wildlife Service, Anchorage, Alaska.

Kuletz, K. J. 1991. Restoration feasibility study number 4 - identification of upland habitats used by wildlife affected by the EVOS: marbled murrelets. Final rep., U.S. Fish and Wildl. Serv., Anchorage, Alas. xxpp.

_____. In prep. Assessment of injury to marbled and Kittlitz's murrelets from the *Exxon Valdez* Oil Spill. NRDA Bird Study No. 6. U.S. Fish and Wildl. Serv., Anchorage, Alas.

_____, D.K. Marks, N.L. Naslund, N.G. Stevens and M.B. Cody. 1994. Information needs for habitat protection: marbled murrelet habitat identification. Restoration Project 93051 Part B. U.S. Fish and Wildlife Service, Anchorage, Alaska.

Manley, I., R. Shortt, and A. E. Burger. 1992. Marbled murrelet activity patterns in the Carmanah Valley on the southwest coast of Vancouver Island. pp 71-75 in The ecology, status, and conservation of marine and shoreline birds on the west coast of Vancouver Island. Can. Wildl. Serv. Occas. Paper 75.

Marks D.K. and N.L. Naslund. in press. Predation on a breeding adult marbled murrelet at a nest site. Wilson Bull.

Marshall, D. B. 1988. Status of the Marbled Murrelet in North America with special emphasis on populations in Washington, Oregon and California. USFWS Biol. Rep. 88(30).

Mendenhall, V. M. 1992. Distribution, breeding, records, and conservation problems of the marbled murrelet in Alaska. pages 5-16 in Status and conservation of the marbled murrelet. H. R. Carter and M. L. Morrison, eds. Proc. of the West. Found. of Vertebr. Zool., Vol. 5.

Morrison, M. L., B. G. Marcot and R. W. Mannan. 1992. Wildlife-habitat relationships, concepts and applications. Univ. of Wisconsin Press. 343 pp.

Naslund, N. L. in review. Ecological and conservation implications of attendance by marbled murrelets at old-growth forest nesting areas during the non-breeding season. Auk.

____, S. W. Singer, and S. A. Singer. 1990. A proposed ground search technique for finding tree nests of the marbled murrelet in open canopy forest. Pac. Seabird Group Bull. 17:28.

Nelson, S. K. 1989. Development of inventory techniques for surveying marbled murrelets (*Brachyramphus marmoratus*) in the central Oregon Coast Range. Final rep., Oreg. Coop. Wildl. Res. Unit, Oreg. State Univ., Corvallis, Oreg.

____. 1990. Distribution of the marbled murrelet in western Oregon. Final rep., Oreg. Dept. of Fish and Wildl., Portland, Oreg.

____ and T. Hamer. 1992. Nest-site characteristics of marbled murrelets in the Pacific Northwest. Pac. Seabird Bull. 19:52.

____, M. L. McAllister, M. A. Stern, D.H. Varoujean, and J.M. Scott. 1992. The Marbled Murrelet in Oregon, 1899-1987. pp 61-91 In Status and conservation of the marbled murrelet in North America, H. R. Carter and M. L. Morrison, eds. Proc. West. Found. of Vert. Zool. vol 5(1).

Neter, J., W. Wasserman and M.H. Kutner. 1990. Applied linear statistical models: regression, analysis of variance and experimental designs. Irwin, Boston MA.

Oakley, K. L. and K. J. Kuletz. 1979. Summer distribution and abundance of marine birds and mammals near Naked Island, Alaska. U.S. Fish and Wildlife Service, Anchorage, Alaska. 95pp.

Paton, P.W.C. and C.J. Ralph. 1990. Distribution of the Marbled murrelet at inland sites in California. Northwestern Naturalist 71:72-84.

____, C. J. Ralph, H. R. Carter, and S. K. Nelson. 1990. Surveying marbled murrelets at inland forested sites: a guide. Gen. Tech. Rep. PSW-120. Berkeley, CA: Pacific Southwest Research Station, Forest Service, U.S. Dep. of Agric. 21pp.

Piatt, J. F., C. J. Lensink, W. Butler, M. Kendziorek, and D. K. Nysewander. 1990. Immediate impact of the 'Exxon Valdez' oil spill on marine birds. Auk 107:387-397.

____ and R. G. Ford. In Press. Distribution and abundance of marbled murrelets in Alaska. Condor.

Quinlan, S. E., and J. H. Hughes. 1990. Location and description of a marbled murrelet tree nest site in Alaska. Condor 92:1068-1073.

Ralph, C. J., and S. K. Nelson. 1992. Methods of surveying marbled murrelets at inland forested sites. Pac. Seabird Group, unpubl. rep. 21pp.

Ralph, C.J., S.K. Nelson, M.M. Shaughnessy and S.L. Miller. 1993. Methods for surveying marbled murrelets in forests. Pacific Seabird Group, Technical Paper No.1.

Rodway, M. S., J. L. Savard, and H. M. Regehr. 1991. Habitat use and activity patterns of marbled murrelets at inland and at-sea sites in the Queen Charlotte Islands, British Columbia. Tech. Rep. Ser. No. 122, Canadian Wildl. Serv. 151pp.

Sealy, S. G. 1975. Aspects of the breeding biology of the marbled murrelet in British Columbia. Bird-Banding 46:141-154.

Simons, T. R. 1980. Discovery of a ground-nesting marbled murrelet. Condor 82:1-9.

Singer, S. W., N. L. Naslund, S. A. Singer, and C. J. Ralph. 1991. Discovery and observations of two tree nests of the marbled murrelet. Condor 93:330-339.

____, D. L. Suddjian, and S. A. Singer. 1992. Discovery, observations, and fledging of a marbled murrelet from a redwood tree nest. Unpubl. rep., Santa Cruz City Museum of Natural Hist., Santa Cruz, Calif. 9pp.

Stein, J. L. and G. S. Miller. 1992. Endangered and threatened wildlife and plants: Determination of threatened status for the Washington, Oregon, and California population of the marbled murrelet. Fed. Register 57:45328-45337.

U.S.D.A. Forest Service. 1992. Ecological definitions for old-growth forest types in the Alaska Region. Final Report. R10-TP-28. Alaska Region, Anchorage, Alaska. 30pp.

Varoujean, D. H., and H. R. Carter. 1989. The Pacific Seabird Group's 1989 marbled murrelet nest site sampling protocol. Unpubl. rep., MARZET, North Bend, Oreg. 15pp.

Viereck, L.A. and E.L. Little. 1978. Alaska trees and shrubs. Agricultural Handbook No. 410. U.S. D.A. Forest Service. Washington, D.C.

APPENDIX A

MURRELET INTENSIVE INVENTORY (DAWN WATCH) FORM GUIDELINES FOR ALASKA

By: Nancy L. Naslund, Kathy J. Kuletz, Dennis Marks, and Mary Cody. U.S. Fish & Wildlife Service, Migratory Bird Management, 1011 E. Tudor Rd., Anchorage, AK 99503

The following are guidelines for filling out an intensive inventory (dawn watch) form. They are based largely on the Pacific Seabird Group's (PSG) guidelines (Paton et al. [1990], Ralph and Nelson [1992]), with additions and modifications based on results from earlier work on Naked Island, Prince William Sound, by Kuletz (1991). Several behaviors and calls have also been added based on work done in Prince William Sound, Alaska, for the *Exxon Valdez* marbled murrelet restoration project (Kuletz et al. 1993) and murrelet studies in California (Naslund, unpubl. data). There are plenty of kinds of data to collect, in fact, too many for busy days. Therefore we have prioritized data to collect below. If you have questions, ask as they come up. The PSG guidelines for censusing murrelets can also be consulted in many instances.

For Prince William Sound, dawn watches **begin 120 minutes prior to and end 15 minutes after official sunrise (or end 15 minutes after the last detection, whichever is later)**. Begin dusk watches 30 minutes prior to and end 90 minutes after official sunset. Dawn (or dusk) watches at nest sites should be done approximately 30-50 m from the nest tree at an observation point that allows clear visibility of the nest.

Murrelet activity is recorded as **detections**, defined as "the sighting or hearing of a single bird or a flock of birds acting in a similar manner". If more than **5 seconds** elapses between calls, then subsequent calls are considered a new detection (unless the bird(s) are seen flying from one location to the other). Or, if a bird disappears and reappears in an unexpected location, the new sighting is considered a separate detection. If a group splits, it is counted as a single detection. If two bird(s) or groups or birds join, it is still considered as separate detections.

Directions for filling out the data form:

Observer: Observer's first and last name.

ID no.: To be given at a later date.

Page: Note current page number and total number of pages for the survey.

Field check: To be completed by supervisor.

Location data:

Site no. - Record the site number or other identification number.
Location - Note the general location of the site (e.g. south Cabin Bay Naked Island).
Aerial# - Record the number of the aerial photo that includes the site.
Grid# -Record the number on the mylar grid when placed over the aerial photo.

Date and Sunrise/sunset: Fill in date, time of sunrise or sunset, and circle sunrise or sunset, whichever is appropriate.

Time - Record beginning and end times of survey.

Weather: For each of the following categories record conditions at both the beginning and end of the survey. Should conditions change during the survey, record these as weather notes (see 'Type') with appropriate times.

> **Weather** - 0 = <50% clouds, 1 = >50% clouds, 2 = patchy fog, 3 = solid fog, 4 = mist/light rain, 5 = med/heavy rain.
> **% Cloud** - Indicate percent cloud cover from 0-100.
> **Ceiling** - Record the predominate ceiling. (Not low patchy wisps of fog if most of the fog is above the ridgeline.) C = clear, A = above ridgeline, B = below ridgeline but above trees, F = below trees.
> **Wind/G** - Estimate wind speed in knots and direction at ground level.
> **WindH** - Estimate wind speed in knots and direction at cloud level.
> **Cld Typ** - See laminated handout.
> **Sight** - Record if there is a clear line of sight from the stand being surveyed out to salt water. Y = yes, N = no.
> **Obst.** - If line of sight is completely obscured, record whether the view to salt water is obscured by topographical features (e.g. hills, mountain range, etc.) or fog/clouds. T = topographical features, F = fog or clouds.
> **Temp C** - Record temperature in degrees C (celsius).

Observer vocalization expertise: Note which calls you are able to distinguish during this survey.

Basic Detection Information:
Det. no.: To be assigned later.

Type: Record the type of detection occurring. Type is based on whether the bird(s) are seen or heard and on whether they occurred over the land or water. If the detection occurs over land or over land and the water then:

- **A**=audio only (calls & wing noises)
- **V**=visual
- **B**=both seen & heard.

If the detection occurs **only** over water, then type is

- **AW**=audio only (calls & wing noises), water only
- **VW**=visual only, water only
- **BW**=both seen and heard, water only.

Similarly, if it is unknown whether the detection occurred over land or water then type is:

- **AU**=audio only, unknown
- **VU**=visual only, unknown
- **BU**= both seen and heard, unknown.

Record **WN** for a weather note entry.

Time: Record time bird(s) were first detected.

NBirds: Record your best estimate of the number of bird(s) heard or seen. If you cannot tell how many birds are being heard or seen but you think it is 2 or more then record '2+'. Similarly, '3+', '4+'... can be used.

Bird(s) Directions & Distances:

Record directions using true (not magnetic) compass directions, rounded to the nearest 5 degrees. (Set your compass for correct adjustment.) Record distances in meters and add an 'e' if the distance is a general estimate.

1stDir: Record the direction in degrees where bird(s) were first detected from the observer.

1stDist: Record the horizontal distance from the observer to the bird(s) when first detected.

LastDir: Record the direction in degrees that the bird(s) are last **flying towards**.

LastDist: Record the horizontal distance from the observer to the bird(s) when last detected.

NearDist: Record the closest horizontal distance from the observer to the bird(s).

Bird Ht. (T/G):
Estimate the **lowest** bird height (in meters) relative to the top of the trees (=T) or relative to the ground (=G). Circle T or G, whichever you are using. If you have a detection where the height is recorded different than the rest, then enter T or G after it.

Visual: Estimate the lowest bird height (in m) for all detections that bird(s) are seen (including both seen and heard).

Aud: Estimate general bird height for birds that are heard only and that are within 100 m. **L**=low, bird(s) are below or within about 15 m above canopy; **M**=medium, bird(s) are about 15-40 m above canopy; **H**=High, bird(s) are 40+ m above canopy. Low birds sound relatively loud. High bird(s) sound very high and relatively faint.

Behavior:
Record all primary and secondary behaviors observed. In general, primary behaviors have priority during busy times unless the purpose of the surveys are to identify nesting behavior. In this case, 'occupied' behaviors also have priorities (see the Ralph and Nelson [1992] for details).

PriBeh: Record which of the following primary behavior(s) are observed:

DB = direct flight below level of top of canopy
DA = direct flight above level of top of canopy
DW = direct flight above water, never occurring over land
DG = direct flight over ground in habitat without forest
CB = circle below level of top of canopy
CA = circle above level of top of canopy
CW = circle over water, never occurring over land
CG = circle above the ground in habitat without forest
SP = 5 or more calls <50 m away and seemingly from a stationary point
SW = swimming

SecBeh: Record which of the following secondary behavior(s) are observed:

LA = lands on a branch
DE = departs from a branch
TG = 'touch & go' - momentarily lands on a branch then departs
EM = emerges from or goes into the crowns of trees

FB = 'fly-by' - flying just outside or through the crown, seeming to be associated with a specific tree or branch
FN = 'fly-by nest' - fly-by associated with a known nest branch or nest tree
SL = 'stall-out' associated with a branch or specific tree
SN = 'stall-out @ nest' - stall-out associated with a known nest branch or nest tree
TC = 'tail-chasing' - one bird flying relatively closely (within 1-2 m) behind another at a moderate to fast speed
TA = 'flying in tandem' - birds flying close to each other (within about 4 body lengths or 1 m apart), generally at low to moderate speed
WS = 'widely separated' - flying widely separated (ca. 15+ m apart)
VA = 'variable' - zig-zagging, splitting, figure 8, etc.
AD = 'aerial dive' - steep aerial dive, sometimes associated with the jet sound
SA = 'aerial stall-out' - stall-out done outside of the canopy, above the canopy or in an open area
CM = circle over muskeg or other open area

Vocalizations/Sounds:
Primary vocalizations:
K = 'keer' - keer calls
A = 'alternate' - raucous or quack type calls
T = 'two-note' - two syllable kee-err
K+ = 'keer plus' - indicates keers plus other calls are heard but the other calls are not identified (important on busy days)
Secondary vocalizations:
S = 'sharp keer' - single sharp keer, emphatic & sometimes cut short
Q = 'soft que' - plaintive call, generally long & drawn out
WC = 'whistle call' - short high whistle call **2A** = '2 alternate' - alternate call with two components
B = 'blunt 1-note' - very short abbreviated almost keer call
H = 'heimlich' - extremely short call, similar to what one might expect to hear when doing the heimlich maneuver on a murrelet
EH = 'eh-eh' - soft calls given sometimes given during incubation exchanges or when landing on branches
SA = short alternate call
SK = short keer call
OT = any other call heard not described above (include description in notes if possible)

Wings: (mechanical wing noises)

Primary Wing Noises: (These have priority over secondary wing noises if it is busy.)
J = 'jet dive' - sound like a B52 bomber diving!
WN = 'wing noise' - any unidentified murrelet wing noise, except a 'jet dive'

Secondary Wing Noises:
WS = 'wing sound' - the low-pitched, generally loud, sound of wings sometimes likened to the sound of a boomerang or helicopter
WB = 'wing beats' - the quiet sounds of wings beating (only for visual birds since they can be confused with bats or other birds) sometimes heard while birds are flying nearby or when landing in trees

SW = 'swoosh' - the swooshing or whizzing sound sometimes heard from fast flying bird(s)

Duration:

No. Voc.: Record the **number** of calls if <10 (e.g. 1-9) or **M** (=multiple) for >9 calls. Record **W** (=wings only) if bird(s) are not seen and do not call but make any of the above wing noises.

ObsSec: Length of time (in seconds) that bird(s) were detected. Enter an 'e' if observation seconds is a general estimate (vs. actual time from watch or stopwatch).

Other Behaviors, notes:

DBtwn: Record the distance between birds either as murrelet body lengths (=bl) or meters.

H/S: Record the number of birds heard over the number seen (e.g. H2/S4).

Notes(Predators, behavior, weather): Record additional observations not included in previous columns, weather notes, or significant other species (e.g. potential predators, unusual species).

Predators: Note presence of all potential predators. Include times when they occurred, either specific or general (e.g. BAEA in area 0520-0555, STJA calling since 0330).

General notes: This space is for additional notes.

Maps: Draw diagrams and maps of notable activities.

Data Collection Priorities

Data collection priorities must be set specifically for each research project, depending on its design and goals. In general, priorities go as follows:

1. occurrence of a detection
2. type & time
3. nearest distance
4. primary behavior
5. number of birds
6. 1st direction
7. bird height (for visual birds)

For studies documenting nesting activity or nesting behavior studies, secondary behaviors and call types that may be associated with nesting are also priorities (e.g. behaviors: LA, DE, TG, EM,FB, FN, SL, SN, TC, TA; calls: S, Q, WC, EH; wings: WS, WB).

For studies investigating general use of large areas should place additional emphasis on 1stDir, 1stDist, LastDir, and LastDist.

Literature Cited:

Kuletz, K. J. 1991. Restoration feasibility study number 4 - identification of upland habitats used by wildlife affected by the EVOS: marbled murrelets. Final rep., U.S. Fish and Wildl. Serv., Anchorage, Alas. xxpp.

Kuletz, K.J., N.L. Naslund and D.K. Marks. 1993. Identification of Marbled Murrelet Nesting Habitat in the *Exxon Valdez* Oil Spill Zone. Annual Progress Report. U.S. Fish and Wildlife Service, Anchorage, Alaska.

Paton, P. W. C., C. J. Ralph, H. R. Carter, and S. K. Nelson. 1990. Surveying marbled murrelets at inland forested sites: a guide. Gen. Tech. Rep. PSW-120. Berkeley, CA: Pacific Southwest Research Station, Forest Service, U.S. Dep. of Agric. 21pp.

Ralph, C. J., and S. K. Nelson. 1992. Methods of surveying marbled murrelets at inland forested sites. Pac. Seabird Group, unpubl. rep. 21pp.

APPENDIX B

MURRELET STAKE-OUT FORM GUIDELINES

By: Nancy L. Naslund, Kathy J. Kuletz, Dennis K. Marks, and Mary Cody. U.S. Fish & Wildlife Service, Migratory Bird Management, 1011 E. Tudor Rd., Anchorage, AK 99503

The following are guidelines for conducting and filling out data forms for a murrelet nest 'stake-out'. These stake-out guidelines were developed from a ground search technique for locating murrelet tree nests in California (Naslund et al. 1990, Singer et al. 1991). Doing a stake-out varies from a dawn watch in that only those **detections that are close** are recorded and **attention is focused on the tree(s) being observed** (with the exception of first and last detections, see below). Much of the data is the same as if doing a dawn watch except that some of the data need not be collected. Also, secondary behaviors (see below) are the priority.

When possible, important observations (e.g. close birds flying through the canopy especially if they appear to be departing or intending to land, birds on branches, incubation exchanges, etc.) should be *recorded to the second* in order to coordinate these observations between observers (unless you are observing alone). Additionally, duration of bird(s) on branches should be recorded (in notes). An easy way to record seconds without spending a lot of time looking at your watch is to leave the microcassette recorder running, note occurrence of the detection or the beginning and end of the behavior, then look at your watch at the next convenient time and record the time. The actual time of the detection can later be determined using a stopwatch. If you have questions, ask as they come up.

The basic components of a stake-out will be discussed in greater detail in the field. However, the important thing to remember is that *your attention must stay focused on the tree(s) being observed and not distracted by more distant activity*. In addition, *when observing only one tree do not look away as incubation exchanges can be brief and difficult to see.* Good luck!!

Filling out the data form:

Observer: Name of person conducting survey.

Other observers: Note other observers who are staking-out the same tree or same general area.

Effort Type: Indicate which of the following type of stake-out effort was carried out: **general** = general survey of a stand; **restricted** = observing restricted area in a stand; **focused** = observing specific trees; **one tree** = focused observations one tree.

Date and **Sunrise/sunset**: Fill in date, time of sunrise or sunset, and circle sunrise or sunset, whichever is appropriate.

ID no.: To be given at a later date.

Page: Note current page number and total number of pages for the survey.

Field check: To be completed by supervisor.

Location data:

Site no. - Record the site number or other identification number.
Location - Note the general location of the site (e.g. south Cabin Bay Naked Island). Also indicate specific site being observed (use bottom of page if necessary).
Aerial#. - Record the number of the aerial photo that includes the site.
Grid# -Record the number on the mylar grid when placed over the aerial photo.

Time - Record beginning and end times of survey.

Weather: For each of the following categories record conditions at both the beginning and end of the survey. Should conditions change during the survey, record these as weather notes (see 'Type') with appropriate times.

Weather - 0 = <50% clouds, 1 = >50% clouds, 2 = patchy fog, 3 = solid fog, 4 = mist/light rain, 5 = med/heavy rain.
% Cld - Indicate percent cloud cover from 0-100.
Ceil. - Record the predominate ceiling. (Not low patchy wisps of fog if most of the fog is above the ridgeline.) C = clear, A = above ridgeline, B = below ridgeline but above trees, F = below trees.
Wind/G - Estimate wind speed in knots and direction at ground level.
Wind/H - Estimate wind speed in knots and direction at cloud level.
Cld Typ - See laminated handout.
Sight - Record if there is a clear line of sight from stand being surveyed out to salt water. Y = yes, N = no.
Obst. - If line of sight is obscured, record whether the view to salt water is obscured by topographical features (e.g. hills, mountain range, etc.) or fog/clouds. T = topographical features, F = fog or clouds.
Temp C - Record temperature in degrees C (celsius).

Observer vocalization expertise: Note which calls you are able to distinguish during this survey.

FirstDet: Record the time of the first detection of the morning here and enter details as you would for close entries below.
LastDet: Record the time of the last detection of the morning here and enter details as you would for close entries below.

Recording murrelet detections:

Det. no.: To be assigned later.

Record **Type**, **Time**, **Nbirds**, **1stDir**, **LastDir**, and **NearDist** as you would during an intensive inventory (e.g. normal dawn watch).
VisBirdHt: Estimate the lowest bird height (in m) for all detections that bird(s) are seen (including both seen and heard). Record this as meters above canopy or above ground by entering a 'T' (=above canopy) or 'G' (=above ground) after the number. This is very important!

Behavior: Indicate all behaviors observed, *especially* secondary behaviors and "occupied" primary behaviors (e.g. DB, CB, and SP) (see guidelines for intensive inventories).

Vocalizations/Sounds:

Indicate which vocalizations are heard, particularly A, S, EH, or OT, and any wing noises that are heard (see guidelines for intensive inventories).

NoVoc: Record the **number** of calls if <10 (e.g. 1-9) or **M** (=multiple) for >9 calls. Record **W** (=wings only) if bird(s) are not seen and do not call but make any of the above wing noises.

Notes, other behaviors: Record any additional details of behaviors, weather changes, or other species of interest here.

Dbtwn: Record the distance between birds either as murrelet body lengths (=bl) or meters.

H/S: Record the number of birds heard over the number seen (e.g. H2/S4).

Predators: Note presence of all potential predators. Include times when they occurred, either specific or general (e.g. BAEA in area 0520-0555, STJA calling since 0330).

General Notes: Also record additional observations not included in previous columns, weather notes, or significant other species (e.g. potential predators, unusual species). This space can also be used for additional details describing murrelet behaviors.

Map: Draw a map of tree(s) being staked-out, position of observers, diagrams showing location of important murrelet behaviors, and maps of areas of activity.

<u>Literature Cited:</u>

Naslund, N.L., S.W. Singer, and S.A. Singer. 1990. A proposed ground search technique for finding tree nests of the Marbled Murrelet in open canopy forest. Pacific Seabird Group Bulletin 17:28.

Singer, S.W., N.L. Naslund, S.A. Singer, and C.J. Ralph. 1991. Discovery and observations of two tree nests of the Marbled Murrelet. Condor 93:330-339.

APPENDIX C

GUIDELINES FOR COLLECTING DATA AT MARBLED MURRELET NEST TREES OR LANDING TREES

By: Nancy L. Naslund and Kathy J. Kuletz U.S. Fish & Wildlife Service, Migratory Bird Management, 1011 E. Tudor Rd., Anchorage, AK 99503

The following guidelines provide descriptions of and methods for collecting data at Marbled Murrelet nest trees or landing trees. Trees that contain active nests should not be climbed until after the nest has failed or the chick has fledged. All data should be collected for nest trees, except in the event that an unattended egg, nestling, or adult is accidentally encountered at the nest (see below). Procedures at landing trees are essentially the same unless the exact landing branch is unknown (collect data only on habitat and tree). In this event, branches of the tree should be searched for signs of landing platforms, nest cups, eggshell fragments, droppings, feathers, or other signs of use, if possible. Some landing branches have 'cups' on them and these should be documented according to 'nest' procedures (see below).

Make an effort to collect data quietly in order to not disturb murrelets nesting nearby. Small radios can be used for communication between the climber and assistants to minimize disturbance. The climber and assistants should go over the following guidelines together, prior to undertaking each climb. These guidelines were developed from Varoujean and Carter (1989), Hamer and Cummins (1991), and Singer et al. (1991), with appropriate modifications and additions. This draft was produced for the 1992 field season and is subject to revision.

<u>Equipment for collecting data</u>

compass
altimeter
clinometer
ruler
angle measure
measuring tape
string
probe
camera & extra film
GPS
tags
sharpie pen
ziplocs
film canisters
small specimen jars
data forms
pencil
radios
microcassette recorder & cassette
tree corer
aerial photo
mylar grid
index cards

Protocol steps

1. collect data (en route to & at nest branch (unless bird is present, see below))
2. photograph at nest
3. collect samples
4. tag tree with ID number (e.g. year, NT#____ or LT#____)
5. photograph, core & measure tree from ground

Directions for data collection

Climb data: Record date, name of climber(s), assistants and data recorder, and beginning and end time of climb

Location data: Record the nest tree (NT) or landing tree (LT) ID #, aerial photo #, grid # (when laid on the aerial photo), latitude, and longitude (using the GPS, when available). Describe the location.

Habitat data: Note altitude, slope, aspect, canopy height, canopy tree species present, and major understory components.

Tree data:

Species - Record nest tree species.
Tree/Top Cond - Indicate the health of the tree (e.g. live, declining, dead - see handout) and condition of top (e.g. broken top, split, snag, etc.). Also record other notes of importance such as presence of heart rot or cavities.
DBH/Circu - Use a measuring tape to measure diameter or circumference at breast height (in cm) and circle whichever is appropriate.
Height - Estimate tree height in meters or use a clinometer if possible.
VertCrown - Estimate (in meters) the extent from the base to the top of the live crown.
CanPosit - Indicate the position of the tree canopy relative to the rest of the canopy (e.g. canopy, super-canopy).
#Platform - Stand at a spot that provides the best view of the tree branches and count all visible platforms that are > 15 cm in diameter and more than 10 m above the ground. Include branches or any other structures that form a platform.
#Witch Br - Record the number of witches brooms separate from other platforms. (Note: We have since included recording how many platforms and witches brooms have light, moderate, or heavy epiphyte cover.)
Epiphytes - Record the percent cover of all epiphytes (moss and lichens) on tree branches according to the following categories:

trace = <1%; **low** = 1-33%; **mod** = 34-66%; and **high** = 67-100%.

1stBranch - Measure the height of the first live branch (encountered from the ground) in meters by hanging the weighted end of a measuring tape from the level of the branch.
Circ@N/L - Measure the circumference of the tree at nest or landing branch level (in cm) using a measuring tape or string.

Branch data:

Height - Measure the branch height in meters by hanging the weighted end of a measuring tape from the level of the nest or landing branch.
Circumference - Measure the branch circumference at the **trunk including moss, at the trunk without moss, at the nest including moss, and at the nest without moss included.** Only take measurements without the moss if it is possible to do so without destroying the integrity of the substrate.
Length - Measure or estimate branch length (in meters).
Condition - Note condition of the branch (e.g. healthy, live, broken, split, etc.).
Angle of Repose - Measure the angle (in degrees) that the branch varies from horizontal from the trunk, either below (-) or above (+), at the trunk and at the nest.
Projection - Indicate the compass direction that the branch projects outward from the trunk.
Position - Indicate the branch position in the live crown (e.g. upper 1/4, lower 1/3, mid-point).
Access - Record the compass direction(s) from which the branch is accessible to flying murrelets.
LineSight - Indicate if there is a clear line of sight view to salt water.

Nest data:

DistTrunk - Record the distance of the nearest edge of the nest to the trunk (in cm).
Shape - Note the shape of the nest (e.g. oval, round).
Moss Depth - Measure the depth of moss *adjacent to* the nest and at *another location* on the branch (in cm) using a probe (a pencil will work).
Dimensions - Record the *width* and *length* of the nest measured at the largest points (in cm), not including the fecal ring (if present). Measure the *depth* of the nest cup from the top edge to its lowest point (in cm) vertically, not diagonally.
Orient - Record the departure of the nest orientation from the branch orientation (in degrees).
Substrate - Indicate components of the nest substrate (e.g. moss, lichens, bare, debris).
Nest Mat - Indicate if nest material is present (e.g. twigs, needles) and whether it appears to have been added or to have accumulated naturally.
Nest Cont - Note the presence of eggshell fragments, feathers, etc.
Cover - Indicate the presence or absence of branches or other structures forming cover within 1 meter over the nest.
Next Brch - Estimate (measure if possible) the distance (in m) of the next closest branch above the nest.
Droppings - Indicate if droppings are present, their location, and if they form a ring. If a fecal ring is present measure *width* and *depth* at outside edges and *depth of droppings* (all in cm).
Landing Platforms - Indicate the presence or absence of worn spots (potentially landing platforms), their *locations* relative to the nest cup and to the trunk, and *dimensions* (length and width) (in cm).

Photographs

Check off all of the following categories as they are completed.

ID Card - Fill out an index card with identification information written on it (date, location, tree ID, photographer) on the branch and place it in the frame of the 1st photograph of the series.
Nest - Take a few shots of the nest itself (bracket).
Branch - Take a few shots of the nest or landing branch (bracket).
Cover - Take one shot each of the view looking directly overhead and directly below.
View Out - Take a series of shots of the view looking out from all directions from the branch, beginning towards the north and taken in a regular clockwise fashion.
Tree - Take from the ground (bracket).
Other Note any other photos taken.
Notes - Record notable landmarks (e.g. mountains, bays, or rivers visible and directions).

Collections

Check off all of the following samples as they are collected. Be sure to leave the nest and branch substrate intact. Mark each wrapped sample noting date, tree ID, and description of sample using a permanent marker (such as a sharpie). Be careful not to crush samples.

Nest Substrate - Carefully remove a sample of the nest substrate including a small pad (approximately 3-5 cm) of moss and lichens, needles and twigs, or nothing (whichever is applicable).
Nest Material - Collect a representative sample of nest material, if present.
Nest Contents - Collect a representative sample of nest contents including feathers, food items, and all eggshell fragments.
Droppings - Collect a sample of droppings from the fecal ring, if present, or all of the droppings if there are only a few.
BranchSub - Collect a sample of the branch substrate as done for the nest substrate.
Epiphyte - Collect any other noticeably different moss or lichens on the tree on the way down, if possible.
Tree Twig - Collect a small branch or twig that includes needles for positive tree species identification.

Notes

Include a sketch of the nest branch and its position in the nest tree. Also indicate anything else that seems noteworthy such as peculiar smells associated with the nest, exposure (does the site feel exposed or protected?), presence of murrelets or potential predators (especially corvids and hawks) in the stand during data collection, etc.

Other

These are good pastimes for unoccupied climbing assistants.

Two Nearest OG Trees - For the two old growth trees closest to the nest or landing tree record the following data:

Species - Record tree species.
DBH/Circu - measure DBH or circumference at breast height (in cm) and circle which is appropriate
Distance to tree - distance from nest or landing tree (in m)

Ground Search - Search the ground in the vicinity of the nest tree for murrelet eggshell fragments, feathers, droppings, or prey remains. Note the location where they were found in 'Notes' above.

Core Sample - Take a core sample of the nest or landing tree and place in a straw and a marked ziploc bag.

<u>In case of an unattended egg or a bird at the nest</u>

If an adult or nestling murrelet is unexpectedly encountered at the nest, data collection should cease except for the following. Every effort should be made for the climber to slowly and quietly return to the ground. Small radios used between the climber and people on the ground can facilitate this.

unattended egg - Collect as much data as can be accomplished in about five minutes, including photographs. Return to the ground so that the adult may return to the nest. First photograph the nest, then collect data on branch height, position of the nest on the branch, and other data as time permits.

adult present - Make a quick mental description of the nest and the plumage of the adult. Remember that any quick movement may cause the bird to depart quickly, possibly kicking an egg or nestling off the branch. If the bird does depart, note if it vocalized as leaving and return quickly to the ground so it may return to the nest.

nestling present - If the nestling is well feathered, thus appearing generally black and white (similar to an adult in basic plumage), respond as if it is an adult. If the nestling is still small and downy, then quickly and carefully collect the following data. (A microcassette recorder may be useful for recording this data but be sure to check that it is working.)

quick description of the nest - Include its location on the branch, substrate, nest material, and presence and size of a fecal ring.

nestling description - Include its size (relative to something known), plumage colors, description of molt and location of down.

nestling behavior & vocalizations - Describe its posture, actions, and record (on the microcassette recorder, if possible) its vocalizations.

photograph - Quickly take a few shots to document the nestling. If you feel the shot will include a reasonable assessment of some of the data described in above, then that data may be omitted.

If at any time you feel the bird is in danger of jumping, discontinue data collection, remain still for a brief period, and slowly return to the ground.

Literature Cited:

Hamer, T.E. and E.B. Cummins. 1991. Relationships between forest characteristics and use of inland sites by Marbled Murrelets in northwestern Washington. Draft report. Wildlife Management Division, Washington Dept. of Wildlife, Olympia, Wash.

Singer, S.W., N.L. Naslund, S.A. Singer, and C.J. Ralph. 1991. Discovery and observations of two tree nests of the Marbled Murrelet. Condor 93:330-339.

Varoujean, D.H. and H.R. Carter. 1989. The Pacific Seabird Group's 1989 Marbled Murrelet nest site sampling protocol. Unpubl. Rept. MARZET, North Bend, Oreg.

APPENDIX D

GUIDELINES FOR COLLECTING HABITAT DATA AT MARBLED MURRELET NEST TREE OR LANDING TREE SITES

By: Nancy L. Naslund and Kathy J. Kuletz U.S. Fish & Wildlife Service, Migratory Bird Management, 1011 E. Tudor Rd., Anchorage, AK 99503

The following guidelines provide descriptions of and methods for collecting data at Marbled Murrelet nest tree or landing tree sites. Methods were developed from Varoujean and Carter (1989) and Singer et al. (1991). Habitat data should not be collected around trees that contain active nests until after the nest has fledged or failed. Efforts should be made to collect data quietly in order to not disturb murrelets nesting nearby. All parties should go over the following guidelines together, prior to data collection.

Collect data in a 25 m radius circular plot centered on the nest tree or landing tree. This plot should then be divided into four quadrants and marked with flagging tape, to increase efficiency in measuring trees.

Equipment for collecting data

altimeter
clinometer
two measuring tapes
compass
flagging tape
GPS
sharpie pen
ziplocs
small specimen jars
data forms
pencil
aerial photo
mylar grid

Directions for data collection

Location Data: Record the names of data collectors, location, site #, aerial photo #, grid #, nest tree (NT) or landing tree (LT) ID #, aerial photo #, grid # (when laid on the aerial photo), date, latitude, and longitude (using the GPS, when available). Describe the location of the plot.

General Habitat: Record altitude, stand slope, stand aspect (e.g. WNW, S, etc.), nearest pond or creek and distance to salt water (note whether in m or km), canopy height (in m), canopy closure, canopy tree species present, and major understory components.

Fallen trees: Record the number of each of the following sizes (dbh) of fallen trees for each quadrant. Size of fallen trees may be estimated.

10-50 cm

51-100 cm
101+ cm

Tree measurements: Measure and record the following data for all trees with a dbh > 2.5 cm.

species - Record tree species according to these abbreviations (note that hemlock species are frequently quite difficult to identify, therefore UNHE is often appropriate):

WEHE - western hemlock
MOHE - mountain hemlock
UNHE - unidentified hemlock species
SISP - Sitka spruce
ALDE - alder
HESN - hemlock snag
SPSN - spruce snag
UNSN - snag unidentifiable to species

dbh/circum - Measure the diameter or circumference at breast height (in cm) and circle which is appropriate.

quad no. - Record which of four quadrants the tree is located in.

Collections: Collect any eggshell fragments and possible murrelet feathers or prey items that are found in the habitat plot. Also collect any possible prey items, pellets, etc. of potential predators. Mark each wrapped sample noting date, tree ID, description of the sample, and location where the sample was found using a permanent marker (such as a sharpie). Be careful not to crush samples.

Notes: Record any other noteworthy observations.

Record any collections made and notes at the bottom of data forms.

Literature Cited:

Singer, S.W., N.L. Naslund, S.A. Singer, and C.J. Ralph. 1991. Discovery and observations of two tree nests of the Marbled Murrelet. Condor 93:330-339.

Varoujean, D.H. and H.R. Carter. 1989. The Pacific Seabird Group's 1989 Marbled Murrelet nest site sampling protocol. Unpubl. Rept. MARZET, North Bend, Oreg.

APPENDIX E

GUIDELINES FOR COLLECTING VEGETATION DATA AT MARBLED MURRELET DAWN WATCH SITES

By: Nancy L. Naslund and Kathy J. Kuletz. U.S. Fish & Wildlife Service, Migratory Bird Management, 1011 E. Tudor Rd., Anchorage, AK 99503

The following guidelines provide details for collecting general vegetation data at Marbled Murrelet dawn watch sites. Data should be collected for a 50 m circular plot, centered on the observation point from which the dawn watch was done.

Equipment for collecting data

altimeter
clinometer (when possible)
measuring tape or pre-measured string
compass
data forms
pencil
aerial photo
mylar grid
ziplocs
sharpie

Directions for data collection

Observer: Name of person completing form.

Location data: Record the following data at each site. Also mark the location on a copy of the appropriate aerial photo for later reference.

> **Location** - Note the general location of the site (e.g. south Cabin Bay Naked Island).
> **Site no.** - Record the site number or other identification number.
> **Aerial no.** - Record the number of the aerial photo that includes the site.
> **Grid no.** - Record the number on the mylar grid when placed over the aerial photo.

ID No.: To be given at a later date.

Date: Fill in date that data is collected.

Time: Indicate the beginning and end times for collecting the data.

Habitat: Note which of the general habitat types is (are) most appropriate: For=coniferous forest, Bog=open bog meadow, Alp=alpine, Alp/Tree=mixed alpine with small trees or small undeveloped forest, Bog/Tree=mixed bog with small trees or small undeveloped forest.

Field check: To be completed by supervisor.

Ten closest canopy trees

Record the following data for each of the ten *closest upper canopy* trees. Upper canopy trees are those trees whose crowns are part of the main or predominate canopy. Super-canopy trees (e.g. trees whose crowns protrude above the canopy) are also counted as canopy trees for the purposes of this form.

species - Record tree species according to these abbreviations (note that hemlock species are frequently quite difficult to identify, therefore UNHE is often appropriate):

WEHE - western hemlock
MOHE - mountain hemlock
UNHE - unidentified hemlock species
SISP - Sitka spruce
ALDE - alder

dbh/circ - Measure the diameter or circumference at breast height (in cm) and circle which measurement was used.

Vigor - Record the condition of the tree (e.g. live, declining, dead; see handout).

top cond - Note the top condition (e.g. broken, split, snag top, live/intact).

platform - Stand at a spot that provides the best view of the tree branches and count all visible platforms that are ca. ≥15 cm in diameter (including moss) and ≥10 m above the ground. Include branches or any other structures that form a platform (record witches brooms separately).

witches br - Record the number of witches brooms that form platforms using the same criteria as above.

epiphyte - Record the percent cover of all epiphytes (moss and lichens) on tree branches according to the following categories: trace = <1%; low = 1-33%; mod = 34-66%; and high = 67-100%.

comments - Other notes such as what appears to be a particularly suitable nest branch(es), etc.

Vegetation of 50 m circular plot around station

% size class of forested area: Estimate the percentage of the *forested area* (not necessarily the entire plot if it includes open areas) covered by each of the four size classes (e.g. 1-10 cm, 11-50 cm, 51-100 cm, and >100 cm dbh) as follows:

total - The total percentage of area covered by each size class.

hemlock - Of *the total percentage of area covered by each size class*, record the percentage that are hemlock species.

spruce - Of *the total percentage of area covered by each size class*, record the percentage that are spruce.

alder - Of *the total percentage of area covered by each size class*, record the percentage that are alder.

snags: Record the number of snags for each of the four size classes.

dominant shrubs: Record the following for each of the dominant shrub species:

> **species** - Note both the common and scientific species name.
> **% cover** - Indicate the percentage of the ground that is covered by each species.
> **height** - Record the tallest height of each species. Be sure to note if height is recorded as cm or m. If the height varies quite a bit in the plot, also note the range.

<u>General for 50 m plot</u>

% w/trees & % open: Record the percentage of the 50 m plot that is forested and the percentage that is open. 'Open' means small openings in the forest, meadows, bog, etc. (not the area between trunks). The two added together should equal 100%.

canopy closure: Estimate the percentage of sky that is blocked by foliage when looking up.

canopy height - Estimate the general canopy height (in m).

<u>General for area</u>

altitude - Record the elevation, noting meters or feet, and the source of this information (e.g. altimeter, topo map).

slope - Record the general slope of the area in degrees, using a clinometer when possible. Record multiple slopes only if you are at a peak.

aspect - Record the general compass direction (in degrees) the slope of the site faces. Record multiple directions only if you are at a peak.

watershed - Name the watershed or drainage associated with the site.

ponds & creeks - Note the distance and direction of nearby ponds or creeks.

<u>Other</u>

predators - Describe actual observations of or signs of any potential murrelet predators in the area, both avian and mammalian.

collections - Record any collections here. Collect twig sample of unidentified trees (for ten closest trees), if possible. Also collect any eggshell fragments, possible murrelet feathers or prey items, and prey items of potential murrelet predators (including owl pellets, hawk castings, feathers at plucking posts) that are encountered in the area. Mark each wrapped sample noting date, location, description of the sample, and location where the sample was found using a permanent marker (such as a sharpie). Be careful not to crush samples.

notes - Record any notes of importance here.

<u>Map</u>

Sketch the general area including boundaries of major habitat types, locations of ponds and creeks, compass directions, and areas of murrelet activity (including observed or suspected flight corridors). Be sure to include a scale indicating what the map represents and names of local landmarks.

APPENDIX F

GUIDELINES FOR AVIAN CIRCULAR PLOTS AT MARBLED MURRELET SURVEY SITES

By: Nancy L. Naslund and Kathy J. Kuletz. U.S. Fish & Wildlife Service, Migratory Bird Management, 1011 E. Tudor Rd., Anchorage, AK 99503

The following are guidelines for conducting surveys for avian species, including potential predators, at murrelet nest sites. In general, they follow previously developed variable circular plot methods, with some modifications (see Ralph and Scott 1981).

Where - Locate the observation point at about 50m from the nest. If the habitat varies dramatically within 200m of the nest (e.g., coniferous forest and open bog meadow) then locate a second observation point in the second habitat type, approximately 250-300 m from the nest. Do another survey in this second habitat following each original census (see 'when' and 'frequency' below). Reverse the order surveys in the two habitat types are done on alternating census days. Surveys should also be done at each dawn watch and stake-out site.

When - Surveys should be executed three times per census day, when possible. Do the first survey during the period of one hour prior through one half hour after each dawn watch or stake-out. Do a second survey within 1 hour of solar noon, and a third at the beginning of a murrelet dusk watch. When this is not possible, do only the first survey.

Duration - Each survey lasts a total of 11 minutes. The first minute is a rest period allowing for birds to acclimate to the observer, but during which birds are recorded. The remaining 10 minutes encompass the official survey period.

Frequency - At least eight survey days should be completed at each nest site, when possible.

How - Bird(s) are recorded as they are heard or seen. Each detection is recorded separately unless the bird is seen flying to the new location. Record the time, species, number, type, etc. (see below) for each detection. Birds that are flushed on approach to the observation point should be recorded using the distance from the observation point to where the bird was first observed as the detection distance.

Filling out the data form:

Page: Note current page number and total number of pages for the survey.

Observer: Name of person conducting the survey.

Location data:

Location - Note the general location of the site (e.g. south Cabin Bay Naked Island).
Site no. (or nest ID no.) - Record identification numbers for the site or known nest.
Aerial no. - Record the number of the aerial photo that includes the site.

Grid no. - Record the number of the mylar grid when placed over the aerial photo.
Date: Record date.

ID no.: To be given at a later date.

Time: Record beginning and end times of the survey (including the 1 minute 'rest' period).

DirNest: Indicate the direction your observation point is relative to the nest tree.

DistNest: Indicate the distance your observation point is from the nest tree. Also mark the location on an aerial photo.

Habitat: Indicate general habitat(s): For=coniferous forest, Bog=open bog meadow, Alp=alpine, Alp/Tree=mixed alpine with small trees or small undeveloped forest, Bog/Tree=mixed bog with small trees or small undeveloped forest.

Field check: To be completed by supervisor.

Weather: Record conditions at the beginning of the survey for each of the following categories.

Weather - 0 = <50% clouds, 1 = >50% clouds, 2 = patchy fog, 3 = solid fog, 4 = mist/light rain, 5 = med/heavy rain.
%Cloud - Indicate percent cloud cover from 0-100.
Ceil - Record the predominate ceiling. (Not low patchy wisps of fog if most of the fog is above the ridgeline.) C = clear, A = above ridgeline, B = below ridgeline but above trees, F = below trees.
Temp - Record temperature in degrees C (celsius)
Wind G - Estimate wind speed in knots and direction at ground level.
Wind H - Estimate wind speed in knots and direction at cloud level.
CloudTyp - See laminated handout.

Bird detection data:

Time: Record time bird(s) were first detected.

Species: Use four letter AOU abbreviations.

No.: Record your best estimate of the number of bird(s) heard or seen.

Check all appropriate columns of the following types for each detection:
Sing - singing;
Call - calling:
Seen - visual, bird(s) seen;
Fly - flying overhead (e.g. an eagle passing by);
Other - (e.g. hammering, drumming), indicate specifics under notes.

Distance: Record the horizontal distance (in meters) when ***first*** detected. For distances up to 150m estimate distance to within 10 m categories. For example, distances of 0-10 m is recorded as

10, 11-20 m as 20, etc. From 150+m use 50m categories. Visually check to confirm species identification or distance if possible.

Same: Check this column if you think the bird(s) are the same as recorded earlier but in a different spot. Link them with the same letter.

Notes: Include anything noteworthy, particularly for predators, such as age (adult, nestling, fledgling), presence of nest, important behaviors.

Other sightings or signs: Record any other potential avian or mammalian predators observed while in the area. This includes actual sightings, tracks, roosts, fecal signs, feeding sites, plucking posts, and pellets. Collect any prey remains, especially if they contain bird bones or feathers. Indicate date, time, number, type of sign (where applicable), and location.

Literature Cited:

Ralph, C.J., and J.M. Scott. 1981. Estimating numbers of terrestrial birds. Studies in Avian Biology No. 6, Cooper Ornithological Society. 630pp.

APPENDIX G

HABITAT TYPES, AREA AND PERCENT COVER: LAND COVERAGE ANALYSIS FOR NAKED, STOREY AND PEAK ISLANDS

CHUGACH NATIONAL FOREST
GIS DATA DICTIONARY

EXISTING VEGETATION LAYER (TIMBER TYPE) CODES
01/09/90

IT-CODE BREAKDOWN IN TIMBER TYPE.PAT FILES

```
                   1       1
         1 2 3 4 5 6 7 8 9 0 1 2 3 4 5
IT-CODE  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
           | | | | | | | | | | |
           | | | | | | | | | | └───── NONS
           | | | | | | | | | └─────── UNST
           | | | | | | | | └───────── DECD
           | | | | | | | └─────────── VOCL
           | | | | | | └───────────── DENS
           | | | | | └─────────────── STCL
           | | | | └───────────────── FTYP
           | | | └─────────────────── UNPR
           | | └───────────────────── OVST
           | └─────────────────────── NFOR
           └───────────────────────── COND
```

COL 1	<u>Code</u>	<u>COND-CODE</u> (Prefix Symbol for Forest Types)
	0	Not a residual stand
	1	Residual Stand

COL 2-3	<u>Code</u>	<u>NFOR-CODE</u> (NonForest Land)
	00	Not nonforest land
	01	NfG 0 Natural Grassland
	02	NfH - Alpine (high meadows
	03	NfM - Muskeg Meadows
	04	NfR - Rock
	05	NfI - Icefields or Snowfields
	06	NfU - Urban, Agric., and Other
	07	NfS - Recurrent Snowslide Zone
	08	NfW - Mass Wasting
	09	NfD - Sand Dunes
	10	NfA - Alder
	11	NfT - Willow
	12	NfB - Brush
	13	NfL - Uplifted Beach
	14	NfF - River Fill
	15	NfO - Other Causes
	16	BP - Borrow Pit
	17	W - Freshwater

COL 4	<u>Code</u>	<u>OVST-CODE</u> (Overstory Code for Nonforest Brush)
	0	No Overstory Class
	1	10% Spruce Overstory (S)

	2	10% Hemlock Overstory (H)
	3	10% Cottonwood Overstory (C)

COL 5-6	<u>Code</u>	<u>UNPR-CODE</u> (UNREPRODUCTIVE FOREST LAND - NCFL)
	00	Not Unproductive Forest Land Class
	01	ScR - Rock
	02	ScL - Low Site
	03	ScM - Muskeg Forest
	04	ScH - High Elevation (Alpine)
	05	ScS - Resurrent Snowslide Zone
	06	ScA - Alder
	07	ScT - Willow
	08	ScG - Glacier Forest

CHUGACH NATIONAL FOREST
GIS DATA DICTIONARY

EXISTING VEGETATION LAYER (TIMBER TYPE) CODES
01/09/90

COL 7-8	<u>Code</u>	<u>FTYP-CODE</u> (FOREST TYPE)
	00	No Forest Type
	01	H - Hemlock
	02	S - Sitka Spruce
	03	W - White Spruce
	04	M - Black Spruce
	05	B - Birch
	06	Q - Aspen
	07	P - Cottonwood-Balsam Poplar
	08	HS - Hemlock-Sitka Spruce
	09	HW - Hemlock-White Spruce
	10	QW - Aspen-White Spruce
	11	BW - Birch-White Spruce
	12	PS - Cottonwood-Sitka Spruce
	13	PW - Cottonwood-Shite Spruce
	14	PB - Cottonwood-Birch
	15	PBW- Cottonwood-Birch-White Spruce
	16	QH - Aspen-Hemlock
	17	QB - Aspen-Birch or Birch-Aspen

COL 9	<u>Code</u>	<u>STCL-CODE</u> (STAND SIZE)