USE OF BOAT-BASED SURVEYS TO DETERMINE COASTAL INLAND HABITAT ASSOCIATIONS OF MARBLED MURRELETS IN PRINCE WILLIAM SOUND, ALASKA

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ABSTRACT—To identify potential marbled murrelet (*Brachyramphus marmoratus*) nesting habitat we surveyed western Prince William Sound, Alaska, for murrelet activity between 12 June and 3 August 1992. We evaluated methods specific to boat-based surveys (vessel and shoreline) by comparing the number of murrelet detections and subcanopy flights during dawn watches adjacent to inland stations. We conducted boat-based surveys from a 19-m vessel ($N = 44$) and from shoreline stations ($N = 23$), and concurrently from adjacent inland stations ($N = 17$). Murrelet activity level and seasonal variation of activity were not significantly different when conducted from the vessel or from shoreline and were similar to surveys at adjacent inland stations. Survey stations near bay heads had higher activity levels than those near exposed coastlines, with the exception of bays that were glaciated or recently deglaciated. We used a timber-type database on a geographic information system to analyze relationships between murrelet activity and habitat within a 1-km radius of each survey station. Forested habitat, particularly forests with trees > 28 cm diameter, showed the strongest correlation to murrelet activity. Boat-based surveys are useful for a preliminary identification of potential murrelet nesting areas in remote and otherwise inaccessible, coastal habitat.

In North America, most marbled murrelets (*Brachyramphus marmoratus*) breed in Alaska (Mendenhall 1992), and within this state, Prince William Sound (PWS) is 1 of 3 major population centers (Piatt and Ford 1993). The PWS population of murrelets was affected in the 1989 *Exxon Valdez* oil spill by direct mortality and possibly by disruption of breeding (Piatt et al. 1990; Ecological Consulting, Inc. 1991; Kuletz, in press). Part of the restoration effort included the identification of marbled murrelet nesting habitat throughout the affected area. During the breeding season most of the murrelet population is found offshore of old-growth forests (Piatt and Ford 1993), and many studies have shown that mature and old-growth forest constitute the primary habitat for nesting marbled murrelets south of Alaska (Paton and Ralph 1990, Rodway et al. 1993, Hamer and Nelson 1995a, Ralph et al. 1995a). In southcentral Alaska, murrelet nesting habitat includes both forested and nonforested areas (Simons 1980, Day et al. 1983, Kuletz et al. 1995).

Search techniques based on observing murrelet behavior or signs of nesting (Singer et al. 1991, Nelson and Hamer 1992, Naslund 1993, Naslund et al. 1995, Nelson and Peck 1995) and radiotelemetry (Quinlan and Hughes 1992) have been used to locate small numbers of murrelet nests. Unlike many seabirds, marbled murrelets are thought to nest at relatively low densities (Carter and Sealy 1986, Naslund et al. 1995). This, combined with their concealing plumage and secretive behavior, make nests difficult to locate. Because of the difficulty in finding nests, many efforts to define habitat use have focused on surveying marbled murrelets when they fly to inland nesting areas around dawn (*e.g.*, Paton et al. 1990).

Large-scale surveys of murrelet activity at inland sites outside of Alaska are facilitated by road and trail systems that provide access to potential nesting habitat. In contrast, much of Alaska is difficult to traverse, and most coastal areas are remote and accessible only by boat or aircraft. Searches from the ground for murrelet nests are too labor-intensive to use over large areas. Before this study, methods for surveying and mapping murrelet nesting habitat over a large and remote geographic area had not been developed for Alaska. We tested new boat-based methods to survey sunrise activity of

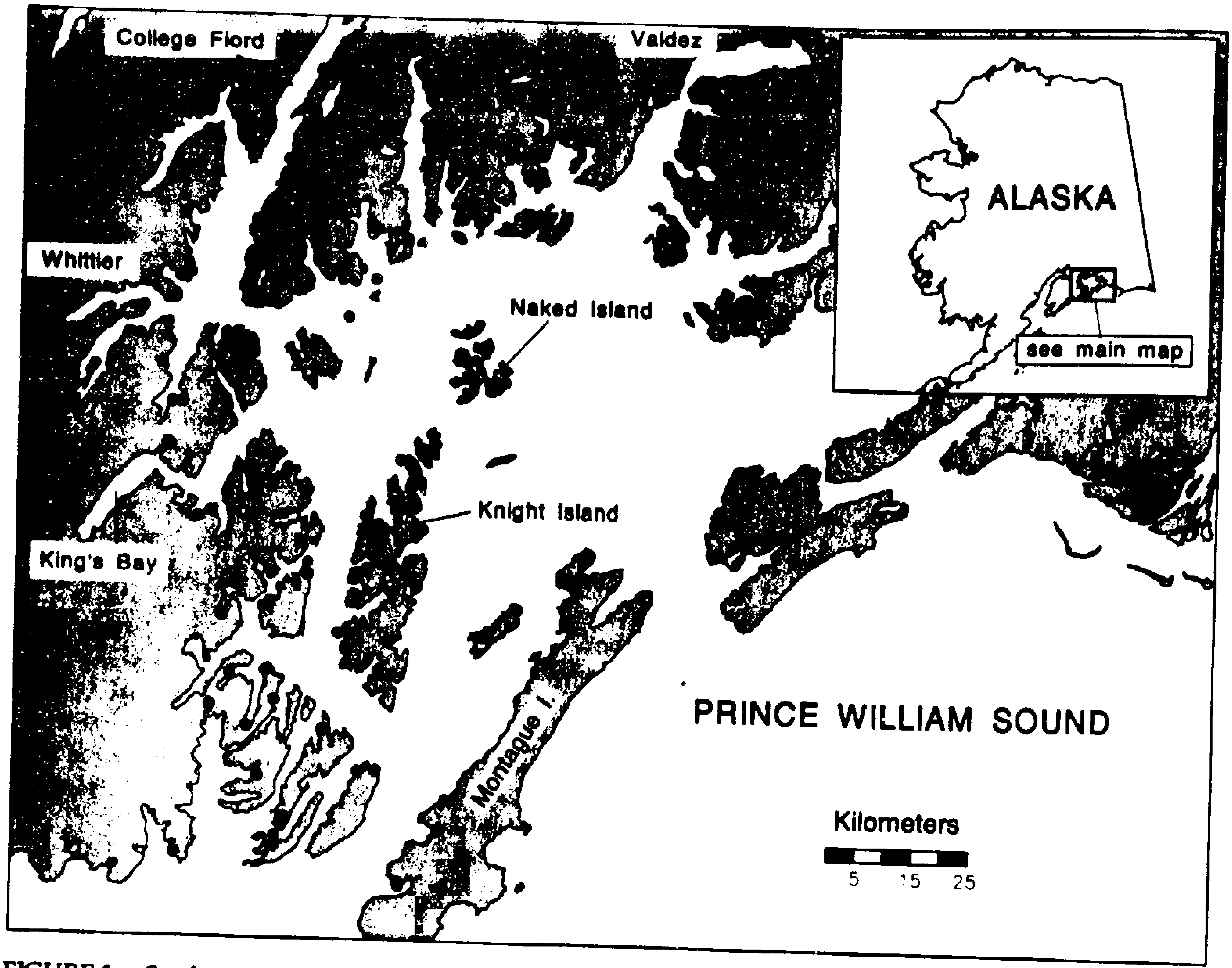

FIGURE 1. Study area and boat-based stations ($N = 67$) for 1992 marbled murrelet habitat survey in Prince William Sound, Alaska. Map points are approximately equal to a 1-km radius around each survey station.

marbled murrelets in a large and remote area in western PWS. Our objectives were to address the effectiveness of boat-based surveys, compare murrelet activity levels (number of detections) to habitat, and examine the application of U.S. Forest Service (USFS) timber-type maps for identification of murrelet habitat throughout the study area.

METHODS

Study Area

We surveyed for murrelets in western PWS (Fig. 1), an area of steep topography, numerous islands, convoluted shorelines, and deep fiords (Islieb and Kessel 1973). Tidewater glaciers and recently deglaciated valleys are common throughout the study area. Most of coastal PWS is forested, and although stands of large trees are common near the shore, much of the land is sparsely covered with small trees. Old-growth forests of mountain hemlock (*Tsuga mertensiana*), western hemlock (*T. heterophylla*), and Sitka spruce (*Picea sitchensis*) grow along the shoreline and many of the slopes. Dominant understory shrubs include blueberry (*Vaccinium* spp.), salmonberry (*Rubus spectabilis*), rusty menziesia (*Menziesia ferruginea*) and devil's club (*Echinopanax horridum*). Although Sitka alder (*Alnus crispa sinuata*) shrubland, peatland ("muskeg"), and alpine habitat can occur, most of coastal PWS, and the majority of our survey stations, were forested.

Surveys

We randomly selected 67 transects from 176 shoreline transects (constructed by the U.S. Fish and Wildlife Service [USFWS] for waterbird surveys) to survey for marbled murrelets in remote areas of PWS. These USFWS transects were used because they were available for the entire coastline of the study area. They also included a large pool from which to make our 67 selections, and were mapped and ready for use. Surveys were conducted from the water or nearby shoreline stations at each transect. Our survey stations were established at the approximate midpoint of each transect (Fig. 1).

Boat-based dawn watches ($N = 44$ surveys) were conducted from a 19-m vessel anchored < 100 m from shore, or from a 4.5-m inflatable boat ($N = 23$) 0–100 m adjacent to shore, depending on weather and topography (Appendix). At 3 of the shoreline stations, surveys were conducted 25–75 m inland when the vantage of adjacent forest was impeded by cliffs. At 45% (20 of 44) of the randomly selected transects, the larger vessel could not anchor safely at the midpoint and the station was moved to the nearest suitable location within the transect. Vessel motors were turned off during dawn watches.

To evaluate the reliability of boat-based dawn watches in detecting inland murrelet activity, we conducted concurrent dawn watches at 17 stations 100–600 m directly inland from the anchored boat. The location of the inland station was chosen for its vantage and was usually placed in a clearing.

At each station we conducted intensive surveys for murrelets (Paton et al. 1990; hereafter referred to as the 'dawn watch') with modifications for Alaskan and coastal conditions. Each station was surveyed for murrelet activity (number of detections) between 12 June and 3 August 1992. Dawn watches were conducted from 1 or 2 survey stations each morning. Surveys lasted for about 2 hr, beginning 105–120 min prior to official sunrise (determined by the National Weather Service) and continuing to 15 min after sunrise or 15 min after the last detection, whichever was later. A trained observer at each station recorded all murrelet sightings and vocalizations, distance from observer to bird, and flight direction (based on the 1993 Pacific Seabird Group [PSG] survey protocol, Redwood Sciences Laboratory, 1700 Bayview Drive, Arcata, CA, unpubl. rep.). Below tree canopy ('subcanopy') flight behaviors, indicative of murrelet nesting, included murrelets flying through, landing in, departing from, or calling from the forest canopy. From boat-based and shoreline stations, we also recorded flight patterns and behaviors of birds sitting, swimming or flying over the ocean, as well as those of murrelets flying over land. Weather conditions were recorded at the beginning and throughout each survey, and included percent cloud cover, height of cloud ceiling, wind speed, and precipitation or fog.

Previous studies on Naked Island showed greater murrelet activity near the heads of bays than in the vicinity of more exposed shoreline (Kuletz et al. 1994). Therefore, we classified 22 stations as bay and 45 as exposed. Bays were defined as recesses or coves where the depth of the 'bay' was greater than the width at the mouth; exposed areas were those not counted as bays.

Habitat Database

Vegetation maps were used to test for association between murrelet activity and surrounding habitat. A timber-type land map of PWS was produced by the USFS using aerial photographs and 1:63,360 scale U.S. Geologic Survey topographic maps. This timber-type map, while defining habitat characteristics for wood production, used several criteria (see below) appropriate for examining murrelet habitat and was the only vegetation-based map available for the entire study area. Timber-type polygons were mapped to a minimum of 4 ha for forested and 2 ha for unforested habitat. Our survey stations were digitized into a geographic information system (GIS) database. We used ARC/INFO, Clip and Frequency Analysis (Environmental Systems Research Institute, Inc. 1992) to determine the area for each timber type that occurred within a 1-km radius of each dawn-watch station. This distance was used to include sufficient inland habitat around boat-based survey stations anchored up to 100 m off shore. Although murrelets are believed to fly long distances within nesting areas and between the shore and nests, a larger radius was not used because of the patchy nature of the environment within the study area. Murrelets detected flying in the area were assumed to be near suitable nesting sites.

Preliminary analysis of these timber maps identified 215 different habitat and vegetation combinations in PWS, 74 of which occurred within 1 km of our dawn-watch stations. However, only 61 of the 67 boat-based stations had associated habitat data. Six of the randomly selected transects had stations adjacent to private lands not mapped in the timber database. The timber-type database included tree species, tree size, tree age, and stand volume, for forested habitat, and categories for several nonforested land types. Nonforested land included polygons with < 10% tree coverage and included rock, alpine, alder (*Alnus* spp.), and willow (*Salix* spp.). Forested land had > 10% tree cover and was divided into 'productive' and 'unproductive' forest, depending on the estimated amount of annual growth. Unproductive forest (< 50 m^3 of growth/ha/yr) included unforested habitat with a sparse coverage of trees. Productive forest (stands with > 50 m^3 of growth/ha/yr) were further divided by tree-size class (called stand-size class, STCL, by USFS) and volume class (VOCL). STCL used average tree size (dbh) and tree age as follows: STCL 1 (0.25–11.9 cm dbh), STCL 2 (12–28 cm dbh), STCL 3 (dbh > 28 cm and age 30–150 yr), and STCL 4 (dbh >28 cm and age >150 yr). Few trees > 28 cm dbh were less than 150 yrs old, placing the majority of trees in STCL 4. VOCL referred to the volume of tree boles: VOCL 1 (0–750 net m^3/ha), VOCL 2 (750–1882 net m^3/ha), VOCL 3 (1883–3765 net m^3/ha), and VOCL 4 (3766–5648 net m^3/ha). We divided the productive forests into 4 types (see Kuletz et al. 1994) ranging from low-volume stands of small trees (forest type 1, FT1) to high volumes of large trees (FT4).

Data Analysis

For analysis, we used all murrelet detections that occurred over land and over the water. We minimized the importance of birds not flying to nearby inland locations by not including those on the water or those whose location, on or over the water, was unknown. We included detections at all distances from the observer to include the maximum number of inland detections. Analyses of detections within a limited (usually 200 m) radius of the observer may better relate murrelet activity to immediate habitat, but is impractical when surveying from a boat anchored up to 100 m offshore.

Previous research in PWS showed a marked increase in murrelet detections around 10 July (Kuletz et al. 1994). Therefore, we divided surveys into early (before 11 July) and late (after 10 July) periods, and examined them for seasonal differences. For all tests, number of detections was standardized, using these 2 periods, for the effect of season (Miller and Ralph 1995), and, unless otherwise stated, the standardized numbers are reported for all numbers of detections. For all parametric tests, number of detections was square-root transformed to obtain a normal distribution. Significance for all tests was accepted at $p \leq 0.05$.

Pearson correlation (SAS Institute, Inc. 1988a) was used to examine relationships between number of detections and dawn-watch station type (inland compared with boat-based), and number of detection and distance from shore. To test for differences in murrelet activity between station location (*i.e.*, from 19-m vessel, inflatable or shoreline, and inland compared with boat-based), we used a t-test (SAS Institute, Inc. 1988b) and the Cochran and Cox approximation of the probability level of the t-statistic (SAS Institute, Inc. 1988b) when variances were unequal. An F-statistic was computed to test for equality of variances. We used Wilcoxon Scores of ranked sums (SAS Institute, Inc. 1988b) to test for differences in number of subcanopy flight behaviors between survey methods. To examine the effect of survey method, weather variables (percent clouds, cloud ceiling height, presence of rain), date, shoreline physiography (bay compared with exposed shoreline), and observer on the number of detections, we used an analysis of variance (ANOVA; SAS Institute Inc. 1988a). Wind was only twice recorded at speeds of > 5 km/hr and therefore was not considered. Likewise, fog was only recorded on 2 mornings and was not included in analyses.

We used broad habitat designations to maintain sufficient sample sizes in each habitat category. We made our comparisons at 3 levels of resolution: (1) nonforested and forested areas, (2) productive and unproductive forests, and (3) 4 designations of productive forests, and compared the actual areas of each habitat type (km^2, for all stations) to number of detections. Kendall's coefficient of rank correlation (SAS Institute, Inc. 1988a) was used to test for relationships between these areas and the number of detections.

RESULTS

Effectiveness of Using Boats to Survey Inland Habitat

In 48 days at sea, we surveyed for marbled murrelets at 67 boat-based stations. Only 2 days were lost to weather. Murrelets were observed flying over land and ocean, as well as sitting and swimming on the water. All but 6 detections were made within 500 m of the station center; these were detected approximately 600 m from the observer.

Number of murrelet detections did not differ between surveys conducted from the 19-m vessel and those from the inflatable boat or shore ($\bar{x}$ = 44.5 and 45.7, respectively; $t = -0.124$, df = 65, $p = 0.903$). In addition, there was no correlation between the number of detections over land and the distance of the vessel station from shore (*tau-b* = -0.009, $p = 0.934$). Therefore, we pooled the data from these dawn-watch stations for analysis and refer to them as 'boat-based surveys'.

The number of detections per dawn watch for boat-based surveys ($N = 67$) ranged from 0 to 149 ($\bar{x}$ = 44.9, SE = 4.53; for unstandardized counts see Appendix). Counts at the adjacent inland stations ($N = 17$) ranged from 7 to 222 ($\bar{x}$ = 66.6, SE = 13.2) and were not different from paired boat-based stations ($t = -0.641$, df = 16, $p = 0.531$). Further, the number of detections from inland surveys were positively correlated with those from the associated boat-based surveys (*tau-b* = 0.370, $p = 0.039$; Fig. 2).

We observed 0–8 subcanopy flight behaviors at each station ($\bar{x}$ = 0.46, SE = 0.13). Subcanopy flight behaviors were observed at 18% of boat-based ($\bar{x}$= 0.34, $N = 67$, SE = 0.11) and 29% of inland stations ($\bar{x}$ = 0.94, $N = 17$, SE = 0.50). The difference between means (boat-based *vs.* inland) was not significant ($\chi 2 = 1.325$, df = 1, $p = 0.250$). Subcanopy flight behaviors were not observed from the boat-based stations adjacent to the 5 inland stations that had subcanopy observations.

Murrelet Activity and Behavior

We found a significant difference in number of detections between seasons (early *vs.* late; F

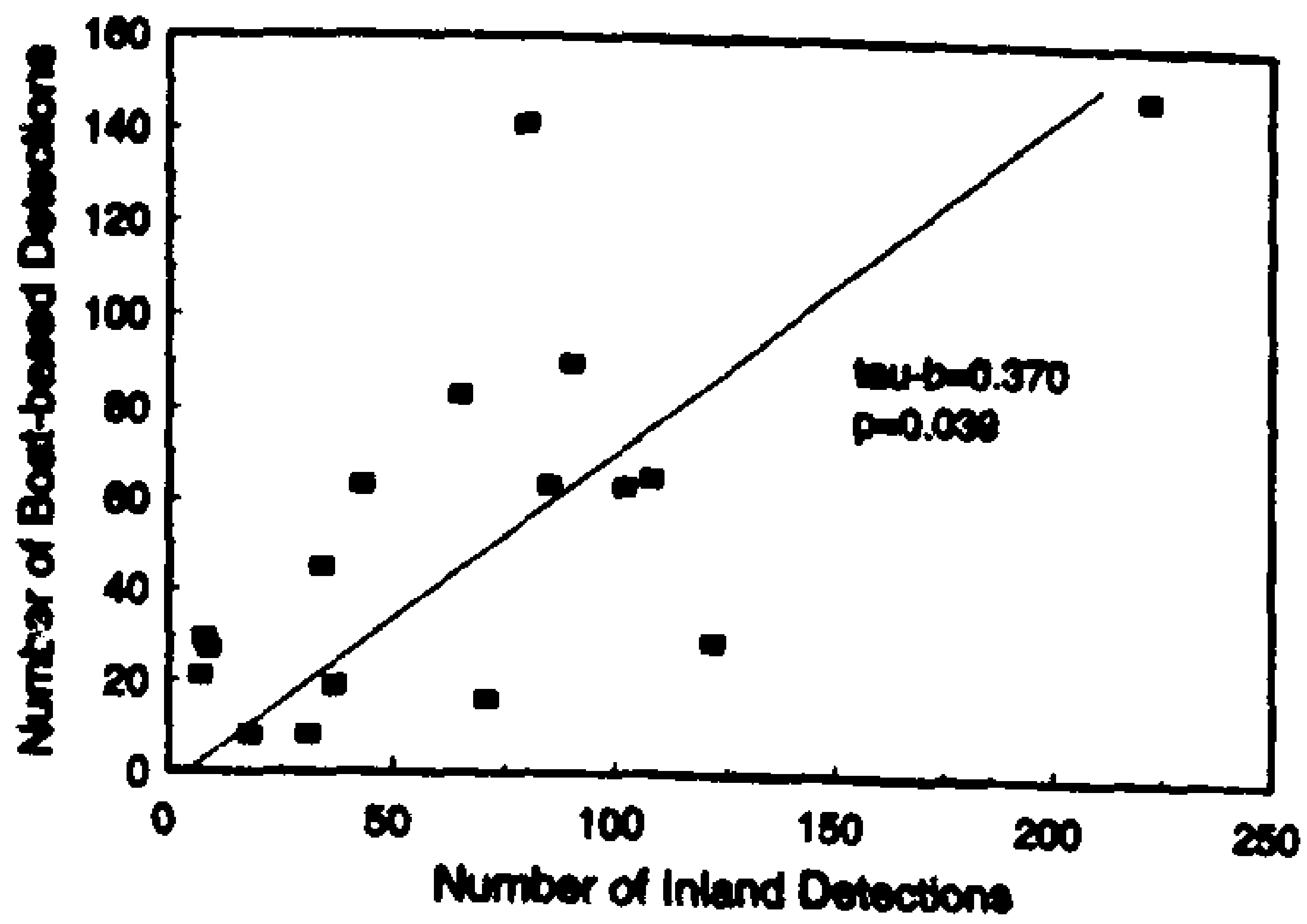

FIGURE 2. Total number of marbled murrelet detections for paired boat-based and inland survey sites, Prince William Sound, Alaska, 1992. The correlation for all sites ($N = 17$) was significant (Kendall's correlation coefficient *tau-b* = 0.370, $p = 0.039$).

= 23.3, df = 1, $p = 0.0001$) for unstandardized counts. Murrelet activity increased around mid-July and showed an approximately 3-fold increase in the number of detections compared to activity during June surveys (Fig. 3). Stations at the heads of bays had more detections than stations near exposed coasts ($\bar{x} = 67.3$, SE = 8.85, $N = 23$; and $\bar{x} = 33.8$, SE = 4.26, $N = 44$; respectively; $F = 7.17$, df = 1, $p = 0.010$). Exceptions to this trend were 4 bays that had glaciers at their heads, or from which the ice had recently retreated. These stations had very low numbers of detections ($\bar{x} = 4$; range 0–9). We found no difference in number of detections when observer and weather variables were tested (ANOVA; $p > 0.640$ for all variables).

We made 4–124 detections per survey at boat-based stations with subcanopy flight behaviors ($N = 12$, $\bar{x} = 51.8$, SE = 11.2), which did not differ from the number of detections at sta-

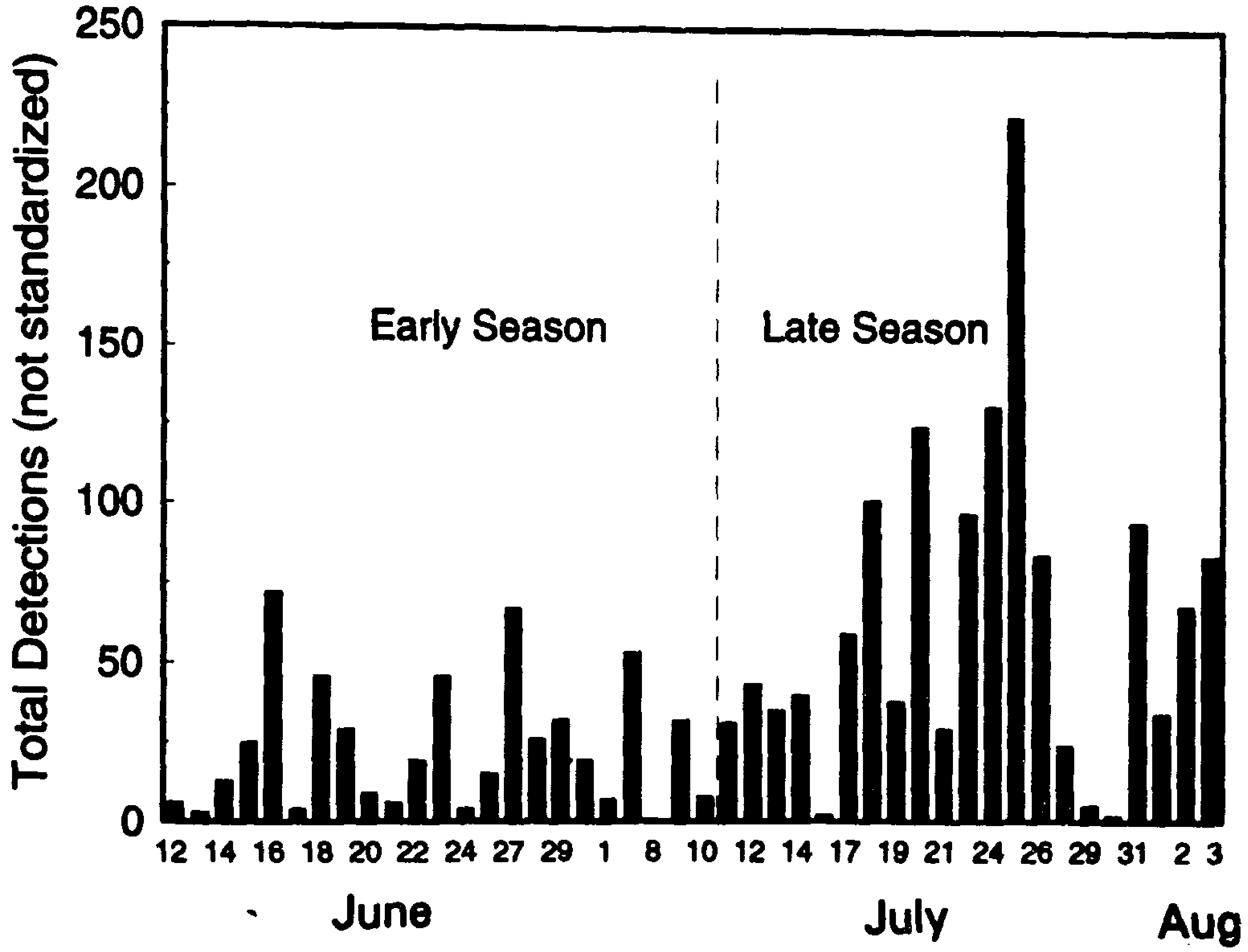

FIGURE 3. Number of marbled murrelet detections, by date, for boat-based surveys at 67 sites in Prince William Sound, Alaska, in 1992. Early season was between 12 June–10 July, and late season between 11 July–3 August. Mean and SE for each are 22.8, 19.6 and 67.6, 53.8, respectively. The difference is significant ($F = 0.020$, df = 1, $p = 0.0001$).

TABLE 1. Timber-type classifications used for analyses of habitat use, including definitions of the amount of area each contributed to cumulative total, for areas within 1 km of 60 dawn-watch stations in western Prince William Sound, Alaska in 1992. Productive forest is defined by 4 forest types (FT1–FT4), which are defined by tree-size class (STCL) and volume class (VOCL; see text).

Land classification	Definition	% land	p
Nonforest	land <10% treed	10	0.492
Forest	land >10% treed	90	0.008
Unproductive	<1.4 m^3/ha growth/yr	78	0.0001
Productive	>1.4 m^3/ha growth/yr	22	0.0009
FT1 Forest	STCL 1, 2; VOCL 1, 2	5	0.785
FT2 Forest	STCL 3, 4; VOCL 1, 2	55	0.043
FT3 Forest	STCL 3, 4; VOCL 3	34	0.0004
FT4 Forest	STCL 3, 4; VOCL 4	6	0.656

tions without subcanopy behaviors ($N = 55$, $\bar{x} = 43.4$, SE = 4.98; $t = -0.685$, df = 15.5, $p = 0.481$). However, only 3 of the 12 boat-based stations with subcanopy flight behaviors had fewer than 30 detections. Further, there was a positive correlation between the total number of detections and the total number of subcanopy flight behaviors observed at each boat-based station (*tau-b* = 0.220, $p = 0.011$). Approximately 15% and 7% of all detections from boat-based watches were unknown behaviors on or over the water, and birds flying over the water, respectively.

Murrelet Activity Relative to Habitat Type

Ninety percent of the total land area within 1 km of all stations was forested (Table 1). Only 2 stations were in completely treeless areas and 2 additional stations had > 85% of the surrounding 1-km area as unforested land. Unproductive forest comprised 78% of the forested land (34 of the stations were in areas of > 75% unproductive forest) while productive forest comprised the remaining 22%. Most (95%) of the productive forest had large trees (STCL 3 and 4). Among the 4 forest types classified by tree-size class and volume class, FT2 and FT3 forests accounted for 89% of all productive forest (Table 1). There was no significant difference between stations at bay heads and those along exposed coastline, in the amount of forested, or productive (FT1, FT2, FT3 or FT4) habitat.

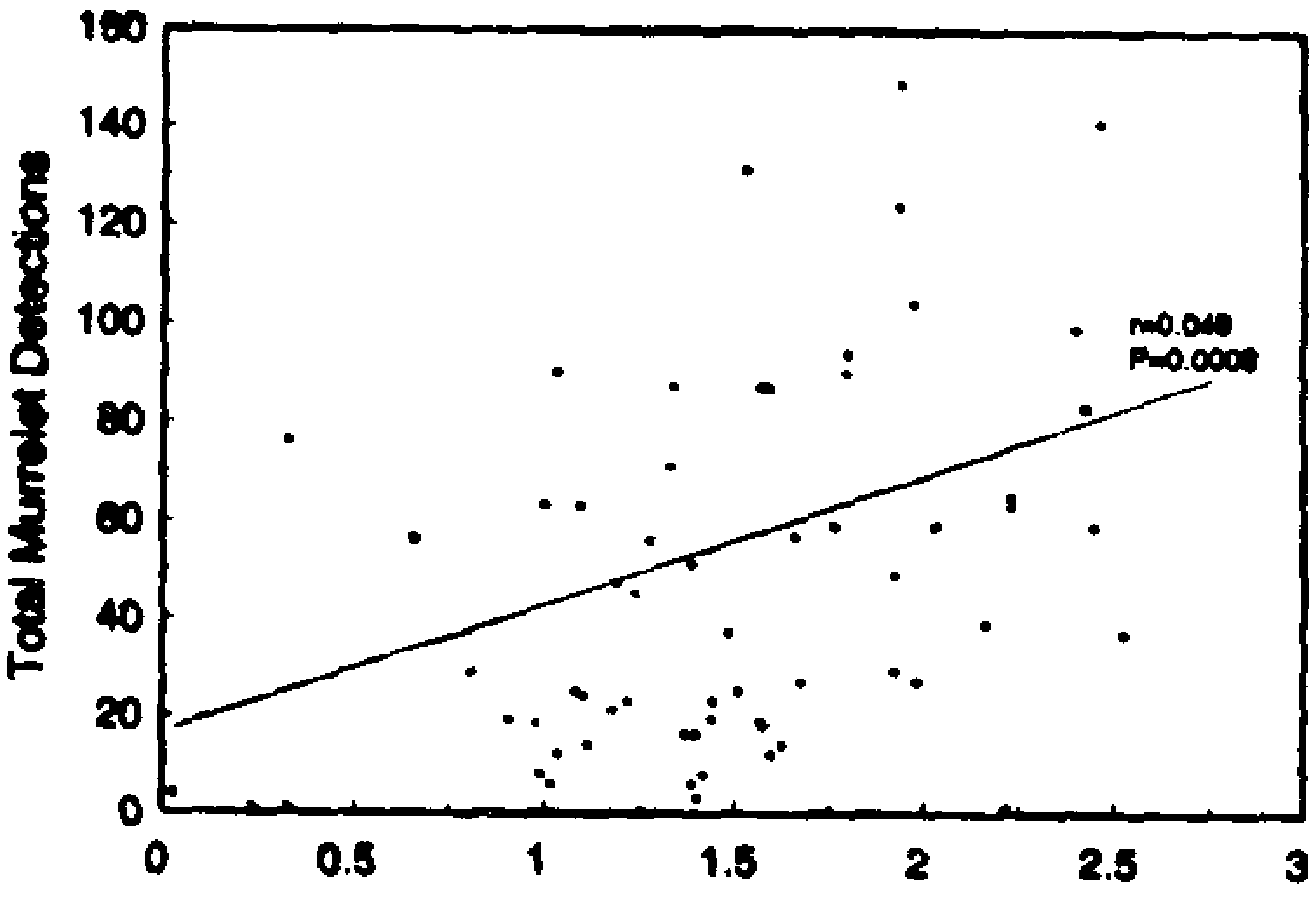

FIGURE 4. Number of marbled murrelet detections during each survey *vs.* the total area of forested habitat within a 1-km radius of each site (Kendall's correlation coefficient *tau-b* = 0.409, $p = 0.0008$). Data are from boat-based surveys in Prince William Sound, Alaska, 1992.

Number of murrelet detections was correlated with the area of forested habitat surrounding each dawn-watch station ($r = 0.409$, $p = 0.0008$; Fig. 4), but not with the area of nonforested lands ($r = 0.085$, $p = 0.492$). Both the area of productive ($r = 0.398$, $p = 0.0009$) and unproductive ($r = 0.561$, $p = 0.0001$) forest lands were positively correlated to the number of murrelet detections. Among the more specific forest types defined by tree-size and volume class, area of FT2 and FT3 habitat within 1 km of all stations showed a significant positive correlation with number of detections ($r = 0.345$, $p = 0.006$ for FT2; $r = 0.248$, $p = 0.043$ for FT3) as did area of FT2, FT3 and FT4 habitat combined ($r = 0.260$, $p = 0.043$). Neither area of FT1 nor FT4 alone was correlated with murrelet activity.

Stations with ($N = 12$) and without ($N = 55$) subcanopy flight behaviors did not differ in the amount of productive forest within 1 km of the station. There was no correlation between the area of forest land within 1 km and the number of murrelet detections at the 17 inland stations.

DISCUSSION

Survey Methods

Boat-based surveys were an effective technique for conducting dawn watches for marbled murrelets in PWS. This assessment was based on the fact that numbers of detections for boat-based surveys were similar to concurrent inland dawn surveys that followed a more standard survey protocol. In addition, boat-based surveys detected the same degree of change over the season as did surveys at monitoring stations on Naked Island in 1991 and 1992 (Kuletz et al. 1994). A trend for greater detections in bays than along exposed coastlines observed elsewhere in Alaska was also evident from boat-based surveys, and the low percentage of stations with subcanopy flight behavior (19%) was similar to that from inland surveys at Naked Island (22%; Kuletz et al. 1995b).

Although we found no significant difference in the number of subcanopy behaviors recorded at inland and boat-based stations, there appeared to be a trend of fewer subcanopy detections at boat-based stations. Because subcanopy detections were usually ≤ 100 m from the observer, the use of boat-based survey stations probably limits observers' abilities to observe subcanopy behaviors. However, subcanopy flight behaviors were detected by boat-based observers, indicating that boat-based surveys can be useful for locating potential nesting areas near shore. Furthermore, while nesting habitat located > 500 m inland probably cannot be evaluated using this method, general activity and subcanopy flight behaviors may be helpful in determining high-use areas to guide more intensive surveys for nesting areas farther inland.

Station locations relative to bays and open coasts influenced murrelet activity. This may reflect a preference for bay heads as nesting habitat or the occurrence of flyways to locations farther inland, although we found no difference in the proportion of forest type between bay and exposed stations. Bay heads may provide protection from weather or suitable microclimatic conditions (*e.g.*, for moss growth). However, it is possible that the difference in number of detections reflects better audio conditions or more land area around survey stations at bay heads (Kuletz et al. 1994).

Although we did not find a significant difference in activity between inland and boat-based surveys, there was a trend of higher numbers of detections at inland surveys. This suggests a difference in habitat use between shoreline and more inland areas, but may also reflect the distance of the boat from land. Standardization of counts from boat-based and inland stations may be required if these counts are used interchangeably.

High winds and heavy rain were not factors in our surveys, and weather (fog, rain) appeared to have little effect on counts. However, murrelet activity was affected by season and detections were greater in mid- to late July. Weather and season (time of year) are known to affect murrelet activity elsewhere (Manley et al. 1992, Naslund 1993, Kuletz et al. 1994, Nelson and Peck 1995, O'Donnell et al. 1995).

Dawn-watch Activity and Habitat

From our analyses, forested areas appeared to be important to murrelets. When forest-type data were analyzed individually, 2 of the 3 forest types with the largest trees (> 28 cm dbh), FT2 and FT3, were positively correlated to murrelet activity. That FT4 alone was not correlated to activity was probably due to the small amount of FT4 forests within 1 km of survey stations. Because all nests on Naked Island were found in FT3 and FT4 forests (Naslund et al. 1995), the high activity observed in FT2 forests might be related to easier detectability in less dense forests (Kuletz et al. 1995b). However, we cannot discount the possibility that FT2 forests, with large trees and low volume, may serve as nesting habitat, habitat that is contiguous with nesting habitat, or areas where marbled murrelets engage in display and social activities with conspecifics.

High activity levels in FT2 and FT3 forests, with the largest trees but not the largest volume class, were consistent with trends observed on Naked Island (Kuletz et al. 1995b, Naslund et al. 1995). However, because FT2 and FT3 habitat composed 90% of the habitat around our survey stations, our ability to extrapolate our results to other areas of PWS is limited. In addition, it may be difficult to identify murrelet use of small patches of a unique habitat, especially if activity levels are low.

Our study suggests that preliminary information on murrelet activity and habitat use can be obtained using boat-based or shoreline surveys. The boat-based surveys allowed us to sample broad habitat types throughout western PWS and was an efficient method for surveying murrelet activity at locations otherwise difficult to access. The boat served as transportation, lodging, and observation platform. Using a boat as the dawn-watch station reduced the need to hike and camp inland, thus allowing more days to conduct surveys, an advantage over inland surveys when covering a large geographic area where the breeding season is short (May through the first week of August in PWS; Kuletz et al. 1994). This method also increases safety for observers where terrain is rugged and remote and bears are prevalent. However, because of the disadvantages of boat-based surveys (*e.g.*, low detectability of subcanopy flight behaviors) murrelets are probably best monitored from inland stations whenever feasible.

Our surveys were possible because much of the nearshore environment in PWS has protected waters with safe anchorages, which may not be typical of other remote locations. PWS may be particularly appropriate to boat-based surveys because of the topography and distribution of habitat. Most nests in Alaska have been found within 1 km from shore (Naslund et al. 1995; Kuletz et al., unpubl. data). Throughout most of PWS, forest and subalpine vegetation is located within a narrow (0.5-1 km) band of the shoreline, therefore, potential murrelet nesting habitat may be concentrated within this restricted habitat. Other geographic regions that may be conducive to boat-based survey methods include southeastern Alaska and the coast of British Columbia.

The results of the habitat analyses suggest that the forest stand definitions for PWS based on tree-size class and volume class could provide preliminary identification of potential nesting habitat, particularly for tree-nesting murrelets. More detailed information on microsite vegetation characteristics (*e.g.*, epiphyte or microclimatic information) would help identify a greater range of habitat types used by murrelets. Additional data on habitat characteristics in relation to nest success is also needed to further refine definitions of suitable habitat.

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APPENDIX. Site, survey type, number of detections, and other data collected at each survey station (N = 84; including boat-based, N = 44, shoreline, N = 23, and inland sites, N = 17), during marbled murrelet habitat survey in Prince William Sound, Alaska, 1992.

Date	Observer	Survey type[a]	Detections		Shoreline (Bay/Exposed)	% clouds	Rain[d]	Ceiling[e]
			Total[b]	Stand (Sub)[c]				
12 June	A	Boat-based	6	12 (1)	Exposed	0	none	clear
12 June	B	Boat-based (I)	7	14	Exposed	0	none	clear
13 June	B	Boat-based	3	6	Exposed	0	none	clear
13 June	A	Boat-based (I)	0	0	Bay	0	none	clear
14 June	C	Boat-based	13	25 (1)	Exposed	20	none	clear
14 June	B	Boat-based (I)	63	124 (4)	Exposed	25	none	clear
15 June	A	Boat-based	25	49	Exposed	100	none	below
15 June	B	Boat-based	12	24	Exposed	100	none	above
16 June	E	Boat-based	72	141	Bay	100	rain	above
16 June	C	Inland	41	80	Bay	100	rain	below
17 June	A	Boat-based	4	8	Exposed	100	rain	fog
17 June	B	Inland	9	18	Exposed	100	rain	clear
18 June	B	Boat-based	46	90 (1)	Bay	100	rain	above
18 June	E	Boat-based (I)	9	18	Exposed	100	rain	above
19 June	C	Boat-based	29	57	Exposed	95	none	above
19 June	D	Boat-based (I)	30	59	Bay	95	none	above
20 June	A	Boat-based	9	18	Exposed	0	none	clear
20 June	D	Boat-based (I)	30	59	Bay	5	none	above
21 June	B	Boat-based	6	12	Exposed	100	rain	below
21 June	D	Boat-based (I)	12	24	Exposed	100	rain	above
22 June	C	Boat-based	19	37	Exposed	80	none	below
22 June	B	Boat-based (I)	2	4	Exposed	60	none	above
23 June	A	Boat-based	46	90	Bay	20	none	above
23 June	D	Inland	45	88 (1)	Bay	40	none	above
24 June	B	Boat-based	4	8	Exposed	100	rain	above
24 June	D	Inland	16	31	Exposed	100	rain	above
25 June	C	Boat-based	15	29	Exposed	35	none	above
25 June	D	Inland	62	122	Exposed	85	none	above
27 June	B	Boat-based	67	131	Bay	100	none	fog
27 June	D	Boat-based (I)	14	27	Exposed	100	rain	below
28 June	C	Boat-based	26	51	Bay	35	none	above
28 June	D	Boat-based (I)	48	94	Bay	25	none	above
29 June	B	Boat-based	32	63	Exposed	95	none	below
29 June	C	Inland	22	43	Exposed	100	none	above
30 June	A	Boat-based	19	37	Exposed	45	none	above
30 June	H	Boat-based (I)	30	59 (2)	Exposed	80	none	above
1 July	C	Boat-based	7	14	Bay	10	none	above
1 July	D	Boat-based (I)	6	12	Exposed	10	none	above
7 July	A	Boat-based	53	104	Bay	100	rain	above
7 July	B	Boat-based (I)	24	47	Exposed	100	rain	above
8 July	B	Boat-based	0	0	Exposed	100	none	above
9 July	C	Boat-based	32	63	Bay	100	rain	above
9 July	A	Inland	52	102	Bay	100	rain	above
10 July	A	Boat-based	8	16	Exposed	100	none	below
10 July	C	Boat-based (I)	39	76	Exposed	100	rain	below
11 July	B	Boat-based	31	21 (1)	Exposed	100	rain	below
11 July	C	Inland	10	7	Exposed	100	rain	below
12 July	G	Boat-based	43	29	Bay	100	rain	above
12 July	C	Inland	12	8	Bay	95	none	below
13 July	F	Boat-based	35	23 (1)	Exposed	95	none	above
13 July	G	Boat-based (I)	56	37	Bay	100	none	above
14 July	C	Boat-based	40	27	Bay	100	rain	below
14 July	F	Inland	13	9	Bay	100	rain	below
16 July	C	Boat-based	2	1	Exposed	100	none	above
16 July	B	Boat-based (I)	106	71	Exposed	100	none	below
17 July	A	Boat-based	59	39	Exposed	95	none	above
18 July	B	Boat-based	101	67 (4)	Exposed	100	none	below

APPENDIX. Continued.

Date	Observer	Survey type[a]	Detections		Shoreline (Bay/Exposed)	% clouds	Rain[d]	Ceiling[e]
			Total[b]	Stand (Sub)[c]				
18 July	C	Boat-based (I)	6	4 (2)	Exposed	100	none	above
19 July	C	Boat-based	38	25	Exposed	100	rain	below
19 July	A	Boat-based (I)	28	19	Bay	100	none	below
20 July	A	Boat-based	124	83	Bay	60	none	above
20 July	B	Inland	97	65	Bay	45	none	above
21 July	B	Boat-based	29	19	Exposed	100	none	above
21 July	C	Inland	55	37 (3)	Exposed	90	none	above
22 July	C	Boat-based	97	65	Bay	100	rain	above
22 July	A	Inland	162	108 (8)	Bay	100	none	below
24 July	A	Boat-based	131	87 (2)	Bay	100	rain	above
24 July	C	Boat-based (I)	148	99	Bay	100	none	above
25 July	B	Boat-based	223	149	Bay	100	rain	below
25 July	A	Inland	333	222 (1)	Bay	100	none	below
26 July	A	Boat-based	84	56	Exposed	100	none	below
26 July	C	Boat-based (I)	130	87	Exposed	100	none	above
28 July	B	Boat-based	24	16	Exposed	100	rain	below
28 July	A	Inland	107	71 (3)	Exposed	100	rain	below
29 July	B	Boat-based	5	3	Bay	100	rain	below
30 July	B	Boat-based (I)	9	6	Exposed	100	none	below
30 July	A	Boat-based	2	1	Exposed	90	none	above
31 July	C	Boat-based	94	63	Exposed	90	none	above
31 July	B	Inland	128	85	Exposed	100	none	above
1 Aug	A	Boat-based	34	23 (2)	Exposed	100	none	above
2 Aug	A	Boat-based	68	45	Bay	100	none	below
2 Aug	C	Inland	51	34	Bay	95	none	above
3 Aug	B	Boat-based	84	56	Exposed	100	rain	below
3 Aug	A	Boat-based (I)	130	87 (2)	Exposed	100	none	below

[a] Survey Type (I) represents boat-based watches conducted from inflatable or shoreline.

[b] Total number of detections.

[c] Total number of standardized detections; number of subcanopy behaviors (in parentheses).

[d] Rain was classified for the ANOVA into days that had rain or days that did not.

[e] Ceiling indicates whether the cloud ceiling was above the dominant ridgeline, below it, or nonexistent ('clear').