AT-SEA ACTIVITY PATTERNS OF MARBLED MURRELETS ADJACENT TO PROBABLE INLAND NESTING AREAS IN THE QUEEN CHARLOTTE ISLANDS, BRITISH COLUMBIA

MICHAEL S. RODWAY AND JEAN-PIERRE L. SAVARD[1]

Canadian Wildlife Service, R.R. 1, 5421 Robertson Road, Delta, British Columbia, Canada V4K 3N2

DONALD C. GARNIER

Biology Department, University of Victoria, Victoria, British Columbia, Canada V8W 2Y2

MOIRA J. F. LEMON

Canadian Wildlife Service, R.R. 1, 5421 Robertson Road, Delta, British Columbia, Canada V4K 3N2

ABSTRACT—We surveyed marbled murrelets (*Brachyramphus marmoratus*) at Long Inlet and Shields Bay in the Queen Charlotte Islands, British Columbia, from May through July during the 1990 breeding season. Abundance varied daily and through the season. Maximum counts at sea were recorded prior to the egg-laying period in early May, and numbers were lowest in mid-June, during incubation, at both Long Inlet and Shields Bay. Mean numbers peaked in July during the latter part of the nestling period at Long Inlet but remained low at Shields Bay. The distribution of birds in Long Inlet changed over the season with a greater proportion of birds gathering at the head of the inlet as the season progressed. More birds were observed on morning surveys, 2–5 hr after sunrise, than on afternoon and evening surveys in Long Inlet. In Shields Bay, birds were more abundant in the evening. Numbers of detections in the forest peaked in late July at both sites and were positively correlated with abundance of murrelets in Long Inlet but not in Shields Bay. Contrasting patterns of abundance in Long Inlet and Shields Bay pose complications for survey design, and indicate that at-sea distribution does not dependably reflect breeding distribution.

Population sizes of marbled murrelets (*Brachyramphus marmoratus*) in North America have been estimated from at-sea surveys (Carter and Erickson 1992, Mendenhall 1992, Nelson et al. 1992, Rodway et al. 1992, Speich et al. 1992), but reliability of estimates is poor, especially in British Columbia and Alaska where most of the nominate subspecies *B. m. marmoratus* occurs (Mendenhall 1992, Rodway et al. 1992, Piatt and Ford 1993). The species is listed as threatened in Canada (Rodway 1990) and the United States (U.S. Fish and Wildlife Service 1992) and reliable methods for censusing and monitoring populations are needed.

Murrelet populations are difficult to census at sea because they are widely distributed in nearshore waters and have a clumped dispersion pattern, with high daily and seasonal variability (Carter and Sealy 1984, 1990; Sealy and Carter 1984; Rodway 1990; Kaiser et al. 1991; Savard and Lemon 1992; Sharpe et al. 1992; Speich et al. 1992). Interpretation and standardization of counts for comparative purposes is problematical because of the extended periods of time required to survey large areas of the sea and the changes in abundance that occur daily and seasonally. The few studies that have investigated variability in marbled murrelet abundance at sea during the breeding season in British Columbia have reported higher numbers on dawn and morning surveys than on afternoon and evening surveys (Carter and Sealy 1984, 1990), movements of large numbers of birds out of coastal inlets near dawn and dusk

[1] Present address: *Canadian Wildlife Service, 1141 Route De L'Eglise, P.O. Box 10100, Ste-Foy, Quebec, Canada* G1V 4H5.

(Prestash et al. 1992), and increases in numbers from May to late June and July (Carter 1984, Kaiser et al. 1991).

Variability in activity levels has been studied at inland sites (Eisenhawer and Reimchen 1990, Paton and Ralph 1990, Paton et al. 1990, Rodway et al. 1991, Manley et al. 1992) but the relationship between activity levels and population numbers is unknown (Paton et al. 1992, Rodway et al. 1993) because techniques have not been developed to census populations at inland sites as they have for populations at sea (Sealy and Carter 1984). The relationship between abundance at sea and activity levels at inland nesting sites has not been investigated (but see Leschner and Cummins 1992a), although it has been suggested that at-sea distribution reflects breeding distribution in adjacent forested areas (Sowls et al. 1980, Nelson et al. 1992, Piatt and Ford 1993).

This paper is part of a larger study of marbled murrelets in the Queen Charlotte Islands, British Columbia (Rodway et al. 1991). Our objectives were: 1) to investigate variability in abundance of marbled murrelets at sea during the breeding season; 2) to determine the relationship between abundance at sea and activity at adjacent inland nesting areas; and 3) to evaluate the implications of observed variation in abundance at sea for survey and monitoring methodology.

METHODS

Study Area

At-sea surveys were conducted in protected nearshore waters in Long Inlet off Lagins Creek and in Shields Bay off Phantom Creek at the southern end of Graham Island in the Queen Charlotte Islands, British Columbia (Fig. 1). Inland stations at Lagins Creek (53° 14′ 14″ N; 132° 22′ 33″ W) and Phantom Creek (53° 20′ 44″ N; 132° 20′ 49″ W) were 3.6 and 4.8 km from the nearest shore of Long Inlet and Shields Bay, respectively. Inland survey stations were located in old-growth (325+ year-old) forest in a western red cedar (*Thuja plicata*)–Sitka spruce (*Picea sitchensis*)–foamflower (*Tiarella unifoliata*) site association within the Wet Hypermaritime Coastal Western Hemlock biogeoclimatic subzone (Banner et al. 1990).

Surveys

Preliminary surveys, which were conducted in early May 1990 to choose study sites, documented use of Long Inlet and Shields Bay by marbled murrelets. Intensive morning surveys (Paton et al. 1990) at the 2 fixed inland stations (see Rodway et al. 1993) and at-sea surveys of the adjacent waters were conducted for 4 consecutive days approximately every second week between 16 May and 27 July 1990. Detailed methods for inland surveys are given in Rodway et al. (1993). Long Inlet was surveyed by inflatable boat 8 times per day at 2-hr intervals ($N = 154$) beginning 30 min after sunrise. Shields Bay was surveyed by telescope from shore at the same times and more frequently ($N = 249$). Sunrise varied from 0419 to 0456 hr PST (Atmospheric Environment Service, Environment Canada) during the course of the study. The start and end times were the earliest and latest that it was dependably light enough to allow good visibility. Rough weather impaired visibility and surveys were not done when sea chop exceeded 20–30 cm, or during heavy rains (5.5% of scheduled survey times).

Long Inlet is 4 km long and 900–1000 m wide. Boat transects began at the head of the inlet, ran out the inlet along the southwest side and then back in the inlet along the northeast side, staying approximately 250 m from shore so as to survey half the area on each transit (Fig. 1). Each survey took 25–30 min. A single observer-driver kept records of murrelets on either side of the boat, which allowed us to characterize the distribution of the birds in southwest, center, and northeast quarters of the inlet. We also divided the inlet into quarters length-wise to analyze the distribution of birds from the head to the mouth of the inlet (Fig. 1). Counted birds were on the water and generally remained on the surface or dove if the boat passed close to them. Rarely, birds flew at our approach. From observations of the behavior of birds as we passed them, we were confident that they were not moving across the inlet and that recounting birds was not a problem. The survey area in Shields Bay was 3 km long and 900–1100 m wide. Observations were made from the east side of the bay (Fig. 1).

At-sea surveys were done on the same days as inland morning surveys at fixed stations, and mean and maximum daily counts on the water were correlated with numbers of detections recorded at inland stations. ANOVA was used to test the effects of date and time of day on murrelet abundance. Tolerance for Type I error was set at 5% for all tests. Residuals were checked for acceptability.

RESULTS

Abundance and Distribution in Long Inlet

Numbers of marbled murrelets counted in Long Inlet varied during the study period from a maximum of 117 individuals on 18 May to a minimum of 10 on 11 June. The highest count of 147 murrelets was recorded on a preliminary survey on 11 May. Numbers counted per sur-

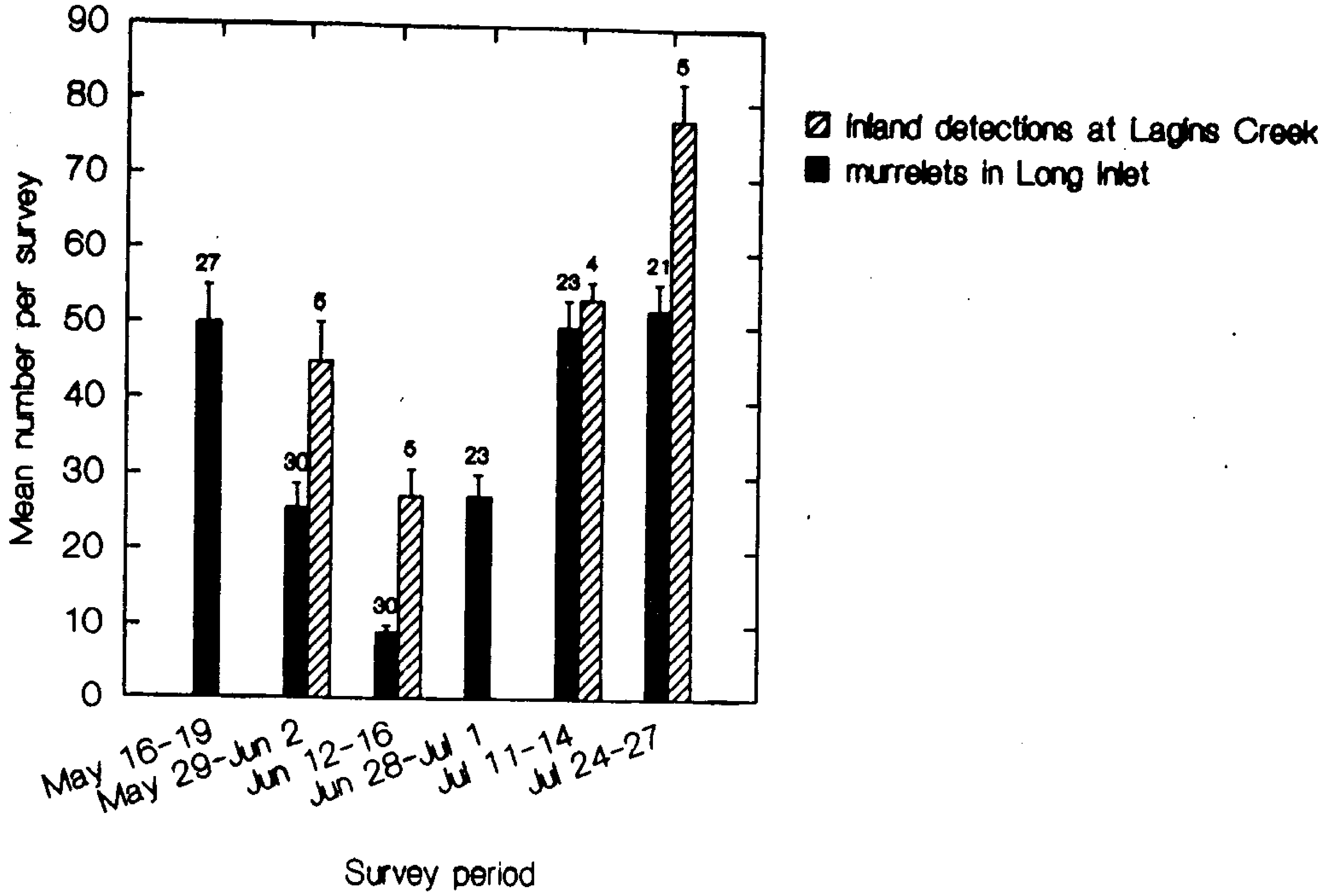

FIGURE 2. Comparison between mean (± SE) number of marbled murrelets counted per survey in Long Inlet and mean number of detections recorded during morning surveys at the adjacent inland station at Lagins Creek. Numbers at the tops of bars give number of surveys per survey period. Missing bars indicate that no surveys were conducted during that survey period.

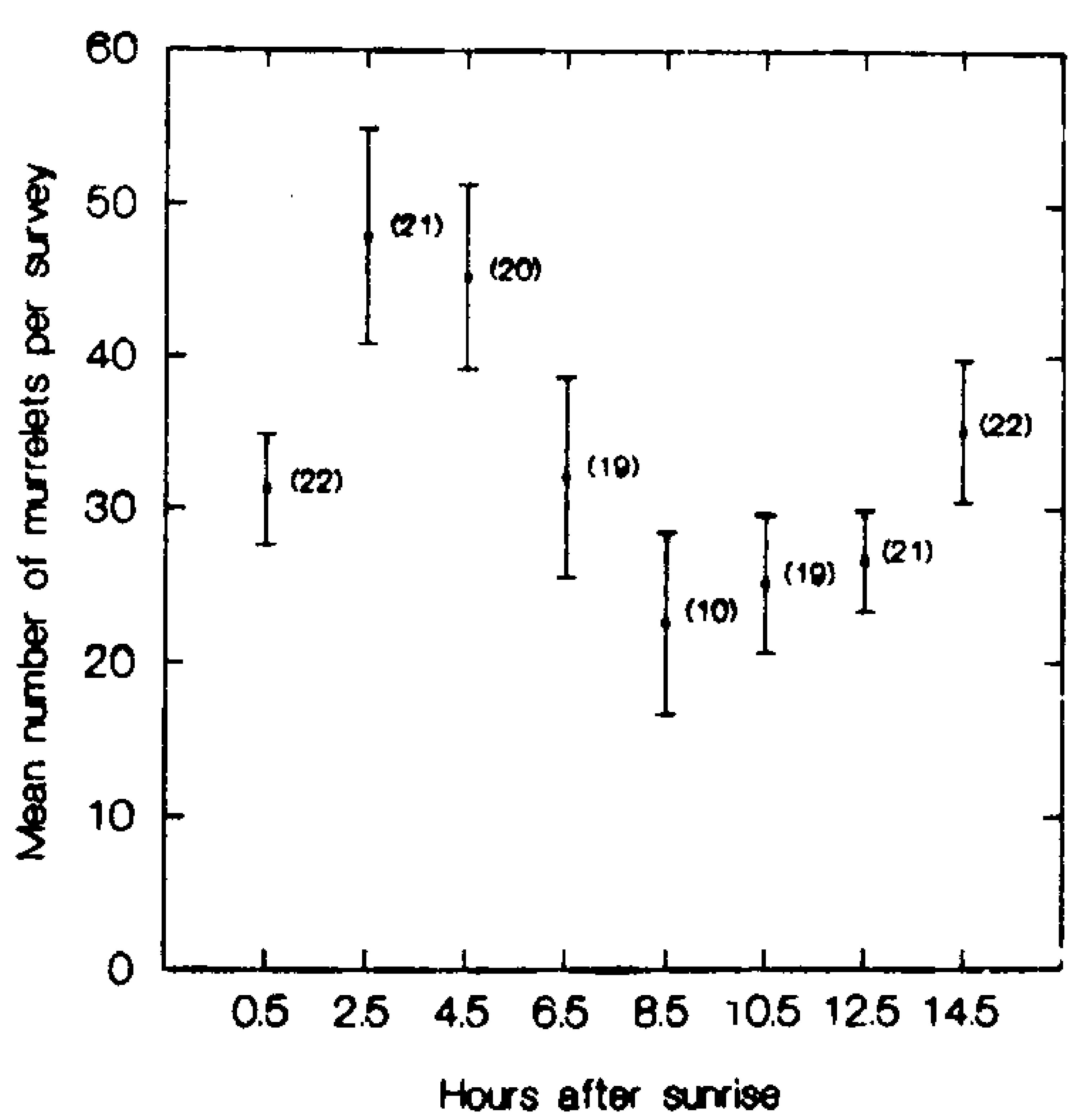

FIGURE 3. Mean (± SE) number of marbled murrelets counted at different times of day in Long Inlet. Numbers in brackets give number of surveys.

vey were higher in mid-May and late July than in mid-June ($F_{5,148} = 24.85$, $p < 0.001$; Fig. 2).

Time of day affected the number of murrelets counted ($F_{7,146} = 2.80$, $p = 0.009$). Peak numbers occurred at various times of day, but on average, numbers increased early in the morning, decreased from the morning to the late afternoon, and increased again in the evening (Fig. 3).

Marbled murrelets were more abundant near the mouth of Long Inlet in mid-May and more abundant at the head of the Inlet in June and July ($\chi^2 = 80.08$, df= 15, $p < 0.0001$; Fig. 4). They were uncommon along the southwest side of the Inlet throughout the study period (2.7% of all birds counted), most birds gathering through the center (77.2%) and northeast (20.1%) sides of the Inlet ($\chi^2 = 1315$, df = 2, $p < 0.0001$, compared to equal numbers per area). The distribution of larger flocks (10–34 birds) was similar to that of all birds ($\chi^2 = 1.11$, df = 2, $p = 0.575$), most occurring in the center of the Inlet (84%, $N = 25$).

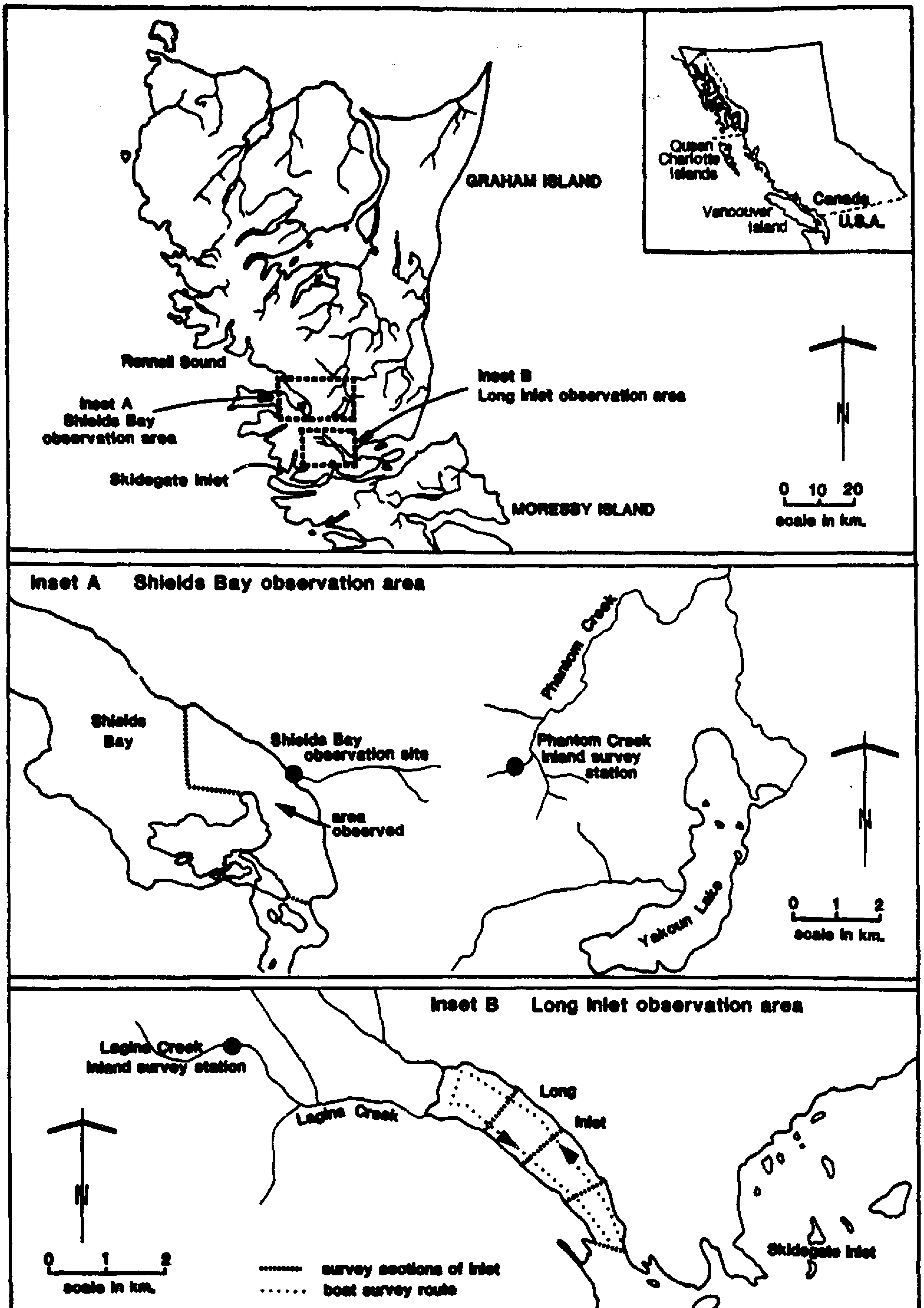

FIGURE 1. Location of marbled murrelet study areas in the Queen Charlotte Islands.

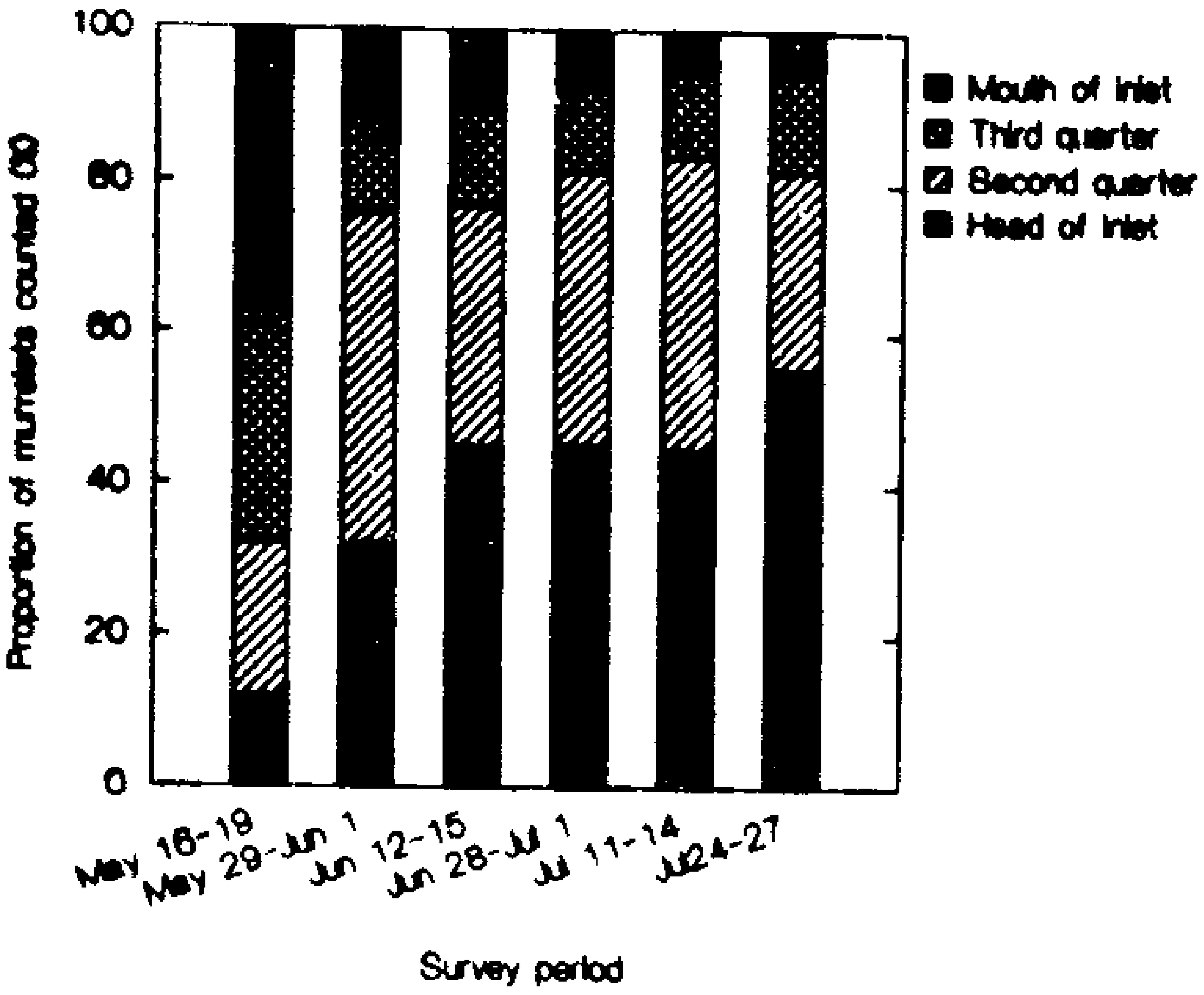

FIGURE 4. Proportion of marbled murrelets counted in 4 sections of Long Inlet during weekly survey periods. Counts from all surveys were combined to calculate proportions. Number of surveys per period are the same as in Fig. 2.

Abundance in Shields Bay

Numbers of marbled murrelets counted in Shields Bay were higher in mid-May than in June and July ($F_{5,25} = 17.88$, $p < 0.001$), with lowest numbers occurring in mid-June (Fig. 5). Counts of ≤ 65 birds recorded prior to the main survey period suggested a larger population of marbled murrelets using the bay in early May. Few birds were seen in June and July, and even in May there were < 10 birds counted on 88% of surveys ($N = 106$).

Time of day also affected numbers counted in Shields Bay ($F_{7,145} = 3.99$, $p = 0.001$), although the daily trend was different than in Long Inlet. On average, numbers declined in the morning and increased to a maximum in the evening (Fig. 6). There were no murrelets present in the bay on many surveys (51%), especially during the middle of the day.

Fourteen percent of birds sighted in Shields Bay were flying, either to or from the north or

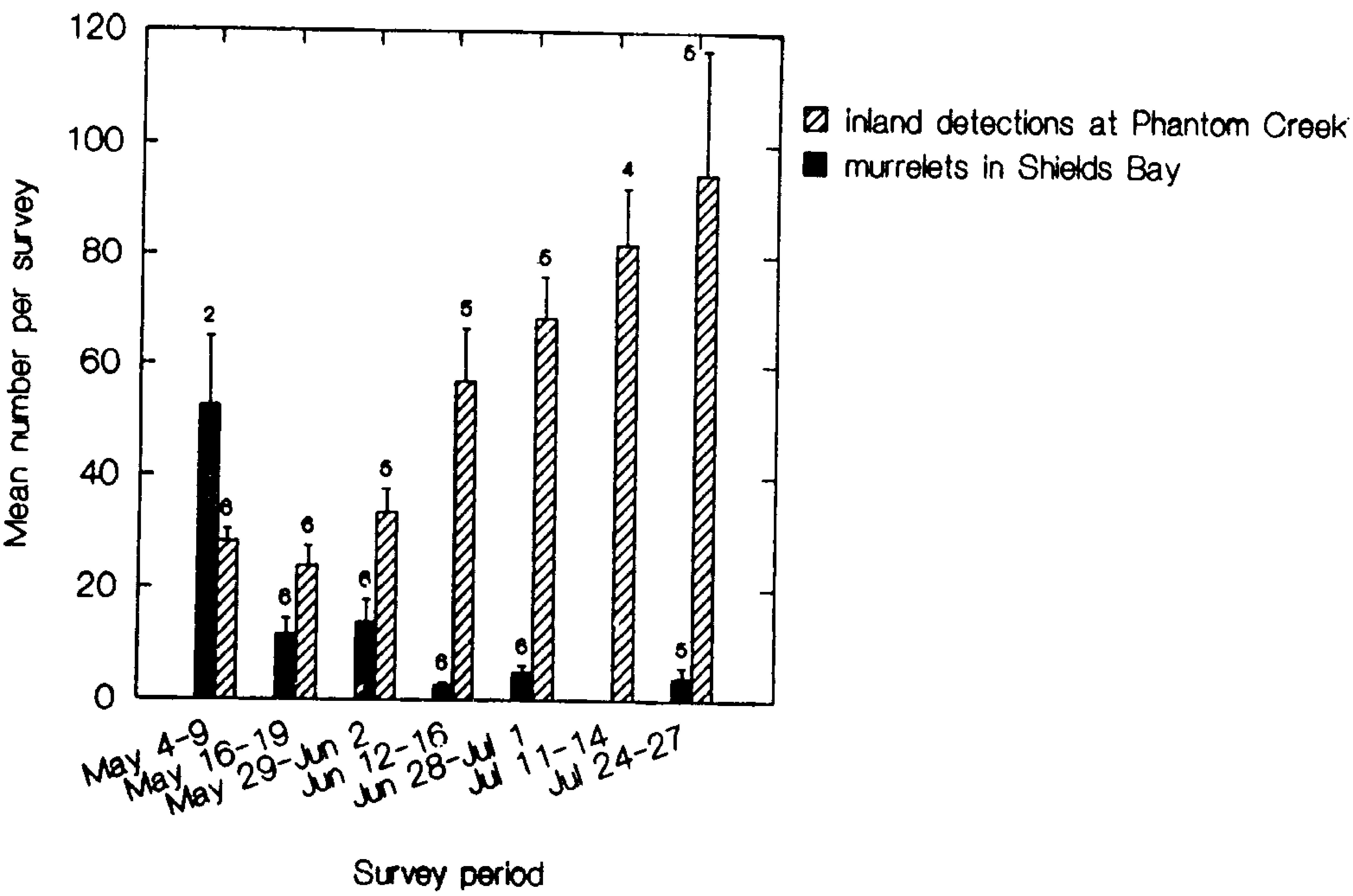

FIGURE 5. Comparison between mean (± SE) maximum number of marbled murrelets counted per day in Shields Bay and mean number of detections recorded during morning surveys at the adjacent inland station at Phantom Creek. Maximum number of murrelets counted in Shields Bay per day were used to calculate weekly means because means from all surveys were so low (see text). Numbers at the tops of bars give number of surveys per survey period. Missing bars indicate that no surveys were conducted during that survey period.

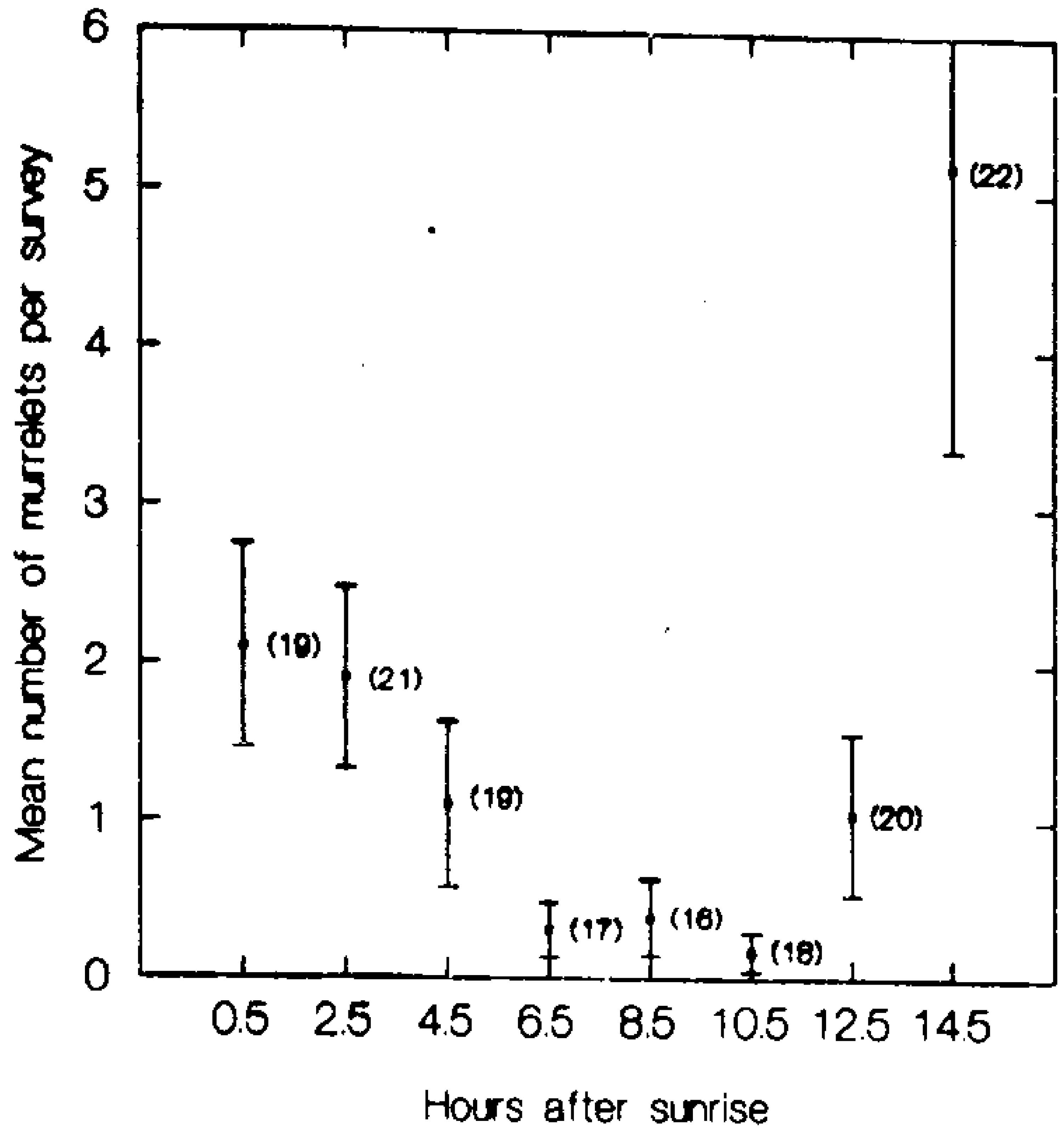

FIGURE 6. Mean (± SE) number of marbled murrelets counted at different times of day in Shields Bay. Numbers in brackets give number of surveys.

northwest. In May, most flying birds (77%, N = 35) were observed in the early morning (0430–0600 hr) flying out of the bay, whereas most flying birds seen in June (67%, N = 46) were flying inland in the evening (1900 to 2130 hr). Proportions of flying birds seen in mornings and evenings differed significantly between May and June ($\chi^2 = 34.20$, df = 1, $p < 0.001$). Only 4 birds were seen flying in July. Surveys conducted outside the study area indicated that murrelets were more abundant to the northwest in Rennell Sound (Rodway et al. 1991).

Relation to Inland Activity Levels

The number of detections recorded at both inland stations increased through the season to a peak in late July (Figs. 2 and 5). The number of detections recorded during morning surveys at the fixed-inland station in Lagins Creek was positively correlated with the mean number of murrelets counted per survey during the day in Long Inlet ($r = 0.81$, $p < 0.001$; Fig. 2). In Shields Bay, the maximum number of murrelets counted per day was negatively correlated with the number of detections at the Phantom Creek inland station, though the relationship was not significant ($r = -0.33$, $p = 0.105$; Fig. 5). We used maximum numbers in the analysis for Shields Bay because daily means were so low.

Discussion

Numbers of marbled murrelets in Long Inlet and Shields Bay varied daily and through the season, suggesting a complex use of the marine environment. The high daily variability in the number of murrelets present indicates that the birds often go outside the inlets to feed. As birds have been observed up to 100 km inland (Rodway 1990), they likely can cover large areas at sea to take advantage of feeding opportunities (Carter and Sealy 1990). Sealy and Carter (1984) observed birds flying considerable distances along shore from feeding areas before flying into forests. D. Varoujean et al. (unpubl. data) followed marbled murrelets with radio telemetry in Oregon during the breeding season and recorded extensive movements of murrelets at sea. In deep mainland fiords of British Columbia, murrelets are known to travel as much as 85 km at sea to reach feeding areas (Prestash et al. 1992). Foraging at distances of 100 km or more from breeding colonies is not uncommon for other alcid species (*e.g.*, Cairns et al. 1990, Hunt et al. 1990).

Maximum counts were recorded in early May and numbers were lowest in mid-June in both Long Inlet and Shields Bay. Numbers increased again in July in Long Inlet, but remained low in Shields Bay. High numbers in early May in both areas suggest that murrelets gather on the water close to breeding areas at the beginning of the breeding season. If so, surveys in early May could be used to indicate the proximity of important breeding grounds. This should be investigated further.

Decreasing numbers from May to mid-June may reflect involvement with incubation duties by part of the population (Sealy 1974, Carter 1984), although decreases exceeded 50% in both areas. An increase in the number of marbled murrelets in July has been observed in other studies (Sealy 1975a, Carter 1984, Paton and Ralph 1990, Kaiser et al. 1991). We believe this is due to the arrival of non-breeders near breeding areas. This has not been confirmed, although Sealy (1975a) observed increased numbers of subadults around Langara Island in July, and the pattern is similar to that observed in other seabirds where the number of nonbreeders increases in the colonies toward the end of the breeding season (Manuwal 1974, Sealy 1976, Wilson 1977, Gaston 1990). Low numbers observed in Shields Bay in July indicate that the influx is not a consistent pattern near breeding areas and is probably associated with feeding opportunities as well as prebreeding behavior.

Numbers of murrelets counted in Long Inlet were generally highest on morning surveys between 2–5 hr after sunrise, with a smaller peak in the evening. Carter and Sealy (1984, 1990) also found highest numbers in the morning in Barkley Sound, but did not report increases in the early morning and evening like those we observed in Long Inlet. Increases in the Inlet in the early morning may be due to the arrival of birds from inland sites, because murrelet activity over the forest in Lagins Creek extended as late as 1 hr after sunrise (Rodway et al. 1993). This suggests that birds fly first to waters close to nest sites before moving to other areas to feed. However, murrelets were often seen in the morning flying directly from inland areas over the local waters of Shields Bay to probable feeding areas farther away (Rodway et al. 1991). Increased numbers in the evening may reflect birds returning with fish for young (Simons 1980, Hirsch et al. 1981, Carter and Sealy 1990). All but 1 sighting of birds holding fish ($N = 17$) in Long Inlet and Shields Bay occurred in the evening (Rodway et al. 1991). Tide cycles have been associated with variation in murrelet abundance (Speckman et al. 1993), but relationships between tide and abundance were not investigated in this study.

Changes in numbers of murrelets within inlets over the breeding season has been reported in other studies (Morgan 1989, Vermeer 1989, Kaiser et al. 1991, Vermeer and Morgan 1992), and changes in distribution at scales of 1–10's of km were observed by Strong (1995) and Strong et al. (1994) along the Oregon coast. We do not know the reason for the seasonal increase in the proportion of birds gathering at the head of Long Inlet, but it may indicate a tendency to gather closer to nesting sites as the season progresses and young are about to fledge. Guiguet (1950) noted that adults tended to concentrate along the coast when young were about to fledge (also see Sealy 1975a).

Results in Long Inlet suggest a possible seasonal relationship between murrelet numbers on the water and activity levels in adjacent forest. The increase in the number of murrelets in Long Inlet in July coincided with an increase in activity in the forest. However, contrary results in Shields Bay caution that at-sea surveys may not always reflect the use of adjacent inland habitat. Speckman et al. (1993) also recorded highest numbers of murrelets in Auke Bay, Alaska during the period before egg-laying and found no relationship between abundance in the bay and activity in adjacent forest nesting area. The peak in inland activity in July has been a common feature of other murrelet studies (Paton et al. 1990, Carter and Erickson 1988, Manley et al. 1992, Marks et al. 1995).

The high variability in murrelet numbers at sea at hourly to seasonal time scales and at spatial scales from 1–10's of km has important implications for survey and monitoring methodology. Surveys conducted at smaller spatial or temporal scales than those over which movements of birds occur may underestimate populations (Prestash et al. 1992). Larger-scale surveys may overestimate populations if birds move within the survey area and are recounted (Gaston et al. 1987, Piatt and Ford 1993). Based on our observations over 1 season, and those of Speckman et al. (1993) in Alaska, we would recommend mornings before egg-laying begins as the best time to obtain estimates of populations using waters adjacent to probable nesting areas. Repeated sampling throughout the breeding season and from year to year in the same location is needed to determine the predictability of the variation observed in this study.

Given logistic constraints of surveying remote, convoluted coastlines and the high variability in distribution and abundance of marbled murrelets, it is unlikely that confident estimates of total populations inhabiting British Columbia or Alaskan waters will be obtained. Confidence limits cannot be placed on current estimates for large geographical areas (*e.g.*, Mendenhall 1992, Rodway et al. 1992, Piatt and Ford 1993) and those estimates will not serve to monitor population trends unless changes are drastic. However, identification and annual monitoring of populations aggregated at important feeding areas and in confined bodies of water like Long Inlet may provide an appropriate mechanism for monitoring population changes. Aggregations of murrelets at feeding areas in Barkley Sound were predictable on a daily and annual basis (Carter 1984, Carter and Sealy 1990). Those areas may provide the best opportunities for monitoring changes in populations over a period of years (*e.g.*, Kelson et al. 1995, Manley et al. 1994). The variation in abundance even in those locations means that repeated surveys will be required to obtain statistical power to detect changes.

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