Exxon Valdez Oil Spill
Restoration Project Final Report

Marbled Murrelet Foraging Patterns and a Pilot Productivity Index for Murrelets in Prince William Sound, Alaska

Restoration Project 94102
Final Report

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Study History : Restoration Project 94102 follows the pilot study conducted under Restoration Project 93501B (Pilot Study on the Capture and Radio Tagging of Murrelets in Prince William Sound, Alaska, July and August 1993). Project 94102 examines murrelet foraging behavior and marine habitat use. Previous marbled murrelet restoration studies described inland nesting habitat; projects 93051B (Information Needs For Habitat Protection: Marbled Murrelet Habitat Identification) and R15 (Identification of Marbled Murrelet Nesting Habitat in the *Exxon Valdez* Oil Spill Zone), preceded by Restoration Feasibility Study No. 4 (Identification of Upland Habitats Used by Wildlife Affected by the EVOS: Marbled Murrelets).

Abstract : We radio-tagged 47 marbled murrelets (*Brachyramphus marmoratus*) in 1994 in Prince William Sound, Alaska, to study foraging patterns during the breeding season. We hypothesized that birds in Port Nellie Juan (PNJ), a deep water fjord, traveled farther than birds at Naked Island (NI), surrounded by relatively shallow water. From 3 June-28 July we tracked 46 birds by air and boat. Relocations made from airplanes for 42 birds were used for analysis. Six inland sites ($\bar{x}$ = 1.6 km inland) were assumed to be nests. From the nests to relocations on water, straight-line distance mean = 16 km (SE = 5, max = 31). Foraging range indexes were used to compare all birds. We found no significant differences in foraging range indexes between birds at PNJ (N=32) and NI (N=10). Average straight-line distances for birds at PNJ were 17 km from capture site, 12 km between consecutive sites and 24 km maximum distance. Birds at NI averaged 16 km, 9 km and 26 km, respectively. Birds from NI selected shallower areas proportionally more than available, but PNJ birds did not. PNJ birds were often found over deep-water sills and near shelf edges. Peak numbers of juveniles in mid August and the disappearance of adults in August were similar at both areas, but the number of juveniles at NI ($\bar{x}$ = 13.1 per survey) was significantly higher than at PNJ ($\bar{x}$ = 7.4 per survey). However, the percentage of juveniles of total birds was not significantly higher. We suggest that the productivity index be refined to monitor murrelet productivity.

Key Words : *Brachyramphus marmoratus*, radio telemetry, foraging, marine habitat, at-sea distribution, productivity, Prince William Sound.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

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EXECUTIVE SUMMARY

This study began the first phase of a long-term study to determine if food is limiting marbled murrelet (*Brachyramphus marmoratus*) recovery in Prince William Sound. In 1994 we attempted to define the diet, foraging patterns and foraging habitat of marbled murrelets in Prince William Sound. We also developed a prototype murrelet productivity index, to determine if the relative reproductive success of murrelets could be compared among areas or years.

Our attempts to identify prey by observations of birds on the water and collection of fecal samples did not produce useful results. We were successful at the primary goal of radio-tagging 47 adults and one juvenile marbled murrelet in two types of marine habitats, a deep-water fjord (Port Nellie Juan) and an island (Naked Island) with a large shallow shelf. Our hypothesis was that murrelets nesting in the fjord would fly farther than birds nesting near shallow water in central Prince William Sound, to reach shallow productive foraging areas, as was observed for black-legged kittiwakes.

We tracked birds during the incubation and early nestling phase in June and July 1994. We mapped 232 relocations made from airplanes and 186 boat-based relocations. We found 6 inland locations assumed to be or documented as nests - 3 in trees and 3 on cliffs or steep slopes. For the six birds with nests (all in Port Nellie Juan), the average distance over water and not crossing land between nest and marine location was 21 km, and one bird averaged 40 km. For the six birds with nests, the average minimum area polygon was 119 km^2, with the largest average area for one bird being 295 km^2.

We found no significant differences in foraging range indexes between birds from the two areas. Murrelets had traveled an average 11 km between two consecutive locations (straight-line distance, separated by at least 1 day), or a maximum distance of 25 km between any two points during the study. One bird had a maximum distance of 94 km. Minimum area polygons varied widely among birds, from 4 to 920 km^2. The tagged juvenile traveled 12 km from its nest after fledging and then remained in a 9 km^2 area for two weeks before we lost contact.

Observations of juvenile murrelets at sea showed similar patterns of abundance at Naked Island and Port Nellie Juan. Juveniles were observed at low levels from 22 July to 8 August. Afterwards they increased and remained high until 1 September, when they began to decline. Concurrently, total numbers of murrelets declined steadily, and by early September they were 5% of July counts. Although absolute numbers of juveniles were significantly higher at Naked Island, fluctuations in total numbers there resulted in a non-significantly higher percentage of juveniles compared to Port Nellie Juan. Additional work is required

to refine this method of monitoring productivity, but it appears promising.

The radio-tagged murrelets demonstrated different use of available habitat between the areas. At Naked Island, birds selected shallow areas ($\bar{x}$ = 52 m deep) more than expected based on availability. At Port Nellie Juan, birds used areas in proportion to their availability, and were found on water that was significantly deeper ($\bar{x}$ = 115 m; because water >200 m was combined in GIS coverage, actual depth was greater) than sites used by birds at Naked Island. Birds at Port Nellie Juan were often found at sites likely to have upwelling, and may have been relying on concentrations of prey caused by local bathymetric and landform features. Thus, between areas, birds modified their habitat use but maintained equivalent foraging range indexes.

Marbled Murrelet Foraging Patterns in Prince William Sound, Alaska

INTRODUCTION

Marbled Murrelets (*Brachyramphus marmoratus*) are the most abundant seabird in Prince William Sound (PWS) in the summer, numbering about 100,000 birds, with approximately 25,000 birds remaining as winter residents (Klosiewski and Laing 1994). Murrelets have declined significantly since the early 1970's, when they were estimated to number 300,000 in the summer (Klosiewski and Laing 1994). An estimated 8,400 murrelets were killed directly during the *Exxon Valdez* oil spill (Kuletz 1994), but it is unlikely that the spill caused the entire 67% reduction in numbers observed in post-spill years. There has been no significant increase in the PWS murrelet population since 1989 (Agler et al. 1994). In other areas of its range, the marbled murrelet has declined due to the loss of old-growth forest nesting habitat (Stein and Miller 1992), but a comparatively small proportion of potential nesting habitat has been harvested in Prince William Sound to date.

Other apex predators that eat small fish in PWS, such as pigeon guillemots (*Cepphus columba*), arctic terns (*Sterna paradisaea*), tufted puffins (*Fratercula cirrhata*) and harbor seals (*Phoca vitulina*), have also declined in number (Agler et al. 1994, Frost et al. 1994, Klosiewski and Laing 1994). The parallel declines in population of several fish-eating species suggest that ecosystem-wide changes in prey species may have occurred.

Diet, foraging behavior and reproductive success of many seabird species are often correlated with prey types and prey availability (review in Furness and Nettleship 1991). Population declines and low reproductive success in seabirds have been associated with the overexploitation of forage fish stocks in commercial fisheries, presumably related to lower food availability (Furness and Nettleship 1991). Long foraging trips and trip times have been correlated with low chick-feeding rates and subsequent breeding failures in PWS seabirds (Kuletz 1983, Irons 1992). Although human disturbance, predation and weather can affect the breeding success of seabirds, the ultimate reason for population declines often appears to be food availability. Montevecchi and Berruti (1991) proposed that to determine how a seabird responds to changes in prey availability we need information on their diet, foraging range and foraging behavior, as well as knowledge about the influences of weather and oceanographic events on seabird foraging.

We have limited information on the prey species used by murrelets in Alaska (Oakley and Kuletz 1979, Krasnow and Sanger 1982, Sanger 1987, Kuletz unpubl. data, Piatt unpubl. data), which include forage fish such as sandlance

(*Ammodytes hexapterous*), capelin (*Mallotus villosus*), herring (*Clupeidae spp*) and pollock (*Gadidae spp*). The spatial and temporal relationships between foraging and nesting habitats for murrelets are unknown, and the types of foraging habitats used by murrelets have only been defined generally.

If marbled murrelets are affected by low food availability, we would expect to find differences in foraging range between birds nesting near more available or abundant food resources than birds nesting near sparse food resources. The most significant differences in murrelet foraging patterns between the two sites should occur during the chick rearing stage, when energetic demands are highest and both members of the nesting pair must return with food to the nest site.

Because prey availability is influenced by oceanographic and bathymetric features (Schneider 1982, Kinder et al. 1983, Haney and McGillivary 1985, Brown and Gaskin 1988, Hunt et al. 1990), it should be possible to test for differences in murrelet foraging behavior between two different types of marine environments, and thus indirectly obtain evidence of food limitations. In PWS, Irons et al. (1985) found summer densities of all birds to be lower in bays, fjords and passes than in more exposed waters. Additionally, Irons (1992) demonstrated that black-legged kittiwakes (*Rissa tridactyla*) in PWS that were nesting in a fjord flew 8 times farther to forage than birds nesting in central PWS, presumably due to lower food availability in the fjord.

The goal of this study is to investigate the hypothesis that food is limiting to marbled murrelets in PWS and could therefore inhibit their recovery. We investigated basic murrelet foraging behavior and tested the hypothesis that food was limiting by comparing the behavior of radio-tagged birds from two oceanographically-distinct habitats of PWS: a deep-water fjord (Port Nellie Juan) and a shallow-water island system (Naked Island). We hypothesized that birds at Naked Island would fly shorter distances and have smaller total foraging ranges than birds at Port Nellie Juan. We also hypothesized that birds would have smaller foraging ranges during the chick-rearing phase than during incubation.

We monitored the murrelet's movements and characterized their foraging habitat. Although our results did not support the hypotheses on foraging distances, we found differences between the two areas in the bird's selection of habitat that suggested the birds were responding to local environmental circumstances. We also conducted preliminary at-sea surveys to quantify relative productivity for murrelets in the two habitats. It was necessary to derive an index of productivity because it was not possible to obtain an adequate sample size to study the reproductive success of marbled murrelets directly. In the long-term, data from subsequent years will be used to make interannual comparisons. Eventually, the results of forage fish studies will be integrated and augment our interpretation of murrelet foraging behavior and productivity.

OBJECTIVES:

1. Identify prey types used by murrelets during the breeding season in PWS.

2. Compare foraging behavior and productivity of murrelets nesting in a deep water fjord vs. a shallow water area in Prince William Sound.

3. Characterize foraging habitat used by radio-tagged murrelets during the breeding season.

METHODS

Study Area

Our study occurred in the western portion of Prince William Sound (PWS), a large, fjord-type embayment in the northern Gulf of Alaska (Fig. 1). The two main study areas were Port Nellie Juan (PNJ), a deep-water fjord in the western mainland of Prince William Sound, and Naked Island (NI), an island in central PWS (Fig. 2). PNJ, which runs east - west approximately 35 km, was largely unaffected by the *Exxon Valdez* Oil Spill. NI, approximately 11 km across, was heavily-oiled on the north and east side, and lightly- or moderately-oiled along sections on the west side (Kuletz 1994).

The bathymetry of PNJ is similar to most fjords of PWS, with a steep abrupt drop-off within 1 km of shore, and often adjacent to shore. Most of PNJ is > 200 m deep, occasionally deeper than 600 m, with the exception of 3 bays on the south side, and West and East Finger Inlets on the north side (Fig. 3). PNJ is generally protected from strong westerly winds and, except for the entrance, from easterly winds as well.

Naked Is and nearby Storey and Peak islands are located 33 km east of PNJ and 19 km from the nearest mainland, and are surrounded by water < 200 m deep out to about 5 km (Fig. 4). The predominant upper-layer current of PWS moves counter-clockwise from Hinchinbrook Entrance, around both the north and south sides of the NI group and south toward Knight Island. In rough weather, most of the outer points of NI are exposed to swell and chop. Winds are predominantly from the east.

During our study (see At-Sea Surveys, this section), surface waters of NI tended to be warmer, more saline and clearer than the waters of PNJ (Appendix A), likely due to less glacial and freshwater runoff. Greystone and Derickson bays in PNJ were opaque on the surface due to glacial silt, and had floating ice throughout the summer. These two bays also had Kittlitz's murrelets, although none were positively identified after 5 August, when most of the juvenile surveys were conducted.

The two study areas also differ in upland topography. PNJ has steep mountains to 1700 m, with mountains separating the smaller inlets and bays that empty into the main channel. One tidewater and eight hanging glaciers occur in PNJ. The shoreline and lower valleys of PNJ bays are forested, but tree line is typically 300 m. Most of the land surrounding PNJ is unforested or recently deglaciated, particularly the upper third of PNJ known as Kings Bay. NI has relatively small hills and mountains, with the highest peaks at 400 m on NI and 460 m on Peak Island. All three islands in the NI group are forested to their summits, except for occasional unforested muskeg and small freshwater ponds.

1. Diet

Our study proposed three methods to obtain information on the diet of murrelets in PWS: (1) collect 30 adult murrelets to obtain stomach samples, (2) collect blood samples for blood lipid analysis and (3) collect ancillary diet information by obtaining fecal samples from captured birds and by observing birds on the water holding fish. Because the Trustee Council did not permit us to obtain stomach or blood samples, only the third component of this objective was completed.

Fecal samples

During the processing of captured adult murrelets for radio-tagging (see below) we collected fecal samples from 15 birds. Samples were placed in plastic bags and frozen and later examined under a dissecting scope. Samples were kept separate and the type and number of items recorded. We examined the samples for the presence of fish otoliths and other hard parts to determine if fecal samples would be useful indicators of diet. Nine samples had potentially identifiable items, which were saved for further examination by experts.

We obtained chick fecal samples from the nest of one radio-tagged murrelet. As is typical of murrelet chicks, a ring of fecal matter was deposited around the rim of the nest cup. We removed pieces of the dried fecal matter after the chick fledged, on 14 August and again on 9 September 1994. The fecal material was kept dry until October, when we dissolved the hard feces in alcohol and water. A few small unidentifiable items were preserved in 80% ethanol for later examination.

Observations of birds with fish

Between 11 June and 7 September 1994 we opportunistically recorded observations of birds on the surface of the water holding fish. We attempted to identify the fish to the lowest possible taxon, estimated the length of the fish relative to bill-length of the bird and attempted to determine the fate of each fish (eg., swallowed, flew off with, or last observed still held by the bird). Location, date and time of day were recorded for each observation.

2. Foraging Behavior and Productivity

Foraging Behavior

Capture, measuring and tagging. -- We captured 51 marbled murrelets by floating mist nets at East Finger Inlet in PNJ (N = 37) and South Cabin Bay, NI (N = 14) between 3 June and 4 July 1994 (Fig. 2). The net system was similar to that described in Burns et al. (1994a), except that on 15 nights at NI, we also deployed a smaller, more portable system designed for shallow water (see Burns et al. 1994b). Nets were usually set between 1 h before sunset and 2 h after sunrise (Appendix B).

All birds were weighed to the nearest g by hand-held Pesola scales. We rated development of the brood patch according to Sealy (1974), and measured bill length and depth, tarsus and wing length (Appendix C) with Venier calipers. An aluminum USFWS band was placed on the right leg of each bird.

We radio-tagged 47 of the captured marbled murrelets. One bird was not tagged because it was in winter plumage and 3 were not tagged because transmitters were temporarily unavailable. After measurements were completed, birds were anesthetized with isoflorane to facilitate tag attachment. The tag was attached with a single silk or absorbable suture through the skin between the scapula (see Burns et al. 1994a). Marine epoxy was applied at the anterior end and sides of the tag and a few back feathers to stabilize the tag. Processing time (from the time a bird was observed in the net to release) varied from 0.5 to 2.8 h ($\bar{x}$ = 1.2 h). Birds recovered from the anesthetic quickly and were released immediately. We did not lose any birds to injury or stress during processing.

All radio-transmitters were model Holohil BD-2G, manufactured by Holohil Systems Ltd. (Woodlawn, Ontario, Canada) and were 20 mm long, with a 15.6 cm antenna at a 30^0 angle from the base. Twenty-one birds had tags weighing 1.95 g with expected battery life of 14 weeks, and 26 birds had tags weighing 1.5 g with expected battery life of 6 weeks. Thirty-three birds were radio-tagged in PNJ (26 with 1.5 g and 7 with 1.95 g tags) and 14 were tagged at NI (all with 1.95 g tags).

We tested for differences in transmitter life by comparing the longevity of signal reception of the two different-sized transmitters (date of capture to date of last relocation) using a *t*-test. We also tested for differences between birds fitted with the two types of transmitters by comparing the number of relocations made by boat and air, and the mean distance between relocations.

We radio-tagged one juvenile marbled murrelet at its nest. The cliff-edge nest in Kings Bay, PNJ, was located by following the radio-tagged parent. On 11 August, the day before the chick fledged, we weighed the chick to the nearest gram with a hand-held Pesola scale and measured the bill, tarsus and wing length with Venier calipers. All down had been plucked off by the chick and it was fully feathered. A 1.5 g transmitter was glued to the feathers in the middle of the bird's back.

Diving activity. -- We measured dive times of murrelets to obtain information on their feeding activity, and as a way to determine if the radio-tags influenced murrelet feeding behavior. Diving observations were done opportunistically on 14 birds without tags (N = 79 dives, 14 sessions) by using a watch to determine the length of surface rest time and underwater dive intervals. A bird was usually followed for as long as the feeding bout lasted, or until the presence of another bird interfered with observations. We recorded the location, time and plumage of the bird (summer, winter, transitional; no untagged juveniles were observed). We recorded the surface and dive intervals of one juvenile (N = 330 dives, 11 sessions) and six adult radio-tagged murrelets opportunistically by monitoring their signal on a receiver (N = 102 dives, 7 sessions; one bird was monitored in different habitats and considered 2 samples). The signal disappeared when the bird went underwater. If the bird remained on the surface for an extended period or flew away, the last surface time was omitted and the session terminated. Two of the tagged birds were monitored the same night they were tagged. We used a Wilcoxon 2-sample test to compare surface and dive intervals between tagged and untagged birds, and between birds diving in PNJ and NI.

Telemetry tracking. -- We used Telonics TR-2 and ATS receivers to track the radio-tagged murrelets by air, by boat and from stationary points on land (Appendix D). Except when searching for a nest or a specific bird, the receiver was set to scan all frequencies, including 2 kilohertz above and below the original frequency to allow for frequency drift. During searches from the air (aerial searches), once a frequency was located it was erased from the receiver for the remainder of the search. On many searches by boat, and on the late-summer searches by air, we used two receivers, each scanning for half of the frequencies, to reduce scanning time.

Air searches. -- We conducted air searches between 4 June and 28 July on 26 days (N = 33 searches, 122 h). Additional searches were conducted for the juvenile murrelet between 9 and 19 August. We used a Cessna 185 fixed-wing float-plane stationed in Cordova, equipped with 2 yagi-H antennas, one attached to each wing. The crew consisted of the pilot, an observer monitoring the receiver, and a recorder, although on late-summer flights both passengers monitored a receiver. Half of the air searches began after 1600, and only 21% were completed between 0800 - 1600 h. Thus most (76%) of the relocations made by plane (termed aerial relocations), were made between 1600-2000 h.

The methodology of the air search followed Burns et al. (1994a). In brief, the plane followed a general pattern around and spiraling out from the core area of NI and PNJ. Flight altitude varied with weather conditions, with the maximum altitude approximately 1700 m and the minimum approximately 500 m. When a signal was located the plane spiraled to lower altitudes and used alternate antennas to pinpoint the signal. The location, time and frequency were recorded on a map at the time of sighting, and a latitude and longitude obtained from the plane's Loran. If the signal was near shore, we circled low or landed the plane to make the bird dive and substantiate that the bird was on the water. If a signal was found inland, we mapped the location and directed a ground crew to the site (see below). We have found in this and previous studies (Burns et. all 1994a, Prestash and Burns, unpubl. data) that 1.95 g transmitters, because the low power reduced signal 'bounce', enabled accurate pinpointing of signals, even in fjord environments, to within 30 m. The accuracy of aerial relocations was confirmed by tracking 3 inland nest sites, 3 dead birds (2 in this study and 1 in 1993 [Burns et al. 1994a]) and 2 test transmitters.

We searched most of PWS one or more times and the NI area and PNJ on almost every flight (Fig. 5). Other areas frequently searched included Perry Island, Eleanor Island, northern Knight Island and the mainland coast south of PNJ to Chenega Island. Less frequently searched areas included Unakwik Inlet and Montague Island. Actual coverage was more extensive than indicated in Fig. 5, which indicates the grid block flown over, because we could hear signals between 13 - 17 km away at 1300 m elevation (Burns et al. 1994a, and this study). This is particularly true of the southern Unakwik area and some open water sections between NI and PNJ, where we believe coverage was comparable to the shoreline of the core study areas.

Boat searches. -- Telemetry searches by boat were conducted from anchored vessels, from a vessel drifting in mid-channel overnight, during at-sea surveys, and during cruises to locate tagged birds or in general transit (Appendix D). Survey boats included a 22 m vessel with 2 H-antennas mounted on a 13 m mast, and a 8 m vessel with 2 H-antennas mounted on a pole 4 m above water. Most of the boat searches were conducted when the boat was anchored at East Finger Inlet in PNJ or Cabin Bay at NI. The other frequently used method was an overnight 'drift', where the boat drifted in a channel or bay, usually the middle of PNJ, outer Cabin Bay or McPherson Bay at NI.

From the boat, signals could be detected up to 1.5 km away if the bird was on the water or flying within 2 m of the water's surface. We observed that most birds flew low over the water, which increased the range to 2 - 2.5 km from the boat. Birds flying high or on a nest on a mountainside could have been up to 7 km away, based on birds at known nest sites. When a signal was heard (N = 186) we recorded the pattern and strength of the signal, or noted if visual contact was made. This provided information on whether the bird was resting on the water, diving or flying by. In 28% of the relocations by boat we could not determine the bird's activity.

Inland searches. -- On 4 days we searched for signals on the water from 2 inland stations on hillsides above Cabin Bay and Outside Bay. Both sites had views of both bays (Appendix D). We mounted two yagi antennas on a 5 m pole and used hand-held H-antennas. We confirmed our ability to pick up signals from these locations by having one crew in an inflatable take a transmitter on the water; from the hillside we could receive the signal in either of the two bays out to at least 4 km.

When an air search located a signal inland, we tracked it by hiking, using a hand-held H-antennae. The observers attempted to get as close as possible to the signal and mark the location on a map and take a GPS reading. Our intent was to get within 200 m of the nest site, but not disturb the area by conducting more extensive searches. We believe we were within at least 50 m of each nest site. We attempted to check the nest area by plane or boat for 3 consecutive days, to determine if the tagged bird demonstrated a 24 h alternate schedule indicative of incubation.

Monitoring Nest Activity

A secondary objective was to investigate the possibility of monitoring nest attendance and/or chick-feeding activity. While at anchor or during overnight drifts (see 'Boat searches' above), the receiver was normally scanning and was not locked on to a single bird's frequency. The continuous, stationary presence of a bird with a known nest site was recorded and entered into the database as a single relocation, unless there was a change in the bird's activity. between 5 June and 28 July.

On two occasions we set one receiver to monitor a single bird's frequency. Between 2300 h on 6 June and 0530 h on 7 June we monitored the night-time incubation and dawn exchange of bird 165.886 in East Finger Inlet. Our platform was a 8 m boat anchored at the mouth of East Finger Inlet. On 26 and 27 July, we monitored the nest of bird 164.712 in Kings Bay between 2000 - 0730 h. The nest was in a crevice of a rock face approximately 7 m high and 5 m from high tide. We were on a 8 m vessel anchored 20 m from the cliff.

Data Analysis

Foraging distances of aerial relocations. -- Signal relocations from air searches were digitized into a geographic information system (GIS; [Atlas GIS 1992]). Although Loran or GPS readings were recorded, we found them inaccurate relative to the points plotted directly on maps, therefore we used the original maps and transferred those points to the GIS. We assumed that errors due to inaccurate mapping on-site did not contain a bias for any direction or association with land. However, we recognized that relocations near recognizable land forms were likely to be more accurate than relocations far from land.

A relocation was ranked as high, medium or low accuracy. High accuracy relocations were circled repeatedly by the plane, the observer noted that it was pinpointed (and usually took a latitude and longitude), and the location was mapped at the time of relocation. Medium accuracy relocations were mapped and gave a detailed description of the site but the pilot was not able to circle repeatedly to pinpoint the location. Low accuracy relocations were approximated, with insufficient time to circle the area, and may or may not have been mapped on-sight. Only two relocations appeared to be of birds flying, therefore we assumed that all remaining aerial relocations were of birds on the water; we could not usually determine if they had been feeding at that site.

We used GIS to measure distance (km) between relocations and the area (km^2) encompassed by the locations (Appendix E). We have never observed a murrelet flying over land during the day, but have observed murrelets using low passes or mountain ridges between bays during dawn activity, and thus we could not assume that birds would not have flown over land. Because aerial relocations were separated by at least one evening and dawn, we measured both straight-line distance (the shortest distance on the map between 2 points, regardless of landscape or topography) and non-straight line distances. Non-straight line distance used a series of lines giving the shortest route over water around land masses.

Six birds with inland locations, excluding the two birds found dead, were assumed to be nesting, with the inland location being the nest site. For these 6 birds we measured the distance from all marine locations and the nest, including the site of capture. Lacking inland sites for the majority of murrelets, we derived foraging range indexes for all radio-tagged murrelets, using aerial relocations only (Appendix F). These included the following distance measurements, taken from the GIS:

1. Distance between capture site and all other relocations.
2. Distance between consecutive sites (sites located on different aerial searches, at least 1 day apart; day 1 to day 2, day 2 to day 3, etc. On 2 days with a morning and afternoon search, only the afternoon location was used if a bird was found on both searches).
3. Maximum distance between any two locations.
4. Minimum area polygon for birds with $\geq$ 4 relocations. The area was defined by the perimeter joining the outer points of the polygon. (For 2 birds with outliers 2X greater than the average maximum distance for all birds, the outlier was not included in the polygon).

For each bird we calculated the mean of each measurement described above. The value for each index was used to compare NI and PNJ birds, using a 2-tailed *t*-test with $\alpha = 0.05$ as significant. Because all 6 birds with inland locations were in PNJ, we could not compare distance from nest site between PNJ and NI birds. To evaluate the foraging range indexes, we calculated the indexes of these 6 birds with and without the inland location. We also compared the indexes calculated without inland sites included to the indexes of the remaining 36 birds with relocations. Comparisons were done with a 2-sample Wilcoxon test.

Four birds were omitted from these analyses; 3 birds without brood patches, all from NI, and 1 bird with what appeared to be abnormal behavior from PNJ. The latter remained primarily in East Finger Inlet, the site of capture, and was observed preening the radio transmitter heavily. Foraging range indexes were obtained for the 3 birds without brood patches, although 2 of those also displayed behavior notably different from the other murrelets, and 1 abraded its wing on the mist net during capture. To compare the foraging distance indexes of these 3 birds to the remaining 42 with brood patches, we used a 2-sample randomization test (Manly 1991, including Manly's RT program). We ran 5000 iterations (351 for the minimum area polygons, because of fewer birds with polygons) and used a 2-tailed probability test on the difference between the means of the two groups.

We also compared foraging range indexes before and after chick hatching. Because of the low number of birds with inland locations, and because other tagged birds could have been nesting, we compared indexes of all birds with brood patches during the estimated pre- and post-hatching period for the population. The population breeding phases were determined by at-sea surveys conducted in the two main study areas. We backdated 28 days from the first record of a juvenile on the water to estimate the beginning of hatching (Sealy 1974, Simons 1980, Hirsch et al. 1981). Thus, we defined incubation as prior to 24 June and post-hatching as $\geq$ 24 June. For each bird, we re-calculated the foraging range indexes (or for 6 birds with nest sites, the mean distance from nest) using only the relocations in the appropriate period. We then compared the foraging range indexes of birds during incubation and post-hatching phases with a *t*-test.

Foraging activity based on relocations by boat. -- Signal relocations by boat were primarily used to determine presence/absence of a bird in a general area and to monitor late evening and early morning activity, between 1800 - 0900 h. Because the relocation from a boat could not usually be pinpointed, we used the boat's location to map the coordinates in GIS. We then used the signal's strength and pattern to define a potential area of presence for that bird. For our maps (Appendix G) and presence / absence of birds, if the signal indicated the bird was on the water and/or diving, the bird was assumed to be within 0.5 or 1.5 km from the boat, depending on the strength of the signal. Because flying above the water gave the signal greater range, birds that appeared to be flying (giving a 'doppler' effect) were assumed to be within 2.0 or 2.5 km of the boat, depending on the signal's strength, although birds flying high could have had greater signal range. Wherever visual contact was made with a tagged bird (during daylight), or if the signal was very loud and passed over the boat, the bird's location was considered the same as that of the boat.

We graphed the number of signals relocated by boat per hour by weighting every hour by the amount of time searched at that hour of the day. Similarly, for the early morning (0000 h - 0900 h), we calculated the number of hours (to 0.01 hrs) from sunrise for each relocation, using a Paradox script (Borland Int. Inc. 1992; script in USFWS files). We then weighted each hour from sunrise by the amount of time searched. To quantify the presence of tagged birds spatially, we divided the marine areas monitored from boats into 'zones' (Fig. 6). We also placed the aerial relocations in these zones, and tallied the number of zones an individual visited, and the number of birds relocated at least once in each zone.

Productivity

At-sea surveys. -- Because few murrelet nests can be found to determine chronology or reproductive success, we conducted at-sea surveys to monitor the timing and relative abundance of juvenile murrelets on the water. At-sea surveys were conducted from a 8 m vessel or 5 m inflatables at the two main study areas. At NI the entire shoreline was surveyed. At PNJ we surveyed the middle section between West Finger Inlet and Mink Island on the north side and between Coxcomb Point and Blue Fjord on the south side. The survey areas were defined by pre-established FWS shoreline transects (see Irons et al. 1985, Klosiewski and Laing 1994).

The vessel traveled 100 m offshore at approximately 7 knots, and 2 observers counted all birds and marine mammals within 200 m from shore. Murrelets were identified as marbled or Kittlitz's, or recorded as *Brachyramphus* murrelets. We categorized murrelets as summer, transitional, winter, juvenile or unknown black-and-white plumage, using criteria developed by Carter and Stein (1995), Ralph and Long (1995), and a reference collection of study skins and photos from southcentral Alaska (Nongame Migratory Bird Management, USFWS, Anchorage, Alaska). Weather permitting, we attempted to survey each area at least twice per week between 16 July - 8 September. On most surveys, at 4 locations along the survey route, we measured surface water temperature by hand-held thermometer, salinity by SSC meter, and water clarity by secchi disc.

Data analysis. -- We assumed that the juveniles we observed in a particular area originated in that area, and calculated a reproductive index using the ratio of adults to juveniles for each survey. We used surveys from the peak of juvenile occurrence, between 8 August - 1 September, to test for differences between areas in the number and percentage of juveniles during those surveys. Because we could not identify 22 % of the black/white birds as juveniles or winter adults, we also conducted the tests on the combined number and percentage of juveniles and black/white birds. The total number of juveniles was used to determine chronology and absolute abundance in each area.

3. Characterization of Foraging Habitat

We examined two aspects of murrelet foraging habitat: distance from shore and water depth, by using the high-accuracy aerial locations (N = 160) of 40 radio-tagged birds digitized to a GIS (see above).

Distance from shore.-- We measured the distance between each aerial relocation and the nearest point of land (including islands) with the GIS. The mean for each bird was used to calculate the average for the population, and to compare birds of PNJ and NI.

Water depth of forage sites.-- To determine the mean water depth used by each bird, we overlaid the high-accuracy aerial locations on GIS bathymetric coverage. The coverage was developed by the U.S. Fish and Wildlife Service (FWS) from bathymetric data developed by Alaska Dept. of Natural Resources. The data originated from National Oceanographic and Aeronautical Administration (NOAA) data and nautical charts. The FWS defined bathymetry for PWS in 8 classes: 0 - 20 m, 20-40 m, 40-60 m, 60-80 m, 80-100 m, 100-120 m, 120-200 m and > 200 m. We defined water depth in each class by the average between contours, and used 200 m for the last category because the coverage did not include deeper increments. Because of potential errors in the mapping of the birds' locations, a 100 m radius was drawn around each aerial location. We calculated the average water depth within that circle with GIS to weight the depth category by the percentage of area covered in that circle.

We defined 4 sub-areas where the tagged birds primarily foraged (Fig. 7). The availability of depth classes for each sub-area was calculated with GIS. For PNJ and NI sub-areas, frequency of use of depth classes by birds was estimated by summing observations in each depth class for each bird by sub-area. Observations by depth class were then tallied across birds for comparison with the distribution of depth class per sub-area. We also determined the availability and use of depth categories for all 4 sub-areas together.

We tested the observed distribution of birds across depth strata with the null hypothesis that they were distributed proportionately across the strata, using a contingency table and the Chi-square statistic. However, to keep expected values in each cell above 5 (Sokal and Rohlf 1981) in the NI area, we combined depth categories for the final analysis of NI; we used 0-40m, 40-80m, 80-200m and >200m. The depth categories had greater range in the latter two because of the large amount of area beyond 200m.

RESULTS

1. Diet

Fecal samples

Nine of the 15 fecal samples from captured adults contained identifiable items. Our preliminary classification of the items were fish vertebrae (6 samples), operculum bone (3 samples), otoliths (2 samples), unidentified bone pieces (1 sample) and a possible euphausid species (1 sample). We could not discern any identifiable items in the chick feces sample, but saved the samples for further examination.

Observations of birds with fish

We observed 97 marbled murrelets holding fish on the water's surface. Of those, 63% could not be identified, 34% were classified as sandlance and 3% were classified as juvenile herring. The birds flew off with the fish (10%), swallowed the fish (14%) or in 76% of the cases the outcome was uncertain (i.e., the bird dove and was lost, was left still holding the fish, or in one case, gave the fish to another adult murrelet). Birds flying off with fish, indicative of chick-feeding, were observed between 9 July and 26 August, with the peak on 26 July (Fig. 8).

2. Foraging Behavior and Productivity

Condition of captured birds. -- The mean weight of the captured adults (Appendix C) was 204 g (N = 51, SE = 3 g). NI birds were significantly heavier than PNJ birds ($\bar{x}$ = 214 g, SE = 6 and 201 g, SE = 3 g, respectively; t = 2.20, df = 49, P = 0.033). The radio-tagged juvenile weighed 118 g, or 58% of mean adult weight. We found no difference between areas in the bird's tarsus length, culmen length, wing chord or average brood patch development (Appendix C). The 3 birds with no brood patch (2 in summer and 1 in transitional plumage) were all from NI. All but 2 of the 39 birds in summer plumage had brood patches. Nine of the 10 birds in transitional plumage and both birds in complete winter plumage also had brood patches. The latter two birds were photographed to document the presence of the brood patch in winter plumage.

Foraging Behavior

Diving activity. -- We found no difference in dive times or rest times (mean per bird) between murrelets with radio-tags (N = 6; underwater $\bar{x}$ = 20.3 sec, SE = 4.3; surface interval $\bar{x}$ = 28.6 sec, SE = 8.1) and those without tags (N = 14; underwater $\bar{x}$ = 28.0 sec, SE = 10.6; surface interval $\bar{x}$ = 26.1 sec, SE = 4.6; underwater Z = -1.38, P = 0.17 and surface interval Z = 0.41, P = 0.68). There was no significant difference in dive times between birds in PNJ and NI. Adult murrelets spent more time underwater ($\bar{x}$ = 25.4 sec, SE = 2.5) and more time resting at the surface between dives ($\bar{x}$ = 26.9 sec, SE = 4.0) than did the radio-tagged juvenile murrelet ($\bar{x}$ = 17.1 sec, SE = 1.1 and $\bar{x}$ = 10.9 sec, SE = 1.4, respectively; underwater Z = -2.08, P = 0.045, surface interval Z = -3.15, P = 0.004).

Telemetry tracking. -- Most of our telemetry data was from the incubation or early nestling phase, based on observations of fish-holding murrelets and the appearance of juveniles on the water. Although most birds were found by air (Appendix D), the attrition of signals was similar to that of boat-based searches, with most signals lost by late July (Fig. 9). The mean length of signal reception (tagging to last relocation) was 14 days (SE = 1.3), and maximum longevity was 32 days. After 28 July, only the radio-tagged juvenile was located. The juvenile transmitter lasted about as long (15 days) as the adult mean. The average number of days of relocation per bird was 8.9 days (SE = 7.3).

Inland relocations. -- Six birds, all in PNJ, were located inland during aerial searches, with 5 of those demonstrating alternate 24-h periods inland and at-sea, indicative of incubation. One bird was only found inland once, but because it was also found at sea on successive days within the period when hatching had begun for the population, we included it as a potential nest site. The potential nest sites averaged 1.7 km from shore.

Three of the potential nests were at the head of East Finger Inlet, within 1 km of each other, and appeared to be tree nests. We hiked to 2 of the sites and were probably within 20 m of the nest tree. The other 3 nests appeared to be ground/cliff nests, one of which was confirmed when we found the chick in a cliff crevice on the coast of Kings Bay. The second ground/cliff nest was 5.7 km inland near Cotterell Glacier in treeless, rugged and inaccessible terrain. The third ground/tree nest was 2.3 km inland, west of West Finger Inlet. Tracking this latter signal, two crew members climbed to the base of a steep vertical cliff in the rocky, treeless area, and believe the nest was within 100 m above them.

Two birds, one each in PNJ and NI, were found dead after being tracked inland (Appendix F). In both cases, the tag was found on the ground near remains of the bird. The NI bird, last relocated on 23 June, was found dead on 26 June, 11 days after tagging. The carcass was found 0.5 km inland at the head of south Cabin Bay. The PNJ bird, last relocated on 28 June, was found dead on 30 June, 25 days after tagging. The carcass was just above high tide on an island in Herring Bay at Knight Island. A climber searched the tree above the transmitter and found remains of the bird in a moss depression similar to a murrelet nest, but he could not determine if it had been brought there by a predator or if it had been killed at a nest.

Foraging range of birds with inland locations. -- The 6 birds with inland locations used the middle portion of PNJ (Fig. 10), but 3 of them also foraged beyond PNJ. One bird was found near Perry Island and Storey Island, another near Herring Bay at Knight Island, and the third in Perry Passage. The mean straight-line distance from the nest to all other relocations for the 6 birds was 16.2 km (SE = 4.6) and the mean non-straight line distance was 20.9 km (SE = 5.6). The bird with the highest mean distance averaged 31.4 km straight-line and 40.1 km non-straight line from the nest (N = 4 aerial relocations on the water). The minimum area polygon for these 6 birds averaged 119 km^2, ranging from 9 - 295 km^2. This was slightly less than for other PNJ birds ($\bar{x}$ = 133 km^2, range 4 - 920 km^2), but the range in both groups was extreme.

Removing the inland location from the distance measurements for these 6 birds did not significantly alter their foraging range indexes (distance from capture site, between consecutive sites, maximum distance and minimum area polygon). The greatest change, although not statistically significant, was a 57% decrease in the minimum area polygon to 51 km^2. The mean value for the indexes for these 6 birds, with inland site removed, did not differ significantly with the distance indexes of the remaining 36 birds.

Foraging range indexes of aerial locations. -- We found no significant differences between birds from the two areas in straight-line (Table 1) or non-straight line distance indexes (Table 2) in any category. When the birds were pooled and we recalculated distances during incubation and post-hatching phase of the population (estimated from juvenile occurrence on the water), only the distance from capture site was greater after hatching phase (pre-hatch N = 31, $\bar{x}$ = 12.8 km, SE = 2.0, post-hatch N = 26, $\bar{x}$ = 19.6 km, SE = 2.8 ; t = -2.06, df = 55, P = 0.045). For 3 birds with sufficient relocations in both phases, the area of the post-hatch polygon ranged from 11% - 30% ($\bar{x}$ = 19%) of the bird's incubation phase polygon. For all birds with polygons, although the mean size of the minimum area polygon in the incubation phase (N = 13, $\bar{x}$ = 126 km^2, SE = 68) was greater than in the post-hatch phase (N = 15, $\bar{x}$ = 83 km^2, SE = 23), the range among birds in both phases was great. In general, we found a significant positive relationship between the size of the polygon and the number of relocations per bird (N = 25 birds, Tau-b = 0.39, P = 0.0096), but the sample sizes used for each bird within a phase, and the number of birds per phase, for this analysis were almost equal.

The maximum non-straight line distance between a relocation and the point of capture for any bird was 91 km by a NI bird, and the greatest distance between any 2 relocations was 94 km by the same bird (see Appendix F for individual maps). Within-day movement appeared to be much lower, although sample size was small for such measurements. Eight birds were relocated on the same day during morning and late afternoon searches on 6 and 7 July. Not counting the 2 birds on nests, the mean non-straight line distance between morning and afternoon relocations was 4.7 km (SE = 1.2, range = 0.7 - 8.8).

Although most relocations were within 17 km of the capture site, there was some overlap in areas used among birds caught in different areas (Fig. 11). Birds from both areas foraged around the southern end of Perry Island and near Eleanor Island. Two birds tagged at PNJ were found at least once at NI, and one bird from NI was found once at PNJ. Two birds from NI were found in or near Unakwik Inlet to the north, and one was found at southern Montague Island. Two birds from PNJ were also found near Montague I. PNJ birds also foraged in the bays along the mainland south of PNJ, especially in Main Bay, and along the northwest side of Knight Island.

Foraging distance indexes of birds without brood patches. -- The distance indexes of the 3 birds without brood patches, all from NI, did not differ significantly from the 42 with brood patches (all $P > 0.1$, except non-straight line distance between consecutive points [P = 0.096] and non-straight line maximum distance [P = 0.06]). However, all distance indexes were smaller for the birds without brood patches. Compared to birds with brood patches, the average non-straight line distance from capture was 8.4 km less, between consecutive points was 10 km less, and maximum distance 24.2 km less. The minimum area polygons averaged 118 km^2 less than birds with brood patches.

Foraging activity based on boat-based relocations. -- Boat relocations were primarily restricted to PNJ (414 search hours) and NI (221 search hours); thus our boat-based observations only pertain to activity within those areas (see Appendix G for individual maps). During daylight hours, most of the relocated tagged birds appeared to be on the water or their activity was unknown (Fig. 12). In the evening hours, within an hour of sunset, and again between 0200 - 0400 h, tagged birds were also detected flying, with the highest number of flying birds recorded between 0300 - 0400 h. The peak in the number of tagged flying birds occurred in the 2 hours before sunrise (Fig. 13). After sunrise, most birds were identified as being on the water. Not including when they were on the nest, birds with inland sights were relocated between 2000 h - 0500 h more frequently (N = 6 birds, $\bar{x}$ = 7.2 relocations, SE = 2.1) than other birds from PNJ (N = 27 birds, $\bar{x}$ = 1.6 relocations, SE = 0.4; Z = 2.53, P = 0.011).

Eleven of the 12 relocations of the tagged juvenile were made by boat (Fig. 14). The day after fledging, the juvenile was near West Finger Inlet, 12 km from its nest. For the next 2 weeks it remained in the vicinity of the mouth of Kings Bay, in an area approximately 12 km^2. When the juvenile was observed visually (N = 4 days), it was nearshore, appeared healthy and was diving frequently. It did not appear to be bothered by the transmitter. We did not relocate the juvenile after 26 August.

Monitoring nest activity. -- All nesting birds were monitored at night at least once ($\bar{x}$ = 8 nights, range = 1 - 12 nights). However, without monitoring one signal continuously, or with the boat drifting, it was usually not possible to determine definitively whether the bird was on the nest or on water, or when an incubation exchange or chick feeding occurred. The boat's movement, especially when distant from the nest, altered the signal of a bird known to be at its nest.

We monitored bird 165.886 continuously while it was incubating at the head of East Finger Inlet from 2300 h to 0530 on 7 June. At 0351 (approximately 49 min before sunrise) the signal got very loud as the bird flew by the boat, and then went off and on near the boat. The bird was diving from 0352 to 0421 near the mouth of East Finger Inlet. The signal disappeared briefly and between 0435 - 0530 the signal was very faint and absent for periods, apparently on the water some distance from the mouth of East Finger Inlet.

The Kings Bay nest, bird 164.712, was monitored during the nestling phase. On 27 July we recorded chick-feeding deliveries at 2340 and 0050 h (sunset was at 2252). In the morning the bird returned at 0448 and 0700 (sunrise was at 0532). We could hear the tagged bird approaching the nest from the direction of the mouth of Kings Bay. When light was sufficient, we also observed the untagged mate going into and out of the nest at 0716.

Productivity

Total murrelet counts during at-sea surveys. -- The total number of murrelets at both study sites peaked in late July and declined steadily throughout the rest of the survey period (Fig. 15). Only 4 - 5% of the peak number of birds remained at either site by the last survey on 7 and 8 September. Although the total number of murrelets was greater at PNJ, the area surveyed was larger, and the average density at PNJ (20.8 birds/ km^2) was only slightly higher than at NI (18.1 birds / km^2). Peak density at NI occurred on 22 July at 36.5 birds / km^2 and at PNJ on 26 July at 58.1 birds / km^2.

Juvenile counts. --Juveniles were first observed at NI on 22 July, and at PNJ on 24 July (Fig. 16). At NI the number of juveniles climbed quickly after 8 August and peaked on 10 August and again on 1 September. At PNJ the number of juveniles peaked on 9 August (not on the graph, because the survey was incomplete that day) and on 24 August, but remained high on 1 September. As the number of juveniles increased, the total number of murrelets decreased, and the percentage of juveniles thus increased through 1 September (Fig. 16).

Based on the at-sea surveys, and backdating from the time of first juvenile observation, peak numbers of juveniles and the decline in numbers, we defined the incubation phase as prior to 24 June. Early hatching was 24 June - 10 July, main hatching phase was 11 July - 4 August and late hatching was after 4 August.

For the entire fledging period, the percentage of juveniles and black/white birds (not including those identified as in winter plumage) was not significantly different between areas (NI, N = 14 surveys, $\bar{x}$ = 9.6 per survey, SE = 3.1; PNJ, N = 12 surveys, $\bar{x}$ = 6.4, SE = 2.3). During the main fledging phase, 8 August to 1 September, the daily mean number of juveniles at NI (N = 7, $\bar{x}$ = 13.1, SE = 2.1) was higher than the mean number of juveniles at PNJ (N = 7, $\bar{x}$ = 7.4, SE = 1.4; Z = 2.06, P = 0.04). However, the percentage of juveniles was not significantly different between areas (P = 0.12).

3. Characterization of Foraging Habitat

Distance from shore. -- The average distance from shore of relocations per bird was 0.62 km (SE = 0.07). We found no significant difference in the bird's average distance from shore between birds from NI and PNJ.

Water depth. -- The radio-tagged birds' use of the available marine habitat varied between the two areas. Birds relocated within the PNJ sub-area (see Fig. 7) used the depth classes proportionate to their availability (Table 3). Birds relocated within the NI sub-area were in shallow areas more than expected, based on availability of water depth classes (Table 3). The average water depth used by birds found in the NI sub-area (N = 10 birds, $\bar{x}$ = 52.4 m, SE = 10.3) was significantly shallower than that of birds in PNJ (N = 26, $\bar{x}$ = 115.0 m, SE = 11.4; t = -3.21, df = 34, P = 0.003). When all relocations within the 4 sub-areas were combined, birds were found in shallow waters in greater frequency than expected based on availability (Table 3).

Areas of frequent use. -- Although radio-tagged birds in PNJ did not show evidence of selecting shallow waters, the shoreline density of murrelets was highest along the relatively shallow bays on the south side of PNJ, as evident from the survey on 26 July, when peak density was recorded (Fig. 17). In contrast, densities were lower overall and more evenly dispersed around NI on 22 July, when peak densities were recorded there (Fig. 18). However, the density in bays was higher than along more exposed coastlines of NI (Fig. 18). The radio-tagged birds at NI also tended to use the inner portions of bays (Fig. 19).

The radio-tagged murrelets were often located along shelf breaks, such as the submerged point at Elbow Island, that projects into the main channel of PNJ (Fig. 20). Concentrations of relocated tagged birds (Fig. 11) were also evident in bands stretching across PNJ from Mink Island to McClure Bay, Elbow Island to Blue Fjord and west of West Finger Inlet (Cotterell Glacier runoff) to Coxcomb Point. All three areas are near bends in the main channel and are bordered on at least one side by a pocket of deep water down to 550 - 650 m (not evident in our GIS bathymetric coverage, which combined waters >200 m). These zones, especially near Elbow Island, were also visited by the greatest number of radio-tagged birds in the course of the summer (Fig. 21). Otherwise, the main concentrations of relocations were in the relatively shallow bays of East Finger Inlet, Greystone and Derickson bays in PNJ, Main Bay to the south of PNJ, South Bay of Perry Island, and Cabin Bay and Outside Bay at NI (Fig. 11 and Fig. 21).

DISCUSSION

Diet and Feeding Behavior

Although we could not obtain data adequate to describe the diet of murrelets in PWS, our observations indicated that in 1994 their diet included sandlance and juvenile herring. The large number of unidentified fish in our observations made it impossible to determine the relative frequency of use among prey species. In PWS, sandlance were used by murrelets in 1978 (Oakley and Kuletz 1979), and sandlance and herring were the most common prey for murrelets in British Columbia (Carter 1984). While murrelets collected in Kachemak Bay in 1989 contained primarily sandlance (J. Piatt, pers. comm.), murrelets from PWS in 1989 were feeding primarily on gadids (Kuletz, unpubl. data). We could not compare diet between PNJ and NI, but based on prey fed to pigeon guillemot chicks in 1994 (Hayes 1995), herring and smelt may have been more abundant in southwestern PWS, closer to PNJ, than at NI.

Because radio-tagged birds from PNJ frequented the Main Bay hatchery, it is possible that salmon smolt were part of the diet locally. Murrelets occasionally feed on salmon smolt (Carter and Sealy 1986), and personnel at the Main Bay hatchery reported seeing murrelets feeding on salmon in the hatchery pens in 1994. In 1995, a study directed at seabirds foraging on salmon fry during release at hatcheries in PWS, found that murrelet numbers increased for 4 days after the release (D. Scheel, pers. comm.). However, it is unlikely that salmon fry are a significant source of food for murrelets, due to the limited time frame and restricted areas of availability.

Our observations of the flight activity of radio-tagged birds and the chick-feeding behavior of one bird monitored by telemetry indicated that foraging and chick-feeding was common prior to and shortly after dawn, with a smaller activity period around sunset. Many of the forage fish used by murrelets demonstrate diel activity patterns of rising to the surface during twilight and darkness (Hourston 1959, Macer 1965). Murrelets appear to respond to this pattern of activity by foraging for chicks during the twilight hours around sunset and dawn (Carter and Sealy 1990). Simons (1980) and Hirsch et al. (1981) recorded prey deliveries to murrelet chicks at dusk, and Carter and Sealy (1990) concluded that most chick-feeding occurred near dusk. However, Nelson and Hamer (1995) summarized other studies showing chick-feeding around dawn.

We found no evidence that the radio-tags affected the diving behavior of birds, indicating that radio tags did not interfere with feeding activity, although we could not determine if they affected flying. In contrast, the significantly shorter dives of the juvenile, compared to adults, suggests it was not a proficient diver. In California, Strachan et al. (1995) also recorded shorter dive times by two possible juveniles compared to adults. Juveniles are only 50 - 70% of adult weight (this study; Nelson and Hamer 1995), and because of strength or a buoyancy effect, they can not dive for long periods, and are likely restricted to upper layers of the water column more than adults. Sealy (1975a) and Ralph and Long (1995) found juveniles concentrated closer to shore than adults, and it may be that prey are more concentrated there, or are easier to catch in shallow areas.

Duration of dives for adult murrelets in PWS was similar to murrelets diving in water 10-30 m deep in British Columbia (Carter and Sealy 1990) and to untagged birds in California (Strachan et al. 1995), suggesting a similar use of the water column. Murrelets are associated with shallow, nearshore areas, and diving times of murrelets suggest they forage within 50 m of the surface (Sealy 1975b, Thoresen 1989). However, Carter and Sealy (1984) suggested, based on birds caught in gillnets, that they foraged primarily within 5 m of the surface.

Dive duration is correlated with dive depth, and diving ability is limited by body size (Watanuki et al. 1995). Thus, the diving capacity of murrelets may limit their exploitation of prey at depths greater than 50 m. Obviously, this does not preclude the use of deep water areas, as evidenced by the radio-tagged birds in PNJ, but suggests that other habitat features influence murrelet foraging patterns. These features may include surface currents, tidal rips, upwelling and diel activity patterns of the prey that concentrate prey in surface waters. A better understanding of what features concentrate murrelet prey, and where these are located in PWS, would guide efforts to minimize disturbance at important foraging habitat.

Foraging Behavior and Productivity

Foraging Behavior

We had hypothesized that birds at NI would have smaller flight distances and foraging ranges than PNJ birds, because NI is surrounded by a large shallow-water shelf, with food presumably more abundant and accessible. Because we only had nest locations in PNJ, we could not make this comparison. However, the foraging distance indexes did not indicate a significant difference in the distances traveled over a 24-h period by birds in the two areas. Variability among individuals overshadowed any regional differences. The average foraging distance indexes in 1994 were similar to those obtained in 1993 from birds caught in Unakwik Inlet (Burns et al. 1994a). Distances traveled on the same day were less than half that of relocations separated by more than 24 h (averaging 5 and 11 km respectively).

Foraging distances from nests. -- The distances between relocations of radio-tagged murrelets in PWS were remarkably similar to the nest-to-coastline distances for documented murrelet nests in the Pacific Northwest. The mean distance between nest and coastline for 45 murrelet nests compiled by Hamer and Nelson (1995a) was 16.8 km, with the farthest nest 40 km inland, although circumstantial evidence (ie., eggs or chicks on the forest floor) suggested that a small number of murrelets may nest up to 100 km inland (Hamer and Nelson 1995a). Our data suggest a foraging range of approximately 20 - 30 km would be more typical for nesting birds, with most trips between 16 - 20 km from the nest. In this study, for birds with known nests, the average straight-line distance between nest and relocation was 16 km, non-straight line distance was 21 km, the maximum mean distance for a bird was 40 km and the longest single measured distance was 60 km. The 57% reduction in the minimum area polygons with the inland site removed, although not significant for these 6 birds as a group, suggests that the distance of the nest inland could be a significant influence on a murrelet's foraging range.

Relatively few relocations were made of birds more than 30 km from their capture site (see Fig. 11). The distances we recorded with telemetry may represent an optimum range for murrelets during the breeding season, even though they have been documented to nest farther from the coast. In California, Ainley et al. (1995) found that the strongest factor explaining variation in murrelet numbers offshore of Point Ano Nuevo was the distance-to-breeding area, with most sightings within 10 km offshore of their nesting area. To date, the average distance from the coast for murrelet nests in Alaska has been substantially less than at lower latitudes (mean = 0.5 km [Naslund et al. 1994], maximum = 5.7 [this study]). Because murrelets in PWS nest near the coast and avoid long flights to the ocean, they potentially gain access to a larger marine area within their foraging range.

Based on the 6 birds with nest sites, the minimum area polygons for the 19 birds (with sufficient relocations) without inland locations might only represent 43% of the actual area used if nests we did not locate were visited. However, the average minimum area polygon for those 19 birds approximated that of the 6 birds with nest sites. Our results are probably crude estimates of a minimum foraging range, because variability among birds was high and the number of relocations per bird was low, considering the potential area of use.

Foraging during incubation v. nestling phase. -- Secondarily, we hypothesized that birds would forage closer to nesting areas once chicks had hatched, due to the energetic demands of chick-rearing. Based on observations at sea, murrelet distribution changes during the breeding season (Carter 1984, Kaiser et al. 1991, Kuletz et al. 1994b). Carter (1984) suggested that murrelets were widely dispersed during incubation phase and concentrated in nearshore waters during the chick-rearing phase. Changes in murrelet distribution may reflect changes in prey distribution, but could also reflect energetic limitations imposed by the requirements of chick feeding. Results from our pooled samples, though inconclusive, did not support this hypothesis.

Our sample size, due partly to the shorter-than-expected longevity of the radio-tags, did not allow us to make comparisons among nests of known status. However, because the 3 birds with both incubation and post-hatch minimum area polygons showed drastic reduction in area after hatching began, and because there was a similar non-significant trend in other birds, this hypothesis should not be rejected without further study. Using the population's first date of hatching could have misclassified the status of individual nests. We did not know the hatching date of birds with nests (including those we did not find, but suspect the birds were nesting) and thus could not accurately categorize every relocation relative to nesting status for individual birds.

One potential problem with comparing distances of birds pre-and post-hatch was our assumption that the location of birds during the day was relevant to the foraging to provision chicks. Carter (1984) and Carter and Sealy (1990) interpreted observations of birds on the water to indicate that birds were feeding themselves at different times and locations than when they foraged for their chicks. They suggested that birds fed on abundant, smaller fish during the day, such as at fjord sills or small-scale fronts, but moved to patches of more difficult-to-obtain larger prey at dusk, when the fish came to the surface. If this occurred in PWS our daytime aerial observations, although primarily from late afternoon, may not have been the locations used by the birds to obtain food for chicks.

Maximum distances of radio-tagged animals tend to increase over time and as the number of relocations increases (White and Garrott 1990); we found a similar relationship between the number of relocations and the minimum area polygon. Alternatively, the significant reduction in range of the murrelets in the latter half of our telemetry tracking could be indicative of latent problems from the tags. We could not determine if the transmitters were malfunctioning after 2 - 4 weeks, if they fell off the birds, if birds were leaving the area, or if they had high mortality. A minimum of 2 (4%) of the birds we tagged this year, and 1 (10%) of the birds in 1993 (Burns et al. 1994a) were found dead and eaten. Quinlan and Hughes (1992) also lost radio-tagged murrelets to bald eagle predation, suggesting either that predation on adults is high in Alaska, or that it is a consequence of radio-tagging. Unfortunately, no radio-tagged murrelet carcass has been found intact to determine the role of the transmitter in the loss of the bird. The relatively small foraging ranges of the 3 birds without brood patches might have been due to physical problems with the tags, but could also have been related to their age or breeding status.

Evening and dawn activity. -- Monitoring nesting activity was most effective when the receiver was locked on one or two specific nests and the boat was anchored. Exact timing of incubation exchanges was only possible using this method. Although we did not have the extra time and equipment necessary, careful monitoring of the cessation of incubation could determine the hatching date of specific nests within a few days. Chick-feeding activity of tagged birds was easily monitored from a boat monitoring one signal, and with sufficient light, would allow for monitoring the separate feeding trips of both parents.

In general, any activity between sunset and sunrise was a good indicator that a bird was nesting. Although the types of activity (i.e., flying, diving or on water), of tagged birds with no known nests were similar to birds with known nests, the former were less active during crepuscular hours. The increase in flights for tagged birds before dawn also corresponded with the timing of peak murrelet detections in PWS, when murrelets fly inland to their nests (see Kuletz et al. 1994a). With sufficient numbers of birds tagged in the same area, regular monitoring of night-time and early-morning flights might serve as an indicator of nesting success.

Productivity

Chronology and timing of surveys. -- The decline in murrelets over the summer and the relatively steady rate of decline was roughly parallel between PNJ and NI. Simultaneously, both the numbers of juveniles and the percentage of juveniles increased. Our results suggest that surveys for juvenile murrelets should begin by mid-July if it is necessary to determine the earliest fledging date. To monitor peak juvenile occurrence, surveys may not be necessary until August. However, we observed a large proportion of adult birds still in winter or transitional plumage in late May of 1994, whereas most adults were in breeding plumage by May in previous years. The late changes in adult plumage in 1994 may indicate that breeding was relatively late that year. In the event that the timing of peak fledging fluctuates, a useful indicator of when to expect juveniles may be the fish-holding behavior of adults. Our observations of fish-holding coincided with the estimated peak nestling phase suggested by juvenile occurrence at sea.

Future work will need to improve the accuracy of plumage identification, or to develop a method that minimizes the need to separate age groups. Ralph and Long (1995) concluded that juvenile surveys in California should end by 15 August to avoid identification errors. At lower latitudes, juveniles first appear in May, their numbers peak in mid-July and show a smaller peak in late August (Hamer and Nelson 1995b). Ralph and Long (1995) also noted that adults in winter plumage were common after 15 August. In contrast, <1% of the total birds we observed were identified as in winter plumage and <1% in unidentified black/white plumage. Also, the total number of murrelets declined continuously throughout late summer, indicating that most adults were leaving the area after breeding and prior to molt. We had no indication of an influx of birds, as occurs in Washington (Hardin, pers. comm.) or California (Strong, pers. comm.). Because of the later occurrence of juveniles in PWS compared to lower latitudes, surveys throughout August may be necessary, and they may be more dependable than at lower latitudes because adults appeared to leave PWS.

Ratio of juveniles. -- Perhaps because the number of juveniles increased as adult numbers decreased, the percentage of juveniles we observed during their peak occurrence was high compared to those observed at lower latitudes. The percentage of juveniles observed at sea in California, Oregon, Washington and British Columbia has ranged from 1- 5% (Burger 1994, Beissinger 1995, Ralph and Long 1995), compared to 5% and 10% at PNJ and NI, respectively, during the 3 weeks of peak juvenile occurrence. However, on some days we observed up to 45% juvenile birds in mid- to late-August. Because of the decline in adults as fledging increased, it may be necessary to compare juvenile counts to surveys conducted earlier in the summer. Compared to the total murrelet counts during early and mid-July, juveniles were approximately 2% of the total adult population present during the main nestling phase, a percentage similar to those at lower latitudes.

Further study will be required to determine what juvenile-to-adult ratio is comparable to the values obtained at lower latitudes, due to differences in nesting chronology and post-breeding migration patterns. Most importantly, to develop a monitoring tool for southcentral Alaska and PWS in particular, it is necessary to determine which ratio is most appropriate and reliable for among-year comparisons in the spill zone. The movements of the radio-tagged juvenile in PNJ coincided with the peak appearance of juveniles, and suggested that juveniles remain in the general area (12 km) of the nest for at least 2 weeks. If this pattern was consistent in PWS, juvenile turnover at the scale of our study areas was minimal during the main juvenile survey period. This would facilitate surveys during the peak of juvenile occurrence.

Regional differences in productivity. -- Our survey data suggested that murrelet chronology at NI may have been up to one week earlier than at PNJ, and the peak number of juveniles was higher. However, perhaps due to daily variability in total murrelet numbers, the percentage of juveniles was not significantly higher than at PNJ.

The productivity of NI birds could have been underestimated if a large portion of the birds present around the island were not nesting there. We base this speculation on the fact that the 3 birds without brood patches were all caught at NI, the body weight of birds was higher at NI (perhaps indicative of non-breeding status), and the relocations of radio-tagged birds in 1993 and 1994. We did not detect any inland locations for birds tagged at NI, and except for the night of capture, only one bird with a brood patch was relocated at night; this bird did not move far and eventually was found dead. In contrast, tagged birds at PNJ were active at night, especially those known to be nesting. Two of 10 birds caught in Unakwik Inlet in 1993, and 2 of 32 birds relocated in PNJ in 1994 (at least one of which was nesting in PNJ) were also relocated at NI.

If NI is a feeding magnet for birds nesting in other areas, or for non-breeding birds, it would affect the juvenile-to-adult ratios. A monitoring program that compares areas within PWS would have to adjust for local patterns. Additional study sites, surveyed over the same season, would indicate if the NI juvenile ratio follows the same pattern as other sites in PWS. Additionally, if periodic increases in adults occurs at a site, it may be more reliable to evaluate productivity using absolute numbers of juveniles, rather than their ratio to adults.

Characterization of Foraging Habitat

Perhaps because murrelets can access fish at depth, unlike the black-legged kittiwakes studied by Irons (1992), murrelets modified their habitat use rather than travel great distances to forage. Supporting this scenario was the selectivity of NI birds for shallow water as opposed to the use of deep-water sills or likely sites of upwelling by PNJ birds.

Radio-tagged murrelets in both study areas used nearshore waters <1 km from shore. This is consistent with the radio-tagged murrelets from Unakwik Inlet in 1993 (Burns et al. 1994a) and with at-sea surveys of murrelets throughout most of their range (Sealy 1975b, Carter and Sealy 1990, Kaiser et al. 1991, Burger 1994, Kuletz et al. 1994b). The propensity for shallow water is likely associated with the preference for nearshore waters. Shoreline murrelet density at PNJ was highest along the south side, in the relatively shallow bays branching off the main channel. At NI, murrelet densities were more evenly spread along the shoreline, reflecting the comparatively ubiquitous occurrence of shallow waters near shore, but were higher in protected bays. At-sea surveys within 5 km of Naked, Storey and Peak islands in 1991 and 1992 also found higher densities over shallow areas (< 60 m) than over deeper areas (Kuletz et al. 1994b).

In contrast, murrelets in PNJ were also found in mid-channel, particularly across the mouth and bends in the main channel. Although our GIS bathymetric coverage did not go deeper than 200 m, these are the approximate locations of deep-water sills. Fjord sills, and the promontories adjacent to them on land, cause upwelling that promotes productivity and concentrates prey (Burrell 1987, Hunt 1995). Although Carter (1984) found that the density of murrelets was lower in deep water fjords, murrelets have been observed to aggregate over sites of upwelling and strong currents (Carter 1984, Sealy and Carter 1984, Kaiser et al. 1991). The strong tidal flows associated with long fjords in Alaska can periodically enhance this process (Burrell 1987). If murrelets respond to episodic prey concentrations, we might expect a stronger tidal influence on the distribution of murrelets at PNJ than at NI. Additionally, tagged murrelets were frequently found along shelf edges at PNJ and NI; underwater shelves, as with land promontories, can cause upwelling and zones of increased productivity. If such areas were identified from bathymetric coverage, predictions of murrelet presence along specific types of underwater contours could be tested by stratified habitat sampling, using standard boat survey methodology.

Because certain features of fjords have the potential to concentrate prey, Hunt (1995) hypothesized that murrelets would forage in fjords with populations of large copepods. These prey are more typical of deep fjords with deep sills (such as PNJ), rather than shallow fjords or fjords with shallow sills. Hunt (1995) also predicted that murrelets would concentrate at the seaward end and near the sills, rather than towards the head of the fjord. The consistent use of PNJ by the radio-tagged murrelets, and their distribution within the fjord, support these predictions. We found no indication, based on murrelet densities or relocations of tagged birds, that the fjord was lacking in food resources for diving birds in June and July.

CONCLUSION

Using radio-telemetry we were able to directly examine many questions about murrelet foraging behavior that had previously only been inferred from observations at sea. Because of the murrelet's wide-ranging flights and lack of a central nesting colony, telemetry is the best option for study of the relationship between nesting and feeding areas. Quinlan and Hughes (1992) first used telemetry in southeast Alaska, and were able to obtain at least one relocation for each of 7 birds. In 1993 and 1994 we were successful in following a relatively large number of murrelets over approximately one month in the incubation and early nestling phase. Although locating nest sites proved difficult, this was partly due to our coverage of two study sites and our focus on at-sea relocations. If the effort focused on one site and searched more inland areas, the success rate could be improved. By focusing on at-sea relocations, however, we were able to determine general foraging patterns and a minimum area of use for 46 birds, including the foraging ranges for 6 nesting birds.

Telemetry could be a valuable tool for studying the chick-feeding patterns of murrelets, although the longevity of radio-tags needs to be improved or recognized in the study design. Currently, it does not appear possible to follow the same sample of birds through incubation and chick-rearing, unless the tagging occurs during late incubation for each bird. Critical to the success of telemetry is sufficient funding and personnel to track the birds by air over a large area for an extended period and on a regular basis.

We found no significant differences in the distance indexes (distance from site of capture, between consecutive sites, maximum between points and minimum area polygon) of murrelets from a deep water fjord (PNJ) and those from a shallow water island (NI). However, between areas, birds modified their habitat use. Birds favored shallow water areas, but in PNJ they also used deep mid-channel areas that were likely sites of upwelling. Future management decisions could benefit by identifying specific types of marine habitats important to murrelets.

Our data suggests a typical foraging range of 20 - 30 km from nest sites for birds in PWS, although some birds fly farther. Based on this, and the movements of a radio-tagged fledgling, surveys for comparing regional productivity would ideally be separated by at least 20 km. Our 1994 productivity surveys should serve as a pilot effort; the patterns observed indicate that surveys for juveniles at sea could provide a means of assessing relative productivity. More information on patterns of murrelet post-breeding dispersal and habitat use by juveniles is required. Corresponding information on oceanographic events and on the abundance and distribution of forage fish will be needed to interpret changes in murrelet foraging behavior and reproductive success in the context of the PWS ecosystem.

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Figure 1. The study area for Restoration Project 94102, Prince William Sound, Alaska.

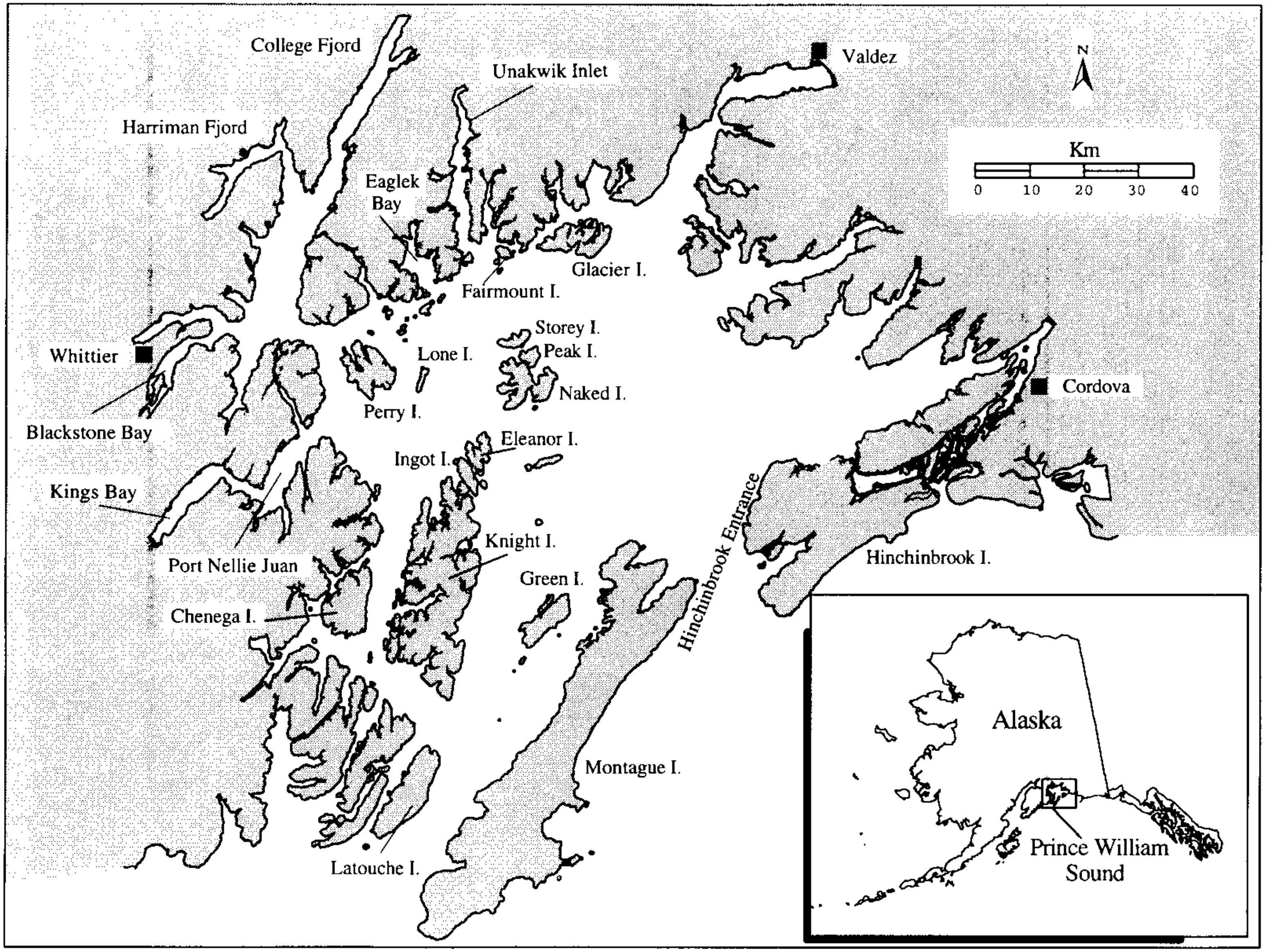

College Fjord
Unakwik Inlet
Valdez
N
Harriman Fjord
Km
0 10 20 30 40
Eaglek Bay
Glacier I.
Fairmount I.
Storey I.
Peak I.
Lone I.
Whittier
Naked I.
Cordova
Perry I.
Blackstone Bay
Eleanor I.
Ingot I.
Kings Bay
Hinchinbrook Entrance
Knight I.
Port Nellie Juan
Hinchinbrook I.
Green I.
Chenega I.
Alaska
Montague I.
Prince William Sound
Latouche I.

Figure 1

Figure 2. Place names for islands, bays, landmarks and murrelet capture locations in the primary study areas of Port Nellie Juan and Naked Island, Prince William Sound, Alaska, in 1994.

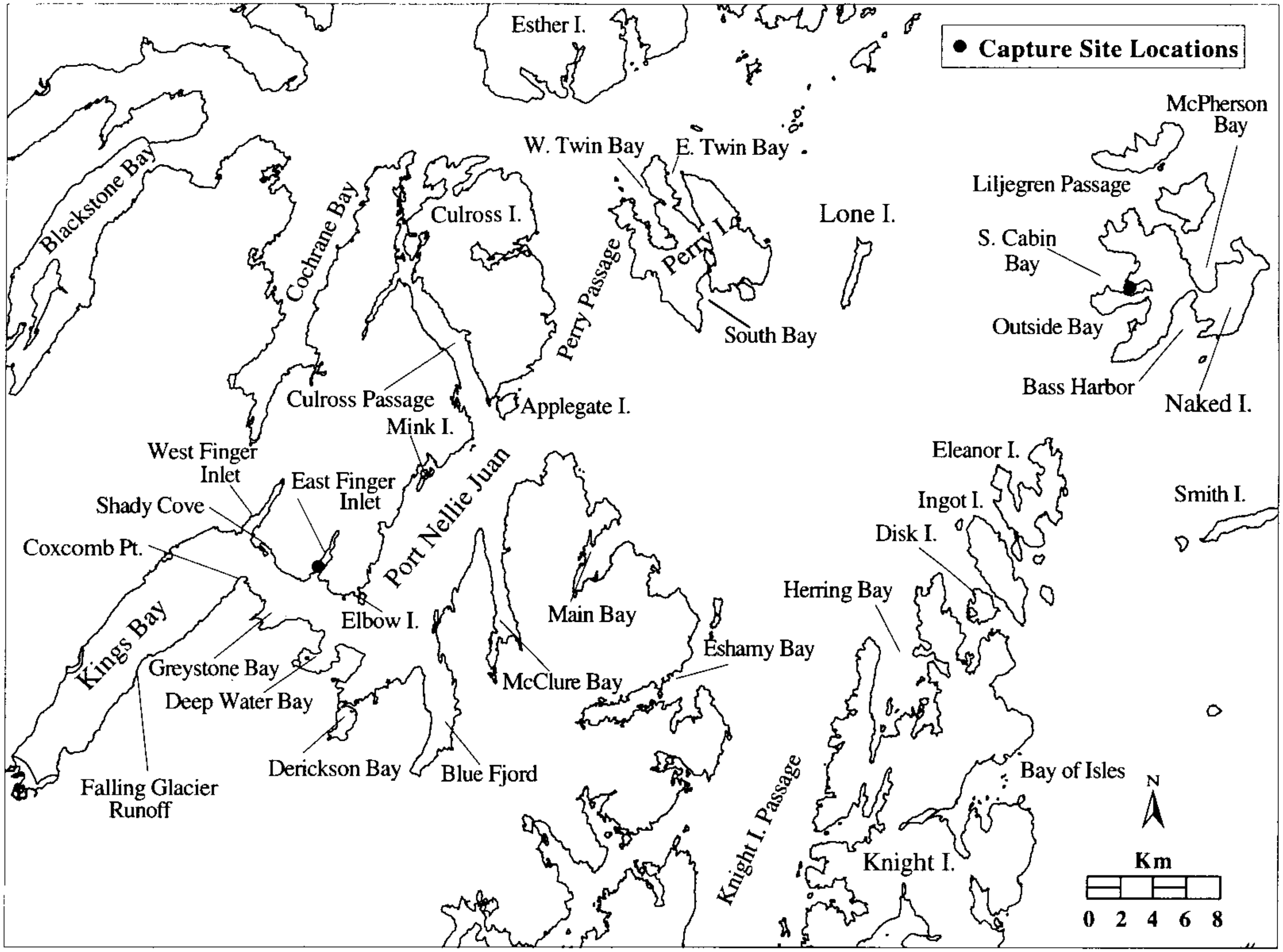

Capture Site Locations
Esther I.
McPherson Bay
W. Twin Bay
E. Twin Bay
Liljegren Passage
Blackstone Bay
Cochrane Bay
Culross I.
Lone I.
S. Cabin Bay
Perry Passage
Perry I.
South Bay
Outside Bay
Bass Harbor
Naked I.
Culross Passage
Applegate I.
Mink I.
West Finger Inlet
East Finger Inlet
Eleanor I.
Smith I.
Shady Cove
Ingot I.
Port Nellie Juan
Disk I.
Coxcomb Pt.
Herring Bay
Elbow I.
Main Bay
Kings Bay
Eshamy Bay
Greystone Bay
McClure Bay
Deep Water Bay
Derickson Bay
Blue Fjord
Bay of Isles
Falling Glacier Runoff
Knight I. Passage
N
Knight I.
Km
0 2 4 6 8

Figure 2

Figure 3. Bathymetry of Port Nellie Juan, Prince William Sound, Alaska.

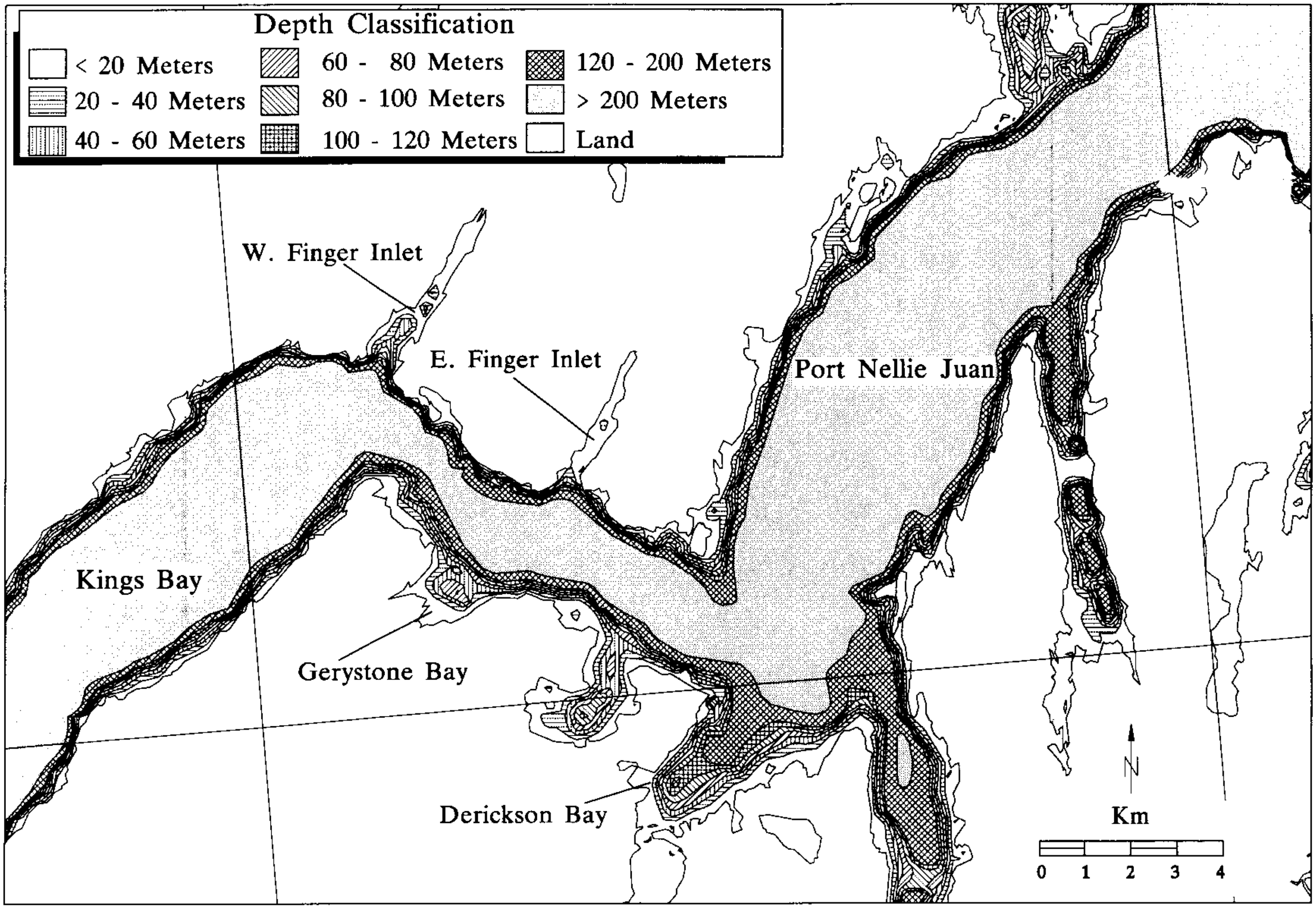

Depth Classification
< 20 Meters
20 - 40 Meters
40 - 60 Meters
60 - 80 Meters
80 - 100 Meters
100 - 120 Meters
120 - 200 Meters
> 200 Meters
Land
W. Finger Inlet
E. Finger Inlet
Port Nellie Juan
Kings Bay
Gerystone Bay
Derickson Bay
N
Km
0 1 2 3 4

Figure 3

Figure 4. Bathymetry of the Naked Island area, Prince William Sound, Alaska.

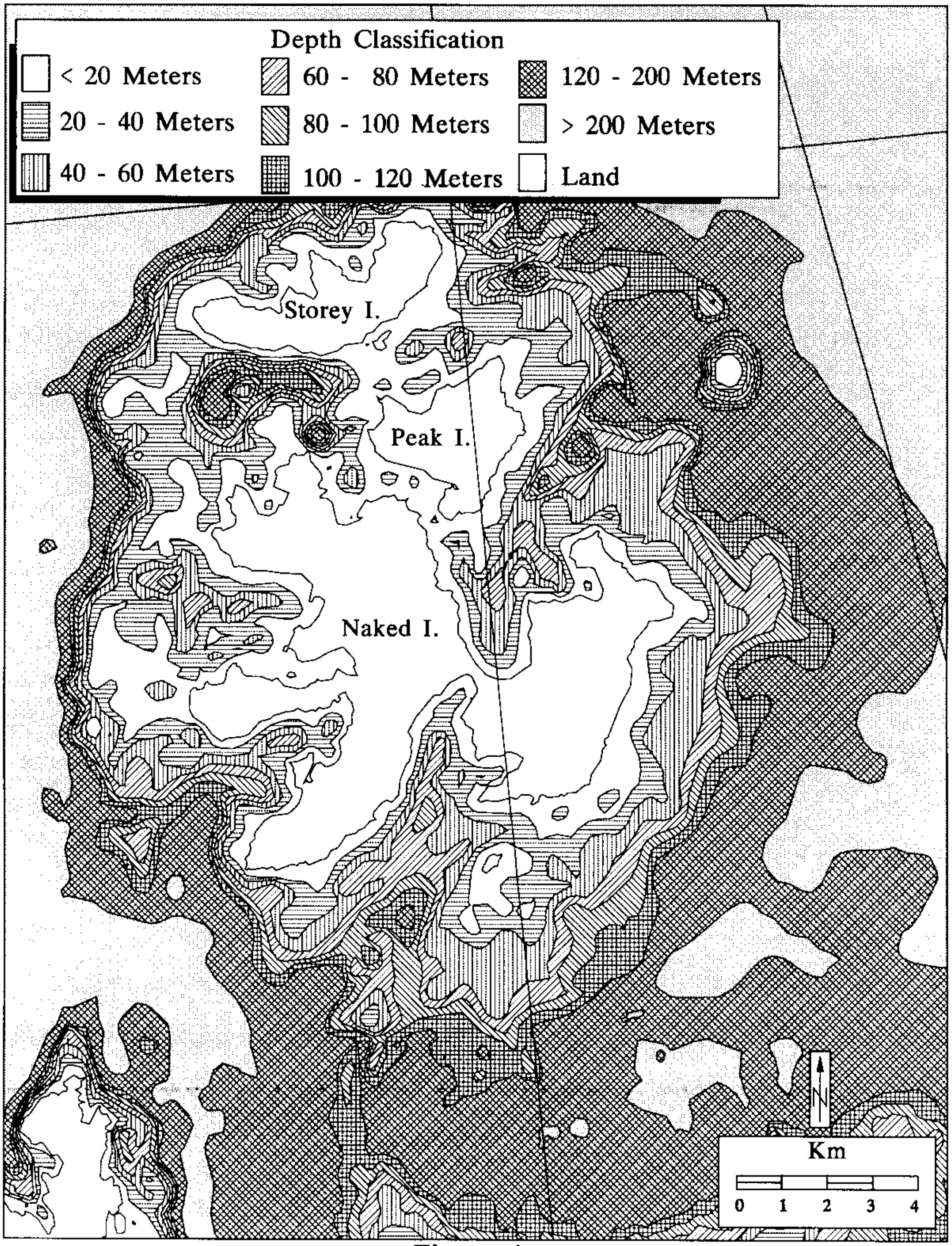

Depth Classification
< 20 Meters
20 - 40 Meters
40 - 60 Meters
60 - 80 Meters
80 - 100 Meters
100 - 120 Meters
120 - 200 Meters
> 200 Meters
Land
Storey I.
Peak I.
Naked I.
Km
0 1 2 3 4

Figure 4

Figure 5. Coverage from airplane-based telemetry searches for radio-tagged marbled murrelets in Prince William Sound, Alaska, in 1994.

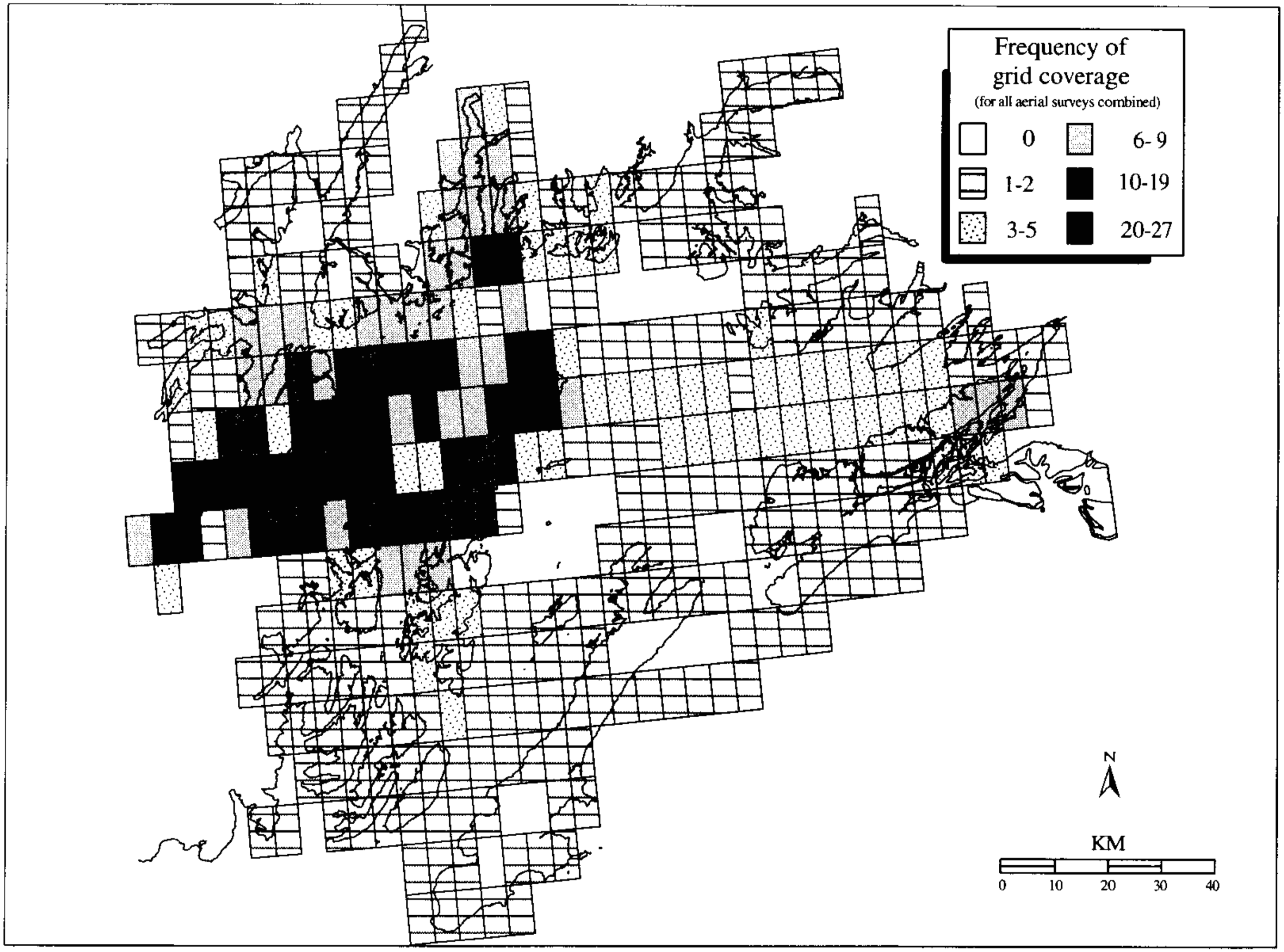
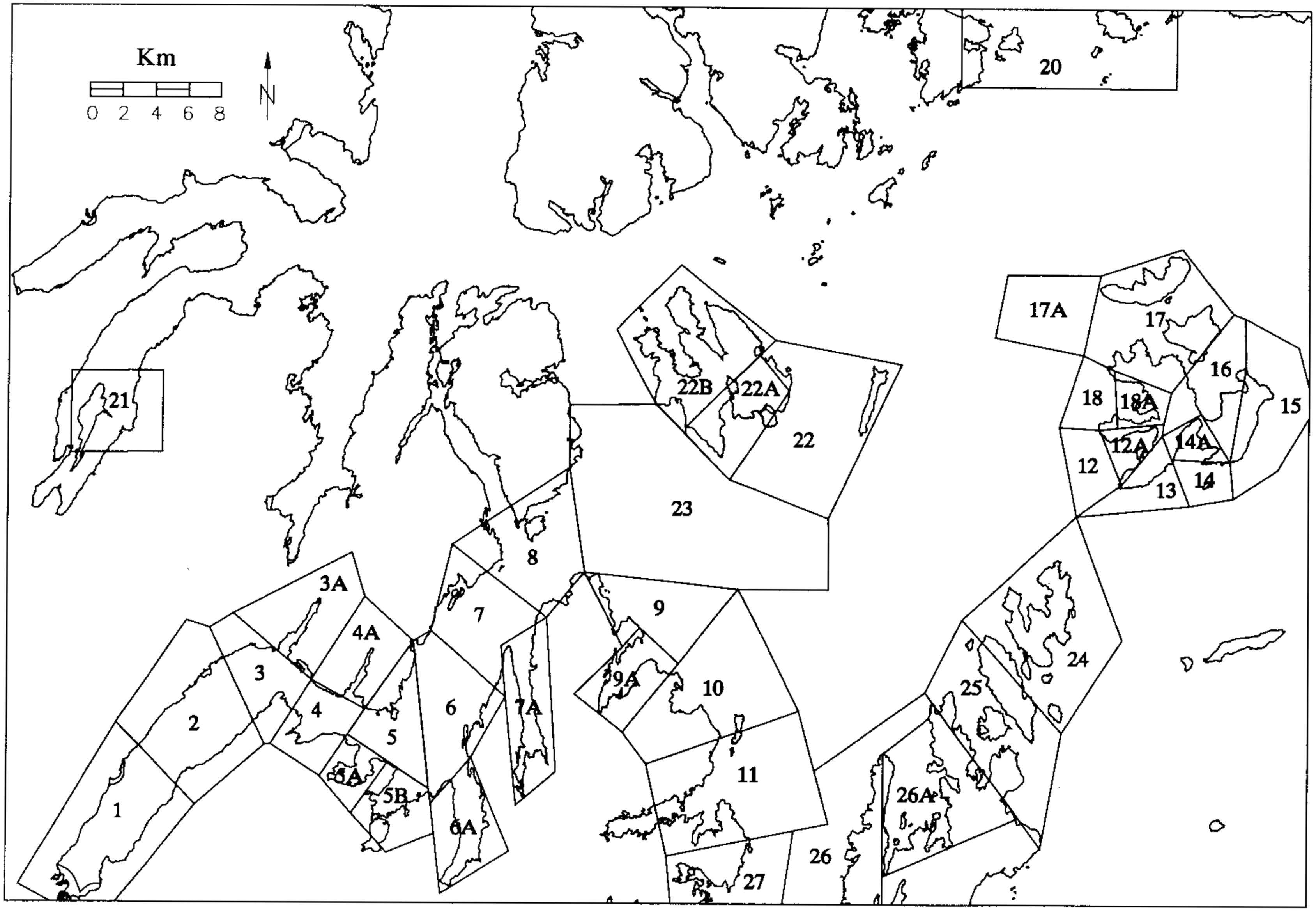

Frequency of grid coverage
(for all aerial surveys combined)
0
1-2
3-5
6- 9
10-19
20-27
N
KM
0
10
20
30
40

Figure 5

Figure 6. Marine zones defined for quantifying presence/absence of radio-tagged marbled murrelets in Prince William Sound, Alaska, in 1994.



Km
0 2 4 6 8
N
20
17A
17
16
15
18
18A
12
12A
14A
13
14
21
22B
22A
22
23
8
3A
4A
7
3
4
2
5
6
7A
9
9A
10
11
24
25
5A
5B
1
6A
26A
26
27

Figure 6

Figure 7. Sub-areas defined for determining availability of water depth categories from Geographic Information System bathymetric coverage of Prince William Sound, Alaska.

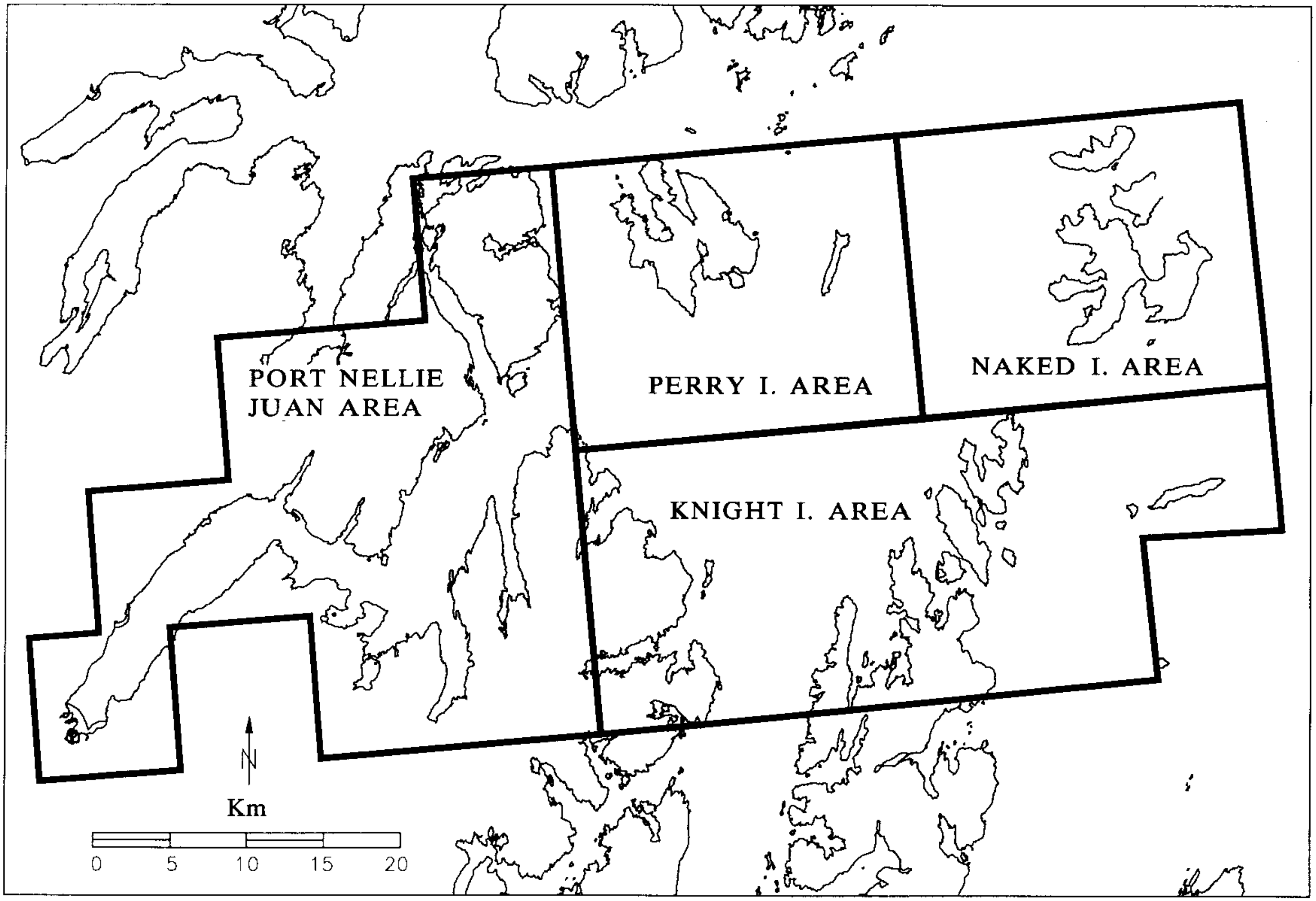
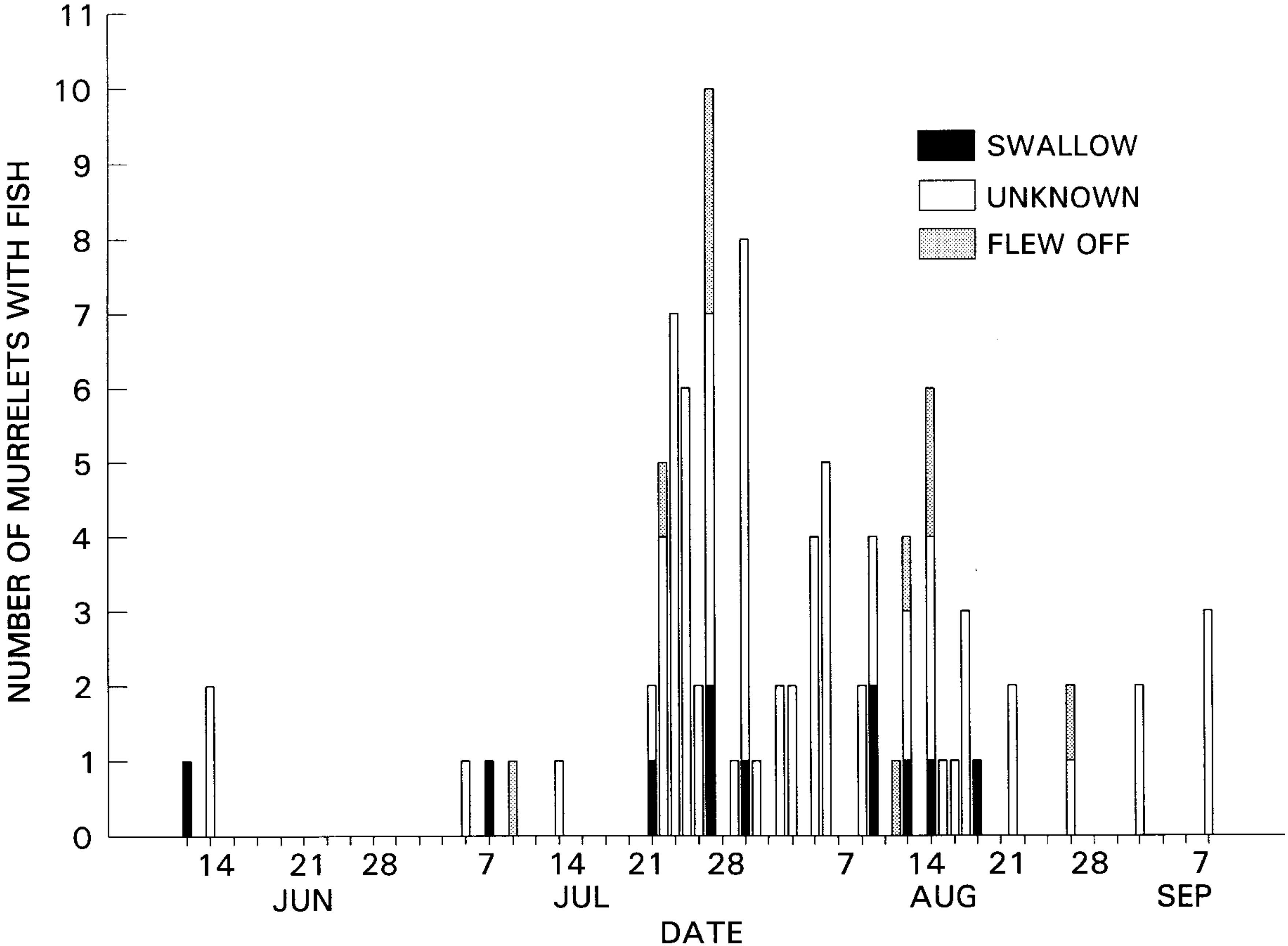

PORT NELLIE
JUAN AREA
PERRY I. AREA
NAKED I. AREA
KNIGHT I. AREA
N
Km
0
5
10
15
20

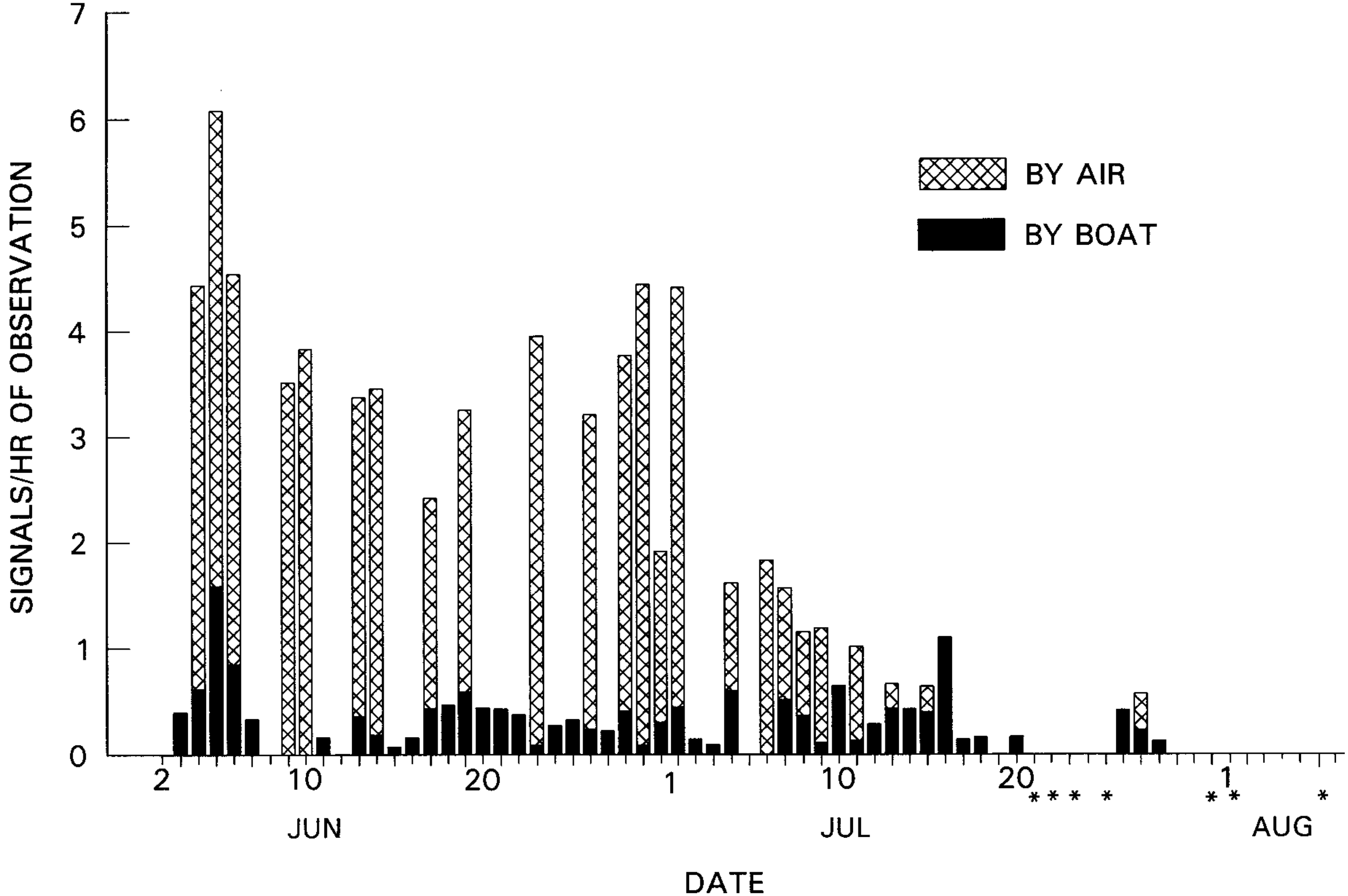
Figure 7

Figure 8. Number of marbled murrelets, by date, observed holding fish on the water surface, and their activity with the fish, in Prince William Sound, Alaska, in June, July and August, 1994.



SWALLOW
UNKNOWN
FLEW OFF
NUMBER OF MURRELETS WITH FISH
0
1
2
3
4
5
6
7
8
9
10
11
14
21
28
JUN
7
14
21
28
JUL
7
14
21
28
AUG
7
SEP
DATE

Figure 9. Number of radio-tagged marbled murrelets relocated, per hour of search effort, on each day by air and by boat in Prince William Sound, Alaska, in June, July and August, 1994. Asterisks designate days where no search was conducted.



SIGNALS/HR OF OBSERVATION
0
1
2
3
4
5
6
7
BY AIR
BY BOAT
2
10
20
1
10
20
1
JUN
JUL
AUG
DATE

Figure 10. Minimum area polygons derived from aerial relocations of 6 radio-tagged marbled murrelets that had inland locations and were believed to be nesting birds. The birds were caught in Port Nellie Juan, Prince William Sound, Alaska, in June and tracked through July, 1994.

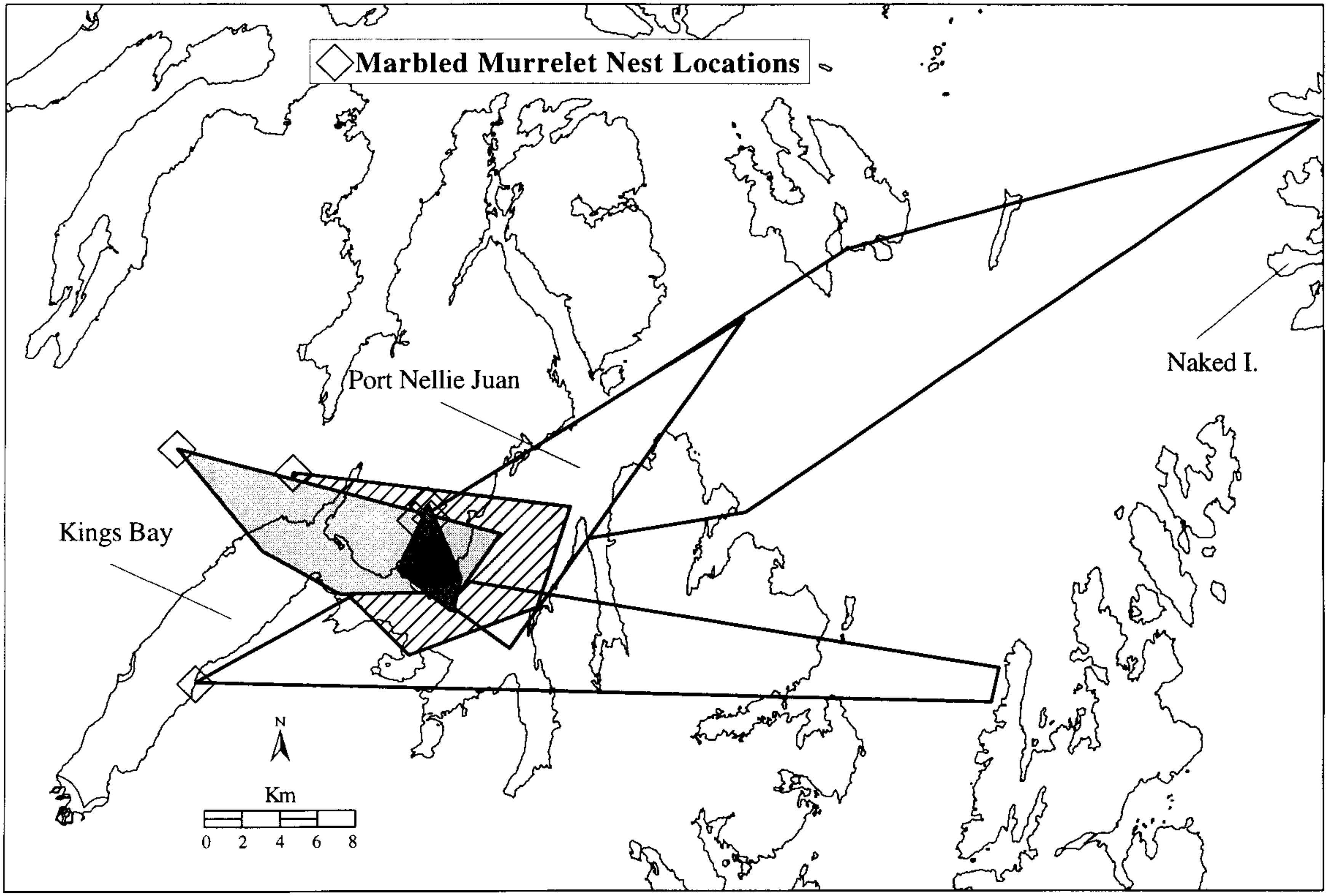

Marbled Murrelet Nest Locations
Port Nellie Juan
Naked I.
Kings Bay
N
Km
0 2 4 6 8

Figure 10

Figure 11. Total aerial (airplane-based) relocations of radio-tagged marbled murrelets caught at Port Nellie Juan (circles) and Naked Island (triangles) in Prince William Sound, Alaska, in June and July 1994.

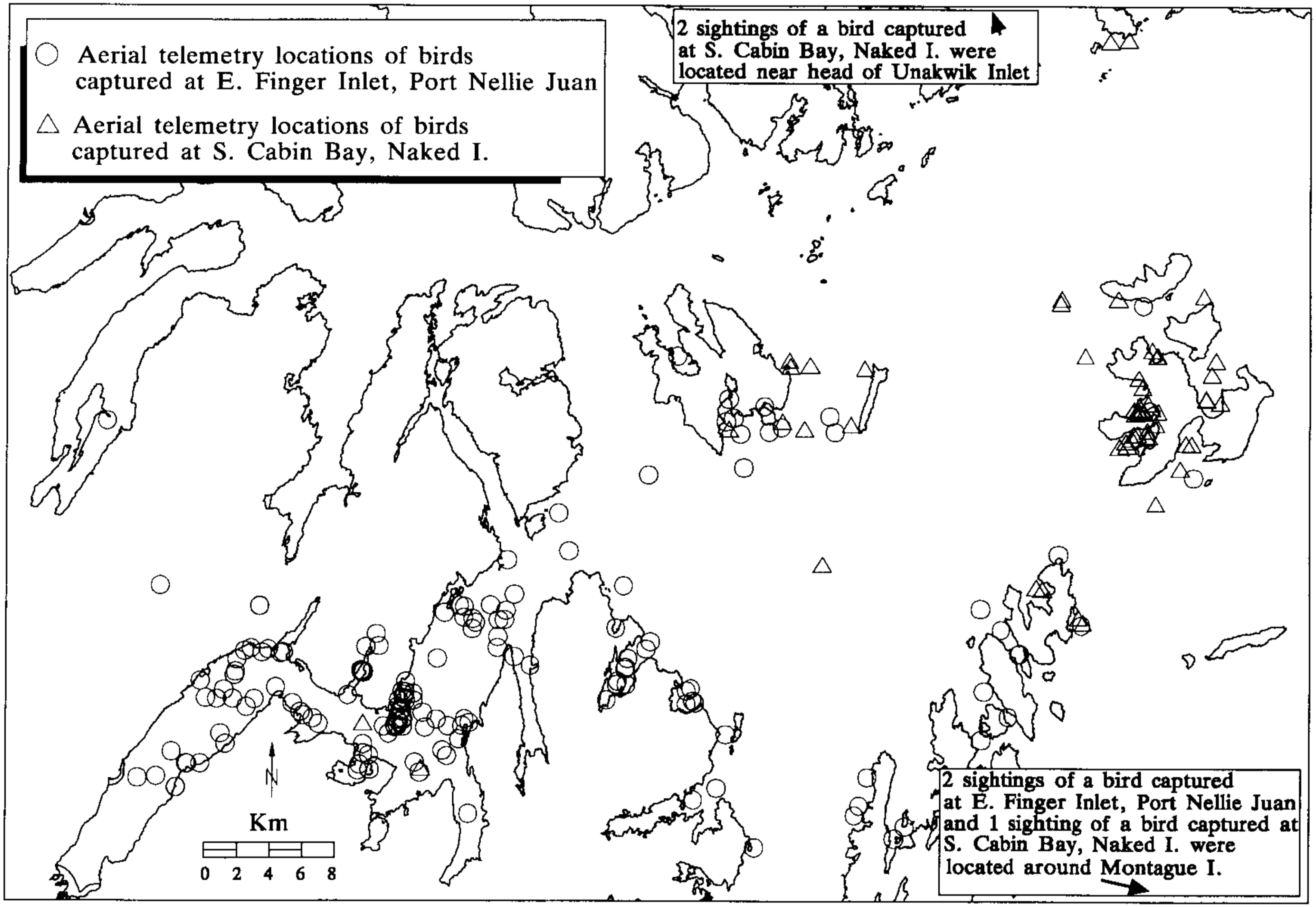
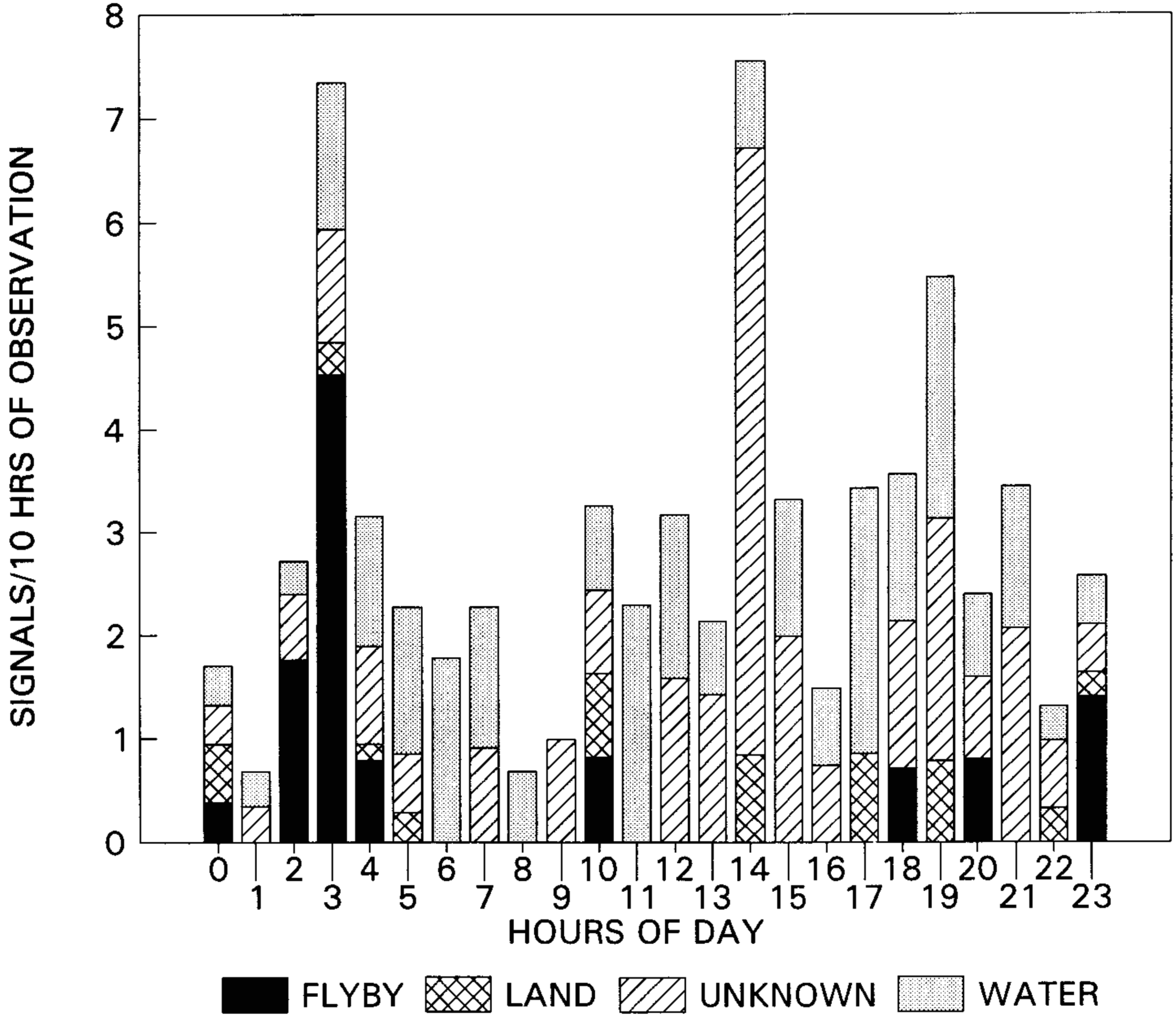

Aerial telemetry locations of birds captured at E. Finger Inlet, Port Nellie Juan
Aerial telemetry locations of birds captured at S. Cabin Bay, Naked I.
2 sightings of a bird captured at S. Cabin Bay, Naked I. were located near head of Unakwik Inlet
2 sightings of a bird captured at E. Finger Inlet, Port Nellie Juan and 1 sighting of a bird captured at S. Cabin Bay, Naked I. were located around Montague I.
Km
0 2 4 6 8
N

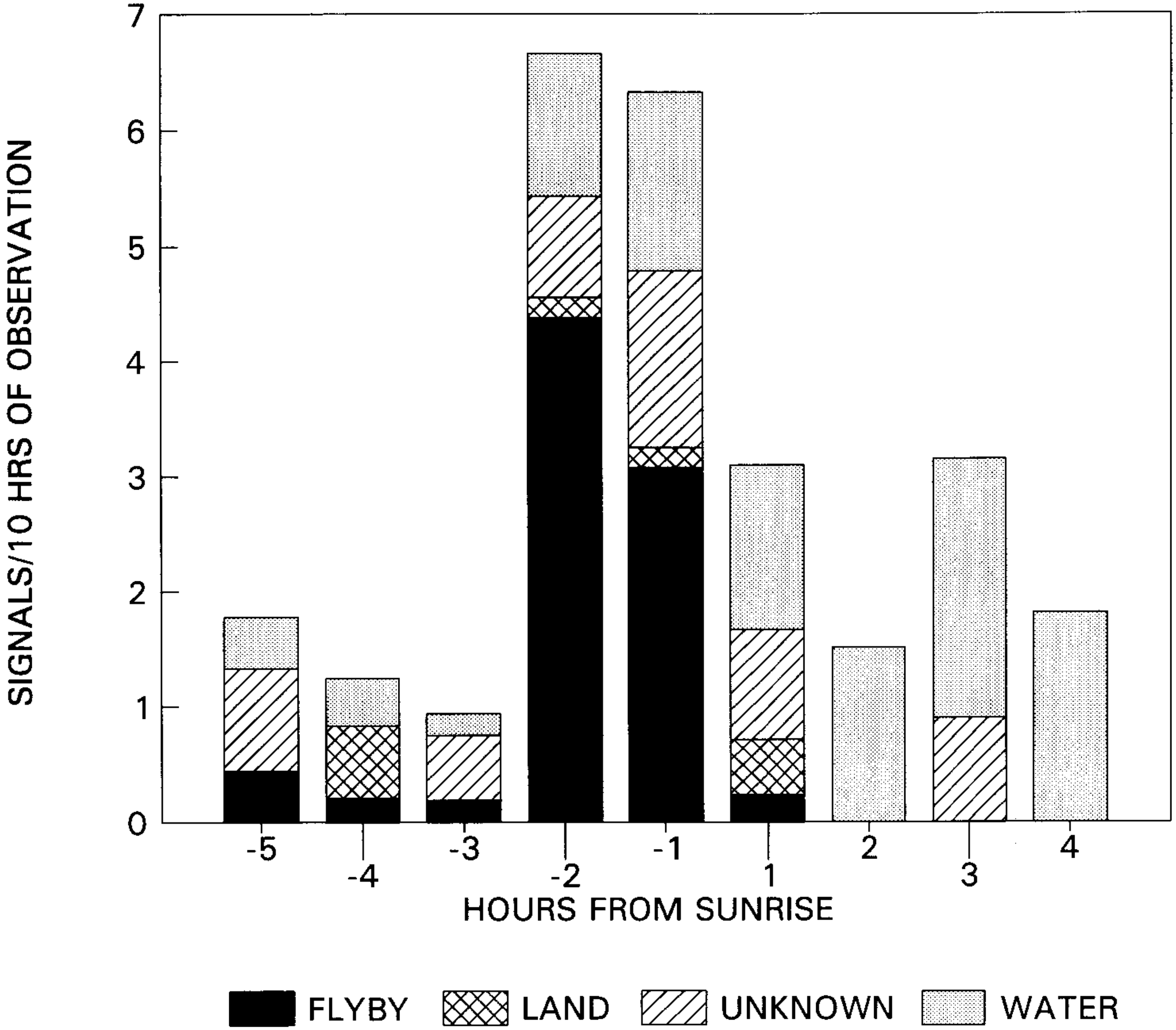
Figure 11

Figure 12. Number of radio-tagged marbled murrelet signals (N = 186) detected by each hour of the day by boat during June and July 1994, in Port Nellie Juan and Naked Island, Prince William Sound, Alaska. The detections per hour were weighted for the number of hours searched during that time of day. Activity was categorized as flying, on land (at nest), unknown and on the water.



SIGNALS/10 HRS OF OBSERVATION
0
1
2
3
4
5
6
7
8
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
HOURS OF DAY
FLYBY
LAND
UNKNOWN
WATER

Figure 13. Number of radio-tagged marbled murrelet signals (N = 116) detected by each hour of the day between 0000 - 0900 h, relative to the hours from sunrise, by boat during June and July 1994, in Port Nellie Juan and Naked Island, Prince William Sound, Alaska. The detections per hour from sunrise were weighted for the number of hours searched during that time from sunrise. Activity was categorized as flying, on land (at nest), unknown and on the water.



SIGNALS/10 HRS OF OBSERVATION
0
1
2
3
4
5
6
7
-5
-4
-3
-2
-1
1
2
3
4
HOURS FROM SUNRISE
FLYBY
LAND
UNKNOWN
WATER

Figure 14. Post-fledging telemetry locations of a juvenile marbled murrelet radio-tagged at its nest in Kings Bay, Port Nellie Juan in Prince William Sound, Alaska, in August, 1994.

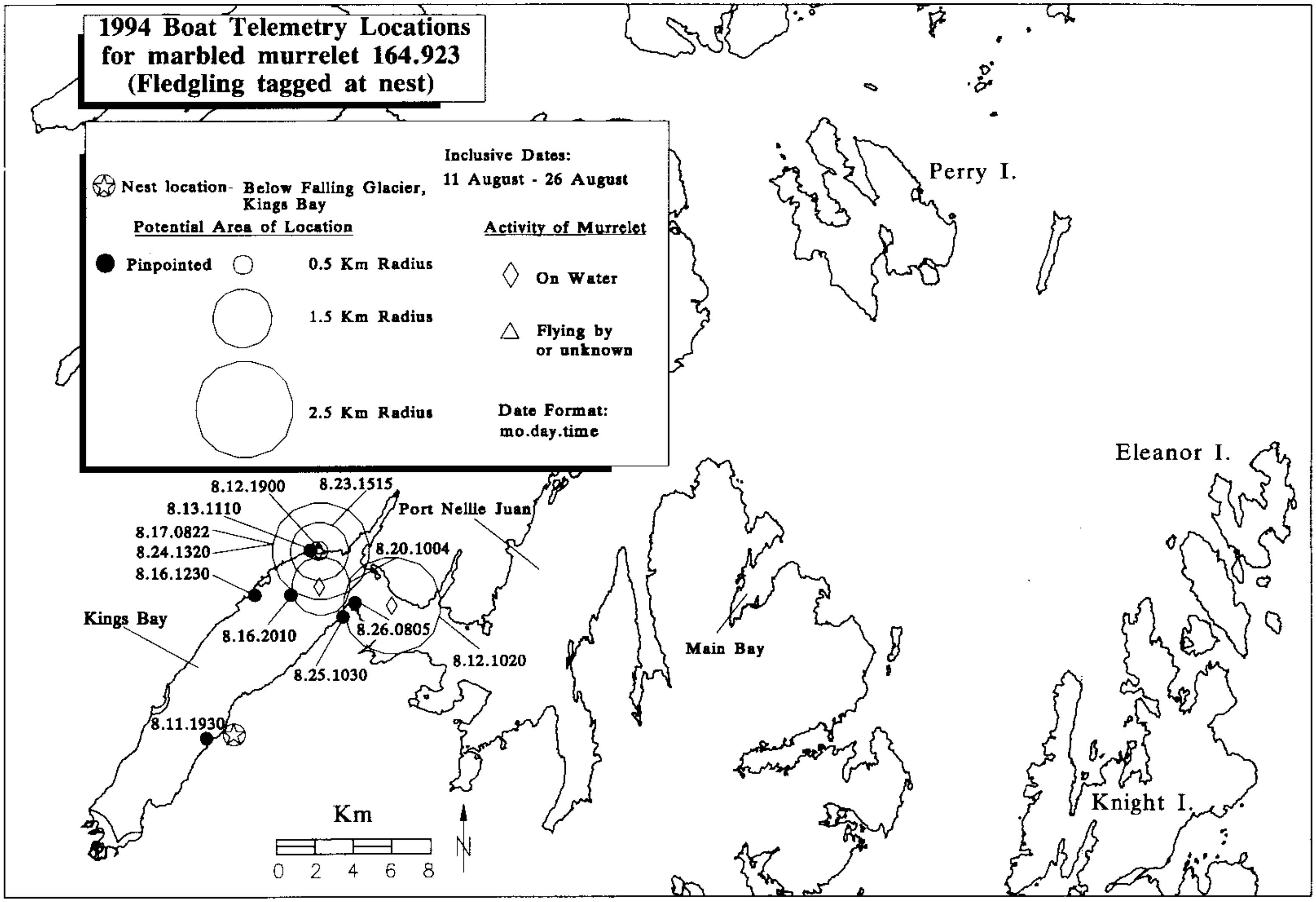
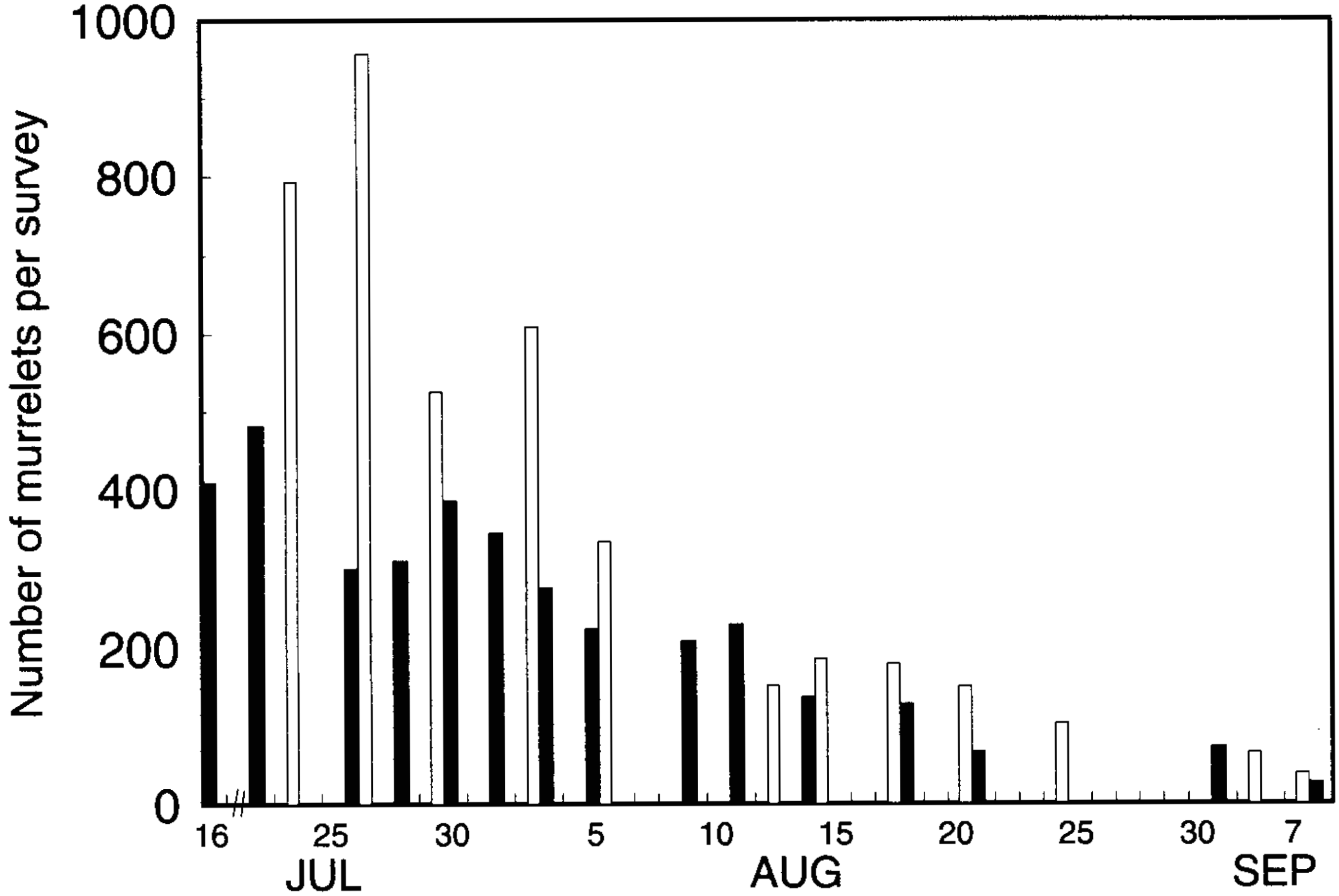

1994 Boat Telemetry Locations for marbled murrelet 164.923 (Fledgling tagged at nest)
Inclusive Dates:
11 August - 26 August
Nest location- Below Falling Glacier, Kings Bay
Potential Area of Location
Activity of Murrelet
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
On Water
Flying by or unknown
Date Format: mo.day.time
Perry I.
Eleanor I.
Knight I.
Main Bay
Port Nellie Juan
Kings Bay
8.12.1900
8.23.1515
8.13.1110
8.17.0822
8.24.1320
8.16.1230
8.20.1004
8.16.2010
8.26.0805
8.12.1020
8.25.1030
8.11.1930
Km
0 2 4 6 8
N

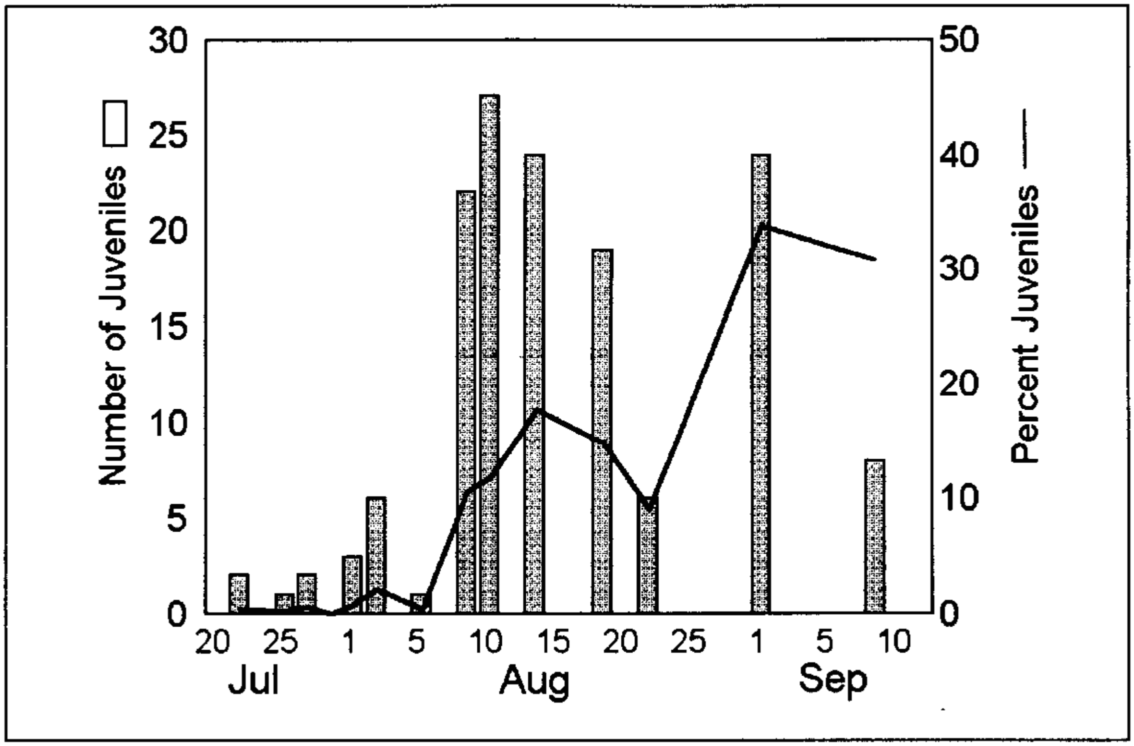
Figure 14

Figure 15. Total numbers of *Brachyramphus* murrelets counted during repeated shoreline surveys of Port Nellie Juan (light bars) and Naked Island (dark bars) between 16 July and 8 September 1994, in Prince William Sound, Alaska.

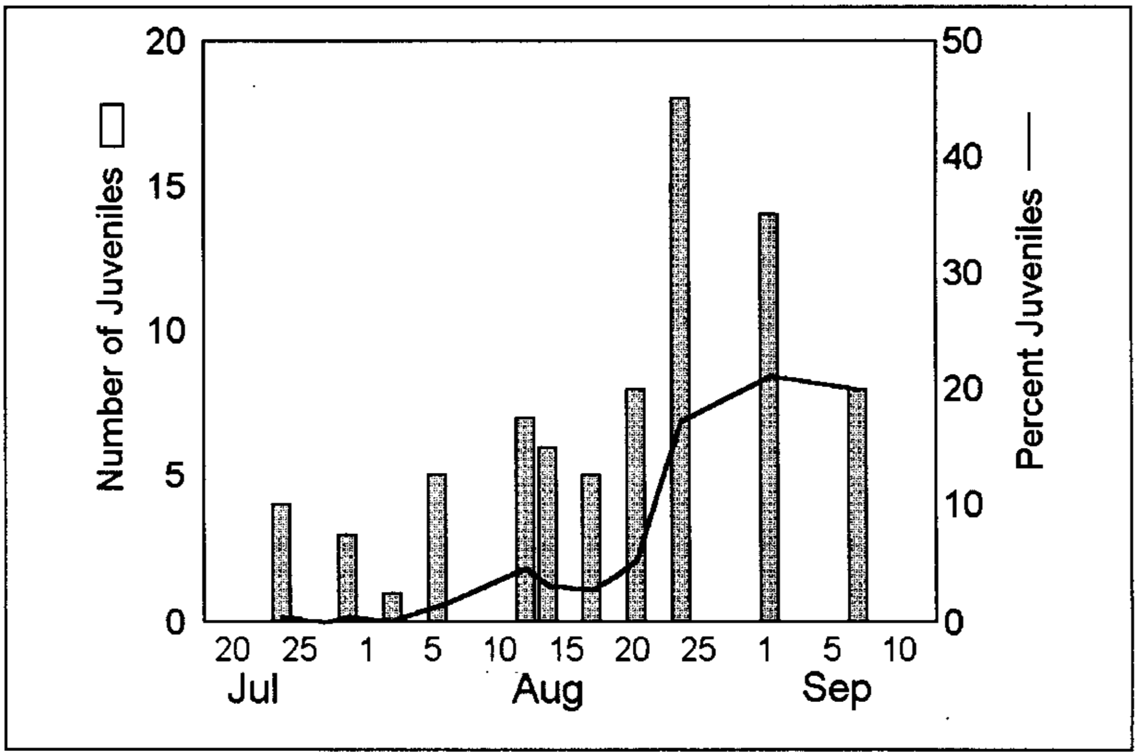


Number of murrelets per survey
1000
800
600
400
200
0
16
25
30
5
10
15
20
25
30
7
JUL
AUG
SEP

Figure 16. Total number (dark bars) of juvenile and unidentified black-and-white *Brachyramphus* murrelets (not including those identified as adults in winter plumage) counted during repeated shoreline surveys of Naked Island (top graph) and Port Nellie Juan (bottom graph) between 16 July and 8 September 1994. Also shown are the percentages (solid line) of juvenile-plumaged birds on each survey, relative to the total number of murrelets counted that day.



Number of Juveniles
Percent Juveniles
30
25
20
15
10
5
0
50
40
30
20
10
0
20 25 1 5 10 15 20 25 1 5 10
Jul
Aug
Sep



Number of Juveniles
Percent Juveniles
20
15
10
5
0
50
40
30
20
10
0
20 25 1 5 10 15 20 25 1 5 10
Jul
Aug
Sep

Figure 17. Density of *Brachyramphus* murrelets (birds / km^2) on shoreline transects in Port Nellie Juan, Prince William Sound, on 26 July 1994.

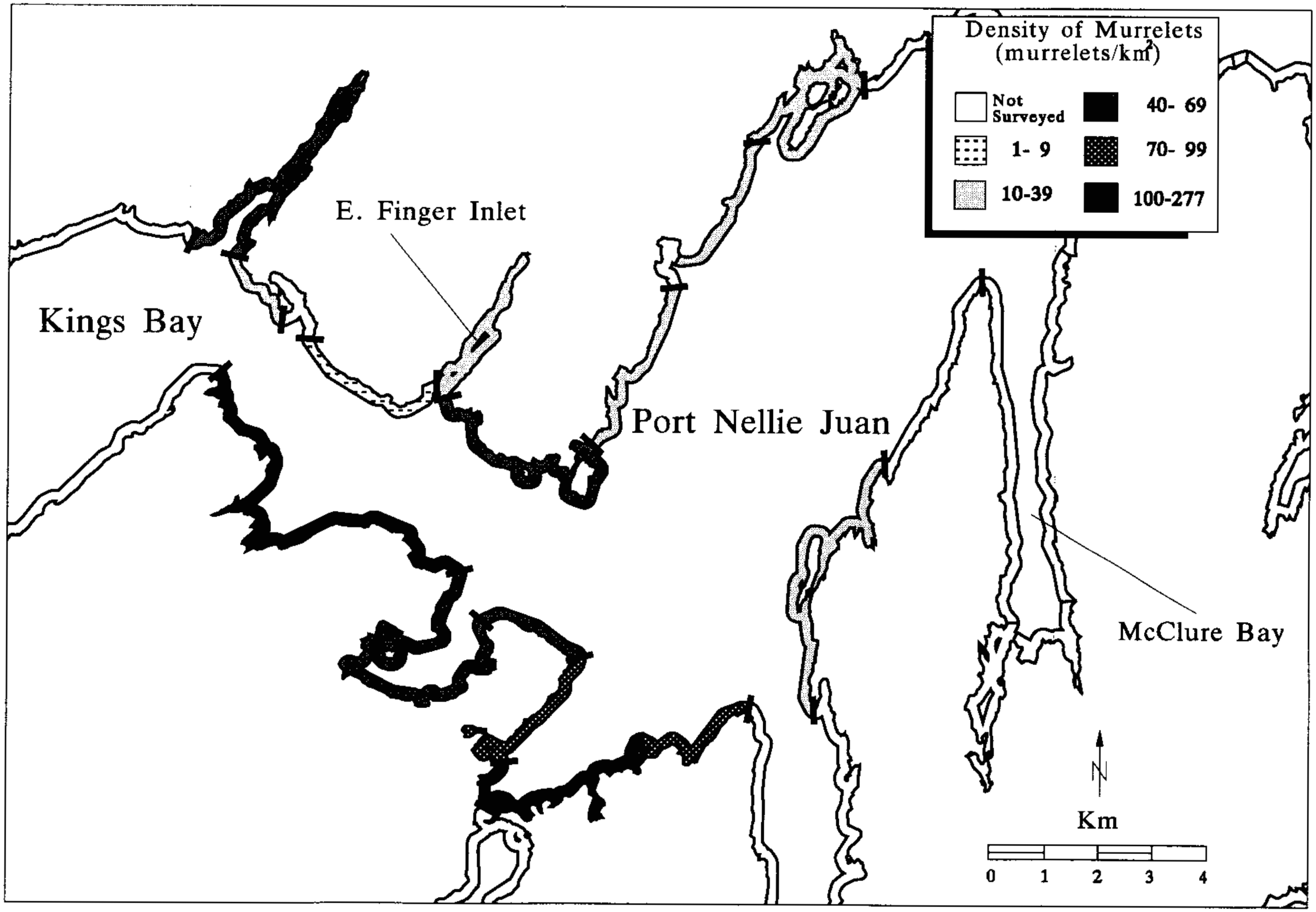

Density of Murrelets
(murrelets/km²)
Not Surveyed
40- 69
1- 9
70- 99
10-39
100-277
E. Finger Inlet
Kings Bay
Port Nellie Juan
McClure Bay
N
Km
0
1
2
3
4

Figure 17

Figure 18. Density of *Brachyramphus* murrelets (birds / km^2) on shoreline transects at Naked Island, Prince William Sound, on 18 July 1994.

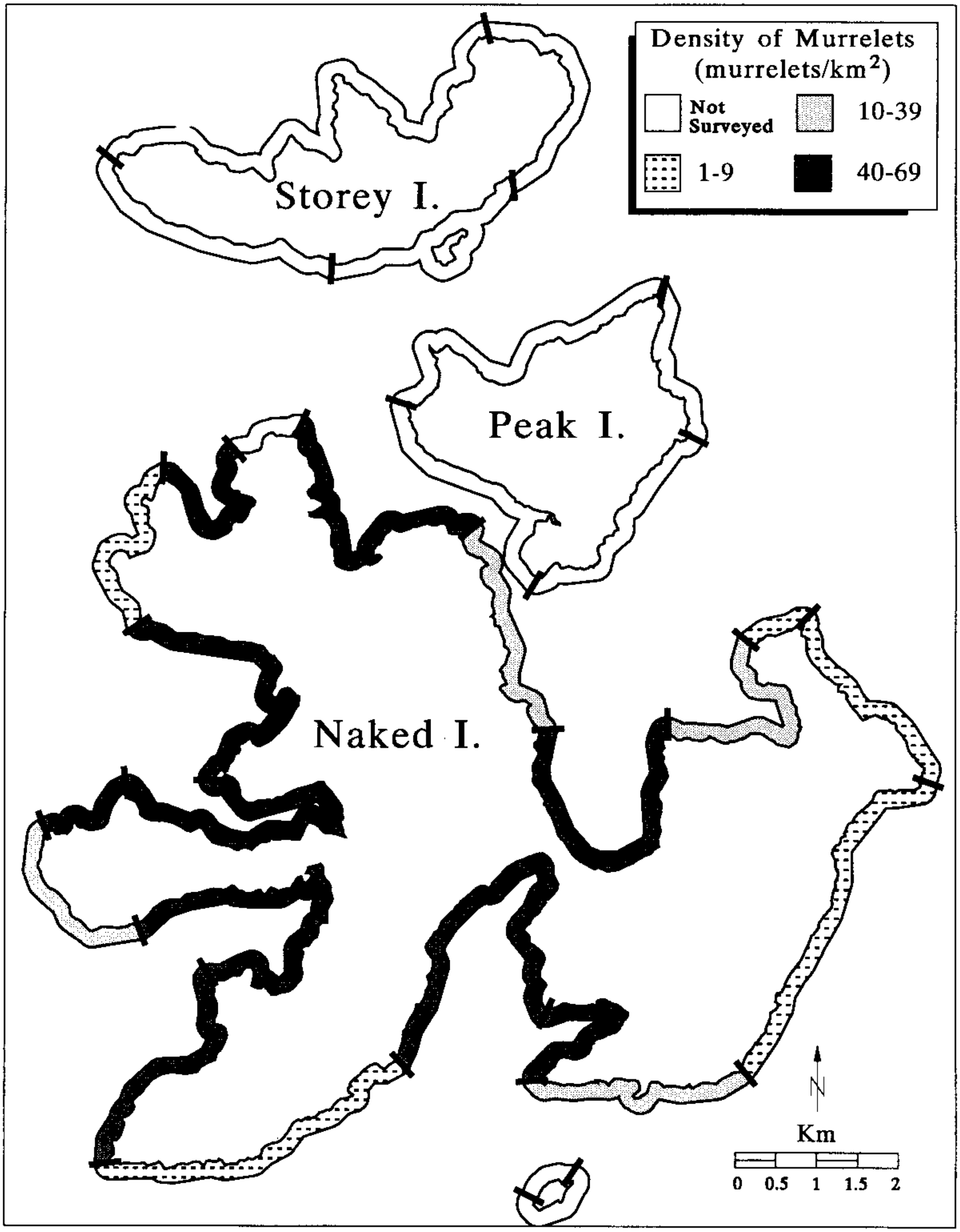

Density of Murrelets
(murrelets/km^2)
Not Surveyed
10-39
1-9
40-69
Storey I.
Peak I.
Naked I.
N
Km
0 0.5 1 1.5 2

Figure 18

Figure 19. Aerial relocations of radio-tagged marbled murrelets near Naked Island, Prince William Sound, Alaska, in June and July 1994, in relation to the bathymetry of the area.

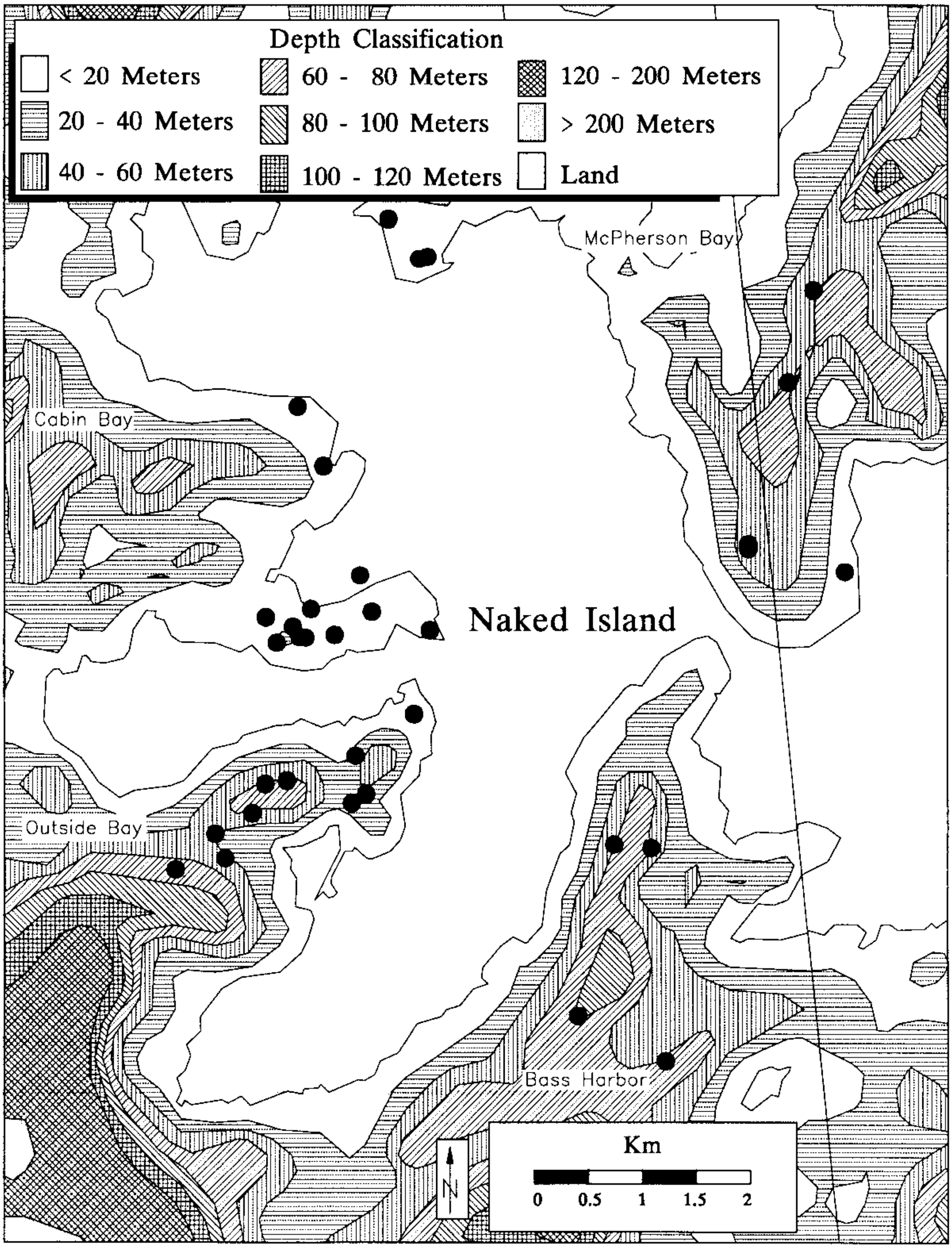
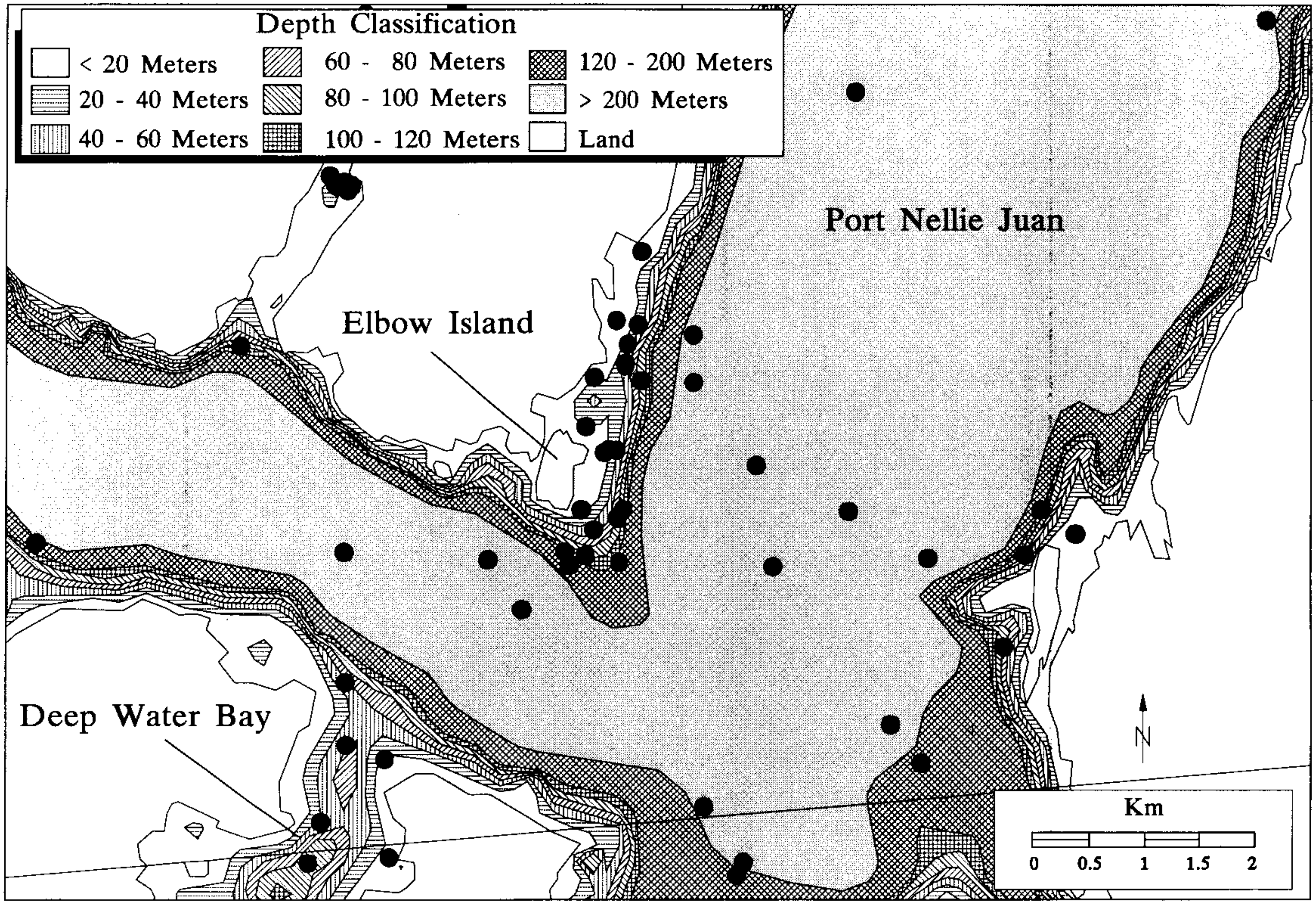

Depth Classification
< 20 Meters
20 - 40 Meters
40 - 60 Meters
60 - 80 Meters
80 - 100 Meters
100 - 120 Meters
120 - 200 Meters
> 200 Meters
Land
McPherson Bay
Cabin Bay
Naked Island
Outside Bay
Bass Harbor
Km
0
0.5
1
1.5
2
N

Figure 19

Figure 20. Aerial relocations of radio-tagged marbled murrelets in central Port Nellie Juan, Prince William Sound, Alaska in June and July 1994, in relation to the bathymetry of the area.



Depth Classification
< 20 Meters
20 - 40 Meters
40 - 60 Meters
60 - 80 Meters
80 - 100 Meters
100 - 120 Meters
120 - 200 Meters
> 200 Meters
Land
Port Nellie Juan
Elbow Island
Deep Water Bay
N
Km
0
0.5
1
1.5
2

Figure 20

Figure 21. The number of individual radio-tagged marbled murrelets that were found by aerial telemetry in each marine zone (see Figure 6) at least once during June and July 1994, in Prince William Sound, Alaska.

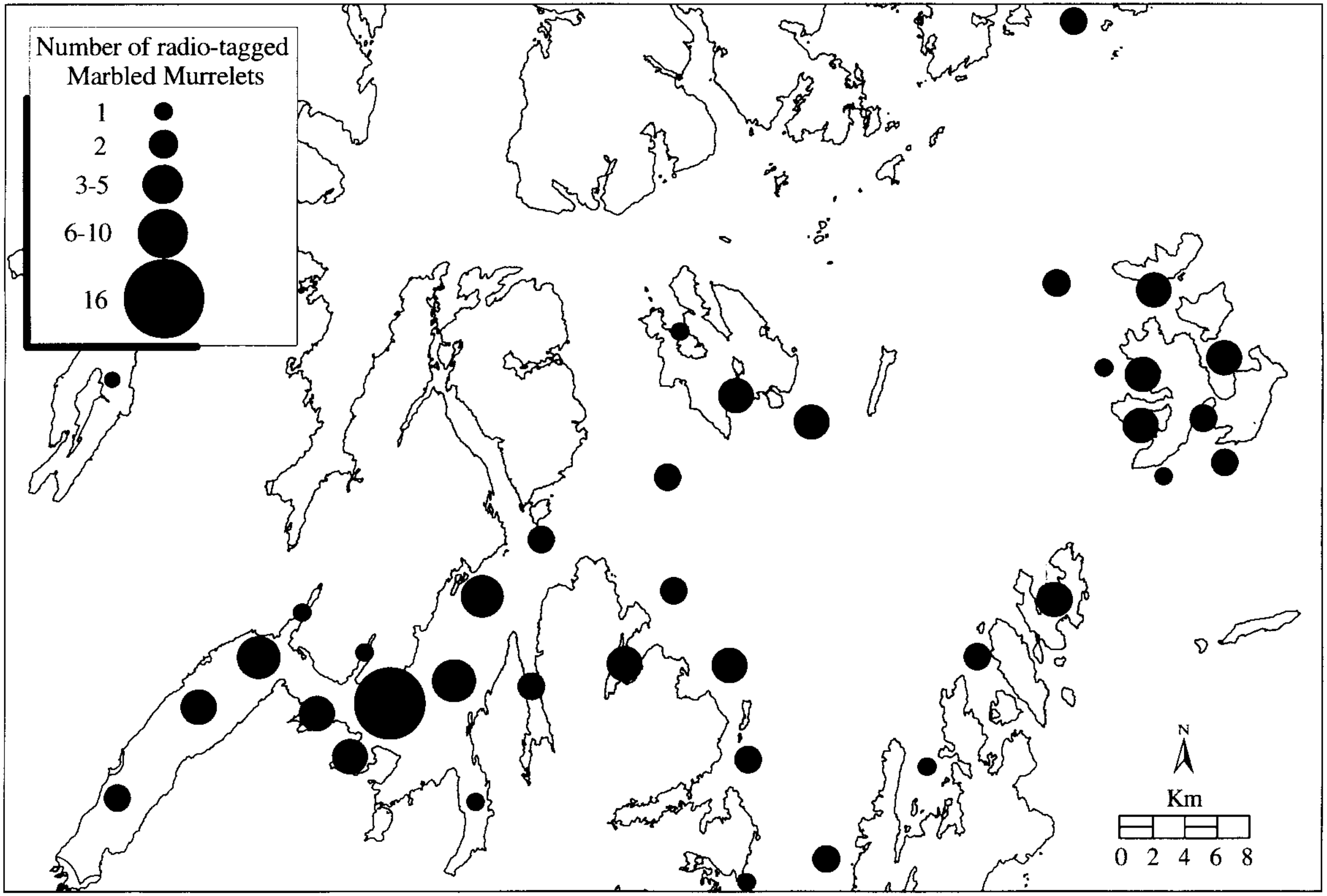

Number of radio-tagged
Marbled Murrelets
1
2
3-5
6-10
16
N
Km
0 2 4 6 8

Figure 21

Table 1. Straight-line distances between capture site and relocations of radio-tagged adult marbled murrelets with brood patches in Prince William Sound, Alaska, in June and July 1994.

	km From Nest			km From Capture Site			km Between Consecutive Sites			km Maximum Between 2 Points			Minimum Area Polygon (km^2)		
	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE
All Birds				42	17.2	2.0	34	11.2	1.6	33	24.6	3.7	25	123.8	36.6
PNJ Birds	6	16.2	4.6	32	17.5	2.3	26	11.8	2.0	26	24.2	3.4	20	136.3	44.1
Naked I Birds	-	-	-	10	16.3	4.5	8	9.1	2.4	7	26.4	12.6	5	73.9	49.1
t-test (PNJ & Naked)	-	-	-		-0.25			-0.71			0.17			-0.68	
df	-	-	-		40			32			6.9			23	
p	-	-	-		0.81			0.48			0.87			0.51	

Table 2. Non-straight line distances between capture site and relocations of radio-tagged adult marbled murrelets with brood patches in Prince William Sound, Alaska, in June and July 1994.

	km From Nest			km From Capture Site			km Between Consecutive Sites			km Maximum Between Two Points		
	N	Mean	SE	N	Mean	SE	N	Mean	SE	N	Mean	SE
All Birds				42	20.2	2.1	34	13.5	1.8	33	31.5	3.9
PNJ Birds	6	20.9	5.9	32	20.6	2.5	26	14.2	2.3	26	32.1	3.9
Naked I. Birds	-	-	-	10	18.9	4.0	8	11.1	2.6	7	29.2	12.2
t-test (PNJ v. Naked)					-0.34			-0.73			-0.30	
df					40			32			31	
p					0.74			0.47			0.77	

Table 3. Frequency of use of water-depth classes compared to the amount available for radio-tagged marbled murrelets in Prince Wiliam Sound, Alaska, in 1994. The areas described for these tests are shown in Figure 7. The percent area (km^2) of the depth classes was determined by bathymetric coverage on a Geographic Information System.

Water Depth (meters)	All areas and bird locations		PNJ area and birds		Naked I. area and birds	
	% Area (km^2) available	% frequency of use by tagged birds	% Area (km^2) available	% frequency use by tagged birds	% Area (km^2) available	% frequency use by tagged birds
0-20	11	21	21	12	11	32
20-40	6	13	6	8	10	8
40-60	5	13	5	12	9	32
60-80	5	10	4	3	6	20
80-100	5	5	4	5	5	0
100-120	8	4	3	3	5	0
120-200	13	14	11	17	14	8
>200	48	22	46	40	40	0
Chi-square	84.8		6.7[a]		35.1[a]	
df	7		3		3	
p	< 0.0001		0.082		< 0.0001	

[a] The Chi-square test was done on four depth categories, due to the number of cells with expected counts of < 5 (in bird use) for Naked Island area. The categories were 0-40 m, 40-80 m, 80-200 m and > 200 m. Test result for PNJ using eight categorires was Chi-square = 10.57, df = 7, P = 0.159.

APPENDICES

Appendix A. Surface water measurements taken during at-sea surveys at Port Nellie Juan and Naked Island, Prince William Sound, Alaska, in July, August and September 1994.

	Water Temperature (°C)			Water Salinity (o/ooo)			Water Clarity (Secchi disc) (in meters)		
	N	Mean	SE	N	Mean	SE	N	Mean	SE
Port Nellie Juan[a]	11	13.0	0.27	13	13.6	1.3	13	6.6	0.6
Naked Island[a]	11	14.8	0.39	7	24.8	1.0	12	9.7	0.4
Wilcoxon 2-sample test									
Z		2.83			3.45			3.18	
p		0.005			0.0006			0.002	

[a] The mean of 3 or 4 samples was used for each of the 11 survey days.

Appendix B-2. Capture effort and success during attempts to net and tag marbled murrelets in Prince William Sound, Alaska, in May, June and July 1994, using the deep water net system.

Date	Location	Number of nets	Effort (hours)	Marbled murrelets captured	Time of capture[a]
30 May	Port Nellie Juan	1	2.0	-	
31 May	Port Nellie Juan	1	4.0	-	
	Port Nellie Juan	3	1.0	-	
1 June	Port Nellie Juan	3	4.0	-	
	Port Nellie Juan	5	2.0	1	2305
2 June	Port Nellie Juan	5	8.5	1	0430
				1	2310
3 June	Port Nellie Juan	5	11.0	2	0350
				1	0440
				2	0545
				1	0600
				1	0700
4 June	Port Nellie Juan	5	10.5	1	0430
				1	0440
				1	0518
				1	2155
				1	2235
				1	2352
5 June	Port Nellie Juan	5	5.0	1	0010
				1	0410
7 June	Naked Island	5	1.0	-	
8 June	Naked Island	5	7.0	1	0050
9 June	Naked Island	5	7.0	1	0105
10 June	Naked Island	5	6.0	-	
11 June	Naked Island	5	7.0	-	
12 June	Naked Island	5	7.0	1	2220
13 June	Naked Island	5	7.0	-	
14 June	Naked Island	5	9.5	1	0625
				1	2250
15 June	Naked Island	5	8.5	-	

[a] Times are in Alaska Daylight Time

Appendix B-1. Capture effort and success during attempts to net and tag marbled murrelets in Prince William Sound, Alaska, in June 1994, using the shallow-water net system.

Date	Location	Number of nets	Effort (hours)	Marbled murrelets captured	Time of capture[a]
7 June	Naked Island	3	1.0	-	
8 June	Naked Island	3	7.0	-	
9 June	Naked Island	3	7.0	2	0115
10 June	Naked Island	3	6.0	-	
11 June	Naked Island	3	7.0	-	
12 June	Naked Island	3	7.0	-	
13 June	Naked Island	3	7.0	-	
14 June	Naked Island	3	9.5	1	2250
15 June	Naked Island	3	8.5	-	
16 June	Naked Island	3	10.0	-	
17 June	Naked Island	3	6.5	1	2355
18 June	Naked Island	3	10.0	1	2300
19 June	Naked Island	3	10.0	-	
20 June	Naked Island	3	9.0	1	0340
				1	0715
21 June	Naked Island	3	7.0	-	
Total	Naked Island		112.5	7	

[a] Times are in Alaska Daylight Time.

Appendix B-2. Capture effort and success during attempts to net and tag marbled murrelets in Prince William Sound, Alaska, in May, June and July 1994, using the deep water net system.

Date	Location	Number of nets	Effort (hours)	Marbled murrelets captured	Time of capture[a]
16 June	Naked Island	5	10.0	-	
17 June	Naked Island	5	6.5	-	
18 June	Naked Island	5	10.0	1	0030
19 June	Naked Island	5	10.0	1	0002
20 June	Naked Island	5	9.0	-	
21 June	Naked Island	5	7.0	-	
22 June	Port Nellie Juan	5	3.0	-	
23 June	Port Nellie Juan	5	5.5	1	0400
				1	0450
				1	0510
25 June	Port Nellie Juan	5	3.0	-	
26 June	Port Nellie Juan	5	5.5	1	0345
				2	0425
				2	0430
27 June	Port Nellie Juan	5	8.0	1	0320
				1	0343
				1	0409
				2	0447
28 June	Port Nellie Juan	5	6.5	1	0415
29 June	Port Nellie Juan	5	7.5	1	2355
30 June	Port Nellie Juan	5	9.5	1	0538
1 July	Port Nellie Juan	5	3.5	1	0039
				1	0305
				1	0315
Total-Port Nellie Juan-1994			100.0	37	
Total-Naked Island-1994			112.5	7	

Appendix C. Measurements of marbled murrelets caught in mist nets at Naked Island and Port Nellie Juan, Prince William Sound, Alaska, in June and July 1994. Murrelets with the same superscript number were caught together.

Location	Radio Frequency	Tag Wt. (g)	Capture Date	Capture Time	Weight (g)	Bill Length (mm)	Bill Depth (mm)	Tarsus (mm)	Wing Chord (mm)	Plumage	Brood Patch Class*	Brood Patch Width (mm)	Brood Patch Length (mm)
Naked Island	164.129	1.95	6/20	0715	223	15.7	6.4	20.4	131	Summer	3	20	27
	164.274	1.95	6/19	0002	236	15.9	5.8	17.7	130	Trans	0	-	-
	164.469	1.95	6/18	2300	235	17.3	6.1	19.9	131	Summer	3	21	28
	164.501	1.95	6/18	0030	236	14.2	5.5	18.0	131	Summer	2	25	20
	164.601	1.95	6/17	2355	189	15.7	5.4	18.1	125	Summer	0	-	-
	164.722	1.95	6/14	2250	213	15.5	5.9	19.7	134	Summer	3	21	32
	164.764	1.95	6/14	2250	189	15.5	5.1	19.6	136	Summer	3	24	28
	164.819	1.95	6/14	0625	207	14.5	5.8	17.1	133	Summer	0	-	-
	164.941	1.95	6/12	2220	250	15.3	5.8	19.5	126	Summer	2	22	27
	164.980	1.95	6/20	0340	184	13.3	6.0	18.1	130	Summer	3	29	30
	165.185[3]	1.95	6/09	0115	207	15.4	5.7	18.5	131	Trans	2	21	32
	165.235[3]	1.95	6/09	0115	228	15.1	5.5	17.2	130	Summer	3	22	27
	165.315	1.95	6/09	0105	218	16.5	5.7	17.1	128	Summer	3	22	26
	165.374	1.95	6/08	0050	187	13.7	5.3	18.4	126	Summer	3	21	25
Port Nellie Juan	164.019[6]	1.50	6/27	0447	190	14.7	4.8	17.0	130	Trans	3	29	30
	164.033	1.95	6/23	0400	215	15.1	5.6	17.6	131	Summer	3	27	32
	164.044	1.50	6/27	0320	215	16.8	5.7	17.0	127	Summer	3	25	27
	164.067[1]	1.50	6/03	0545	193	16.0	5.5	18.9	129	Summer	1	25	30
	164.077[6]	1.50	6/27	0447	194	15.3	6.0	19.6	132	Winter	3	29	30
	164.183	1.50	6/27	0343	194	14.9	5.5	17.8	132	Summer	3	29	21
	164.243	1.50	6/27	0409	193	17.6	5.6	19.0	136	Summer	3	25	32
	164.290	1.50	6/28	0415	121	16.0	6.1	17.7	137	Summer	3	28	27
	164.328	1.50	7/01	0039	197	14.5	5.9	18.6	134	Summer	3	16	30
	164.410	1.50	6/30	0538	206	17.3	5.7	18.1	130	Summer	3	17	21
	164.440	1.50	6/26	0345	200	14.0	5.7	17.5	130	Summer	3	21	30

* Brood Patch classes based on Sealy (1974): class 0 = no defeathering, 1 = loss of down and some contour feathers, 2 = loss of down and most contour feathers, vascularization beginning, 3 = loss of feathers and heavy vascularization, 4 = regression beginning with down appearing, 5 = downy, feathers beginning, 6 = complete regression.

Appendix C - continued.

Location	Radio Frequency	Tag Wt. (g)	Capture Date	Capture Time	Weight (g)	Bill Length (mm)	Bill Depth (mm)	Tarsus (mm)	Wing Chord (mm)	Plumage	Brood Patch Class	Brood Patch Width (mm)	Brood Patch Length (mm)
Port Nellie Juan	164.540	1.50	6/29	2355	201	14.1	5.4	18.0	133	Summer	3	25	23
	164.622	1.50	6/03	0600	203	14.4	5.5	20.4	136	Summer	1	23	20
	164.643[4]	1.50	6/26	0425	212	15.5	5.5	16.7	131	Summer	3	26	31
	164.675[5]	1.50	6/26	0430	213	14.3	5.8	18.0	131	Trans	3	20	25
	164.712[4]	1.50	6/26	0425	181	14.3	5.5	18.8	132	Summer	3	24	35
	164.796[5]	1.50	6/26	0430	195	14.6	5.3	18.0	130	Trans	3	27	22
	164.900	1.50	7/01	0315	186	14.2	5.6	18.9	130	Trans	3	·25	28
	164.923[a]	1.50	8/11	2100	118	11.4	5.2	17.8	113	Juvenile	NA	-	-
	165.403	1.50	6/03	0700	185	16.0	5.1	19.0	129	Summer	2	24	28
	165.486[1]	1.50	6/03	0545	212	15.5	5.3	17.6	133	Summer	3	30	26
	165.527	1.50	6/04	0430	220	15.5	5.3	19.2	130	Summer	2	28	27
	165.543	1.50	6/03	0440	209	15.0	5.8	20.7	132	Trans	3	17	24
	165.604	1.95	6/04	0518	221	14.8	6.6	18.1	136	Summer	2	22	24
	165.724	1.50	6/02	0430	218	16.2	5.4	21.5	138	Summer	3	24	27
	165.733	1.95	6/04	2155	222	15.3	5.5	16.6	132	Trans	2	23	29
	165.755	1.95	6/04	2235	218	14.5	5.3	18.1	133	Summer	2	23	29
	165.780	1.50	6/04	0440	208	15.3	5.8	19.9	132	Summer	2	17	25
	165.861	1.50	6/02	2310	215	15.0	5.6	17.6	129	Summer	3	24	31
	165.886	1.50	6/03	0350	189	14.6	5.3	17.5	134	Trans	3	26	30
	165.944[2]	1.95	6/05	0010	201	14.3	5.4	17.7	129	Summer	3	22	25
	165.964[2]	1.95	6/04	2352	212	14.1	5.2	18.4	134	Summer	2	20	23
	165.988	1.50	6/01	2305	200	14.7	5.4	20.6	130	Summer	3	23	28
	165.995	1.95	6/05	0410	201	14.5	5.1	18.3	127	Summer	3	24	30
	None	-	6/03	0350	178	16.7	5.8	22.5	126	Winter	3	24	27
	None	-	6/23	0450	198	16.6	5.6	18.0	131	Summer	3	27	31
	None	-	6/23	0510	218	15.8	5.8	17.9	133	Summer	3	20	16
	None	-	7/01	0305	213	14.8	5.3	18.5	131	Trans	2	19	20

[a] Murrelet 164.923 was a juvenile tagged at its nest prior to fledging. The tagged parent was murrelet 164.712.

Appendix D. Telemetry search effort and success in locating radio-tagged marbled murrelets in Prince William Sound, Alaska, in June, July and August 1994. A sighting refers to the finding of a bird's signal during a search.

Search Type	Dates	Number of Days	Number of Searches	Total Hours	Hours per Search	Number of Sightings	Sightings per Hour	Maximum per Search
Boat-Anchored	2 Jun-7 Sep	40	105	341.4	3.3	80	0.23	9
Boat-Drifting	2 Jun-26 Aug	47	121	184.9	1.5	79	0.43	7
Boat-travel/search	5 Jun-6 Sept	30	51	84.2	1.7	22	0.26	3
Boat-Surveys	19 Jun-7 Sep	15	33	34.0	1.0	15	0.44	5
Boat-Sub Total	2 Jun-7 Sep	71	310	644.5	2.1	196	0.30	8
Air	4 Jun-28 Jul	26	33	122.4	3.7	231	1.89	18
Inland	26 Jun-12 Jul	4	6	12.3	2.1	0	0.00	0
Total	2 Jun-7 Sep	74	349	779.2	2.2	427	0.55	18

Appendix E-1. Summary of telemetry observations for marbled murrelets radio-tagged in Prince William Sound, Alaska, in June, July and August 1994.

Area	Frequency	Number of Relocations			Number of Sub-Areas Used	Tag Date	Date last located		Mean Km to Shore	Min. Area Polygon (SqKm)
		By Air	By Boat	At Night			By Air	By Boat		
Naked Island	164.129	8	3	1	7	20 Jun	8 Jul	21 Jun	0.5	39
	164.274	7	11	7	4	19 Jun	4 Jul	28 Jun	0.2	2
	164.469	1	2	0	2	18 Jun	23 Jun	24 Jun	0.1	-
	164.501	1	0	0	1	18 Jun	23 Jun	-	0.6	-
	164.601	7	7	3	4	17 Jun	1 Jul	7 Jul	0.7	8
	164.722	2	2	0	3	14 Jun	26 Jun	27 Jun	0.7	-
	164.764	2	0	0	1	14 Jun	23 Jun	-	0.3	-
	164.819	3	1	1	2	14 Jun	29 Jun	1 Jul	0.6	-
	164.941	6	9	6	6	12 Jun	23 Jun	21 Jun	0.3	11
	164.980	5	0	0	4	20 Jun	30 Jun	-	0.4	28
	165.185	12	0	0	6	9 Jun	7 Jul	-	1.7	269
	165.235	2	1	0	3	9 Jun	10 Jun	11 Jun	1.6	-
	165.315	4	1	0	3	9 Jun	14 Jun	11 Jun	<.1	22
	165.374	0	0	0	0	8 Jun	-	-	-	-
Port Nellie Juan	164.019	9	1	1	5	27 Jun	9 Jul	27 Jun	1.3	232
	164.033	1	0	0	1	23 Jun	23 Jun	-	0.1	-
	164.044	3	0	0	2	27 Jun	30 Jun	-	0.6	-
	164.067	11	9	8	6	3 Jun	30 Jun	30 Jun	0.6	48
	164.077	1	0	0	1	27 Jun	27 Jul	27 Jun	-	-
	164.183	9	1	1	6	27 Jun	11 Jul	7 Jul	0.7	295
	164.243	1	3	3	2	27 Jun	28 Jun	20 Jul	0.6	-
	164.290	7	11	8	6	28 Jun	13 Jul	16 Jul	2.2	95

Appendix E-1. Continued

Area	Frequency	Number of Relocations By Air	By Boat	At Night	Number of Sub-Areas Used	Tag Date	Date last located By Air	By Boat	Mean Km to Shore	Min. Area Polygon (SqKm)
Port Nellie Juan	164.328	5	3	3	5	1 Jul	11 Jul	18 Jul	1.1	31
	164.410	5	0	0	2	30 Jun	8 Jul	-	0.7	4
	164.440	1	0	0	1	26 Jun	28 Jun	-	0.2	-
	164.540	7	3	2	5	29 Jun	11 Jul	11 Jul	0.8	100
	164.622	5	6	4	4	3 Jun	26 Jun	6 Jun	0.7	117
	164.643	2	0	0	2	26 Jun	6 Jul	15 Jul		-
	164.675	10	6	5	8	26 Jun	15 Jul	15 Jul	0.9	113
	164.712	6	15	14	6	26 Jun	11 Jul	28 Jul	0.5	160
	164.796	6	0	0	3	26 Jun	8 Jul	-	0.7	99
	164.900	1	0	0	1	1 Jul	6 Jul	-	0.9	-
	164.923[a]	1	11	0	3	11 Aug	17 Aug	26 Aug	0.5	12
	165.403	7	15	7	4	3 Jun	17 Jun	17 Jun	0.1	0
	165.486	3	1	0	4	3 Jun	10 Jun	3 Jun	0.2	-
	165.527	2	1	1	3	4 Jun	5 Jun	5 Jun	0.3	-
	165.543	5	2	1	5	3 Jun	28 Jun	4 Jun	0.3	69
	165.604	7	1	0	4	4 Jun	14 Jun	14 Jun	0.6	67
	165.724	13	22	18	13	2 Jun	30 Jun	25 Jun	0.3	94
	165.733	8	8	2	8	4 Jun	23 Jun	24 Jun	0.4	920
	165.755	3	1	0	4	4 Jun	9 Jun	6 Jun	0.3	-
	165.780	4	7	6	7	4 Jun	9 Jun	20 Jun	0.6	43
	165.861	9	10	10	9	2 Jun	23 Jun	25 Jun	0.4	62
	165.886	6	8	4	5	3 Jun	14 Jun	17 Jun	0.3	9
	165.944	3	2	2	4	5 Jun	23 Jun	21 Jun	0.5	-
	165.964	1	0	0	1	4 Jun	5 Jun	-	0.2	-
	165.988	5	5	4	7	1 Jun	1 Jul	1 Jul	0.9	69
	165.995	5	1	0	6	5 Jun	13 Jun	6 Jun	0.9	77

[a] Murrelet 164.923 was a juvenile tagged at its nest prior to fledging. The tagged parent was murrelet 164.712.

Appendix E-2. Summary of telemetry observations for marbled murrelets radio-tagged in Prince William Sound, Alaska, in June, July and August 1994. Only aerial (plane-based) relocations were used for measured distances to shore, area polygons, distances from nests and between locations.

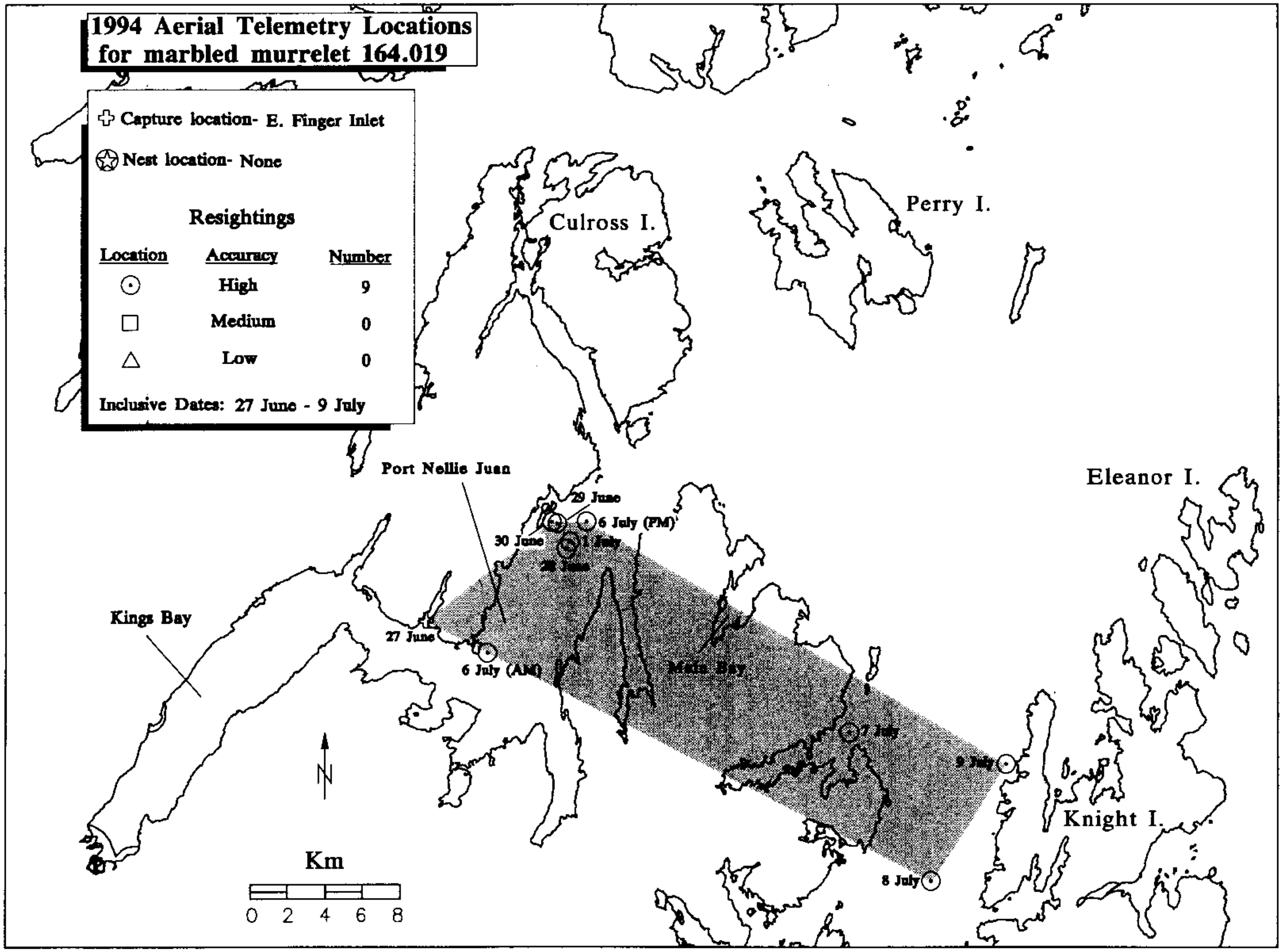
		Mean Straight-line Distances (km)				Mean Non-straight Line Distances (km)			
Area	Frequency	From Nest Site	From Capture Site	Between Consecutive points	Max. between two pts	From Nest Site	From Capture Site	Between Consecutive Points	Maximum Between 2 pts
Naked Island	164.129		18	22	94		22	25	94
	164.274		1	1	3		1	2	6
	164.469		5				13		
	164.501		23				23		
	164.601		2	3	6		5	3	8
	164.722		50	3	3		51	3	3
	164.764		13	<1	<1		14	<1	<1
	164.819		24	5	7		24	5	7
	164.941		3	4	6		5	9	13
	164.980		5	6	11		10	13	16
	165.185		17	11	26		18	12	33
	165.235		6	11	11		10	11	11
	165.315		23	15	43		23	15	44
	165.374		-	-	-		-	-	-
Port Nellie Juan	164.019		16	7	28		22	7	40
	164.033		17					23	
	164.044		13	16	32		15	16	32
	164.067		8	5	21		8	6	24
	164.077		52				55		
	164.183	29	28	18	52	38	31	20	60
	164.243		40				44		
	164.290	11	9	12	21	16	10	15	28

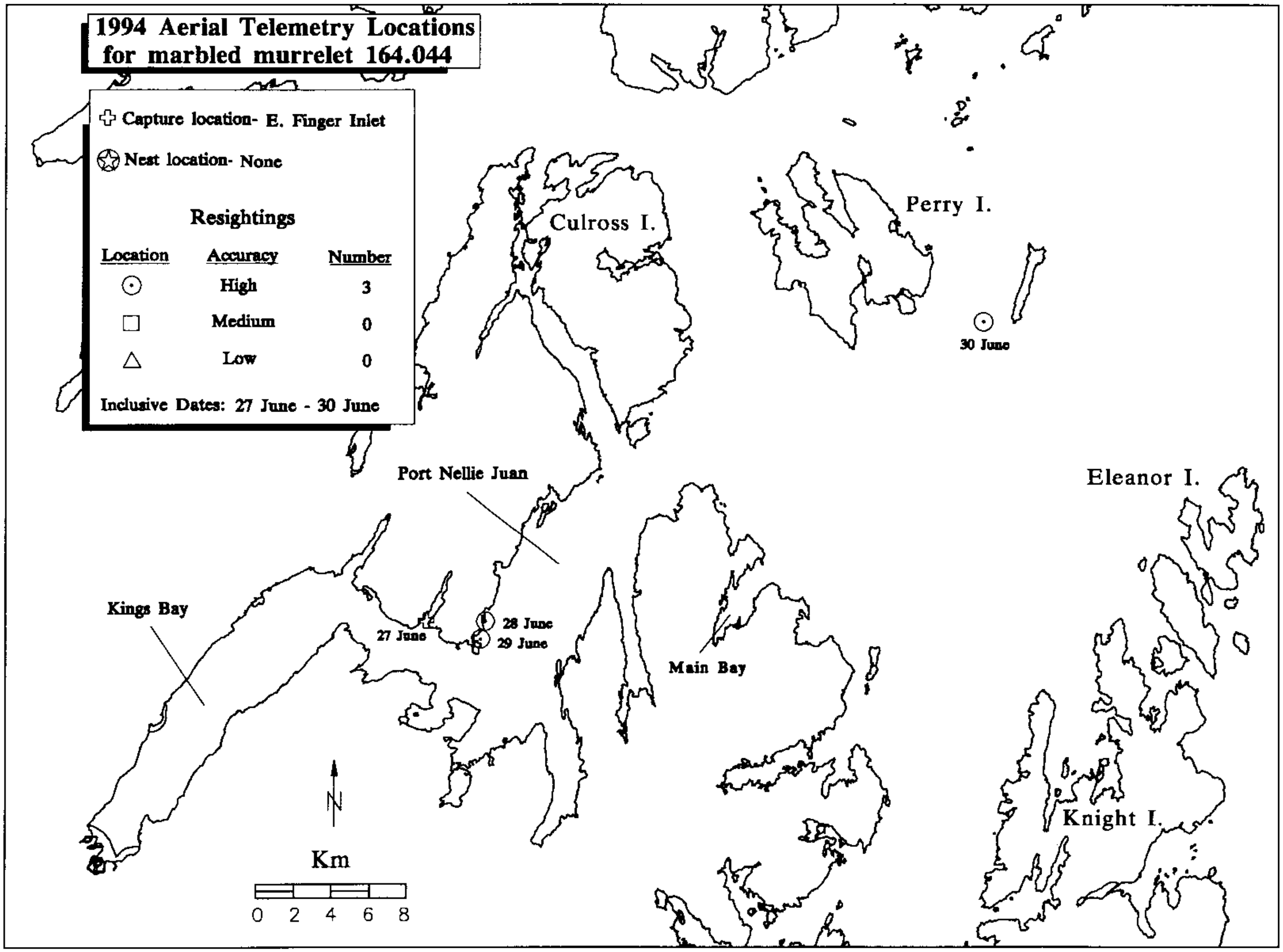
Appendix E-2. Continued

Area	Frequency	Mean Straight-line Distances (km)				Mean Non-straight Line Distances (km)			
		From Nest Site	From Capture Site	Between Consecutive points	Max. between two pts	From Nest Site	From Capture Site	Between Consecutive Points	Maximum Between 2 pts
Port	164.328		10	6	17		10	7	18
Nellie	164.410		4	1	2		5	1	2
Juan	164.440		44				48		
	164.540		11	11	32		11	11	32
	164.622		41	4	7		46	6	12
	164.643		28	51	51		30	53	53
	164.675		10	4	14		13	7	28
	164.712	31	17	15	43	40	21	33	55
	164.796		40	19	74		44	20	82
	164.900		18				21		
	164.923[a]		12				12		
	165.403		1	1	2		1	1	2
	165.486		9	18	21		10	21	24
	165.527		5	4	4		6	4	4
	165.543		18	11	32		24	13	42
	165.604		17	4	15		23	5	19
	165.724	8	6	7	15	10	7	8	21
	165.733		21	26	58		29	32	74
	165.755		11	13	24		14	16	31
	165.780		15	4	11		23	6	17
	165.861	13	8	11	18	14	9	13	21
	165.886	5	4	3	6	8	4	4	9
	165.944		13	17	31		18	24	45
	165.964		7					8	
	165.988		10	12	31		10	13	34
	165.995		12	6	20		16	8	27

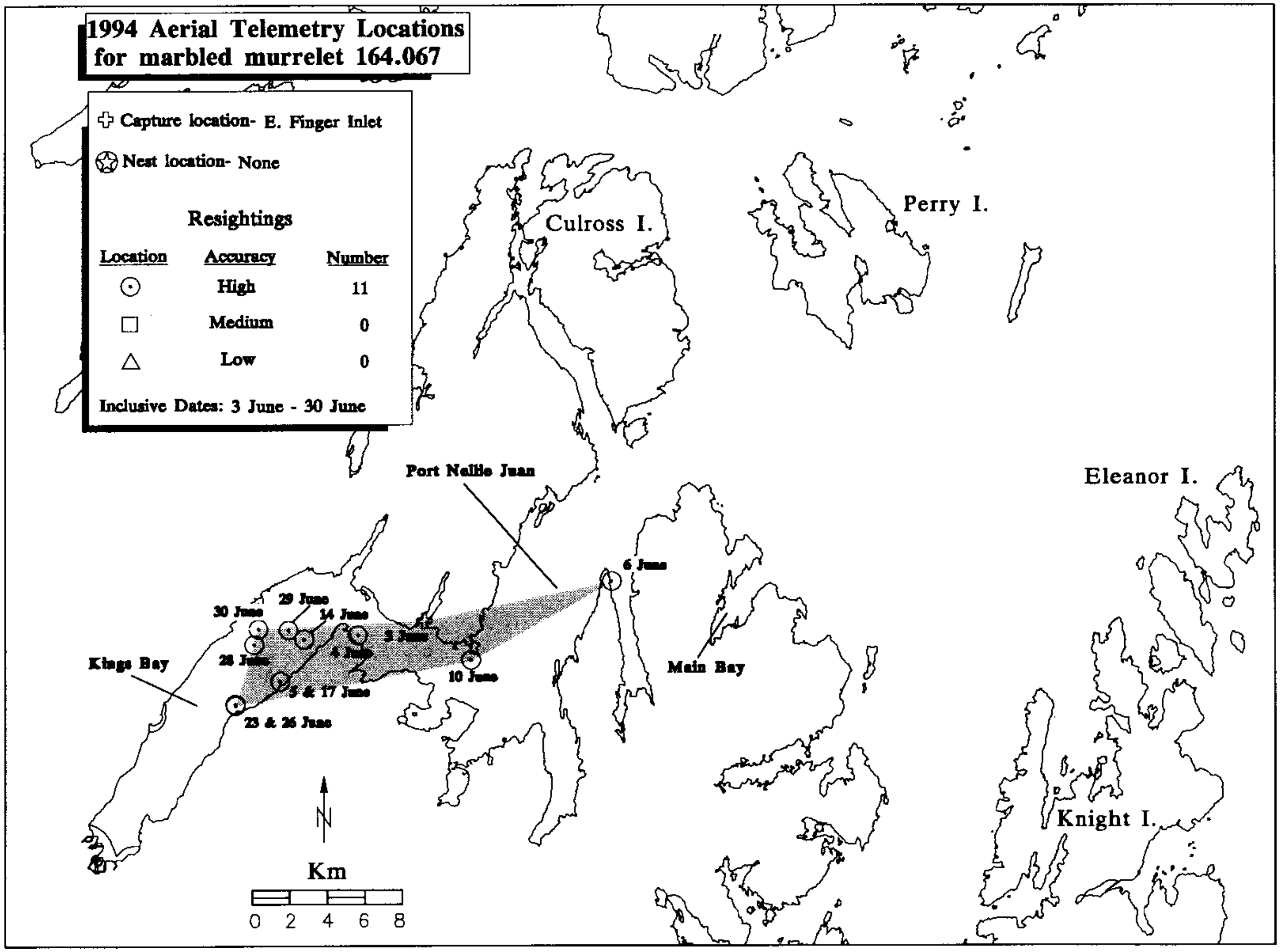
a Murrelet 164.923 was a juvenile tagged at its nest prior to fledging. The tagged parent was murrelet 164.712.

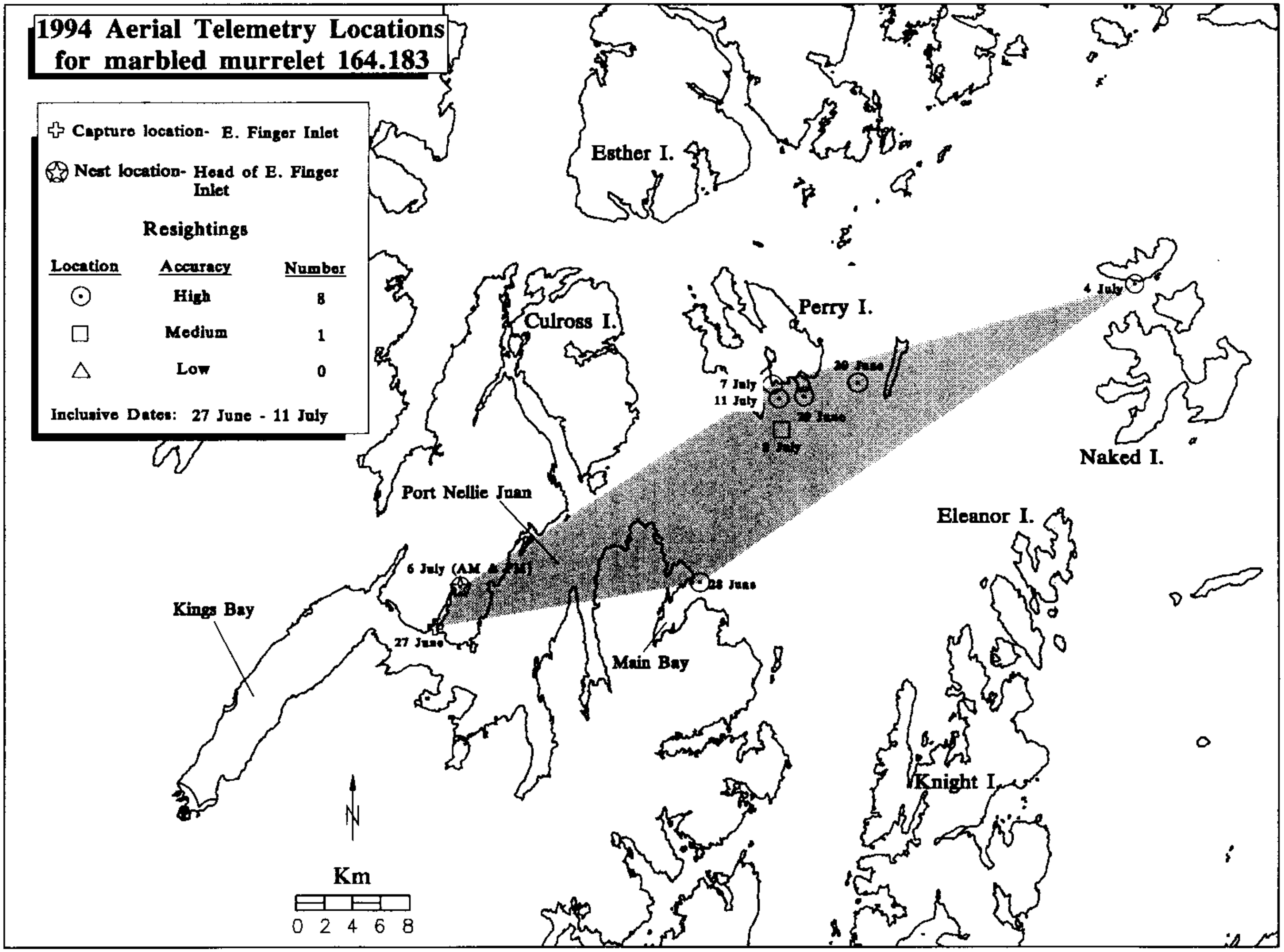
Appendix F. Maps of telemetry locations made from an airplane for each marbled murrelet, identified by their transmitter frequency, radio-tagged at Port Nellie Juan and Naked Island, Prince William Sound, Alaska, in June and July 1994.


1994 Aerial Telemetry Locations for marbled murrelet 164.019
Capture location- E. Finger Inlet
Nest location- None
Resightings
Location
Accuracy
Number
High
9
Medium
0
Low
0
Inclusive Dates: 27 June - 9 July
Culross I.
Perry I.
Eleanor I.
Knight I.
Port Nellie Juan
Kings Bay
Main Bay
29 June
6 July (PM)
30 June
1 July
27 June
6 July (AM)
7 July
9 July
8 July
N
Km
0 2 4 6 8

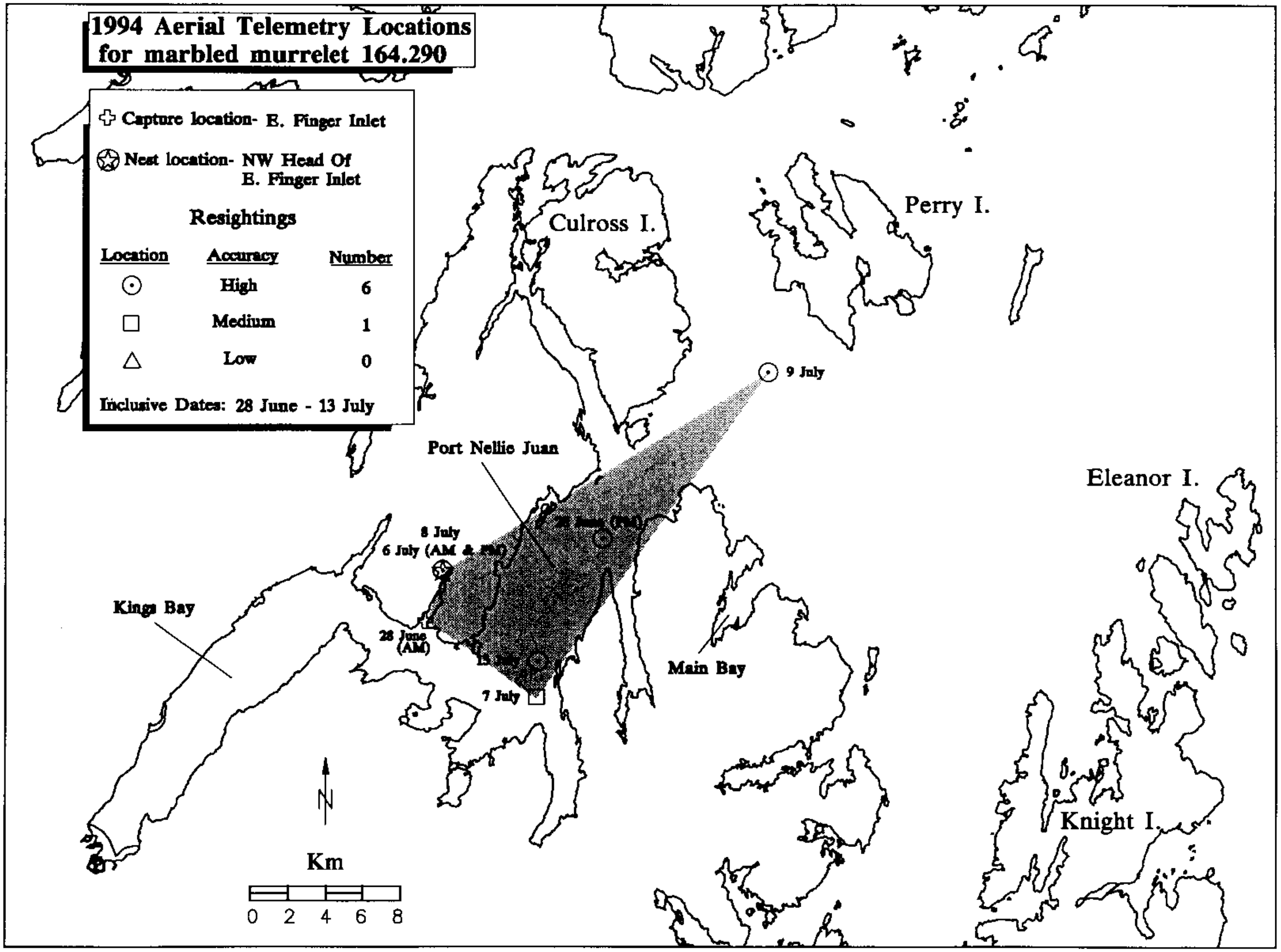


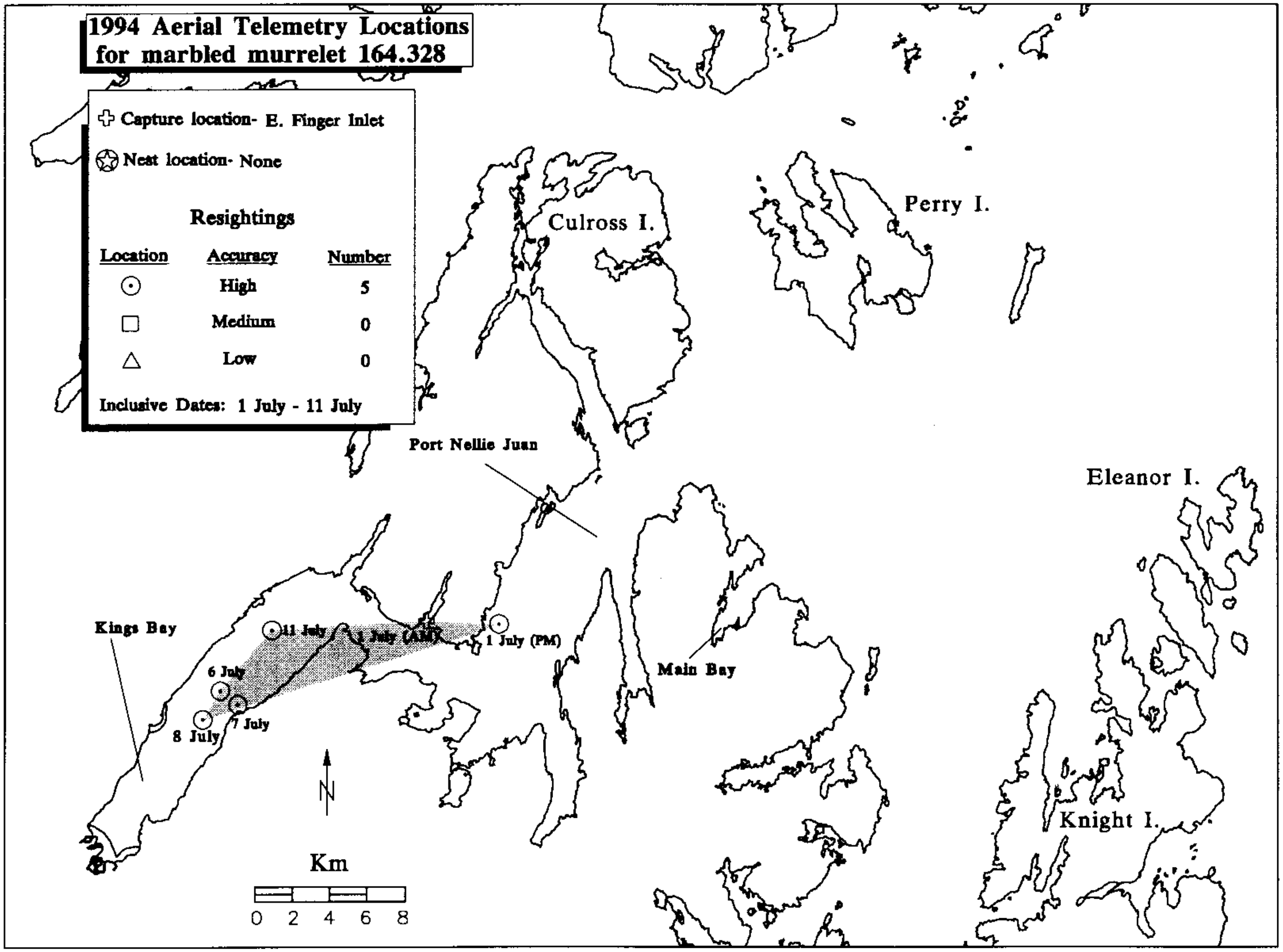
1994 Aerial Telemetry Locations
for marbled murrelet 164.044
Capture location- E. Finger Inlet
Nest location- None
Resightings
Location
Accuracy
Number
High
3
Medium
0
Low
0
Inclusive Dates: 27 June - 30 June
Culross I.
Perry I.
30 June
Port Nellie Juan
Eleanor I.
Kings Bay
28 June
27 June
29 June
Main Bay
N
Km
0 2 4 6 8
Knight I.


1994 Aerial Telemetry Locations
for marbled murrelet 164.067
Capture location- E. Finger Inlet
Nest location- None
Resightings
Location
Accuracy
Number
High
11
Medium
0
Low
0
Inclusive Dates: 3 June - 30 June
Culross I.
Perry I.
Eleanor I.
Knight I.
Port Nellie Juan
Main Bay
Kings Bay
6 June
29 June
30 June
14 June
3 June
28 June
4 June
10 June
5 & 17 June
23 & 26 June
N
Km
0 2 4 6 8

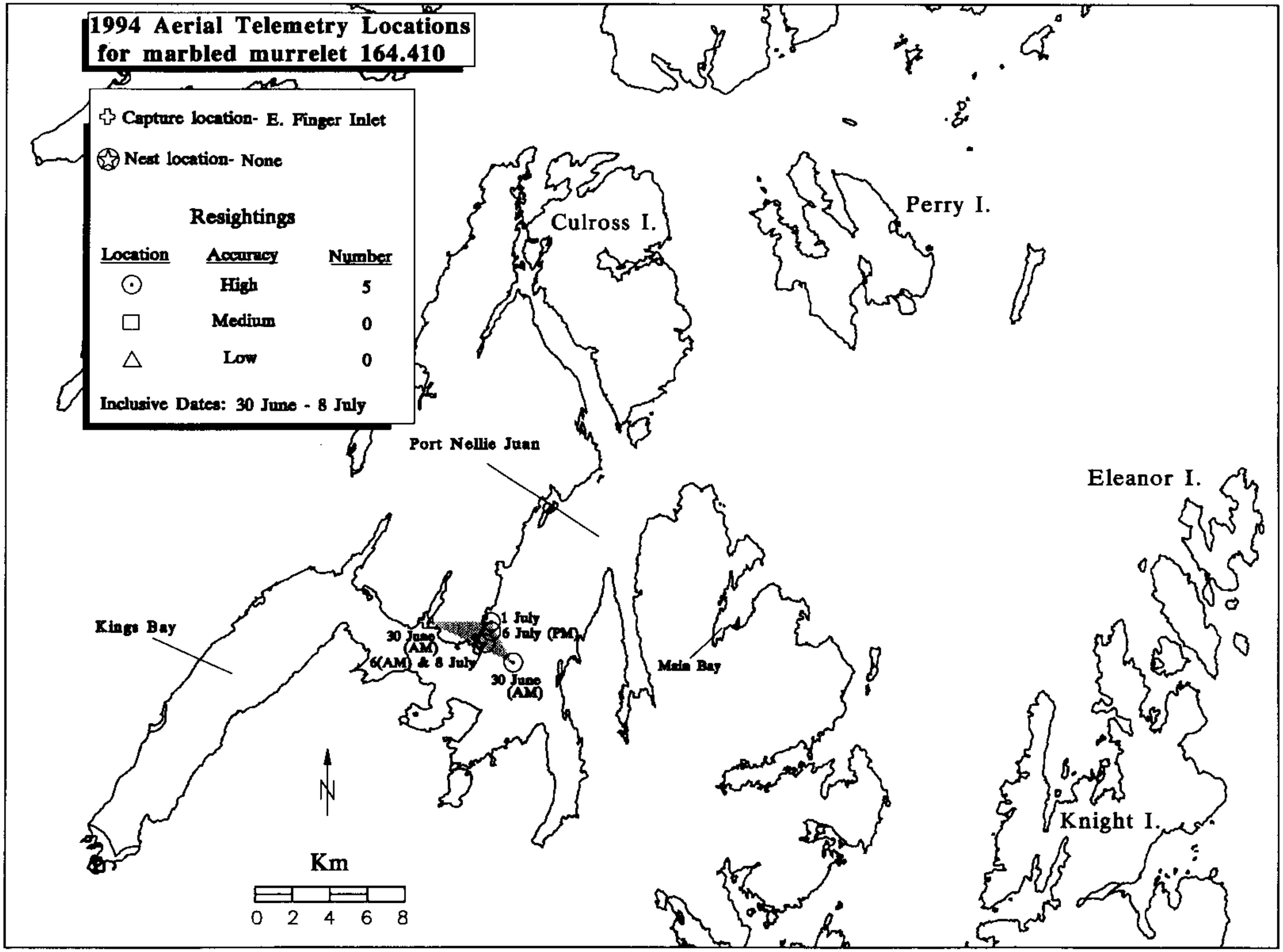


1994 Aerial Telemetry Locations for marbled murrelet 164.183
Capture location- E. Finger Inlet
Nest location- Head of E. Finger Inlet
Resightings
Location
Accuracy
Number
High
8
Medium
1
Low
0
Inclusive Dates: 27 June - 11 July
Esther I.
Culross I.
Perry I.
Naked I.
Eleanor I.
Knight I.
Port Nellie Juan
Kings Bay
Main Bay
4 July
7 July
11 July
6 July (AM & PM)
27 June
28 June
Km
0 2 4 6 8
N

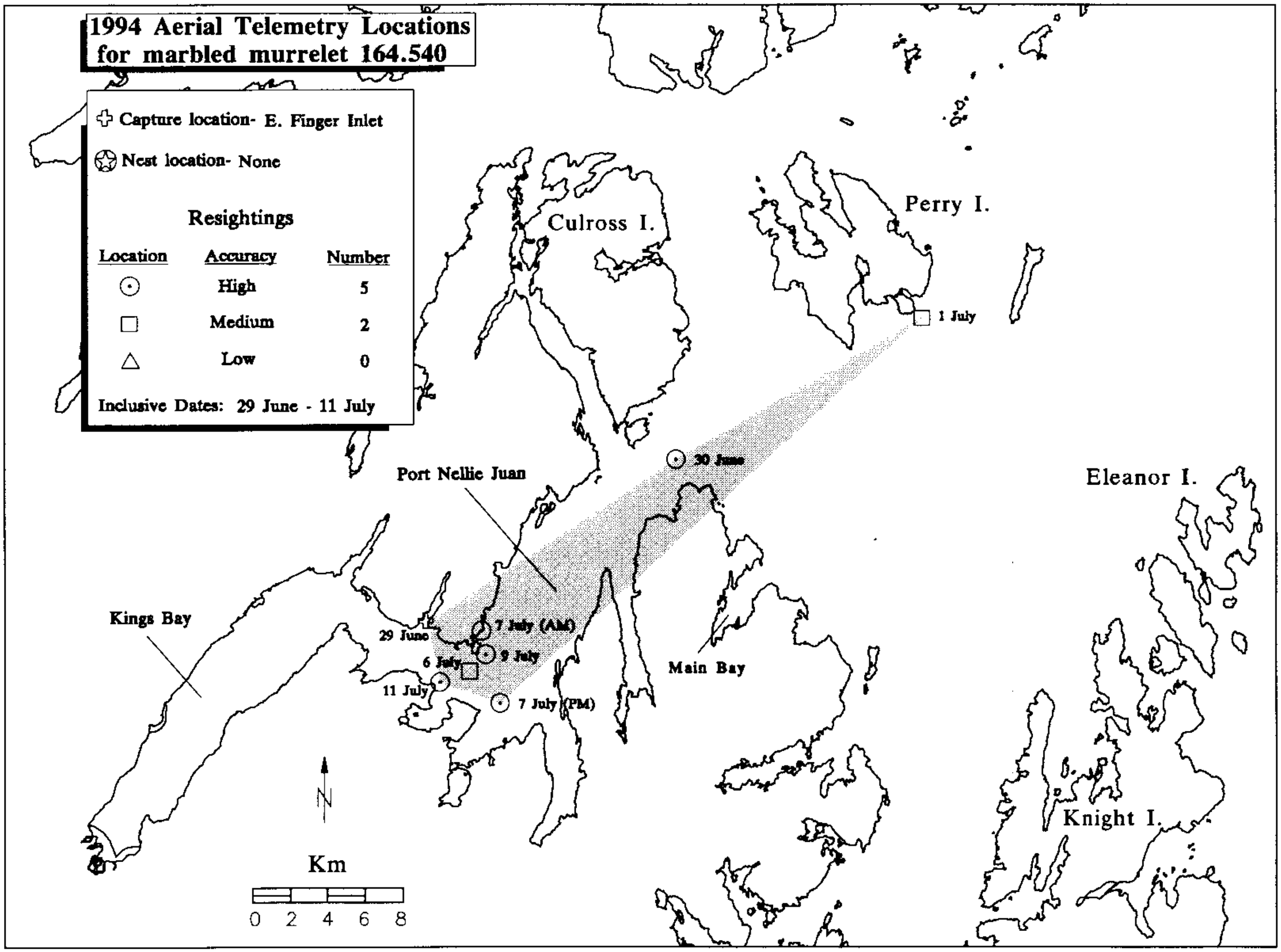

1994 Aerial Telemetry Locations for marbled murrelet 164.290
Capture location- E. Finger Inlet
Nest location- NW Head Of E. Finger Inlet
Resightings
Location
Accuracy
Number
High
6
Medium
1
Low
0
Inclusive Dates: 28 June - 13 July
Culross I.
Perry I.
Eleanor I.
Knight I.
Port Nellie Juan
Kings Bay
Main Bay
9 July
8 July
6 July (AM & PM)
28 June (AM)
13 July
7 July
N
Km
0 2 4 6 8



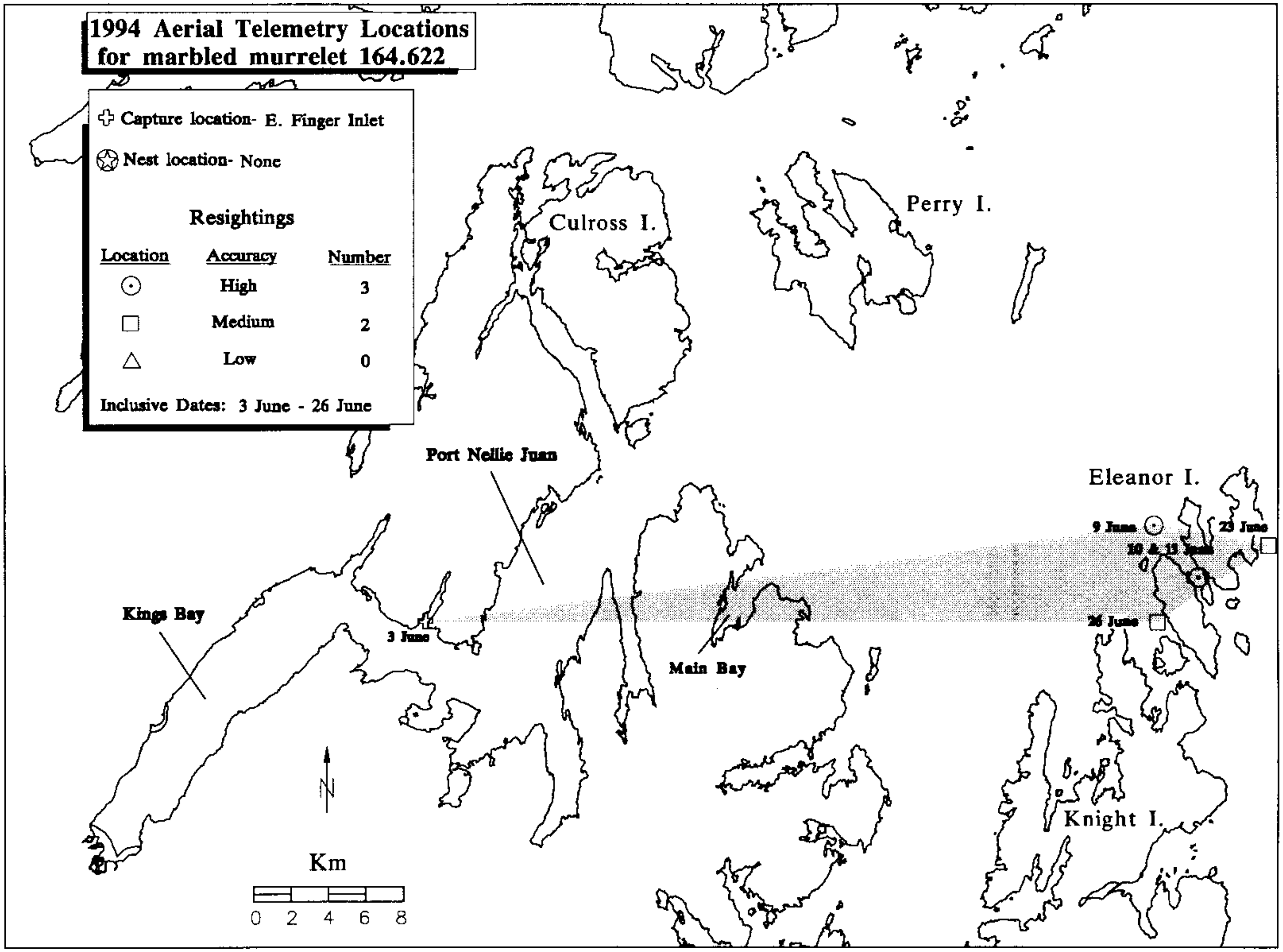
1994 Aerial Telemetry Locations
for marbled murrelet 164.328
Capture location- E. Finger Inlet
Nest location- None
Resightings
Location
Accuracy
Number
High
5
Medium
0
Low
0
Inclusive Dates: 1 July - 11 July
Culross I.
Perry I.
Port Nellie Juan
Eleanor I.
Kings Bay
11 July
1 July (AM)
1 July (PM)
6 July
7 July
8 July
Main Bay
Knight I.
N
Km
0 2 4 6 8

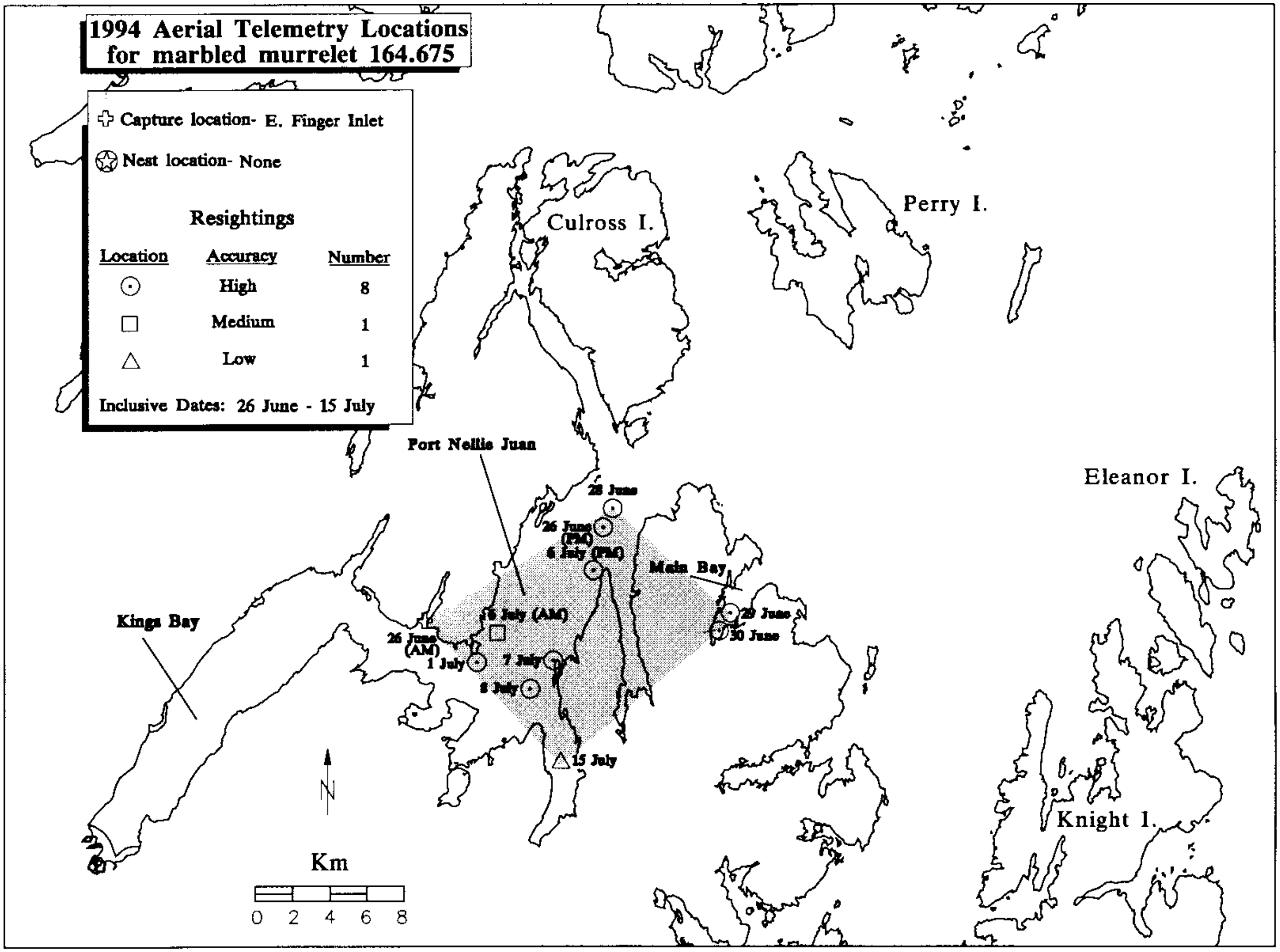


1994 Aerial Telemetry Locations
for marbled murrelet 164.410
Capture location- E. Finger Inlet
Nest location- None
Resightings
Location
Accuracy
Number
High
5
Medium
0
Low
0
Inclusive Dates: 30 June - 8 July
Culross I.
Perry I.
Port Nellie Juan
Eleanor I.
Kings Bay
1 July
6 July (PM)
30 June (AM)
6(AM) & 8 July
30 June (AM)
Main Bay
Knight I.
N
Km
0 2 4 6 8

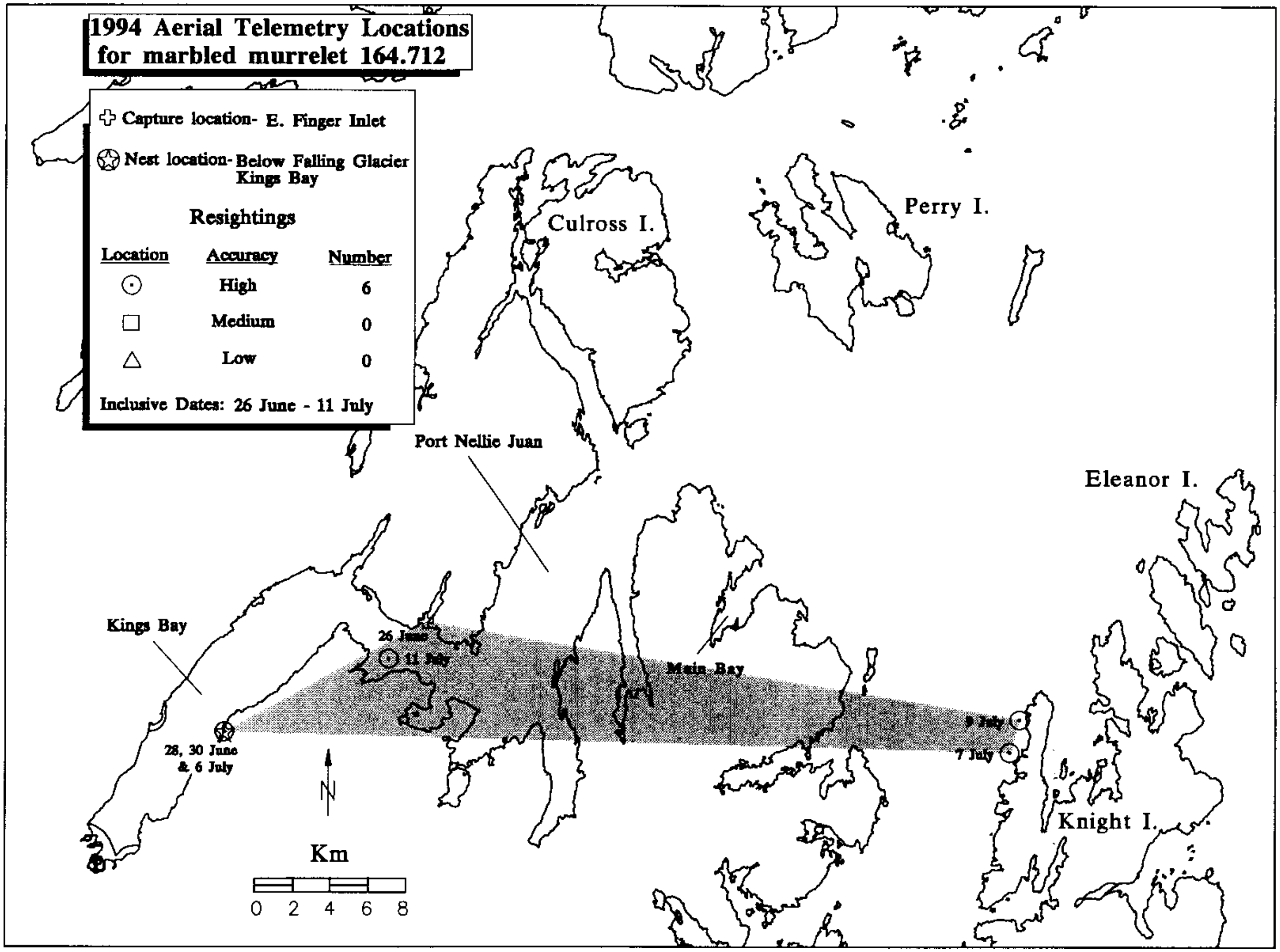


1994 Aerial Telemetry Locations
for marbled murrelet 164.540
Capture location- E. Finger Inlet
Nest location- None
Resightings
Location
Accuracy
Number
High
5
Medium
2
Low
0
Inclusive Dates: 29 June - 11 July
Culross I.
Perry I.
1 July
30 June
Eleanor I.
Port Nellie Juan
Kings Bay
29 June
7 July (AM)
9 July
6 July
11 July
7 July (PM)
Main Bay
Knight I.
Km
0 2 4 6 8

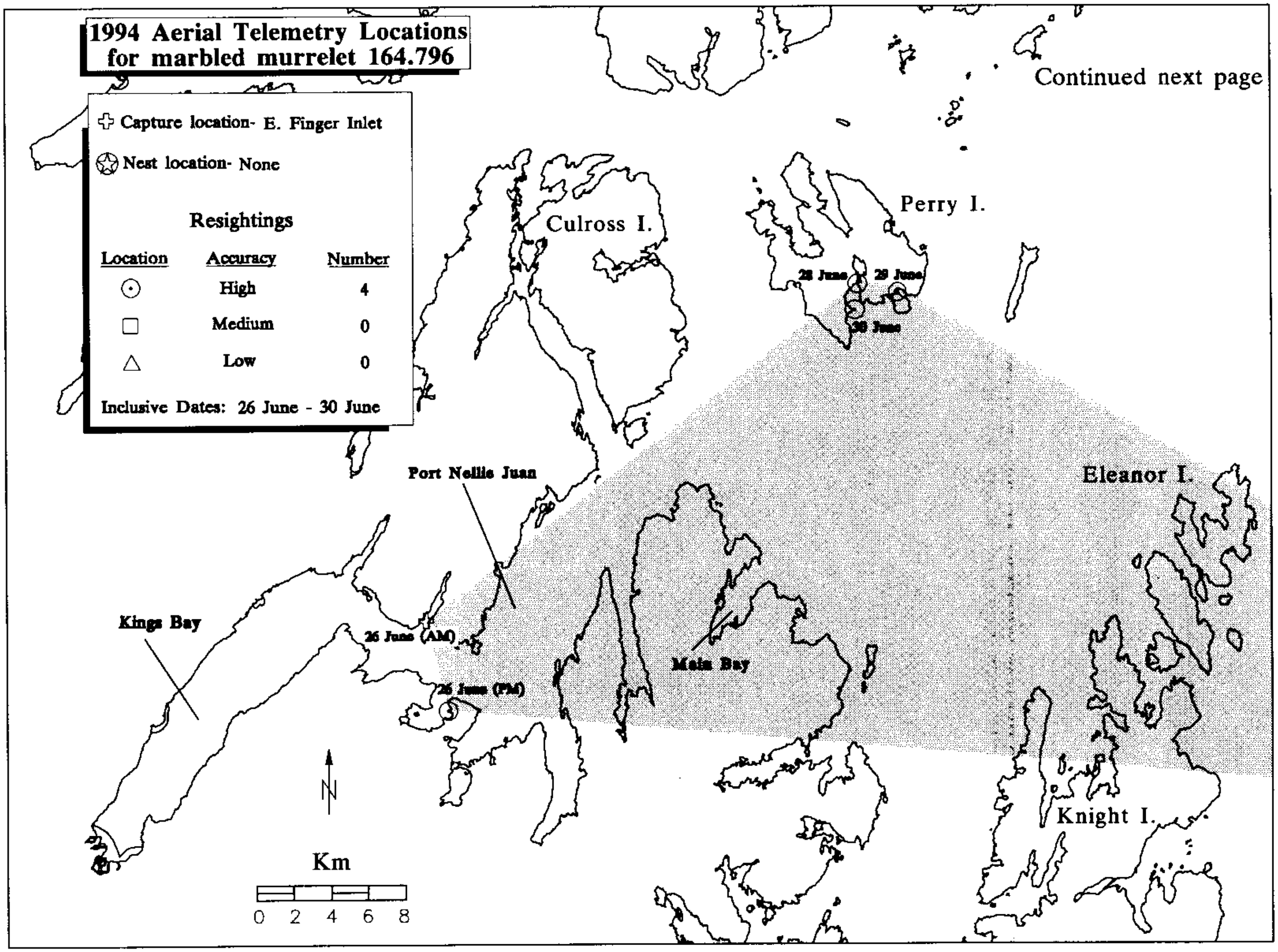

1994 Aerial Telemetry Locations
for marbled murrelet 164.622
Capture location- E. Finger Inlet
Nest location- None
Resightings
Location
Accuracy
Number
High
3
Medium
2
Low
0
Inclusive Dates: 3 June - 26 June
Culross I.
Perry I.
Eleanor I.
Port Nellie Juan
Kings Bay
Main Bay
Knight I.
3 June
9 June
23 June
10 & 11 June
26 June
N
Km
0 2 4 6 8

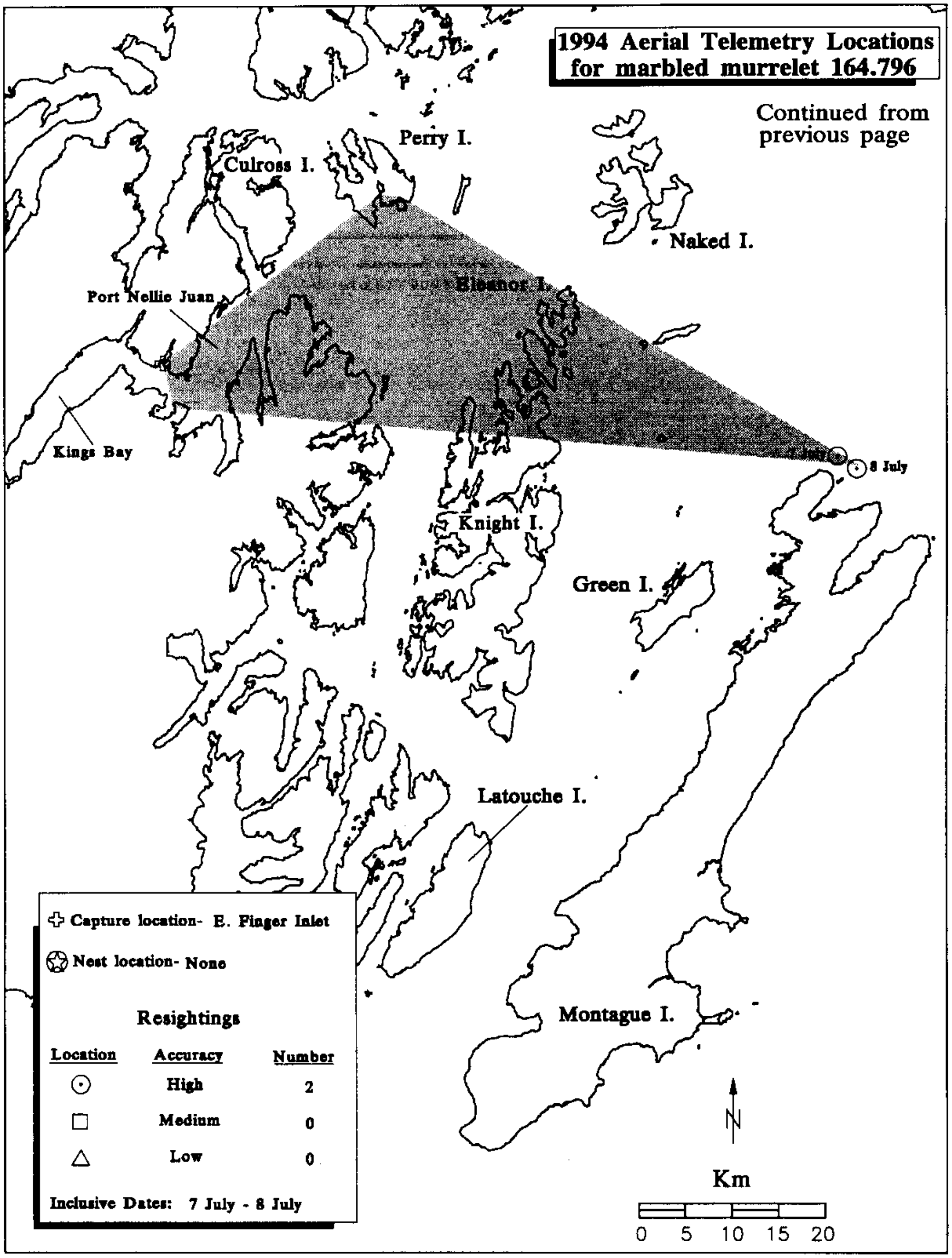


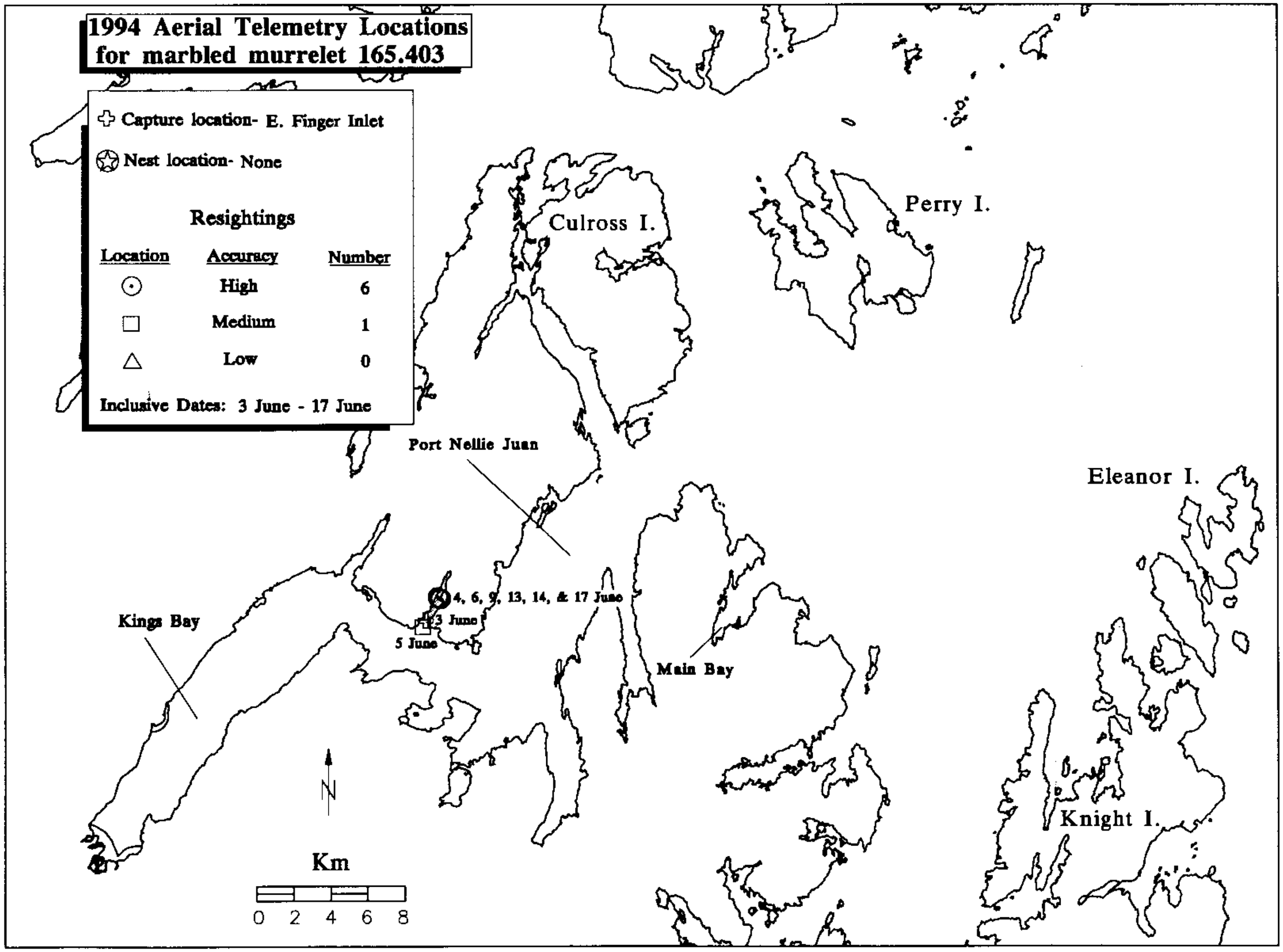
1994 Aerial Telemetry Locations for marbled murrelet 164.675
Capture location- E. Finger Inlet
Nest location- None
Resightings
Location
Accuracy
Number
High
8
Medium
1
Low
1
Inclusive Dates: 26 June - 15 July
Culross I.
Perry I.
Eleanor I.
Knight I.
Port Nellie Juan
Main Bay
Kings Bay
28 June
26 June (PM)
6 July (PM)
6 July (AM)
26 June (AM)
1 July
7 July
8 July
29 June
30 June
15 July
N
Km
0 2 4 6 8



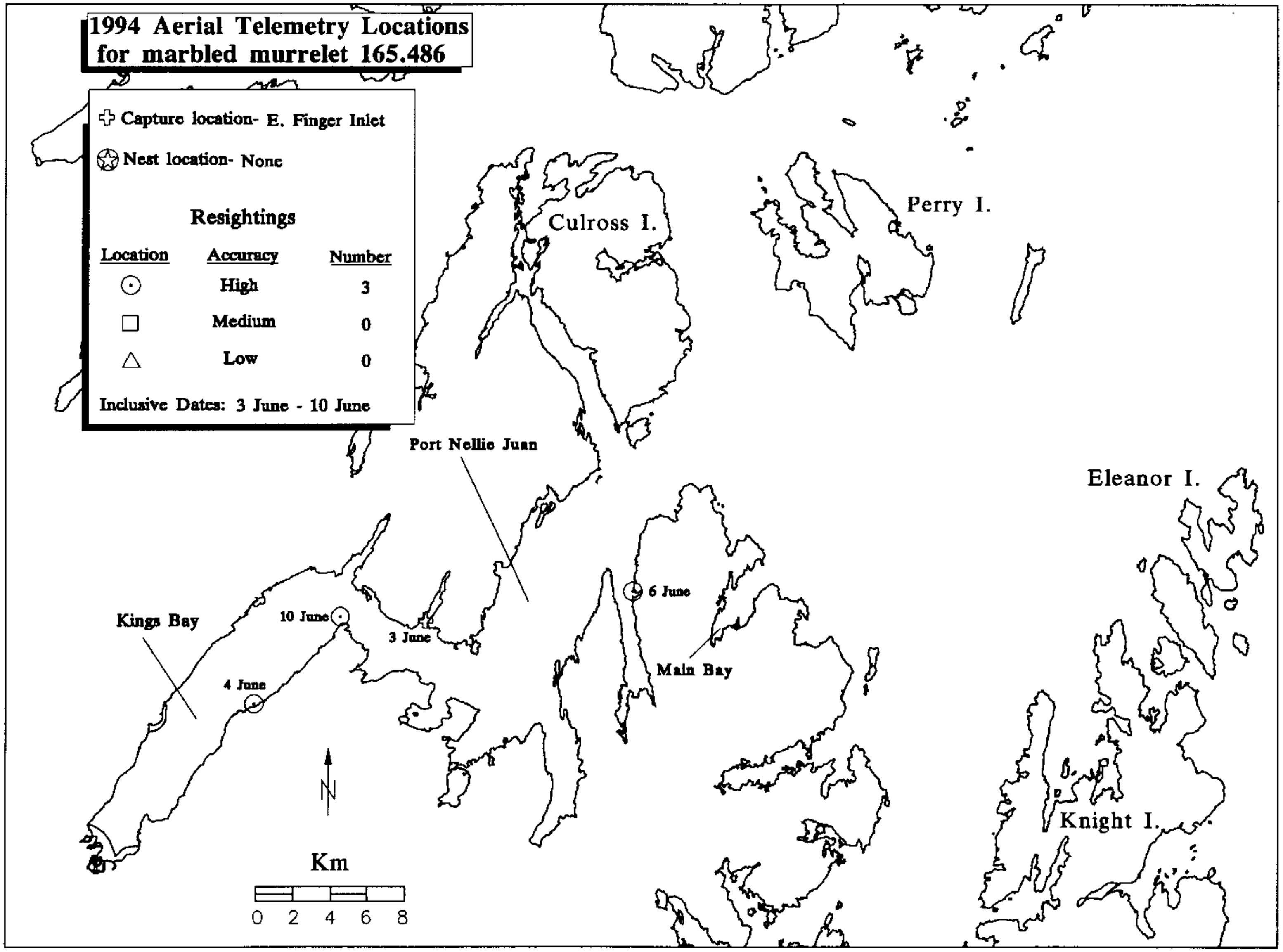
1994 Aerial Telemetry Locations for marbled murrelet 164.712
Capture location- E. Finger Inlet
Nest location- Below Falling Glacier Kings Bay
Resightings
Location
Accuracy
Number
High
6
Medium
0
Low
0
Inclusive Dates: 26 June - 11 July
Culross I.
Perry I.
Port Nellie Juan
Eleanor I.
Kings Bay
26 June
11 July
Main Bay
9 July
7 July
28, 30 June & 6 July
N
Knight I.
Km
0 2 4 6 8

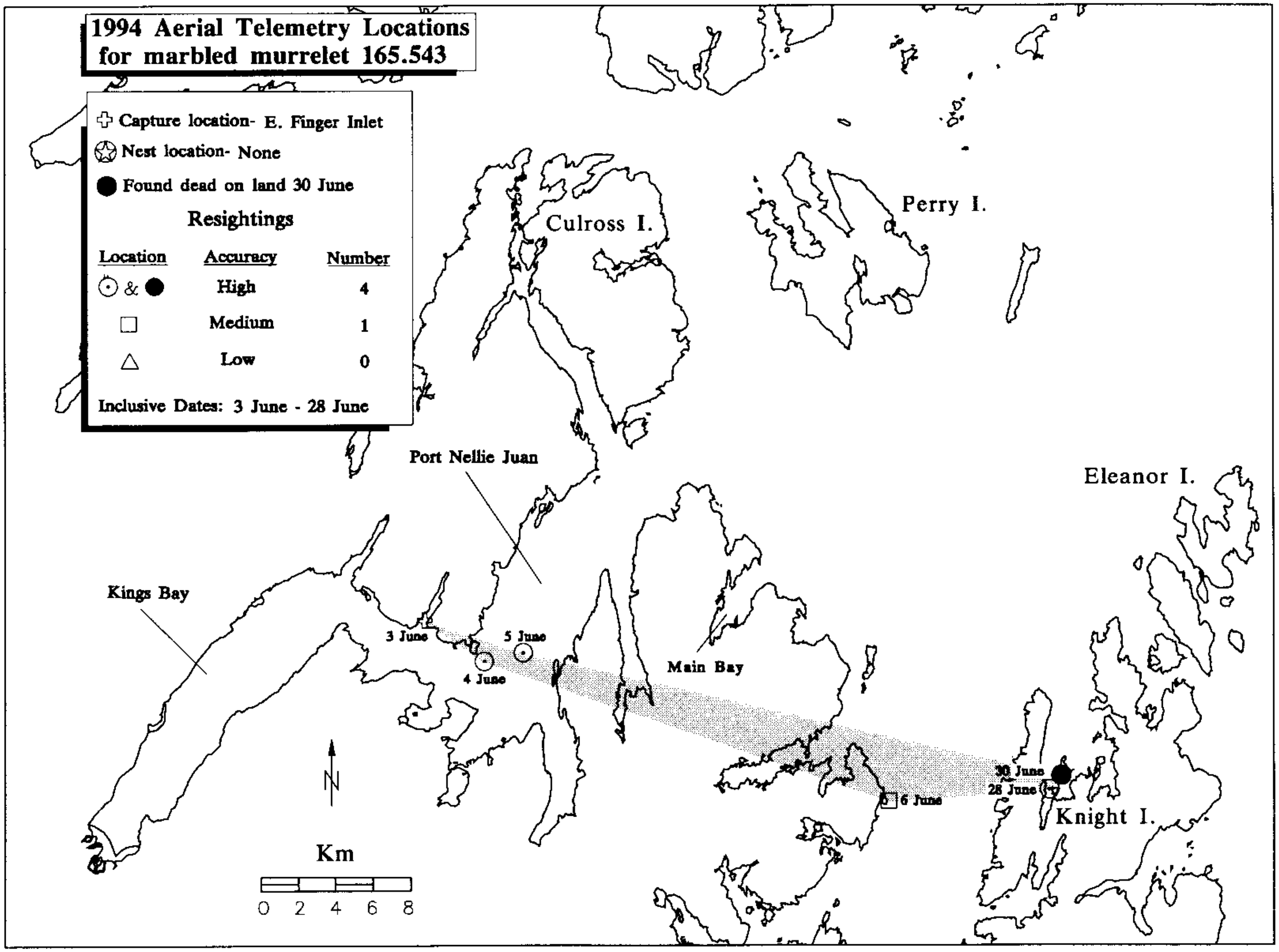

1994 Aerial Telemetry Locations
for marbled murrelet 164.796
Capture location- E. Finger Inlet
Nest location- None
Resightings
Location
Accuracy
Number
High
4
Medium
0
Low
0
Inclusive Dates: 26 June - 30 June
Continued next page
Culross I.
Perry I.
28 June
29 June
30 June
Eleanor I.
Port Nellie Juan
Kings Bay
26 June (AM)
26 June (PM)
Main Bay
Knight I.
N
Km
0 2 4 6 8


1994 Aerial Telemetry Locations
for marbled murrelet 164.796
Continued from
previous page
Perry I.
Culross I.
Naked I.
Eleanor I.
Port Nellie Juan
Kings Bay
7 July
8 July
Knight I.
Green I.
Latouche I.
Montague I.
Capture location- E. Finger Inlet
Nest location- None
Resightings
Location
Accuracy
Number
High
2
Medium
0
Low
0
Inclusive Dates: 7 July - 8 July
N
Km
0 5 10 15 20

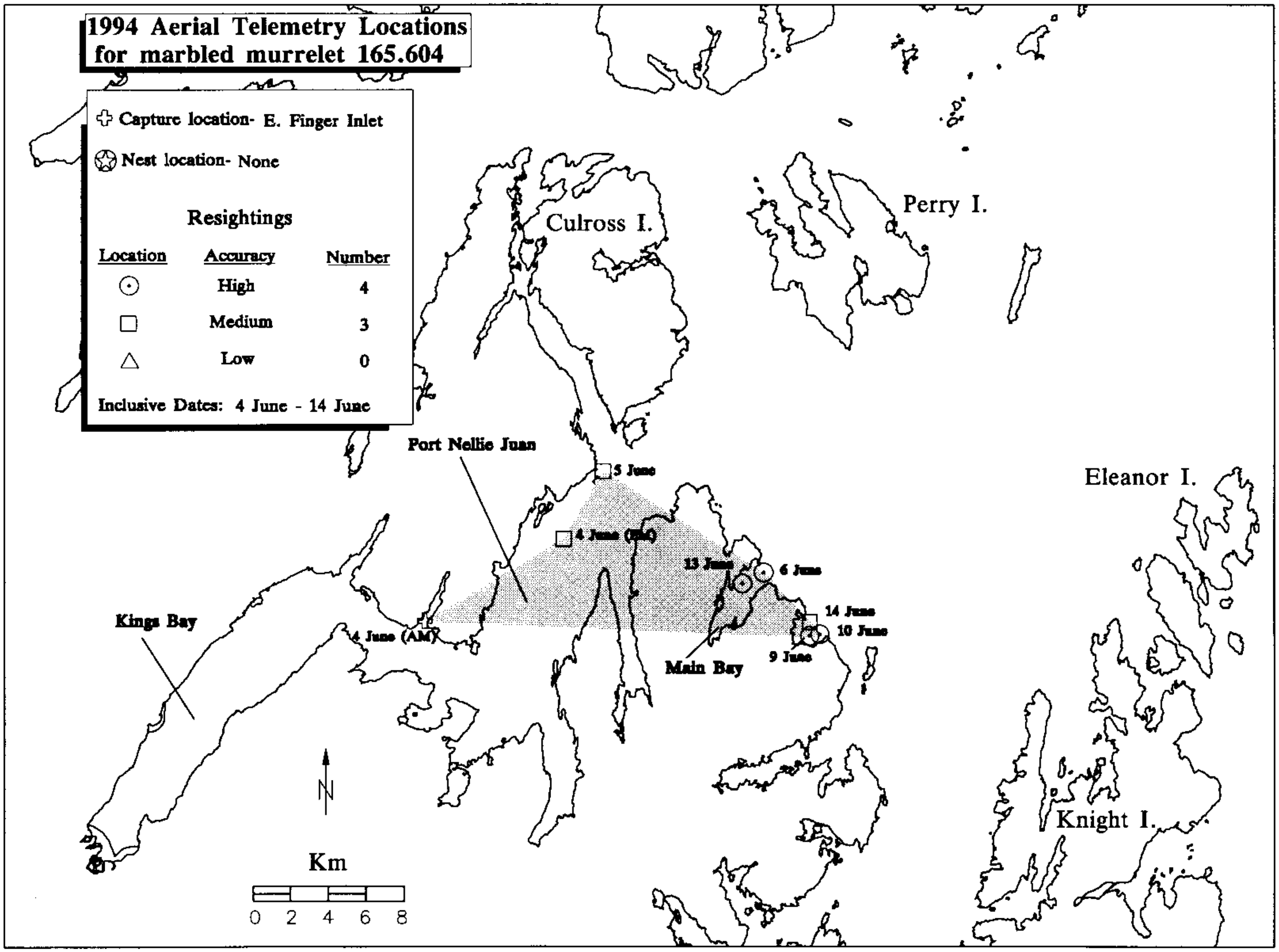


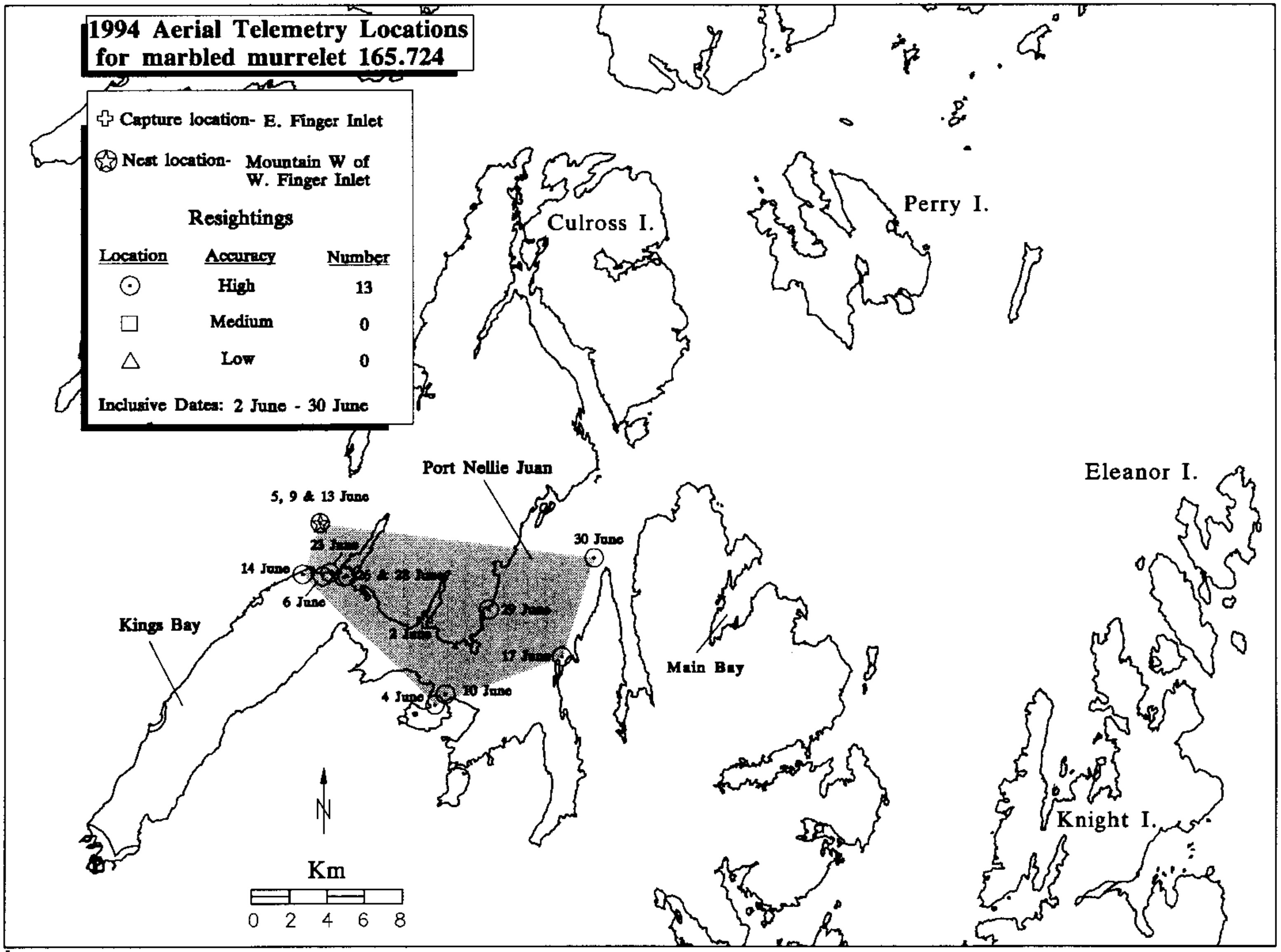
1994 Aerial Telemetry Locations
for marbled murrelet 165.403
Capture location- E. Finger Inlet
Nest location- None
Resightings
Location
Accuracy
Number
High
6
Medium
1
Low
0
Inclusive Dates: 3 June - 17 June
Culross I.
Perry I.
Port Nellie Juan
Eleanor I.
4, 6, 9, 13, 14, & 17 June
3 June
5 June
Kings Bay
Main Bay
Knight I.
N
Km
0 2 4 6 8

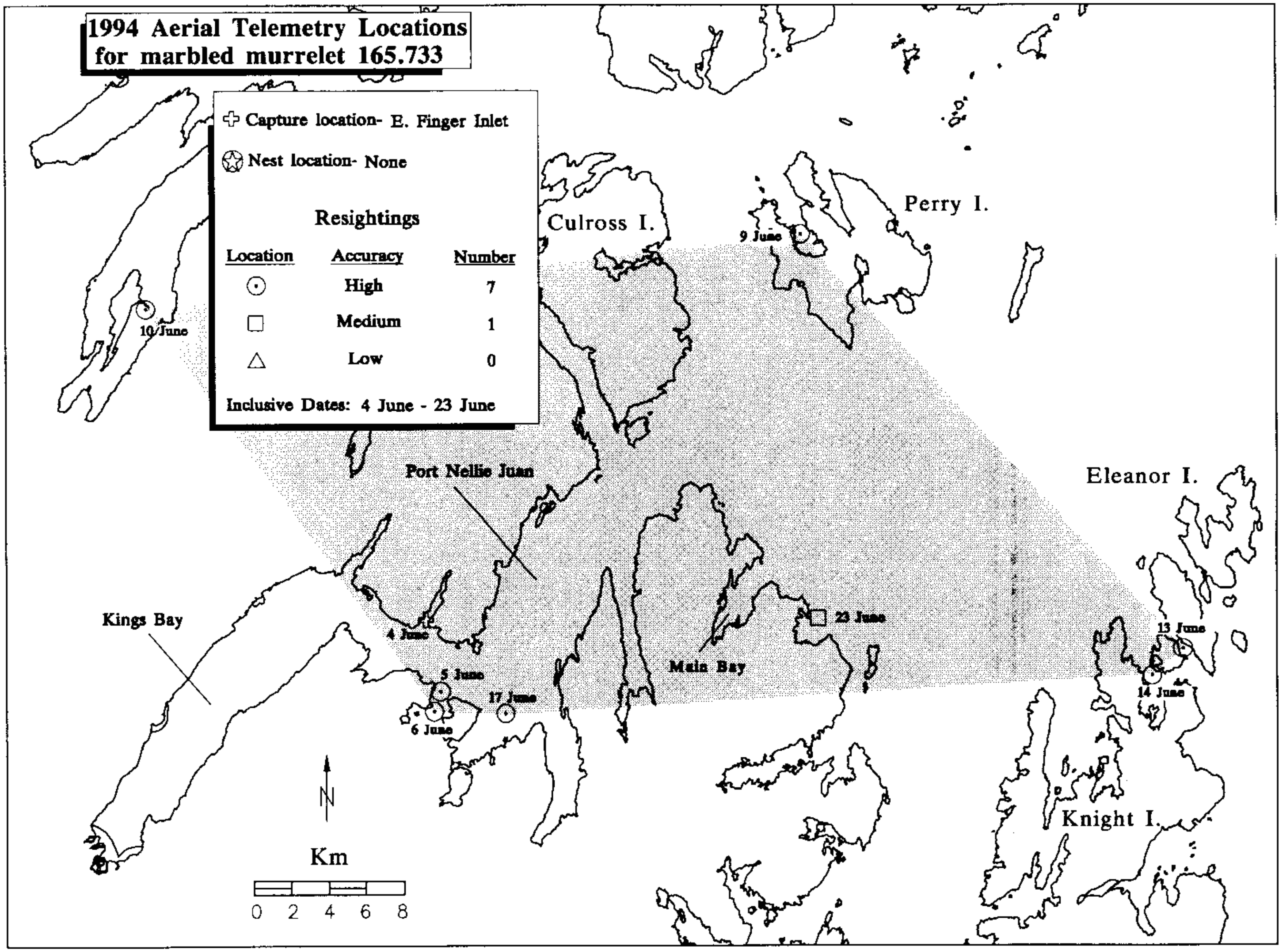

1994 Aerial Telemetry Locations
for marbled murrelet 165.486
Capture location- E. Finger Inlet
Nest location- None
Resightings
Location
Accuracy
Number
High
3
Medium
0
Low
0
Inclusive Dates: 3 June - 10 June
Culross I.
Perry I.
Port Nellie Juan
Eleanor I.
Kings Bay
10 June
3 June
4 June
6 June
Main Bay
Knight I.
N
Km
0 2 4 6 8



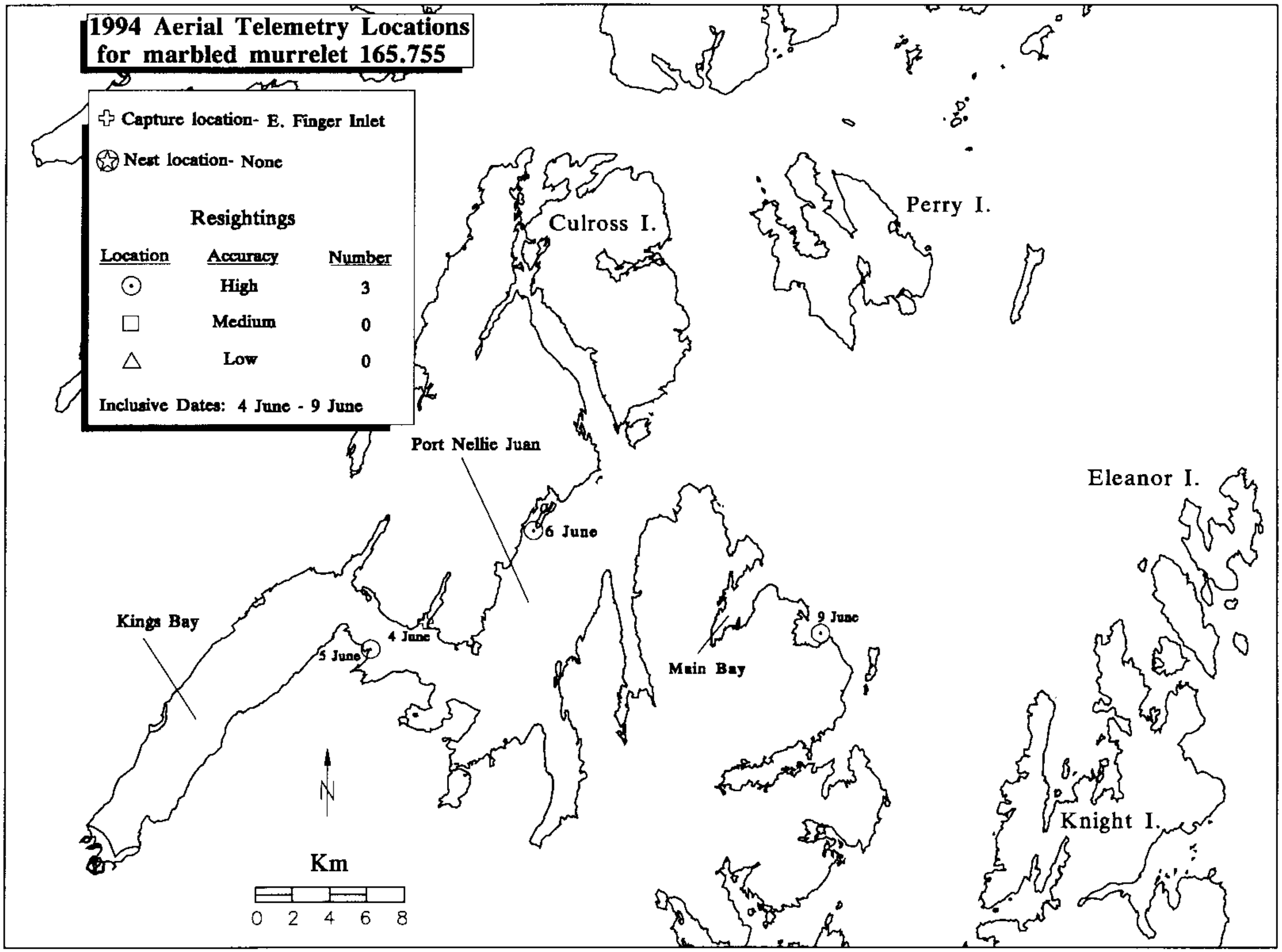
1994 Aerial Telemetry Locations
for marbled murrelet 165.543
Capture location- E. Finger Inlet
Nest location- None
Found dead on land 30 June
Resightings
Location
Accuracy
Number
High
4
Medium
1
Low
0
Inclusive Dates: 3 June - 28 June
Culross I.
Perry I.
Port Nellie Juan
Eleanor I.
Kings Bay
3 June
5 June
4 June
Main Bay
30 June
28 June
6 June
Knight I.
N
Km
0 2 4 6 8


1994 Aerial Telemetry Locations
for marbled murrelet 165.604
Capture location- E. Finger Inlet
Nest location- None
Resightings
Location
Accuracy
Number
High
4
Medium
3
Low
0
Inclusive Dates: 4 June - 14 June
Culross I.
Perry I.
Eleanor I.
Knight I.
Port Nellie Juan
Kings Bay
Main Bay
5 June
4 June (PM)
4 June (AM)
13 June
6 June
14 June
10 June
9 June
Km
0 2 4 6 8

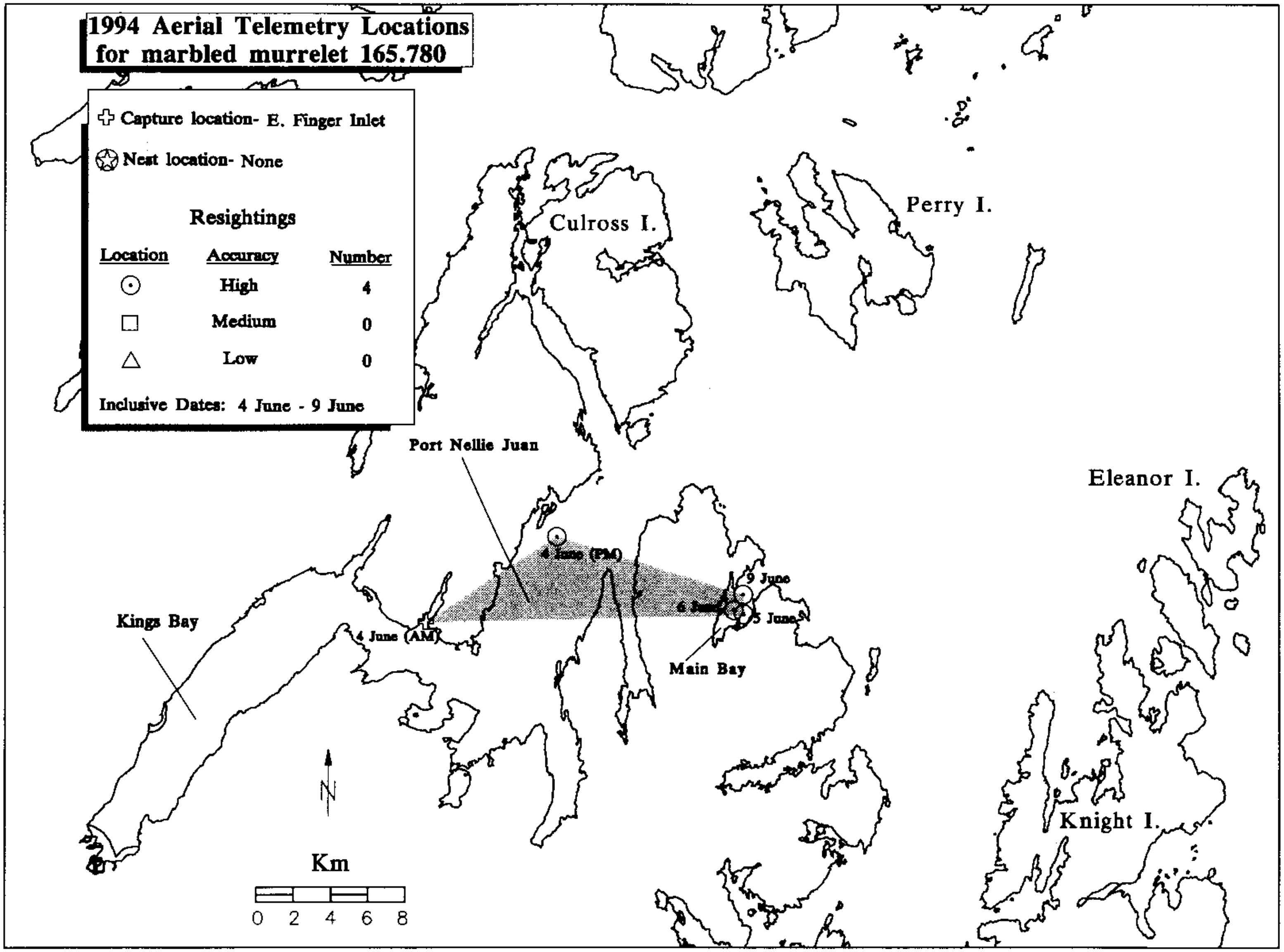

1994 Aerial Telemetry Locations
for marbled murrelet 165.724
Capture location- E. Finger Inlet
Nest location- Mountain W of W. Finger Inlet
Resightings
Location
Accuracy
Number
High
13
Medium
0
Low
0
Inclusive Dates: 2 June - 30 June
Culross I.
Perry I.
Eleanor I.
Port Nellie Juan
5, 9 & 13 June
30 June
14 June
6 June
29 June
2 June
17 June
Kings Bay
Main Bay
4 June
10 June
Knight I.
N
Km
0 2 4 6 8



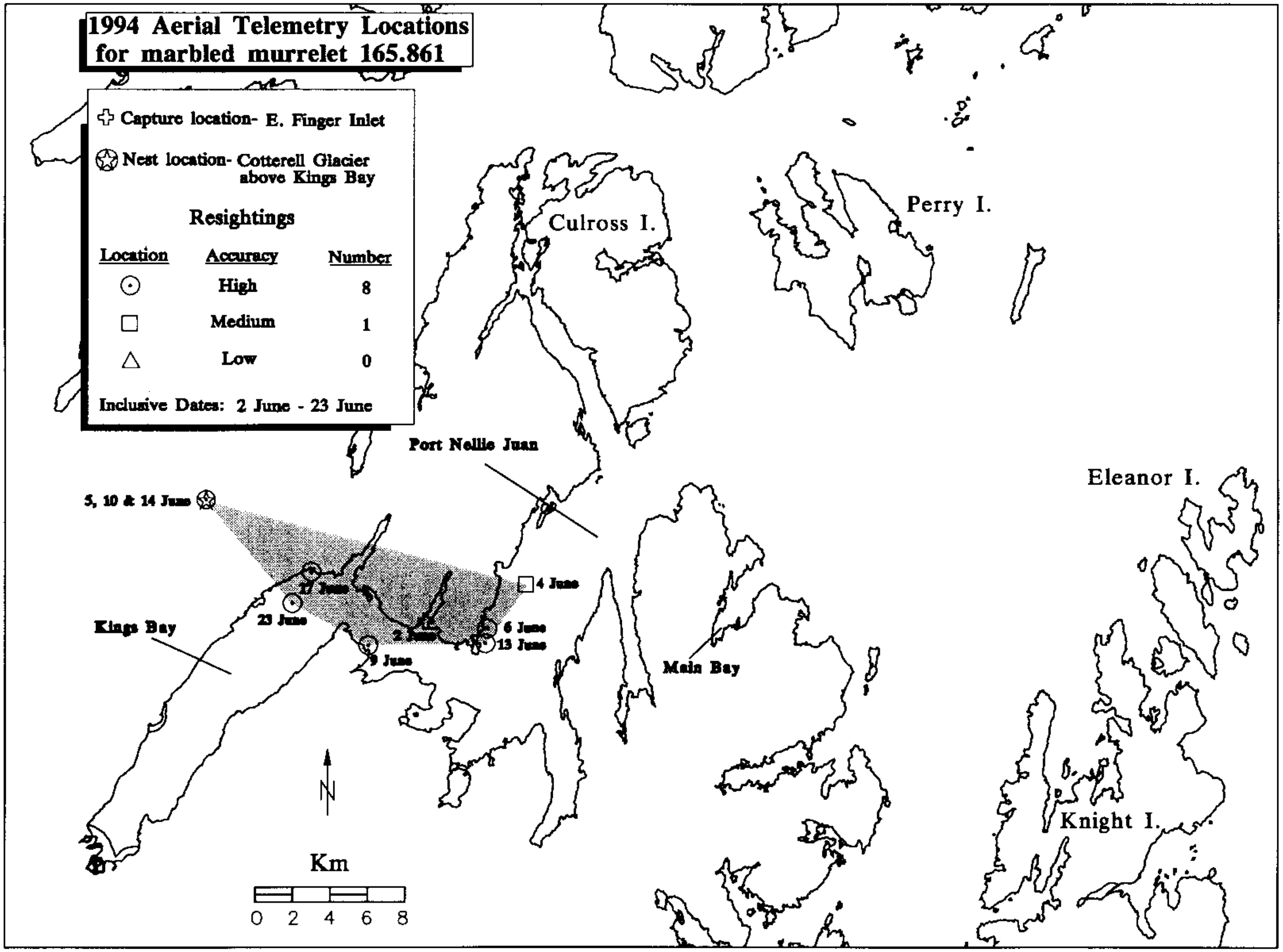
1994 Aerial Telemetry Locations
for marbled murrelet 165.733
Capture location- E. Finger Inlet
Nest location- None
Resightings
Location
Accuracy
Number
High
7
Medium
1
Low
0
Inclusive Dates: 4 June - 23 June
Culross I.
Perry I.
Eleanor I.
Knight I.
Port Nellie Juan
Kings Bay
Main Bay
9 June
10 June
4 June
5 June
6 June
17 June
23 June
13 June
14 June
N
Km
0 2 4 6 8



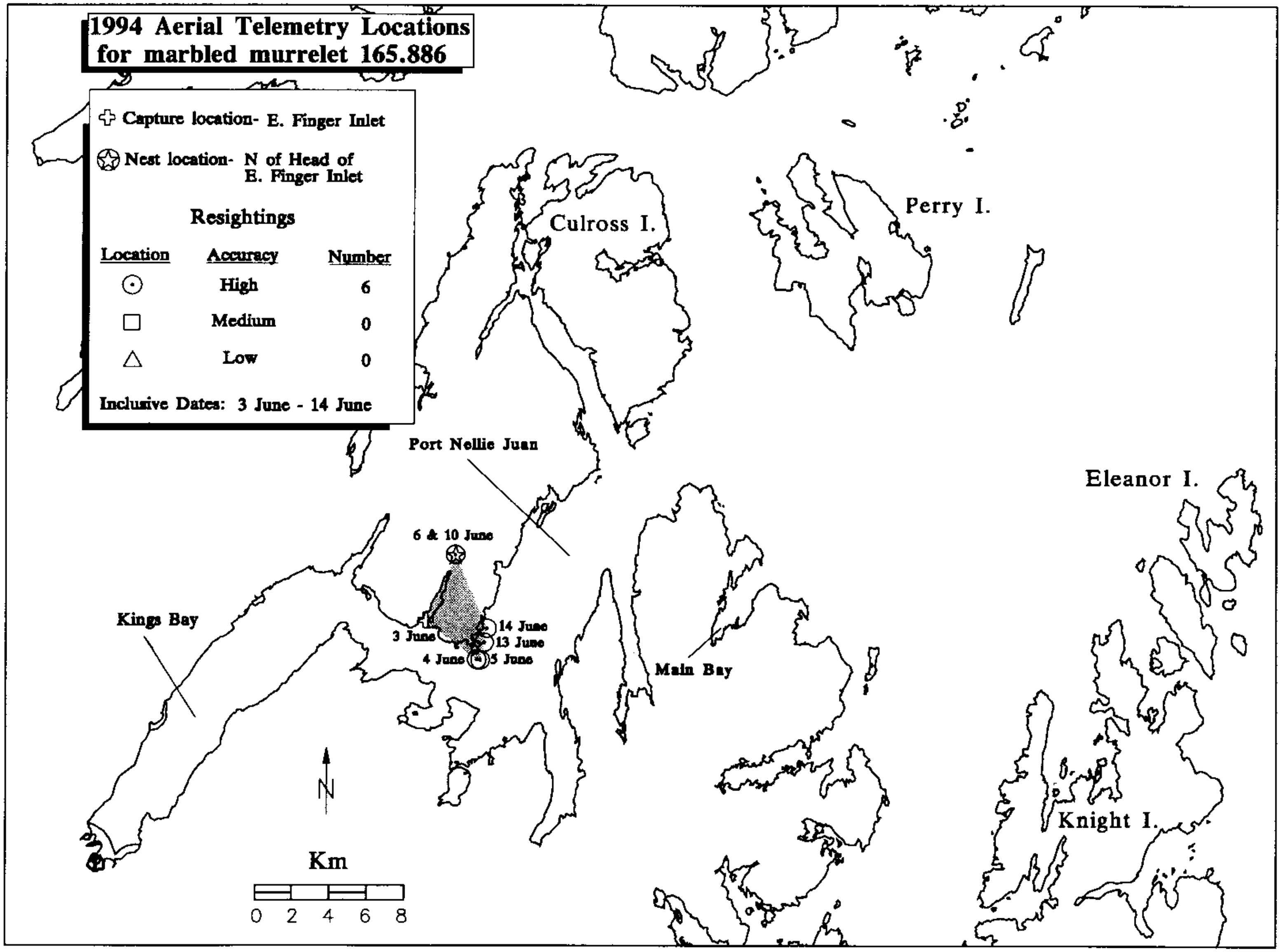
1994 Aerial Telemetry Locations
for marbled murrelet 165.755
Capture location- E. Finger Inlet
Nest location- None
Resightings
Location
Accuracy
Number
High
3
Medium
0
Low
0
Inclusive Dates: 4 June - 9 June
Culross I.
Perry I.
Port Nellie Juan
Eleanor I.
6 June
Kings Bay
4 June
5 June
9 June
Main Bay
Knight I.
Km
0 2 4 6 8



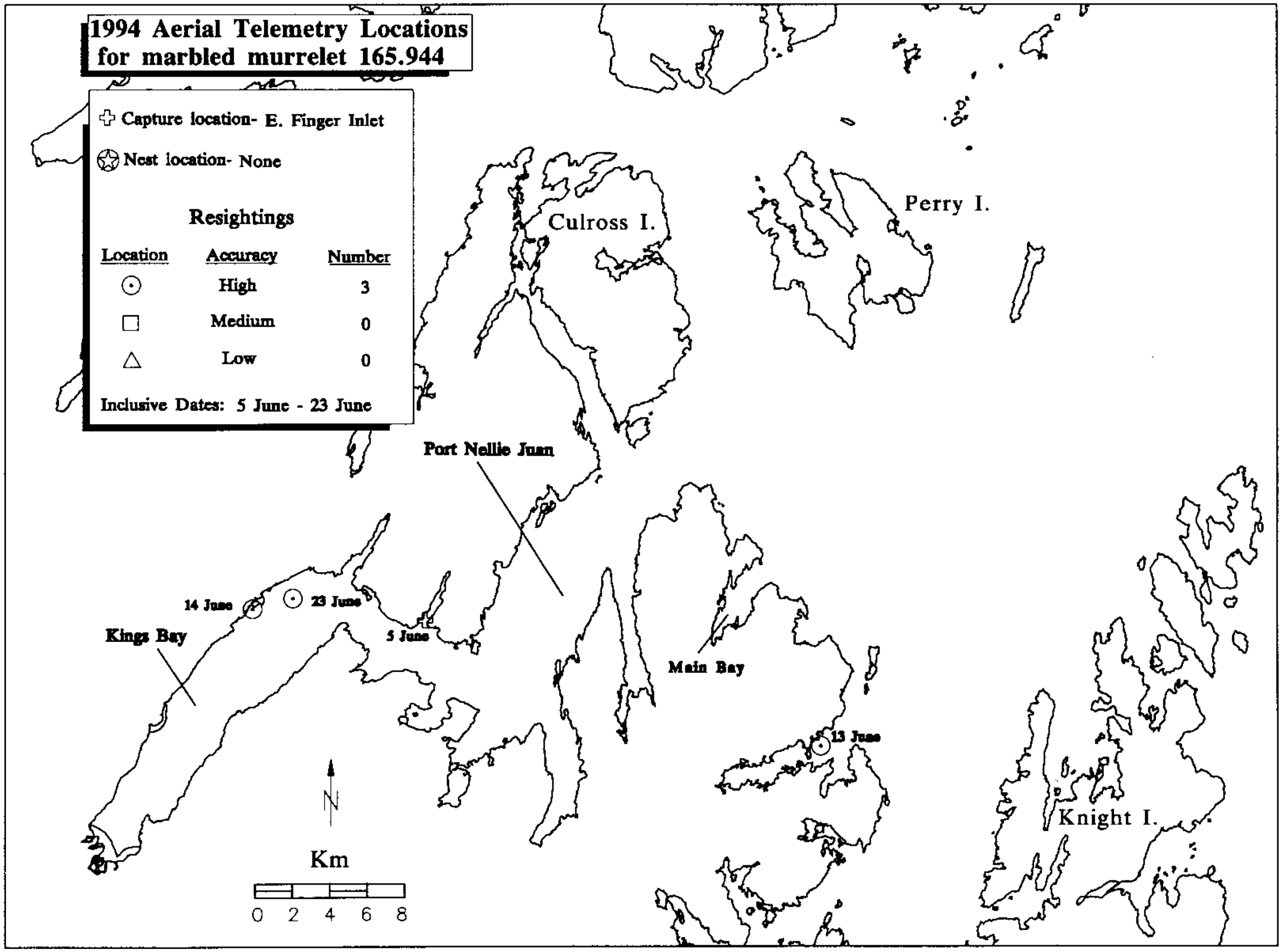
1994 Aerial Telemetry Locations
for marbled murrelet 165.780
Capture location- E. Finger Inlet
Nest location- None
Resightings
Location
Accuracy
Number
High
4
Medium
0
Low
0
Inclusive Dates: 4 June - 9 June
Culross I.
Perry I.
Port Nellie Juan
Eleanor I.
4 June (PM)
9 June
6 June
5 June
4 June (AM)
Kings Bay
Main Bay
N
Km
0 2 4 6 8
Knight I.



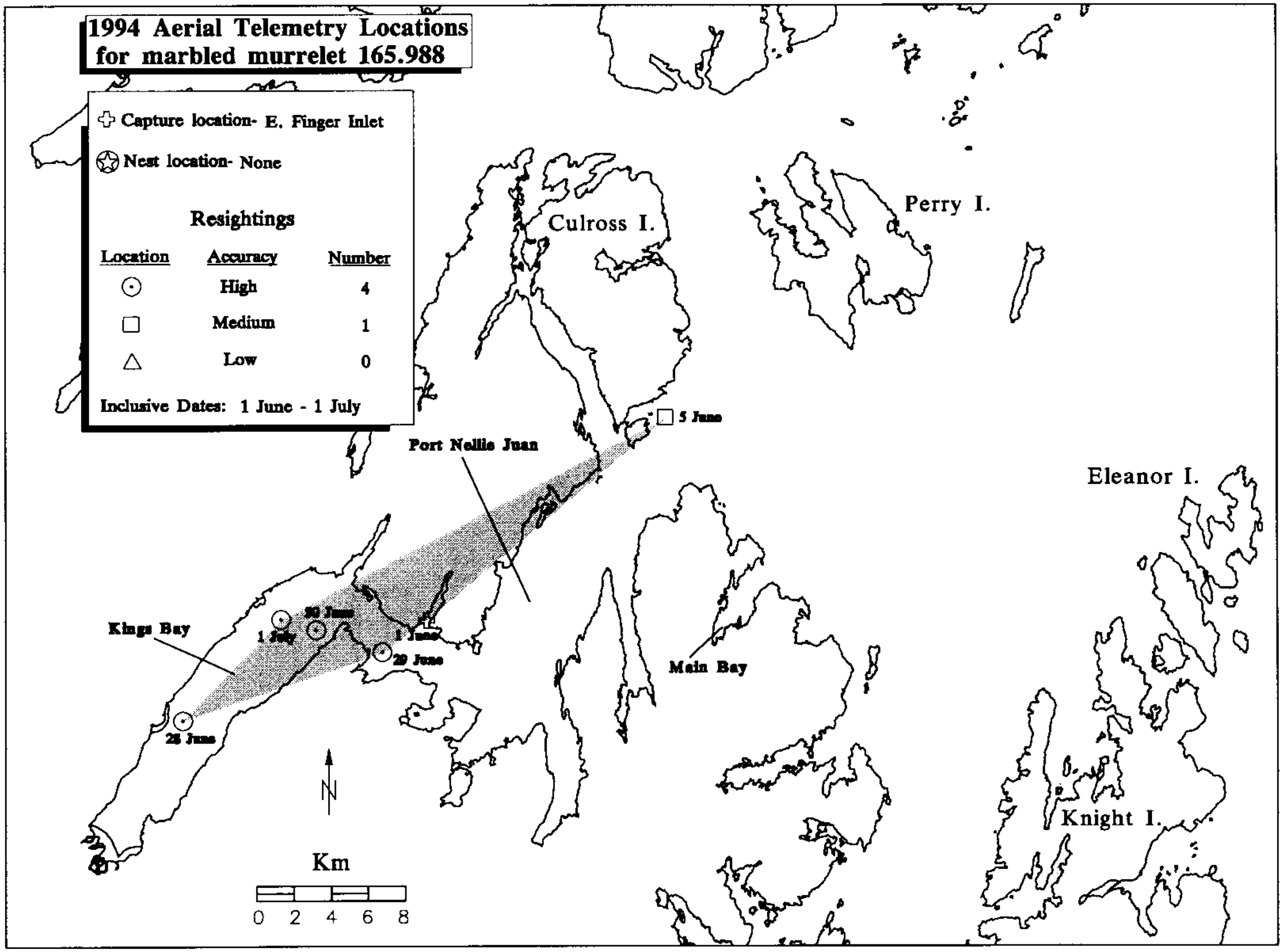
1994 Aerial Telemetry Locations
for marbled murrelet 165.861
Capture location- E. Finger Inlet
Nest location- Cotterell Glacier above Kings Bay
Resightings
Location
Accuracy
Number
High
8
Medium
1
Low
0
Inclusive Dates: 2 June - 23 June
Culross I.
Perry I.
Port Nellie Juan
Eleanor I.
5, 10 & 14 June
4 June
17 June
23 June
Kings Bay
6 June
2 June
13 June
9 June
Main Bay
Knight I.
N
Km
0 2 4 6 8

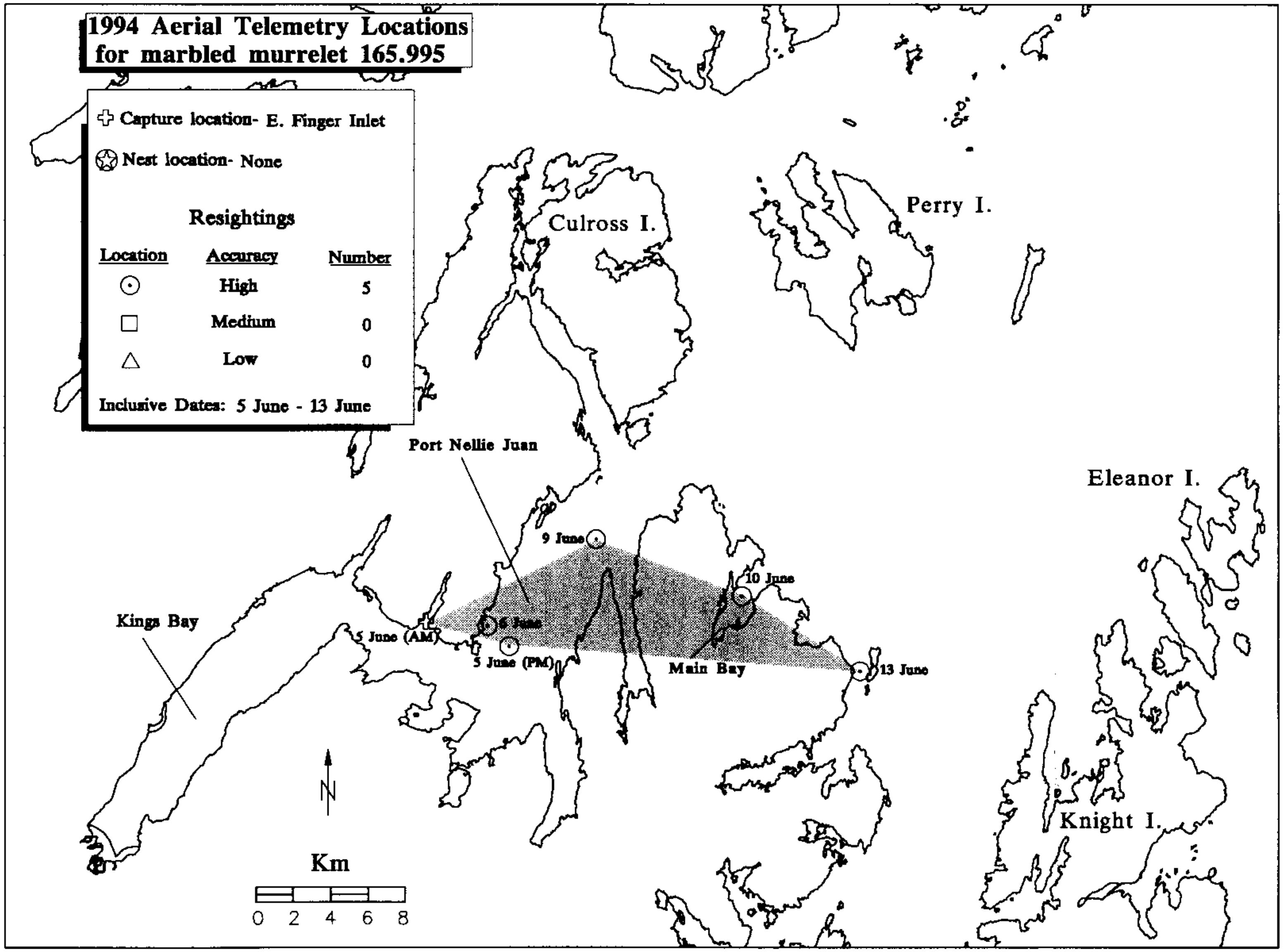


1994 Aerial Telemetry Locations
for marbled murrelet 165.886
Capture location- E. Finger Inlet
Nest location- N of Head of
E. Finger Inlet
Resightings
Location
Accuracy
Number
High
6
Medium
0
Low
0
Inclusive Dates: 3 June - 14 June
Culross I.
Perry I.
Port Nellie Juan
Eleanor I.
6 & 10 June
14 June
13 June
3 June
4 June
5 June
Kings Bay
Main Bay
Knight I.
N
Km
0 2 4 6 8

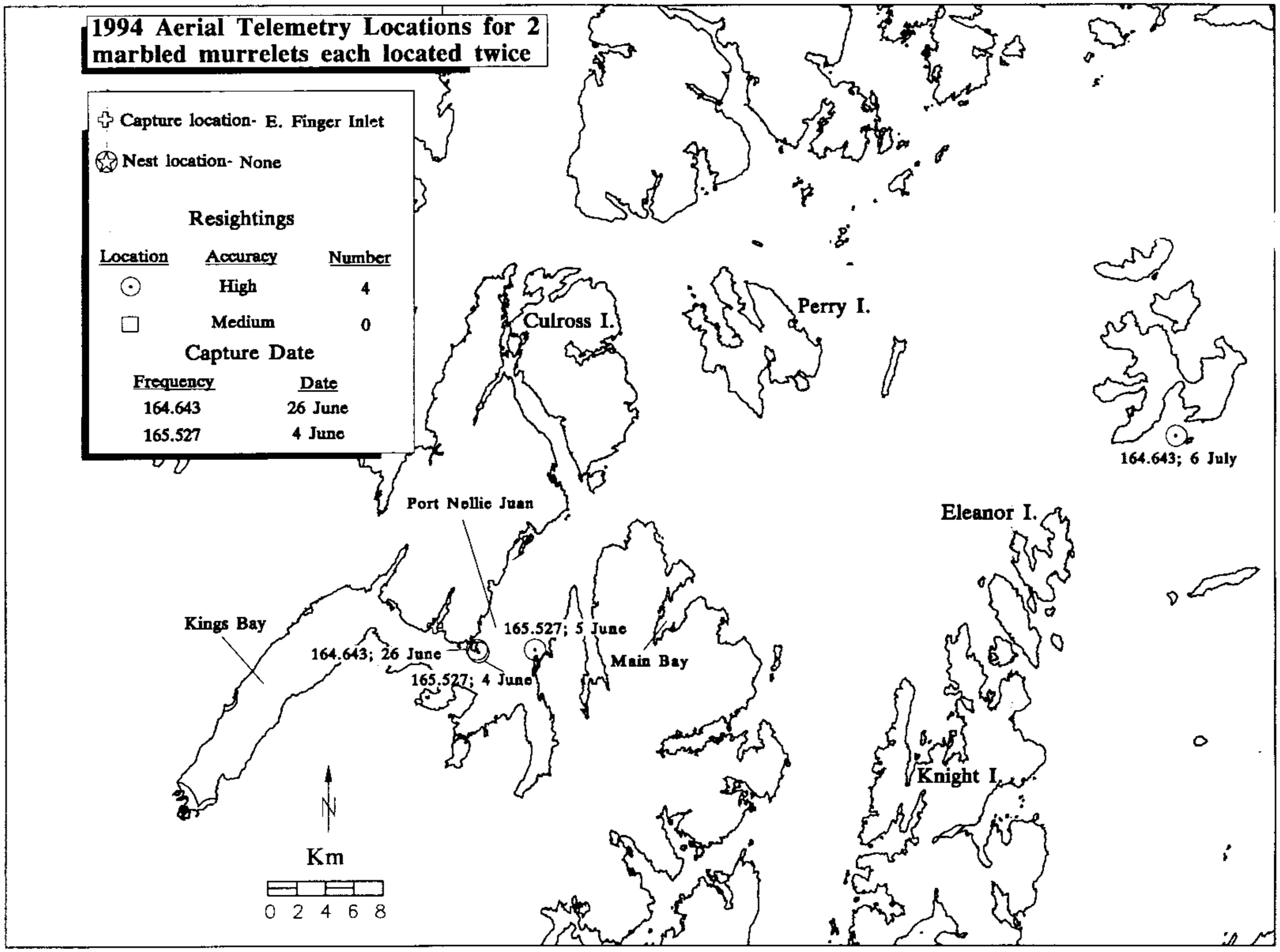


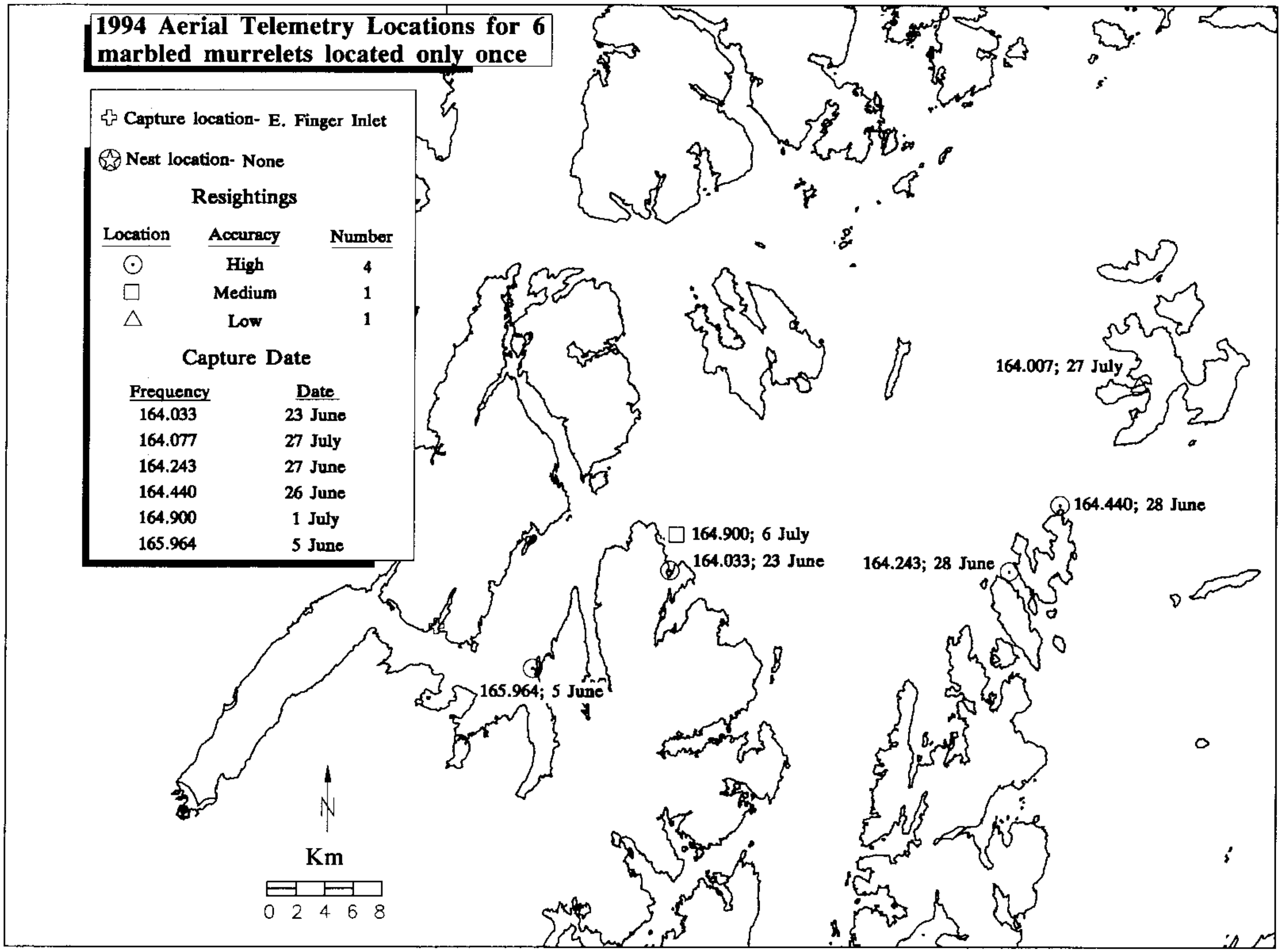
1994 Aerial Telemetry Locations
for marbled murrelet 165.944
Capture location- E. Finger Inlet
Nest location- None
Resightings
Location
Accuracy
Number
High
3
Medium
0
Low
0
Inclusive Dates: 5 June - 23 June
Culross I.
Perry I.
Port Nellie Juan
14 June
23 June
5 June
Kings Bay
Main Bay
13 June
Knight I.
Km
0 2 4 6 8


1994 Aerial Telemetry Locations
for marbled murrelet 165.988
Capture location- E. Finger Inlet
Nest location- None
Resightings
Location
Accuracy
Number
High
4
Medium
1
Low
0
Inclusive Dates: 1 June - 1 July
Culross I.
Perry I.
5 June
Port Nellie Juan
Eleanor I.
Kings Bay
30 June
1 July
1 June
29 June
28 June
Main Bay
Knight I.
N
Km
0 2 4 6 8

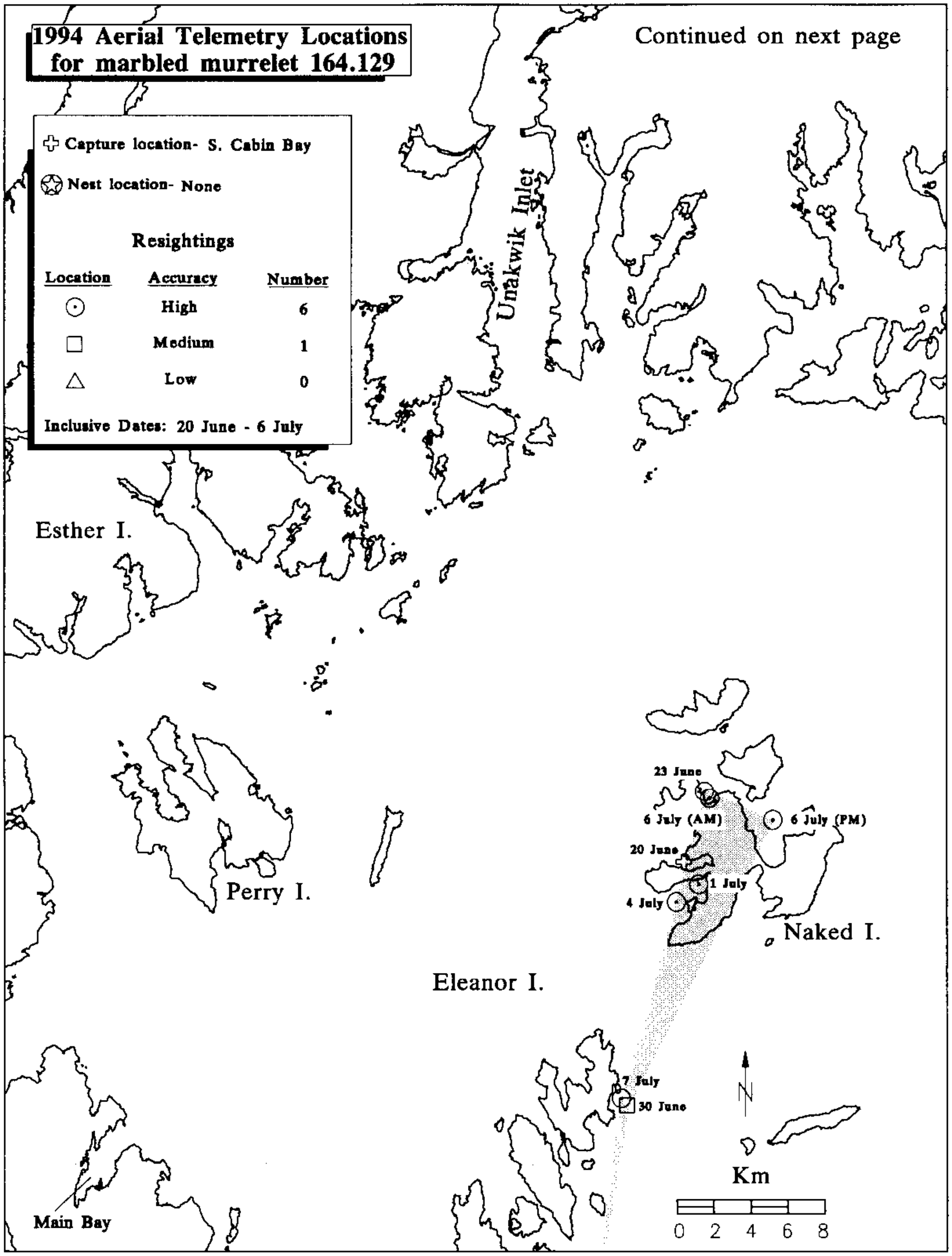


1994 Aerial Telemetry Locations
for marbled murrelet 165.995
Capture location- E. Finger Inlet
Nest location- None
Resightings
Location
Accuracy
Number
High
5
Medium
0
Low
0
Inclusive Dates: 5 June - 13 June
Culross I.
Perry I.
Port Nellie Juan
Eleanor I.
9 June
10 June
6 June
5 June (AM)
5 June (PM)
Main Bay
13 June
Kings Bay
N
Km
0 2 4 6 8
Knight I.

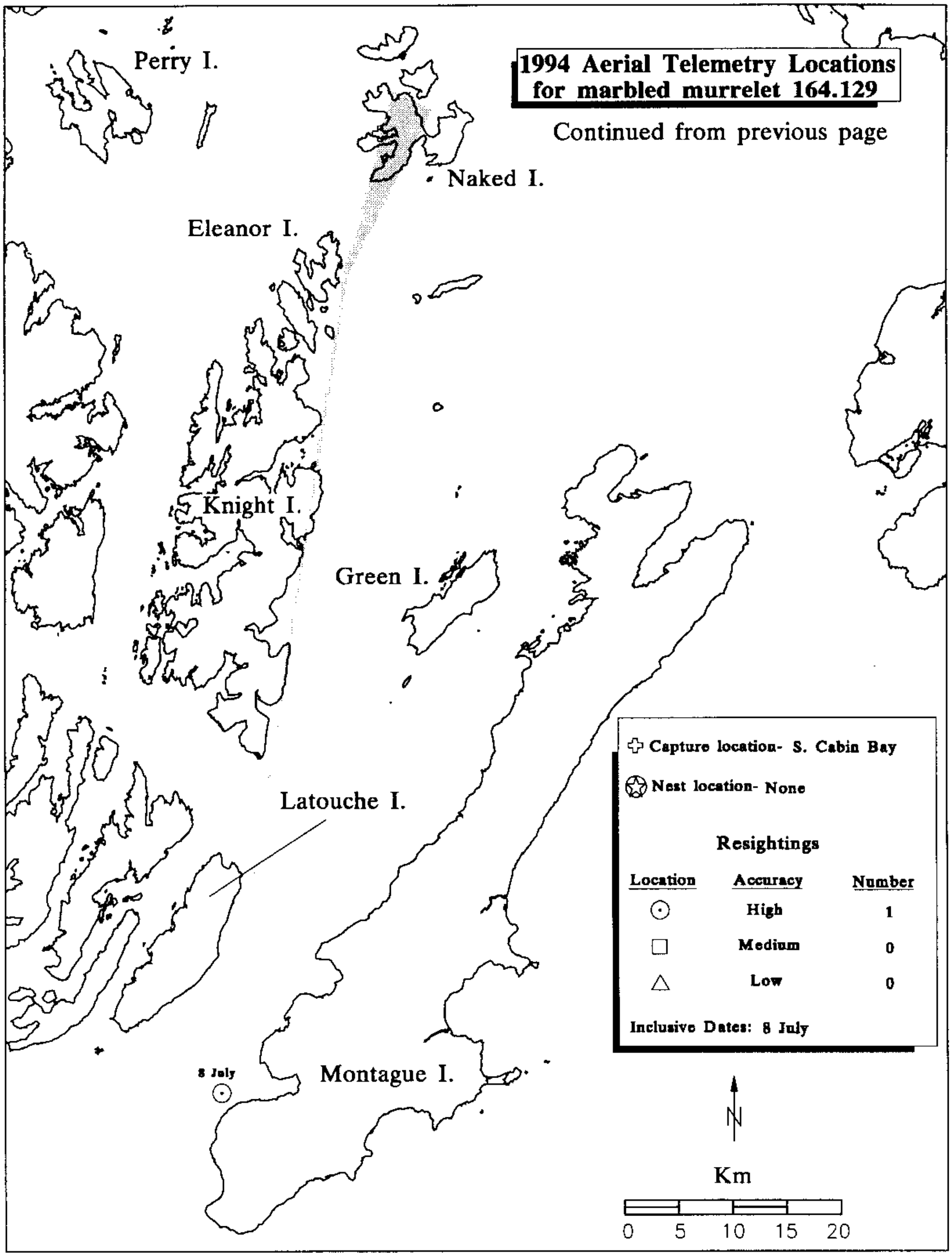

1994 Aerial Telemetry Locations for 2 marbled murrelets each located twice
Capture location- E. Finger Inlet
Nest location- None
Resightings
Location
Accuracy
Number
High
4
Medium
0
Capture Date
Frequency
Date
164.643
26 June
165.527
4 June
Culross I.
Perry I.
164.643; 6 July
Port Nellie Juan
Eleanor I.
Kings Bay
165.527; 5 June
164.643; 26 June
Main Bay
165.527; 4 June
Knight I.
N
Km
0 2 4 6 8

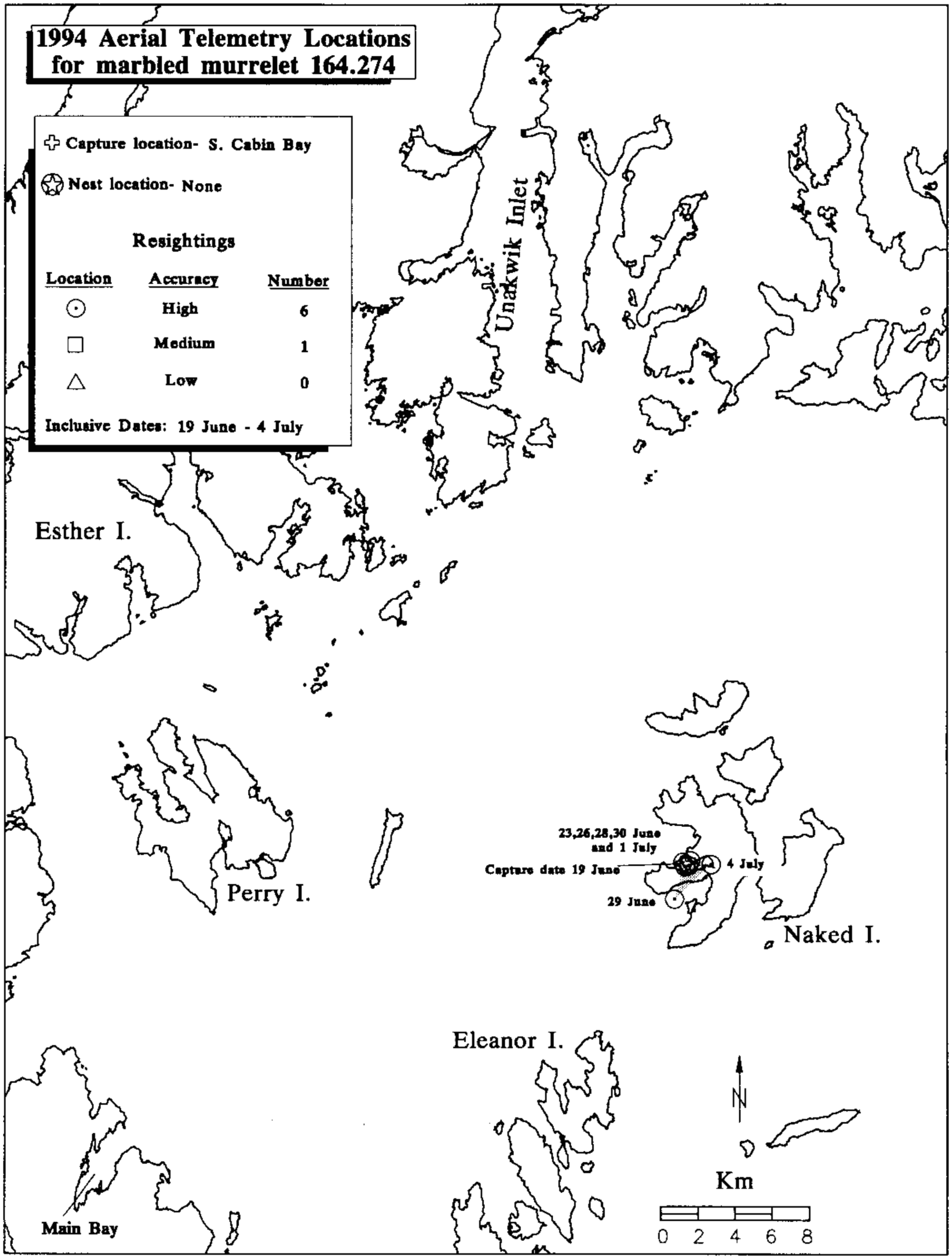


1994 Aerial Telemetry Locations for 6 marbled murrelets located only once
Capture location- E. Finger Inlet
Nest location- None
Resightings
Location
Accuracy
Number
High
4
Medium
1
Low
1
Capture Date
Frequency
Date
164.033
23 June
164.077
27 July
164.243
27 June
164.440
26 June
164.900
1 July
165.964
5 June
164.007; 27 July
164.440; 28 June
164.900; 6 July
164.033; 23 June
164.243; 28 June
165.964; 5 June
N
Km
0 2 4 6 8

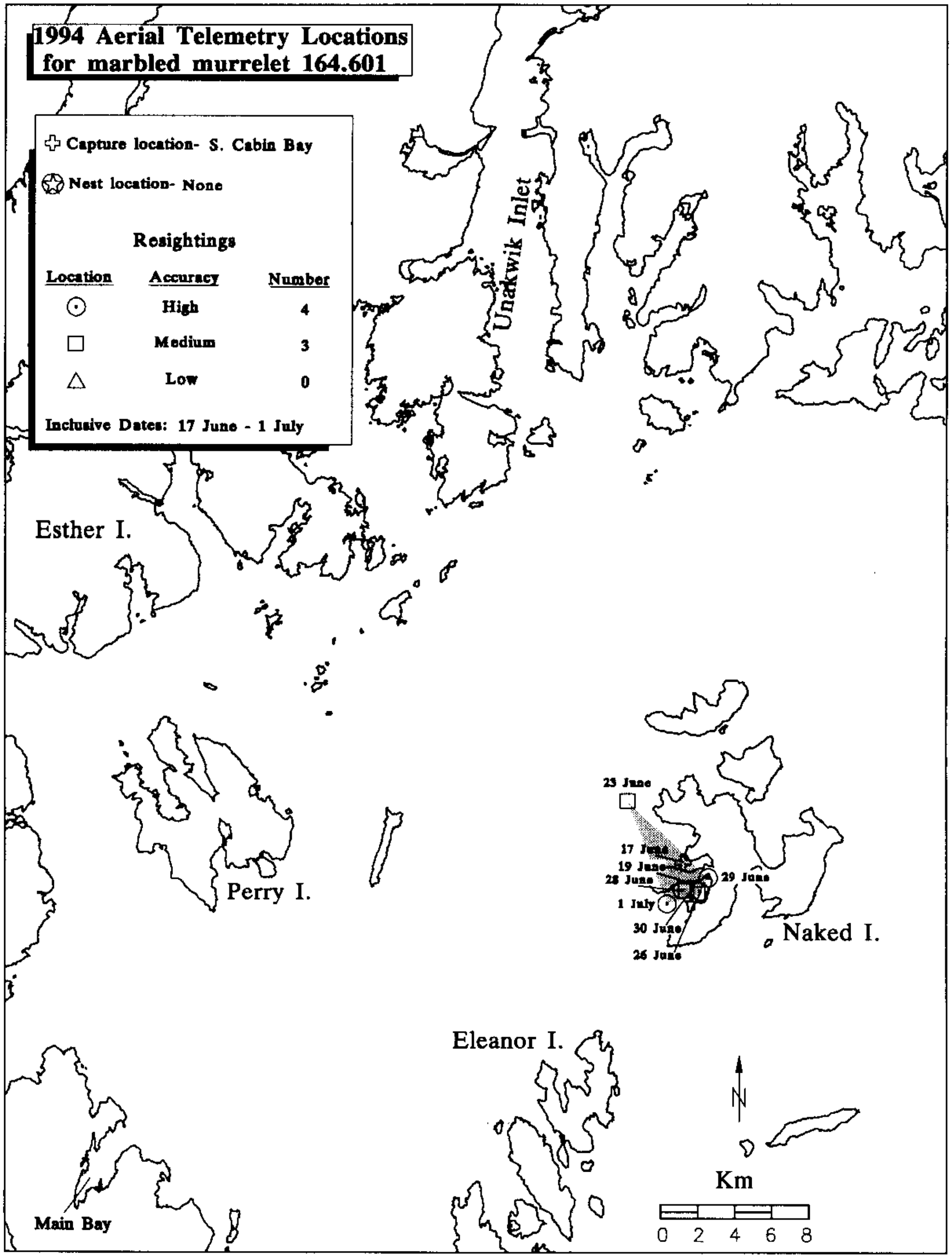


1994 Aerial Telemetry Locations
for marbled murrelet 164.129
Continued on next page
Capture location- S. Cabin Bay
Nest location- None
Resightings
Location
Accuracy
Number
High
6
Medium
1
Low
0
Inclusive Dates: 20 June - 6 July
Unakwik Inlet
Esther I.
Perry I.
Eleanor I.
Naked I.
23 June
6 July (AM)
6 July (PM)
20 June
1 July
4 July
7 July
30 June
N
Km
0 2 4 6 8
Main Bay

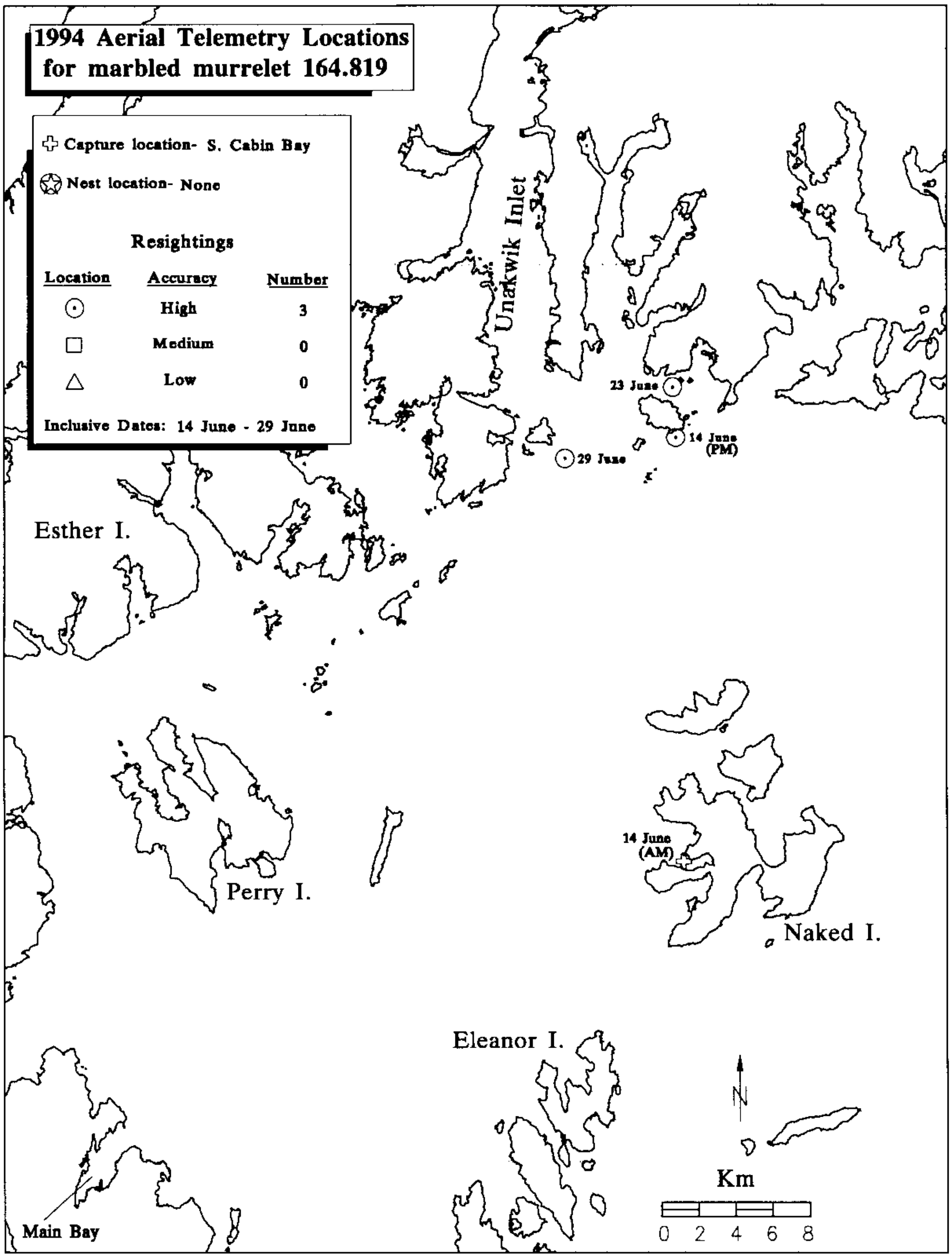

1994 Aerial Telemetry Locations
for marbled murrelet 164.129
Continued from previous page
Perry I.
Naked I.
Eleanor I.
Knight I.
Green I.
Latouche I.
Montague I.
8 July
Capture location- S. Cabin Bay
Nest location- None
Resightings
Location
Accuracy
Number
High
1
Medium
0
Low
0
Inclusive Dates: 8 July
N
Km
0
5
10
15
20

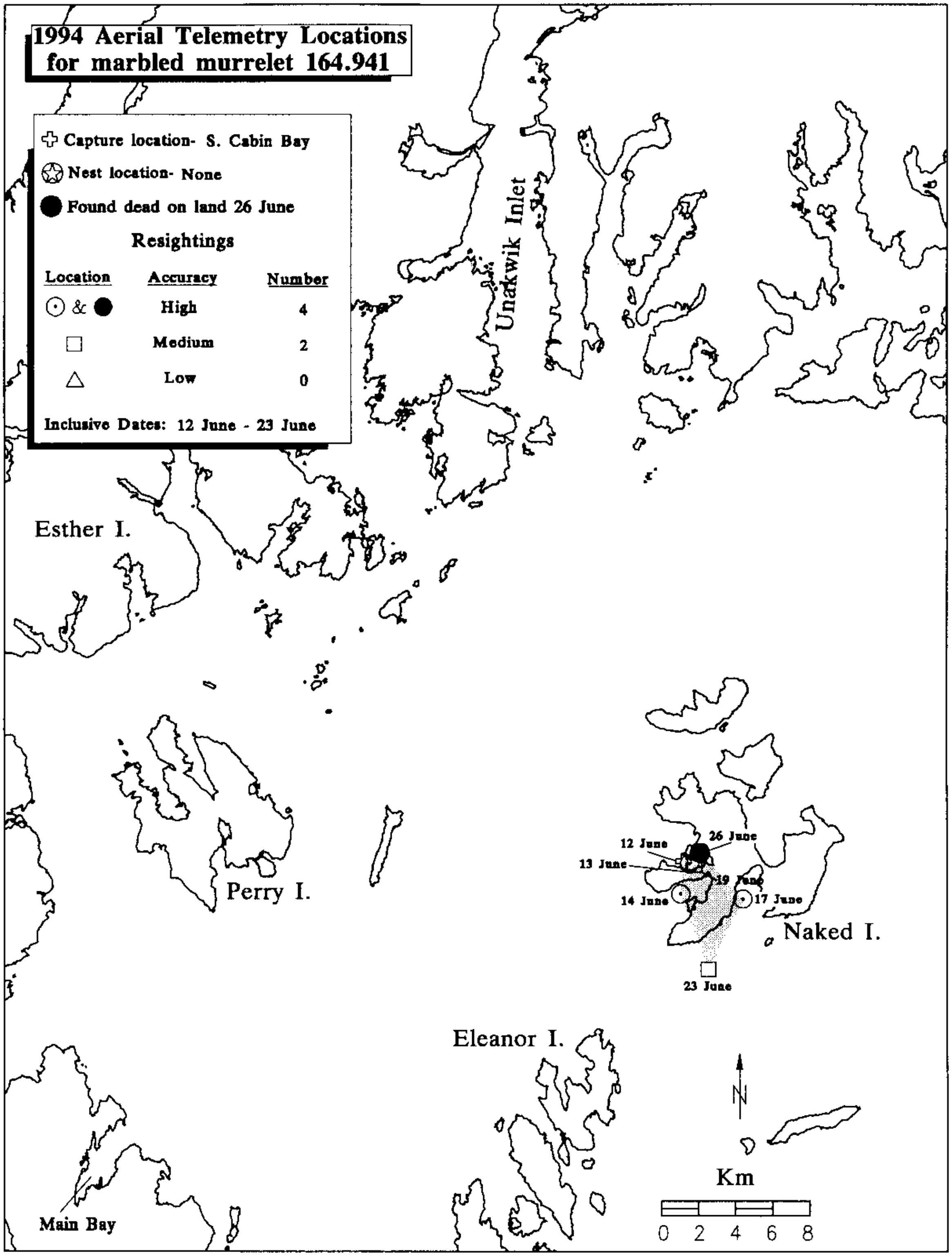


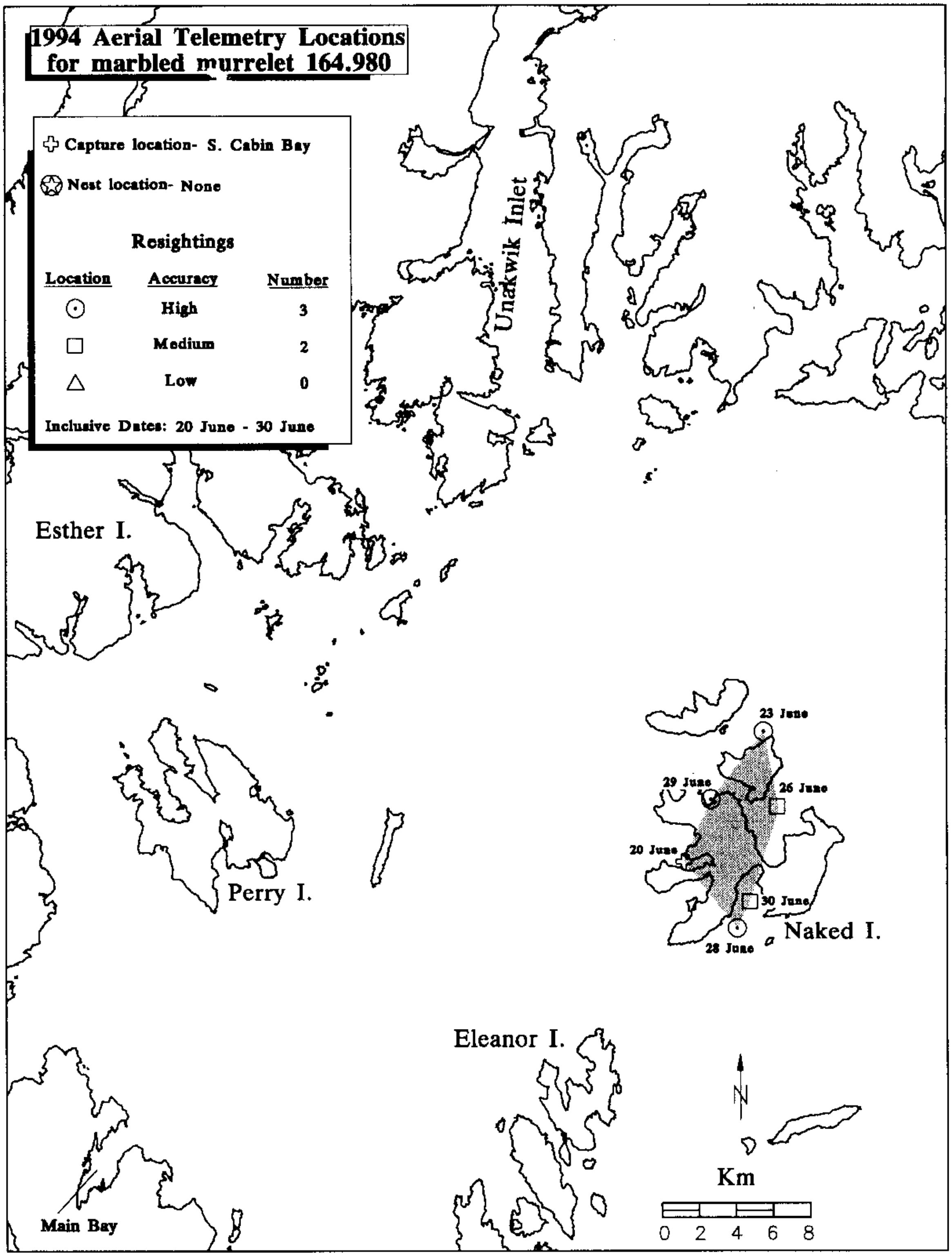
1994 Aerial Telemetry Locations
for marbled murrelet 164.274
Capture location- S. Cabin Bay
Nest location- None
Resightings
Location
Accuracy
Number
High
6
Medium
1
Low
0
Inclusive Dates: 19 June - 4 July
Unakwik Inlet
Esther I.
Perry I.
23,26,28,30 June
and 1 July
Capture date 19 June
4 July
29 June
Naked I.
Eleanor I.
N
Km
0 2 4 6 8
Main Bay

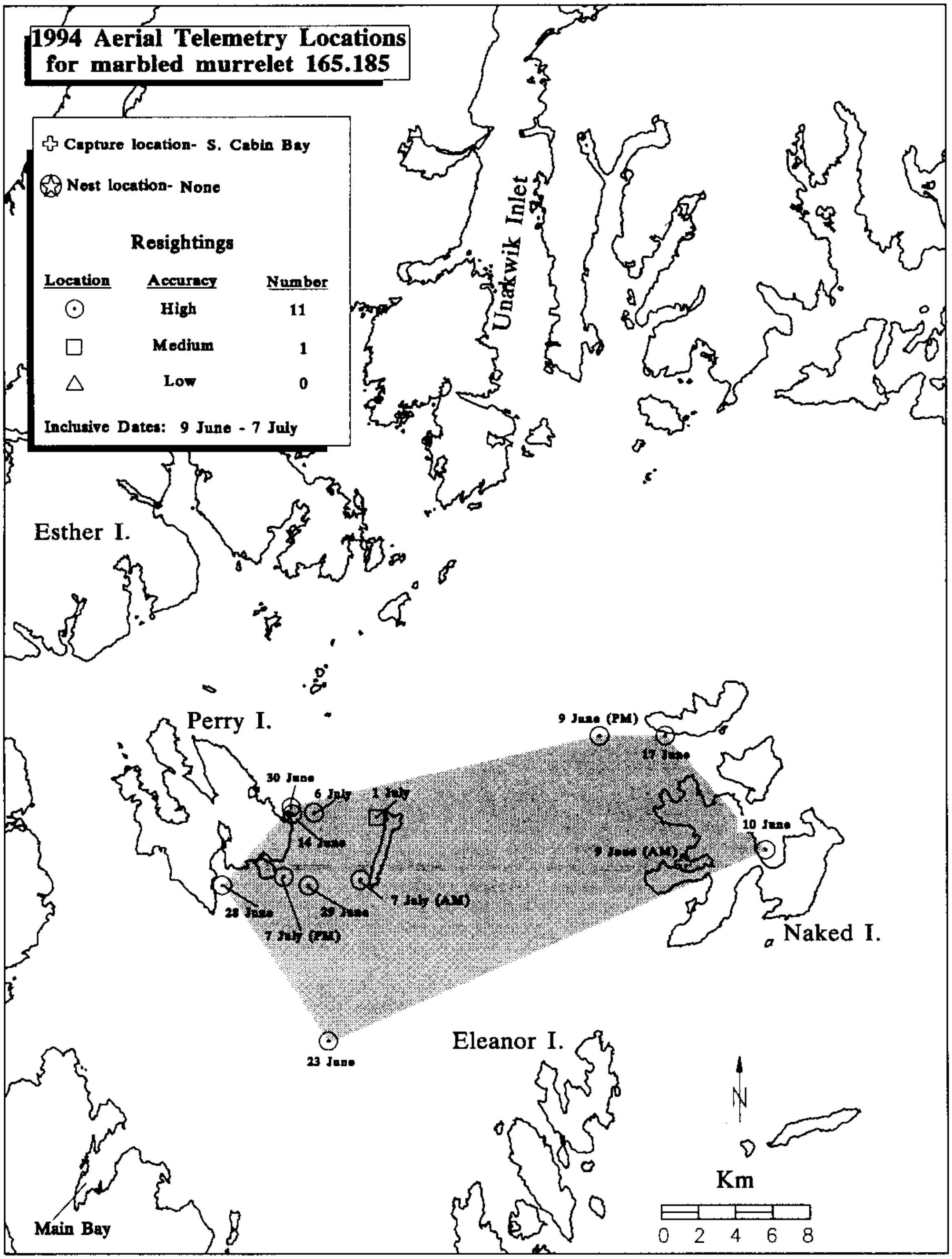


1994 Aerial Telemetry Locations for marbled murrelet 164.601
Capture location- S. Cabin Bay
Nest location- None
Resightings
Location
Accuracy
Number
High
4
Medium
3
Low
0
Inclusive Dates: 17 June - 1 July
Unakwik Inlet
Esther I.
Perry I.
23 June
17 June
19 June
28 June
29 June
1 July
30 June
26 June
Naked I.
Eleanor I.
N
Km
0 2 4 6 8
Main Bay

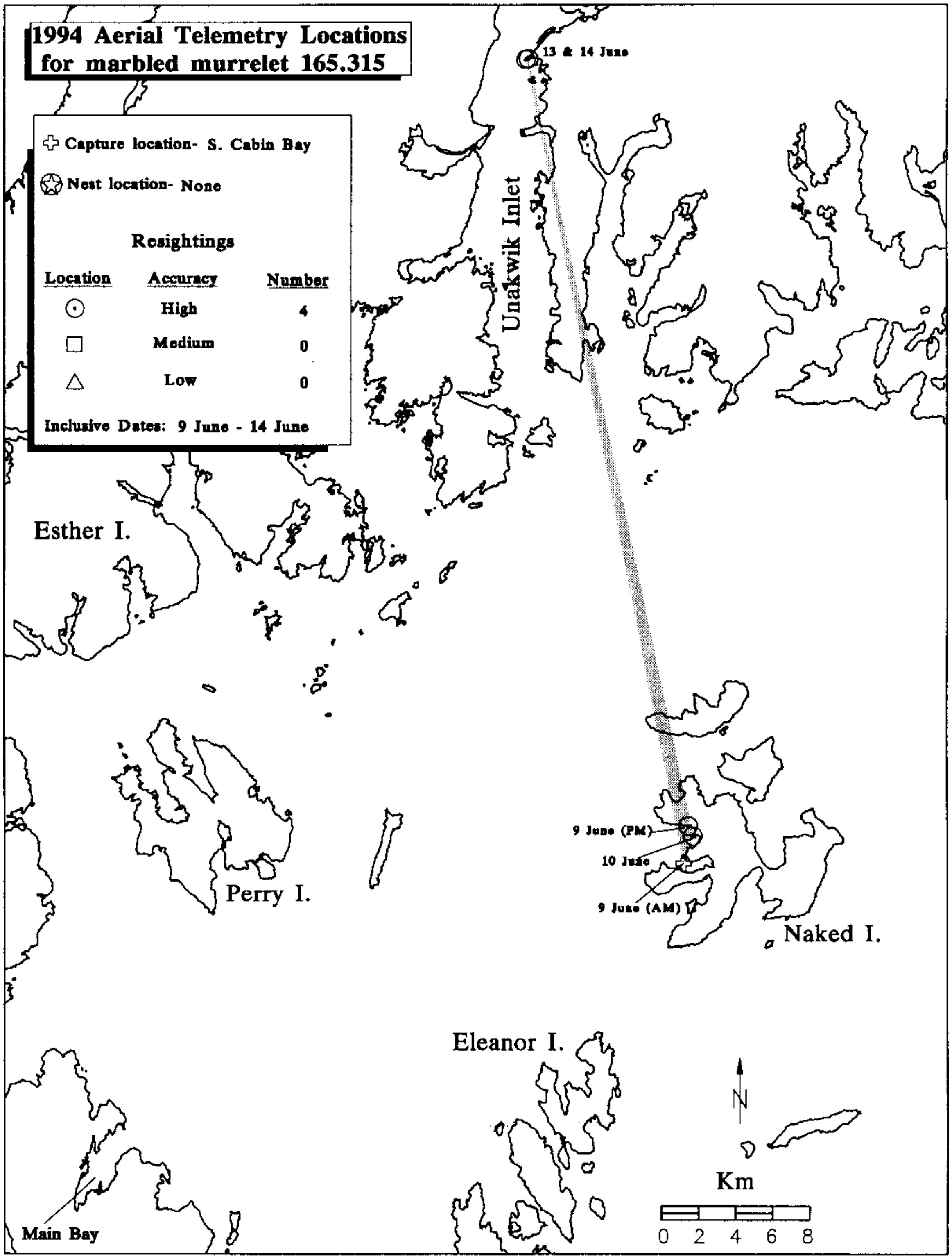

1994 Aerial Telemetry Locations
for marbled murrelet 164.819
Capture location- S. Cabin Bay
Nest location- None
Resightings
Location
Accuracy
Number
High
3
Medium
0
Low
0
Inclusive Dates: 14 June - 29 June
Unakwik Inlet
23 June
14 June (PM)
29 June
Esther I.
Perry I.
14 June (AM)
Naked I.
Eleanor I.
N
Km
0 2 4 6 8
Main Bay

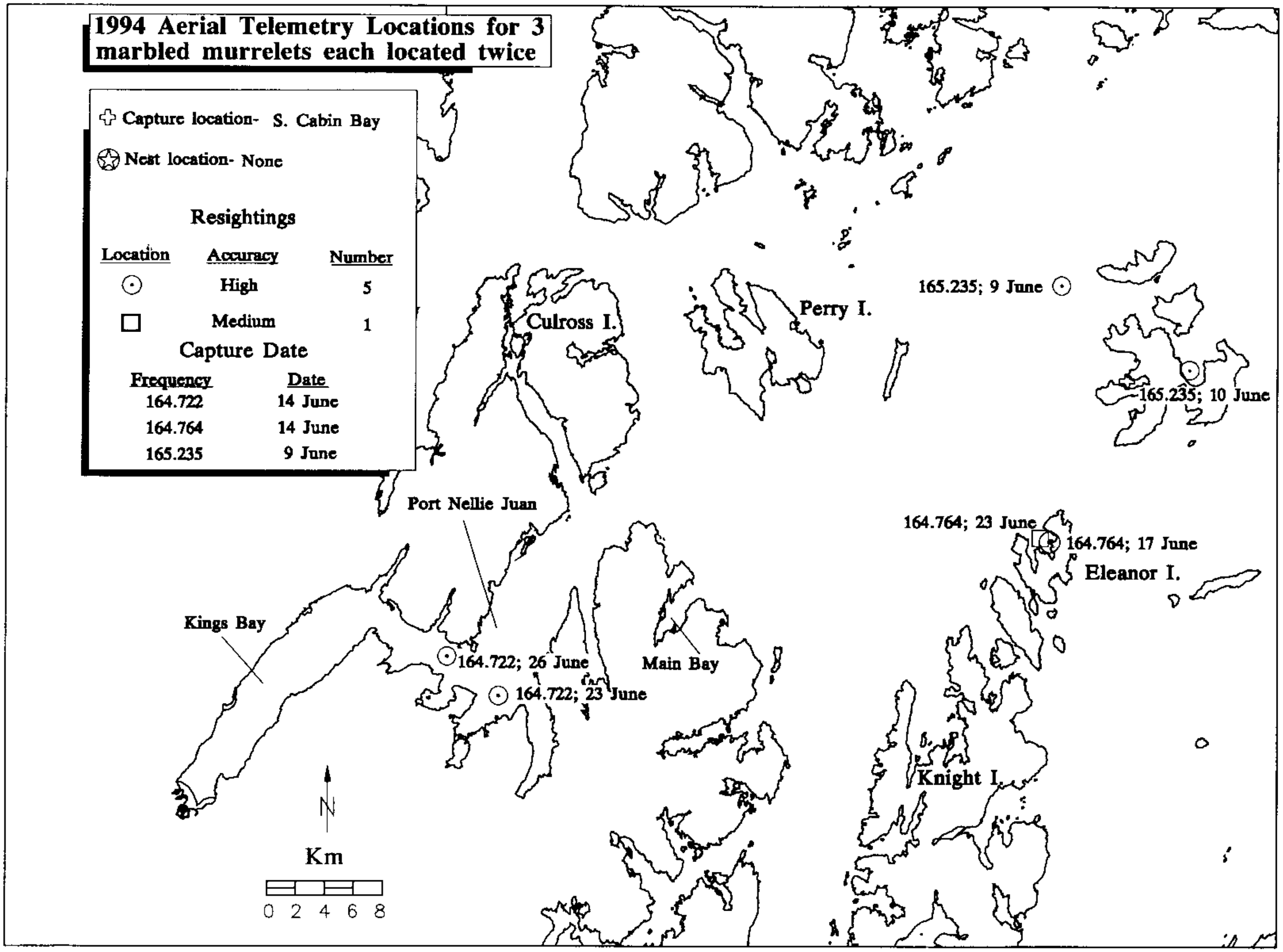

1994 Aerial Telemetry Locations
for marbled murrelet 164.941
Capture location- S. Cabin Bay
Nest location- None
Found dead on land 26 June
Resightings
Location
Accuracy
Number
&
High
4
Medium
2
Low
0
Inclusive Dates: 12 June - 23 June
Unakwik Inlet
Esther I.
Perry I.
12 June
13 June
26 June
19 June
14 June
17 June
Naked I.
23 June
Eleanor I.
N
Km
0 2 4 6 8
Main Bay

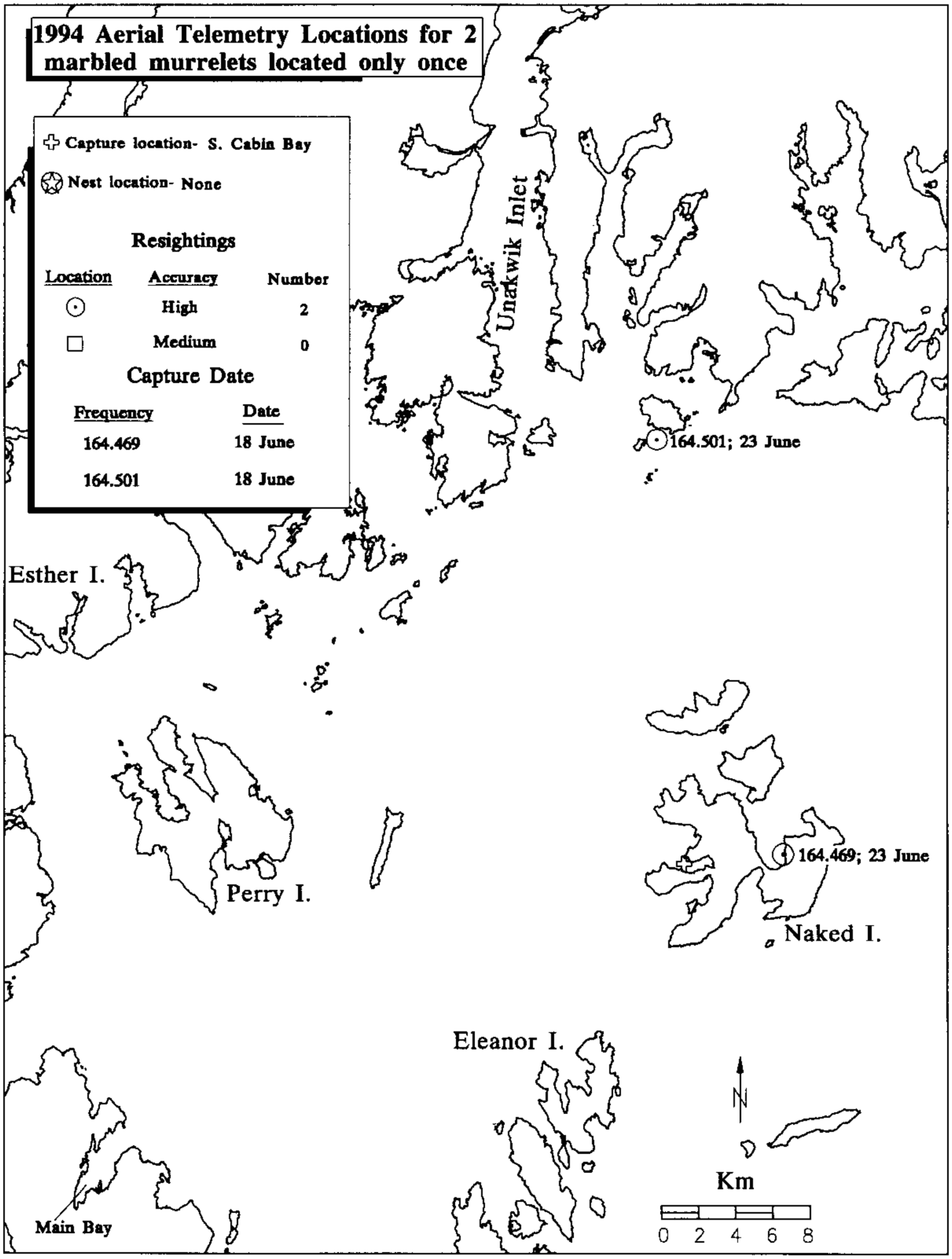

1994 Aerial Telemetry Locations
for marbled murrelet 164.980
Capture location- S. Cabin Bay
Nest location- None
Resightings
Location
Accuracy
Number
High
3
Medium
2
Low
0
Inclusive Dates: 20 June - 30 June
Unakwik Inlet
Esther I.
Perry I.
Naked I.
Eleanor I.
23 June
29 June
26 June
20 June
30 June
28 June
Main Bay
N
Km
0 2 4 6 8



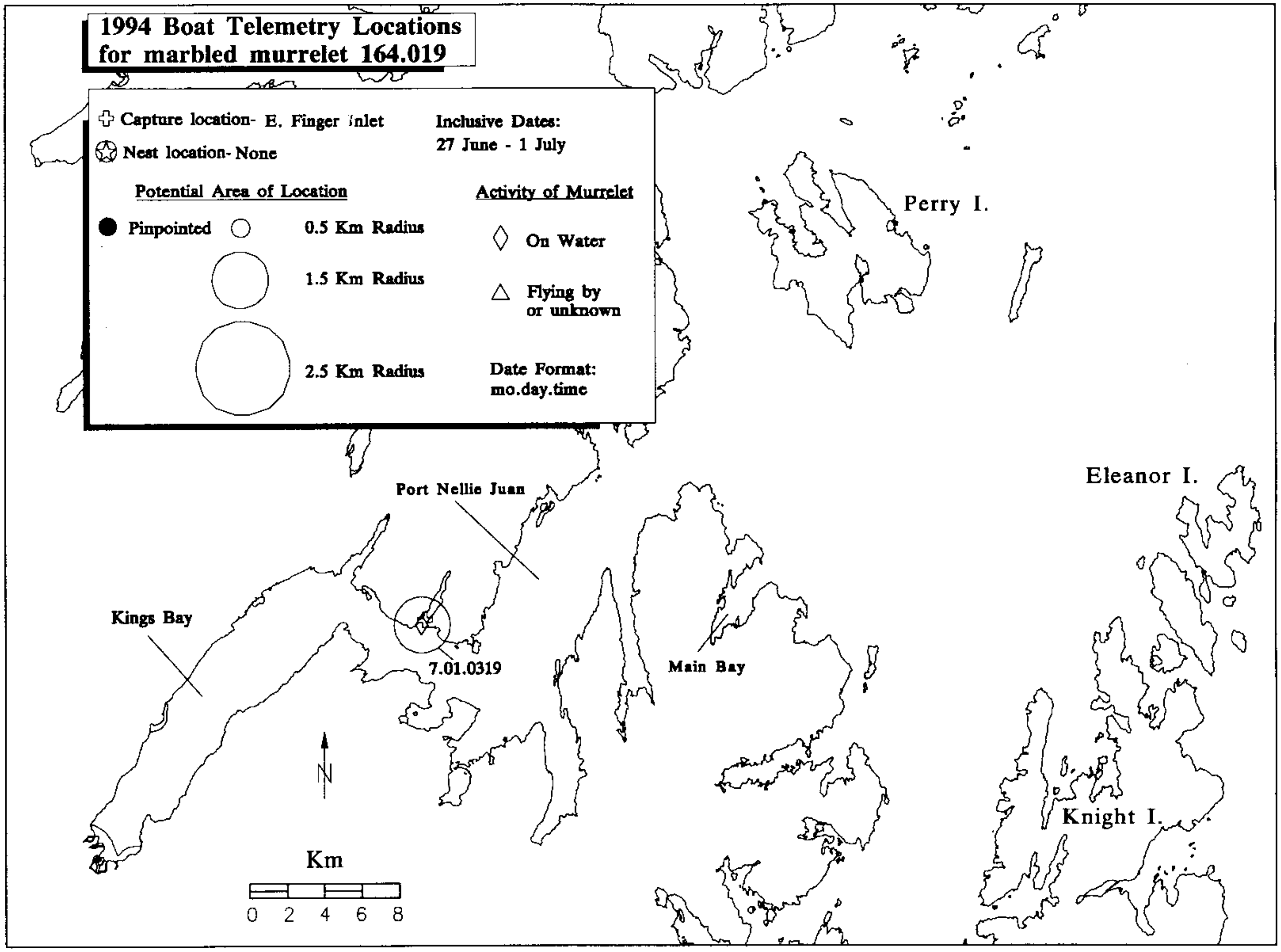
1994 Aerial Telemetry Locations
for marbled murrelet 165.185
Capture location- S. Cabin Bay
Nest location- None
Resightings
Location
Accuracy
Number
High
11
Medium
1
Low
0
Inclusive Dates: 9 June - 7 July
Unakwik Inlet
Esther I.
Perry I.
9 June (PM)
17 June
30 June
6 July
1 July
14 June
10 June
9 June (AM)
7 July (AM)
28 June
29 June
7 July (PM)
Naked I.
Eleanor I.
23 June
N
Km
0 2 4 6 8
Main Bay

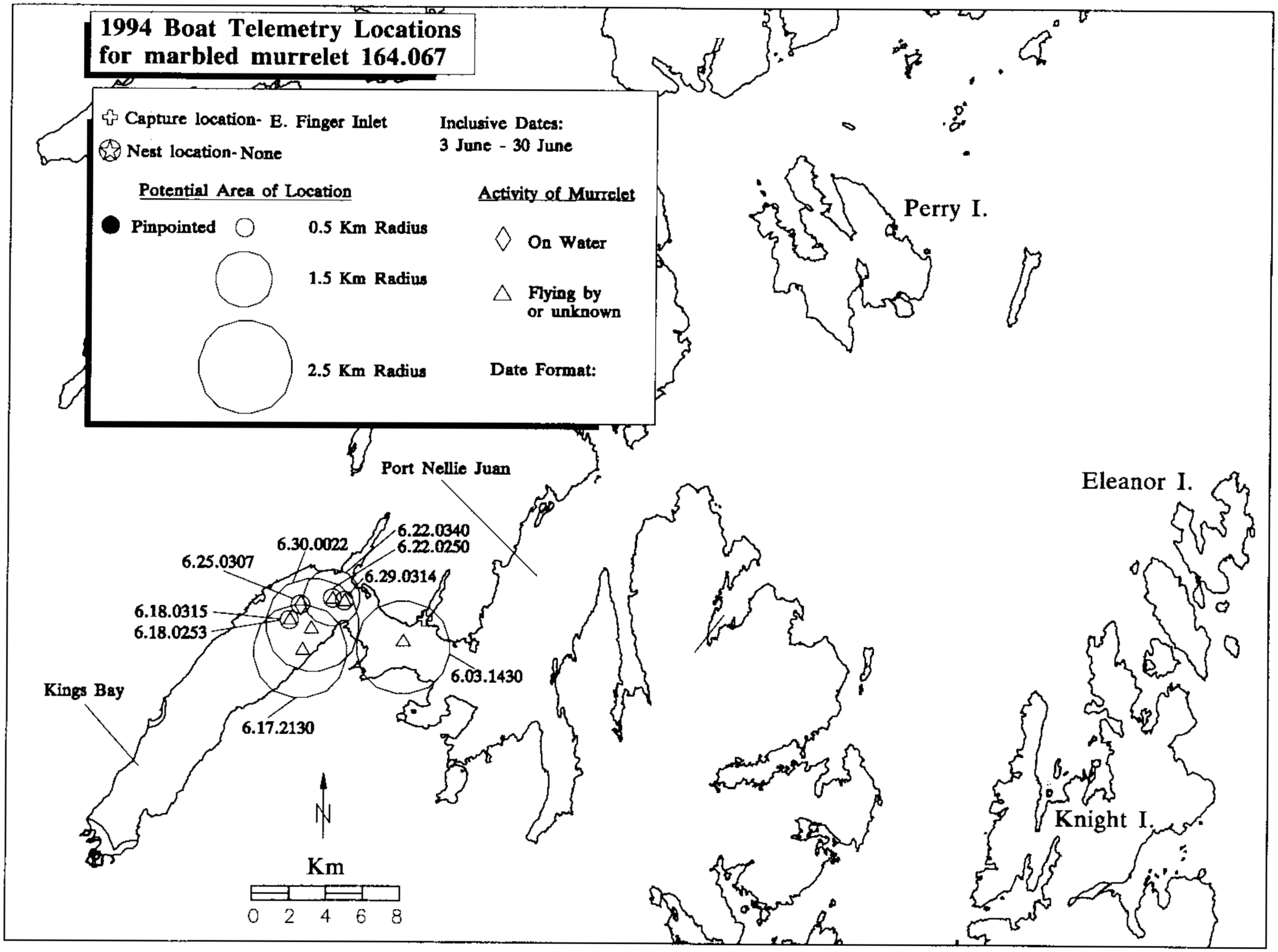

1994 Aerial Telemetry Locations
for marbled murrelet 165.315
Capture location- S. Cabin Bay
Nest location- None
Resightings
Location
Accuracy
Number
High
4
Medium
0
Low
0
Inclusive Dates: 9 June - 14 June
13 & 14 June
Unakwik Inlet
Esther I.
Perry I.
9 June (PM)
10 June
9 June (AM)
Naked I.
Eleanor I.
N
Km
0 2 4 6 8
Main Bay


1994 Aerial Telemetry Locations for 3 marbled murrelets each located twice
Capture location- S. Cabin Bay
Nest location- None
Resightings
Location
Accuracy
Number
High
5
Medium
1
Capture Date
Frequency
Date
164.722
14 June
164.764
14 June
165.235
9 June
Culross I.
Perry I.
165.235; 9 June
165.235; 10 June
Port Nellie Juan
164.764; 23 June
164.764; 17 June
Eleanor I.
Kings Bay
164.722; 26 June
164.722; 23 June
Main Bay
Knight I.
N
Km
0 2 4 6 8

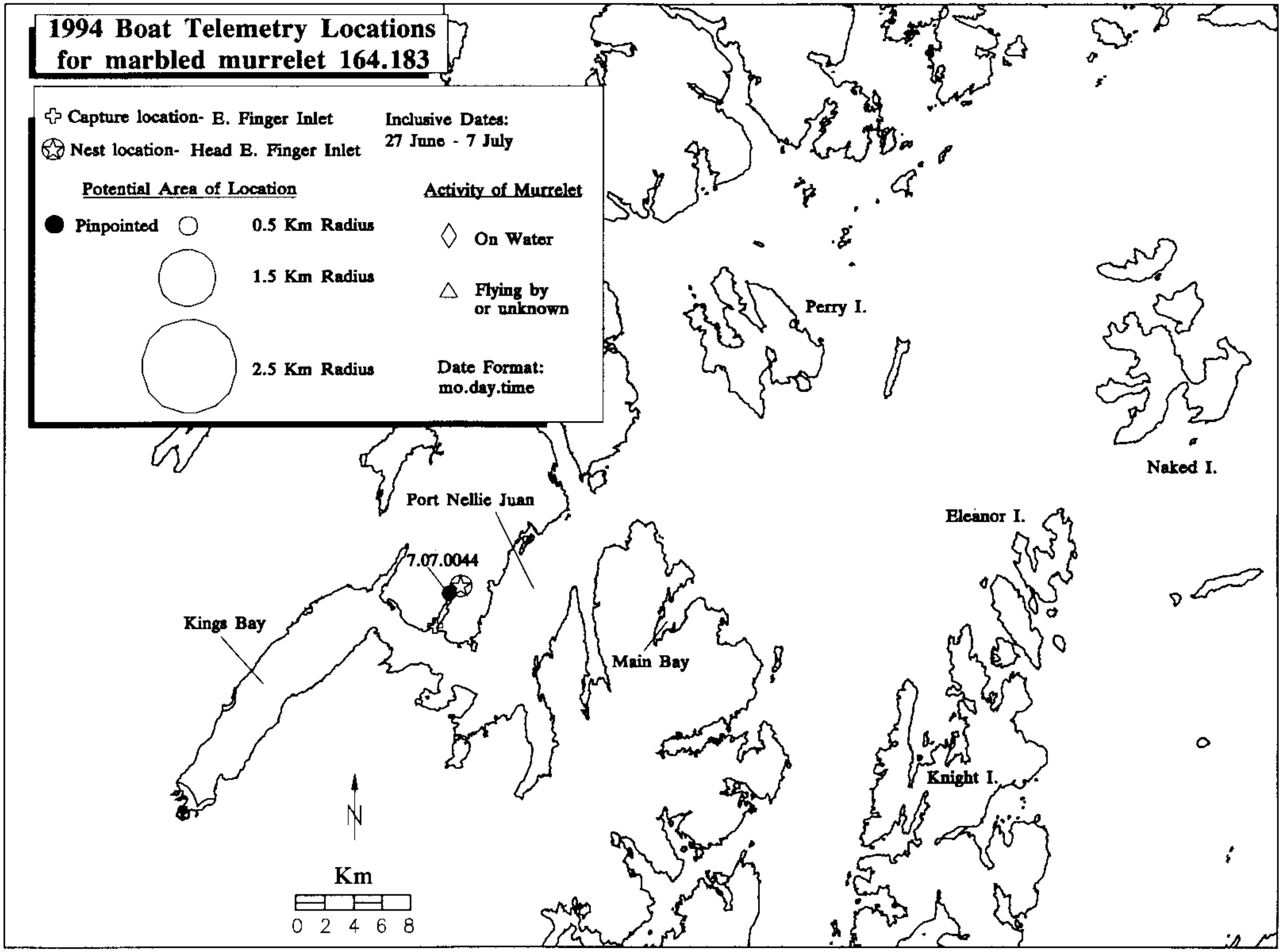

1994 Aerial Telemetry Locations for 2 marbled murrelets located only once
Capture location- S. Cabin Bay
Nest location- None
Resightings
Location
Accuracy
Number
High
2
Medium
0
Capture Date
Frequency
Date
164.469
18 June
164.501
18 June
Unakwik Inlet
164.501; 23 June
Esther I.
Perry I.
164.469; 23 June
Naked I.
Eleanor I.
N
Km
0 2 4 6 8
Main Bay

Appendix G. Maps of telemetry locations made from boats for each marbled murrelet, identified by their transmitter frequency, radio-tagged at Port Nellie Juan and Naked Island, Prince William Sound, Alaska, in June and July 1994.

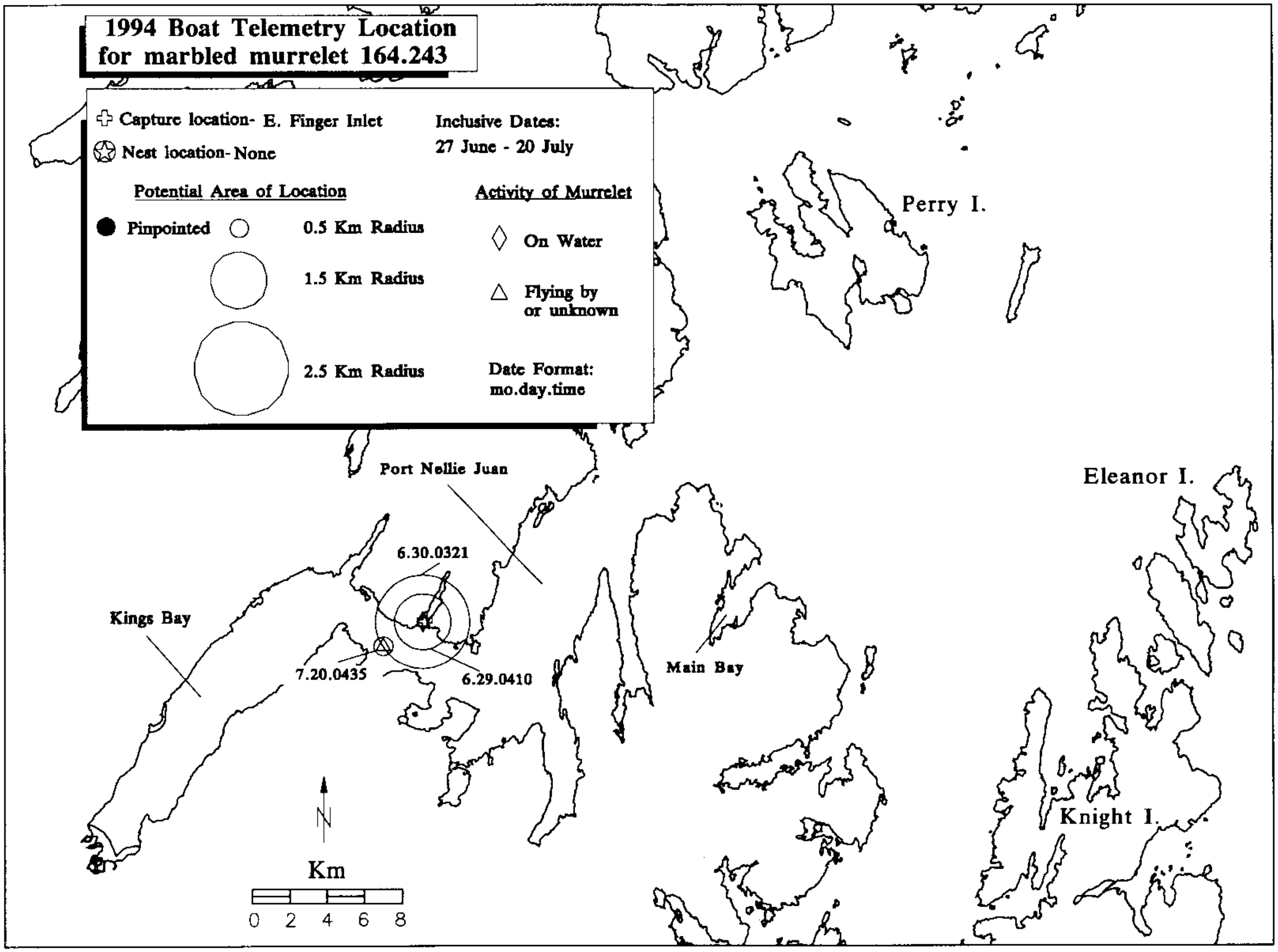

1994 Boat Telemetry Locations
for marbled murrelet 164.019
Capture location- E. Finger Inlet
Nest location- None
Inclusive Dates:
27 June - 1 July
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
mo.day.time
Perry I.
Eleanor I.
Port Nellie Juan
Kings Bay
7.01.0319
Main Bay
Knight I.
N
Km
0 2 4 6 8

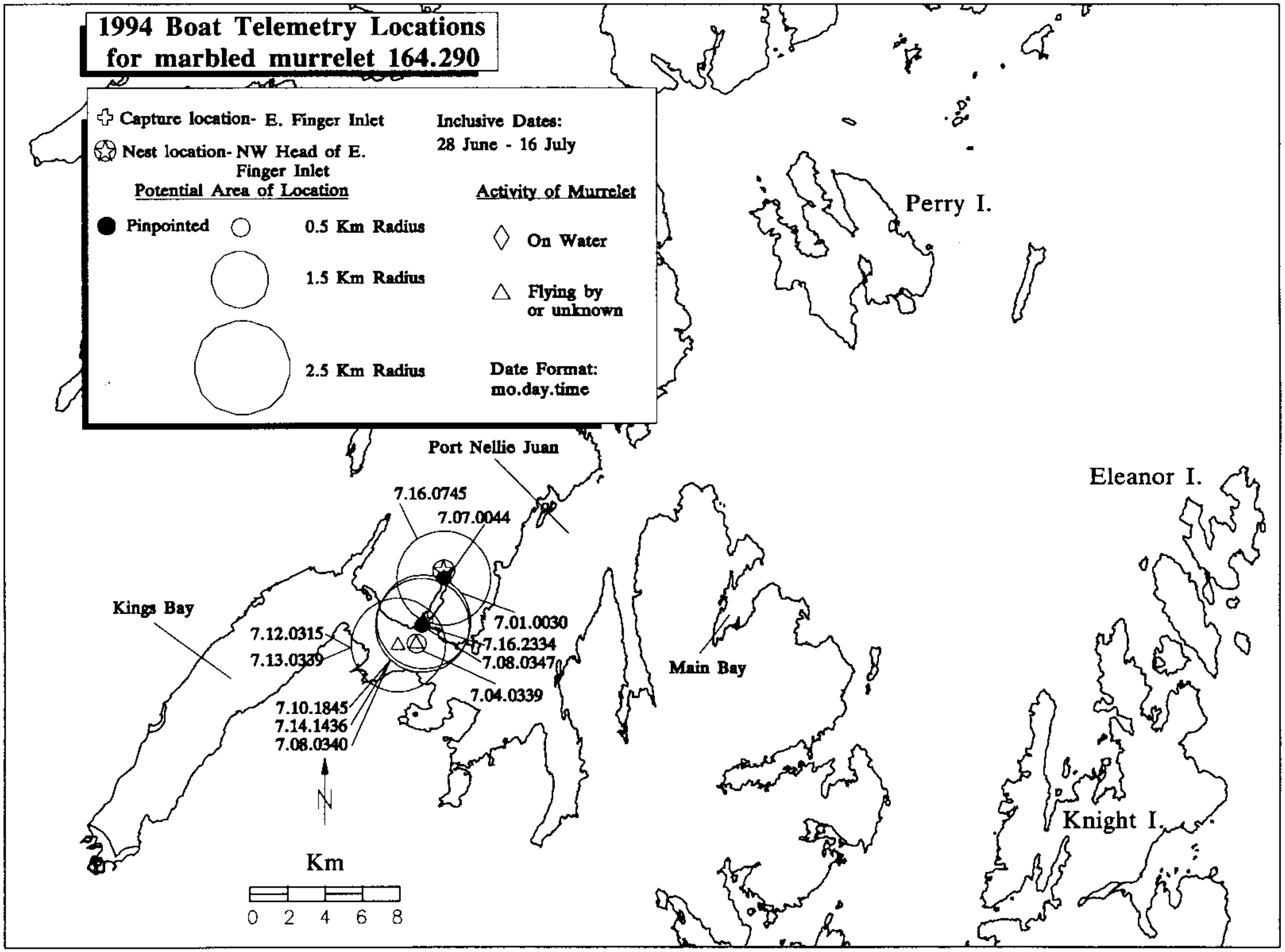


1994 Boat Telemetry Locations
for marbled murrelet 164.067
Capture location- E. Finger Inlet
Nest location- None
Inclusive Dates:
3 June - 30 June
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
Perry I.
Eleanor I.
Knight I.
Port Nellie Juan
Kings Bay
6.30.0022
6.22.0340
6.22.0250
6.25.0307
6.29.0314
6.18.0315
6.18.0253
6.03.1430
6.17.2130
N
Km
0 2 4 6 8

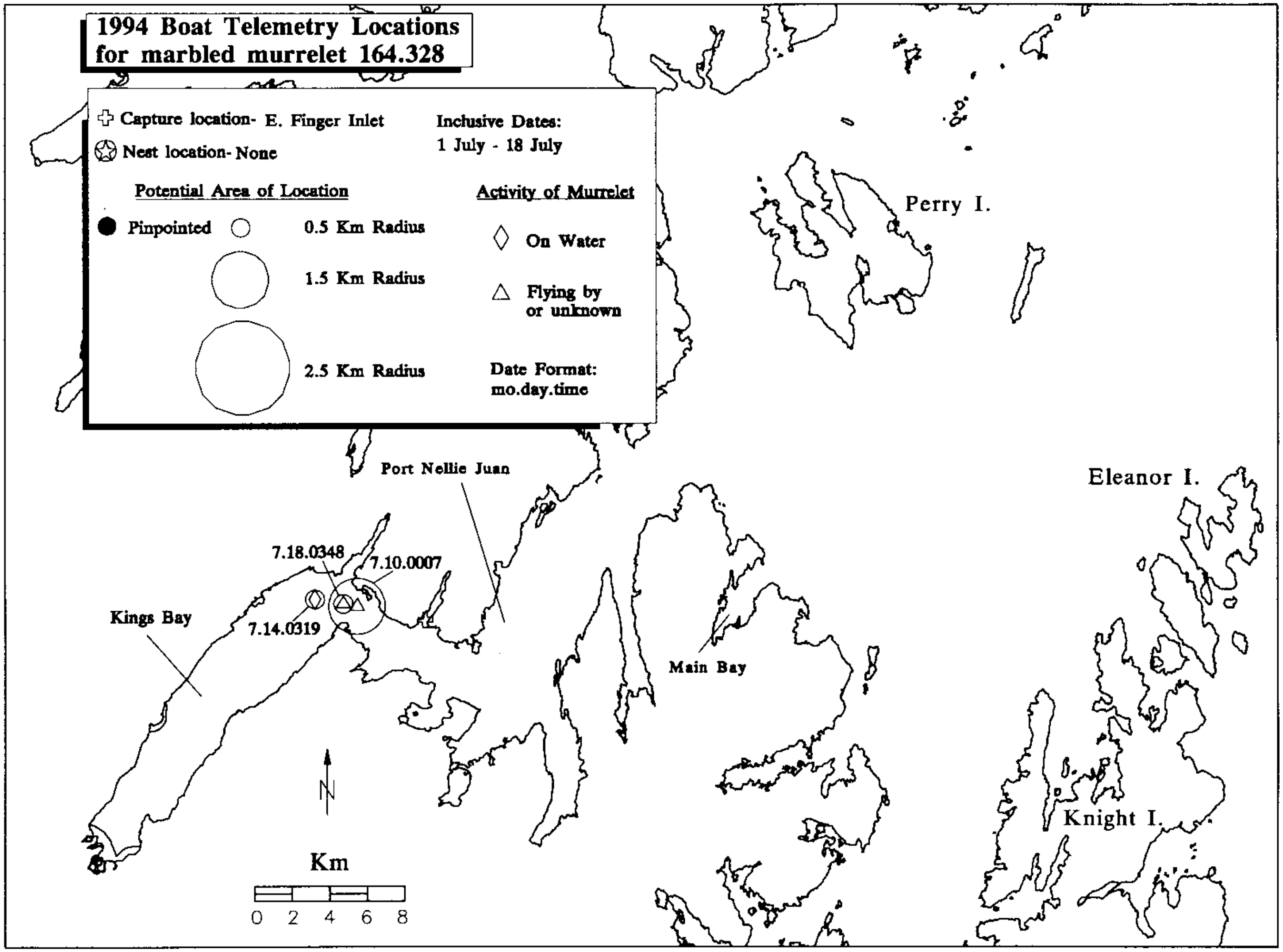


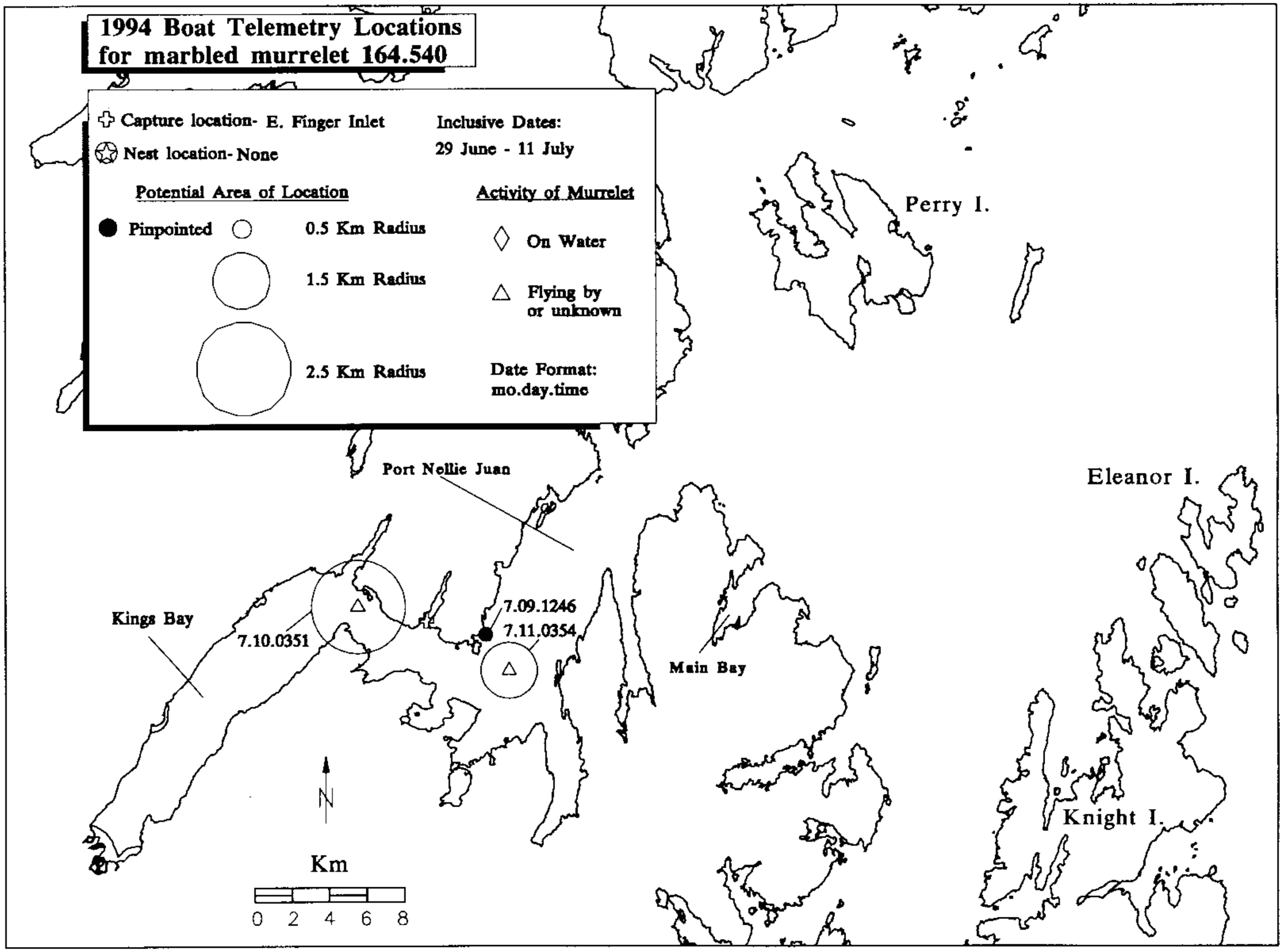
1994 Boat Telemetry Locations
for marbled murrelet 164.183
Capture location- E. Finger Inlet
Nest location- Head E. Finger Inlet
Inclusive Dates:
27 June - 7 July
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
mo.day.time
Perry I.
Naked I.
Eleanor I.
Port Nellie Juan
7.07.0044
Kings Bay
Main Bay
Knight I.
N
Km
0 2 4 6 8

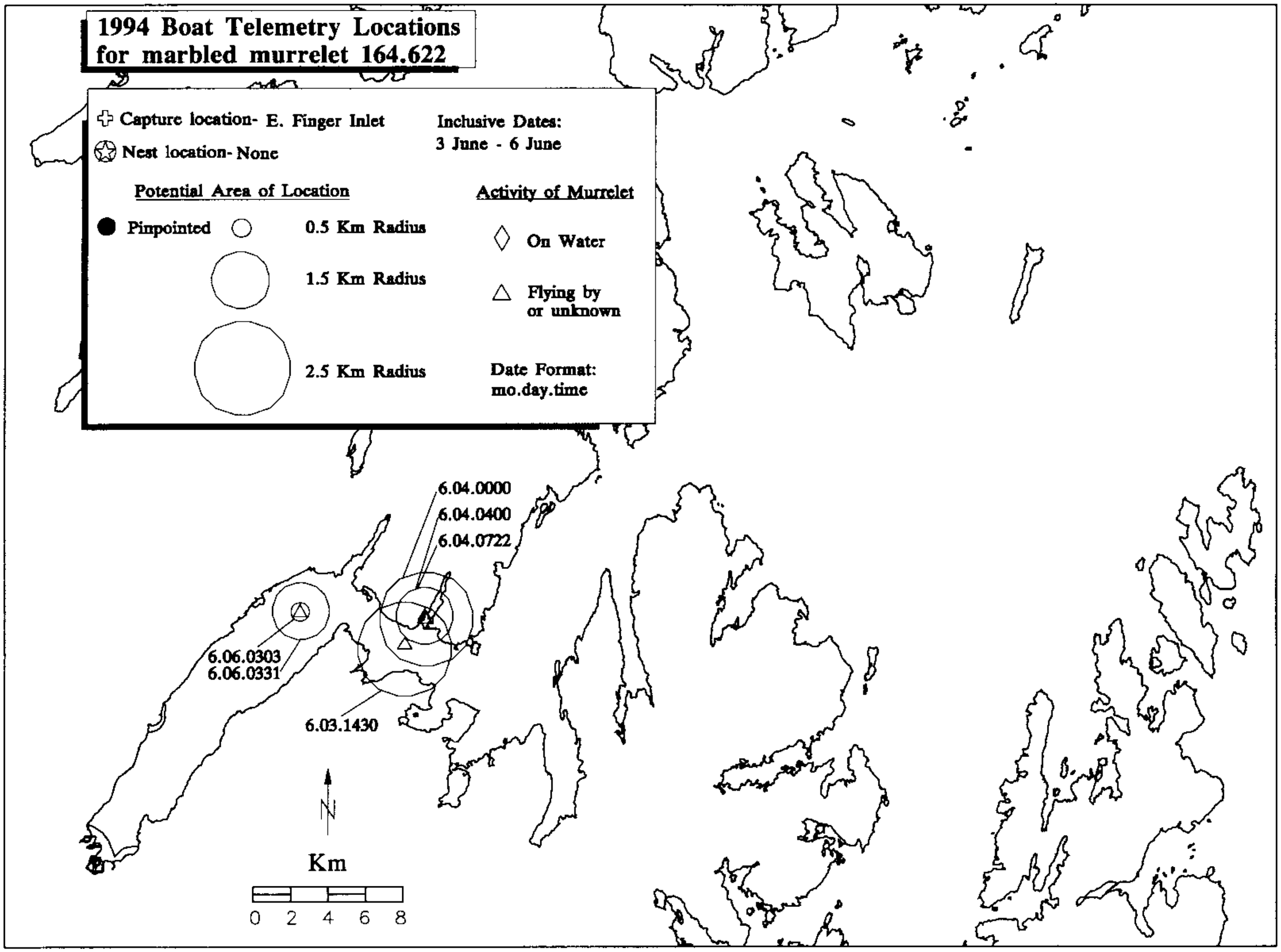

1994 Boat Telemetry Location
for marbled murrelet 164.243
Capture location- E. Finger Inlet
Nest location- None
Inclusive Dates:
27 June - 20 July
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
mo.day.time
Perry I.
Port Nellie Juan
Eleanor I.
6.30.0321
Kings Bay
Main Bay
7.20.0435
6.29.0410
N
Km
0 2 4 6 8
Knight I.

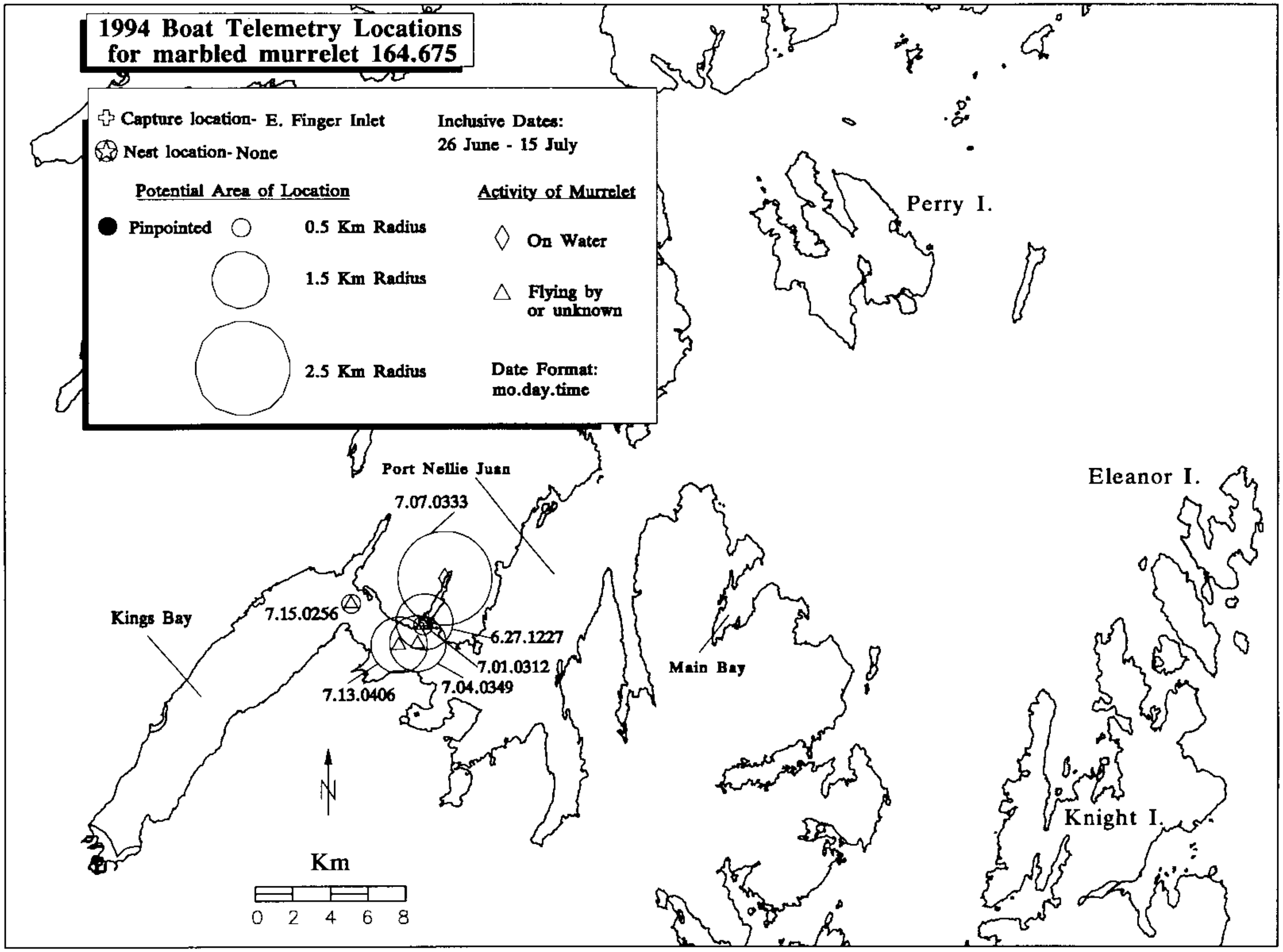


1994 Boat Telemetry Locations
for marbled murrelet 164.290
Capture location- E. Finger Inlet
Nest location- NW Head of E. Finger Inlet
Inclusive Dates:
28 June - 16 July
Potential Area of Location
Activity of Murrelet
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
On Water
Flying by or unknown
Date Format:
mo.day.time
Perry I.
Eleanor I.
Knight I.
Port Nellie Juan
Main Bay
Kings Bay
7.16.0745
7.07.0044
7.01.0030
7.16.2334
7.08.0347
7.04.0339
7.12.0315
7.13.0339
7.10.1845
7.14.1436
7.08.0340
N
Km
0 2 4 6 8

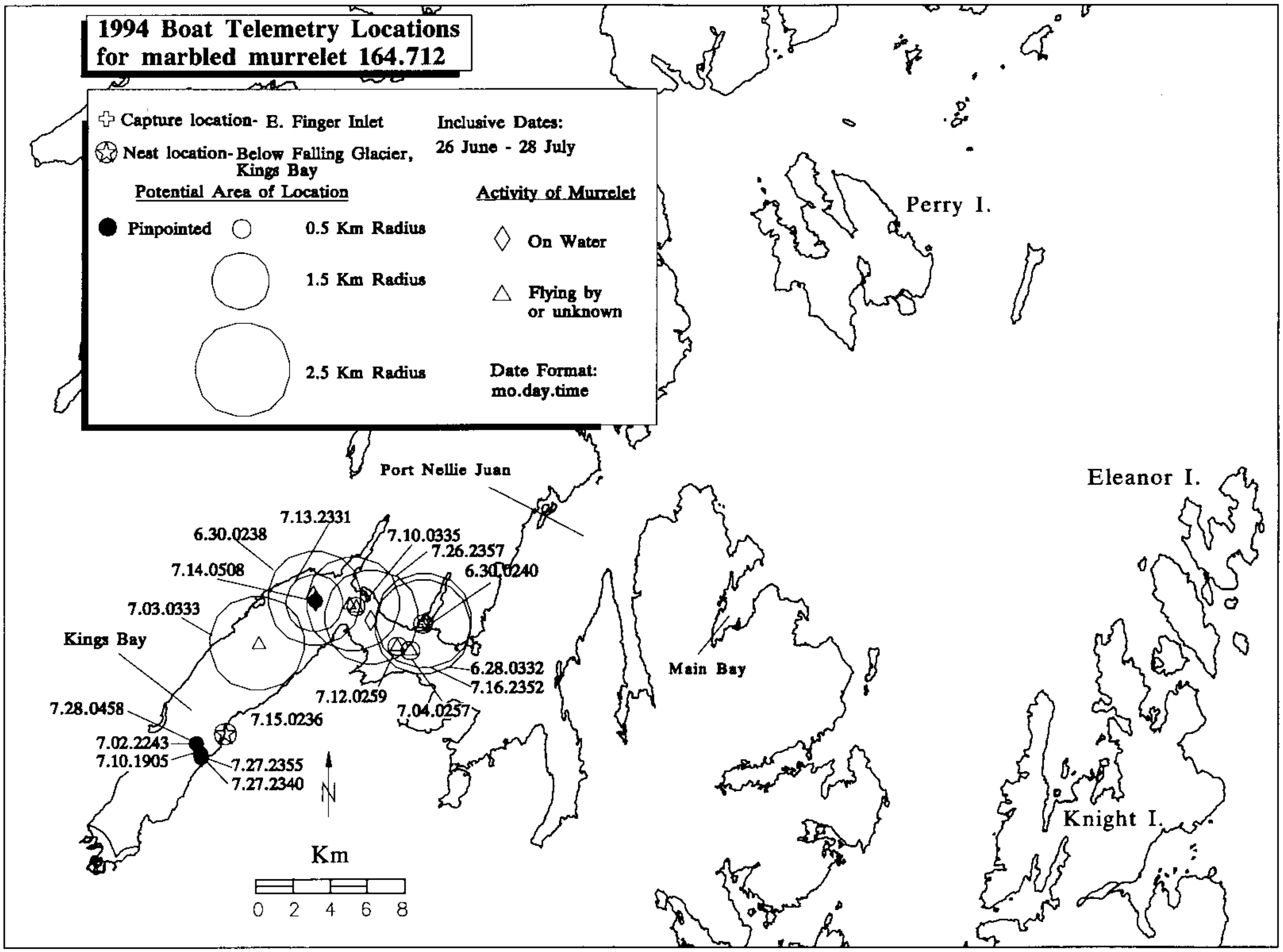

1994 Boat Telemetry Locations
for marbled murrelet 164.328
Capture location- E. Finger Inlet
Nest location- None
Inclusive Dates:
1 July - 18 July
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
mo.day.time
Perry I.
Eleanor I.
Port Nellie Juan
7.18.0348
7.10.0007
7.14.0319
Kings Bay
Main Bay
Knight I.
N
Km
0 2 4 6 8

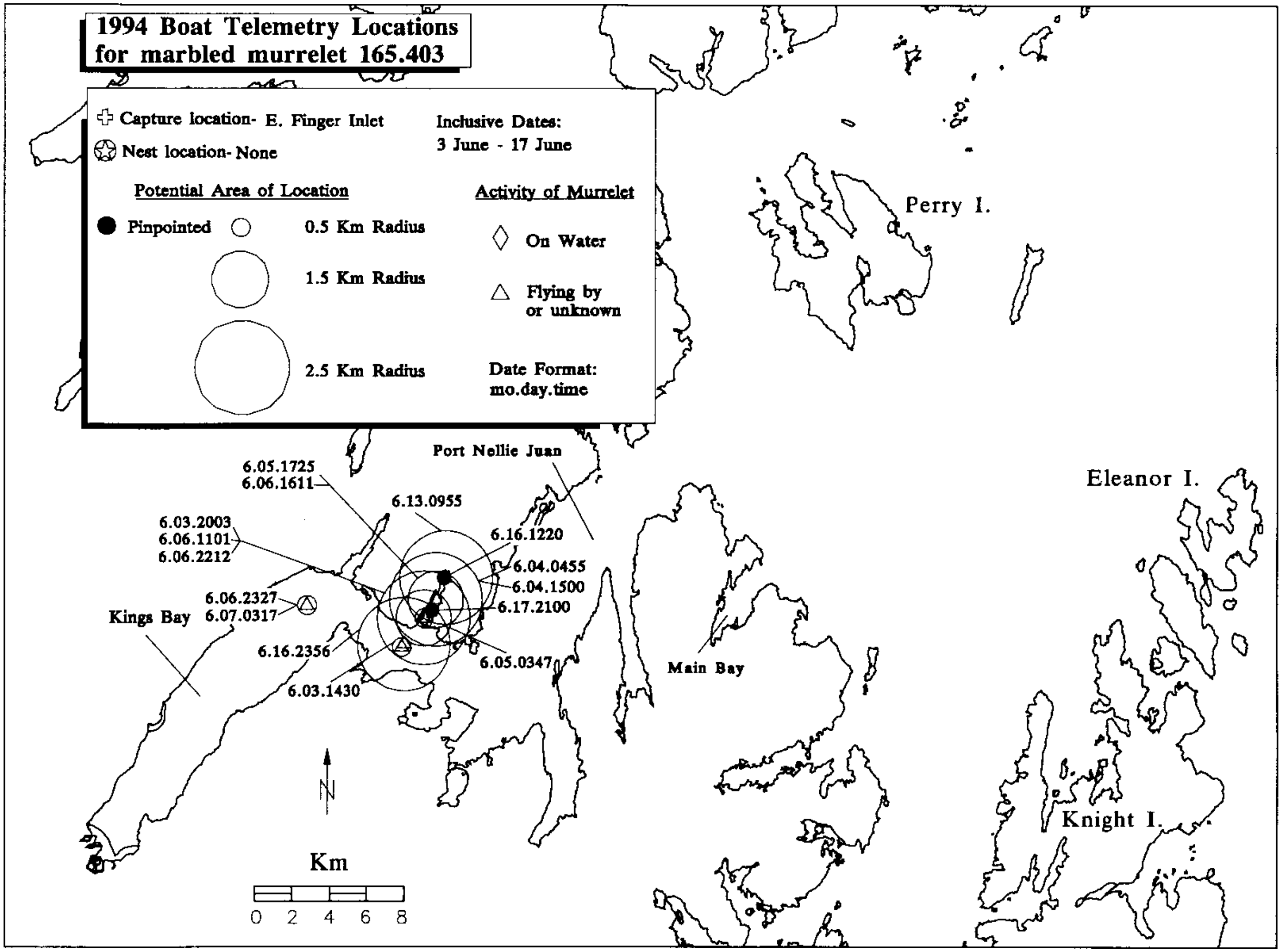

1994 Boat Telemetry Locations
for marbled murrelet 164.540
Capture location- E. Finger Inlet
Nest location- None
Inclusive Dates:
29 June - 11 July
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
mo.day.time
Perry I.
Eleanor I.
Port Nellie Juan
Kings Bay
7.10.0351
7.09.1246
7.11.0354
Main Bay
Knight I.
N
Km
0 2 4 6 8


1994 Boat Telemetry Locations
for marbled murrelet 164.622
Capture location- E. Finger Inlet
Nest location- None
Inclusive Dates:
3 June - 6 June
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
mo.day.time
6.04.0000
6.04.0400
6.04.0722
6.06.0303
6.06.0331
6.03.1430
N
Km
0 2 4 6 8

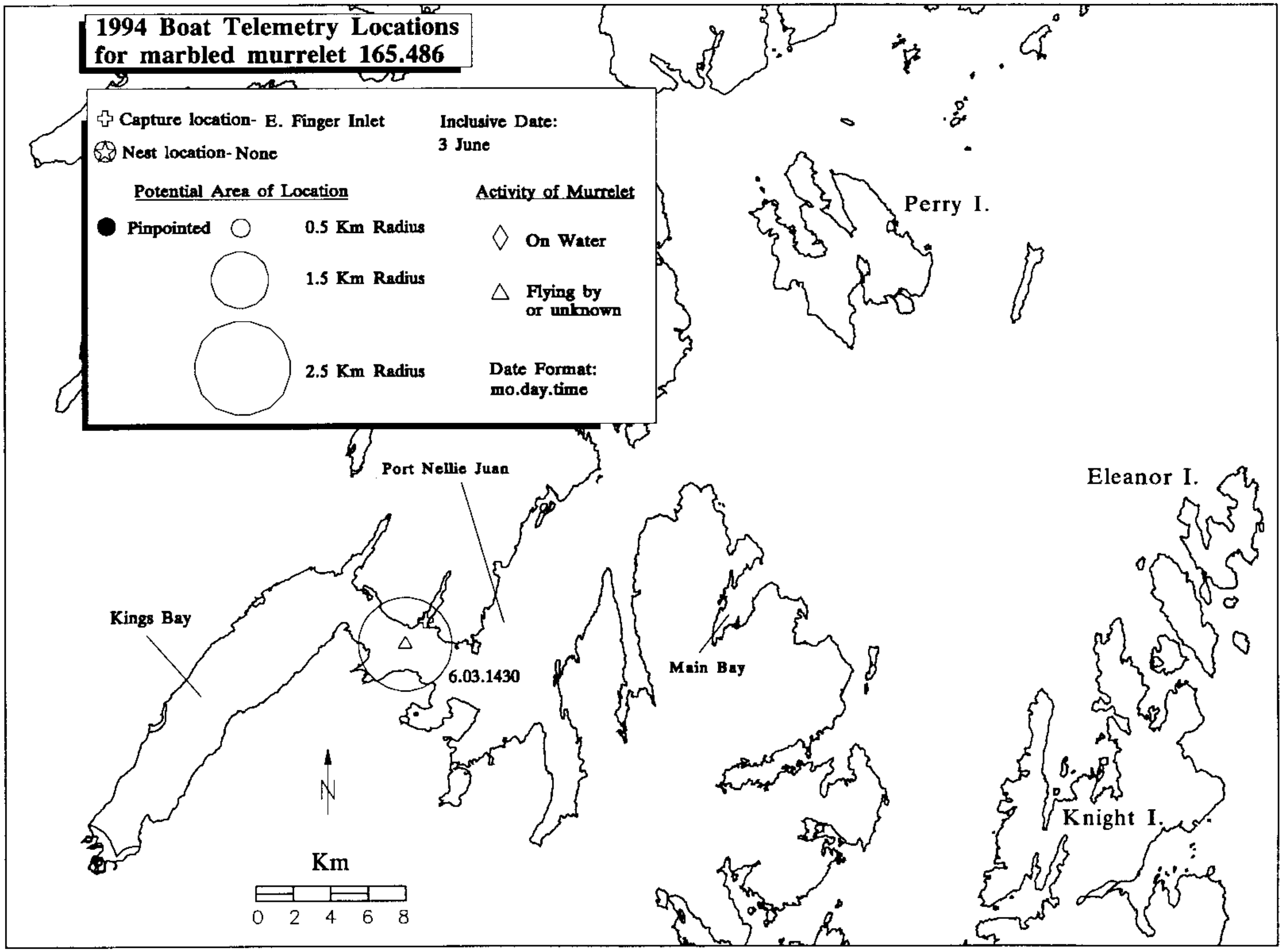


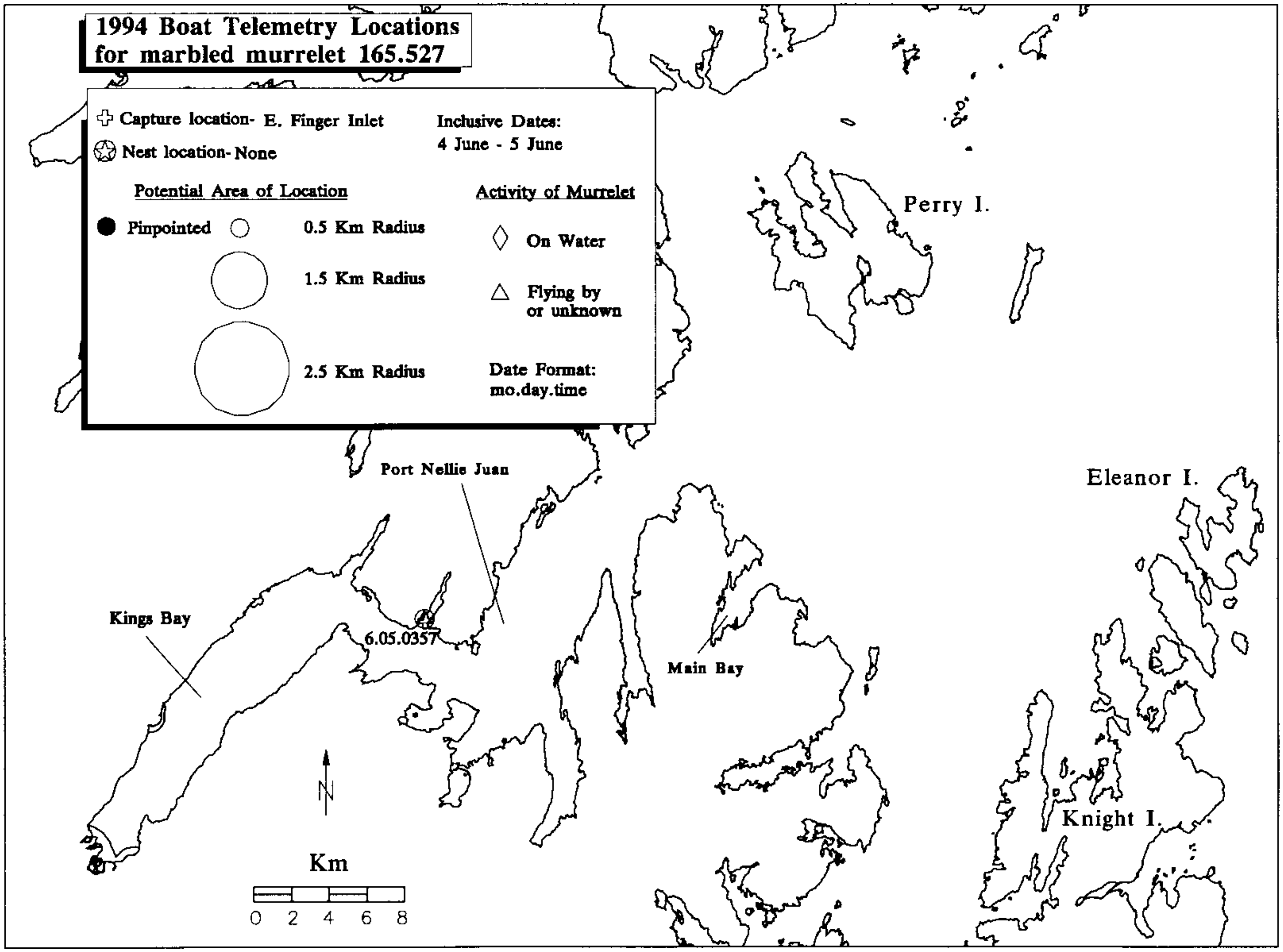
1994 Boat Telemetry Locations
for marbled murrelet 164.675
Capture location- E. Finger Inlet
Nest location- None
Inclusive Dates:
26 June - 15 July
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
mo.day.time
Perry I.
Eleanor I.
Knight I.
Port Nellie Juan
Kings Bay
Main Bay
7.07.0333
7.15.0256
6.27.1227
7.01.0312
7.04.0349
7.13.0406
N
Km
0 2 4 6 8


1994 Boat Telemetry Locations for marbled murrelet 164.712
Capture location- E. Finger Inlet
Nest location- Below Falling Glacier, Kings Bay
Inclusive Dates: 26 June - 28 July
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by or unknown
Date Format: mo.day.time
Perry I.
Eleanor I.
Knight I.
Port Nellie Juan
Main Bay
Kings Bay
7.13.2331
6.30.0238
7.10.0335
7.26.2357
6.30.0240
7.14.0508
7.03.0333
6.28.0332
7.16.2352
7.12.0259
7.04.0257
7.15.0236
7.28.0458
7.02.2243
7.10.1905
7.27.2355
7.27.2340
N
Km
0 2 4 6 8

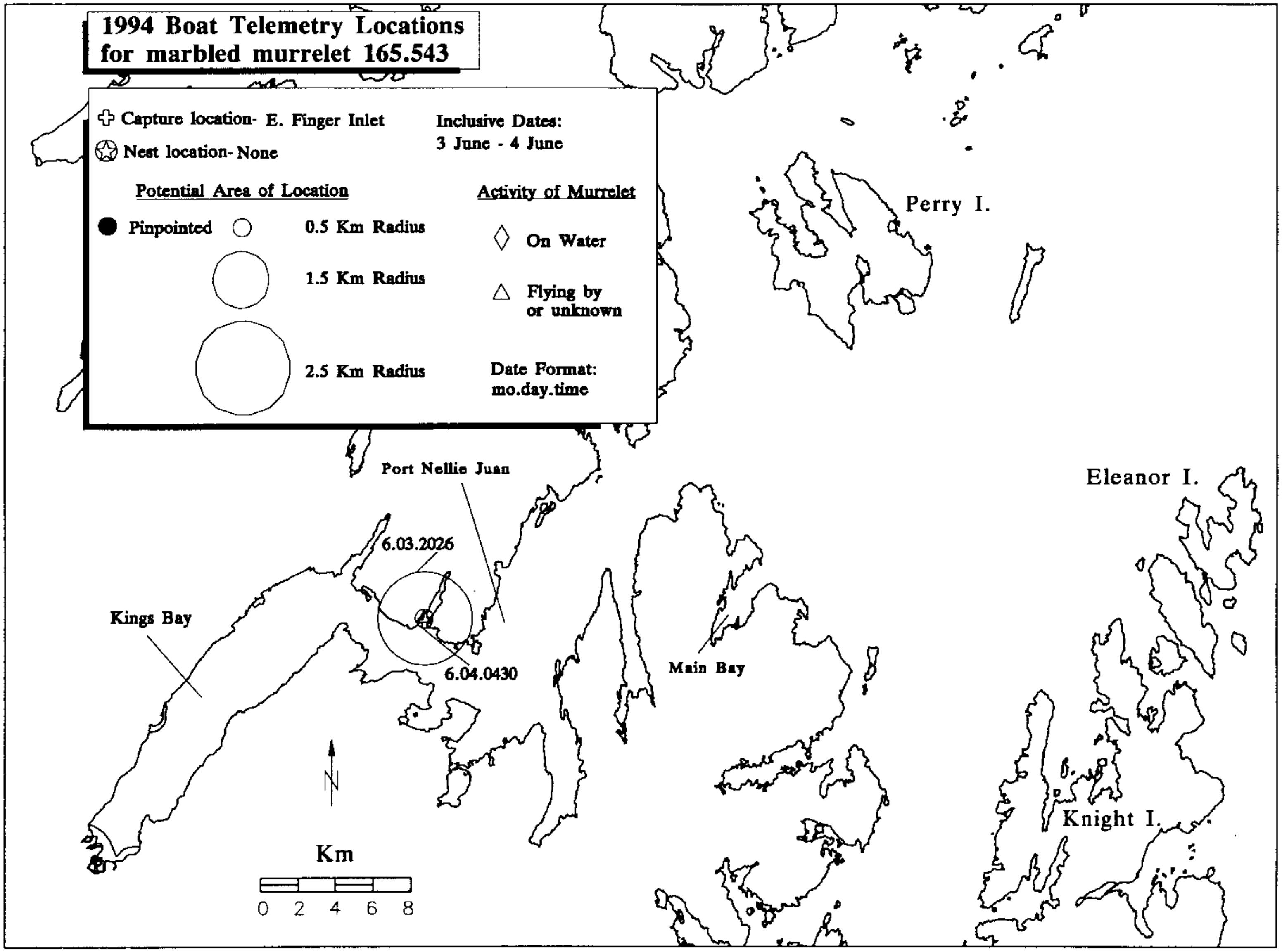


1994 Boat Telemetry Locations
for marbled murrelet 165.403
Capture location- E. Finger Inlet
Nest location- None
Inclusive Dates:
3 June - 17 June
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
mo.day.time
Perry I.
Eleanor I.
Knight I.
Port Nellie Juan
Main Bay
Kings Bay
6.05.1725
6.06.1611
6.13.0955
6.03.2003
6.06.1101
6.06.2212
6.16.1220
6.04.0455
6.04.1500
6.17.2100
6.06.2327
6.07.0317
6.16.2356
6.05.0347
6.03.1430
N
Km
0 2 4 6 8

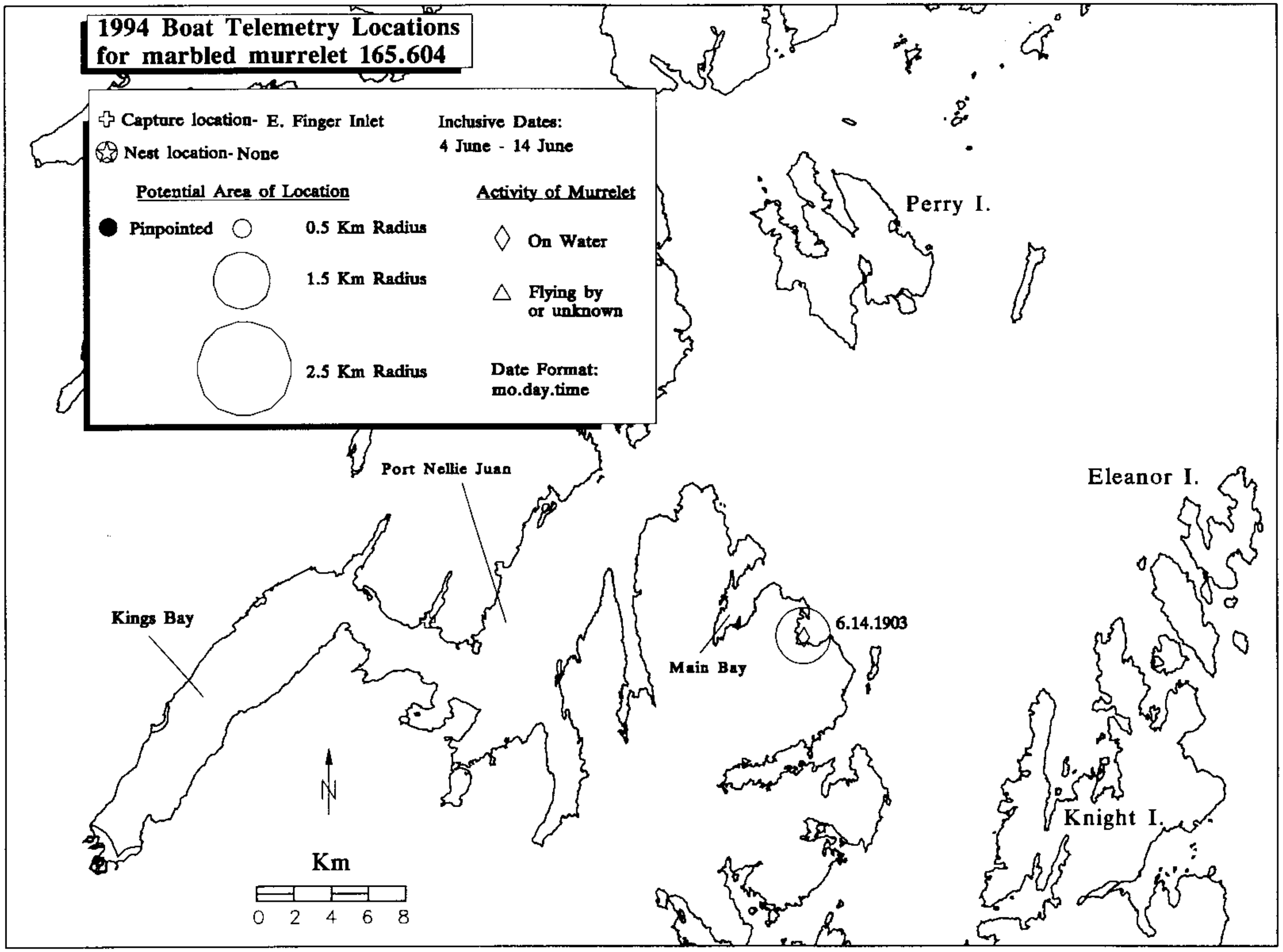

1994 Boat Telemetry Locations
for marbled murrelet 165.486
Capture location- E. Finger Inlet
Nest location- None
Inclusive Date:
3 June
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
mo.day.time
Perry I.
Port Nellie Juan
Eleanor I.
Kings Bay
6.03.1430
Main Bay
Knight I.
N
Km
0 2 4 6 8

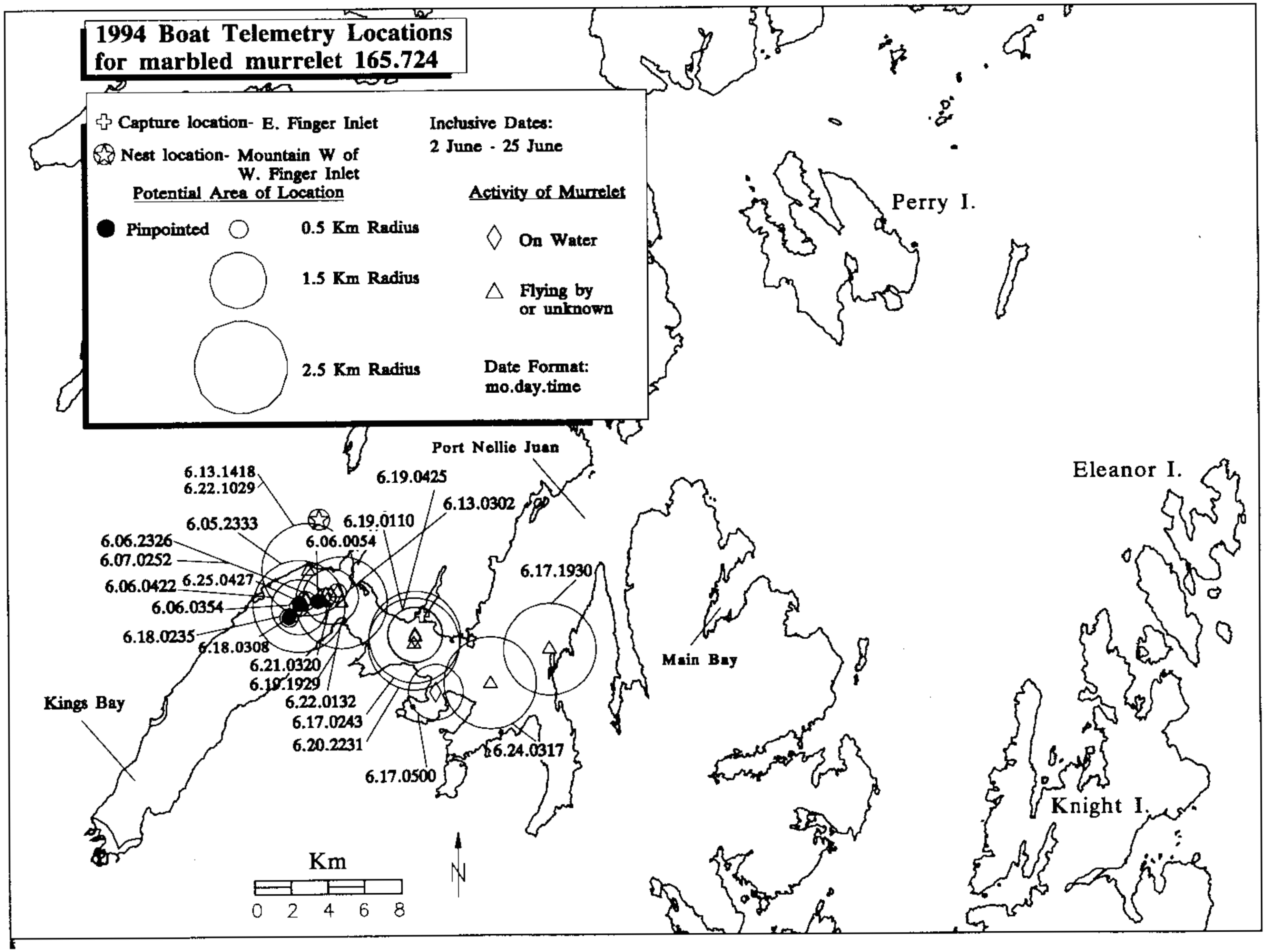


1994 Boat Telemetry Locations
for marbled murrelet 165.527
Capture location- E. Finger Inlet
Nest location- None
Inclusive Dates:
4 June - 5 June
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
mo.day.time
Perry I.
Port Nellie Juan
Eleanor I.
Kings Bay
6.05.0357
Main Bay
Knight I.
N
Km
0 2 4 6 8

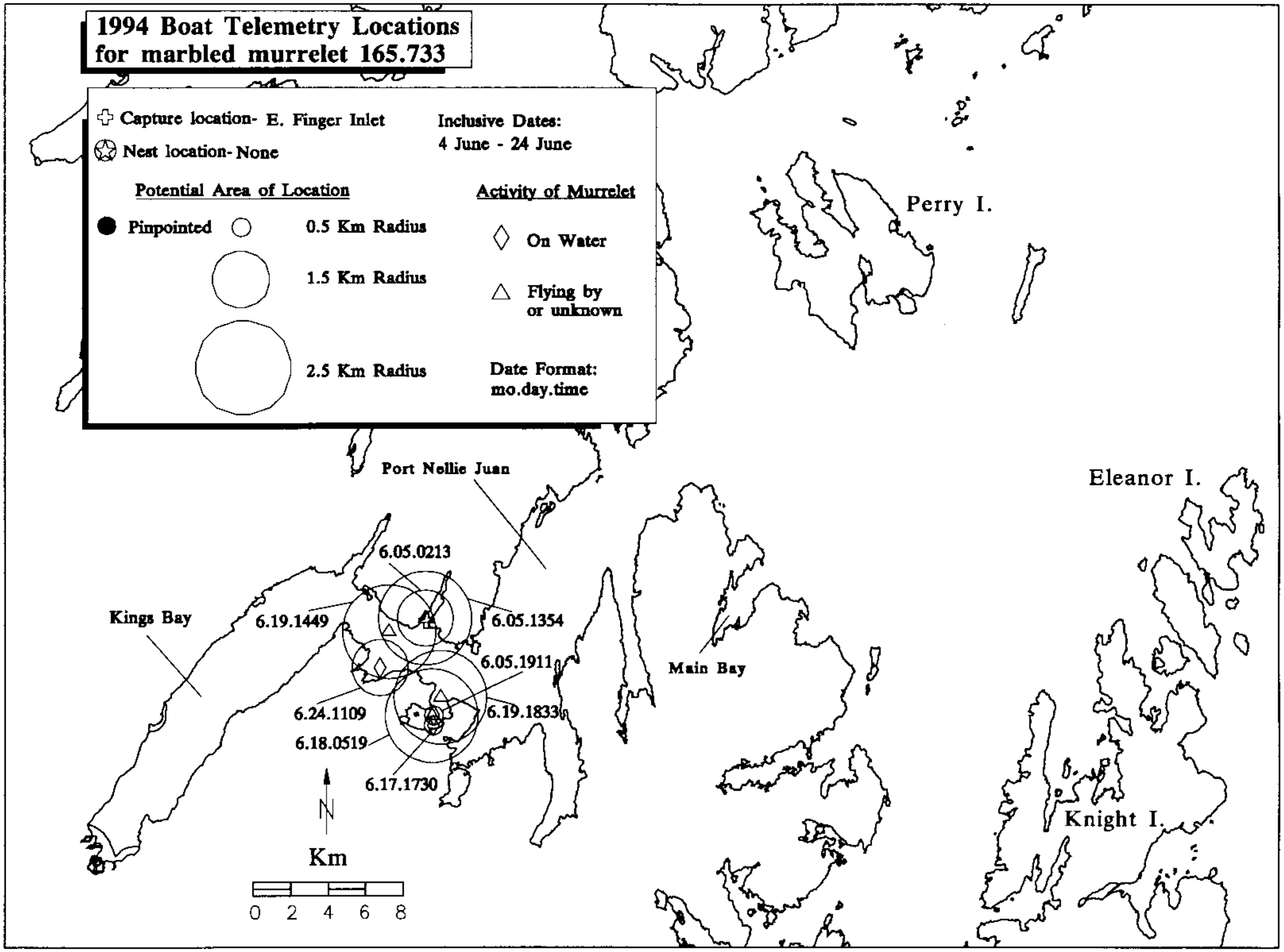


1994 Boat Telemetry Locations
for marbled murrelet 165.543
Capture location- E. Finger Inlet
Nest location- None
Inclusive Dates:
3 June - 4 June
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
mo.day.time
Perry I.
Eleanor I.
Port Nellie Juan
6.03.2026
6.04.0430
Kings Bay
Main Bay
Knight I.
N
Km
0 2 4 6 8

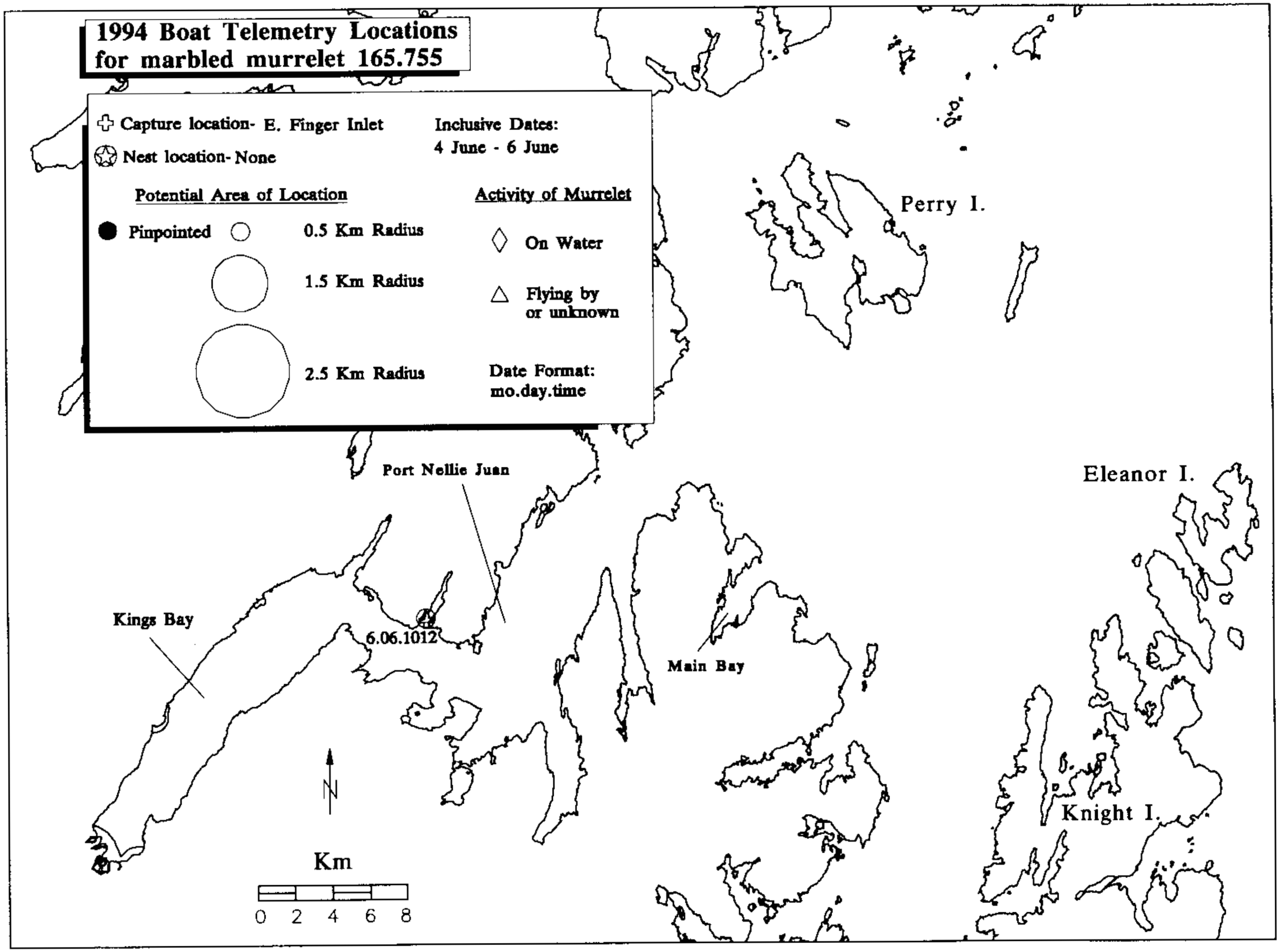

1994 Boat Telemetry Locations
for marbled murrelet 165.604
Capture location- E. Finger Inlet
Nest location- None
Inclusive Dates:
4 June - 14 June
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
mo.day.time
Perry I.
Eleanor I.
Port Nellie Juan
Kings Bay
Main Bay
6.14.1903
Knight I.
N
Km
0 2 4 6 8

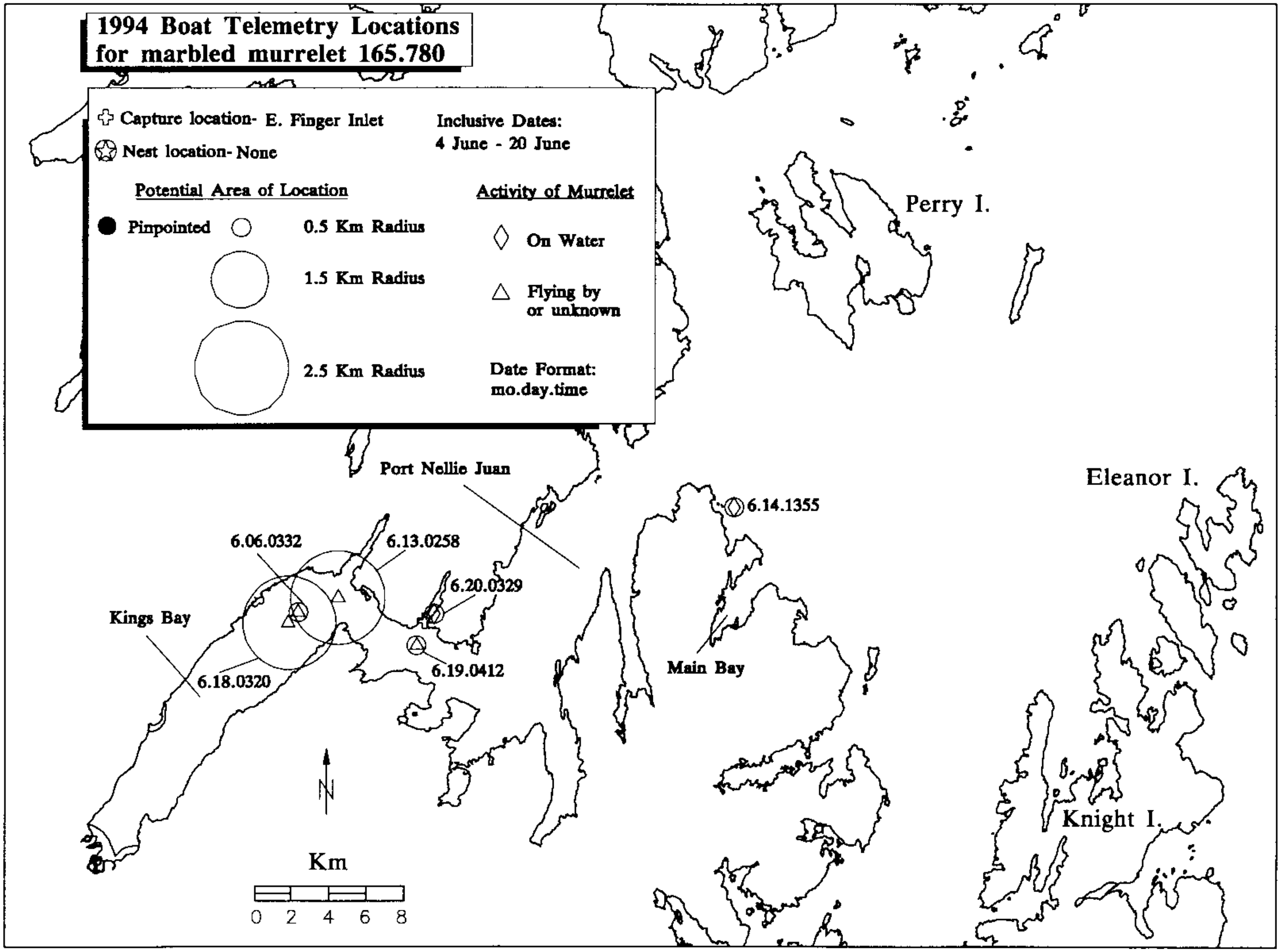


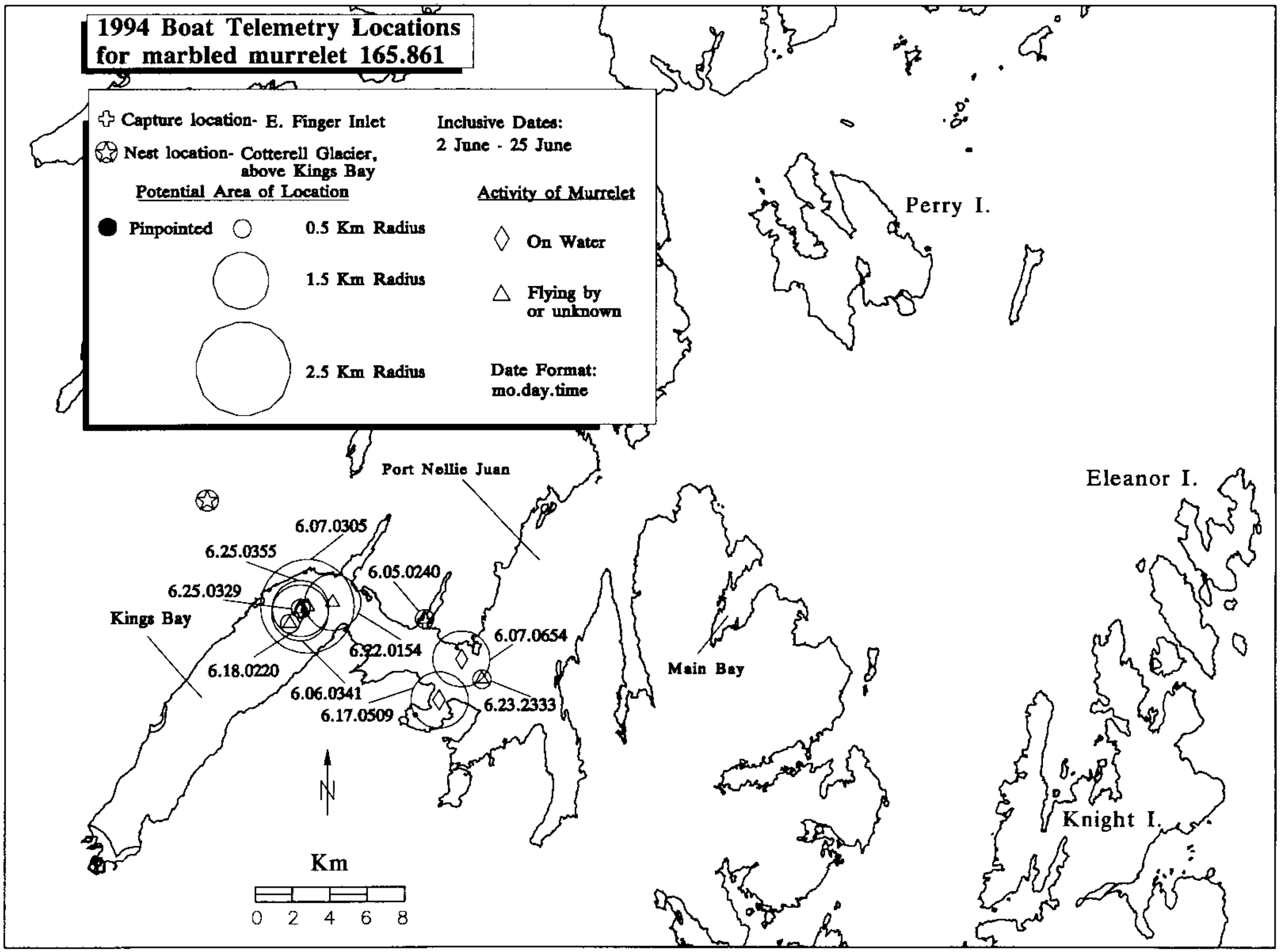
1994 Boat Telemetry Locations
for marbled murrelet 165.724
Capture location- E. Finger Inlet
Nest location- Mountain W of W. Finger Inlet
Inclusive Dates:
2 June - 25 June
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by or unknown
Date Format:
mo.day.time
Perry I.
Eleanor I.
Knight I.
Port Nellie Juan
Main Bay
Kings Bay
6.13.1418
6.22.1029
6.05.2333
6.06.2326
6.07.0252
6.06.0422
6.25.0427
6.06.0354
6.18.0235
6.18.0308
6.21.0320
6.19.1929
6.22.0132
6.17.0243
6.20.2231
6.17.0500
6.24.0317
6.17.1930
6.19.0425
6.13.0302
6.19.0110
6.06.0054
Km
0 2 4 6 8
N

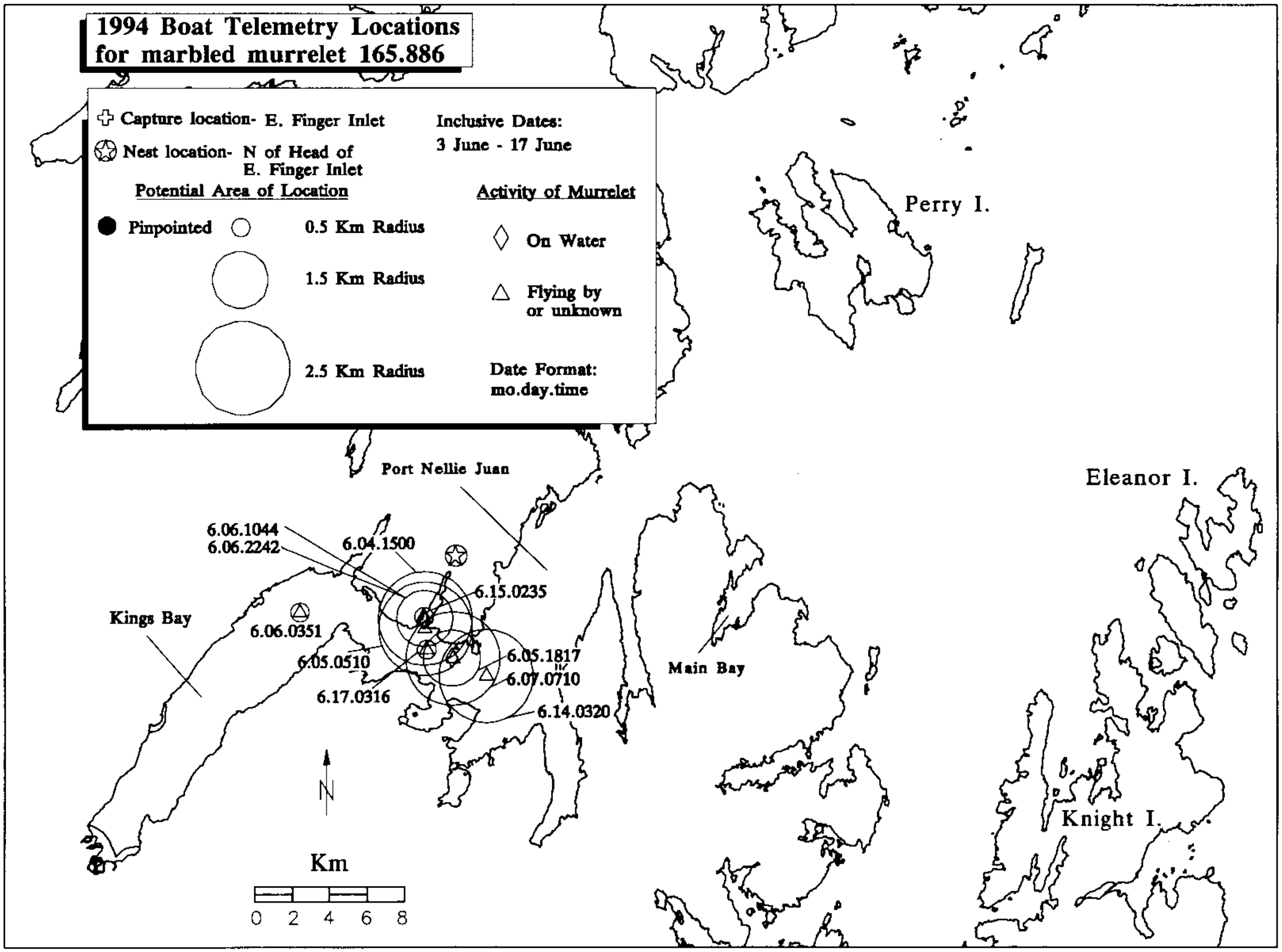


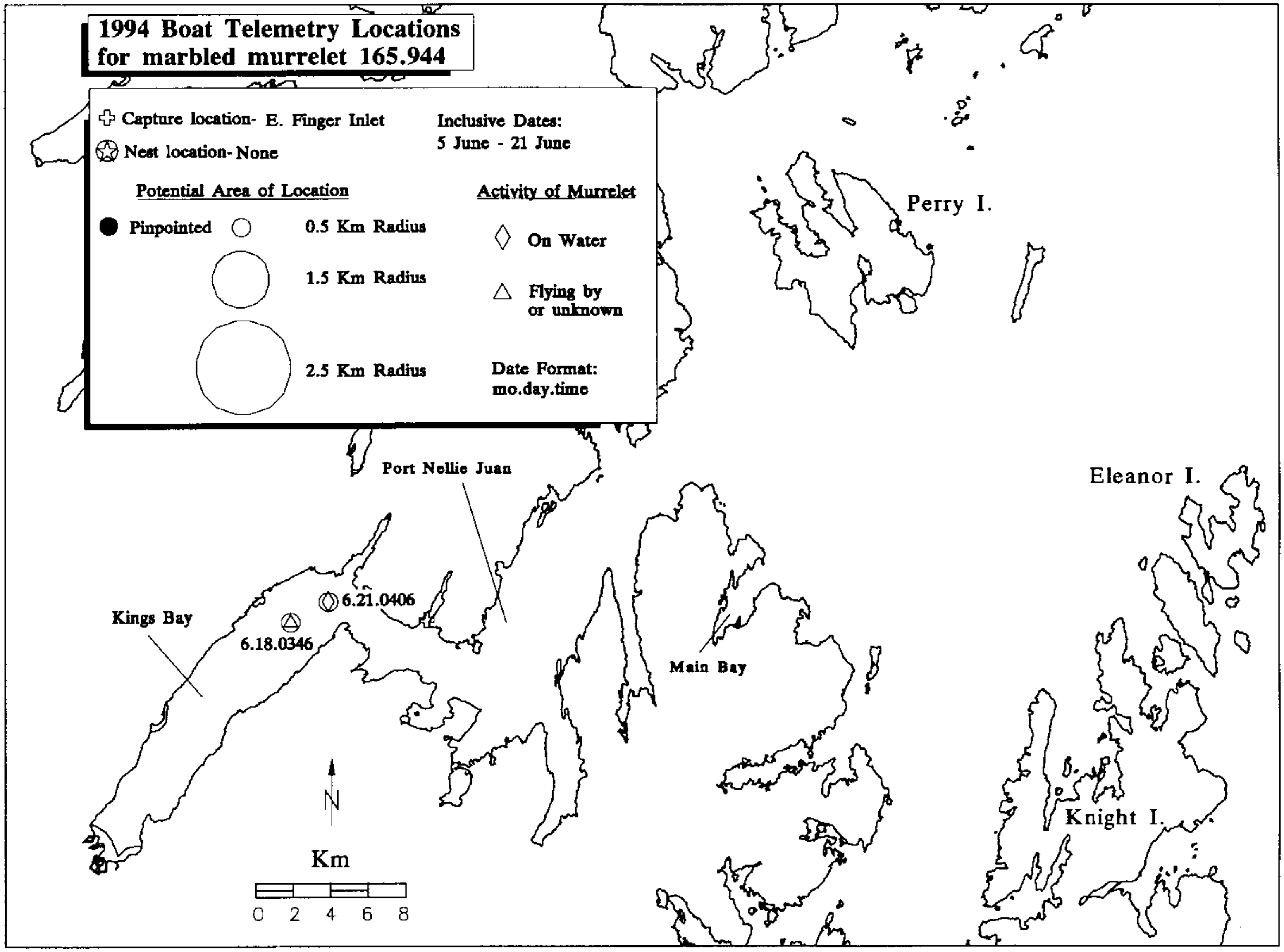
1994 Boat Telemetry Locations
for marbled murrelet 165.733
Capture location- E. Finger Inlet
Nest location- None
Inclusive Dates:
4 June - 24 June
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
mo.day.time
Perry I.
Eleanor I.
Knight I.
Port Nellie Juan
Kings Bay
Main Bay
6.05.0213
6.19.1449
6.05.1354
6.05.1911
6.24.1109
6.19.1833
6.18.0519
6.17.1730
N
Km
0 2 4 6 8


1994 Boat Telemetry Locations
for marbled murrelet 165.755
Capture location- E. Finger Inlet
Nest location- None
Inclusive Dates:
4 June - 6 June
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
mo.day.time
Perry I.
Eleanor I.
Port Nellie Juan
Kings Bay
6.06.1012
Main Bay
Knight I.
N
Km
0 2 4 6 8

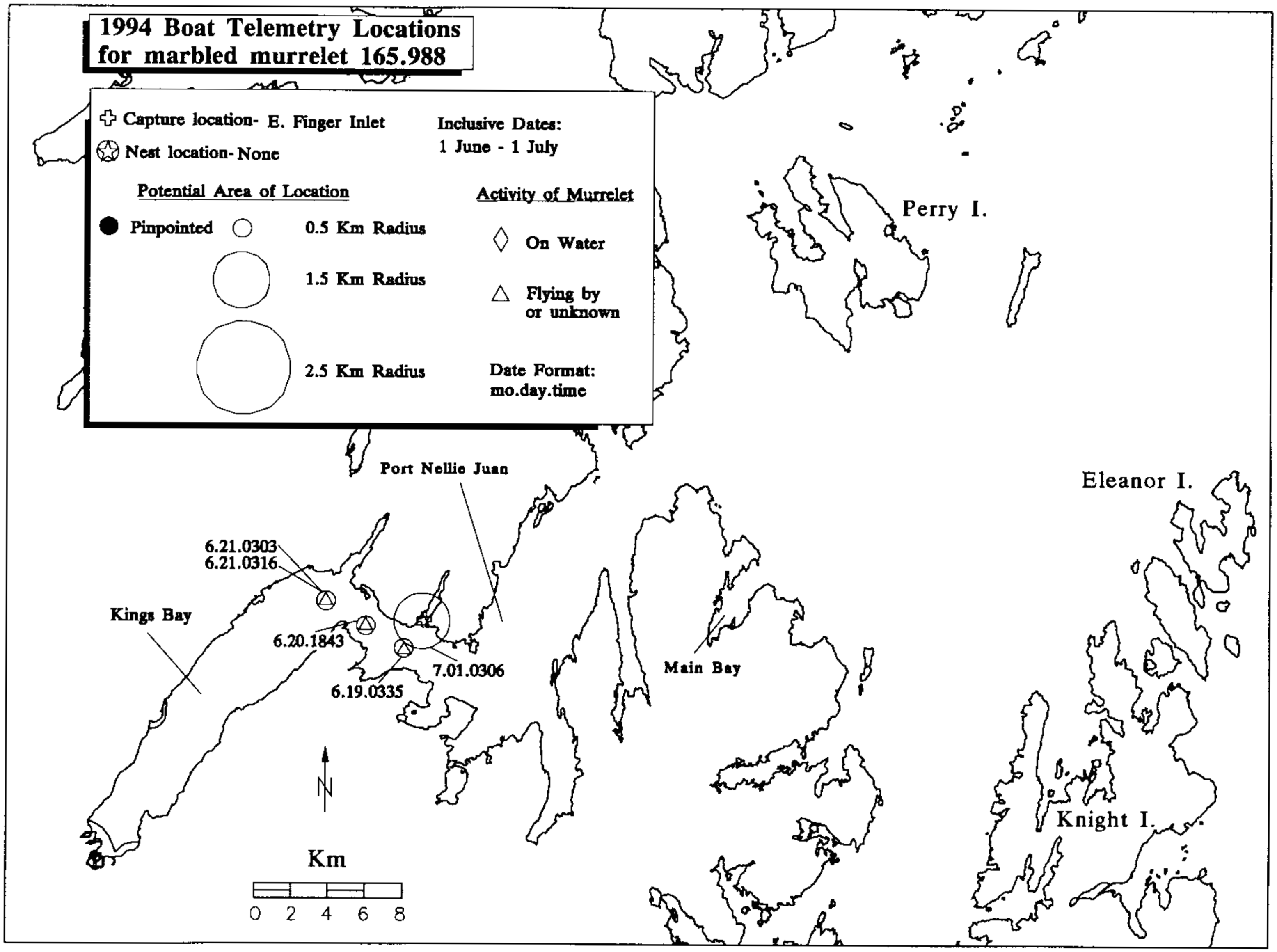

1994 Boat Telemetry Locations
for marbled murrelet 165.780
Capture location- E. Finger Inlet
Nest location- None
Inclusive Dates:
4 June - 20 June
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
mo.day.time
Perry I.
Eleanor I.
Knight I.
Port Nellie Juan
Main Bay
Kings Bay
6.06.0332
6.13.0258
6.20.0329
6.19.0412
6.18.0320
6.14.1355
N
Km
0 2 4 6 8


1994 Boat Telemetry Locations
for marbled murrelet 165.861
Capture location- E. Finger Inlet
Nest location- Cotterell Glacier,
above Kings Bay
Inclusive Dates:
2 June - 25 June
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
mo.day.time
Perry I.
Eleanor I.
Knight I.
Port Nellie Juan
Main Bay
Kings Bay
6.07.0305
6.25.0355
6.05.0240
6.25.0329
6.22.0154
6.07.0654
6.18.0220
6.06.0341
6.17.0509
6.23.2333
N
Km
0 2 4 6 8

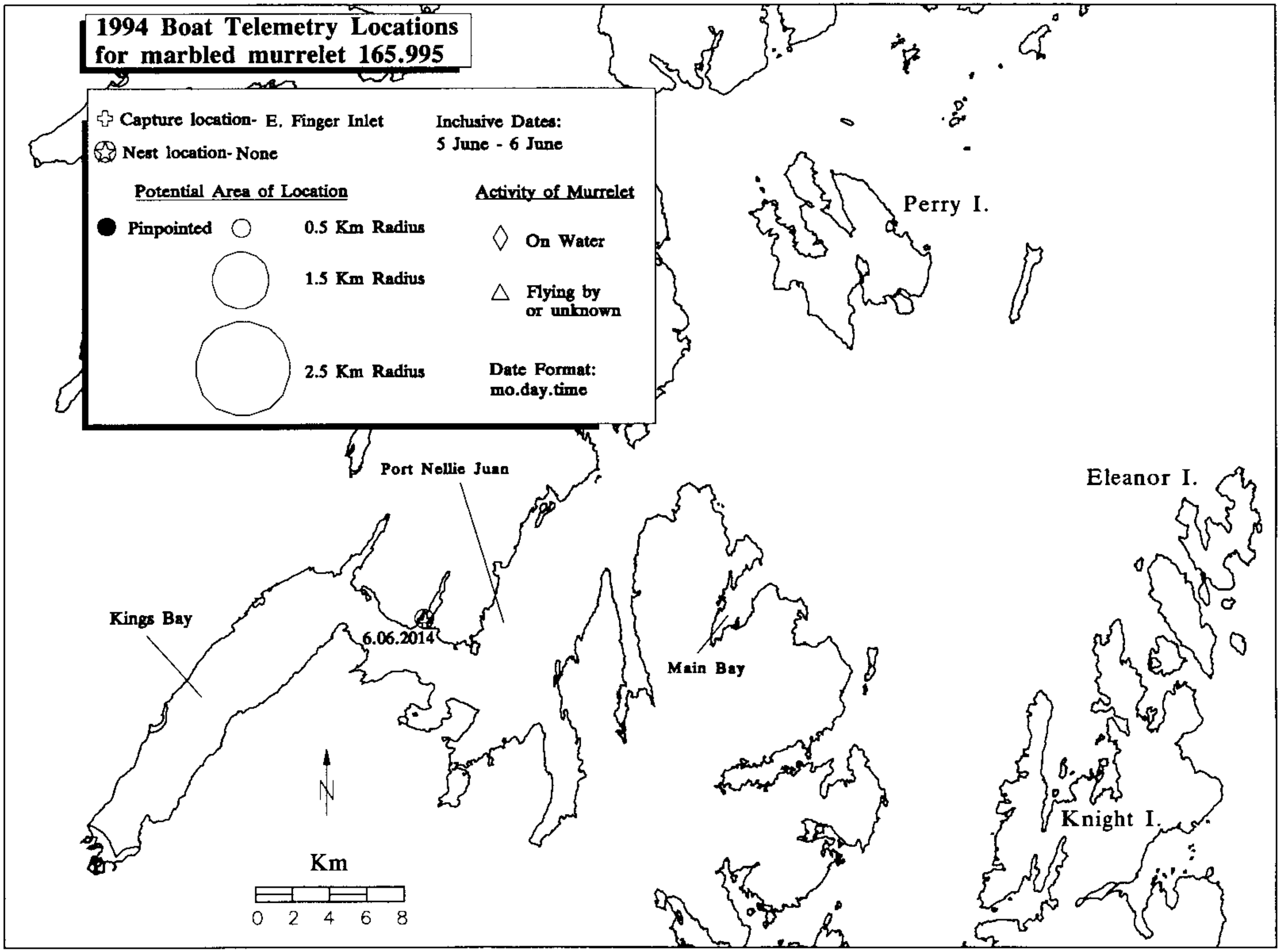

1994 Boat Telemetry Locations
for marbled murrelet 165.886
Capture location- E. Finger Inlet
Nest location- N of Head of
E. Finger Inlet
Inclusive Dates:
3 June - 17 June
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
mo.day.time
Perry I.
Eleanor I.
Knight I.
Port Nellie Juan
Kings Bay
Main Bay
6.06.1044
6.06.2242
6.04.1500
6.15.0235
6.06.0351
6.05.0510
6.17.0316
6.05.1817
6.07.0710
6.14.0320
N
Km
0 2 4 6 8



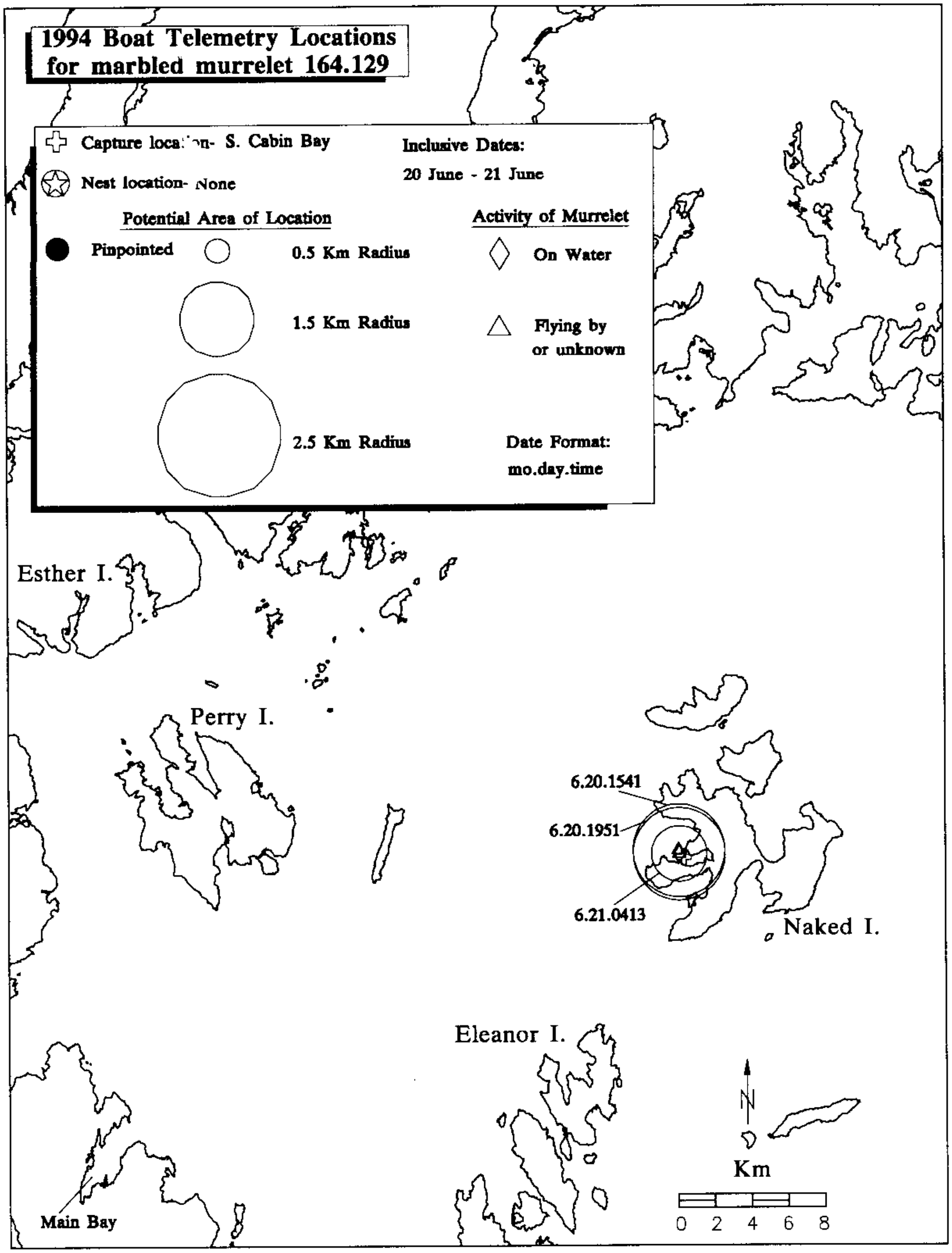
1994 Boat Telemetry Locations
for marbled murrelet 165.944
Capture location- E. Finger Inlet
Nest location- None
Inclusive Dates:
5 June - 21 June
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
mo.day.time
Perry I.
Eleanor I.
Port Nellie Juan
Kings Bay
6.21.0406
6.18.0346
Main Bay
Knight I.
N
Km
0 2 4 6 8



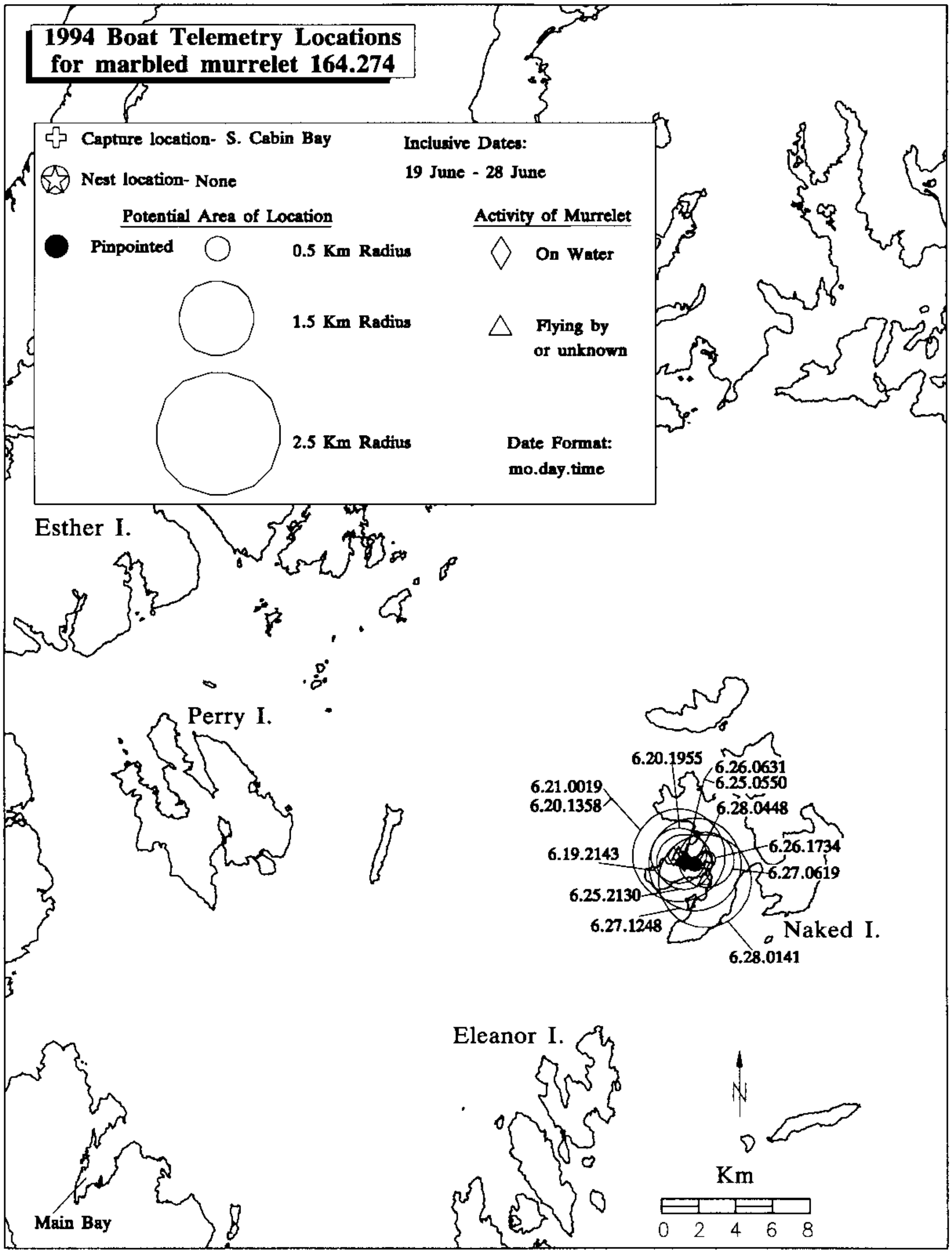
1994 Boat Telemetry Locations
for marbled murrelet 165.988
Capture location- E. Finger Inlet
Nest location- None
Inclusive Dates:
1 June - 1 July
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
mo.day.time
Perry I.
Eleanor I.
Knight I.
Port Nellie Juan
Main Bay
Kings Bay
6.21.0303
6.21.0316
6.20.1843
6.19.0335
7.01.0306
N
Km
0 2 4 6 8



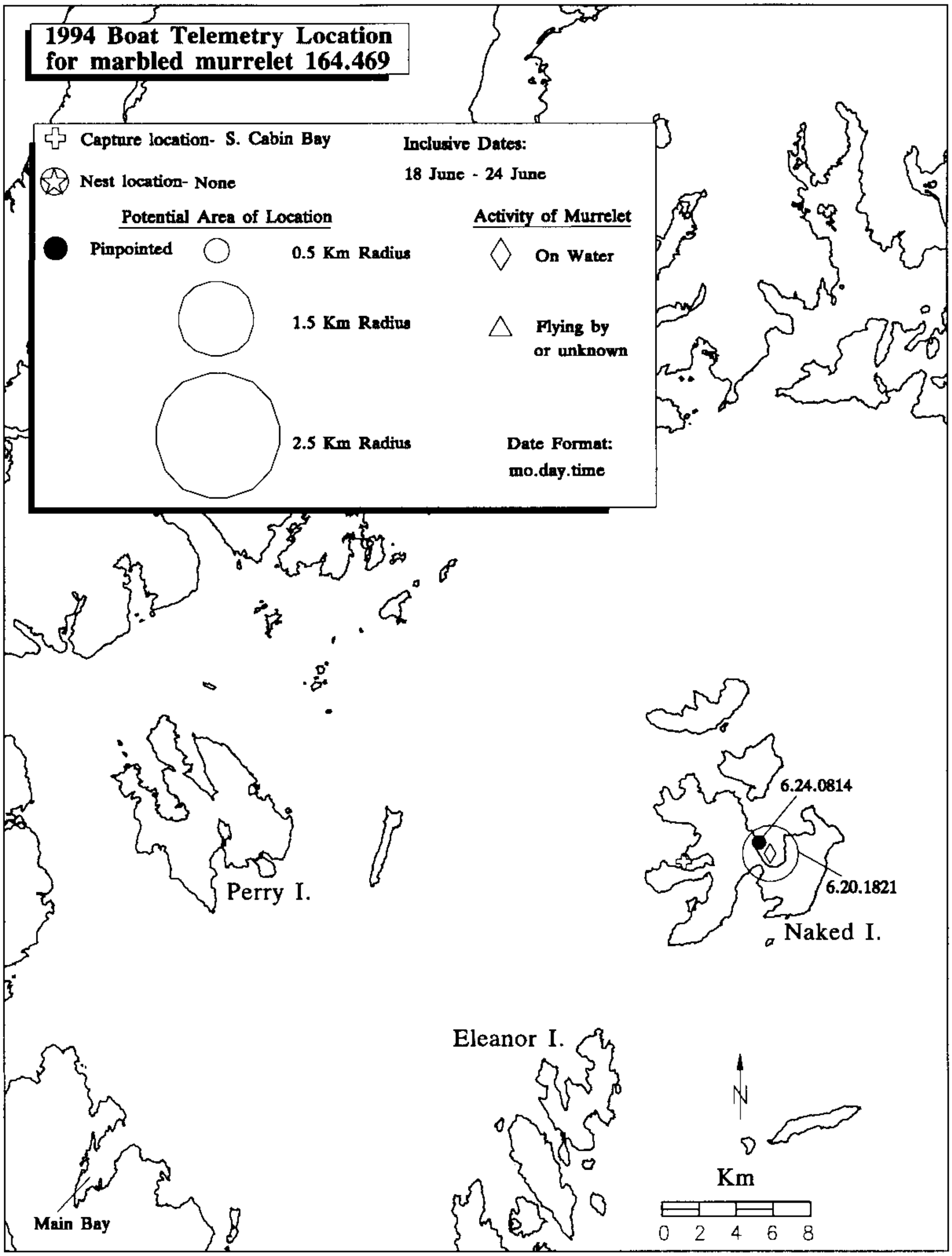
1994 Boat Telemetry Locations
for marbled murrelet 165.995
Capture location- E. Finger Inlet
Nest location- None
Inclusive Dates:
5 June - 6 June
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
mo.day.time
Perry I.
Eleanor I.
Port Nellie Juan
Kings Bay
6.06.2014
Main Bay
Knight I.
N
Km
0 2 4 6 8

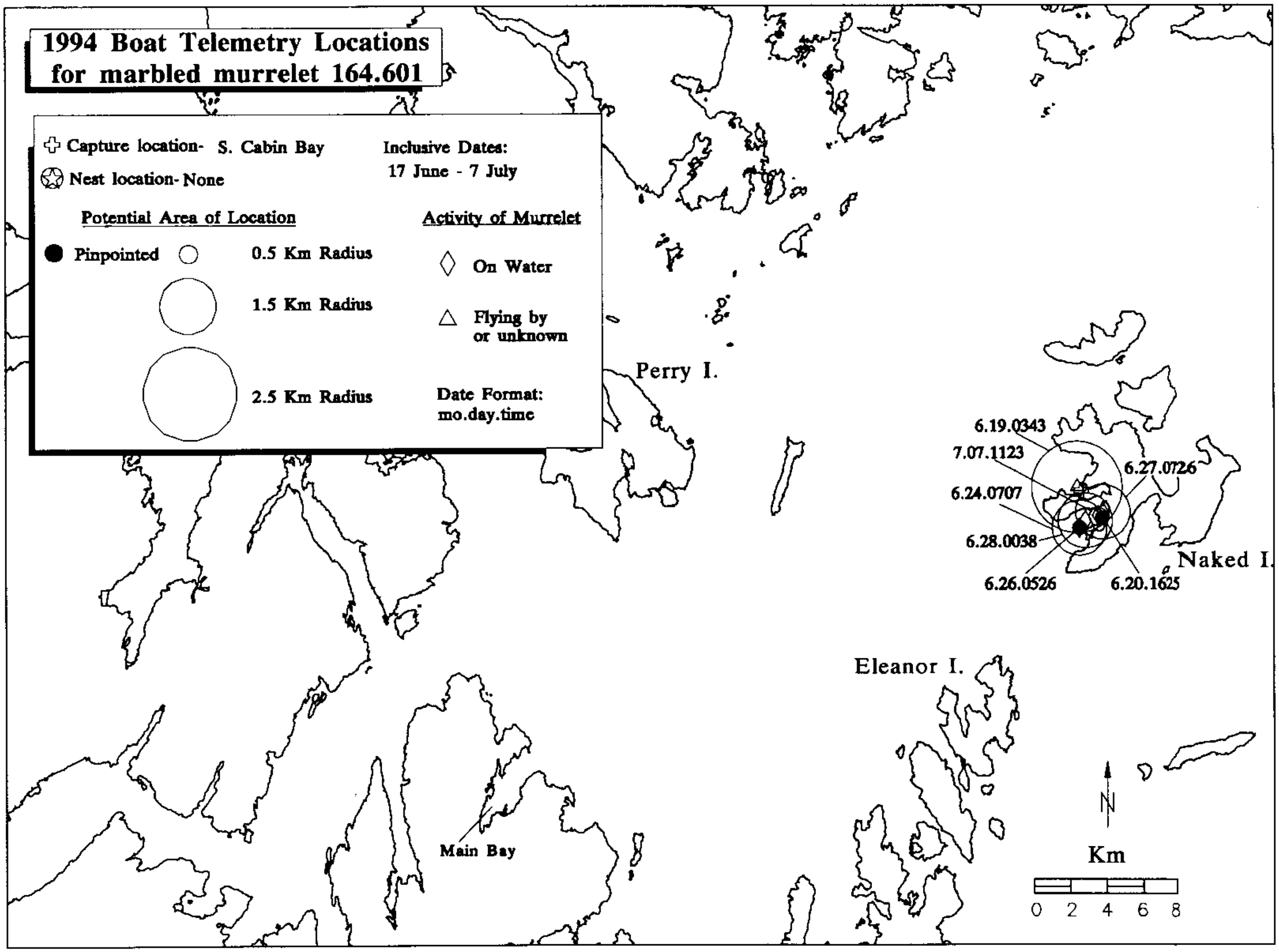


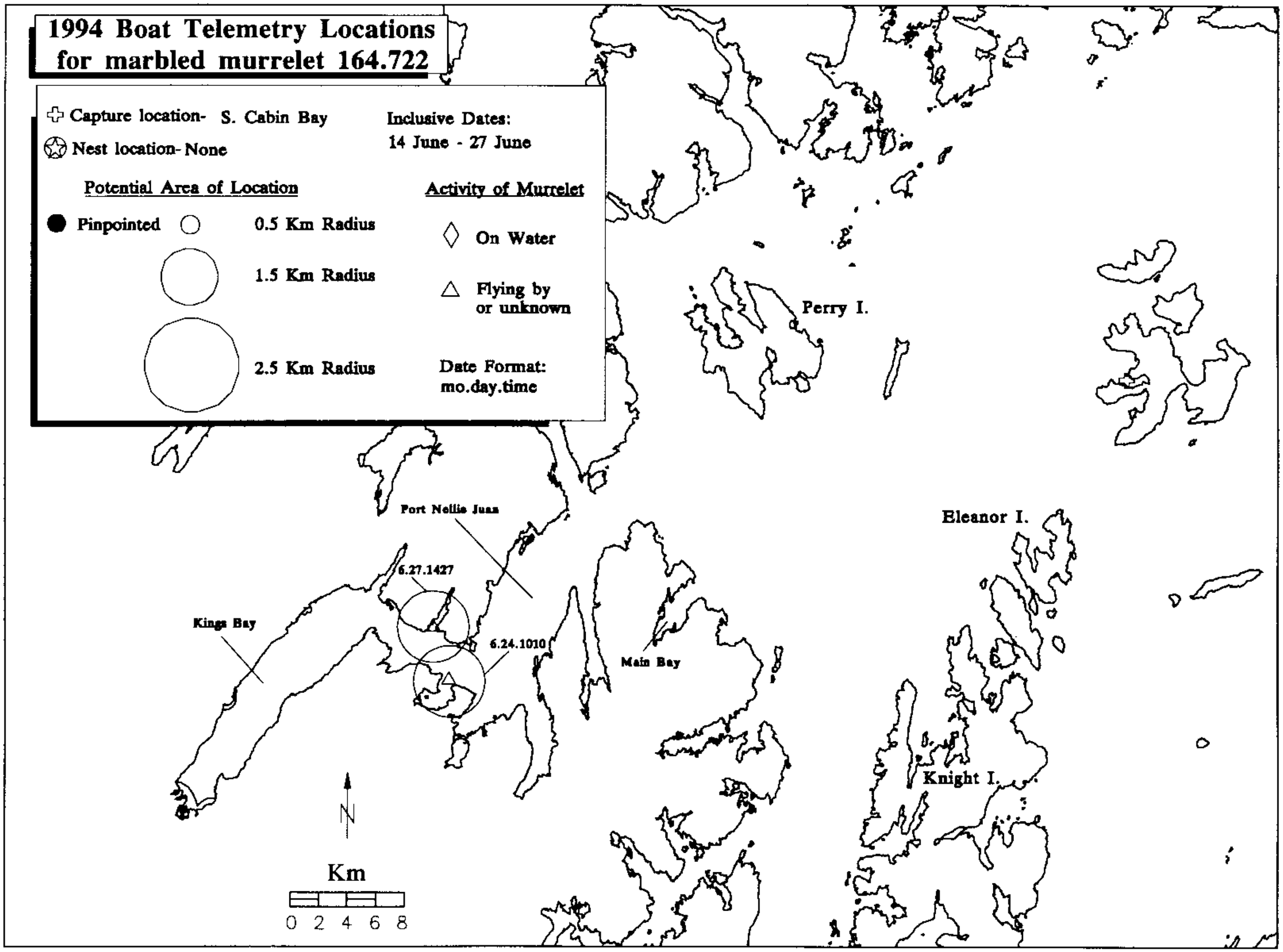
1994 Boat Telemetry Locations
for marbled murrelet 164.129
Capture loca:'on- S. Cabin Bay
Nest location- None
Inclusive Dates:
20 June - 21 June
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
mo.day.time
Esther I.
Perry I.
6.20.1541
6.20.1951
6.21.0413
Naked I.
Eleanor I.
N
Km
0 2 4 6 8
Main Bay



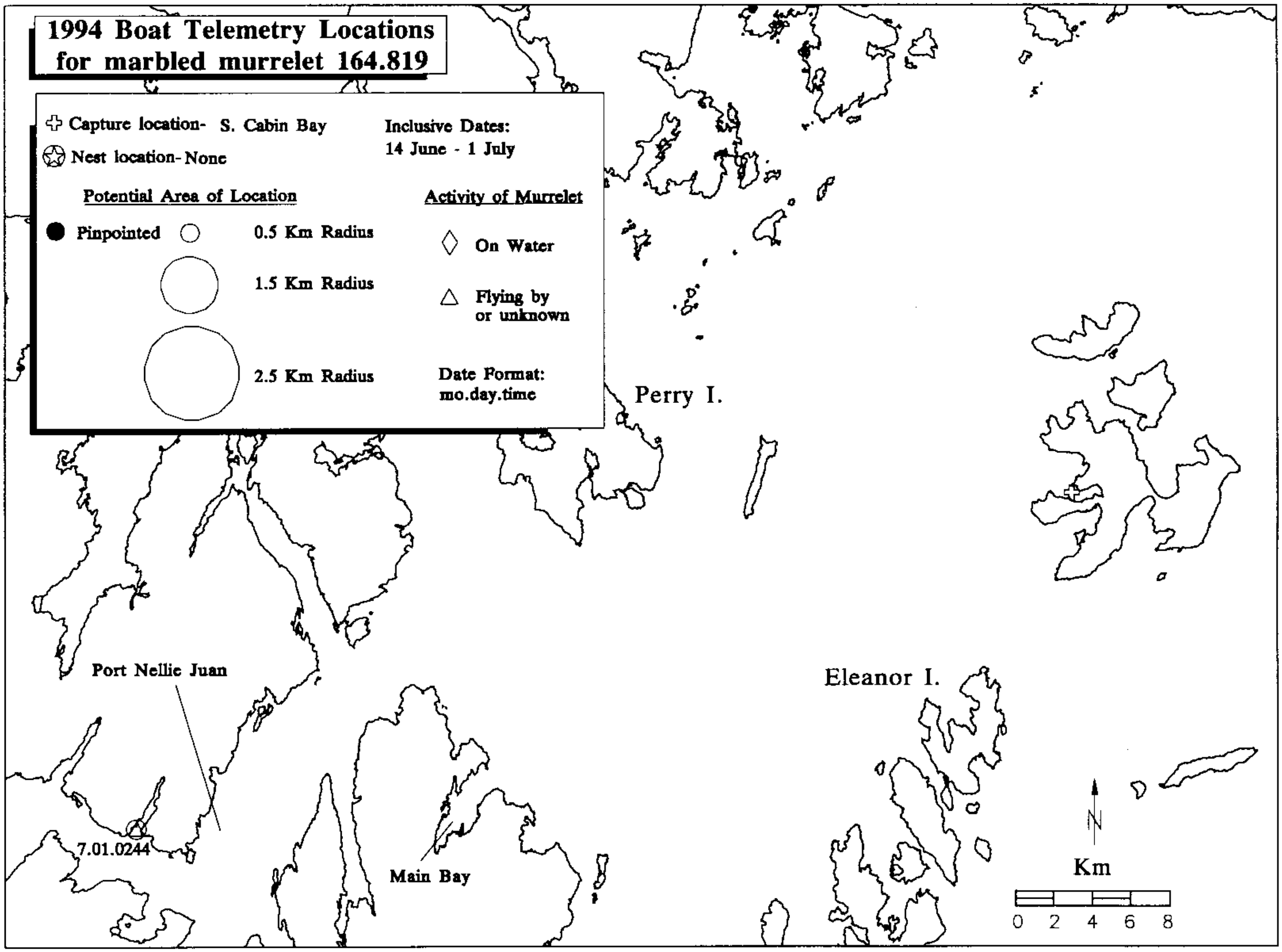
1994 Boat Telemetry Locations
for marbled murrelet 164.274
Capture location- S. Cabin Bay
Nest location- None
Inclusive Dates:
19 June - 28 June
Potential Area of Location
Activity of Murrelet
Pinpointed
0.5 Km Radius
On Water
1.5 Km Radius
Flying by
or unknown
2.5 Km Radius
Date Format:
mo.day.time
Esther I.
Perry I.
6.20.1955
6.26.0631
6.25.0550
6.21.0019
6.20.1358
6.28.0448
6.26.1734
6.19.2143
6.27.0619
6.25.2130
6.27.1248
Naked I.
6.28.0141
Eleanor I.
N
Km
0 2 4 6 8
Main Bay


1994 Boat Telemetry Location
for marbled murrelet 164.469
Capture location- S. Cabin Bay
Nest location- None
Inclusive Dates:
18 June - 24 June
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
mo.day.time
6.24.0814
6.20.1821
Perry I.
Naked I.
Eleanor I.
Main Bay
N
Km
0 2 4 6 8

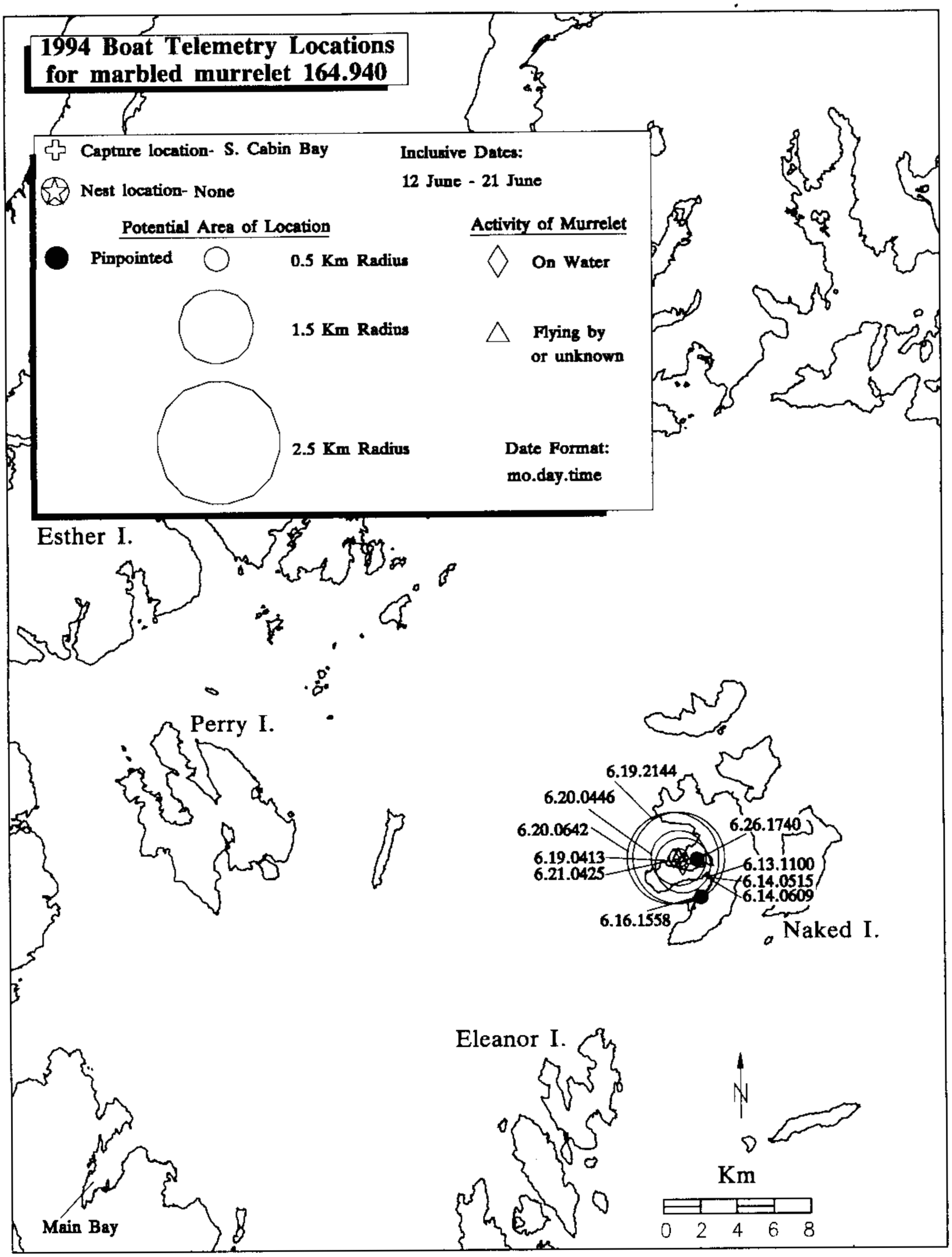

1994 Boat Telemetry Locations
for marbled murrelet 164.601
Capture location- S. Cabin Bay
Nest location- None
Inclusive Dates:
17 June - 7 July
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
mo.day.time
Perry I.
6.19.0343
7.07.1123
6.27.0726
6.24.0707
6.28.0038
6.26.0526
6.20.1625
Naked I.
Eleanor I.
Main Bay
N
Km
0 2 4 6 8



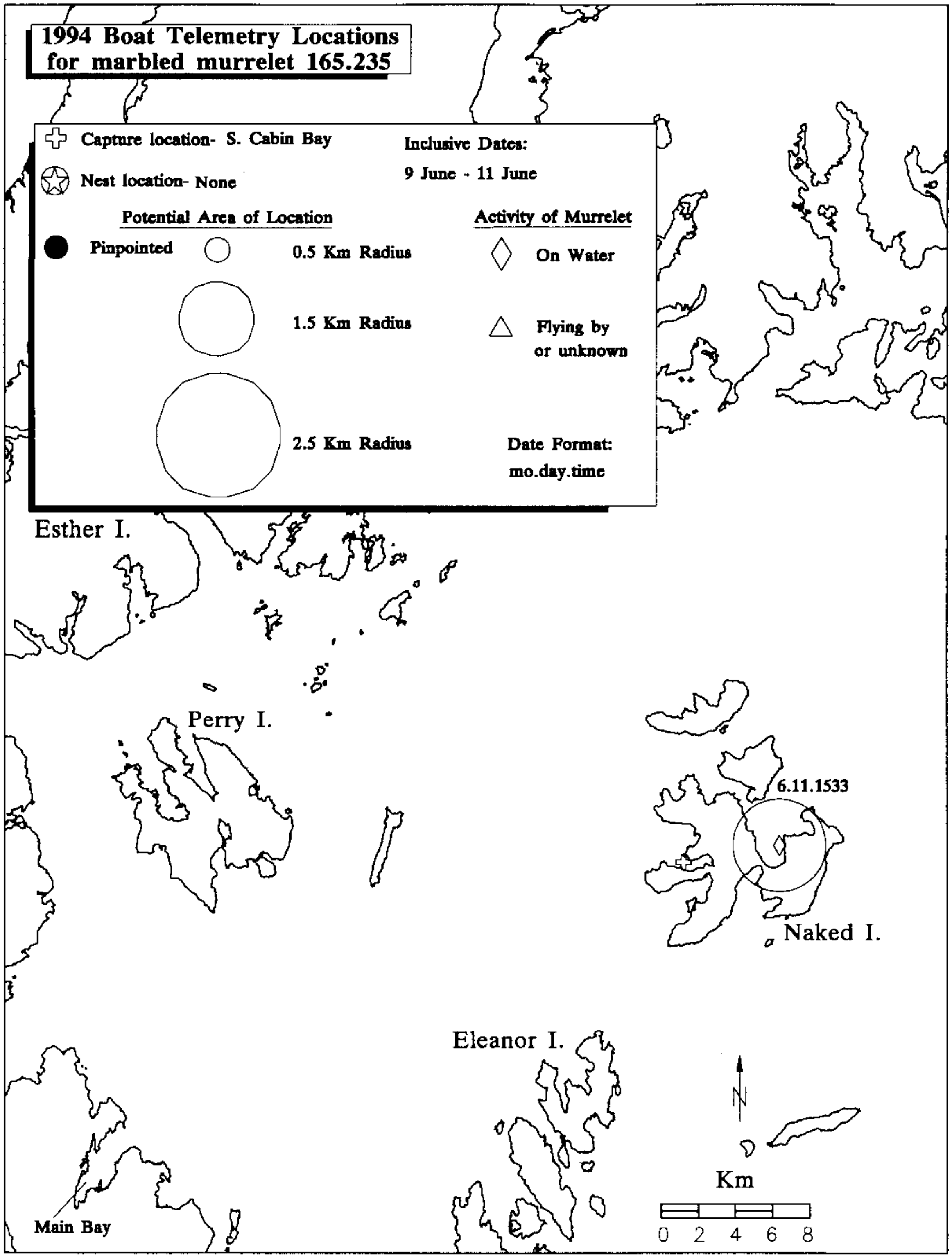
1994 Boat Telemetry Locations
for marbled murrelet 164.722
Capture location- S. Cabin Bay
Nest location- None
Inclusive Dates:
14 June - 27 June
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
mo.day.time
Perry I.
Eleanor I.
Port Nellie Juan
6.27.1427
6.24.1010
Kings Bay
Main Bay
Knight I.
N
Km
0 2 4 6 8



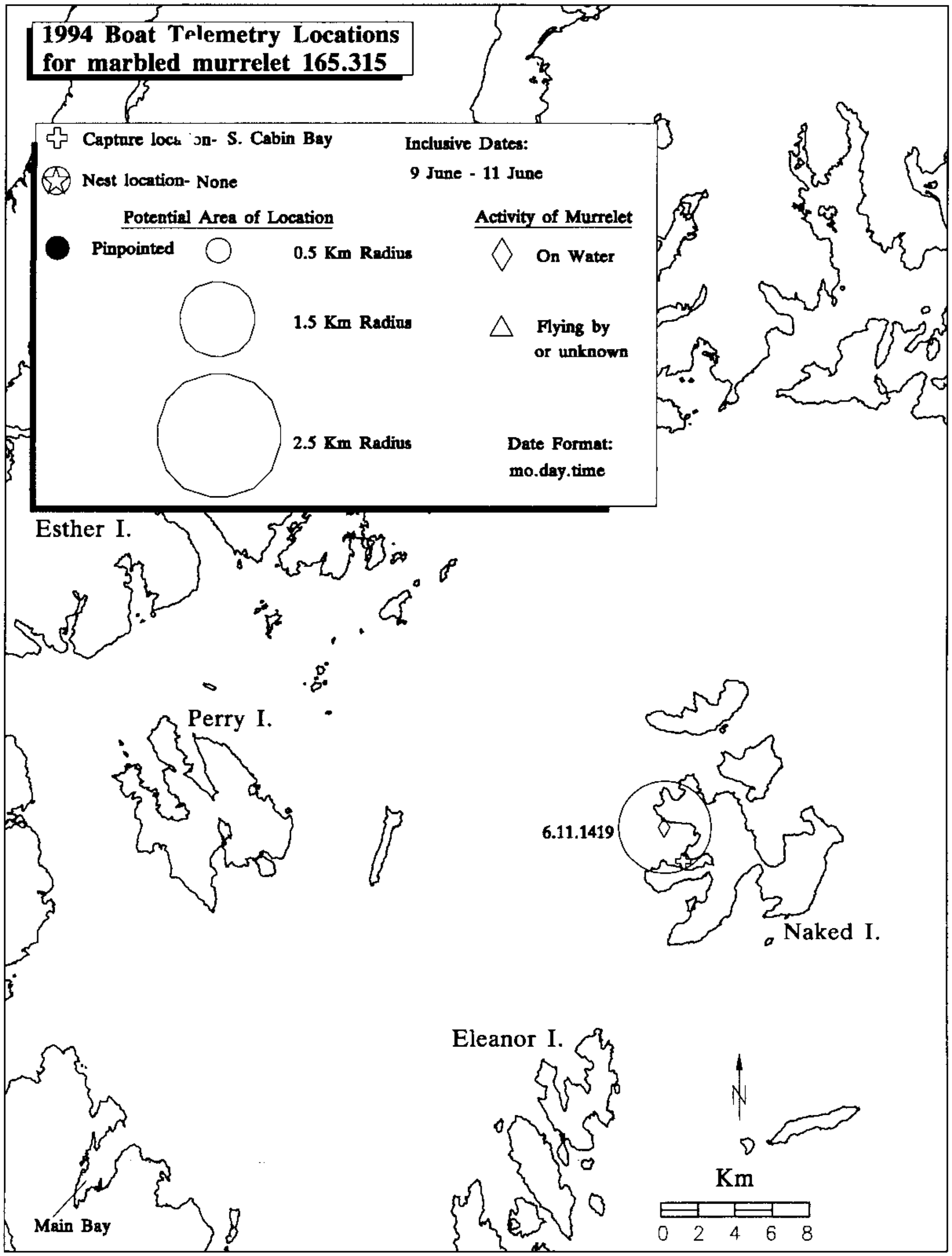
1994 Boat Telemetry Locations
for marbled murrelet 164.819
Capture location- S. Cabin Bay
Nest location- None
Inclusive Dates:
14 June - 1 July
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
mo.day.time
Perry I.
Eleanor I.
Port Nellie Juan
7.01.0244
Main Bay
N
Km
0 2 4 6 8



1994 Boat Telemetry Locations
for marbled murrelet 164.940
Capture location- S. Cabin Bay
Nest location- None
Inclusive Dates:
12 June - 21 June
Potential Area of Location
Pinpointed
0.5 Km Radius
1.5 Km Radius
2.5 Km Radius
Activity of Murrelet
On Water
Flying by
or unknown
Date Format:
mo.day.time
Esther I.
Perry I.
6.19.2144
6.20.0446
6.20.0642
6.19.0413
6.21.0425
6.26.1740
6.13.1100
6.14.0515
6.14.0609
6.16.1558
Naked I.
Eleanor I.
N
Km
0 2 4 6 8
Main Bay



1994 Boat Telemetry Locations
for marbled murrelet 165.235
Capture location- S. Cabin Bay
Nest location- None
Inclusive Dates:
9 June - 11 June
Potential Area of Location
Activity of Murrelet
Pinpointed
0.5 Km Radius
On Water
1.5 Km Radius
Flying by
or unknown
2.5 Km Radius
Date Format:
mo.day.time
Esther I.
Perry I.
6.11.1533
Naked I.
Eleanor I.
N
Km
0 2 4 6 8
Main Bay



1994 Boat Telemetry Locations
for marbled murrelet 165.315
Capture loca on- S. Cabin Bay
Inclusive Dates:
9 June - 11 June
Nest location- None
Potential Area of Location
Activity of Murrelet
Pinpointed
0.5 Km Radius
On Water
1.5 Km Radius
Flying by
or unknown
2.5 Km Radius
Date Format:
mo.day.time
Esther I.
Perry I.
6.11.1419
Naked I.
Eleanor I.
N
Km
0 2 4 6 8
Main Bay