Exxon Valdez Oil Spill
Restoration Project Final Report

Pilot Study On The Capture And Radio Tagging Of Murrelets In Prince William Sound, Alaska
July and August, 1993

Restoration Project 93051**3**
Final Report

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Study History: This study was part of restoration project 93051B (Information Needs For Habitat Protection: Marbled Murrelet Habitat Identification), and was a pilot effort to test the feasibility of radio tagging murrelets for future studies. The project follows restoration project R15 (Identification of Marbled Murrelet Nesting Habitat in the *Exxon Valdez* Oil Spill Zone) and R4 (Feasibility Study On Identification Of Upland Habitats Used By Wildlife Affected By EVOS: Marbled Murrelets). An article regarding the findings of the main project, 93051B, was published in 1995 (Kuletz et al. 1995. Inland habitat suitability for the marbled murrelet in southcentral Alaska. Pages 141-150 *In*: C.J. Ralph, G.L. Hunt, Jr., M.G. Raphael, and J.F. Piatt [eds]. Ecology and Conservation of the Marbled Murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Dept. of Agriculture).

Abstract: This was a pilot study to determine the feasibility of using floating mist nets to capture murrelets in Prince William Sound, and to determine if radio telemetry was an effective method to track murrelets. At two sites in Unakwik Inlet we set mist nets between twilight and dawn, and captured and radio-tagged nine marbled murrelets (*Brachyramphus marmoratus*) and one Kittlitz's murrelet (*B. brevirostris*) on 11-17 July 1993. The tags (2 g, and a battery life of three months) were glued and attached with a single absorbable suture to the middle of the bird's back. We tracked by boat until 22 July and by plane until 25 August. Because the project began after the incubation period we did not find nests, but nine of the murrelets had brood patches, indicating they were breeding birds. We found one marbled murrelet dead four days after release, possibly from eagle predation. We did not relocate the Kittlitz's murrelets after the first day. We tracked the eight remaining murrelets for 12-26 days ($\bar{x} = 14.8$) after release. One bird traveled 83 km, and two made round trips of 54 km and 150 km, but the average distance from capture site was 10.7 km and average distance between consecutive relocations was 8.8 km. Three birds demonstrated crepuscular flight activity which suggested they were feeding chicks in northern Unakwik Inlet. We conclude that the methods used in this pilot study could be successfully applied in the future, and the likelihood of finding nests is high if trapping is begun in late May or early June. Tracking bird locations on the water is very successful for the first two weeks, and some birds can be tracked up to a month after tagging.

Key Words: *Brachyramphus marmoratus*, *Brachyramphus brevirostris*, capture, foraging distances, Kittlitz's murrelet, marbled murrelet, Prince William Sound, radio-tagging, telemetry.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX FIGURES

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EXECUTIVE SUMMARY

This was a pilot study to determine the feasibility of using floating mist nets to capture murrelets in Prince William Sound, and to determine if radio telemetry was an effective method to track murrelets. We did reconnaissance surveys to find concentrations of murrelets near narrow passageways in Unakwik Inlet, and used stationary counts to determine if there was sufficient murrelet activity for mist-netting. We used the mist net system to catch murrelets flying low over the water at twilight or dark. Murrelets were anesthetized prior to suturing a radio tag to their backs.

Nine marbled murrelets (*Brachyramphus marmoratus*) and one Kittlitz's murrelet (*Brachyramphus brevirostris*) were caught and radio-tagged in Unakwik Inlet, Prince William Sound, during July 1993. Nine of the murrelets had brood patches indicating that they were breeding adults. We did not find nests because this project began after the incubation period.

One of the marbled murrelets was found dead four days after release, possibly from eagle predation. We were not able to relocate the Kittlitz's murrelet after the first day. The eight remaining murrelets were tracked regularly for the first 12 days. Five were found 18 days after release, and two were found 26 days after release. One murrelet was located 83 km from the capture site and another made round trips of 54 km and 150 km from the capture site. Six of the eight murrelets were found at least once outside of Unakwik Inlet. In northern Unakwik Inlet, three birds demonstrated an activity which suggested they were feeding chicks.

Radio telemetry can be used to study an individual's daily movement and activity pattern, and as well, can be used to track birds to their nesting and feeding grounds. Because this species can fly long distances in a 24 hour period, and sometimes flies at night, radio tracking may be the only practical method of determining this information.

INTRODUCTION

The marbled murrelet (*Brachyramphus marmoratus*) is a small seabird whose range extends from northern California to southwestern Alaska (Marshall 1988). Marbled murrelets are resident on the south coast of Alaska year round, although there are seasonal fluctuations in populations (Medenhall 1992). The Prince William Sound population has shown a marked decline in recent years (Klosiewski and Laing ms.) and the Exxon Valdez oil spill in 1989 killed large numbers of marbled murrelets (Piatt et al. 1990, Kuletz ms.). As in other parts of their range, marbled murrelets in Alaska also face threats from mortality in fishing nets and loss of nesting habitat due to logging (Marshall 1988). More information about marbled murrelet nesting requirements, feeding ecology, and seasonal movements is needed to develop a sound recovery plan for murrelets in the spill zone.

Early efforts to use radio telemetry to study marbled murrelets have met with only limited success. Capturing murrelets has proven difficult. Quinlan and Hughes (1992) could not capture murrelets with a dip net, a spotlight at night, or a sunken gillnet, but had some success with a net gun. Ralph et al. (1989) and Varoujean et al. (1989) also had difficulty capturing murrelets, and the radio tags on the birds they did capture appeared to fall off long before the end of the battery life of the transmitter. This study tested the use of a capture technique developed in British Columbia which uses floating mist nets (Burns et al. in review and this report), and an attachment technique employed by Daniel H. Varoujean which uses a suture to attach the radio tag to the bird's back. To reduce stress, the birds were anesthetized prior to tagging.

In 1991, 1992, and 1993, in British Columbia, 79 marbled murrelets were caught using floating mist nets. Twenty-seven of these birds were radio-tagged using 2 g radio tags, some of which stayed on for up to 29 days (Burns et al. in prep). Radio telemetry offers researchers the opportunity to follow marbled murrelets to nesting locations and feeding grounds, and to follow movement patterns of individuals on a daily basis.

This study was implemented as a pilot project to determine the feasibility of using floating mist nets to capture murrelets in Prince William Sound, to experiment with the new attachment technique, and to determine if radio telemetry could be used to track these birds. We captured and radio-tagged nine marbled murrelets and one Kittlitz's murrelet (*B. brevirostris*). Eight of the tagged birds were located repeatedly for at least 12 days after release, and two birds were located 26 days after release. Radio signals from land and water were pinpointed exactly, and information on movement patterns and activities of individual birds was obtained. The results of this study suggest that radio telemetry can be effectively used to study murrelets in Prince William Sound.

OBJECTIVES

The primary objective of this project was to determine the feasibility of using radio telemetry to determine nesting habitat of murrelets in the spill-affected area. To do this, we looked at the success of the capture method, the success of tagging efforts using the new attachment technique, and the ability to locate radio signals. Secondarily, we examined the survival of radio-tagged murrelets, evidence of changes in behaviour of tagged birds, the longevity of radio transmitters during the study, the possibility of identifying habitat use in steep terrain and finally, the relative effort and cost per murrelet tracked to an inland site compared with dawn watch techniques.

METHODS

Study Area

Murrelets were captured and radio-tagged at Siwash Bay and Miners Bay, both in Unakwik Inlet, located in northwestern Prince William Sound (Figs. 1 and 2). Unakwik Inlet is 33 km long and approximately 3.5 km wide. The Inlet is steep-sided with maximum water depths ranging from 308 m at its mouth to 261 m near its head. A glacial sill covered by 1.8 m of water at low tide extends across the Inlet approximately half way up its length. There are numerous small islands and bays along the shores of the Inlet, the most prominent bays being Siwash, Jonah, and Miners. Meares Glacier enters the head of the Inlet, and ice from this glacier was present in the upper half of the Inlet during the study period. Rolling hills of up to 740 m near the Inlet mouth culminate in sharp, jagged mountains up to 2,847 m at its head. Tree line extends from sea level to altitudes as low as 30 m or occasionally as high as 600 m (Isleib and Kessel 1973). A salmon hatchery is located half way up the Inlet on the eastern shore. Commercial gillnet and seine fisheries occur sporadically in the Inlet during July and August.

The study area was expanded during the radio tracking phase of this study to encompass primarily the northwestern, central, and southwestern portions of Prince William Sound. The search effort was concentrated around Eaglek Bay, Unakwik Inlet, Wells Bay, and the Naked Island area. Searches were also done along the southern portion of Prince William Sound and southern Kenai Peninsula (Fig. 1).

Capture and Tagging

The capture and radio-tagging of murrelets (*Brachyramphus sp.*) was conducted from 9 to 21 July, 1993 using a 20 m vessel (*Alaskan Gypsy*) as the base of operations. We used mist nets suspended over the water to capture murrelets (see Appendix). Radio-tagged murrelets were tracked by boat until 22 July and by plane until 25 August.

Selection of Capture Locations -- The capture system requires nets to be placed where murrelets are flying low over the water during twilight or darkness. The chances of capture are known to increase if the birds are flying through narrow passageways or if their flight path is close to a point of land (Prestash et al. 1992, Burns et al. in review). Unakwik Inlet was selected as the capture site because it has high densities of murrelets (Kuletz et al. unpubl. data), and because its topography is similar to a fiord in British Columbia where murrelets have been captured (Prestash et al. 1992, Burns et al. in prep).

We looked for concentrations of murrelets near restricted passages in Unakwik Inlet by conducting shoreline reconnaissance surveys by boat during mid day on 9 and 11 July. Any area containing more than 100 murrelets was noted as a potential mist-netting site. The short duration of this pilot project did not allow for a systematic survey of the Inlet, and areas that were too shallow or too difficult to navigate were not inspected.

Stationary counts (Prestash et al. 1992) were done to determine if murrelet activity at dawn and dusk was suitable for mist-netting. Morning and evening stationary counts were conducted from inside the wheelhouse of the *Alaskan Gypsy*, which provided a viewing platform approximately 1.4 m above the water. Two observers with binoculars, stationed on opposite sides of the vessel, called out all bird species seen between them and the opposite shore during 10 min intervals. Because marbled murrelets and Kittlitz's murrelets could not be accurately distinguished from each other, all murrelets seen were recorded as *Brachyramphus* species.

Morning counts lasted for two hours and 20 minutes, and evening counts lasted for two hours. The first morning count began 20 minutes before sunrise and subsequent morning counts began one hour and 20 minutes prior to sunrise, to coincide with first light. Evening counts began one hour and 30 minutes before sunset. All times were recorded as Alaska Daylight Time. Murrelet activity was recorded as: (i) "Flying out"- birds flying past the observer and continuing down inlet; (ii) "Flying in"- birds flying past the observer and continuing up inlet; and (iii) "On the water"- birds swimming on the water, including birds that land or take off.

Two morning stationary counts were conducted on 10 and 11 July while the vessel drifted with the engine off in the middle of Unakwik Inlet (Fig. 2). At this point the Inlet is approximately 3,700 m wide.

Five stationary counts were conducted about 1,000 m inside the mouth of Siwash Bay where the bay narrows to 600 m (Fig. 2). The vessel was anchored in mid-channel, and the counts were conducted by one or two people on the morning of 15 July and the evenings of 14, 15, 16, and 17 July.

Mist-netting Murrelets -- A single net system (Appendix - Fig. a) was deployed on the evenings of 11, 12, and 13 July to assess the likelihood of capturing murrelets in various locations (Fig. 2). On 11 July, a net was placed near the southern entrance of Miners Bay in 58 m of water (Site 1). At this site a narrow channel was formed between a series of small islands and the mainland. On 12 July, a net was set in 94 m of water in a channel between Olsen Island and the mainland (Site 2). On 13 July, a net was set in 20 m of water in the narrowest part of Siwash Bay, approximately 1,000 m inside the mouth near the northern shore (Site 3). A series of three nets (Appendix - Fig. b) was deployed on the evenings of 14 through 17 July in Siwash Bay in 20 m of water (Site 3), and on 18 July near Miners Bay, in 160 m of water (Site 4). We removed the net support system at Site 4 on 19 July to avoid interfering with the commercial gillnet fishery occurring that night, and replaced the system on 20 July after the gillnetters left.

At Sites 2, 3, and 4 the *Alaskan Gypsy* was anchored 300 m from the nets in a position to help direct flying birds towards the area where the nets were set. At Site 1 a suitable place to anchor was not found and the vessel drifted near the net for the night. Mist nets were attached to the supports before sunset, left in place until sunrise, and checked every 20 minutes throughout the night by lighting up the area with a spotlight and scanning the nets with binoculars.

Processing and Tagging -- Using a small skiff, two researchers removed murrelets from the nets, put each in a cotton bird bag, and brought them to the *Alaskan Gypsy*. Because of the difficulties associated with working on the water (wind, waves, tidal currents), it was often necessary to cut the net to remove the birds. We did not wear gloves when handling the birds. Each captured bird was examined as soon as it was brought on board the *Alaskan Gypsy* and any mesh on the bird was removed. When two or more birds were caught within a short time, they were held on deck in bird bags until each could be processed in turn. Birds caught together were released together. To avoid stressing the birds, noise was kept to a minimum and birds were held in a dark, cool place while awaiting processing.

Each bird was weighed to the nearest gram, measured (length and depth of culmen, flat wing chord, and tarsus), examined for a brood patch, banded with a U.S.F.W.S. leg band (size 3B), and radio-tagged.

Prior to radio-tagging, we anesthetized each murrelet. We used isoflurane, an inhalation anesthetic, administered via a portable anesthetic machine developed by Daniel H. Varoujean (MARZET, Marine Estuarine Research Co., North Bend, Oregon). Radio tags (Holohil BD-2G transmitters, Woodlawn, Ontario, coloured brown, with frequencies ranging from 164.000 to 165.999 khz, 20 mm long, weighing 2 g, battery life-three months, with an antenna extending back 15.6 cm off the top of the tag at a 30^{o} angle) had been prepared in advance by threading an absorbable suture through a belt loop on the top of the tag, then tying the suture around the body of the tag. The needle, suture and attached radio tag, and related equipment were sterilized with isopropyl alcohol. We parted the feathers on the bird's back, sterilized the attachment site, then used forceps to draw up a small fold of skin. The needle and suture were inserted through the folded skin (taking care that no muscle tissue was caught in the process), then tied off with a square knot. The radio tag was then stabilized on the bird by gluing it to several back feathers with an epoxy glue (four minute epoxy, Titan Corp., Seattle).

Radio Telemetry Data Collection

Radio frequencies were monitored using Telonics TR-2 receivers and TS-1 scanners equipped with either Telonics H or Yagi antennae. Before releasing a radio-tagged murrelet, the receiver - scanners were tuned into the activated transmitter. Signals were monitored from the water on seven days, the air on 10 days, and the ground on one day for a total of 132.0 hours. When conducting telemetry, the following information was recorded: (1) the time the receiver was turned on, (2) the time, duration, and type of signal received, and (3) the time the receiver was turned off.

<u>Tracking From the Water</u> -- We tracked birds from the water using the *Alaskan*

Gypsy and a 3 m skiff. On the *Alaskan Gypsy*, two H antennae were attached to the rigging 9 m above the water at the stern of the vessel. They were positioned at right angles to each other facing to the stern and to the port side to avoid interference from the vessel's rigging, and were attached to a switch box permitting either simultaneous or individual use. On occasion a hand held H antenna and receiver were used at the bow of the boat.

Radio telemetry was occasionally conducted from the skiff using an H antenna held in the hand or mounted on a 2.2 m aluminum pole. The skiff was used to scan areas that were not easily accessible to the larger vessel, to try and make visual contact with a radio-tagged murrelet that was first detected from the larger vessel, and to help pinpoint the location of a transmitter that was near the shoreline.

After the first murrelet was tagged, the receiver on the *Alaskan Gypsy* was monitored continuously during darkness, and at all times when the vessel was under way. At other times the receiver was monitored sporadically to check for presence or absence of signals. Frequencies were scanned at the slow scanning speed of the scanner. Based on previous tests (Burns et al. unpubl. data), signals received from a bird on the water were assumed to be within 1.5 km of the vessel. We did not determine the distance at which we could receive a signal from a flying bird. Unless visual contact was made with a radio-tagged murrelet, all signals detected from the boat were recorded as being within the general area of the vessel's position. Most telemetry conducted from the *Alaskan Gypsy* was opportunistic because the boat was engaged in other tasks such as setting the net supports, or mist-netting. The two exceptions were a concentrated search conducted on 16 July, when we ran to Naked Island and back, and a search on 20 July for a tagged bird that was detected in the Miners Bay area.

To assess the feasibility of monitoring and observing a radio-tagged murrelet from the water, we calculated the daytime (0400 to 2300) rate of signal detections from the vessel by dividing the hours of daytime telemetry monitoring by the number of signals received (excluding detections from flying birds). This rate enabled us to estimate the number of opportunities that would be available in future telemetry projects to make visual contact with a radio-tagged bird and study its behaviour. To estimate the amount of time available to find and study a bird during each opportunity, we calculated the duration of each daylight detection which occurred when both the bird and the *Alaskan Gypsy* were stationary. We did not include detections from flying birds or detections made while the vessel was under way. The sum of these times divided by the number of detections equalled the average length of time that we detected a bird in an area. We calculated the average number of radio-tagged murrelets available for detection each day, and the average number of murrelets we actually detected, to determine the success rate for relocating radio-tagged birds while radio tracking from the water .

Tracking From the Air -- Telemetry tracking flights were conducted on 10 days between 18 July and 25 August using a Cessna 185 float plane based in Cordova. Telemetry on the last four flights was conducted by a technician from the Copper River Delta Institute (USFS, Cordova). Search flights over land were restricted to areas adjacent to Unakwik Inlet and to the islands in Prince William Sound. We attempted to locate all birds each day.

Two Yagi antennae, attached to the wing struts of a Cessna 185 float plane, were orientated to point downwards at a 45^{o} angle and were connected to a switch box so that both antennae could be monitored together or individually. The pilot and one observer monitored signals by using a splitter which allowed two headsets to be connected to the receiver-scanner. A second observer recorded the plane's position, air speed, and altitude. As each radio frequency was detected, the observer recorded the time and place of first detection, and the time and place when the signal was pinpointed. Location was also noted on a copy of a chart of the area. Longitude and latitude were recorded from a Global Positioning System (GPS).

On two occasions, to determine the range of signal reception, a test transmitter was activated and left on an overhanging branch one m above the water in Siwash Bay. Survey altitude and speed varied considerably depending on weather conditions and type of terrain. During all flights, frequencies were scanned at the medium scanning speed of the scanner. When a signal was detected, that frequency was locked in until pinpointed, then it was deleted from the receiver. The search for the remaining signals resumed from the point where the deleted signal was first detected.

When a signal was first received its approximate position was established by flying in the direction that increased the strength of the signal. When observers decided the aircraft was close to the signal, the volume of the receiver was reduced so the signal could barely be heard. By crisscrossing the area, the signal was localized by identifying the place where it suddenly increased in volume. Only the antenna that was facing in the direction of the transmitter could receive the loud signal. By using the directionality of the antennae, and by flying a box pattern in the area, the radio tag's location was finally pinpointed. Three or four passes were made to confirm each location. If a murrelet was continually diving, its location was listed as approximate if a satisfactory pinpoint could not be made. If the position of a signal could not be established after 15 minutes, because the signal neither increased in volume nor provided clear directionality, the search for that bird was suspended. The plane then returned to the place where that signal was first detected, and the search for all remaining frequencies was continued. The frequency of the signal which could not be pinpointed was included in the scan, and if that signal became more clear later, we again attempted to pinpoint it. A constant signal emanating from a position that could not be pinpointed to either land or water (i.e. the transmitter appeared to be right near the water's edge) was pinpointed by conducting telemetry searches from the boat and ground.

To determine the success rate for locating all radio-tagged birds during an aerial search we calculated the average number of murrelets available for detection each day we flew and compared that with the average number of murrelets we actually detected. To determine the effort and the cost required for radio-tracking murrelets in the northern and central portion of Prince William Sound, we calculated the average range at which we could detect a signal, the average time required to pinpoint a signal after first detection, and the average altitude and speed at which signals were first detected. The linear distance of the survey route combined with the effort required to pinpoint signals enabled us to estimate the cost of aerial tracking.

Tracking From the Ground -- The location of a signal coming from a land position was pinpointed by conducting a ground search. A hand held H antenna was used to determine direction and the signal was followed until the receiver was so close to the transmitter that it could pick up the signal even when the antenna was disconnected from the receiver. With the antenna disconnected, the searcher moved the receiver away from the signal until it could no longer be heard and that position was marked with flagging tape. This was repeated until the area had been crisscrossed and the outer limits of the signal reception marked in a rough circle. If the strength of the signal was fairly evenly distributed throughout much of the enclosed area the transmitter was assumed to be in a tree. It was also assumed, based on previous telemetry experience (R. Burns and L. Prestash, pers. obs.), that if the transmitter was on the ground it would be found when crisscrossing the area. Lastly, it was also assumed that if the bird was on the ground, it would flush during the crisscross process.

Analysis of Murrelet Activity

Murrelet activity was inferred by the type of signal received. The factors we considered in determining signal type were the volume, the regularity, and the tone of the signal.

When tracking from the water or from the air, a signal of constant volume which repeatedly disappeared and reappeared for intervals of 10 to 60 seconds was recorded as a diving bird. Signals that had a distinctive "bloop" sound for the first one or two pulses after the signal reappeared further indicated that the bird had just emerged from a dive (R. Burns and L. Prestash, pers. obs.). Time spent underwater by diving murrelets can be accurately recorded because the signal disappears instantly when the bird dives and reappears when the bird surfaces.

When tracking signals from the water, a continuous signal of steady volume indicated that the bird was fairly stationary, although we could not determine if it was on land or water unless visual contact was made. A signal which appeared abruptly and faintly, increased quickly in volume, then rapidly became faint and disappeared was considered a flying bird. The direction of flight could not be determined.

During aerial searches, if a signal was constant in volume and pulse, and if the pinpointed location could only be on the water, the murrelet was assumed to be floating. To be certain the floating bird was alive, the plane flew over the area at an altitude of 30 m causing the bird to either dive or fly away. If this procedure was unsuccessful, the plane landed and taxied on the water until the bird either flew or dove or visual contact was made. A loud signal which rapidly faded in volume and disappeared when the plane flew a box pattern indicated a bird that had taken flight.

The combined results of water, air, and ground searches were compiled for each radio-tagged murrelet to infer patterns of activity. The number and times of observations, and the location of each signal were plotted on maps to determine both the maximum straight-line distance of individual murrelets from the capture site, and the maximum straight-line distance travelled by each bird between consecutive relocations. For each bird, the sum of all distances divided by the number of detections gave the average distance from the capture site and between relocations. To determine average maximum distance, we used the greatest distance for each bird (from point of capture or between any two relocations) divided by the number of birds (n=10).

Following the activity patterns of individually tagged birds allowed us to address the secondary tasks of this project: survival of tagged murrelets, changes in behaviour, longevity of transmitters, locating birds in this terrain, and cost analysis.

RESULTS

Capture and Tagging

Selection of Capture Locations -- During shoreline reconnaissance surveys of Unakwik Inlet conducted during mid day on 9 and 11 July, we found approximately 350 murrelets (including more than 20 Kittlitz's Murrelets) in Miners Bay, and up to 200 murrelets near the head of Siwash Bay (Fig. 2). In both bays, murrelets were flying through narrow channels which appeared to be suitable for netting.

We had clear skies on 10 and 11 July for the stationary counts in the middle of Unakwik Inlet (Fig. 2). We estimated that we could see flying birds up to 1500 m, and birds on the water up to 300 m, on either side of the boat. There were no other seabirds of similar size to murrelets in the Inlet, and the only other alcid seen was one pigeon guillemot (*Cepphus columba*). Flying murrelets were easily seen against the backdrop of silver grey water. Murrelets flew low over the water and were dispersed over the width of the Inlet. They appeared to avoid the area near our vessel. We consider the number of birds counted to represent a minimum number because of the problem of reduced detectability at greater distances. Ninety-five per cent (n=1674) of all murrelets seen on both days were flying out of the Inlet (Table 1). Peak activity occurred 30 minutes before sunrise (Fig. 3). Single murrelets accounted for 34% of all murrelets seen, groups of two - 43%, and groups of three or more - 23%.

We had clear skies on 14 and 15 July, and overcast skies on 16 and 17 July, for the stationary counts in Siwash Bay (Fig. 2). Our position enabled us to count all murrelets between the boat and each shore. Murrelets flew low (<2 m) over the water, and favoured the northern shore. They appeared to avoid the area where the boat was anchored. There were fewer murrelets present during the morning count of 15 July than for any of the four evening counts of 14 to 17 July (Table 1). Evening stationary counts were done at the same time the nets were being set at Site 3. We saw murrelets avoid the nets by flying around them, and it appeared that most passed between the net system and the anchored vessel. We could discern no pattern of activity for the single morning count, but during the four evening counts, peak activity occurred 10 minutes after sunset (Fig. 4). Single murrelets accounted for 69% of all murrelets seen, groups of two - 21%, and groups of three or more - 10%. On many occasions during the evening counts, we saw murrelets carrying fish.

Mist-netting Murrelets -- No murrelets were caught in 17.2 hours of effort at the three sites (Sites 1, 2, and 3) where we set a single mist net (Fig. 2). We had clear skies and a bright moon on the nights of 11 to 13 July. The darkest period of the night was from 0130 to 0230, but the net support system was still visible to the unaided eye from a distance of 500 m. At Site 1, we set the net near a narrow channel where earlier we had seen over 100 murrelets. After we set our net, commercial gillnetters arrived in the area and used this channel as a route to their fishing grounds. After that, few murrelets flew out of the channel although we saw murrelets flying in the main part of the Inlet. At Site 2 less than 40 murrelets were seen during the time the net was up and none flew close to the net site. At site 3 we counted more than 100 murrelets, many of which passed close to the net as they flew in or out of the bay in the late evening. We saw fewer murrelets in the early morning.

When we set a series of three nets at Sites 3 and 4 (Fig. 2), ten murrelets were caught in 40.7 hours of effort (.25 birds/hour). Skies were clear on the the nights of 14 and 15 July, but became cloudy by 0100 on 16 July, and remained overcast until we finished mist-netting on the morning of 21 July. On overcast nights between 0130 and 0230, we could not see the net support system without the aid of a spotlight. We caught nine marbled murrelets, one black-legged kittiwake (*Rissa tridactyla*), and one fork-tailed storm-petrel (*Oceanodroma furcata*) at Site 3, and one Kittilitz's murrelet and two fork-tailed storm-petrels at Site 4. All murrelets were caught during overcast conditions between 2310 and 0431 (Table 2). Two murrelets were caught during the evening count of 16 July near the period of peak flying activity (Fig.4). While tending the nets in the skiff on the morning of 18 July, we flushed a Kittlitz's murrelet that appeared on the water close to us. It flew straight into the net and did not struggle after becoming entangled. This was the only bird that we saw hit the nets.

Processing and Tagging -- It took between 0.2 and 0.3 hours from the time a bird was spotted in the net until it was brought to the base vessel, and an average of 0.6 hours (0.5 - 0.7 hours) to weigh, measure, band, and radio tag each murrelet. The time from when a murrelet was spotted in the net to the time it was released varied from 0.9 hours to 2.1 hours depending on the length of time each bird was held before and after processing. We could only process one bird at a time, which required holding birds caught within one hour of each other (6 of 10 murrelets [Figs. 6, 8, 9, 10, 11, and 12, Table 2]). When we caught two birds at the same time (Figs. 9 and 10, Table 2), we held them until both were processed so they could be released together. One murrelet (Fig. 5, Table 2) was held for one hour after processing because it was very subdued after recovering from the anesthetic.

One of the marbled murrelets with a fully developed brood patch was in winter plumage, and two were in transitional plumage. One murrelet did not have a brood patch. Bird weights ranged from 175 g to 241 g (Table 2).

Murrelets were lively (looking around, pecking at observers) when removed from the bird bags. Anesthesia was induced in each bird in two to three minutes, and was maintained until the suturing procedure was finished. Recovery required two to four minutes. All murrelets were alert soon after recovery with the exception of one bird (Fig. 5). This murrelet was also the only bird injured in the net, receiving minor abrasions on each wing.

Radio Telemetry Data Collection

Tracking From the Water --We monitored the telemetry equipment on the *Alaskan Gypsy* for 89.0 hours from 16 to 22 July (Table 3). Excluding signals received at the time of release, we detected radio-tagged murrelets from the boat on 31 occasions, 30 of which occurred during 80.9 hours of opportunistic telemetry. Two birds (Figs. 7 and 14) were not detected again from the water after release. One concentrated search was conducted on 16 July for 7.3 hours when we ran from Siwash Bay, around the south end of Naked Island, and back. We detected one of the two birds tagged at that time (Fig. 5). The second concentrated search lasted 0.8 hours on 20 July, when we tried to make visual contact with a bird (see below). Some detection times were as short as one minute, for example, when a bird flew past our position (Fig. 12); other times were much longer. The pattern of detections from one bird indicated that it remained at the same site for 18.6 hours (Fig. 10). All detections from the *Alaskan Gypsy* occurred in Unakwik Inlet (Table 3).

We could not get clear directionality from the antennae mounted on the boat, and using this method we were only able to establish presence or absence of radio-tagged murrelets. On two occasions, when the boat receiver detected a signal we used a hand held antenna and receiver to try to pinpoint the bird. Neither attempt was successful. When we got close to the first signal on 16 July (Fig. 5) during a concentrated search, it suddenly faded and disappeared, suggesting that the bird flew away. We abandoned the search for the second signal after 0.8 hours on 20 July (Fig. 9), because the signal remained faint and changed direction frequently.

We monitored the telemetry equipment for 57.7 hours during the daylight hours between 0400 and 2300. Twenty-five detections began in or continued into this period (Table 3). Three detections (Figs. 9, 11, and 13) were of flying birds, four detections were made while the boat was under way (Figs. 5, 8, 11, and 13, Table 3), and the remaining 18 detections (Figs. 5, 6, and 8 through 13) were of birds that were stationary near the vessel's position. The daytime rate of signal detections from stationary birds was one detection per 2.6 hours of monitoring or approximately three detections per day. The average length of time that a bird was detected in an area during daylight was 3.2 hours (1 minute to 12.2 hours, n=18). On average, during the seven days of telemetry conducted from the boat, there were eight radio-tagged murrelets available each day for detection. We were able to detect, on average, three murrelets a day while tracking from the water (Table 3) for a relocation success rate of 37.5%.

The skiff was used for radio tracking on three occasions for a total of 3.0 hours. On 17 July, we searched without success for radio-tagged murrelets near the Cow Pens in Unakwik Inlet (Fig. 2). The search was terminated after 1.4 hours when the outboard motor broke down. On 18 July, we tried for 1.1 hours to pinpoint a bird (Fig. 13) in Siwash Bay but could not locate it within a group of about 100 diving murrelets. On 19 July, we used the skiff for 0.5 hours to confirm that a signal detected during an air search was coming from land and not from the near shore water (Fig. 5).

<u>Tracking From the Air</u> -- The dates and routes of the 10 aerial searches are presented in Figures 15a through 15j. We used the GPS to establish the latitude and longitude of pinpointed birds on 34 occasions. Thirty two percent (11 of 34) of these GPS positions did not correspond to the positions we had recorded on our charts. The GPS was off by 0.5 to 3.0 km.

We usually pinpointed a signal from the air without any problem. On one occasion however, we located a signal at the shoreline but could not determine if it came from the land or the water. Low flights over this area did not cause the signal to change (as would occur if the plane flushed the bird and caused it to dive or fly away). A ground search conducted later that day pinpointed the signal on land (see below and Fig. 5). On another occasion a bird was diving so frequently that we could only record its position as "approximate" (Fig. 12). On a third occasion, we detected a steady signal on the water but could not flush the bird to ensure it was alive, so we landed and taxied toward the signal until the bird flew away. Later that day this bird (Fig. 6) was again pinpointed at this location.

In addition, an unknown outside source caused severe interference on frequency #164.430 during part of all flights and this frequency had to be deleted from the scanner until we were out of the central part of Prince William Sound. Low level interference on all frequencies was noticed while flying in the central part of the Sound or when flying near cruise ships. Some of this interference may have come from the marine radio telephone transmitter located at Johnstone Point, Hinchinbrook Island (Fig.1). We did not consider it bad enough to affect our telemetry efforts. The technician from the Copper River Delta Institute reported that all frequencies were affected by interference in the northern part of the Sound on 22 August during a commercial salmon opening, causing the search to be abandoned (Fig. 15i).

We detected the test transmitter from a distance of seven km at an altitude of 215 m, and from 13 km at an altitude of 700 m. Once, after a bird was pinpointed, we flew directly above it at 1800 m and still received the signal clearly.

We were able to detect, on average, 5.6 of 9.1 murrelets each day we flew, for a relocation success rate of 61.5%. All radio-tagged murrelets were located within one km of the shoreline (Figs. 5 to 14). We pinpointed 56 of 59 signals detected during

38.2 hours of monitoring from the air. Total flying time (including travel time) was 41.1 hours. The average distance between the location of first detection and the pinpoint location was 4.6 km (0.6 to 13.7 km, n=51). The average altitude at first detection was 465 m (90 to 1035 m, n=32), and the average speed at first detection was 170 km/hr (135 to 210 km/hr, n= 28). The average time required to pinpoint a signal after it was first detected was seven minutes (1.0 to 24.0 min, n=45).

Tracking From the Ground -- On 19 July, an air search located a stationary signal (frequency 165.206) near the west shore of Unakwik Inlet but we were unable to ascertain if the transmitter was on land or on water. We used the skiff to confirm the signal was on land and then conducted a ground search for 1.7 hours to pinpoint the signal. We found the transmitter on a rocky point above the high tide mark (Fig. 5) in a pile of marbled murrelet feathers. The wind had not yet scattered the feathers which appeared to have been there only a few hours. A piece of tissue with feathers attached was still fresh. The upper part of the bird's head and the upper mandible were found. We could not find the bird's legs or leg band. The weathered remains of what appeared to be two other marbled murrelets were located 3.7 m and 8.3 m farther inland from the fresh remains. Within this area we also found the feathers of at least one other unidentified bird, and fish remains consisting of portions of skin and skeletons. During the air search earlier that day we had spotted a bald eagle (*Haliaetus leucocephalus*) sitting in a tree next to this site.

Patterns of Murrelet Activity

Telemetry data for each murrelet is presented in Figures 5 to 14. Immediately after release, seven of ten murrelets flew out of the detection range of our anchored vessel and three remained on the water within range for up to 8.8 hours. Three of the seven birds that flew away (Figs. 6, 10, and 11), returned to the capture site within 19.8 hours of release. One marbled murrelet was located daily for three days at the capture site and was found dead on the fourth day seven km away (Fig. 5). The Kittlitz's murrelet (Fig. 14) was located 12.1 km from the capture site 9.2 hours after release, but was not located again. The remaining eight marbled murrelets were all detected regularly during the first 12 days after release. Five were detected on the 18th day, and two were detected on the 26th day after release (Table 4). The average detection time for all radio-tagged murrelets (n=10) was 14.8 days. Excluding the day of release, five birds (Figs. 5, 8, 10, 11, and 13) were found at least one more time near the capture site, with two of these birds (Figs. 8 and 13) detected regularly in this area for up to 26 and 18 days respectively. Six birds (Figs. 6 to 10, and 12) were relocated outside of Unakwik Inlet at least once during this study. One murrelet was found 83 km from the capture site (Fig. 9). Another ranged back and forth between Siwash Bay, and Naked and Green Islands, making at least one round trip of 150 km in a seven day period (Fig. 8). The average distance that all murrelets were found from the capture site was 10.7 km and the average distance individual murrelets were found between consecutive relocations was 8.8 km. The average distance that marbled murrelets (n=9) were found from the capture site was 10.5 km and the average distance individual marbled murrelets were found between consecutive relocations was 9.7 km. The average maximum range for all murrelets was 35.6 km, and the average maximum range for marbled murrelets was 38.2 km (Table 4).

On 10 occasions, spanning three nights, we detected murrelets flying past our anchored position near Miners Bay between 2345 and 0452 (Figs. 9, 11, 12, and 13). Three of these four birds (Figs. 9, 12, and 13), each on separate occasions, flew past our position twice in one night, with the intervals between flights ranging from 20 to 41 minutes. The two murrelets that were caught and released together (Figs. 9 and 10) were not found together during any of the telemetry searches.

DISCUSSION

Capture and Tagging

<u>Selection of Capture Locations</u> -- To find capture sites, reconnaissance surveys should be done to locate concentrations of murrelets in or near narrow channels. Evening stationary counts at these locations can assess the potential of the area as a capture site because the counts accurately depict murrelet numbers and activity. We recommend using evening counts before setting nets to evaluate potential capture sites because the counts require less effort and provide more information. Siwash Bay was suitable for mist-netting murrelets because the birds flew low over the water in a narrow channel during twilight and darkness. Morning stationary counts in the middle of Unakwik Inlet revealed that large numbers of murrelets flew out of the Inlet. However, this area was not suitable for mist-netting because the peak of activity occurred in daylight, and the birds were widely dispersed over the width of the Inlet. The topography of Prince William Sound appears to be well suited for mist-netting murrelets because it contains many constricted waterways. Besides Siwash Bay, other potential net sites noted during telemetry flights included Naked and Knight Islands, two areas where murrelets are known to concentrate (Kuletz unpubl. data).

While doing stationary counts over a three year period in Mussel and Kynoch Inlets (two fiords on the central coast of British Columbia), we found a pattern of morning flights out of the inlets similar to those in Unakwik Inlet. Large numbers of marbled murrelets (up to 579) flew out of the inlets each morning near sunrise during the breeding season (Prestash et al. 1992, Burns et al. in prep). This pattern of movement may be a common feature of murrelet activity and can be used to monitor numbers, locate corridors between nesting and feeding areas, or to locate potential evening reconnaissance sites.

Mist-netting Murrelets -- Mist nets suspended over the water are a reliable way to capture murrelets. Using this technique, 79 murrelets were caught in British Columbia from 1991 to 1993 (Prestash et al. 1992, Burns et al. in review, G. Kaiser pers. comm.), and 10 were caught in this manner during this project.

Other techniques used to catch murrelets include using sunken gillnets, dip nets, net guns, and mist nets in the forest (Ralph et al. 1989, Varoujean et al. 1989, Paton et al. 1991, Quinlan and Hughes 1992). The last two techniques were the most successful. A total of 55 marbled murrelets have been caught with the net gun (Quinlan and Hughes 1992, Dan Varoujean pers. comm.). Quinlan and Hughes (1992) report a capture rate of one murrelet per seven to 12 hours of effort. Using mist nets set in the forest canopy, Ralph et al. (1989) captured three marbled murrelets in 27 hours of netting spread over 18 days, for a capture rate of one bird per nine hours of effort.

Our capture rate of one bird per four hours of effort during this project (using the triple net system) should be interpreted with caution. Seven of ten murrelets were caught during one night, and on three of the six nights we caught no birds. Weather conditions may affect chances for capture because we only caught murrelets on overcast nights.

The stage of the breeding cycle may also affect the capture rate. Our capture effort occurred in mid to late July, which appears to be the nestling phase in Prince

William Sound (Kuletz et al. 1994a). Because two of 10 murrelets captured had regressing brood patches, and because we observed many murrelets holding fish in the evenings, we assumed that most of the captured birds had chicks. If this was true, then both adults would be commuting daily to the nest to feed young (Simons 1980, Hirsch et al. 1981). Thus, there were potentially twice as many breeding adults available for capture during our study than during the incubation period, when one bird remains at the nest for 24 hours (Simons 1980, Singer et al. 1991). In his study at Langara Island, Sealy (1975) found that during the nestling period, subadults began to congregate in the same areas as the breeding adults. If the same phenomenon occurs in Prince William Sound, then there are more birds available for capture in the nestling period than in the incubation period. Also, activity patterns and densities of murrelets may vary depending on the time of year and this would likely affect the capture rate. Presumably, if more nets are deployed, both the capture rate and the number of murrelets caught would increase.

We moved the mist-netting system to Miners Bay on 18 July to try to catch a Kittlitz's murrelet. Even though the number of Kittlitz's murrelets in the area was small (~20) we caught one bird on the first attempt. This suggests that Kittlitz's murrelets may also be caught using this method, and if mist-netting attempts are made in areas that support mixed populations of both marbled and Kittlitz's murrelets, future radio telemetry projects may be able to track and study both species simultaneously.

Mist-netting should be done in areas closed to or away from commercial salmon fishing to avoid potential conflicts. This ensures the mist net support system does not interfere with the boats or their gear, and the boats do not flush murrelets out of an area (Kuletz ms.) or affect the birds' flight patterns.

Processing and Tagging

Nine of ten murrelets showed no visible ill effects from the anesthetic. An advantage of using anesthetic is that the birds are immobilized so it is easy to work on them. But anesthetizing birds also increases the handling time, and there are some risks associated with all anesthetics (Harrison 1986). In British Columbia, one of 14 anesthetized marbled murrelets died while under anesthetic (Burns et al. in prep.). We could not monitor the dosage of isoflurane delivered to the murrelets using the anesthetic delivery system employed on this project, nor did we have a system available for delivering oxygen directly to the bird if the bird showed an adverse reaction to the anesthetic. To overcome these problems, it has been suggested by Dr. Ken Langelier (Island Veterinary Hospital, Nanaimo, British Columbia) that we use a portable precision vaporizer. If a murrelet does not recover quickly from the anesthetic, it is necessary to have a warm, dark, quiet place for the bird to be held until it can be released (Harrison 1986, Heard 1988).

Processing time for several of the murrelets was increased because they were held for 0.1 to 1.2 hours awaiting measuring and tagging, but this extended holding period did not seem to affect their survivability. The one bird found dead four days after release was slightly injured by the net (wing abrasions) and was held for 1.1 hours after processing because it did not recover well from the anesthetic. It is possible that because of the injuries sustained during capture, or because of the effect of the anesthetic, the murrelet either died and was scavenged by a bald eagle, or its behaviour was altered and it was predated by a bald eagle. It is also possible that the death of the murrelet was unrelated to its capture experience because the bird appeared to be active (flying and diving) for three days after capture.

Including our capture effort in British Columbia, we radio-tagged 37 murrelets during the 1992 and 1993 field seasons. Of these, 13 murrelets were radio-tagged using only epoxy glue and 24 were radio-tagged by suturing the transmitter to the bird's back. Sixteen of the sutured tags were detected from 12 to 29 days after release of the bird, but only one of the glued tags was detected after 12 days of release (Burns et al. in prep. and this report). In the past, researchers who radio-tagged marbled murrelets by using epoxy glue to attach the radio tags to contour feathers were often plagued by loss of the signals long before the end of the radio tag's life (Varoujean et al. 1989, Ralph et al. 1989, but see Quinlan and Hughes 1992). The glue may soften and allow the tag to fall off (Varoujean et al. 1989), the bird may pull the tag off (Ralph et al. 1989), or the bird may preen out or moult the feathers to which the tag is glued. Suturing the tag keeps it on for longer periods of time, but because the suture material is absorbable the tag will be sloughed off eventually. We conclude that suturing the radio tag onto the bird's back is the best technique found to date.

The degree of disturbance caused by capturing and radio-tagging murrelets is unknown. When tagged murrelets are found on the water they should be followed by boat or skiff to record their activity and behaviour and compare their actions with murrelets which have not been tagged. If nests are located, remote video cameras could be installed at the site to compare the behaviour of the tagged murrelet to that of its untagged mate. It was promising that during this project, five of nine marbled murrelets returned to the capture site area, and that the activities of most of the birds we detected was consistent with those of other murrelets in the area.

Radio Telemetry Tracking

<u>Tracking From the Water</u> -- The average daily success rate of 37.5% for

relocating radio-tagged murrelets in this project suggests that radio tracking from the water may not be an efficient means of locating every bird that is tagged. Although this rate is based mainly (91%, n=89.0 hours) on opportunistic searches, even concentrated searches conducted from a boat are limited by the small area that can be covered, because the vessel's speed and the restricted range of receiving telemetry signals from antennae mounted in the boat's rigging.

Reception range can vary greatly depending on the height the antennae are mounted above the water, weather conditions, and wave height. Reception range is greater if the antennae are pointed in the direction of the transmitter. However, the observer will not know, when a signal is detected, whether the antennae are pointing at or away from the bird. Tests should be conducted to determine the maximum distances a signal can be detected from the boat in varying weather conditions. This would be especially important at night because the boat is usually at anchor and the antennae direction constantly changes as the boat swings with the tide or the wind. Signals received from the boat are also subject to "bounce" making it difficult to determine the direction the signal is coming from (R. Burns and L. Prestash, pers. obs.). Unless visual contact is made with the radio-tagged bird, the position of the bird should always be recorded as being in the general vicinity of the vessel.

Telemetry conducted from the boat appears to be best suited for determining the presence or absence of birds in a given area. It is also possible to monitor lengths of underwater dives and total foraging bouts. In addition, if a nest site is found, and is in direct line of sight of the water, the times of arrival and departure of the tagged bird can be monitored. In Unakwik Inlet, we were unsuccessful in making visual contact with radio-tagged murrelets on the water. However, we only made three attempts, and we feel that with more effort we would have been successful. In

Mussel Inlet, British Columbia, we were able to locate and observe individual murrelets on the water from a large vessel on three of four attempts (R. Burns and L. Prestash, unpubl. data).

Tracking From the Air -- Our daily average success rate (61.5%) for relocating all available tagged murrelets over the 10 days of aerial tracking suggests that air searches are the most effective means of relocating radio-tagged birds. We experienced no problem with "bounced" signals when locating birds in Prince William Sound, and the problems associated with interference can be reduced by conducting surveys when commercial salmon fishing is not occurring. Based on our success in locating signals, we believe that intensive air surveys in Prince William Sound would find all or most of the operating transmitters within the survey area, whether on water or on land.

Because all murrelets were located within one km of the shoreline, we suggest that survey routes designed to locate feeding areas follow the coastline at an altitude of 465 m and within 4.6 km of the shore (the average range and altitude at which we were able to detect signals).

Inland surveys have detected murrelets up to 84.3 km inland in Washington state (Hamer and Cummins 1992), and telemetry surveys in British Columbia have detected one murrelet up to 111.1 km from its suspected nest site (Burns et al. in prep). The average maximum range of 35.6 km for individuals in Prince William Sound suggests that future telemetry projects in this area would need the capability to cover large areas repeatedly, and that aerial tracking is the only practical means of conducting these surveys. Therefore, we suggest a survey route to cover the northern and central potions of Prince William Sound (the area in which we detected radio-tagged murrelets during this project) that would start at Cordova, then go to

Glacier Island, Wells Bay, Unakwik Inlet, and Eaglek Bay; then to Long Island, around Naked Island, along the east coast of Knight Island, to Green Island, and then back to Cordova, an approximate distance of 400 km (Fig.1). At an average speed of 170 km/hr it would require 2.4 hours to fly this route. Another 1.2 hours (approximately seven minutes of searching per pinpointed location) would be required to locate 10 radio-tagged murrelets in this area.

For the purpose of estimating the cost of conducting radio telemetry surveys in Prince William Sound, we suggest that four hours of fixed winged aircraft time be allocated for every day of search effort. At approximately $250 per hour for flight time, we estimate approximately $1,000 per day for tracking effort. If the purpose of future telemetry projects includes finding nests, then further funds will have to be allocated to get to the nest sites if they are in inaccessible areas. A helicopter is the most practical means of providing access. Assuming that nests are found in the Unakwik Inlet area, a helicopter could be brought from Valdez (Fig. 1) which is the closest base. Based on our experience in locating suspected nest sites in British Columbia (Burns et al. in prep.), two hours of helicopter flight time would be required for each nest site found (one hour of travelling time and one hour to reach the site). At approximately $750 per hour, the cost would be about $1500 for each nest.

Tracking From the Ground -- Ground searches can localize the signal from a transmitter to a small area. If the signal is suspected to be coming from a tree, then trees in the area can be climbed. The search area could be reduced substantially if the climber takes the receiver up each tree. When the receiver and transmitter are close to the same height the direction of the signal should become more clear, thus eliminating some of the marked off search area. The least likely nesting trees should be climbed first to minimize disturbance of the nesting bird.

In British Columbia, three murrelets have been tracked to suspected nest sites by first pinpointing the location from the air, and then conducting a ground search. The signals were localized on the ground to within 100 m, and the type of signal received indicated that the birds were in trees. The trees were not climbed to locate the actual nests, but the pattern of signals received were consistent with those of an incubating bird, that is, the signals were present, then absent, for alternate 24 hour periods (Burns et al. in prep).

We confirmed the accuracy of locating signals from the air and from the ground in Prince William Sound by finding the transmitter from the dead murrelet. We had no other opportunity to test inland tracking from the ground during this project so we can not determine the cost effectiveness of finding nests with this method compared to dawn watch techniques.

Patterns of Murrelet Activity

We could not make detailed behavioural observations of individuals because we did not make visual contact with any of the radio-tagged birds. However, daily patterns of activity of tagged birds, such as foraging trips, were consistent with daily activity patterns of untagged murrelets observed in this study. The morning stationary counts show that large numbers of murrelets flew towards the mouth of Unakwik Inlet before sunrise, probably en route to feeding grounds near the mouth of the Inlet. Five radio-tagged murrelets (Figs. 6, 7, 10, 11, and 12) were also found regularly in the southern Unakwik Inlet area, among many other murrelets. Five of the nine marbled murrelets were relocated in Siwash Bay, one of which was detected there on seven different days (Fig. 8). This area was frequently used by up to 200 murrelets as a foraging area.

The areas most frequently used by the tagged birds tended to be shallow waters near islands or exposed rocks, or in protected bays. Maximum water depth in Siwash Bay is 44 m, but the upper third of the bay is less than four m, and the waters near the bay's mouth are about 22 m. The waters around Olsen and Fairmount islands, near the mouth of Unakwik Inlet, are less than 17 m, with many exposed rocks. Deep water runs up the center of the inlet, which may be conducive to upwelling. Similarly, Storey, Naked, and Green islands, where a few relocations were made, all have extensive underwater shelves, with water depths of less than 17m. The birds were recorded as diving in these areas, and presumably prey was readily accessible in the shallow water. Our results complement those of Kuletz et al. (1994b) which demonstrated that nearshore, shallow waters in the Naked Island area had higher densities of murrelets than deeper waters further from shore.

Inferred activities of radio-tagged individuals were also consistent with the activities of untagged birds seen in the same areas. Radio-tagged birds were detected by signal to be diving when other murrelets were, and often when the signals from tagged birds indicated they were sitting on the water, other murrelets in the vicinity were seen loafing on the water.

We observed patterns of activity suggesting individuals had consistent habits related to time of day and foraging areas. Seven radio-tagged birds (Figs. 6 to 8, and 10 to 13) were frequently found in the same areas during air searches. This is consistent with observations made in other studies which noted that murrelets were repeatedly found foraging in the same areas (Rodway et al. 1992). Four murrelets were recorded flying past Miners Bay at night (between 2345 and 0337) or during the early morning hours (between 0350 and 0452). The intervals between the flights of three of these birds, each with a brood patch, suggested that they were feeding chicks (Simons 1980, Hirsch et al. 1981) and that the vessel's position was on their route between their feeding grounds and their nest sites.

These general patterns of activity, and the inferred activities of individuals suggest that most murrelets were not adversely affected by capturing and tagging (the exceptions, perhaps, being the dead bird, and the Kittlitz's murrelet, which was relocated only once after release).

Sealy (1974) suggested that activity patterns of murrelets changed as the breeding cycle progressed. Changing activity patterns during the breeding season were also noted in the three year Mussel Inlet study in British Columbia. In particular, most birds ranged farther to foraging areas before and during the incubation period than during the nestling period, when large numbers of birds remained in the Inlet to forage (Burns et al. in prep). The present study was conducted in the nestling period. If the pattern in Unakwik Inlet is similar to the pattern in Mussel Inlet, murrelets radio-tagged in Unakwik Inlet and followed during the incubation period may range farther than those which were tagged and followed during the nestling period in this study.

Conclusion

This pilot study has shown that it is feasible to use radio telemetry to track murrelets in Prince William Sound. Although data is limited by the length of time available to track murrelets, and a small sample size, we were able to get information on foraging activity of individual murrelets relative to the capture site. Our results demonstrate that some murrelets travel long distances (up to 150 km in a seven day period). Tracking murrelets from the air is necessary to cover the range used by murrelets in Prince William Sound, and is cost effective compared to boat searches for the same purpose. However, monitoring activity from boats can provide valuable information on repeat visits to foraging areas (once identified), and could be used to monitor visits to nests once they are located. Boat telemetry can also be used to gather information during periods of unfavourable weather conditions or at night when aerial searches are not feasible. Locating nests should be possible if netting and tracking would begin in late May.

Table 1. Number of murrelets flying out, flying in, and on the water during stationary counts in Unakwik Inlet, Prince William Sound, July 1993.

Date	Location	Type of count	Birds flying out	Birds flying in	Birds on water	Total
10 July	middle of Unakwik Inlet	morning	676	30	4	710
11 July	middle of Unakwik Inlet	morning	921	39	4	964
14 July	Siwash Bay	evening	144	51	18	213
15 July	Siwash Bay	morning	43	24	44	111
15 July	Siwash Bay	evening	170	54	17	241
16 July	Siwash Bay	evening	208	43	7	258
17 July	Siwash Bay	evening	140	37	9	186

Table 2. Measurements of murrelets caught in Unakwik Inlet, Prince William Sound, July 1993.

Murrelet species	Date of capture	Time of capture	Location of capture	Radio-tag frequency number	Plumage	Weight (g)	Culmen Length (mm)	Culmen Depth (mm)	Flat wing chord length (mm)	Tarsus length (mm)	Brood patch Present	Brood patch Development score*
marbled	16 July	0110	Siwash Bay	165.206	winter	241.0	12.1	5.1	134.0	17.6	yes	3
marbled	16 July	0135	Siwash Bay	165.257	summer	204.1	15.2	* *	130.0	17.8	yes	4
marbled	16 July	2240	Siwash Bay	164.933	transitional	204.0	16.9	5.6	127.0	12.5	yes	3
marbled	16 July	2310	Siwash Bay	164.809	summer	227.0	17.0	5.5	133.0	18.8	yes	3
marbled	16 July	2355	Siwash Bay	165.365	transitional	194.0	17.0	* *	130.0	18.2	yes	3
marbled	16 July	2355	Siwash Bay	164.869	summer	175.0	16.2	5.6	125.0	18.1	yes	3
marbled	17 July	0015	Siwash Bay	165.434	summer	233.0	16.7	5.9	135.0	18.6	no	-
marbled	17 July	0045	Siwash Bay	164.889	summer	223.0	17.4	5.9	135.0	18.5	yes	3
marbled	17 July	0418	Siwash Bay	164.430	summer	229.0	17.8	5.6	136.0	17.6	yes	4
Kittlitz's	19 July	0431	Miners Bay	165.643	summer	222.0	9.9	5.0	145.0	18.2	yes	3

* Scoring scheme for marbled murrelet brood patches after Sealy (1974) :

class 0, no evidence of defeathering;
class 1, loss of down and some contour feathers;
class 2, almost complete loss of down and most contour feathers with vascularization beginning;
class 3, complete loss of feathers with heavy vascularization (maximum development);
class 4, regression beginning with down appearing, especially around the edges, and sheaths of new contour feathers appearing;
class 5, most of area down-covered, contour feathers beginning to break out of sheaths;
class 6, complete regression, appearance as in class 0.

** Data not available

Table 3. Times and locations of *Alaskan Gypsy*, and number of detections made during hours of daylight and darkness while radio tracking murrelets in Prince William Sound from 16 to 22 July, 1993.

Date	Time vessel in area	Hours of telemetry during darkness [a]	Number of detections during darkness [b+d]	Hours of telemetry during daylight [c]	Number of detections during daylight [b+d]	Total number of detections [d+e]	Number of frequencies detected [f]	Number of murrelets tagged to date	Location of vessel
16 July	0000 to 1215	1.3	1 (1)	1.1	2 (1)	2	2	2	Siwash Bay (net site 3)
	1216 to ~1700	-	-	4.7	0	0	0	2	Siwash Bay to south end of Naked Island
	~1701 to 1937	-	-	2.6	1	1	1	2	south end of Naked Island to Siwash Bay
	~1938 to 2400	1.0	0	3.4	0	0	0 (2)	3	Siwash Bay (net site 3)
17 July	0000 to 1430	4.0	2 (1)	4.1	2 (1)	3	3	9	Siwash Bay (net site 3)
	1431 to 1803	-	-	1.1	1	1	1	9	to glacial sill in Unakwik Inlet, then back to Siwash Bay and net site 3
	1804 to 2400	1.0	3 (3)	4.9	6 (3)	5	4 (5)	9	Siwash Bay (net site 3)
18 July	0000 to 1610	4.0	4 (2)	6.9	3 (2)	2	2	9	Siwash Bay (net site 3)
	1611 to 1659	-	-	0.8	0	0	0	9	moved to Miners Bay (net site 4)
	1700 to 2400	1.0	0	1.4	0	0	0 (4)	9	Miners Bay (net site 4)
19 July	0000 to 1630	4.0		2.6	1	1	1	10	Miners Bay (net site 4)
	1631 to ~2045	-	-	-	-	-	-	10 [g]	to seven km south of Siwash Bay, then back to Miners Bay (net site 4)
	2046 to 2215	-	-	-	-	-	-	9	Miners Bay (net site 4)
	2216 to 2400	1.0	1	0.6	0	1	1 (2)	9	Cow Pens
20 July	0000 to 1300	4.0	3	1.2	1	4	3	9	Cow Pens
	1301 to 2400	1.0	1 (1)	5.0	2 (1)	2	1 (3)	9	Miners Bay (net site 4)
21 July	0000 to 1600	4.0	4 (1)	6.3	3 (1)	6	3	9	Miners Bay (net site 4)
	1601 to 1652	-	-	0.9	2	2	2	9	Miners Bay to Siwash Bay
	1653 to 2045	-	-	3.9	1	1	1	9	Siwash Bay to Liljegren Passage (Naked Island)
	2046 to 2400	1.0	0	2.2	0	0	0 (5)	9	Liljegren Passage (Naked Island)
22 July	0000 to 0420	4.0	0	0.3	0	0	0	9	Liljegren Passage (Naked Island)
	0421 to ~0800	-	-	3.7	0	0	0 (0)	9	Liljegren Passage (Naked Island) to south end of Knight Island
		31.3	19 (9)	57.7	25 (9)	31			

a From 2300 to 0400

b Detections which extended from daylight into dark or from dark into daylight are listed in both categories. The number of such detections are shown in () in each category.

c From 0400 to 2300

d Excluding signals received at time of release.

e Detections that continued into the next time period are only listed in the time period in which they were first detected.

f Number in () represents the number of individuals detected for that day.

g One murrelet was found dead during this period.

Table 4. Summary of telemetry data collected during water, air, and ground tracking, showing longevity of radio-tags, number of detections, and distances travelled by each radio-tagged murrelet in Prince William Sound, July and August, 1993.

Murrelet species	Radio-tag frequency number	Number of days after release signal detected	Number of detections of each signal	Average distance found from capture site* (km)	Average distance between consecutive relocations** (km)	Maximum range for each murrelet*** (km)
marbled	165.206	4	7	1.9	2.4	7.0
marbled	165.257	13	8	13.1	6.7	40.8
marbled	164.933	12	7	12.8	9.3	32.3
marbled	164.809	26	9	15.2	30.3	75.7
marbled	165.365	12	13	22.4	12.9	101.3
marbled	164.869	18	8	5.3	5.7	16.5
marbled	165.434	18	12	4.6	6.5	21.2
marbled	164.889	26	12	13.4	8.5	33.0
marbled	164.430	18	13	5.8	5.3	16.1
Kittlitz's	165.643	1	1	12.1	-	12.1
Total			90			
Average		14.8		10.66	8.76	35.6

* Determined by calculating the linear distance from each relocation site to the capture site. The sum of all the distances divided by the number of detections equals the average linear distance each murrelet was found from the capture site.

** Determined by calculating the linear distance between each consecutive relocation point. The sum of all the distances divided by the number of distances calculated equals the average linear distance each murrelet travelled between subsequent relocation points.

*** Maximum range for each murrelet determined by calculating the greatest linear distance between any two relocation points or between a relocation point and the capture site, whichever was the furthest.

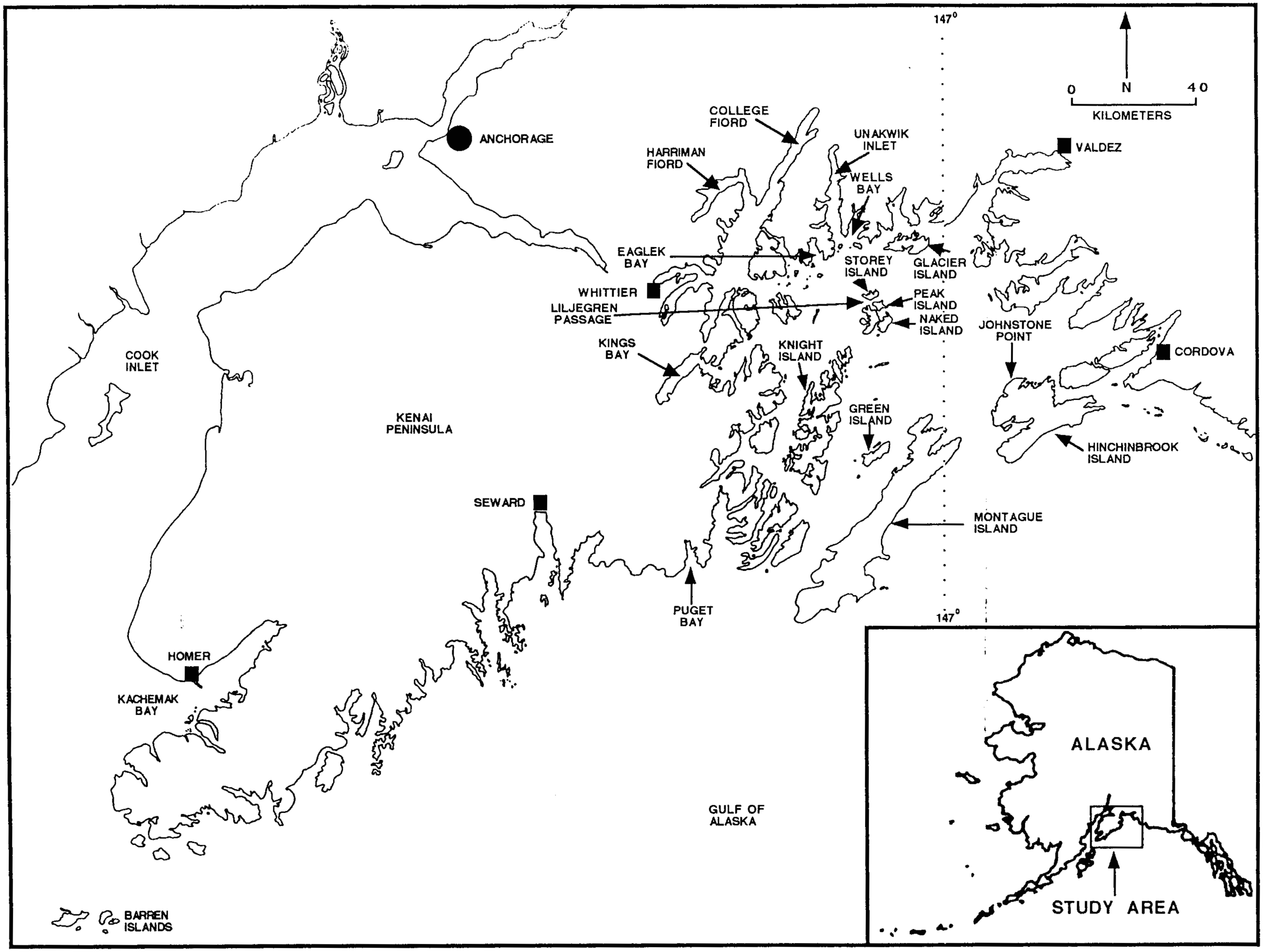


Figure 1. Study location for capturing and radio tagging murrelets in Prince William Sound, and search area for radio tracking murrelets, July and August, 1993.

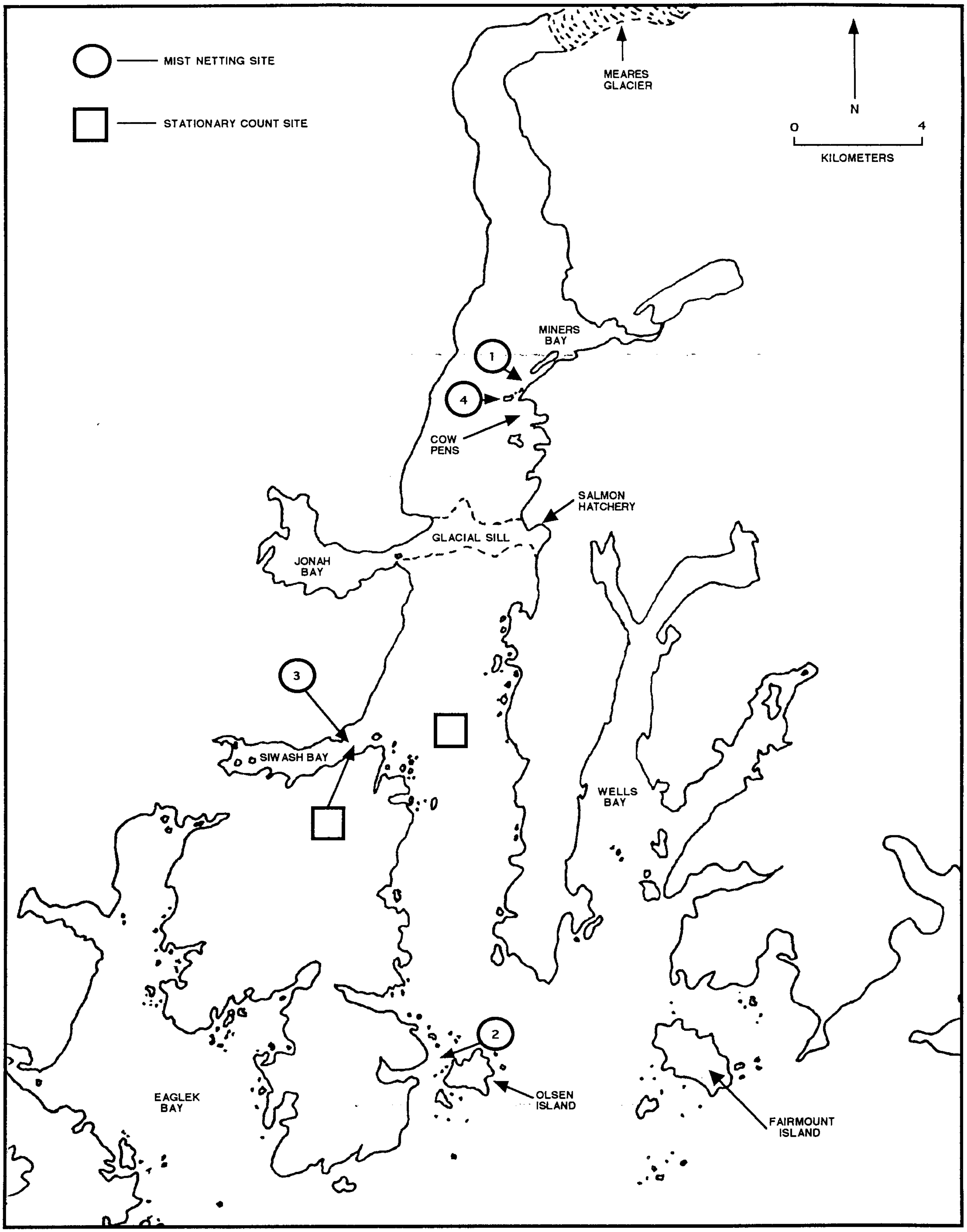


Figure 2. Location of stationary counts and mist netting sites for murrelets in Unakwik Inlet, Prince William Sound, July 1993.

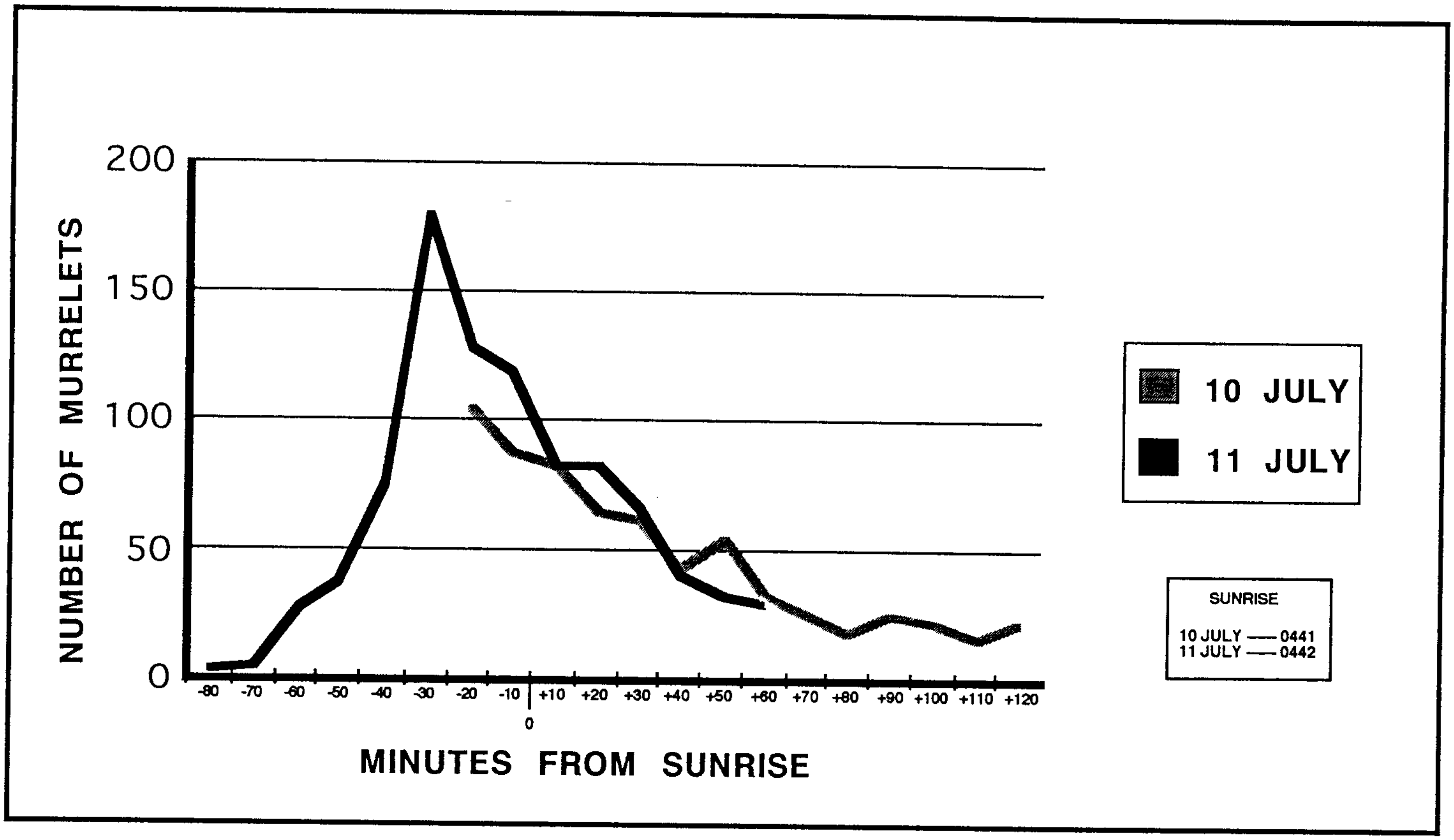


Figure 3. Number of murrelets flying out of Unakwik Inlet, Prince William Sound, before and after sunrise during morning stationary counts, 10 and 11 July, 1993.

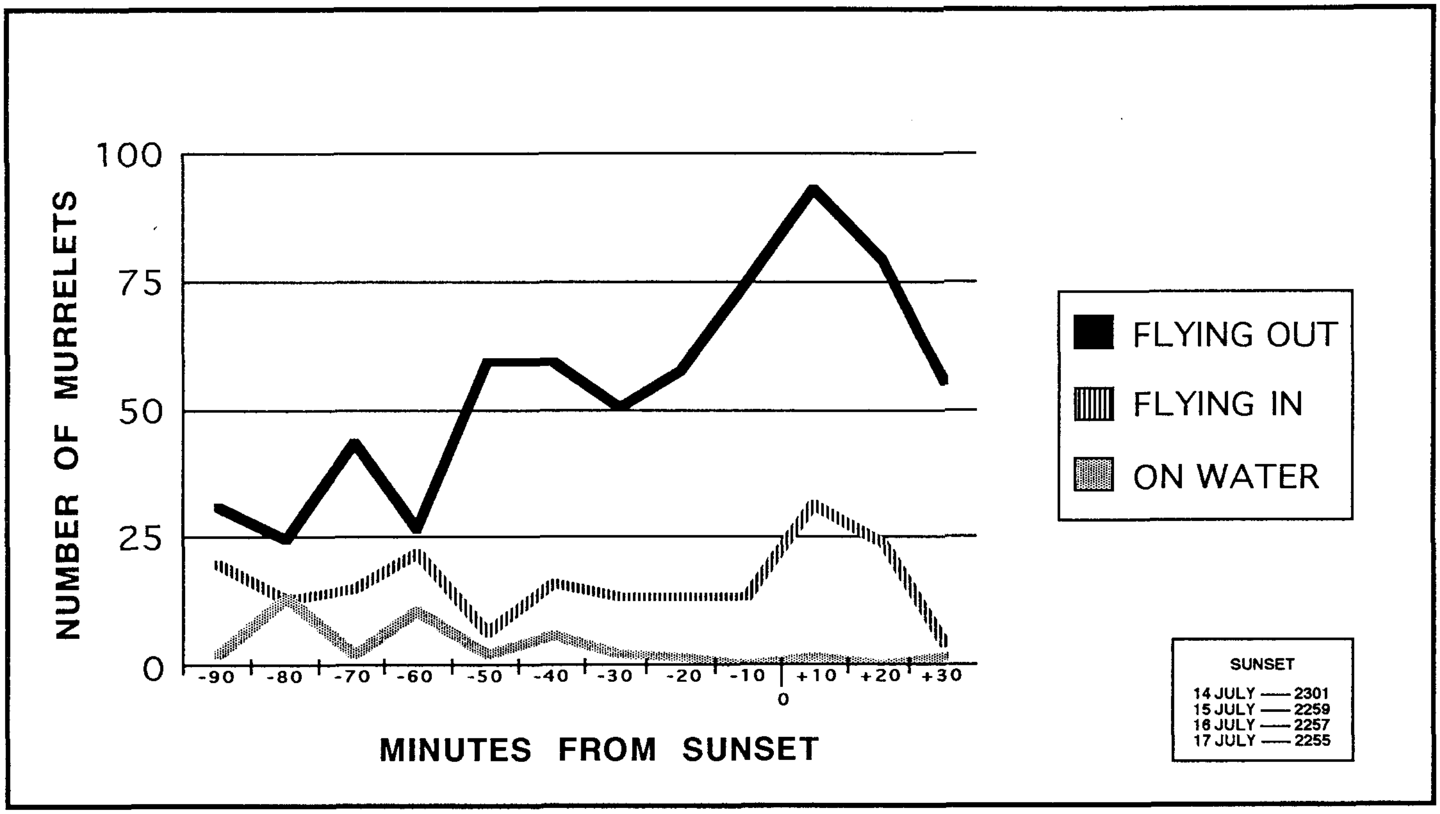


Figure 4. Activity of murrelets in Siwash Bay, Unakwik Inlet, Prince William Sound, before and after sunset during evening stationary counts on 14 through 17 July, 1993.

DATE		SEARCH TYPE	TIME	ACTIVITY	POSITION
16 JULY	A	RELEASED	0314	ON WATER	1 A
	B	WATER	0314 TO 0458, BIRD LEFT AREA BETWEEN 0459 AND 1000	DOVE CONTINUALLY FOR 23 MINUTES IMMEDIATELY AFTER RELEASE	1 B
	C	WATER	1937	ON WATER, THEN FLEW OUT OF AREA WHEN BOAT APPROACHED	1 C
17 JULY	A	WATER	PRESENT WHEN BOAT ENTERED AREA AT 1811, BIRD LEFT AREA AT 1930	NOT KNOWN	2 A
	B	WATER	BIRD RETURNED AT 1950 AND LEFT AT 2037	NOT KNOWN	2 B
	C	WATER	BIRD RETURNED AT 2143 AND WAS STILL PRESENT AT 2400	NOT KNOWN	2 C
18 JULY	A	WATER	0000 TO 0338 WHEN BIRD LEFT AREA	NOT KNOWN	3 A
	B	AIR	1423	DIVING	3 B
19 JULY	A	WATER	-	-	NOT FOUND
	B	AIR	1515	NOT KNOWN WHETHER ON LAND OR WATER	4 A
	C	GROUND	1945	BIRD DEAD, TRANSMITTER FOUND	4 B

○ — PINPOINTED LOCATION

□ — IN GENERAL AREA - BOX REPRESENTS POSITION OF VESSEL OR AIRCRAFT AT TIME OF DETECTION

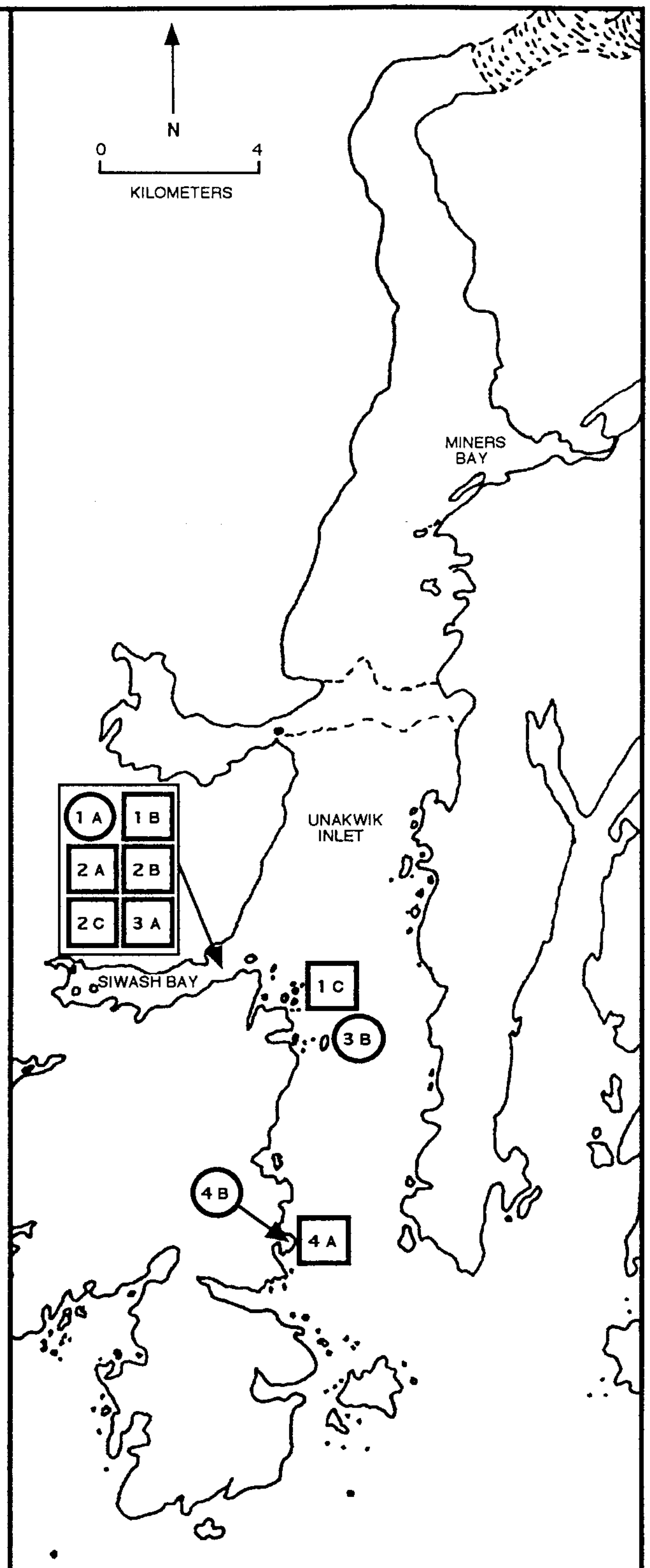
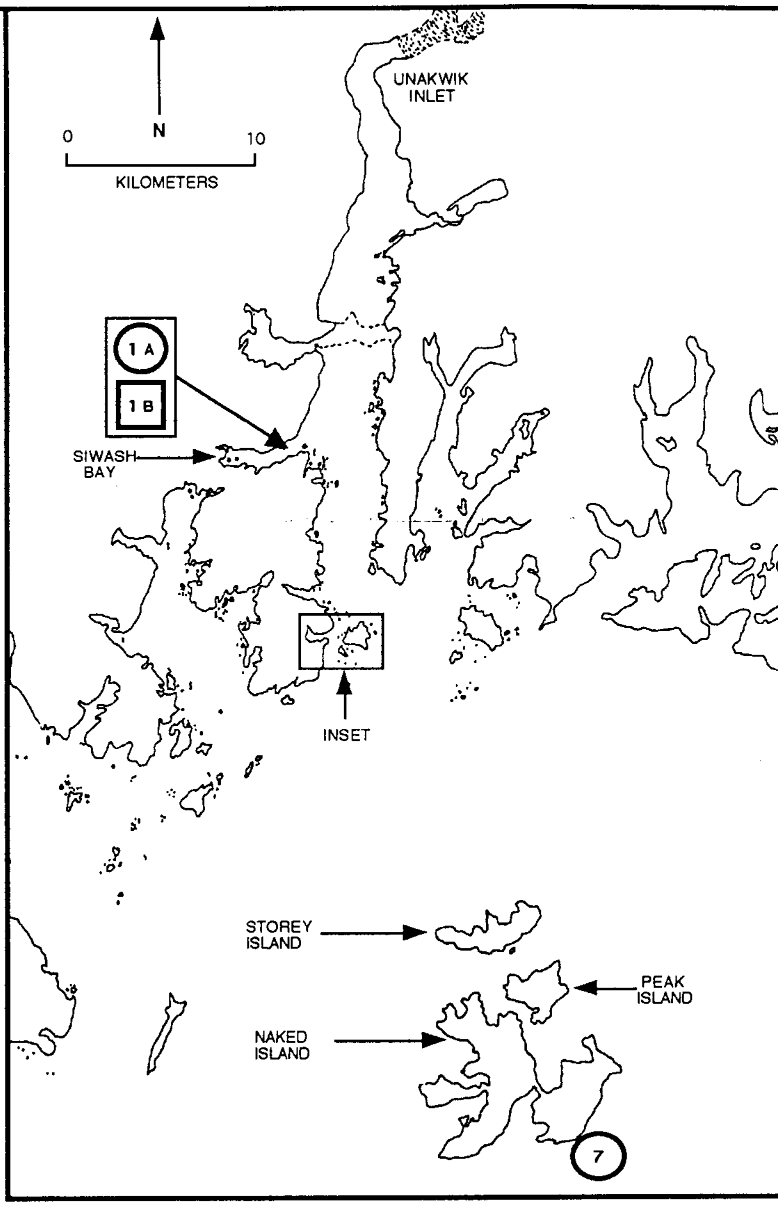


Figure 5. Date and times of detection, search type, activity, and position of marbled murrelet frequency number 165.206 determined by radio telemetry in Prince William Sound, July 1993.

DATE		SEARCH TYPE	TIME	ACTIVITY	POSITION
16 JULY	A	RELEASED	0242	FLEW AWAY	1 A
	B	WATER	0419 TO 0458, BIRD LEFT AREA BETWEEN 0459 AND 1000	NOT KNOWN	1 B
17 JULY		WATER	-	-	NOT FOUND
18 JULY	A	WATER	-	-	NOT FOUND
	B	AIR	1434	DIVING	2
19 JULY	A	WATER	-	-	NOT FOUND
	B	AIR	1656	DIVING	3
20 JULY		WATER	-	-	NOT FOUND
21 JULY		WATER	-	-	NOT FOUND
22 JULY		WATER	-	-	NOT FOUND
24 JULY		AIR	1242	ON WATER	4
26 JULY	A	AIR	1437	ON WATER, THEN FLEW AWAY	5 A
	B	AIR	1551	ON WATER	5 B
27 JULY		AIR	0707	DIVING	6
28 JULY	A	AIR	-	-	NOT FOUND
	B	AIR	2036	ON WATER	7
3 AUGUST		AIR	-	-	NOT FOUND
11 AUGUST		AIR	-	-	NOT FOUND
22 AUGUST		AIR	-	-	NOT FOUND
25 AUGUST		AIR	-	-	NOT FOUND



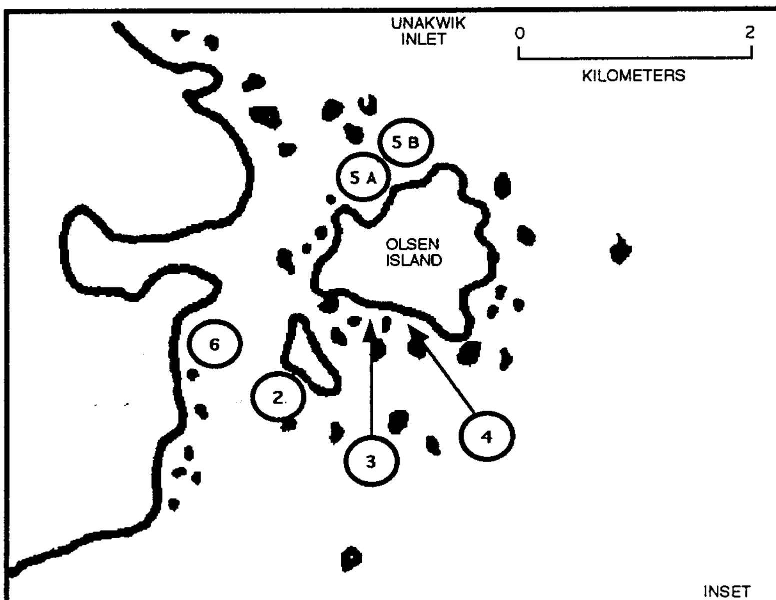
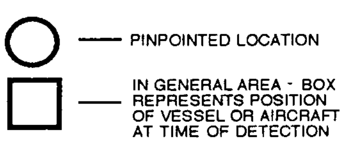


Figure 6. Date and times of detection, search type, activity, and position of marbled murrelet frequency number 165.257 determined by radio telemetry in Prince William Sound, July and August, 1993.

DATE		SEARCH TYPE	TIME	ACTIVITY	POSITION
16 JULY		RELEASED	2355	FLEW AWAY	1
17 JULY		WATER	-	-	NOT FOUND
18 JULY	A	WATER	-	-	NOT FOUND
	B	AIR	1433	DIVING	2
19 JULY	A	WATER	-	-	NOT FOUND
	B	AIR	1543	ON WATER	3
20 JULY		WATER	-	-	NOT FOUND
21 JULY		WATER	-	-	NOT FOUND
22 JULY		WATER	-	-	NOT FOUND
24 JULY		AIR	1047	ON WATER	4
26 JULY	A	AIR	1551	ON WATER, THEN FLEW AWAY	5 A
	B	AIR	1609	ON WATER	5 B
27 JULY		AIR	0630	DIVING	6
28 JULY	A	AIR	-	-	NOT FOUND
	B	AIR	1904	DIVING	7
3 AUGUST		AIR	-	-	NOT FOUND
11 AUGUST		AIR	-	-	NOT FOUND
22 AUGUST		AIR	-	-	NOT FOUND
25 AUGUST		AIR	-	-	NOT FOUND



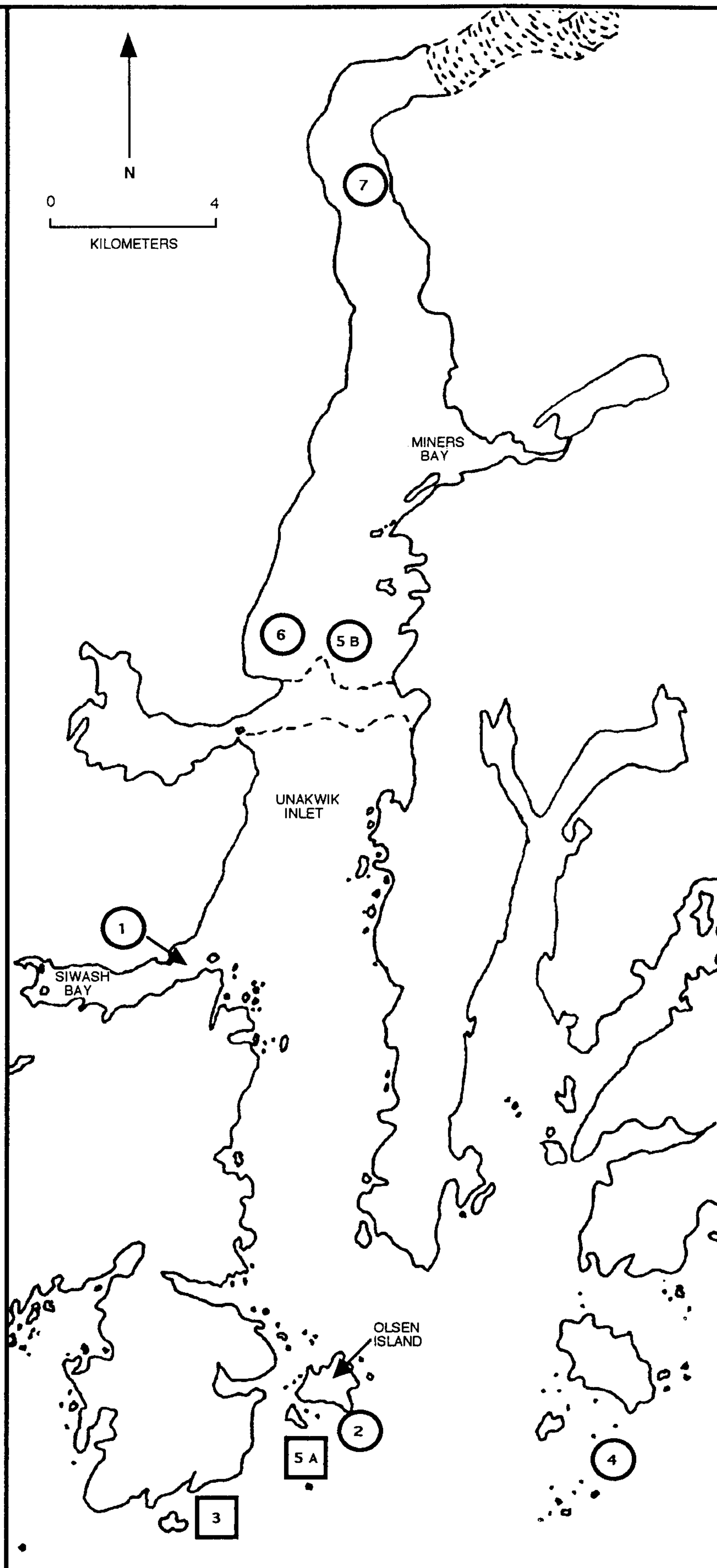
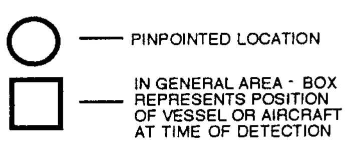
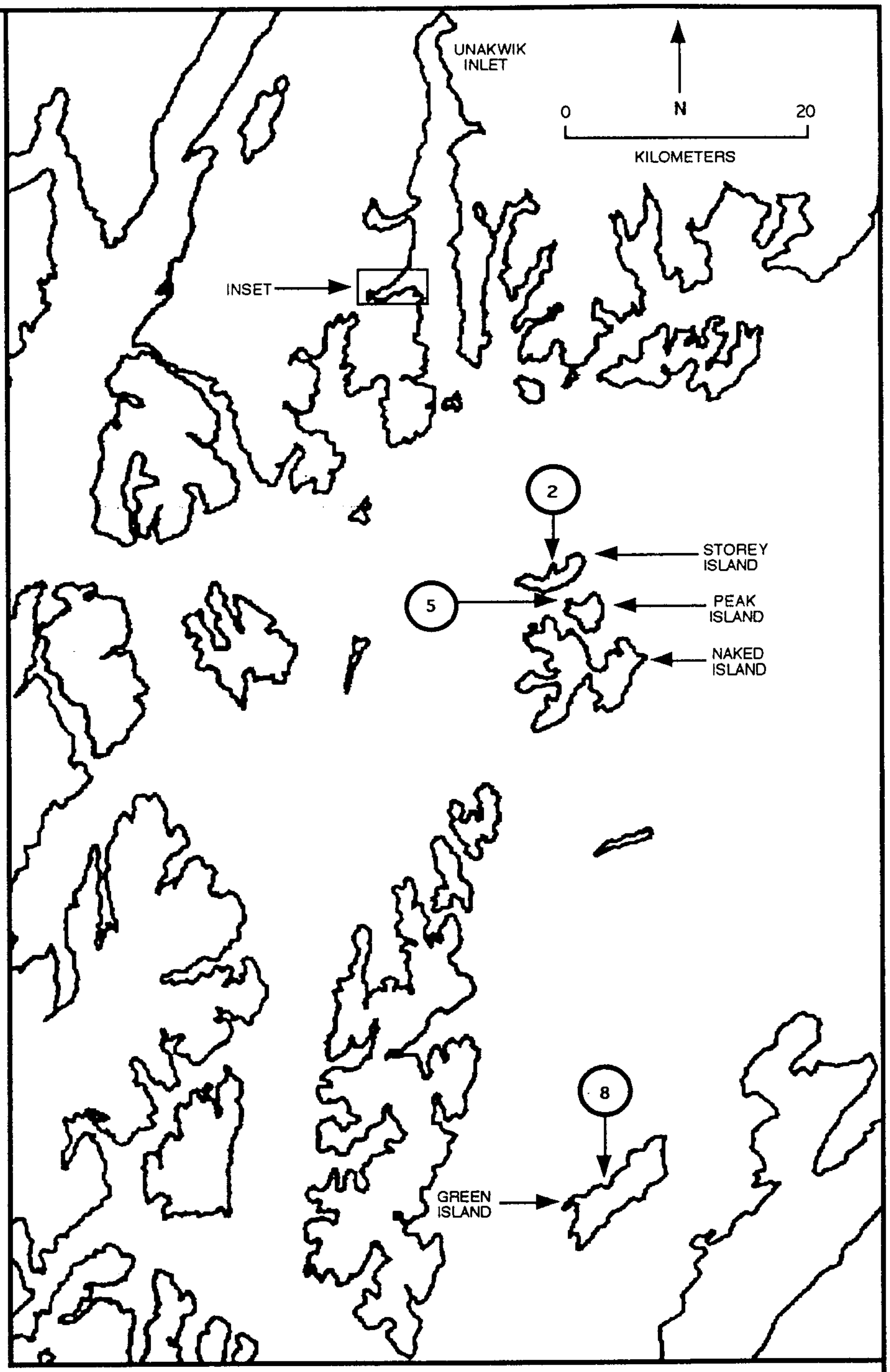


Figure 7. Date and times of detection, search type, activity, and position of marbled murrelet frequency number 164.933 determined by radio telemetry in Prince William Sound, July and August, 1993.

DATE		SEARCH TYPE	TIME	ACTIVITY	POSITION
17 JULY	A	RELEASED	0035	FLEW AWAY	1
	B	WATER	-	-	NOT FOUND
18 JULY	A	WATER	-	-	NOT FOUND
	B	AIR	1545	ON WATER	2
19 JULY	A	WATER	-	-	NOT FOUND
	B	AIR	1523	ON WATER	3
20 JULY		WATER	-	-	NOT FOUND
21 JULY		WATER	1640	NOT KNOWN	4
22 JULY		WATER	-	-	NOT FOUND
24 JULY		AIR	1314	DIVING	5
26 JULY		AIR	1707	DIVING	6
27 JULY		AIR	0645	ON WATER	7
28 JULY	A	AIR	1505	DIVING	8
	B	AIR	-	-	NOT FOUND
3 AUGUST		AIR	1111	ON WATER	9
11 AUGUST		AIR	1543	ON WATER	10
22 AUGUST		AIR	-	-	NOT FOUND
25 AUGUST		AIR	-	-	NOT FOUND





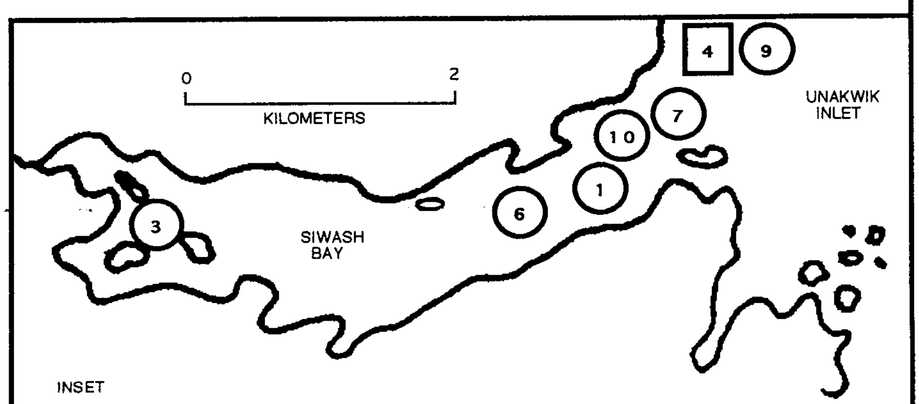


Figure 8. Date and times of detection, search type, activity, and position of marbled murrelet frequency number 164.809 determined by radio telemetry in Prince William Sound, July and August, 1993.

DATE		SEARCH TYPE	TIME	ACTIVITY	POSITION
17 JULY	A	RELEASED	0145	FLEW AWAY	1
	B	WATER	-	-	NOT FOUND
18 JULY	A	WATER	-	-	NOT FOUND
	B	AIR	1517	ON WATER	2
19 JULY	A	WATER	0442	FLEW PAST	3 A
	B	AIR	1438	ON WATER	3 B
20 JULY	A	WATER	0033	FLEW PAST	4 A
	B	WATER	ARRIVED 1341 LEFT 1810	DIVING AT TIMES	4 B
	C	WATER	ARRIVED 2259 LEFT 2315	NOT KNOWN	4 C
21 JULY	A	WATER	0330	FLEW PAST	5 A
	B	WATER	ARRIVED 0350 LEFT 0411	FLEW IN AND BEGAN DIVING	5 B
	C	WATER	ARRIVED 1035 LEFT 1305	NOT KNOWN	5 C
22 JULY		WATER	-	-	NOT FOUND
24 JULY		AIR	1214	DIVING	6
26 JULY		AIR	1616	DIVING	7
27 JULY		AIR	-	-	NOT FOUND
28 JULY	A	AIR	1453	DIVING	8 A
	B	AIR	2057	ON WATER	8 B
3 AUGUST		AIR	-	-	NOT FOUND
11 AUGUST		AIR	-	-	NOT FOUND
22 AUGUST		AIR	-	-	NOT FOUND
25 AUGUST		AIR	-	-	NOT FOUND

○ — PINPOINTED LOCATION

□ — IN GENERAL AREA - BOX REPRESENTS POSITION OF VESSEL OR AIRCRAFT AT TIME OF DETECTION

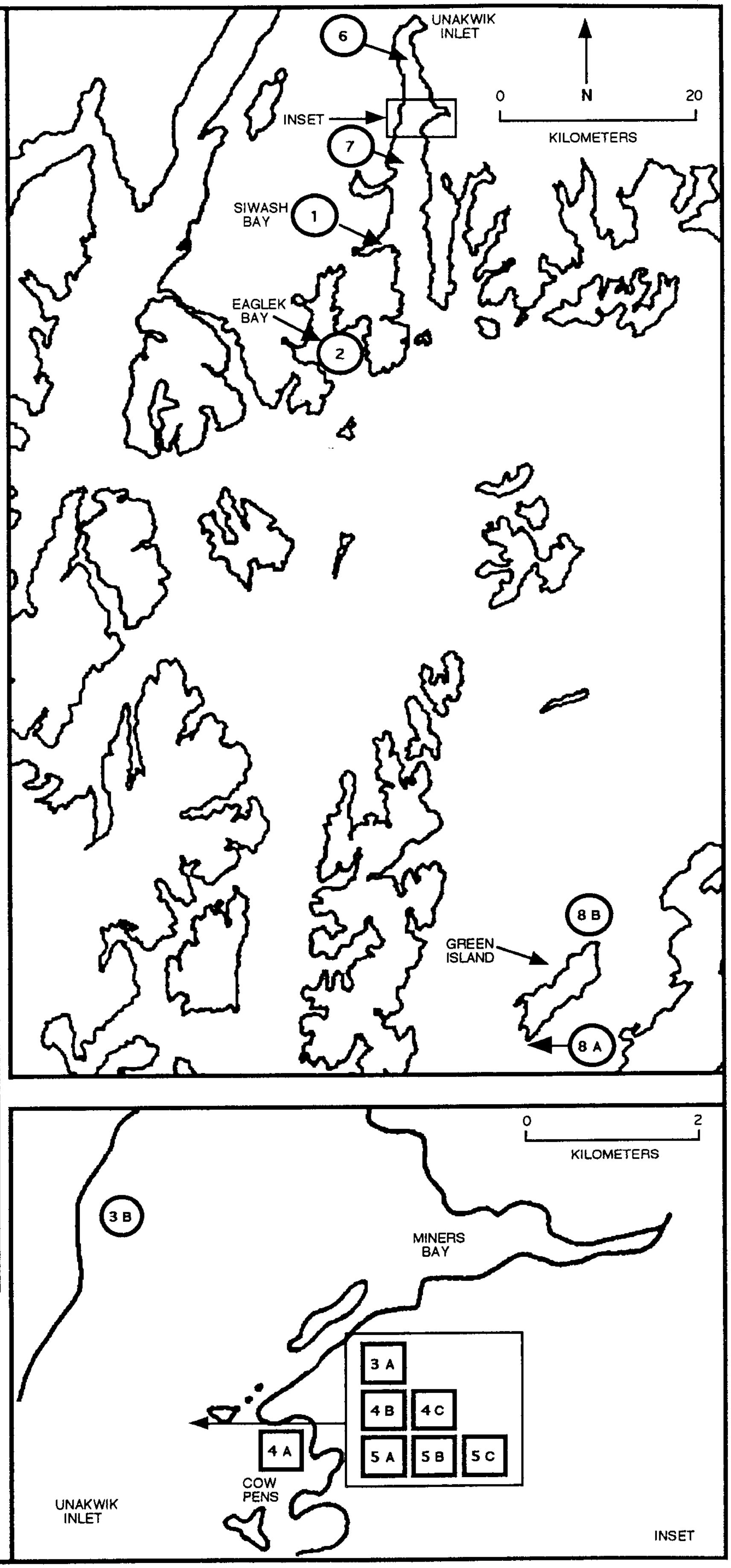
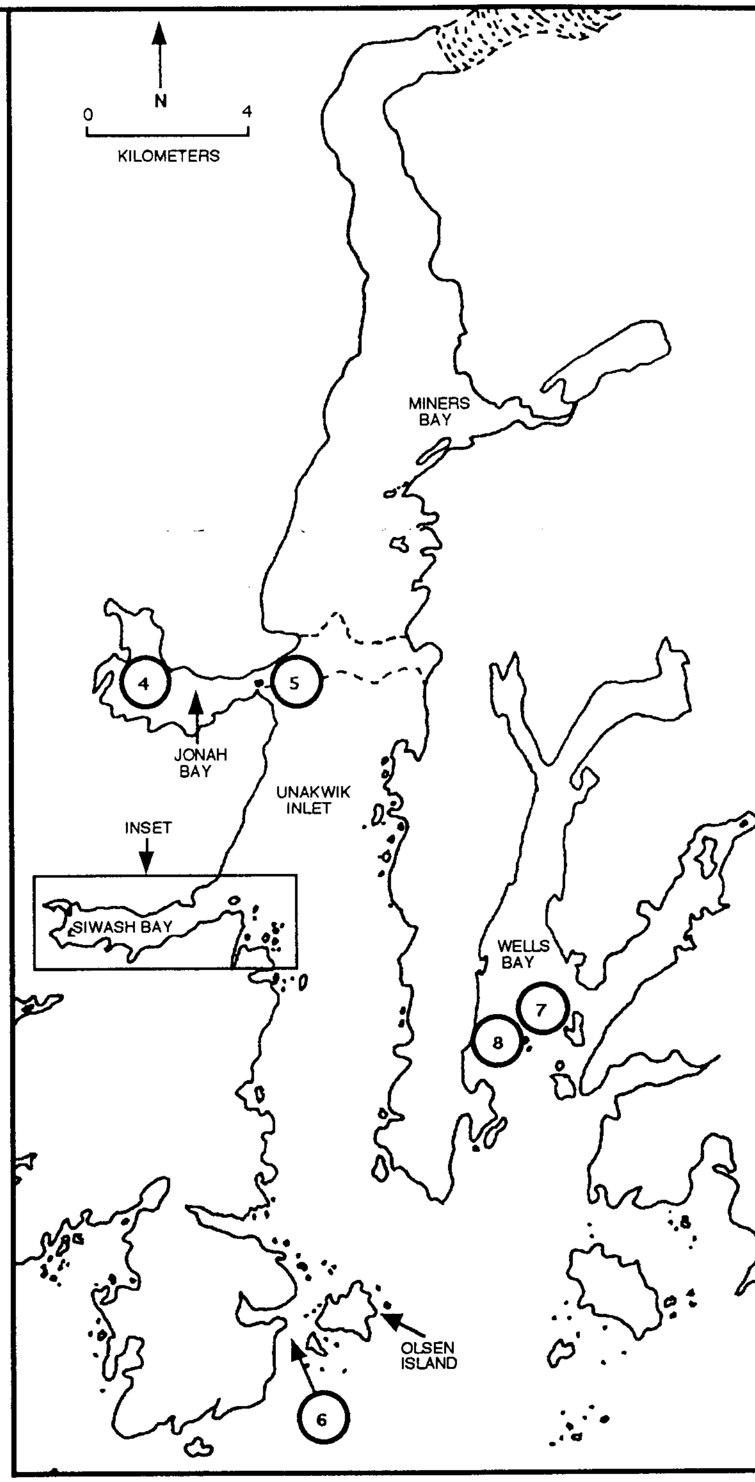
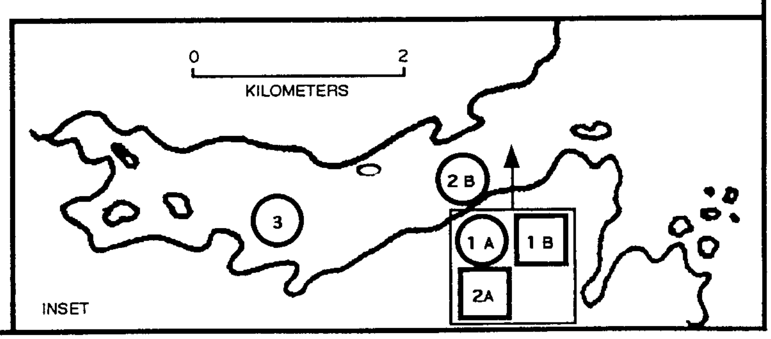


Figure 9. Date and times of detection, search type, activity, and position of marbled murrelet frequency number 165.365 determined by radio telemetry in Prince William Sound, July and August, 1993.

DATE		SEARCH TYPE	TIME	ACTIVITY	POSITION
17 JULY	A	RELEASED	0145	FLEW AWAY	1 A
	B	WATER	ARRIVED 2132 AND PRESENT TO 2400	NOT KNOWN	1 B
18 JULY	A	WATER	0000 TO 1610 WHEN BOAT LEFT AREA	DIVING AT TIMES	2 A
	B	AIR	1417	ON WATER DOVE ONCE	2 B
19 JULY	A	WATER	-	-	NOT FOUND
	B	AIR	1526	ON WATER	3
20 JULY		WATER	-	-	NOT FOUND
21 JULY		WATER	-	-	NOT FOUND
22 JULY		WATER	-	-	NOT FOUND
24 JULY		AIR	1124	ON WATER DOVE ONCE	4
26 JULY		AIR	1618	DIVING	5
27 JULY		AIR	0714	DIVING	6
28 JULY	A	AIR	-	-	NOT FOUND
	B	AIR	1839	ON WATER	7
3 AUGUST		AIR	1143	DIVING	8
11 AUGUST		AIR	-	-	NOT FOUND
22 AUGUST		AIR	-	-	NOT FOUND
25 AUGUST		AIR	-	-	NOT FOUND



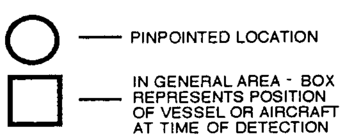


○ —— PINPOINTED LOCATION

□ —— IN GENERAL AREA - BOX REPRESENTS POSITION OF VESSEL OR AIRCRAFT AT TIME OF DETECTION

Figure 10. Date and times of detection, search type, activity, and position of marbled murrelet frequency number 164.869 determined by radio telemetry in Prince William Sound, July and August, 1993.

DATE		SEARCH TYPE	TIME	ACTIVITY	POSITION
17 JULY	A	RELEASED	0214	FLEW AWAY	1 A
	B	WATER	ARRIVED 0308 LEFT 0347	DIVING AT TIMES	1 B
	C	WATER	PRESENT WHEN BOAT ENTERED AREA AT 1803 BIRD LEFT AREA AT 2138	NOT KNOWN	1 C
18 JULY	A'	WATER	ARRIVED 0216 LEFT 0332	NOT KNOWN	2 A
	B	AIR	1428	DIVING	2 B
19 JULY	A	WATER	-	-	NOT FOUND
	B	AIR	1552	ON WATER	3
20 JULY		WATER	-	-	NOT FOUND
21 JULY	A	WATER	0452	FLEW PAST	4 A
	B	WATER	1742	NOT KNOWN	4 B
22 JULY		WATER	-	-	NOT FOUND
24 JULY		AIR	1110	DIVING	5
26 JULY		AIR	1603	ON WATER	6
27 JULY		AIR	0656	ON WATER	7
28 JULY	A	AIR	-	-	NOT FOUND
	B	AIR	1828	ON WATER	8
3 AUGUST		AIR	1055	ON WATER	9
11 AUGUST		AIR	-	-	NOT FOUND
22 AUGUST		AIR	-	-	NOT FOUND
25 AUGUST		AIR	-	-	NOT FOUND



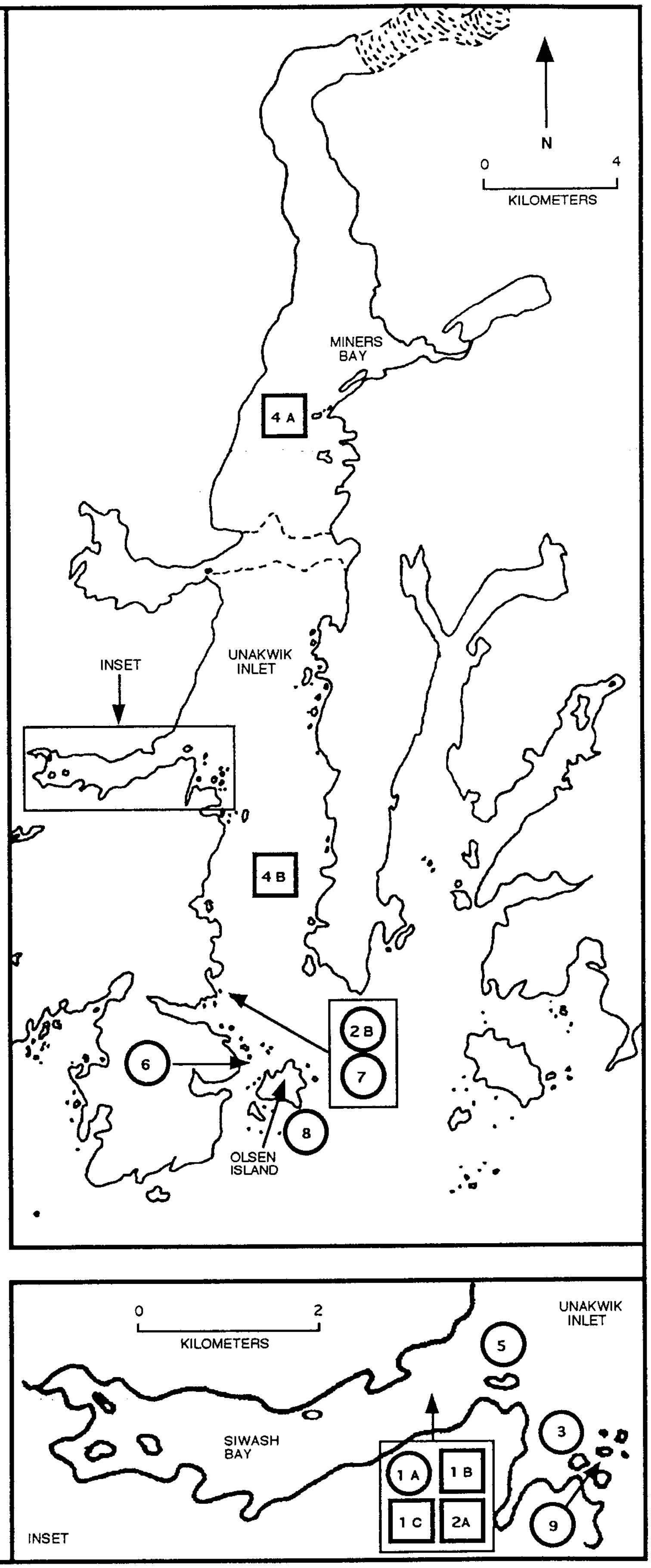
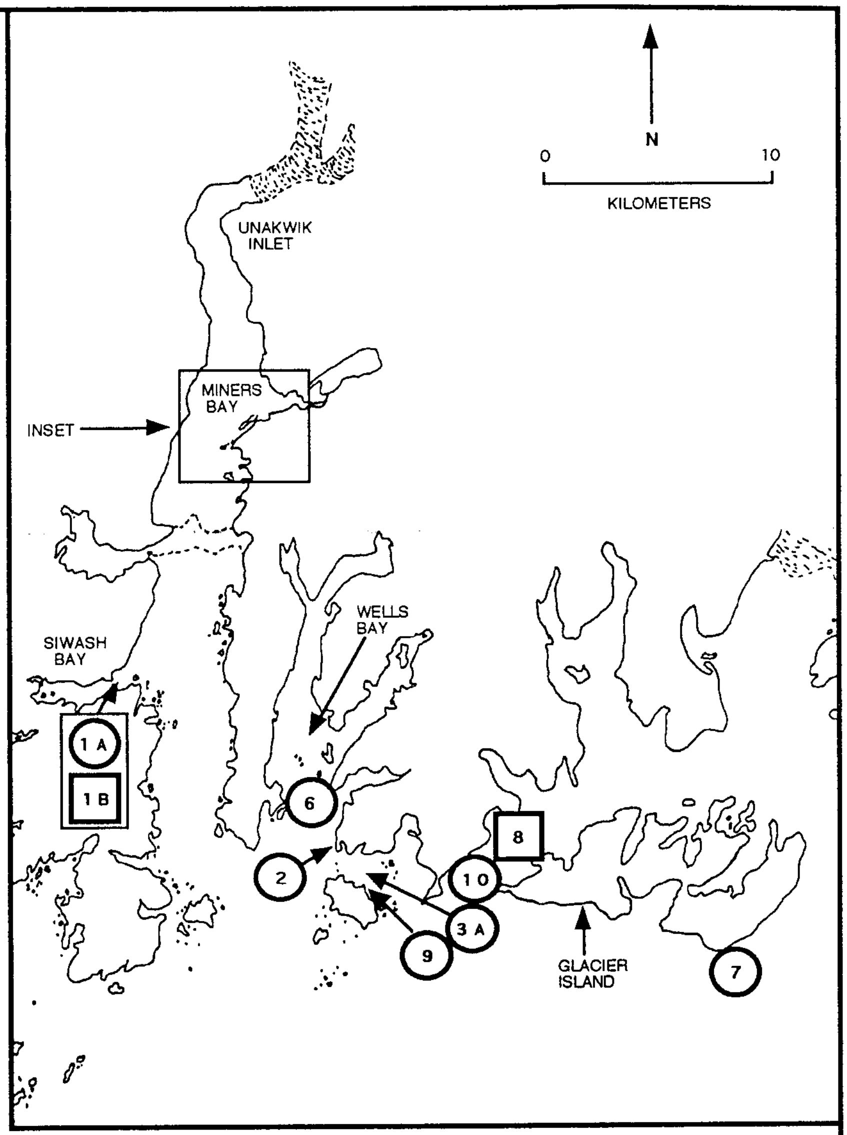


Figure 11. Date and times of detection, search type, activity, and position of marbled murrelet frequency number 165.434 determined by radio telemetry in Prince William Sound, July and August, 1993.

DATE		SEARCH TYPE	TIME	ACTIVITY	POSITION
17 JULY	A	RELEASED	0245	ON WATER	1 A
	B	WATER	0245 TO 1000, BIRD LEFT AREA BETWEEN 1001 AND 1042	DIVING AT TIMES	1 B
18 JULY	A	WATER	-	-	NOT FOUND
	B	AIR	1445	ON WATER	2
19 JULY	A	AIR	1616	DIVING	3 A
	B	WATER	2345	FLEW PAST	3 B
20 JULY		WATER	0025	FLEW PAST	4
21 JULY	A	WATER	0220	FLEW PAST	5 A
	B	WATER	ARRIVED IN AREA 0256 AND LEFT 0320	NOT KNOWN	5 B
22 JULY		WATER	-	-	NOT FOUND
24 JULY		AIR	1058	ON WATER	6
26 JULY		AIR	1407	DIVING	7
27 JULY		AIR	-	-	NOT FOUND
28 JULY	A	AIR	-	-	NOT FOUND
	B	AIR	1819	DIVING	8
3 AUGUST		AIR	1045	DIVING	9
11 AUGUST		AIR	1500	ON WATER	10
22 AUGUST		AIR	-	-	NOT FOUND
25 AUGUST		AIR	-	-	NOT FOUND

○ —— PINPOINTED LOCATION

□ —— IN GENERAL AREA - BOX REPRESENTS POSITION OF VESSEL OR AIRCRAFT AT TIME OF DETECTION



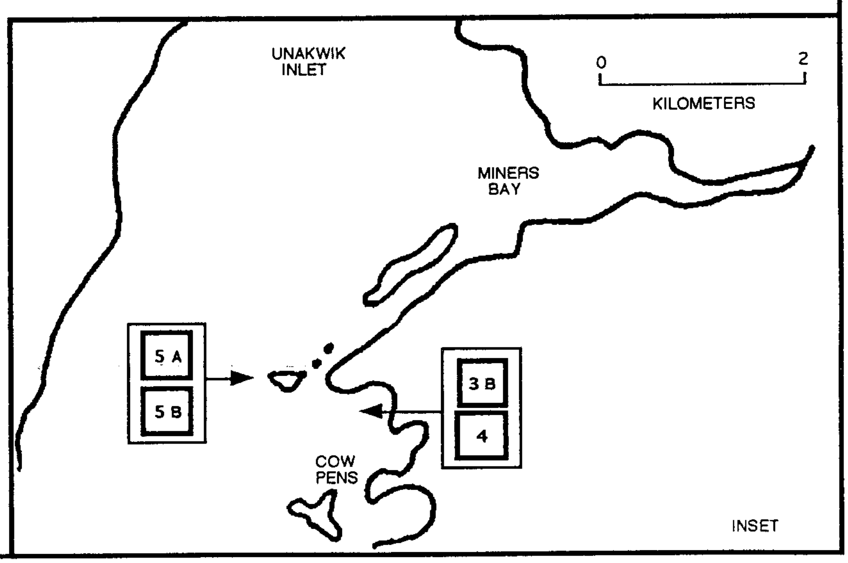
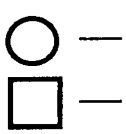


Figure 12. Date and times of detection, search type, activity, and position of marbled murrelet frequency number 164.889 determined by radio telemetry in Prince William Sound, July and August, 1993.

DATE		SEARCH TYPE	TIME	ACTIVITY	POSITION
17 JULY	A	RELEASED	0515	ON WATER	1 A
	B	WATER	0515 TO 1403 BIRD LEFT AREA BETWEEN 1404 AND 1440	NOT KNOWN	1 B
	C	WATER	PRESENT WHEN BOAT RETURNED TO AREA AT 1812, BIRD STILL PRESENT AT 2400	NOT KNOWN	1 C
18 JULY	A	WATER	0000 TO 0425 WHEN BIRD LEFT AREA	DIVING AT TIMES	2 A
	B	WATER	0931 TO 1610 WHEN BOAT LEFT AREA	DIVING AT TIMES	2 B
	C	AIR	1411	ON WATER	2 C
19 JULY	A	WATER	-	-	NOT FOUND
	B	AIR	1559	ON WATER	3
20 JULY	A	WATER	0337	FLEW PAST	4 A
	B	WATER	0418	FLEW PAST	4 B
21 JULY		WATER	1652	NOT KNOWN	5
22 JULY		WATER	-	-	NOT FOUND
24 JULY		AIR	1139	ON WATER	6
26 JULY		AIR	1631	ON WATER	7
27 JULY		AIR	0626	ON WATER	8
28 JULY	A	AIR	-	-	NOT FOUND
	B	AIR	1853	ON WATER	9
3 AUGUST		AIR	1106	DOVE ONCE	10
11 AUGUST		AIR	-	-	NOT FOUND
22 AUGUST		AIR	-	-	NOT FOUND
25 AUGUST		AIR	-	-	NOT FOUND



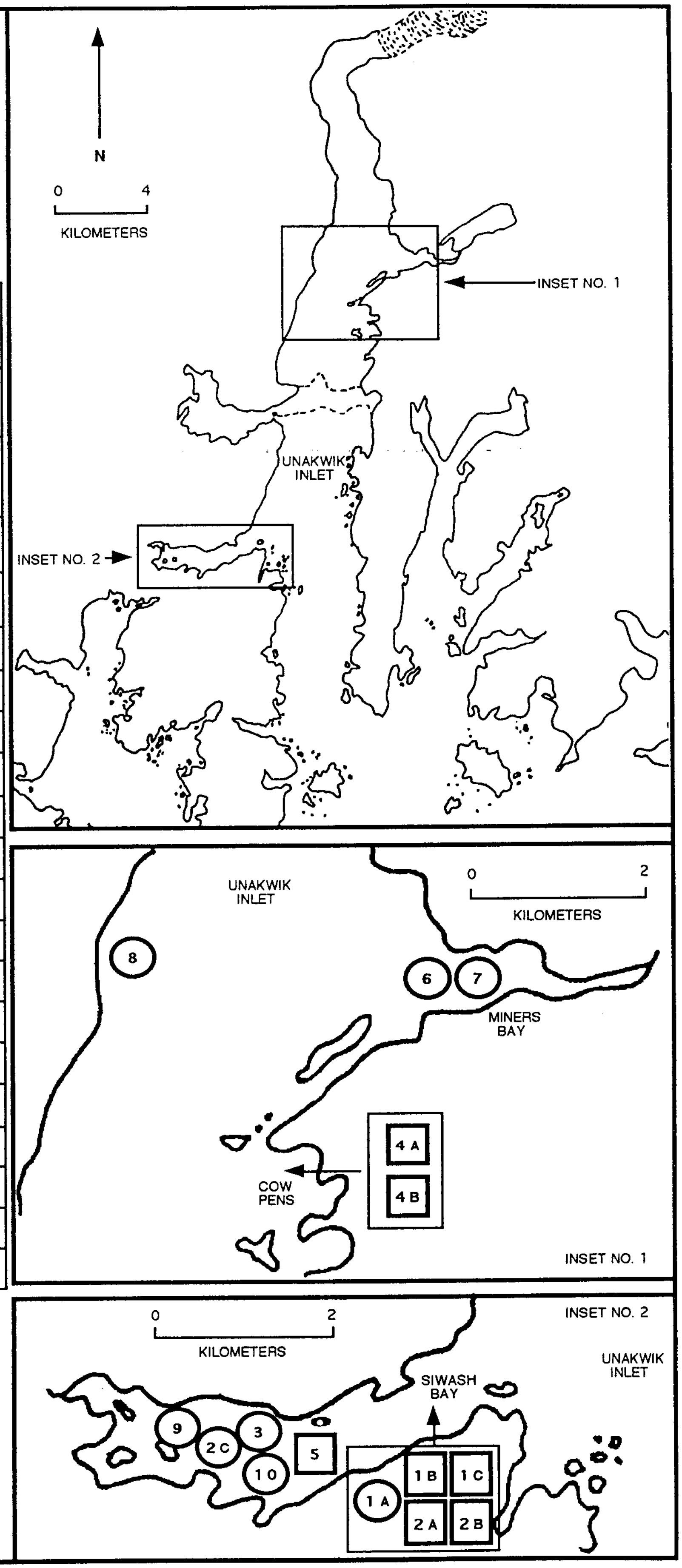


Figure 13. Date and times of detection, search type, activity, and position of marbled murrelet frequency number 164.430 determined by radio telemetry in Prince William Sound, July and August, 1993.

DATE		SEARCH TYPE	TIME	ACTIVITY	POSITION
19 JULY	A	RELEASED	0543	FLEW AWAY	1 A
	B	WATER	-	-	NOT FOUND
	C	AIR	1454	ON WATER, DOVE ONCE	1 B
20 JULY		WATER	-	-	NOT FOUND
21 JULY		WATER	-	-	NOT FOUND
22 JULY		WATER	-	-	NOT FOUND
24 JULY		AIR	-	-	NOT FOUND
26 JULY		AIR	-	-	NOT FOUND
27 JULY		AIR	-	-	NOT FOUND
28 JULY	A	AIR	-	-	NOT FOUND
	B	AIR	-	-	NOT FOUND
3 AUGUST		AIR	-	-	NOT FOUND
11 AUGUST		AIR	-	-	NOT FOUND
22 AUGUST		AIR	-	-	NOT FOUND
25 AUGUST		AIR	-	-	NOT FOUND

○ —— PINPOINTED LOCATION

□ —— IN GENERAL AREA - BOX REPRESENTS POSITION OF VESSEL OR AIRCRAFT AT TIME OF DETECTION

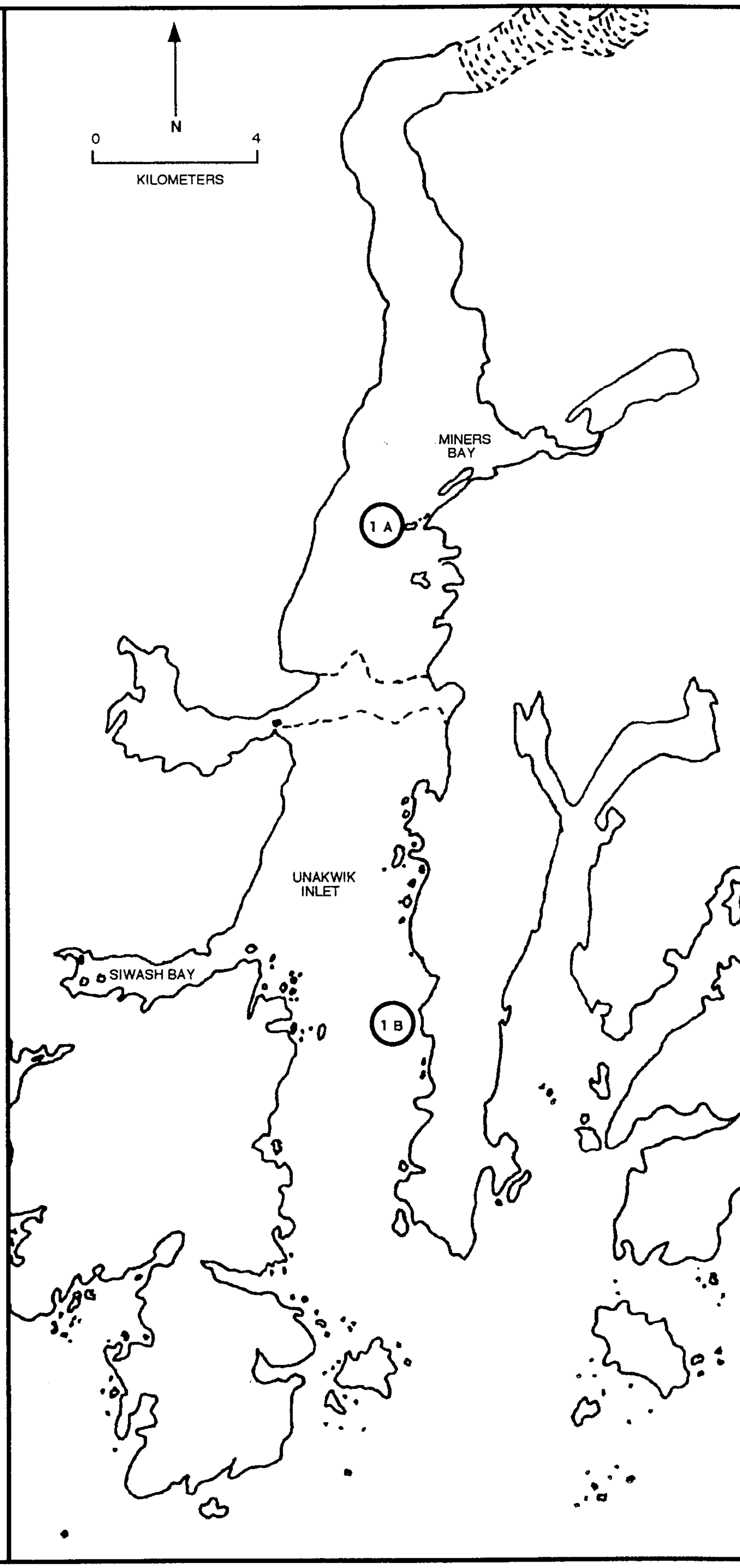


Figure 14. Date and times of detection, search type, activity, and position of Kittlitz's murrelet frequency number 165.643 determined by radio telemetry in Prince William Sound, July and August, 1993.

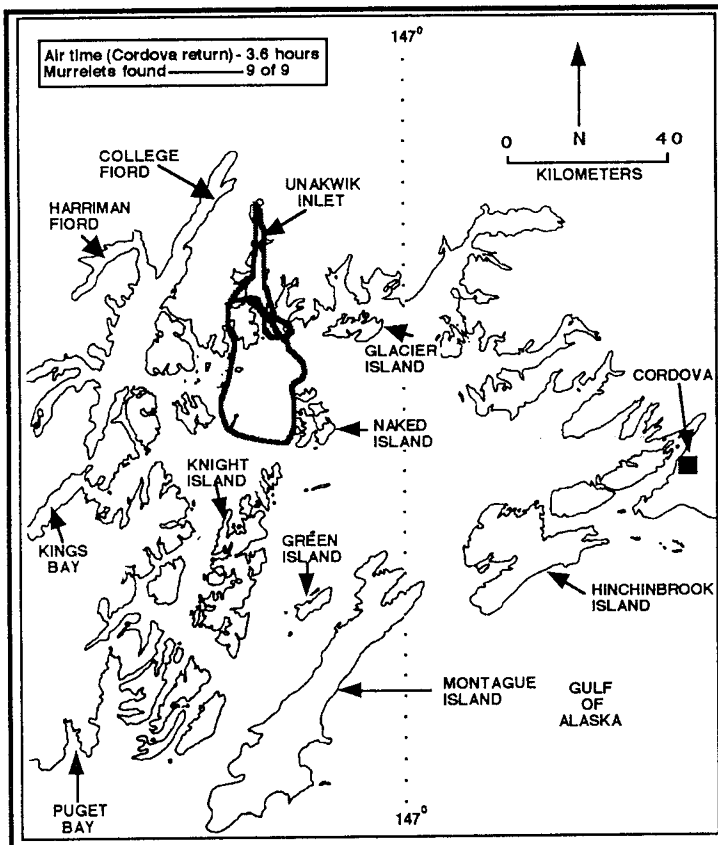


Figure 15a. Telemetry route, duration of flight, and number of radio tagged murrelets found in Prince William Sound, 18 July, 1993.

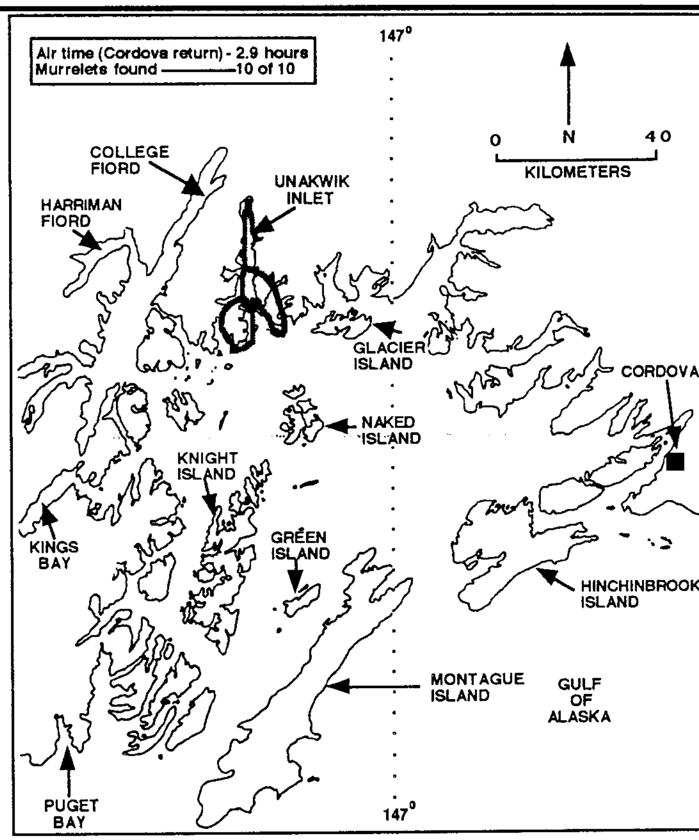


Figure 15b. Telemetry route, duration of flight, and number of radio tagged murrelets found in Prince William Sound, 19 July, 1993.

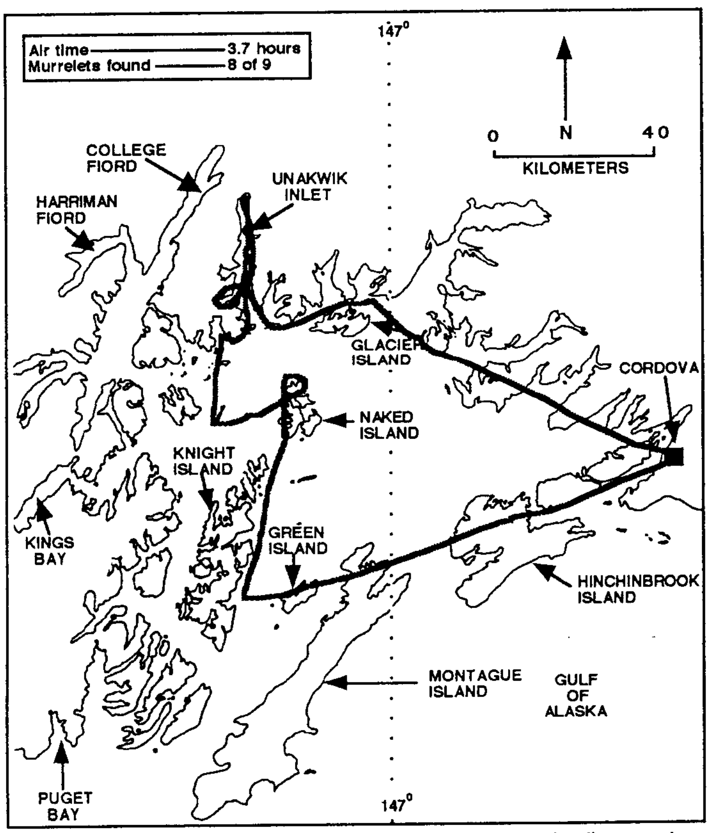


Figure 15c. Telemetry route, duration of flight, and number of radio tagged murrelets found in Prince William Sound, 24 July, 1993.

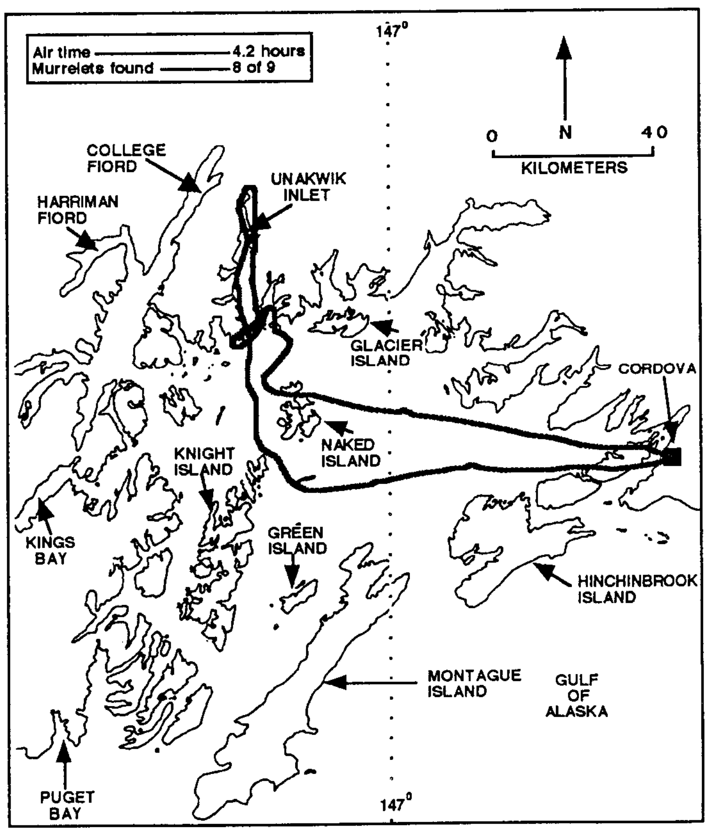


Figure 15d. Telemetry route, duration of flight, and number of radio tagged murrelets found in Prince William Sound, 26 July, 1993.

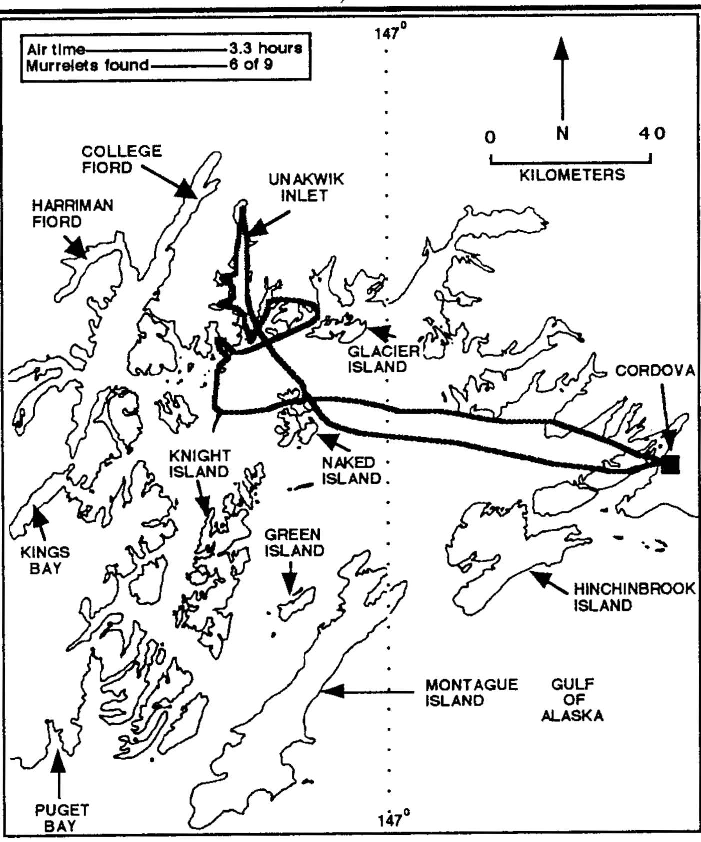


Figure 15e. Telemetry route, duration of flight, and number of radio tagged murrelets found in Prince William Sound, 27 July, 1993.

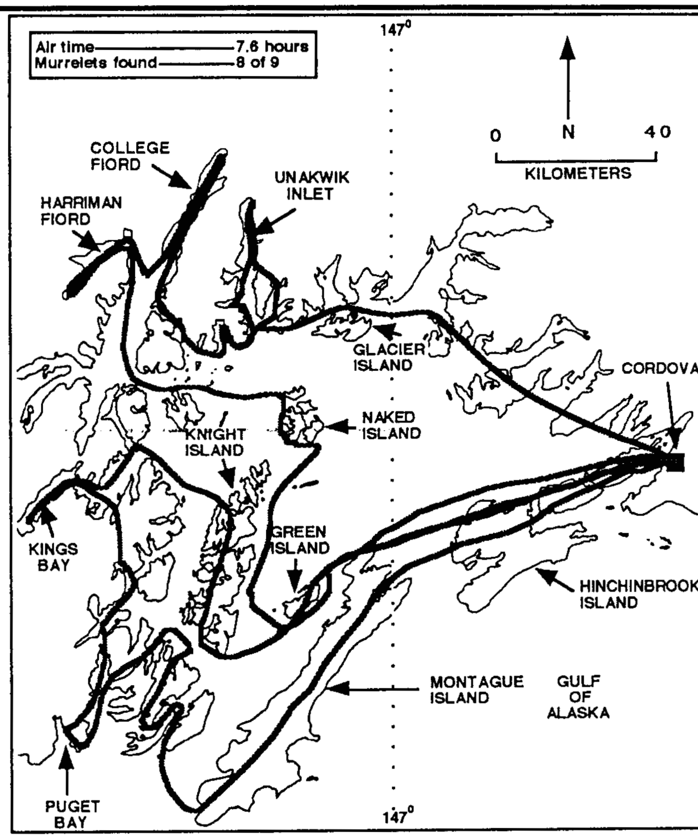


Figure 15f. Telemetry route, duration of flight, and number of radio tagged murrelets found in Prince William Sound, 28 July, 1993.

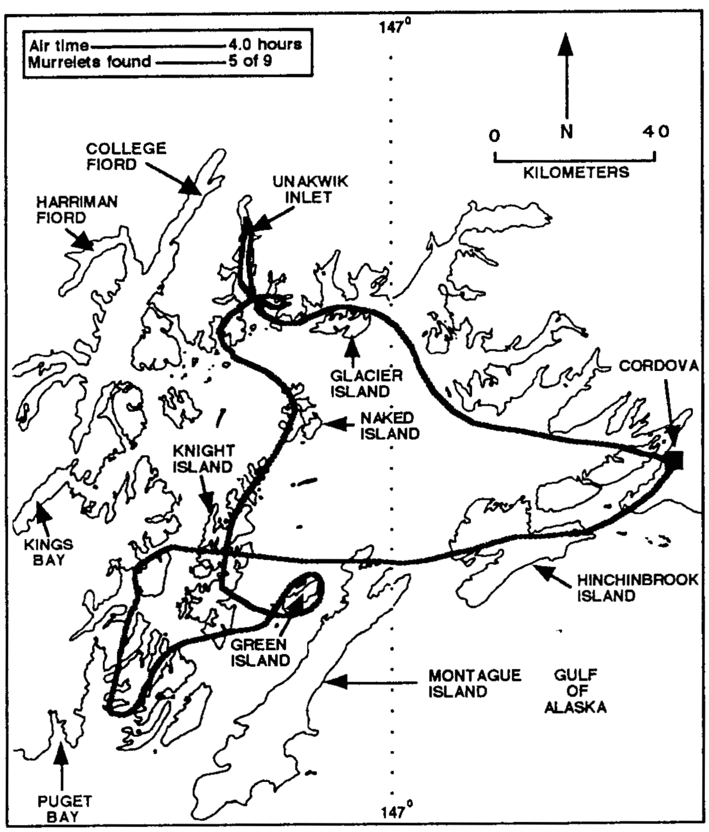


Figure 15g. Telemetry route, duration of flight, and number of radio tagged murrelets found in Prince William Sound, 3 August, 1993.

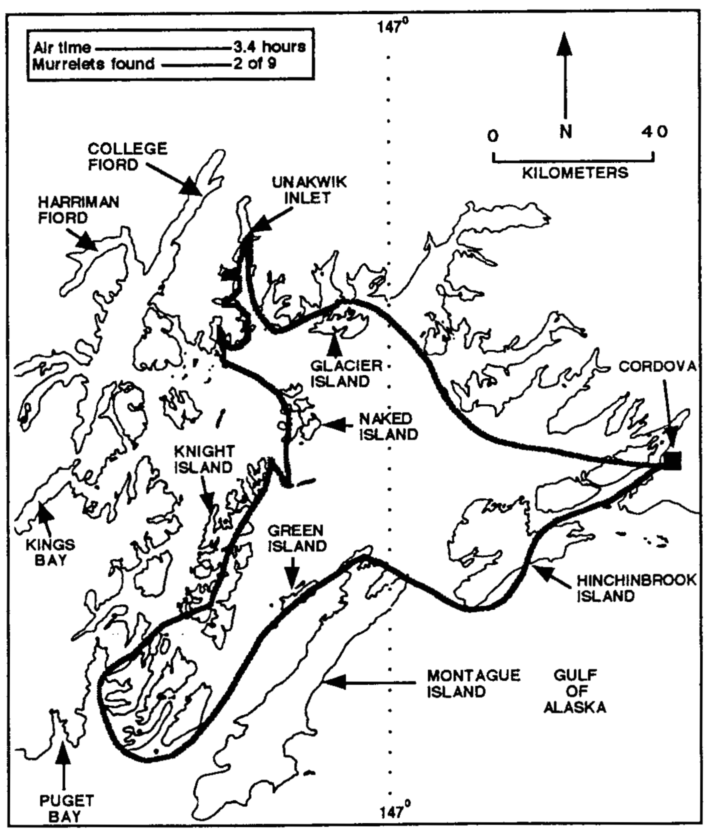


Figure 15h. Telemetry route, duration of flight, and number of radio tagged murrelets found in Prince William Sound, 11 August, 1993.

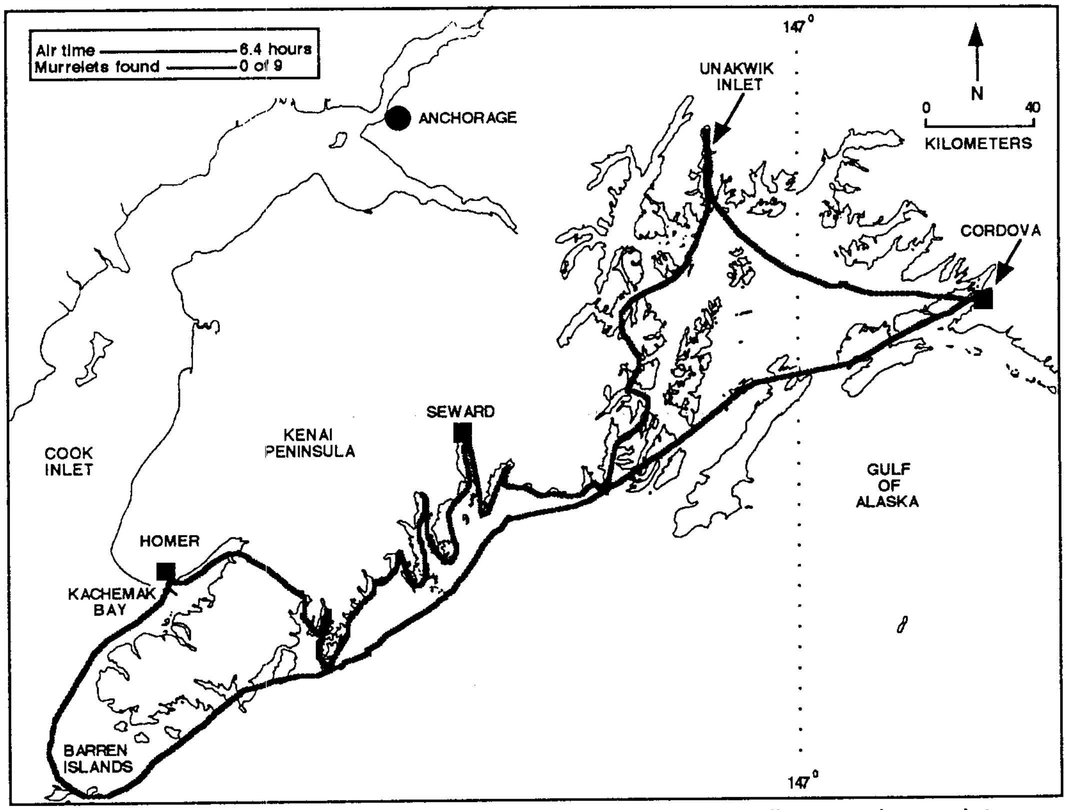


Figure 15i. Telemetry route, duration of flight, and number of radio tagged murrelets found in Prince William Sound, 22 August, 1993.

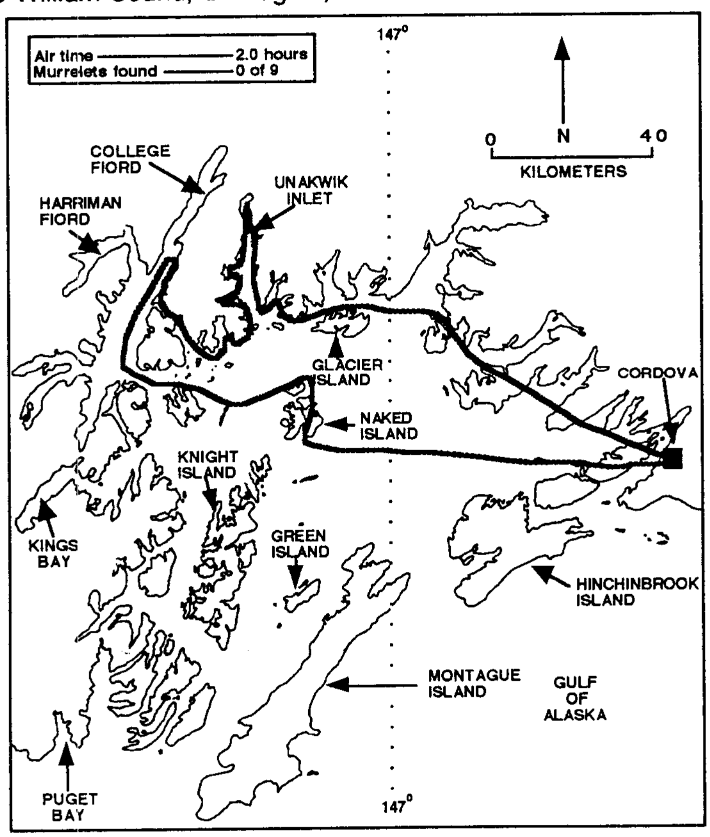


Figure 15j. Telemetry route, duration of flight, and number of radio tagged murrelets found in Prince William Sound, 25 August, 1993.

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Appendix

MIST NET SYSTEM USED FOR CAPTURING MURRELETS OVER WATER

A mist net system used for capturing Marbled Murrelets over water was developed in British Columbia in 1991 (Prestash et al. 1992, Burns et al. in review). Based on that prototype, a sturdier, more portable version was constructed in 1993. In Prince William Sound, Alaska, the 20 m motor sailer *Alaskan Gypsy* was used for transporting the equipment and for deploying and retrieving the anchors for this system. A two person skiff was used for erecting poles, setting nets, and retrieving birds.

This system was deployed in various places in Unakwik Inlet, Prince William Sound, in depths ranging from 20 to 160 m. The net support system was designed for use in a variety of depths of water, and to be able to withstand the strong tidal currents and the unfavourable weather conditions found on the coast. The net poles were constructed of aluminium and were painted grey with black mottling. All other equipment used in the net support system was purchased at a commercial fishing supply outlet.

POLES AND NETS

Equipment

See Figure 1.

(a) Two watertight aluminium cylinders, 1.8 m long and 25.4 cm in diameter, each with 27 kg of lead ballast in the base, and filled with polyethylene foam. The ballast caused the cylinder to float upright in the water and the foam ensured that the cylinder could not fill with water and sink. A .45 m length of aluminium pipe (2.54 cm I.D.) was welded to the top of each cylinder and a coupling was fitted to the end of the pipe. The anchoring gear was attached to a welded bracket at the bottom of each cylinder. An aluminium ring was welded near the top of each cylinder to aid in adjusting the net.

(b) Two aluminium pipes, each 3.15 m long (2.54 cm I.D.), were threaded at their bases. Five aluminium rings, spaced 53 cm apart, were welded along the length of each pipe starting at the top. These pipes were also coupled in the middle so they could be disassembled for easy transport.

(c) Two chains 2 m long (8 mm link);

(d) Two jaw and eye stabilizer swivels (8 mm link);

(e) Two nylon pulleys (10 cm diam);

(f) 25 m of 8 mm polypropylene rope;

(g) One nylon mist net (2.1 m x 18 m, 6 or 10 cm mesh);

(h) Ten pieces of 2 m twine to attach the net to the support poles;

(i) Ten plastic snaps tied to the twine;

(j) One painted board on which the mist net was wrapped and stored (not shown).

ANCHORING

Equipment

See Figure 1.

(k) Two 18 kg halibut kedge anchors, each with an added 18 kg lead ball;

(l) Two 11 kg lead balls used as counterbalance weights.

(m) Two coils of 8 mm polypropylene rope - the length of the rope depended on the depth of the water (e.g. in 100 m of water we used 200 m of rope).

Polypropylene rope must be used because it floats.

(n) Two large floats or boat bumpers (not shown).

SAFETY

Equipment

(o) One battery powered light for each pole (not shown).

DEPLOYMENT

A prominent shoreline feature was selected and the net support system was set along a bearing from it that would cross the murrelets' flight path at right angles. The net was positioned so that a backdrop of land made it difficult for birds to see the net. A weighted anchor (k) on one of the long lines (m) was set along the bearing line. The excess rope was tied in a coil and secured to a float (n). The second weighted anchor was set along the same bearing line approximately 125 m from the first and the procedure with the excess rope repeated. A skiff was used to uncoil the rope floating above each anchor so that each rope reached half way to the other anchor. Each rope was cut when it reached the half way point and the float (n) reattached. This ensured that a good angle was maintained between the anchors and the net supports, and provided sufficient rope for the attachment of the counterweights (l).

One end of the chain (c) was attached to the bottom of the aluminium cylinder (a) with a shackle and the other end connected to the stabilizer swivel (d). The pulley (e) was then connected to the swivel (d).

The first cylinder (a) was attached to an anchor by removing the float (n), running the anchor line (m) through the pulley (e) on the end of the cylinder chain assembly, and reattaching the float. This process was repeated for the second cylinder. The two cylinders now floated upright in the water. To maintain the correct distance between them, the 25.5 m line (f) was attached to the upper half of each swivel (d). The two floats were replaced with the counterweights (l) and the system self adjusted so that approximately 0.5 m of each aluminium cylinder was visible above the water. The aluminium pipes (b) were screwed into the couplings at the top of the cylinders (a). The net support system could then be left in place for as long as required.

The mist net (g) was attached to the poles (b) by tying twine (h) from the rings on the poles to plastic snaps (i) which were in turn clipped to the shelf loops on the net. By adjusting the twines the proper tension on the net could be maintained. Once the proper tension was achieved the net could be removed and replaced simply by using the snaps.

Four net poles (a+b) were used in Prince William Sound. At first the poles were set as in Figure 1 so that 2 poles supported one net. Later, all four poles were set in a row, spaced apart by the rope (f) so that a third net could be added (Fig. 2).

RESULTS

With practice, the time for deploying a single net support system (Fig. 1) was reduced from 2.5 hours on the first attempt to 1.7 hours on the third attempt. The time of retrieval was reduced from 1.5 to 0.8 hours. The alternate deployment method (Fig. 2) took approximately 4 hours to set up and 1.5 hours to remove.

Once the net support system (either Fig. 1 or Fig. 2) was in place it took 40 minutes to set a net the first time, half of that time being needed to adjust the tension on the net twines (h). All subsequent times averaged about 20 minutes per net because the net was simply snapped onto the twines. Removal of each net took 10 minutes. Each time a net support system was relocated the tension on the twines had to be readjusted.

DISCUSSION

The net support system (Figs. 1 and 2) was used for a total of nine days in Unakwik Inlet. In Unakwik Inlet, strong winds were not encountered, but strong tidal flows were experienced at Miner's Bay near the head of the Inlet. One of the poles became partially submerged and, as a safety precaution, a float was tied to each net pole. No further problems were encountered. In British Columbia the system (Fig. 1) was established in a single place in a fiord for over 60 days (Burns et al. in prep). During that time it was unaffected by the strong winds and tides common in a fiord environment because the counterweight system maintained the proper tension on the net supports at all times.

The net system we used in Unakwik Inlet has several features that make it well suited for use in future efforts to capture marine birds. It is not restricted by the depth of the water and has been deployed successfully in depths up to 400 m for 35 consecutive days (Burns et al. in review). The use of a hydraulic crab puller made the deployment and retrieval of the system easy and efficient. The system (Fig. 1 or Fig. 2) could be moved to a different location in one day. All ropes associated with the support system are at least 3 m under the surface of the water, reducing the risk of entanglement with passing boats. When the system is not attended at night, battery powered lights can be attached for safety. The support system is able to deflect most tidal debris and the pieces of glacial ice encountered in Unakwik Inlet did not pose a problem. However, floating ice and debris may catch on nets left in place, therefore nets should be closely monitored. The height of the net above the water can be adjusted to allow for sag if the net becomes wet. If sea otters are in the area, it can be raised to lessen the chances of their entanglement. Because proper tension on the net is maintained at all times by the counterweight system, when birds are caught they rarely touch the water.

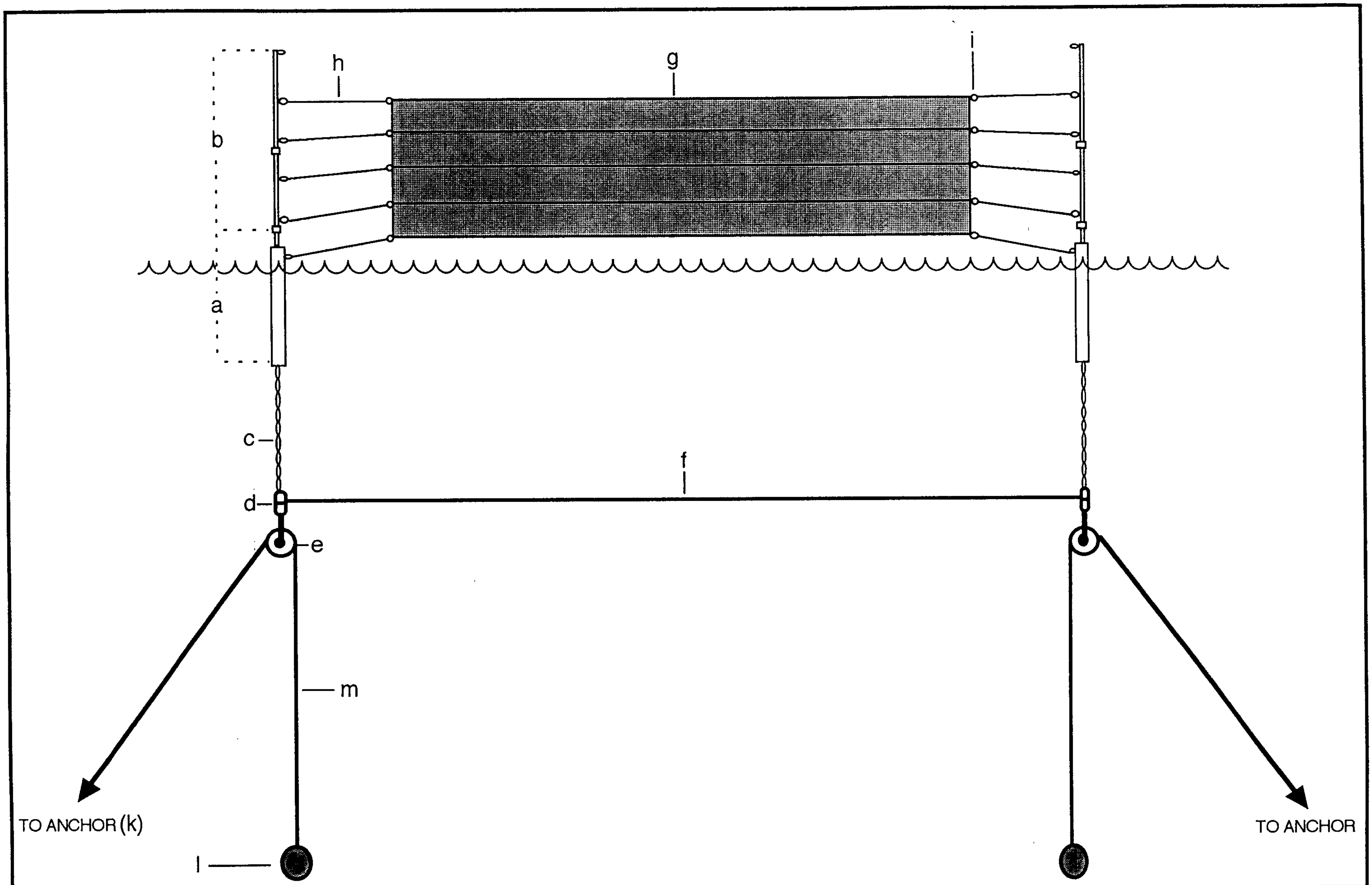

Figure 1. Components of anchoring and flotation system for mist nets.

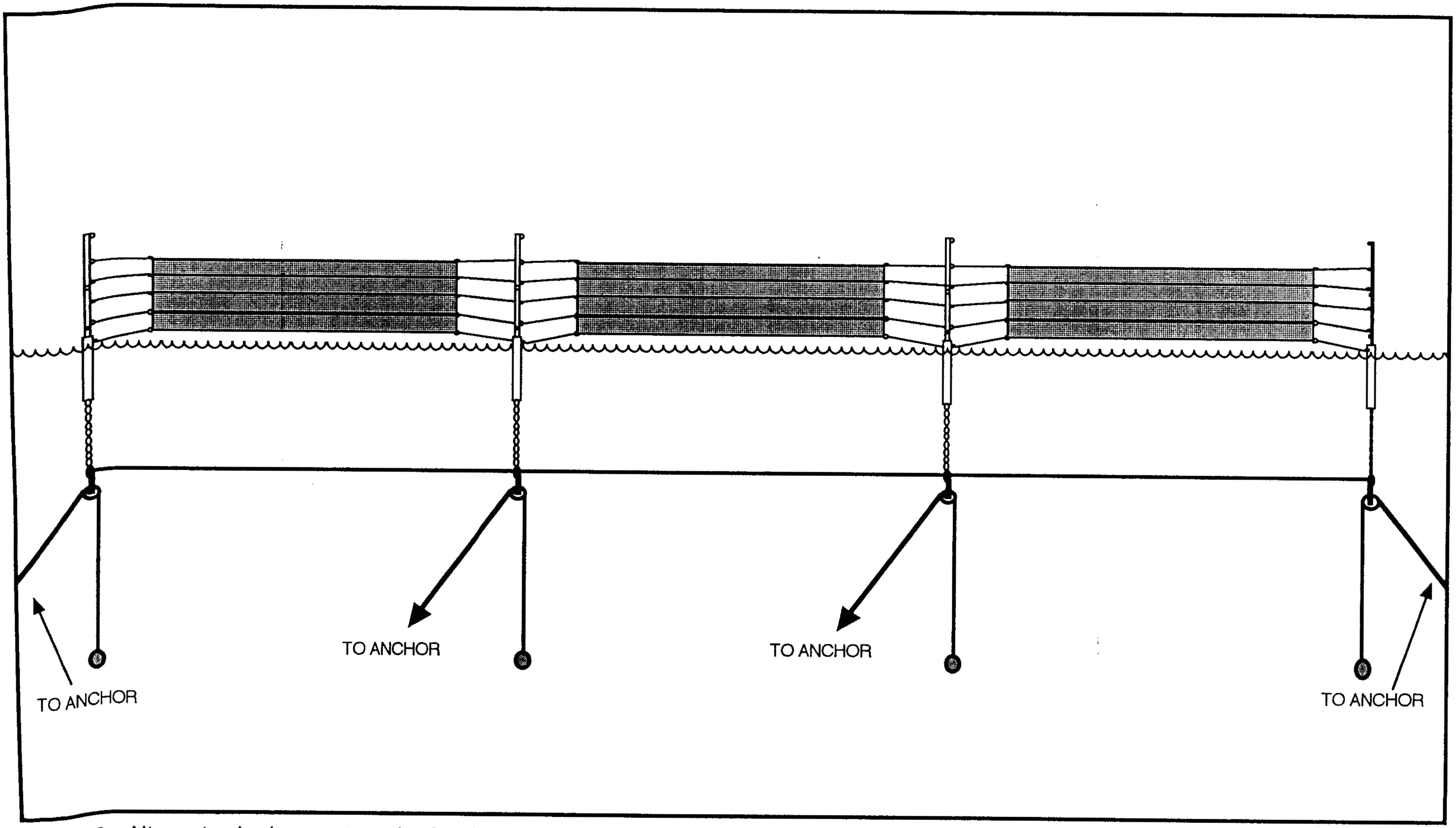

Figure 2. Alternate deployment method to increase number of nets used.