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# **Research on Marbled Murrelets in the Desolation Sound area during the 1994 breeding season**

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**Andrew E. Derocher  
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## ABSTRACT

Marbled Murrelets (*Brachyramphus marmoratus*) were studied near Desolation Sound on the southern mainland coast of British Columbia between May 17 and July 22, 1994. Our objective was to examine the applicability of several field techniques to investigate the ecology of Marbled Murrelets. We used a floating support system to suspend mist nets over the water to capture birds flying into and out of Theodosia Inlet. We captured 176 birds, 101 during morning sessions and 75 during the evening. Mean capture times were 5 minutes before sunrise and 22 minutes after sunset. A Marbled Murrelet originally captured on July 12, 1993 in Theodosia Inlet was recaptured at the same location June 9, 1994. This is the first report of a recaptured Marbled Murrelet and the first indication of site fidelity. Radio transmitters were attached to 43 murrelets. Blood samples were collected from 66 birds for endocrine and genetic analyses. Morphometric measurements from captured birds suggested that some sexual dimorphism may be present in bill height. The marine distribution of Marbled Murrelets varied throughout the study with birds concentrating in Desolation Sound until early June when most birds moved into the inner inlets. Single birds and pairs were the most frequent group sizes although we saw groups of up to 43 birds. The first juvenile bird was recorded July 2. We tracked one Marbled Murrelet with a radio tag to a nest site in a mountain hemlock tree (*Tsuga mertensiana*) at 1200 m elevation. The tree was in a patch of old growth forest in a side drainage of the Theodosia River 12 km from salt water. The 1994 field season demonstrated that the floating mist net system was capable of capturing the large numbers of Marbled Murrelets needed to support a multi-faceted research initiative.

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## INTRODUCTION

Marbled Murrelets (*Brachyramphus marmoratus marmoratus* Gmelin) are small alcids found in coastal waters of the North Pacific Ocean from the Aleutian Islands to northern California. A subspecies (*Brachyramphus marmoratus perdix* Pallas) is found off the Pacific coast of Asia and is being considered by some as a separate species (*B. perdix*) (Konyukhov and Kitaysky 1995). Unlike other Alcidae, Marbled Murrelets nest in large trees found in old-growth coniferous forests from southeastern Alaska and British Columbia to California (Campbell *et al.* 1990, Ralph *et al.* 1995). Marbled Murrelets were classified as a "Threatened species" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 1990. Concern over the status of Marbled Murrelets in Washington, Oregon, and California arose in 1988 when the National Audubon Society petitioned the U.S. Wildlife Service to list the species as threatened (Ralph *et al.* 1995). Loss of nesting habitat through harvest of coastal old growth forests is the most serious threat to Marbled Murrelets (Rodway 1990, Nelson *et al.* 1992, Ralph *et al.* 1995). Additional threats come from gill-net fishing and oil spills (Rodway 1990, Carter and Erickson 1992, Leschner and Cummins 1992). Marbled Murrelets are vulnerable to oil pollution because of their clumped distribution in near shore waters (Rodway 1990, Leschner and Cummins 1992). Loss of foraging areas to aquaculture and other marine developments may be a concern (Leschner and Cummins 1992).

Anecdotal evidence suggests the Marbled Murrelet population in B.C. has declined in areas where extensive logging has occurred (Brooks 1926, Pearse 1946, Sowls *et al.* 1980, Sealy and Carter 1984). More convincing evidence, obtained from distributional data both in the forests and at sea, indicates the distribution of the species has changed in northern California, probably due to extensive removal of old growth forests. Marine concentrations of Marbled Murrelets are now only found offshore from remnant old growth forests (Sowls *et al.* 1980, Nelson *et al.* 1987, Marshal 1988a, 1988b, Carter and Erickson 1988, Ralph *et al.* 1995). Continued loss of old growth forests in B.C. will increase concerns over this species.

Between 20 and 30% of the world's Marbled Murrelets breed along the coast of British Columbia (Campbell *et al.* 1990, Kaiser *et al.* 1992). A north and south migration of Marbled Murrelets in B.C. has been suggested (Campbell *et al.* 1990, Rodway *et al.* 1992, Speich and Manuwal 1992) but little data exist. Public awareness of species that rely on old-growth forests has heightened in recent years and Marbled Murrelets are perceived by many as the quintessential old-growth species in coastal British Columbia. Absence of data on Marbled Murrelet biology reduces our ability to manage this species.

Marbled Murrelets are sometimes locally abundant in protected nearshore waters, coastal inlets, and exposed waters within 5 km of land. Densities of Marbled Murrelets on salt water vary widely and populations may be highly concentrated (Carter 1984, Kaiser *et al.* 1991, Prestash *et al.* 1992). They occur on coastal fresh-water lakes during the breeding season but are rare on fresh water at other times of the year (Campbell *et al.* 1990). Little information is available on the spatial relationship between foraging and nesting areas (Ralph *et al.* 1995).

Nesting begins in mid-April and ends by October (Campbell *et al.* 1990). Marbled Murrelets have low reproductive rates and lay only one egg per clutch (Drent and Guiguet 1961, Sealy 1972). Eggs are present from mid-April through the end of August. The incubation period lasts approximately 27-30 days (Carter and Sealy 1987, De Santo and Nelson 1995). Nest failure appears high. Nest predation may be a major source of failure with rates greater than 70%. Corvids are the major nest predators (Singer *et al.* 1991, Nelson and Hamer 1995). Mean fledging age was estimated at 27-40 days (De Santo and Nelson 1995). Recently fledged young have been found from May 20 to September 17 (Carter 1984, Kaiser *et al.* 1991, Ralph *et al.* 1995).

If we assume low reproductive rates and long life span, management of this species will be difficult, due to the long time required to detect declines in population size. The adult population may remain relatively stable for some time before effects of low recruitment and possible senescence are apparent. Surveys of birds at sea and counts of calls in forests are not likely to give us the precise information with which we can monitor population trends. However,

population models, such as that attempted by Beissinger (1995) and Boulanger *et al.* (submitted ms) will help us focus on critical factors and set acceptable ranges from which to assess populations trends.

The goal of this study was to locate and establish a long-term site for multi-faceted research on the ecology and population dynamics of Marbled Murrelets with an emphasis on individually marked birds. Research objectives included: determination of nesting habitat, survival and population size estimations using capture, mark, recapture (CMR) techniques, recruitment rates, reproductive success, marine distribution and abundance, foraging behaviour, and oceanographic features as they affect Marbled Murrelet distribution. In this report we present the results of the 1994 field season and data collected in 1991-93 during pilot studies. Recommendations for future research directions are also presented.

## STUDY AREA

We chose Desolation Sound and the adjoining Malaspina, Okeover, Lancelot, and Theodosia inlets (Fig. 1) as the study site because large numbers of Marbled Murrelets were known to be present during the breeding season and there is a history of Marbled Murrelet studies in the area (Mahon *et al.* 1992, Kaiser *et al.* 1991). Ease of access from major centres makes field research cost-effective. Part of Desolation Sound is a provincial park with both marine and terrestrial areas. Maximum water depth in Desolation Sound is about 500 m. The inlets are shallow with a maximum depth of 100 m in Okeover Inlet and about 60 m in Malaspina and Lancelot inlets. Theodosia Inlet (50° 05'N, 124° 40'W) was selected as the capture site because hundreds of murrelets were known to move between Theodosia and adjacent Lancelot and Malaspina inlets in May-July (Kaiser *et al.* 1991, Mahon *et al.* 1992). Theodosia Inlet is narrow (200 m between shoreline trees), shallow (<20 m deep), sheltered water, and forms a funnel between potential nesting and marine foraging areas.

We selected a netting site based on observed characteristics of murrelet behaviour. We had seen murrelets flying low over Theodosia Inlet at dawn and dusk. Therefore, we chose a site

where Theodosia Inlet narrowed in the elbow of a sharp bend near which murrelets foraged. Nets were set against a forested background which reduced their visibility to approaching murrelets. The site was not exposed to large waves, but strong currents developed with each major tide change, and there were occasional strong outflow winds.

## **METHODS**

### **Capture techniques**

Details of capture technique and equipment are described in Kaiser *et al.* (1995). The method uses an array of aluminum tubing and floats to support mist nets over the water to intercept passing murrelets. In the evenings, we scheduled the opening of the nets for 2100 hours if wind and weather permitted and left them open until 30 min. after the last capture (between 2230 and 2315 hours). For morning captures, we set the nets at 0400 hours and left them open until daylight at 0630 hours. These times were chosen on the basis of known patterns of flight activity in forest sites at this time of year (Naslund and O'Donnell 1995).

Two people in an inflatable boat monitored the nets and retrieved birds. Once a bird became entangled in the net, the boat was positioned by a small (15 hp) outboard or by pulling the boat along the line between rafts. Captured murrelets were placed in cotton bags after they had been extracted from the net. On shore, the bander recorded time of capture, weather conditions, and the murrelet's direction of travel. Between captures, we waited close to the shore or at the anchor end of the pulley line. During full darkness, we checked the nets frequently with a strong light and used head lamps to work on birds in the nets. A notice to mariners filed with the Coast Guard was broadcast on marine band radio to warn marine traffic of the capture operation.

## **Measurements and samples**

Murrelets were taken ashore for banding and measurements. Mass was measured using a 500 g Pesola scale. All murrelets were banded with a stainless steel U.S.F.W.S band (3B). We measured wing length (flattened length from elbow to tip of primary) with a ruler and tarsus length, exposed culmen, bill height, bill width, and head height using dial calipers. Head height was the height measured between the chin of the murrelet and the crown of its head. We searched for a brood patch on the underside of the murrelets body between the sternum and the cloaca. We measured the length and width of the brood patch and recorded evidence of refeathering. We used the product of length and width as a size index to compare the size of the defeathered areas among captured birds.

We glued coloured turkey feathers to the back of each murrelets head using ShoeGoo II®. They were attached in either left/right or top/bottom combinations to create unique patterns for later identification on the water.

We drew blood samples from the brachial vein. When the bird did not bleed freely, we reduced handling time and stress by ceasing to attempt collection. Depending on the amount of blood collected, samples were taken for both DNA and hormone analysis. Two or three small contour feathers were collected and feathers were placed in a small, plastic vial filled with 70% ethanol for subsequent DNA analysis. All blood, plasma, and feather samples were stored frozen.

## **Focal observations**

We monitored the behaviour of murrelets on the water by randomly selecting a focal bird and recording the frequency and duration of its preening, wing flapping, diving, feeding, vocalizing, bathing, displaying, flying, loafing (sitting still or slowly swimming), and fish holding. Focal birds were monitored by telescope and binocular and activities were timed by stop watch.

### **Scan surveys**

From eight points on shore, we recorded group size and behaviours by scanning a fixed area (Fig. 1). We used spotting scopes and binoculars to determine the abundance, group size, and behaviour of Marbled Murrelets during a single scan. Scans were performed: June 14-18, June 30-July 3, and July 15-19. Four scans were conducted at intervals of 10 minutes. Observations were placed into dawn (0600-1000 hours), morning (1000-1400 hours), afternoon (1400-1800 hours), and evening (1800-2200 hours) categories.

We used relative size of birds, coloration of throat and breast, back coloration, and wing condition to identify fledged juveniles and birds in basic/winter plumage (Carter and Stein 1995).

Observations of the number of Marbled Murrelets flying or swimming past the net site were collected on an opportunistic basis while the nets were open. Direction of transit, group size, and time of movement were recorded.

### **At sea surveys**

In order to monitor changes in the distribution of murrelets, we completed six counts of birds on the water between May 22 and July 21. The surveys were spaced every 10 days, weather and sea conditions permitting. On each count, we surveyed 32 km<sup>2</sup> within the four connected inlets and a portion of Desolation Sound over two consecutive days. Surveys were conducted from early to mid-morning and completed from late morning to early afternoon.

We divided the study area into 46 transects 1-2 km long using obvious landmarks, each taking several minutes to navigate. We surveyed all areas 150 m from shore and murrelets were counted within 150 m on each side of the boat. In Desolation Sound, additional transects were conducted 600 m offshore. Observers on each side of the boat scanned in a 180° arc with emphasis being placed on the forward 90° to spot murrelets before they dove upon approach of the boat



## **Oceanography**

We measured temperature, salinity, and turbidity where similar measurements were taken in 1991 (Kaiser *et al.* 1995). Temperature and salinity were recorded at 22 stations (YSI Model 33 SCT meter, Yellow Springs Instrument Co., Yellow Springs, Ohio) at the surface and at 1.0-m, 5.0-m, and 10.0-m depths. Turbidity was measured as the mean of a lowered and raised secci disk. Measurements were usually taken the day of or on the day following at-sea transects. All stations were sampled 5 times from May 23 to July 22. For comparison we used data from the same stations sampled eight times from June 1 to July 22, 1991. Stations were grouped into five areas and mean temperature, salinity, and turbidity were calculated for each area; Okeover (four stations), Lancelot (five stations), Theodosia (three stations) Malaspina (four stations), and Desolation Sound (six stations).

## **Prey sampling**

We used a herring rake (a 2-m aluminum pole with dozens of 6-cm needles about 1.0 cm apart) to opportunistically sample Marbled Murrelet prey items. When prey items were concentrated on the surface by Marbled Murrelets, we powered the boat into the area and swept the area with the herring rake.

## **Radio telemetry**

We attached 1.5-g radio transmitters (Holohil Systems Ltd., Woodlawn, Ontario) on 43 murrelets. Each radio was secured to the bird's neck using a nylon covered elastic collar threaded through a channel in the transmitter body with the ends of the elastic joined by a corrodable iron staple. The radio was held in place at the top of the neck with a drop of cyanoacrylic glue. The antenna wire was oriented along the murrelet's back.

Radio telemetry surveys were conducted by helicopter (Bell 206) on June 26, 27, and 28 for four to five hours per day. The surveyed route was Powell River, Savory Island, Copeland Islands, southern Cortez Island, Desolation Sound, East Redonda Island, east to the headwaters

of Powell Lake, Theodosia River drainage, Bunster Hills, the inner inlets of the study area, and back to Powell River.

## RESULTS

### Captures

We began capture sessions on May 17 and continued until July 22, 1994. In that period, we captured and released 176 Marbled Murrelets with no mortality. Of these captures 173 were newly captured and banded, one was a recapture from 1993 and 2 were intra-seasonal recaptures. Marbled Murrelets were captured in both morning and evening sessions (Fig. 2). In general the numbers of birds captured per day was correlated with the number of hours the nets were open (linear regression,  $F = 12.6$ ,  $df = 1,33$ ,  $P = 0.0012$ ,  $r^2 = 0.28$ ) but the low  $r^2$  value suggests that other factors also influenced capture rates. Overall, the number of birds captured per hour varied from 0.0 to 4.5 with a mean ( $\pm$  SE) of  $2.1 \pm 0.2$  birds/h. Capture rate during morning sessions ( $\bar{x} = 2.5 \pm 0.4$  birds/h) did not differ ( $t$ -test,  $P = 0.22$ ) from evening sessions ( $\bar{x} = 1.9 \pm 0.3$  birds/h). Numbers rose from early June to peak around in the second half of June and then dropped in July (Fig. 2). During morning sessions, murrelets were caught from 60 minutes before sunrise until 40 minutes after ( $\bar{x} = 5$  min. before sunrise) (Fig. 3). In evening sessions, murrelets were caught from 60 minutes before sunset to 100 minutes after ( $\bar{x} = 22$  min. after sunset) (Fig. 3). The limits may have been influenced by the length of time we deployed the nets.

The proportion of murrelets passing the net site peaked at 0520 hours ( $n = 12$  capture sessions) and 2155 hours ( $n = 14$  capture sessions) (Fig. 4). Additional birds passed the net site, but were not recorded during periods that birds were being removed from the nets. The period of peak movement of murrelets through Theodosia Inlet was longer in the morning session than the evening.

Total number of murrelets recorded crossing the net line in Theodosia Inlet but missing the net was recorded during 24 netting sessions. Number of murrelets recorded varied from 9 to 76 ( $\bar{x} = 32 \pm 4$  birds/ session) (Fig. 5). Eighty-seven murrelets (11.3% ) were captured out of

771 murrelets recorded passing the nets during these sessions. Many birds were flying >50 m above the Inlet. There was no linear relationship between number of birds observed and captured (linear regression,  $F = 0.75$ ,  $df = 1, 22$ ,  $P = 0.39$ ). We did not detect a change in ratio of observed to captured birds through the season (linear regression,  $F = 0.76$ ,  $df = 1, 22$ ,  $P = 0.39$ ).

Of the birds observed, 90% (651/722) were flying westward toward the mouth of Theodosia Inlet and 10% (71/722) toward the east or the head of the Inlet. During the morning, 8% (28/364) and during evening 12% (43/358) of the birds were flying east into the Inlet.

### **Body measurements**

Mean mass for captured murrelets was  $199 \pm 1$  g (range 164-234 g;  $n = 168$ ). The mass of birds was normally distributed ( $D = 0.065$ ,  $p > 0.10$ ) (Fig. 6). A drop in mean mass of 8 g (202 to 194 g) (one-tailed t-test,  $t = 4.18$ ,  $p < 0.001$ ) occurred between the June 8-July 2 period and July 3-22 (Fig. 7). Body Index (mass/tarsus) ranged from 7.5 g/mm to 11.5 g/mm with a mean of  $9.4 \pm 0.05$  g/mm ( $n = 167$ ).

Mean body measurements of captured birds are listed in Table 1. Distribution of bill heights suggests a bimodal distribution with peaks at 6.2 and 6.9 mm (Fig. 8) and is the only indication of sexual dimorphism. Measurements of bill widths, exposed culmen, head height, tarsus and wing length, however, were not bimodally distributed (Figs. 9 -13). Analysis of mean wing length for each five day interval indicated a decline over the study duration (Fig. 14).

Table 1. Morphometrics of Marbled Murrelets captured in Theodosia Inlet, 1994.

Measurement (mm)	$\bar{x}$	SE	max.	min.	<i>n</i>
tarsus	21.1	0.1	23.9	17.9	175
wing length	133.1	0.3	146	122	175
exposed culmen	17.1	0.1	19.8	14.1	172
bill height	6.5	0.03	7.7	5.9	173
bill width	5.3	0.02	6.1	4.7	175
head height	23.0	0.1	27.8	20	174

Brood patch size index, ranged from 132 to 1312 mm<sup>2</sup> (Fig. 15) with a mean of  $557 \pm 14$  mm<sup>2</sup> (*n* = 164). We observed no change in brood patch area over the capture period in those birds with brood patches (linear regression, *P* = 0.065). However, when the birds without brood patches were included in the regression, the brood patch size index increased with time (Fig. 16). The first refeathering brood patch was observed June 21.

### Blood and DNA samples

We collected blood samples from 66 different birds (Table 2) and feather samples from 162 birds. Blood and DNA samples are currently being analyzed and the findings will be presented in a separate publication.

Table 2. Number of Marbled Murrelets captured in Theodosia Inlet which provided blood samples in 1994.

Date	a.m.	p.m.	total
June 10-20	4	3	7
June 20-30	13	12	25
July 1-10	6	10	16
July 11-20	10	8	18

### Recaptures

One Marbled Murrelet was captured at the Theodosia Inlet net site on July 12, 1993 and again on June 9, 1994. The mass was 208 g in 1993 and 205 g in 1994. A brood patch was present and measured in 1993, but not in 1994. This recapture was among the first captures in the 1994 field season, and it is possible that a brood patch was present but not found by inexperienced observers.

Two murrelets were recaptured within the 1994 season. One was captured on June 21 and 22 days later on July 13. The other was captured on June 29 and 16 days later on July 15. There was no change in the mass of the first bird between captures while the second dropped 18 g (10%) to 167 g. The second recaptured bird appeared underweight at recapture and its brood patch was partially refeathered with down.

### Behaviour

Marbled Murrelets spent 74.9% of the time loafing on the water, 10.2% diving, 8.1% preening, 5.9% fish-holding, and 0.9% on other activities such as flying and displaying ( $n = 50$ ). Diving and flying were likely under-represented in the samples because these activities are difficult to monitor and often not visible in scan samples.

## **Distribution**

The densities of murrelets on the water varied geographically and temporally. Approximately 80-85% of the murrelets were in Desolation Sound during the May 23 and June 2 surveys (Fig. 17). By June 12, most murrelets sighted were observed in Malaspina, Okeover, Theodosia, and Lancelot inlets (inner inlets). By the last survey on July 22, most sightings were in Desolation Sound and Malaspina Inlet. The highest density of Marbled Murrelets was 33.3 birds/ km<sup>2</sup> recorded in Theodosia Inlet on June 22 (Fig. 18) and corresponded with our peak capture period.

The initial survey (May 22-23) had the lowest count with only 101 murrelets with most in the outer transects (Fig. 19). The number of murrelets reached 316 by June 11-12 with more murrelets on inner than outer transects. The count declined slightly during the fourth survey but was highest on the fifth survey with 457 murrelets. Only 83 murrelets were in Desolation Sound while the remaining 374 were in the inner inlets. The final count of 230 murrelets on July 22-23 was more evenly split between the inner and outer inlets.

## **Group sizes**

Groups sizes varied during the study period (Fig. 20), with two being the commonest group size throughout the period. Groups of sixteen, nineteen, twenty-five, twenty-six, and forty-three were found on the fifth survey (07 to 09 July).

## **Resightings**

We made 59 resightings of 33 individuals: 37 relocations of 20 individuals were made by aerial telemetry, 6 relocations of 2 individuals by boat based telemetry, 13 resightings of coloured feathers on 9 birds were made, and 2 individuals were recaptured in mist nets. Resightings occurred up to 21.0 km from the capture site from 12 hours after capture up to 22 days later. Mean distance from the capture site was  $5.9 \pm 0.6$  km ( $n = 53$ ) with 94% of

resightings occurring within eight days of an individual's first capture. Distance from the capture site did not increase with time.

## Scans

Susan Islet, Isabel Bay, Cochrane Island, and Galley Bay had relatively low numbers of murrelets (<40 birds/scan) at all times of day (Appendix I). Numbers on Galley Bay were generally higher in morning and afternoon. Okeover Inlet, Edith Island, Isbister Island, and Manne's Point all had one or more periods with >100 birds/scan. Numbers peaked July 1-3 at Edith Island, Manne's Point, and Isbister Island and June 15-17 at Okeover Inlet. Numbers peaked in the afternoon at all of those stations except Edith Island which peaked at dawn. Maximum numbers at Manne's Point and Isbister Island occurred on the same day and time (surveys were done simultaneously). During these peaks, groups of >5 birds were common and dive and flight activity was low (Table 3).

Numbers of birds at Susan Islet were low relative to other locations, with the highest 35 birds/scan at dawn on June 17. Behaviour at this location was unique; flight activity was high (15-25%) and the highest frequency of fish holding (19%) was recorded in evening scans. At the other 7 stations the proportion of birds flying was highest at dawn or morning periods and <10% in the afternoon and evening.

The proportion of birds diving was low at all times of the day (<2% for all stations combined). Diving activity during scans is likely to be underestimated because it is recorded only if the bird is seen diving or surfacing, which is easily missed during a scan. For individual stations, the highest proportion of birds diving was recorded in morning scans at Okeover Inlet 12.5% (12/96) and Susan Islet 16.7% (9/54).

Table 3. Behaviour of large groups of Marbled Murrelets observed during scan surveys in the Desolation Sound study area, 1994.

Site	Date	Time	birds/scan	Proportion of group members (%)			
				In clusters >5 birds	Swimmi ng	Diving	Flying
Edith	June 16	1205	83	42	98	0.3	2
Edith	June 30	801	116	18	80	0.5	16
Edith	July 2	1233	90	35	74	2	12
Isbister	July 1	1720	183	47	86	4	6
Manne's	July 1	1731	163	30	81	2	5
Okeover	June 19	1629	117	48	85	0	8

Birds holding fish were observed at 4 of 8 stations at dawn and morning, at 5 stations in the afternoon, and at all stations during evening scans. The highest proportion of fish-holding birds was in the evening, 19% ( $n = 209$ ) at Susan Islet and 10% ( $n = 293$  birds) at Edith Island. Pooling all stations, 0.2% of the birds were holding fish at dawn, 0.1% during morning, 0.8% during afternoon, and 4.9% in the evening. We observed herring (*Clupea pallasii*) and sand lance (*Ammodytes hexapterus*) being held by murrelets but never more than a single fish at once

### Plumage

During the scans we saw only 7 birds in winter (basic) plumage. The first fledgling was recorded July 2 (Table 4). Table 4 includes scans only when juveniles were recorded. This approach inevitably leads to an over-estimate of the proportion of juveniles.



Table 4. Juvenile and adult Marbled Murrelets observed during those scan surveys in the Desolation Sound study area in which juveniles were present, July 2-20 1994.

Date	Site name	Number of juveniles	Number of adults	Percent juveniles	Time of observation
July 2	Cochrane	1	68	1.5	1935
July 3	Galley	1	22	4.5	929
	Okeover	3	39	7.7	1043
July 15	Isbister	1	15	6.7	1453
	Edith	1	31	3.2	1941
July 16	Cochrane	1	55	1.8	918
	Galley	3	55	5.5	930
	Galley	4	34	11.8	1208
	Manne's	2	54	3.7	1023
	Isbister	1	4	25.0	1826
July 18	Isbister	2	54	3.7	1058
	Cochrane	1	39	2.6	1103
July 20	Manne's	1	38	2.6	936
	Cochrane	2	19	10.5	1829

### Prey sampling

In general, balls of prey fish pushed to the surface by murrelets, dispersed rapidly as the boat approached and we were successful in collecting samples of prey on only two occasions. On June 6, Pacific sand lance (*Ammodytes hexapterus*) with a mean fork length of  $92 \pm 1$  mm ( $n = 8$ ) were collected at a prey ball created by a single murrelet. On June 27, Pacific herring (*Clupea pallasii*) with a mean fork length of  $63 \pm 2$  mm ( $n = 9$ ) were captured in Okeover Inlet from a prey ball created by three murrelets. In the latter case, eight Glaucous-winged gulls (*Larus glaucescens*) were feeding on the prey ball. An addition prey sample was obtained, on July 9 (2104 hours) when a murrelet captured in the mist net dropped a sand lance (102 mm long).

### Oceanography

Stations in Desolation sound had the highest surface temperature (SST) and the lowest surface salinity (SSS) on most sampling dates (Appendices II and III). Waters in Desolation sound were also the least turbid throughout the season. Malaspina Inlet, which becomes

turbulent on each tide change, had the coldest waters. We recorded the highest temperatures in all areas July 20-22 (Appendix II). Changes in water temperature followed patterns similar to 1991 and 1994. Turbidity results are given in Appendix IV.

### **Nest site**

In the afternoon of June 26 we detected the signal from a radio-tagged Marbled Murrelet in a patch of old growth timber in the Mountain Hemlock biogeoclimatic zone. The signal was not detected on June 27 but reappeared on June 28. We tracked it to a Mountain Hemlock (*Tsuga mertensiana*) at approximately 1200 m elevation in a side drainage on the east side of the Theodosia River (50° 09.25' N and 124° 27.08' W), 12 km from the nearest saltwater in Homfray Channel and 20 km from the capture site. Once we found the tree, we were able to see the murrelet on a mossy platform created by a "J" in the stem of the tree. The tree was on a steep slope (> 30%) above a marsh in a bowl-shaped depression. There was logging below the site and to the south at the same elevation. The patch of timber (30-60 ha in area) also contained Yellow cedar (*Chamaecyparis nootkatensis*) and was approximately 50 m below a treeless area of granitic outcrops. We also found pine marten (*Martes americana*) tracks nearby. We did not complete a formal site description during the first visit to reduce disturbance of the nest, but one of us (I. M.) revisited the site after fledging and confirmed the presence of a nest.

## **DISCUSSION**

### **Methodology**

Overall, the 1994 field season produced an excellent base from which to continue a long-term study. Experience gained will permit greater efficiency in field operations. Some recommendations follow.

The netting system proved very functional under field use and does not require additional modifications. Use of 2-ply nets will not be continued as many (>20 birds) flew through the nets.

The attachment of radios to murrelets must be modified to increase retention and likelihood of locating nest sites. One of the intra-year recaptured bird had lost its radio within 16 days. Sutures to attach the radios have been used on Marbled Murrelets (K. Kuletz pers. comm.). On Eared Grebes (*Podiceps nigricollis*), sutures migrate out of the skin without lesion in 3 to 6 weeks (S. Boyd, pers. comm.). Retention of radios for at least 4 weeks would be desirable.

The reason why only one nesting bird was located is unknown. There are a number of possibilities. Perhaps some of the radio tagged birds were non-breeders, failed breeders, transients, or immature. Capture and handling could have induced nest abandonment. Some nesting birds may have been on the water during telemetry surveys or outside the survey area. The timing of the telemetry survey relative to breeding chronology is not known and some birds may not have initiated nesting at the time of the survey.

Substantially more helicopter time is needed for locating nests. In addition, radio telemetry flights should commence immediately after the radios are deployed to increase the likelihood that radios are still attached. Use of 2 independent radio telemetry systems on the helicopter should increase telemetry efficiency and increase the number of radios relocated and the use of 2 pulse rates on each frequency and would reduce the number of frequencies that are being searched.

## **Captures**

In the past, investigation of the life history of Marbled Murrelets has been hampered by the difficulty of catching the birds. The results of this study indicate that given the appropriate geographic, oceanographic, and behaviour patterns, capture of Marbled Murrelets can be cost-effective and reasonable samples are possible. Our capture success allows us to expand the scientific questions that we can address. Implementation of a long-term mark-recapture study is possible with the caveat that the birds are reasonably philopatric to the breeding grounds and that adequate numbers can be recaptured in future years. A Marbled Murrelet first banded in 1993 in

Theodosia Inlet and recaptured at the same site in 1994 is the first evidence of philopatry in this species. It is impossible to determine how common this behaviour is until banding operations are available from a greater number of years and a significant proportion of the population is marked. However, re-use of a nest site by Marbled Murrelets (although not necessarily by the same individuals) in the Caren Range on the Sechart Peninsula (P.H. Jones 1994) is suggestive of nest-site tenacity. Other examples are documented by Divoky and Horton (1995).

### **Demographics**

Results during 1994 indicate the Desolation Sound population has the potential to yield data that are not being collected by other studies. To increase the power of mark and recapture techniques to estimate population size and survival, it will be necessary to increase capture effort but required sample sizes are difficult to determine until a rough estimate of the population size is available. Adding a second netting crew to the Susan Islet area may result in many additional birds being captured. Additional capture sites may be required.

### **Measurements**

Alcids are typically monomorphic in plumage, ornaments, and body size resulting in no obvious external characteristics that permit identification of sex (Bédard 1985). Sexual dimorphism was found for bill depth (height) and head width in Ancient Murrelets (*Synthliboramphus antiquus*) (Gaston 1992). Identification of sex was approximately 87% accurate using bill depth, bill width, head width, and tarsus length in Ancient Murrelets (I.L. Jones 1985). Sexual dimorphism of bill depth and culmen length was present in Crested Auklets (*Aethia cristatella*) (I.L. Jones 1993). The bimodal distribution of bill heights of Marbled Murrelets in our data suggests that this measure may be useful in identifying the sex of individuals, but the other measurements showed no evidence of bimodality. Some of the measurements suggested that whole number and certain divisions of the decimal scale were

recorded significantly more than others, suggesting some bias in measurement, so the values should be interpreted with caution.

We observed a significant decline in mass after the beginning of July. I.L. Jones (1994) speculated that a similar mass loss in Least Auklets (*Aethia pusilla*) was a programmed response, at the time of chick hatch, to increasing flight demands rather than a consequence of reproductive stress. Sample sizes are insufficient to describe the pattern of mass changes in Marbled Murrelets. If confirmed in future years it may be useful as a rough indicator of hatching dates. The mean mass of birds captured in 1994 ( $199 \pm 1$  g. range 164-234g;  $n=168$ ) was similar to that of birds caught in 1993 ( $202 \pm 3$  g. range 189-227g;  $n=15$ ) and in 1991 ( $196 \pm 3$ g. range 169-230g;  $n = 21$ ) in 1991 in the same area (unpubl. data).

The decline in wing length (Fig. 14) may indicate an increase in the proportion of sub-adult or poor quality birds captured as the season progressed. However, there was no decline in the frequency of brood patches (Fig. 16).

### **Food habits**

Marbled Murrelets feed opportunistically on locally abundant prey and were observed preying on sand lance and herring. In other areas, prey such as shiner perch (*Cymatogaster aggregata*), squid (*Loligo opalescens*), northern anchovy (*Engraulis mordax*), euphausiids, and salmon (*Oncorhynchus* spp.) smolts have been recorded (Sealy 1975, Carter 1984, Carter and Sealy 1986).

Marbled Murrelets play an important role in mixed-species feeding flocks in nearshore waters (Mahon *et al.* 1992). Numerous mixed-species feeding flocks were seen but not studied in detail.

Oceanographic features and their impact on the distribution of Marbled Murrelets are poorly understood. Oceanographic data should be collected for the purpose of testing specific distributional and behavioural questions. We may be able to learn about the factors affecting

Marbled Murrelet distribution by studying water temperature and salinity and how it impacts prey distribution.

## **Behaviour**

The majority (90%) of birds that were observed flying past the nets were moving towards the mouth of Theodosia Inlet. The reasons for this are not known but may relate to the flight patterns of birds to and from nests. We would have predicted that if murrelets were simply moving back and forth between foraging areas or if birds were travelling between foraging areas and nesting sites, the proportion flying in each direction would have been approximately equal.

Future studies should place more emphasis on trying to obtain reliable estimates of adult to juvenile ratios, since this measure may be an important indicator of long-term population trends in productivity. Scan and focal observation surveys should continue only when specific hypotheses are developed to be tested. Our objective was to assess the Desolation Sound area as a suitable area for a long-term study on the demographics and natural history of Marbled Murrelets. Specific hypotheses could be developed on foraging behaviour and social behaviour and Desolation Sound provides a good site to perform these studies.

## **Nest site**

The nest site located during this study is only the second confirmed site on the mainland coast of B.C. The first site was found in the Caren Range on the Sechelt Peninsula and was also found in high elevation old growth forest in a yellow cedar (P.H. Jones 1993). One other potential nest site was located in the Mussel Inlet area but no birds were sighted during radio tracking (Burns and Prestash, pers. comm.).

There has not been a careful assessment of the distribution of potential nesting habitat within the Desolation Sound study area. However, preliminary assessments suggest that old-growth habitat is not abundant within a 100 km radius of the capture site.

All nests south of Alaska have been found in trees (Ralph *et al.* 1995). In Alaska, five Marbled Murrelet ground nests have been confirmed in the alpine zone (Simons 1980, Hirsch *et al.* 1981, Johnston and Carter 1985). Most ground nests have been in the open but sheltered by small rock ledges. One nest was in a rock cavity 50 cm deep with a 20 cm x 20 cm entrance (Johnston and Carter 1985). Rock and talus slopes are abundant within the study area and if Marbled Murrelets are using these habitats we should be able to determine their importance during the course of the study.

## CONCLUSIONS

The results from the 1994 field season build on the pilot studies conducted in 1991 and 1993. The population of Marbled Murrelets in Desolation Sound is now unique in that it contains the only large group of banded birds and that group has a determinable genetic background. Recoveries of banded birds and knowledge of the genetic material offers the potential to study the ecology and population structure of Marbled Murrelets in ways that are not available in any other area. Taking advantage of such opportunities will help us cope with the difficult conservation and management questions posed by such a secretive species.

## LITERATURE CITED

- Bédard, J. 1985. Evolution and characteristics of the Atlantic Alcidae. Pp. 1-53 in D.N. Nettleship and T.R. Birkhead (eds.). The Atlantic Alcidae. Academic Press, New York, N.Y.
- Beissinger, S.B. 1995. Population trends of the Marbled Murrelet projected from demographic analyses. Pp. 385-393 in C. J. Ralph, G. L. Hunt, Jr., M. G. Raphael, J. F. Piatt (eds.). Ecology and conservation of the Marbled Murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA. Pac. Southwest Res. Station, For. Serv., U.S. Dept. Agric. 420 pp.
- Boulanger J.K., K. Martin, G.W. Kaiser and A.E.Derocher. (submitted to Conservation Biology) Marbled Murrelet conservation priorities: Insights from matrix models.
- Brooks, A. 1926. Scarcity of the Marbled Murrelet. Murrelet 7:39.
- Campbell, R.W., N.K. Dawe, I.McT. Cowan, J.M. Cooper, G.W. Kaiser, and M.C.E. McNall. 1990. Birds of British Columbia Vol. 1. Royal B. C. Museum and Can. Wildl. Serv. Victoria, B.C.
- Carter, H.R. 1984. At-sea biology of the Marbled Murrelet (*Brachyramphus marmoratus*) in Barkley Sound, British Columbia. M.Sc. Thesis. Univ. Manitoba, Winnipeg, Man.
- Carter, H.R., and R.A. Erickson. 1988. Population status and conservation problems of the Marbled Murrelet in California, 1892-1987. Unpub. Rep. Cal. Fish Game, Sacramento, CA. 68 pp.
- Carter, H.R., and R.A. Erickson. 1992. Status and conservation of the Marbled Murrelet in California 1892-1987. Proc. West. Found. Vertebr. Zool. 5:91-108.
- Carter, H.R., and S.G. Sealy. 1984. Marbled Murrelet mortality due to gill-net fishing in Barkley Sound, British Columbia. in D.N. Nettleship, G.A. Sanger, and P.F. Springer (eds.). Marine Birds: their feeding ecology and commercial relationships. Can. Wildl. Serv. Spec. Publ., Ottawa. 212-220.
- Carter, H.R., and S.G. Sealy. 1986. Year-round use of coastal lakes by Marbled Murrelets. Condor 88: 473-477.



- Carter, H.R., and S.G. Sealy. 1987. Fish-holding behavior of Marbled Murrelets. *Wils. Bull.* 99:289-291.
- Carter, H.R., and J.L. Stein 1995. Molts and plumages in the annual cycle of the Marbled Murrelet. Pp. 99-112 in C. J. Ralph, G. L. Hunt, Jr., M. G. Raphael, J. F. Piatt (eds.). Ecology and conservation of the Marbled Murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA. Pac. Southwest Res. Station, For. Serv., U.S. Dept. Agric. 420 pp.
- De Santo, T.L. and S.K. Nelson 1995. Comparative reproductive ecology of the auks (Family Alcidae) with emphasis on the Marbled Murrelet. Pp 33-47 in C. J. Ralph, G. L. Hunt, Jr., M. G. Raphael, J. F. Piatt (eds.). Ecology and conservation of the Marbled Murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA. Pac. Southwest Res. Station, For. Serv., U.S. Dept. Agric. 420 pp.
- Divoky, G.J., and M. Horton 1995. Breeding and natal dispersal, nest habitat loss and implications for Marbled Murrelet populations. Pp. 83-87 in C. J. Ralph, G. L. Hunt, Jr., M. G. Raphael, J. F. Piatt (eds.). Ecology and conservation of the Marbled Murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA. Pac. Southwest Res. Station, For. Serv., U.S. Dept. Agric. 420 pp.
- Drent, R.H., and C.J. Guiguet. 1961. A catalogue of British Columbia sea-bird colonies. B.C. Prov. Mus. Occ. Paper No. 12. Victoria, B.C. 173 pp.
- Gaston, A.J. 1992. The Ancient Murrelet: A natural history in the Queen Charlotte Islands. T and A D Poyser, London.
- Hirsch, K.V., D.A. Woodby, L.B. Astheimer. 1981. Growth of a nestling Marbled Murrelet. *Condor* 83:264-265.
- Jones, I.L. 1985. Structure and function of vocalizations and related behaviour of the Ancient Murrelet (*Synthliboramphus antiquus*). M.Sc. thesis, Univ. Toronto, Toronto, Ont.
- Jones, I.L. 1993. Sexual differences in bill shape and external measurements of crested auklets. *Wilson Bull.* 105:525-529.

- Jones, I.L. 1994. Mass changes of least auklets *Aethia pusilla* during the breeding season: evidence for programmed loss of mass. *J. Anim. Ecol.* 63:71-78.
- Jones, P.H. 1993. Canada's first active Marbled Murrelet nest discovered and observations. *British Columbia Naturalist* 31:8.
- Jones, P.H. 1994. Canada's second Marbled Murrelet chick sighting, Caren Range, BC. *Discovery (VNHS)* 23:99.
- Johnston, S. and H.R. Carter. Cavity-nesting Marbled Murrelets. *Wils. Bull.* 97:1-3.
- Kaiser, G.W., T.E. Mahon, and M.D. Fawcett. 1991. Studies of Marbled Murrelets in marine habitats, during 1990. *Can. Wildl. Serv. Tech. Rep. Ser. No. 131*, Delta, B.C.
- Kaiser, G.W., A.E. Derocher, S. Crawford, M.J. Gill, and I.A. Manley. 1995. A capture technique for Marbled Murrelets in coastal inlets. *J. Field Ornith.* 66: 321-333.
- Kaiser, G.W., H.J. Barclay, A.E. Burger, D. Kangasniemi, D.J. Lindsay, W.T. Munro, W.R. Pollard, R. Redhead, J. Rice, and D. Seip. 1992. National recovery plan for the Marbled Murrelet. Canadian Wildlife Service.
- Konyukhov, N.B., and A.S. Kitaysky. 1995. The Asian race of the Marbled Murrelet. Pp. 23-29, in C. J. Ralph, G. L. Hunt, Jr., M. G. Raphael, J. F. Piatt (eds.). *Ecology and conservation of the Marbled Murrelet*. Gen. Tech. Rep. PSW-GTR-152. Albany, CA. Pac. Southwest Res. Station, For. Serv., U.S. Dept. Agric. 420 pp.
- Leschner, L.L., and E.B. Cummins. 1992. Breeding records, inland distribution and threats to the Marbled Murrelet in Washington from 1905 to 1987. *Proc. West. Found. Vertebr. Zool.* 5:42-47.
- Mahon, T.E., G.W. Kaiser, and A.E. Burger. 1992. The role of Marbled Murrelets in mixed-species feeding flocks in British Columbia. *Wils. Bull.* 104:738-743.
- Marshall, D.B. 1988a. Status of the Marbled Murrelet in North America, with special emphasis on populations in California, Oregon, and Washington. *Biol. Rep.* 88(30), U.S. Fish Wildl. Serv., Washington, D.C.

- Marshall, D.B. 1988*b*. The Marbled Murrelet joins the old-growth forest conflict. *Amer. Birds* 42:208-212.
- Naslund, N.L., and B.P. O'Donnell. 1995 Daily patterns of Marbled Murrelet activity at inland sites. Pp 129-134 *in* C. J. Ralph, G. L. Hunt, Jr., M. G. Raphael, J. F. Piatt (eds.). *Ecology and conservation of the Marbled Murrelet*. Gen. Tech. Rep. PSW-GTR-152. Albany, CA. Pac. Southwest Res. Station, For. Serv., U.S. Dept. Agric. 420 pp.
- Nelson, S. K., M.L.C. McAllister, M.A. Stern, D.H. Varoujean, J.M. Scott. 1992. The Marbled Murrelet in Oregon, 1899-1987. *Proc. West. Found. Vert. Zool.* 5:61-91.
- Nelson, S.K., and T.E. Hamer 1995. Nesting biology and behavior of the Marbled Murrelet. Pp. 57-68 *in* C. J. Ralph, G. L. Hunt, Jr., M. G. Raphael, J. F. Piatt (eds.). *Ecology and conservation of the Marbled Murrelet*. Gen. Tech. Rep. PSW-GTR-152. Albany, CA. Pac. Southwest Res. Station, For. Serv., U.S. Dept. Agric. 420 pp.
- Pearse, T. 1946. Notes on changes in bird populations in the vicinity of Comox, British Columbia - 1917 to 1944. *Murrelet* 27:4-9.
- Prestash, L., R. Burns, and G.W. Kaiser. 1992. Surveys of Marbled Murrelets during the breeding season on the central coast of British Columbia, 1991. *Can. Wildl. Serv. Tech. Rep. Ser. No. 160*. Delta, BC. 98 pp.
- Ralph, C.J., Hunt, G.L., Jr., Raphael, M.G., Piatt, J.F., Technical editors. 1995. *Ecology and conservation of the Marbled Murrelet*. Gen. Tech. Rep. PSW-GTR-152. Albany, CA. Pac. Southwest Res. Station, For. Serv., U.S. Dept. of Agric. 420 pp.
- Rodway, M.S. 1990. Status report on the Marbled Murrelet. Unpublished working document. Committee on the Status of Endangered Wildlife in Canada (COSEWIC), Ottawa.
- Rodway, M.S., J.-P. L. Savard, and H.M. Regehr. 1991. Habitat and activity patterns of Marbled Murrelets at inland and at-sea sites in the Queen Charlotte Islands, British Columbia. *Can. Wildl. Serv. Tech. Rep. Ser. No. 122*, Delta, B.C.
- Rodway, M.S., H.R. Carter, S.G. Sealy, and R.W. Campbell. 1992. Status of the Marbled Murrelet in British Columbia. *Proc. West. Found. Vertebr. Zool.* 5:17-41.

- Sealy, S.G. 1972. Adaptive differences in breeding biology in the marine family Alcidae. Ph. D. Thesis. U. Mich. Ann Arbor, MI.
- Sealy, S.G. 1975. Feeding ecology of Ancient and Marbled Murrelets near Langara Island, B.C. *Can. Jour. Zool.* 53:418-433.
- Sealy, S.G. and H.R. Carter. 1984. At-sea distribution and nesting habitat of the Marbled Murrelet in British Columbia: problems in conservation of a solitary nesting seabird. Pages 737-756 in J.P. Croxall, P.G.H. Evans, and R.W. Schreiber (eds.). Status and conservation of the world's seabirds. Internat. Council Bird Preserv. Tech. Pub. No. 2. Cambridge, U.K.
- Simons, T.R. 1980. Discovery of a ground-nesting Marbled Murrelet. *Condor* 82:1-9.
- Singer, S.W., N.L. Naslund, S.A. Singer, C.J. Ralph. 1991. Discovery and observation of two tree nests of the Marbled Murrelet. *Condor* 93:330-339.
- Sowls, A.L., A.R. DeGange, J.W. Nelson, and G.S. Lester. 1980. Catalog of California seabird colonies. U.S. Fish Wildl. Serv., Washington, D.C. FWS/OBS 37/80.
- Speich, S.M., and D.A. Manuwal. 1992. The numbers of Marbled Murrelets in Washington marine waters. *Proc. West. Found. Vertebr. Zool.* 5:48-60.

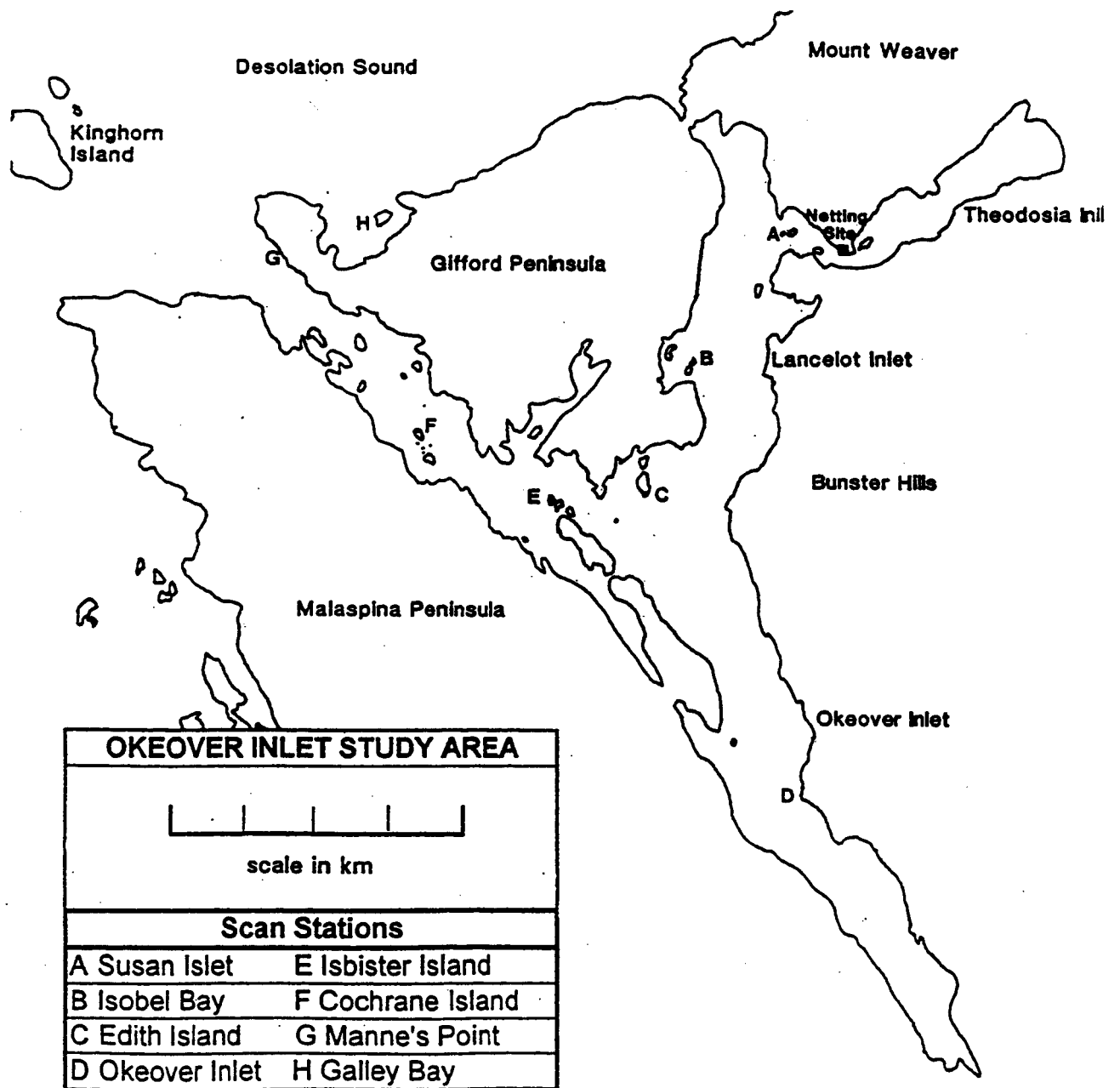


Figure. 1. Location of the study area and scan survey sites near Desolation Sound, B.C.

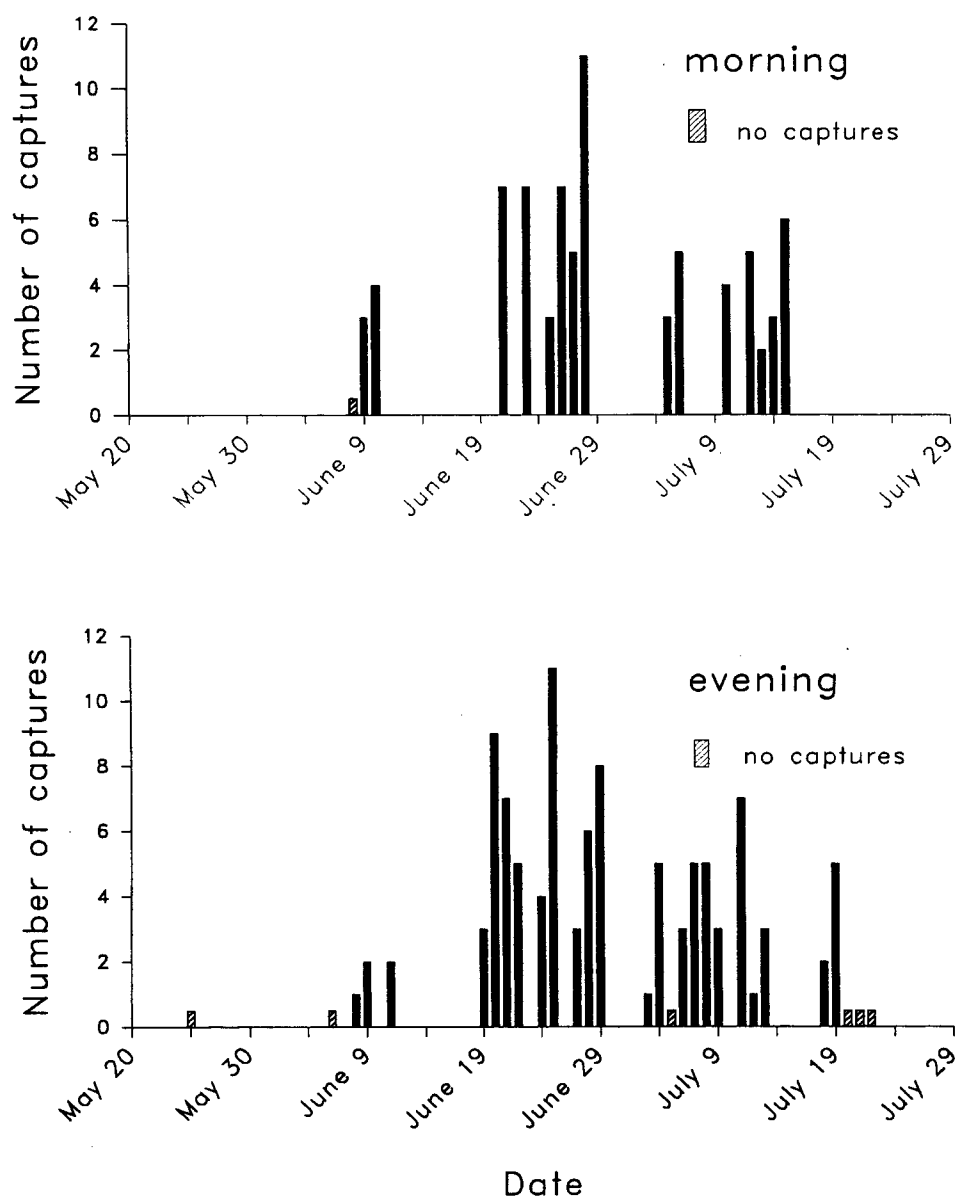


Figure 2. Number of Marbled Murrelets captured during the morning and evening netting sessions, Theodosia Inlet 1994 (Kaiser *et al.* 1995).

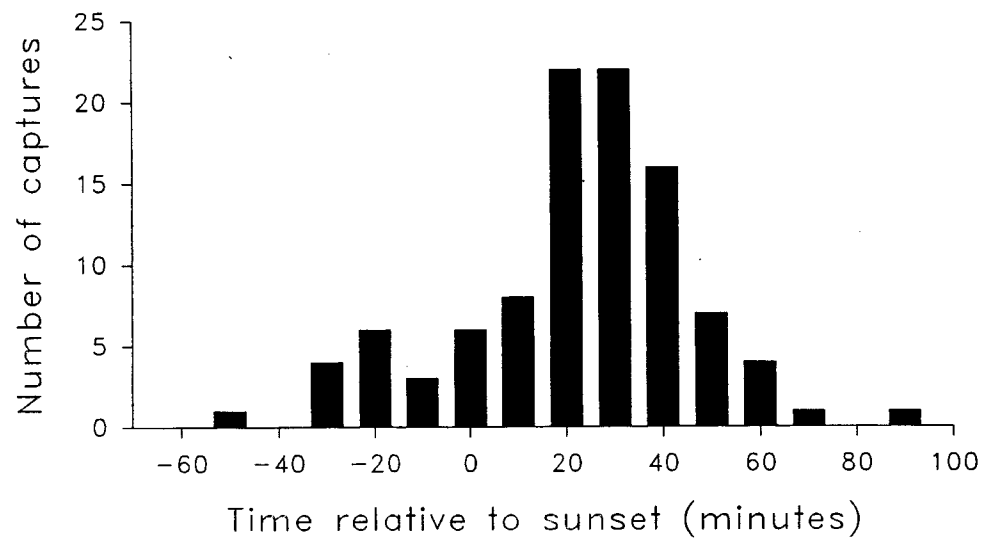
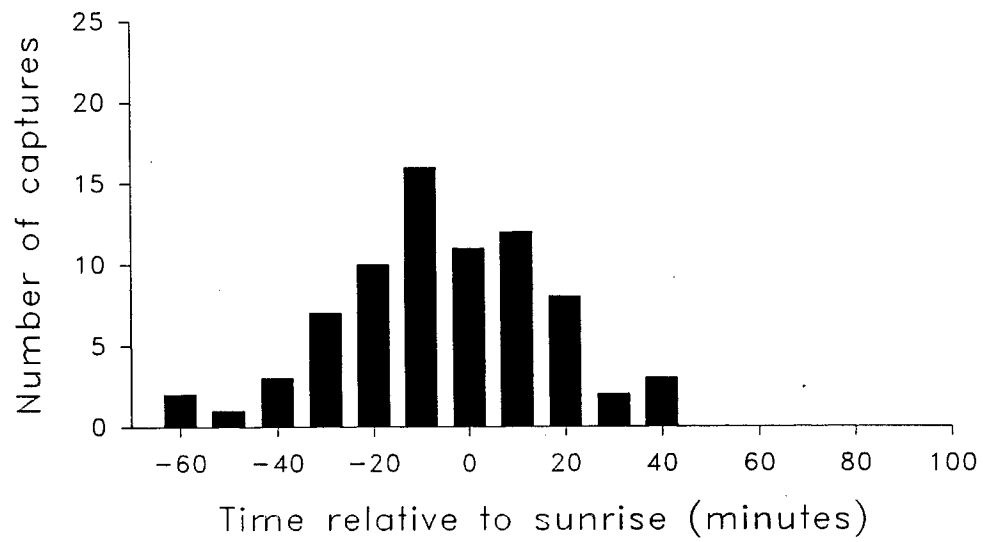


Figure 3. Time of capture of Marbled Murrelets relative to sunrise ( $n = 75$ ) and sunset ( $n = 101$ ) in Theodosia Inlet, 1994 (Kaiser *et al.* 1995).

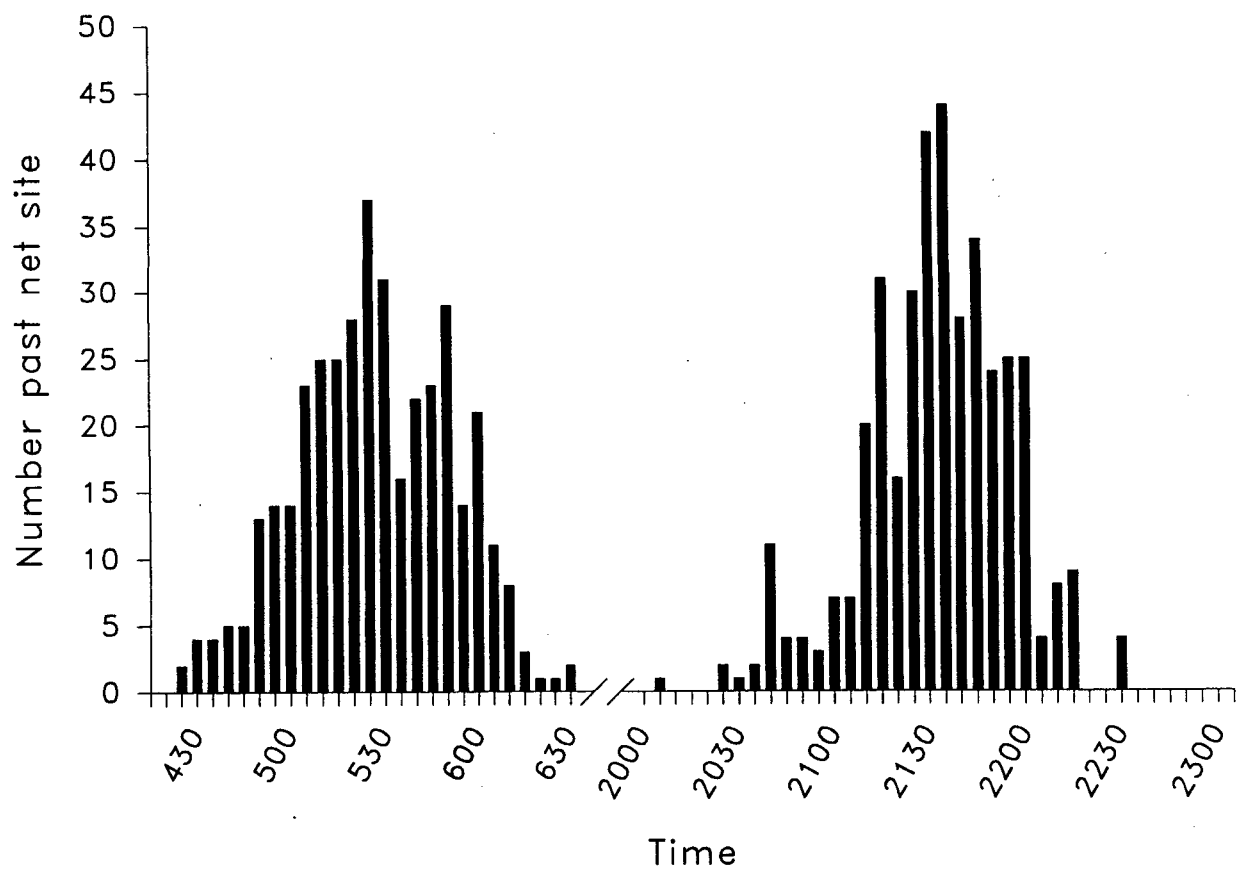


Figure 4. Number of Marbled Murrelets passing the net site relative to time of day in Theodosia Inlet, 1994.



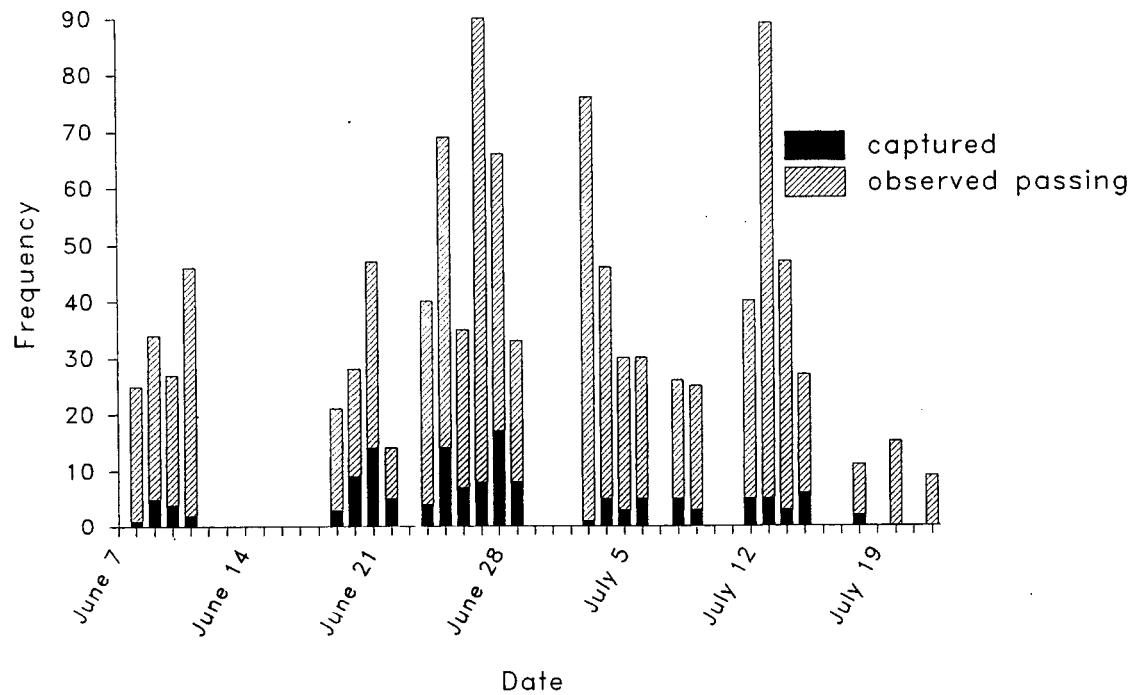


Figure 5. Number of Marbled Murrelets captured and observed flying during morning ( $n = 10$ ) and evening netting sessions ( $n = 14$ ) in Theodosia Inlet, 1994.

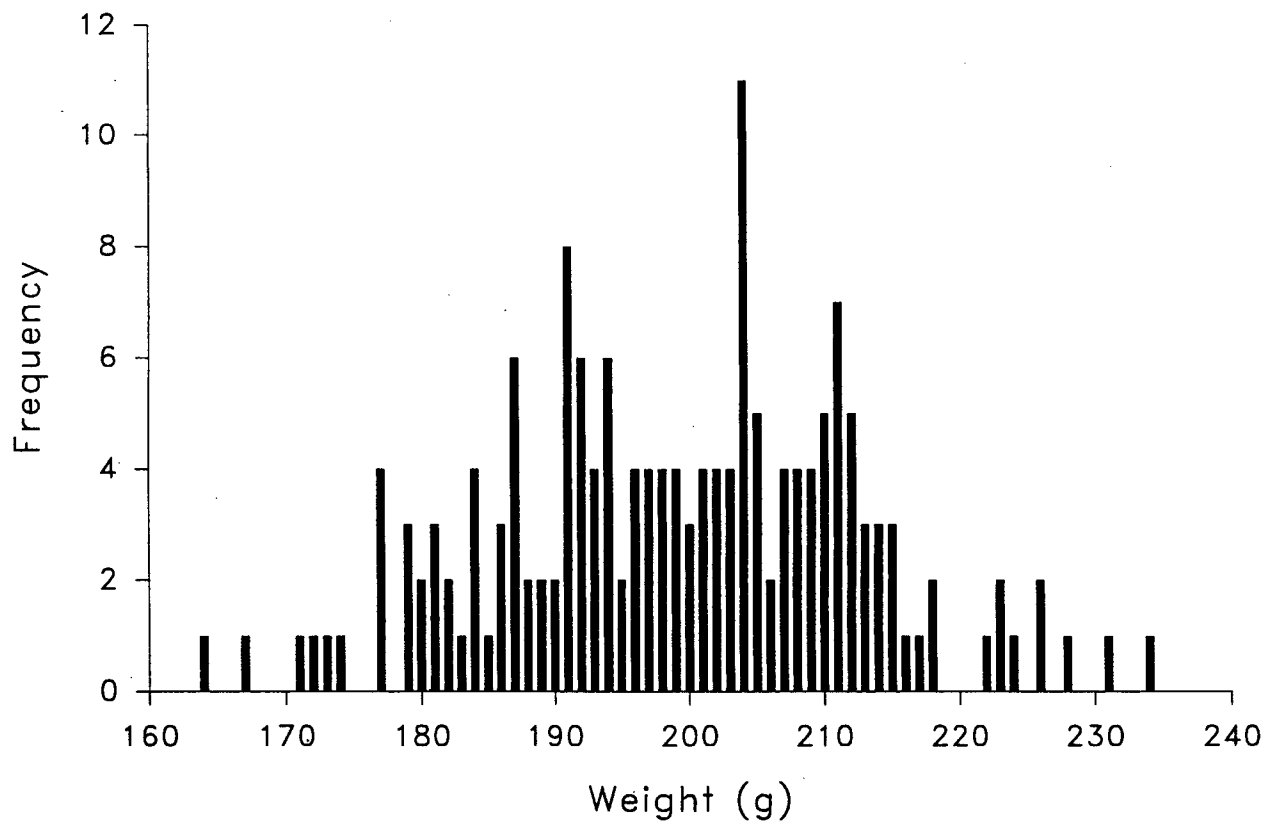


Figure 6. Body mass (g) ( $n = 168$ ) of Marbled Murrelets captured in Theodosia Inlet, 1994.

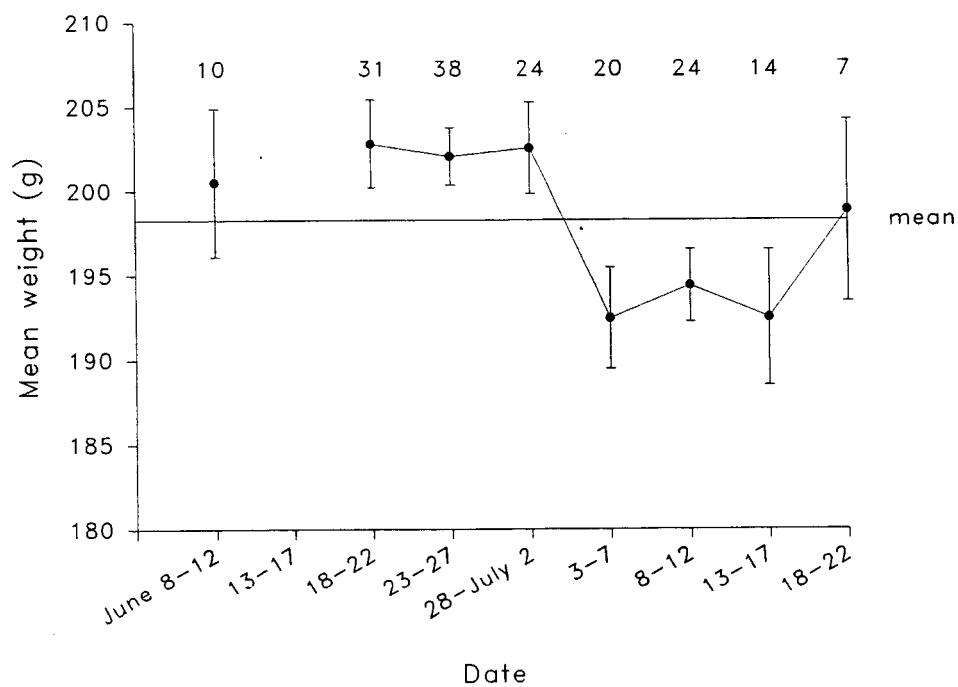


Figure 7. Mean body mass of Marbled Murrelets by date of capture in Theodosia Inlet, 1994.  
Sample size above each point.

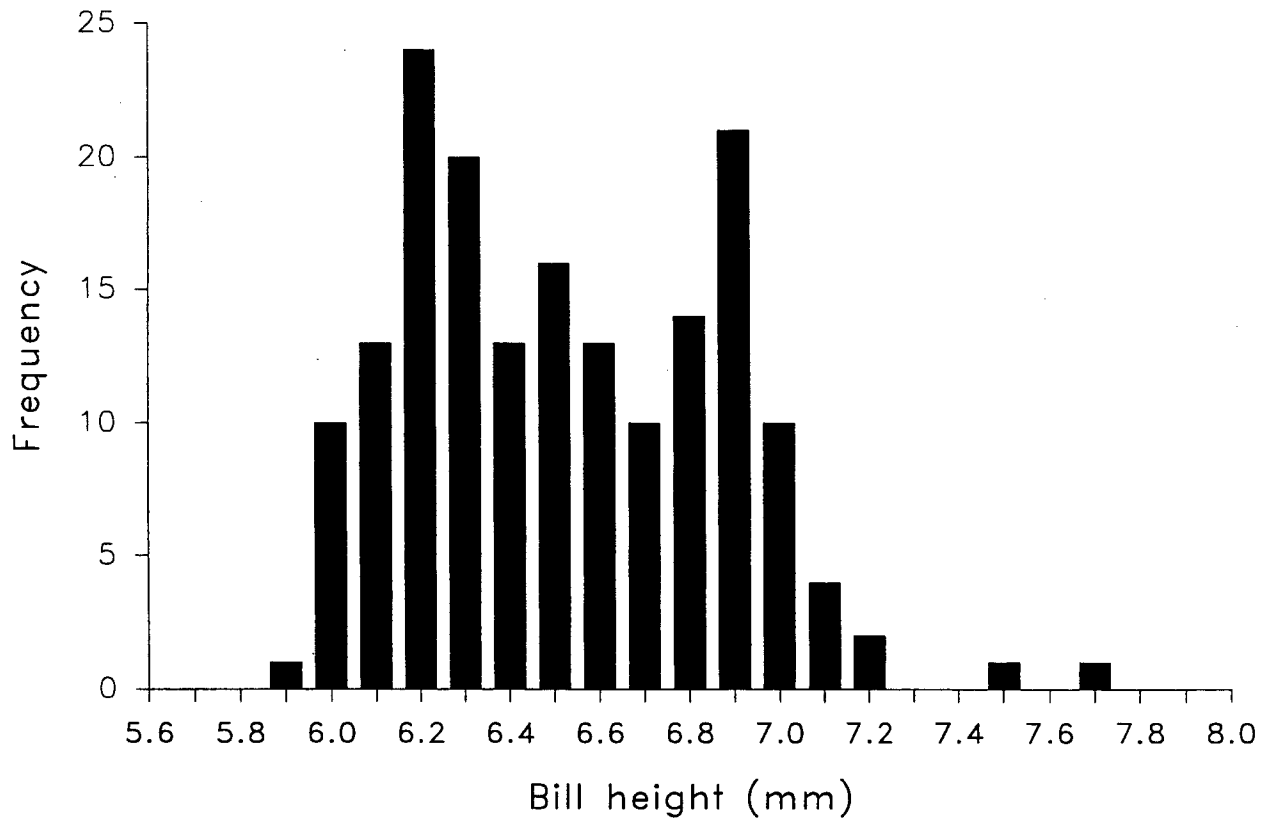


Figure 8. Bill heights ( $n = 173$ ) of Marbled Murrelets captured in Theodosia Inlet, 1994.

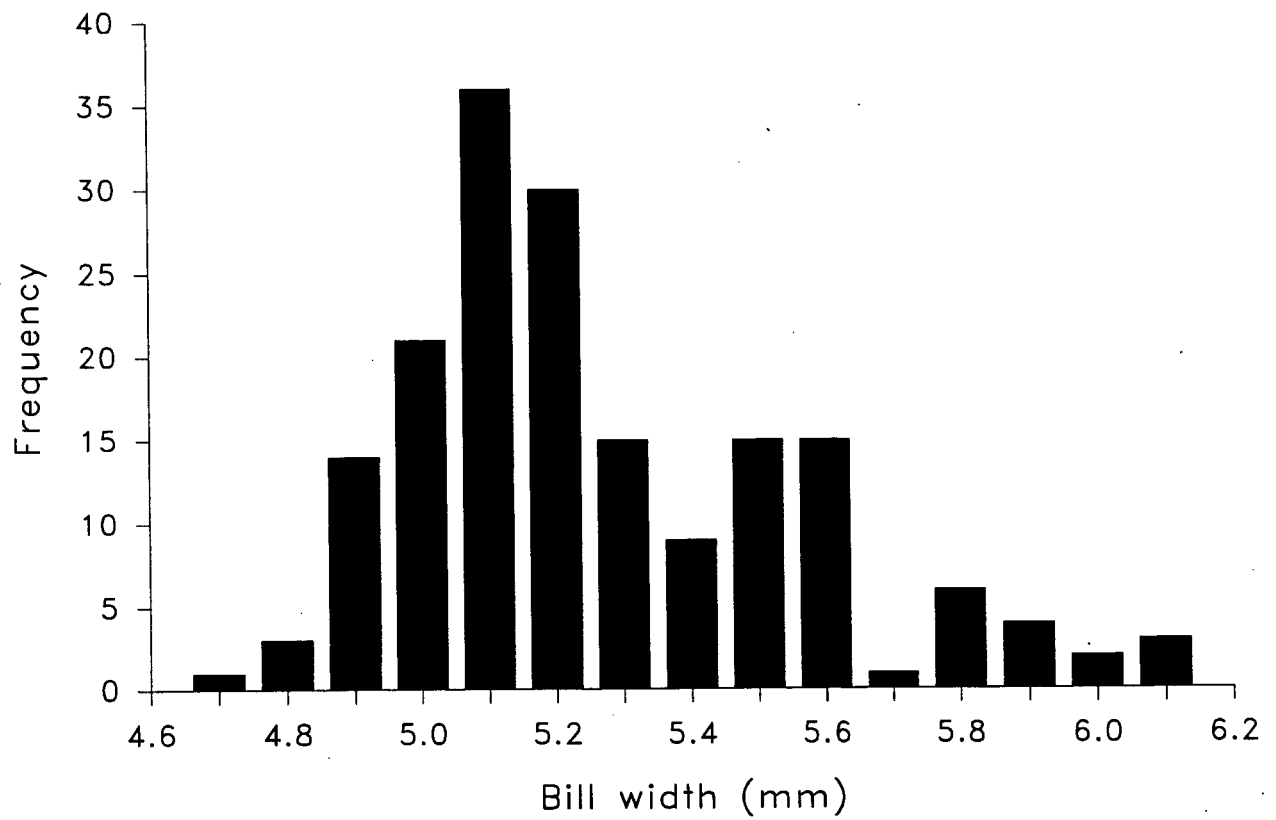


Figure 9. Bill widths ( $n = 175$ ) of Marbled Murrelets captured in Theodosia Inlet, 1994.

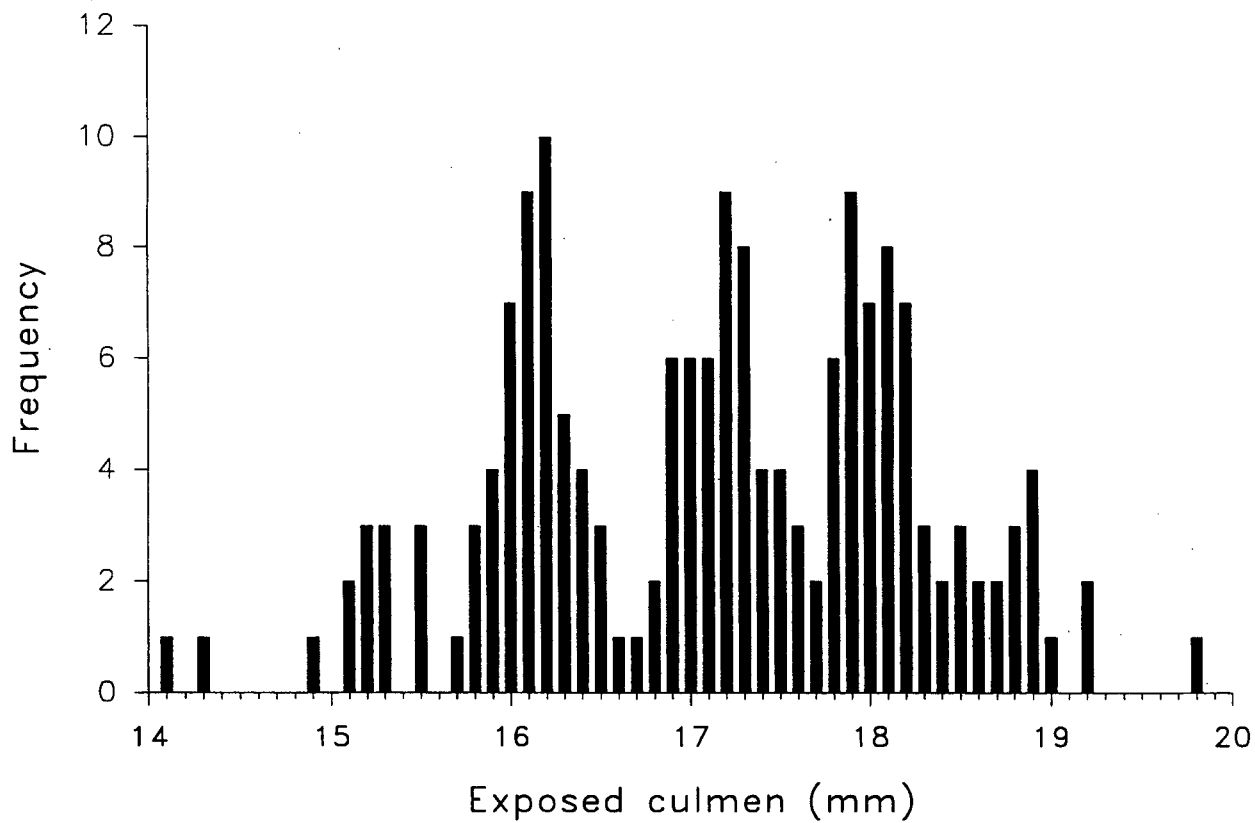


Figure 10. Exposed culmen lengths ( $n = 172$ ) of Marbled Murrelets captured in Theodosia Inlet, 1994.

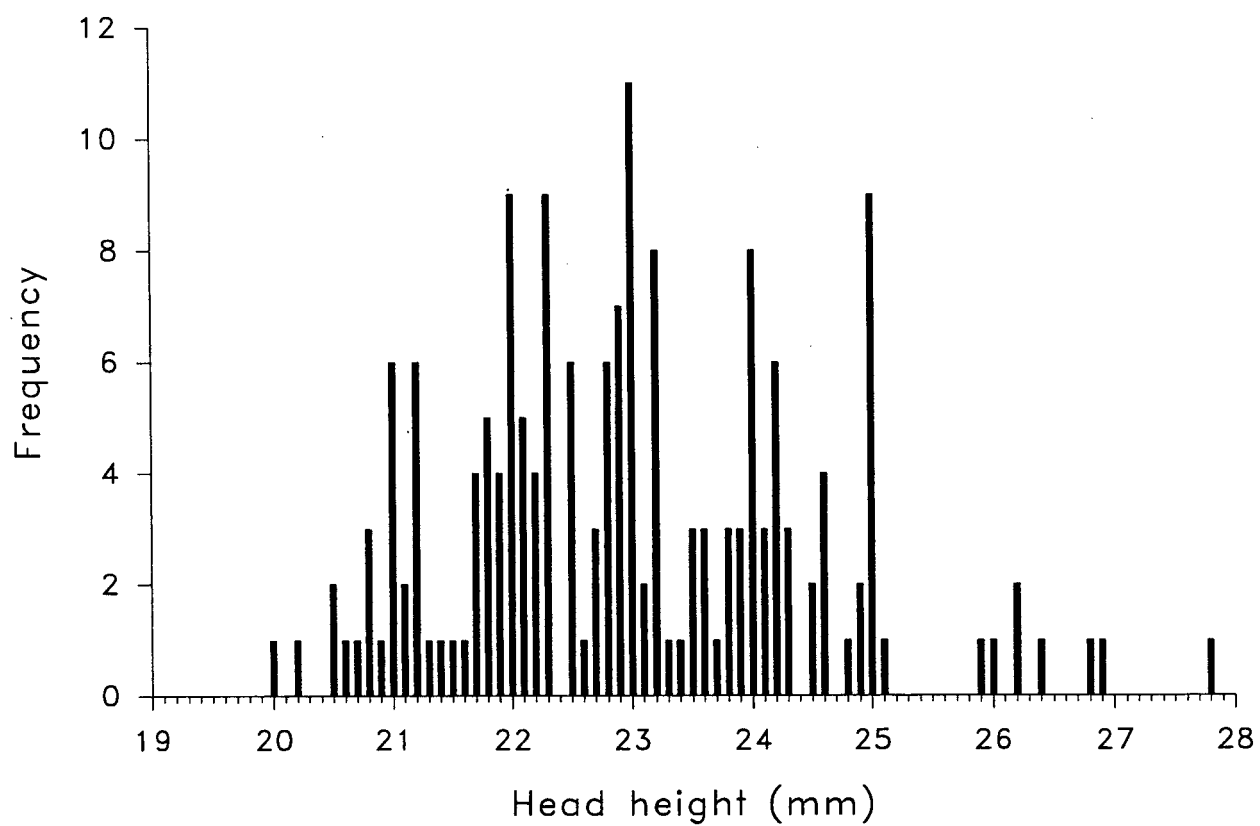


Figure 11. Head heights ( $n = 174$ ) of Marbled Murrelets captured in Theodosia Inlet, 1994.

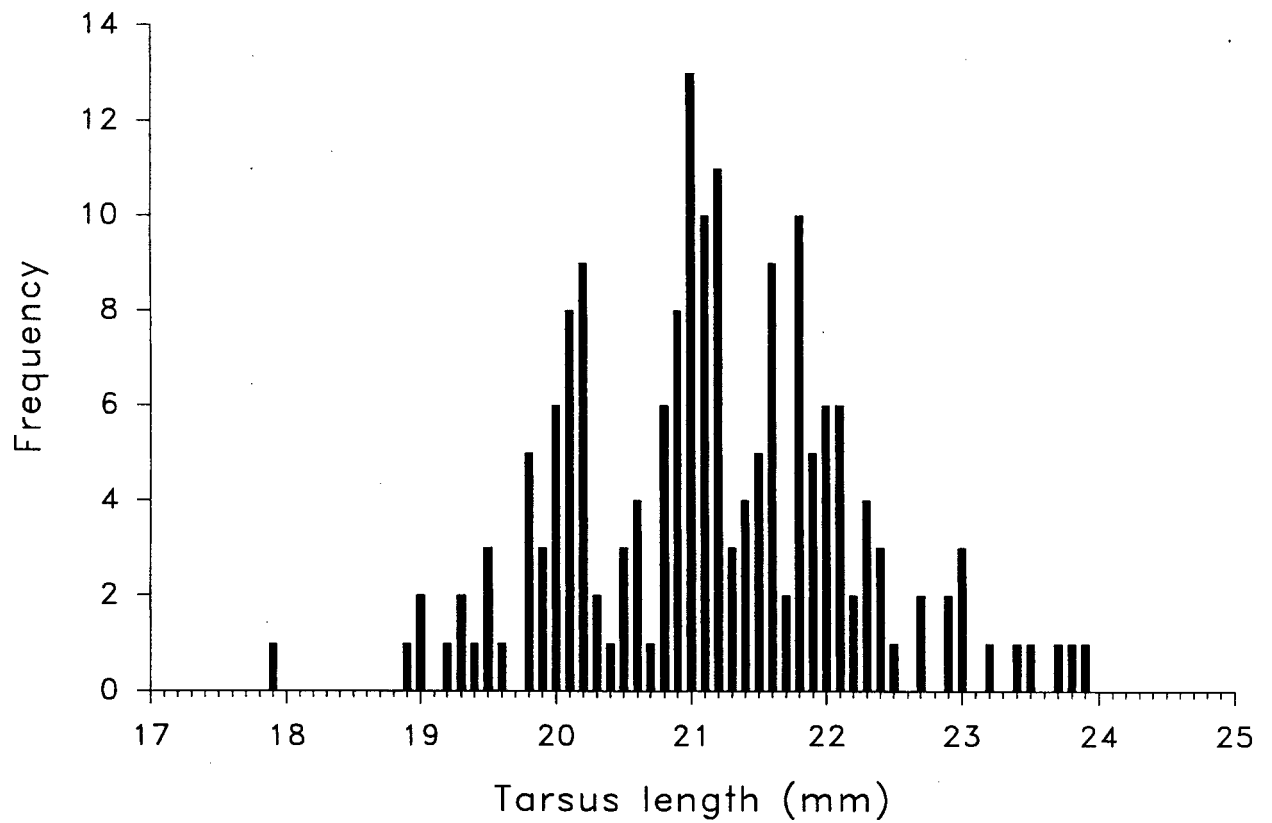


Figure 12. Tarsus lengths ( $n = 175$ ) of Marbled Murrelets captured in Theodosia Inlet, 1994.



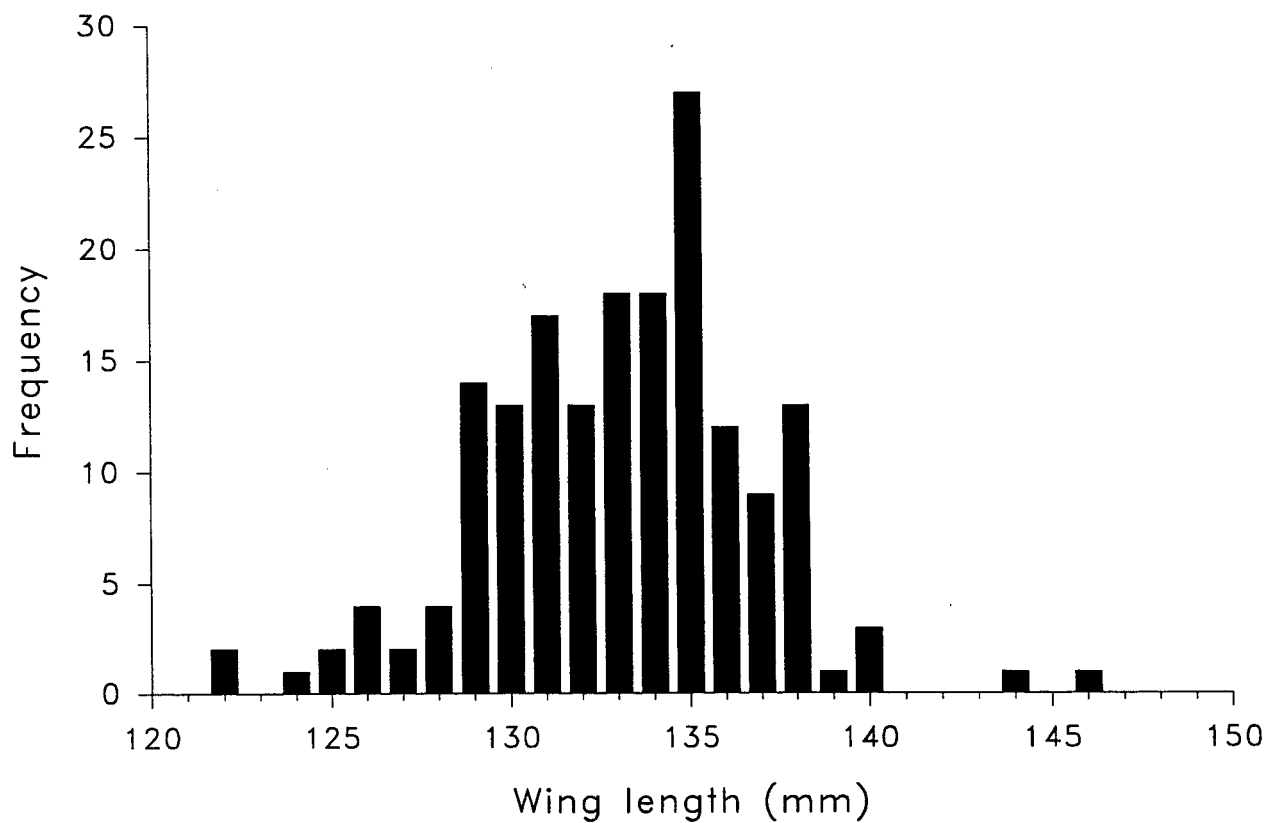


Figure 13. Wing lengths ( $n = 175$ ) of Marbled Murrelets captured in Theodosia Inlet, 1994.

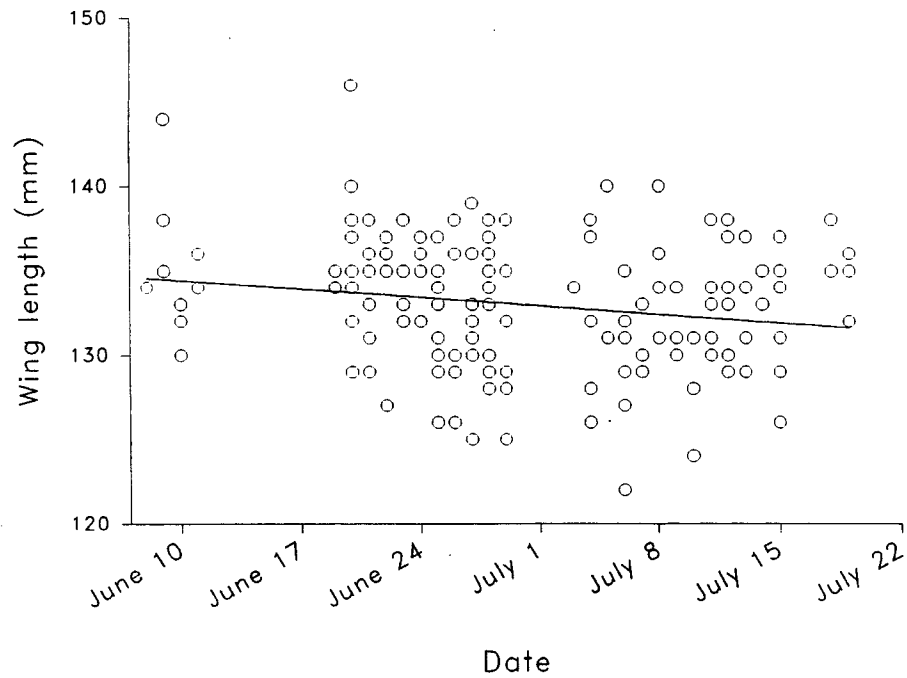


Figure 14. Marbled Murrelets wing lengths ( $n = 175$ ) and regression line by date of capture in Theodosia Inlet, 1994 (linear regression,  $F = 6.88$ ,  $df = 1, 778$ ,  $P = 0.0095$ ; wing length =  $146.05 - 0.072 \cdot \text{date}$ ).

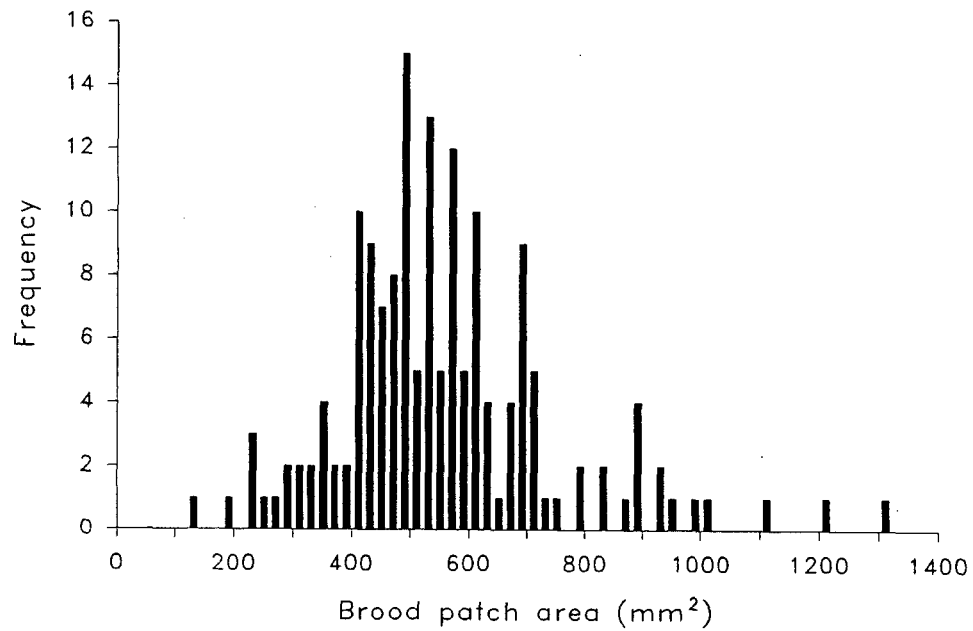


Figure 15. Brood patch size index (length x width) ( $n = 162$ ) of Marbled Murrelets captured in Theodosia Inlet, 1994.

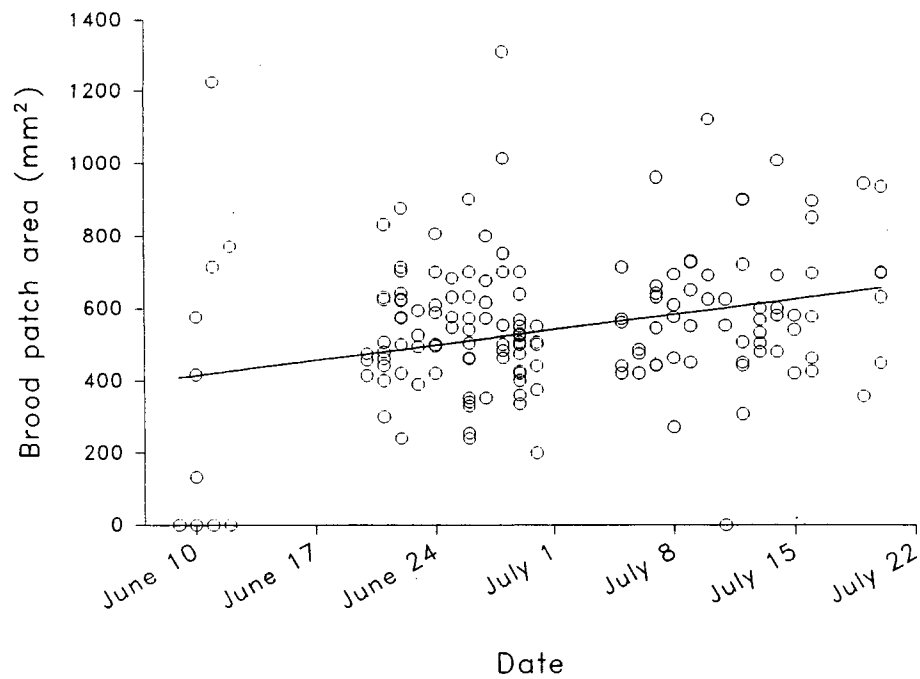


Figure 16. Brood patch size index (length x width) of Marbled Murrelets and regression line by date of capture in Theodosia Inlet, 1994 (linear regression,  $F = 15.2$ ,  $df = 1, 175$ ,  $P < 0.001$ ,  $r^2 = 0.08$ ).

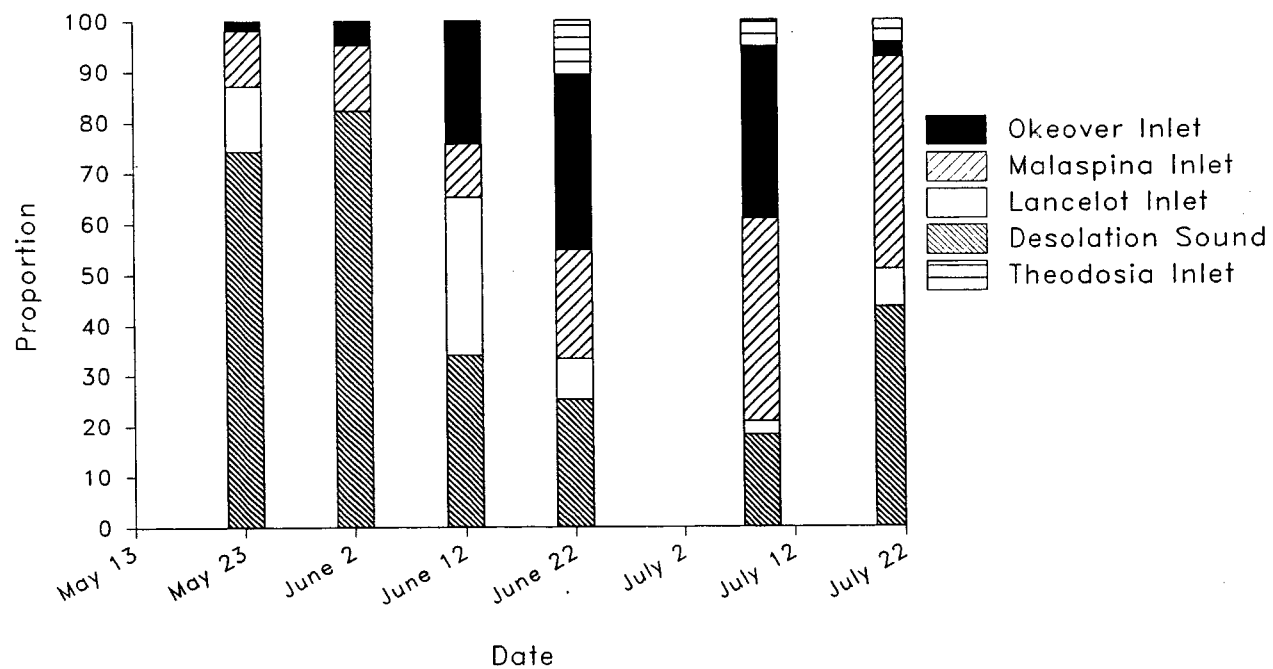


Figure 17. Distribution of Marbled Murrelets during marine surveys in the Desolation Sound study area, 1994.

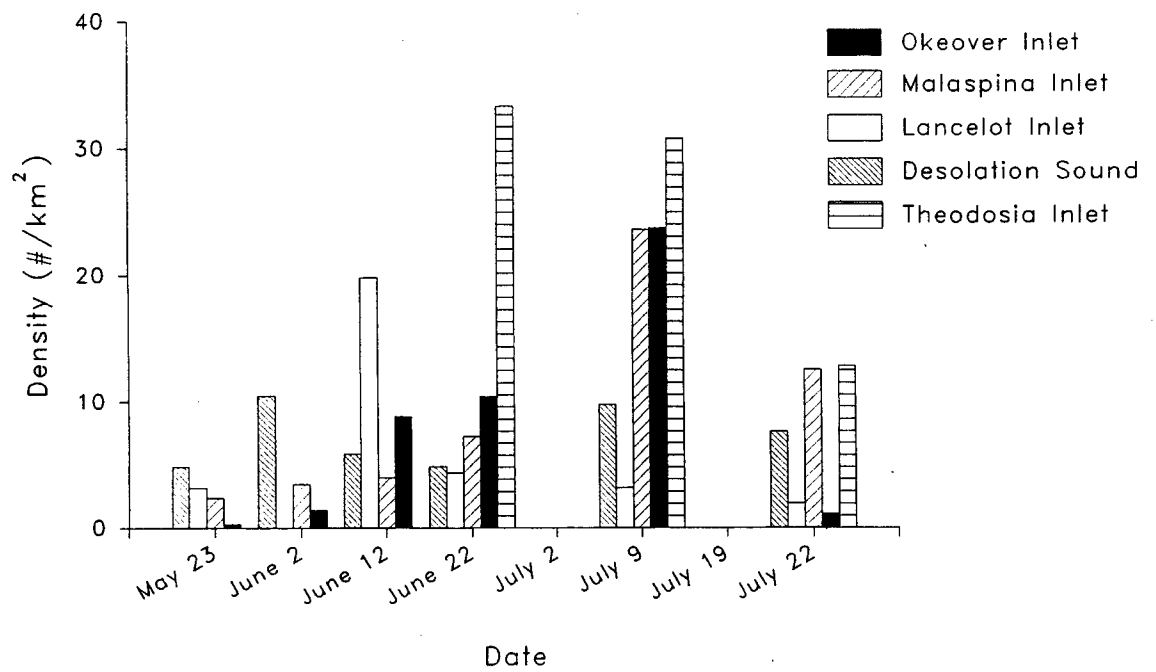


Figure 18. Relative density of Marbled Murrelets by sampling areas during marine surveys in the Desolation Sound study area, 1994.

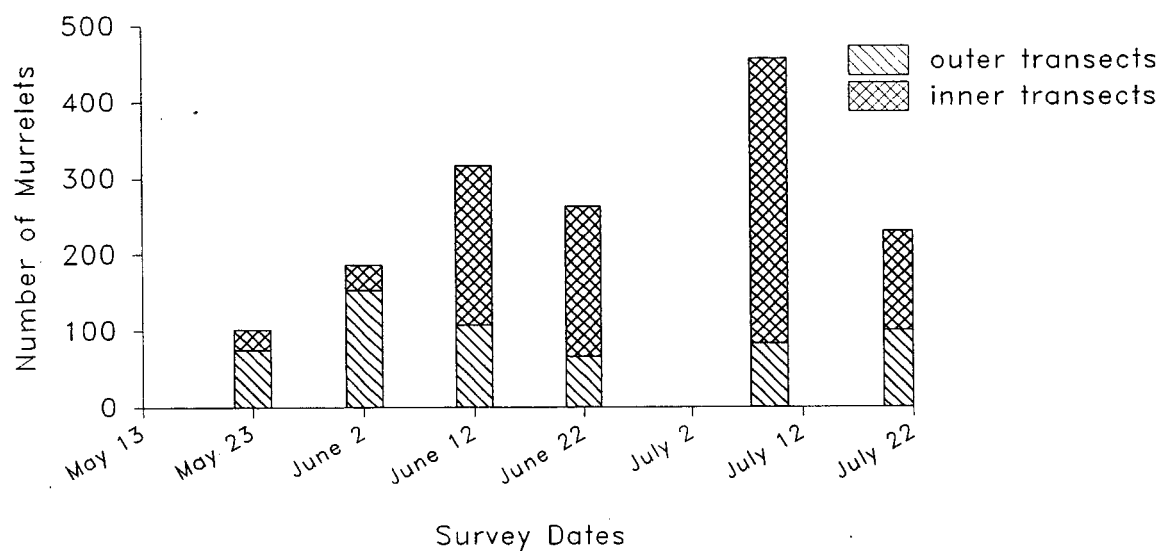


Figure 19. Number of Marbled Murrelets counted in inner (Theodosia, Lancelot, Malaspina, and Okeover) and outer transects (Desolation Sound) during marine surveys in the Desolation Sound study area, 1994.

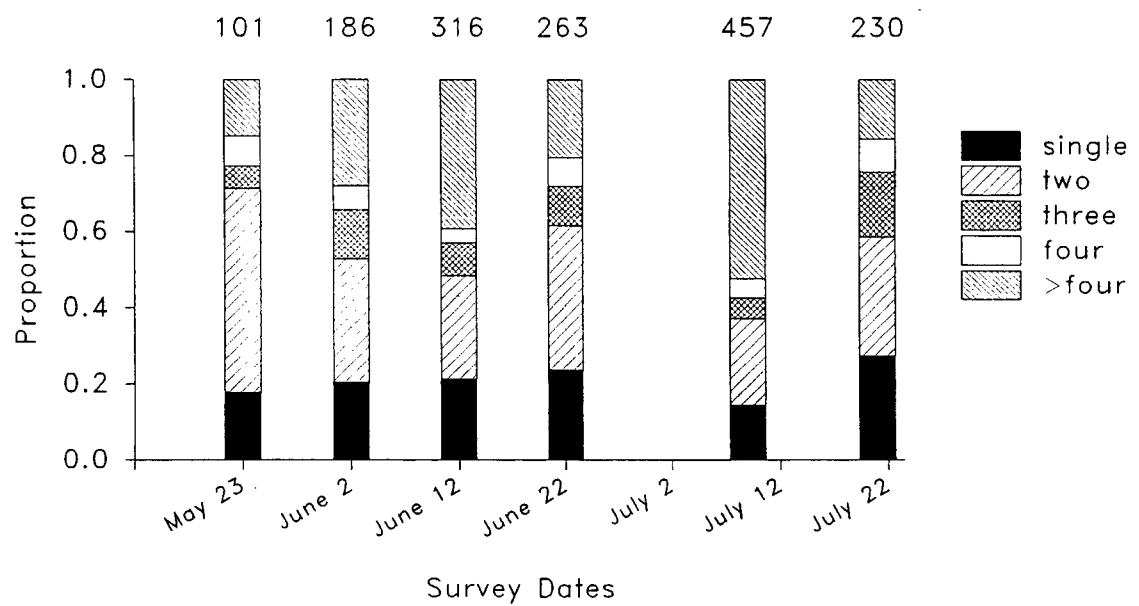
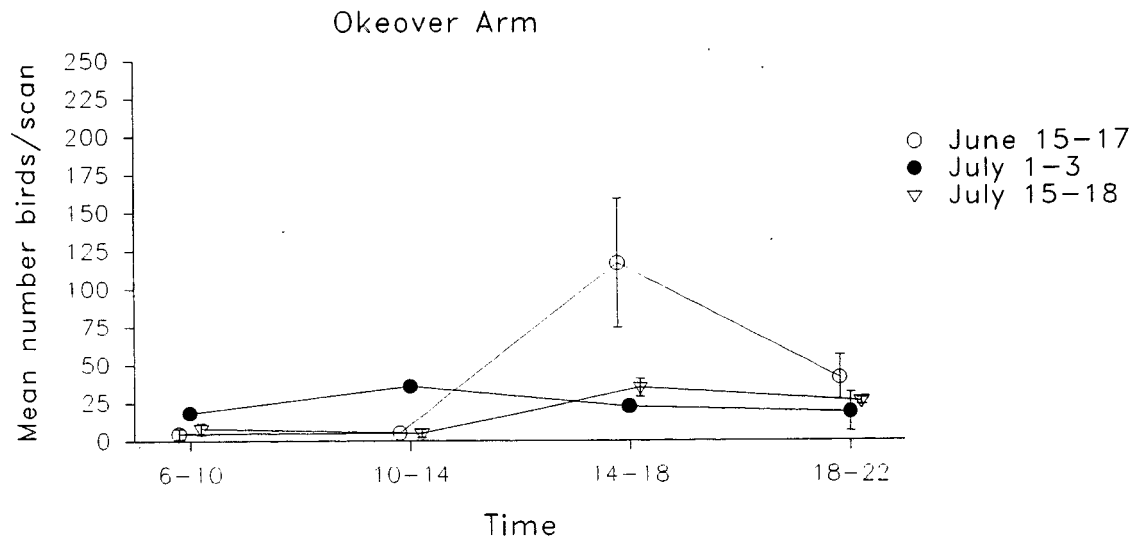
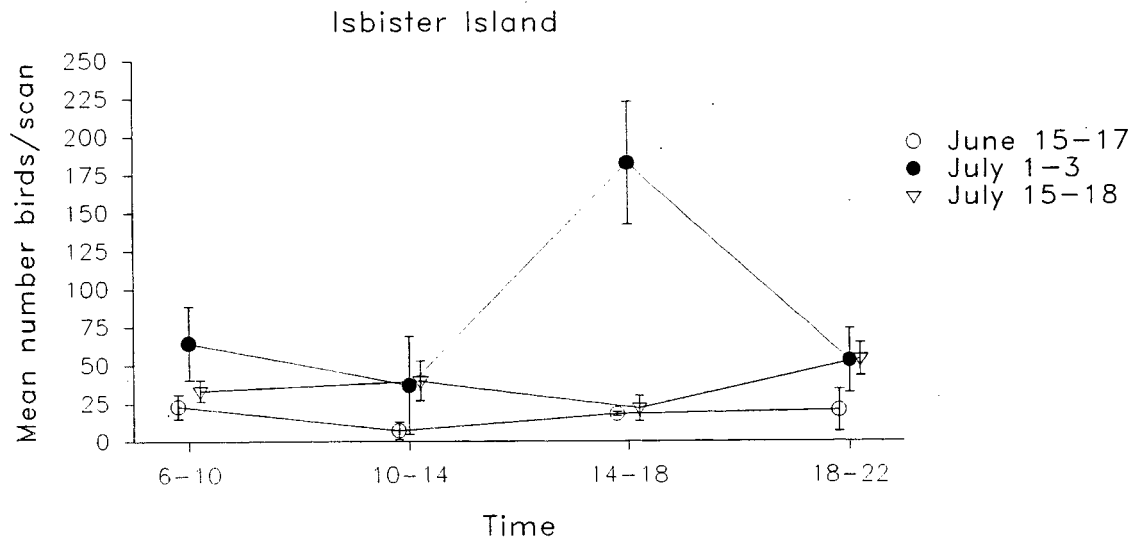


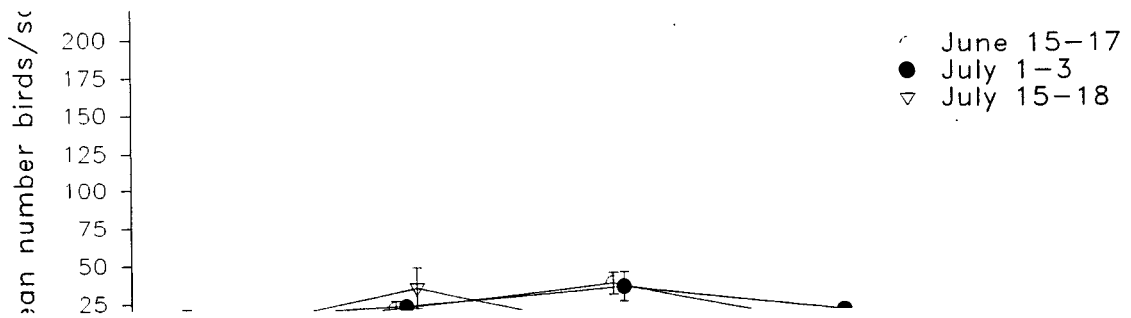
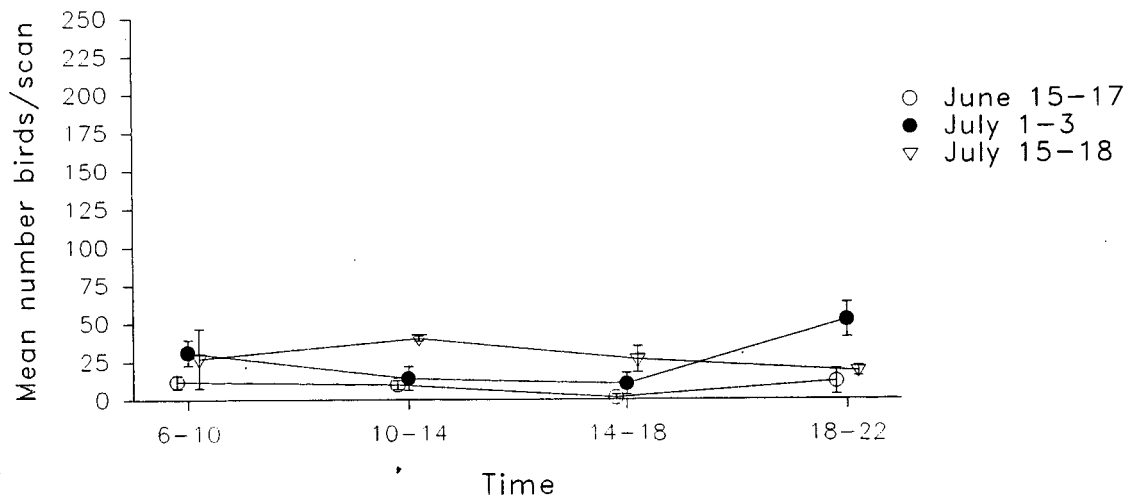
Fig. 20. Group sizes of Marbled Murrelets observed during marine surveys May 22 to July 20 in the Desolation Sound study area, 1994. Sample size indicated above each bar.



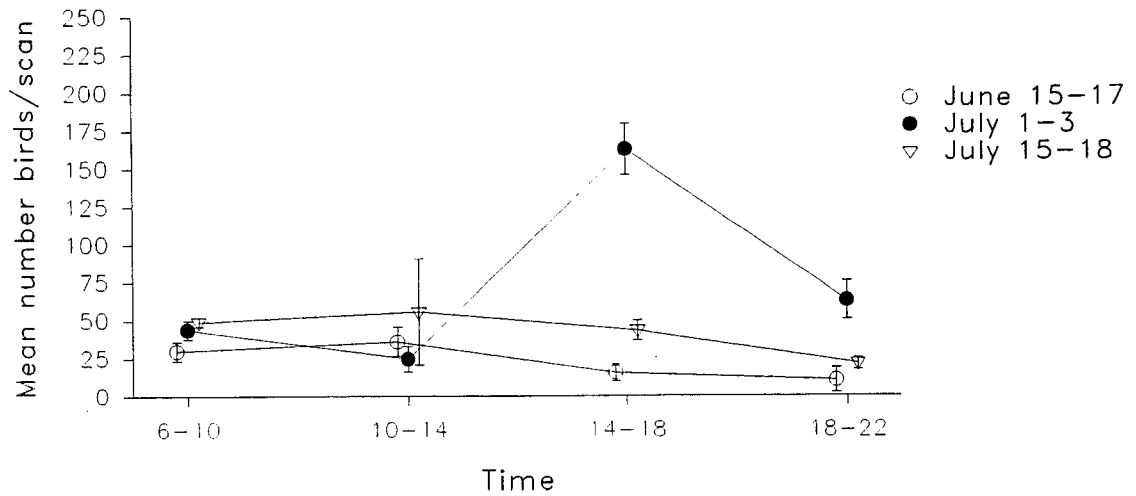
Appendix I. Mean number of Marbled Murrelets ( $\pm$ SE) observed/scan from 8 scan stations in Desolation Sound, 1994.



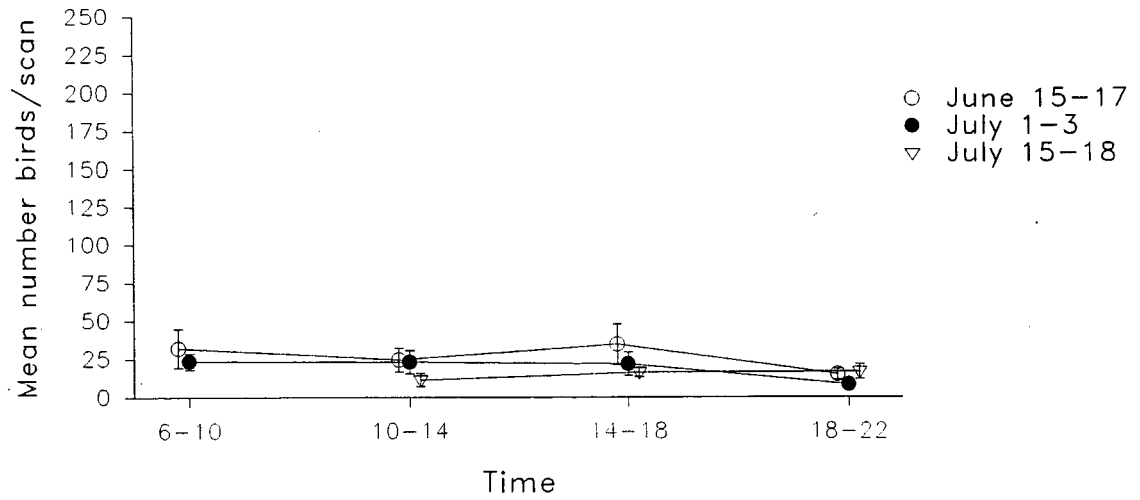
### Cochrane Island



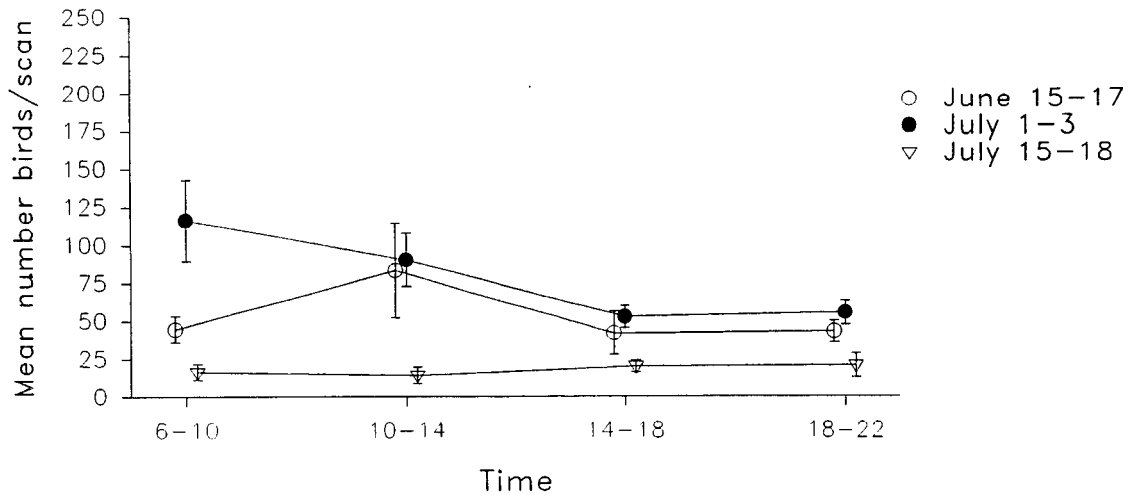
### Manne's Point



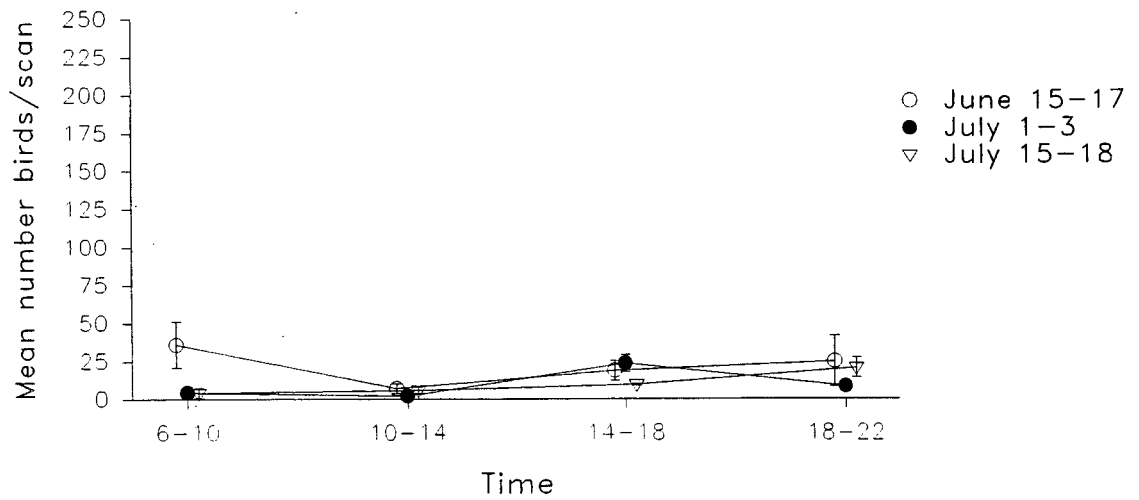
### Isabel Bay



### Edith Island



### Susan Island



Appendix II. Water temperature (degree centigrade) at the surface and at 10 m in the Desolation Sound study area, 1994.

<b>a. SURFACE TEMPERATURE</b>							
	STATION	MAY 23-24	JUNE 1-2	JUNE 11-12	JULY 7-9	JULY 20-21	
	A	15.0	15.2	15.0	21.0	20.5	
	B	16.0	16.0	16.0	20.5	22.5	
	C	16.5	19.0	16.0	20.0	23.2	
	D	16.0	15.0	16.0	19.5	22.3	
<b>OKEOVER</b>	<b>MEAN</b>	<b>15.9</b>	<b>16.3</b>	<b>15.8</b>	<b>20.3</b>	<b>22.1</b>	
	<b>STDEV</b>	<b>0.6</b>	<b>1.9</b>	<b>0.5</b>	<b>0.6</b>	<b>1.2</b>	
	E	16.0	17.5	16.0	20.5	21.5	
	F	15.5	17.2	16.0	19.5	23.0	
	G	14.0	16.4	15.0	18.0	20.2	
	H	15.0	15.9	15.0	19.0	21.0	
	I	15.0		14.0	17.0	20.0	
<b>LANCELOT</b>	<b>MEAN</b>	<b>15.1</b>	<b>16.8</b>	<b>15.2</b>	<b>18.8</b>	<b>21.1</b>	
	<b>STDEV</b>	<b>0.7</b>	<b>0.7</b>	<b>0.8</b>	<b>1.4</b>	<b>1.2</b>	
	J	14.0	12.0	14.0	18.0	19.4	
	K	15.0	11.0	14.0	16.5	21.0	
	L	15.1	11.4	13.0	17.6	22.9	
<b>THEODOSIA</b>	<b>MEAN</b>	<b>14.7</b>	<b>11.5</b>	<b>13.7</b>	<b>17.4</b>	<b>21.1</b>	
	<b>STDEV</b>	<b>0.6</b>	<b>0.5</b>	<b>0.6</b>	<b>0.8</b>	<b>1.8</b>	
	M	15.0	14.0	16.0	18.0	16.5	
	N	13.5	14.0	15.0	17.5	16.0	
	O	13.0	13.5	14.0	16.0	20.0	
	P	13.0	13.8	15.0	16.0	24.0	
<b>MALASPINA</b>	<b>MEAN</b>	<b>13.6</b>	<b>13.8</b>	<b>15.0</b>	<b>16.9</b>	<b>19.1</b>	
	<b>STDEV</b>	<b>0.9</b>	<b>0.2</b>	<b>0.8</b>	<b>1.0</b>	<b>3.7</b>	
	Q	15.0	14.0	15.0	20.5	22.9	
	R	16.9	15.0	17.0	20.8	24.0	
	S	17.2	14.8	16.1	20.9	24.0	
	T	17.9	15.0	17.0	20.5	23.0	
	U	18.0	16.0	16.8	20.9	23.0	
	V	16.5	15.0	17.0	20.2	24.5	
<b>DESOLATION</b>	<b>MEAN</b>	<b>16.9</b>	<b>15.0</b>	<b>16.5</b>	<b>20.6</b>	<b>23.6</b>	
	<b>STDEV</b>	<b>1.1</b>	<b>0.6</b>	<b>0.8</b>	<b>0.3</b>	<b>0.7</b>	

<b>b. TEMPERATURE AT 10 METERS</b>						
	STATION	MAY 23-24	JUNE1-2	JUNE11-12	JULY 7-9	JULY 20-21
	A	13.0	13.1	14.0		14.0
	B	13.0	13.2	14.0		14.8
	C	13.5	13.2	14.0		14.5
	D	13.5	13.0	13.0		14.8
<b>OKEOVER</b>	<b>MEAN</b>	<b>13.3</b>	<b>13.1</b>	<b>13.8</b>		<b>14.5</b>
	<b>STDEV</b>	<b>0.3</b>	<b>0.1</b>	<b>0.5</b>		<b>0.4</b>
	E	13.0	13.0	13.0		13.0
	F	13.5	12.8	13.0		14.0
	G	13.0	12.8	13.0	14.0	13.9
	H	13.0	12.8	13.0	15.0	13.5
	I	12.5	12.8	13.0	18.9	13.9
<b>LANCELOT</b>	<b>MEAN</b>	<b>13.0</b>	<b>12.8</b>	<b>13.0</b>	<b>16.0</b>	<b>13.7</b>
	<b>STDEV</b>	<b>0.4</b>	<b>0.1</b>	<b>0.0</b>	<b>2.6</b>	<b>0.4</b>
	J	13.0	12.8	14.0	15.5	15.6
	K	13.0		14.0	15.5	15.5
<b>THEODOSIA</b>	<b>MEAN</b>	<b>13.0</b>	<b>12.8</b>	<b>14.0</b>	<b>15.5</b>	<b>15.5</b>
	<b>STDEV</b>					
	M	13.0	12.4	13.0		
	N	12.5	12.9	13.0		13.0
	O	12.5	12.6	13.0		13.5
	P	12.5	13.0	13.0		13.0
<b>MALASPINA</b>	<b>MEAN</b>	<b>12.6</b>	<b>12.7</b>	<b>13.0</b>		<b>13.2</b>
	<b>STDEV</b>	<b>0.3</b>	<b>0.3</b>			<b>0.3</b>
	Q	13.0	14.0	14.0		13.0
	R	14.1	13.6	14.5	13.9	14.0
	S	13.9	13.6	14.9	15.2	14.9
	T	13.1	14.0	16.0	13.6	15.5
	U	14.5	14.0	15.0	14.9	14.0
	V	14.0	14.0	14.1	15.8	14.0
<b>DESOLATION</b>	<b>MEAN</b>	<b>13.8</b>	<b>13.9</b>	<b>14.8</b>	<b>14.7</b>	<b>14.2</b>
	<b>STDEV</b>	<b>0.6</b>	<b>0.2</b>	<b>0.7</b>	<b>0.9</b>	<b>0.9</b>

Appendix III. Salinity (ppm) at the surface and at 10 m in the Desolation Sound study area, 1994.

<b>a. SURFACE SALINITY</b>							
		<b>MAY 23-24</b>	<b>JUNE1-2</b>	<b>JUNE11-12</b>	<b>JULY 7-9</b>	<b>JULY 20-21</b>	
	A	27.0	25.5	27.0	24.0	25.0	
	B	27.0	24.9	26.0	25.0	25.0	
	C	27.0	23.6	26.0	25.0	24.8	
	D	26.0	24.0	24.0	24.0	24.9	
<b>OKEOVER</b>	<b>MEAN</b>	<b>26.8</b>	<b>24.5</b>	<b>25.8</b>	<b>24.5</b>	<b>24.9</b>	
	<b>STDEV</b>	<b>0.5</b>	<b>0.9</b>	<b>1.3</b>	<b>0.6</b>	<b>0.1</b>	
	E	25.5	23.5	25.0	23.0	24.8	
	F	25.5	22.5	24.0	22.0	24.6	
	G	25.5	22.2	23.0	24.0	25.2	
	H	25.5	25.8	24.0	22.1	24.6	
	I	24.5		25.0	24.0	24.4	
<b>LANCELOT</b>	<b>MEAN</b>	<b>25.3</b>	<b>23.5</b>	<b>24.2</b>	<b>23.0</b>	<b>24.7</b>	
	<b>STDEV</b>	<b>0.4</b>	<b>1.6</b>	<b>0.8</b>	<b>1.0</b>	<b>0.3</b>	
	J	23.0	9.5	14.0	17.0	24.1	
	K	10.9	7.8	7.0	10.0	23.2	
	L	10.5	8.5	5.0	10.0	21.8	
<b>THEODOSIA</b>	<b>MEAN</b>	<b>14.8</b>	<b>8.6</b>	<b>8.7</b>	<b>12.3</b>	<b>23.0</b>	
	<b>STDEV</b>	<b>7.1</b>	<b>0.9</b>	<b>4.7</b>	<b>4.0</b>	<b>1.2</b>	
	M	26.5	26.6	25.0	25.0	25.0	
	N	27.0	26.0	26.0	25.0	24.5	
	O	27.0	25.9	26.0	26.0	18.5	
	P	27.5	25.0	24.0	25.0	15.0	
<b>MALASPINA</b>	<b>MEAN</b>	<b>27.0</b>	<b>25.9</b>	<b>25.3</b>	<b>25.3</b>	<b>20.8</b>	
	<b>STDEV</b>	<b>0.4</b>	<b>0.7</b>	<b>1.0</b>	<b>0.5</b>	<b>4.8</b>	
	Q	26.0	24.5	25.0	14.0	17.1	
	R	24.8	25.5	22.0	14.3	15.0	
	S	24.5	25.5	23.1	14.0	16.0	
	T	24.6	24.8	23.2	14.2	16.0	
	U	23.0	24.8	23.0	12.3	16.0	
	V	24.5	25.2	22.8	13.2	16.0	
<b>DESOLATION</b>	<b>MEAN</b>	<b>24.6</b>	<b>25.1</b>	<b>23.2</b>	<b>13.7</b>	<b>16.0</b>	
	<b>STDEV</b>	<b>1.0</b>	<b>0.4</b>	<b>1.0</b>	<b>0.8</b>	<b>0.7</b>	

<b>b. Salinity at 10 meters</b>						
	Station	MAY 23-24	JUNE1-2	JUNE11-12	JULY 7-9	JULY 20-21
	A	27.5	27.5	27.0		26.5
	B	27.5	27.5	27.0		25.2
	C	27.0	27.0	26.0		26.5
	D	27.0	27.0	27.0		26.2
<b>OKEOVER</b>	<b>MEAN</b>	<b>27.3</b>	<b>27.3</b>	<b>26.8</b>		<b>26.1</b>
	<b>STDEV</b>	<b>0.3</b>	<b>0.3</b>	<b>0.5</b>		<b>0.6</b>
	E	27.0	27.0	27.0		27.0
	F	27.5	27.4	27.0		26.8
	G	27.0	27.6	27.0	26.2	27.2
	H	27.5	27.5	27.0	26.0	27.2
	I	27.5	26.0	27.0	26.0	26.1
<b>LANCELOT</b>	<b>MEAN</b>	<b>27.3</b>	<b>27.1</b>	<b>27.0</b>	<b>26.1</b>	<b>26.9</b>
	<b>STDEV</b>	<b>0.3</b>	<b>0.7</b>	<b>0.0</b>	<b>0.1</b>	<b>0.5</b>
	J	27.0	26.9	26.0	25.3	25.3
	K	27.0		25.0	13.7	25.6
<b>THEODOSIA</b>	<b>MEAN</b>	<b>27.0</b>	<b>26.9</b>	<b>25.5</b>	<b>19.5</b>	<b>25.5</b>
	<b>STDEV</b>			<b>0.7</b>	<b>8.2</b>	<b>0.2</b>
	M	27.5	27.2	27.0		
	N		26.8	27.0		27.0
	O	27.5	27.0	27.0		26.5
	P	27.5	25.6	27.0		27.0
<b>MALASPINA</b>	<b>MEAN</b>	<b>27.5</b>	<b>26.7</b>	<b>27.0</b>		<b>26.8</b>
	<b>STDEV</b>		<b>0.7</b>			<b>0.3</b>
	Q	27.5	25.8	26.0		27.0
	R	27.0	26.0	25.8	24.4	24.8
	S	26.9	26.5	26.1	19.3	26.0
	T	27.5	26.0	24.7	25.2	25.5
	U	25.0	26.4	26.0	25.2	26.5
	V	25.0	26.0	26.7	24.9	27.0
<b>DESOLATION</b>	<b>MEAN</b>	<b>26.5</b>	<b>26.1</b>	<b>25.9</b>	<b>23.8</b>	<b>26.1</b>
	<b>STDEV</b>	<b>1.2</b>	<b>0.3</b>	<b>0.7</b>	<b>2.5</b>	<b>0.9</b>

Appendix IV. Water turbidity (m of visibility) in the Desolation Sound study area, 1994.

	STATION	MAY23-26	JUNE1-2	JUNE 11-12	JULY9-10	JULY 20-21
	A	5.5	4.0	5.4	4.8	5.6
	B	6.0	3.5	5.4	4.1	5.7
	C	5.0	3.5	5.2	4.9	4.2
	D	4.5	3.9	5.9	4.3	4.1
<b>OKEOVER</b>	<b>MEAN</b>	<b>5.3</b>	<b>3.7</b>	<b>5.5</b>	<b>4.5</b>	<b>4.9</b>
	<b>STDEV</b>	<b>0.6</b>	<b>0.3</b>	<b>0.3</b>	<b>0.4</b>	<b>0.8</b>
	E	6.0	3.5	5.4	5.1	4.5
	F	6.0	4.0	5.8	4.7	4.5
	G	6.5	3.5	5.3	4.8	4.7
	H	6.0	3.5	6.6	5.1	4.6
	I	6.0		7.6	5.0	4.3
<b>LANCELOT</b>	<b>MEAN</b>	<b>6.1</b>	<b>3.6</b>	<b>6.1</b>	<b>4.9</b>	<b>4.5</b>
	<b>STDEV</b>	<b>0.2</b>	<b>0.3</b>	<b>0.9</b>	<b>0.2</b>	<b>0.2</b>
	J	5.0	4.1	6.6	4.0	3.9
	K	3.0	4.0		5.1	4.1
	L					3.5
<b>THEODOSIA</b>	<b>MEAN</b>	<b>4.0</b>	<b>4.0</b>	<b>6.6</b>	<b>4.6</b>	<b>3.8</b>
	<b>STDEV</b>	<b>1.4</b>	<b>0.0</b>		<b>0.8</b>	<b>0.3</b>
	M	4.1	4.3	4.9	3.9	6.0
	N		4.4	5.0	4.1	7.2
	O		4.6	6.4	6.0	5.8
	P	6.0	4.7	7.4	6.9	6.0
<b>MALASPINA</b>	<b>MEAN</b>	<b>5.1</b>	<b>4.5</b>	<b>5.9</b>	<b>5.2</b>	<b>6.2</b>
	<b>STDEV</b>	<b>1.3</b>	<b>0.2</b>	<b>1.2</b>	<b>1.5</b>	<b>0.6</b>
	Q	6.0	5.0	6.4	5.5	
	R	6.5	5.0	10.1	5.9	7.5
	S	7.0	5.5	7.5	5.3	6.3
	T	6.0	6.0	9.2	5.7	6.9
	U	6.0	6.0	10.0		6.9
	V	6.9	6.0	9.4	5.8	6.4
<b>DESOLATION</b>	<b>MEAN</b>	<b>6.4</b>	<b>5.6</b>	<b>8.7</b>	<b>5.6</b>	<b>6.8</b>
	<b>STDEV</b>	<b>0.5</b>	<b>0.5</b>	<b>1.5</b>	<b>0.2</b>	<b>0.5</b>