Alaska
Fisheries Science
Center

National Marine
Fisheries Service

U.S DEPARTMENT OF COMMERCE

AFSC PROCESSED REPORT 98-10

Marine Mammal Protection Act and Endangered Species Act Implementation Program 1997

December 1998

Marine Mammal Protection Act and Endangered Species Act Implementation Program 1997

Edited by:
P. Scott Hill
Bete Jones
Douglas P. DeMaster

Annual Reports of research carried out on the population biology of marine mammals by the National Marine Mammal Laboratory to meet the 1994 amendments to the Marine Mammal Protection Act and the Endangered Species Act

Submitted to:
Office of Protected Resources
National Marine Fisheries Service
1335 East-West Highway
Silver Spring, MD 20910

National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center
National Marine Mammal Laboratory
7600 Sand Point Way Northeast
Seattle, WA 98115-0070

December 1998

Preface

Beginning in 1991, the National Marine Mammal Laboratory (NMML) has been partially funded by the National Marine Fisheries Service's (NMFS) Office of Protected Resources to determine the abundance of selected species in U.S. waters of the eastern North Pacific Ocean. On 30 April 1994, Public Law 103-238 was enacted allowing significant changes to provisions within the Marine Mammal Protection Act (MMPA). Interactions between marine mammals and commercial fisheries are addressed under three new Sections. This new regime replaced the interim exemption that had regulated fisheries-related incidental takes since 1988. The 1994 MMPA amendments continue NMFS' responsibility to carry out population studies to determine the abundance, distribution and stock identification of marine mammal species that might be impacted by human-related or natural causes.

The following report, containing 18 papers, is a compilation of studies carried out with fiscal year 1997 (FY97) funding as part of the NMFS MMPA/ESA Implementation Program. The report contains information regarding studies conducted on beluga whales, Dall's porpoise, harbor porpoise, harbor seals, humpback whales, northern fur seals, and Steller sea lions.

This report does not constitute a publication and is for information only. All data herein are to be considered provisional. Further, most of the papers included in this report may be published elsewhere. Any question concerning the material contained within this document should be directed to the authors, or ourselves. Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

P. Scott Hill
Bete Jones
Douglas P. DeMaster

MMPA/ESA Implementation Program
Report for 1997

Reporting Center: National Marine Mammal Laboratory
Alaska Fisheries Science Center

Administrative Office: Office of Protected Resources
National Marine Fisheries Service

Steller Sea Lions:

Other:

AERIAL SURVEYS OF BELUGA WHALES IN COOK INLET, ALASKA, JUNE 1997

David J. Rugh, Roderick C. Hobbs, Kim E.W. Shelden, and Janice M. Waite

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington 98115

Abstract

The National Marine Mammal Laboratory (NMML), in cooperation with the NMFS Alaska Regional Office, the Alaska Beluga Whale Committee (ABWC) and the Cook Inlet Marine Mammal Council (CIMMC), conducted an aerial survey of the beluga whale (*Delphinapterus leucas*) population in Cook Inlet, Alaska, during 8-10 June 1997. This provided a 100% coverage of coastal areas around the entire inlet (1,388 km), where belugas were expected during this season. The 23 hour survey was flown in a twin-engine, high-wing aircraft at 244 m (800 ft) altitude and 185 km/hour (100 kt) along a trackline 1.4 km from shore. Throughout most of this survey, a test of sighting rates was conducted with multiple independent observers on the coastal (left) side of the plane, where virtually all sightings occur. A single observer and a computer operator/data recorder were on the right side. After finding beluga groups, a series of aerial passes were made to allow at least two pairs of observers to make four or more counts of whales. The sum of the aerial estimates (using median counts from each site, not corrected for missed whales) ranged from 217 to 264 whales, depending on survey day. Only 1 beluga whale was found in lower Cook Inlet, 51-73 were counted near the Susitna River, 139-161 were seen in Knik Arm and 26-29 were counted in Chickaloon Bay. Combining data from 1994 to 1997, almost half (46%) of the initial sightings occurred >1.4 km from the aircraft - the perimeter of the standard viewing area - with mean sighting distances of 1.2 km for small groups (< 20 whales) and 1.9 km for larger groups (≥ 20). In only 8 of 59 instances were whale groups > 1.4 km from the trackline. Of 106 groups recorded by paired, independent observers in 1994-97, 20 were reported by only one primary observer, while 86 (81%) were reported by both observers.

Introduction

Beluga whales are distributed around most of Alaska from Yakutat to the Alaska/Yukon border (Hazard 1988). This species occurs in five apparent stocks around Alaska: Cook Inlet, Bristol Bay, Norton Sound, Eastern Chukchi Sea, and the Beaufort Sea (Hill et al. 1997). The most isolated of these is the Cook Inlet stock, separated from the others by the Alaska Peninsula. Beluga whales in Cook Inlet are very concentrated in a few river mouths during parts of the year (as reviewed in Shelden 1994). The geographic and genetic isolation of the whales in Cook Inlet, in combination with their tendency towards site fidelity, makes this stock vulnerable to impacts from large or persistent harvest takes. The Alaska Scientific Review Group (AKSRG) "felt very strongly that every effort should be made to survey this population every year" (letter from L. Lowry, Chair of AKSRG, to S. Pennoyer, NMFS, dated 13 May 1997).

Since 1993, NOAA's National Marine Mammal Laboratory and its Alaska Regional Office have conducted annual aerial surveys to study the distribution and abundance of beluga whales in Cook Inlet (Withrow et al. 1994; Rugh et al. 1995, 1996, 1997). These studies have been in cooperation with the ABWC and the CIMMC. Aerial surveys have been the established method used to collect distribution and abundance data for beluga whales in Cook Inlet since the 1960s (Klinkhart 1966; Calkins 1984; Calkins et al. 1975; Murray and Fay 1979).

The objectives of the aerial surveys were to make a complete search for beluga whales around the perimeter of Cook Inlet and to circle groups of belugas for aerial estimations of group sizes and video documentation. Aerial survey procedures were kept similar to those used in previous studies since 1994. Emphasis was placed on having independent searches and counts of belugas made by at least two observers on the same (nearshore) side of the aircraft.

Methods

Survey Aircraft

The survey aircraft, a DeHavilland Twin Otter, has twin-engines, high-wings and a seating capacity for six passengers plus two pilots. There are large bubble windows at two of the three primary observer positions (left and right front). An intercom system allowed communication among the observers, data recorder and pilots. During systematic search efforts, the two primary observers on the left side removed the cabling to their headset earphones such that they could not hear others report whales, but they could still be heard by the recorder, thereby allowing for independent search efforts. Positional data were collected from the aircraft's Global Positioning System (GPS) interfaced with the laptop computer used to enter sighting data. Data entries included routine updates of locations, percent cloud cover, sea state (Beaufort scale), glare (on the left and right) and visibility (on the left and right). Each start and stop of a transect leg was reported to the recorder. Observer seating positions were recorded each time they were changed, generally every 1-2 hours to minimize fatigue.

Tides

Because of the broad geographical range of these surveys, and because tide heights in Cook Inlet are highly variable from place to place, our aerial surveys were not synchronized with the predicted low tide with the exception of surveys timed to occur within one hour of low tide at the Susitna Delta, where most of the whales have been seen in the past. This effort to synchronize the counts of whales with low tide was based on the premise that the whales concentrated in narrow channels, making them easier to count than when they dispersed at the higher tides. We also took advantage of lower tides in Knik and Turnagain Arms to reduce the effective survey area (at low tide, large areas of mudflats are exposed that would otherwise have to be surveyed), but the timing with the tidal cycle was more opportunistic here than was our timing at the Susitna Delta.

Aerial Tracklines

Coastal surveys were conducted on a trackline approximately 1.4 km offshore. The objective was to find beluga whales in shallow, nearshore waters where they typically have been seen in summer (Calkins 1984). The trackline distance from shore was monitored with an inclinometer such that the waterline was generally 10° below the horizon while the aircraft was at the standard altitude of 244 m (800 ft). Ground speed was approximately 185 km/hour (100 knots). This coastal survey included searches up rivers until the water appeared to be less than 1 m deep, based on the appearance of rapids and riffles. In 1997, no offshore transects were flown across the inlet. This was to maximize the efficiency of the survey by not searching away from the coast where whales have not been found during past surveys.

Sighting Records

Immediately on seeing a beluga group, each observer reported the sighting to the recorder. As the aircraft passed abeam of the whales, the observer informed the recorder of the species, inclinometer angle, whale travel direction and notable behaviors but not group size. With each sighting, the observer's position (left front, left rear, etc.) was also recorded. An important component of the effort by the observers on the left was that they not cue each other to their sightings. They had visual barriers between them, and their headsets did not allow them to hear each other, but they could be heard by the recorder. As these data were being entered, the aircraft continued past each whale group until it was out of sight; then the aircraft returned to the group and began the circling routine. The pilot and data recorder did not call out whale sightings or in any way cue the observers to the presence of a whale group.

The whale group location was established at the onset of the aerial passes by flying a criss-cross pattern over the group, recording starts and stops of group perimeters. The perimeter point closest to the aircraft's location at the initial sighting was used to calculate the sighting distance.

Counting Techniques

The flight pattern used to count a whale group involved an extended oval around the longitudinal axis of the group with turns made well beyond the ends of the group. Whale counts were made on each pass down the long axis of the oval. Because groups were circled at least four times (4 passes for each of two pairs of observers on the left side of the aircraft), there were typically 8 or more separate counts per group. Counts began and ended on a cue from the left rear observer (whose peripheral search was limited by having a flat window instead of a bubble window), starting when the group was close enough to be counted and ending when it went behind the wing line. This provided a record of the duration of each counting effort. The paired observers made independent counts and wrote down their results along with date, time, pass number and quality of the count. The quality of a count (A through F) was a function of how well the observers saw a group, rated A if no glare, whitecaps or distance compromised the counting effort, and rated down to F if it was not practical to count whales on that pass. Only quality A and B estimates were used in the analysis. Sighting notes were not exchanged with anyone else on the aerial team until after all of the aerial surveys were completed. This was done to maximize the independence of each observer's estimates.

Video images were studied in the laboratory, and counts of whales were made to compare to the infield counts (see Waite and Hobbs 1995). Analysis of both the aerial counts and counts from the video tapes are described in Hobbs et al. (1995) for 1994 data. Corrections for whales missed during aerial counts of beluga whales will be developed in a separate document.

Results

Survey Effort

A total of 22.6 hours of aerial surveys were flown around Cook Inlet 8-10 June 1997. All of these surveys (4 flights ranging from 3.4 to 6.7 hours) were based out of Anchorage. Systematic search effort was conducted for 13.0 hours, not including time spent circling whale groups, deadheading without a search effort, or periods with poor visibility. Visibility and weather conditions interfered with the survey effort during 1.9 hours (9% of the total flight time) when the left-front observer considered the visibility poor or worse. There were 1.1 hours of video tape collected over whales. Results from video analysis will be reported in a separate document.

On 8 and 10 June, the survey area included the perimeter of upper Cook Inlet north of East and West Forelands, including Knik Arm, Turnagain Arm and the lower portions of the McArthur, Beluga, and Susitna Rivers. On 9 June, the survey covered the east shore of Cook Inlet from Pt. Possession to Elizabeth Island and all of the west shore from Cape Douglas to Pt. Mackenzie, including St. Augustine and Kalgin Islands (Fig. 1).

The composite of these aerial surveys provided a thorough coverage of the coast of Cook Inlet (1,388 km) for all waters within approximately 3 km of shore (Fig. 1). Assuming a 2.0 km transect swath (1.4 km on the left plus 1.4 km on the right, less the 0.8 km blind zone beneath the aircraft), our coastal tracklines covered 2,776 km^2, which is approximately 14% of the surface area of Cook Inlet; however, these surveys covered virtually 100% of the coastal area where beluga whales were expected. Most of upper Cook Inlet was surveyed three times, in particular the Susitna Delta where large groups of beluga whales have usually been found. Each of the surveys in this area were timed near the low tide (-0.6 to -0.4 m, with a maximum low of -0.7 m on 8 June; +2.0 to +2.3 m, with a maximum low of -0.3 m on 9 June; +0.6 to +0.3 m, with a maximum low of +0.2 m on 10 June).

Distance to Initial Sighting

Distances between the aircraft and a beluga group at the moment of the initial sighting ranged from 0.00 to 4.26 km (n = 59, combining data from 1994 to 1997; Table 1 shows data from the 1997 survey). Almost half (46%) of the initial sightings occurred beyond 1.4 km, the perimeter of the standard viewing area, because observers searched well ahead of the aircraft. The mean sighting distance was 1.2 km (CI = 0.23) for groups with less than 20 whales and 1.9 (CI = 0.38) for groups of 20 or more (different at the P = 0.005 level, F = 2.68). Figure 2 demonstrates the frequency distribution of distances relative to whether the groups were small (< 20) or large (≥ 20). This group size (n = 20) formed a convenient definition because it split the sample size in half (30 of 59 groups in the sample had < 20 whales each).

Distance at Closest Pass

Minimum distances between whale groups and the trackline ranged from 0.00 to 3.25 km. Figure 3 shows that these sighting distances were affected by whether whale groups were small (< 20) or large (≥ 20)($P = 0.006$, $F = 2.67$; combining data from 1994 to 1997; $n = 59$). Table 1 shows data from 1997. Mean distances were 0.63 km for small groups and 0.95 for large groups. In 20 of 59 instances, the trackline was within 0.5 km of a beluga group, including flying directly over it, and in 8 instances groups were more than 1.4 km from the trackline; 7% of small groups (< 20 whales) and 20% of large groups were beyond 1.4 km at the closest pass, generally up rivers.

Missed Groups

All four of the primary observers in 1997 had prior experience surveying for beluga whales in Cook Inlet. One other observer accompanied one of the flights, but this effort was not included in the inter-observer analysis. Results from June 1997 were combined with those from 1994 to 1996 to increase the sample size of the test of paired, independent observers, many of whom flew with this project several seasons in succession. These records do not account for the possibility of whale groups missed by all observers.

Of 49 groups recorded in 1994-97, 18 were reported by only one primary observer, while 31 groups (63%) were reported by both observers. Whether or not an observer saw a whale group was affected in part by the size of the group. The mean group size of those missed by an observer ($\bar{x} = 23.4$; $SD = 37.4$) and groups reported by both observers ($\bar{x} = 67.3$; $SD = 67.8$) were significantly different ($F = 3.28$, $P = 0.009$).

Distance did not significantly affect the probability of missing a group ($F = 1.87$, $P = 0.110$ for initial sighting distances; $F = 1.00$, $P = 0.48$ for closest distances). However, of 14 recorded groups that were < 0.5 km from the trackline at the closest pass, only 3 (21%) were missed by one observer, and 11 (79%) were seen by both. Of 4 groups that were beyond 1.4 km at the closest pass, 2 were missed by one observer, and 2 were seen by both.

Group size affected sighting rates ($F = 3.28$, $P = 0.009$) as evidenced by the low missed rate (3 out of 22, or 14%) for groups of ≥ 20 whales and the relatively higher missed rate for groups with < 20 whales (13 missed out of 25, or 52%).

Observer performance affected sighting rates. The summary of the 1994-97 data shows that inexperienced observers have higher missed rates (67%) relative to those who have already done aerial searches for beluga whales (19%). Furthermore, two of the experienced observers had higher missed rates (41%) compared to the other four primary observers (10%). However, the sample size is considered too small to be conclusive with the number of observers and the number of covariates that should be treated in this analysis.

Aerial Estimates of Beluga Group Sizes

Aerial counts of beluga whales are shown in Table 2, and sighting locations are shown in Figure 4. These counts are the medians of each primary observers' median counts on multiple passes over a group. The consistency of locations of resightings between days, particularly the whales near the Susitna River, Knik Arm, and in Chickaloon Bay, allowed us to combine results among survey days, assuming whales did not travel long distances within the 3-day survey period.

Therefore, using median counts from each site, the sum of the counts ranged from 217 to 264. This sum is not corrected for missed whales. Calculations for whales missed during these aerial counts and an estimate of abundance will be developed in a separate document.

Discussion

In Cook Inlet, beluga whales concentrate near river mouths during spring and early summer, especially in the northwest corner of the inlet between the Beluga and Little Susitna Rivers (Fig. 1), described here as the Susitna Delta. Fish also concentrate along the northwest shoreline of Cook Inlet, especially in June and July (Moulton 1994). Most of our of sightings of beluga whales have been in the Susitna Delta (56% in June 1993; 81% to 91% in June/July 1994-96), although in June 1997 the primary concentration was in Knik Arm. These concentrations of beluga whales apparently last from mid-May to mid-June (Calkins 1984) or later and are very likely associated with the migration of anadromous fish, particularly eulachon (*Thaleichthys pacificus*) (Calkins 1984; 1989). We did not find a change of the density of these whale groups between early June and late July, but there was some indication that the whales were dispersing out of the Susitna Delta, especially by the time we made observations in September. Elsewhere in upper Cook Inlet in June and July, we have consistently found a group of 20-50 whales in Chickaloon Bay. Groups seen in Knik Arm and Trading Bay may be associated with the large concentrations in the Susitna Delta, while whales seen in Turnagain Arm are thought to be a part of the concentration in Chickaloon Bay. All of these groups potentially interact to some degree, especially in the winter when much of this area is ice-covered, but the consistency of sightings in a few locations suggests there is some amount of territoriality. In lower Cook Inlet, we have occasionally seen small groups: 1 just south of West Foreland in 1993, 9 in Kachemak Bay in 1994, 2 in Iniskin Bay in 1994, 14 in Big River in 1995 and 1 in Tuxedni Bay in 1997. Only 0-4% of our sightings in June and July from 1993 to 1997 have occurred in lower Cook Inlet (Table 3).

Others who surveyed in June (Calkins 1984) also found the majority of animals in the northwest corner of the inlet (88% of the sightings made 1974-79), but far fewer in July (15% in 1974-79). Calkins (1984) reported seeing 26 beluga whales in Redoubt Bay and 25 whales south of Kasilof River in June. In July, 44% of his sightings were in the lower inlet. These were in groups ranging in size from 11 to 100 found between the Forelands and Tuxedni Bay, most well away from the coast. Calkins (1979:p.40) indicated that belugas were "seen throughout the year in the central and lower Inlet." However, we have not found whales here in spite of excellent viewing conditions in some years.

There have been sightings of beluga whales in the Gulf of Alaska outside of Cook Inlet. Harrison and Hall (1978) saw belugas near Kodiak Island in March and July. Murray and Fay (1979) also found belugas near Kodiak Island, as well as in Shelikof Strait, south of Prince William Sound and in Yakutat Bay. Leatherwood et al. (1983) recorded one beluga near the southwest entrance of Shelikof Strait on 6 August 1982, but no other belugas were seen by them on the north or south shores of the Alaska Peninsula. Some sightings have been made in Prince William Sound in March (Harrison and Hall 1978) and Yakutat Bay in May (Calkins and Pitcher 1977), September (R. Ream, NMFS, NMML pers. commun.) and February (B. Mahoney, NMFS, AKR, Anchorage, pers. comm.), perhaps as occasional visitors from Cook Inlet (Calkins 1989). These sightings indicate that at least some of the time there are beluga whales in the northern Gulf of Alaska outside of Cook Inlet. However, no sightings of belugas were made during our survey of Yakutat Bay on 7 June 1997 (NMFS, NMML unpubl. data) and during many intensive aerial surveys around the Alaska Peninsula (Brueggeman et al. 1989; Frost et al. 1983; Harrison and Hall 1978; Leatherwood et al. 1983; Murie 1959; NMFS, NMML unpubl. data) supporting the hypothesis that the Cook Inlet stock is isolated from stocks in the Bering Sea, and that the Cook Inlet stock is not widely dispersed.

Survey methods for the 1997 study were developed from similar studies in 1993 (Withrow et al. 1994), 1994 (Rugh et al. 1995), 1995 (Rugh et al. 1996) and 1996 (Rugh et al. 1997). These studies were some of the most thorough and intensive surveys yet conducted for beluga whales in Cook Inlet. They were also among the first aerial surveys for cetaceans in which paired, independent observation efforts were conducted systematically throughout the studies, with whale counts kept confidential until the field projects were concluded. It became evident that observers without previous experience had low sighting rates relative to experienced observers. This may in part be due to a need for developing appropriate search images and search patterns, and may also be a function of becoming familiar with the complex research protocol. Results from new observers may be compared to trained observers for use in future analysis for surveys that might be conducted without trained observers; however, more studies are needed to document the consistency of sighting rates or variances between observers. Details on survey protocol can be found in Rugh (1996).

Whale groups could sometimes be seen over 4 km away, but most initial sightings were at the limits of the typical search zone: 10° below the horizon or 1.4 km from the aircraft. By keeping the aerial trackline 1.4 km offshore, the survey optimized opportunities for seeing belugas. Calculations of initial sighting distances are conservative because inevitably a few seconds lapsed between the first sighting of the group, the reporting to the recorder and the computer entry that grabbed the GPS position. At 185 km/hr, there would be a 50 m error for every 1 second delay. On the other hand, group locations were often determined as the center of the group because the perimeters are difficult to define. This potentially overestimated sighting distances if the initial sighting was actually on the near side of the group.

The distribution of intial sightings, particularly as a function of group size (Fig. 2) suggests there are whale groups that were not recorded. Differences in sighting rates between large and small groups is often more a function of the number of sighting cues available than the total surface area of the group, except when a group is so dense it provides a large visual target. In our studies from 1994 to 1997, there have been 106 sightings made while independent search efforts were underway. Of these, only 86 (81%) were seen by both primary observers. Inexperienced observers had lower sighting rates (33%), and there was some inconsistency in sighting rates among the experienced observers, but the sample size is too small to make different correction factors for each observer. These records do not include groups missed by both observers.

The proximity of the aircraft to belugas did not seem to reduce sighting opportunities as the whales showed no apparent reaction to the survey aircraft. This is consistent with observations in other years (Withrow et al. 1994; Rugh et al. 1995, 1996, 1997) and may be due to habituation to the dense air traffic in the area. Our aircraft was not a novel stimulus: during most of our surveys in upper Cook Inlet, many other aircraft were in view at any one time.

The uncorrected sum of median estimates made from the June 1997 aerial observations in Cook Inlet ranged from 217 to 264 beluga whales. Using the same procedure of summarizing median estimates from the highest seasonal counts at each site, for June or July for each year 1993-97, there were, respectively, 305, 281, 324, 307, and 264 beluga whales (Table 3). The process of using medians instead of maximum numbers reduces the effect of outliers (extremes in high or low counts) and makes the results more comparable to other surveys which lack multiple passes over whale groups. Medians or means are also more appropriate than maximums when counts will be corrected for missed whales. Not until the respective correction factors have been applied will absolute abundances be calculated.

Acknowledgments

Funding for this project was provided by the Marine Mammal Assessment Program, NMFS, NOAA. Douglas DeMaster was the Cetacean Assessment and Ecology Program Leader, whose dedicated support made this project possible. Our pilots, Jeff Hagan and John Longenecker of NOAA's Office of Aircraft Operations, very capably carried out the complex flight protocol. Joel Blatchford, chairman of the Cook Inlet Marine Mammal Council, flew with these surveys on 10 June.

Citations

Brueggeman, J.J., G.A. Green, R.A. Grotefendt, R.W. Tressler, and D.G. Chapman. 1989. Marine mammal habitat use in the North Aleutian Basin, St. George Basin, and Gulf of Alaska. Chap.14 in L.E. Jarvela and L.K. Thorsteinson (eds.) Proceedings of the Gulf of Alaska, Cook Inlet, and North Aleutian Basin Information Update Meeting, Feb.7-8, 1989, Anchorage, Alaska. NOAA, Ocean Assessments Div., Alaska Office, Fed. Bldg., U.S. Courthouse, Rm. A13, 222 W Eighth Ave. No.56, Anchorage, AK 99513-7543.OCS Study, MMS 89.

Calkins, D.G. 1979. Marine mammals of lower Cook Inlet and the potential for impact from Outer Continental Shelf oil and gas exploration, development and transport. Alaska Dept. Fish and Game. 89 p.

Calkins, D.G. 1984. Belukha whale. Vol. IX in Susitna hydroelectric project; final report; big game studies, Alaska Dept. Fish and Game. Doc. no. 2328.

Calkins, D.G. 1989. Status of belukha whales in Cook Inlet. Chap 15; in L.E. Jarvela and L.K. Thorsteinson (eds.) Proceedings of the Gulf of Alaska, Cook Inlet, and North Aleutian Basin Information Update Meeting, Feb.7-8, 1989, Anchorage, Alaska. NOAA, Ocean Assessments Div., Alaska Office, Fed. Bldg., U.S. Courthouse, Rm. A13, 222 W Eighth Ave. No.56, Anchorage, AK 99513-7543. OCS Study, MMS 89.

Calkins, D.G. and K.W Pitcher. 1977. Unusual sightings of marine mammals in the Gulf of Alaska. Abstract, Proceedings of the Second Conf. on the Biol. of Mar. Mammals, San Diego, Calif.

Calkins, D.G., K.W. Pitcher, and K. Schneider. 1975. Distribution and abundance of marine mammals in the Gulf of Alaska. Rep. for USDC/NOAA. Alaska Dept. Fish and Game, Anchorage, AK. 67 p.

Frost, K.J., L.F. Lowry, and J.J. Burns. 1983. Distribution of marine mammals in the coastal zone of the Bering Sea during summer and autumn. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. 20:365-562.

Harrison, C.S., and J.D. Hall. 1978. Alaskan distribution of the beluga whale, *Delphinapterus leucas*. Can. Field-Nat. 92(3):235-241.

Hazard, K. 1988. Beluga whale, *Delphinapterus leucas*. Pp. 195-235, in J.W. Lentfer (ed.) Selected marine mammals of Alaska: Species accounts with research and management recommendations. Mar. Mammal Comm., Washington D.C. 275 p.

Hill, P.S., D.P. DeMaster, and R.J. Small. 1997. Alaska marine mammal stock assessments, 1996. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-78, 150 p.

Hobbs, R.C., J.M. Waite, D.J. Rugh, and J.A. Lerczak. 1995. Abundance of beluga whales in Cook Inlet based on NOAA's June 1994 aerial survey and tagging experiments. Unpubl. doc. submitted to Sci. Comm. Int. Whal. Commn (SC/47/SM11).

Klinkhart, E.G. 1966. The beluga whale in Alaska. Alaska Dept. Fish and Game, Juneau, Fed. Aid Wildl. Restor. Proj. Rep. Vol. VII, Proj. W-6-R and W-14-R. 11 p.

Leatherwood, S., A.E. Bowles, and R.R. Reeves. 1983. Aerial surveys of marine mammals in the Southeastern Bering Sea. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. 42(1986):147-490.

Moulton, L.L. 1994. 1993 northern Cook Inlet smolt studies. ARCO Alaska Sunfish Proj. Prepared for ARCO Alaska, Inc, 700 G St., Anchorage AK 99510.

Murie, O.J. 1959. Fauna of the Aleutian Islands and Alaska Peninsula. U.S. Fish Wildl. Serv., No. Am. Fauna. No. 61.

Murray, N.K., and F.H. Fay. 1979. The white whales or belukhas, *Delphinapterus leucas*, of Cook Inlet, Alaska. Unpubl. doc. prepared for June 1979 meeting of the Sub-committee on Small Cetaceans of the Sci. Comm. of the Int. Whaling Comm. College of Env. Sci., Univ. Alaska, Fairbanks. 7 p.

Rugh, D.J. 1996. Proposed protocol for conducting aerial surveys of beluga whales in Cook Inlet, Alaska, in 1996. Unpubl. rept for National Marine Mammal Laboratory, AFSC, NMFS, NOAA, 7600 Sand Point Way NE, Seattle, WA 98115-0070. 7 p.

Rugh, D.J., Angliss, R.P., DeMaster, D.P., and Mahoney, B.A. 1995. Aerial surveys of belugas in Cook Inlet, Alaska, June 1994. Unpubl. doc submitted to Int. Whal. Commn. (SC/47/SM10).

Rugh, D.J., Shelden, K.E.W., Angliss, R.P., DeMaster, D.P., and Mahoney, B.A. 1996. Aerial surveys of beluga whales in Cook Inlet, Alaska, July 1995. Unpubl. doc submitted to Int. Whal. Commn. (SC/48/SM8).

Rugh, D.J., K.E.W.Shelden, J.M. Waite, R.C. Hobbs, and B.A.Mahoney. 1997. Aerial surveys of beluga whales in Cook Inlet, Alaska, June 1996. Pp. 1-23 in P.S. Hill, and D.P. DeMaster (eds.), Marine Mammal Protection Act and Endangered Species Act implementation program 1996. AFSC Processed Rep. 97-10. Available Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE, BIN C15700, Seattle WA 98115-0070.

Shelden, K.E.W. 1994. Beluga whales (*Delphinapterus leucas*) in Cook Inlet - A review. Appendix in D.E. Withrow, K.E. Shelden, and D.J. Rugh. Beluga whale (*Delphinapterus leucas*) distribution and abundance in Cook Inlet, summer 1993. Annual rept. to the Mar. Mammal Assess. Prog., Office of Protected Resources, NMFS, NOAA, 1335 East-West Highway, Silver Spring, MD 20910. 31 p.

Waite, J.M., and R.C. Hobbs. 1995. Group count estimates and analysis of surfacing behavior of beluga whales from aerial video in Cook Inlet, Alaska, 1994. Unpubl. doc. submitted to Int. Whal. Commn. (SC/47/SM14).

Withrow, D., K. Shelden, and D. Rugh. 1994. Beluga whale (*Delphinapterus leucas*) distribution and abundance in Cook Inlet, summer 1993. Annual rept. to the Mar. Mammal Assess. Prog., Office of Protected Resources, NMFS, NOAA, 1335 East-West Highway, Silver Spring, MD 20910. 31 p.

Table 1. Initial sighting information on each group of beluga whales recorded during the June 1997 survey in Cook Inlet. Group size is the median estimate made by all observers doing counts on that pass. An x indicates which observer missed a sighting while on transect. Observers A, B, and C were in previous year's surveys and did not return in 1997. Dashes indicate that distance calculations could not be made due to irregularities in the flight path.

Date	Group	Location	Group size	Left Front obsv	Left Mid obsv	Right Front obsv	Initial Sighting Distance (km)	Closest dist. (km)
8 June	1	Knik Arm	14	G*	D*		0.90	0.78
	2	Knik Arm	43	E	F	D	1.16	0.58
	3	Knik Arm	42	D	G		1.60	1.34
	4	Knik Arm	1	D*	G*		0.62	---
	5+6	Knik Arm	38	D*	G*		---	---
	7	Knik Arm	2			D	---	---
	8	Chickaloon	16	Fx	E		1.16	0.75
	9	Chickaloon	13	F	E		1.26	0.43
	10	Susitna	72	G	D		1.71	0.83
9 June	1	Tuxedni Bay	1	E	---		---	---
	2	Susitna	51	Gx	E		0.56	0.47
10 June	1	Chickaloon	26	Ex[1]	D		1.74	1.05
	2	Susitna	73	F	G		1.18	1.10
	3	Knik Arm	109			D	2.55	2.41
	4	Knik Arm	46			D	1.00	0.53
	5	Knik Arm	1			D	---	---
	6	Knik Arm	5	D	E		---	---

*There was open communication between observers, so sightings were not included in inter-observer analysis.
[1] This whale group was missed during poor visibility conditions.

Table 2. Summary of counts of beluga whales made during aerial surveys of Cook Inlet in June 1997. Medians from experienced observer counts were used from aerial passes where observers considered visibility good or excellent (conditions B or A). Dashes indicate no survey, and zeros indicate that the area was surveyed but no whales were seen. Sites are listed in a clockwise order around Cook Inlet.

	Flight dates in June 1997						
Location	8 June median	high	9 June median	high	10 June median	high	Med-max Counts
Turnagain Arm (East of Chickaloon Bay)	0*		---		0*		0
Chickaloon Bay/ Pt. Possession	29	46	---		26	35	29-46
Pt. Possession to East Foreland	0		0		0		0
Mid-inlet east of Trading Bay	---		0		---		0
East Foreland to Homer	---		0		---		0
Kachemak Bay	---		0		---		0
W side of lower Cook Inlet (Tuxedni only)	---		1*		---		1
Redoubt Bay	---		0		---		0
Trading Bay	0		0		0		0
Susitna Delta (N Foreland to Pt. Mackenzie	72	95	51	95	73	97	73-97
Fire Island	0		---		---		0
Knik Arm	139	259	---		161	227	161-259
						Total =	264-403

* Visibility compromised in some area due to high winds.

Table 3. Summary of beluga whale sightings made during aerial surveys of Cook Inlet. Medians were used when multiple counts occurred within a day, and the high counts among days were entered here.

			Percent Sightings		
Year	Dates	Counts	Lower Cook Inlet	Susitna Delta	Elsewhere in upper Cook Inlet
1993	June 2-5	305	0	56	44
1993	July 25-29	271	0	74	26
1993	Sept 3, 19	157	9	16	75
1994	June 1-5	281	4	91	5
1995	July 18-24	324	4	89	7
1996	June 11-17	307	0	81	19
1997	June 8-10	264	0	28	72

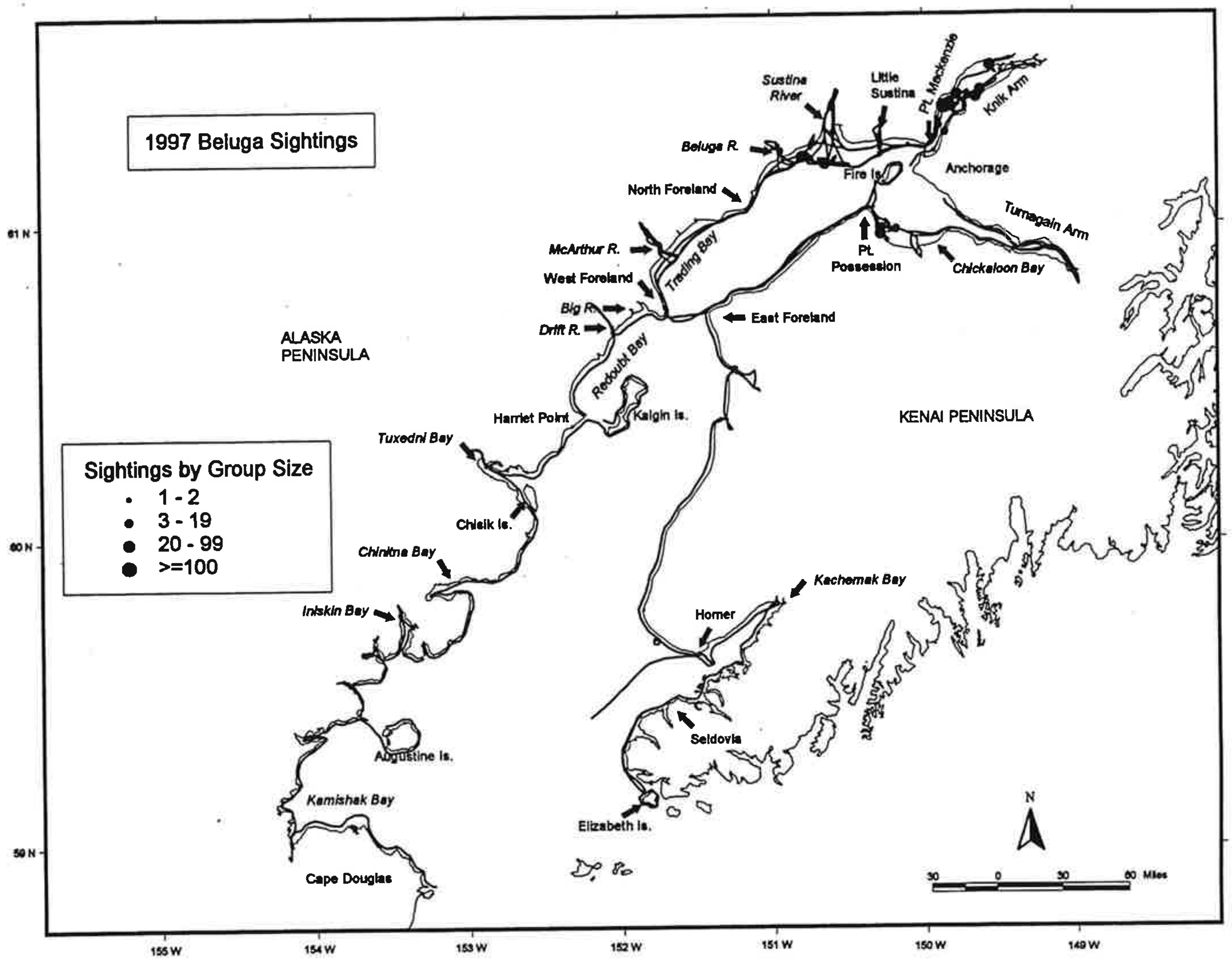

Fig. 1. Aerial survey tracklines for 8-10 June 1997 covering the coastal areas of Cook Inlet. All beluga whale sightings occurred in the upper inlet.

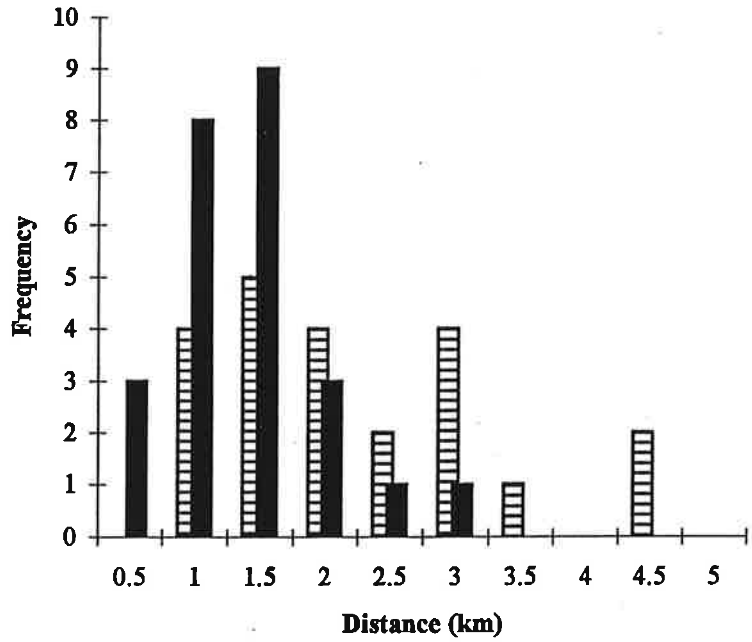

Fig. 2. Distance between the aircraft and beluga groups when they were initially sighted. Solid bars indicate groups of less than 20 animals each; stripped bars indicate groups of more than 20.

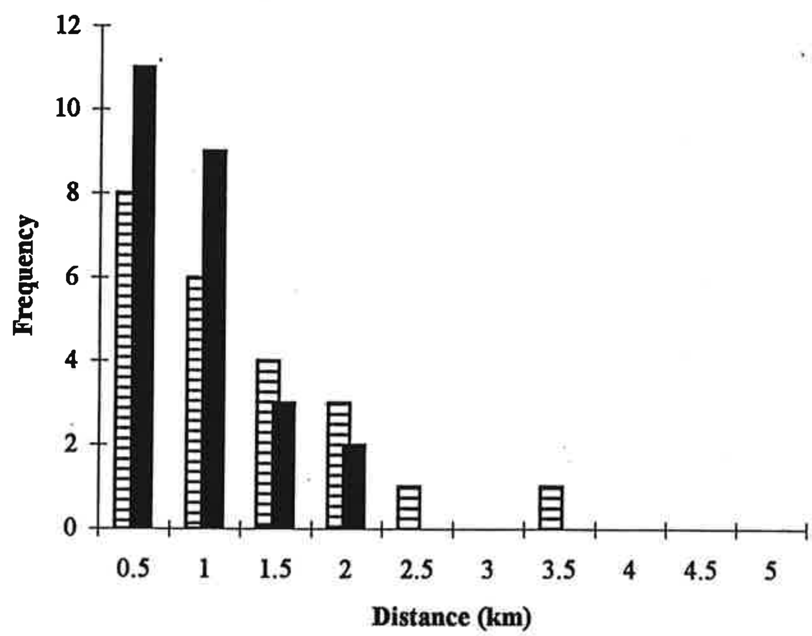

Fig. 3. Distance between the aerial trackline and beluga groups at the closest pass. Solid bars indicate groups of less than 20 animals each; stripped bars indicate groups of more than 20.

1997 COOK INLET BELUGA WHALE TAGGING PROJECT

Richard C. Ferrero

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington 98115

Introduction

This report summarizes the 1997 field research effort to capture and satellite tag beluga whales (*Delphinapterus leucas*) in Cook Inlet, Alaska. Operations were conducted 3 - 24 June by a team of biologists from the National Marine Mammal Laboratory, NMFS Anchorage Regional Office, and Eco Marine Corporation, with the assistance of Native Alaskan beluga whale hunters from Anchorage, the Cook Inlet Marine Mammal Council (CIMMC), and the Alaska Beluga Whale Commission (ABWC).

The beluga whales in Cook Inlet are considered a separate stock from those located elsewhere in Alaska waters (Dizon et al. 1992, Frost and Lowry 1990), with a minimum population estimate of 752 whales (Hill et al. 1997). The stock may be in decline based on changes in distribution and aerial counts (Rugh et al. in prep.) Beluga whales in Cook Inlet are the target of subsistence harvest in late spring through autumn. Estimated removals by subsistence hunters currently exceeds 30 animals per year (DeMaster 1995). If the population and harvest estimates are accurate, then the current level of subsistence removal is likely to exceed the population's maximum net productivity rate. Determination of current population status would be improved by correction for animals below the surface at the time of survey. Thus, the objective of this field effort was to place satellite telemetry tags, equipped with time/depth recorders on belugas for use in developing a correction factor for aerial sightings.

Methods

Previous attempts to capture and tag beluga whales in Cook Inlet were made during 1994 and 1995. In 1994, VHF radio transmitters were attached to whales using suction cups, yielding limited surfacing data (Lerczak 1995). In 1995, suction cup tags were again deployed, and a significant, but unsuccessful, attempt was also made to capture and equip belugas with satellite tags (Waite et al. 1996). Observations from the previous capture attempts, as well as recommendations from beluga whale researchers in Canada, suggested that entanglement in large mesh gillnets was considered the most promising approach. Accordingly, the Marine Mammal Protection Act (MMPA) research permit (No. 957) was modified to include capture with nets.

The wide deltas at the mouth of the Susitna Rivers were chosen as the study area based on consistent presence of beluga whales in that area during late spring and early summer (Rugh et al. in prep.). Dr. Tom Smith (Eco Marine Corporation, Lady Smith, British Columbia) was contracted to provide beluga whale capture and handling expertise. His recommendations, resulting from direct participation in over 60 previous beluga captures in the Canadian Arctic, formed the basis for the field strategy. Two Native Alaskan beluga hunters (Art Nuglene and Mike Saccheus) were also contracted to aid in the location and tracking of target animals. The general plan entailed location of beluga whales in the shallow waters of the Susitna Delta. Boats would then isolate an individual target animal and lay a gillnet ahead of the animal's line of travel. Subsequent commotion by small boats behind the animal was expected to drive it into the net. The net, up to 125 m long and 4 m deep (0.3 m braided mesh) was deployed from the stern of a small boat while a second boat followed the target animal closely to mark its location. In total, up to 4 small craft were required to move the target animal in a constant direction prior to net deployment and to keep it moving towards the net once set. These boats were also in position to immediately reach and stabilize the beluga once entangled, prior to its movement to a nearby calm, shallow location where the satellite transmitter package then could be attached.

Tag attachment was to be achieved by first boring four 1 cm diameter holes through the whale's dorsal ridge. Nylon bolts (30 cm long) would pass through each hole and attach on either side to paired saddle straps glued to the tag body. The tags themselves, built by Wildlife Computers, Redmond, Washington, measured 18 cm × 9 cm × 3 cm and weighed about 500 g. Full specifications are contained in the tag instruction manual (Wildlife Computers 1994).

The project was based at a field camp near the proposed capture sites in order to maximize opportunities to locate belugas. Because the topography around the river mouths is low and nearly all sites flood on extreme high tides, a location above the high water mark 7.5 km up the Little Susitna River was chosen for the project base.

Results

Unfortunately, both the extreme physical environment and evasive behavior of the beluga whales confounded all attempts at capture. Field efforts were constrained by 8-10 m tides which limited suitable capture conditions and movement in and out of the base camp. Boat anchorage, prevention of boat damage by river debris, and mobility up and down 3-10 m mud banks were constant problems. In addition, the tidal river flow, reaching 12 knots, reversed direction twice per day, regularly tearing the boats from their moorings. Navigation in and out of the Little Susitna River was restricted to a 6-7 hour window around the high tide, while water depth over the flats in the capture areas were suitable for about 4 hours bracketing the tide at high slack. In particular, broad mud bars in about 2-3 m of water were required to see the wake produced by traveling belugas. Except when surfacing for air, the whales were otherwise invisible in the turbid, muddy waters.

Wind conditions in upper Cook Inlet further impacted capture efforts. Strong winds out of Turnagain Arm were characteristic in the afternoons. Winds together with tidal currents, created dangerous standing waves and confused sea conditions. While operations were possible with winds up to 10-15 knot, sea conditions became marginal for capture attempts even in the most protected locations because belugas were difficult to locate and their wakes were nearly indistinguishable from the surrounding chop. Without the wakes, they could not be tracked. Of the 21 days of field work, winds or logistical problems precluded efforts during one or both tidal windows on 12 occasions.

The beluga whales appeared to change their behavior and distribution during the course of the field season. After the first week (3-10 June), they became more dispersed, and when located they were more wary of our approach. Three factors may have influenced their behavior: timing of the salmon (*Oncorhynchus* spp.) and eulachon (*Thaleichthys pacificus*) spawning runs, increased frequency of hunters in the area, and recognition of our presence. The peak of the eulachon spawning run occurred in May and had dwindled considerably by our arrival. At the beginning of the field season the whales were seen in the rivers or very close to the river mouths, presumably feeding on the fish runs. As the runs diminished, the belugas appeared to be less aggregated at the river mouths. Concurrently, however, the intensity of subsistence hunting activity increased, particularly in the mouth of the Big Susitna River. During this time, most animals became very difficult to approach, fleeing to deeper water well before we could begin positioning them for capture in the shallows.

The following represents a summary of capture activity on the nine occasions when we were able to locate belugas:

<u>11 June</u> - A group of approximately 50 belugas were loosely aggregated over a 1 or 2 square mile area of the Big Susitna River delta. Individual beluga whales were isolated and coaxed into capture positions in shallow water four times. According to MMPA Scientific Research Permit No. 957, we limited our capture attempts to two tries per animal; thus, two separate whales were targeted. On each try, 50 m of net was set ahead of the animal. Three times the number of animals doubled back from the net and swam around the small boats attempting to drive it into the net; the whales avoided the area of the net despite efforts to move them back toward it. However, on the first set, the animal did hit the net and was briefly entangled. After approximately 10 seconds, it broke free, and doubled back under the chase boats. The animals appeared quite capable of detecting the net and moving rapidly into channels offering deeper water.

<u>12 June</u> - A group of about 50 belugas were found near the mouth of the Big Susitna River. Four capture attempts were made using 100 m of net which allowed formation of a semicircular barrier. Two animals were targeted two times each for a total of four sets. Once again, one animal hit the net, but appeared to graze it rather than becoming entangled. The other three avoided the net by circling around the ends of the net. On all four occasions, the whales moved into deeper water and evaded further efforts to move them into suitable capture position.

<u>13 June</u> - A group of about 100 animals were briefly seen from a distance of about 4 km in Knik Arm, but attempts to approach them were unsuccessful. No animals were targeted, nor were any sets made.

<u>17 June</u> - A scattered group of about 35 whales were located on the west side of the mouth of the Big Susitna River. One animal was isolated, moved to shallow water, and a set was made with 100 m of net, the middle 35 m of which had been modified to a mesh size of approximately 0.6 m

in hopes of increasing the probability of entanglement with minimal contact. As in earlier attempts, however, the whale turned before hitting the net, reversed direction and swam around the net end. Subsequent attempts to move the animal into capture position were unsuccessful. A second animal was located and two attempts at capture failed. The capture position was adjacent to a deep water channel which provided an escape route after initial avoidance of the net.

18 June - Small, scattered groups of belugas (4 groups of 5-10 animals each) were seen well outside the Big Susitna River mouth. None of the animals could be moved into shallow water; thus, no sets were made.

19 June - Rough seas and poor visibility outside river mouths curtailed capture efforts in the river deltas; however, a group of approximately 20 belugas were located 3.0 km up the Little Susitna River and two capture attempts were made. The channel depth was over 8 m, well beyond the reach of our nets, so we set the nets rapidly in front of the animals in hopes of entangling them before they changed direction. But, each time a targeted animal approached the net, it dove, subsequently resurfacing downstream. The belugas were clearly able to respond just as rapidly, avoid the net, and dive beneath it.

20 June - The capture team worked both of the high tide periods across the entire length of the study area. Belugas were sighted in deep water each time, but well away from the river deltas. Those individuals were in widely scattered small groups and essentially unapproachable, diving before we could close within 1.0 km. No sets were attempted.

21 June - On the morning tide, a small group of belugas was located in the mouth of the Big Susitna River. One individual was moved into the shallows in a suitable capture location, and a set was made. The animal struck the net twice, each time very briefly, perhaps with its flukes as it turned away from the net. Attempts to move the animal back toward the net were unsuccessful, and it eventually reached a deep water channel and swam away from the river.

22 June - A group of 6 belugas were sighted in the Big Susitna River delta and approached. All six animals were gray, indicating that they were young, and not suitable as capture targets. No sets were made, and no other belugas were found in the area.

Discussion

Despite failure to successfully capture and tag any belugas in 1997, the project provided critical insights for modification of the technique for future tagging efforts. In particular, three logistical requirements must be met. First, the timing of the project should be earlier, beginning in mid-May, or as early as ice conditions allow. The earlier start would coincide with both eulachon and chinook salmon (*Oncorhynchus tshawytscha*) runs which may concentrate belugas closer to the river mouths and keep them there more consistently.

Second, the base of operations should be in the mouth of the Big Susitna River since the majority of beluga sightings and capture opportunities occurred there. The hunters camp on Big

Island would offer the most efficient base to observe belugas and to stage the capture work. However, the occupation of the camp by hunters or their activity in the vicinity coincident with capture efforts would be counter-productive because the animals become less approachable as they are harassed by the hunters' boats. Efforts to partition capture efforts and hunting activity should, therefore, be considered a priority.

Third, the capture technique itself should incorporate full encirclement of the target animal rather than relying upon it to hit the straight or semicircular net on its own. The 1997 field observations suggest that the belugas in upper Cook Inlet are too wary to warrant further use of the drive technique that we tried, despite its success in some parts of the Canadian Arctic (Smith and Martin 1994). Subsequent work in July 1998 by the Canadians in the Makenzie Delta resulted in the capture of 6 belugas using full encirclement. A boat equipped to set up to 300 m of gillnet would substantially increase the probability of capture. Thus, a 3-4 week capture effort in May and June, based at the mouth of the Big Susitna River and using much longer encirclement nets is recommended.

Acknowledgments

I thank the participants in the field project for their dedicated work, including Jack Cesarone (NMML), Artur Andriolo (NMML), Scott Hill (NOAA Corps), Dan Voss (F/AKR), Barbara Mahoney (F/AKR), Matt Eagleton (NOAA Corps), Rod Hobbs (NMML), and Doug DeMaster (NMML). The assistance of our Native Alaskan guides, Art Nuglene and Mike Saccheus, and beluga capture expert Tom Smith are equally appreciated. Ron Morris (F/AKR) generously provided logistical and planning support. Funding for this project was provided through NMFS, Office of Protected Resources. The capture efforts were made in accordance with MMPA Scientific Research Permit No. 957.

Citations

DeMaster, D.P. 1995. Minutes from the 16-17 February meeting of the Alaska Scientific Review Group, Anchorage, Alaska. National Marine Mammal Laboratory, 7600 Sand Point Way, N.E., Seattle, WA 98115. 22 p.

Dizon, A.E., C. Lockyer, W.F. Perrin, D.P. DeMaster, and J. Sisson. 1992. Rethinking the stock concept: a phylogeographic approach. Conserv. Biol. 6:24-36.

Frost, K.J., and L.F. Lowry. 1990. Distribution, abundance, and movements of beluga whales, *Delphinapterus leucas*, in coastal waters of western Alaska. In T.G. Smith, D.J. St. Aubin, and J.R. Geraci (eds.), Advances in research on the beluga whale, *Delphinapterus leucas*. Can. Bull. Fish. Aquat. Sci. 224:39-57.

Hill, P.S., D.P. DeMaster, and R.J. Small. 1997. Alaska marine mammal stock assessments, 1996. U.S. Dep. Commer. NOAA Tech. Memo. NMFS-AFSC-78, 150 p.

Lerczak, J.A. 1995. Radio-tagging of belugas in Cook Inlet, Alaska, June 1994. Unpubl. doc. submitted to Int. Whal. Commn. (SC/47/SM9).

Rugh, D.J., K.E. Shelden, and B.A. Mahoney. In prep. Distribution of beluga whales in Cook Inlet, Alaska, during June and July 1993-97. National Marine Mammal Laboratory, 7600 Sand Point Way, N.E., Seattle, WA 98115.

Smith, T.G. and A.R. Martin. 1994. Distribution and movements of belugas, *Delphinapterus leucas*, in the Canadian High Arctic. Can J. Zool. 68:359-367.

Waite, J.M., J.A. Lerczak and R.C. Hobbs. 1996. Field report for tagging studies of beluga whales in Cook Inlet, Alaska, July/August 1995. Unpubl. doc. submitted to Int. Whal. Commn. (SC/48/SM9).

Wildlife Computers. 1994. Satellite-linked time-depth recorder instruction manual, 81p. Wildlife Computers, Redmond, WA.

SMALL CETACEAN AERIAL AND VESSEL SURVEY IN SOUTHEAST ALASKA AND THE EASTERN GULF OF ALASKA, 1997

Janice M. Waite and Roderick C. Hobbs

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington 98115

Introduction

In 1997, the National Marine Mammal Laboratory began a three-year aerial survey for small cetaceans in Alaska to complete a new abundance estimate for harbor porpoise (*Phocoena phocoena*), Dall's porpoise (*Phocoenoides dalli*), and Pacific white-sided dolphins (*Lagenorhynchus obliquidens*) by 1999, given sufficient sample sizes. The aerial survey was split into three regions corresponding to the stock boundaries for harbor porpoise. Because of the immense coastline to be surveyed, the three regions will take three years to cover (1997 to 1999). The 1997 survey included the inland waters of Southeast Alaska and the eastern Gulf of Alaska from Dixon Entrance to Cape Suckling. The 1998 survey will include Prince William Sound, the Gulf of Alaska from Cape Suckling to Unimak Pass, including waters around Kodiak Island. The 1999 survey will include Bristol Bay and the eastern Aleutian Islands. We report here the survey of the eastern region of the subarctic waters of Alaska from Dixon Entrance to Cape Suckling.

Harbor porpoise and Dall's porpoise are the only small cetaceans, other than beluga whales (*Delphinapterus leucas*), commonly found in Alaska waters. Three harbor porpoise stocks exist in Alaska: the Southeast Alaska, Gulf of Alaska and Bering Sea stocks. The population estimates for these stocks are, respectively, 10,301, 8,497, and 10,946 (Hill et al. 1997). These estimates are based on a three-year survey of sub-arctic Alaskan waters conducted from 1991 to 1993 (Dahlheim et al. in press), and a correction factor developed for harbor porpoise surveys in Oregon and Washington (Calambokidis et al. 1993, Hill et al. 1997). Known fishery takes do not exceed the PBR, but a reliable estimate of human-caused mortality is unavailable due to the lack of observer placements in a large part of the range. It has been recommended that abundance estimates based on data older than 8 years not be used to calculate a PBR (Wade and Angliss 1997). Therefore, data from the previous three-year harbor porpoise survey will become invalid for stock assessment purposes by the year 1999.

Correction factors for harbor porpoise from Puget Sound, Washington (3.1; CV = 0.171; Calambokidis et al. 1993) and California (3.2; Barlow 1988) were applied to the minimum abundance estimates of harbor porpoise in Alaska but may not be appropriate for Alaska due to differences in sighting conditions. Neither sightability bias ($G(0) < 1$) nor availability bias (fraction of animals below the surface) has been estimated for harbor porpoise in Alaska. In this study, dual, independent observers were used to estimate sightability bias. Sightings made by an independent observer in a belly window will help determine the number of animals missed by the primary observers on the trackline.

Dall's porpoise occur both pelagically and in coastal waters in Alaska and are considered to be one continuous stock. A corrected population estimate is 83,400 Dall's porpoise in the Alaska stock (Hill et al. 1997), using an abundance estimate produced by Hobbs and Lerczak (1993) and a correction for vessel attraction produced by Turnock and Quinn (1991).

The Pacific white-sided dolphin is the only dolphin frequently reported in coastal Alaska waters, and its occurrence is highly variable (Leatherwood et al. 1984, Dahlheim and Towell 1994). An abundance estimate for the Central North Pacific stock of Pacific white-sided dolphins is 931,000 (Buckland et al. 1993), though this may be an overestimate because no vessel attraction correction factor has been applied.

The three-year small cetacean survey, running from 1997 through 1999, will complete a new abundance estimate for harbor porpoise, Dall's porpoise, and Pacific white-sided dolphins (assuming sufficient sample sizes). The previous harbor porpoise surveys (1991 to 1993) used a vessel platform for the inside waters of Southeast Alaska. The current survey was conducted from aircraft, but included a calibration study with a survey vessel. In an area of high harbor porpoise density, both a vessel and an aerial team surveyed concurrently. Resulting sightings will be matched to compare sighting rates.

Methods

Survey Design

To design the aerial survey for the inside waters of Southeast Alaska, waterways were divided into blocks based on obvious separations of straits and inlets. The average density of harbor porpoise from surveys in June 1992 and June 1993 was determined for each block. The number of trackline miles for each block was then determined based on the density of harbor porpoise and the area of each block (determined using the mapping program CAMRIS). Blocks were stratified by density: high density (greater than twice the average density observed in the 1993 aerial survey), low density (less than twice the average density observed in the 1993 aerial survey), and unknown density (areas that were not surveyed in previous years). The low density blocks (including all offshore blocks) were given a weight of 1. The high density blocks were weighted by the square root of the ratio of the average density of the high density blocks to the average density of the low density blocks. The unknown density blocks were weighted by the square root of the ratio of the average density of all surveyed blocks to the average of the low density blocks. The patterns of the lines were designed in each block to represent the greatest amount of habitat diversity. Therefore, areas with a low density of lines resulted in a zigzag pattern, while blocks with high density could be covered more efficiently with parallel lines. Southeast Alaska includes many small inlets that were not surveyed in past years. A number of these were chosen throughout Southeast Alaska. A random selection criteria was used with consideration to the practicality and safety of flying through each inlet.

Two series of sawtooth lines were designed for the offshore waters from Dixon Entrance to Cape Suckling. Each line consisted of two strata. The first strata ("short" sawtooth) went out to 17 nautical miles (nmi) or the 100 fathom (fm) line, whichever was farthest from shore. The second strata ("long" sawtooth) went out to 40 nmi or the 1000 fm line, whichever was farthest from shore. The base of each sawtooth was 17 nmi wide. Each series of transects consisted of a pattern of two short sawtooths and one long sawtooth. The only exception was in Dixon Entrance where the U.S. Exclusive Economic Zone created a boundary. The start point (in Dixon Entrance) for each line was a random number between 0 and 17, used as the number of nautical miles west of the 132° longitude line on the south end of Prince of Wales Island.

Vessel survey lines were designed to replicate the aerial survey lines in the Glacier Bay/Icy Strait area as closely as possible. Diversions were necessary to go around islands and to allow for the ship to return to Bartlett Cove in Glacier Bay each night.

Aerial Survey Methods

A DeHavilland Twin Otter (NOAA) was used as the survey platform. Surveys were flown at 152.5 m (500 ft) and at a speed of 100 knots. Five observers rotated through the two primary observer positions (a right and left observer at bubble windows), an independent observer position at a belly window, a computer operator, and a rest position. A headset system was used by all observers except the belly window observer. A Global Positioning System (GPS) unit was connected directly to a portable computer. The date, time, and position of the plane were automatically entered into the survey program every minute and whenever data were entered by the computer operator. At the start of each trackline, waypoint numbers, observer positions, and environmental conditions were entered into the computer. These included cloud cover, Beaufort sea state, visibility and glare for each observer. When a sighting was made, the observer called out "mark" when the animal (or the water that the animal was seen in) crossed the beam of the plane. The observer used an inclinometer to obtain the distance (angle) of the animal from the plane. At the "mark", the recorder hit a hot key on the computer corresponding to the appropriate observer, which grabbed the time and position. The observer then reported to the recorder the species, inclinometer angle, and group size. Sightings made by the pilots and off-watch observers were recorded as "off-effort" and were not used in density estimate calculations. The observers also reported to the recorder any environmental changes that occurred along a trackline. The two primary observers searched through bubble windows which allowed each to see slightly further than directly below the plane so that sightings on the trackline were available to both observers. Sightings in this overlap area were resolved by open communication between the primary observers to prevent duplicate records. The belly observer, with no headset, remained independent. This helped determine the number of animals missed by the primary observers on the trackline. To alert the recorder of sightings, the belly observer tugged on a string attached to the observer's leg, and then passed the information on a notepad.

Vessel Survey Methods

A complete line-transect vessel survey was conducted in Icy Strait and Glacier Bay to estimate the abundance of harbor porpoise as a comparison to the aerial survey. The survey was conducted on the NOAA ship *John N. Cobb* at a speed of 10 knots. Five observers rotated through three positions: starboard observer, computer operator, and port observer. Each position was 40 minutes long, resulting in an observer schedule of 2 hours on effort and 1 hour and 20 minutes off effort. The starboard and port observers scanned using both the naked eye and 7 X

50 Fujinon binoculars, searching from 0° (ship's bow) to 90° or 270°, respectively. The computer operator, using a portable computer on the bridge, also acted as an observer. They concentrated on the trackline, using binoculars only to confirm species identification and numbers. Sightings made by the officers, crew, and off-watch observers were recorded as "off-effort" and were not used in density estimate calculations. A GPS unit was connected directly to the survey computer. The date, time, and position of the ship were automatically entered into the survey program every ten minutes and whenever data were entered by the computer operator. Search effort was recorded on the computer by marking the beginning and end of each transect. The recorder also entered the Beaufort sea state, weather description (rain and fog), visibility index, and observer positions (port, computer operator, and starboard). When a sighting was made, the observer alerted the computer operator to hit the hot key for that observer (recording time and ship's position). The computer operator entered the following data as they were determined: angle to the sighting, distance to the sighting, radar distance (nmi) to the shoreline at the same angle of the sighting, species, and the number seen (best, high and low counts). The observer determined the angle to the sighting using a pelorus mounted on the bridge wing's rail. Internal reticle marks in the binoculars were used to obtain distance to a sighting. The top reticle was placed on the horizon or shoreline and the number of marks counted down to where the sighting occurred. The distance to shore was obtained by the computer operator from a radar on the bridge.

Experiment

In addition to the line transect surveys, a harbor porpoise calibration experiment was conducted. Based on the harbor porpoise sightings made during the ship survey, a location with high harbor porpoise density was chosen. The ship ran a 10 nmi trackline back and forth through the chosen area, while the aircraft flew multiple lines ahead of the ship and perpendicular to the course of the ship. During the experiment, both survey crews used the same sighting methods as those used for the line transect surveys.

Results and Discussion

The line transect aerial survey for small cetaceans was conducted 27 May to 7 June and 10 July to 28 July 1997 in the inside waters of Southeast Alaska, Yakutat Bay, Icy Bay, and offshore waters from Dixon Entrance to Cape Suckling (Fig. 1). Necessary repairs on the survey plane resulted in an unplanned month-long break in the survey. A total of 52.92 survey hours were flown. Concurrent with the aerial survey, the line-transect vessel survey was conducted in Glacier Bay and Icy Strait 31 May to 5 June and totaled 45.1 hours (Fig. 2). The vessel/aerial experiment was conducted on 2 June and 4 June and consisted of 4.48 aerial hours and 6.2 vessel hours. Time during aerial turns were subtracted from the total aerial time, resulting in a shorter total time than the vessel time. Harbor porpoise and Dall's porpoise sightings for the aerial and vessel surveys are shown in Figures 3 - 6. Numbers of all cetaceans sighted during the surveys and the experiment are shown in Table 1.

Table 1. Number of cetacean sightings made while on-effort during the 1997 survey.

Species	Aerial survey	Vessel survey	Aerial experiment	Vessel experiment
Phocoena phocoena	144	152	59	77
Phocoenoides dalli	222	61		
Lagenorhyncus obliquidens	2	0		
Orcinus orca	2	0		
Balaenoptera acutorostrata	0	1		2
Balaenoptera physalus	2	0		
Megaptera novaeangliae	33	65	1	4
Physeter macrocephalus	2	0		
Eschrichtius robustus	1	0		
unidentified dolphin/porpoise	43	20	1	
unidentified large whale	22	4		
unidentified beaked whale	1	0		

In the final analysis, 1997 survey data will be combined with 1998 survey data to determine an abundance estimate for harbor porpoise, Dall's porpoise and Pacific white-sided dolphins (if the sample size allows) for Southeast Alaska, Prince William Sound and the Gulf of Alaska. The line-transect analysis program DISTANCE (Laake et al. 1993) will be used. A correction factor will be determined for animals missed on the trackline from comparisons of sightings made by the belly observer and the two primary observers.

Surveys in 1991 - 93 in Southeast Alaska were conducted only from a vessel platform. The 1997 survey used an aerial platform for the majority of Southeast Alaska. In order to look at trends in abundance in that region, it is necessary to assess differences in sighting rates between the two platforms. Two methods of comparison between the two platforms will be used. A separate abundance estimate from both the 1997 aerial and vessel surveys conducted in the Glacier Bay/Icy Strait region will be made. The two surveys in that region were close in time (aerial: 28, 29, 30 May; vessel: 31 May to June 5) and so it is assumed that major numbers of animals did not change. The difference in the abundance estimate between the two platforms will show if there is a significant difference between the two. Analysis of the sighting experiment will include the comparison of sightings between the plane and the vessel. Locations for each sighting will be determined using the distance information gathered at the time of the sighting (reticle readings from the vessel and inclinometer readings from the plane). Time and location will then be used to determine matches between the two platforms.

Acknowledgments

We thank many people for participating as observers in these surveys: Artur Andriolo, Robyn Angliss, Chris Gabriele, Scott Hill, Kristi Leinbach, Beth Mathews, Sally Mizroch, Dave Rugh, Kim Shelden, Paul Wade, and Noel Weems. Kim Shelden assisted with data editing. We thank the captain (Ken Barton) and crew of the NOAA ship *John N. Cobb* and the pilots of the NOAA Twin Otter (Matt Pickett, John Longenecker, Jeff Hagan, and Michele Finn) for their dedication and excellent handling of vessel and aircraft. The Glacier Bay Park and Reserve generously allowed Chris Gabriele and Beth Mathews to participate in the vessel survey. Dave Rugh provided a review of this manuscript.

Citations

Barlow, J. 1988. Harbor porpoise, *Phocoena phocoena,* abundance estimation for California, Oregon and Washington: I. Ship Surveys. Fish. Bull., U.S. 86:417-432.

Buckland, S. T., K. L. Cattanach, and R. C. Hobbs. 1993. Abundance estimates of Pacific white sided dolphin, northern right whale dolphin, Dall's porpoise and northern fur seal in the North Pacific, 1987/90. Pp. 387-407, In W. Shaw, R. L. Burgner, and J. Ito (eds.), Biology, Distribution and Stock Assessment of Species Caught in the High Seas Driftnet Fisheries in the North Pacific Ocean. Intl. North Pac. Fish. Comm. Symposium; 4-6 November 1991, Tokyo, Japan.

Calambokidis, J., J. R. Evenson, J. C. Cubbage, S. D. Osmek, D.J. Rugh, and J. L. Laake. 1993. Calibration of sighting rates of harbor porpoise from aerial surveys. Final report to the National Marine Mammal Laboratory, AFSC, NMFS, NOAA, 7600 Sand Point Way, NE, Seattle, WA 98115. 55 p.

Dahlheim, M., A. York, R. Towell, J. Waite, and J. Breiwick. In press. Abundance and distribution of Alaskan harbor porpoise (*Phocoena phocoena*) based on aerial surveys: Bristol Bay to Southeast Alaska. Mar. Mammal Sci.

Dahlheim, M. A., and R. G. Towell. 1994. Occurrence and distribution of Pacific white-sided dolphins (*Lagenorhynchus obliquidens*) in southeastern Alaska, with notes on an attack by killer whales (*Orcinus orca*). Mar. Mammal Sci. 10:458-464.

Hill, P. S., D. P. DeMaster, and R. J. Small. 1997. Alaska marine mammal stock assessments, 1996. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-78, 150 p.

Hobbs, R. C., and J. A. Lerczak. 1993. Abundance of Pacific white-sided dolphin and Dall's porpoise in Alaska estimated from sightings in the North Pacific Ocean and the Bering Sea during 1987 through 1991. Annual rept. to the Mar. Mammal Assess. Prog., Office of Protected Resources, NMFS, NOAA, 1335 East-West Highway, Silver Spring, MD 20910.

Laake, J. L., Buckland, S. T., Anderson, D. R., and Burnham, K. P. 1993. DISTANCE User's Guide V.2.0. Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University, Fort Collins, CO. 72 p.

Leatherwood, S., R. R. Reeves, A. E. Bowles, B. S. Stewart, and K. R. Goodrich. 1984. Distribution, seasonal movements, and abundance of Pacific white-sided dolphins in the Eastern North Pacific. Sci. Rep. Whales Res. Inst. 35:129-157.

Turnock, B. J., and T. J. Quinn. 1991. The effect of responsive movement on abundance estimation using line transect sampling. Biometrics 47:701-715.

Wade, P. R., and R. P. Angliss. 1997. Guidelines for assessing marine mammal stocks: report of the GAMMS workshop April 3-5, 1996, Seattle, Washington. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-OPR-12, 93 p.

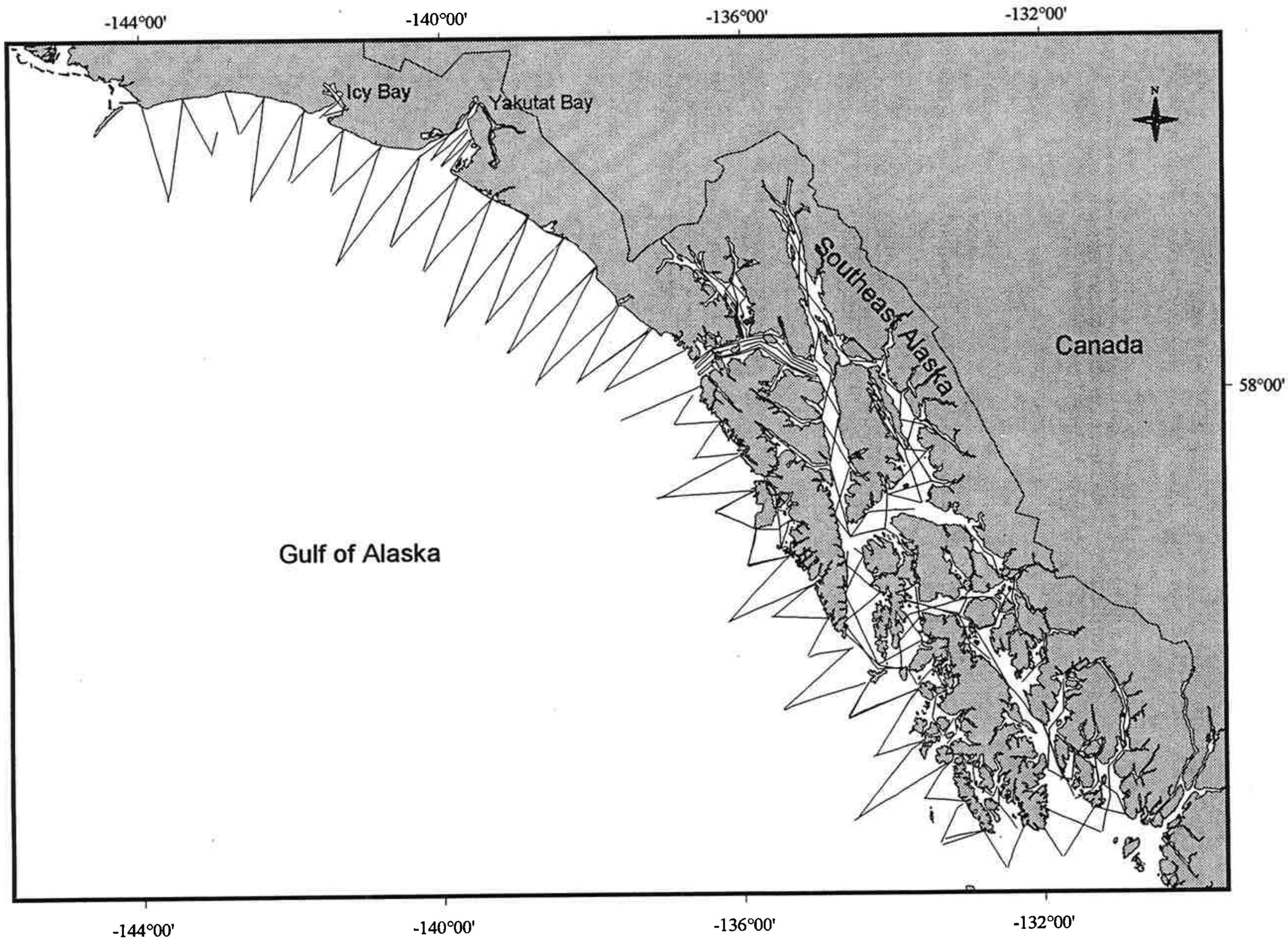

Figure 1. Aerial survey tracklines completed during the 1997 small cetacean survey.

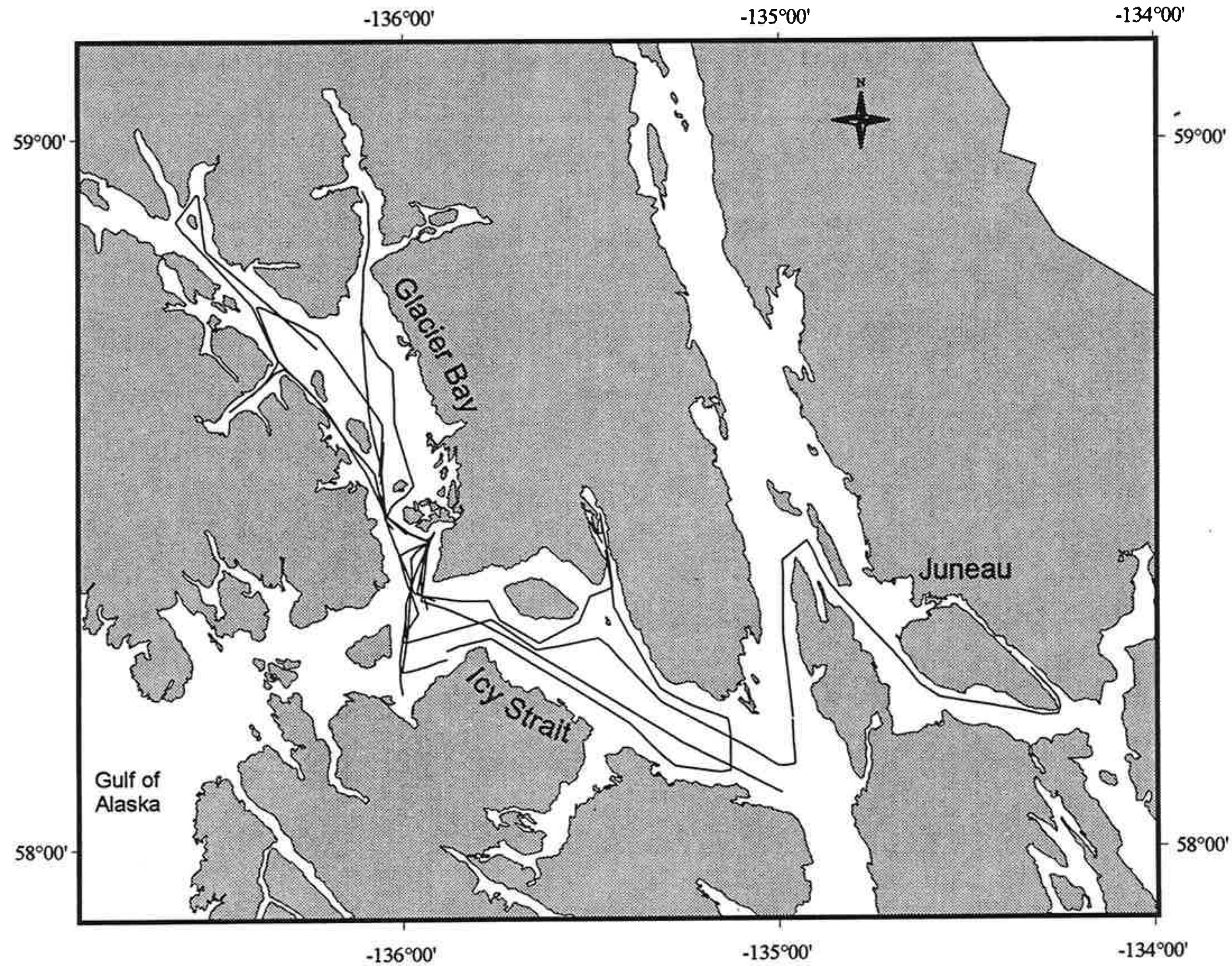

Figure 2. Vessel survey tracklines completed during the 1997 small cetacean survey.

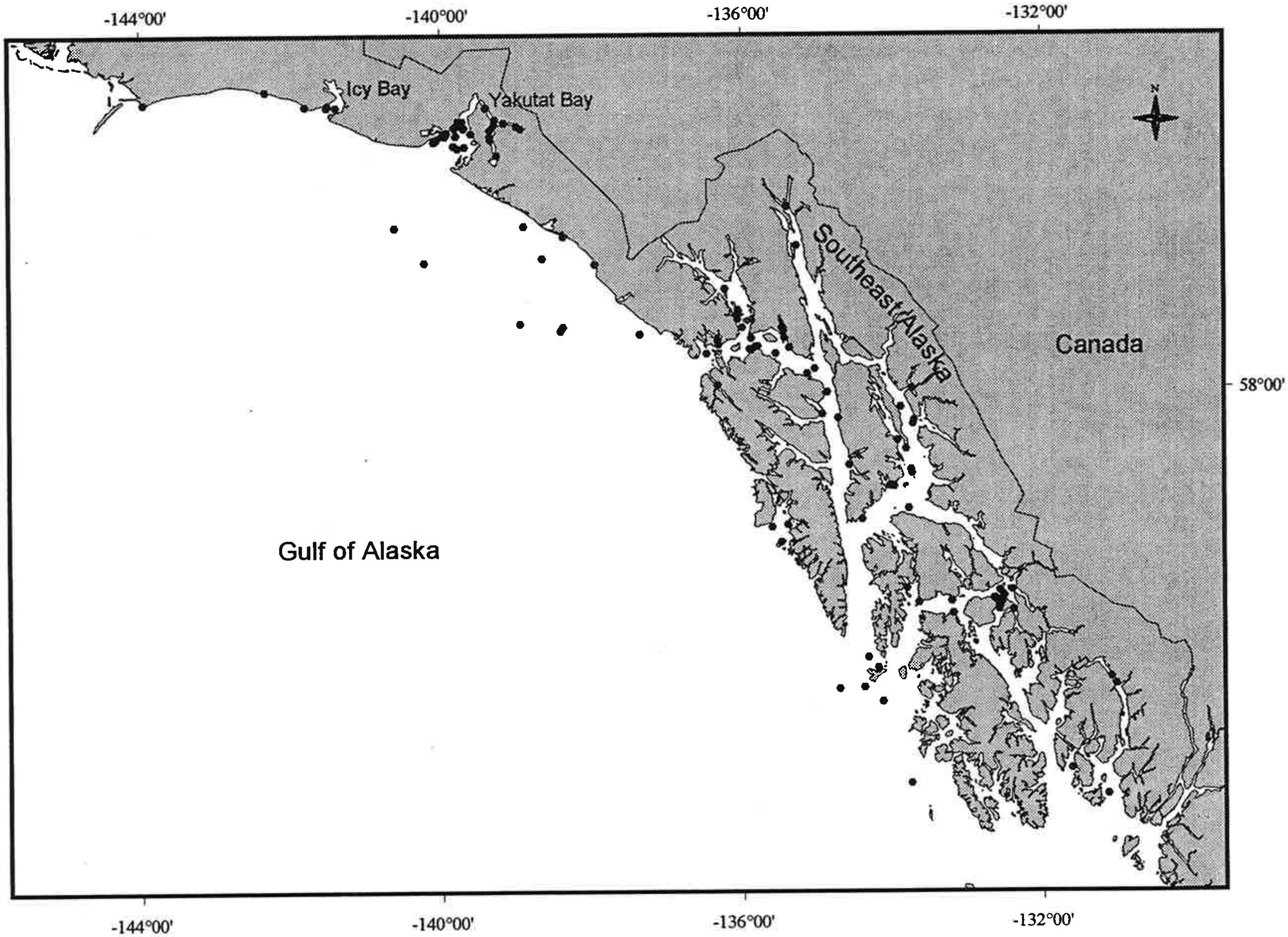

Figure 3. Harbor porpoise sightings during the 1997 aerial survey.

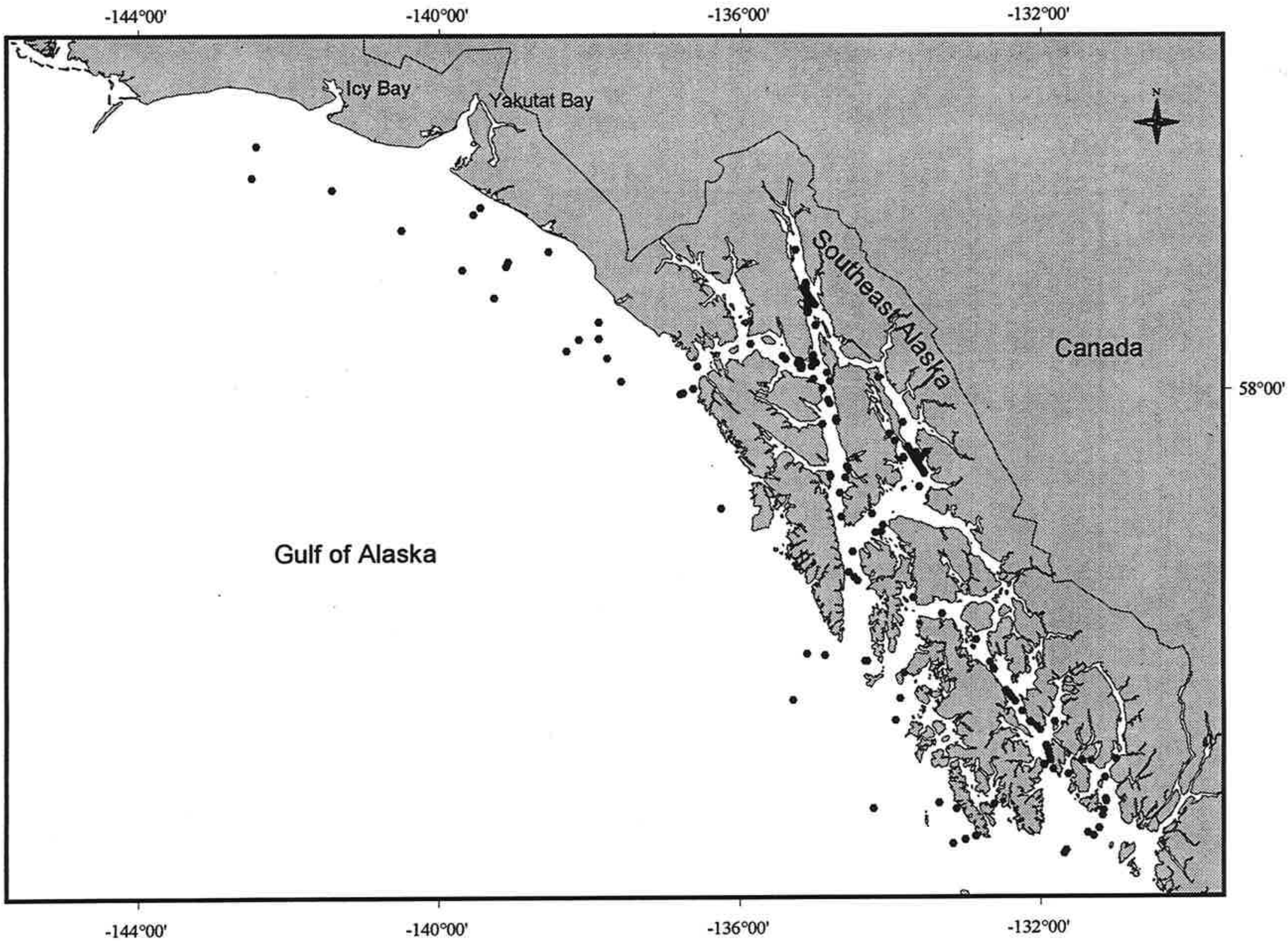

Figure 4. Dall's porpoise sightings during the 1997 aerial survey.

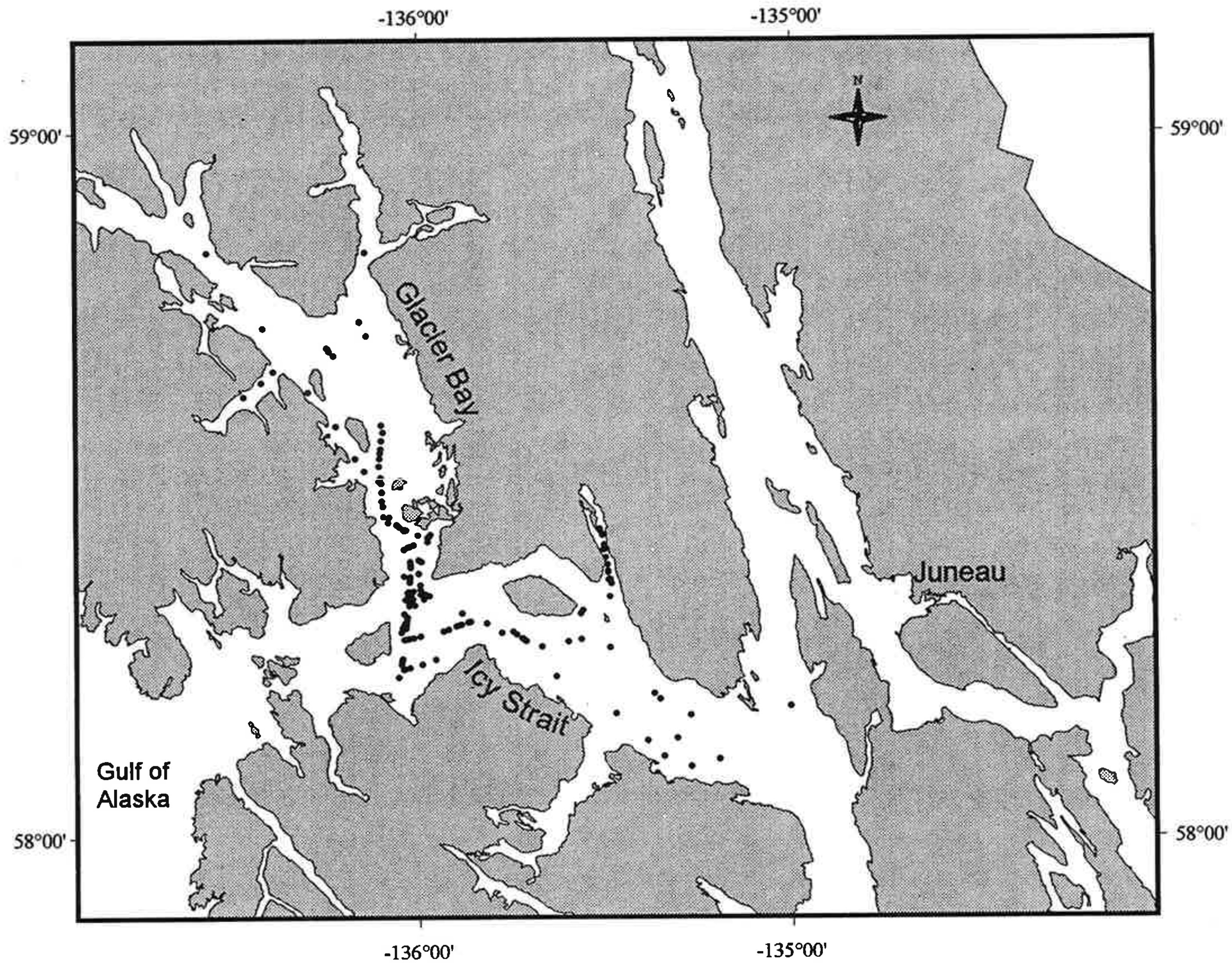

Figure 5. Harbor porpoise sightings during the 1997 vessel survey.

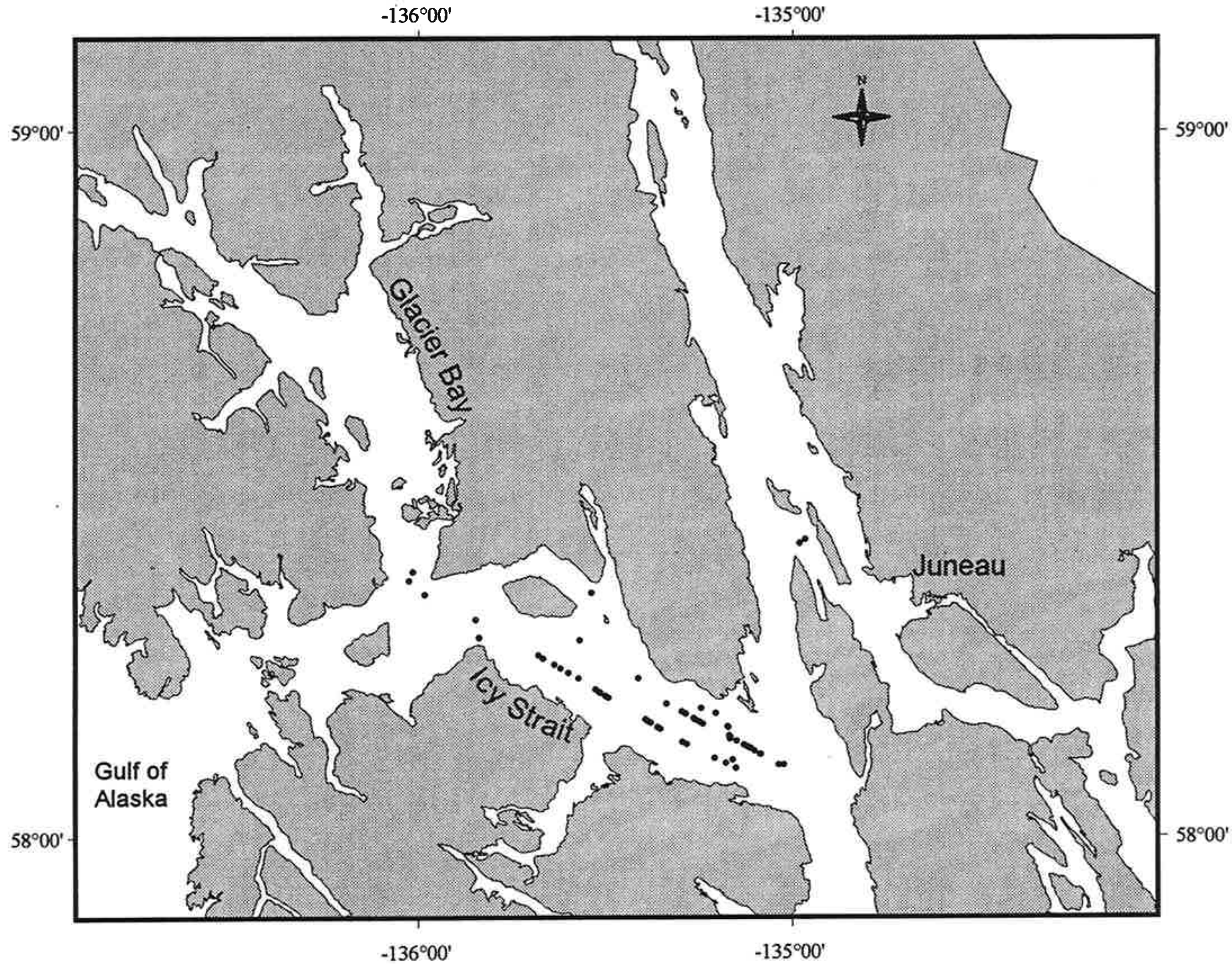

Figure 6. Dall's porpoise sightings during the 1997 vessel survey.

DESIGN CONSIDERATIONS FOR TELEMETRY TAGS FOR SMALL CETACEANS

M. Bradley Hanson

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington, 98115

Abstract

Fluid-dynamic principles were used to develop several hydrodynamically-efficient mock-up tag designs for use on small cetaceans, taking into account the constraints of available telemetry components, dorsal fin vascular morphology, and commonly used attachment schemes. In wind tunnel testing, all but one mock-up added substantially less drag than designs deployed previously on wild porpoises, but no particular position on the dorsal fin was clearly superior. However, because tag deployment durations appeared to be longest for side-mounted tags, this configuration was used for a VHF tag designed for Dall's porpoises (*Phocoenoides dalli*). Potting the completed VHF transmitter in a urethane fairing served to streamline the tag as well as act as the attachment saddle. The flexibility of this material may result in reduced stress concentrations in tissue at the attachment sites. This tag design had approximately the same volume as currently available satellite tags, but created only about one-third the drag. It was deployed on three Dall's porpoises in inland Washington waters during May 1997, one of which was reported to have been resighted 4.5 months later. Although these results suggest that low drag tag designs have the potential for prolonged attachments, even on species which likely create high loads due to the high-velocities they attain, drag is likely only one of several complex factors influencing attachment duration. Determining these factors will require additional lab studies on tag-caused load concentrations as well as the continued deployment of tags on animals that have a reasonable likelihood of being resighted.

Introduction

Although it has long been realized that many marine organisms are very hydrodynamically efficient (Gray 1936), allowing them to move at relatively high velocities in a very dense medium (seawater) with minimal energy expenditure, it has not been until more recently that the drag these organisms experience has been quantified. Among marine organisms, the penguins, sea lions, and small cetaceans have been found to have extremely low drag coefficients (Bannasch et al. 1994, Feldkamp 1985, Hanson et al. 1998a, this volume), the same as a flat plate with turbulent flow which is virtually perfect by fluid dynamics standards (Vogel 1994). They can achieve this low drag due to fluid dynamic characteristics associated with the spindle shape of their bodies and foil shape of their appendages (Hertel 1966, Vogel 1994). Despite the best efforts of equipment designers to streamline man-made objects (e.g., submarines, torpedoes), the drag these create is still much greater than biological forms (Nachtigall 1981). Consequently, it would be expected that any human-designed devices (i.e., tags) attached to these animals could add a substantial amount of drag, particularly if little consideration has been given to streamlining these devices. Although several researchers have suggested the potential importance of hydrodynamics in marine mammal tag designs (Martin et al. 1971, Evans 1974, Würsig 1982, Scott et al. 1990, Mate et al. 1995), only recently have the additional loads these tags add been quantified (see Hanson et al. 1998a, this volume, Bannasch 1996). Because it has been demonstrated that these devices can affect the behavior of marine animals (Croll et al.1991, Irvine et al. 1982, Würsig 1982, Walker and Boveng 1995), the potential exists for jeopardizing the health of the tagged animal as well as the quality of the data. Therefore, it is important to quantify the additional burden these devices create in order to serve as a baseline from which to optimize designs (see Bannasch et al. 1994, Bannasch 1996). Besides potentially affecting behavior, a consistent problem is that the load these tags generate is transferred to the tissue adjacent to the pins that hold the tag such that tissue necrosis occurs, resulting in pin out-migration (Irvine et al. 1982, B. Hanson, NMML, unpubl. data). Consequently, because the amount of drag a tag (or any object) creates is a function of its shape (Vogel 1994) and velocity, the rate of pin out-migration might be decreased if tag drag is reduced and thus attachment duration possibly increased. While the goals of most telemetry studies allow some latitude in the package configuration and size, these are constrained by where and how the devices can be attached to the animals as well as the engineering prerequisites necessary for them to function properly (i.e., transmitter and battery size, antenna length). Because signal reception is only possible for the most commonly used telemetry systems when the transmitter antenna is above the surface, location of the transmitter high on the back of the animal is necessary. The dorsal fin or ridge have been a popular attachment sites on small cetaceans, using some type of pin, which has been threaded on the outer ends to secure the tag with nuts. However, the dorsal fin serves a thermoregulatory role that may be important to reproduction (Rommel et al. 1992, Rommel et al. 1993). Consequently, avoidance of the vascularization network distributed throughout the connective tissue is desirable in order to maintain blood flow to adjacent tissues, which in turn limits the number of potential pin locations. The lack of any bony structure makes the fin somewhat flexible, providing a less than stable attachment platform for a rigid telemetry tag given the dynamic conditions the animal subjects it to. In addition, some fins are small (porpoises and immature animals of other species) relative to the currently available telemetry hardware. All telemetry tags are comprised of some type of attachment saddle and transmitter (which includes the signal producing unit, batteries, and antenna), but unfortunately, these components are typically available only in cubes or cylinders, shapes that tend to create a substantial amount of drag. Drag is likely further increased when these linear shapes are attached to a strut-like dorsal fin.

The generalized ideal low drag shape is like that of a spindle (Hertel 1966) or a strut; that is, a blunt nose and a relatively long tapered tail (Vogel 1994). Drag is minimized for strut shapes when the length/maximum thickness ratio (fineness ratio) is approximately 2.7:1 (Hoerner 1965) and dorsal fins from several small cetaceans are known to approximate these shapes (Lang 1966). However, adding an object to an already streamlined body requires the object be of a slightly different shape to perform optimally because the drag it adds is greater than the sum of the drag for the objects measured separately (von Mises 1945). Based on wind tunnel testing, it has been determined that the optimal shape for an additional object approximates a half a teardrop in shape with a fineness ratio of 10:1 (Hoerner 1965). In addition, the forebody edge should be lengthened/flattened to avoid flow separation while the trailing edge should be approximately one-third the maximum width, even if the afterbody extends beyond the existing trailing edge of the main object (Hoerner 1965). Interference drag also occurs at the junction of two adjoining bodies but this can be reduced if the junction angle is decreased from 90°, the effect of which can also be enhanced in combination with afterbody fairings (Hoerner 1965). Surface imperfections, such as nuts, or bolts or holes, also contribute to drag; however, for a given size, holes create much less drag than nuts/bolts, particularly if the edge of the holes are rounded on the trailing edge (Hoerner 1965).

With these hydrodynamic principles, fin morphology, and hardware constraints in mind, wind tunnel testing was conducted to develop a low drag VHF transmitter for deployment on Dall's porpoises. This report provides a preliminary consideration of some of the factors that may affect tag drag, and ultimately attachment duration.

Methods

Based on hydrodynamic principles (Hoerner 1965) and currently available electronic components, eight mockup tag designs were produced in "clax" (a mixture of clay and wax) which could be attached to the leading edge, side, or trailing edge of a dorsal fin (see Table 1).

The drag on these designs was measured by attaching them to a full-size fiberglass model of a harbor porpoise (*Phocoena phocoena*) mounted in a wind tunnel. The porpoise model was constructed from a mold that was taken off an adult male that had been killed incidental to commercial fishing operations and subsequently frozen in the glide position by hanging it by its tail. This model was configured to mount on the drag balance strut of the University of Washington's Kirsten Wind Tunnel, a subsonic, closed circuit, double-return tunnel with a test section 8 ft high, 12 ft wide and 10 ft long.

Testing protocol included a baseline test of the model only at the beginning of the testing session and a subsequent test, either in the middle or near the send of the testing session. Tests were conducted at a dynamic pressure (q - a function of velocity and air density) of 40 q (equivalent to 10.2 mph in water) because this dynamic pressure is commonly used in wind tunnel tests. Pitch was varied from -10.0° to +10.0° degrees in 2° increments and yaw was maintained at 0° for all tests. Drag values were typically lowest at 6° pitch such that all comparisons in the data analyses were made at this pitch.

The VHF tag designed for Dall's porpoise was based on the VHF portion of mock-up 6 following wind tunnel evaluation (see below). It was reproduced in low sulfur clay on a fiberglass replica of a Dall's porpoise dorsal fin. The locations of the three pin attachment system (based on the pattern used on tags deployed by Read and Westgate (1997)) were integrated into the clay prototype with two anterior pins located approximately 1.0" posterior to the leading edge of the dorsal fin, approximately 1.625 inches apart. A pair of posterior pin locations were located approximately 6.25 inches and 6.5 inches from the leading edge in order to provide alternate penetration sites in order to avoid the primary vascular trunks. The 0.25 inch diameter pin location holes were incorporated into the mold and, to minimize nut size, threaded for a 6 mm nut. The recesses for these nuts were 0.5 inches in diameter and varied in depth from 0.125 inches to 0.25 inches. The tag was 6.5 inches in length and 0.75 inches in height yielding a fineness ratio of approximately 11.5. The trailing edge of the fairing was approximately 1.0 inch wide, corresponding to 0.3 of the tag's maximum width. A silicone mold was made of the clay mock-up and the dorsal fin. An ATS model 201 transmitter powered by a 1035 battery which initially incorporated a saltwater switch (the saltwater switch was eliminated from the design in subsequent tags due to malfunction) was used with a 13.5 inch long, rigid stainless steel wire antenna exiting the dorsal posterior part of the tag fairing at approximately 45 degrees. A transmitter was potted in the mold with 65 A scale durometer urethane with 0.25 inch diameter stainless steel washers embedded in the urethane at each pin location (to provide reinforcement). This tag design was also tested in the Kirsten wind tunnel under the same protocol as the mock-ups except that it was run at 2, 4, 5, 6, 8, 10, 25, and 40 q.

Results

The proportional increase in drag caused by the mock-up designs ranged between approximately 1% and 17% with all but one (mock-up 5), adding approximately 1% and 5% more drag (Table 1). The design that added the most drag (mock-up 5) was a front mount and the design that added the least was a back mount (mock-up 1B). Of the two front mounts tested, the design that added the most drag (17%) exceeded the maximum width of the dorsal fin. The back mounted tag with a blunt after-body (mock-up 1A) appeared to add substantially more drag than a design with a streamlined after-body (mock-up 1B).

A pair of the VHF tags developed for Dall's porpoises were tested twice on the harbor porpoise model (Table 2). The percent increase in drag increased rapidly between 2 q and 8 q from 12-15% to 27% before decreasing slightly to 25%-26% at 40 q.

During May 1997, three Dall's porpoises were live-captured and tagged (see Hanson et al. 1998b, this volume). Transmitter signals were received for up to five days for each animal, indicating the animals remained within 25 km of the capture site. Aerial searches of the waters of northern Washington and southern British Columbia, subsequent to signal loss, failed to pick up any transmitter signals, suggesting transmitter failure which may have been associated with deeper than expected dives (see Baird and Hanson 1996, Baird and Hanson 1998, this volume), or failure of the attachment system due to forces associated with this species' relatively high swim speed. Despite a dedicated resighting effort for these animals in their known range during the three weeks post-signal loss, they were not observed, suggesting extended movements outside this area. However, an unsolicited report of a tagged Dall's porpoise in Becher Bay, southwest of Victoria, Vancouver Island, was received in mid-October, 4.5 months after tag deployment.

Discussion

This study represents only a preliminary examination of the drag characteristics of several mock-up designs due to the small number of trials and the limited dynamic pressures used. Despite these limitations, the much lower drag values obtained for almost all the mock-ups as well as the Dall's tags in comparison to previously deployed tags (see Hanson et al. 1998a, this volume), suggests that substantial reductions in tag drag are possible through careful consideration of hydrodynamic characteristics during tag design. Although part of the reason for the low drag observed for the mock-ups can be attributed to the lack of antennas, these would be expected to add only about 5% for a satellite transmitter and just slightly more for a VHF antenna (Hanson et al. 1998a, this volume). While antennas are typically of small diameter, their cylindrical shape produces poor hydrodynamic performance (Hoerner 1965, Vogel 1994), such that as transmitter and saddle drag are reduced, antenna drag may come to be a significant factor. Therefore, modifications in antenna shape should be investigated with special attention to ensure that signal quality is not degraded. An additional source of variability is likely associated with this tunnel's drag balance accuracy. Because the proportional drag increase of most of the mock-ups was very small, limitations in the balance accuracy for the lowest drag design could account for up to 50% of the drag value obtained. Consequently, while these biases preclude conclusive determination of which, if any, position on the dorsal fin was the most efficient, the results do show that a front-mount tag that exceeds the maximum width of the dorsal fin is clearly very inefficient, while a "backpack" style tag, particularly if equipped with a tapered after-body, may have potential. The importance of tapered after-bodies in decreasing drag has been shown in the designs of other objects (Hoerner 1965, Vogel 1994). Nonetheless, additional testing with a more sensitive drag balance will be required to better evaluate tag position and configurations.

Development of the Dall's porpoise tag as a side-mount was largely based on the observation of longer attachment durations for this type of configuration (see Read and Westgate 1997). Subsequent comparison of front- and side-mounted tags in two independent studies with two different species clearly indicate that side-mount tags have longer attachment durations (see Westgate and Read 1998, Martin and da Silva 1998). While a front-mount design (that does not exceed the maximum width of the dorsal fin) appears to be fairly hydrodynamically comparable to a side-mount (this study, Hanson et al. 1998a, this volume), and would seem to offer the advantage of distributing the tag's additional drag over the portion of the leading edge of the fin in contact with the saddle rather than just the pins, the results from these tag deployment studies suggest that the forces being applied to the tag are different from those being simulated in the wind tunnel. Possible reasons for reduced attachment durations in front mount tags include: 1) that this position is likely more vulnerable to rubbing, which has been documented (Bowers and Henderson 1972) or suspected to damage tags in several species (Irvine et al. 1982, B. Hanson, NMML, unpubl. data), the net result being that the tag is likely subjected to loads greatly in excess of those that normally occur while the animal is swimming; 2) the pin out-migration path is much shorter than a side mount (out the leading edge of the fin), particularly with the load vectors most likely associated with rubbing as well as when the animal is surfacing and diving (due to water periscoping up the fin, B. Hanson, NMML, unpubl. data); and 3) a rigid tag mounted on the front of a flexible fin creates a bending moment where excessive stress concentrations develop at the pin/saddle interface.

The Dall's VHF tag developed in this study represents a substantial hydrodynamic improvement in small cetacean tag design. It has approximately the same volume as currently available satellite transmitters (about ~180 cm^3) but because of its streamline design has about one-third the drag of the currently produced ST10 in a side-mount configuration (see Hanson et al. 1998a, this volume), based on the drag of the pair of these tags divided in half. Unfortunately, current satellite transmitter components will not fit this fairing, but may in the future as miniaturization of these parts occurs. Alternatively, this design is likely scalable, and as such would be suitable for other small cetaceans with larger dorsal fins. The drag performance of a pair of these tags compares favorably with a similar optimized design (see Bannasch 1996). The designs are somewhat similar (elongated, half body teardrop) except that the Bannasch (1996) tag is larger and extends anterior and posterior of the harbor porpoise dorsal fin in order to contain transmitter components. Interestingly, the tag in that study added proportionally more drag at lower velocities (31% at 2.2 mph), and decreased to 17-18% at velocities of 3.4 mph and greater. This is the reverse pattern of the sharp increase observed at 4.0 mph in this study. Reasons for the differences in drag patterns between these two tag designs are currently unclear. Although the proportional increase in drag appears similar for these two tags, a direct comparison is confounded because the porpoise model used by Bannasch (1996) lacked pectoral fins and flukes. The dorsal fin, pectoral fins and flukes, although small, are thought to represent approximately 28% of the total body drag (Lang and Pryor 1966). Consequently, the Bannasch (1996) tag may actually contribute proportionally less to a "complete" animal. However, it is important to note that this tag lacked an antenna which would likely increase drag by approximately 5% (see Hanson et al. 1998a, this volume).

The design of the Dall's tag system offers several other potential benefits that may be important in improving attachment longevities. While its position on the side of the fin likely provides some protection from rubbing or interaction with conspecifics, its streamline shape lacks the acute angles at the saddle/dorsal fin or saddle/transmitter junctions characteristic of other tags, such that gaining a purchase on this tag during these activities may be difficult, thus minimizing its exposure to potentially extreme loads. The use of a pair similarly sized/shaped side mounted tags should apply typical loads symmetrically (likely mostly posterior or to a limited extent, vertically) compared to the asymmetric load likely applied by a single side mounted tag. A tag on each side of the fin will likely also provide more stability to the pins than a single side mount, minimizing dynamic movements. The use of urethane in the construction of this tag may offer the advantage of providing a better match to the material properties of the dorsal fin (compared to the polycarbonate or foam PVC typically used), thus potentially reducing stress concentrations at the pin penetration points, which should reduce tissue pressure necrosis. This may be particularly important if, as noted previously, these tags are subjected to rubbing on objects. In addition, the urethane is extremely abrasion resistant, providing another measure of protection for the tag if subjected to rubbing. Finally, while recessing the pins and nuts likely reduces drag, it also eliminates structures which can serve as points of entanglement for debris such as fishing gear or kelp (see Irvine et al. 1982, Würsig 1982).

Besides, tag position and configuration, tag drag reduction warrants continued consideration if multiple month or full year attachments are to be achieved. The promise of long-term tag attachments for small cetaceans has been evident for some time based on the notably long attachment durations of roto tags (see Scott et al. 1990), likely because these tags are very small and have little "hydrodynamically induced strain" (Norris and Pryor 1970). The challenge of tag drag reduction lies primarily in component development, which will necessitate that manufacturers further miniaturize transmitters and increase the energy density of batteries. However, a conundrum will be that maintaining service life will not be sufficient if tag attachment durations increase such that more efficient power use (e.g., reliable saltwater switches and improved duty cycles) will be necessary. Further, drag reduction will depend on the efficient packaging of the components and incorporation of the attachment system. Improving tag attachment longevities will require a thorough evaluation of the factors influencing this by defining the problem in terms of what the tags actually are: percutaneous devices experiencing dynamic loads in an aquatic environment. For percutaneous devices, tissue degeneration can be expected to occur at these sites from: 1) a foreign body response due to the interaction of the pinning material and adjacent tissue, 2) infection due to bacterial invasion of the wound; 3) mechanical stresses disrupting the healing process (von Recum and Park 1981), or 4) pressure necrosis, due to chronic stress concentrations which have occluded blood flow (Levy 1962). Biocompatibilty of the pinning materials with marine mammal skin has been examined in implant studies conducted on captive animals (Geraci and Smith 1990). That none of the test materials were readily accepted may stem from the open wounds' constant exposure to the non-sterile aquatic environment, allowing infection to develop (Geraci and Smith 1990). Although stainless steel was the most readily rejected material in this implant study, this same material yielded one of the longest attachment durations recorded for cetaceans when used for pins with a killer whale tag (4.5 months, Erickson 1978). In addition, infections associated with pin out-migrations have typically not been observed (Irvine et al. 1982, Martin and da Silva 1998). These results suggest that tissue structure response to loading stress have a greater influence on tag retention than pin biocompatibility or infection. However, the extent to which reducing tag drag might increase attachment duration remains unclear. Because the dorsal fin is more elastic than the pins and tag saddles that are typically attached to it, this mismatch in material properties likely causes stress concentrations in the tissue. The flexibility of the urethane fairing used in this study may be beneficial in reducing stress concentrations. While pressure necrosis appears to have been the source of tag loss in studies where the tagged animals have been reobserved (see Irvine et al. 1982, Orr et al. 1998, Martin and da Silva 1998, B. Hanson, NMML, unpubl. data) it is unknown if the pressure (load/unit area) that these, or any other recently deployed tags cause, were sufficient to occlude blood flow. The stress/strain distribution within the fin (drag caused by the tag) will be a function of the structural composition of the tissue and the attachment scheme's load distribution in the tissue, which is dependent on the position of the tag on the fin and the number, diameter, and location of pins. Drag measurements on a model or an animal in the glide position represent simplified estimates of the loads the tissue actually experiences, such that these types of analyses may provide only limited application in estimating the actual loads experienced in the tissue. An additional possible source of pressure necrosis that has received no attention is the pressure of the tag against the skin, associated with the tightness of the attachment nuts. It is possible that some of the apparent variability in attachment durations could be related to inconsistencies in tag application. While there is currently no satisfactory way to assess how tight tags should be fastened, it may be important to assess this factor.

An additional level of complexity is added to this situation because the animals frequently change velocity and heading while swimming such that the loads and their associated vectors will be dynamic, which may possibly disrupt the healing process. As well, the unloading that occurs upon surfacing and reloading occurring upon diving (which may significant) are additional sources of dynamic loads and vectors. Modeling of stress distribution in the fin during the surfacing cycle, by incorporating wind tunnel loads and changes in velocity and depth from TDR data will be an important next step in better understanding the roles of factors suspected to influence tag attachment longevity.

Increasing tag attachment durations will likely come about as small improvements are made and the key factors become better understood. While lab studies will be important in identifying and evaluating these factors, tag deployments on sufficient numbers of animals in the wild coupled with dedicated resighting efforts will be critical to evaluating tag attachment performance.

Acknowledgments

Dr. Bob Breidenthal and student test engineers Brad Pratt and Seung Chung, of the University of Washington Department of Aeronautics and Astronautics, provided considerable assistance and were instrumental in tag design evaluation. Testing would not have been possible without the enthusiastic cooperation of the staff of the Kirsten Wind Tunnel. Lloyd Murrey and Dave Molegro of Moeller Design were of considerable assistance in urethane fairing production. The capture and tagging portion of this project would not have been possible without the skilled efforts and moral support of Artur Andriolo, Robin Baird, Jeff Foster, Nolan Harvey, and William Walker. Robin Baird, Pam Willis, and Chris Malcolm assisted in monitoring for tagged porpoises. Roberta Scholz skillfully translated Bannasch 1996. Robin Baird provided numerous constructive comments on the manuscript.

Citations

Bannasch, R. 1996. Zur strömungsdynamischen Formoptimierung von Telemetriegeräten für Schweinswale (*Phocoena phocoena*). Meer and Museum. 12:11-16.

Bannasch, R., R.P. Wilson, and B. Culik. 1994. Hydrodynamic aspects of design and attachment of a back-mounted device in penguins. J. Exp. Biol. 194:83-96.

Baird, R.W., and M.B. Hanson. 1998. A preliminary analysis of the diving behavior of Dall's porpoise in the transboundary waters of British Columbia and Washington (this volume). Pp. 94-105, in P.S. Hill, B. Jones, and D.P. DeMaster (eds.), Marine Mammal Protection Act and Endangered Species Act implementation program 1997. AFSC Processed Rep. Available Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE, BIN C15700, Seattle WA 98115-0070.

Baird, R.W., and M.B. Hanson. 1996. Dall's porpoise diving behaviour and reactions to tagging attempts using a remotely-deployed suction-cup tag. Report prepared under Contract No: 43ABNF601492 to the National Marine Mammal Laboratory, National Marine Fisheries Service, Seattle, WA

Bowers, C.A., and R.S. Henderson. 1972. Project Deep OPS: Deep object recovery with pilot and killer whales. NUC TP 306. Undersea Surveillance and Oceans Sciences Dept. , Naval Undersea Center, San Diego, Calif. 86 p.

Croll, D.A., S.D. Osmek, and J.L. Bengtson. 1991. An effect of instrument attachment on foraging trip duration in chinstrap penguins. Condor 93:777-779.

Erickson, A.W. 1978. Population studies of killer whales (*Orcinus orca*) in the Pacific Northwest: A radio-marking and tracking study of killer whales. Natl. Tech. Inform. Serv. Rep. No. PB-285615. 34 p.

Evans, W. E. 1974. Radio-telemetric studies of two species of small cetaceans. Pp. 385-394, in W.E. Schevill (ed.), The whale problem: a status report. Harvard Univ. Press, Cambridge, Mass.

Feldkamp, S.D. 1985. Swimming and diving in the California sea lion, *Zalophus californianus.* Ph. D. Dissertation, University of California, San Diego. 176 p.

Geraci, J.R., and G.J.D. Smith. 1990. Cutaneous response to implants, tags, and marks in beluga whales, *Dephinapterus leucas*, and bottlenose dolphins, *Tursiops truncatus*. Pp. 81-95, in T.G. Smith, D.J. St. Aubin, and J.R, Geraci (eds.), Advances in research on the beluga whale, *Dephinapterus leucas*. Can. Bull. Fish. Aqat. Sci. 224.

Gray, J. 1936. Studies in animal locomotion: VI. The propulsive powers of the dolphin. J. Exp. Biol. 13(2):192-199.

Hanson, M.B., A.J. Westgate, and A. J. Read. 1998a. Evaluating small cetacean tags by measuring drag in a wind tunnel (this volume). Pp. 51-62, in P.S. Hill, B. Jones, and D.P. DeMaster (eds.), Marine Mammal Protection Act and Endangered Species Act implementation program 1997. AFSC Processed Rep. Available Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE, BIN C15700, Seattle WA 98115-0070.

Hanson, M.B., R.W. Baird, and R.L. DeLong. 1998b. Movements of tagged Dall's porpoise in Haro Strait, Washington (this volume). Pp. 111-120, in P.S. Hill, B. Jones, and D.P. DeMaster (eds.), Marine Mammal Protection Act and Endangered Species Act implementation program 1997. AFSC Processed Rep. Available Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE, BIN C15700, Seattle WA 98115-0070.

Hertel, H. 1966. Structure, form, movement. Reinhold Publishing, NY.

Hoerner, S.F. 1965. Fluid dynamic drag. Published by the author. Bricktown, New Jersey, v.p.

Irvine, A.B., R.S. Wells and M.D. Scott. 1982. An evaluation of techniques for tagging small odontocete cetaceans. Fish. Bull., U.S. 80:135-143.

Lang, T.G. 1966. Hydrodynamic analysis of dorsal fin profiles. Nature 209(5028):1110-1111.

Lang, T.G., and K. Pryor. 1966. Hydrodynamic performance of porpoises (*Stenella attenuata*). Science 152 (3721):531-533.

Levy, S.W. 1962. Skin problems of the leg amputee. Arch. Derm. 85:65-81

Martin, H., W.E. Evans, and C.A. Bowers. 1971. Methods of radio tracking marine mammals in the open sea. Pp. 44-49, IEEE 1971 Conf. Eng. Ocean Environ.

Martin, A.R., and V. M. F. da Silva. 1998. Tracking aquatic vertebrates in dense tropical rainforest using VHF telemetry. Mar. Tech. Soc. J. 32(1):82-88.

Mate, B.R., K.A. Rossbach, S.A. Nieukirk, R.S. Wells, A.B. Irvine, M.D. Scott, and A.J. Read. 1995. Satellite-monitored movements and dive behavior of a bottlenose dolphin (*Tursiops truncatus*) in Tampa Bay, Florida. Mar. Mammal Sci. 11(4):452-463.

Nachtigall, W. 1981. Hydromechanics and biology. Biophys. Struct. Mech. 8:1-22.

Norris, K.S., and K.W. Pryor. 1970. A tagging method for small cetaceans. J. Mammal. 51(3):609-610.

Orr, J., D.J. St. Aubin, P.R. Richard, and M.P. Heide-Jørgeson. 1998. Recapture of belugas, *Delphinapterus leucas*, tagged in the Canadian arctic. Mar. Mammal Sci. 14(4):829-834.

Read, A. J., and A.J. Westgate. 1997. Monitoring the movements of harbour porpoises *(Phocoena phocoena)* with satellite telemetry. Mar. Biol. 130:315-322.

Rommel, S.A., D.A. Pabst, W.A. McLellan., J.G. Mead, and C.H. Potter. 1992. Anatomical evidence for a counter current heat exchanger associated with dolphin testes. The Anatomical Record 232:150-156.

Rommel, S.A., D.A. Pabst, and W.A. McLellan. 1993. Functional morphology of the vascular plexus associated with the cetacean uterus. The Anatomical Record 237:538-546.

Scott, M.D., R.S. Wells, A.B. Irvine, and B.R. Mate. 1990. Tagging and marking studies on small cetaceans. Pp. 489-514, in S. Leatherwood and R.R Reeves (eds.), The Bottlenose Dolphin, Academic Press, San Diego.

Vogel, S. 1994. Life in moving fluids: the physical biology of flow. Willard Grant, Boston.

von Mises, R. 1945. Theory of flight. Dover Publications, New York.

von Recum, A.F., and J.B. Park. 1981. Permanent percutaneous devices. Crit. Rev. Bioeng. 5(1):37-77.

Walker, B.G., and P.L. Boveng. 1995. Effects of time-depth recorders on maternal foraging and attendance behavior of Antarctic fur seals (*Arctocephalus gazella*) Can. J. Zool. 73:1538-1544.

Westgate, A. J., and A. J. Read. 1998. Applications of new technology to the conservation of porpoises. Mar. Tech. Soc. J. 32(1):70-81.

Würsig, B. 1982. Radio tracking dusky porpoises (*Lagenorhynchus obscurus*) in the South Atlantic. Pp. 145-160, in Mammals in the seas, Vol. 4, FAO Fish. Ser. No. 5.

Table 1. Clax (clay-wax) mock-up tag designs tested on a full-size model of a harbor porpoise in the University of Washington's Kirsten wind tunnel.

	Number of transmitters/type	location of transmitters	location/orientation of batteries	saddle configuration	Percent increase in drag
1A	1 VHF/ 2/3A battery	trailing edge	trailing edge/vertical	posterior wraparound /blunt trailing edge	5%
1B	1 VHF 2/3A battery	trailing edge	trailing edge/vertical	posterior wraparound/tapered trailing edge	1%
2	1 VHF AA battery	trailing edge	trailing edge/vertical	posterior wraparound/tapered trailing edge	4%
3A	1 PTT*	side	trailing edge/vertical	posterior wraparound/tapered trailing edge	3%
3B	1 PTT*, 1VHF 2/3 A	leading edge, side	leading edge/vertical, trailing edge/vertical	anterior/posterior wraparound/tapered trailing edge	4%
4	1VHF, 2/3A battery	leading edge	leading edge/vertical	leading edge/vertical	3%
5	1 PTT*	leading edge	leading edge/vertical	leading edge/vertical	17%
6	1 PTT*, 1 VHF AA battery	side, side	side/vertical, side/horizontal	posterior wraparound/tapered trailing edge	5%

*flat board ST10, rectangular

Table 2. Percent increase in drag for a pair of tags deployed on Dall's porpoise as tested on a wind tunnel-mounted harbor porpoise model.

	dynamic pressure (q)	2	4	5	6	8	10	25	40
	simulated swim velocity (mph)	2.3	3.2	3.6	4.0	4.6	5.1	8.1	10.2
Run									
1		12%	15%	17%	26%	27%	26%	27%	25%
2		15%	17%	14%	25%	27%	27%	26%	26%

EVALUATING SMALL CETACEAN TAGS BY MEASURING DRAG IN A WIND TUNNEL

M. Bradley Hanson[1], Andrew J. Westgate[2], and Andrew J. Read[2]

[1] National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington 98115

[2] Duke University Marine Laboratory
135 Duke Marine Lab Rd.
Beaufort, North Carolina 28516

Abstract

The attachment of satellite-linked transmitters is an important technique for obtaining information on the movements and diving behavior of small cetaceans. Drag caused by these telemetry and data-logger packages may influence the longevity of attachment and possibly induce changes in the behavior of tagged animals. To quantify the drag caused by these tags, a life-sized fiberglass model of a harbor porpoise was mounted in a wind tunnel and fitted with three tag designs that had previously been deployed on wild porpoises. The percent increase in drag caused by these tags ranged from approximately 18% to 32% at simulated swim speeds of 2.3 mph and this increased to 29% to 68% at simulated swim speeds of 10 mph. The tag design that added the least drag overall also apparently exhibited the longest attachment durations on wild porpoises (33 to 212 days). Although drag likely plays a role in attachment longevity, the influence of other factors may confound determining its true effect. Additional research is required to more thoroughly evaluate the factors influencing attachment duration as well as to investigate the energetic costs of this increase in drag to tagged dolphins and porpoises.

Introduction

Movements of individual animals can provide important information on population stock structure and its habitat use. Interchange between suspected population subunits can be investigated directly by monitoring seasonal movements of animals instrumented with telemetry devices. Additionally, this technique can provide valuable information on local movements and distribution relative to potential sources of anthropogenic take. Numerous species of small cetaceans have been tagged with a variety of telemetry devices and attachment schemes over the last 25 years (see Scott et al. 1990). In most studies, tags were surgically attached to the dorsal fin or dorsal ridge because this procedure was generally thought to have less impact on the skin and behavior of animals than if harnesses were used for longer term attachments (see Leatherwood and Evans 1979). Tags have been secured with one or more plastic or metal pins which were considered to be biocompatible. Applications are typically made by surgically punching or drilling holes (the same diameter as the pins) through the fin or ridge tissue. The pins, which are usually threaded at both ends, are inserted in the fin and the tag is then positioned on the fin and secured with nuts made of a corrodible material. This allows the tag to be shed after the batteries have been exhausted. Because seasonal movements are important in determining population subunit interchange, attachment durations on the order of months are necessary. However, until recently (see Westgate and Read 1998), movement data have typically been collected for only shorter time periods because signals were received from the tags for only a few weeks before being lost (see Scott et al. 1990). While most tagging studies did not (or could not) undertake systematic follow-up monitoring to determine causes of signal loss, those which have been documented or suspected include animals moving out of VHF monitoring range (Read and Gaskin 1985, Erickson and Hanson in prep.), transmitter failure (Hanson et al. 1998, this volume), or tag loss. This loss could be due to structural failure of the tag's saddle (Irvine et al. 1979, Read and Westgate 1997) or attachment pins (Read and Westgate 1997), or development of tissue necrosis, which in extreme cases has lead to severe tissue damage and pin out-migration (Irvine et al. 1982, B. Hanson, NMML, unpubl. data).

While signal loss due to an animal's movements, or transmitter failure, can be relatively straightforward to assess, understanding the factors associated with attachment failures is likely more complicated and has received little consideration. As a prerequisite to evaluating attachment failures, the factors likely to be acting on these animals and any devices attached to them need to be identified. Small cetaceans have extremely hydrodynamically efficient body forms (Bannasch 1995, 1996), exceeding that of most man-made shapes (Nachtigall 1981). Consequently, even the best designed telemetry tags might be expected to add a substantial amount of drag to these animals while the animal is swimming underwater. This drag is a load which is transferred to the saddle, the pins, and ultimately the adjacent tissue. The nearly continuous loading of the tissue can cause pressure necrosis, which will result in a cycle of tissue breakdown leading to pin out-migration. Because the amount of drag a tag (or any object) creates is a function of its shape (Vogel 1994) and velocity, the rate of pin out-migration (and thus attachment duration) might be related to the amount of drag the tag adds. Consequently, quantifying the additional drag of previously deployed tags may help explain the differences that have been observed in attachment durations. While tag hydrodynamics have been noted by some as a design consideration (Martin et al. 1971, Evans 1974, Würsig 1982, Scott et al. 1990, Mate et al. 1995), none of the tags previously deployed on small cetaceans have been subjected to an assessment of their drag characteristics. In addition to the potential relationship of drag and pressure necrosis, there have been cases where the additional drag has been substantial enough to affect the animals' normal behavior (Irvine et al. 1979, Würsig 1982), which could have an adverse impact on the well-being of the animal, as well as making the data non-representative.

Wind tunnels are routinely used to assess the drag characteristics of a variety of objects (Rae and Pope 1984) and can be qualitative (flow visualization) or quantitative (drag loads). Determination of the additional burdens of telemetry packages has previously been conducted for flying birds and penguins using this technique (Obrecht et al. 1988, Culik et al. 1994). In this study, the proportional increase in drag for three tag designs previously deployed on wild harbor porpoises (*Phocoena phocoena*) was measured on a model porpoise in a wind tunnel.

Methods

Drag forces for three different tag designs were measured by attaching them to a full-size fiberglass model of a harbor porpoise mounted in a wind tunnel. The porpoise model was constructed from a mold that was taken off an adult male that had been killed incidental to commercial fishing operations and subsequently frozen in the glide position by hanging it by its tail. This model was configured to mount on the drag balance strut of the University of Washington's (UW) Kirsten Wind Tunnel, a subsonic, closed-circuit, double-return tunnel with a test section 8 ft high, 12 ft wide and 10 ft long.

Three different tags which had all been previously deployed on harbor porpoises were tested (Table 1). Tag 1 is referred to as the dual-side mount because it consisted of two transmitters, each attached with two hose clamps to a thermoplastic saddle, lined with 0.125 in neoprene foam that wrapped around each side of the dorsal fin. On the left side was a cylindrical configuration of a Telonics ST 10 Platform Terminal satellite Transmitter (PTT)(1.0 in diameter, 4.6 in long), with a 7.5 in long rigid stainless steel wire antenna (0.046 in diameter) exiting the tag at 45 degrees from the back of the transmitter. On the right side was an ATS model 201 VHF transmitter with 2 AA batteries (0.75 in diameter, 5.75 in long) arranged in line with a 0. 0625 in diameter, 13.5 in long, rigid stainless steel wire antenna, also exiting from the posterior end of the transmitter. The pack was attached with three 0.1875 in diameter Delrin pins. This design was deployed on one animal off the Washington coast in 1995 and signals were received for 20 days from both transmitters (Osmek et al. in prep). Tag 2 is described as the single front-mount. It consists of the same cylindrical ST10 (except for a 0.084 in diameter flexible braided wire antenna) which in the first two deployments was secured with plastic tie wraps (subsequent versions used three hose clamps) to a thermoplastic saddle that fit around the leading edge of the dorsal fin. It was attached with three 0.31 in high density polyethylene or Delrin pins. It was deployed on five animals in the Bay of Fundy in 1994 and 1995 with signals received for 2-21 days (Westgate and Read 1998). The tag used in these tests was a mock-up of the original tag and lacked an antenna which was determined to add negligible drag. Tag 3 is described as a single side-mount and is a rectangular configuration of the ST10 (0.84 in high, 3.6 in long, 1.9 in wide). The Lexan transmitter housing was epoxied to a flat plastic saddle that was fit on the right side of the dorsal fin and fastened with three 0.25 in Delrin pins. The same flexible antenna was mounted vertically at the front of the transmitter. This design was deployed on 9 animals in the Bay of Fundy in 1995 and 1997 and yielded signals for 33 to 212 days (Westgate and Read 1998).

Testing protocol included a baseline test of the model only at the beginning of the testing session and a subsequent test, either in the middle or near the end of the testing session. After preliminary runs with dynamic pressures (q - a function of velocity and air density) of 10, 20, 30, 40, 50 and 60 q (speeds of 62, 88, 108, 125, 140, 153 mph in air and 5.0, 7.1, 8.7, 10.1, 11.2, 12.3 mph in water), 40 q was selected for early comparisons because this is commonly used in many other wind tunnel tests. In subsequent testing, qs of 2, 4, 5, 6, 8, 10, 25, and 40 (2.3, 3.2, 3.6, 4.0, 4.6, 5.1, 8.1, and 10.2 mph in water) were used in order to better evaluate drag levels at speeds which are more typically attained by free-ranging harbor porpoises (B. Hanson, NMML, unpubl. data). However, at dynamic pressures as low as 2 q detection of differences between tags was likely limited by the accuracy of the drag balance, as this may have accounted for approximately 30% of the observed variability for the lowest drag tag. Conversely, at 40 q the relative contribution of the drag balance accuracy was likely to account for only about 3% of the variability. During early tests, pitch was varied from -10.0° to +10.0° in 2° increments, and yaw was varied from 0° to +10.0° in 2° increments. Drag values were typically lowest at 6° pitch and 0° yaw. Thus, yaw was maintained at 0° for all further tests and the range of pitch angles tested was reduced to +4.0° to +8.0° degrees with 0.5° steps. All comparisons in the data analyses were made at 6° pitch and 0° degrees yaw.

The degree to which each tag's drag could be reduced was undertaken by applying "clax" (a mixture of clay and wax) to streamline the package on the porpoise model and running the tunnel at 40 q.

In order to evaluate the relative drag contribution of each of the components of the tags (saddle, transmitter, antenna), test runs were made with the saddle only, saddle and transmitter without antenna, and the saddle and transmitter with antenna. All test were conducted at 40 q with pitch angles -10.0° to +10.0° and all comparisons were made at 6° pitch and 0° yaw.

Results

The proportional increase in drag that the tags added to the porpoise model all generally increased with velocity (Table 2, Fig. 1). Tag 3 was an exception to this pattern. It reached a plateau at a simulated swim speed of 5.1 mph before decreasing slightly. A consistent feature of this increasing trend was the abrupt and substantial increase that occurred between 3 and 4 mph. At the slowest simulated swim speed (2.3 mph), both Tag 2 and Tag 3 added an average of approximately 18% (n = 3, SD = 2.0 and 2.0, respectively) more drag while the dual side mount (Tag 1) added about 32% (n = 3, SD = 5.0). At about 10 mph simulated swim speed, the additional drag of the single side-mount had increased to an average of about 29% (n = 5, SD = 2.0), while the front mount had increased to about 37% (n = 5, SD = 3.0), and dual side-mount had increased to 68% (n = 5, SD = 4.0).

The percent increase in drag was reduced for all tags by streamlining using clax (at 40 q; Tag 1 = 41%, Tag 2 = 19%, Tag = 21%). The most substantial reduction was for Tag 2, for which the drag was nearly halved.

The relative contribution of tag components to the total drag varied substantially between all three tags (Fig. 2). Whereas Tag 1's transmitters had the greatest drag of the three components, the saddles contributed the largest amount of drag for Tags 2 and 3.

Discussion

This is the first study to investigate the drag which telemetry tags add to the very hydrodynamically efficient bodies of small cetaceans. The drag which Tags 1 and 2 contributed to the model increased with increasing velocity (Fig. 1), similar to studies on penguin models in a wind tunnel (Bannasch et al. 1994). Although Tag 3's drag increased initially, the decreasing trend observed from mid- to high velocities is similar to a prototype design tested on a harbor porpoise model in a water tunnel (Bannasch 1996). It is suspected that this decrease in drag is associated with the boundary layer turning turbulent (Anderson 1991).

The lower drag at higher velocities and consistently longer periods of signal production for the single side-mount tag (33 to 212 day for Tag 3 vs. ~21 days for Tags 1 and 2; Westgate and Read 1998, Osmek et al. in prep.) suggests that lower drag might be related to longer tag attachment durations. However, Tags 2 and 3 appeared to have very similar drag values at simulated velocities close to typical swimming speeds, yet had substantially different signal durations, suggesting that either drag differences existed but were not detected, or that other factors may be affecting tag attachment duration. First, it is important to note that the accuracy of the drag balance used in the current study is approximately 0.013 lbs. The added drag at 2 q for Tag 2 or 3 is approximately 0.04 lbs, such that the limitations associated with the accuracy of the drag balance may represent about 30% of the observed variation at this dynamic pressure. Consequently, it is possible that differences in drag could exist but are undetectable. Testing of these tags in a smaller wind tunnel with a more sensitive drag balance will be important in enumerating drag differences at more typical swim speeds. An additional step in validating these wind tunnel tests will be to conduct deceleration glide studies on live animals (see Williams 1987) with these tags temporarily attached.

It is also important to note that despite the generally longer signal periods for Tag 3, considerable variability existed, suggesting that other factors may be important. Reasons for signal loss fall into three primary categories: 1) the animal moved out of range, 2) the transmitter failed, or 3) tag loss. Movements out of range is only an issue for VHF transmitters, and transmitter failure would be expected to occur shortly after deployment (premature battery failure is likely rare). Tag loss, however, can be caused by exceeding the material properties of the attachment system for the transmitter, the tag saddle, attachment pins, or by pressure necrosis leading to pin out-migration. In two deployments of the front mount type (Tag 2), short attachment durations were documented due to the material properties of the attachment systems being exceeded (Read and Westgate 1997). In one case, the high density polyethelene (HDPE) pins (which are thought to have a lower shear strength than Delrin) were known to have failed. In another case, the plastic tie wraps that attached the instrument to the saddle were suspected to have been broken. It is currently unclear if the drag generated under normal swimming conditions would have resulted in sufficient force to cause the attachments of the front mount to shear. It is possible that sufficient force could be generated by rubbing the tag on some other object. Although this behavior has not been previously reported for harbor porpoises, a tagged harbor porpoise in Washington State was recently known to have lost the rigid antenna from its VHF tag, mostly likely due to rubbing (B. Hanson, NMML, unpubl. data), which indicates that this species is capable of generating considerable force on a tag. Some of the tag losses observed in bottlenose dolphins are suspected to have been due to rubbing, most likely on the bottom (Irvine et al. 1982). Two factors may have made the front mount more susceptible to this type of loss; 1) its position on the leading edge of the fin may have made it more vulnerable to rubbing, and 2) the use of Delrin pins, while likely less susceptible to shearing than HDPE, would be more likely to break than the higher shear strength titanium pins used on the Washington porpoise. In the case of the other front mount deployments, it is not possible to determine whether they detached due to pin shear or if the pins out-migrated. Irvine et al. (1982) noted that in 22 days a bolt had migrated 1.5 cm posteriorly in the dorsal fin of a bottlenose dolphin. The mounting pins on the front mount (Tag 2) were approximately 2.5 cm from the leading edge. Based on observations of killer whales instrumented with front mount tags, the pin out-migration path would be out the leading edge of the fin (B. Hanson, NMML, unpubl. data). Although the pin out-migration rate is unknown for this front mount, this tag loss scenario remains possible. In the case of the dual side mount (Tag 1), because the signals from both transmitters were lost simultaneously after three weeks, the source of failure cannot be determined. However, the tag design and three-point pin arrangement suggest that out-migration is unlikely in that time frame. Because the tag wrapped around the front of the fin and the pin diameters were the smallest of any of the tags, shearing seems to be the more likely reason for tag loss.

The signal durations, and consequently the inferred attachment durations, of the side-mount tag are of particular note because these were substantially longer than those observed by most other researchers (see Scott et al. 1990). Unfortunately, no drag data exist for these other tags, but their generally larger size (i.e., greater cross-sectional frontal area) would be expected to generate more drag (Vogel 1994) which could have accelerated pressure necrosis, which has been documented to cause pin out-migration (Irvine et al. 1982). Taken together, these results suggest the lower drag tags have the potential to yield longer attachment durations, but other factors such as tag position or pin materials may play a more immediate role. These results also point to the need for an analyses of the forces required to cause failure of tag and saddle materials, as well as additional deployments of lower drag tags coupled with an intensive resighting effort.

The analysis of the relative drag contribution by the different tag components is confounded by the fact that the total drag of the main object and second object is greater than the drag of the two objects tested separately (von Mises 1945). Despite this limitation, an examination of these general trends may still be useful in identifying major sources of drag. An object's drag is related to the object's size and shape, as well as the speed at which it is moving, and viscosity and density of the medium (Vogel 1994). Consequently, non-streamlined tags with greater cross-sectional frontal areas would be expected to produce more drag. While the areas associated with these tags have yet to be quantified, relative areas can be compared. Because the transmitters most likely have the greatest cross-sectional frontal area of all the tag components, they would be expected to contribute a substantial amount of the overall drag. This is apparent in comparing Tag 1 with Tags 2 and 3 and is likely due to the presence of two transmitters such that halving the value (22%) would make it more comparable. However, this value is still somewhat higher than the drag of the transmitter for Tag 2, which likely had more cross-sectional frontal area due its angled position on the front of the fin, although it is important to note that Tag 2's position in front of the fin likely does not increase the overall total area. Even when the single transmitter value for Tag 1 (22%) is used for comparison with Tag 3, it still had substantially more drag despite its cross-sectional frontal area being only slightly greater than Tag 1's satellite transmitter. The reasons for this discrepancy are unclear but may be related to the difference in the shape of the tags. Of particular note was that the saddles of Tags 2 and 3 were the predominant drag component for these tags. Tag 2's saddle had the highest drag value, which was not unexpected given that it likely had more cross-sectional frontal area than the saddles of the other two designs. However, the large contribution by Tag 3's saddle was surprising given that it likely has less cross-sectional frontal area than Tags 1 or 2. It is possible that these relatively large contributions are due to interference drag in the boundary layer because bodies with low height to length ratios will be expected to produce higher drag than expected (Hoerner 1965). This suggests that more attention should be paid to the design of the junction between the tag and the fin. The highest value for antennas was associated with Tag 1, due to the presence of two antennas. However, even when divided in half (7%) this value is still greater than the antenna for Tags 2 and 3 and is probably a result of Tag 1's VHF transmitter, which has a much longer antenna than the satellite transmitter. The relatively low amount of drag from the antenna of Tag 2 is most likely because it was oriented almost parallel to flow.

Consideration should be given to how much of a burden the additional drag created by these tags represents to an animal the size of a harbor porpoise, and what effects this might have on the tagged animal. Although swimming motion increases total drag such that the tag's relative contribution is likely lessened, these animals experience extremely low drag (Vogel 1994). Impacts of tags may be manifested as relatively obvious changes in behavior, such as the unusual surfacing observed in bottlenose dolphins (Irvine et al. 1982), or the longer foraging trips in penguins and seals (Croll et al. 1991, Walker and Boveng 1995), or more subtle changes such as slower swim speeds in penguins (Bannasch et al. 1994). Although quantifying the drag for a swimming porpoise is not possible because the same body parts produce thrust and drag, which cannot be separated (Vogel 1994), it may be possible to determine the energetic burden these tags impose, and may ultimately be the most important measure to the animal. While no empirical data are currently available for the energetic costs associated with carrying these or other tags by harbor porpoises, greater energy output has been documented in tagged penguins (Bannasch et al. 1994). In that study, a tag that added 15-25% more drag at typical swim speeds on a wingless wind tunnel model was determined to increase the mean energy expenditure by 5.6% for a live bird. The extent to which harbor porpoises can "afford" to carry tags is unknown but it has been noted that energy reserves may be marginal, particularly for reproductive age females (Yasui 1980). The only reliable approach is to quantify additional energetic demands by direct metabolic evaluation on this species. Such a study will be an important next step in assessing the impact of these or other tag designs.

Acknowledgments

Steve Osmek provided a tremendous amount of effort in the tag design, capture, and tag deployment on the harbor porpoise off the Washington coast in 1995. Dr. Bob Breidenthal and student test engineers Brad Pratt and Seung Chung, of the University of Washington's Department of Aeronautics and Astronautics, provided considerable assistance and advice. Testing would not have been possible without the enthusiastic cooperation of the staff of the Kirsten Wind Tunnel. Roberta Scholz skillfully translated Bannasch 1996. Robin Baird provided many useful comments.

Citations

Anderson, J.D. 1991. Fundamentals of Aerodynamics. McGraw Hill, New York.

Bannasch, R. 1995. Hydrodynamics of penguins - an experimental approach. Pp. 141-176, in P. Dann, I. Norman, and P. Reilly (eds.), The Penguin. Surrey Beatty and Sons, Berlin.

Bannasch, R. 1996. Zur strömungsdynamischen Formoptimierung von Telemetriegeräten für Schweinswale (*Phocoena phocoena*). Meer and Museum 12:11-16.

Bannasch, R., R.P. Wilson, and B. Culik. 1994. Hydrodynamic aspects of design and attachment of a back-mounted device in penguins. J. Exp. Biol. 194:83-96.

Croll, D.A., S.D. Osmek, and J.L. Bengtson. 1991. An effect of instrument attachment on foraging trip duration in chinstrap penguins. Condor 93: 777-779.

Culik, B.M., R. Bannasch, and R. Wilson. 1994. External devices on penguins: how important is shape? Mar. Biol.(Berl.) 118:1851-1855.

Erickson, A.W., and M. B. Hanson. In prep. A radio-telemetry package attachment technique for killer whales.

Evans, W.E. 1974. Radio-telemetric studies of two species of small cetaceans. Pp. 385-394, in W.E. Schevill (ed.), The whale problem: A status report. Harvard Univ. Press, Cambridge, MA.

Hanson, M.B., R.W. Baird, and R.L. DeLong. 1998. Movements of tagged Dall's porpoise in Haro Strait, Washington (this volume). Pp. 111-120, in P.S. Hill, B. Jones, and D.P. DeMaster (eds.), Marine Mammal Protection Act and Endangered Species Act implementation program 1997. AFSC Processed Rep. Available Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE, BIN C15700, Seattle WA 98115-0070.

Hoerner, S.F. 1965. Fluid Dynamic drag. Published by the author. Bricktown, New Jersey, v.p.

Irvine, A.B., M.D. Scott, R.S. Wells, J.H. Kaufman, and W.E. Evans. 1979. A study of the activities and movements of the Atlantic bottlenosed dolphin, *Tursiops truncatus*, including an evaluation of tagging techniques. Marine Mammal Commission Rept. No. MMC-75/14. Available from NTIS, Springfield, VA, as PB-298-042.

Irvine, A.B., R.S. Wells, and M.D. Scott. 1982. An evaluation of techniques for tagging small odontocete cetaceans. Fish. Bull., U.S. 80:135-143

Leatherwood, S., and W.E. Evans. 1979. Some recent uses and potentials of radio-telemetry in field studies of cetaceans. Pp. 1-31, in H. E. Winn and B. L. Olla (eds.), Behavior of marine animals, Vol. 3. Plenum Press.

Martin, H., W.E. Evans, and C.A. Bowers. 1971. Methods of radio tracking marine mammals in the open sea. Pp. 44-49, IEEE 1971 Conf. Eng. Ocean Environ.

Mate, B.R., K.A. Rossbach, S.A. Nieukirk, R.S. Wells, A. B. Irvine, M.D. Scott, and A.J. Read. 1995. Satellite-monitored movements and dive behavior of a bottlenose dolphin *(Tursiops truncatus*) in Tampa Bay, Florida. Mar. Mammal Sci. 11(4):452-463.

Nachtigall, W. 1981. Hydromechanics and biology. Biophys. Struct. Mech. 8:1-22.

Obrecht III, H.H., C.J. Pennycuick, and M.R. Fuller. 1988. Wind tunnel experiments to assess the effect of back-mounted radio transmitters on bird body drag. J. Exp. Biol. 135:265-273.

Osmek, S.D., M.B. Hanson, and R.L. DeLong. In prep. First directed live-capture and movements of a harbor porpoise from the northeast Pacific Ocean.

Rae, Jr., W.H., and A. Pope. 1984. Low-speed wind tunnel testing. John Wiley and Sons, New York.

Read, A.J., and D.E. Gaskin. 1985. Radio tracking the movements and activities of harbor porpoises, *Phocoena phocoena* (L.), in the Bay of Fundy, Canada. Fish. Bull., U.S. 83(4):543-552.

Read, A.J., and A.J. Westgate. 1997. Monitoring the movements of harbour porpoises (*Phocoena phocoena*) with satellite telemetry. Mar. Biol. 130:315-322.

Scott, M.D., R.S. Wells, A.B. Irvine, and B.R. Mate. 1990. Tagging and marking studies on small cetaceans. Pp. 489-514, in S. Leatherwood and R.R. Reeves (eds.), The Bottlenose Dolphin. Academic Press, San Diego.

Vogel, S. 1994. Life in moving fluids: the physical biology of flow. Willard Grant, Boston.

von Mises, R. 1945. Theory of flight. Dover Publications, New York.

Walker, B.G., and P.L. Boveng. 1995. Effects of time-depth recorders on maternal foraging and attendance behavior of Antarctic fur seals (*Arctocephalus gazella*). Can. J. Zool. 73:1538-1544.

Westgate, A.J., and A.J. Read. 1998. Applications of new technology to the conservation of porpoises. Mar. Tech. Soc. J. 32(1):70-81.

Willams, T. M. 1987. Approaches for the study of exercise physiology and hydrodynamics in marine mammals. Pp. 127-145, in Approaches to marine mammal energetics, A.C. Huntley, D.P. Costa, G.A.J. Worthy and M.A. Castellini (eds.), Spec. Pubs. Soc. Mar. Mamm. No 1. Allen Press, Kansas.

Wursig, B. 1982. Radio tracking dusky porpoises in the south Atlantic. Pp. 145-160, in Mammals in the seas, Vol 4. FAO Fish Ser. No. 5.

Yasui, W.Y. 1980. Morphometrics, hydrodynamics and energetics of locomotion for a small cetacean, *Phocoena phocoena* (L.). Master's thesis, Univ. of Guelph. 86 p.

Table 1. Transmitter designs tested on a full-size model of a harbor porpoise in the University of Washington's Kirsten wind tunnel.

	Number of transmitters/type	Transmitter configuration	Transmitter location	Saddle style
Tag 1	2 (PTT, VHF)	both cylindrical	sides of dorsal fin	anterior wraparound
Tag 2	1 (PTT)	cylindrical	leading edge of fin	anterior wraparound
Tag 3	1 (PTT)	rectangular	side of fin	flat plate

Table 2. Percent increase in drag for three tag designs previously deployed on harbor porpoises as tested on a wind tunnel model.

	dynamic pressure (q)	2	4	5	6	8	10	25	40
	simulated swim velocity (mph)	2.3	3.2	3.6	4.0	4.6	5.1	8.1	10.2
Tag									
T1	n	3	2	2	2	2	2	2	6
	Mean	32	35	41	55	60	64	69	68
	SD	5	2	0	0	1	3	1	4
T2*	n	3	2	2	2	2	2	2	5
	Mean	18	20	21	31	34	36	38	37
	SD	2	1	2	1	1	1	1	1
T3	n	3	2	2	2	2	2	2	6
	Mean	18	20	22	31	32	33	31	29
	SD	2	1	2	0	0	1	1	2

* without antenna

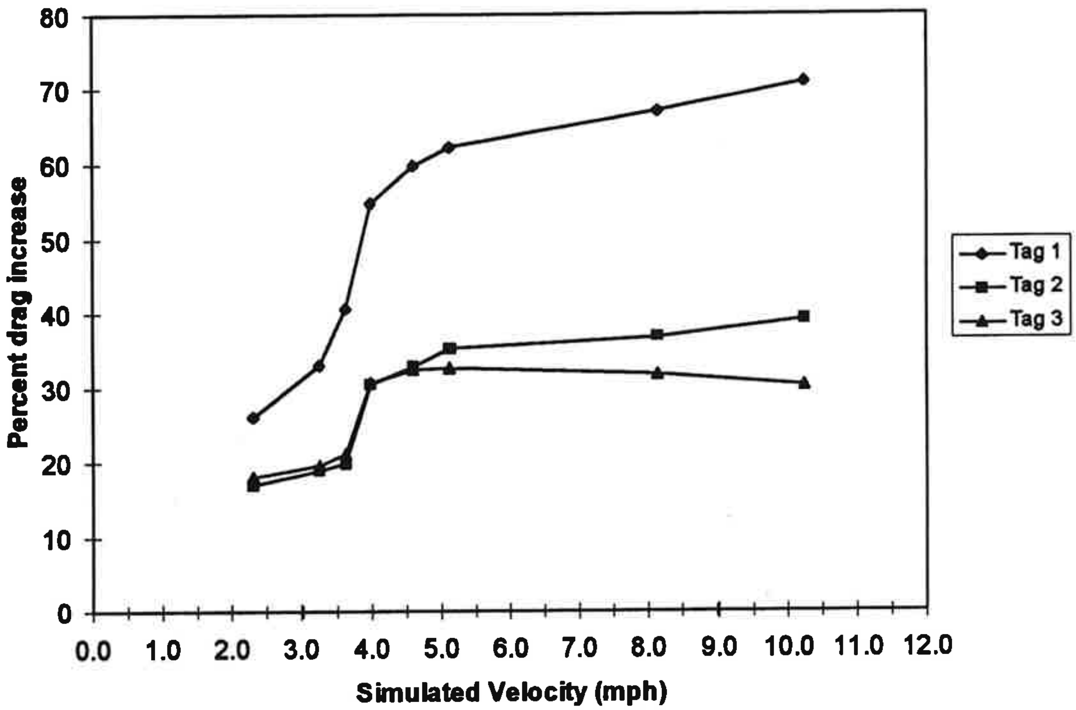

Figure 1. Percent drag increase caused by different telemetry tag designs on a harbor porpoise model in the University of Washington's Kirsten wind tunnel.

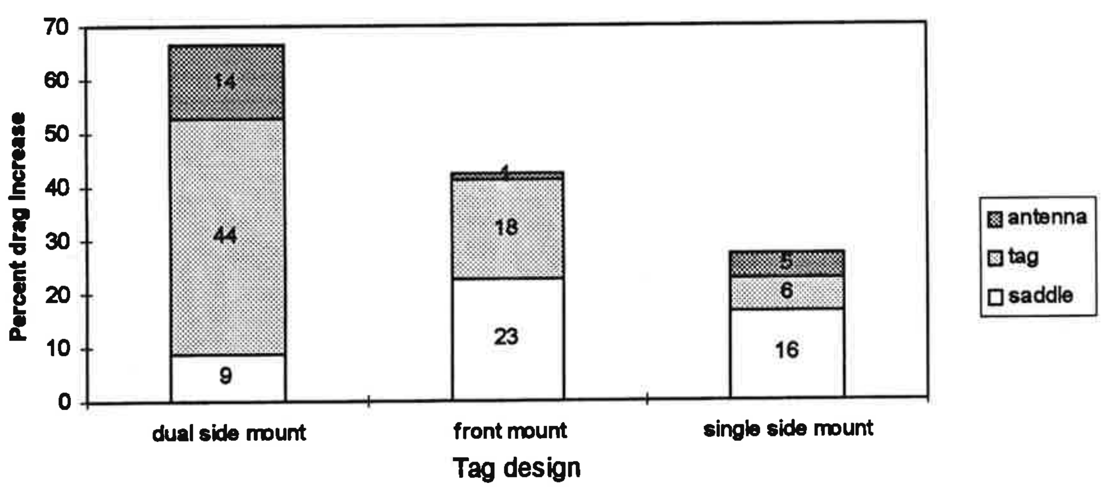

Figure 2. Percent drag increase caused by different components of telemetry tags on a harbor porpoise model in the University of Washington's Kirsten wind tunnel.

FOOD HABITS OF THE HARBOR PORPOISE, *PHOCOENA PHOCOENA*, AND DALL'S PORPOISE, *PHOCOENOIDES DALLI*, IN THE INLAND WATERS OF BRITISH COLUMBIA AND WASHINGTON

William A. Walker[1], M. Bradley Hanson[1], Robin W. Baird[2], and Tamara J. Guenther[3]

[1] National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington 98115

[2] Department of Biology
Dalhousie University
Halifax, Nova Scotia
Canada, B3H 4J1

[3] Marine Mammal Research Group
Box 6244, Victoria, British Columbia
Canada, V8P 5L5

Abstract

Stomach contents were analyzed from 22 Dall's porpoise, *Phocoenoides dalli*, and 26 harbor porpoise, *Phocoena phocoena*, collected primarily from single strandings in the inland waters of British Columbia and Washington during the 1990-97 period. Eighteen species of fish and four species of cephalopods were identified from both samples. In the Dall's porpoise sample, fishes comprising nine families were predominant and made up 99.0% of the total number of prey with an occurrence of 95.5%. Two families of cephalopods made up only 0.6% of the total with an occurrence of 13.6%. In the harbor porpoise sample, fishes comprising ten families made up 52.2% of the total number of prey with an occurrence of 88.5%. Three families of cephalopods made up 46.5% of the prey with an occurrence of 15.4%. Juvenile blackbelly eelpout, *Lycodopsis pacifica*, ranging in size from 80-110 mm were the dominant prey by number in both the Dall's (92.2%) and harbor porpoise (49%) samples. Six other prey species, including Pacific herring, *Clupea harengus pallasi*; eulachon, *Thaleichthys pacificus*; walleye pollock, *Theragra chalcogramma*; Pacific hake, *Merluccius productus*; Pacific sandlance, *Ammodytes hexapterus*; and market squid, *Loligo opalescens*, were common to the diets of both species of porpoise. The presence of very large numbers of very small juvenile blackbelly eelpout in both samples has the effect of biasing the importance of other prey in the samples downward. Calculating the contribution by mass for seven prey common to both samples minimizes the exaggerated importance of the blackbelly eelpout and presents a more realistic picture on importance of the other major prey species represented. Using this technique for Dall's porpoise the contribution by total mass index of importance of blackbelly eelpout is 63.0% compared to the 96.6% by number. The contribution by mass for this prey species in the harbor porpoise is 18.8% compared to the 49.6% by number. Differences in the occurrence and numbers of blackbelly eelpout between the

two samples is probably due to temporal differences in the collection of the porpoise samples. Occurrence of juvenile blackbelly eelpout in the study area is seasonal. Juveniles in the 80-110 mm size range occur only in the spring months (March-May). Ninety-five percent of the Dall's and only 61.5% of the harbor porpoise were collected in the spring. In general, the food habits of both species of porpoises is very similar. They differ primarily in the presence of small numbers of lanternfish, family Myctophidae, which occur only in the Dall's porpoise samples. The presence of these mesopelagic species suggests that Dall's porpoise spend some of their time feeding at greater depths than the harbor porpoise.

Introduction

Food habits accounts of Dall's and harbor porpoise off the coast of North America have been largely confined to samples obtained from the outer coast (Cowan 1944, Scheffer and Slipp 1948, Scheffer 1953, Norris and Prescott 1961, Pike and McAskie 1969, Loeb 1972, Morejohn 1979, Jones 1981, Stroud et al. 1981, Gearin and Johnson 1990, Gearin et al. 1994). Little information on the feeding habits of these two species of porpoise is available from the inland nearshore environments of their distribution. Only two accounts of stomach contents of harbor porpoise from the inland waters exist in the literature. Pike and MacAskie (1969) reported on the stomach of one animal incidentally taken in a salmon gillnet in Baynes Sound off the east side of Vancouver Island as " containing only herring". Scheffer and Slipp (1948) reported on the stomach contents of a single animal netted at Samish Flats near Bellingham, Washington as containing "slender, non-armored fish" about 4.5 to 15 cm long. No stomach contents of Dall's porpoise from inland waters have been described in the literature.

This paper constitutes a preliminary report of an on-going study on the food habits of these two species of porpoise. Recently, additional stomach samples have become available but have yet to be examined and included in the database.

Methods

Stomach samples from 22 Dall's porpoise and 26 harbor porpoise were collected during 1990-97 by the Marine Mammal Research Group, Victoria, B.C., Canada, and The Whale Museum, San Juan Island, Washington (Table 1). Most of the samples were collected from stranded animals occurring on the southern tip and eastern side of Vancouver Island, Canada, and the general area around the San Juan Archipelago (Figs.1 and 2). All but five of the samples were obtained from singly stranded animals. The exceptions were four harbor porpoise taken incidentally in local salmon gillnets and one harbor porpoise retrieved from a killer whale attack.

Stomachs were removed intact in the field, tagged with a collection number and placed in frozen storage prior to preliminary sorting and specimen preservation. After removal of the contents the stomach lining was thoroughly rinsed with water in order to collect all otoliths, cephalopod beaks and other small prey items. Stomach contents were then stored in alcohol for later identification, enumeration and measurement. Otolith length and lower rostral length of cephalopod beaks were measured to the nearest 0.05 mm with either vernier calipers or an optical micrometer. Damaged or eroded specimens were not measured. Length measurements of these beaks and otoliths were used to estimate the body lengths and weight of fish and cephalopod prey where supplementary regression data was available.

In most instances, prey length and weight estimates were derived from regression equations presented in Frost and Lowry (1981), Harvey et al. (in press) and Wolff (1984). In those instances where regression data for commonly ingested prey were not available from the literature, prey length and weight estimates were derived from specimens and data available in the food habits reference collection of the National Marine Mammal Laboratory, Seattle, Washington, and the fish collection of the University of Washington, School of Fisheries, Seattle, Washington.

Contribution by mass of commonly ingested fish and cephalopod prey was calculated as: (No. of prey of each species x mean prey weight) ÷ (total mass of prey consumed by each species) × 100 (Recchia and Read 1989, Walker 1996).

There is a strong temporal bias in the seasonal time frame in which the samples were collected. Twenty-one (95.5%) of the Dall's porpoise stomach samples were collected during the spring months (March - May). Over half (61.5%) of the harbor porpoise samples were collected in the spring with the summer months (June - August) accounting for another 31% of the sample.

Results

Dall's Porpoise

All of the 22 stomachs examined contained prey remains. Thirteen species of fish and three species of cephalopods were identified in the sample (Table 2). Fishes comprising nine families were predominant and made up 99.0% of the total number of prey, with an overall occurrence of 95.5%. Two families of cephalopods made up 0.6% of the total number of prey ingested with an overall occurrence of 13.6%. One species of crustacean occurred in trace amounts in one animal and may have been incidentally ingested. Mandibles from the polychaete worm, *Nereis vexillosa*, were a common finding in the samples.

One species of fish was predominant in the sample. The blackbelly eelpout, *Lycodopsis pacifica*, represented 96.2% of the total prey in 81.8% of the stomachs examined. Five other species of fish demonstrated a frequency of occurrence greater than 10%. These were Pacific herring, *Clupea harengus pallasi*; eulachon, *Thaleichthys pacificus;* walleye pollock, *Theragra chalcogramma*; Pacific whiting, *Merluccius productus;* and Pacific sand lance, *Ammodytes hexapterus*. Collectively these five species represented 2.6% of the total prey consumed. Nine other species of fish were taken in small numbers and combined represented less than 0.5% of the total prey. Three species of cephalopods were represented in the sample. These were the market squid, *Loligo opalescens*, and two species of gonatids, *Gonatus berryi* and *G. pyros*. Collectively these three species made up only 0.6% of the total prey.

Composition of the sample by the total mass generally supports the numeric findings on relative prey importance of seven commonly ingested species (Table 3). This index of relative importance is useful in that it minimizes the effect of the upward bias of smaller more numerous prey. This is particularly evident with the large numbers of juvenile blackbelly eelpout for which the calculated total mass is 63% compared to the 96.2% by number.

Prey size estimates were available for seven of the commonly ingested species (Table 3). These data indicate that the porpoise ingested prey ranging in size from 69 mm (*Loligo opalescens*) to as large as 438 mm (*Merluccius productus*).

Harbor Porpoise

All of the 26 stomachs examined contained prey remains. Twelve species of fish and three species of cephalopods were identified in the sample (Table 2). Fishes comprising ten families made up 52.2% of the total number of prey with an overall occurrence of 88.5%. Three families of cephalopods made up slightly more than 46.5% of the prey ingested with an overall occurrence of 15.4%. One species of crustacean occurred in trace amounts. Mandibles from the polychaete worm, *Nereis vexillosa*, were a common finding.

Juveniles of the blackbelly eelpout, *Lycodopsis pacifica*, were also the dominant fish species in the sample and represented 49.6% of the total prey with a frequency of occurrence of 26.9%. Five other species of fish were commonly ingested. These were Pacific herring, *Clupea harengus pallasi*; walleye pollock, *Theragra chalcogramma*; Pacific hake, *Merluccius productus*; eulachon, *Thaleichthys pacificus*; and Pacific sanddab, *Citharichthys sordidus*. Collectively these five species represented 2.4% of the total number of prey. Three species of cephalopods were represented in the sample. The dominant cephalopod, *Loligo opalescens*, represented 46.5% of the total prey in 15.4% of the stomachs. The remaining two species, *Onychoteuthis borealijaponica* and *Gonatus berryi* were found in trace amounts.

Composition of the sample by the estimated total mass generally supports the numeric findings on relative prey importance of seven of the commonly ingested prey (Table 3). The exaggerated importance reflected by the large numbers of juvenile blackbelly eelpout (49.6%) in the sample is reduced in the total mass estimate to 18.8%.

Prey size estimates were available for eight of the commonly ingested species (Table 3). These data indicate that the harbor porpoise ingested prey ranging in size from 58 mm (*Loligo opalescens*) to 371 mm (*Merluccius productus*).

Discussion

The small stomach sample sizes and seasonal bias in the dates of collection of the two samples prevents any detailed statistical analyses of potential differences in the food habits of the Dall's and harbor porpoise at this time. General comparison of the primary prey of these two species of porpoises using the percent by number, frequency of occurrence and estimated total prey mass indices reveals similar food habits for both species of porpoises. However, the complete absence of the lanternfish family, Myctophidae, in the harbor porpoise sample and the greater number and occurrence of gonatid squid in the Dall's porpoise sample (Table 2) indicates that the Dall's porpoise are spending some time feeding deeper in the water column than the harbor porpoise. The size range of the gadid fishes, *Theragra chalcogramma* and *Merluccius productus*, indicated that Dall's porpoise are capable of ingesting larger prey.

Utilizing the contribution by mass index of importance of the blackbelly eelpout, *Lycodopsis pacifica*, presents a more realistic picture on the importance of this species in the diets of the Dall's and harbor porpoise. However, the large numbers and high frequency of occurrence of the blackbelly eelpout in both samples is a seasonal occurrence which biases the importance of the other major prey in the samples downward. In Puget Sound this species of fish spawns during the late fall and early winter (Levings 1969). The 80-110 mm size range for this species found in the porpoise samples is consistent with juveniles from the previous fall-winter spawning period. Additional evidence of the seasonal importance of this species is that all the remains of *L. pacifica* found occurred in samples collected in the spring months (March-May). The differences in the frequency of blackbelly eelpout between the harbor porpoise (26.9%) and Dall's porpoise (81.8%) samples is probably due, at least in part, to temporal differences between the two samples in that 95.5% of the Dall's porpoise were collected during the spring months and only 61.5% of the harbor porpoise samples were collected during the same period.

The frequency of occurrence of the polychaete worm, *Nereis vexillosa*, was high in both the Dall's (59.1%) and harbor porpoise (30.8%) samples. This species of worm reaches up to 30 cm in length and is vulnerable to predation while swimming in open water during its seasonal spawning activity (Johnson 1943, Ricketts and Calvin 1962). While it is possible that the porpoise fed directly on *N. vexillosa* during these spawning events, the possibility that the worm remains were introduced secondarily as prey of larger prey ingested is still being investigated.

Acknowledgments

We appreciate the efforts of Brian Urbain, Collection Manager, University of Washington Fish Collection, and Jeff Christiansen, Curator of the Seattle Aquarium, for providing us with fish specimens that enabled us to identify several of the key prey species. The following people assisted in the collection of specimens over the many years of stranded marine mammal recovery in the study area and with out whose efforts the samples could never have been obtained: Ron Bates, Tracy Cornish, Graeme Ellis, John Ford, Louise Hahn, Ken Langelier, Malcolm McAdie, Alexandra Morton, Rich Osborne, Pam Stacey, Pam Willis and Steve Wischniowski. Funding support for the stranded whale and dolphin program in British Columbia was provided by World Wildlife Fund Canada.

Citations

Cowan, I. M. 1944. The Dall's porpoise, *Phocoenoides dalli* (True) of the North Pacific Ocean. J. Mammal. 25:295-306.

Frost, K. J., and L. F. Lowry. 1981. Trophic importance of some marine gadids in northern Alaska and their body-otolith size relationships. Fish. Bull., U.S. 79:187-192.

Gearin, P. J. and M.A. Johnson. 1990. Prey identified from stomachs of harbor porpoise and chinook salmon from the 1988-89 Makah chinook salmon set-net fishery. In H. Kajimura (ed.), Harbor porpoise abundance and interactions with the Makah salmon set-net fishery in coastal Washington waters, 1988-89. U.S. Dep. Commer., NOAA, Unpubl. Rep. (available upon request - P. Gearin, National Marine Mammal Laboratory, 7600 Sand Point Way NE, Seattle, WA 98115).

Gearin, P. J., S. R. Melin, R. L. DeLong, H. Kajimura, and M. A. Johnson. 1994. Harbor porpoise interactions with a chinook salmon set-net fishery in Washington state. Rep. Int. Whal. Commn. Special Issue 15:427-438.

Harvey, J. T., T. R. Loughlin, M. A. Perez, and D. S. Oxman. In press. Relationship between fish size and otolith length for 62 species of fishes from the eastern North Pacific Ocean. U.S. Dep. Commer., NOAA Tech. Rep.

Johnson, M. W. 1943. Studies on the life history of the marine annelid, *Nereis vexillosa*. Biol. Bull. 84(1):106-114.

Jones, R. E. 1981. Food habits of smaller marine mammals from northern California. Proceed. Calif. Acad. Sci. 42(16):409-423.

Levings, C. D. 1969. The zoarcid *Lycodopsis pacifica* in outer Burrard Inlet, British Columbia. J. Fish. Res. Board Can. 26:2403-2412.

Loeb, V. J. 1972. A study of the distribution and feeding habits of the Dall porpoise in Monterey Bay, California. M.S. Thesis, San Jose State College, San Jose, Calif., 62 p.

Morejohn, G.V. 1979. The natural history of Dall's porpoise in the North Pacific Ocean. Pp. 45-83, In Winn, H.E. and B.L. Olla (eds.), Behavior of marine mammals, Vol. 3: Cetaceans, Plenum Press. New York-London.

Norris, K. S., and J. H. Prescott. 1961. Observations on Pacific cetaceans of Californian and Mexican waters. Univ. Calif. Publ. Zool. 63(4):291-402.

Pike, G. C. and I. B. MacAskie. 1969. Marine mammals of British Columbia. Fish. Res. Board Can., Bull. No. 171, 54 p.

Recchia, C. A., and A. J. Read. 1989. Stomach contents of harbour porpoises, *Phocoena phocoena* (L.), from the Bay of Fundy. Can. J. Zool. 67:2140-2146.

Ricketts, E. F., and J. Calvin. 1962. Between Pacific tides. Revisions by J. W. Hedgpeth, Stanford University Press. 516 p.

Scheffer, V. B. 1953. Measurements and stomach contents of eleven delphinids from the northeast Pacific. Murrelet 34:27-30.

Scheffer, V. B., and J. W. Slipp. 1948. The whales and dolphins of Washington state with a key to the cetaceans of the west coast of North America. Am. Midland Nat. 39: 257-337.

Stroud, R. K., C. H. Fiscus, and H. K. Kajimura. 1981. Food of the Pacific white-sided dolphin, *Lagenorhynchus obliquidens*, Dall's porpoise, *Phocoenoides dalli*, and northern fur seal, *Callorhinus ursinus*, off California and Washington. Fish. Bull., U.S. 78:951-959.

Walker, W. A. 1996. Summer feeding habits of Dall's porpoise, *Phocoenoides dalli*, in the southern Sea of Okhotsk. Mar. Mammal Sci. 12 (2):167-181.

Wolff, G. A. 1984 Identification and estimation of size from the beaks of 18 species of cephalopods from the Pacific Ocean. U.S. Dep. Commer., NOAA Tech. Rep. NMFS-17, 50 p.

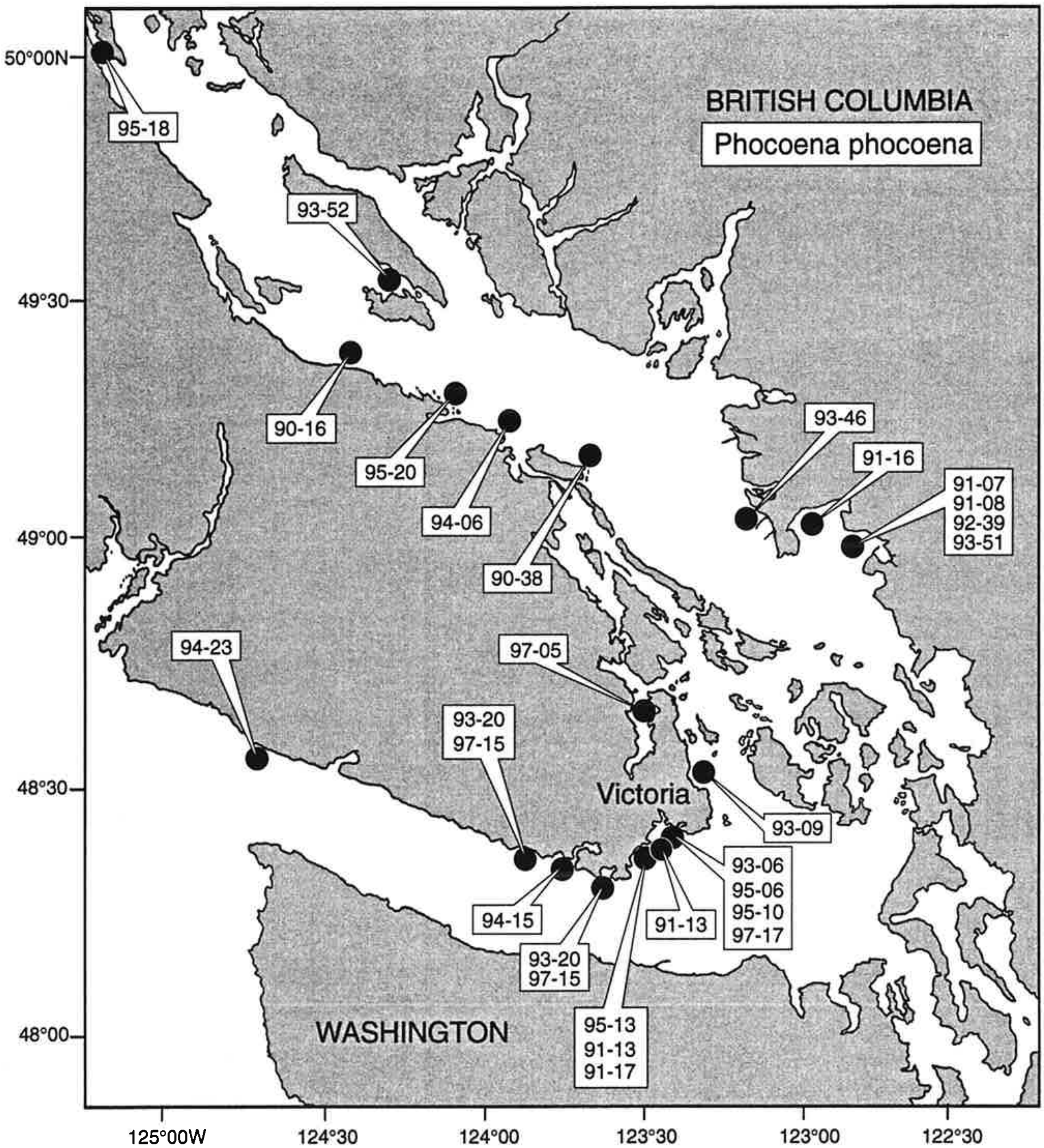

Figure 1. Approximate locations for harbor porpoise stomach samples collected in the inland waters of British Columbia and Washington.

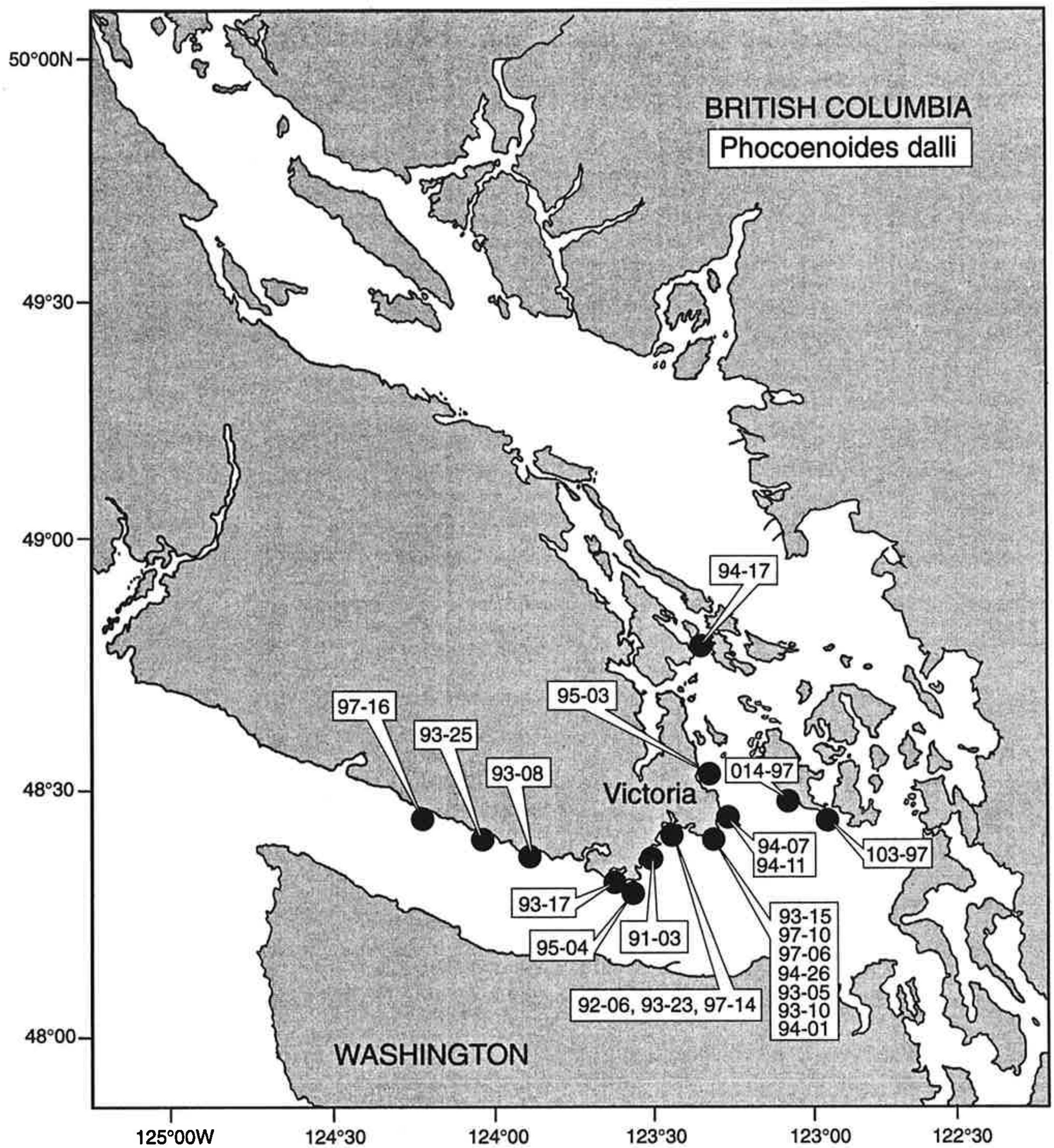

Figure 2. Approximate locations for Dall's porpoise stomach samples collected in the inland waters of British Columbia and Washington.

Table 1. Summary of harbor porpoise and Dall's porpoise included in stomach content samples from the inland waters of British Columbia and Washington.

COLL. NO.	DATE COLL.	LENGTH (cm)	SEX	LOCALITY
		HARBOR PORPOISE		
SWDP 90-16	7/25/90	146	M	Qualicum River, Vancouver Island (salmon gillnet)
SWDP 90-38	12/8/90	190	F	Vance Island
SWDP 91-07	4/16/91	143	F	White Rock, N. Semiahmoo Bay (salmon gillnet)
SWDP 91-08	4/18/91	149	M	White Rock, N. Semiahmoo Bay
SWDP 91-13	5/9/91	121	M	Esquimalt, Vancouver Island
SWDP 91-17	5/15/91	143	F	Saxe Point, Esquimalt, Vancouver Island
SWDP 91-16	5/15/91	159	F	Boundary Bay (salmon gillnet)
SWDP 92-39	9/5/92	131 est.	M	White Rock, N. Semiahmoo Bay
SWDP 93-06	4/22/93	134	F	250 m W. Holland Pt., Victoria, Vancouver Island
SWDP 93-09	4/28/93	146	M	Ten Mile Point, Victoria, Vancouver Island
SWDP 93-20	5/19/93	114	F	Caffrey Point, Becher Bay, Vancouver Island
SWDP 93-00	8/4/93	und.	und.	1 mile north of Fife Sound (killer whale kill)
SWDP 93-46	8/23/93	119	M	Tsawwassen, ferry terminal N. Pt. Roberts
SWDP 93-51	8/28/93	131	M	White Rock, N. Semiahmoo Bay
SWDP 93-52	8/31/93	146	F	Sabine Channel (salmon gillnet)
SWDP 94-06	3/16/94	110	M	Keel Bay, Nanaimo, Vancouver Island
SWDP 94-15	4/26/94	123	M	Sooke Bay, Vancouver Island
SWDP 94-23	5/12/94	111	M	Carmanah Point, Vancouver Island
SWDP 95-06	4/21/95	118	M	Clover Point, Vancouver Island
SWDP 95-10	5/18/95	125	F	Clover Point,Victoria, Vancouver Island
SWDP 95-13	5/30/95	129	F	Fleming Beach, Victoria, Vancouver Island
SWDP 95-18	7/18/95	159	F	Campbell River, Vancouver Island
SWDP 95-20	7/24/95	149	F	north of Parksville, Vancouver Island
SWDP 97-05	4/30/97	155	M	Patricia Bay, Vancouver Island
SWDP 97-15	5/23/97	136	M	Church Rock, Vancouver Island
SWDP 97-17	6/4/97	131	M	Holland Point, Victoria, Vancouver island
		DALL'S PORPOISE		
SWDP 91-03	3/19/91	160	M	William Head, Vancouver Island
SWDP 92-06	4/30/92	152	M	Esquimalt, Vancouver Island
SWDP 93-05	4/10/93	140	M	McMicking Point, Victoria, Vancouver Island
SWDP 93-08	4/23/93	160	M	Church Point, Vancouver Island
SWDP 93-10	5/4/93	160	M	300 m W.Clover Point,Victoria, Vancouver Island
SWDP 93-15	5/14/93	179	F	East side Ross Bay, Vancouver Island
SWDP 93-17	5/17/93	162	M	S. Crekye Point, Vancouver Island
SWDP 93-23	5/26/93	147	F	Albert Head, Vancouver Island
SWDP 93-25	5/27/93	152	F	1 km E.Tugwell Creek, Vancouver Island
SWDP 94-01	1/7/94	133	M	Ross Bay, Victoria, Vancouver Island
SWDP 94-07	3/25/94	152	F	N.E. shore Discovery Island
SWDP 94-11	4/15/94	190	F	Ten mile Point, Victoria, Vancouver Island
SWDP 94-17	4/29/94	206	F	Stanley point, North Pender Island
SWDP 94-26	5/15/94	169	M	Ross Bay,Victoria, Vancouver Island
SWDP 95-03	4/7/95	188	M	Island View Beach, Vancouver Island
SWDP 95-04	4/9/95	141	F	Race Rocks
SWDP 97-06	5/1/97	140	F	Ross Bay, Vancouver Island
SWDP 97-10	5/15/97	140	F	Clover Point, Vancouver Island
SWDP 97-14	5/20/97	175	M	Albert Head, Vancouver Island
SWDP 97-16	5/24/97	153	F	French Beach, Vancouver Island
SJ103-97	4/10/97	164	M	Cattle Point Lighthouse, San Juan Island.
SJ014-97	5/8/97	184	F	Edward's Point, San Juan Island.

SWDP = Stranded Whale and Dolphin Program, B. C., Canada; SJ = Record numbers of the San Juan County Marine Mammal Stranding Network, The Whale Museum, Friday Harbor, Washington

Table 2. **Number and frequency of occurrence for prey recovered from Dall's porpoise, *Phocoenoides dalli*, and harbor porpoise, *Phocoena phocoena*, from the inland waters of British Columbia and Washington.**

	DALL'S PORPOISE (n=22)				HARBOR PORPOISE (n= 26)			
	Number		Frequency of occurrence		Number		Frequency of occurrence	
	No.	%	No.	%	No.	%	No.	%
Total Prey	10581				3602			
FISHES	10473	99.0	21	95.5	1891	52.5	23	88.5
Clupeidae								
Clupea harengus pallasi	66	0.6	10	45.5	53	1.5	8	30.8
Osmeridae								
Thaleichthys pacificus	21	0.2	4	18.2	3	0.1	1	3.9
Myctophidae	18	0.2	2	9.1	0	-	0	-
Stenobrachius leucopsaurus	12	0.1	2	9.1	0	-	0	-
Lampanyctus ritteri	2	< 0.1	1	4.5	0	-	0	-
Diaphus theta	3	< 0.1	1	4.5	0	-	0	-
Protomyctophum sp.	1	< 0.1	1	4.5	0	-	0	-
Batrachoididae								
Porichthys notatus	0	-	0	-	1	< 0.1	1	3.9
Gadidae	120	1.1	13	59.0	18	0.5	2	7.7
Theragra chalcogramma	113	1.1	15	68.2	3	0.1	2	7.7
Merluccius productus	7	0.1	3	13.6	15	0.4	2	7.7
Zoarcidae								
Lycodopsis pacifica	10175	96.2	18	81.8	1786	49.6	7	26.9
Ammodytidae								
Ammodytes hexapterus	61	0.6	6	27.3	2	< 0.1	2	7.7
Embiotocidae								
Cymatogaster aggregata	0	-	0	-	5	0.1	2	7.7
Scorpaenidae								
Sebastes sp. (juv.)	0	-	0	-	1	< 0.1	1	3.9
Cottidae	3	< 0.1	2	9.1				
Icelinus borealis	2	< 0.1	1	4.5	8	0.2	2	7.7
unident. cottid	1	< 0.1	1	4.5				

Table 2. Continued.

	Number		Frequency of occurrence		Number		Frequency of occurrence	
	No.	%	No.	%	No.	%	No.	%
Bothidae								
Citharichthys sordidus	1	< 0.1	1	4.5	10	0.3	2	7.7
Pleuronectidae	5	< 0.1	2	9.1	0	-	0	-
Glyptocephalus zachirus	1	< 0.1	1	4.5	0	-	0	-
Isopsetta isolepis	1	< 0.1	1	4.5	0	-	0	-
Parophrys vetulus	1	< 0.1	1	4.5	0	-	0	-
unidentifiable pleuronectid	2	< 0.1	1	4.5	0	-	0	-
unidentifiable teleosts	3	< 0.1	2	9.1	4	0.1	4	15.4
INVERTEBRATES	108	1.0	14	63.6	1711	47.5	13	50.0
Cephalopoda	66	0.6	3	13.6	1677	46.6	5	19.2
Loliginidae								
Loligo opalescens	44	0.4	2	9.1	1673	46.5	4	15.4
Onychoteuthidae								
Onychoteuthis borealijaponica	0		0	-	2	< 0.1	1	3.9
Gonatidae	22	0.2	2	9.1			1	3.9
Gonatus berryi	20	0.2	2	9.1	2	< 0.1	1	3.9
Gonatus pyros	2	< 0.1	1	4.5	0	-	0	-
Crustacea	3	< 0.1	1	4.5	1	< 0.1	1	3.9
Crangonidae								
Crago sp.	3	< 0.1	1	4.5	0	-	0	-
Penaeidae								
Sergestes sp.	0	-	0	-	1	< 0.1	1	3.9
Polychaeta								
Nereidae								
Nereis vexillosa	39	0.4	13	59.1	33	0.9	8	30.8

Table 3. Summary of size, weight estimates and indices of importance for seven commonly ingested prey of Dall's and harbor porpoise collected in the inland waters of British Columbia and Washington.

	DALL'S PORPOISE						HARBOR PORPOISE					
Prey species	Length range (mm)	Mean length (mm)	Mean weight (gms)	% Total mass *	% No.	% Freq.	Length range (mm)	Mean length (mm)	Mean weight (gms)	% Total mass *	% No.	% Freq.
FISHES				98.8	98.8	95.5				45.2	51.8	88.5
Clupea harengus pallasi	102 - 217	151.0	67.3	7.1	0.6	45.5	123 - 228	178.6	88.2	12.0	1.5	30.8
Thaleichthys pacificus	128 - 176	158.0	37.8	1.3	0.2	18.2	124 - 181	153.0	33.8	0.3	0.1	3.9
Theragra chalcogramma	127 - 363	259.0	118.0	21.1	1.1	68.2	185 - 188	186.4	34.7	0.3	0.1	7.7
Merluccius productus	397 - 438	417.5	521.0	5.7	0.1	13.6	338 - 371	353.0	316.9	12.2	0.4	7.7
Lycodopsis pacifica	80 - 105	95.0	3.9	63.0	96.2	81.8	80 - 110	104.3	4.1	18.8	49.6	26.9
Ammodytes hexapterus	93 - 133	109.0	6.0	0.6	0.6	27.3	undet.	157.0	10.0	0.1	< 0.1	7.7
Citharichthys sordidus	-	-	-	-	-	0	125 - 176	152.0	57.7	1.5	0.3	7.7
CEPHALOPODS				1.2	0.6	13.6				54.8	46.6	19.2
Loligo opalescens	69 - 127	95.2	19.6	1.2	0.4	9.1	58 - 125	81.4	12.7	54.8	46.5	15.4

* Calculation of the total mass percentages is based only on the cumulative contribution of these seven prey species.

SURVEY REPORT FOR THE 1997 AERIAL SURVEYS FOR HARBOR PORPOISE AND OTHER MARINE MAMMALS OF OREGON, WASHINGTON AND BRITISH COLUMBIA OUTSIDE WATERS

Jeffrey Laake[1], John Calambokidis[2], and Steve Osmek[2]

[1] National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington 98115

[2] Cascadia Research
Waterstreet Building
218½ West Fourth Ave
Olympia, Washington 98501

Abstract

We report the methods and a summary of the August-September 1997 aerial surveys for marine mammals that occupy the outside coastal waters of Oregon, Washington and southern British Columbia. Encounter rates, frequency distribution of group size, and other important summary information required for abundance estimation are provided for the most commonly seen species: harbor porpoise (*Phocoena phocoena*), Steller sea lions (*Eumetopias jubatus*), harbor seals (*Phoca vitulina richardsi*) and Dall's porpoise (*Phocoenoides dalli*). From these survey data, we estimated that the population size of the Washington/Oregon outer coast stock of harbor porpoise was 44,644 (CV = 0.38). This represents a substantial increase over the 1991 estimate of 26,175 which resulted from the larger sampling region in the 1997 survey, a different estimate of g(0), and potentially a northward shift in distribution during the El Niño.

Background

Several aerial surveys have been conducted over the past 15 years to collect sighting data of marine mammals occupying Oregon and Washington outside coastal waters (Barlow et al. 1988; Calambokidis et al. 1991, 1992, 1993). Most of these surveys were flown with the primary objective of estimating abundance of harbor porpoise, a species that is incidentally killed in gillnets set for salmon in several areas of this region (Stacey et al. 1990, Gearin et al. 1995, Pierce et al. 1996) and has declined in abundance in several areas of the northeast Pacific (central California: Forney 1995; southern Puget Sound: Osmek et al. 1995).

Calambokidis et al. (1993) reviewed these aerial surveys of Oregon-Washington waters and found the 1990 and 1991 survey data (Calambokidis et al. 1991, 1992) were suitable for pooling and calculating improved estimates of harbor porpoise abundance. These estimates were subsequently used to calculate potential biological removal (PBR) levels for two recently designated harbor porpoise stocks: 1) Oregon-Washington Coast and 2) Inland Washington (Osmek et al. 1996).

To adequately protect these harbor porpoise and other marine mammal stocks, it was recommended that abundance and PBR estimates be calculated at five-year intervals (Barlow et al. 1995). As a result, aerial surveys for harbor porpoise of the inland Washington stock were conducted during August 1996 (Calambokidis et al. 1997, Osmek et al. 1997) using the same methods as were used during the 1991 surveys (Calambokidis et al. 1992). Surveys for harbor porpoise of the Washington/Oregon stock were delayed until summer 1997 to coincide with harbor porpoise surveys conducted off California by NMFS, Southwest Fisheries Science Center, La Jolla, CA.

Two methodological changes were made for this 1997 survey: 1) altitude was increased from 183 m (600 ft) to 198 m (650 ft) to make the these data comparable with the 1997 surveys in California waters, and 2) water depths out to 200 m were sampled during 1997, compared to mostly 100 m in 1991, to ensure that the subsequent abundance estimate would include virtually all waters off Oregon/Washington where harbor porpoise occur. The waters of southern British Columbia were also flown during 1997 because no dedicated marine mammals surveys have previously been conducted in this transboundary region.

Methods

Study Area

The study area includes the coastal waters of Oregon, Washington, and southern British Columbia south of 49° N latitude, from shore out to a depth of 200 m (Fig. 1). The waters of the west half of the U.S.-Canada Strait of Juan de Fuca were also surveyed in 1997 to overlap a portion of the 1996 survey area (Calambokidis et al. 1997, Osmek et al. 1997) and the harbor porpoise stock boundary located at the Strait's west entrance (see Osmek et al. 1996).

Survey Design and Procedures

A total of 107 transect lines were planned to provide complete coverage for areas of similar water depths in Regions I-VI (Fig. 1). In each region, either 3 or 4 replicate sets of lines were chosen. The lines in each replicate were systematically spaced with a random starting point. In Region I, three replicate sets of parallel transects were used for this irregularly shaped region. In the remaining regions, the lines were placed in a saw-tooth pattern (Cooke 1985) in a rectangular region parallel to the coast. The end of a sawtooth was truncated were it intersected the coast and the truncated end along the coast was not included in the survey. Transects were generally stratified to sample water depths out to 100 m and 200 m, with most of the effort being expended in the shallower depths where the highest harbor porpoise densities have been observed (Green et al. 1992). Region IV transect lines all extended out to a depth of 200 m because bathymetry was more variable over Heceta Bank. Each transect was designed to be flown once and when possible from south to north to reduce glare from the sun.

Flights generally originated and ended at Hoquiam, Washington, although both cities of Coos Bay and Newport, Oregon were also used as a base of operation when southern and central Oregon were surveyed. Other airports such as Port Angeles, Washington, and Astoria and Tillamook, Oregon, were also used for refueling and waiting for improvements in weather to occur.

Surveys were conducted using a high-wing (Partenavia P-68) twin-engine aircraft equipped with left- and right-side bubble windows and a belly window. This arrangement made it possible to observe marine mammals slightly ahead of, to the side, and beneath the aircraft. Three experienced observers located at left, center and right positions in the aircraft viewed the water for marine mammals while the aircraft flew at an altitude of 198 m (650 ft) and a speed of 167 km/hour (90 knots). Observers rotated to a new position at the beginning of each flight. Surveys were generally limited to visibility conditions of Beaufort sea state 3 or less and cloud cover 50% or less. When a transect line was aborted prematurely because of poor visibility conditions, these lines were later re-flown when conditions improved.

The data recorder, who also navigated from the copilot's chair, entered survey information using a custom Data Acquisition System (DAS) on a laptop computer that was interfaced with a Geographic Positioning System (GPS) navigational system. Visibility conditions and altitude were recorded at the beginning of a transect line and when conditions changed. The date, time, and location were updated automatically by the computer each minute and when other data entries were made. When a marine mammal sighting was made, the species, group size, number of calves, and any unusual behavior was called out to the data recorder. In addition, the side observers also called out the clinometer-measured angle of the sighting as the group of animals passed abeam of the aircraft so the perpendicular distance (distance from the survey trackline to the sighting) could be determined. The center observer called out sighting angles from a clinometer-calibrated scale mounted above the belly window.

When a group was sighted from center, the observer would delay for 2-3 seconds waiting for the side observers to register their sighting with the data recorder. This method of recording data was used to avoid confusion at a moment when both the center and a side observer would have traditionally reported the same sighting in unison. Initially, the center observer also told the recorder if they saw a sighting made by the side observer to provide information on the number of sightings missed by center within the overlapping search area of 90-65 degrees. This practice of recording "center saw" data was discontinued after 22 August because of its possible effect of decreasing the number of sightings made at the center observer position.

Data Editing and Preliminary Analysis

Error checks of the electronic data were conducted prior to analysis, both visually and using computer programs written to test for reasonable speed between one-minute position fixes, altitudes, clinometer angles, and species codes. On several occasions it was found that the GPS failed to provide reliable positions for portions of a flight (e.g., position format error). In these instances, latitude and longitude were interpolated using the time and position which proceeded and followed it. Species codes included a designation for probable, but not certain, species identification as well as codes for unidentified species. Probable sightings were included in the data summaries for that species.

Harbor Porpoise Abundance Estimation

For the estimate of harbor porpoise abundance, we used data collected when the Beaufort sea state was 2 or better and cloud cover was 25% or less. The survey data in the six regions were sub-divided into 12 strata for analysis (Fig. 1) as follows: 1) Region I was sub-divided into Canadian outside waters (I-N), Washington outside waters (I-S) and inland waters (I-E); and 2) Regions II,III, V and VI were sub-divided into a nearshore and offshore strata to accommodate the lower sampling effort in the lower density offshore regions. Survey lines that crossed strata boundaries were divided into two lines. The area contained within each stratum, A_i, was measured using a Geographic Information System (GIS).

The computer software DISTANCE (Buckland et al. 1993) was used to analyze the line transect data. We estimated the abundance in each strata but we used a single detection model for all of the strata. Prior to analysis, the distance data were binned using the distance cutpoints that correspond with 8° vertical angle bins (e.g., at the altitude of 650 feet 82° is 27.8 m). An initial inspection of the data was used to set the truncation distance (W) for the analysis. We fitted half-normal, hazard-rate and uniform key functions and cosine adjustment terms to the binned distance data and we chose the model with the minimum AIC (Buckland et al. 1993). We tested for size-bias by regressing ln(school size) on $g(x)$ for all of the data with $\alpha = 0.15$. The observed (uncorrected) density (assuming $g(0) = 1$) within stratum i was estimated as:

$$\hat{D}_i = \frac{n_i f(0)\, E(s_i)}{2L_i} \quad .$$

The estimate of abundance N_c was computed by dividing the observed abundance $N_u = A_i D_i$ by the estimated g(0) = 0.292 (SE = 0.107) of Laake et al. (1997). The abundance in the Washington/Oregon coastal stock of harbor porpoise was the sum of the stratum abundances except I-N and I-E. The coefficient of variation (CV) of the corrected abundance was computed as:

$$cv(N_c) = \sqrt{cv^2[N_u] + cv^2[g(0)]} \quad ,$$

and

$$cv^2(N_u) = cv^2[f(0)] + \frac{\sum_{i=1}^{r}\left(cv^2\left[\frac{n_i}{L_i}\right] + cv^2(E(s_i))\right)}{N_u^2} \quad ,$$

where r is the number of strata included in the estimate.

Results

Aerial surveys of Regions I-VI off south British Columbia, Washington, and Oregon were conducted from 15 August through 9 September 1997. A practice flight was conducted on 15 August off of Hoquiam, Washington (Region II) to re-familiarize all members of the team with survey operations, viewing marine mammals from the air, and recording data. Over the entire survey period, more than 78 hours of flight time, during 29 flights, including the ferry of the aircraft back to Oxnard, California, was required to complete the project (Table 1-2). Of this total, 31.4 hours were spent surveying on-effort.

Weather conditions during the 1997 survey period were generally favorable for sighting harbor porpoise, except from 11-14 August and 23-28 August when excessive cloud cover and occasional high winds prevailed. Approximately 99% (5,329 km) and 93% (5,039 km) of all survey effort (5,397 km) was flown in the acceptable cloud cover categories of 50% and less and <25% and less, respectively, while 86% (4,645 km) of the effort was flown when sea conditions were Beaufort 2 and less (Table 3). Survey lines flown during good weather (both Beaufort 2 and less and 25% cloud cover and less) amounted to 81% (4,366 km) of the total. It is important to note that the total effort includes all on-effort data, even those sections of transect lines that were repeated when weather conditions improved (roughly 650 km). The planned survey lines included 4,744 km, so 92% of the planned survey effort was conducted during good weather conditions.

A total of 727 sightings of 1,290 animals (including 93 calves/pups) from 15 marine mammal species (plus 7 leatherback sea turtle sightings) were made during on-effort portions of the surveys (Table 4). An additional 140 sightings of 1,191 animals (22 calves/pups) were made while off-effort. Harbor porpoise (n = 360), Steller sea lions (n = 130), harbor seals (n = 106), and Dall's porpoise (n = 68) were the most frequently sighted marine mammals and accounted for 91% of the on-effort marine mammal sightings. Other on-effort marine mammal group sightings included California sea lions (n = 30), northern elephant seals (n = 9), a northern fur seal, humpback whales (n = 8), gray whales (n = 10), a minke whale, a pod of killer whales, and sea otters (n = 3). Distributions of sightings are illustrated in Figures 2-5 for the most frequently sighted species.

The frequency distributions by group size are summarized for the four primary species (Fig. 6). The amount of regional variation in mean group size for these species was especially interesting (Table 5). Group sizes for both porpoise species were substantially higher in Regions IV-VI than Regions I-III. This variation might be related to changes in foraging behavior influenced by factors such as the blue water observed near shore in these southern regions and warmer water temperatures brought about by the 1997 El Niño event. Mean group sizes for harbor seals and Steller sea lions varied much less throughout the study area. One exception was for Regions III and VI, where the mean group size of Steller sea lions was relatively high and likely influenced by the hauling areas near the mouth of the Columbia River (Region III) and Rogue Reef (Region VI).

During the 4,336 km of survey effort in good weather conditions, 321 harbor porpoise groups were detected. We truncated 1% (3 sightings) of the sightings that were detected beyond a clinometer angle of 26° (perpendicular distance of W = 0.406 km). A half-normal key function with no adjustment terms provided the best fit (i.e., minimum Akaike Information Criterion) to the distance data (Fig. 7). The fit of the detection function was adequate ($X^2 = 2.96$, 6 df, P = 0.81). Assuming g(0) = 1, P = 44% of the porpoise groups within the strip were detected. The estimated effective strip width (PW) was 0.1776 km which corresponds to an f(0) of 1/0.1776 = 5.63 (CV = 0.043). In the 1991 survey, the detection curve had a slightly broader shoulder which resulted in a slightly lower f(0) estimate of 4.93 [Note: the units of f(0) are the inverse of distance units and Osmek et al (1996) incorrectly multiplied instead of dividing in transforming from nautical miles to kilometers. The estimate of f(0) in Table 1 of Osmek et al. (1996) should be 4.93 instead of 16.92.]. The slope of the size-bias regression was not significant (t = -1.00, 316 df, P = 0.16) so average cluster size ($\bar{s}$) was used to estimate the expected cluster size E(s) within each stratum.

We estimated a harbor porpoise population size of 52,295 (CV = 0.38) in the entire survey area which encompassed 48,198 km^2 for an average corrected density of 1.09 harbor porpoise per km^2 and an observed (uncorrected) density of 0.32 (Table 6). Within the Washington/Oregon stock boundaries, we estimated a corrected abundance of 44,644 (CV = 0.38) harbor porpoise and an observed abundance of 13,036 (CV = 0.11). In comparison, the observed abundance from the 1991 survey was 8,443 (CV = 0.12) (Osmek et al. 1996). The 1997 estimate is over 50% greater than the 1991 estimate (z = 2.67, P = 0.01).

Discussion

An increase of over 50% is substantial and should not be misrepresented as population growth because it would be unlikely for a harbor porpoise population to increase by 7% per year. An increase in the population estimate was expected because the 1991 survey region was primarily limited to waters within the 100 m isobath. We purposefully increased the survey region in 1997 to include all waters within the 200 m isobath so that we would obtain a more accurate estimate of the abundance. For the strata that were strictly offshore beyond the 100 m isobath (IIF,IIIF,VF, VIF), the average observed density was 0.079, which was about one-sixth the density in the corresponding inshore strata (II ,III,V,VI). Although, the density was lower in these regions they accounted for 7.4% of the total population estimate and 8.6% of the population estimate for the Washington/Oregon coastal stock. In addition to the offshore strata, Region IS and Regions II through VI sampled larger areas than the 1991 survey area (Fig. 2) and portions of those strata included water depths exceeding 100 m. We have not analyzed the 1997 survey data contained within the 1991 survey region in this report. Without doing so it is not possible to estimate directly what percentage of the increase was associated with the increase in the survey region. However, it is possible that increasing the survey region explains as much as one half of the increase because during fall, Green et al. (1992) observed 25% of the porpoise in waters between the 100 and 200 m isobaths.

In addition to the increased survey region, there is reason to believe that the abundance increased at least temporarily. When the 1997 survey was conducted, oceanographic conditions were being influenced by an El Niño event that had raised sea surface temperatures along the west coast of the United States. From surveys spanning two decades in California, Forney (1997) has shown that relative abundance in California decreases when sea surface temperature increases. It is quite plausible that harbor porpoise distribution shifts northward to cooler waters during these El Niño events.

Acknowledgments

Bruce Cruser, Aspen Helicopters Inc., Oxnard, CA, piloted the aircraft and Jennifer Quan recorded observational data. Steve Jeffries (Washington Department of Fish and Wildlife), Tom Norris, and Rob Schick were observers. Jim Cubbage, Cascadia Research Collective, made modifications to the Data Acquisition System used on the surveys. The Seattle, Washington and Portland, Oregon marine weather forecasters (NOAA, U.S. Weather Service) were extremely helpful in providing detailed weather forecasts for the study area and allowed us to make efficient use of the aircraft. Graham Ellis, Department of Fisheries and Oceans, B.C., assisted with the logistical aspects of the surveys conducted in Canadian waters. We are thankful for the assistance from all of these people.

Citations

Barlow, J., C.W. Oliver, T.D. Jackson, and B.L. Taylor. 1988. Harbor porpoise, *Phocoena phocoena*, abundance estimation for California, Oregon and Washington: II. Aerial Surveys. Fish. Bull., U.S. 86:433-444.

Barlow, J., S. Swartz, T.C. Eagle, and P.R. Wade. 1995. U.S. marine mammal stock assessments: guidelines for preparation, background, and a summary to the 1995 assessments. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-OPR-6, 73 p.

Buckland, S.T., D.R. Anderson, K.P. Burnham and J.L. Laake 1993. Distance sampling: estimating abundance of biological populations. London: Chapman and Hall. 446 p.

Calambokidis, J., J.C. Cubbage, S.J. Jeffries, P. Gearin, and R. Brown. 1991. Harbor porpoise distribution and abundance estimates off Washington from aerial surveys in 1990. Final contract Report to the Natl. Mar. Mammal Lab., Alaska Fish Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Seattle, WA, 98115-0070. 35 p.

Calambokidis, J., J.R. Evenson, J.C. Cubbage, P.J. Gearin, and S.D. Osmek. 1992. Harbor porpoise distribution and abundance estimate off Washington from aerial surveys in 1991. Final contract Report to the Natl. Mar. Mammal Lab., Alaska Fish Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Seattle, WA, 98115-0070. 44 p.

Calambokidis, J., J.C. Cubbage, J.R. Evenson, S.D. Osmek, J.L. Laake, P.J. Gearin, B.J. Turnock, S.J. Jeffries, and R.F. Brown. 1993. Abundance estimates of harbor porpoise in Washington and Oregon waters. Final contract Report to the Natl. Mar. Mammal Lab., Alaska Fish Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Seattle, WA, 98115-0070. 55 p.

Calambokidis, J., S.D. Osmek, and J.L. Laake. 1997. Abundance estimates of harbor and Dall's porpoise in Washington and British Columbia inside waters. *Part I of:* Aerial surveys for marine mammals in Washington and British Columbia inside waters. Final contract Report to the Natl. Mar. Mammal Lab., Alaska Fish Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Seattle, WA, 98115-0070. 107 p.

Cooke, J.G. 1985. Notes on the estimation of whale density from line transects. Rep. Int. Whal. Commn. 35:319-324.

Forney, K.A. 1995. A decline in the abundance of harbor porpoise, *Phocoena phocoena*, in near shore waters off California, 1986-93. Fish. Bull., U.S. 93:741-748.

Forney, K.A. 1997. Patterns of variability and environmental models of relative abundance for California cetaceans. Ph.D. Dissertation, Univ. Calif., San Diego, La Jolla, CA. 135 p.

Gearin, P., S.R. Melin, R.L. DeLong, H. Kajimura, and M.A. Johnson. 1995. Harbor porpoise interactions with a chinook salmon set-net fishery in Washington state. In W.F. Perrin, G.P. Donovan, and J. Barlow (editors). Rep. Int. Whal. Commn. Special Issue 15, p. 427-438.

Green, G.A., J.J. Brueggeman, C.E. Bowlby, R.A. Grotefendt, M.L. Bonnell, and K.T. Balcomb, III. 1992. Cetacean distribution and abundance off Oregon and Washington, 1089-1990. Final Report prepared by Ebasco Environmental and Ecological Consulting, Inc. for Min. Manag. Serv., Pacific OCS Region. OCS Study MMS 91-0093. 100 p.

Laake, J.L., J.C. Calambokidis, S.D. Osmek, and D.J. Rugh 1997. Probability of detecting harbor porpoise from aerial surveys: estimating g(0). J. Wildl. Manage. 61:63-75.

Osmek, S.D., M.B. Hanson, J.L. Laake, S.J. Jeffries, and R.L. DeLong. 1995. Harbor porpoise, *Phocoena phocoena*, population assessment studies for Oregon and Washington in 1994. Pp. 141-172, in D.P. DeMaster, H.W. Braham, and P.S. Hill. Marine mammal assessment program: status of stocks and impacts of incidental take 1994. Annual report submitted to the NMFS, Office of Protected Resources, Silver Spring, MD. Available Natl. Mar. Mammal Lab., Alaska Fish Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Seattle, WA, 98115-0070.

Osmek, S., J. Calambokidis, J. Laake, P. Gearin, R. DeLong, S. Jeffries, and R. Brown. 1996. Assessment of the status of harbor porpoises (*Phocoena phocoena)* in Oregon and Washington waters. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-76, 46 p.

Osmek, S.D., J. Calambokidis, and J.L. Laake. 1997. Distribution and habitat preferences of marine mammals in Washington and British Columbia inside waters. *Part II of:* Aerial surveys for marine mammals in Washington and British Columbia inside waters. Final report to the Natl. Mar. Mammal Lab., Alaska Fish Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Seattle, WA, 98115-0070. 107 p.

Pierce, J. D., M. Alexandersdottir, S.J. Jeffries, P. Erstad, W. Beattie, and A. Chapman. 1996. Interactions of marbled murrelets and marine mammals with the 1994 Puget Sound sockeye gill net fishery. Final Rep., Wash. Dept. Fish and Wildl., Olympia, WA. 21 p.

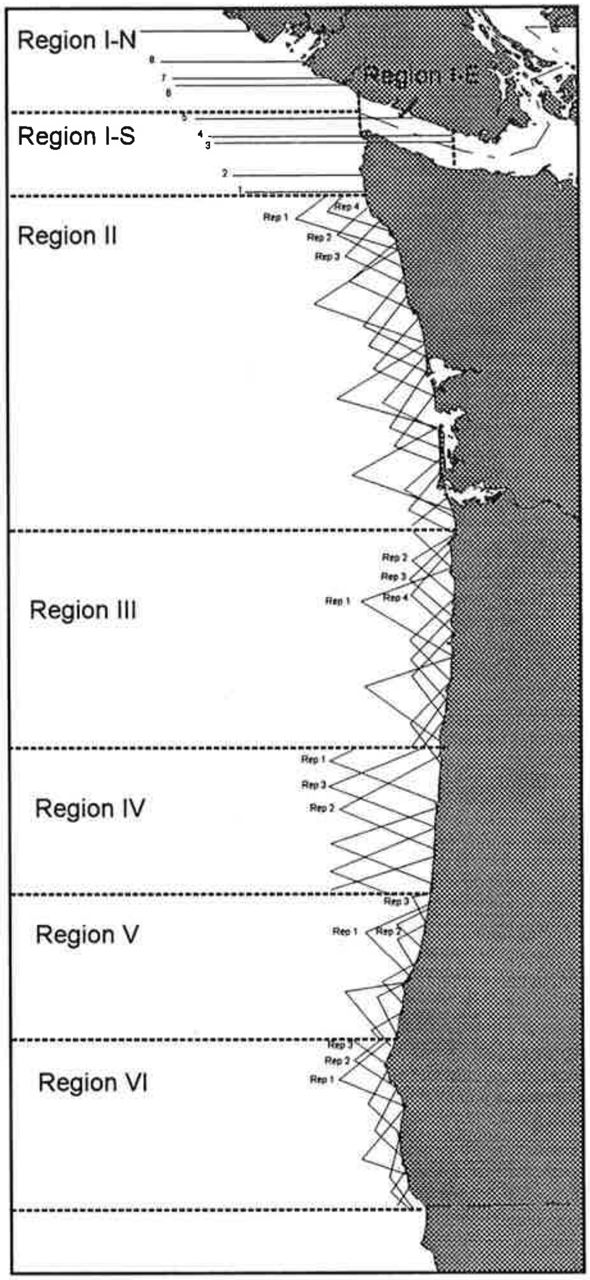

Figure 1. Study area, regions, and replicate sets of transect lines for aerial surveys flown in 1997. In Region I, there were 3 replicates of 3 lines with a random start and systematic spacing (lines 1,4, and 7 were replicate 1, etc.). In the other regions, there were 3-4 replicate sets of sawtooth flight lines each with a random start point.

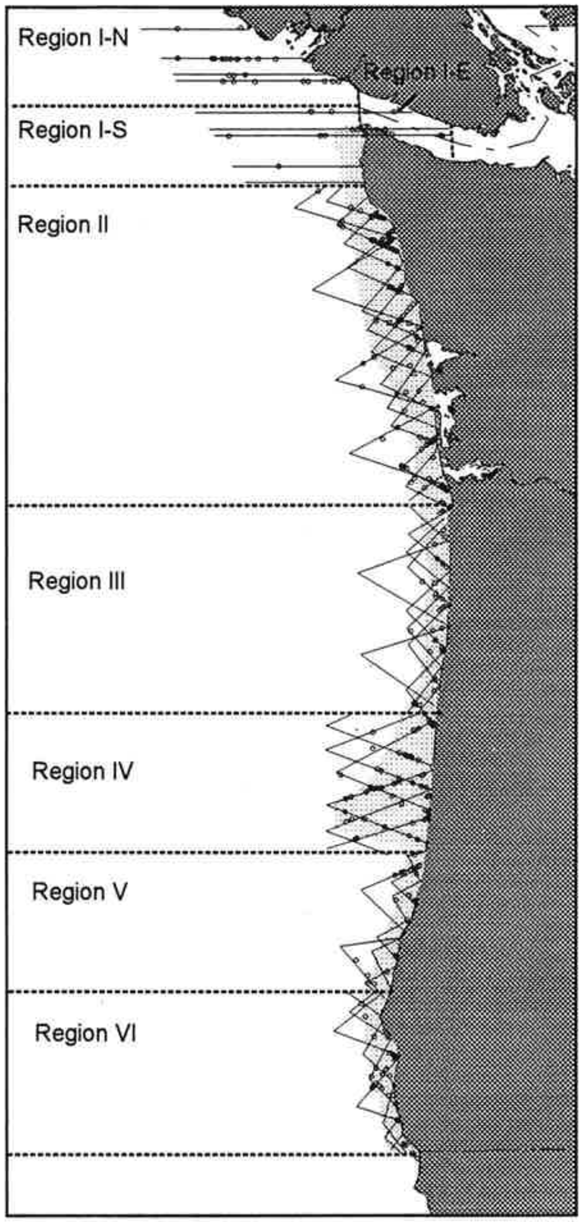

Figure 2. Sightings of harbor porpoise on-effort.
The stippled area is the 1991 survey region, which contains 16,000 km^2 .

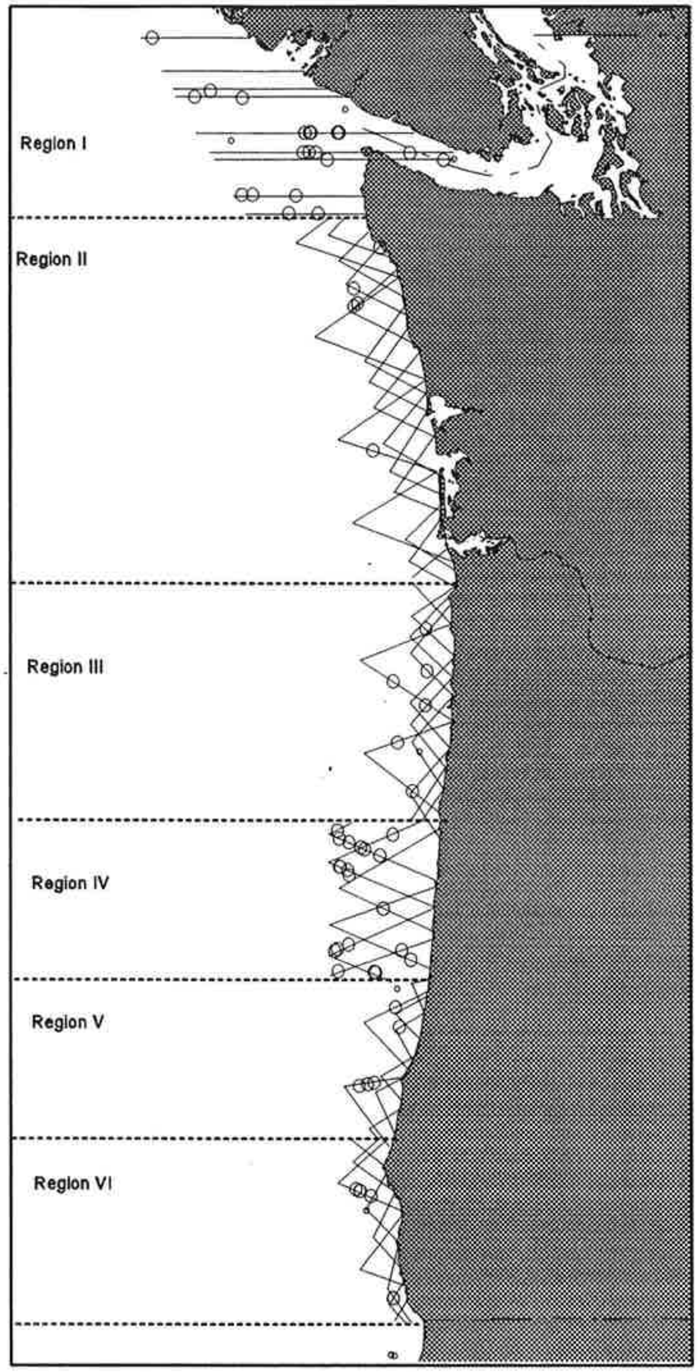

Figure 3. Sightings of Dall's porpoise on-effort (large circles) and off-effort (small circles).

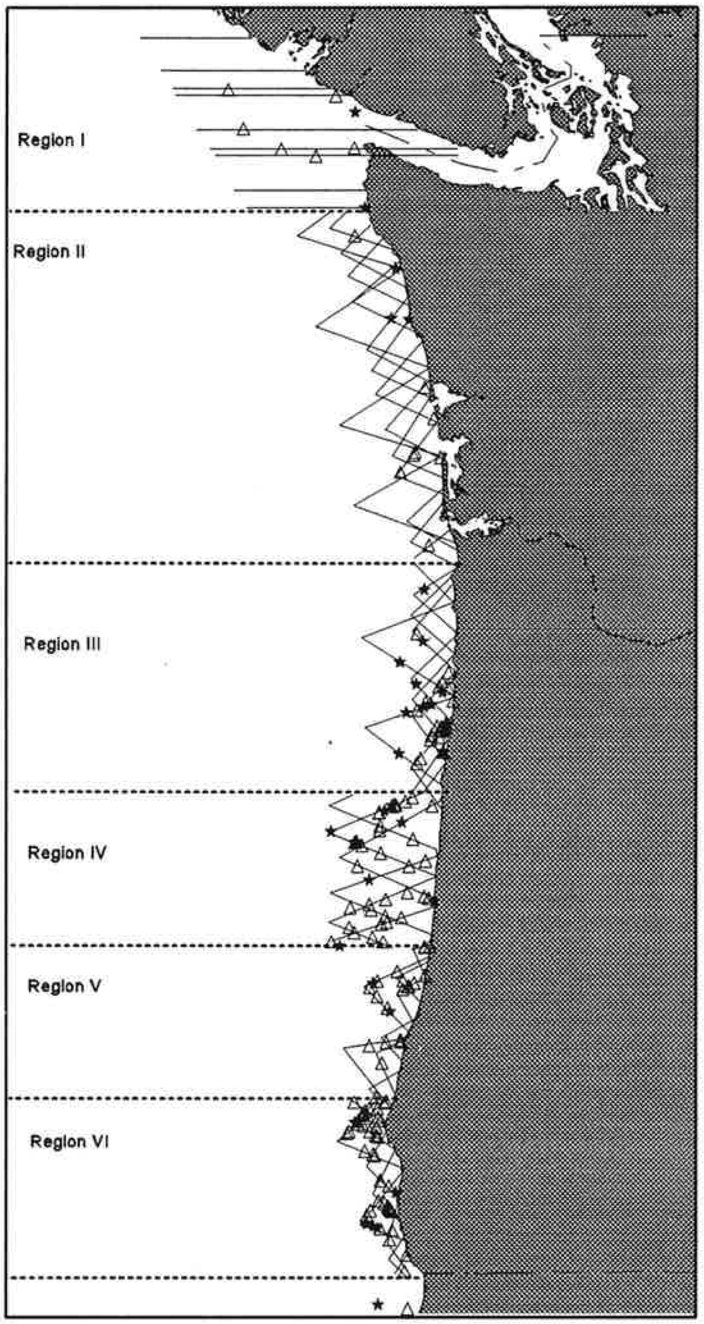

Figure 4. Sightings of California sea lions (star) and Steller sea lions (triangle).

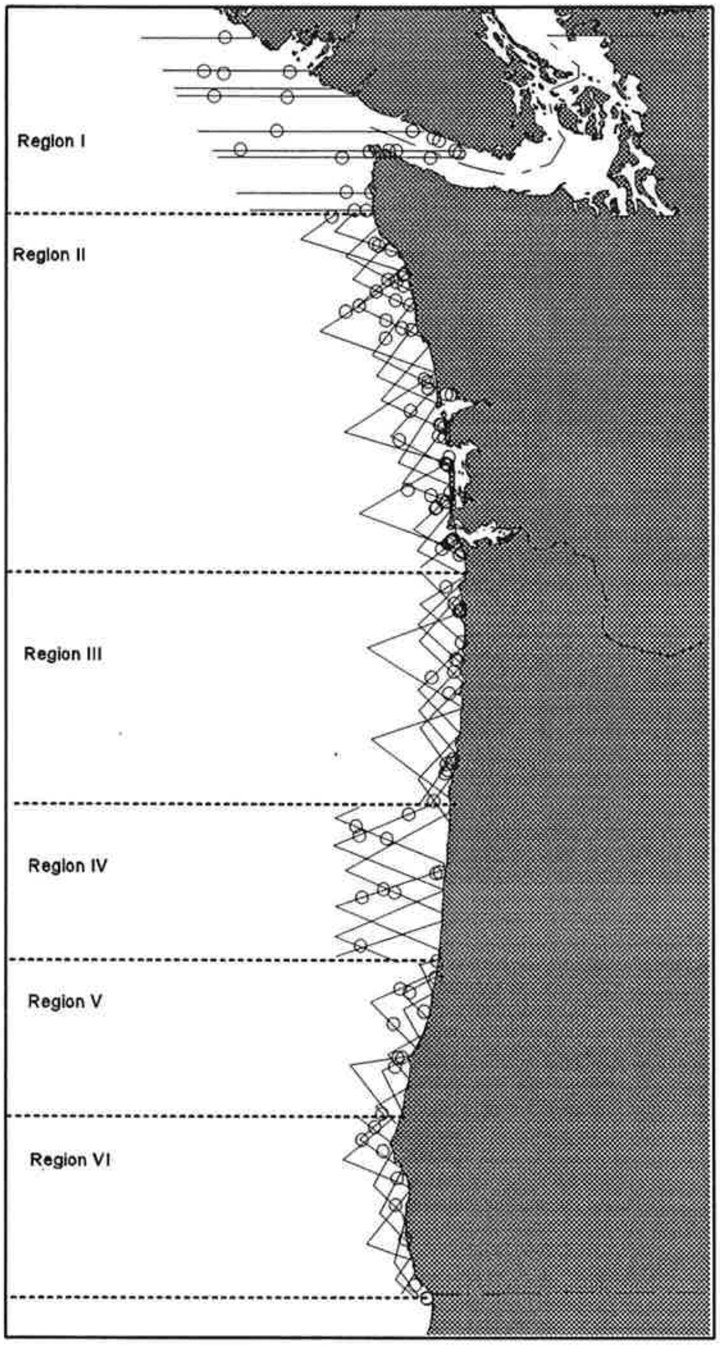

Figure 5. Sightings of harbor seals.

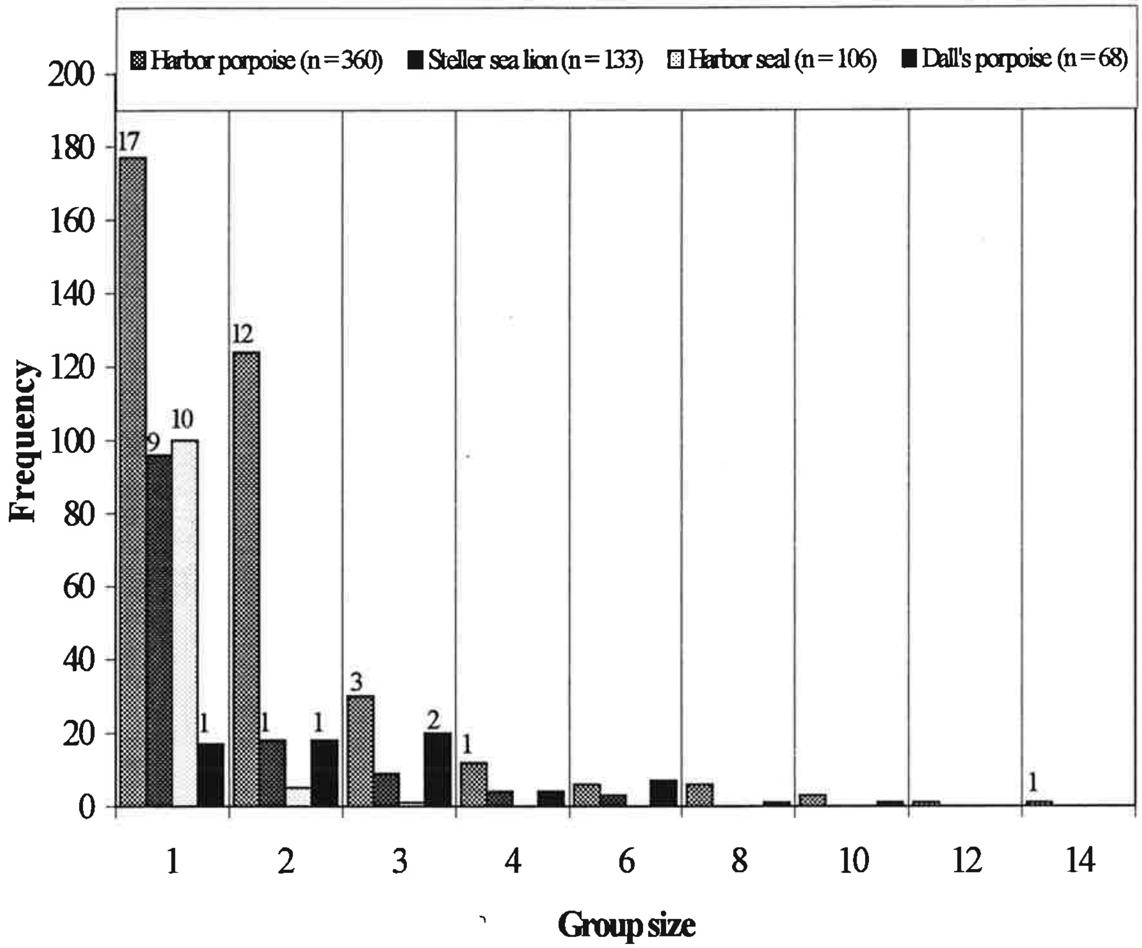

Figure 6. Histogram of group size for commonly observed species(n>50): harbor porpoise, Steller sea lion, harbor seal, and Dall's porpoise.

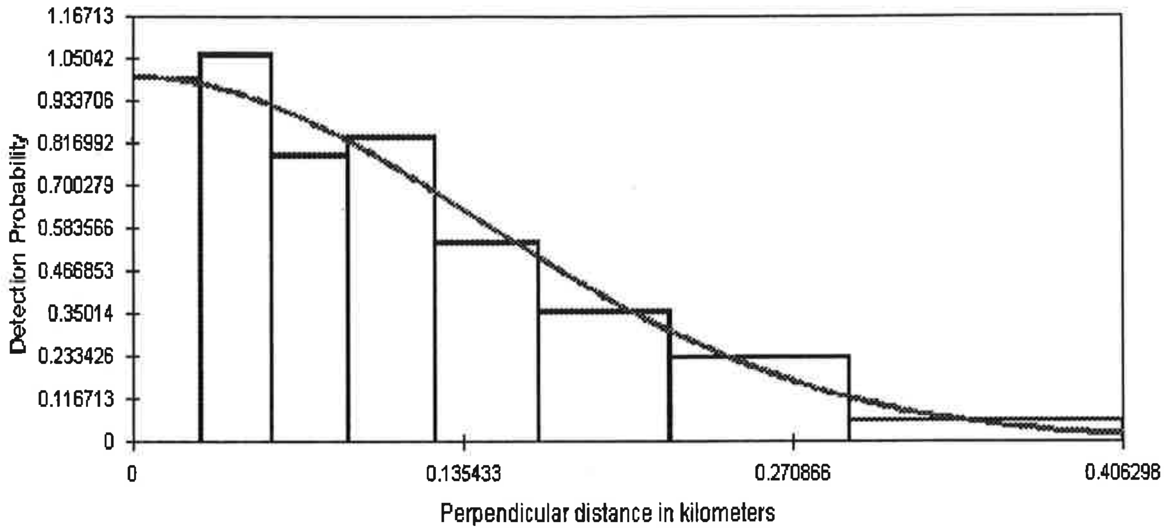

Figure 7. Fitted half-normal detection curve overlayed on histogram of perpendicular distances to harbor porpoise groups detected during 1997 survey in good weather conditions.

Table 1. Summary of the 1997 aerial surveys and time expenditures by day.

Survey		Depature time			Arrival time			Time (d-hours)	
date	Regions surveyed or attempted	Airport*	Eng. on	Take off	Airport	Landing	Eng. off	Taxi	Flight
15 Aug	Practice flight	HQM	14:37	14:47	HQM	15:28	15:38	0.01	1.02
	Region II	HQM	17:01	17:06	HQM	18:14	18:23	0.01	1.37
16 Aug	Regions II and I	HQM	10:21	10:31	AST	13:41	13:46	0.01	3.42
	Region I	AST	15:09	15:17	HQM	15:53	15:55	0.01	0.77
17 Aug	Region I	HQM	8:18	8:30	PA	10:43	10:46	0.01	2.47
	Region I	PA	11:56	12:02	PA	16:13	16:18	0.01	4.37
	Ferry to Hoquiam from PA	PA	17:07	17:12	HQM	17:55	17:58	0.01	0.85
19 Aug	Region II	HQM	11:11	11:19	AST	12:05	12:09	0.01	0.97
	Aborted after attempting Region II	AST	14:21	14:28	HQM	15:04	15:08	0.01	0.78
21 Aug	Regions II and III	HQM	12:50	12:59	HQM	18:39	18:43	0.01	5.88
22 Aug	Regions II and III	HQM	7:35	7:46	TLMK	9:08	9:11	0.01	1.60
	Aborted after attempting Region III and II	TLMK	18:06	18:15	HQM	19:05	19:09	0.01	1.05
29 Aug	Regions II, III, IV, V and VI	HQM	9:51	10:01	COOS	14:34	14:36	0.01	4.75
30 Aug	Regions V and VI	COOS	7:22	7:34	COOS	12:35	12:37	0.01	5.25
1 Sep	Region VI	COOS	9:03	9:12	COOS	12:45	12:49	0.01	3.77
	Region IV	COOS	13:43	13:50	COOS	14:58	15:03	0.01	1.33
2 Sep	Aborted after attempting Region IV	COOS	7:59	8:08	COOS	8:26	8:28	0.01	0.48
	Regions IV and III	COOS	9:46	9:58	NWPT	11:25	11:28	0.01	1.70
3 Sep	Region IV	NWPT	8:08	8:18	NWPT	8:49	8:52	0.01	0.73
4 Sep	Region IV	NWPT	7:57	8:10	NWPT	12:41	12:43	0.01	4.77
	Region II	NWPT	13:27	13:36	NWPT	14:57	14:57	0.01	1.50
5 Sep	Region II	NWPT	9:47	9:56	HQM	11:21	11:25	0.01	1.63
6 Sep	Regions II and III	HQM	8:36	8:46	HQM	12:23	12:25	0.01	3.82
	Region II	HQM	13:16	13:24	HQM	16:46	16:49	0.01	3.55
7 Sep	Region II and I	HQM	10:24	10:36	HQM	13:20	13:23	0.01	2.98
	Region II and III	HQM	14:19	14:27	HQM	16:47	16:52	0.01	2.55
8 Sep	Region I	HQM	8:10	8:19	PA	12:33	12:35	0.01	4.42
9 Sep	Region I	PA	17:56	18:05	HQM	20:23	20:26	0.01	2.50
Total flight time								0.25	70.27
Ferry (back to Oxnard, CA)									8
Total hours									78.51

* AST = Astoria; COOS = Coos Bay; HQM = Hoquiam; NWPT = Newport; PA = Port Angeles; TLMK = Tillamook

Table 2. Survey effort (line length) in each replicate by region.

Region	Replicate	Line Length(km)
I	1	418.9
	2	329.8
	3	352.1
	Total	1100.8
II	1	534.3
	2	322.2
	3	303.9
	4	364.2
	Total	1524.7
III	1	388.0
	2	218.9
	3	181.2
	4	168.4
	Total	956.4
IV	1	268.2
	2	240.8
	3	361.9
	Total	870.9
V	1	168.3
	2	124.3
	3	124.6
	Total	417.2
VI	1	183.3
	2	154.9
	3	188.8
	Total	527.1
Grand Total		5397.1

Table 3. Summary of survey effort in each region classified by visibility conditions (Beaufort sea state and cloud cover).

Region	Beaufort	Cloud Cover <=25	>25
I	<=2	849.2	0.0
	>2	251.6	0.0
II	<=2	1149.9	181.0
	>2	172.1	21.6
III	<=2	786.7	73.2
	>2	83.1	13.5
IV	<=2	736.5	51.6
	>2	69.1	13.8
V	<=2	353.1	0.0
	>2	64.1	0.0
VI	<=2	460.7	3.6
	>2	62.8	0.0

Table 4. Number of groups and animals seen by all personnel (including pilot and recorder) during the 1997 aerial surveys.

	On-effort totals			Off-effort totals			Total for all effort		
Species	Groups	Animals	Calves/pups	Groups	Animals	Calves/pups	Groups	Animals	Calves/pups
Harbor porpoise	360	693	79	66	181	14	426	874	93
Dall's porpoise	68	185	15	8	22	2	76	207	17
Steller sea lion (+hauled)	130 (3)	190 (300)	0	6 (1)	6 (8)	0	136 (4)	196 (308)	0
Harbor seal (+hauled)	106 (1)	113 (3)	1	19 (2)	21 (355)	0	125 (3)	134 (358)	1
California sea lions	30	44	0	9	15	0	39	59	0
N elephant seal	9	9	0	0	0	0	9	9	0
N fur seal	1	1	0	0	0	0	1	1	0
Humpback	8	23	0	12	24	2	20	47	2
Gray whale	10	10	0	11	15	0	21	25	0
Killer whale	1	16	0	0	0	0	1	16	0
Minke whale	1	1	0	2	2	0	3	3	0
Risso's dolphin	0	0	0	4	503	4	4	503	4
N right whale dolphin	0	0	0	1	15	0	1	15	0
Pacific white-sided dolphin	0	0	0	2	387	0	2	387	0
Sea otter	3	5	0	0	0	0	3	5	0
Leatherback turtle	7	7	0	1	1	0	8	8	0
Unidentified otariid	11	11	0	1	2	0	12	13	0
Unidentified pinniped	2	2	0	1	2	0	3	4	0
Unidentified large whale	2	2	0	2	4	0	4	6	0
Total (all categories)	749 (4)	1312 (303)	95	145 (3)	1200 (363)	22	894 (7)	2512 (666)	117

Table 5. Mean group size by region and species for good weather (25% cloud cover or less and Beaufort 2 or less). Results includes all non-hauled animals sighted by the three primary observers (PP - harbor porpoise, PD - Dall's porpoise, EJ - Steller sea lion, PV - harbor seal).

Region	PP	n	PD	n	EJ	n	PV	n
I	1.60	40	2.14	22	1.00	4	1.07	15
II	1.65	125	2.00	5	1.00	7	1.07	41
III	1.71	35	2.00	5	1.73	15	1.08	13
IV	2.52	62	3.42	19	1.17	30	1.10	10
V	2.10	20	2.40	5	1.18	17	1.13	8
VI	2.38	37	3.80	5	1.73	42	1.00	7
TOTAL	1.93	319	2.67	61	1.44	115	1.07	94

Table 6. Summary statistics and harbor porpoise density and abundance estimates for 1997 survey data collected when Beaufort sea state < 3 and cloud cover ≤ 25% (W = 0.406 km).

Stratum	Area (km^2)	L (km)	n	n/L	cv(n/L)	$\bar{s}$	cv($\bar{s}$)	D_s	cv(D_s)	D	cv(D)	N_u	cv(N_u)	N_c	cv(N_c)
IE	1459	111.3	8	0.071	0.36	1.75	0.14	0.20	0.37	0.35	0.39	517	0.39	1771	0.54
IN	5440	329.9	25	0.076	0.24	1.48	0.07	0.21	0.24	0.32	0.25	1717	0.25	5880	0.44
IS	5053	408.0	10	0.025	0.33	1.70	0.15	0.07	0.33	0.12	0.36	593	0.36	2031	0.51
II	7424	1004.3	116	0.115	0.14	1.65	0.04	0.35	0.15	0.54	0.16	3974	0.16	13610	0.40
IIF	6100	145.6	4	0.027	0.40	1.75	0.27	0.08	0.40	0.14	0.49	826	0.49	2829	0.61
III	3668	601.2	35	0.058	0.23	1.69	0.12	0.16	0.23	0.28	0.26	1013	0.26	3469	0.43
IIIF	4397	185.5	0	0.000	-	-	-	0.00	-	0.00	-	0	-	0	0.37
IV	6884	736.5	61	0.083	0.17	2.49	0.12	0.23	0.18	0.58	0.22	3999	0.22	13695	0.43
V	1735	247.3	18	0.073	0.32	2.61	0.26	0.20	0.32	0.53	0.41	928	0.41	3178	0.55
VF	2119	105.8	3	0.028	0.59	1.33	0.25	0.08	0.59	0.11	0.64	226	0.64	774	0.74
VI	2246	396.3	37	0.093	0.29	2.38	0.15	0.26	0.29	0.62	0.32	1404	0.32	4808	0.49
VIF	1671	64.4	1	0.016	1.03	1.00	-	0.04	1.03	0.04	1.03	73	1.03	250	1.09
Total	48198	4336.1	318									15270	0.10	52295	0.38
WA/OR	41299	3894.9	285									13036	0.11	44644	0.38

A PRELIMINARY ANALYSIS OF THE DIVING BEHAVIOR OF DALL'S PORPOISE IN THE TRANSBOUNDARY WATERS OF BRITISH COLUMBIA AND WASHINGTON

Robin W. Baird[1] and M. Bradley Hanson[2]

[1] Department of Biology
Dalhousie University
Halifax, Nova Scotia
Canada, B3H 4J1

[2] National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington 98115

Abstract

Suction-cup attached time-depth recorder (TDR)/VHF radio tags were used to study the diving behavior of Dall's porpoise (*Phocoenoides dalli*) in the transboundary waters of British Columbia and Washington State. Three tags were deployed on captured animals in 1997, for a total of 23.5 hours of TDR data. Each porpoise exhibited a bimodal distribution of time spent in dives of different durations, generally representing shallow inter-ventilation dives (< 0.67 minutes), and longer, deeper dives which likely function for foraging. We used the low point in this bimodal distribution (approximately 0.67 minutes) to separate these dive types. Median dive durations and depths for these longer dives ranged from 1.33 to 1.85 minutes and from 22 to 33 m, though maximum dive duration was 5.63 minutes, and maximum dive depth was recorded as 236 m (at the limits of the instruments used). Maximum dive depth was estimated to be 278 m, based on extrapolation of dive profiles. Bottom depths in areas where the tagged animals were documented typically ranged between 100 to 300 m. Predicted potential maximum diving ability for this species, based on the maximum dive duration and maximum rates of descent and ascent recorded for deep dives, was 409 m. The individuals spent between 34 and 58% of their time in the top 10 m of the water column during daylight hours, with time spent in the top 2 m being highly variable between the individuals (from 5 to 39%). This represents the first empirical data on the diving behavior of this species, but the inter-individual differences suggest that a larger sample size is necessary to accurately characterize sub-surface behavior.

Introduction

Cetaceans spend the vast majority of their time beneath the water's surface, where they are difficult to observe and study. Knowledge of the duration of dives, diving patterns, and proportion of time spent in the upper portions of the water column are all required in calibration of surveys for estimating abundance (Laake et al. 1997). Determining diving patterns in relation to habitat or at night is important for assessing exposure to depth-specific threats (such as fishing gear or high-intensity underwater sounds), as well as for defining critical habitats and evaluating behavioral features such as night-time foraging rates. Methods for examining cetacean diving behavior are not well developed, and thus relatively little is known regarding their subsurface activities.

Dall's porpoise are generally thought to be a deep-diving species, although actual depths of dives have not been reported. This perception seems to be based on several factors: 1) they are generally distributed off-shore over deep water; 2) the occurrence of deep-water fish in stomach contents; 3) more massive skeletal musculature than other small cetaceans; 4) high blood-oxygen content; and 5) a relatively higher heart weight than other species (Ridgway 1966; Morejohn 1979; review in Jefferson 1988). We have begun a study of the diving behavior of Dall's porpoise in the transboundary waters of British Columbia and Washington State, an area where they are fairly common (Baird and Guenther 1994) and regularly approach vessels to bow-ride. Virtually nothing is known of the biology of Dall's porpoise in that area.

Time-depth recorders (TDRs) have been used with several species of small cetaceans to study habitat use and sub-surface behavior (e.g., Martin and Smith 1992; Scott et al. 1993; Baird 1994, 1998; Martin et al. 1994, Westgate et al. 1995; Davis et al. 1996). The incorporation of TDRs into radio tags allows for detailed collection of data on sub-surface activities, specifically proportion of time spent at different depths in the water column, depth of dives, dive "shape" or profile, and rates of ascent and descent. On small cetaceans, such tags have been deployed either by using captured or stranded animals and surgically attaching tags, or by remotely attaching tags to free-ranging animals using suction-cups. Capture operations can be both difficult and expensive, and they run a risk of injuring or killing animals. Deploying tags by remote methods can also be difficult. Crossbow deployed suction-cup tags often bounce off (Baird 1994), and their large size necessitates a close application range. Deployments by pole also have a limited range and are essentially restricted to species that bow-ride, or to larger, slower moving species that can be approached closely. On small cetaceans, remotely deployed suction-cup tags have been applied to a few species, including killer whales (*Orcinus orca*), Hector's dolphins (*Cephalorhynchus hectori*), belugas (*Delphinapterus leucas*), short-finned pilot whales (*Globicephala macrorhynchus*), northern bottlenose whales (*Hyperoodon ampullatus*), Dall's porpoise, and bottlenose dolphins (*Tursiops* sp.) (Baird 1994, 1998; Stone et al. 1994; Lerczak 1995; Baird and Amano, unpubl. data; Hooker and Baird, unpubl. data; Hanson and Baird 1998; Schneider et al. 1998).

In this study, we applied suction-cup attached TDR/VHF tags to three Dall's porpoise for periods ranging from 2 hours and 51 minutes to 13 hours and 13 minutes, using tags deployed on captured animals. The purpose of this report is to present a preliminary analysis of selected aspects of the diving behavior of these three individual Dall's porpoise. A more detailed and thorough analysis will be forthcoming.

Methods

Tags used in this study were the same tags used on killer whales (Baird et al. 1998), short-finned pilot whales (Baird and Amano, unpubl. data), and northern bottlenose whales (Hooker and Baird, unpubl. data). Tags (total weight from 340 to 380 g) were composed of an 8 cm diameter black rubber suction-cup (available from Canadian Tire, Canada - used for automobile roof racks and removing dents from automobile fenders) attached with flexible plastic tubing (allowing the tag to swivel) to a flattened, oval tag body constructed of syntactic foam, and covered with a thin layer of plastic. The tag contained a time-depth recorder (TDR model Mk6, Wildlife Computers, Redmond, WA USA, with a 236 m depth capacity, at 1 m depth resolution), and a VHF transmitter with a 44 cm custom-built flexible wire antennae. To facilitate recovery of the tags, a custom-built magnesium release system (designed by J. Goodyear) was incorporated into the suction-cup, limiting the maximum duration the tag would remain attached. The inner surface of the suction-cup was coated with silicone grease (Dow Corning 111 valve lubricant and sealant) prior to tagging attempts. The tag was designed to float upright after detaching from an animal, with the antennae clear of the water's surface. The TDR had three sensors which were activated, a pressure (depth) sensor, a velocity sensor, and a salt-water switch. The accuracy of the pressure sensor was previously tested by subjecting the TDR to known pressures using a pressure chamber, and comparing the depth readings measured by the TDR. The sampling rates for the sensors were set at once per second for depth and once per five seconds for velocity.

Tagging activities were based out of Friday Harbor, Washington, and were undertaken in the U.S. waters of northern Haro Strait (off Turn Point, Stuart Island). When weather conditions permitted, we traveled through the study area in a 7 m boat looking for Dall's porpoise in areas of known abundance (see Baird and Guenther 1994). When porpoise were sighted, the vessel was slowed and maneuvered in the direction of the animals. Tags were deployed on porpoise which were captured with a break-away hoop-net, and temporarily restrained. All animals also had VHF radio tags surgically attached to the dorsal fin. Details on the surgically attached tags and data collected on movement patterns can be found in Hanson et al. (1998, this volume). Upon release, the tagged animals were tracked for periods of between 45 and 90 minutes, as they moved through the transboundary waters of northern Haro Strait and Boundary Pass. Information on location, behavior, and the presence of other Dall's porpoise with the tagged animals were noted.

Upon tag retrieval, data were downloaded to a laptop computer in a hexadecimal format. Data were processed with several programs provided by the TDR manufacturer: *Minimum-Maximum-Mean Ver. 1.17* was used to convert the raw data from hexadecimal to an ASCII listing; *Zero-Offset-Correction Ver. 1.26* was used to correct temperature-related drift in the depth readings so that the start and end points of dives could be accurately determined; and the zero-offset-corrected file was run though the program *Dive-Analysis Ver. 4.08* to calculate dive statistics. These were: time of dive onset, duration of dive, maximum depth of dive, time spent at "bottom" of dive (defined as 85% of the maximum depth of the dive), and the average rates of descent and ascent (defined as the period from the start of the dive to the point where 85% of the maximum depth was first reached, or from the last point which was at 85% of the maximum depth, to the end of the dive, respectively).

For animals the size of Dall's porpoise, using TDRs with only 1 m resolution and using *Dive-Analysis* to determine dive durations, a bias towards longer and deeper dives likely occurs. During a surfacing bout, when performing only short (4 or 5 second) inter-ventilation dives, a tagged animal may stay within the top meter or two of the water column, thus producing erroneous "dive" records, or missing dives. "Dives" determined through *Dive-Analysis* as shorter than three seconds were deleted from the data set, as such short duration inter-breath intervals are extremely rare for Dall's porpoise (P.M. Willis, pers. comm., Simon Fraser Univ., Burnaby, B.C., Canada). To produce a continuous visual representation of dives, the program *Strip-Chart Ver. 3.03* was used to plot all depth and velocity data.

For dives where depth exceeded the maximum recording limits of the units (236 m), maximum depth was estimated by extrapolating the dive profile for the descent and ascent, until these two points intersected. Deep dives (e.g., 200-230 m) of this species were typically V-shaped, thus such extrapolation likely gives a realistic estimate of the maximum depth obtained in these dives. The time of sunset was used to differentiate between dives during the day and at night. Using the highest average rates of descent and ascent during long dives, and the maximum dive duration, we have calculated the maximum dive depth that could potentially be reached during a V-shaped dive.

Results and Discussion

Three TDR tags were deployed on Dall's porpoise in 1997 in Haro Strait (Fig. 1), yielding a total of 23.5 hours of time-depth information (Table 1). As well as the data collected from a 41 minute deployment on a free-ranging animal in 1996 (Hanson and Baird 1998), this represents the first empirical data on Dall's porpoise sub-surface behavior.

We present the cumulative amount of time each individual spent engaged in dives of different durations in Figure 2. This measure is less "observer-centric" (i.e., more representative of what the animal actually experiences) than are frequency distributions of dive durations. The distribution of cumulative time spent in dives of different durations were generally bimodal for all three porpoises (Fig. 2). We have used the approximate minimum value between the two modes (ie., 0.67 minutes) to discriminate between "short" and "long" dives. The peak in dives less than 0.67 minutes in duration primarily appears to represent short-duration shallow dives while the animal is near the surface for gas exchange (termed inter-ventilation dives). The longer duration peak represents deeper dives which probably function primarily for foraging. The relative spread in duration values seen for individual 97-01 (Fig. 2) is likely due to the small sample size available for that individual. Measures of central tendency for each mode were calculated using 0.67 minutes as the cutoff between short and long dives. Summary statistics for dives of each animal are presented in Table 2. Median duration of long dives ranged between 1.33 and 1.85 minutes for the three individuals. Maximum dive duration recorded was 5.63 minutes. The median of the maximum depths for long dives ranged between 22 and 33 m for the three individuals. Maximum dive depth was recorded as 236 m (at the limits of the instruments used), but was estimated to be 278 m, based on extrapolation of dive profiles. Bottom depths in areas where the tagged animals were documented typically ranged between 100 and 300 m (Fig. 1), thus tagged animals were likely diving close to, or to the bottom, at least occasionally. Predicted potential maximum diving ability for this species, based on the maximum dive duration and maximum rates of descent and ascent recorded for deep dives, was 409 m. Dall's porpoise may reach a length of 220 cm (Jefferson 1988), and all three animals tagged in this study were relatively small (Table 1), thus larger Dall's porpoise can likely dive longer, and thus deeper (cf. Schreer and Kovacs 1997).

Information on the proportion of time spent in the top portion of the water column can provide important information for calibration of aerial survey data. The proportion of time spent at different depths in the water column for each individual during daylight hours is shown in Figure 3, with a detailed breakdown for distribution within the top 10 m of the water for each individual (also during daylight hours) shown in Figure 4. All individuals spent a substantial amount of time in the top 10 m of the water column (34.6-58.6%; Fig. 3), but within the top 10 m there was considerable variability between the three individuals (4.9-38.9% of their time in the top 2 m; Fig. 4). However, there is some temperature-related drift in the values recorded by the depth sensor, such that when an animal moves through strongly temperature-stratified waters, the value recorded at the surface may actually read at 1 or 2 m depth. Reanalyses of these data using values corrected for this temperature shift (using the *Zero-Offset-Correction* program) will be undertaken at a later date.

A substantial amount of variability exists in the subsurface behavior between individual Dall's porpoise such that a larger sample size of individuals is necessary to accurately characterize the diving behavior of this species, taking into account differences in gender, body size (or age), location (or habitat), seasonal variability, behavior, and potential diurnal patterns. Subsequent to this study, additional dive data have been collected from two more individuals, and will be presented in a future report.

Acknowledgments

We would like to thank the following for assisting with tagging and/or tracking: Artur Andriolo, Jeff Foster, Nolan Harvey and William Walker. We would also like to thank Marilyn Dahlheim (National Marine Mammal Laboratory), and Dave Duffus (University of Victoria) for providing some of the tagging and tracking equipment. Pam Willis and Chris Malcolm constructed the tag body. Melinda Braun and Roger Hill (Wildlife Computers) answered numerous questions regarding the TDR, as well as about downloading and analyzing data. RWB was supported during this project by a post-doctoral fellowship from the Natural Sciences and Engineering Research Council of Canada (NSERC). This research was undertaken in U.S. waters under permit No. 782-1349 issued by the National Marine Fisheries Service. Sascha Hooker provided comments on the manuscript.

Citations

Baird, R.W. 1994. Foraging behaviour and ecology of transient killer whales (*Orcinus orca*). Ph.D Thesis, Simon Fraser University, Burnaby, B.C. Canada. 157 p.

Baird, R.W. 1998. Studying diving behavior of whales and dolphins using suction-cup attached tags. Whalewatcher 31(1):3-7.

Baird, R.W., and T.J. Guenther. 1994. Status of porpoises in the British Columbia/Washington trans-boundary area: a Canadian perspective. Puget Sound Notes 34:5-8.

Baird, R.W., P.M. Willis, T.J. Guenther, P.J. Wilson, and B.N. White. 1998. An intergeneric hybrid in the family Phocoenidae. Can. J. Zool. 76:198-204.

Davis, R.W., G.A.J. Worthy, B. Wursig, S.K. Lynn, and F.I. Townsend. 1996. Diving behavior and at-sea movements of an Atlantic spotted dolphin in the Gulf of Mexico. Mar. Mammal Sci. 12:569-581.

Hanson, M.B., and R.W. Baird. 1998. Dall's porpoise reactions to tagging attempts using a remotely-deployed suction-cup tag. Mar. Technol. Soc. J. 32: in press.

Hanson, M.B., R.W. Baird, and R.L. DeLong. 1998. Movements of tagged Dall's porpoises in Haro Strait, Washington (this volume). Pp. 111-120, in P.S. Hill, B. Jones, and D.P. DeMaster (eds.), Marine Mammal Protection Act and Endangered Species Act implementation program 1997. AFSC Processed Rep. in press. Available Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE, BIN C15700, Seattle WA 98115-0070.

Jefferson, T.A. 1988. *Phocoenoides dalli*. Mamm. Species 319:1-7.

Laake, J.L., J. Calambokidis, S.D. Osmek, and D.J. Rugh. 1997. Probability of detecting harbor porpoise from aerial surveys: estimating $g(0)$. J. Wild. Manage. 61:63-75.

Lerczak, J.A. 1995. Radio-tagging of belugas in Cook Inlet, Alaska, June, 1994. Unpubl. doc. submitted to Int. Whal. Commn. (SC/47/SM9).

Martin, A.R., and T.G. Smith. 1992. Deep diving in wild, free-ranging beluga whales, *Delphinapterus leucas*. Can. J. Fish. Aquat. Sci. 49:462-466.

Martin, A.R., M.C.S. Kingsley, and M.A. Ramsay. 1994. Diving behaviour of narwhals (*Monodon monoceros*) on their summer grounds. Can. J. Zool. 72:118-125.

Morejohn, G.V. 1979. The natural history of Dall's porpoise in the North Pacific Ocean. Pp. 45-83 in H.E. Winn and B.L. Olla (eds.), Behavior of Marine Animals, Volume 3: Cetaceans. Plenum Press, New York.

Ridgway, S.H. 1966. Dall porpoise, *Phocoenoides dalli* (True): observations in captivity and at sea. Norsk Hvalfangst-Tidende 5:97-110.

Schneider, K., R.W. Baird, S. Dawson, I. Visser, and S. Childerhouse. 1998. Reactions of bottlenose dolphins to tagging attempts using a remotely-deployed suction-cup attached tag. Mar. Mammal Sci. 14:316-324.

Schreer, J.F., and K.M. Kovacs. 1997. Allometry of diving capacity in air-breathing vertebrates. Can. J. Zool. 75:339-358.

Scott, M.D., S.J. Chivers, R.J. Olson, and R.J. Lindsay. 1993. Radiotracking of spotted dolphins associated with tuna in the eastern tropical Pacific. P. 97 in Abstracts of the Tenth Biennial Conference on the Biology of Marine Mammals, Galveston, TX, November 11-15, 1993.

Stone, G.S., J. Goodyear, A. Hutt, and A. Yoshinaga. 1994. A new non-invasive tagging method for studying wild dolphins. Mar. Technol. Soc. J. 28:11-16.

Westgate, A.J., A.J. Read, P. Berggren, H.N. Koopman, and D.E. Gaskin. 1995. Diving behaviour of harbour porpoises, *Phocoena phocoena*. Can. J. Fish. Aquat. Sci. 52:1064-1073.

Table 1. Details on tagged Dall's porpoise

Tagging number	Date	Sex	Size	Total duration	Daytime duration
97-01	05/20/97	M	159 cm	2 h, 51 min	2h, 51 min
97-02*	05/25/97	F	164 cm	7 h, 27 min	1h, 34 min
97-03	05/26/97	F	169 cm	13 h, 13 min	2h, 49 min
Total				23 h, 31 min	7 h, 14 min

* This animal was atypically pigmented, and is believed to be a hybrid between a Dall's porpoise and harbor porpoise (see Baird et al. 1998). A tissue sample was collected for genetic analysis, to be undertaken by P.M. Willis, Simon Fraser University.

Table 2. Summary of dive characteristics for tagged Dall's porpoise

Tagging number	Dive category[a]	Number of dives	Dive depth (median, range)	Dive duration (median, range)
97-01	short	203	3 (2-16)	0.10 (0.05-0.57)
	long	59	24 (6-197)	1.85 (0.68-5.63)
97-02	short	1102	2 (2-29)	0.08 (0.05-0.66)
	long	157	33 (4-236[b])	1.35 (0.71-3.63)
97-03	short	1856	2 (2-27)	0.08 (0.05-0.67)
	long	297	22 (6-236[c])	1.33 (0.68-4.02)

a) "Short"dives were those less than 0.67 minutes, "long" dives were those greater than 0.67 minutes; b) This is the maximum depth capacity of the meters used. The estimated maximum dive depth for individual 2 was calculated as 278 m. The tag detached from the animal during the ascent from this dive (at 152 m depth), thus this final dive duration is not included in the range. The extrapolated duration of this dive, assuming a constant rate of ascent, was approximately 4.8 minutes; and c) The extrapolated maximum depth for individual 97-03 was calculated as 270 m.

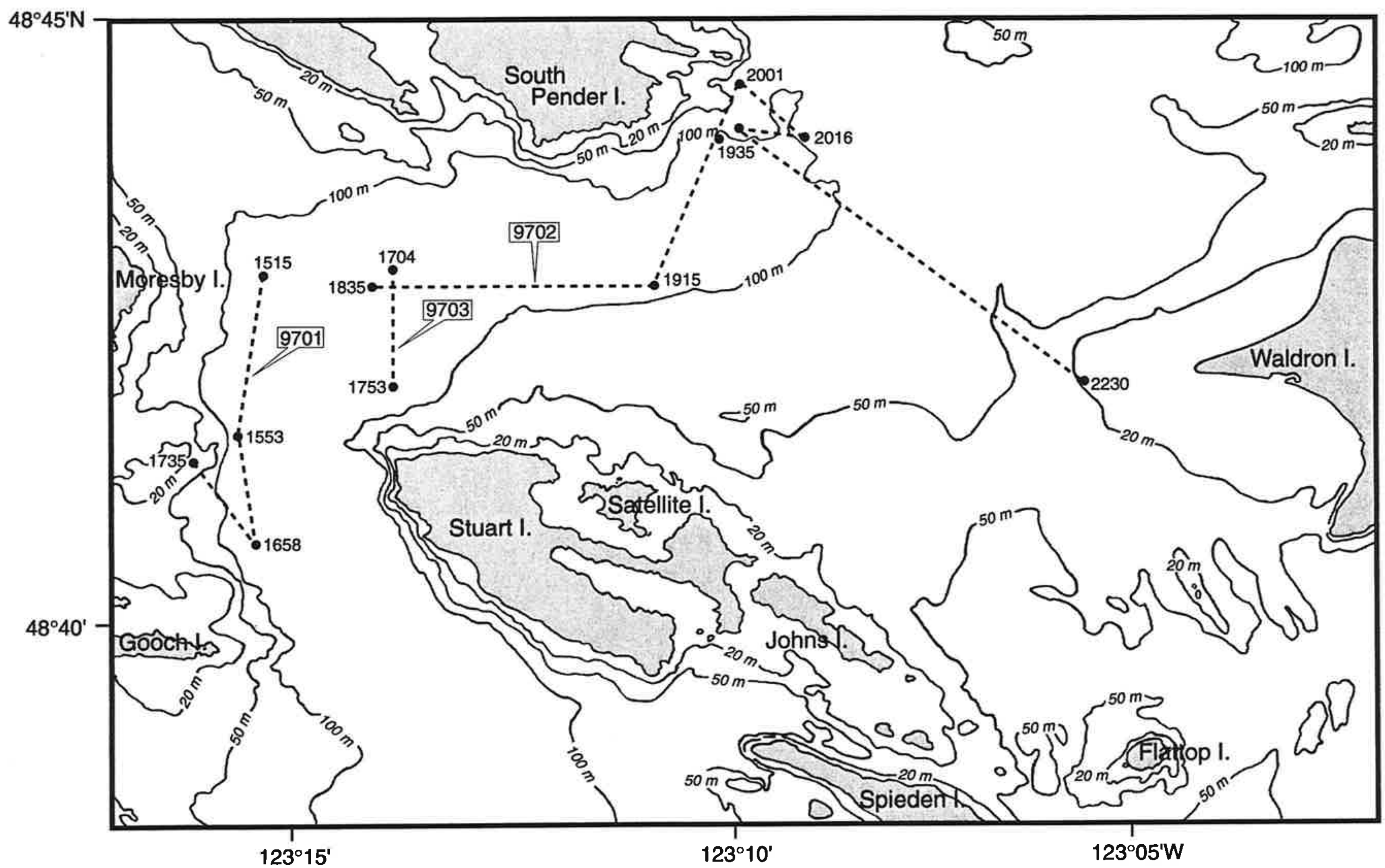

Figure 1. Movements of Dall's porpoise during tracking while suction-cup Time-Depth Recorder (TDR) was attached.

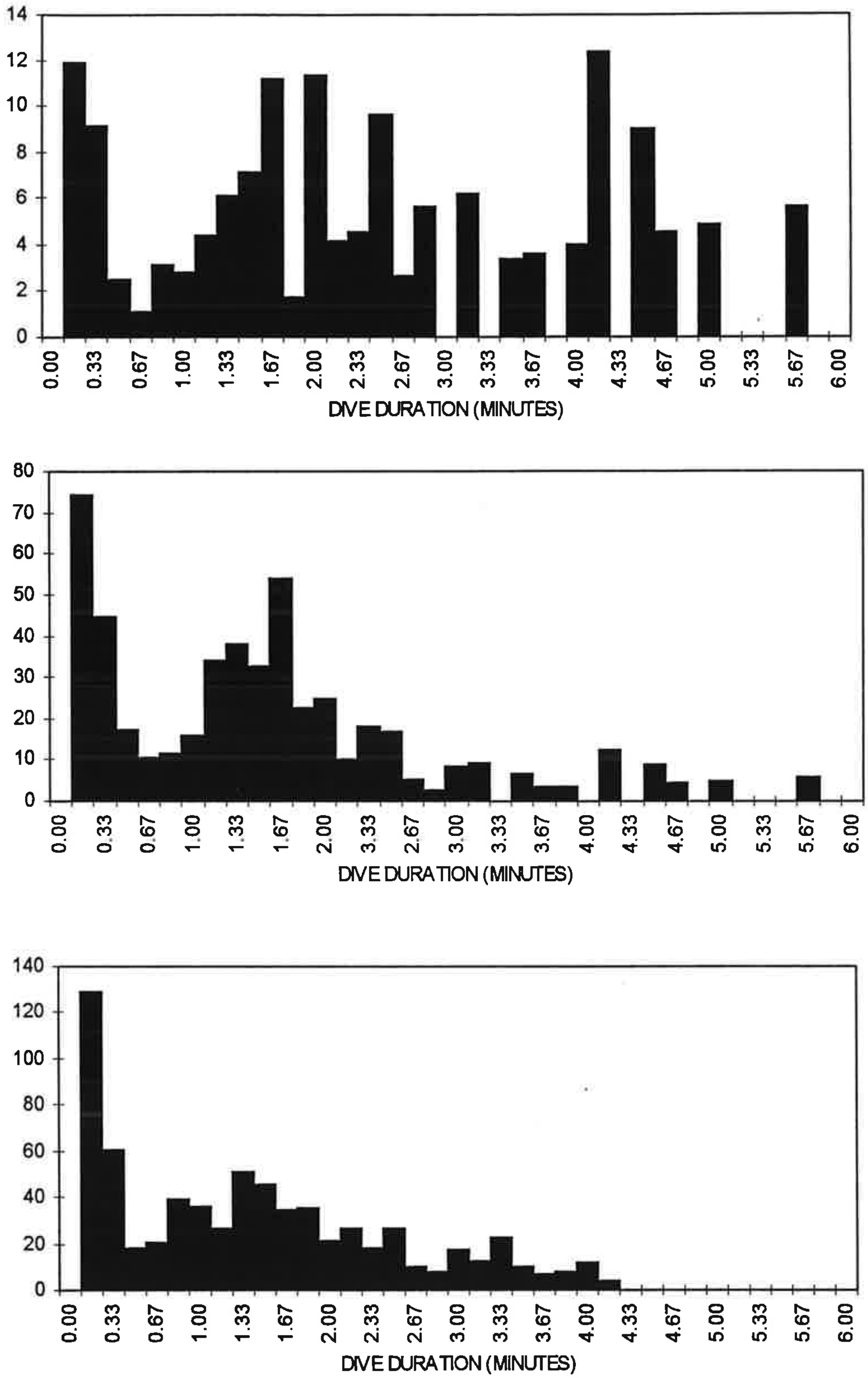

Figure 2. Cumulative amount of time (in minutes) spent in dives for 97-01 (top), 97-02 (middle) and 97-03 (bottom).

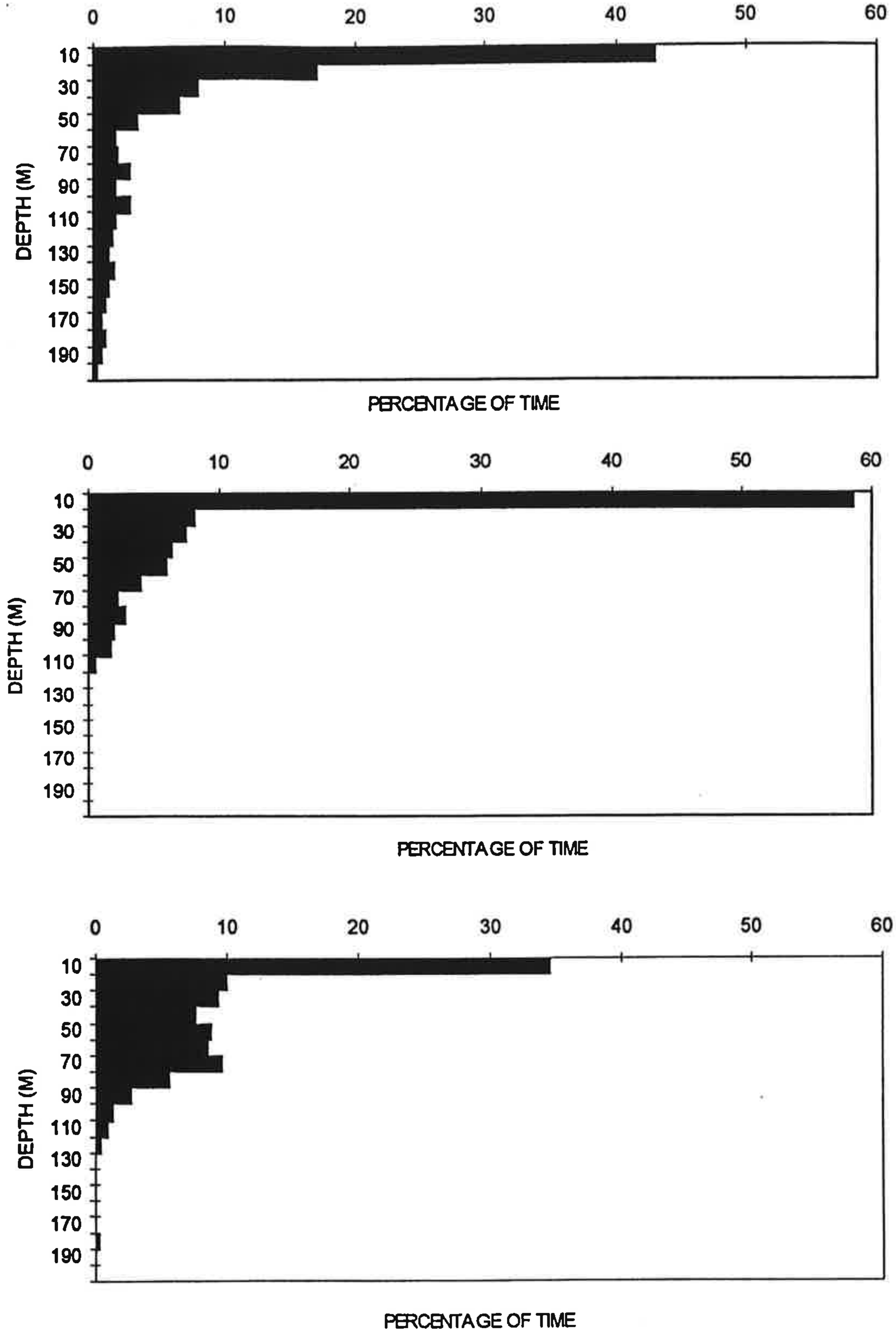

Figure 3. Proportion of time spent at depth during daylight hours for Dall's porpoises 97-01 (top), 97-02 (middle), and 97-03 (bottom).

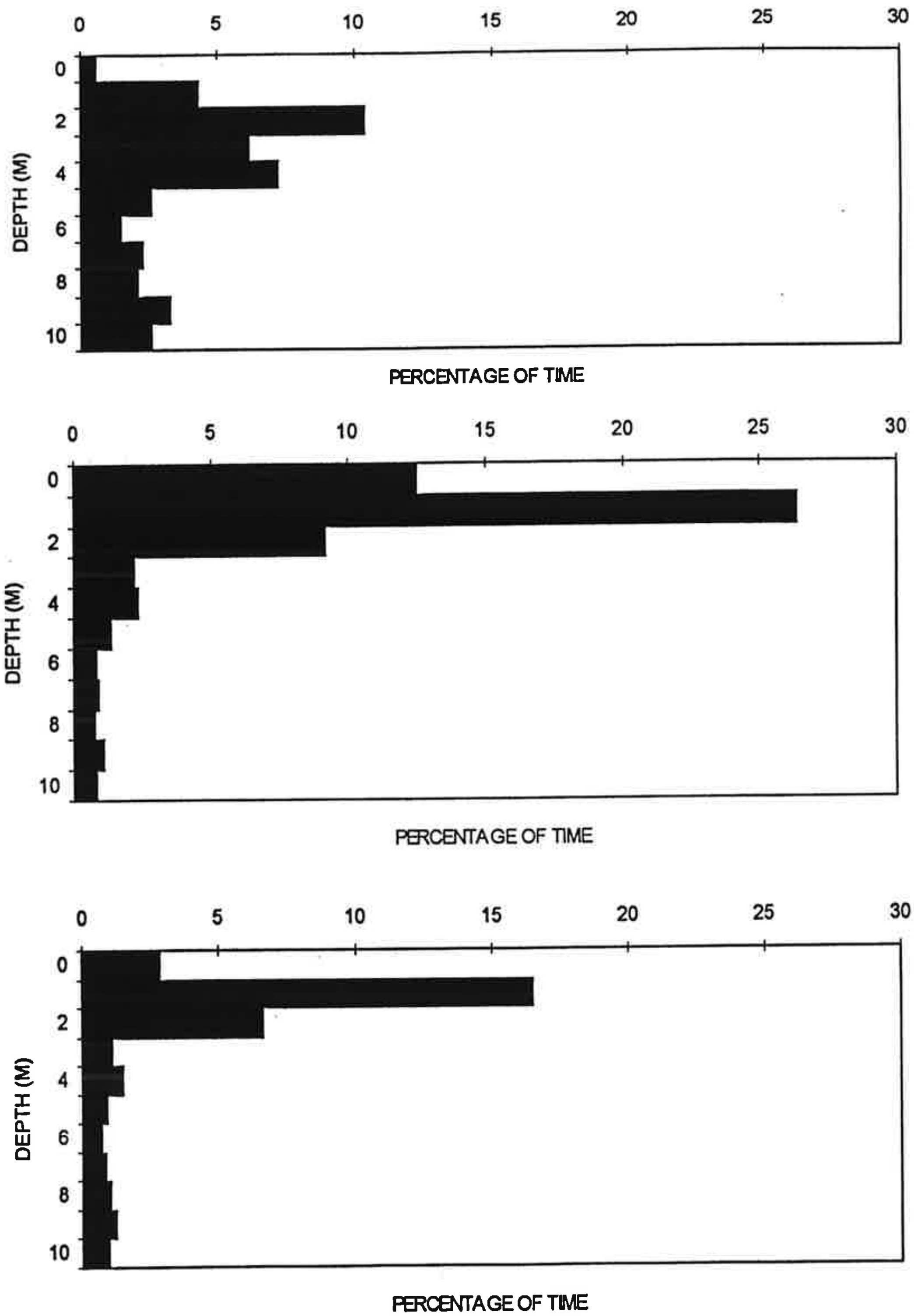

Figure 4. Proportion of time spent in the top 10 m of the water column during daylight hours for Dall's porpoises 97-01 (top), 97-02 (middle), and 97-03 (bottom).

MOVEMENTS OF TAGGED DALL'S PORPOISES IN HARO STRAIT, WASHINGTON

M. Bradley Hanson[1], Robin W. Baird[2], and Robert L. DeLong[1]

[1] National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington 98115

[2] Department of Biology
Dalhousie University
Halifax, Nova Scotia
Canada, B3H 4J1

Abstract

Movements of cetaceans tagged with telemetry packages can provide important information for assessing stock structure and habitat use. Dall's porpoises (*Phocoenoides dalli*) are common in Haro Strait (Washington State), but little is known about the biology of this species in the region. During May 1997, five Dall's porpoises were live-captured using a breakaway hoop-net. Two of the animals were released within several minutes and three were retained for tagging and processed in a stretcher that kept the animal partially immersed. While this capture technique has been used on this species before, the processing technique is believed to reduce capture stress, thereby minimizing the probability of capture-related mortality. Each of the three retained animals had two hydrodynamically efficient VHF transmitters attached to its dorsal fin, the first tag attachment of this type on this species. Transmitter signals were received for three to seven days for each animal, indicating the animals remained within a 25 km stretch of Haro Strait and Boundary Pass, although localized movements of several kilometers occurred within a few hours. Aerial searches of the waters of northern Washington and southern British Columbia subsequent to signal loss failed to pick up any transmitter signal. This suggests transmitter failure, which may be associated with the extreme dive depths, or failure of the attachment system due to forces associated with this species' relatively high swim speed. Despite a dedicated resighting effort in their known range spanning approximately four months post-signal loss, the tagged animals were not resighted. A report of a tagged Dall's porpoise 60 km southwest of the capture site in mid-October suggests extended movements outside this area.

Introduction

A fundamental component of population assessment under the Marine Mammal Protection Act is identifying population stocks. Stock discrimination has been an ongoing effort in several U.S. small cetacean populations (e.g., eastern North Pacific harbor porpoise, Barlow et al. 1997, western North Atlantic harbor porpoise, and southeastern US/Gulf of Mexico bottlenose dolphins, Blaylock et al. 1995). Populations can be subdivided from information on distribution and movements, population trends, or differences in morphology, genetics, contaminants or natural isotope loads, parasites, or habitat (Dizon et al. 1992, Perrin and Brownell 1994). While differences in genetic and morphological data might imply low rates of interchange between subunits, it cannot be concluded that a lack of difference means that the rate of interchange is high enough to be demographically significant (Dizon et al. 1992, Taylor and Dizon 1996). Consequently, if stocks are inappropriately pooled because differences were not detected, some subunits could be adversely impacted by incidental take.

Population subunit interchange of these species can be investigated directly by monitoring seasonal movements of animals instrumented with telemetry devices. Because seasonal movements are important in determining interchange, attachment durations on the order of months are necessary. Additionally, this technique can provide important information on movements and distribution relative to potential sources of anthropogenic take.

Various species of small cetaceans in the United States have been tagged with a variety of telemetry devices over the last 25 years (see Scott et al. 1990), and although Dall's porpoises have been captured (Ridgway 1966, Walker 1975) this species has never had tags attached for long-term monitoring (see Hanson and Baird 1998 for an example of short-term tag attachments). Although Dall's porpoise are common in Washington coastal and inland waters (Everitt et al. 1980), little is known about their movements (see Miller 1990). The purpose of this study was to develop a reliable system for capturing Dall's porpoise that minimized stress, to deploy hydrodynamically efficient tags with a six-month service life to evaluate tag design and attachment system, as well as to monitor Dall's porpoise movements.

Methods

In May 1997, the inland waters of Washington State near the San Juan Islands were transited to find Dall's porpoise, using a 7 m vessel with a 1 m bow platform extension. Using a breakaway hoop-net tethered to the capture vessel, Dall's porpoise were captured while bow riding on the research vessel (See Ridgway 1966, Walker 1975, Asper 1975). The hoop was approximately 0.7 m in diameter and the net was constructed of 5 cm stretch-mesh knot-less nylon. As the porpoise surfaced next to the bow to breathe, the hoop was quickly placed in front of the animal such that it swam through the hoop, detaching the net (which surrounded the animal's body back to just behind the dorsal fin). The additional drag of the net slowed the animal substantially, but the design allowed the animal to still use its flukes to reach the surface to breath. Approximately 25 m of line was attached from the net to the capture vessel to allow retrieval. Animals were maneuvered into a sling alongside the capture vessel and then transferred to a frame supported on each side by two small boats, similar to the porpoise chute system successfully used on Eastern Tropical Pacific dolphins (Perrin et al. 1979). This system allows the animal to be partially supported in the sling by the water while the tag is attached. Instrument attachment was conducted as quickly as possible in order to minimize stress. Stress was monitored by timing the animal's respirations and observing other behaviors.

A pair of VHF tags were attached to the dorsal fin. Each transmitter was powered by a 10 by 35 mm lithium battery and was pulsed at 150 ppm, with an expected service life of 180 days (using a saltwater switch). The transmitter (with a 40 cm long, 0.4 cm rigid stainless steel wire antenna) had a range of approximately 8 km, using a 4 element Yagi antenna mounted on the capture vessel. Each transmitter, measuring 7.6 cm long × 1.9 cm in diameter, was potted in a urethane fairing that also doubled as the attachment saddle (Hanson 1998, this volume), and the total unit weighed approximately 90 g. Although package weight needs to be considered and was minimized in the tag design, this burden is likely inconsequential due to the buoyancy provided by the marine environment. It is likely that hydrodynamic drag is more important to aquatic animals (Wilson et al. 1986). Based on a review of drag of streamlined shapes (Hoerner 1965), and wind tunnel testing, a hydrodynamically efficient shape was developed that added only 12% more drag, for a pair of these tags attached to a harbor porpoise model in a wind tunnel (Hanson 1998, this volume).

Both tags were attached with three 6 mm diameter Delrin pins, threaded on both ends with a 6 mm nut. After the tags were positioned on the fin, 18 gauge needles were inserted through the fin to serve as alignment guides for the pin holes, as well as to test for the presence of major blood trunks. Attachment pin holes were made with a tool similar to a laboratory cork borer, which had been cold sterilized. High carbon nuts secured next to a stainless steel flat washer acted as a corrodible link to ensure that the package freed itself from the animal after the batteries were exhausted. Porpoises also had suction-cup attached time depth recorder tags placed on them prior to release (see Baird and Hanson 1998, this volume).

Animals were initially followed for several hours to monitor condition, and on subsequent days were located opportunistically while other capture operations were conducted. Respiration data were also collected opportunistically by monitoring a radio receiver from land (on Mt. Dallas, San Juan Island), and using a custom program running on a laptop computer, by entering the number of radio signal pulses at each surfacing into the computer, which was then time stamped. Dive duration was calculated from the time difference between respiration events.

Results

Five Dall's porpoises were captured near Turn Point, Stuart Island, Haro Strait. Three were retained for tagging and two were deemed unsuitable for tagging (due to excessive activity) and were safely released. One of the retained porpoises was a sub-adult male and the other two appeared to be adult females (Table 1). All animals appeared to be in good health and tag attachments were accomplished in 23 to 37 minutes. Porpoise 97-02 was unusual in pigmentation and body form. Although it associated with and behaved like a Dall's porpoise (rooster-tailing and bowriding), its physical appearance was more similar to a harbor porpoise. The body pigmentation was uniform gray, dorsally and ventrally, with only a faint gape to flipper stripe. The body form was less robust than a Dall's porpoise, and dorsal fin shape was like that of a harbor porpoise.

Tagged porpoises were relocated almost daily during the 3-7 days that they appeared to remain in the Haro Strait/ southern Boundary Pass area after tagging (Table 1, Fig. 1). Based on daily monitoring during this time they moved extensively throughout the area. They were highly mobile, covering substantial distances (12 km/hour) within short periods of the day, although rates of 2.2 km/hour to 5.2 km/hour were more typical.

Signals were lost from all individuals by 31 May (one of the two transmitters failed within minutes after deployment on both porpoise 97-01 and 97-02). Aerial monitoring flights conducted on 1 and 4 June throughout the inland and coastal waters of Washington and British Columbia failed to pickup any signals. During approximately 319 hours of observations over 62 days in Haro Strait between 6 June and 2 October, none of the approximately 2,350 Dall's porpoises observed were tagged or showed any evidence of having been tagged. Although detailed analysis of the sighting data have not been conducted, there appeared to be a decreasing trend in porpoise abundance over the monitoring period. Although none of the tagged animals were observed in the Haro Strait area during resighting effort, a Dall's porpoise with a "light-colored" tag on its dorsal fin was reported to have been observed off Becher Bay, southwest of Victoria, British Columbia, in mid-October.

Surfacing data were collected for 1.6 hours on 31 May from porpoise 97-02. During this time it surfaced 353 times. The distribution of dive times was bimodal, with no dive durations between 0.33 and 1.00 minutes. Two hundred and ninety-nine dives shorter than 0.33 minutes, and 54 dives longer than one minute, were documented. The median was 1.68 minutes for the long duration dives and 0.09 minutes for short duration dives. Approximately 8.5% of the animal's time was spent at the surface.

Discussion

Few Dall's porpoises had been captured prior to this study. In these cases, acute signs of stress were manifested in several of the captured animals (Walker 1975). However, as noted by Walker (1975), lowering these animals back into the sea appeared to calm them such that keeping these animals partially submerged during the processing phase of this study likely aided in minimizing capture stress.

The unusually pigmented porpoise captured (97-02) is thought to have been a Dall's/harbor porpoise hybrid, based on the intermediate morphology and behavioral characteristics, and the fact that hybridization between these two species has been documented in this area (Baird et al. 1998). Genetic analyses will be conducted on tissue samples collected from this animal in cooperation with Pam Willis, Simon Fraser University. Although gray color phase animals have been reported from other areas (California, Morejohn et al. 1973; Alaska, Hall 1981), the frequency of these unusually pigmented animals appears to be high in the Haro Strait area. On several days, 1-3 different gray individuals were observed during resighting efforts and on one day 4-5 individuals were observed. The implications of these observations on the stocks of Dall's and harbor porpoise in this area is unclear, but may be related to mate availability (Baird et al. 1998).

The lack of signals in the aerial monitoring and the resighting of a tagged animal (off Becher Bay) suggests that instrument failure, rather than tag loss, was the most likely cause of signal loss. Although incorporation of the saltwater switch appeared to be a desirable power saving mechanism, it is most likely the source of the transmitter failure. Consequently, such a design feature should not be included without further testing, or other options, such as programmable chips that turn the tag off for specified intervals, should be considered.

The lack of resightings also suggests movement by the tagged animals out of the area. However, it should be noted that based on observations of tagged animals during tracking, they could be extremely difficult to detect visually, either with binoculars or unaided, particularly when other animals are in the area at the same time. Dall's porpoises are widely distributed in the nearshore, slope, and offshore temperate waters of the north Pacific Ocean (Morejohn 1979), and based on the low resighting rate of identifiable individuals in Puget Sound, Miller (1990) also suggested that a high interchange rate was occurring between areas. The decreasing sighting rate over the course of the summer and the resighting of a tagged animal to the west of the primary study area also suggests a seasonal movement out of the Haro Strait area, most likely into the Strait of Juan de Fuca or farther west. Although Dall's porpoise are present in the inland waters year-round (Everitt et al. 1980), changes in sighting patterns from recent aerial and shipboard surveys of the coastal waters suggest north-south movements between states that occur on a seasonal or inter-annual basis (see Barlow et al. 1997); movement to offshore waters in winter/spring was also speculated (Green et al. 1992). Deployment of satellite-linked transmitters will be required to address this question.

Despite a substantial effort to resight individually marked animals, this effort was unsuccessful. The resightability of the tagged individual Dall's porpoises may be limited due to the inconspicuous nature of this species, such that resighting efforts for tagged individuals of this species is likely of limited value.

The median dive duration for long dives was longer than the TDR data recorded for that animal in the first few hours immediately after release (Baird and Hanson 1998, this volume), but it is within the range of other observations. Such differences are likely due to the small sample sizes. Taken together, these data suggest a large degree of individual variation in time near the surface. Monitoring VHF signals has the potential to provide a large amount of surfacing data that will be useful for determining correction factors for aerial surveys.

Acknowledgments

We would like to thank the following for assisting with tagging and/or tracking: Artur Andriolo, Jeff Foster, Nolan Harvey and William Walker. RWB was supported during this project by a post-doctoral fellowship from the Natural Sciences and Engineering Research Council of Canada (NSERC). This research was undertaken in U.S. waters under permit No. 782-1349 issued by the National Marine Fisheries Service. Jeff Laake skillfully wrote the computer program to collect respiration data. Pam Willis, Chris Malcolm, and their field assistants conducted a substantial amount of the resighting effort.

Citations

Asper, E.D. 1975. Techniques of live capture of smaller Cetacea. J. Fish. Res. Board. Can. 32:1191-1196.

Baird, R.W., and M.B. Hanson. 1998. A preliminary analysis of the diving behavior of Dall's porpoise in the transboundary waters of British Columbia and Washington (this volume). Pp. 99-110 in P.S. Hill, B. Jones, and D.P. DeMaster (eds.), Marine Mammal Protection Act and Endangered Species Act implementation program 1997. AFSC Processed Rep. in press. Available Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE, BIN C15700, Seattle WA 98115-0070.

Baird, R.W., P.W. Willis, T.J. Guenther, P.W. Wilson, and B.N. White. 1998. An intergeneric hybrid in the family Phocoenidae. Can. J. Zool. 76:198-204.

Barlow, J., K.A. Forney, P.S. Hill, R.L. Brownell, Jr., J.V. Carretta, D.P. DeMaster, F. Julian, M.S. Lowry, T. Ragen, and R.R. Reeves. 1997. U.S. Pacific marine mammal stock assessments: 1996. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SWFSC-248, 223 p.

Blaylock, R.A., J.W. Hain, L.J. Hansen, D.L. Palka, and G.T. Waring. 1995. U.S. Atlantic and Gulf of Mexico marine mammal stock assessments. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SEFSC-363, 211 p.

Dizon, A.E., C. Lockyer, W.F. Perrin, D.P. DeMaster, and J. Sisson. 1992. Rethinking the stock concept: a phylogeographic approach. Conserv. Biol. 6:24-36.

Everitt, R.D., C.H. Fiscus, and R.L. DeLong. 1980. Northern Puget Sound marine mammals. DOC/EPA Interagency Energy Research and Development Program, EPA-600/7-80-139, Washington D.C. 134 p.

Green, G.G., J.J. Brueggeman, C.E. Bowlby, R.A. Grotefendt, M. L. Bonnell, and K.C. Balcomb III. 1992. Cetacean distribution and abundance off Oregon and Washington, 1989-1990. Final Rept. by Ebasco Environmental and Ecological Consulting Inc. for the Minerals Management Service, Pacific OCS Region. OCS Study MMS 91-0093. 100 p.

Hall, J.D. 1981. Aspects of the natural history of cetaceans of Prince William Sound, Alaska. Ph.D. Thesis, Univ. California, Santa Cruz. 148 p.

Hanson, M.B. 1998. Design considerations for telemetry tags for small cetaceans (this volume). Pp. 37-49 in P.S. Hill, B. Jones, and D.P. DeMaster (eds.), Marine Mammal Protection Act and Endangered Species Act implementation program 1997. AFSC Processed Rep. in press. Available Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE, BIN C15700, Seattle WA 98115-0070.

Hanson, M.B., and R.W. Baird. 1998. Dall's porpoise reactions to tagging attempts using a remotely-deployed suction-cup attached tag. Mar. Tech. Soc. J. 32(2):8-23.

Hoerner, S. F. 1965. Fluid-dynamic drag. Published by the author. Bricktown, New Jersey, v.p.

Miller, E.J. 1990. Photo-identification techniques applied to Dall's porpoise (*Phocoenoides dalli*) in Puget Sound, Washington. M.S. Thesis, Univ. Washington. 96 p.

Morejohn, G.V. 1979. The natural history of the Dall's porpoise in the North Pacific Ocean. Pp. 45-83, in H.E. Winn and B.L. Olla (eds.), Behavior of Marine Mammals, Vol. 3: Cetaceans. Plenum Press, New York.

Morejohn, G.V., V. Loeb, and D.M. Baltz. 1973. Coloration and sexual dimorphism of the Dall's porpoise. J. Mammal. 54:977-982.

Perrin, W.F. , and R.L. Brownell, Jr. 1994. A brief review of stock identity in small marine cetaceans in relation to assessment of driftnet mortality in the North Pacific. Rep. Int. Whal. Comm. Spec. Iss. 15:393-401.

Perrin, W.F. , W.E. Evans, and D.B. Holts. 1979. Movements of pelagic dolphins, (*Stenella* spp.) in the eastern tropical Pacific as indicated by results from tagging with a summary of tagging operations, 1969-1976. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-737.

Ridgway, S.H. 1966. Dall porpoise, *Phocoenoides dalli* (True):observations in captivity and at sea. Norsk Hvalfangst-Tidende 55:97-110.

Scott, M.D., R.S. Wells, A.B. Irvine, and B.R. Mate. 1990. Tagging and marking studies on small cetaceans. Pp. 489-514, in S. Leatherwood and R.R Reeves (eds.), The Bottlenose Dolphin, Academic Press, San Diego.

Taylor, B.L. and A.E. Dizon. 1996. The need to estimate power to link genetics and demography for conservation. Conserv. Biol. 2:661-664.

Walker, W.A. 1975. Review of the live-capture fishery for smaller cetaceans taken in southern California waters for public display. J. Fish. Res. Board Can. 32:1197-1211.

Wilson, R.P., W.S. Grant, and D.C. Duffy. 1986. Recording devices on the free-ranging marine animals: does measurement affect foraging performance? Ecology 67:1091-1093.

Table 1. Details on Dall's porpoises radio-tagged in Haro Strait, Washington.

Porpoise	Capture date	Sex	Length (cm)	Age class	Handling time (minutes)	Number of locations	Number of days in study area (minimum)
97-01	20 May 1997	M	159	Sub-adult	37	7	3
97-02	25 May 1997	F	164	Adult	33	18	7
97-03	26 May 1997	F	169	Adult	24	7	5

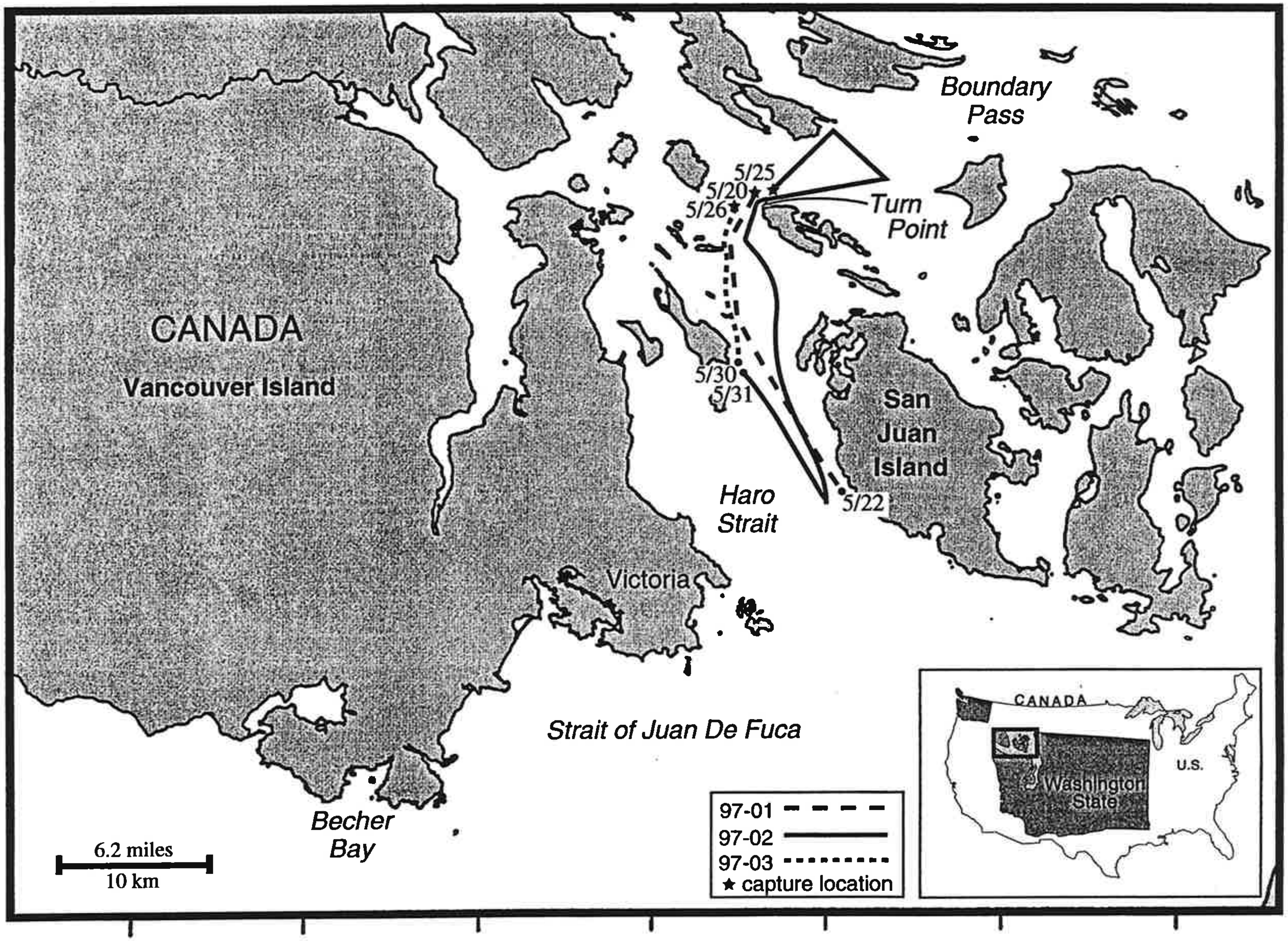

Figure 1. Movements of radio-tagged Dall's porpoises.

EVALUATION OF HARBOR PORPOISE HABITUATION TO PINGERS IN A SET GILLNET FISHERY

Jeffrey L. Laake, Patrick J. Gearin, Merrill E. Gosho, and Robert L. DeLong

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington 98115

Abstract

Experimental field tests of acoustic pingers on nets in the Makah tribal fishery in northern Washington during 1995 and 1996 have demonstrated dramatic decreases in the incidental mortality of harbor porpoise. The experimental nets were alternately fished with and without pingers which led us to question whether pingers in continual use would remain effective throughout the normal 6-8 week fishing season or whether harbor porpoise would habituate and begin to ignore the acoustic barrier. Between 3 July and 16 August 1997, four 100-fathom set gillnets were continually fished with pingers attached. Between 27 June and 14 August 1997, observers stationed on a cliff overlooking the nets systematically scanned the region around the northernmost net for harbor porpoise and recorded the position of any porpoise seen at the surface. We observed an increase in porpoise entanglement in the second half of the study, but the overall entanglement probability was not significantly higher than for nets with pingers in 1995 and 1996. We observed very few porpoise in the vicinity of the nets prior to deployment of the pingers and a gradual reduction in the approach distance of porpoise. Unfortunately this trend could easily reflect choice of foraging area and may be completely independent of the pinger usage. The results of the 1997 study are equivocal relative to harbor porpoise habituation to pingers; however, the study did demonstrate that with continual use of pingers for over 6 weeks the porpoise entanglement rate (1 porpoise per 15 net days) was much lower than nets without pingers in 1995 and 1996 (1 porpoise per 2 net days). Pingers were not 100% effective, but clearly they have been very effective in reducing mortality in this fishery with historically high levels of mortality.

Pinger Mortality Studies

Four 100 fathom (183m) set gillnets were fished between 3 July and 16 August 1997 in the Spike Rock Fishery Area, at the northwestern edge of the Olympic National Park in Washington State. During the entire fishing season, each net was equipped with 11 pingers positioned at 16.6 m intervals along the corkline. The pingers produced a broadband signal with peaks at 3 and 20 kHz, with overall source levels between 121.7-124.7 dB re 1 micropascal at 1 m. The nets were typically checked daily unless weather conditions compromised safety. Defective pingers were replaced when the nets were checked.

With 88 net days (22 days with 4 nets) during 3-24 July, one harbor porpoise was entangled and with 92 net days during 25 July - 16-August eleven porpoise were entangled in 9 of the net days (2 porpoise were caught on two different occasions). The probability that one or more porpoise entangled was significantly greater during the second half of the fishing season (Fisher exact test, P = 0.02). However, the 1997 entanglement probability for the entire season was not significantly different than for nets with pingers in 1995 and 1996 ($X^2 = 2.5$, df = 2, P = 0.29) (Table 1).

Table 1. Number of net days with pingers attached in which entanglement did or did not occur for 1995-97.

	One or more porpoise entangled		
Year	Yes	No	Total
1995	1	50	51
1996	1	60	61
1997	10	170	180

Harbor Porpoise Observations

Observations of harbor porpoise at the Spike Rock Fishery Area were made during 27 June - 14 August 1997 from an exposed bluff south of Portage Head. Initially between 27 June and 2 July, we used the 1996 observation site at 48°16'31"N, 124°40'44"W (Laake et al. 1998) which had been chosen in 1996 as a compromise between visibility and enabling communication with the acoustic field team. Beginning 3 July, we moved to a site about 280 m to the north (48°16'39"N, 124°40'48"W) which had been used in a previous study of harbor porpoise distribution in this region (Dave Rugh, NMML, pers comm.). From this site, we had a larger field of view (Fig. 1) which contained the field of view at the initial site. Also, the cliff height, was nearly 4 m higher than the 1996 site which offered slightly better precision in measuring the positions of observed harbor porpoise. The cliff height was 49.96 m and was computed using GPS positions to known targets and vertical angles measured with a theodolite (Laake et al. 1998).

An observation team of 3 persons conducted 30-minute systematic watches of the field of view. One observer scanned the inshore area while another scanned the offshore area, and a third person recorded data. Each 2-hour block of time consisted of three 30-minute searches and one 30-minute rest period. At each 30-minute period observers rotated to the next position. Searching was conducted through 7X50 binoculars (Fujinons), which have a 5.44° optical field of view with 14 vertical reticle marks (17' per reticle mark) and 16 horizontal reticle marks (not used). An internal magnetic compass provided 360° bearings, accurate to within 3°. The search consisted of a systematic, continuous scan horizontally across the survey area, swinging the binocular from right to left or left to right, but not back and forth, at 7-8 minutes per scan. During the watch the visibility conditions were subjectively rated on a scale of 1-5 with 1 being ideal. Typically, search was terminated when visibility conditions were rated as a 5. The primary determinants of visibility included fog, glare and sea state. Daily observations typically began at 0700 if visibility conditions allowed and ended at 1500. Afternoon glare typically precluded observations in the afternoon unless there was sufficient cloud cover.

For each observed harbor porpoise surfacing, we recorded the bearing and the binocular reticle (interpolated to the nearest tenth). Using the cliff height and position, we computed the distance to the observation and the latitude and longitude of the observation. Using the GPS position of net No. 12, we computed the closest distance between the surfacing and net No. 12 (note this net was in a similar position as net No. 10 in 1996), which was closest to the observation site.

During the 49 day period, 180 hours of observations were conducted on 43 days with 0.5 to 6 hours per day. There were 3,488 harbor porpoise surfacings recorded with 0 to 379 recorded per day. For each day, we computed the closest approach distance of any harbor porpoise (Table 2). We used a Wilcoxon signed-rank test to compare the daily minimum approach distance between three periods: 27 June - 2 July, the first 6 days prior to pinger deployment on the afternoon of 2 July, 3-25 July; the first 19 days of observation (no observations were conducted on 4 days); and 26 July - 14 August, the second 19 days of observation. A histogram of the daily minimum distance (Fig. 2) and plots of the harbor porpoise positions (Fig. 3) both suggest a decreasing trend in the minimum approach distance. The minimum approach distance was significantly closer in Period 3 relative to Periods 1 and 2 ($P = 0.003$, $P = 0.014$) but Periods 1 and 2 were not different ($P = 0.367$).

Unfortunately, harbor porpoise were not seen using the region around net No. 12 prior to pinger deployment. Thus, the trend in the minimum approach distance may be independent of pinger usage. The observational data suggest that the increase in mortality in the second half of the study may have resulted from an increasing trend in porpoise using the area around the nets that may have been independent of pinger usage. The results of the 1997 study are equivocal relative to harbor porpoise habituation to pingers; however, the study did demonstrate that with continual use of pingers for over 6 weeks the porpoise entanglement rate (1 porpoise per 15 net days) was much lower than nets without pingers in 1995 and 1996 (1 porpoise per 2 net days). Pingers were not 100% effective, but clearly they have been very effective in reducing mortality in this fishery with historically high levels of mortality.

Table 2. Daily minimum approach distance to net No. 12 by harbor porpoise.

Period I		Period II		Period III	
Date	Minimum distance (m)	Date	Minimum distance (m)	Date	Minimum distance (m)
6/28/97	418	7/3/97	433	7/26/97	667
6/29/97	433	7/4/97	428	7/27/97	122
6/30/97	572	7/5/97	585	7/28/97	121
7/1/97	676	7/7/97	1763	7/29/97	20
7/2/97	614	7/9/97	1035	7/30/97	34
		7/10/97	510	7/31/97	41
		7/11/97	1237	8/1/97	104
		7/12/97	2130	8/2/97	345
		7/13/97	32	8/3/97	187
		7/15/97	32	8/4/97	334
		7/16/97	149	8/5/97	32
		7/18/97	367	8/6/97	338
		7/19/97	548	8/7/97	346
		7/20/97	366	8/8/97	616
		7/21/97	352	8/9/97	403
		7/22/97	308	8/10/97	82
		7/23/97	227	8/12/97	409
		7/24/97	180	8/13/97	159
		7/25/97	660	8/14/97	228

Citations

Laake, J., D. Rugh, and L. Baraff. 1998. Observations of harbor porpoise in the vicinity of acoustic alarms on a set gill net. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-84, 40 p.

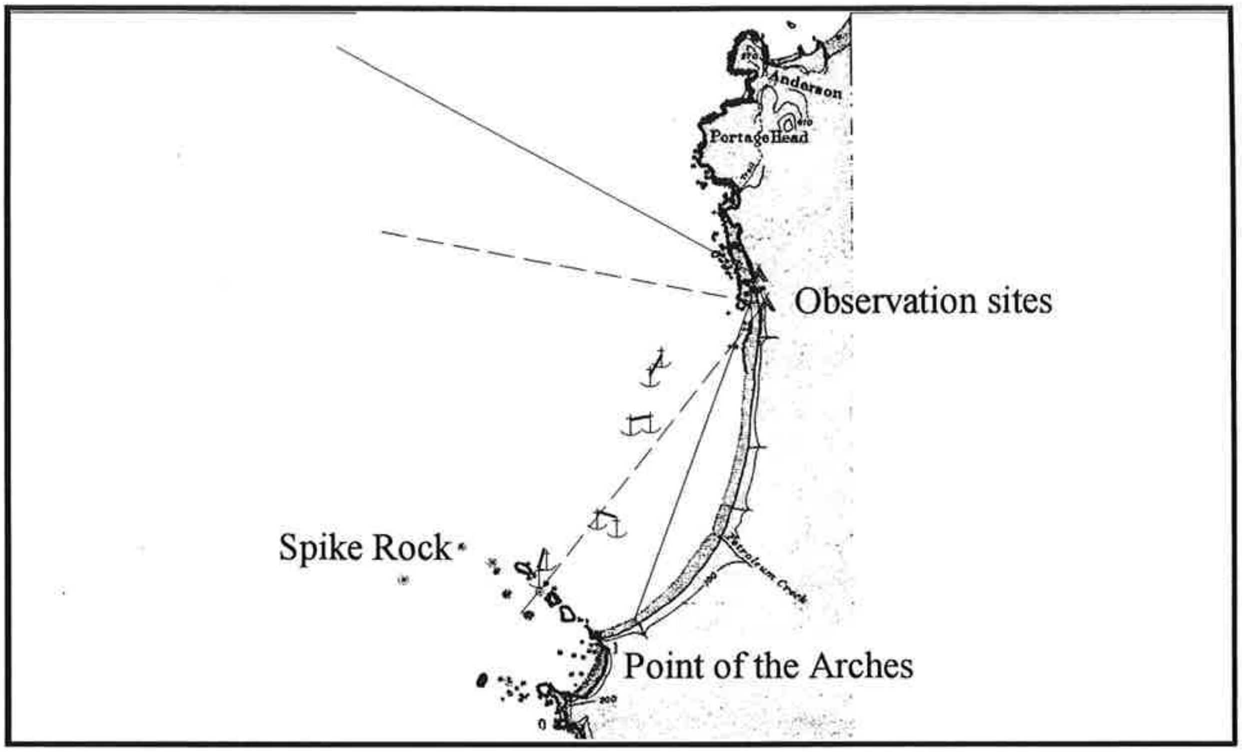

Figure 1. Field of view from 1996 observation site (dashed line) and primary 1997 observation site (solid line). Net positions are indicated by anchors. Positions of harbor porpoise were measured relative to the northernmost net.

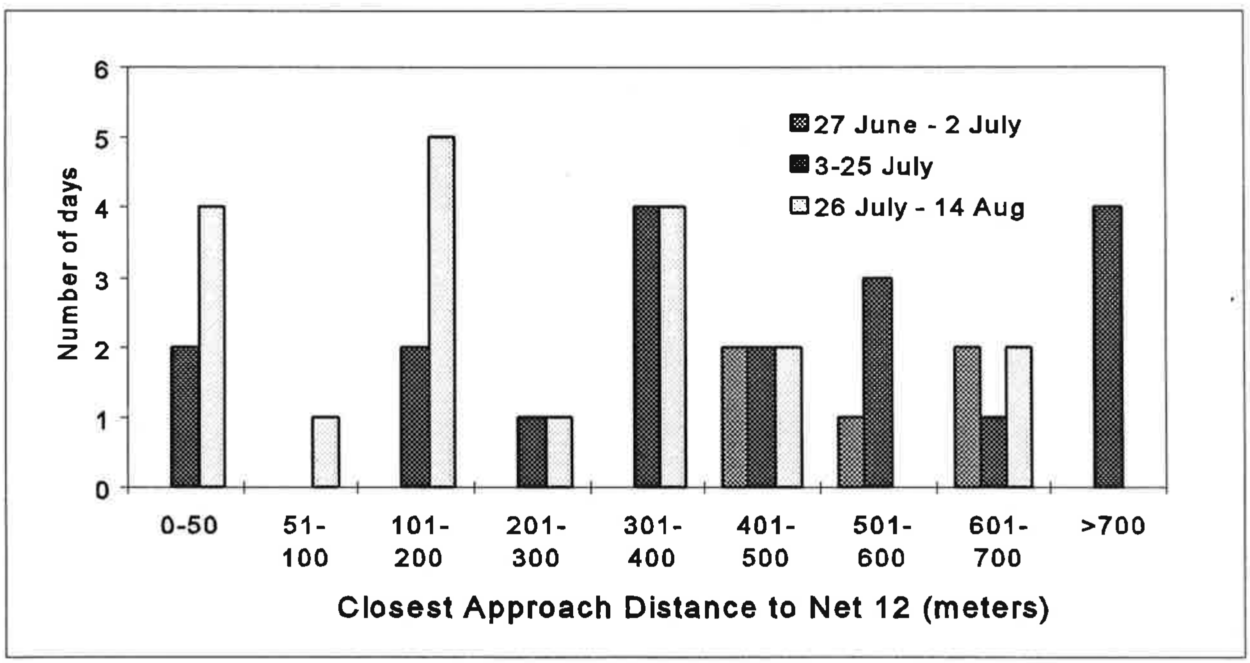

Figure 2. Distribution of daily closest approach distance by harbor porpoise to net No. 12 during the 3 periods.

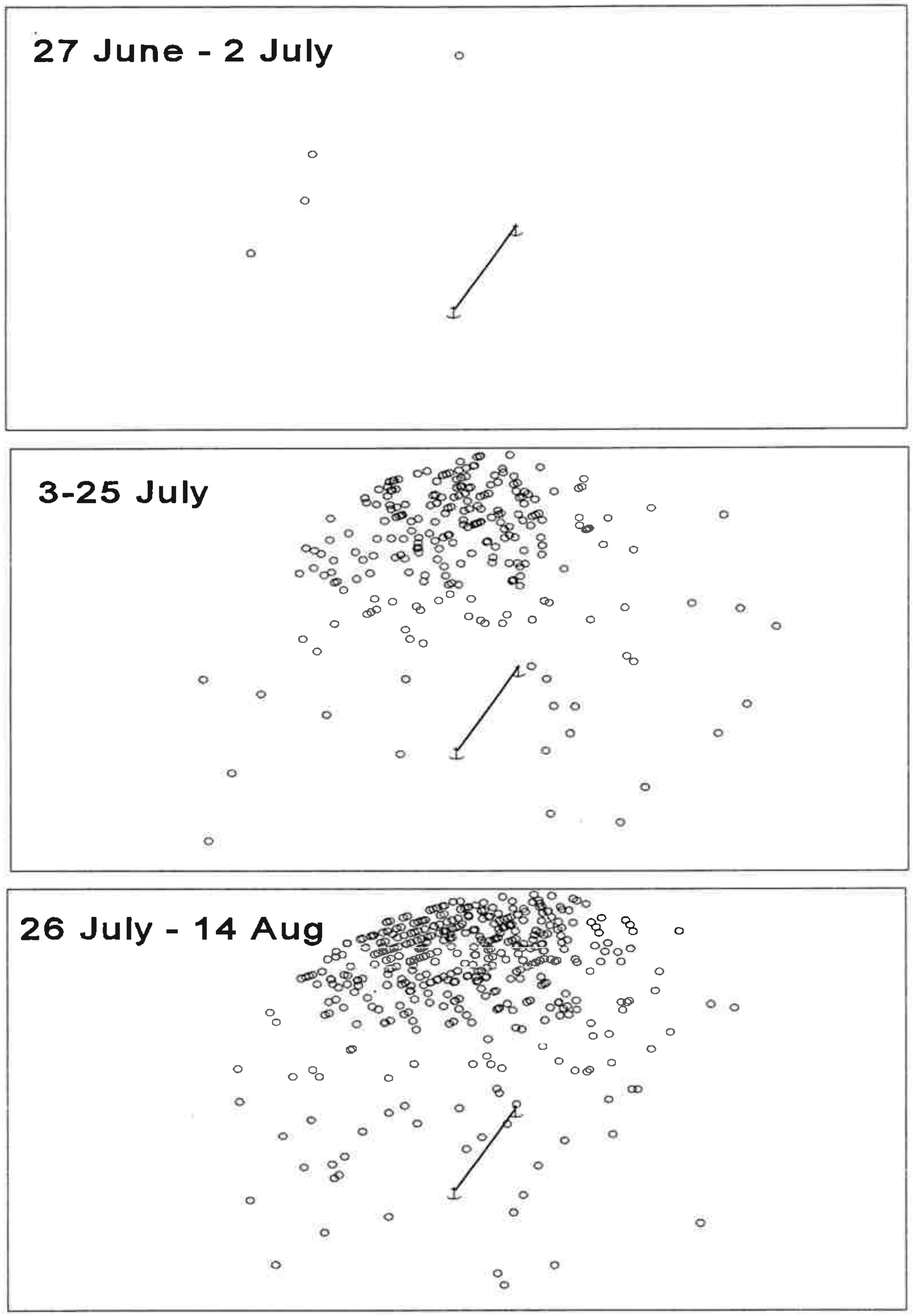

Figure 3. Positions of harbor porpoise sightings within 500 m of the net before pingers were attached (27 June - 2 July), and for 19 observation days between 3-25 July and 19 days between 26 July and 14 August.

ABUNDANCE AND DISTRIBUTION OF HARBOR SEALS (*PHOCA VITULINA RICHARDSI*) FOR NORTHERN SOUTHEAST ALASKA FROM KAYAK ISLAND TO FREDERICK SOUND IN 1997

David E. Withrow and Jack C. Cesarone

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way, NE
Seattle, WA 98115

Abstract

Minimum population estimates were obtained for harbor seals, *Phoca vitulina richardsi*, in the northern portion of Southeast Alaska during August 1997. The mean number of seals counted was 18,933 (95% confidence interval between 18,059 and 19,806). The coefficient of variation (CV) of the mean was equal to 2.35%. Comparisons were made between similar surveys conducted in September of 1993. The 1993 surveys covered the entire southeast Alaska region while the 1997 surveys only censused the portion from Kayak Island to Frederick Sound. More survey aircraft and observers were utilized in the 1997 study and area coverage was much more complete. In 1997, one survey route was censused both in August and September with approximately 2,005 fewer seals (44%) being observed during the September survey. A site-to-site comparison was made for locations where there was a high degree of confidence that sites could be matched correctly. Observers more precisely delineated the location of sites in 1997 than in 1993. Observers recorded seals at 313 sites in 1997 and 130 sites in 1993. Over 11,000 more seals were recorded in 1997 than in 1993. Explanations for the increased number of seals observed include: more complete area coverage, surveys conducted earlier when more seals are expected to haul out and weather is generally better, and the population growth is real and/or seals are immigrating from other areas.

Introduction

Declines in harbor seal abundance have been observed in several locations throughout Alaska (e.g., Pitcher 1990). Recent amendments to the Marine Mammal Protection Act (April 30, 1994, Public Law 103-238) required the Secretary of Commerce to reduce the overall mortality and serious injury to zero marine mammals caught incidental to commercial fisheries. In order to evaluate the status of incidentally caught marine mammals, certain key parameters are required for each stock. These parameters include an estimate of population size and trends, current and net productivity rates, and current takes by commercial fisheries and subsistence hunters. These values are required to determine optimum sustainable levels and allowable removable levels. The purpose of our study is to provide an estimate of the number of seals throughout Alaska and, where possible, determine current population trends.

In Alaska, harbor seals range from southeastern Alaska in the south to north of Bristol Bay (to about 59°N; Frost et al. 1982). In previous years we have arbitrarily sub-divided the state into 4 regions for census purposes. These were: southeast Alaska, the Gulf of Alaska (from Prince William Sound to the Shumagin Islands), the Aleutian Islands, and the north side of the Alaska Peninsula including Bristol Bay. These regions roughly follow the putative stock management areas, but logistical considerations were the primary factor used for this delineation. For the 1997 surveys, due to the large size and number of resources necessary to survey southeast Alaska, we further subdivided the region in half to provide better coverage. The National Marine Mammal Laboratory (NMML), with funding from the NMFS Office of Protected Resources, has censused each of these 4 regions once, starting in 1991 (Loughlin 1992 [Prince William Sound], Loughlin 1994 [southeast Alaska], Withrow and Loughlin 1995a [Aleutian Islands]). In order to provide current population estimates with low coefficients of variation (CVs) and estimates of population trend, especially in areas of decline and neighboring locations, the NMML began Phase II, a re-census and evaluation of each of the four regions, in 1995. The north side of the Alaska Peninsula and Bristol Bay was surveyed in 1995 (Withrow and Loughlin 1996) and the Gulf of Alaska was censused in 1996 (Withrow and Loughlin 1997). This paper describes the results of our census efforts in the northern portion of southeast Alaska including the region from Kayak Island, along Icy Bay to Cross Sound, Sitka region, Chatham Straits, Lynn Canal, and Stephens Passage down to Frederick Sound. The southern portion of southeast Alaska will be censused in 1999.

Methods

Study Area

The study in 1997 consisted of aerial surveys in seven areas. The first area was censused by Jim Thomason along Lynn Canal (16-24 August; Fig. 2, Table 2). Una Swain surveyed Cross Sound, Icy and Chatham Straits (16-24 August; Fig. 3). Peter Olesiuk surveyed Stephens Passage including the glacial sites of Tracy and Endicott Arms (16-24 August and repeated the same route again 17-21 September; Fig. 4). Barbara Mahoney censused Baranof Island (the south portion of the Sitka region 16-23 August; Fig. 5). Sally Mizroch surveyed Chichagof and Kruzof Islands (the northern Sitka region 16-24 August, Fig. 6). Bob Small and Lloyd Lowry censused from Kayak Island, Icy Bay down to Cross Sound (18-26 August; Fig. 7). Grey Pendleton surveyed Tenakee Inlet and Peril Strait, the Alaska Department of Fish and Game's (ADF&G) Sitka trend route, plus a few additional sites (18-26 August, Fig. 8). See Table 1 for the affiliations of the surveyors.

Survey Methods

Fixed-wing aircraft were used to photograph harbor seals while they were on land during their fall molt; this is the optimal period to obtain minimum population estimates because it is when the greatest number of harbor seals spend the greatest amount of time hauled out (Pitcher and Calkins 1979; Calambokidis et al. 1987). At locations that are affected by tides, harbor seals haul out in greatest numbers at and around the time of low tide. Aerial surveys were arranged and timed such that terrestrial haulout sites were flown within 2 hours on either side of low tide, when available daylight and weather permitted. Initially, the entire coastline was flown to determine the location of any new harbor seal haulout sites as well as all known haulout sites. Subsequently, four to seven repetitive photographic counts were conducted for each major haulout site within each study area over the 2 week survey period. We have determined that four or more repetitive surveys are necessary to obtain CV estimates (standard deviation of the counts divided by the mean count) less than 30%. Past surveys, where at least four or five replicates were flown, have proven to be an effective way of counting the maximum number of animals (Loughlin 1992, 1993; Pitcher 1989, 1990; Withrow and Loughlin 1995a).

Harbor seals on land or in the water adjacent to the haulout sites were photographed with 35 mm cameras with a 70-210 mm or 35-135 mm zoom lens using ASA 400 color slide film. Transparencies were later projected onto a white background and the number of seals counted. In most cases, two counters scored the number of seals on the photographs for each area for each survey day and the arithmetic mean was calculated for each site. The largest arithmetic mean obtained for each area was used as the minimum population estimate. Visual estimates of abundance were also recorded at the time of the survey. Small groups of seals (generally less than 10) were counted as the plane passed by (no photographs were taken), while larger groups were circled and photographed.

Most surveys were flown between 100 and 300 m (wind permitting) at about 90 knots. Thomason, Swain, Olesiuk, and Pendleton flew out of Juneau; Mahoney and Mizroch used Sitka as their base; and Small and Lowry flew out of Yakutat and Gustavus.

Data Analysis

The maximum number of animals counted on one day for each site was accepted as that site's minimum number of seals. The maximum number for each site did not occur on the same day, resulting in the possible double-counting of some animals if they moved from one major area to another. The number of seals moving between areas was assumed to be small considering each area's large geographic size.

The mean and standard deviation (SD) of the mean for each area were also calculated. Estimates of the number of animals hauled out during the survey were calculated by summing the mean number of harbor seals ashore at each site. The CVs were calculated for all sites with two or more counts. The SD for sites with only one count was estimated based on the maximum of the calculated CVs of the mean (1.0 used in 1997) multiplied by the count for that site. The variance of the total for each area was calculated as the sum of the individual variances and the SD as the square root of that variance. This method of estimating the expected total and its variance assumes that there is no migration between areas and that there was no trend in the number of animals ashore over the survey period. The assumption that seals did not move between areas may not be valid (as mentioned above) and a small number of seals may have been counted twice. All areas that could be surveyed were censused, given weather and safety constraints.

The exact location of each seal haulout was recorded and given an individual site number (Table 2).

Results

Lynn Canal Route

This area contained 27 individual sites. One to nine replicate counts were recorded for each site during the 9 day survey window. The maximum count of 2,805 harbor seals was obtained by combining the maximum count for each area regardless of day censused. The sum of means was $\bar{x}$ = 1,960 harbor seals (SD = 88.87), with a CV = 4.53% (Table 3).

Cross Sound and Chatham Strait Route

This area contained 49 individual sites. One to eight replicate counts were recorded for each site during the 9 day survey window. The maximum count of 2,121 harbor seals was obtained by combining the maximum count for each area regardless of day censused. The sum of means was $\bar{x}$ = 1,215 harbor seals (SD = 112.43), with a CV = 9.25% (Table 4).

Stephens Passage Route

This area contained 42 individual sites. One to seven replicate counts were recorded for each site during the 9 day survey window. The maximum count of 6,378 harbor seals was obtained by combining the maximum count for each area regardless of day censused. The sum of means was $\bar{x}$ = 4,513 harbor seals (SD = 183.18), with a CV = 4.06% (Table 5). This area was also surveyed again in September, when seals were found on 47 individual sites. Weather allowed surveys on only three days during the tidal cycle. The maximum count of 3,255 harbor seals was obtained by combining the maximum count for each area regardless of day censused. The sum of means was $\bar{x}$ = 2,508 harbor seals (SD = 199.32), with a CV = 7.95% (Table 6). Seal numbers in the glacial sites (Tracey Arm and Endicott Arm) were observer estimates and not from aerial photographs.

Southern Sitka Route Area

This area (Baranof Island) contained 54 individual sites. One to seven replicate counts were recorded for each site during the 7 day survey window. The maximum count of 2,160 harbor seals was obtained by combining the maximum count for each area regardless of day censused. The sum of means was $\bar{x}$ = 1,483 harbor seals (SD = 126.28), with a CV = 8.51% (Table 7).

Nothern Sitka Route Area

This area (Chichagof and Kruzof Islands) contained 59 individual sites. One to six replicate counts were recorded for each site during the 7 day survey window. The maximum count of 3,444 harbor seals was obtained by combining the maximum count for each area regardless of day censused. The sum of means was $\bar{x}$ = 2,511 harbor seals (SD = 194.83), with a CV = 7.76% (Table 8).

Kayak Island to Cross Sound Route

This area contained 43 individual sites from Kayak Island, Cape Suckling, Icy Bay down to Cross Sound. One to ten replicate counts were recorded for each site during the 10 day survey window. The maximum count of 7,322 harbor seals was obtained by combining the maximum count for each area regardless of day censused. The sum of means was $\bar{x}$ = 4,841 harbor seals (SD = 261.21), with a CV = 5.40% (Table 9). Seal numbers in the glacial sites (Icy Bay, Dry Bay, and Hubbard Glacier) were observer estimates and not from aerial photographs.

Tenakee Inlet and Peril Strait (ADF&G Sitka Trend Sitka Route Area)

This area contained 30 individual sites. One to seven replicate counts were recorded for each site during the 7 day survey window. The maximum count of 3,582 harbor seals was obtained by combining the maximum count for each area regardless of day censused. The sum of means was $\bar{x}$ = 2,409 harbor seals (SD = 147.89), with a CV = 6.14% (Table 10).

Estimated Population Size for the Northern Portion of Southeast (All Areas Combined)

The entire region from Kayak Island to Frederick Sound contained 302 individual sites (only sites where seals were observed at least once in August 1997 are included). One to nine replicate counts were recorded for each site during the 9 day survey window. The maximum count of 27,812 harbor seals was obtained by combining the maximum count for each area regardless of day censused. The sum of means was $\bar{x}$ = 18,933 harbor seals (SD = 445.08), with a CV = 2.35% (Table 11).

August vs. September Counts

In order to compare surveys conducted in August (1997) and September (1993), we surveyed one route (Stephens Passage) both in August and in September. This route has seals which utilize rocky, sandy, as well as a few glacial haulouts. Seals were found at five more locations (n = 47) in September than in August (n = 42, Table 12). Overall, 2,005 (44%) fewer seals were observed in the mean September counts compared to mean August counts. Some areas had increases in September, but most declined. The largest declines were observed at the glacial sites.

1997 and 1993 Comparisons

Site locations in 1997 were compared with those from 1993. Since exact positions (latitude and longitude) were not recorded in 1993, it was difficult to cross-match all locations exactly. In addition, observers in 1997 were encouraged to delineate positions as precisely as possible. For example, in 1997, 4-6 sites might have been identified for an area which was delineated as a single site in 1993. The total area surveyed was identical, however. Table 13 shows these comparisons where sites could be matched between years with a high degree of confidence. Sites were more precisely delineated and observer coverage was greater in 1997 (n = 313) than in 1993 (n = 130). Small differences between Table 13 and Table 11 exist and are explained by the fact that exact fractional mean numbers were used in Table 11 and rounded whole numbers were utilized in Table 13. Also, Table 13 includes counts and sites sighted in September whereas Table 11 represents only August data. More seals were observed in 1997 (19,101; includes additional sites from September) than in 1993 (7,368).

Discussion

The 1997 harbor seal census surveys were conducted in a similar manner to those of 1993 (Loughlin 1994). We used seven aircraft, each with an experienced observer, to cover the survey area (Figs. 1-8). The Glacier Bay region was surveyed by Beth Mathews and the results will be reported at a later time. Loughlin (1994) used 6 aircraft to survey the same area, including Glacier Bay, in 1993. He felt some of his routes were too long to adequately cover the entire area in one tidal cycle (Loughlin 1994). We essentially added two more aircraft to cover the same area and modified some routes slightly to limit deadhead (transit/non-survey) time. Our observers felt that the routes used in 1997 were long, but allowed sufficient coverage and that all areas could be censused within 2 hours of either side of low tide.

The Kayak Island to Cross Sound route, flown by Small and Lowry (ADF&G), was much more manageable in 1997. They utilized a twin-engine Aero Commander aircraft (a Cessna 185 was used in 1993). This area is characterized by several densely populated glacial sites (Icy Bay, Dry Bay, and Hubbard Glacier) interspersed with large areas with no haulouts. The route covers nearly 300 nmi. The twin-engine aircraft allowed them to intensively cover the populated areas at low survey speeds, but transit the large areas between sites at much faster speeds than was capable by a single-engine aircraft. They also surveyed one way each day, using towns at either end of their route (Yakutat and Gustavus) from which to base their operations. One day they would fly south from Yakutat to Gustavus and the next fly north from Gustavus to Yakutat.

The 1993 surveys were handicapped with logistical requirements to conduct ten concurrent surveys using ten different aircraft and observers. These surveys were conducted between 12 and 20 September. We decided to split southeast Alaska in half and survey the northern section in 1997 and the southern section in 1998. This allowed us to better utilize the resources that we had. By splitting the region, we could devote more of our budget, add survey aircraft, utilize experienced observers, and conduct surveys earlier, when higher number of seals were expected.

Our census surveys were conducted between 16 and 26 August 1997, nearly three weeks earlier than in 1993. We initially had to make a decision whether to survey in September so that counts would be the most comparable with the 1993 surveys or survey in August when we felt greater number of seals would be found. We decided to survey in August, but resurvey one of the routes again in September. This proved very useful. The Stephens Passage route was reflown, because we felt it was most representative of all areas. It included rocky, sandy, as well as glacial haulouts. In August, the mean number of seals observed was 4,513 (Table 5). By September, this count dropped to 2,508 (Table 6). Table 12 shows this more clearly with a site-by-site comparison. More sites were utilized in September (n = 47 vs n = 42), but over-all, there were 2,005 fewer seals were observed in September. Weather is generally worse in September and in fact we were limited to only 4 days of flying during the tide cycle. Since our goal is to obtain the best counts possible (higher), we recommend that future surveys be conducted in August. We did notice, however, that a few sites did increase in number during September (Table 12). This was not expected. In early September, we also noted increased numbers of seals using haulouts in southern southeast Alaska in 1994 during our correction factor study (Withrow and Loughlin 1995b). Although the general pattern is for seals to haul out less as they complete their molt, there is obviously some movement between sites and perhaps larger areas that we don't yet understand.

More seals were observed in 1997 than in 1993. A complete southeast Alaska abundance estimate will be produced next year after the southern portion of southeast Alaska is censused. In order to compare counts from the northern portion in 1997 with those counts made in 1993, we did a site-to-site comparison where we had a high degree of confidence that sites could be matched correctly (Table 13). Observers recorded seals at 313 sites in 1997 and 130 sites in 1993. Also, observers were able to cover their areas more completely in 1997 since their routes were shorter and two more aircraft and observers were added. Over 11,000 more seals were recorded in 1997 (n = 19,101; includes additional sites observed in September) than in 1993 (n = 7,368) in this area. There are several possible reason for this:

1) more complete area coverage (as discussed above)
2) surveys done approximately three weeks earlier when more animals haul out and weather is generally better, and
3) population growth is real and/or seals are migrating from other areas.

British Columbia has been experiencing a rapid growth in the number of harbor seals over the last 10 years, but their numbers have leveled-off recently (Peter Olesiuk, Canadian Department of Fisheries and Oceans, pers. com.).

Our overall population estimate, without corrections for seals in the water and not present at the time census counts were made, is 18,933 with a 95% confidence interval between 18,059 and 19,806. The coefficient of variation is a low 2.35, but this is in part due to the large number of sites (n = 302) and large number of replicates (n = 1,363, Table 11).

Acknowledgments

This report is a summary of surveys conducted by the people listed in Table 1 and who are gratefully acknowledged for their time and effort. The Alaska Department of Fish and Game provided experienced observers and aerial support. Lisa Applesand recounted all slides and suggested improvements to our observer protocol instructions. Anne York provided analytical advice. This paper was improved by comments from John Bengtson.

Citations

Calambokidis, J., B.L. Taylor, S.D. Carter, G.H. Steiger, P.K. Dawson, and L.D. Antrim. 1987. Distribution and haul out behavior of harbor seals in Glacier Bay, Alaska. Can. J. Zool. 65:1391-1396.

Frost, K. J., L. F. Lowry, and J. J. Burns. 1982. Distribution of marine mammals in the coastal zone of the Bering Sea during summer and autumn. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. 20(1983):365-561.

Loughlin, T. R. 1992. Abundance and distribution of harbor seals (*Phoca vitulina richardsi*) in Bristol Bay, Prince William Sound, and Copper River Delta during 1991. Unpubl. Rep., 27 p. Available Nat. Mar. Mammal Lab., Alaska Fish. Sci. Cent., 7600 Sand Point Way, Seattle, WA 98115.

Loughlin, T. R. 1993. Abundance and distribution of harbor seals (*Phoca vitulina richardsi*) in the Gulf of Alaska and Prince William Sound in 1992. Unpubl. rep., 25 p. Available Natl. Mar. Mammal Lab., Alaska Fish. Sci. Cent., 7600 Sand Point Way, Seattle, WA 98115.

Loughlin, T. R. 1994. Abundance and distribution of harbor seals (*Phoca vitulina richardsi*) in Southeastern Alaska during 1993. Unpubl. rep., 42 p. Available Natl. Mar. Mammal Lab., Alaska Fish. Sci. Cent., 7600 Sand Point Way, Seattle, WA 98115.

Pitcher, K. W. 1989. Harbor seal trend count surveys in southern Alaska, 1988. Final rep. to Mar. Mammal Comm., Contract MM4465853-1. 15 p.

Pitcher, K. W. 1990. Major decline in number of harbor seals, *Phoca vitulina richardsi*, on Tugidak Island, Gulf of Alaska. Mar. Mammal. Sci. 6:121-134.

Pitcher, K. W., and D. G. Calkins. 1979. Biology of the harbor seal (*Phoca vitulina richardsi*) in the Gulf of Alaska. U.S. Dep Commer., NOAA, OCSEAP Final Rep. 19(1983):231-310.

Withrow, D.E., and T.R. Loughlin. 1995a. Abundance and distribution of harbor seals (*Phoca vitulina richardsi)* along the Aleutian Islands during 1994. Annual report to the MMPA Assessment Program, Office of Protected Resources, NMFS, NOAA, 1335 East-West Highway, Silver Spring, MD 20910.

Withrow D.E., and T.R. Loughlin. 1995b. Haulout behavior and method to estimate the proportion of harbor seals missed during molt census surveys in Alaska. Annual report to the MMPA Assessment Program, Office of Protected Resources, NMFS, NOAA, 1335 East-West Highway, Silver Spring, MD 20910.

Withrow, D.E., and T.R. Loughlin. 1996. Abundance and distribution of harbor seals (*Phoca vitulina richardsi*) along the north side of the Alaska Peninsula and Bristol Bay during 1995. Annual report to the MMPA Assessment Program, Office of Protected Resources, NMFS, NOAA, 1335 East-West Highway, Silver Spring, MD 20910.

Withrow, D.E., and T.R. Loughlin. 1997. Abundance and distribution of harbor seals *(Phoca vitulina richardsi)* along the south side of the Alaska Peninsula, Shumigan Islands, Cook Inlet, Kenai Peninsula and the Kodiak Archipelago in 1996. Pp. 119-156 in P.S. Hill and D.P. DeMaster (eds.), Marine Mammal Protection Act and Endangered Species Act implementation program 1996. AFSC Processed Rep. 97-10. Available Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE, BIN C15700, Seattle WA 98115-0070.

Table 1. Survey route locations, observers, affiliations, and dates for harbor seal surveys in northern southeast Alaska in 1997.

Survey area	Observer	Affiliation	Dates
Lynn Canal	Jim Thomason	NMFS/NMML	8/16/97 - 8/24/97
Icy and Chatham Straits	Una Swain	ADF&G	8/16/97 - 8/24/97
Stephens Passage	Peter Olesiuk	DFO	8/16/97 - 8/24/97 9/17/97 - 9/21/97
Southern Sitka	Barbara Mahoney	NMFS/A	8/16/97 - 8/23/97
Northern Sitka	Sally Mizroch	NMFS/NMML	8/16/97 - 8/24/97
Kayak Island to Cross Sound	Bob Small & Lloyd Lowry	ADF&G	8/18/97 - 8/26/97
Tenakee Inlet & Peril Strait (ADF&G Sitka Trend Route)	Grey Pendleton	ADF&G	8/18/97 - 8/26/97

ADF&G	Alaska Department of Fish and Game
DFO	Canadian Department of Fisheries and Oceans
NMFS/A	National Marine Fisheries Service, (Anchorage Area Office)
NMFS/NMML	National Marine Fisheries Service, (National Marine Mammal Laboratory)

Table 2. Site location number, name, haulout type, latitude, longitude (in decimal degrees), and observer for 1997 harbor seal surveys in northern southeast Alaska.

Location Number	Location Name	Haulout type	Latitude	Longitude	Observer
1	Gastineau Channel	Sandy	58.3239	134.4684	Thomason
2	Taku Point	Sandy	58.3881	134.0366	Thomason
3	Hole in theWall	Sandy	58.4915	133.9468	Thomason
4	Annex Creek	Sandy	58.3159	134.0627	Thomason
5	Little Island	Cobble	58.5357	135.0445	Thomason
6	Berners River	Sandy	58.7939	134.9816	Thomason
7	Eldred Rock	Rocky	58.9688	135.2174	Thomason
8	Shikogi Island	Rocky	59.0411	135.2755	Thomason
9	Horse Shoals	Rocky	58.2554	134.7093	Thomason
10	Favorite Reef	Rocky	58.3829	134.8668	Thomason
11	Aaron Island	Rocky	58.4400	134.8244	Thomason
12	Eagle Reef	Rocky	58.4606	134.8243	Thomason
13	Sentinel Island	Rocky	58.5516	134.9249	Thomason
14	Skull Island	Rocky	58.2074	134.6446	Thomason
15	North Tip Shelter	Rocky	58.4915	134.9203	Thomason
16	Berners River Mouth	Sandy	58.7777	134.9742	Thomason
17	Hump Island	Rocky	58.4675	134.9888	Thomason
18	Auke Bay	Rocky	58.3575	134.6746	Thomason
19	Taku Sands	Sandy	58.3611	134.0220	Thomason
20	Annex Sands	Sandy	58.3119	134.0496	Thomason
21	Point Styleman	Rocky	57.9779	133.9259	Thomason
22	Whiting River	Sandy	58.0029	133.6789	Thomason
23	Prospect Point	Rocky	58.0478	133.7936	Thomason
24	Speel Point	Sandy	58.1243	133.7189	Thomason
25	North Benjamin	Rocky	58.5788	134.9145	Thomason
26	Upper Whiting	Sandy	58.0306	133.5864	Thomason
27	Berners Sands	Sandy	58.8059	134.9996	Thomason
28	North Couverden	Rocky	58.2473	135.0623	Swain
29	Couverden Rock	Rocky	58.2192	135.0410	Swain
30	Rocky Island	Rocky	58.1775	135.0487	Swain
31	Hanus Reef	Rocky	58.1335	134.9938	Swain
32	Sisters	Rocky	58.1818	135.2632	Swain
33	Homeshore	Rocky	58.2992	135.3740	Swain
34	Excursion Inlet	Sandy	58.5023	135.5068	Swain
35	Saw Mill Bay	Rocky	58.4483	135.4750	Swain
36	Porpoise Island	Rocky	58.3367	135.4707	Swain
37	Pleasant Island Reef	Rocky	58.3093	135.6425	Swain
38	North Pleasant Island 1	Rocky	58.3877	135.6282	Swain
39	Lemesurier NE	Rocky	58.2615	136.0292	Swain/Small
40	Lemesurier SE	Rocky	58.2655	136.0402	Swain/Small
41	Shaw Island	Rocky	58.1940	136.2447	Swain/Small
42	Gull Cove	Rocky	58.2155	136.1752	Swain
43	Midway Rocks	Rocky	58.0005	135.6180	Swain
44	Spasski Island	Rocky	58.1335	135.2775	Swain

Table 2. Continued.

45	Whitestone Harbor	Rocky	58.0738	135.0697	Swain
46	Heide Rock	Rocky	57.8677	135.0292	Swain
47	South Point Hepburn	Rocky	57.9257	134.7517	Swain
48	Naked Island	Rocky	58.2582	134.9425	Swain
49	Hawk Point	Rocky	58.0948	134.7808	Swain
50	South Hawk Point	Rocky	58.0797	134.7938	Swain
51	Cube Cove North	Rocky	57.9543	134.7685	Swain
52	Point Hepburn	Rocky	57.9248	134.7500	Swain
53	Ward Creek	Rocky	57.8788	134.7350	Swain
54	Chaik Bay North	Rocky	57.3338	134.5658	Swain
55	Chaik Bay South	Rocky	57.3130	134.5890	Swain
56	Russian Reef	Rocky	57.2887	134.6138	Swain
57	Whitewater Bay North	Rocky	57.2625	134.6163	Swain
58	Whitewater Bay Island	Rocky	57.2393	134.6012	Swain
59	Point Caution	Rocky	57.2522	134.6435	Swain
60	Wilson Cove	Rocky	57.1650	134.6395	Swain
61	Wilson Cove North	Rocky	57.1687	134.6267	Swain
62	Wilson Cove South	Rocky	57.1435	134.6318	Swain
63	Point Gardner	Rocky	57.0107	134.6000	Swain
64	Yasha Island	Rocky	56.9665	134.5563	Swain
65	Gaff Rock	Rocky	58.1965	136.4122	Swain/Small
66	Point Althorp Rocks	Rocky	58.1708	136.3720	Swain/Small
67	Althorp	Rocky	58.1420	136.4175	Swain/Small
68	Cape Spencer	Rocky	58.1832	136.6367	Swain/Small
69	Taylor Bay	Rocky	58.3097	136.5738	Swain
70	Dundas Bay Island	Rocky	58.3568	136.5099	Swain
71	Dundas Bay Forks	Rocky	58.4061	136.4827	Swain
72	Dundas River	Rocky	58.3685	136.3083	Swain
73	North of Lemesurier	Rocky	58.3013	136.1317	Swain/Small
74	West Taylor Bay	Rocky	58.2805	136.5597	Swain
75	George Island	Rocky	58.1928	136.3822	Swain
76	West Inian Island	Rocky	58.2458	136.3873	Swain/Small
77	Northwest Inian Island Sou	Rocky	58.2525	136.3755	Swain/Small
78	Three Hill Island	Rocky	58.1747	136.4007	Swain/Small
79	Quartz Point	Rocky	58.2243	136.0692	Swain/Small
80	South Point Brightman	Rocky	57.0568	134.4597	Swain
81	False Bay	Rocky	57.9603	134.9265	Swain
82	Point Augusta	Rocky	58.0453	134.9543	Swain
83	Noon Point (Pleasant Islan	Rocky	58.3397	135.5260	Swain
84	Mitchell Bay	Rocky	57.5368	134.4480	Swain
85	Mitchell Bay Island	Rocky	57.5405	134.4257	Swain
86	Kootznahoo Inlet	Rocky	57.5330	134.4743	Swain
87	North Pleasant Island 2	Rocky	58.3815	135.6838	Swain
88	West of Whitestone Harbo	Rocky	58.0947	135.1402	Swain
89	North Square Cove	Rocky	57.9965	134.7707	Swain
90	North Ward Creek	Rocky	57.8757	134.7293	Swain
91	Noname Wash	Rocky	57.0928	134.6332	Swain
92	South Noname Wash	Rocky	57.0685	134.6188	Swain
93	Cove Point	Rocky	58.1201	134.1721	Olesiuk
94	Doty Cove Soutn	Rocky	58.0724	134.1653	Olesiuk
95	Morse Peak West	Rocky	57.8648	133.9714	Olesiuk

Table 2. Continued.

96	Midway Point South	Rocky	57.7137	133.8809	Olesiuk
97	Dorn Island South	Rocky	57.8318	134.0186	Olesiuk
98	Swan Island East	Rocky	57.9480	134.1968	Olesiuk
99	King Salmon Bay East	Rocky	58.0113	134.2410	Olesiuk
100	Tiedeman Island SW	Rocky	57.7953	134.1391	Olesiuk
101	Beacon Rock	Rocky	57.6647	134.0225	Olesiuk
102	Donkey Bay Rock	Rocky	57.3638	134.1452	Olesiuk
103	Round Rock	Rocky	57.2606	133.9332	Olesiuk
104	Brother Island SW	Rocky	57.2708	133.8706	Olesiuk
105	Brother Island E	Rocky	57.2935	133.7923	Olesiuk
106	Gambier Bay	Rocky	57.4703	134.0405	Olesiuk
107	Price Island	Rocky	57.4200	133.8848	Olesiuk
108	Pybus Point West	Rocky	57.3025	134.0193	Olesiuk
109	Cannery Cove SE	Rocky	57.3073	134.0875	Olesiuk
110	Elliott Island South	Rocky	57.2522	134.0561	Olesiuk
111	Pybus Bay South	Rocky	57.2211	134.1120	Olesiuk
112	Pybus Bay North	Rocky	57.2355	134.1178	Olesiuk
113	Spruce Island	Rocky	57.2089	134.0899	Olesiuk
114	Five Fingers A	Rocky	57.2661	133.6356	Olesiuk
115	Five Fingers B	Rocky	57.2704	133.6578	Olesiuk
116	Five Fingers C	Rocky	57.2756	133.6384	Olesiuk
117	Five Fingers D	Cobble	57.2841	133.6705	Olesiuk
118	Akusua Island	Cobble	57.2981	133.6488	Olesiuk
119	Sail Island	Rocky	57.3413	133.7095	Olesiuk
120	Midway Island	Rocky	57.8437	133.8144	Olesiuk
121	Sunset Island	Rocky	57.4929	133.5810	Olesiuk
122	Twin Island East	Rocky	57.4198	133.5363	Olesiuk
123	Twin Island West	Rocky	57.4228	133.5550	Olesiuk
124	West Bird Rock	Rocky	57.2073	133.5958	Olesiuk
125	Wapole Point	Rocky	57.3126	133.5260	Olesiuk
126	Windham Bay South	Rocky	57.5170	133.5292	Olesiuk
127	Windham Bay	Rocky	57.5607	133.5137	Olesiuk
128	Point Windham	Rocky	57.5650	133.5401	Olesiuk
129	Endicott Arm	Ice	57.4974	132.8346	Olesiuk
130	Harbor Island NE	Cobble	57.7758	133.6134	Olesiuk
131	Tracey Arm	Ice	57.8617	133.3200	Olesiuk
132	Robert Island NW	Rocky	57.3090	133.4994	Olesiuk
133	Swan Island South	Rocky	57.9033	134.0296	Olesiuk
134	Pybus Point South	Cobble	57.2972	133.9770	Olesiuk
135	Station Point North	Rocky	58.0228	134.1045	Olesiuk
136	Station Point South	Rocky	57.9970	134.0849	Olesiuk
137	Five Fingers East	Rocky	57.2833	133.6333	Olesiuk
138	Harbor Island East	Rocky	57.7510	133.6022	Olesiuk
140	Kelp Bay Middle Arm	Rocky	57.3375	135.0052	Mahoney
141	Kelp Bay South Arm	Rocky	57.3085	134.9340	Mahoney
142	Pond Island North	Rocky	57.2870	134.9052	Mahoney
143	Kasnyku Bay	Rocky	57.2063	134.8348	Mahoney
144	Takatz Bay North	Rocky	57.1533	134.8042	Mahoney
145	Takatz Bay South	Rocky	57.1227	134.7862	Mahoney
146	North of Baranof Warm Sp	Rocky	57.1063	134.7838	Mahoney
147	North of Cascade Bay	Water	57.0375	134.7492	Mahoney

Table 2. Continued.

148	Cascade Bay North	Rocky	57.0263	134.7513	Mahoney
149	Nelson Bay	Rocky	56.9523	134.7327	Mahoney
150	South of Nelson Bay	Rocky	56.9258	134.7098	Mahoney
151	North of Red Bluff Bay 1	Rocky	56.8947	134.6917	Mahoney
152	North of Red Bluff Bay 2	Rocky	56.8828	134.6892	Mahoney
153	Red Bluff Bay	Rocky	56.8393	134.7037	Mahoney
154	North of Gut Bay	Rocky	56.7400	134.6350	Mahoney
155	Gut Bay	Water	56.7187	134.6893	Mahoney
156	North of Patterson Point	Rocky	56.5590	134.6215	Mahoney
157	South of Point Herbert	Rocky	56.4133	134.6340	Mahoney
158	North of Point Lucy	Water	56.3667	134.6417	Mahoney
159	Point Conclusion	Rocky	56.2703	134.6343	Mahoney
160	East of Port Alexander	Rocky	56.2398	134.6342	Mahoney
161	South of Port Alexander	Rocky	56.2075	134.6512	Mahoney
162	First Kekur	Rocky	56.3670	134.9402	Mahoney
163	North of Snipe Bay	Rocky	56.4135	134.9633	Mahoney
164	North of Sandy Bay	Rocky	56.4683	135.0112	Mahoney
165	Third Kekur	Rocky	56.4685	135.0022	Mahoney
166	Tikhaia Island	Rocky	56.5585	135.0520	Mahoney
167	Port Banks	Rocky	56.5932	135.0072	Mahoney
168	Small Arm	Rocky	56.6253	135.0162	Mahoney
169	South of North Cape	Rocky	56.5915	135.1162	Mahoney
170	North of North Cape	Rocky	56.9892	135.2222	Mahoney
171	Guilbert Islets	Rocky	56.6440	135.1567	Mahoney
172	Necker Bay Island	Rocky	56.7245	135.0548	Mahoney
173	Necker Bay NE	Rocky	56.7560	135.0313	Mahoney
174	Jamboree Bay	Rocky	56.7190	135.2045	Mahoney
175	Cedar Pass	Rocky	56.7557	135.1857	Mahoney
176	Crawfish Inlet	Rocky	56.7812	135.1267	Mahoney
177	West of Gornoi Island	Rocky	56.7892	135.3717	Mahoney
178	SW of Gornoi Island	Rocky	56.7858	135.3715	Mahoney
179	NE of Rogers Island	Rocky	56.7937	135.4428	Mahoney
180	NW of Tava Island	Rocky	56.8402	135.4717	Mahoney
181	North of Tava Island	Rocky	56.8627	135.4692	Mahoney
182	NW of Legine Island	Rocky	56.8335	135.4517	Mahoney
183	NE of Tava Island	Rocky	56.8393	135.4678	Mahoney
184	West of Camel Mountain	Rocky	56.8687	135.3913	Mahoney
185	North Biorka Island	Rocky	56.8583	135.5342	Mahoney
186	East Biorka Island	Rocky	56.8543	135.4928	Mahoney
187	NW Peigar Island	Rocky	56.8887	135.4422	Mahoney
188	NE Peigar Island	Rocky	56.8897	135.4578	Mahoney
189	NW Kanga Bay	Rocky	56.8347	135.4508	Mahoney
190	Kanga Bay Mouth	Rocky	56.8883	135.3422	Mahoney
191	Povorotni Point	Rocky	56.9403	135.4202	Mahoney
192	East Povorotni Point	Rocky	56.9400	135.4100	Mahoney
193	South Povorotni Point	Rocky	56.9365	135.4202	Mahoney
194	Bird Rock	Rocky	57.2149	133.5722	Olesiuk
195	Low Island	Rocky	57.0049	135.6196	Mizroch
196	Kruzof Island South	Rocky	56.9861	135.8400	Mizroch
197	Kruzof Island North	Rocky	57.0230	135.8531	Mizroch
198	Point Kruzof	Rocky	57.3368	135.8462	Mizroch

Table 2. Continued.

199	Point Leo	Rocky	57.3854	135.8191	Mizroch
200	Klochachef Island	Rocky	57.4045	135.9042	Mizroch
201	Potato Patch	Rocky	57.4764	135.9760	Mizroch
202	Pehil Pass	Rocky	57.5213	136.0583	Mizroch
203	Cobol	Rocky	57.4741	135.8757	Mizroch
204	Herbert Graves West	Rocky	57.6593	136.2712	Mizroch
205	Hogan Island North	Rocky	57.7241	137.2867	Mizroch
206	Hill Island North	Rocky	57.7577	136.3222	Mizroch
207	Lisianski Strait South	Rocky	57.7899	136.3968	Mizroch
208	Lisianski Strait North	Rocky	57.8242	136.4354	Mizroch
209	Minor Island	Rocky	57.9932	136.3076	Mizroch
210	Salisbury	Rocky	57.3897	135.7045	Mizroch
211	South of Pelican	Rocky	57.9035	136.1427	Mizroch
212	Hoonah Sound North	Rocky	57.7586	135.8048	Mizroch
213	Arm Rock North	Rocky	57.6732	135.6060	Mizroch
214	Emmons	Cobble	57.6199	135.5752	Mizroch
215	Gilmer Bay	Rocky	57.2334	135.8222	Mizroch
216	North Sea Lion Rocks	Rocky	57.2873	135.8596	Mizroch
217	Middle Sea Lion Rocks	Rocky	57.2747	135.8735	Mizroch
218	Shark Hole	Rocky	57.3411	135.8262	Mizroch
219	North Sister Lake	Rocky	57.6232	136.0225	Mizroch
220	Point Satchrun	Rocky	57.8922	136.5199	Mizroch
221	Surge Bay	Rocky	57.9930	136.5672	Mizroch
222	Takanis Bay	Rocky	58.0032	136.5689	Mizroch
223	West Takanis Bay	Rocky	58.0211	136.5533	Mizroch
224	Soapstone	Rocky	58.0847	136.5589	Mizroch
225	Pelican	Rocky	57.9388	136.2038	Mizroch
226	Hoonah	Rocky	57.8415	136.0357	Mizroch
227	Hoggatt Reef	Rocky	57.5544	135.5032	Mizroch
228	NW Cape Edgecumbe	Rocky	57.1170	135.7584	Mizroch
229	North Gilmer Bay	Rocky	57.2340	135.8566	Mizroch
230	Kakul Narrows	Rocky	57.3685	135.7180	Mizroch
231	Bingham	Rocky	57.9873	136.5590	Mizroch
232	Cape Cross	Rocky	57.9052	136.5348	Mizroch
233	Sergius Narrows	Rocky	57.4097	135.6049	Mizroch
234	SW Cape Edgecumbe	Rocky	57.0914	135.8403	Mizroch
235	Sea Lion Rocks	Rocky	57.2742	135.8860	Mizroch
236	S. Sea Lion Rocks	Rocky	57.2742	135.8860	Mizroch
237	Ford Arm	Rocky	57.5697	135.9517	Mizroch
238	E. Sisters Lake	Rocky	57.5886	136.0217	Mizroch
239	Apple Island	Rocky	57.0712	135.4598	Mizroch
240	Khaz Peninsula 1	Rocky	57.5380	136.0745	Mizroch
241	Khaz Peninsula 2	Rocky	57.5512	136.0834	Mizroch
242	Khaz Peninsula 3	Rocky	57.5741	136.1512	Mizroch
243	Khaz Peninsula 4	Rocky	57.5678	136.1575	Mizroch
244	Khaz Peninsula 14	Rocky	57.6016	136.0669	Mizroch
245	Khaz Peninsula 5	Rocky	57.5763	136.1397	Mizroch
246	Khaz Peninsula 7	Rocky	57.5890	136.2011	Mizroch
247	Khaz Peninsula 6	Rocky	57.5864	136.1519	Mizroch
248	Khaz Peninsula 8	Rocky	57.6011	136.2097	Mizroch
249	Khaz Peninsula 9	Rocky	57.5841	136.2194	Mizroch

Table 2. Continued.

250	Khaz Peninsula 10	Rocky	57.6001	136.2187	Mizroch
251	Khaz Peninsula 11	Rocky	57.5858	136.1367	Mizroch
252	Khaz Peninsula 12	Rocky	57.5835	136.1380	Mizroch
253	Khaz Peninsula 13	Rocky	57.5875	136.2229	Mizroch
254	Martin Islands	Rocky	60.1780	144.5573	Small
255	Wingham Island	Sandy	60.0780	144.3192	Small
256	Kayak Island 1	Rocky	59.9152	144.4723	Small
257	Kayak Island 2	Rocky	59.8723	144.5588	Small
258	Kayak Island 3	Rocky	59.7885	144.5668	Small
259	Kayak Island 4	Rocky	59.8975	144.4085	Small
260	Kayak Island 5	Rocky	59.9587	144.2440	Small
261	Cape Suckling 1	Rocky	59.9878	144.0192	Small
262	Cape Suckling 2	Rocky	59.9845	143.9095	Small
263	Icy Bay NW	Ice	60.1185	141.4712	Small
264	Icy Bay NE	Ice	60.1345	141.3965	Small
265	Otmeloi Island	Rocky	59.6458	139.6535	Small
266	Krutoi Island	Rocky	59.6692	139.6480	Small
267	Foxy Reef	Rocky	59.6652	139.6300	Small
268	Knight Island Reef	Rocky	59.7140	139.6280	Small
269	Russell Fiord	Sandy	59.5837	139.3160	Small
270	Blacksand Spit	Sandy	59.4068	139.4748	Small
271	Dry Bay	Sandy	59.1567	138.5943	Small
272	Lituya Bay	Ice	58.6577	137.4977	Small
273	Astrolabe Rocks	Rocky	58.3400	136.8908	Small
274	Venisa Point	Rocky	58.2972	136.8317	Small
275	Hubbard Glacier	Ice	60.0247	139.5530	Small
276	Turner Glacier	Ice	59.9883	139.6177	Small
277	Dangerous River	Sandy	59.3770	139.3155	Small
278	Graves Rocks	Rocky	58.2497	136.7450	Small
279	Nunatak Fiord	Sandy	59.8027	138.9190	Small
280	Tsaa Fiord (Icy Bay)	Ice	60.0948	141.5293	Small
281	Dundas Bay SW	Rocky	58.3527	136.4952	Small
282	Kriwoi Isl.	Rocky	59.6272	139.6753	Small
283	Dundas Bay N	Rocky	58.3997	136.4537	Small
284	Cape Spencer (South)	Rocky	58.2073	136.6678	Small
285	Midway Island	Rocky	58.1483	135.6367	Pendleton
286	N of Basket Bay	Rocky	57.8093	134.9850	Pendleton
287	Appletree	Rocky	57.9372	135.1212	Pendleton
288	Strawberry Rock	Rocky	57.7747	135.1943	Pendleton
289	Tenakee Rock	Rocky	57.8235	135.2840	Pendleton
290	Crab Bay	Sandy	57.7897	135.4418	Pendleton
291	Saltery Bay	Rocky	57.9298	135.4548	Pendleton
292	Mid Inlet Shoal	Rocky	57.9518	135.5078	Pendleton
293	Long Bay	Rocky	58.0183	135.7737	Pendleton
294	Grassy Island	Cobble	58.0655	136.0000	Pendleton
295	Head of Tenakee	Sandy	58.1260	135.9343	Pendleton
296	Plover Island	Rocky	57.3258	134.9827	Pendleton
297	Point Hayes	Rocky	57.6023	134.9998	Pendleton
298	Midway Reef	Rocky	57.4820	134.9355	Pendleton
299	Traders	Rocky	57.6348	134.9448	Pendleton
300	Pt. Moses	Rocky	57.5455	135.1292	Pendleton

Table 2. Continued.

301	Krugloi Island	Cobble	57.7002	135.4717	Pendleton
302	Hoggatt Reef	Rocky	57.5808	135.5360	Pendleton
303	Vixen Island	Rocky	57.6625	135.6043	Pendleton
304	Southarm	Rocky	57.7038	135.7707	Pendleton
305	Northarm	Rocky	57.8083	135.8885	Pendleton
306	Moser Island N	Rocky	57.7442	135.6680	Pendleton
307	E Catherine Island	Rocky	57.4570	134.8338	Pendleton
308	W of Moser Island	Rocky	57.8787	135.8450	Pendleton
309	W of Point Moses	Rocky	57.5407	135.1977	Pendleton
310	N of Point Lull	Rocky	57.4327	134.8578	Pendleton
311	N of Cedar Cove	Rocky	57.9660	135.1917	Pendleton
312	E of Appleton Cove	Rocky	57.6287	135.3932	Pendleton
313	N of Saook Point	Rocky	57.5752	135.1872	Pendleton
314	W Tenakee Inlet	Sandy	58.0160	135.8510	Pendleton

Table 3. The number of harbor seals counted, by day, at haulout sites along the Lynn Canal route in 1997. Surveyed by Thomason.

Location #	Location Name	Max	Mean	8/16/97	8/17/97	8/18/97	8/19/97	8/20/97	8/21/97	8/22/97	8/23/97	8/24/97
1	Gastineau Channel	37	20	23	25	0		37	28	0	24	
2	Taku Point	300	225	225	212	140	175	249	240	239	249	300
3	Hole in theWall	68	29	7	0	47	68		64	48	0	0
4	Annex Creek	50	26	50	42	35	47	8		16	11	0
5	Little Island	413	336	275	350	308	395	349	341	299	298	413
6	Berners River	752	491		425	451	523	457	543	752	350	426
7	Eldred Rock	121	98	77	106	90	98	83	114	88	108	121
8	Shikogi Island	59	23	37	0	0	38	0	32	59	18	
9	Horse Shoals	57	38		57	36	38	54	43	24	14	
10	Favorite Reef	12	4		12	0	0	0	0	12		
11	Aaron Island	21	10		8	17	21	0	0	16		
12	Eagle Reef	31	15		7	16	31	0	23	13	17	
13	Sentinel Island	20	8		10	6	0	3	12	20		6
14	Skull Island	55	30		0	40	55	23		32		
15	North Tip Shelter	10	1			10	0	0	0	0	0	0
16	Berners River Mouth	24	24				24					
17	Hump Island	19	16				13		16	17	17	19
18	Auke Bay	15	5				15		8	3	0	0
19	Taku Sands	7	5					7		6	5	2
20	Annex Sands	12	12					12				
21	Point Styleman	30	26					30	29	20	21	28
22	Whiting River	54	42					36		54	37	
23	Prospect Point	284	199					129	130	253	284	
24	Speel Point	50	21					50	34	22	0	0
25	North Benjamin	5	2							5	0	0
26	Upper Whiting	281	233								185	281
27	Berners Sands	18	18									18

Max	Mean
2805	1960

95 % Confidence Interval			
1784	=LOW	2136	=HIGH

CV	COUNT	SD
4.53	150	88.87

Table 4. The number of harbor seals counted, by day, at haulout sites along Icy and Chatham Straits in 1997. Surveyed by Swain.

Location #	Location Name	Max	Mean	8/16/97	8/17/97	8/18/97	8/19/97	8/20/97	8/21/97	8/22/97	8/23/97	8/24/97
28	North Couverden	36	27	15		34	19	29	16	36	30	33
29	Couverden Rock	158	98	5		128	158	84	31	98	129	153
30	Rocky Island	14	10	7		6	13	14	6	9	9	13
31	Hanus Reef	4	2			2	3	0	2	1		4
32	Sisters	22	12	7		15	10		22	17	5	10
33	Homeshore	52	22	16		42	0		43	0	2	52
34	Excursion Inlet	106	77	68		94	31		106	91	51	98
35	Saw Mill Bay	7	3	6		3	7			0	0	0
36	Porpoise Island	63	25	63		56	7		15	31	1	3
37	Pleasant Island Reef	24	12	14		13	24		15	3	1	17
38	North Pleasant Island 1	33	12	31		18	0		2	0	0	33
42	Gull Cove	3	3	2			3					
43	Midway Rocks	2	1	1						2	0	
44	Spasski Island	24	10	0		24	24			0	0	
45	Whitestone Harbor	4	1	0		0		0	0	4	0	0
46	Heide Rock	321	224	126				321				
47	South Point Hepburn	50	27	12	0			25		33	42	50
48	Naked Island	15	7	0	4		6	15	1	7	9	10
49	Hawk Point	137	85	0	116	122	60	70		50	137	126
50	South Hawk Point	34	25	0	30	31	34	30		34	27	13
51	Cube Cove North	8	3	0	8			0		4	4	0
52	Point Hepburn	19	3	0	19			0		0	0	0
53	Ward Creek	10	2		10			0		0	0	0
54	Chaik Bay North	74	38		37			32		18	31	74
55	Chaik Bay South	14	8		10			14		0	10	7
56	Russian Reef	46	14		25			46		0	0	0
57	Whitewater Bay North	32	14		32			0		23	12	1
58	Whitewater Bay Island	76	26		76			39		12	5	0
59	Point Caution	6	2		6			0		0	3	0
60	Wilson Cove	95	48		95			91		5	17	32
61	Wilson Cove North	3	2								3	0
62	Wilson Cove South	93	52		29			93		12	84	44
63	Point Gardner	90	51		90			65		34	27	38
64	Yasha Island	109	84		87			109		91	70	62
74	West Taylor Bay	8	8			8						
75	George Island	1	1			1						
80	South Point Brightman	121	87							60	121	80
81	False Bay	12	5	0				9		4	0	12
82	Point Augusta	7	5	0				7		7	6	7
83	Noon Point (Pleasant Islan	3	1	0					1	3	1	0
84	Mitchell Bay	39	14		0				30	39	0	0
85	Mitchell Bay Island	50	24		0				0		50	45
86	Kootznahoo Inlet	4	2		0						3	4

Table 4. Continued.

87	North Pleasant Island 2	15	4	0						15	0	0
88	West of Whitestone Harbo	25	6	0						25	0	0
89	North Square Cove	12	6	0						2	10	12
90	North Ward Creek	11	7							9	11	0
91	Noname Wash	21	14		0					14	20	21
92	South Noname Wash	8	4		0					8	6	0

Max	Mean
2121	1215

95 % Confidence Interval			
993	=LOW	1437	=HIGH

CV	COUNT	SD
9.25	251	112.43

Table 5. The number of harbor seals counted, by day, at haulout sites along Stephens Passage in 1997. Surveyed by Olesiuk.

Location #	Location Name	Max	Mean	8/16/97	8/17/97	8/18/97	8/19/97	8/20/97	8/21/97	8/22/97	8/23/97	8/24/97
93	Cove Point	39	26	31		21	24	20	39		22	24
94	Doty Cove Soutn	46	37	31		33	38	29	46		44	40
95	Morse Peak West	21	11	21		17		0	7		15	5
96	Midway Point South	35	26	34		21		13	23		27	35
97	Dorn Island South	98	82	66		83					81	98
98	Swan Island East	454	328	196		213			411		364	454
99	King Salmon Bay East	234	184	234		179			164		178	167
100	Tiedeman Island SW	141	87	141		121					66	20
101	Beacon Rock	50	38	41		50			48		0	50
102	Donkey Bay Rock	120	77	84	120				40	44	92	80
103	Round Rock	25	10	6					25	5	7	7
104	Brother Island SW	40	27	9					36		40	21
105	Brother Island E	55	38	35					55		14	46
106	Gambier Bay	203	185		150				203		196	189
107	Price Island	211	152		75				151		211	171
108	Pybus Point West	25	10		25				16		0	0
109	Cannery Cove SE	16	5		16				11	0	0	0
110	Elliott Island South	69	22		31				69	0	1	7
111	Pybus Bay South	283	162		283				270	0	129	130
112	Pybus Bay North	479	253		96				90	320	280	479
113	Spruce Island	280	121		181				280	41	62	41
114	Five Fingers A	54	28		33			36	54		9	8
115	Five Fingers B	48	23		24			31	48		2	9
116	Five Fingers C	22	12		22			20	15		0	1
117	Five Fingers D	163	127		90			163	130		130	121
118	Akusua Island	94	56		55			94	25		45	59
119	Sail Island	50	30		8			40	20		50	30
120	Midway Island	290	272		260	290		289			290	232
121	Sunset Island	60	38		25	60		40	17		30	53
122	Twin Island East	176	162		175	176		170	174		120	159
123	Twin Island West	68	42		56	68		38	45		19	26
124	West Bird Rock	80	21		9			12	0		80	2
125	Wapole Point	10	3		3			4	10		0	0
126	Windman Bay South	43	28		41	43					14	12
127	Windman Bay	253	171		155	253					107	169
128	Point Windman	171	120		146	95					67	171
129	Endicott Arm	970	820		578			783	949		970	
130	Harbor Island NE	80	63			50		60				80
131	Tracey Arm	690	543			352		475	690		656	

Table 5. Continued.

132	Robert Island NW	11	6								11	0
133	Swan Island South	12	12									12
194	Bird Rock	109	60		9			93	87		0	109

Max	Mean
6378	4513

95 % Confidence Interval			
4152	=LOW	4875	=HIGH

CV	COUNT	SD
4.06	199	183.18

Table 6. The number of harbor seals counted, by day, at haulout sites along Stephens Passage in September, 1997. Surveyed by Olesiuk.

Location #	Location Name	Max	Mean	9/17/97	9/18/97	9/21/97
93	Cove Point	58	42	40	58	28
94	Doty Cove Soutn	65	52	36	65	54
95	Morse Peak West	39	29	24	25	39
96	Midway Point South	83	72	62	70	83
97	Dorn Island South	53	45	53	45	38
98	Swan Island East	86	67	82	86	33
99	King Salmon Bay East	50	41	40	32	50
100	Tiedeman Island SW	82	31	9	2	82
101	Beacon Rock	50	41	44	50	30
102	Donkey Bay Rock	85	41	85	2	35
103	Round Rock	11	5	11	1	3
104	Brother Island SW	74	52	67	74	15
105	Brother Island E	26	20	12	21	26
106	Gambier Bay	81	65	81	70	44
107	Price Island	194	121	103	194	65
108	Pybus Point West	4	2	4	3	0
109	Cannery Cove SE	5	2	5	0	0
110	Elliott Island South	19	6	19	0	0
111	Pybus Bay South	150	102	108	150	47
112	Pybus Bay North	29	27	25	29	
113	Spruce Island	127	76	127	101	0
114	Five Fingers A	10	7	10	2	8
115	Five Fingers B	10	7	1	9	10
116	Five Fingers C	13	11	13	13	6
117	Five Fingers D	57	50	45	49	57
118	Akusua Island	53	46	43	42	53
119	Sail Island	33	27	28	21	33
120	Midway Island	138	122	119	110	138
121	Sunset Island	49	44	40	43	49
122	Twin Island East	79	66	63	79	56
123	Twin Island West	114	86	60	83	114
124	West Bird Rock	5	3	5	4	1
125	Wapole Point	6	3	0	4	6
126	Windham Bay South	121	69	27	58	121
127	Windham Bay	172	157	169	172	131
128	Point Windham	128	97	87	77	128
129	Endicott Arm	347	318	347		289
130	Harbor Island NE	10	7	7	3	10
131	Tracey Arm	174	174			174
132	Robert Island NW	31	16	0	31	
133	Swan Island South	20	8	0	5	20
134	Pybus Point South	121	96	81	121	85

Table 6. Continued.

135	Station Point North	6	4		6	2
136	Station Point South	37	31		25	37
137	Five Fingers East	30	18		5	30
138	Harbor Island East	7	7			7
194	Bird Rock	113	97	113	79	99

Max	Mean
3255	2508

95 % Confidence Interval			
2112	=LOW	2905	=HIGH

CV	COUNT	SD
7.95	131	199.32

Table 7. The number of harbor seals counted, by day, at haulout sites along the southern Sitka route in 1997. Surveyed by Mahoney.

Location #	Location Name	Max	Mean	8/16/97	8/18/97	8/19/97	8/20/97	8/21/97	8/22/97	8/23/97
140	Kelp Bay Middle Arm	12	3	12	0			0		0
141	Kelp Bay South Arm	65	41	15	65			35		47
142	Pond Island North	27	14	14	0					27
143	Kasnyku Bay	13	7	5	13			2		8
144	Takatz Bay North	60	34	27	30		60	27		25
145	Takatz Bay South	55	33	28	55		31	17		
146	North of Baranof Warm Springs	16	10				13	0		16
147	North of Cascade Bay	1	1				0	1		
148	Cascade Bay North	34	9	34	0		0			0
149	Nelson Bay	54	35	50	54		30	31		9
150	South of Nelson Bay	5	3				0			5
151	North of Red Bluff Bay 1	17	15	13				17		
152	North of Red Bluff Bay 2	20	12		20			7		9
153	Red Bluff Bay	35	27	23	20		35			29
154	North of Gut Bay	18	11		3					18
155	Gut Bay	3	1	0	3			0		
156	North of Patterson Point	26	18	8	26			26		11
157	South of Point Herbert	18	8	0	14			18		0
158	North of Point Lucy	4	4	4						
159	Point Conclusion	56	40	44	56			39		19
160	East of Port Alexander	8	8							8
161	South of Port Alexander	126	82	54	126			97		51
162	First Kekur	27	13		12			27		0
163	North of Snipe Bay	11	6		11			0		
164	North of Sandy Bay	59	53		47			59		
165	Third Kekur	63	63							63
166	Tikhaia Island	166	107	49	111	166	126	92		97
167	Port Banks	39	25	5	31	37	39	19		18
168	Small Arm	74	61		65	58	65	74		45
169	South of North Cape	2	2					2		
170	North of North Cape	8	4		8		0			
171	Guilbert Islets	19	4	0	7	19	0	0		0
172	Necker Bay Island	97	74		71	74	97	65		61
173	Necker Bay NE	13	3		13	0	0	0		0
174	Jamboree Bay	25	16	0	19	14	18	25		22
175	Cedar Pass	55	37	12	55		18	50		48
176	Crawfish Inlet	3	1	0	3		0			
177	West of Gornoi Island	59	57				59	54		58

Table 7. Continued.

178	SW of Gornoi Island	36	36							36
179	NE of Rogers Island	66	66				66			
180	NW of Tava Island	41	41						41	
181	North of Tava Island	23	23		23					
182	NW of Legine Island	57	45			26		48	57	47
183	NE of Tava Island	37	27		32		18	20		37
184	West of Camel Mountain	11	6				0	6	11	
185	North Biorka Island	16	4		4	16	0	1		0
186	East Biorka Island	36	17		26	36	0	14	28	0
187	NW Peigar Island	104	67				0	104	83	79
188	NE Peigar Island	84	28		84				0	0
189	NW Kanga Bay	22	5			22	0	0	5	0
190	Kanga Bay Mouth	6	6						6	
191	Povorotni Point	91	67	24	91	89	73	74	59	60
192	East Povorotni Point	26	26			26				
193	South Povorotni Point	111	83					79	60	111

Max	Mean	95 % Confidence Interval				CV	COUNT	SD
2160	1483	1233	=LOW	1733	=HIGH	8.51	183	126.28

Table 8. The number of harbor seals counted, by day, at haulout sites along the northern Sitka route in 1997. Surveyed by Mizroch.

Location #	Location Name	Max	Mean	8/16/97	8/17/97	8/18/97	8/20/97	8/21/97	8/22/97	8/23/97	8/24/97
195	Low Island	574	474	500		574	372	517		395	485
196	Kruzof Island South	13	8	3		9		13			
197	Kruzof Island North	1	1	1							
198	Point Kruzof	18	13	7			12	18		13	15
199	Point Leo	40	25	16	24	40	18	24		30	
200	Klochachef Island	59	50	25	45	54	59	59		55	
201	Potato Patch	73	58	40	63	62	50	73		60	
202	Pehil Pass	108	76	60	108	73	37	102			
203	Cobol	4	3	4			4	2		3	
204	Herbert Graves West	47	36	13		47	42	45		34	
205	Hogan Island North	2	2	2							
206	Hill Island North	1	1	1							
207	Lisianski Strait South	59	45	30						59	
208	Lisianski Strait North	73	65	70		73	62	56			
209	Minor Island	31	27	30	26	31	25			22	
210	Salisbury	60	43		21		43	43		60	49
211	South of Pelican	8	5		7	0				8	
212	Hoonah Sound North	3	2		3					0	
213	Arm Rock North	75	29		75		10			2	
214	Emmons	374	270		250	250	207	268		374	
215	Gilmer Bay	70	49			32	55	36		70	51
216	North Sea Lion Rocks	44	25			25	35	44		16	5
217	Middle Sea Lion Rocks	47	34			31	33	47		39	22
218	Shark Hole	15	15			15					
219	North Sister Lake	22	10			7	9	22		0	
220	Point Satchrun	15	13			10				15	
221	Surge Bay	82	71			60				82	
222	Takanis Bay	8	8			8					
223	West Takanis Bay	30	30			30					
224	Soapstone	6	6			6				6	
225	Pelican	9	3			9		0		0	
226	Hoonah	72	36			0				72	
227	Hoggatt Reef	129	97			94	129			69	
228	NW Cape Edgecumbe	39	33				26				39
229	North Gilmer Bay	3	3				3				
230	Kakul Narrows	35	26				12	28		35	29
232	Cape Cross	21	21				21			20	
233	Sergius Narrows	57	46				57			34	
234	SW Cape Edgecumbe	33	33					33			
235	Sea Lion Rocks	5	4					3			5
236	S. Sea Lion Rocks	3	3					3			
237	Ford Arm	77	53				77	35		48	
238	E. Sisters Lake	100	61				84	0		100	

Table 8. Continued.

239	Apple Island	5	3						5	0	
240	Khaz Peninsula 1	102	56	60	38	52	54	76		102	9
241	Khaz Peninsula 2	13	10	8		13		8		11	
242	Khaz Peninsula 3	85	38	15		17	85	33		40	
243	Khaz Peninsula 4	146	38	13		13	13	7		146	
244	Khaz Peninsula 14	11	11							11	
245	Khaz Peninsula 5	59	44	40			58	59		18	
246	Khaz Peninsula 7	133	80	8		99				133	
247	Khaz Peninsula 6	40	40	40							
248	Khaz Peninsula 8	16	16	16							
249	Khaz Peninsula 9	58	49	40				58			
250	Khaz Peninsula 10	34	19	3		34					
251	Khaz Peninsula 11	31	31			31					
252	Khaz Peninsula 12	154	154			154					
253	Khaz Peninsula 13	12	12			12					

Max	Mean
3444	2511

95 % Confidence Interval				CV	COUNT	SD
2126	=LOW	2897	=HIGH	7.76	175	194.83

Table 9. The number of harbor seals counted, by day, at haulout sites from Kayak Island south to Cross Sound in 1997. Surveyed by Small (and Swain in italics).

Location #	Location Name	Max	Mean	8/16/97	8/17/97	8/18/97	8/19/97	8/20/97	8/21/97	8/23/97	8/24/97	8/25/97	8/26/97
254	Martin Islands	5	5			5							
255	Wingham Island	38	32			38	25						
256	Kayak Island 1	6	5			3	6						
257	Kayak Island 2	16	14			16	11						
258	Kayak Island 3	20	19			18	20						
259	Kayak Island 4	5	5			5	5						
260	Kayak Island 5	93	80			93	67						
261	Cape Suckling 1	35	31			35	27						
262	Cape Suckling 2	4	2			4	0						
263	Icy Bay NW	2501	1691				1225	2210	2501	1680	1140	1390	
264	Icy Bay NE	253	166			113	220	151	253	120	120	185	
265	Otmeloi Island	20	10				8	17	20	0	10	7	8
266	Krutoi Island	6	3				1	2	3	1	6	5	0
267	Foxy Reef	50	36				40	50	31	35	38	28	28
268	Knight Island Reef	30	16				9	6	30	14	16	19	18
269	Russell Fiord	195	108				101	106	130	195	10	130	82
270	Blacksand Spit	9	2				9	0	0	0	0	0	
271	Dry Bay	1306	1044				1008	724	1039	1122	1306	1082	1024
272	Lituya Bay	127	44				27	35	127	8	31	42	38
273	Astrolabe Rocks	69	45				29	30	47	52	61	69	26
274	Venisa Point	2	0				2	0	1	0	0	0	0
68	Cape Spencer (East)	38	19				12	23	4	21	37	38	0
66	Point Althorp Rocks	53	34		*3*	*53*	5	43	36	45	34	40	47
65	Gaff Rock	33	20	*14*	*24*	*33*	21	22	24	18	24	23	0
76	West Inian Island	100	76			*53*	*59*	91	100	50	100	75	76
73	North of Lemesurier	275	195		*4*	*275*	*209*	231	251	238	201	170	179
275	Hubbard Glacier	946	556				350	740	946	440	642	420	356
276	Turner Glacier	312	123				24	262	63	312	34	140	25
277	Dangerous River	109	72					64	60	23	109	104	70
278	Graves Rocks	44	32					31	44	22	37	38	20
78	Three Hill Island	38	20			*0*	*16*	18	38	33	33	11	13
41	Shaw Island	27	10	*26*	*0*	*27*	*11*	11	20	0	0	0	0
79	Quartz Point	84	27	*0*		*2*	*37*	43	84	0	24	35	18
279	Nunatak Fiord	81	64					75	67	30	81	55	73
67	Althorp	41	25			*5*	*35*	*38*	33	18	41	22	8
280	Tsaa Fiord (Icy Bay)	86	39							15	16	86	
281	Dundas Bay SW	35	28							35	27	26	24
282	Kriwoi Isl.	12	7									12	2
283	Dundas Bay N	25	24									25	23
284	Cape Spencer (South)	20	10				20	11	14	0	6	17	0

Table 9. Continued.

77	Northwest Inian Island South	28	12			*11*	*26*	6	28	2	7	11	4
39	Lemesurier Isl NE	99	66	*13*		*57*	*83*	22	82	65	96	99	73
40	Lemesurier Isl SE	46	29	*35*		*35*	*31*	20	17	16	18	41	46

Max	Mean
7322	4841

95 % Confidence Interval			
4326	=LOW	5356	=HIGH

CV	COUNT	SD
5.40	253	261.21

Table 10. The number of harbor seals counted, by day, at haulout sites along the ADF&G Sitka Trend Route in 1997. Surveyed by Pendleton.

Location #	Location Name	Max	Mean	8/18/98	8/20/98	8/21/98	8/22/98	8/24/98	8/25/98	8/26/98
285	Midway Island	7	4		7		5	0		
286	N of Basket Bay	10	5						10	0
287	Appletree	388	224	238	328		388	25	215	149
288	Strawberry Rock	40	26	6	8	36	34	40	26	29
289	Tenakee Rock	323	248	285	132	238	253	227	276	323
290	Crab Bay	331	292	331	326	304	327	296	251	206
292	Mid Inlet Shoal	42	26	34	42	17	15	15	19	40
293	Long Bay	304	219	250	304		196	187	216	161
294	Grassy Island	142	20	0	0	0	142	0	0	0
295	Head of Tenakee	185	128	185	169	108	57	126		122
296	Plover Island	196	144	168	191	107	120	62	166	196
297	Point Hayes	74	32		74	0	15	31	72	0
298	Midway Reef	125	63	101	125	51	28	14	63	56
299	Traders	45	30	28	39	45	30	37	15	13
300	Pt. Moses	27	4	27	0	0	0	0	0	1
301	Krugloi Island	61	20	61	0		58	0	0	0
302	Hoggatt Reef	238	128	238	173	114	121	96	105	49
303	Vixen Island	557	479	321	537	500	443	516	557	481
304	Southarm	14	4	0	0	14	10	0	0	4
305	Northarm	88	69				48	71	88	
306	Moser Island N	77	29	77	26	29	12	10	19	29
307	E Catherine Island	37	22		16		36	37	12	9
308	W of Moser Island	3	3		3					
309	W of Point Moses	6	1			6	0	0	0	0
310	N of Point Lull	4	2				4	2	0	0
311	N of Cedar Cove	110	44					110	21	0
312	E of Appleton Cove	31	30						31	28
313	N of Saook Point	2	1						2	0
314	W Tenakee Inlet	115	115							115

Max	Mean	95 % Confidence Interval				CV	COUNT	SD
3582	2409	2116	=LOW	2702	=HIGH	6.14	152	147.89

Table 11. The number of harbor seals counted at each haulout site for all areas combined in 1997. (Northern part of Southeast Alaska from Icy Bay to Frederick Sound)

Location #	Location Name	Max	Mean	8/16/97	8/17/97	8/18/97	8/19/97	8/20/97	8/21/97	8/22/97	8/23/97	8/24/97	8/25/97	8/26/97
1	Gastineau Channel	37	20	23	25	0		37	28	0	24			
2	Taku Point	300	225	225	212	140	175	249	240	239	249	300		
3	Hole in theWall	68	29	7	0	47	68		64	48	0	0		
4	Annex Creek	50	26	50	42	35	47	8		16	11	0		
5	Little Island	413	336	275	350	308	395	349	341	299	298	413		
6	Berners River	752	491		425	451	523	457	543	752	350	426		
7	Eldred Rock	121	98	77	106	90	98	83	114	88	108	121		
8	Shikogi Island	59	23	37	0	0	38	0	32	59	18			
9	Horse Shoals	57	38		57	36	38	54	43	24	14			
10	Favorite Reef	12	4		12	0	0	0	0	12				
11	Aaron Island	21	10		8	17	21	0	0	16				
12	Eagle Reef	31	15		7	16	31	0	23	13	17			
13	Sentinel Island	20	8		10	6	0	3	12	20		6		
14	Skull Island	55	30		0	40	55	23		32				
15	North Tip Shelter	10	1			10	0	0	0	0	0	0		
16	Berners River Mouth	24	24				24							
17	Hump Island	19	16				13		16	17	17	19		
18	Auke Bay	15	5				15		8	3	0	0		
19	Taku Sands	7	5					7		6	5	2		
20	Annex Sands	12	12					12						
21	Point Styleman	30	26					30	29	20	21	28		
22	Whiting River	54	42					36		54	37			
23	Prospect Point	284	199					129	130	253	284			
24	Speel Point	50	21					50	34	22	0	0		
25	North Benjamin	5	2							5	0	0		
26	Upper Whiting	281	233								185	281		
27	Berners Sands	18	18									18		
28	North Couverden	36	27	15		34	19	29	16	36	30	33		
29	Couverden Rock	158	98	5		128	158	84	31	98	129	153		
30	Rocky Island	14	10	7		6	13	14	6	9	9	13		
31	Hanus Reef	4	2			2	3	0	2	1		4		
32	Sisters	22	12	7		15	10		22	17	5	10		
33	Homeshore	52	22	16		42	0		43	0	2	52		
34	Excursion Inlet	106	77	68		94	31		106	91	51	98		
35	Saw Mill Bay	7	3	6		3	7			0	0	0		
36	Porpoise Island	63	25	63		56	7		15	31	1	3		
37	Pleasant Island Reef	24	12	14		13	24		15	3	1	17		
38	North Pleasant Island 1	33	12	31		18	0		2	0	0	33		
42	Gull Cove	3	3	2			3							
43	Midway Rocks	2	1	1						2	0			
44	Spasski Island	24	10	0		24	24			0	0			

Table 11. Continued.

45	Whitestone Harbor	4	1	0		0		0	0	4	0	0		
46	Heide Rock	321	224	126				321						
47	South Point Hepburn	50	27	12	0			25		33	42	50		
48	Naked Island	15	7	0	4		6	15	1	7	9	10		
49	Hawk Point	137	85	0	116	122	60	70		50	137	126		
50	South Hawk Point	34	25	0	30	31	34	30		34	27	13		
51	Cube Cove North	8	3	0	8			0		4	4	0		
52	Point Hepburn	19	3	0	19			0		0	0	0		
53	Ward Creek	10	2		10			0		0	0	0		
54	Chaik Bay North	74	38		37			32		18	31	74		
55	Chaik Bay South	14	8		10			14		0	10	7		
56	Russian Reef	46	14		25			46		0	0	0		
57	Whitewater Bay North	32	14		32			0		23	12	1		
58	Whitewater Bay Island	76	26		76			39		12	5	0		
59	Point Caution	6	2		6			0		0	3	0		
60	Wilson Cove	95	48		95			91		5	17	32		
61	Wilson Cove North	3	2								3	0		
62	Wilson Cove South	93	52		29			93		12	84	44		
63	Point Gardner	90	51		90			65		34	27	38		
64	Yasha Island	109	84		87			109		91	70	62		
74	West Taylor Bay	8	8			8								
75	George Island	1	1			1								
80	South Point Brightman	121	87							60	121	80		
81	False Bay	12	5	0				9		4	0	12		
82	Point Augusta	7	5	0				7		7	6	7		
83	Noon Point (Pleasant Island)	3	1	0					1	3	1	0		
84	Mitchell Bay	39	14		0				30	39	0	0		
85	Mitchell Bay Island	50	24		0				0		50	45		
86	Kootznahoo Inlet	4	2		0						3	4		
87	North Pleasant Island 2	15	4	0						15	0	0		
88	West of Whitestone Harbor	25	6	0						25	0	0		
89	North Square Cove	12	6	0						2	10	12		
90	North Ward Creek	11	7							9	11	0		
91	Noname Wash	21	14		0					14	20	21		
92	South Noname Wash	8	4		0					8	6	0		
93	Cove Point	39	26	31		21	24	20	39		22	24		
94	Doty Cove Soutn	46	37	31		33	38	29	46		44	40		
95	Morse Peak West	21	11	21		17		0	7		15	5		
96	Midway Point South	35	26	34		21		13	23		27	35		
97	Dorn Island South	98	82	66		83					81	98		
98	Swan Island East	454	328	196		213			411		364	454		
99	King Salmon Bay East	234	184	234		179			164		178	167		
100	Tiedeman Island SW	141	87	141		121					66	20		
101	Beacon Rock	50	38	41		50			48		0	50		
102	Donkey Bay Rock	120	77	84	120				40	44	92	80		
103	Round Rock	25	10	6					25	5	7	7		
104	Brother Island SW	40	27	9					36		40	21		

Table 11. Continued.

105	Brother Island E	55	38	35					55		14	46		
106	Gambier Bay	203	185		150				203		196	189		
107	Price Island	211	152		75				151		211	171		
108	Pybus Point West	25	10		25				16		0	0		
109	Cannery Cove SE	16	5		16				11	0	0	0		
110	Elliott Island South	69	22		31				69	0	1	7		
111	Pybus Bay South	283	162		283				270	0	129	130		
112	Pybus Bay North	479	253		96				90	320	280	479		
113	Spruce Island	280	121		181				280	41	62	41		
114	Five Fingers A	54	28		33			36	54		9	8		
115	Five Fingers B	48	23		24			31	48		2	9		
116	Five Fingers C	22	12		22			20	15		0	1		
117	Five Fingers D	163	127		90			163	130		130	121		
118	Akusua Island	94	56		55			94	25		45	59		
119	Sail Island	50	30		8			40	20		50	30		
120	Midway Island	290	272		260	290		289			290	232		
121	Sunset Island	60	38		25	60		40	17		30	53		
122	Twin Island East	176	162		175	176		170	174		120	159		
123	Twin Island West	68	42		56	68		38	45		19	26		
124	West Bird Rock	80	21		9			12	0		80	2		
125	Wapole Point	10	3		3			4	10		0	0		
126	Windman Bay South	43	28		41	43					14	12		
127	Windman Bay	253	171		155	253					107	169		
128	Point Windman	171	120		146	95					67	171		
129	Endicott Arm	970	820		578			783	949		970			
130	Harbor Island NE	80	63			50		60				80		
131	Tracey Arm	690	543			352		475	690		656			
132	Robert Island NW	11	6								11	0		
133	Swan Island South	12	12									12		
194	Bird Rock	109	60		9			93	87		0	109		
140	Kelp Bay Middle Arm	12	3	12		0			0		0			
141	Kelp Bay South Arm	65	41	15		65			35		47			
142	Pond Island North	27	14	14		0					27			
143	Kasnyku Bay	13	7	5		13			2		8			
144	Takatz Bay North	60	34	27		30		60	27		25			
145	Takatz Bay South	55	33	28		55		31	17					
146	North of Baranof Warm Springs	16	10					13	0		16			
147	North of Cascade Bay	1	1					0	1					
148	Cascade Bay North	34	9	34		0		0			0			
149	Nelson Bay	54	35	50		54		30	31		9			
150	South of Nelson Bay	5	3					0			5			
151	North of Red Bluff Bay 1	17	15	13					17					
152	North of Red Bluff Bay 2	20	12			20			7		9			
153	Red Bluff Bay	35	27	23		20		35			29			
154	North of Gut Bay	18	11			3					18			
155	Gut Bay	3	1	0		3			0					
156	North of Patterson Point	26	18	8		26			26		11			

Table 11. Continued.

157	South of Point Herbert	18	8	0		14			18		0			
158	North of Point Lucy	4	4	4										
159	Point Conclusion	56	40	44		56			39		19			
160	East of Port Alexander	8	8								8			
161	South of Port Alexander	126	82	54		126			97		51			
162	First Kekur	27	13			12			27		0			
163	North of Snipe Bay	11	6			11			0					
164	North of Sandy Bay	59	53			47			59					
165	Third Kekur	63	63								63			
166	Tjkhaia Island	166	107	49		111	166	126	92		97			
167	Port Banks	39	25	5		31	37	39	19		18			
168	Small Arm	74	61			65	58	65	74		45			
169	South of North Cape	2	2						2					
170	North of North Cape	8	4			8		0						
171	Guilbert Islets	19	4	0		7	19	0	0		0			
172	Necker Bay Island	97	74			71	74	97	65		61			
173	Necker Bay NE	13	3			13	0	0	0		0			
174	Jamboree Bay	25	16	0		19	14	18	25		22			
175	Cedar Pass	55	37	12		55		18	50		48			
176	Crawfish Inlet	3	1	0		3		0						
177	West of Gornoi Island	59	57					59	54		58			
178	SW of Gornoi Island	36	36								36			
179	NE of Rogers Island	66	66					66						
180	NW of Tava Island	41	41							41				
181	North of Tava Island	23	23			23								
182	NW of Legine Island	57	45				26		48	57	47			
183	NE of Tava Island	37	27			32		18	20		37			
184	West of Camel Mountain	11	6					0	6	11				
185	North Biorka Island	16	4			4	16	0	1		0			
186	East Biorka Island	36	17			26	36	0	14	28	0			
187	NW Peigar Island	104	67					0	104	83	79			
188	NE Peigar Island	84	28			84				0	0			
189	NW Kanga Bay	22	5				22	0	0	5	0			
190	Kanga Bay Mouth	6	6							6				
191	Povorotni Point	91	67	24		91	89	73	74	59	60			
192	East Povorotni Point	26	26				26							
193	South Povorotni Point	111	83						79	60	111			
195	Low Island	574	474	500		574		372	517		395	485		
196	Kruzof Island South	13	8	3		9			13					
197	Kruzof Island North	1	1	1										
198	Point Kruzof	18	13	7				12	18		13	15		
199	Point Leo	40	25	16	24	40		18	24		30			
200	Klochachef Island	59	50	25	45	54		59	59		55			
201	Potato Patch	73	58	40	63	62		50	73		60			
202	Pehil Pass	108	76	60	108	73		37	102					
203	Cobol	4	3	4				4	2		3			
204	Herbert Graves West	47	36	13		47		42	45		34			

Table 11. Continued.

205	Hogan Island North	2	2	2										
206	Hill Island North	1	1	1										
207	Lisianski Strait South	59	45	30							59			
208	Lisianski Strait North	73	65	70		73		62	56					
209	Minor Island	31	27	30	26	31		25			22			
210	Salisbury	60	43		21			43	43		60	49		
211	South of Pelican	8	5		7	0					8			
212	Hoonah Sound North	3	2		3						0			
213	Arm Rock North	75	29		75			10			2			
214	Emmons	374	270		250	250		207	268		374			
215	Gilmer Bay	70	49			32		55	36		70	51		
216	North Sea Lion Rocks	44	25			25		35	44		16	5		
217	Middle Sea Lion Rocks	47	34			31		33	47		39	22		
218	Shark Hole	15	15			15								
219	North Sister Lake	22	10			7		9	22		0			
220	Point Satchrun	15	13			10					15			
221	Surge Bay	82	71			60					82			
222	Takanis Bay	8	8			8								
223	West Takanis Bay	30	30			30								
224	Soapstone	6	6			6					6			
225	Pelican	9	3			9			0		0			
226	Hoonah	72	36			0					72			
227	Hoggatt Reef	129	97			94		129			69			
228	NW Cape Edgecumbe	39	33					26				39		
229	North Gilmer Bay	3	3					3						
230	Kakul Narrows	35	26					12	28		35	29		
232	Cape Cross	21	21					21			20			
233	Sergius Narrows	57	46					57			34			
234	SW Cape Edgecumbe	33	33						33					
235	Sea Lion Rocks	5	4						3			5		
236	S. Sea Lion Rocks	3	3						3					
237	Ford Arm	77	53					77	35		48			
238	E. Sisters Lake	100	61					84	0		100			
239	Apple Island	5	3							5	0			
240	Khaz Peninsula 1	102	56	60	38	52		54	76		102	9		
241	Khaz Peninsula 2	13	10	8		13			8		11			
242	Khaz Peninsula 3	85	38	15		17		85	33		40			
243	Khaz Peninsula 4	146	38	13		13		13	7		146			
244	Khaz Peninsula 14	11	11								11			
245	Khaz Peninsula 5	59	44	40				58	59		18			
246	Khaz Peninsula 7	133	80	8		99					133			
247	Khaz Peninsula 6	40	40	40										
248	Khaz Peninsula 8	16	16	16										
249	Khaz Peninsula 9	58	49	40					58					
250	Khaz Peninsula 10	34	19	3		34								
251	Khaz Peninsula 11	31	31			31								
252	Khaz Peninsula 12	154	154			154								

Table 11. Continued.

253	Khaz Peninsula 13	12	12			12								
254	Martin Islands	5	5			5								
255	Wingham Island	38	32			38	25							
256	Kayak Island 1	6	5			3	6							
257	Kayak Island 2	16	14			16	11							
258	Kayak Island 3	20	19			18	20							
259	Kayak Island 4	5	5			5	5							
260	Kayak Island 5	93	80			93	67							
261	Cape Suckling 1	35	31			35	27							
262	Cape Suckling 2	4	2			4	0							
263	Icy Bay NW	2501	1691				1225	2210	2501		1680	1140	1390	
264	Icy Bay NE	253	166			113	220	151	253		120	120	185	
265	Otmeloi Island	20	10				8	17	20		0	10	7	8
266	Krutoi Island	6	3				1	2	3		1	6	5	0
267	Foxy Reef	50	36				40	50	31		35	38	28	28
268	Knight Island Reef	30	16				9	6	30		14	16	19	18
269	Russell Fiord	195	108				101	106	130		195	10	130	82
270	Blacksand Spit	9	2				9	0	0		0	0	0	
271	Dry Bay	1306	1044				1008	724	1039		1122	1306	1082	1024
272	Lituya Bay	127	44				27	35	127		8	31	42	38
273	Astrolabe Rocks	69	45				29	30	47		52	61	69	26
274	Venisa Point	2	0				2	0	1		0	0	0	0
68	Cape Spencer (East)	38	19				12	23	4		21	37	38	0
66	Point Althorp Rocks	53	34		3	53	5	43	36		45	34	40	47
65	Gaff Rock	33	20	14	24	33	21	22	24		18	24	23	0
76	West Inian Island	100	76			53	59	91	100		50	100	75	76
73	North of Lemesurier	275	195		4	275	209	231	251		238	201	170	179
275	Hubbard Glacier	946	556				350	740	946		440	642	420	356
276	Turner Glacier	312	123				24	262	63		312	34	140	25
277	Dangerous River	109	72					64	60		23	109	104	70
278	Graves Rocks	44	32					31	44		22	37	38	20
78	Three Hill Island	38	20			0	16	18	38		33	33	11	13
41	Shaw Island	27	10	26	0	27	11	11	20		0	0	0	0
79	Quartz Point	84	27	0		2	37	43	84		0	24	35	18
279	Nunatak Fiord	81	64					75	67		30	81	55	73
67	Althorp	41	25			5	35	38	33		18	41	22	8
280	Tsaa Fiord (Icy Bay)	86	39								15	16	86	
281	Dundas Bay SW	35	28								35	27	26	24
282	Kriwoi Isl.	12	7										12	2
283	Dundas Bay N	25	24										25	23
284	Cape Spencer (South)	20	10				20	11	14		0	6	17	0
77	Northwest Inian Island South	28	12			11	26	6	28		2	7	11	4
39	Lemesurier Isl NE	99	66	13		57	83	22	82		65	96	99	73
40	Lemesurier Isl SE	46	29	35		35	31	20	17		16	18	41	46
285	Midway Island	7	4					7		5		0		
286	N of Basket Bay	10	5										10	0
287	Appletree	388	224			238		328		388		25	215	149

Table 11. Continued.

288	Strawberry Rock	40	26			6		8	36	34		40	26	29
289	Tenakee Rock	323	248			285		132	238	253		227	276	323
290	Crab Bay	331	292			331		326	304	327		296	251	206
292	Mid Inlet Shoal	42	26			34		42	17	15		15	19	40
293	Long Bay	304	219			250		304		196		187	216	161
294	Grassy Island	142	20			0		0	0	142		0	0	0
295	Head of Tenakee	185	128			185		169	108	57		126		122
296	Plover Island	196	144			168		191	107	120		62	166	196
297	Point Hayes	74	32					74	0	15		31	72	0
298	Midway Reef	125	63			101		125	51	28		14	63	56
299	Traders	45	30			28		39	45	30		37	15	13
300	Pt. Moses	27	4			27		0	0	0		0	0	1
301	Krugloi Island	61	20			61		0		58		0	0	0
302	Hoggatt Reef	238	128			238		173	114	121		96	105	49
303	Vixen Island	557	479			321		537	500	443		516	557	481
304	Southarm	14	4			0		0	14	10		0	0	4
305	Northarm	88	69							48		71	88	
306	Moser Island N	77	29			77		26	29	12		10	19	29
307	E Catherine Island	37	22					16		36		37	12	9
308	W of Moser Island	3	3					3						
309	W of Point Moses	6	1						6	0		0	0	0
310	N of Point Lull	4	2							4		2	0	0
311	N of Cedar Cove	110	44									110	21	0
312	E of Appleton Cove	31	30										31	28
313	N of Saook Point	2	1										2	0
314	W Tenakee Inlet	115	115											115

Max	Mean
27812	18933

95 % Confidence Interval			
18059	=LOW	19806	=HIGH

CV	COUNT	SD
2.35	1363	445.08

Table 12. Comparison of harbor seal numbers between surveys conducted in August versus September along Stephens Passage. Surveyed by Olesiuk.

		August		September		Mean Difference
Location #	Location Name	MAX	MEAN	MAX	MEAN	Aug. to Sept.
93	Cove Point	39	26	58	42	16
94	Doty Cove Soutn	46	37	65	52	14
95	Morse Peak West	50	11	39	29	18
96	Midway Point South	42	26	83	72	46
97	Dorn Island South	98	82	53	45	-37
98	Swan Island East	454	328	86	67	-261
99	King Salmon Bay East	234	184	50	41	-143
100	Tiedeman Island SW	141	87	82	31	-56
101	Beacon Rock	50	38	50	41	4
102	Donkey Bay Rock	120	77	85	41	-36
103	Round Rock	25	10	11	5	-5
104	Brother Island SW	40	27	74	52	26
105	Brother Island E	55	38	26	20	-18
106	Gambier Bay	203	185	81	65	-120
107	Price Island	211	152	194	121	-31
108	Pybus Point West	25	10	4	2	-8
109	Cannery Cove SE	16	5	5	2	-4
110	Elliott Island South	69	22	19	6	-15
111	Pybus Bay South	283	162	150	102	-61
112	Pybus Bay North	479	253	29	27	-226
113	Spruce Island	280	121	127	76	-45
114	Five Fingers A	54	28	10	7	-21
115	Five Fingers B	48	23	10	7	-16
116	Five Fingers C	22	12	13	11	-1
117	Five Fingers D	163	127	57	50	-76
118	Akusua Island	94	56	53	46	-10
119	Sail Island	50	30	33	27	-2
120	Midway Island	290	272	138	122	-150
121	Sunset Island	60	38	49	44	7
122	Twin Island East	176	162	79	66	-96
123	Twin Island West	68	42	114	86	44
124	West Bird Rock	80	21	5	3	-17
125	Wapole Point	10	3	6	3	0
126	Windman Bay South	43	28	121	69	41
127	Windman Bay	253	171	172	157	-14
128	Point Windman	171	120	128	97	-22
129	Endicott Arm	970	820	347	318	-502
130	Harbor Island NE	80	63	10	7	-57
131	Tracey Arm	690	543	174	174	-369
132	Robert Island NW	11	6	31	16	10
133	Swan Island South	12	12	20	8	-4
134	Pybus Point South			121	96	96
135	Station Point North			6	4	4
136	Station Point South			37	31	31
137	Five Fingers East			30	18	18
138	Harbor Island East			7	7	7
194	Bird Rock	109	60	113	97	37

August = 4513

September = 2508

Net Difference -2005

Table 13. Comparisons between 1997 and 1993 mean harbor seal counts by haulout site.
Site locations grouped using best available data.

1997 Location Code	1993 Area\Code #	1997 Location Name	Haulout Type	1997 Latitude	1997 Longitude	1997 Mean	1993 Mean	1993 Location Name
1		Gastineau Channel	Sandy	58.3239	134.4684	20		
6	2\2	Berners River	Sandy	58.7939	134.9816	491	129	Bemers Bay
16	2\2	Berners River Mouth	Sandy	58.7777	134.9742	24		
27	2\2	Berners Sands	Sandy	58.8059	134.9996	18		
10	2\5	Favorite Reef	Rocky	58.3829	134.8668	4	14	Favorite Reef
9	2\6	Horse Shoals	Rocky	58.2554	134.7093	38	11	Horse Island Reef
17	2\4	Hump Island	Rocky	58.4675	134.9888	16	24	Hump Island
5		Little Island	Cobble	58.5357	135.0445	336		
23	2\12	Prospect Point	Rocky	58.0478	133.7936	199	76	Prospect Island
2	2\8	Taku Point	Sandy	58.3881	134.0366	225	136	Taku Inlet
19	2\8	Taku Sands	Sandy	58.3611	134.0220	5		
4	2\8	Annex Creek	Sandy	58.3159	134.0627	26		
20	2\8	Annex Sands	Sandy	58.3119	134.0496	12		
3	2\8	Hole in theWall	Sandy	58.4915	133.9468	29		
26	2\13	Upper Whiting	Sandy	58.0306	133.5864	233	93	Whiting River
22	2\13	Whiting River	Sandy	58.0029	133.6789	42		
11	2\1	Aaron Island	Rocky	58.4400	134.8244	10	254	Favorite Channel
12	2\1	Eagle Reef	Rocky	58.4606	134.8243	15		
18		Auke Bay	Rocky	58.3575	134.6746	5		
7		Eldred Rock	Rocky	58.9688	135.2174	98		
25		North Benjamin	Rocky	58.5788	134.9145	2		
15		North Tip Shelter	Rocky	58.4915	134.9203	1		
21	2\11	Point Styleman	Rocky	57.9779	133.9259	26	22	Pt. Styleman Rf.
13		Sentinel Island	Rocky	58.5516	134.9249	8		
8		Shikogi Island	Rocky	59.0411	135.2755	23		
14		Skull Island	Rocky	58.2074	134.6446	30		
24		Speel Point	Sandy	58.1243	133.7189	21		
54	8\35	Chaik Bay North	Rocky	57.3338	134.5658	38	78	Chaik Bay
55	8\35	Chaik Bay South	Rocky	57.3130	134.5890	8		
51	3\9	Cube Cove North	Rocky	57.9543	134.7685	3	6	Cube Cove-Fishe
52	3\9	Point Hepburn	Rocky	57.9248	134.7500	3		
47	3\9	South Point Hepburn	Rocky	57.9257	134.7517	27		
53	3\9	Ward Creek	Rocky	57.8788	134.7350	2		

Table 13. Continued.

71	1\24	Dundas Bay Forks	Rocky	58.4061	136.4827	0	33	Dundas Bay Forks
70	1\25	Dundas Bay Island	Rocky	58.3568	136.5099	0	27	Dundas Bay Island
72	1\23	Dundas River	Rocky	58.3685	136.3083	0	44	Dundas River Delta
81		False Bay	Rocky	57.9603	134.9265	5		
42	1\13	Gull Cove	Rocky	58.2155	136.1752	3	18	Gull Cove
86	8\37	Kootznahoo Inlet	Rocky	57.5330	134.4743	2	2	Kootznahoo Bay
43		Midway Rocks	Rocky	58.0005	135.6180	1		
84		Mitchell Bay	Rocky	57.5368	134.4480	14		
85		Mitchell Bay Island	Rocky	57.5405	134.4257	24		
63	8\33	Point Gardner	Rocky	57.0107	134.9522	51	25	Pt. Gardner
30	1\17	Rocky Island	Rocky	58.1775	135.0487	10	32	Rocky I.
32	3\3	Sisters	Rocky	58.1818	135.2632	12	10	Sisters I.
44	3\2	Spasski Island	Rocky	58.1335	135.2775	10	22	Spasski I.
69	1\26	Taylor Bay	Rocky	58.3097	136.5738	0	23	Taylor Bay
74	1\26	West Taylor Bay	Rocky	58.2805	136.5597	8		
88	3\4	West of Whitestone Harbor	Rocky	58.0947	135.1402	6	25	Whitestone Hrbr.
45	3\4	Whitestone Harbor	Rocky	58.0738	135.0697	1		
58	8\47	Whitewater Bay Island	Rocky	57.2393	134.6012	26	39	Whitewater Bay
57	8\47	Whitewater Bay North	Rocky	57.2625	134.6163	14		
60	3\34	Wilson Cove	Rocky	57.1650	134.6395	48	102	Wilson Cove
61	8\34	Wilson Cove North	Rocky	57.1687	134.6267	2		
62	8\34	Wilson Cove South	Rocky	57.1435	134.6318	52		
64	8\38	Yasha Island	Rocky	56.9665	134.5563	84	73	Yasha I.
29	3\6	Couverden Rock	Rocky	58.2192	135.0410	98	44	Pt. Couverden
28	3\6	North Couverden	Rocky	58.2473	135.0623	27		
34		Excursion Inlet	Sandy	58.5023	135.5068	77		
75		George Island	Rocky	58.1928	136.3822	1		
31		Hanus Reef	Rocky	58.1335	134.9938	2		
49		Hawk Point	Rocky	58.0948	134.7808	85		
46	3\12	Heide Rock	Rocky	57.8677	135.0292	224	14	Pavlof & Freshw
33		Homeshore	Rocky	58.2992	135.3740	22		
48		Naked Island	Rocky	58.2582	134.9425	7		
91		Noname Wash	Rocky	57.0928	134.6332	14		
83		Noon Point (Pleasant Island)	Rocky	58.3397	135.5260	1		
38		North Pleasant Island 1	Rocky	58.3877	135.6282	12		
87		North Pleasant Island 2	Rocky	58.3815	135.6838	4		
89	3\8	North Square Cove	Rocky	57.9965	134.7707	6	18	Game Cove to Cube Cove
90		North Ward Creek	Rocky	57.8757	134.7293	7		

Table 13. Continued.

37		Pleasant Island Reef	Rocky	58.3093	135.6425	12		
82	3\7	Point Augusta	Rocky	58.0453	134.9543	5	8	Pt. Aug. to Flin.
59	8\51	Point Caution	Rocky	57.2522	134.6435	2	5	Point Caution
36		Porpoise Island	Rocky	58.3367	135.4707	25		
56		Russian Reef	Rocky	57.2887	134.6138	14		
35		Saw Mill Bay	Rocky	58.4483	135.4750	3		
50		South Hawk Point	Rocky	58.0797	134.7938	25		
92	8\48	South Noname Wash	Rocky	57.0685	134.6188	4	25	P Wilson/Gardner
80	8\31	South Point Brightman	Rocky	57.0568	134.4597	87	60	Pt. Bright/Carro
120		Midway Island	Rocky	57.8437	133.8144	272		
129	2\17	Endicott Arm	Ice	57.4974	132.8346	820	191	Endicott Arm
114	2\30	Five Fingers A	Rocky	57.2661	133.6356	28	103	Five Fingers
115	2\30	Five Fingers B	Rocky	57.2704	133.6578	23		
116	2\30	Five Fingers C	Rocky	57.2756	133.6384	12		
117	2\30	Five Fingers D	Cobble	57.2841	133.6705	127		
137	2\30	Five Fingers East	Rocky	57.0270	134.6300	18		
107	2\26	Price Island	Rocky	57.4200	133.8848	152	132	Price I.
132	2\21	Robert Island NW	Rocky	57.3090	133.4994	6	46	Robert I. Reefs
103	2\24	Round Rock	Rocky	57.2606	133.9332	10	16	Round Rock
119	2\22	Sail Island	Rocky	57.3413	133.7095	30	26	Sail I.
113	2\25	Spruce Island	Rocky	57.2089	134.0899	121	92	Spruce I.
135	2\10	Station Point North	Rocky	58.0228	134.1045	4	27	Station Point Area
136	2\10	Station Point South	Rocky	57.9970	134.0849	31		
121	2\18	Sunset Island	Rocky	57.4929	133.5810	38	48	Sunset I.
131	2\16	Tracey Arm	Ice	57.8617	133.3200	543	127	Tracy Arm
118		Akusua Island	Cobble	57.2981	133.6488	56		
101	2\28	Beacon Rock	Rocky	57.6647	134.0225	38	69	Lower Seymour C.
194	7\3	Bird Rock	Rocky	57.2149	133.5722	60	55	Storm I/Bird Rock
124	7\3	West Bird Rock	Rocky	57.2073	133.5958	21		
105		Brother Island E	Rocky	57.2935	133.7923	38		
104	2\23	Brother Island SW	Rocky	57.2708	133.8706	27	66	SW Brother
109		Cannery Cove SE	Rocky	57.3073	134.0875	5		
93	2\9	Cove Point	Rocky	58.1201	134.1721	26	33	Doty Cove Area
94	2\9	Doty Cove South	Rocky	58.0724	134.1653	37		
102		Donkey Bay Rock	Rocky	57.3638	134.1452	77		
97	2\29	Dorn Island South	Rocky	57.8318	134.0186	82	112	Upper Seymour C
99	2\29	King Salmon Bay East	Rocky	58.0113	134.2410	184		
98	2\29	Swan Island East	Rocky	57.9480	134.1968	328		

Table 13. Continued.

133	2\29	Swan Island South	Rocky	57.9033	134.0296	12		
100	2\29	Tiedeman Island SW	Rocky	57.7953	134.1391	87		
110		Elliott Island South	Rocky	57.2522	134.0561	22		
106	2\27	Gambier Bay	Rocky	57.4703	134.0405	185	68	Inner Gambier
138		Harbor Island East	Rocky	57.7510	133.6022	7		
130		Harbor Island NE	Cobble	57.7758	133.6134	63		
96		Midway Point South	Rocky	57.7137	133.8809	26		
95		Morse Peak West	Rocky	57.8648	133.9714	11		
128		Point Windham	Rocky	57.5650	133.5401	120		
112		Pybus Bay North	Rocky	57.2355	134.1178	253		
111		Pybus Bay South	Rocky	57.2211	134.1120	162		
134		Pybus Point South	Cobble	57.2972	133.9770	96		
108		Pybus Point West	Rocky	57.3025	134.0193	10		
122	2\20	Twin Island East	Rocky	57.4198	133.5363	162	43	Inner Twin I.
123	2\19	Twin Island West	Rocky	57.4228	133.5550	42	68	Outer Twin I.
125		Walpole Point	Rocky	57.3126	133.5260	3		
127		Windham Bay	Rocky	57.5607	133.5137	171		
126		Windham Bay South	Rocky	57.5170	133.5292	28		
148	5\22	Cascade Bay North	Rocky	57.0263	134.7513	9	24	Cascade Bay
147	5\22	North of Cascade Bay	Water	57.0375	134.7492	1		
186	5\5	East Biorka Island	Rocky	56.8543	135.4928	17	28	Biorka
185	5\5	North Biorka Island	Rocky	56.8583	135.5342	4		
160	5\15	East of Port Alexander	Rocky	56.2398	134.6342	8	51	Port Alexander
161	5\15	South of Port Alexander	Rocky	56.2075	134.6512	82		
192	5\40	East Povorotni Point	Rocky	56.9400	135.4100	26	40	Povorotni Pt.
191	5\40	Povorotni Point	Rocky	56.9403	135.4202	67		
193	5\40	South Povorotni Point	Rocky	56.9365	135.4202	83		
162	5\18	First Kekur	Rocky	56.3670	134.9402	13	33	First Kekur
171	5\36	Guilbert Islets	Rocky	56.6440	135.1567	4	0	Guilbert I.
155	5\29	Gut Bay	Water	56.7187	134.6893	1	28	Gut Bay
154	5\29	North of Gut Bay	Rocky	56.7400	134.6350	11		
140	5\58	Kelp Bay Middle Arm	Rocky	57.3375	135.0052	3	53	Kelp Bay
141	5\58	Kelp Bay South Arm	Rocky	57.3085	134.9340	41		
142	5\58	Pond Island North	Rocky	57.2870	134.9052	14		
179	5\38	NE of Rogers Island	Rocky	56.7937	135.4428	66	0	Rogers I.
172	5\51	Necker Bay Island	Rocky	56.7245	135.0548	74	0	Necker Bay
173	5\51	Necker Bay NE	Rocky	56.7560	135.0313	3		
149	5\24	Nelson Bay	Rocky	56.9523	134.7327	35	18	Nelson Bay

Table 13. Continued.

150	5\24	South of Nelson Bay	Rocky	56.9258	134.7098	3		
170	5\35	North of North Cape	Rocky	56.9892	135.2222	4	2	N. Cape
156	5\10	North of Patterson Point	Rocky	56.5590	134.6215	18	32	Patterson Pt.
151		North of Red Bluff Bay 1	Rocky	56.8947	134.6917	15		
152		North of Red Bluff Bay 2	Rocky	56.8828	134.6892	12		
153	5\26	Red Bluff Bay	Rocky	56.8393	134.7037	27	31	Red Bluff Bay
164	5\19	North of Sandy Bay	Rocky	56.4683	135.0112	53	63	Sandy Bay
163		North of Snipe Bay	Rocky	56.4135	134.9633	6		
167	5\47	Port Banks	Rocky	56.5932	135.0072	25	20	Port Banks
168	5\48	Small Arm	Rocky	56.6253	135.0162	61	84	Small Arm
178	5\49	SW of Gornoi Island	Rocky	56.7858	135.3715	36	2	Gornoi I. (SW)
177	5\49	West of Gornoi Island	Rocky	56.7892	135.3717	57		
144	5\20	Takatz Bay North	Rocky	57.1533	134.8042	34	33	Takatz Bay
145	5\20	Takatz Bay South	Rocky	57.1227	134.7862	33		
166	5\9	Tikhaia Island	Rocky	56.5585	135.0520	107	20	Tikhaia I.
184		West of Camel Mountain	Rocky	56.8687	135.3913	6		
175		Cedar Pass	Rocky	56.7557	135.1857	37		
176		Crawfish Inlet	Rocky	56.7812	135.1267	1		
174		Jamboree Bay	Rocky	56.7190	135.2045	16		
190		Kanga Bay Mouth	Rocky	56.8883	135.3422	6		
143		Kasnyku Bay	Rocky	57.2063	134.8348	7		
183		NE of Tava Island	Rocky	56.8393	135.4678	27		
188	5\1	NE Peigar Island	Rocky	56.8897	135.4578	28	7	E. Peisar I.
146	5\21	North of Baranof Warm Spring	Rocky	57.1063	134.7838	10	12	Warm Springs B
158		North of Point Lucy	Water	56.3667	134.6417	4		
181		North of Tava Island	Rocky	56.8627	135.4692	23		
189		NW Kanga Bay	Rocky	56.8347	135.4508	5		
182		NW of Legine Island	Rocky	56.8335	135.4517	45		
180		NW of Tava Island	Rocky	56.8402	135.4717	41		
187	5\2	NW Peigar Island	Rocky	56.8887	135.4422	67	18	W. Peisar I.
159	5\14	Point Conclusion	Rocky	56.2703	134.6343	40	37	Pt. Conclusion
169		South of North Cape	Rocky	56.5915	135.1162	2		
157		South of Point Herbert	Rocky	56.4133	134.6340	8		
165		Third Kekur	Rocky	56.4685	135.0022	63		
239		Apple Island	Rocky	57.0712	135.4598	3		
232	6\26	Cape Cross	Rocky	57.9052	136.5348	21	48	Cape Cross
214	3\34	Emmons	Cobble	57.6199	135.5752	270	19	Emmons I.
215	6\10	Gilmer Bay	Rocky	57.2334	135.8222	49	20	Gilmer Bay

Table 13. Continued.

229	6\10	North Gilmer Bay	Rocky	57.2340	135.8566	3		
227	3\33	Hoggatt Reef	Rocky	57.5544	135.5032	97	50	Hoggatt I.
230	6\4	Kakul Narrows	Rocky	57.3685	135.7180	26	31	Kakul Narrows
240		Khaz Peninsula 1	Rocky	57.5380	136.0745	56		
250		Khaz Peninsula 10	Rocky	57.6001	136.2187	19		
251		Khaz Peninsula 11	Rocky	57.5858	136.1367	31		
252		Khaz Peninsula 12	Rocky	57.5835	136.1380	154		
253		Khaz Peninsula 13	Rocky	57.5875	136.2229	12		
244		Khaz Peninsula 14	Rocky	57.6016	136.0669	11		
241		Khaz Peninsula 2	Rocky	57.5512	136.0834	10		
242		Khaz Peninsula 3	Rocky	57.5741	136.1512	38		
243		Khaz Peninsula 4	Rocky	57.5678	136.1575	38		
245		Khaz Peninsula 5	Rocky	57.5763	136.1397	44		
247		Khaz Peninsula 6	Rocky	57.5864	136.1519	40		
246		Khaz Peninsula 7	Rocky	57.5890	136.2011	80		
248		Khaz Peninsula 8	Rocky	57.6011	136.2097	16		
249		Khaz Peninsula 9	Rocky	57.5841	136.2194	49		
200	6\30	Klochachef Island	Rocky	57.4045	135.9042	50	55	Klochachef I.
195	5\41	Low Island	Rocky	57.0049	135.6196	474	145	Low I.
217	6\14	Middle Sea Lion Rocks	Rocky	57.2747	135.8735	34	14	Sealion Rock
216	6\14	North Sea Lion Rocks	Rocky	57.2873	135.8596	25		
236	6\14	S. Sea Lion Rocks	Rocky	57.2742	135.8860	3		
235	6\14	Sea Lion Rocks	Rocky	57.2742	135.8860	4		
228	6\13	NW Cape Edgecumbe	Rocky	57.1170	135.7584	33	13	Cape Edgecumbe
234	6\13	SW Cape Edgecumbe	Rocky	57.2340	135.8566	33		
198	6\20	Point Kruzof	Rocky	57.3368	135.8462	13	13	Pt. Kruzof
199	6\21	Point Leo	Rocky	57.3854	135.8191	25	3	Pt.Leo
221	6\27	Surge Bay	Rocky	57.9930	136.5672	71	29	Surge Bay
238		E. Sisters Lake	Rocky	57.5886	136.0217	61		
213	3\38	Arm Rock North	Rocky	57.6732	135.6060	29	27	Northarm
212	3\38	Hoonah Sound North	Rocky	57.7586	135.8048	2		
231		Bingham	Rocky	57.9873	136.5590	0		
203		Cobol	Rocky	57.4741	135.8757	3		
237		Ford Arm	Rocky	57.5697	135.9517	53		
204	6\16	Herbert Graves West	Rocky	57.6593	136.2712	36	43	Cape Edwards
206		Hill Island North	Rocky	57.7577	136.3222	1		
205		Hogan Island North	Rocky	57.7241	136.2867	2		
226		Hoonah	Rocky	57.8415	136.3357	36		

Table 13. Continued.

197		Kruzof Island North	Rocky	57.0230	135.8531	1		
196	5\54	Kruzof Island South	Rocky	56.9861	135.8400	8	10	Sitka Pt.
208		Lisianski Strait North	Rocky	57.8242	136.4354	65		
207		Lisianski Strait South	Rocky	57.7899	136.3968	45		
209		Minor Island	Rocky	57.9932	136.3076	27		
219		North Sister Lake	Rocky	57.6232	136.0225	10		
202		Pehil Pass	Rocky	57.5213	136.0583	76		
225		Pelican	Rocky	57.9388	136.2038	3		
220		Point Satchrun	Rocky	57.8922	136.5199	13		
201		Potato Patch	Rocky	57.4764	135.9760	58		
210	6\15	Salisbury	Rocky	57.3897	135.7045	43	29	Scraggy Pt.
233		Sergius Narrows	Rocky	57.4097	135.6049	46		
218		Shark Hole	Rocky	57.3411	135.8262	15		
224		Soapstone	Rocky	58.0847	136.5589	6		
211		South of Pelican	Rocky	57.9035	136.1427	5		
222		Takanis Bay	Rocky	57.9500	136.5689	8		
223		West Takanis Bay	Rocky	57.9402	136.5533	30		
254		Martin Islands	Rocky	60.1780	144.5573	5		
255		Wingham Island	Sandy	60.0780	144.3192	32		
256		Kayak Island 1	Rocky	59.9152	144.4723	5		
257		Kayak Island 2	Rocky	59.8723	144.5588	14		
258		Kayak Island 3	Rocky	59.7885	144.5668	19		
259		Kayak Island 4	Rocky	59.8975	144.4085	5		
260		Kayak Island 5	Rocky	59.9587	144.2440	80		
261		Cape Suckling 1	Rocky	59.9878	144.0192	31		
262		Cape Suckling 2	Rocky	59.9845	143.9095	2		
263	1\1	Icy Bay NW	Ice	60.1185	141.4712	1691	496	Icy Bay
264	1\1	Icy Bay NE	Ice	60.1345	141.3965	166		
280	1\1	Tsaa Fiord (Icy Bay)	Ice	60.0948	141.5293	39		
265		Otmeloi Island	Rocky	59.6458	139.6535	10		
266	1\5	Krutoi Island	Rocky	59.6692	139.6480	3	27	Krutio I.
267	1\5	Foxy Reef	Rocky	59.6652	139.6300	36		
268	1\5	Knight Island Reef	Rocky	59.7140	139.6280	16		
269	1\4	Russell Fiord	Sandy	59.5837	139.3160	108	17	Russel Fiord
270	1\6	Blacksand Spit	Sandy	59.4068	139.4748	2	59	Dangerous River
277	1\6	Dangerous River	Sandy	59.3770	139.3155	72		
271	1\7	Dry Bay	Sandy	59.1567	138.5943	1044	748	Dry Bay
272		Lituya Bay	Ice	58.6577	137.4977	44		

Table 13. Continued.

273	1\9	Astrolabe Rocks	Rocky	58.3400	136.8908	45	39	Astrolabe
274	1\8	Venisa Point	Rocky	58.2972	136.8317	0	8	Boussole Bay
275	1\2	Hubbard Glacier	Ice	60.0247	139.5530	556	361	Hubbard Glacier
276	1\2	Turner Glacier	Ice	59.9883	139.6177	123		
278	1\10	Graves Rocks	Rocky	58.2497	136.7450	32	15	Polka Pen Rocks
279	1\3	Nunatak Fiord	Sandy	59.8027	138.9190	64	19	Nunatak Fiord
283	1\23-25	Dundas Bay N	Rocky	58.3997	136.4537	24	105	Dundas Bay Area
281	1\23-25	Dundas Bay SW	Rocky	58.3527	136.4952	28		
282		Kriwoi Isl.	Rocky	59.6272	139.6753	7		
284	1\11	Cape Spencer (South)	Rocky	58.2073	136.6678	10	80	Cape Spencer
68	1\11	Cape Spencer (East)	Rocky	58.2123	136.6123	19		
66	1\21	Point Althorp Rocks	Rocky	58.1677	136.3597	34	24	Althorp Rocks
67	1\21	Althorp	Rocky	58.1358	136.4178	25		
65	1\20	Gaff Rock	Rocky	58.1928	136.4252	20	25	Gaff Rock
76	1\22	West Inian Island	Rocky	58.2472	136.3860	76	23	Inian I.
77	1\22	Northwest Inian Island South	Rocky	58.2547	136.3785	12		
73	1\14	North of Lemesurier	Rocky	58.3083	136.1185	195	143	I. N of Lemesurier
39	1\15	Lemesurier Isl NE	Rocky	58.3107	136.0360	66	110	Lemesurier I. NE
40	1\16	Lemesurier Isl SE	Rocky	58.2685	136.0347	29	34	Lemesurier I. SE
78	1\19	Three Hill Island	Rocky	58.1730	136.4085	20	9	Three Hill I.
41	1\12	Shaw Island	Rocky	58.2013	136.2330	10	38	Shaw I.
79	1\17	Quartz Point	Rocky	58.2220	136.0487	27	30	Quartz Point
285		Midway Island	Rocky	58.1483	135.6367	4		
286		N of Basket Bay	Rocky	57.8093	134.9850	5		
287	3\11	Appletree	Rocky	57.9372	135.1212	224	120	Apple Tree
288	3\13	Strawberry Rock	Rocky	57.7747	135.1943	26	62	Strawberry Rock
289	3\15	Tenakee Rock	Rocky	57.8235	135.2840	248	98	Tenakee
290	3\16	Crab Bay	Sandy	57.7897	135.4418	292	111	Crab Bay
291	3\17	Saltery Bay	Rocky	57.9298	135.4548	0	18	Saltery Bay
292		Mid Inlet Shoal	Rocky	57.9518	135.5078	26		
293	3\20	Long Bay	Rocky	58.0183	135.7737	219	165	Long Bay
294	3\21	Grassy Island	Cobble	58.0655	136.0000	20	28	Grassy
295	3\23	Head of Tenakee	Sandy	58.1260	135.9343	128	49	Tenakee Head
296	3\24	Plover Island	Rocky	57.3258	134.9827	144	47	Plover Rock
297	3\26	Point Hayes	Rocky	57.6023	134.9998	32	24	Pt. Hayes
298	3\27	Midway Reef	Rocky	57.4820	134.9355	63	11	Midway Reef
299	3\28	Traders	Rocky	57.6348	134.9448	30	12	Traders I.
300	3\30	Pt. Moses	Rocky	57.5455	135.1292	4	1	Pt. Moses

Table 13. Continued.

301	3\32	Krugloi Island	Cobble	57.7002	135.4717	20	12	Krugloi I.
302	3\33	Hoggatt Reef	Rocky	57.5808	135.5360	128	50	Hoggatt I.
303	3\35	Vixen Island	Rocky	57.6625	135.6043	479	86	Vixen I.
304	3\37	Southarm	Rocky	57.7038	135.7707	4	16	Southarm
305	3\38	Northarm	Rocky	57.8083	135.8885	69	27	Northarm
306	3\39	Moser Island N	Rocky	57.7442	135.6680	29	22	Moser I N.
307		E Catherine Island	Rocky	57.4570	134.8338	22		
308		W of Moser Island	Rocky	57.8787	135.8450	3		
309		W of Point Moses	Rocky	57.5407	135.1977	1		
310		N of Point Lull	Rocky	57.4327	134.8578	2		
311		N of Cedar Cove	Rocky	57.9660	135.1917	44		
312		E of Appleton Cove	Rocky	57.6287	135.3932	30		
313		N of Saook Point	Rocky	57.5752	135.1872	1		
314		W Tenakee Inlet	Sandy	58.0160	135.8510	115		

	1997	1993
# Sites	313	130
TOTALS	19101	7368
Difference	11733	

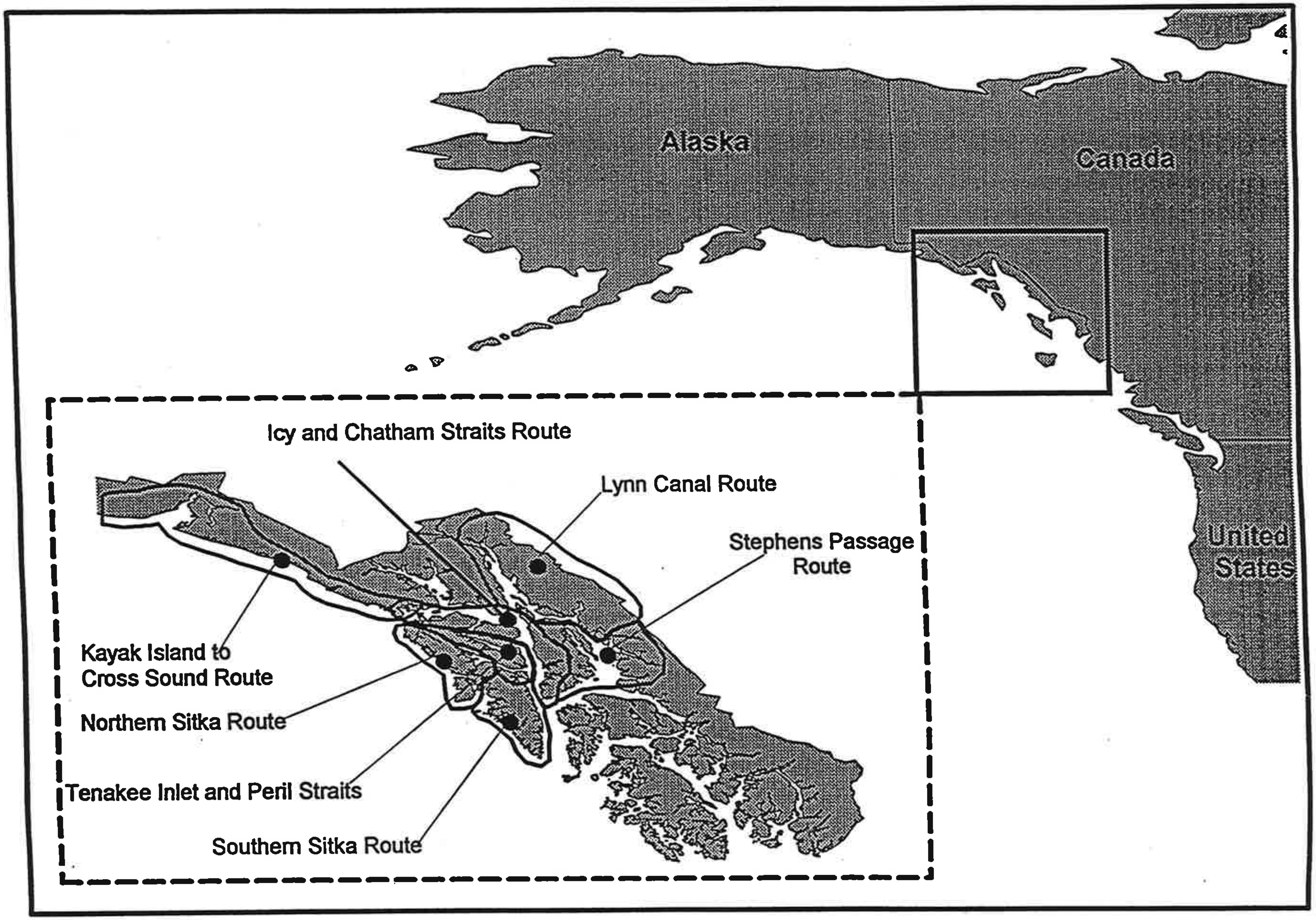

Figure 1. Overview chart of Alaska and 1997 harbor seal survey areas in northern Southeast Alaska.

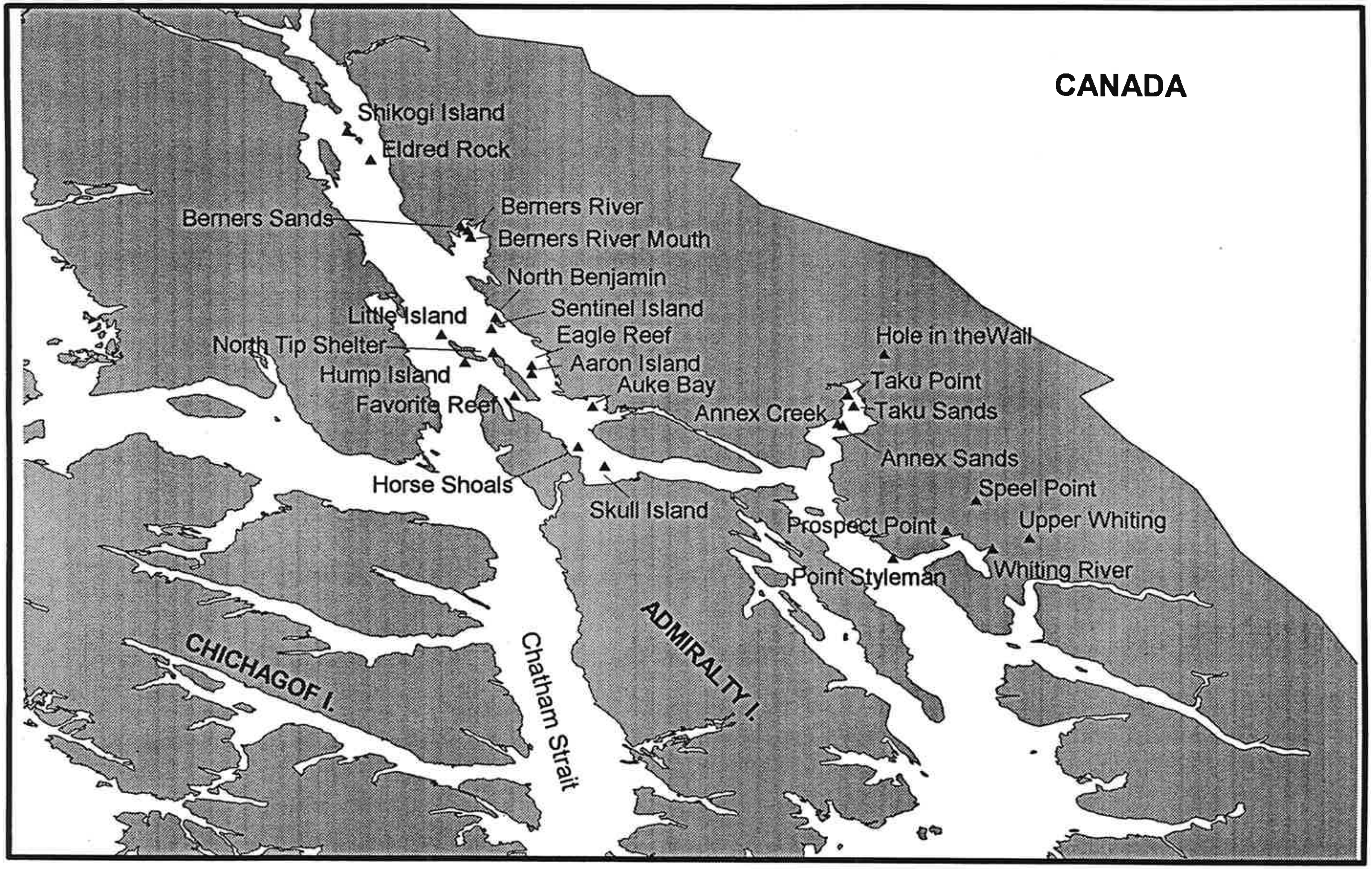

Figure 2. Harbor seal locations for the Lynn Canal route surveyed in August 1997. Refer to Table 2 for site type and positions.

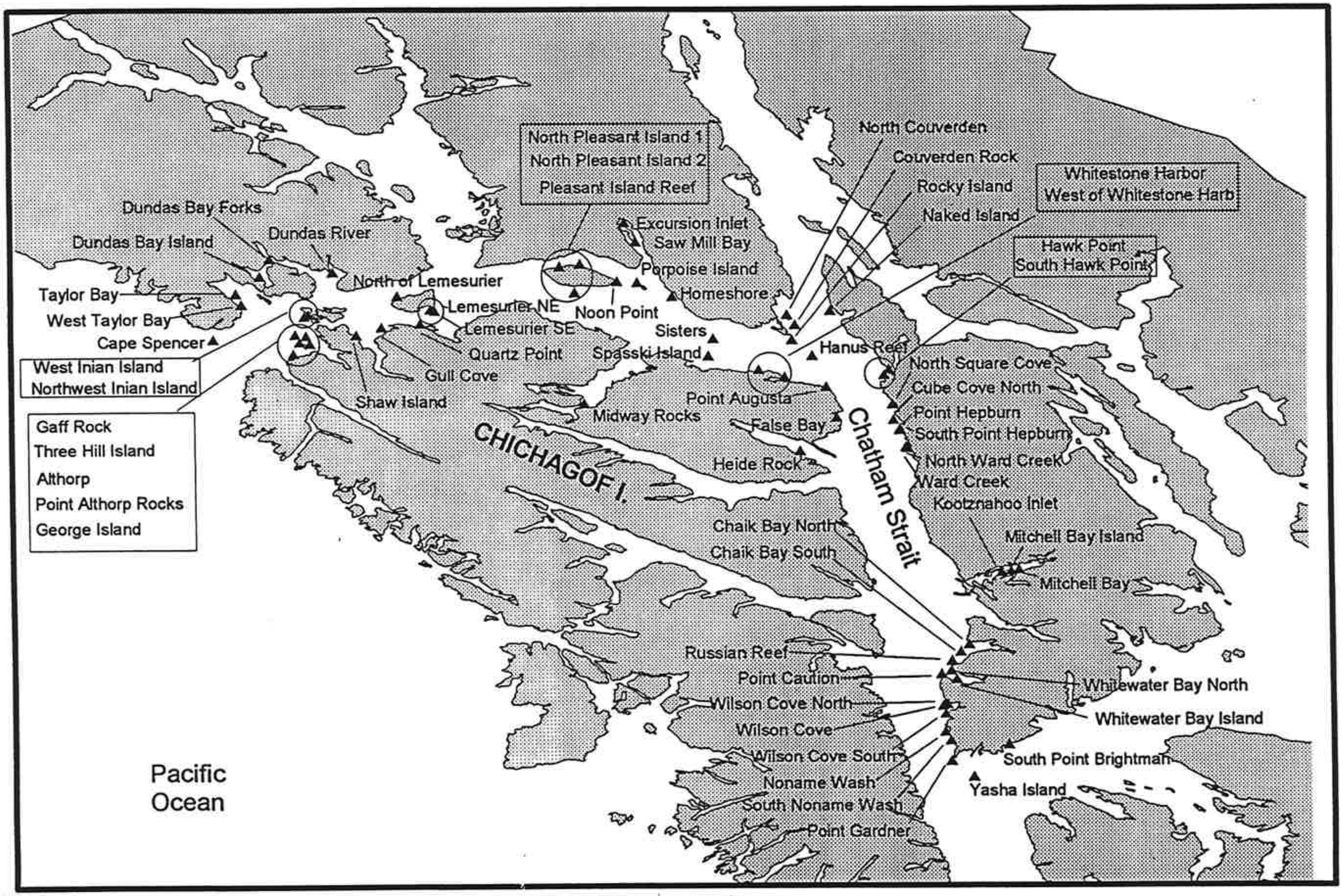

Figure 3. **Harbor seal locations for the Icy and Chatham Straits route surveyed in August 1997. Refer to Table 2 for site type and positions.**

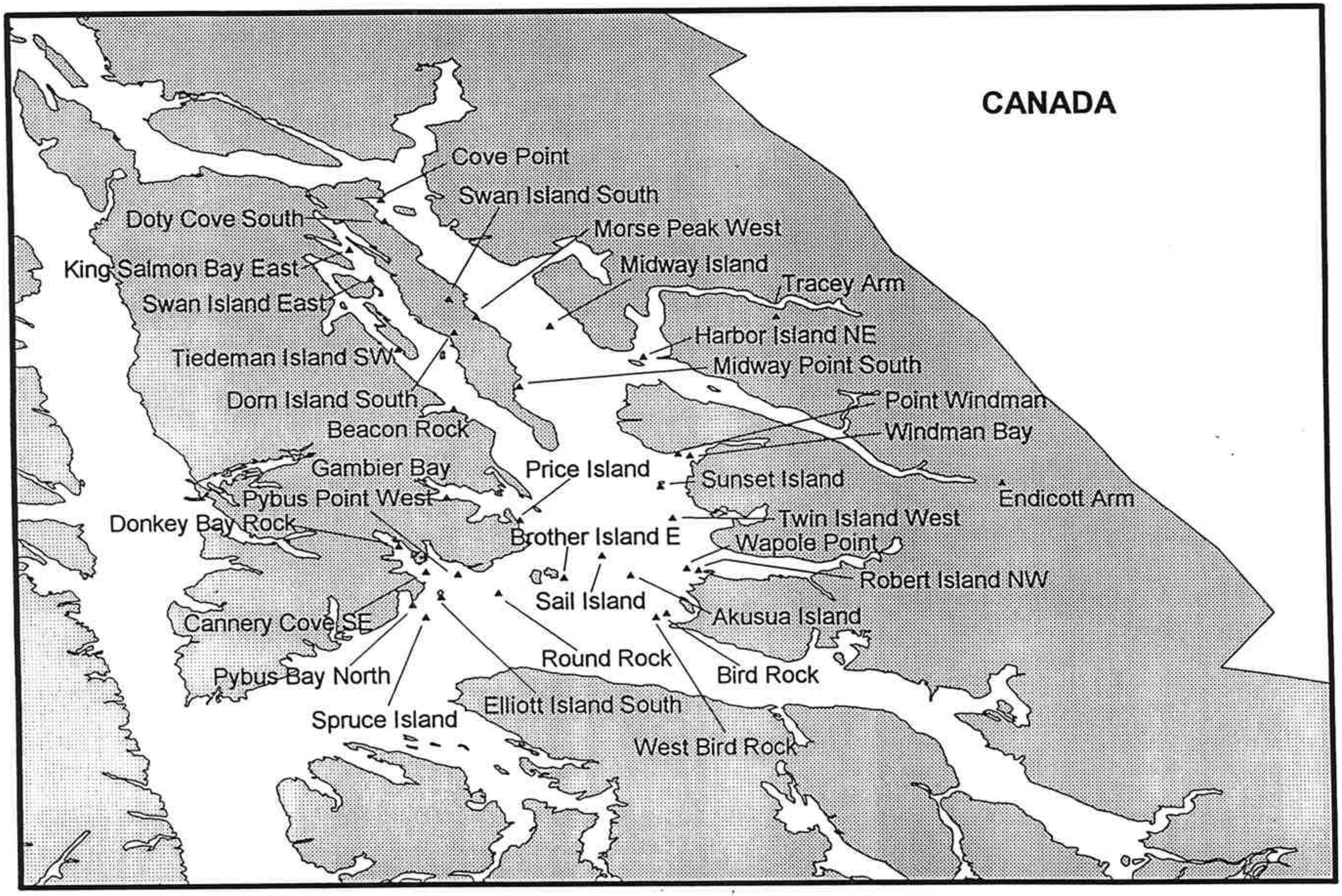

Figure 4. **Harbor seal locations for the Stephens Passage route surveyed in August and September 1997. Refer to Table 2 for site type and positions.**

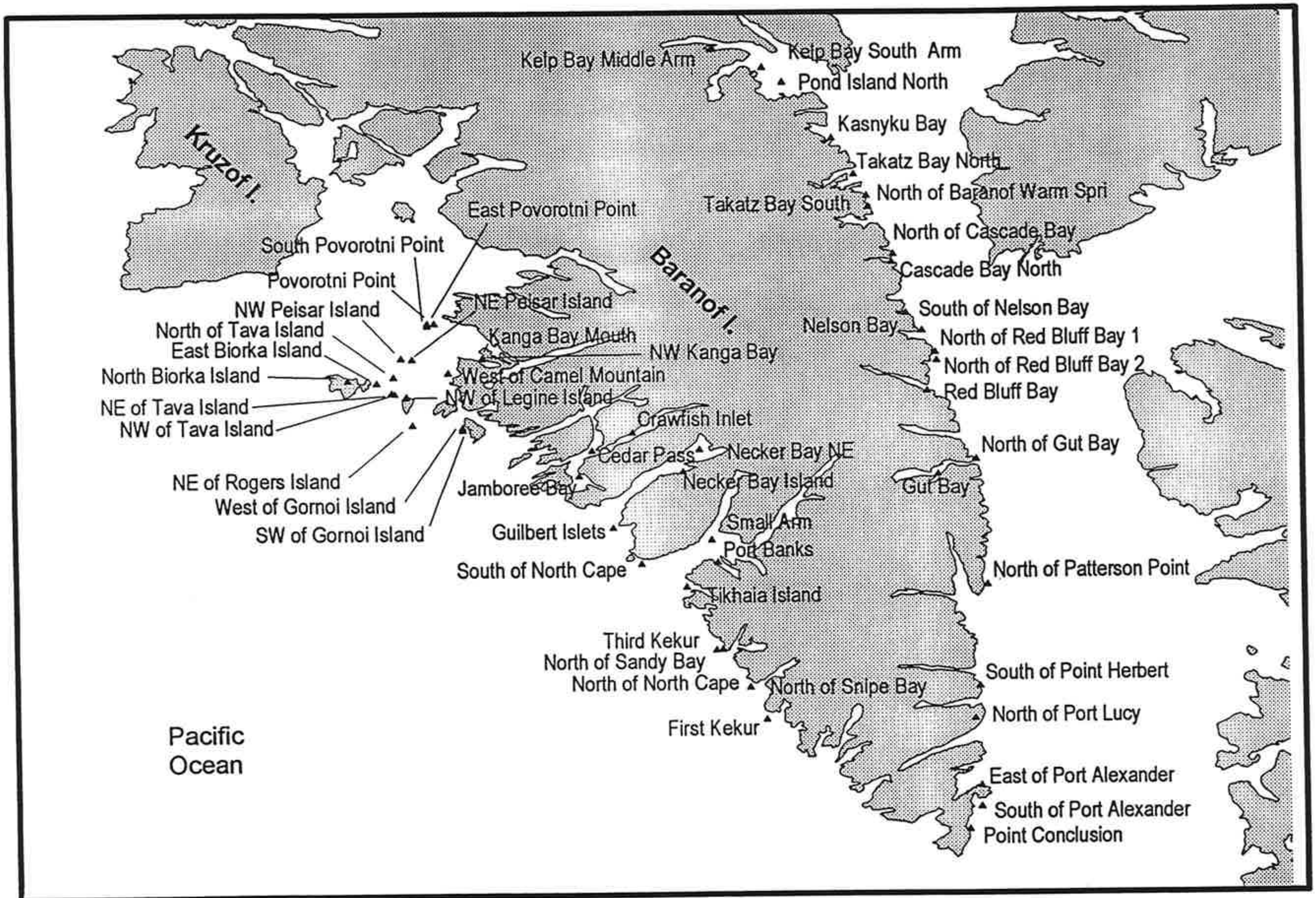

Figure 5. **Harbor seal locations for the southern Sitka route surveyed in August 1997. Refer to Table 2 for site type and positions.**

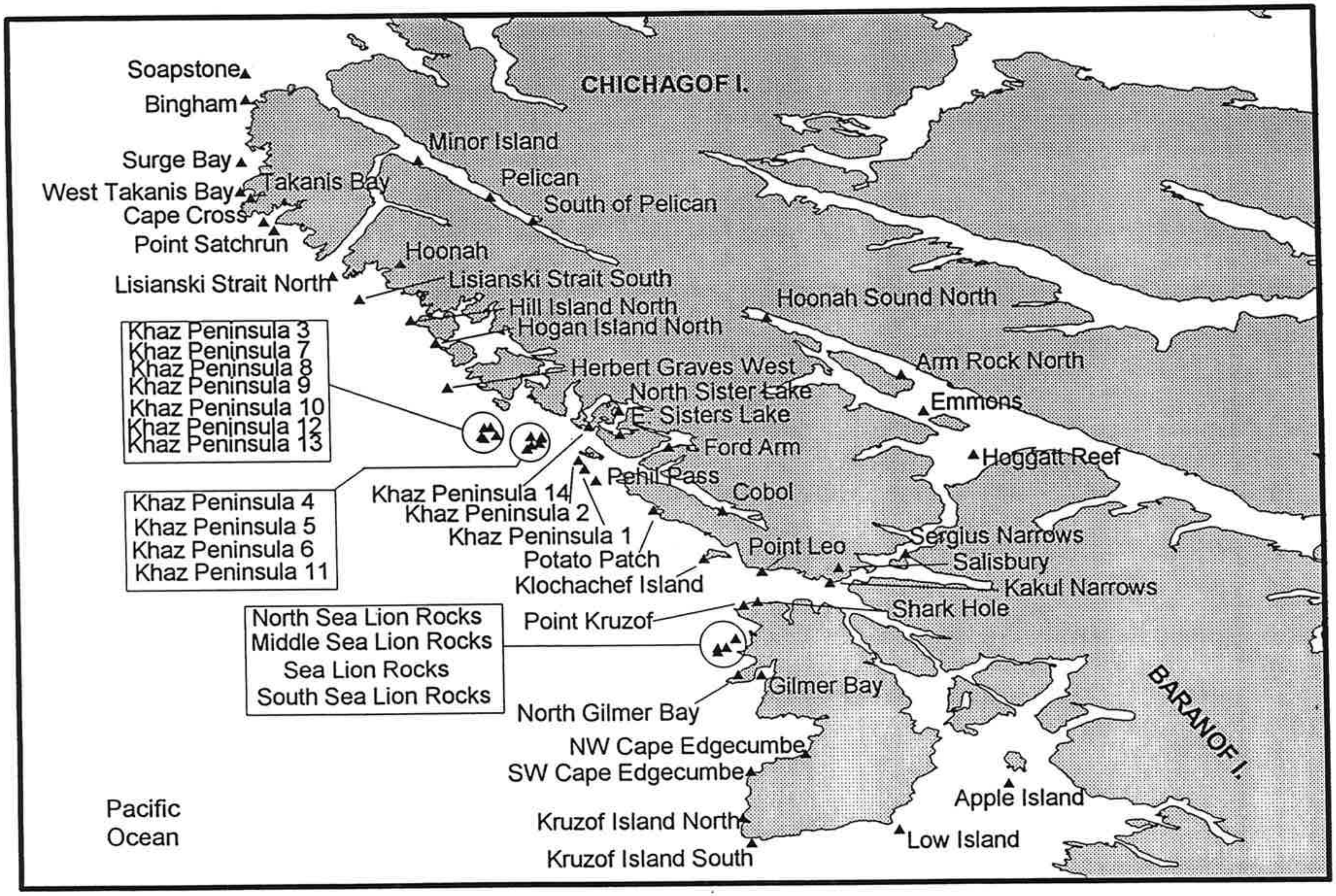

Figure 6. **Harbor seal locations for the northern Sitka route surveyed in August 1997. Refer to Table 2 for site type and positions.**

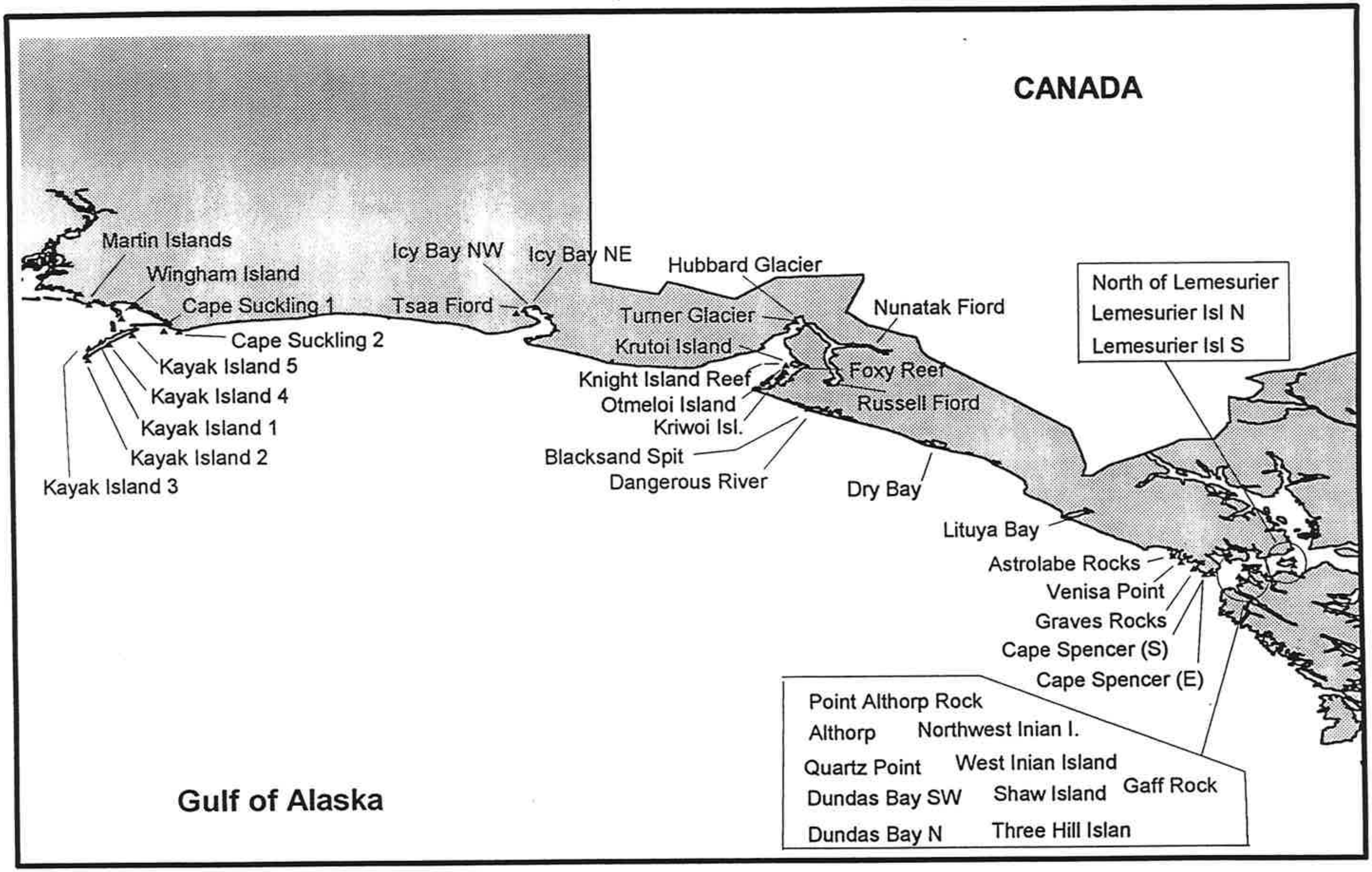

Figure 7. **Harbor seal locations for the Kayak Island to Cross Sound route surveyed in August 1997. Refer to Table 2 for site type and positions.**

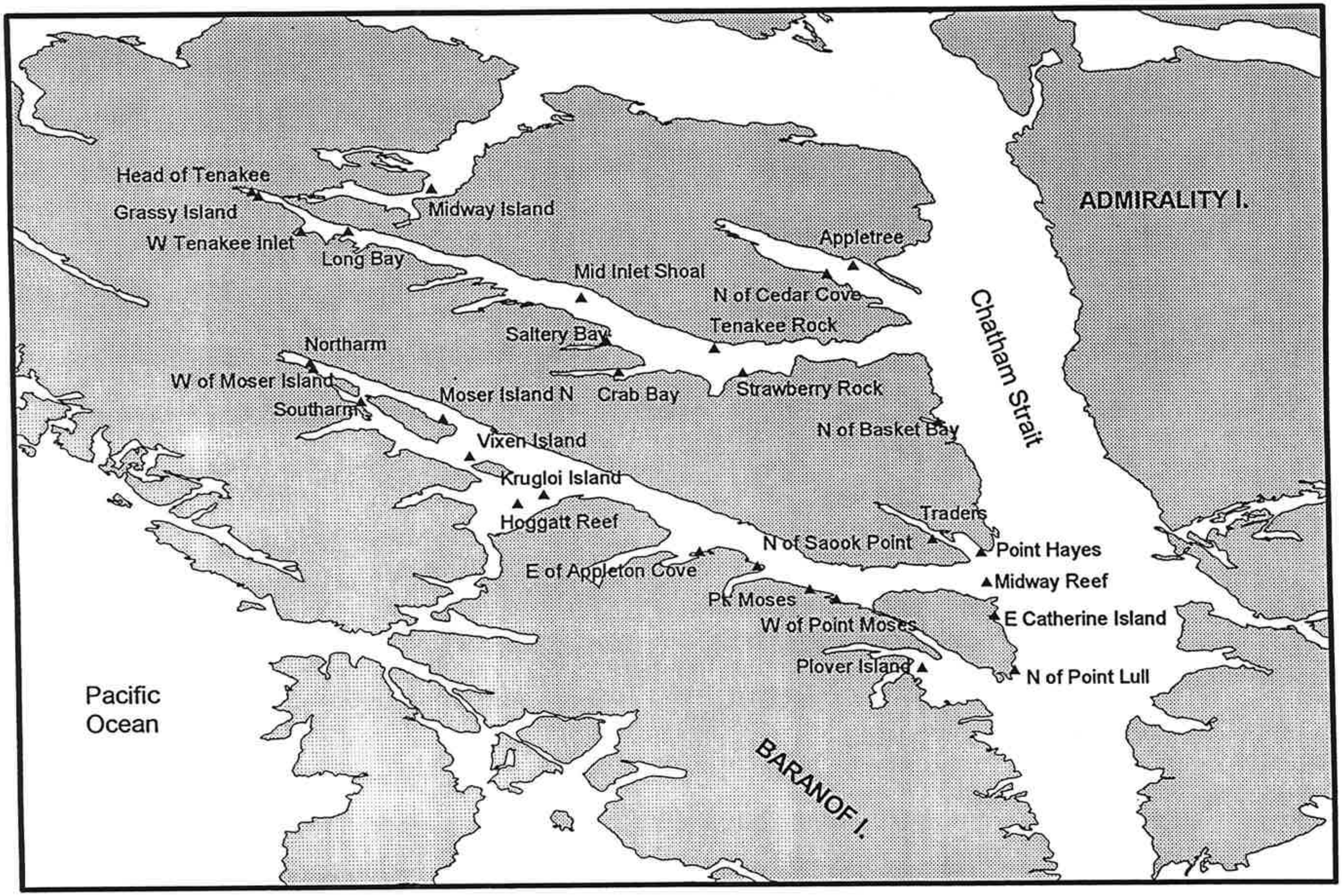

Figure 8. **Harbor seal locations for the Tenakee Inlet and Peril Strait route surveyed in August 1997. Refer to Table 2 for site type and positions. (ADF&G Sitka Trend Route)**

DIET OF HARBOR SEALS (*PHOCA VITULINA*) ON THE COLUMBIA RIVER, 1995-1997

Patience Browne, Jeffrey L. Laake, Robert L. DeLong

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington 98115

Abstract

Fecal samples (scats) were collected from Desdemona Sands, the largest harbor seal (*Phoca vitulina*) haul out site on the lower Columbia River during spring, summer, and fall from 1995 through 1997 to investigate their diet. Samples were collected intermittently during 1995, and attempts were made to collect at least 50 scats every two weeks from March through August of 1996 and March through October of 1997. Scats were rinsed in nested sieves and all hard parts were preserved for identification. Otoliths and other skeletal structures of prey isolated from harbor seal scats were enumerated, identified to lowest possible taxon, and prey masses were estimated from regressions of otolith length to fish length and mass. Harbor seal diet was described by frequency of occurrence, number of individuals, and estimated prey mass of all major prey taxa for spring, summer, and fall. More than 45 prey species were identified from over 1385 scats, but harbor seal diet could be characterized by about 15 common prey taxa. Though the diet was extremely variable within sampling date, seasons, and between years, there were differences in seasonal frequencies of 13 of 18 prey taxa tested. The frequency and number of individual prey were at least two times greater for most prey taxa when prey structures in addition to otoliths were identified. While problematic, examining estimated prey mass in addition to frequency and number resulted in an extremely different picture of the relative importance of prey in the harbor seal diet.

Introduction

Increases in marine mammal populations in Washington and Oregon have coincided with decreases in wild salmon populations in these and other western states. Recently, several salmon stocks in the western U.S. have been listed as threatened, endangered, or are under status review. These include coastal Oregon coho (*Oncorhynchus kisutch*), upper Columbia River steelhead (*O. mykiss*), and Snake River spring and fall chinook (*O. tshawytscha*), steelhead, and sockeye salmon (*O. nerka*) (NMFS 1997). Endangered salmon often co-occur with marine mammals and predation may substantially reduce fish populations (Gearin et al. 1986). In 1996, the National Marine Mammal Laboratory began a project to quantify pinniped predation on salmonids in the lower Columbia River.

Three species of pinnipeds, California sea lions (*Zalophus californianus*), Steller sea lions (*Eumetopias jubatus*), and harbor seals, occur in the Columbia River. California sea lions are present in the lower river system from fall through the following spring. Their primary haul out is in the vicinity of a fish processing plant and examination of prey remains from fecal material indicated California sea lions fed on fish discarded from the plant, including sockeye and chinook salmon carcasses (Brown et al. 1995). Consumption of processed fish carcasses by pinnipeds is impossible to distinguish from predation on live salmon. Steller sea lions are rare in the Columbia River and only haul out near the river mouth. The impact of Steller sea lions on salmon in the Columbia River is assumed to be small. Harbor seals, the most abundant pinniped in the lower river, haul out in numbers exceeding 2000 on a tidal sandbar adjacent to Astoria, Oregon. Our investigation focused on the diet of harbor seals on the lower Columbia River.

Typically, pinniped prey are identified from fish sagitta (otoliths) recovered from fecal material (scat) (Brown 1980, Beach et al. 1983, Harvey 1989, Ochoa-Acuña and Francis 1995). This method yields biased results due to partial or complete digestion of otoliths, greater probability of recovering otoliths from larger individuals of a species, greater probability of recovering species with robust otoliths, and greater probability of identifying otoliths of species with distinctive morphological characteristics (Harvey 1989, Gates and Cheal 1992, Cottrell et al. 1996). Estimates of harbor seal predation on species such as adult salmonids are particularly poor due to extremely low otolith recovery and because harbor seals may not completely ingest large prey (Pitcher 1980, Harvey 1989, Boyle et al. 1990, Harvey and Antonelis 1994, Cottrell et al. 1996, Riemer and Brown 1997).

We attempted to describe harbor seal diet on the lower Columbia River during spring, summer, and fall, from otoliths and all skeletal elements (cranial bones, vertebrae, teeth, gill rakers, etc.) recovered from scats. In previous studies, identification of all skeletal elements has resulted in a frequency of occurrence of some prey taxa at least two times greater than frequencies exclusively from otoliths (Reimer and Brown 1997, Boyle et al. 1990, Cottrell et al. 1996). We used frequency of occurrence, number of individuals, and average estimated mass of prey to describe the diet of harbor seals on the Columbia River.

Methods

During 1995, 1996, and 1997, scat samples were collected from Desdemona Sands (river km 26, Fig. 1), the largest harbor seal haul out site in the lower Columbia River (H. Huber, NMML, unpubl. data). Scats were collected intermittently during 1995. From March through August 1996 and March through October 1997, we attempted to collect 50 harbor seal scats every two weeks at extreme low tides. This sampling period coincided with Columbia River runs of spring, summer, and fall chinook salmon. Scats were collected from haul outs, placed in individual plastic bags, transported back to the National Marine Mammal Laboratory (NMML, Seattle, WA), and frozen. Scats were thawed, rinsed in nested sieves (2 mm, 1 mm, and 0.5 mm mesh width), and all fish remains were dried and stored in vials. Cephalopod remains were stored in 70% isopropyl or ethyl alcohol. Other invertebrate remains were disregarded due to difficulties determining if individuals were primary or secondary (consumed by large fishes) prey. Otoliths were identified to lowest possible taxon, separated into left and right, and enumerated (greater number left or right otoliths). Lengths of intact left or right otoliths were measured parallel to the sulcus to the nearest 0.1 mm using an ocular micrometer. Micrometer measurements were verified with hand-held calipers. Other structures (teeth, vertebrae, cranial bones, etc.) were identified to lowest possible taxon by comparing prey remains to reference samples (NMML reference collection).

Scat collections were divided into three seasons: spring (samples collected prior to 15 May), summer (samples collected 15 May to 15 July), and fall (samples collected after 15 July). These are the distinctions between summer, and fall chinook salmon passing Bonneville Dam (river km 235), minus two weeks to allow for travel from the lower Columbia River (Fryer 1998).

For each season, harbor seal diet was described by frequency of occurrence (FO), number of individuals (NI), and estimated prey mass of all major prey taxa. Frequency of occurrence (FO) of prey taxon *j* in season *k* was defined as:

$$FO_{jk} = \frac{\sum_{i=1}^{n_k} O_{ijk}}{n_k} \quad ,$$

where O_{ijk} is a binary variate indicating presence (1) or absence (0) of taxon *j* in sample *i* in season *k*, and n_k is the total number of scats containing identifiable prey remains in season *k*. Rare prey taxa were grouped with other similar taxa for analyses. Unknown prey remains that were clearly distinct from known taxa were considered "unidentified taxa" in samples containing "identified" hard parts. Scats containing skeletal remains considered "unidentifiable", i.e. extremely eroded bone or fragmented material, were assumed to be one several common prey taxa and excluded from analyses. Samples containing only "unidentifiable" remains were not included in n_k. Number of individuals (NI) was estimated from the maximum number of left or right otoliths and unique or paired bone structures when possible and expressed within each season as total NI or average NI per scat (total NI/number of scats collected). Presence of non-unique fish remains (non-unique vertebrae, gillrakers, teeth) constituted a single individual. For example, if a scat sample contained five left otoliths, three right otoliths, and six atlas/axis vertebrae of a prey taxon, NI was six. FO and NI were calculated from otoliths and again from all prey remains. Prey mass was estimated for the three seasons from linear regressions of otolith length to fish length, and fish length to mass for most taxa (Table 1). When regressions were not available for a species, relationships for similar species were used. Otolith lengths were multiplied by a species-specific correction factor when available, or an average correction factor to account for reduction in length due to digestion (Harvey 1989). Mean mass was calculated for all prey taxa for each season. For several salmon species, suitable morphometric regressions were not available or did not include juvenile fish and we had to generate regressions that included sub-adult age classes specifically for this study. Relationships between salmon otoliths and fish mass used in this study were calculated from reference samples at NMML, the private collection of William Walker (Seattle, WA), and from Natural Resources Consultants, Inc. (Seattle, WA, Jeff June pers. comm.), in addition to published relationships (Harvey et al. In Press) (Table 1). Because of the discrepancy in mass of adult and juvenile salmonids, otoliths were identified to species and classified as adult or juvenile based on species-specific lengths estimated from regression equations. "Adults" described all returning upriver migrants, including reproductively mature individuals and jacks. "Juveniles" described outgoing migrants and may have included two-year-old fish of some species (Groot and Margolis 1991). *Oncorhynchus clarki, O. kisutch, O. nerka*, and *O. mykiss* less than 30 cm in length and *O. tshawytscha* salmon less than 35 cm in length, were considered out-migrating juveniles (Groot and Margolis 1991). All distinguishable salmon otoliths were identified to species and all identifications were verified by William Walker (NMML, pers. comm.).

Annual and seasonal variation in frequency of occurrence (FO) were examined with generalized linear models (Venables and Ripley 1994). We limited our analyses to prey taxon with FO of at least 5% in one season. Frequency of occurrence at each sampling date was modeled as a binomial random variable with over-dispersion. For each prey taxon, we fit five models: constant, season (S), year (Y), season+year (S+Y), and season+year with interactions (S*Y). The constant (residual deviance/degrees of freedom) was estimated with the S*Y model and was used to scale Akaike's Information Criterion (AIC) to account for over-dispersion (Venables and Ripley 1994). The model with the smallest scaled AIC was considered best description of seasonal and annual variation in FO.

Results

Over 1500 scats were collected from March 1995 through October 1997. Sample sizes varied among years and within sampling periods (Table 2). More than 45 prey taxa were identified in 1385 samples with identifiable prey remains; however, most of the diet by number and frequency was composed of about 15 prey taxa (Table 3). Frequency of scats without remains increased during April and May (Table 2). Olesiuk et al. (1990) observed similar samples from British Columbia and suggested harbor seals were feeding on soft-bodied prey and roe. Occurrence of these scats in our study coincided with pupping on the lower Columbia River (H Huber, NMML, unpubl. data) and a second possibility is that these may have been from nursing pups.

Describing harbor seal diet from all skeletal elements recovered in scat increased NI and FO of all prey taxa (Table 3). The FO of most taxa at least doubled when all hard parts were examined, and differences were even more pronounced when data were presented seasonally (Table 3, Figs. 1-3). To examine the effect of including bone on the number of prey consumed, we estimated total NI from exclusively otoliths, all skeletal elements, and otoliths multiplied by a species-specific correction factor to account for incomplete recoverey (Harvey 1989) for several common harbor seal prey (Table 4). Total NI estimated by corrected otoliths was comparable to values based on bone for several species, but highly variable (Table 4).

Frequency and number of individuals consumed by harbor seals on the Columbia River were extremely variable, even among sample collections less than two weeks apart. Effort and sample sizes were unequal for season and years but we chose not to exclude any data to better describe harbor seal diet. Annual variation in the FO was important only for lamprey species (*Lampetra* spp.), Pacific hake (*Merluccius productus*), northern anchovy (*Engraulis mordax*), and elasmobranchs. Seasonal variation was an important predictor of FO for 13 taxa (Table 3).

Three prey taxa had significant year-season interaction (Table 3). All prey taxa had variances in FO greater than predicted by a binomial model (over-dispersion values, $b > 1$) (Table 3).

Prey masses were widely variable among seasons (Table 5). In some instances, estimates were based on very few otolith measurements, values were taken from the literature, or mass was averaged from other seasons when no intact otoliths were recovered (Table 5). Because some species were very rare or regression relationships were unavailable, species were grouped by phylogenetic or size similarities (Table 5). Smelts (Osmerids) were pooled by family and the mass was based on whitebait smelt (*Allosmerus elongatus*), the most abundant species by distinguishable otoliths, and eulachon (*Thaleichthys pacificus*), though longfin (*Spirinchus thaleichthys*) and surf smelt (*Hypomesus pretiosus*) were also identified in harbor seal scats. Ideally, smelt species can be distinguished by otoliths; however, smelt bone could not be identified to species, otoliths were often from juveniles and/or eroded, and more than one species was temporally available. Smelt mass estimates included eulachon because although relatively rare (FO < 3%, total NI = 40 individuals in all sampling periods for all three years), eulachon were much larger than the three other smelt species, which were similar in size. Masses of salmonids were estimated separately for adults and juvenile of all five species identified in harbor seal scat with the exception of sockeye salmon which was represented by one otolith from an adult fish. The mass of the sockeye was based on regressions generated for coho salmon. *Oncorhynchus clarki* and *O. mykiss* were not always distinguishable by otoliths, and all otoliths that were not distinguishable as *O. clarki* were assumed to be *O. mykiss* due to their numerical dominance in the lower Columbia River. The sticheid/pholid group included fish from a variety of families; three spine stickleback (*Gasterosteus aculeatus*), snake prickleback (*Lumpenus sagitta*), high cockscomb (*Anoplarchus purpurescens*), wattled eelpout (*Lycodes palearis*), Pacific sandfish (*Trichodon trichodon*), and saddleback gunnel (*Pholis ornata*). Though not taxonomically related, these species were seldom represented by otoliths, individuals were very small, and with the exception of gunnels, were rare by number and frequency (Figs. 2 - 4). Overall, they contributed very little to the total mass of prey consumed. Little has been published about relationships between otolith length and fish length or fish length and mass for these families. Rather than ignore their occurrence, these species were pooled and mass estimates were based on measurements of wattled eelpout and sandfish otoliths (Table 5). Scorpaenidae was composed of mostly juvenile fish (*Sebastes* and *Sebastolobus* spp.). Neither juvenile rockfish bones nor otoliths can usually be distinguished to species. Mass estimates were based on black rockfish (*Sebastes melanops*) (Table 5). Morphometeric relationships for peamouth (*Mylocheilus caurinus*) were unavailable in the literature. Peamouth are small, slender members of the minnow family, less than 36 cm in length, with a shape similar to several other small harbor seal prey. Mass was assumed to be less than 100 g. Hexagrammids included ling cod (*Ophiodon elongatus*) and greenlings (*Hexagrammos* spp.) and were also poorly represented by otoliths. Mass was estimated from ling cod otoliths (Table 5). Mass of flatfish other than starry flounder (*Platichthys stellatus*) was calculated from the average of estimated masses of identified otoliths (rex sole, *Errex zachirus*; English sole, *Pleuronectes vetulus*; Dover sole, *Microstomus pacificus*; rock sole, *Pleuronectes bilineatus*; Slender sole, *Eopsetta exilis*) for each season.

Several taxa were not represented by otoliths due to complete digestion or because the species entirely lacked otoliths. No intact Pacific mackerel (*Scomber japonicus*) otoliths were recovered from scat and their mass was assumed to be less than 700 g, the upper limit reported by Eschmeyer and Herald (1983). Lamprey species included river (*Lampetra ayresii*) and Pacific lamprey (*L. tridentata*). Mass was estimated from the upper limit of outgoing Pacific and river lamprey from Pacific Northwest river systems (Beamish 1980). Little information was available for predicting mass of elasmobranchs; however, all elasmobranchs (spiny dogfish, *Squalus acanthias*, and skates, *Rajidae* spp.) consumed by harbor seals appeared to be juveniles. Elasmobranch mass was extrapolated from a regression of vertebral centrum width to mass from another skate species (Zeiner and Wolf 1993), yielding an upper estimate of 490 g. We assumed the mass of skates and spiny dogfish consumed by harbor seals to be of a similar size, and all less than 500 g. Cephalopod (*Loligo opalescens*, and *Octopus* spp.) mass was estimated from regressions of beak measurements to mantle length and mass (Wolf 1982).

Discussion

As with all investigations of marine mammal diet, there were obstacles in sampling, analyzing, and interpreting data. Some complications inherent to pinniped prey investigations may have been compounded by identifying skeletal structures other than otoliths; however, we feel additional effort and possible biases were justified by the improvements. Describing harbor seal diet exclusively from otoliths drastically underestimated the occurrence of many prey taxa (Figs. 1-3).

Identifying remains in addition to otoliths assumes an equal probability of detecting all prey species and recovering remains relative to their consumption. These assumptions are violated to some extent because identification and detection of prey from skeletal elements depend on the structures passed in scats and are taxon-specific. Unequal recovery of prey remains affects each descriptor of diet differently and the degree to the effect differs among prey taxa. For example, in controlled feeding experiments, herring (*Clupea pallasi*) were identified by 11 structures (other than otoliths) while smelt were represented by only vertebrae (Cottrell et al. 1996). Additionally, several of the herring bones common in scats are unique or sided structures (prootics, atlas/axis vertebrae), whereas the smelt vertebrae are not useful for enumerating individuals. Additionally, highly eroded herring bone can be identified to species. In contrast, bones of some taxa such as pleuronectids erode rapidly, losing species characteristics and can be identified only to family. Given these factors, identification of all skeletal structures recovered from scats probably represents herring closer to its relative consumption than many other prey.

Behavior of both predator and prey also affect identification and enumeration of prey remains in scats. Small, schooling fish such as smelts are more likely to be consumed in greater numbers than larger, solitary fish such as hexagramids. Smelts are most frequently identified from non-unique vertebrae, so NI is more severely underestimated because more than one individual is likely to be consumed. Captive feeding studies also have indicated activity of the pinniped, meal size, size of prey, the physical structure of the prey bone all affect passage rate and therefore, the degree of erosion (Cottrell et al. 1996, Marcus et al. 1998).

Despite the many complications of including bone, prey identification based on all skeletal elements is an improvement over identifying only otoliths. Although passage rate and identification of structures is taxa-specific, this is also true for otoliths (Harvey 1989, Cottrell et al. 1996, Marcus et al. 1998). Frequency of occurrence is greatly improved by including all structures, particularly taxa that are extremely underestimated by otolith identifications such as Pacific tomcod (*Microgadus proximus*), Pacific hake, American shad (*Alosa sapidissima*), salmon, and hexagrammids, or entirely lacking otoliths such as lamprey and elasmobranchs (Figs. 1-3). Although estimating NI from all prey structures recovered in scats presents a variety of complications, it avoids using NI estimated from corrected number of otoliths. Otolith correction factors based on recovery rates from controlled feeding experiments are highly variable between repeated trials of the same individuals, different individuals, and different pinniped species (Harvey 1987, Cottrell et al. 1996).

Identification of prey remains indicated that harbor seal diet on the Columbia River was temporally variable and seals appeared to exploit prey when species were abundant (e.g., spawning) or available (e.g., migrating). While a variety of prey were identified from hard parts recovered from scats, the general diet can be described by about 15 taxa. Many of the dominant prey by number and frequency appeared to be small fish such as herring, smelts, northern anchovy, juvenile flatfish, and sculpins (Table 3, Figs. 1-3). Pacific herring, Pacific staghorn sculpin (*Leptocottus armatus*), and smelt species were three of the top six prey taxa by number and frequency for all three seasons (Figs. 1-3). Other numerous and frequent prey in harbor seal scats were species that were seasonally abundant in the Columbia River. Harbor seals are generalist feeders and differences in frequency and number of prey probably reflect the temporal availability and abundance of the prey rather than selection of the predator.

This also is reflected in the over-dispersion constant (Table 3). All prey taxa had over-dispersion constants (b) greater than one (Table 3), indicating variances greater than predicted by a simple binomial model. The binomial model assumes an equal probability of any prey taxa occurring in scats collected on any sampling date within a season. Harbor seal prey entering the river in large numbers for brief periods of time are going to have highly unequal probabilities of occurrence within a season. The over-dispersion constant was probably greater than estimated for some prey groups that included more than one species such as salmonids and smelts. Because the abundance and temporal availability of these species may have been offset, the probability of occurrence of the taxa within a season was potentially more variable than indicated when all species were examined simultaneously.

Annual differences in frequency of occurrence may be largely the result of differences in sample timing or year-class strength. For instance, the timing, size, and abundance of hake in the Columbia River varies with year-class strength (Dark and Wilkins 1994). Hake appear to use estuaries seasonally, however, different sizes of fish enter the estuary during different seasons (Moyle and Cech 1982). Greater frequencies of hake during 1996 and 1997 may a result of increased sampling effort during those years, coinciding with the occurrence of strong cohorts (Table 2). Differences in FO of anchovy also appeared to be due to a strong cohort. The number and frequency of anchovy were greater during fall, and although no samples were collected during fall of 1995, FO for fall of 1996 was 63%, while for fall of 1997, it was only 2% and samples were collected on similar days of the year (Table 1).

Most of the prey taxa examined had seasonally variable FO. Only American shad and adult salmon did not have significant season effects or season-year interaction (Table 3). Even prey taxa prevalent in harbor seal diets in all three seasons tended to have a period of increased occurrence in diet when fish were reproducing, young of the year were available, or perhaps fewer individuals of other prey species were available and harbor seals relied more heavily on consistently available species. Although not significant when grouped by family, recoverey of adult salmon otoliths measured for weight calculations indicated seasonal trends when separated into species (Table 5). Analyzing species-specific occurrence of salmon was not possible due to the small sample sizes, and seasonal effects on FO of adult salmon were attenuated by grouping species.

Interaction between year and season may be explained by strength of year class. Different size classes of several prey taxa are abundant in the Columbia River during different seasons. For example, mean mass of staghorn sculpin was greater during spring than summer or fall (Table 4). This is probably due to a greater availability of adults during spring, and juveniles during summer and fall. If the 1995 year-class was particularly strong, juveniles may be expressed as greater FO during summer of 1995, and then return as a mature fish resulting in a greater FO during spring of 1997.

Many Columbia River harbor seal prey are not of commercial interest, however, salmon are an exception. Harbor seals consumed several species and sizes of salmon throughout our study, but the greatest frequency occurred during spring. From otoliths, most of these appeared to be juvenile chinook. Fryer (1998) reported no difference in mean fork lengths of adult spring-summer *O. tshawytscha* with scars from pinnipeds and those without scars at the Bonneville Dam and observed a greater percentage of fish with scars earlier in the year. Our data suggest that adult salmonids were consumed primarily during fall, though these findings are not necessarily contradictory. Scarred fish represent failed predation and perhaps harbor seal attempts to capture fish beyond their ability when spring run-off results in greater turbidity. In addition, part of the discrepancy may be due to the classification of "adult" salmon. For our purposes, we categorized all fish with estimated lengths greater than outgoing migrants (30 to 35 cm depending on the species) as "adults". The mean lengths of scarred spring-summer *O. tshawytscha* from 1994 to 1996 (75.9 to 79.3 cm fork length) were greater than the mean length of "adult" fish estimated from prey remains (73.4 cm mean standard length). The inter-canine distance of scars on salmon indicated 90% were caused by harbor seals and only 10% caused by California sea lions (Fryer 1998). This may be due to the relative failure of harbor seals and success of California sea lions predating on adult fish (Gearin et al. 1986).

Frequency of occurrence of salmonids in harbor seal scat collected from the Columbia River has been greater in previous investigations (Riemer and Brown 1997); however, those results summarize four years of data based on only 154 samples collected on eight dates. Timing of sample collections is highly relevant to interpreting data. For instance, Riemer and Brown (1997) report salmon FO as great as 39% for a single sampling date but found no salmonid remains in scats collected during February and March. Monthly FO are each based on a single sampling collection. During our study, we had an FO of 50% of juvenile salmon on a sampling date during March of 1997; however, FO collected a week earlier during 1995 was zero. Additionally, we found salmonid remains in harbor seal scat during every month of our data collection. Single sample collections are not sufficient to categorize marine mammal diets given the temporal variability of the prey.

Many common harbor seal prey are present in the lower Columbia River for discrete time periods at critical life stages such as out-migrating juveniles, returning spawners, or newly recruited young-of-the-year. The occurrence of prey may be low over the entire study, but high within a single season or sampling date. The impact of predation should be considered temporally and in the context of the life history of the prey.

In addition to considering pinniped diet seasonally, the size-class of fish being predated needs to be estimated to address the impact on prey populations and relative contribution of prey to the overall pinniped diet. Because of the inherent complications, previous investigations of pinniped diet identifying prey remains in addition to otoliths have not estimated prey mass. Many studies rank FO or percent of total individuals by number (%N) of each prey. Certainly estimating mass of prey taxa is problematic and some of our estimates may be flawed, however, relative importance of prey in the harbor seal diet changes when estimated mass is considered (Tables 3 and 5). Most pinniped species are considered generalist feeders and may eat many, frequent prey but may rely on infrequent, large prey to sustain them. A few species were both abundant and frequent (herring, smelts, sculpins, flatfish), yet their estimated masses were small. Large, infrequent species such as ling cod, hake, rockfish, and salmon may contribute more total mass to a hypothetical "meal". Unfortunately, these prey were also poorly represented by otoliths, so these mass estimates may be inaccurate. For example, hexagrammid mass was estimated from two ling cod otoliths recovered from summer scat collections and two ling cod otoliths from fall collections. These were all from adult fish and the only intact hexagrammid otoliths recovered. Estimated mass for this taxon is based on adult individuals, yet many of the bones recovered from scat appeared to be from sub-adult fish. Additionally, ling cod are larger than other hexagrammids and may overestimate mass for the taxa, however, they also are more common than any other hexagrammid in the Columbia River (Dark and Wilkins 1994).

Many of our mass values are likely to be overestimates resulting from higher recovery rates of otoliths from larger fish or estimates taken from literature sources, however, our mass estimate for lamprey is an upper limit of out-migrants in north Pacific river systems which assumes, incorrectly, all individuals are juveniles. Because lamprey do not have otoliths and currently there are no methods for estimating size from supraoral structures, their relative contribution in the pinniped diet is often completely disregarded. Our 50 g estimate is probably reasonable based on mass values reported for adult Pacific and river lamprey for other geographic regions. Although our mass is an upper limit for juveniles, returning adults do not feed during spawning. Estimated masses Pacific lamprey returning to British Columbia river systems ranged from 63 g to 167 g, varying with the length of their marine life-stage (Whyte et al. 1993), and mass of river lamprey ranged from 12 g to 230 g in European river systems, varying with location (Bartel et al. 1993). Given the relatively high FO and NI of the family, a more precise estimate is necessary.

Conclusions

All methods of examining marine mammal diet such as fecal analyses, stomach lavage, or stomach content analyses are all inherently biased to some degree. Stomach lavage requires capture and anesthetization, and direct analysis of stomach contents requires sacrificing the individual, therefore both of these methods result in undesirable impacts on marine mammals and small sample sizes. Biases of fecal analyses have been well discussed in the literature; however, this technique remains the least invasive, least expensive, and allows for large sample sizes. Identification of all skeletal elements rather than exclusively otoliths is an improvement on other techniques. While results are still subject to biases, prey taxa represented by hard parts in fecal material represent an absolute minimum estimate of prey consumed.

Learning to identify bone of common harbor seal prey is a relatively rapid process. Initially, rare prey and the total number of individuals will be underestimated by the novice; however, most investigations of marine mammal diets are concerned with changes in diet over time or consumption of commercially important prey. In both of these cases, rare prey taxa are unimportant. In addition, examining skeletal elements other than otoliths is mandatory for assessing the impact of harbor seals on certain prey species, in particular, protected salmon stocks. Limiting analyses of diet to qualitative measures such as FO would reduce the biases of including bone identification; however, the overall importance of frequent, small prey may be much less than indicated by their relative frequency. Harbor seals do eat Columbia River salmon; however, they feed on mostly juvenile fish during the spring, and from otolith identifications, most of those are chinook. Unfortunately, salmonid bone cannot be identified to species. The National Marine Mammal Laboratory has begun investigating alternative methods of quantifying harbor seal consumption of salmonids including identification of salmonid species from skeletal remains using genetic techniques. Identifying all skeletal remains is an improvement over relying exclusively on otoliths, and future techniques may further reduce biases inherent in examining prey recovered from fecal samples.

Citations

Bartel, R., B. Bradauskas, E. Ikonen, A. Mitans, W. Borowski, A. Wesolowska, A. Witkowski, and J. Blachuta. 1993. Comparison of length and weight of river lamprey from Finland, Latvia, Lithuania, and Poland. Abstract in: ICES Council Meeting Papers, ICES, Copenhagen (Denmark), 1993, 14 p.

Beach, R. J., A. C. Geiger, S. J. Jefferies, S. D. Treacy, and B. L. Troutman. 1985. Marine mammals and their interactions with fisheries of the Columbia River and adjacent waters, 1980-1982. NMFS/NWAFC Processed Rep. 85-03. 316 p.

Beamish, R. J. 1980. Adult biology of the river lamprey (*Lampetra ayresi*) and the Pacific lamprey (*Lampetra tridentata*) from the Pacific coast of Canada. Can. J. Fish. Aquat. Sci. 37:1906-1923.

Boyle, P. R., G. J. Pierce, and J. S. W. Diack. 1990. Sources of evidence for salmon in the diet of seals. Fish. Res. 10:137-150.

Brown, R. F. 1980. Abundance, movements and feeding habits of the harbor seal, *Phoca vitulina*, at Netarts Bay, Oregon. M.S. Thesis. Oregon State University. 69 p.

Brown, R. F., S. D. Riemer, and S. J. Jeffries. 1995. Food of pinnipeds collected during the Columbia River Area Commercial Salmon Gillnet Observation Program, 1991 - 1994. ODFW Wildlife Diversity Program Tech. Rept. 95-6-01. 16pp.

Cottrell, P. E., A. W. Trites, and E. H. Miller. 1996. Assessing the use of hard parts in faeces to identify harbour seal prey: results of captive-feeding trials. Can J., Zool. 74: (875-880).

Dark, T. A., and M. E. Wilkins. 1994 Distribution, Abundance, and Biological Characteristics of Groundfish off the Coast of Washington, Oregon, and California, 1977-1986. NOAA Tech. Rept. NMFS-117. 73 p.

Eschmeyer, W. N., and E. S. Herald, and H. Hammann. 1983. A field guide to Pacific coast fishes of North America. Houghton Mifflin Co., Boston, MA. 336 p.

Fryer, J. K. 1998. Frequency of pinniped-caused scars and wounds on adult spring-summer chinook and sockeye salmon returning to the Columbia River. N. Am. J. Fish. Manage. 18: 46-51.

Gates, N. J. And A. J. Cheal. 1992. Estimating the diet composition of the Australian sea-lion (*Neophoca cinerea*) from scat analysis: an unreliable technique. Wildl. Res. 19: 447-456.

Gearin, P., B. Pfeifer, and S. Jeffries. 1986. Control of California sea lion predation of winter-run steelhead at the Hiram M. Chittenden Locks, Seattle, December 1985 - April 1986, with observations on sea lion abundance and distribution in Puget Sound. Wash. Dep. Game Fish. Manage. Rep. 86-20. 108 pp.

Groot, C., and L. Margolis (editors). 1991. Pacific Salmon Life Histories. University of British Columbia Press, Vancouver, B.C. 564 pp.

Harvey, J. T., T. R. Loughlin, M. A. Perez, and D. S. Oxman. *In Press*. Relationship between fish size and otolith length for 62 species of fishes from the eastern north Pacific Ocean. NOAA Tech. Rep. 48 pp.

Harvey, J. T. 1989. Assessment of errors associated with harbour seal (*Phoca vitulina*) faecal sampling. J. Zool., Lond. 219: 101 - 111.

Harvey, J. T. and G. A. Antonelis. 1994. Biases associated with non-lethal methods of determining the diet of northern elephant seals. Mar. Mammal. Sci. 10: 178-187.

Marcus, J., W. D. Bowen, J. D. Eddington. 1998. Effects of meal size on otolith recovery from fecal samples of gray and harbor seal pups. Mar. Mammal. Sci. 14:789-802.

Merrick, R. L., M. K. Chumbley, and G. V. Byrd. 1997. Diet diversity of Steller sea lions (*Eumetopias jubatus*) and their population decline in Alaska: a potential relationship. Can. J. Fish. Aquat. Sci. 54:1342-1348.

Moyle, P. B., and J. J. Cech Jr. 1982. Fishes: An Introduction to Ichthyology. Prentice-Hall Inc., Englewood Cliffs, N. J. 592 p.

National Marine Fisheries Service (NMFS). 1997. Investigation of scientific information on the impacts of California sea lions and Pacific harbor seals on salmonids and on the coastal ecosystem of Washington, Oregon, and California. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-NWFSC-28, 172 p.

Nehlsen, W., J. E. Williams, J. A. Lichatowich. 1991. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16: 4-21.

Ochoa-Acuña, H., and J. M Francis. 1995. Spring and summer prey of the Juan Fernandez fur seal, *Arctocephalus philippii*. Can . J. Zool. 73: 1444-1452.

Olesiuk, P. F, M. A. Bigg, G. M. Ellis, S. J. Crockford, and R. J. Wigen. 1990. An Assessment of the feeding habits of harbour seals (*Phoca vitulina*) in the Strait of Georgia, British Columbia, based on scat analysis. Can. Tech. Rep. Fish. Aquat. Sci. 1730: 135 p.

Pitcher, K. W. 1980. Stomach contents and feces as indicators of harbour seal foods in the Gulf of Alaska. NOAA Fish. Bull., U.S. 78:544-549.

Riemer, S. D., and R. F. Brown. 1997. Prey of pinnipeds at selected sites in Oregon identified by scat (fecal) analysis, 1983 - 1996. ODFW Wildlife Diversity Program Tech. Rep. 97-6-02. 34 pp.

Venables, W.N. and B.D. Ripley. 1994. Modern Applied Statistics with S-Plus. Springer-Verlag, New York. 462p.

Whyte, J. N. C., R. J. Beamish, N. G. Ginther, and C. E. Neville. 1993. Nutritional condition of the Pacific lamprey (*Lempetra tridentata*) deprived of food for periods of up to two years. Can. J. Fish. Aquat. Sci. 50:591-599.

Wolf, G. A. 1982. A beak key for eight eastern tropical Pacific cephalopod species with relationships between their beak dimensions and size. Fish. Bull., U.S. 80: 357-370.

Zeiner, S.J., and P. Wolf . 1993. Growth characteristics and estimates of age at maturity of two species of skates (*Raja binoculata* and *Raja rhina*) from Monterey Bay, California,. In: Conservation biology of elasmobranchs pp. 87-99. U.S. Dep. Commer., NOAA Tech. Rep. NMFS-115.

Table. 1. Regression parameters for predicted length ($y = a + bx$) and weight ($y = c + L^d$), and sources of information for common harbor seal prey species. Calculations for groups of fish are based on species (in parentheses). Sockeye salmon calculations are based on regressions for coho salmon.

Taxon	Species	Otolith:length a	Otolith:length b	Length:weight c	Length:weight d	Source
Ammodytidae	Pacific sand lance	0.727	0.137	-2.94	3.46	NMML reference collection
Clupeidae	Pacific herring	-1.85	5.24	0.0044	3.398	Harvey et al. *In Press*
	American shad	-11.08	11.46	0.0135	3.046	Harvey et al. *In Press*
Cottidae	Pacific staghorn sculpin	-2.26	2.58	0.011	3.229	Harvey et al. *In Press*
Embiotocidae	Shiner surfperch	-0.52	1.74	0.01	3.515	Harvey et al. *In Press*
Engraulidae	Northern anchovy	0.85	2.28	0.0485	2.413	Harvey et al. *In Press*
Gadidae	Pacific hake	0.96	2.04	0.0081	2.966	Harvey et al. *In Press*
Gadidae	Pacific tomcod	-3.51	1.77	0.0064	3.191	Harvey et al. *In Press*
Hexagrammidae	Hexagrammids (ling cod)	-6.03	8	0.0023	3.567	Harvey et al. *In Press*
Osmeridae	Whitebait smelt	3.02	2.11	0.0063	3.233	Harvey et al. *In Press*
	Eulachon	-2.7	4.71	0.0077	3.075	Harvey et al. *In Press*
Pleuronectidae	Dover sole	12.23	2.75	0.0094	3.092	Harvey et al. *In Press*
	English sole	-2.76	3.82	0.0163	2.939	Harvey et al. *In Press*
	Rex sole	-2.5	4.8	0.0238	2.692	Harvey et al. *In Press*
	Slender sole	1.08	3.37	0.0058	3.293	Harvey et al.*In Press*
	Starry flounder	0.23	3.35	0.0107	3.268	Harvey et al. *In Press*
Salmonidae	Chinook salmon	-10.4	6.73	0.0043	3.207	(length: W. Walker collection; weight: NRC unpubl. data)
	Cutthroat trout	-91.2	89.3	0.0155	2.97	(W. Walker collection)
	Coho salmon	3.29	9.33	0.0103	3.092	(length: W. Walker collection; weight: Harvey et al. *In Press*)
	Sockeye salmon (coho salmon)	3.29	9.33	0.0103	3.092	length: W. Walker collection
	Steelhead trout	-32.43	14.77	0.0275	2.895	Harvey et al. *In Press*
Scorpaenidae	Rockfishes (black rockfish)	8.7	1.6	0.1225	2.499	Harvey et al. *In Press*
Stichaeidae/Pholididae	gunnel/prickelback (wattled eelpout)	12.42	5.22	0.0007	3.483	Harvey et al. *In Press*
	gunnel/prickelback (Pacific sand fish)	-4.57	6.06	0.0171	2.953	Harvey et al. *In Press*

Table 2. Sample collection dates, harbor seal scats with prey remains, with identifiable remains, and without remains for samples collected from Desdemona Sands 1995 through 1997. Spring (<15 May), summer (15 May to 15 July), and fall (>15 July) designate timing of chinook salmon runs on the Columbia River.

		Harbor seal scats		
Season	**Collection date**	**With identified remains**	**With unidentified remains**	**Without remains**
spring	3/5/95	13	2	0
	5/3/95	29	2	0
	3/14/96	29	1	1
	3/21/96	11	1	1
	4/10/96	42	4	0
	5/2-8/96	44	2	1
	3/11/97	16	1	0
	3/26/97	7	4	0
	4/10-11/97	31	7	1
	4/15/97	22	6	0
	4/28-5/1/97	28	4	11
	5/9-10/97	45	6	12
summer	5/18-19/95	53	1	4
	6/14-16/95	81	1	0
	6/28-29/95	78	1	0
	7/14/95	32	3	0
	5/30-31/96	52	2	1
	6/18-19/96	50	1	1
	7/2/96	52	3	0
	5/27/97	34	6	10
	6/6/97	24	8	0
	6/23/97	47	8	9
	7/8/97	74	2	1
fall	8/15/96	78	1	0
	8/29/96	59	2	0
	7/22/97	64	5	6
	8/4/97	102	1	0
	8/19/97	56	1	0
	9/3/97	51	5	0
	9/16/97	41	6	0
	10/16-17/97	40	6	0
Total		**1385**	**103**	**59**

Table 3. Total number of individuals (NI), frequency of occurrence (FO), significant effects on frequency of occurrence of major prey taxa identified from all skeletal remains recovered from harbor seal scat (S indicates season, Y indicates year, S*Y indicates interaction, and N indicates no effects), and an estimate of over-dispersion of the binomial model (b). Samples were collected during spring, summer, and fall of 1995 - 1997. Data were described for seasons (spring, < 15 May; summer, 15 May - 15 July; fall, >15 July) to distinguish spring, summer, and fall chinook salmon runs on the Columbia River.

		MNI			FO		Effect	b
Prey taxon	**Spring**	**Summer**	**Fall**	**Spring**	**Summer**	**Fall**		
Pacific herring	168	511	141	0.36	0.57	0.22	*S*	8.4
Pacific staghorn sculpin	256	170	284	0.41	0.19	0.25	*S*Y*	2.4
Smelt species	133	204	625	0.28	0.18	0.35	*S*	6.2
Pacific tomcod	66	73	251	0.18	0.09	0.39	*S*	7.2
Lamprey species	109	204	41	0.26	0.25	0.06	*S+Y*	2.0
Starry flounder	136	105	160	0.30	0.14	0.12	*S*Y*	2.7
American shad	36	108	116	0.11	0.19	0.22	*N*	6.1
Other flatfish	132	90	135	0.20	0.12	0.18	*S*	2.2
Pacific hake	30	72	136	0.09	0.12	0.28	*S+Y*	4.0
Shiner surfperch	26	131	69	0.07	0.18	0.08	*S*	2.2
Gunnel/prickelback	47	55	30	0.15	0.08	0.06	*S*	3.0
Salmon species - juvenile	92	71	30	0.19	0.05	0.05	*S*	3.2
Northern anchovy	3	63	290	0.01	0.06	0.19	*S+Y*	2.9
Salmon species - adult	22	33	50	0.06	0.04	0.10	*N*	4.6
Peamouth chub	12	63	41	0.03	0.08	0.05	*S*Y*	2.4
Pacific sand lance	37	18	11	0.10	0.03	0.02	*S*	1.5
Rockfish species	23	14	18	0.07	0.02	0.03	*S*	1.5
Elasmobranch	24	3	3	0.07	0.01	0.01	*S+Y*	1.5
Unidentified species	10	11	8	0.03	0.02	0.02		
Hexagrammid species	5	6	13	0.02	0.01	0.03		
Cephalopod	4	14	2	0.01	0.02	<0.01		
Pacific mackerel	5	2	5	0.02	<0.01	0.01		
Total number of scats	315	578	491					

Table 4. Total number of individuals (NI) estimated from harbor seal scats collected from Desdemona Sands during 1995, 1996, and 1997. Data are for three season of collections. NI is estimated from otoliths, all structures, and otoliths multiplied by a species-specific correction factor (Harvey 1989).

	Spring			Summer			Fall		
Prey taxon	Otoliths	All stuctures	Corrected otolith	Otoliths	All stuctures	Corrected otolith	Otoliths	All stuctures	Corrected otolith
Pacific herring	77	168	238.7	301	511	933	78	141	242
Pacific staghorn sculpin	194	256	407.4	100	170	210	208	284	437
Pacific tomcod	27	66	37.8	28	73	39	116	251	162
Shiner surf perch	12	26	20.4	85	131	145	50	69	85
Salmonid spp. (juvenile)*	51	93	81.6	56	71	90	10	30	16
Salmonid spp. (adult)*	12	22	19.2	22	33	35	8	50	13
Sebastes spp.	6	23	6.6	5	14	6	5	14	6
Smelt species**	99	133	287	175	204	508	593	625	1720

*based on correction factors for steelhead.

**based on correction factors for eulachon.

Table 5. Average mass (g) of harbor seal prey, standard deviation of the estimate (s), and the number of otoliths measured (n) to arrive at the estimated mass for spring, summer, and fall prey of harbor seals on the Columbia River. Boldface values are estumates calculated from other seasons (when no intact otoliths were recovered within a season) or from literature sources (when no structures were available for measurement).

		Spring			Summer			Fall		
Family	**Species**	**Average mass**	***s***	***n***	**Average mass**	***s***	***n***	**Average mass**	***s***	***n***
Clupeidae	American shad	198	224	4	517	601	5	523	284	11
	Pacific herring	93	35	50	96	64	238	97	73	54
Engraulidae	Norther anchovy	9		1	12	2	30	14	5	192
Osmeridae	Smelt species	15	23	84	6	2	147	7	3	331
Gadidae	Pacific tomcod	128	115	24	180	106	25	228	132	107
	Pacific hake	67		1	421		1	446	292	2
Pleuronectidae	Starry flounder	70	117	64	114	243	52	89	168	101
	Other flatfish	181	100	35	181	111	42	225	82	35
Cottidae	Pacific staghorn sculpin	140	84	136	160	84	88	115	42	45
Salmonidae	Chinook juvenile	206	150	22	41	93	21			0
	Chinook adult	1385		1	8515	6854	2	6862	1757	4
	Cutthroat juvenile	225	56	7	255	66	6	315		1
	Cutthroat adult	509	51	7	426	52	2			0
	Coho juvenile	277		1			0	88	103	2
	Coho adult	1607	983	2	671	241	15	4317	3545	3
	Steelhead juvenile	488		1	283	81	2			0
	Steelhead adult	1637		1	897		1			0
	Sockeye adult	2832		1			0			0
Embiotocidae	Shiner surfperch	79	39	7	85	43	80	79	42	45
Stichaeidae/Pholididae	Gunnels and prickelbacks	**90**	**84**	0	97	38	3	84	127	3
Hexagrammidae	Hexagrammids	**2090**	**1727**	0	3410	1375	2	756	135	2
Scorpaenidae	Rockfish species	187	87	6	132	7	2	114		1
Ammodytidae	Pacific sand lance	73	63	151	28	58		3	8	1
Elasmobranchs	Elasmobranchs	**500**		0	**500**		0	**500**		0
Scombridae	Pacific mackerel	**700**		0	**700**		0	**700**		0
Petromyzontidae	Lamprey species	**50**		0	**50**		0	**50**		0
Ptychocheilus	Peamouth chub	**100**		0	**100**		0	**100**		0
Cephalopods	Cephalopods	**21**	**1**	0	**21**	**1**	0			0

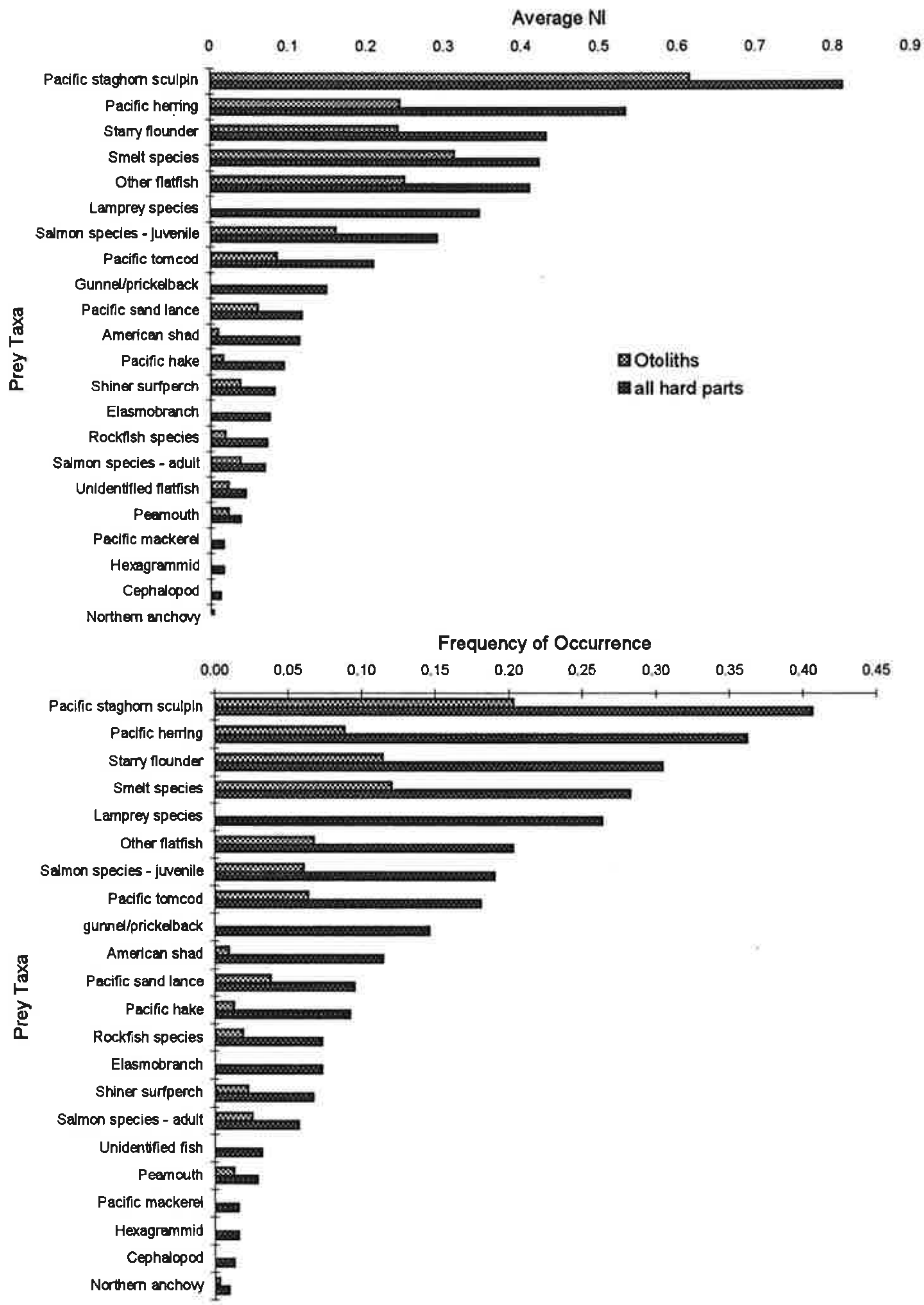

Figure 1. Average number of individuals (NI) and frequency of occurrence of prey taxa from otoliths and all prey remains recovered from harbor seal scat collected from the lower Columbia River during spring from 1995 through 1997.

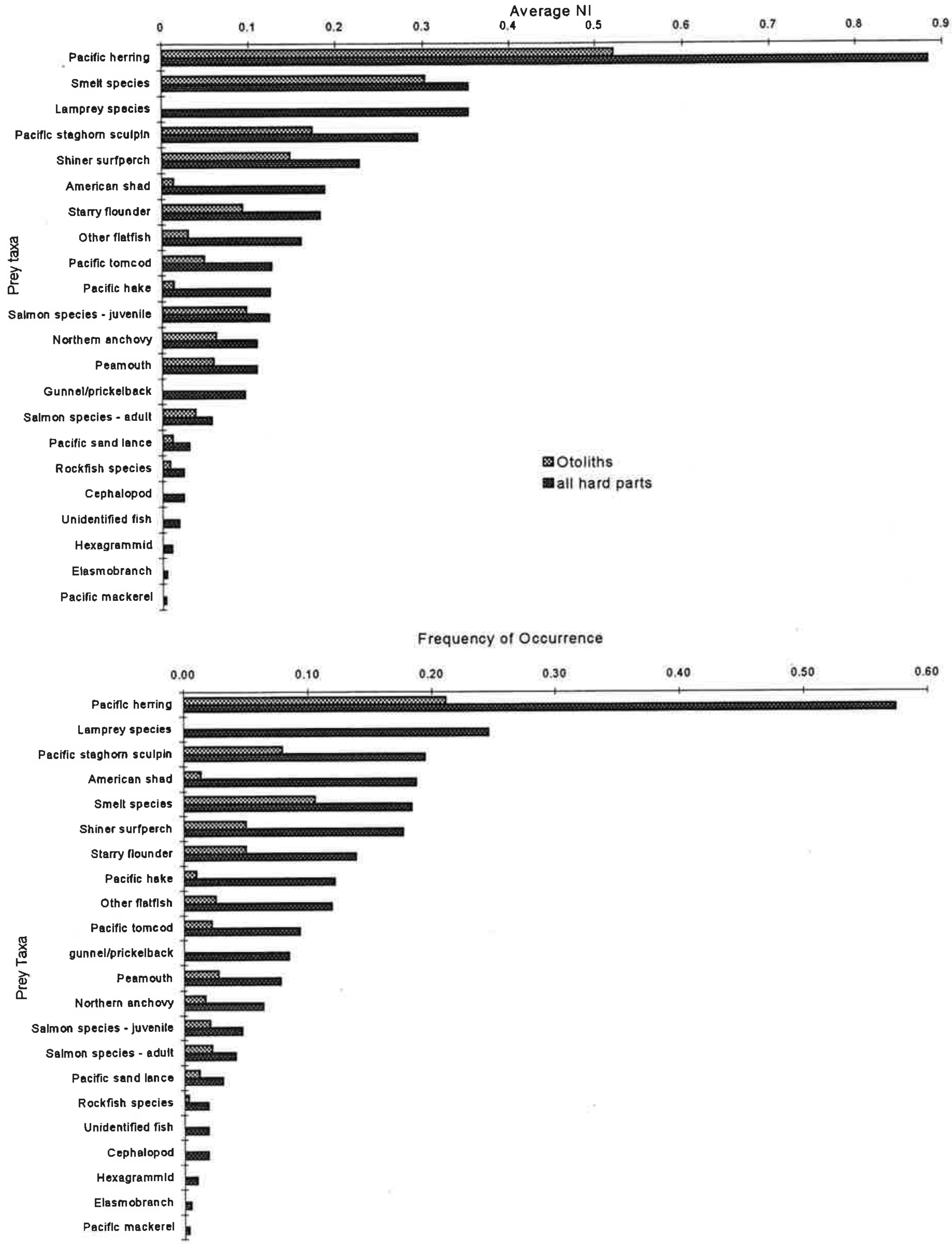

Figure 2. Average number of individuals (NI) and frequency of occurrence of prey taxa from otoliths and all prey remains recovered from harbor seal scat collected from the lower Columbia River during summer from 1995 through 1997.

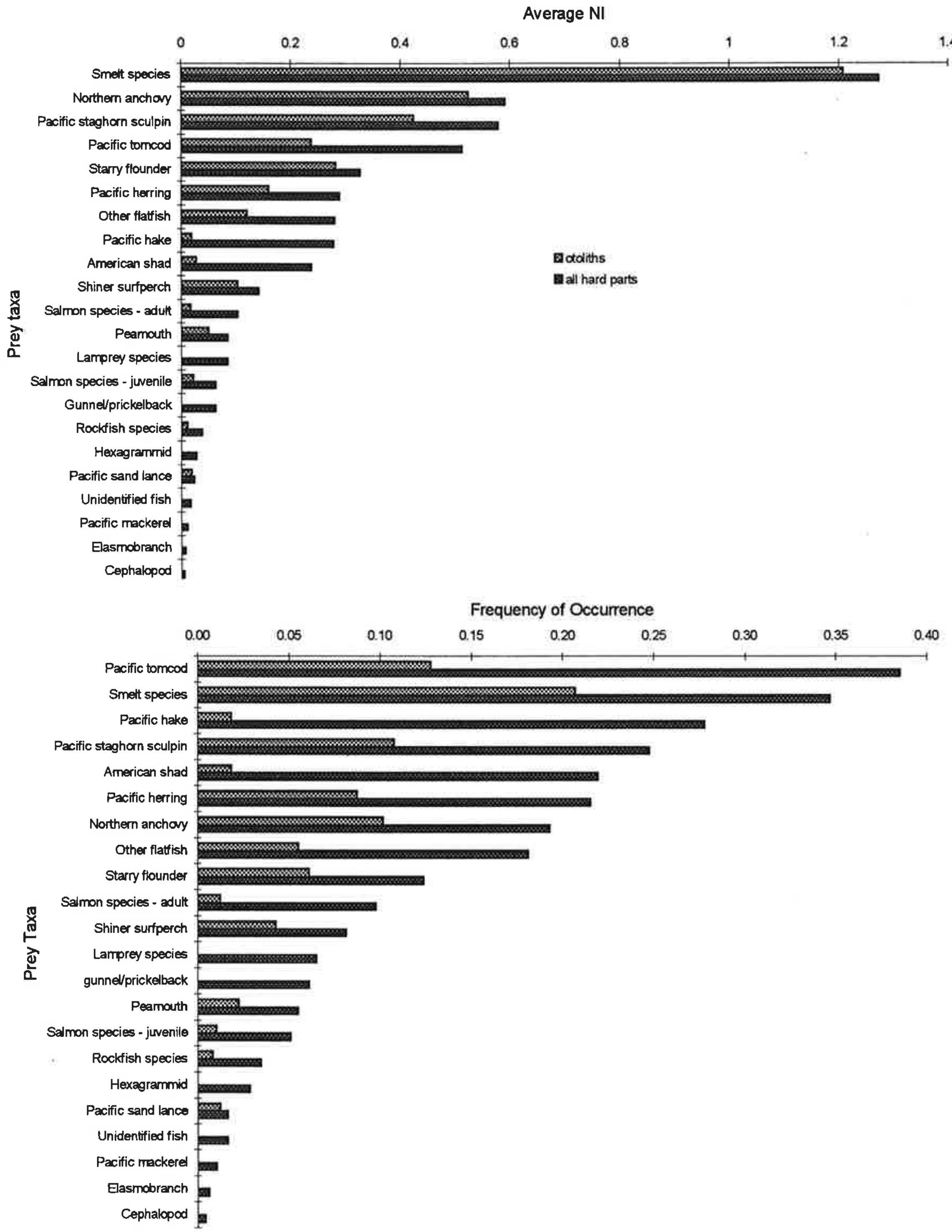

Figure 3. Average number of individuals (NI) and frequency of occurrence of prey taxa from otoliths and all prey remains recovered from harbor seal scat collected from the lower Columbia River during fall from 1995 through 1997.

UPDATE ON THE NORTH PACIFIC HUMPBACK WHALE FLUKE PHOTOGRAPH COLLECTION, APRIL 1998

Sally A. Mizroch and Suzanne A. D. Harkness

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington, 98115

Introduction

Since 1985, the National Marine Mammal Laboratory (NMML) has been developing and curating a collection of humpback whale (*Megaptera novaeangliae*) fluke photographs taken in North Pacific waters using a computer-assisted matching system (Mizroch et al. 1990). The collection of North Pacific humpback whale fluke photographs grew from about 750 photographs in 1986 to over 24,000 photographs by 1998, representing contributions from over 16 research groups, taken from all regions in the North Pacific (Tables 1 and 2).

Matches in The Database

Unique ID numbers (NMMLID) are assigned when there are at least 2 photographs of a particular individual whale in the database. As of April 1998, there were 12,033 fluke photographs with a NMMLID (3,091 unique NMMLID numbers) and 12,257 fluke photographs without a NMMLID. The exact number of individual whales in the database cannot be determined at this time because the database has not yet been thoroughly cross-matched between areas and different research collections. Some of the unmatched photos may be unique whales that have only one photograph in the database, and other photos may be unmatchable due to poor photo quality.

Preliminary List of Matches Between Areas

A summary of matches of whales that have been photographed in different areas is presented in Table 2. This list is preliminary and should not be assumed to imply rates of exchange between areas because the database has not been thoroughly cross-matched within and between areas. Additional information about matches between areas has become available from the matching project funded by NMFS and coordinated by Cascadia Research Collective (Calambokidis et al., 1997), which involved a collaboration of 16 research groups to produce a population estimate based on sightings and resightings from 1991 to 1993, defined here as the NPAC91-93 dataset.

The NPAC91-93 dataset has been thoroughly cross-matched between areas, and recently, NMML has begun the process of comparing and integrating the matches made during that project into the larger collection. After the integration is complete, the distribution of matches between areas will be much more comprehensive.

Long-Term Sighting Histories

In the past year, special emphasis was placed on encoding the older photos that had been archived at the NMML that were taken in the late 1970s and early 1980s. After entering and matching these older photographs, long-term sighting histories of many whales seen currently have been extended back over a 20-year period. Many whales have been seen over a long time period: 1,010 whales have been seen over a period of 5 years, and 381 of those were seen over a 10-year span, 116 of those were seen over a 15-year span, and 5 whales were seen over a 20-year time span (Fig. 1). The whale with the longest sighting history in the database is NMMLID 229, who was first photographed by M. Tillman in Alaska in 1976, and photographed as recently as 1997 in Hawaii by J. Darling.

Re-examination of Quality Codes

Each photograph in the North Pacific database is assigned two quality codes: one based on quality of the photograph (focus, lighting, distance) and the other based on how distinctive the natural markings are (see Mizroch et al. 1990, for further explanation).

NMML and Cascadia are exploring the possibility of using the integrated dataset of photos from NPAC91-93 and photos matched by the NMML to model the effects of photo quality coding on population estimates (see Friday 1997). The NPAC91-93 dataset was selected by choosing only those photos above a certain photo quality rating, resulting in a subset of 3,650 photographs for the years 1991-93. The subset of photos in the larger North Pacific database for that time period is 8,229, including some photographs that were solicited for the NPAC91-93 study but omitted due to photo quality. Because the NMML matches all photos, regardless of photo quality, it will be possible to explore the effects of including photos of varying degrees of photo quality on the population estimates.

Life History Parameter Workshops

When the computer-assisted matching system was developed, and researchers were asked to send humpback whale fluke photographs to a central collection, it was decided to hold a series of workshops to conduct studies on mortality, reproduction, and other topics.

To date, a two-part workshop on the Estimation of Calf Mortality in North Pacific Humpback Whales has been held. The first part was held at the NMML from 20 to 23 November 1991 and the second was held at the NMML from 25 to 27 November 1996 (Mizroch, in review).

At the second workshop, C. Gabriele of Glacier Bay National Park and Preserve volunteered to take lead authorship on a paper estimating calf mortality, comparing sightings of mothers with calves in Hawaii to sightings of mothers with or without calves in Alaska in the same season. J. Straley of University of Alaska volunteered to take lead authorship on a paper on birth intervals using the method developed by Barlow (Barlow and Clapham, 1997). Data preparation is complete for these analyses, and a draft of Gabriele's paper should be available by June 1998, and Straley's paper by November 1998.

There were approximately 374 whales seen in Hawaii or Alaska at least one time with a calf, and 58 of these whales have been seen in Alaska and Hawaii in the same season. While developing sighting histories of these whales, it has become apparent that approximately 3 or 4 of these purported females may have been designated erroneously. Gabriele and Straley will address the question of this type of error in their papers.

Citations

Barlow, J., and P. J. Clapham. 1997. A new birth-interval approach to estimating the demographic parameters of humpback whales. Ecology 78(2):535-546.

Calambokidis, J., G. H. Steiger, J. M. Straley, T. J. Quinn II, L. M. Herman, S. Cerchio, D. R. Salden, M. Yamaguchi, F. Sato, R. J. Urbán, J. Jacobsen, O. von Ziegesar, K. C. Balcomb, C. M. Gabriele, M. E. Dahlheim, N. Higashi, S. Uchida, J. K. B. Ford, Y. Miyamura, P. P. Ladrón de Guevara, S. A. Mizroch, L. Schlender, and K. Rasmussen, 1997. Abundance and population structure of humpback whales in the North Pacific basin. Final Contract Report 50ABNF500113 to Southwest Fisheries Science Center, P.O. Box 271, La Jolla, CA 92038. 72 p. (Available on request - Southwest Fisheries Science Center, P.O. Box 271, La Jolla CA, 92038)

Friday, N. 1997. Evaluating photographic capture-recapture estimates of abundance of North Atlantic humpback whales. Ph.D. Dissertation, University of Rhode Island. 173 p.

Mizroch, S. A. in review. Report of the workshops on the estimation of calf mortality in North Pacific humpback whales. 38 p.

Mizroch, S. A., J. A. Beard, and M. Lynde. 1990. Computer assisted photo-identification of humpback whales. Rep. Int. Whaling Comm. (special issue 12):63-70.

Table 1. Abbreviations and main contact people from the major contributing research groups.

Abbreviation	Research group	Contact people
CCS	Center for Coastal Studies	D. Mattila
CRC	Cascadia Research Collective	J. Calambokidis, G. Steiger
CWR	Center for Whale Research	K. Balcomb, D. Claridge
CWS	Center for Whale Studies	D. Glockner-Ferrari, M. Ferrari
GBNP	Glacier Bay National Park and Preserve	C. Gabriele
HWRF	Hawaii Whale Research Foundation	D. Salden
JSI	J. Straley Investigations	J. Straley
KBMML	Kewalo Basin Marine Mammal Laboratory	L. Herman, A. Craig
MLML	Moss Landing Marine Labs	S. Cerchio
NGOS	North Gulf Oceanic Society	O. von Ziegesar, C. Matkin
NMML	National Marine Mammal Laboratory	S. Mizroch
OEA	Okinawa Expo Aquarium	S. Uchida, N. Higashi
PBS-GE	Pacific Biological Station	G. Ellis
PWF	Pacific Whale Foundation	M. Osmond
UABCS	Univ. Autonoma de Baja Calif. Sur	J. Urban
UNAM	Univ. Nacional Autonoma de Mexico	M. Salinas, J. Jacobsen
WCWRF	West Coast Whale Research Foundation	J. Darling, E. Mathews, D. McSweeney, K. Mori

Table 2. Number of individual whales seen within and between areas in the North Pacific. Some individuals have visited areas multiple times, and those revisits are not reflected on this table.

Area	Alaska	California	Canada	Hawaii	Ogasawara	Baja	Mainland	Revillagigedos	Oregon	Washington
Alaska	878	1	6	360	-	4	7	9	-	-
California	1	522	2	1	-	28	57	1	14	4
Canada	6	2	48	20	-	4	3	2	-	9
Hawaii	360	1	20	1806	2	8	-	22	1	-
Japan - Ogasawara	-	-	-	2	6	-	-	-	-	-
Mexico - Baja	4	28	4	8	-	122	24	13	2	3
Mexico - Mainland	7	57	3	2	-	24	99	7	6	2
Mexico - Revillagigedos	9	1	2	22	-	13	7	125	-	1
Oregon	-	17	-	1	-	2	6	-	20	-
Washington	-	4	9	-	-	3	2	1	-	16

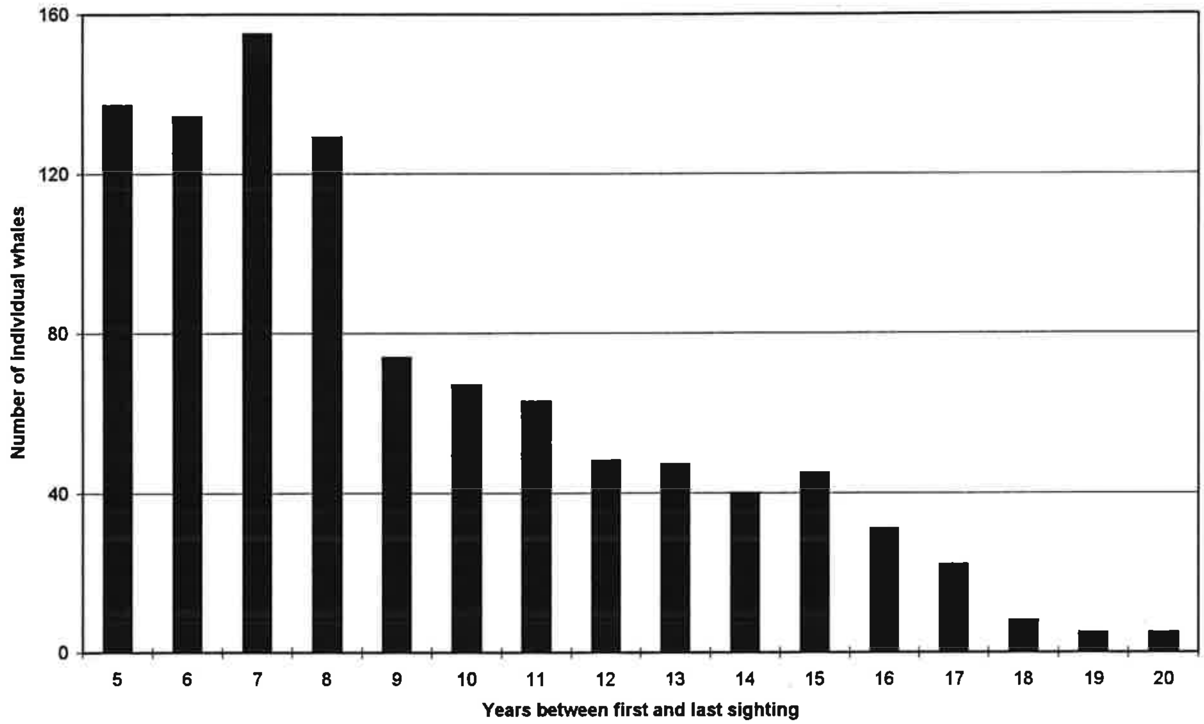

Figure 1. Number of individual humpback whales that have been sighted over the span of at least 5 years.

NORTHERN FUR SEAL STUDIES CONDUCTED ON THE PRIBILOF ISLANDS AND BOGOSLOF ISLAND, 1997

Thomas R. Loughlin and Elizabeth H. Sinclair

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington, 98115

Introduction

In 1997, studies of northern fur seals (*Callorhinus ursinus*) were carried out on the Pribilof Islands, Alaska, during July to November, and on Bogoslof Island during the month of September. Areas of research included subsistence harvest tissue collections, adult male counts, offspring condition, prey selection, incidence of entanglement, pup mortality and disease, as well as special studies of female foraging and migration of pups. Research was conducted by National Marine Mammal Laboratory (NMML) staff, their contractors, and various collaborators including individuals and groups in the Aleut communities of St. Paul and St. George Islands, the Japanese National Research Institute of Far Seas Fisheries, the University of California, and the University of Alaska. Results of monitoring studies are published annually in the Alaska Fisheries Science Center's, NOAA *Technical Memorandum* series, *Fur Seal Investigations* (FSI) report.

Population Assessment

Subsistence Harvest

A total of 1,153 sub-adult male seals were taken in the subsistence harvest by St. Paul Island residents in 1997. Three female fur seals were harvested accidentally on St. Paul Island. On St. George Island, 227 sub-adult male seals were taken in the subsistence harvest in 1997. Tooth samples were obtained from 206 and 40 juvenile males harvested during subsistence takes on St. Paul and St. George Islands, respectively. Teeth are collected for age determination and as a record for studies of tooth microstructure. Serum and other tissues were collected from a sample of harvested seals and archived in the long-term fur seal tissue bank at NMML.

Living Adult Male Seals Counted

Total counts of adult male seals were conducted by section for each rookery on St. Paul Island from 11 to 15 July. A total of 5,064 harem and 8,560 idle adult male seals, also referred to as bulls, were counted on St. Paul Island. On St. George Island, a total of 910 harem and 1,474 idle adult male seals were counted from 11 to 16 July. There was a decrease in the count of territorial males with females on St. Paul Island between 1996 and 1997 (10.3%). The count of territorial males on St. George Island decreased by 27.1% between 1996 and 1997. These numbers may reflect a decline in adult males overall; however, due to the high degree of variability in such counts, several more years of data are needed to assess this information for possible trends.

Pup Condition Study

Each year during late August, a sample of pups is rounded up at four trend sites on St. Paul Island and at each of six rookeries on St. George Island for determination of sex, mass and length. Pups are sampled as described in Antonelis (1992) and Robson et al. (1994). Pups were weighed to the nearest 0.2 kg using a spring scale and length was determined to the nearest 1 cm. During 25-27 August 1997, a total of 1,020 pups (495 female, 525 male) were weighed and measured on St. Paul Island. A total of 639 pups (311 female, 328 male) were weighed and measured on St. George Island during 25-28 August 1997.

Prey Selection Monitoring

In order to monitor prey selection of northern fur seals foraging in the Bering Sea, scats are collected from rookeries and haul outs. During 24-28 August 1997, a total of 407 scats and 37 spews were collected on the Pribilof Islands. An additional 89 scats and 6 spews were collected on Bogoslof Island during 9-20 September 1997. Hard parts of prey from these samples have been separated and most prey remains have been identified. This information will be combined and analyzed with a food habits database initiated in 1988.

Entanglement Studies

In 1997, in cooperation with the St. Paul and St. George Islands Tribal Councils and the Pribilof Islands Stewardship Program, NMML completed the final year of a study of juvenile and adult male fur seal entanglement using a combination of research roundups and surveys during the subsistence harvest. The objective of this study, initiated in 1995, was to determine current trends in the rate of observed on-land entanglement of northern fur seals in marine debris on St. Paul and St. George Islands. This information was collected in order to provide: 1) a continuing index of entanglement rates, 2) a comparison of entanglement rates on St. Paul and St. George Islands, 3) a means of indirectly assessing the relative amount of entangling debris within the habitat of the fur seal, and 4) an assessment of the proportion of debris types associated with different fisheries that are impacting fur seals. In addition to the continuation of juvenile male entanglement studies, researchers continued to collect information on seasonal and annual (1991-96) rates of entanglement among adult female fur seals. As in previous years, researchers continued to capture and remove debris from entangled seals encountered during other research projects.

Twenty-two subsistence harvest surveys and 33 roundups were conducted on St. Paul Island (55 total) and 18 roundups and 8 harvest surveys (26 total) were conducted on St. George Island during July and early August of 1997. Observers sampled 36,239 and 6,289 seals of all age groups combined on St. Paul and St. George Islands, respectively. Samples included 19,265 juveniles (2-4 years old) on St. Paul Island and 2,987 juveniles on St. George island. Fifty-eight entangled juvenile and adult male seals were captured, examined, and the debris was removed during harvest surveys and roundups (49 on St. Paul Island and 9 on St. George Island). The rate of entanglement for juvenile males was 0.19% (36/19,265) on St. Paul Island and 0.23% (7/2,987) on St. George Island. Among adult males, the rate of entanglement was 0.11% (18/16,974) on St. Paul Island and 0.07% (3/4,145) on St. George Island.

Two entangled and 9 scarred (evidence of previous entanglement) adult female fur seals were observed during female entanglement surveys on St. Paul Island. The rate of entanglement among females was calculated at 0.007% for entangled females, 0.029% for scarred females and 0.036% for the two categories combined. The 1997 data are comparable to the observed rate of entangled and entangled and scarred females combined in 1995-96, and to that observed in 1992 and 1993.

As in previous years, entangling debris consisted primarily of pieces of trawl net, plastic packing bands, and loops of synthetic or natural twine. On St. Paul Island, an equal proportion (42.9%) of entangled adult males had packing bands or trawl net around their necks. On St. George Island, only 1 adult male, entangled in a plastic packing band was observed during entanglement surveys. Packing bands comprised the largest proportion of entangling debris among juveniles on St. Paul Island (50.0%) followed by trawl net (28.6%). Conversely, trawl net was the most frequent debris type (66.7%) observed on St. George Island followed by packing bands (25.0%). As in 1995 and 1996, more entanglement in packing bands was observed on St. Paul Island (46.9%) relative to St. George Island (23.0%) for all age groups combined.

Surveys to assess the rate of entanglement of adult and juvenile male fur seals in marine debris conducted on the Pribilof Island during 1995, 1996, and 1997 indicate that the incidence of entanglement among juvenile males on St. Paul Island is within the range of entanglement rates observed from 1988 to 1992. Decline in the rate of entanglement on St. Paul Island from a mean rate of 0.4% between 1976 and 1985 to a mean rate of 0.2% between 1995 and 1997 may be attributable to a reduction in the fraction of seals entangled in trawl net fragments. Entanglement rates between St. Paul and St. George Islands were not significantly different ($p<0.05$) with the exception of the first year of data in 1995. The higher rate on St. George during 1995 can be attributed to the lack of an organized effort to capture and remove debris from entangled seals prior to the initiation of this study. Details on entanglement rates and debris types will be presented in the 1997 FSI report.

Pup Mortality and Disease

On St. Paul Island, dead pups from two sites were collected on a daily basis from 4 July to 9 August 1997. A total of 165 dead pups were collected and necropsied. Tissues for toxicological and disease studies were collected from 15 female pups, 18 male pups and 3 male fetuses. A detailed contract report prepared by Wildlife Pathology International regarding disease surveillance in 1997 is available at NMML.

Female Foraging

Studies of the foraging behavior of lactating northern fur seal females initiated during a 2-year study conducted on St. Paul and St. George Islands during 1995-96 were continued during 1997 on Bogoslof Island. The questions being asked in this study draw on the findings from the 1995-96 Pribilof Islands study and are applied in the context of the rapidly increasing fur seal population on Bogoslof Island. These include:

- Do females from different islands, or from different breeding areas within islands, use distinctly different foraging areas?
- How does prey selection vary with foraging location and time and depth of diving?
- Do female foraging patterns indicate that interactions with commercial fisheries are likely?

In 1997, a total of 6 females were tracked during foraging trips to sea with satellite transmitters, dive recorders and radio transmitters during foraging studies on Bogoslof Island. Another 4 females were instrumented with a dive recorder and radio transmitter only. From all females captured during 1997, fecal material (in the form of scat or enema) was collected for detailed prey analysis. Preliminary information from radio and satellite telemetry indicated that, during 1997, female northern fur seals on Bogoslof Island tended to make foraging trips that were very short in duration and distance. Preliminary analysis of fecal samples indicate that northern smoothtounge (*Leuroglossus stilbius*) and gonatid squid are primary prey species of female fur seals on Bogoslof Island.

Pup Migration

Each fall and winter, weaned pups migrate from the breeding islands and maintain a completely pelagic existence, usually for about 18 months. This is a critical period in the life history of northern fur seal pups when they learn to forage independently. Over half die during this first winter of life. In 1996, NMML began a 3-year study to determine the timing, direction, and foraging habits during migration. During the first year of the study (1996), six pups were instrumented with satellite transmitters, which transmit data on location and dive behavior. Four of these pups were tracked for 2-4.5 months, providing the first detailed information on where pups go and what they do after disappearing from the Pribilof Islands. During the second year of the study (1997), 8 satellite transmitters were deployed on pups on St. Paul Island (3 females and 5 males) and 4 pups on St. George Island (2 females and 2 males). Instruments continued to transmit into the early spring and initial data indicated differences in the direction of migration between the first and second years of the study.

Citations

Antonelis, G. 1992. Northern fur seal research techniques manual. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-214, 47 p.

Robson, B. W., G. A. Antonelis, and J. L. Laake. 1994. Assessment of measurement error in weights and length of northern fur seal pups in 1992. Pages 35-45, in E.H. Sinclair (editor), Fur seal investigations, 1993. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-46.

WINTER STELLER SEA LION PREY AND FORAGING STUDIES, (CRUISE SMMOCI-981) 4-25 MARCH 1998

Kathryn Chumbley

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington, 98115

Abstract

Scientists from the National Marine Fisheries Service and the U.S. Fish and Wildlife Service conducted a hydroacoustic-midwater trawl survey for Steller sea lion (*Eumetopias jubatus*) prey near three sea lion rookeries in Alaska waters (Buldir, Kasatochi, and Ugamak Island rookeries) during 4-25 March 1998. A total of 438 km of transects were completed as part of the basic surveys. Strong echo sign was rarely seen during the day, though faint scattered sign of zooplankton and fish were observed after 1-2 a.m. Preliminary biomass estimates suggest that midwater biomass was greatest at Ugamak Island and declined to the west. One midwater trawl was conducted to identify selected echo sign. Two long-line sets was completed in rough bottom near Buldir and Kasatochi to sample large fish and their prey. Oceanographic data were collected via a continuously operated thermosalinograph and conductivity-temperature-density (CTD) casts (76) conducted during the cruise. Sea surface temperature was typically around 3-4° C, with surface salinity in the range of 32-33‰. Thirty hours of seabird and marine mammal sighting surveys were completed simultaneous with hydroacoustic transects. The most common seabird species observed were common and thick-billed murres, crested auklets, white winged scoters, and glaucous winged gulls; distinctly different from the species assemblage observed during summer surveys. Killer whales were seen in sufficient numbers to attempt photography on four occasions. No pinnipeds were seen at sea; however, Steller sea lion counts were made at a number of rookeries and haulout sites and 184 scat samples were collected.

Introduction

Scientists from the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USF&WS), aboard the USF&WS vessel M/V *Tiĝlax̂* conducted a hydroacoustic -midwater trawl survey for Steller sea lion prey at three sites in Alaska waters during 4-25 March 1998 for a total of 21 sea days. The area of operations included the Buldir, Kasatochi and Ugamak rookeries and waters surrounding these sites.

The principal objectives of the cruise were to 1) conduct hydroacoustic - midwater trawl surveys around Buldir, Kasatochi, and Ugamak Islands to compare to surveys conducted during July 1997, and 2) collect scat samples at rookeries and haul outs in the region. Secondary objectives included sighting surveys of marine mammals and seabirds during hydroacoustic surveys, collection of blubber plugs from sea lions for fatty acid analysis, counts of sea lions by age and sex, and capture and instrumentation of juvenile sea lions.

Cruise Narrative

The cruise began at Adak, Alaska on 4 March 1998 on the M/V *Tiĝlax̂* with the scientific party boarding at that time. Departure from Adak was delayed until the early morning of 5 March due to inclement weather (Tables 1 and 2). After departure the vessel proceeded to Kanaga Island to support the three USF&WS refuge fox camps. Fox trappers were brought onboard the vessel and ferried to remote areas of the island to look for signs of fox and to set traps. During the fox work, orcas (n = 8) were sighted in the vicinity of Kanaga ranch and effort was redirected to obtain photographs for identification of individuals. Fox related work was then resumed and concluded in the late afternoon.

Upon completion of the fox work the vessel departed for Amchitka Island, transiting Amchitka Pass during the night in rough weather. On the morning of 6 March, sea lions were counted from the vessel at Column Rocks and Cape St. Makarius (Table 3) and continued the transit to Kiska Island. Due to stormy weather the vessel was unable to transit to Buldir Island and anchored for the night at Gertrude Bay on Kiska. On 7 March the vessel attempted to cross the pass to Buldir again but turned back due to rough weather and anchored in Dark Cove, Kiska. A skiff was sent to shore for scat collection at Cape St. Stephens, Kiska, where 27 samples were collected. Several more attempts to make the crossing to Buldir were made and aborted before the vessel turned east back to Amchitka. Late on 8 March the weather subsided enough to turn around again and depart back to Kiska and Buldir.

On 9 March the vessel arrived at Buldir where the first of the three sites to be visited for prey studies began. The three central transects were surveyed during both daylight and nighttime periods to contrast prey densities by time of day. Prey surveys (161 km), 10.5 hours of sighting surveys, and 23 CTD casts were completed by the early evening of 10 March and the vessel departed for Amchitka. A longline survey was not made at Buldir due to approaching storms and a lack of adequate anchorage.

The trip proceeded eastward in the central Aleutians on 11 March. A group of 8-10 orcas were sighted and photographed in Amchitka Pass. The vessel then continued on to Ulak with a skiff going ashore to collect 35 scat samples. The vessel departed for Kanaga for more fox camp support. However, due to stormy weather, assistance to the camps was not possible and the vessel proceeded on to dock at Adak through 13 March.

Arriving on 14 March at Kasatochi, surveys began again with both day and night prey studies (161 km), 10 hours of sighting surveys, 25 CTD casts and 1 longline set conducted by the evening of 15 March, when the vessel then departed for Seguam. On the south side of Seguam at Lava Cove a group of 5 orcas was sighted and photographed. Satellite telemetry (PTT) instrumentation of juvenile sea lions was attempted during the next several days. From 17 to 18 March the vessel traveled through the central Aleutians counting sea lions (Table 3) and collecting scats at Seguam (35) and Chuginadak (37).

On 19 March, we arrived at Ugamak where a group of 12-15 orcas were sighted and photographed. Day and night prey studies (161 km), 10.4 hours of sighting surveys, and 24 CTD casts continued through the afternoon of 20 March. One longline set and 1 mid-water trawl were conducted. From 21 to 23 March, satellite telemetry was attempted at both Aiktak and Akun and scats (49) were collected at Ugamak.

A final pass by Akun at Billingshead was made on 23 March to assess conditions for satellite telemetry or scat collection. With storms approaching (SE 50-W 65) and a surge onshore a decision was made to proceed to Akutan for possible scat collections. With no animals present at North Head or Lava/Reef (Akutan) the vessel continued on toward Unalaska. Just past Cape Wislow the storm arrived so the vessel turned toward Dutch Harbor. Upon arrival in Dutch Harbor, winds were blowing a steady 85 mph with reported gusts over 100 mph. The vessel then anchored off the town of Unalaska for the night due to high winds and no dockside space availability (end of crab season). The cruise ended and the scientific party disembarked on 24 March.

Methods

Hydroacoustic Surveys

Acoustic data were collected along a series of parallel transects within a 10 nautical mile (nmi) radius of the three sites (Buldir, Kasatochi and Ugamak). Transect spacing was around 3 nmi. The vessel generally operated at 10 knots during this work. These data were collected using the vessel's BioSonics 102 system, with hull mounted (4 m deep) 38 and 120 kHz transducers operated in a multiplexing mode. All legs were surveyed once during daylight hours. The central three transects were also surveyed at night at all three sites. Settings for the 102 unit was: receiver gain -6 dB (120 kHz) or -18 dB (38 kHz), TVG20, band width 5, pulse width 0.5, blanking distance 0.5 m, trigger interval 0.5 sec, and transmit power -3 dB. The system was run in multiplexing mode to obtain separate estimates of total biomass and fish biomass. All data was echo-integrated in real time using BioSonics ESP software running on the ship's computer.

Data will be analyzed post-survey using additional ESP software and EXCEL. Indices of total biomass will be developed by averaging the biomass density (per m^2) obtained from each one minute segment of the survey across all segments for a site.

Trawls

Midwater trawls were conducted in support of the hydroacoustic surveys to identify selected echo sign. These trawls were conducted using a 6 m modified herring trawl towed for 15 minutes at 2-3 knots. A netsounder attached to the herring trawl foot rope was used to determine fishing depth. Samples collected from these tows (euphausiids, pollock and larval fish) were counted, identified (as possible), and then frozen.

Long Line Sets

One long line set was made offshore of two of the three sites. The long line consisted of one skate with 90-100 hooks baited with herring. Sets were made in water with hard bottom, approximately 50 m deep, and were allowed to soak around 2 hours. All sets were made at slack water. Fish caught (halibut and cod, *Gadus macrocephalus*) were measured, weighed, and sexed. Stomachs were then removed and preserved in formalin. Stomach contents will be identified at NMFS.

Seabird and Marine Mammal Sighting Surveys

During daylight hours of the hydroacoustic surveys members of the scientific party also conducted sighting surveys of marine mammals and seabirds from the flying bridge (depending on visibility). Standard USF&WS seabird sighting protocols were observed. This involved two persons; one observer and one recorder. The 90° area from amidships to the bow (usually to port only) was observed continuously, with marine mammals and seabirds recorded by species and number.

Off-effort sightings of marine mammals were recorded on the vessel's bridge using NMFS Form 11.

Oceanographic Data

A continuous thermosalinograph record was maintained throughout all hydroacoustic transects using the ship's Seabird Seacat SBE 21 thermosalinograph. A portable CTD (the ship's Seabird Seacat SBE-19 Profiler) was deployed at the beginning and end of each transect, and at the end of most tows and long line sets to obtain salinity and temperature profiles for the entire water column.

Results

Hydroacoustic Surveys

A total of 483 km of transects were run as part of the basic surveys conducted at the three sites; 355 km during the day and 128 km at night.

Strong echo sign was rarely seen at any site during the day and on few occasions at night. At those sites where night time transects were run (Buldir, Kasatochi, and Ugamak Islands) faint scattered sign of zooplankton and fish were observed after 1-2 am. A tow on a layer of widely scattered strong signal return sign showed it was composed of adult walleye pollock (*Theragra chalcogramma*), euphausiids, and larval fish.

Preliminary estimates suggest that midwater biomass was greatest at Ugamak Island and declined to the west. These data remain to be analyzed.

Trawls

One midwater trawl was made with the herring trawl. The midwater trawl found a variety of fish (including adult pollock), as well as euphausiids, a few jelly fish and larval fish. Larval fishes obtained were preserved for identification by NMFS.

Long Line Sets

Two long line sets were made, one each at Kasatochi and Buldir Islands. The longline gear was deployed within 2 miles of each rookery on rough bottom. The gear caught Pacific halibut, Pacific cod, and sculpins. Stomachs were collected from 11 halibut and 8 cod at 40 m depth near Kasatochi Island, and from 10 cod and 4 halibut at 50 m depth near Ugamak Island. Stomach contents will be analyzed by the Alaska Fisheries Science Center, Resource Ecology Fisheries Management, Food Habits Lab in Seattle.

Oceanographic Data

A total of 76 CTD casts were made during the period. These remain to be analyzed. Continuous sea surface temperature (SST) and salinity data were obtained from virtually all transects. SST was typically around 3-4° C, with surface salinity in the range of 32-33‰.

Marine Mammal and Seabird Sighting Surveys

Sighting surveys were run at all locations where hydroacoustics work was performed. Thirty hours of surveys were obtained simultaneous to the hydroacoustic surveys. The most common species observed were common and thick-billed murres, crested auklets, white winged scoters, and glaucous winged gulls. This was distinctly different from the species observed at the sites during summer--shearwaters, northern fulmars, tufted puffins, common murres, black-legged kittiwakes, and ancient murrelets. Sighting data is presently being entered for analyses of sea bird associations with hydroacoustic results.

Sighting records of marine mammals were maintained throughout the cruise. Marine mammal species sighted include killer whales (*Orcinus orca*), minke whale (*Balaenoptera acutororostrata*) and Dall's porpoise (*Phocoenoides dalli).* Killer whales were seen in sufficient numbers to attempt photography on four occasions; Kanaga (8), Amchitka Pass (8-10), Seguam (5) and Ugamak (12-15) areas.

No pinnipeds were seen at sea. However, Steller sea lions were seen and counts were made at the sites listed in Table 3.

Conclusions

The cruise was a success even though rough weather conditions were more frequent than in past trips. The vessel and crew performed admirably, during periods of stormy weather, especially during the first 8 days. Thus, the vessel provides an excellent platform for winter work.

The ship's BioSonics 102 system performed well throughout the cruise. The results have not been analyzed. However, a preliminary analysis of the 120 kHz biomass densities suggests that the results are comparable to running the 120 kHz system by itself.

In combination with the NetMind system, the modified herring trawl provided a powerful tool for sampling midwater prey. Taxa from euphausiids and larval fish to adult pollock were obtained using the net, and as a result it appears to resolve the problem of sampling the midwater. The next net that needs to be obtained is a small bottom trawl net with roller or "rock-hopper" gear. The best sampling of midwater prey appears to be the late night or early morning, as midwater sign was rarely seen in trawlable concentrations during the day. Thus, future survey work will need to focus more on this night time period.

The long line gear also provides a simple sampling technique, and is now completely operational. However, the small samples obtained in the single skate (100 hook) sets are too small for statistical analysis. Thus, either additional skates or more sets will be necessary in the future.

Sighting surveys were run at all locations where hydroacoustics work was performed: Buldir, Kasatochi, and Ugamak Islands. Over 30 hours of sightings were obtained. Direct entry of data as collected into a shipboard GIS (D-Log program) has increased the speed of data entry and analysis. The seabird sighting results have not been analyzed. However, in general, fewer seabirds were sighted during this trip as compared with the March 1997 trip, especially the numbers of crested auklets sighted. Additionally, occurrences of dead murres increased from the previous year and from the western Aleutains to the eastern Aleutians. NMFS in Dutch Harbor has received many reports of dead murres and has been collecting specimens for analysis.

Table 1. Itinerary and activities for March 1998 cruise (SMMOCI-981).

Date	Location	Activity	Comments
04 March	Adak	Scientific party arrive	
04 March	Adak	Vessel arrives	Storm NW35-40; 20 ft seas
05 March	Adak	Depart for Kanaga	USF&WS fox camps
06 March	Kiska	Transit	
07 March	Kiska	Transit to Buldir (aborted)	Storm N/NW 45; 20 ft seas; scats at Kiska
08 March	Kiska	Transit to Buldir (aborted) Transit to Amchitka	Storm N 35; 20 ft seas
09 March	Amchitka	Transit back to Kiska & Buldir, begin Buldir day/night transects; sightings	Weather subsiding
10 March	Buldir	Completed transects; sightings Transit to Amchitka	NW 15; 2 ft seas; storm approaching
11 March	Ulak	Scat collection Transit to Tanaga	NE 35-40
12 March	Tanaga	Transit to Kanaga & Adak	Storm approaching N 35
13 March	Adak	At Adak - offload Macone; load Hill	Storm N 40-50; 20 ft seas
14 March	Kasatochi	Transit; transects & sightings	NW 20; 3 ft seas
15 March	Kasatochi	Transects, sightings & longline Transit to Seguam	
16 March	Seguam	Darting	2 shots no instruments out

Table 1. (cont.)

Date	Location	Activity	Comments
17 March	Seguam	Transit to Amukta, Chuginadak	NW 20; 3 ft seas
18 March	Chuginadak Ogchul Transit to Ugamak	Scat collection; Too rough to land	NW 15, 2 ft seas Big swell
19 March	Ugamak	Transects; sightings	NW 20; 2 ft seas
20 March	Ugamak	Transects; sightings; Long line; trawl	
21 March	Ugamak/Aiktak	Scat collection; Darting; Transit to Akun	2 shots - no instruments out
22 March	Akun Aiktak	Darting Transit back to Akun	No shore landing Animals too close to water
23 March	Akun	Darting/scats Transit to Dutch Harbor; anchor off Unalaska	Too rough to land; Outlook SE 50 building to W 65; NW 85, gusts to 130 in harbor
24 March	Dutch Harbor	Offload Scientific party	End of Cruise
25 March	Dutch Harbor	Weathered In	
26 March	Dutch Harbor	Depart for Seattle	

Table 2. Scientific personnel involved with March 1998 cruise (SMMOCI-981).

Name	Sex/nationality	Position	Organization
K. Chumbley	F/USA	Party Chief	NMFS
J. Sease	M/USA	Asst. Party Chief	NMFS
M. Strick	M/USA	Wildlife Biologist	NMFS
J. Thomason	M/USA	Wildlife Biologist	Contract employee
L. Chilton	F/USA	Fisheries Biologist	Contract employee
D. Dragoo	M/USA	Seabird biologist	USF&WS
S. Woodward	F/USA	Seabird biologist	USF&WS

Table 3. Counts of Steller sea lions, March 1998.

Site	Hour	Day	Month	Year	Count	Comments
Kanaga/Ship Rock		3-4	March	1998	0	continuous NW wind
Kanaga/North Cape		3-5	March	1998	0	continuous NW wind
Amchitka/St.Makarius	1030	6	March	1998	<50	
Amchitka/Column Rks	1250	6	March	1998	6	also 1 fur seal
Kiska/Sobaka-Vega	830	7	March	1998	0	did not get a great view of site
Kiska/C.St.Stephen	1330	7	March	1998	100	collected 27 scats
Kiska/Gertrude Cove	1400	8	March	1998	14	
Kiska/Bukhti Point	1430	8	March	1998	0	
Rat/Krysi Point	1730	8	March	1998	0	surf breaking over point
Ayugadak	1825	8	March	1998	30	S side of largest island off Ayugadak Pt.
Buldir		9	March	1998	0	circumnavigate island - no sea lions
Amatignak/Nitrof Point	1500	11	March	1998	150	too rough to go ashore
Amatignak/Knob Point	1530	11	March	1998	0	
Ulak/Hasgox Point	1555	11	March	1998	200	collected 33 scats
Kasatochi	1815	14	March	1998	50	too rough to go ashore
Seguam/Saddleridge	800	16	March	1998	20	
Seguam/Saddleridge	1040	17	March	1998	50	
Seguam/waterfall	845	16	March	1998	150	just east of waterfall, under concrete bunker
Seguam/Finch Point	850	16	March	1998	16	
Seguam/Wharf Point	915	16	March	1998	200	two groups of 150 and 50
Seguam/Turf Point	1500	16	March	1998	350	unsuccessful darting, collected 38 scats
Seguam/SW rip	920	17	March	1998	100	could be some kicked off Turf Point on 16th
Amukta	1615	17	March	1998	10+	
Yunaska/S side	1830	17	March	1998	5	southwestern tip of the island
Chuginadak/Concord Pt.	850	18	March	1998	50	collected 37 scats
Ogchul	1545	18	March	1998	180	too rough to go ashore
Ugamak/North side	800	19	March	1998	0	
Round Island	1910	19	March	1998	15	
Ugamak/Ugamak Bay	1915	19	March	1998	60	
Ugamak/Ugamak Bay	1030	21	March	1998	60	lots of pups, collected 49 scats
Aiktak	1030	21	March	1998	198	lots of pups
Akun/E tip of Billingshd	1830	21	March	1998	8	several miles E of rookery
Akun/E of Billingshead	1840	21	March	1998	100	½ mile east of navigation aid on hillside
Akun/Billingshead rook	1845	21	March	1998	0	

Table 4. Prey survey transects during 4-25 March 1998 cruise (SMMOCI 98-1).

		Begin						End								
Transect	Date	Time (GMT)	Lat.	Long.	SST	Salinity	CTD No.	Time (GMT)	Lat.	Long.	SST	Salinity	CTD No.	Trawl No.	Files Hydro	Files T-S
BD-1	9-Mar	1937	52 30	175 48	3.5	33.1	0	2026	52 30	176 01	3.4	33	1		BD1	BD1
BD-2	9-Mar	2131	52 27	176 09	3.2	33.1	2	2328	52 27	175 40	3.5	33	3		BD2	BD2
BD-3	10-Mar	28	52 24	175 39	3.6	33.1	4	233	52 24	176 10	3.3	33.1	5		BD3	BD3
BD-4E	10-Mar	340	52 21	176 11	3.3	33.1	6	425	52 21	175 59	3.5	33.2	7		BD4E	BD4
BD-3N	10-Mar	829	52 24	176 10	3.3	33.1	8	1037	52 24	175 39	3.5	33.1	9		BD3N	
BD-4WN	10-Mar	1142	52 21	175 38	3.3	33	10	1234	52 21	175 51	3.5	33.2	11		BD4WN	
BD-4EN	10-Mar	1340	52 21	175 59	3.4	33.1	12	1423	52 21	176 11	3.2	33.1	13		BD4EN	
BD-5N	10-Mar	1521	52 18	176 10			14	1741	52 18	175 39			15		BD5N	
BD-4W	10-Mar	1921	52 21	175 51	3.5	33.2	16	2020	52 21	175 38	3.2	33	17		BD4W	BD4W
BD-5	10-Mar	2108	52 18	175 39	3.3	32.9	18	2304	52 18	176 10	3.3	33.1	19		BD5	BD5
BD-6	10-Mar	2353	52 15	176 09	3.5	33.2	20	147	52 15	175 40	3.4	32.9	21		BD6	BD6
BD-7	10-Mar	257	52 12	175 48	3.4	32.9	22	346	52 12	176 01	3.5	33.2	23		BD7	BD7
KA-7	14-Mar	1934	52 06	175 15	4.5	32.8	24	2030	52 14	175 15	3.9	33.0	25		KA7	KA7
KA-6	14-Mar	2134	52 18	175 20	3.8	33.0	26	2309	52 02	175 20	4.4	32.8	27		KA6	KA6
KA-5	14-Mar	2346	52 01	175 25	4.5	32.8	29	144	52 19	175 25	3.7	33.1	30		KA5	KA5
KA-4N	15-Mar	238	52 20	175 30	3.9	33.1	31	327	52 12	175 30	4.2	33.0	34		KA4N	KA4N
KA-4S	15-Mar	436	52 09	175 30	4.5	32.8	35	531	52 00	175 30	4.6	32.8	36		KA4S	KA4S
KA5N	15-Mar	805	52 01	175 25	4.5	32.8	37	1005	52 19	175 25	3.8	33	38		KA5N	
KA4NN	15-Mar	1057	52 20	175 30	4.0	33.1	39	1145	52 12	175 30	4.2	32.9	40		KA4NN	
KA4SN	15-Mar	1230	52 09	175 30	4.3	32.9	41	1329	52 00	175 30	4.6	32.8	42		KA4SN	
KA-3N	15-Mar	1409	52 01	175 35	4.4	32.8	43	1600	52 19	175 35	4.1	33.0	44		KA3	KA3N
KA-1	15-Mar	1910	52 06	175 45	4.2	32.9	45	2002	52 14	175 45	4.1	33.0	46		KA1	KA1
KA-2	15-Mar	2213	52 18	175 40	4.1	33.0	47	2348	52 02	175 40	4.3	32.9	48		KA2	KA2
KA-3	15-Mar	29	52 01	175 35	4.7	32.8	49	220	52 19	175 35	4.2	33.0	50		KA3	KA3

Table 4. (cont.).

Transect	Date	Begin Time (GMT)	Begin Lat.	Begin Long.	Begin SST	Begin Salinity	Begin CTD No.	End Time (GMT)	End Lat.	End Long.	End SST	End Salinity	End CTD No.	Trawl No.	Files Hydro	Files T-S
UG7	19-Mar	1912	54 04	164 40	3.8	31.7	51	2012	54 04	164 54	3.6	31.7	52		UG7	UG7
UG6	19-Mar	2049	54 07	164 54	3.9	31.9	53	2203	54 07	164 34	3.4	31.5	54		UG6	UG6
UG5	19-Mar	2252	54 10	164 31	3.1	31.5	55	107	54 10	165 03	3.8	31.8	56		UG5	UG5
UG4W	20-Mar	140	54 13	165 04	4.1	32.1	57	225	54 13	164 51	3.5	31.8	58		UG4W	UG4W
UG4E	20-Mar	306	54 13	164 45	3.2	31.3	59	357	54 13	164 30	3.2	31.3	60		UG4E	UG4E
UG5N	20-Mar	744	54 10	164 31	3.2	31.6	61	948	54 10	165 03	3.9	31.9	62		UG5N	UG5
UG4WN	20-Mar	1030	54 13	165 04	3.5	31.8	63	1115	54 13	164 50	3.3	31.6	64		UG4WN	UG4W
UG4EN	20-Mar	1156	54 13	164 45	3	31.5	65	1248	54 13	164 30	3.2	31.5	66	M01	UG4EN	UG4E
UG3N	20-Mar	1507	54 16	164 30			67	1711	54 16	165 03			68		UG3N	UG3
UG1	20-Mar	1909	54 22	164 40	2.6	31.2	69	2004	54 22	164 54	2.8	31.4	70		UG1	UG1,UGA
UG2	20-Mar	2050	54 19	165 00	3.1	31.6	71	2215	54 19	164 34	2.8	31.4	72		UG2	UG2
UG3	20-Mar	2256	54 16	164 31	3.3	31.6	73	139	54 16	165 03	4	32	74		UG3	UG3

Table 5. Trawls and long line sets made during 4-25 March 1998 cruise (SMMOCI-98-1).

			Begin			End					
Station	Tow#	Date	Time	Latitude	Longitude	Time	Latitude	Longitude	Area	Gear	Depth (m)
1	L01	3/15/98	1744	52.10.5	175.32.0	1945	52.10.7	175.32.0	KASATOCHI	Lline	50
2	L02	3/20/98	1715	54.73.0	164.47.0	1915	54.60.0	164.47.6	UGAMAK	Lline	62
2	M01	3/20/98	0343	54.13.0	164.28.8	0405	54.12.7	164.30.1	UGAMAK	trawl	98

AN APPROACH TO CLASSIFYING LARGE WHALES UNDER THE U.S. ENDANGERED SPECIES ACT

Douglas P. DeMaster

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington, 98115

Introduction

The U.S. Endangered Species Act (ESA) defines categories for endangered and threatened species, but provides no objective criteria for deciding when a species should be listed, downlisted, or delisted. As a result, listing and recovery actions for marine mammals, as well as other species are widely inconsistent. Of the twenty marine mammal species listed under the ESA, only six have Recovery Plans. Within these plans, criteria to delist a species vary greatly between species.

Eight of the eleven species of large cetaceans, including blue (*Balaenoptera musculus*), fin (*B. physalus*), sei (*B. borealis*), humpback (*Megaptera novaeangliae*), right (*Eubalaena glacialis*), bowhead (*Balaena mysticetus*), gray (*Eschrichtius robustus*) and sperm (*Physeter macrocephalus*) whale, were listed as endangered under the ESA in 1973 due to concern about overutilization and inadequate protective regulations. Since 1985-86 for pelagic seasons and 1986 for coastal seasons, the IWC has imposed a moratorium on commercial whaling of large whales, and has subsequently worked to develop a new regime for managing levels of take by commercial whalers should the moratorium be lifted. Therefore, it has been proposed by some (e.g., Brownell et al. 1989, Braham 1991) that at least some stocks/species of large whales should be considered for removal from the List of Endangered and Threatened Wildlife (hereafter referred to as the List) because of the following: 1) the original justification for listing is no longer valid for all of the stocks originally listed as endangered, and 2) many stocks of large whale species have been completely protected for many years and many of these are known to have increased significantly in abundance since the early 1970s. A case in point being the removal of the eastern North Pacific stock of gray whales from the List in June of 1994.

The ESA mandates that the National Marine Fisheries Service (NMFS) develop specific criteria to determine when a stock/species should be removed from the List. Towards this goal, a joint project was developed and subsequently funded by the Office of Protected Resources to develop such criteria for several stocks of large whales that inhabit the North Pacific. Of central importance to this project were the three stocks of humpback whales in the North Pacific. The project is anticipated to be completed by the end of March 1999. This report summarizes work done with funding received in FY97. A draft final report including recommendations for classification criteria for humpback, fin, bowhead and right whales is scheduled for completion by June 1999. The Principal Investigators for this project are Douglas P. DeMaster (NMML-AFSC), Glenn VanBlaricom (University of Washington), Leah Gerber (University of Washington), and Kim Shelden (NMML-AFSC).

Criteria for Classifying Stocks of North Pacific Humpack Whales

A summary of preliminary results for the central North Pacific stock of humpback whales are provided below.

In 1991, NMFS finalized the Humpback Whale Recovery Plan which describes three types of recovery related goals. The first is a biological goal of building and maintaining populations large enough to endure changes in oceanographic conditions, epizootics, anthropogenic stress, environmental catastrophes or inbreeding depression. Second is a numerical goal to select desirable population sizes consonant with the biological goal and with continuing human use of the oceans. Specifically, this goal aims to increase humpback whale populations to at least 60% of either the number existing before commercial exploitation began (i.e., historical carrying capacity) or the current carrying capacity of the environment. Because an accurate estimate of carrying capacity is not available, an interim goal in the Recovery Plan is to double existing populations sizes within the next 20 years. Finally, the third goal is to develop objective criteria to classify stocks of humpback whales as either endangered or threatened.

The second goal, to increase humpback whale stocks to at least 60% of the carrying capacity, is of questionable relevance to ESA classification. This goal stems from a concept known as the optimum sustainable populations level (OSP) and is used in implementing sections of the Marine Mammal Protection Act. For most populations, the lower limit of the OSP level (i.e., the population level where maximum net production is achieved) is significantly larger than the upper limit of what would constitute an endangered population. Further, the interim goal of doubling the population size is also of questionable relevance to ESA classification. This is because unless the absolute abundance of a population is taken into account, a determination as to the likelihood of extinction can not be made using only information on trends in abundance.

Therefore, based on the above shortcomings of the existing classification criteria for humpback whales, a new approach was developed for consideration. This approach was based on the results of a workshop held at the National Marine Mammal Laboratory (January 1997: see Gerber and DeMaster 1997a). It should be noted that the stock structure of humpback whales in the North Pacific is not well understood at this time. Therefore, the example presented in this report should be considered a preliminary conclusion at this time, as designating a different stock structure will change the stock-specific estimates of abundance, which will in turn affect the classification criteria proposed herein. The basic approach was to determine a minimum population size (referred to as the threshold level for endangered), where there would be a negligible probability that a population of that size with a specified distribution around the population rate of change would fall below a population level from which extinction was inevitable in a specified period of time (Fig. 1). The estimated probability distribution for the rate of change in this analysis was based on available data for the central stock of humpback whales in the North Pacific.

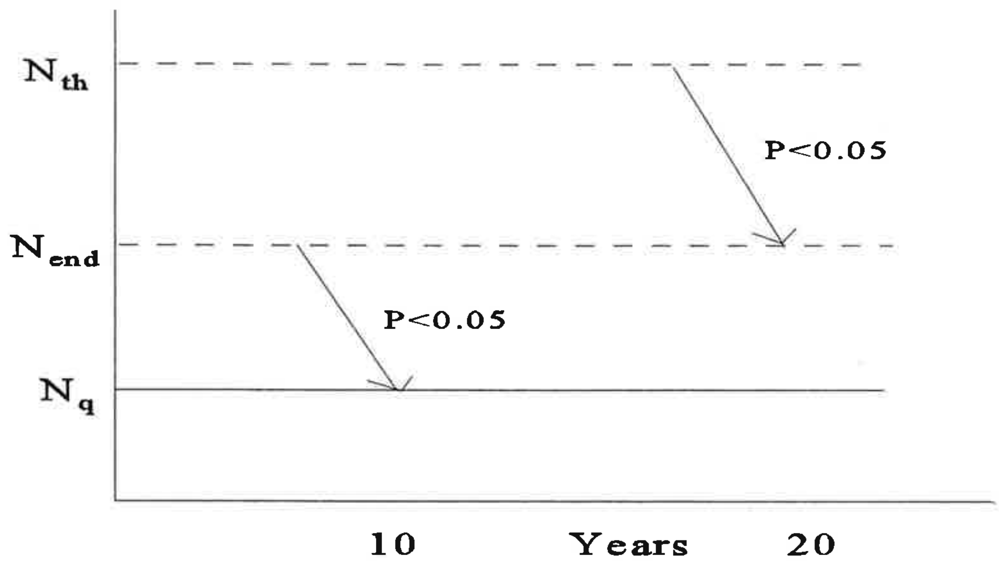

Figure 1. Schematic relationship among quasi-extinction level (N_q), the threshold for endangered and the threshold for threatened.

Such an approach incorporates many of the elements of a population viability analysis, in that it incorporates information on population abundance and trends in abundance, as well as information on uncertainty in both of these parameters (see Gerber and DeMaster 1997b for details). To implement such an approach, a number of parameters must be specified. Most of these parameters need to be approved by the management side of NMFS, as they establish policy. As a starting point, we assumed that a negligible probability was equal to a 5% chance or less and that a reasonable period of time for defining what it means to be an endangered population was 10 years (see recommendations reported in Gerber and DeMaster 1997a). We further assumed that a population of less than 500 individuals was likely to go extinct in the foreseeable future.

The above definition of endangered formed the basis for the proposed definition of threatened. In this case, the approach was to determine a minimum population size (referred to as the threshold level for threatened), where there was a negligible probability that a population of that size with a specified distribution around the population rate of change would fall below the threshold for endangered in a specified period of time. As before, input from management is needed to define acceptable level of risk of extinction and to specify certain parameters. However, as a starting point we again assumed that a negligible probability was equal to a 5% chance or less. Unlike the previous example we assumed a time period of 25 years for evaluating whether a population should be classified as threatened.

To implement the basic approach involved for evaluating status relative to the endangered classification under the ESA for the central North Pacific stock of humpback whales, the following steps were taken: 1) information on the current population size was specified, 2) available information on vital rates or changes in abundance over time was used to generate a probability distribution for the population's underlying rate of change (ROC), 3) from the frequency distribution for the ROC the 5th %-ile value for ROC was estimated, and 4a) if the 5th %-ile ROC was less than 1.0, a backwards population trajectory starting at 500 individuals for a period of 10 years was performed and the resulting population size was used as the threshold for endangered, or 4b) if the 5th %-ile ROC was greater than or equal to 1.0, the threshold for endangered was set at 500 animals. As shown in Figure 2, as the 5th %-ile value for ROC is reduced the threshold level for endangered increases.

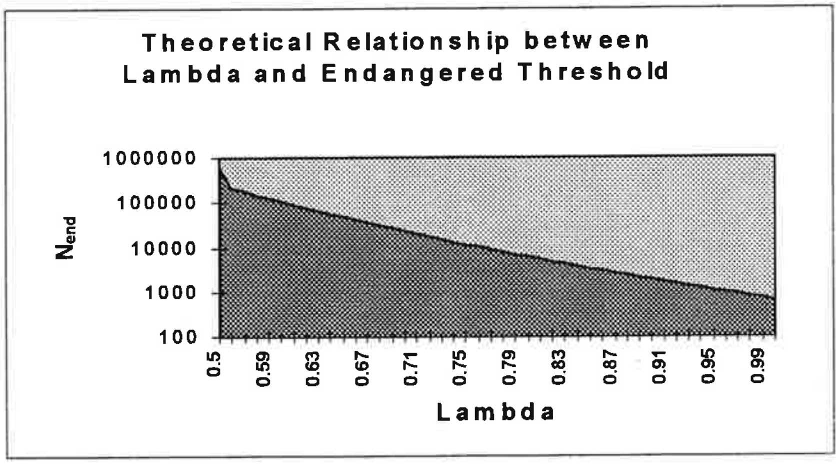

Figure 2. Relationship between the 5th %-ile value for the rate of change and the resulting estimate of the threshold level for endangered. In this case, the quasi-extinction level was set at a value of 500 animals.

A similar approach was used to determine the threshold for threatened under the ESA, except that the population trajectory was started at the population level equal to the threshold for endangered and the number of years for the backwards trajectory was changed to 25 (from 10).

The available life history data for the central stock of North Pacific humpback whales were used to determine the 5th %-ile of ROC, which was 0.93 (i.e., a population with this ROC would be declining at 7% per year). In this case, the best estimate of the ROC was 1.04 (i.e., a population growing at 4% per year, given the available data on life history). Using the 5th %-ile ROC, it was determined that the best estimate of current abundance (i.e., 4,000 animals) was larger than the estimated threshold for endangered; however, the best estimate of current abundance was less than the estimated threshold for threatened. If the previously stated parameters in the model were adopted by NMFS (a process which has yet to be initiated) and no other criteria were included in the classification protocol (note: this is unlikely, see Gerber and DeMaster 1997a), the above analysis would be consistent with a recommendation to downlist this particular stock of humpback whale to a status of threatened.

As noted earlier, one of the key features of this approach is that as our uncertainty for various parameters increases, the threshold for endangered (and threatened) would necessarily increase. Therefore, with less precise information it becomes more difficult to delist or downlist a species/stock listed as endangered, while with more precise information it becomes less difficult to delist or downlist a species/stock listed as endangered. Also, it should be noted that the uncertainty associated with the estimate of abundance has been incorporated into the classification scheme at this point by using the lower 5th %-ile estimate for abundance rather than the median estimate.

Criteria for Classifying Stocks of Bowhead Whales

A very different approach was used for the development of classification criteria for bowhead whales. The details regarding the recommended classification scheme can be found in Shelden (1998) and Shelden et al. (In prep.). Preliminary criteria (Classification Criteria for Bowhead Whales, CCBW) were developed for bowhead whales to set thresholds for endangered, threatened and recovered status in the absence of a recovery plan (Tables 1 and 2). The status-determining criteria presented in the CCBW are based on a review of existing criteria in recovery plans, criteria created for the IUCN Red List, and intuitive processes used in population viability analyses. Current abundance estimates and trends in population growth are necessary to meet the requirements of the CCBW Abundance (endangered threshold = 5,000 animals; threatened threshold = 10,000 animals) and Trends ($r>0$) criteria. Aspects of genetic discreteness and vigor are incorporated into the CCBW Genetics criteria (related stocks not suffering from inbreeding will be reclassified together when their combined numbers exceed either the endangered (5,000) or threatened (10,000) threshold). And finally, the CCBW Safety Factor criteria addresses the need for long-term monitoring and regulatory mechanisms that provided adequate assurance that over-harvesting will not take place. These criteria were created to: 1) clearly define the level of the species' vulnerability; 2) show where gaps in data on life history parameters exist, allowing managers to focus research efforts; and 3) address uncertainty in existing data by adopting a precautionary, conservative approach and by including safety factors such as policy alternatives and decision analyses. Obtaining an abundance estimate is the first requirement prior to application of these criteria (demonstrated in Figs. 3-5). Using these criteria (CCBW) and assuming each of the five stocks were managed as discrete stocks and no other criteria were included in the classification protocol, the Bering-Chukchi-Beaufort stock of bowhead whale would be downlisted to threatened, while the other four stocks would remain listed as endangered.

Citations

Brownell, R.L., K. Ralls, and W.F. Perrin. 1989. The plight of the "forgotten" whales. Oceanus 32(1):5-11.

Braham, H.W. 1991. Endangered Whales: Status Update. A Report to the 5-Year Status of Stocks Reviewed under the 1978 Amendments to the U.S. Endangered Species Act. Unpubl. Rep. 56 p. (Available at the National Marine Mammal Laboratory, Alaska Fish. Sci. Cent., NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115).

Gerber, L.R., and D.P. DeMaster. 1997a. Report on the Humpback Whale Classification Workshop: 27-28 January 1997. Unpubl. Rep. 16 p. (Available at the National Marine Mammal Laboratory, Alaska Fish. Sci. Cent., NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115).

Gerber, L.R., and D.P. DeMaster. 1997b. Endangered Species Act classification criteria for North Pacific humpback whales. Pp. 203-211, in Hill, P.S. and D.P. DeMaster (eds.), Marine Mammal Protection Act and Endangered Species Act implementation program 1996. AFSC Processed Rep. 97-10. Available Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE, BIN C15700, Seattle WA 98115-0070.

Shelden, K.E.W. 1998. The bowhead whale: A case study for development of criteria for classification on the List of Endangered and Threatened Wildlife. Master of Marine Affairs Thesis, University of Washington. 137 p.

Shelden, K.E.W., D.P. DeMaster, D.J. Rugh, and A.M. Olson. In prep. A proposal for developing classification criteria for bowhead whales under the U.S. Endangered Species Act. (Available at the National Marine Mammal Laboratory, Alaska Fish. Sci. Cent., NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115).

Table 1. Classification criteria for bowhead whales (CCBW) developed in this study to downlist stocks from endangered to threatened status*.

Abundance and Trends	
Effective population size:	$N_e \geq 500$
Total population size:	$N_t \geq 5{,}000$
and	
The stock must exhibit a positive trend in population growth ($r>0$) based on census data;	
Genetics	
Behavioral and genetic data indicate a "high" level of relatedness among 2 or more stocks (e.g., $N_em >> 1$) and within-stock patterns demonstrate "low" levels of inbreeding (e.g., band sharing < 0.40 (with J33.15)) which leads to redefining existing stock structure. Related stocks whose combined N_t exceeds 5,000 will be downlisted together;	
Safety Factor	
Adequate long-term monitoring and regulatory mechanisms are in place at the international and national level to ensure anthropogenic effects will allow continued recovery.	

* The only exception to this process occurs in the unlikely event that a stock is found to number greater than 10,000 and is still listed as endangered. In this case, the stock would automatically be downlisted to threatened status without having to meet the Trends criterion, and would not have to meet the Safety Factor criteria.

Table 2. Classification criteria for bowhead whales (CCBW) developed in this study to delist stocks from threatened to recovered status.

Abundance and Trends

Effective population size: $N_e \geq 1{,}000$
Total population size: $N_t \geq 10{,}000$
and
The stock must exhibit a positive trend in population growth ($r>0$) based on census data;

Genetics

Behavioral and genetic data indicate a "high" level of relatedness among 2 or more stocks (e.g., $N_e m >> 1$) and within-stock patterns demonstrate "low" levels of inbreeding (e.g., band sharing < 0.40 (with J33.15)) which leads to redefining existing stock structure. Related stocks whose combined N_t exceeds 10,000 will be delisted together;

Safety Factor

Adequate long-term monitoring and regulatory mechanisms are in place at the international and national level to ensure anthropogenic effects will allow continued recovery.

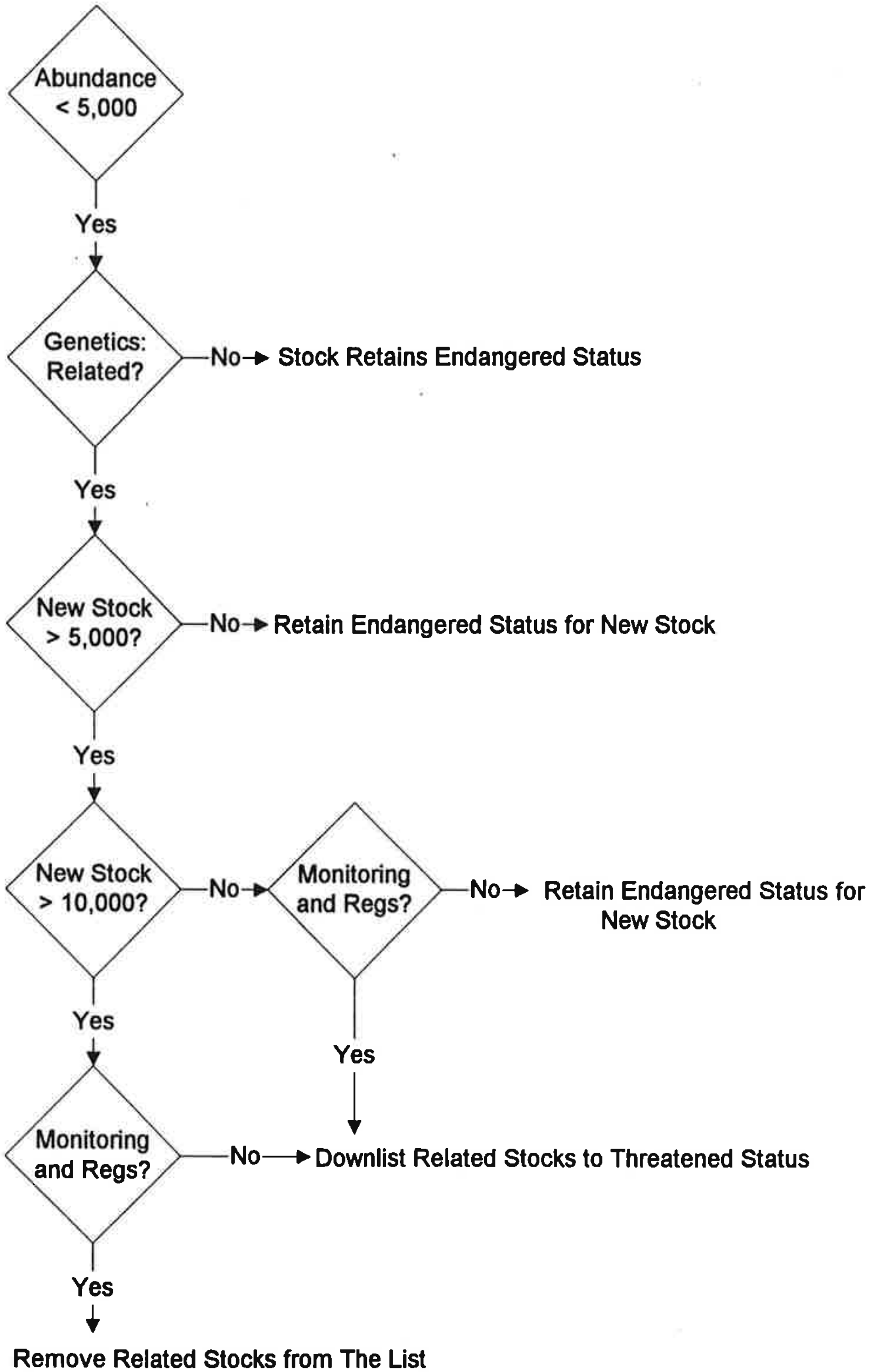

Figure 3. Flow diagram of reclassification decisions for bowhead whale stocks with <5,000 animals.

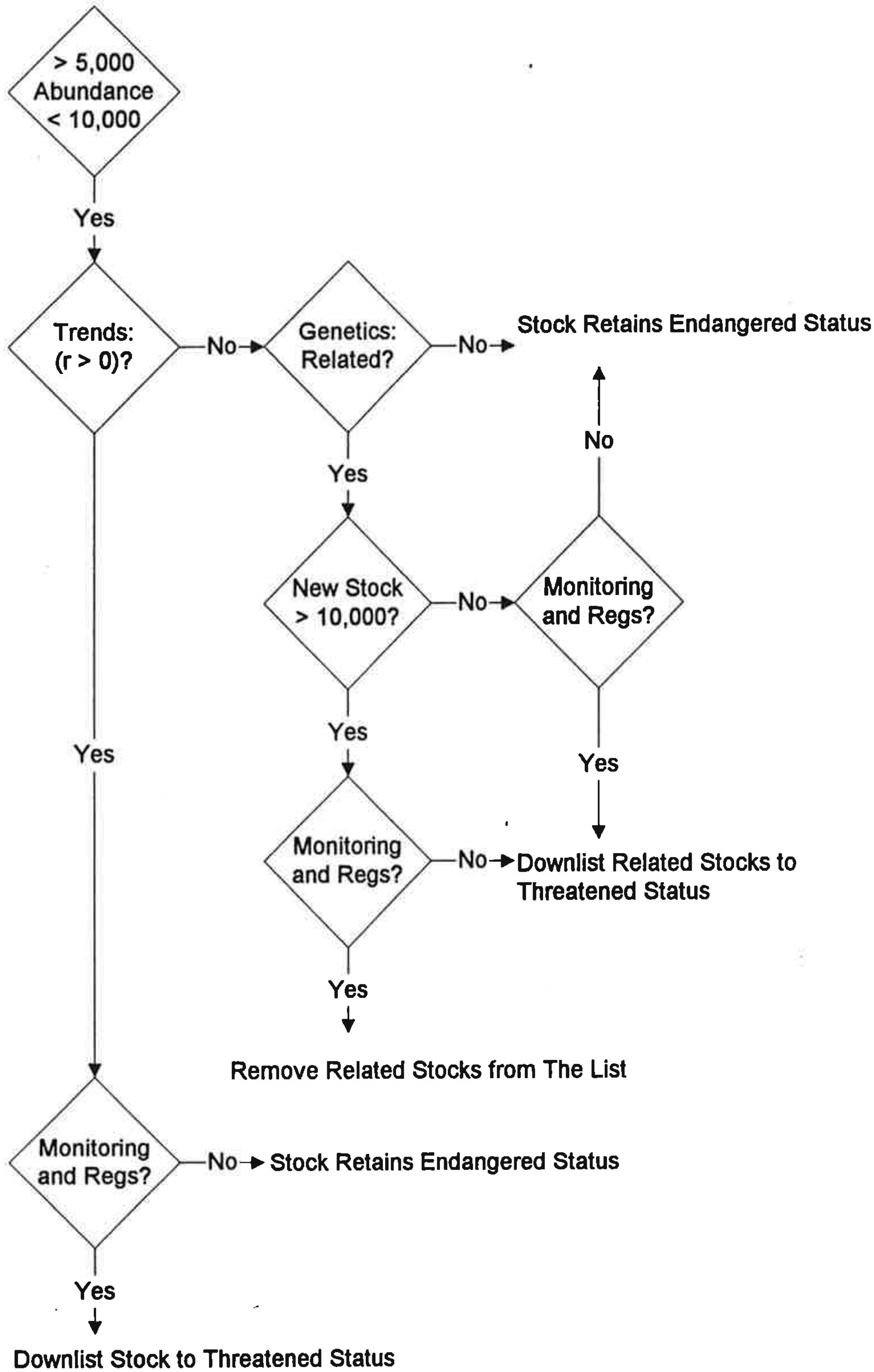

Figure 4. Flow diagram of reclassification decisions for bowhead whale stocks numbering between 5,000 and 10,000 animals.

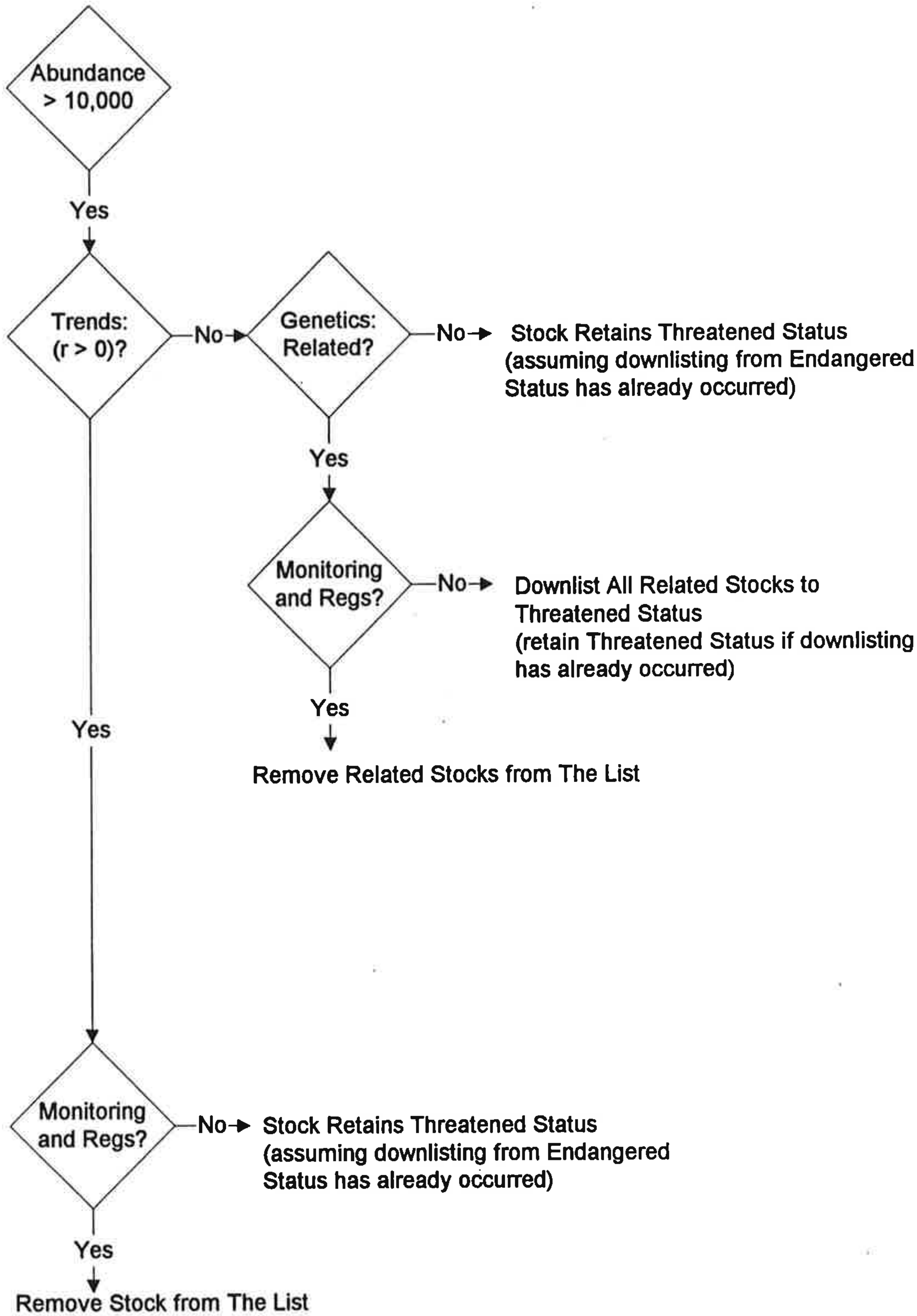

Figure 5. Flow diagram of reclassification decisions for bowhead whale stocks with >10,000 animals.

DEVELOPMENT OF AN INSTRUMENT TO MONITOR PINNIPED UNDERWATER FEEDING BEHAVIOR

John L. Bengtson and Peter L. Boveng

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington, 98115

Background and Goals

Understanding the behavioral interactions among pinnipeds and their prey is vitally important for developing appropriate management measures. This need pertains not only to populations that are declining, but is also of particular importance for mitigating certain types of pinniped/fisheries interactions (e.g., depredations at fish ladders, interference at aquaculture pens, and interactions with active fishing gear). The development and deployment of time-depth recorders (TDRs) and satellite-linked monitors over the past two decades produced tremendous new insights into pinniped behavior. The further miniaturization of electronic devices in recent years holds rich promise for additional tools that could be applied to future studies of pinniped behavior.

One of the most dramatic of these recent advances has been the development of underwater video cameras that can be deployed on pinnipeds. The National Geographic Society funded the construction of a small instrument called the "critter-cam", which has been deployed successfully on a number of pinniped species. Because the critter-cam was designed for obtaining broadcast-quality video footage that could be used in television specials, the unit is larger than might otherwise be necessary for scientific purposes (the critter-cam weighs approximately 5 kg and is about 30 cm long by 20 cm in diameter). Moreover, its availability to scientists on a routine basis is limited. There has been some additional experimental work with a similar system, but the costs associated with those prototypes have been rather high. Our preliminary discussions with engineers suggested that a video camera suitable for monitoring pinniped underwater feeding behavior (and one which builds on the innovations pioneered by the critter-cam) could be constructed at a smaller size and lower cost than the examples noted above.

The main goals of this project were to develop and to test an integrated recording instrument to monitor pinniped underwater feeding behavior. We wanted to develop an instrument that would be capable of being directly deployed on a pinniped (e.g., fastened to its back) so that free-ranging behavior under natural conditions can be observed. Our ultimate objective was to integrate currently available technology into a cost-effective instrument package that could be made widely accessible to scientists for use in studying detailed hunting and prey capture behavior of pinnipeds.

Aspects of Instrument Design

Because of the rapidly developing field of electronics and microprocessor-controlled devices, the instrument designs considered by this project have gone through several iterations.

We had initially been developing design plans around a solid state, digital instrument that would have no moving parts and could be potted in epoxy resin. Such a design would have the advantages of: 1) avoiding any potential leakage (i.e., from a pressure housing), 2) minimizing battery consumption (to drive an electric motor in a tape recorder) and therefore reducing the overall size and weight of the instrument, and 3) interfacing easily with controller boards on solid state time-depth recorders. After our initial design evaluations, we had concluded that a totally solid state design was not yet practical, and we therefore began building our design around a small, high density tape storage medium. However, the storage capacity of newly developed storage devices made us reconsider this decision. In particular, the newly available Type III PCMCIA ATA format of data storage appeared to be quite suitable for our design needs. Therefore, since our last year's progress report, we have shifted back to our original (or close to original) design goals: the prototype described below is an all-digital, solid state camera system utilizing PCMCIA mass storage, and is potted in epoxy resin.

The camera lens to be used will have a fixed focal length but a relatively deep depth of field so that activities will be in focus within a zone from the rear portion of a seal's head out to about 2 meters in front of the seal's mouth; a LED infrared light source will be optional if ambient light conditions do not provide adequate illumination for clear recording.

Rather than redeveloping a custom controller board, we designed the camera unit to interface electronically with microprocessor-controlled time-depth recorders (e.g., Wildlife Computers Mk V, Redmond, WA). This approach has the dual advantages of: a) cost-savings by using reliable, off-the-shelf instruments and accompanying software already being used by much of the pinniped research community, and b) using a programmable controller board that will integrate the camera's recording with other aspects of seal behavior (e.g., dive depth, ascent and descent rates of dives, surfacing intervals, haulout patterns, and ambient light levels).

Prototype Instrument

In July 1998, we completed construction of a working prototype of an underwater camera. The prototype's electronic core is built around a Hitachi MP-EG1A digital camera. This camera is available off-the-shelf, and provides a flexible image acquisition platform that we have modified to meet the design needs of this project. The off-the-shelf version utilizes a 260 MB PCMCIA hard disk drive to store digital image data. The main disadvantage of this type of storage device is its relatively high power consumption required to run the motor in the hard disk. The hard disk also generated a considerable amount of heat when it was running, and aside from the wasted energy that such heat production represents, the possibility of unwanted heat buildup was considered a potential problem in a potted electrical instrument. Therefore, we succeeded in replacing the hard disk with a 160 MB PCMCIA flash memory card, which has no moving parts and therefore uses much less energy to operate. Although the smaller capacity of the flash card storage has drawbacks at present, the capacity of such storage devices is increasing so rapidly that we don't consider this a long-term problem. We have focused on getting the instrument's basic design right, and expect that image storage capacity will just keep getting better in the future. The prototype's specifications follow:

Size:	Dimensions after potting: 80 × 55 × 125 mm Approximate weight in air: 500 g

Image acquisition:	Programmable in one of three modes per deployment on a seal: 1) video (approximately 20 minutes) 2) single still images (maximum frame speed is 1 image per 2 sec) 3) multiple still images (5 frames per 3.5 sec as often as every 10 sec) (approximately 3,000 still images can be stored at present)
Lens:	Programmable zoom (wide angle 28 mm to telephoto 80 mm)
Illumination:	10 infrared LEDs potted in a rosette around lens
Power source:	Lithium-ion rechargable batteries, 7.2 volts, 1300 mAh

Prototype Testing

Because of changes in the instrument's design, the development of the prototype instrument has taken longer than expected. Consequently, our testing schedule has been pushed back and is now planned mostly for 1999. We have sufficient resources from the equipment and supplies already purchased to continue refinement of the prototype (e.g., testing the illumination power of the LED rosette) prior to starting trials on captive pinnipeds sometime in spring of 1999. If those trials go well, we hope to test prototype instruments on free-ranging pinnipeds during the next summer. Based on those tests, and whatever subsequent modifications to the prototype are necessary, we expect that a finalized model of underwater camera, as developed by this project, may be available for replication and deployment late in the summer of 1999. A final report, including a detailed description of the instrument's design and specifications, is expected to be available by September 1999.

LINE TRANSECT SAMPLING: DEVELOPMENT OF ANALYSIS TOOLS

Len Thomas[1] and Jeffrey Laake[2]

[1]Research Unit for Wildlife Population Assessment
University of St. Andrews, St. Andrews, Scotland

[2]National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS,NOAA
7600 Sand Point Way NE
Seattle, Washington 98115

Abstract

The current version of DISTANCE was developed in the late 1980s. DISTANCE has become the standard for analyses of distance sampling data, but its command-based user interface has become dated and is now seen as a barrier to many potential users. Thus, NMML contracted the Research Unit for Wildlife Population Assessment (RUWPA) at the University of St Andrews to produce a new, fully windows-based user interface. This interface is now completed as specified, and will be released to the public as DISTANCE version 3.5.

New features in DISTANCE 3.5

We anticipate that users will find DISTANCE 3.5 significantly easier to learn and use than previous versions of DISTANCE. In addition, it contains a number of new features and options that increase the scope of the program. The new features of DISTANCE 3.5 are summarized in this section.

Graphical User Interface

- Well defined menu structure and button-bars allow user to navigate through program
- Interactive "Wizards" guide the user through the process of setting up new projects
- Spreadsheet-based "Data Explorer" for entering data
- Summary table ("Analysis Browser") allows the user to view and compare analyses, and is the starting point for creating and running new analyses
- Analyses can be grouped into sets for convenient archiving
- Analysis specification is completely graphical – users do not need to learn a command language to use the program
- Each analysis is split into two components: Data Filter and Model Definition, allowing for easy re-use of the components to create new analyses

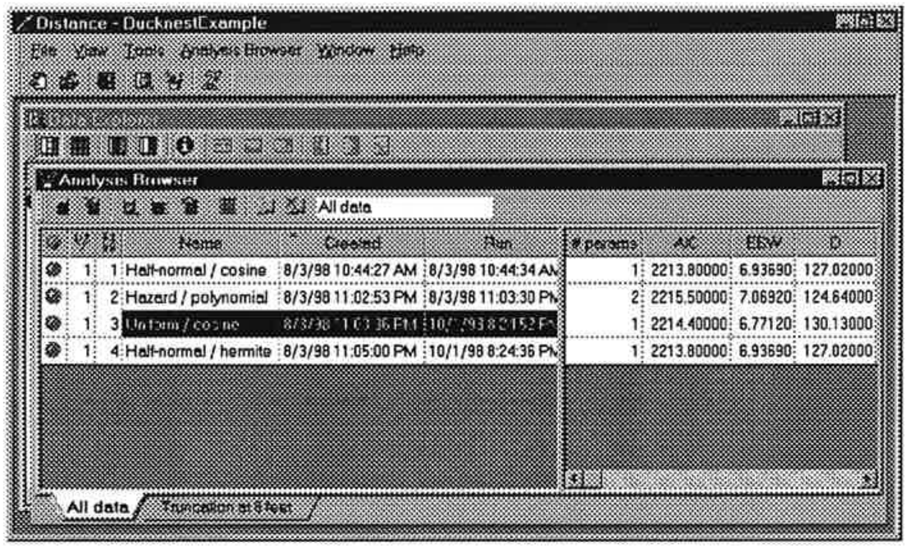

Figure 1. Example screen from DISTANCE 3.5 showing summary results for 4 analyses of Monte Vista duck nest data.

- Results of multiple analyses can be compared side-by-side in "Analysis Details" windows
- Any error and warning messages generated during the analysis are clearly displayed
- Detailed results output is split into pages for ease of viewing
- Fitted detection functions are displayed as high resolution plots
- Extensive windows-based help; context sensitive help available at any point in the program

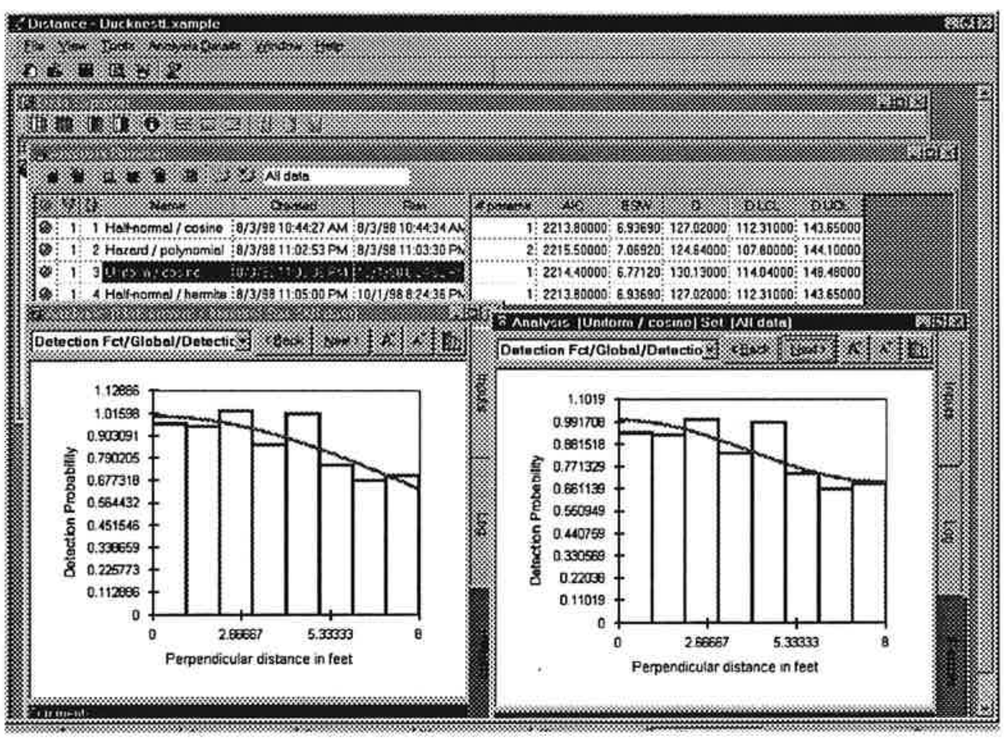

Figure 2. Fitted detection functions for two models fitted to Monte Vista duck nest data.

Robust data storage

- Data and analyses stored in single file (a "distance project file"), which has a robust, industry standard database structure

New utilities

- Import of data from text files – "flat file" format allows easy export from common database and spreadsheet applications
- Import of command files from previous versions of distance

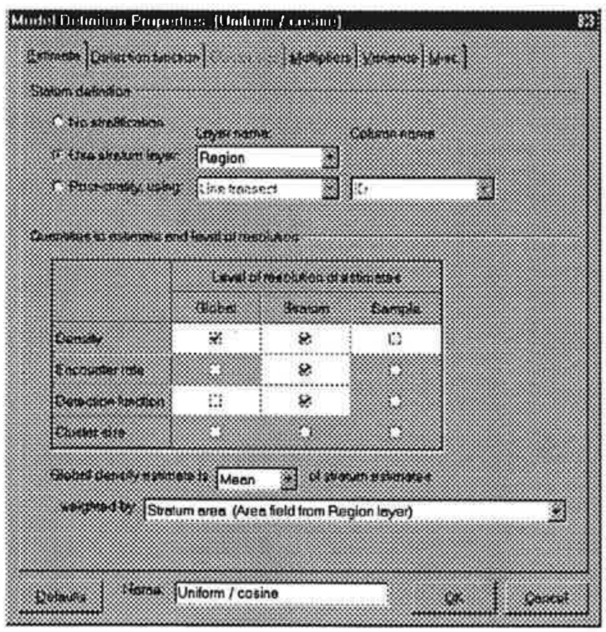

Figure 3. Example page showing graphical specification of an analysis

New analysis options

- Additional information can be stored in the Data Explorer, and this can be used to subset or post-stratify the data during later analysis
- Data Filter allows selection of subsets of the data for analysis
- Data can be post-stratified (for example by sex or species) for estimation of components of the analysis
- Multiple analyses can be run at one time
- A number of improvements in the analysis engine

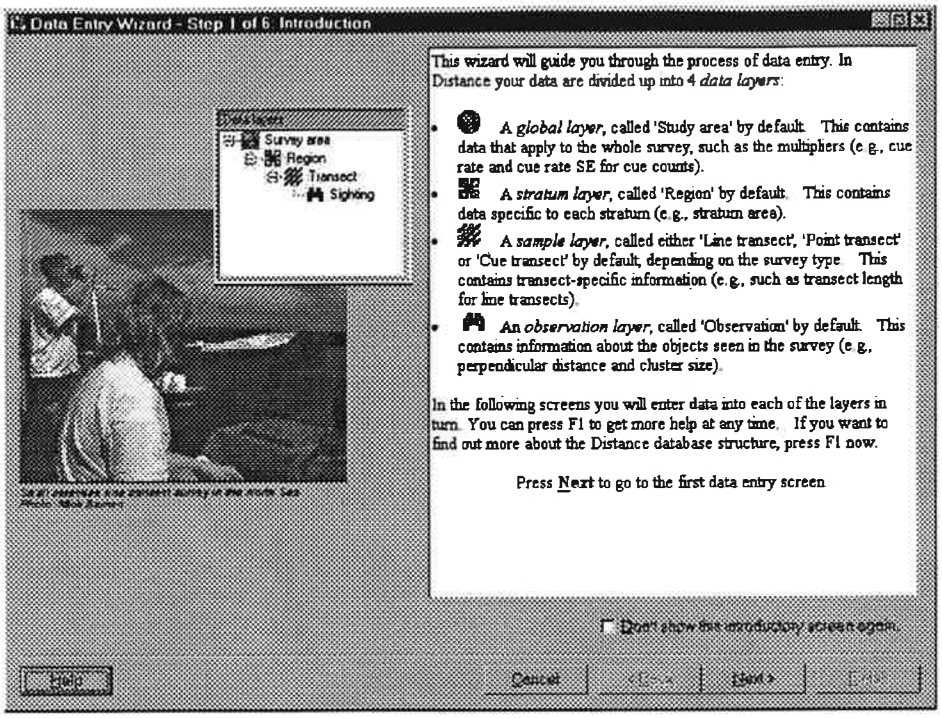

Figure 4. Introductory page of the Data Entry Wizard

Obtaining Software and Source Code

DISTANCE 3.5 is currently undergoing rigorous testing prior to public release via the world-wide web (www) in October 1998. The software will be available from the NMML DISTANCE web site http://nmml.afsc.noaa.gov/distance/map.htm

The current version, Release 1, was tested and evaluated by a group of biologists at a distance sampling workshop run by RUWPA, at St. Andrews in August 1998. The feedback was generally extremely positive. Release 1 is available for downloading over the internet via anonymous FTP from the site dolphin.dcs.st-and.ac.uk in the directory /pub/len/distance, filename distance35release1.zip. To install the software, download this file, unzip it into a temporary directory and follow the instructions in the file readme.rtf. The source code for Release 1 is available in the same directory in the file distance35release1code.zip.

Future work

The development of DISTANCE 3.5 is part of a larger project to develop the next generation of analysis software for distance sampling – DISTANCE 4. The funding for this project came from the UK research councils and from the Marine Mammal Protection Act (MMPA) research monies. Future analysis capabilities in program DISTANCE will include spatially-explicit analyses and analyses using covariates. In addition, FY98 MMPA funds are being used to facilitate programming of an automated, spatially-explicit survey design tool within DISTANCE. This tool will be GIS-based and will allow users to simulate and compare a number of common survey designs (e.g., systematic parallel transects, point transects, zig-zag designs) and compare their efficiency.