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Marine Mammal Protection Act and Endangered Species Act Implementation Program 1998

Edited by:
Anita L. Lopez
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

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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

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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 20 papers, is a compilation of studies carried out with fiscal year 1998 (FY98) funding as part of the NMFS MMPA/ESA Implementation Program. The report contains information regarding studies conducted on beluga whales, California sea lions, gray whales, harbor porpoise, harbor seals, humpback whales, ice seals, 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 in 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.

Anita L. Lopez
Douglas P. DeMaster

MMPA/ESA Implementation Program
Report for 1998

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Alaska Fisheries Science Center

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National Marine Fisheries Service

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AERIAL SURVEYS OF BELUGA WHALES IN COOK INLET, ALASKA, JUNE 1998

David J. Rugh[1], Roderick C. Hobbs[1], Kim E.W. Shelden[1],
Barbara A. Mahoney[2] and Laura K. Litzky[1]

[1]National Marine Mammal Laboratory
Alaska Fisheries Science Center
National Marine Fisheries Service, NOAA
7600 Sand Point Way NE
Seattle, Washington 98115, U.S.A.
and
[2]Alaska Regional Office
National Marine Fisheries Service, NOAA
222 W 7th Ave., Box 43
Anchorage, Alaska 99513, U.S.A.

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 population in Cook Inlet, Alaska, during 9-15 June 1998. The 39.4 hr survey was flown in a twin-engine, high-wing aircraft at an altitude of 244 m (800 ft) altitude and speed of 185 km/hr (100 kt) along a trackline 1.4 km from shore. This provided complete coverage of coastal areas around the entire inlet (1,388 km) one or more times and 1,320 km of transects across the inlet. 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 4 or more counts of each group. The sum of the aerial estimates (using median counts from each site, not corrected for missed whales) ranged from 173 to 192 whales, depending on survey day. There were 57-109 belugas counted near the Susitna River, 42-93 in Knik Arm and 23-42 in Chickaloon Bay, but only one (dead) beluga whale was found in lower Cook Inlet. Abundance estimates are being developed for this and other recent years.

Introduction

Beluga whales (*Delphinapterus leucas*) are distributed around most of Alaska from Yakutat to the Alaska/Yukon border (Hazard 1988). Five stocks are recognized: Cook Inlet, Bristol Bay, Eastern Bering Sea, Eastern Chukchi Sea and the Beaufort Sea (Hill and DeMaster 1998; O'Corry-Crowe 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 harvests. The Alaska Regional Scientific Review Group (ASRG) "felt very strongly that every effort should be made to survey this population every year" (letter from L. Lowry, Chair of ASRG, to S. Pennoyer, NMFS, dated 13 May 1997).

Since 1993, NOAA's National Marine Mammal Laboratory (NMML) 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, 1997a, 1997b) in cooperation with the Alaska Beluga Whale Commission (ABWC) and the Cook Inlet Marine Mammal Council (CIMMC). Aerial surveys have been 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 most recent studies have been some of the most thorough and intensive surveys 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. Currently, several reports are in preparation for publication in the Marine Fisheries Review; these will include abundance estimates for 1994-98 (Hobbs, et al. in prep.), distribution of belugas within Cook Inlet (Rugh et al. in prep.), distribution of belugas in the Gulf of Alaska (Laidre et al. in prep.), video analysis of aerial counts of belugas (Hobbs and Waite, in prep.), surfacing behavior of belugas (Lerczak et al. in prep.), and the habitat of Cook Inlet (Moore et al. in prep.).

Methods

Survey Aircraft

The survey aircraft , an Aero Commander 680 FL (N7UP), has twin-engines, high-wings, 10-hr flying capability, and a five-passenger plus one pilot seating capacity. There are bubble windows at each of the three primary observer positions, maximizing the search area. An intercom system provided communication among the observers, data recorder, and pilot. A selective listening control device was used to aurally isolate the observer positions. Location 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 hrs to minimize fatigue.

Tides

With the exception of surveys at the Susitna Delta, there was generally no attempt at synchronization of tidal height and survey time. The broad geographical range of these surveys in conjunction with highly variable tide heights made it impractical to survey at specific tidal conditions throughout the inlet. We occasionally 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 the 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/hr (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 addition to the coastal surveys, offshore transects were flown across the inlet. A sawtooth pattern of tracklines was designed to cross over shore at points approximately 30 km apart starting from Anchorage and zigzagging to the southern limits of Cook Inlet, between Cape Douglas and Elizabeth Island (Fig. 1).

Sighting Records

Immediately upon 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. When a group of whales was first seen, the aircraft continued on until the group was out of sight; then the aircraft returned to the group and began the circling routine. This allowed each observer full opportunity to independently sight the whale group. 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 until it was out of sight.

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 front observer, 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 was a function of how well the observers saw a group, rated A (if no glare, whitecaps or distance compromised the counting effort) through 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 (Hobbs and Waite in prep). Analysis of both the aerial counts and counts from the video tapes are described in Hobbs et al. (in prep) for 1994-98 data.

Results

Survey Effort

A total of 39.4 hr of aerial surveys were flown around Cook Inlet 9-15 June 1998. All of these surveys (11 flights ranging from 1.5 to 6.8 hr) were based out of Anchorage. Systematic search effort was conducted for 21.3 hr, 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 1.7 hr (8% of the total flight time) when the left-front observer considered the visibility poor or worse.

On 9 June, a test flight was conducted in which problems with the GPS/data recorder interface were discovered; therefore, positional data were not collected for that day. On 10, 12 and 15 June, surveys were made around upper Cook Inlet, north of the East and West Forelands. On 13 and 14 June, the lower inlet and offshore waters were surveyed (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). In addition, there were 1,320 km of systematic transects flown across the inlet. 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), the coastal tracklines covered 5,709 sq km, which is approximately 29% 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.

Distribution and Aerial Estimates of Beluga Group Sizes

Aerial counts of beluga whales are shown in Table 1, and sighting locations are shown in Figure 1. The 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 assume that whales did not travel long distances within the 7-day survey period, which meant results could be combined among survey days. Using median counts from each site, the sum of the counts ranged from 173 to192. 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 (Hobbs et al. in prep.).

Discussion

In Cook Inlet, beluga whales concentrate near river mouths during spring and early summer, especially across the northernmost portion of upper Cook Inlet between the Beluga and Little Susitna Rivers (Fig. 1), described here as the Susitna Delta, or in Knik Arm. Fish also concentrate along the northwest shoreline of Cook Inlet, mostly in June and July (Moulton

1994). 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). Elsewhere in upper Cook Inlet in June and July, we have consistently found a group of 20-50 whales in Chickaloon Bay. Other, smaller, groups have been observed in the inlet during aerial surveys prior to 1996, such as in Kachemak, Redoubt and Trading Bays, but only single or dead whales have been seen south of North Foreland since then. Only 0-4% of the sightings in June and July from 1993-98 have occurred in lower Cook Inlet (Table 2).

Other aerial surveys conducted in June (Calkins 1984) also found the majority of animals were in the northwest portion of the inlet (88% of the sightings made 1974-79); however, during the 1970s even in June some groups were seen in the lower inlet, such as in Redoubt Bay and south of Kasilof River. But by July 1974-79 only 15% of the sightings were in the northwest and 44% were in the lower inlet (Calkins 1984). Many groups were seen in the lower inlet, ranging in size from 11 to 100 found between the Forelands and Tuxedni Bay, primarily away from the coast. Calkins (1979, page 40) indicated that belugas were "seen throughout the year in the central and lower Inlet." However, whales have not been found there recently in spite of excellent viewing conditions in some years.

There have been a few reports of small numbers 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 August 1998 (D. Janka, pers. commun.) and in Yakutat Bay in May (Calkins and Pitcher 1977), September (R. Ream, NMFS, NMML pers. commun.) and February (B. Mahoney, NMFS, pers. commun.), 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 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 unpubl. data) supporting the genetic evidence showing that the Cook Inlet stock is isolated from stocks in the Bering Sea (O'Corry-Crowe et al. 1997), and that the Cook Inlet stock is not widely dispersed.

The uncorrected sum of median estimates made from the June 1998 aerial observations in Cook Inlet ranged from 173 to 192 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 1993-98, there were, respectively, 305, 281, 324, 307, 264 and 193 beluga whales (Table 2). 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 or inter-year trends be calculated.

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Citations

Brueggeman, J.J., Green, G.A., Grotefendt, R.A., Tressler, R.W., and Chapman, D.G. 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, US Courthouse, Rm A13, 222 W Eighth Ave #56, Anchorage, AK 99513-7543.

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 pp.

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. Chp 15; pp 109-112 in Jarvela, L. E. and L.K. Thorsteinson (eds) Proceeding of the Gulf of Alaska, Cook Inlet, and North Aleutian Basin Information update meeting, Feb. 7-8, 1989. OCS Study, MMS 89-0041.

Calkins, D.G. and Pitcher, K.W. 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, CA.

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

Frost, K.J., Lowry, L. F., and Burns, J.J. 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 Hall, J.D. 1978. Alaskan distribution of the beluga whale, *Delphinapterus leucas*. Can. Field-Nat. 92(3):235-241.

Hazard, K. 1988. Beluga whale, *Delphinapterus leucas*. Pages 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. 275pp.

Hill, P.S., and DeMaster, D.P. 1998. Alaska marine mammal stock assessments, 1998. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-97, 166 pp.

Hobbs, R.C., D.J. Rugh, and D.P. DeMaster. In prep. Abundance of beluga whales in Cook Inlet, Alaska, 1994-1998. Mar. Fish. Rev.

Hobbs, R.C., and Waite, J.M. In prep. Estimates of beluga whale group size in Cook Inlet, Alaska, from aerial video recordings. Mar. Fish. Rev.

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. 11pp.

Laidre, K.L., K.E.W. Shelden, D.J. Rugh, and B.A. Mahoney. in prep. Distribution of beluga whales and survey effort in the Gulf of Alaska. Mar. Fish. Rev.

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

Lerczak, J.A., K.E.W. Shelden, and R.C. Hobbs. In prep. The surfacing behaviour of beluga whales in Cook Inlet, Alaska: results from suction cup attached VHF transmitter studies. Mar. Fish. Rev.

Moore, S.E., D.J. Rugh, K.E. Shelden, and B.A. Mahoney. In prep. Beluga whale habitat associations in Cook Inlet, Alaska. Mar. Fish. Rev.

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 and Wildlife Serv., North Am. Fauna. No. 61.

Murray, N.K., and Fay, F.H. 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. 7pp.

O'Corry-Crowe, G.M., Suydam, R.S., Rosenberg, A., Frost, K.J., and Dizon, A.E. 1997. Phylogeography, population structure and dispersal patterns of the beluga whale *Delphinapterus leucas* in the western Nearctic revealed by mitochondrial DNA. Mol. Ecol. 6:955-970.

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. Comm. (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. 1997a. Aerial surveys of beluga whales in Cook Inlet, Alaska, June 1996. Annual Rept. to MMPA, Office of Protected Resources (F/PR) NOAA.

Rugh, D.J., R.C. Hobbs, K.E.W.Shelden, and J.M. Waite. 1997b. Aerial surveys of beluga whales in Cook Inlet, Alaska, June 1997. Paper SC/49/SM20 presented to Int. Whal. Comm., Sept. 1997 (unpublished) 17pp.

Rugh, D.J., K.E.W. Shelden, and B.A. Mahoney. in prep. Distribution of beluga whales in Cook Inlet, Alaska, during June and July. Mar. Fish. Rev.

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. 1994. Beluga whale (Delphinapterus leucas) distribution and abundance in Cook Inlet, summer 1993. Annual rept. to the Mar. Mammal Assessment Program, Office of Protected Resources, NMFS, NOAA, 1335 East-West Highway, Silver Spring, MD 20910. 31 pp.

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

Table 1. Summary of counts of beluga whales made during aerial surveys of Cook Inlet in June 1998. Medians from experienced observers 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.

Location	9 June median	high	10 June median	high	12-14 June median	high	15 June median	high	Med-max Counts
Turnagain Arm (East of Chickaloon Bay)	---	---	0	0	0	0	0	0	0
Chickaloon Bay/ Pt. Possession	---	---	23	34	42	77	41	65	42-77
Pt. Possession to East Foreland	---	---	0	0	0	0	---	---	0
Mid-inlet east of Trading Bay	---	---	---	---	0	0	---	---	0
East Foreland to Homer	---	---	---	---	0	0	---	---	0
Kachemak Bay	---	---	---	---	0	0	---	---	0
W side of lower Cook Inlet	---	---	---	---	0	0	---	---	0
Redoubt Bay	---	---	---	---	0	0	---	---	0
Trading Bay	---	---	0	0	0	0	---	---	0
Susitna Delta (N Foreland to Pt. Mackenzie	59	59	57	98	69	76	109	186	109-186
Fire Island	---	---	11	11	0	0	0	0	0*
Knik Arm	---	---	82	102	72	145	42	89	42-89
							Total =		193-352

*Included in Knik Arm counts

Table 2. 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
1998	June 9-15	193	0	56	44

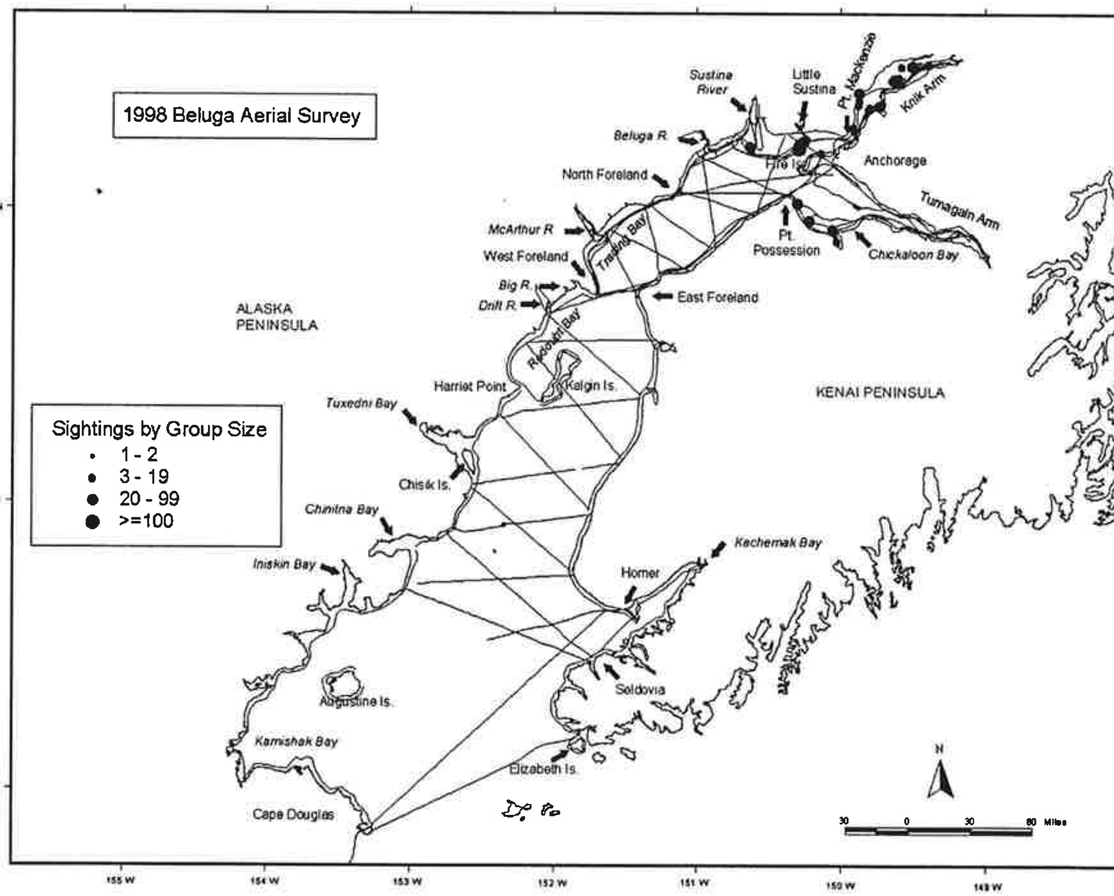

Fig. 1. Aerial survey tracklines and beluga groups seen 9-15 June 1998 during aerial surveys of Cook Inlet.

SURVIVAL AND NATALITY RATES OF CALIFORNIA SEA LIONS (ZALOPHUS CALIFORNIANUS) FROM A BRANDING STUDY AT SAN MIGUEL ISLAND, CALIFORNIA

Sharon Melin, Robert L. DeLong, and Jeffrey L. Laake
National Marine Mammal Laboratory,
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington 98115

Abstract

Individual identification of animals via natural or man-made marks provides an effective method of assessing basic biological data on long-lived species and enables measurement of vital rates that are needed to understand their population dynamics. In 1987 a branding program for California sea lions on San Miguel Island (SMI), California was initiated to obtain information on age at first reproduction, age-specific natality rates, survival rates and coastal distribution. Focused re-sighting effort was conducted at SMI from 1990-1999, Año Nuevo Island in 1994 and 1996-1999 and at Farallon Islands in 1996 and 1998. In this report, we provide estimates of age, year and sex-specific survival rates using re-sighting data collected between 1990-1999 and describe issues involved with estimating natality rate from re-sighting data.

Introduction

California sea lions (*Zalophus californianus*) are an abundant pinniped along the California, Oregon and Washington coasts. The primary breeding areas of California sea lions are the California Channel Islands and offshore islands of Baja California, Mexico (Fig. 1). Hauling areas occur from Mexico northward to Vancouver Island, British Columbia including the breeding islands, however hauling sites north of the Farallon Islands are only occupied during the winter migration of males. Besides the breeding islands, sea lions have several preferred hauling areas along the central and northern California coast where large aggregations occur year around. These areas include the Big Sur coast (Cape San Martin, Grimes Point, Seal Rock), Monterey Bay, Año Nuevo Island, San Francisco Bay, and the Farallon Islands (Fig. 2).

Although the behavioral aspects of their life history have been well described (Peterson and Bartholomew 1967, Odell 1981, Heath 1989), there have been no comprehensive studies to estimate their life history parameters such as age at first reproduction, age-specific natality and age-specific survival rates. In 1987, a long-term branding and re-sighting study was initiated to describe the life history parameters and the movement patterns of the California sea lion population at San Miguel Island, California. The goals of the study were to 1) obtain longitudinal records of known-age individuals to estimate age at first reproduction, age-specific natality and survival rates, and 2) document movements and distribution of known-age individuals. Estimates of life history parameters can be used with an age-structured population model to provide a correction factor for pup counts to produce total sea lion population estimates. Additionally, annual variation in life history parameters relative to population size can increase our understanding of California sea lion population dynamics and mechanisms of density dependence.

The ultimate objective of the branding study is to assess the status of the California sea lion population relative to maximum net productivity levels (MNPL). It is a particularly important objective for the California sea lion population because interactions between California sea lions, humans, and fisheries are increasing proportionally to the population. In some cases, these interactions are contributing to the demise of other species in the ecosystem (Gearin et al. 1988). If the sea lion population continues to increase, management of sea lions in areas where they are in conflict with humans and fisheries may be required and information on the population dynamics will become critical for making effective management decisions.

Methods

Branding/Sighting

From 1987 through 1998, California sea lion pups at San Miguel Island, California were permanently marked using hot brands. Pups were four to five months old when branded. Each pup was branded on the left or right shoulder with a unique number and tagged in the fore-flippers with yellow roto tags. The tags facilitated location of branded animals in large groups and provided a returnable identification for animals found dead on beaches or in nets. At branding each pup was weighed to the nearest 0.1 kg. Also, since 1994 length and girth was measured but they were not used in this analysis.

Sampling all age and sex classes is complicated by the expansive range of sea lions. At no time during the year are all age and sex classes of California sea lions present at any hauling or rookery area. However, during the breeding season the range contracts primarily to the breeding islands and the central and northern California hauling sites. Thus, the breeding season is the best time to survey for marked individuals to observe the greatest proportion of all the age and sex classes.

Prior to 1994, all observation effort of marked animals was conducted at San Miguel Island under the assumption that California sea lions would have fairly high fidelity to their natal site. However, a study in 1994 indicated that juveniles were primarily hauling out at Año Nuevo Island during the breeding season (Birch and Ono, unpubl. report). In 1996, the surveys were extended to include Año Nuevo Island, Farallon Islands, and the coast in the vicinity of Monterey Bay. Since 1996, Año Nuevo Island has been surveyed each year and the Farallon Islands were surveyed in 1998 during an El Niño event and opportunistically during other years.

Observations of branded sea lions and the reproductive status of sighted females were recorded throughout the pupping and breeding season (May through August). The dates have varied slightly from year to year but we have restricted the analysis to observations made between 15 May through 15 August. Animals were identified using binoculars or a 20X to 60X zoom scope. Females were considered reproductive if they were sighted nursing a pup or were associated with a pup by vocalizing or nuzzling.

Survival Analysis

Survival rates were estimated using the computer program MARK developed by Dr. Gary White at Colorado State University (http://www.cnr.colostate.edu/~gwhite/mark/mark.htm). MARK provides estimates of sighting probability and survival rate for general open population capture-recapture models (e.g., Jolly-Seber) and allows models to specify time- and individual-specific covariates for re-sighting and survival probabilities. We fitted a variety of models that allowed capture probability and survival to vary by age, sex, year and interactions of these main effects. For capture (sighting) probability, age was classified based on the sea lion's approximate age at the time of capture. Thus, pups were first able to be re-sighted at their first birthday during the breeding season following branding, so they were treated as yearlings. Four levels were used for age/stage classification in females (yearling,2,3, and >3 years old) and 5 levels were used for males (yearling,2,3,4,5 and >5 years old) to account for the disparity between the sexes in their attendance at SMI during breeding. For survival probability, age was classified based on the age of the sea lion during the applicable survival period. Survival periods for non-pups were considered to extend between years from 15 July, the mid-point of the sighting interval, and were labeled with the year ending the period (e.g., survival from 15 July 1994 through 15 July 1995 was labeled as 1995). Pup survival applied to the period from branding until 15 July of the following year. Initially, we used three age-levels for survival of females and males (pup, yearling, ≥2) as in previous analyses (Melin et al 1997). We then considered expanded models with five age classes of pup, yearling, 2-4, 5-7 and 8+.

We examined the effect of the pup's weight at branding on its first year survival. Continuous covariates such as weight can be included in MARK but at present their use excludes the option of bootstrapping to evaluate over-dispersion. To retain the bootstrapping feature, we included pup weight as a categorical factor by grouping pups based on their weight. Female pups were divided by the following six weight (kg) intervals: <14.3, 14.3-16.0, 16.1-17.5, 17.6-19.0, 19.1-20.5, and >20.5. Likewise, males were divided by the following four weight (kg) intervals: <17.3, 17.3-20.2, 20.3-23.0, and >23.0. These intervals were chosen such that nearly equal numbers of pups were in each group when all of the cohorts were combined. Since 1993, pups were branded at a ratio of 2:1 females:males, so fewer weight intervals were used with males such that each group was nearly the same size.

In developing models with MARK we took some precautions to ensure parameter identifiability. In the standard Jolly-Seber model with time-dependent survival and sighting probabilities, on the last sighting occasion only the products of the probabilities are identifiable (i.e., the parameters are confounded). In other models which constrain sighting or survival probabilities (e.g., constant sighting probability) the individual parameters are identifiable. We expected that the simpler models would not be sufficient for our data, so we chose to estimate the confounded parameters separately for all models rather than include them into the model for survival or sighting. Initially, we did so by setting all of the sighting probabilities to unity and including parameters for each confounded product under the most general model which assumed differences in survival based on age, sex and pup weight. This required 40 parameters which effectively fit the model exactly to the observations made during 1999. Also, because little or no sighting effort was conducted during 1988 and 1989, an additional 20 nuisance parameters were needed to model the 3-year survival rate for the 1987 cohort and a 2-year survival rate for the1988 cohort until 1990 for each of the ten weight groups (4 male and 6 female). Sighting probability was set to zero for 1988 and 1989. Each model was then fitted to the data with the 60 nuisance parameters included. After some initial models were fitted, we discovered that some of the 60 parameters were not always identifiable because the data were sparse in some cells, so we collapsed adjacent weight intervals (2 for males and 4 for females) to reduce the number of nuisance parameters to 48 which allowed all of them to be estimated. For the remainder of the parameters, we did not collapse groups, ages or years unless specific parameters were not identifiable.

To select the most parsimonious model, we used Akaike's information criterion (AIC) adjusted for over-dispersion (QAIC) (Burnham and Anderson 1999). We used the bootstrap feature of MARK to estimate the over-dispersion coefficient ($\hat{c}$) under the most general model with all interactions included. As recommended by White et al. (in press), we divided observed $\hat{c}$ from the most general model by the mean bootstrap estimate of $\hat{c}$ which contains no over-dispersion in the simulation. The ratio was then used as the value for over-dispersion to compute QAIC and to adjust parameter standard errors and confidence intervals to reflect additional uncertainty resulting from over-dispersion.

Natality Analysis

Naive age-specific estimates of natality rate were constructed as the proportion of branded females seen with a pup divided by the number of branded females seen during the pupping and breeding season. These naive estimates assume that any females seen without a pup did not have a pup. We evaluated this assumption by conducting surveys in the winter and comparing the assessed reproductive status (with or without pup) of females in the winter with their status assigned during the summer (pupping/breeding) season. We used this comparison to estimate the proportion of females which did have pups but were incorrectly recorded as without a pup. We define the following notation:

n_{pp} - number of females seen with a pup in both seasons
n_{ww} - number of females seen without a pup in both seasons
n_{wp}- number of females seen without a pup in summer but with a pup in winter
n_{pw} - number of females seen with a pup in summer but without a pup in winter.

The errors are represented by n_{wp} because the female did have a pup, but n_{pw} is not an error because the pup may have died but more likely was alive and not near the mom because the pups are more independent and mobile during the winter. The ratio $p_1 = n_{wp}/(n_{wp}+n_{ww})$ provides a naive estimate of the proportion mis-classified which assumes that no errors are made during the winter assessment. In fact, females are less likely to be associated with their pups during winter because the pups are more mobile and independent or the pup may have died post-breeding. Also, the winter surveys are less intensive than the summer surveys. Thus, the naive estimate is likely to be too low. The ratio $p_2 = n_{pp}/(n_{pw}+n_{pp})$ provides an estimate of the probability that a female that had a pup and was seen in both seasons would be seen in association with her pup. We used the ratio of p_1/p_2 as an estimate of the proportion of females that were incorrectly classified during the summer as without a pup. This estimator will be biased high if females that did not produce a pup were less likely to remain on the island during winter. Reasonable lower and upper bounds on the error rate are provided by p_1 and p_1/p_2.

Results

Branding/Sighting Data Summary

Twelve annual cohorts of pups were branded between 1987-1998, which included 3,005 females and 2,040 males (Table 1). The re-sighting effort conducted between 15 May and 15 August from 1990 -1999 resulted in 23,267 re-sightings of sea lions at San Miguel (SMI), Año Nuevo (ANI) and Farallon (FAI) islands. The broad-scale intensive re-sighting effort resulted in high re-sighting rates with as much as 77% of a female cohort and 70% of a male cohort seen once or more after branding (Table 1, Fig. 3). The variation in re-sighting rates reflected both the distribution and quantity of re-sight effort and the survival of individual cohorts. In particular, beginning in 1994 the percentage re-sighted reflects the additional effort expended on re-sighting at SMI and the extension of re-sighting to ANI and FAI.

Most of the branded sea lions were seen at SMI with the exception of female juveniles (< 4 years) and in particular male juveniles (<6 years) (Tables 2- 3). Año Nuevo Island and to a lesser degree the Farallon Islands were primary haulouts for juveniles during the breeding/pupping season. The use of the Farallon Islands increased during and after El Niño events in 1992/93 and 1997/98. The regional shifts resulting from El Niño events was highlighted by the complete absence of sightings of two year-old males at SMI in 1998, but nearly 20% of the 1996 male cohort was seen in 1998 at ANI and FAI (Table 3). The effect of sampling at ANI in 1994 and but not in 1995 was reflected most in the re-sighting of male juveniles (Fig. 4).

Annual variation in pup weights at branding was quite evident in shifts in the median weight interval (Table 4). As pup weight increased so did the proportion of the individuals re-sighted which suggested a very plausible influence of pup weight on first year survival (Fig. 5). However, pup weight was not the sole determinant of first year survival. For example, the 1991 and 1993 cohorts had very similar pup weight distributions (Table 4), but a larger percentage of the 1993 cohort was re-sighted (Fig. 5) which suggested decreased survival during the 1992 El Niño.

Survival Analysis

Small sparse data sets and short-time frames typically will only support a simple model. Neither applied to this data set, so it was not surprising that a fairly complex model was needed to describe the data adequately. We expected that both sighting probability and survival probability would vary by sex, age and year and pup survival would be affected by weight. Therefore, we specified a global model which included those factors and their interactions. We used MARK to create 50 bootstrap simulations under the global model to obtain an average estimate of $\hat{c}$ = 4.02 (SE=0.01). The observed $\hat{c}$ for the global model was 4.58, so we used a value of $\hat{c}$ =1.14 (4.58/4.02) for QAIC values and to adjust standard errors and confidence intervals.

The annual variation in sighting effort and distribution of the effort at SMI, ANI and FAI and the non-random distribution of the age and sex classes at the various islands guaranteed that the full model with all main effects and their interactions of sex, age and year would be required to model adequately the variability in sighting probability. None of the reduced models (i.e., fewer parameters without some interactions) for sighting probability provided a QAIC that was close to the full model, so we have only provided results of the full model for sighting probability (Table 5). The full model required 83 parameters that were all identifiable (Table 6). As expected, sighting probability increased with age because juveniles were less likely to be at SMI during the breeding season. The annual variation in juvenile male sighting probabilities reflected the absence of sampling at ANI and FAI in 1995 and a general increase over time which was also apparent in sighting probabilities for the other sex and age classes.

The best model for survival probability (Table 5) was less complex than sighting probability but still required 38 identifiable parameters in the model which included main effects for age (with 5 levels), year and sex, and interactions of age with sex and year and for pup survival a factor for each weight-sex group except that the two largest weight intervals for males were collapsed to obtain parameter identifiability. The interaction of age and year was limited to the initial age classification with 3 levels because expansion to the 5-level interaction produced several additional non-identifiable parameters and did not lower QAIC. The interaction levels for ≥2 year-olds with years was collapsed for 1991 and 1992 to obtain parameter identifiability.

First-year survival from time of branding to the following breeding season was highest for heavier male pups and lowest for lighter female pups (Table 7). In general the average survival for male pups in a cohort was greater than their female counterparts (Fig. 6). Pup survival was affected both by changes in pup weights and other sources of annual variation such as the El Niño conditions in 1992/93 and 1997/98. The 1997/98 El Niño substantially reduced pup and yearling survival in comparison to 1995/96 when El Niño conditions did not exist (Fig. 7). Peak annual survival was observed for 2-4 year-old for females and 5-7 year-old males. Female survival was greater than male survival except for pup survival.

Natality Analysis

Although adult females were sighted at all areas, females with pups were sighted only at San Miguel Island. In 1996, of 292 females sighted that were of reproductive age (age four or older), 36% were sighted with pups in 1996 (Table 9). In 1998, the overall observed natality rate was lower at 24% presumably due to the effects of the strong 1997/98 El Niño oceanographic conditions. No 4 year-old females gave birth during 1996 but in 1998, 7% of the observed four year old females gave birth.

Females seen in association with a pup at least once during the season were seen typically on six to eight occasions during the season, whereas females never seen with a pup were typically only seen on two to three occasions (Fig. 8). Females seen with a pup were seen in association with their pup on approximately 50% of the sighting occasions (Fig. 8). If we assume the association with the pup was independent between occasions, that would suggest that a female with a pup would have to be seen on four occasions to be relatively certain (i.e., four occasions would yield a 6% error,1-0.5**4 = 0.06) that the female would be seen with her pup. Because most females classified as without a pup were seen fewer than four times, many could indeed have had a pup. The comparison of summer and winter observations suggested that as many as 43% and possibly as few as 6% of the females not seen with pups may have had pups (Table 10).

Discussion

The branding of California sea lions is providing a wealth of information on movements and distribution of sea lions, spatial segregation of the sex and ages, and most important a means to estimate and examine the factors that affect survival and natality rates. Branding provides a permanent mark which is not subject to the same problems as tags which become worn and unreadable or fall off. Also, the brand can be easily read from a distance providing much higher re-sight rates than tags.

However, the possibility does exist for mis-reading or incorrectly recording the brand numbers. The effect of recording an incorrect brand number will depend on the true status (i.e., alive or dead) of the animal represented by the number that was recorded. Incorrectly recording a number of an animal that is alive should not greatly affect the estimate of survival, but could affect the sighting probability estimate. However, incorrectly recording a number of a dead sea lion will make it appear as if it were alive until that sighting and most likely dead afterwards, unless the same mistake is made again. Schwarz and Stobo (1999) used simulation to show that mis-reading brands creates a positive bias in survival for occasions shortly after branding and a negative bias in survival for later occasions. It is difficult to predict the resulting bias because it would depend on the pattern of errors. Extreme care is taken in recording brand numbers and if there is any uncertainty the brand is not recorded. However, we need to investigate this further with simulation and consider ways of filtering the data to minimize brand misreads.

Research on long-lived species requires long-term studies and while we have not yet followed a cohort through their complete natural life, we have begun to develop a picture of survival in California sea lions. That picture shows age and sex specific differences and pup survival being affected by weight. But, the dominant dynamic is the large annual variations associated with El Niño oceanographic events. The El Niño events lower pup survival because their weight is reduced and when they are weaned they are confronted with a lack of food resources. Male pup survival is affected less by El Niño events which may be explained by their heavier weight and possibly because they are more likely to move to northern California during their first year. During the last several decades, El Niño events have played a central role in the population dynamics of California sea lions through lower survival and lower reproduction.

Age-specific natality in California sea lions appears to be similar to northern fur seals (*Callorhinus ursinus*) in that young females have lower natality rates than older females (Lander 1981). However, the 1996 natality rates of age classes seven (36.6%) to nine (56.8%) are lower than the pregnancy rates reported for northern fur seals (over 80% for 8 to 16 year old seals) (Lander 1981). In part this difference can be explained by the possibility of abortion and the loss of a full-term pup prior to observing the female. However, the most likely explanation is the potential for bias in the observations.

There are two potential sources of bias in the observed rate: 1) non-random sampling of females and 2) missed observations of pups. Most of the observation is done at SMI where both breeding and pupping occur. If a female does not go to SMI either to pup or breed then she will be less likely to be observed. Observations at ANI and FAI improve the sampling but may not completely overcome the bias. Also, females that breed in a year but do not produce a pup may also be less likely to be seen. However, all breeding areas at San Miguel were surveyed at regular intervals (generally every other day) to increase the probability that a female would be sighted if she was present during the breeding season. Over-sampling of females that produce pups would tend to overestimate natality rather than underestimate; whereas, missed observations of pups would produce an underestimate and is the most likely source of bias. Females with pups may be mis classified because of topography of haul-out site, location of haul out-site, or nursing behavior each of which may reduce the probability of seeing a female with a pup when she has one. By sampling during the winter we demonstrated that females with pups during the winter were seen during the summer but never in association with their pup. Thus, the observed rates may be sufficient to show trends in reproduction or the effects of environmental impacts such as El Niño, but they are not sufficient to provide an unbiased estimate for use in population modeling.

Mark-recapture approaches have been used to estimate reproductive rates but most approaches make fairly restrictive assumptions relevant to the species of interest. For example, Clobert et al.(1994) developed a model for colonial nesting birds assumed that all birds breed after a specific age. Many marine mammals do not reproduce every year even once they attain sexual maturity. Barlow and Clapham (1997) created a model for whales that allowed for non-annual birth intervals but assumed that those with young and those without had equal chances of being re-sighted. The equal capture probability is not reasonable for sea lions. Nichols et al. (1994) relaxed the equal capture probability assumption by using a multi-state model but they required that the breeder/non-breeder status of the animal to be determined at re-sighting. As we have demonstrated with the summer-winter comparisons, many females with pups are recorded as without pups because they are not seen in close association with the pup. We have identified two different approaches that may work because both only use re-sighting data for females that are seen with a pup. The first would require a slight modification of a model for right whale photo-ID data by Payne et al (1990) which has been further developed by J. Cooke (pers. comm). In their model observations of females with pups in a year is a "1" in a capture history and a "0" includes not seen and seen but not with a pup. They fitted a model which contains a birth-interval distribution and survival and sighting probabilities. An equivalent model for sea lions would require some modification because all are marked as young so all of the information can be age-specific. An alternative is the model developed by Schwarz and Stobo (1997) which would also only use the sightings of females with pups but it would use all sightings of those females with their pups during the season to estimate the probability of observing a female with her pup during the season. Their method is a modification of the robust design which nests a within-year capture-recapture within a series of annual capture-recapture occasions. Our future work will apply one or both of these approaches to estimate natality from the female-pup resight data.

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Literature Cited

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

Birch, E.M., and K. Ono. Unpubl. rep. Female and juvenile occurrences of the California sea lion (*Zalophus californianus*) on Año Nuevo Island, CA.

Burnham, K.P., and D.R. Anderson. 1999. Model Selection and Inference: a practical information-theoretic approach. Springer-Verlag, NewYork. 353p.

Clobert, J. J-D. Lebreton, D. Allaine, and J.M. Gaillard. 1994. The estimation of age-specific breeding probabilities from recapture or resightings in vertebrate populations: II. Longitudinal models. Biometrics 50:375-387.

Gearin, P.J., R. Pfeifer, S.J. Jeffries, R.L. DeLong, and M.A. Johnson. 1988. Results of the 1986-87 California sea lion-steelhead trout predation control program at the Hiram M. Chittenden Locks. Northwest and Alaska Fisheries Center Processed Report 88-30. Seattle, WA. 111 pp.

Heath, C.B. 1989. The behavioral ecology of the California sea lion, *Zalophus californianus*. PhD dissertation, University of California, Santa Cruz. 255 p.

Lander, R.H. 1981. A life table and biomass estimate for Alaskan fur seals. Fish. Res., 1: 55-70.

Melin, S., R.L. DeLong, and J.L. Laake. 1997. Evaluation of life history parameters and breeding season distribution of California sea lions (*Zalophus californianus*) from a branding study at San Miguel Island, California. In: Marine Mammal Protection Act and Endangered Species Act Implementation Program 1996, Edited by P.S. Hill and D. P. Demaster, AFSC Processed Report 97-10, Alaska Fisheries Science Center, NMFS.

Nichols, J.D., J.E. Hines, K. H. Pollock, R.L. Hinz, and W.A. Link. 1994. Estimating breeding proportions and testing hypotheses about costs of reproduction with capture-recapture data. Ecology 75(4):2052-2065.

Odell, D.K. 1981. California sea lion, *Zalophus californianus* (Lesson, 1828). Pages 67-97. In: S.H. Ridgeway and R.J. Harrison (editors), Handbook of Marine Mammals: Volume 1 The Walrus, sea lions, fur seals, and sea otter. Academic Press.

Payne, R., V. Rowntree, J.S. Perkins, J.G. Cooke, and K. Lankester. Population size, trends and reproductive parameters of right whales (*Eubalaena australis*) off Peninsula Valdes, Argentina. Rep. Int. Whal. Comm. Spec. Issue 12:271-278.

Peterson, R.S., and G.A. Bartholomew. 1967. The natural history and behavior of the California sea lion. Spec. Pub.No. 1, Am. Soc. of Mammal. 79 pp.

Schwarz, C., and W.T. Stobo. 1999. Estimation and effects of tag-misread rates in capture-recapture studies Can. J. Fish. Aquat. Sci. 56: 551-559.

Schwarz, C., and W.T. Stobo. 1997. Estimating temporary migration using the robust design. Biometrics 53(1):178-194.

White, G.C., K.P. Burnham, and D.R. Anderson. In press. Advanced features of program MARK. Available at http://www.cnr.colostate.edu/~gwhite/mark/mark.htm.

Table 1. Number of male and female pups branded at San Miguel Island between 1987-1998 and the proportion re-sighted during 15 May - 15 August at San Miguel Island, Año Nuevo Island or Farallon Islands during each year.

Sex	Year Branded	Number Branded	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Never Re-sighted
Female	1987	110	30.9%	14.5%	24.5%	19.1%	38.2%	37.3%	40.9%	42.7%	30.9%	30.0%	23.6%
	1988	95	23.2%	11.6%	17.9%	26.3%	31.6%	31.6%	27.4%	36.8%	38.9%	25.3%	23.2%
	1989	108	13.9%	13.0%	12.0%	27.8%	30.6%	34.3%	34.3%	33.3%	36.1%	28.7%	27.8%
	1990	245		14.3%	7.3%	15.9%	37.1%	30.2%	31.0%	32.7%	34.3%	34.3%	34.7%
	1991	259			7.7%	8.1%	22.4%	21.6%	20.8%	26.6%	35.1%	26.3%	45.2%
	1992	229				11.4%	23.6%	24.0%	25.3%	33.2%	29.7%	29.3%	46.3%
	1993	341					32.0%	36.1%	33.7%	51.3%	48.7%	46.3%	22.9%
	1994	366						27.9%	37.4%	49.2%	48.6%	47.3%	27.0%
	1995	326							26.7%	50.6%	39.0%	39.9%	32.2%
	1996	313								31.0%	20.4%	18.2%	57.2%
	1997	313									18.5%	13.4%	75.4%
	1998	300										37.3%	62.7%
Male	1987	90	16.7%	6.7%	10.0%	10.0%	12.2%	16.7%	18.9%	15.6%	20.0%	15.6%	51.1%
	1988	85	17.6%	2.4%	10.6%	15.3%	17.6%	22.4%	15.3%	18.8%	18.8%	17.6%	50.6%
	1989	90	10.0%	6.7%	3.3%	11.1%	27.8%	21.1%	24.4%	25.6%	24.4%	20.0%	51.1%
	1990	254		12.6%	6.7%	9.4%	38.6%	26.4%	26.0%	27.6%	28.3%	26.4%	36.6%
	1991	238			5.5%	2.9%	29.8%	23.5%	29.0%	26.9%	30.3%	23.9%	42.0%
	1992	261				8.4%	26.8%	15.3%	18.0%	23.0%	24.5%	22.6%	49.0%
	1993	145					35.2%	13.8%	31.7%	35.9%	35.9%	37.2%	30.3%
	1994	134						15.7%	33.6%	40.3%	30.6%	35.8%	36.6%
	1995	174							27.0%	34.5%	33.3%	39.7%	32.8%
	1996	184								33.2%	19.6%	26.1%	47.3%
	1997	185									15.7%	13.5%	75.1%
	1998	200										36.0%	64.0%

Table 2. Regional distribution of re-sightings of female sea lions during 15 May thru 15 Aug at San Miguel(SMI), Año Nuevo(ANI) and Farallon(FAI) islands. Sea lions seen at more than one island during a year were assigned to a single island in the following priority: SMI, ANI and FAI. A sea lion was only assigned to ANI if it wasn't seen at SMI, and a sea lion was only assigned to FAI if it wasn't seen at either SMI or ANI. Entries are shaded at ANI or FAI if more than 20% of the sea lions were seen on that island during the year. Entries are shaded for SMI if fewer than 80% were seen at SMI in that year.

Año Nuevo Island

Age	1990	1991	1992	1993	1994[1]	1995	1996[1]	1997[1]	1998[1]	1999[1]
1	0.0%	0.0%	0.0%	0.0%	21.1%	0.0%	24.1%	29.9%	17.2%	2.7%
2	0.0%	0.0%	0.0%	0.0%	59.3%	0.0%	23.4%	11.5%	78.1%	38.1%
3	0.0%	0.0%	0.0%	0.0%	50.0%	0.0%	10.4%	2.2%	27.6%	33.3%
4		0.0%	0.0%	0.0%	35.2%	0.0%	6.9%	1.7%	19.1%	10.8%
5			0.0%	0.0%	3.0%	0.0%	5.6%	1.3%	11.4%	3.5%
6				0.0%	10.0%	0.0%	11.8%	1.4%	7.4%	1.3%
7					4.8%	0.0%	0.0%	5.0%	13.2%	1.5%
8						0.0%	7.7%	0.0%	14.3%	1.5%
9							4.4%	0.0%	5.1%	1.2%
10								4.3%	5.4%	6.5%
11									2.9%	0.0%
12										0.0%

Farallon Islands

Age	1990	1991	1992	1993	1994	1995	1996[2]	1997	1998[2]	1999
1	0.0%	0.0%	5.0%	11.5%	0.0%	2.0%	0.0%	2.1%	5.2%	0.0%
2	0.0%	0.0%	5.6%	14.3%	0.0%	0.0%	1.5%	1.2%	14.1%	0.0%
3	0.0%	0.0%	0.0%	2.6%	0.0%	0.0%	0.0%	0.0%	2.4%	0.0%
4		0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	0.0%	2.2%	0.0%
5			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%	0.0%
6				0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
7					0.0%	0.0%	0.0%	0.0%	3.3%	0.0%
8						0.0%	3.8%	0.0%	1.2%	0.0%
9							2.2%	0.0%	2.6%	0.0%
10								0.0%	0.0%	0.0%
11									0.0%	0.0%
12										0.0%

San Miguel Island

Age	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1	100.0%	100.0%	95.0%	88.5%	78.9%	98.0%	75.9%	68.0%	77.6%	97.3%
2	100.0%	100.0%	94.4%	85.7%	40.7%	100.0%	75.2%	87.3%	7.8%	61.9%
3	100.0%	100.0%	100.0%	97.4%	50.0%	100.0%	89.6%	97.8%	70.1%	66.7%
4		100.0%	100.0%	100.0%	64.8%	100.0%	91.4%	98.3%	78.7%	89.2%
5			100.0%	100.0%	97.0%	100.0%	94.4%	98.7%	88.0%	96.5%
6				100.0%	90.0%	100.0%	88.2%	98.6%	92.6%	98.7%
7					95.2%	100.0%	100.0%	95.0%	83.5%	98.5%
8						100.0%	88.5%	100.0%	84.5%	98.5%
9							93.3%	100.0%	92.3%	98.8%
10								95.7%	94.6%	93.5%
11									97.1%	100.0%
12										100.0%

[1]contracted observer provided sightings
[2]contracted observer provided sightings; remaining sightings at FAI were opportunistic

Table 3. Regional distribution of re-sightings of male sea lions during 15 May thru 15 Aug at San Miguel(SMI), Año Nuevo(ANI) and Farallon(FAI) islands. See Table 2 for a more detailed description.

Año Nuevo Island

Age	1990	1991	1992	1993	1994[1]	1995	1996[1]	1997[1]	1998[1]	1999[1]
1	0.0%	0.0%	0.0%	0.0%	33.3%	0.0%	53.2%	44.3%	6.9%	22.2%
2	0.0%	0.0%	0.0%	0.0%	87.1%	0.0%	66.7%	50.0%	72.2%	64.0%
3	0.0%	0.0%	0.0%	0.0%	67.6%	0.0%	39.1%	13.0%	43.1%	41.7%
4		0.0%	0.0%	0.0%	51.0%	0.0%	29.8%	5.8%	34.1%	18.8%
5			0.0%	0.0%	40.0%	0.0%	23.2%	10.0%	17.3%	20.8%
6				0.0%	13.3%	0.0%	15.2%	4.7%	20.3%	7.4%
7					9.1%	0.0%	0.0%	7.1%	9.7%	8.5%
8						0.0%	0.0%	4.3%	8.3%	10.5%
9							11.8%	12.5%	4.5%	10.4%
10								7.1%	12.5%	5.6%
11									0.0%	0.0%
12										0.0%

Farallon Islands

Age	1990	1991	1992	1993	1994	1995	1996[2]	1997	1998[2]	1999
1	0.0%	0.0%	15.4%	18.2%	0.0%	0.0%	14.9%	6.6%	6.9%	0.0%
2	0.0%	0.0%	35.3%	57.1%	1.4%	0.0%	6.7%	1.7%	27.8%	0.0%
3	0.0%	0.0%	0.0%	25.0%	1.4%	2.5%	0.0%	0.0%	25.9%	0.0%
4		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5			0.0%	7.7%	0.0%	0.0%	1.4%	0.0%	0.0%	0.0%
6				0.0%	0.0%	0.0%	1.5%	1.6%	1.6%	0.0%
7					0.0%	0.0%	0.0%	0.0%	2.8%	0.0%
8						0.0%	0.0%	0.0%	0.0%	0.0%
9							0.0%	0.0%	0.0%	0.0%
10								0.0%	0.0%	0.0%
11									0.0%	0.0%
12										0.0%

San Miguel Island

Age	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1	100.0%	100.0%	84.6%	81.8%	66.7%	100.0%	31.9%	49.2%	86.2%	77.8%
2	100.0%	100.0%	64.7%	42.9%	11.4%	100.0%	26.7%	48.3%	0.0%	36.0%
3	100.0%	100.0%	100.0%	75.0%	31.0%	97.5%	60.9%	87.0%	31.0%	58.3%
4		100.0%	100.0%	100.0%	49.0%	100.0%	70.2%	94.2%	65.9%	81.2%
5			100.0%	92.3%	60.0%	100.0%	75.4%	90.0%	82.7%	79.2%
6				100.0%	86.7%	100.0%	83.3%	93.8%	78.1%	92.6%
7					90.9%	100.0%	100.0%	92.9%	87.5%	91.5%
8						100.0%	100.0%	95.7%	91.7%	89.5%
9							88.2%	87.5%	95.5%	89.6%
10								92.9%	87.5%	94.4%
11									100.0%	100.0%
12										100.0%

[1]contracted observer provided sightings

[2]contracted observer provided sightings; remaining sightings at Farallon were opportunistic

Table 4. Annual distributions of male and female branded pups in weight categories. The median weight category for each year is shaded.

	Male				Female					
Cohort	<17.3	17.3-20.2	20.3-23.0	>23.0	<14.3	14.3-16.0	16.1-17.5	17.6-19.0	19.1-20.5	>20.5
1987	8.9%	26.7%	35.6%	28.9%	12.7%	17.3%	20.0%	20.9%	13.6%	15.5%
1988	18.8%	21.2%	41.2%	18.8%	11.6%	9.5%	18.9%	29.5%	17.9%	12.6%
1989	0.0%	8.9%	15.6%	75.6%	1.9%	2.8%	7.4%	6.5%	7.4%	74.1%
1990	12.6%	15.7%	33.9%	37.8%	3.3%	16.7%	15.1%	18.4%	18.0%	28.6%
1991	8.4%	14.7%	33.2%	43.7%	4.6%	13.5%	11.6%	17.8%	18.5%	34.0%
1992	40.6%	30.3%	18.4%	10.7%	34.1%	27.5%	15.7%	10.0%	4.4%	8.3%
1993	16.6%	31.0%	30.3%	22.1%	7.9%	16.7%	17.9%	23.8%	18.2%	15.5%
1994	20.1%	40.3%	24.6%	14.9%	16.7%	20.2%	21.3%	21.6%	13.1%	7.1%
1995	8.0%	33.3%	28.7%	29.9%	4.6%	13.5%	21.8%	26.4%	17.2%	16.6%
1996	8.7%	26.1%	35.3%	29.9%	4.2%	12.5%	17.9%	23.0%	21.1%	21.4%
1997	57.3%	27.0%	13.0%	2.7%	39.0%	31.3%	12.1%	9.3%	5.1%	3.2%
1998	62.0%	22.0%	12.5%	3.5%	46.3%	23.0%	12.7%	11.3%	3.0%	3.7%

Table 5. Model selection results for the six best models. Global model is shaded and k is the number of parameters.

Age Classification	Survival Model	k	QAIC	Deviance
Pup, Yearling, 2-4, 5-7, 8+	age + year+sex + age:year + sex:age	169	23027.3	6034.8
	age + year+sex + age:year + sex:age + sex:year	177	23032.6	6022.0
	age + year+sex + age:year + sex:age + sex:year + sex:age:year	188	23060.6	6027.9
Pup, Yearling, 2+	age + year+sex + age:year + sex:age	165	23035.6	6053.6
	age + year+sex + age:year + sex:age + sex:year	173	23038.6	6038.2
	age + year+sex + age:year + sex:age + sex:year + sex:age:year	185	23067.7	6043.1

Table 6. Estimated sighting probabilities for branded male and female California sea lions. No focused sighting effort was conducted prior to 1990, so the few re-sightings in 1988 and 1989 were excluded and the probabilities were set to zero.

	Male										
Cohort	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1987	0.00	0.00	0.31	0.13	0.20	0.21	0.34	0.48	0.55	0.64	0.81
1988		0.00	0.30	0.06	0.19	0.31	0.34	0.48	0.55	0.64	0.81
1989			0.10	0.11	0.06	0.19	0.54	0.48	0.55	0.64	0.81
1990				0.14	0.09	0.13	0.62	0.52	0.55	0.64	0.81
1991					0.06	0.06	0.48	0.44	0.64	0.64	0.81
1992						0.10	0.49	0.35	0.48	0.68	0.81
1993							0.36	0.19	0.52	0.65	0.76
1994								0.17	0.53	0.74	0.70
1995									0.29	0.49	0.60
1996										0.40	0.50
1997											0.32

	Female										
Cohort	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1987	0.00	0.00	0.37	0.18	0.27	0.33	0.51	0.49	0.53	0.71	0.80
1988		0.00	0.28	0.13	0.27	0.33	0.51	0.49	0.53	0.71	0.80
1989			0.15	0.17	0.16	0.33	0.51	0.49	0.53	0.71	0.80
1990				0.17	0.10	0.24	0.51	0.49	0.53	0.71	0.80
1991					0.10	0.13	0.40	0.49	0.53	0.71	0.80
1992						0.15	0.42	0.47	0.53	0.71	0.80
1993							0.35	0.49	0.48	0.71	0.80
1994								0.32	0.55	0.76	0.80
1995									0.33	0.80	0.68
1996										0.57	0.70
1997											0.56

Table 7. Estimated survival rate of branded pups from time of branding to breeding season of following year (e.g., first column is survival of 1989 cohort from branding to 15 July 1990). Standard error is given in parenthesis.

Sex	Weight	1990	1991	1992	1993	1994	1995	1996	1997	1998
Male	<17.3	0.82 (0.16)	0.74 (0.08)	0.63 (0.09)	0.78 (0.07)	0.88 (0.05)	0.87 (0.05)	0.76 (0.07)	0.47 (0.08)	0.33 (0.07)
	17.3-20.2	0.91 (0.09)	0.87 (0.06)	0.79 (0.08)	0.89 (0.05)	0.94 (0.03)	0.94 (0.03)	0.88 (0.05)	0.66 (0.09)	0.53 (0.11)
	>20.2	0.98 (0.03)	0.98 (0.04)	0.96 (0.06)	0.98 (0.03)	0.99 (0.01)	0.99 (0.02)	0.98 (0.03)	0.92 (0.10)	0.87 (0.15)
Female	<14.3	0.71 (0.21)	0.60 (0.09)	0.48 (0.08)	0.65 (0.08)	0.80 (0.07)	0.78 (0.06)	0.63 (0.07)	0.32 (0.06)	0.21 (0.04)
	14.3-16.0	0.80 (0.16)	0.72 (0.07)	0.60 (0.07)	0.76 (0.07)	0.87 (0.05)	0.86 (0.05)	0.74 (0.06)	0.44 (0.06)	0.31 (0.05)
	16.1-17.5	0.84 (0.14)	0.77 (0.06)	0.67 (0.07)	0.81 (0.07)	0.90 (0.04)	0.89 (0.04)	0.79 (0.05)	0.51 (0.06)	0.37 (0.06)
	17.6-19.0	0.88 (0.10)	0.83 (0.05)	0.74 (0.07)	0.85 (0.05)	0.93 (0.03)	0.92 (0.03)	0.84 (0.04)	0.59 (0.06)	0.45 (0.07)
	19.1-20.5	0.84 (0.13)	0.78 (0.06)	0.67 (0.07)	0.81 (0.07)	0.90 (0.04)	0.89 (0.04)	0.79 (0.05)	0.51 (0.06)	0.37 (0.07)
	>20.5	0.93 (0.06)	0.89 (0.04)	0.83 (0.05)	0.91 (0.04)	0.96 (0.02)	0.95 (0.02)	0.90 (0.03)	0.71 (0.07)	0.59 (0.09)

Table 8. Age and year-specific annual survival rates of non-pup sea lions. Survival applies to year prior to 15 July of year given in table (e.g., for column 1995, survival rate is for 15 July 1994 to 15 July 1995). Standard error is given in parenthesis.

Sex	Age	1991	1992	1993	1994	1995	1996	1997	1998
Male	Yearling	0.69 (0.09)	0.82 (0.07)	0.74 (0.07)	0.64 (0.06)	0.74 (0.05)	0.69 (0.05)	0.73 (0.05)	0.44 (0.06)
	2-4	0.97 (0.05)	0.97 (0.05)	0.90 (0.07)	0.92 (0.04)	0.83 (0.03)	0.87 (0.03)	0.88 (0.02)	0.81 (0.02)
	5-7			0.93 (0.04)	0.95 (0.03)	0.89 (0.02)	0.92 (0.02)	0.92 (0.02)	0.88 (0.02)
	8+						0.82 (0.04)	0.83 (0.04)	0.75 (0.05)
Female	Yearling	0.78 (0.06)	0.87 (0.05)	0.82 (0.05)	0.74 (0.05)	0.82 (0.03)	0.78 (0.03)	0.81 (0.04)	0.56 (0.05)
	2-4	0.98 (0.02)	0.98 (0.02)	0.95 (0.03)	0.96 (0.02)	0.92 (0.02)	0.94 (0.01)	0.94 (0.01)	0.90 (0.01)
	5-7			0.94 (0.04)	0.96 (0.03)	0.90 (0.02)	0.92 (0.02)	0.93 (0.01)	0.88 (0.02)
	8+						0.90 (0.03)	0.90 (0.02)	0.84 (0.03)

Table 9. Age-specific natality of branded females sighted at San Miguel Island, California, June-August 1996. All females sighted with pups were sighted at San Miguel Island.

Year	Age	Number sighted	Number sighted with pups	Proportion sighted with pups
1996	9	44	25	0.57
	8	27	14	0.52
	7	41	15	0.37
	6	76	31	0.41
	5	56	21	0.38
	4	48	0	0.00
	Total	292	106	0.36
1998	11	33	9	0.27
	10	37	12	0.32
	9	38	12	0.32
	8	74	25	0.34
	7	76	24	0.32
	6	65	24	0.37
	5	150	33	0.22
	4	143	10	0.07
	Total	616	149	0.24

Table 10. Bounds on proportion of females with pups that were incorrectly classified as without a pup during the summer season. The years were grouped based on similar levels of winter survey effort.

Year	n_{pp}	n_{pw}	n_{wp}	n_{ww}	p_1	p_2	p_1/p_2
1996/98	21	68	8	132	0.057	0.236	0.242
1995/97	15	55	5	49	0.093	0.214	0.432

Figure 1. Coastal map

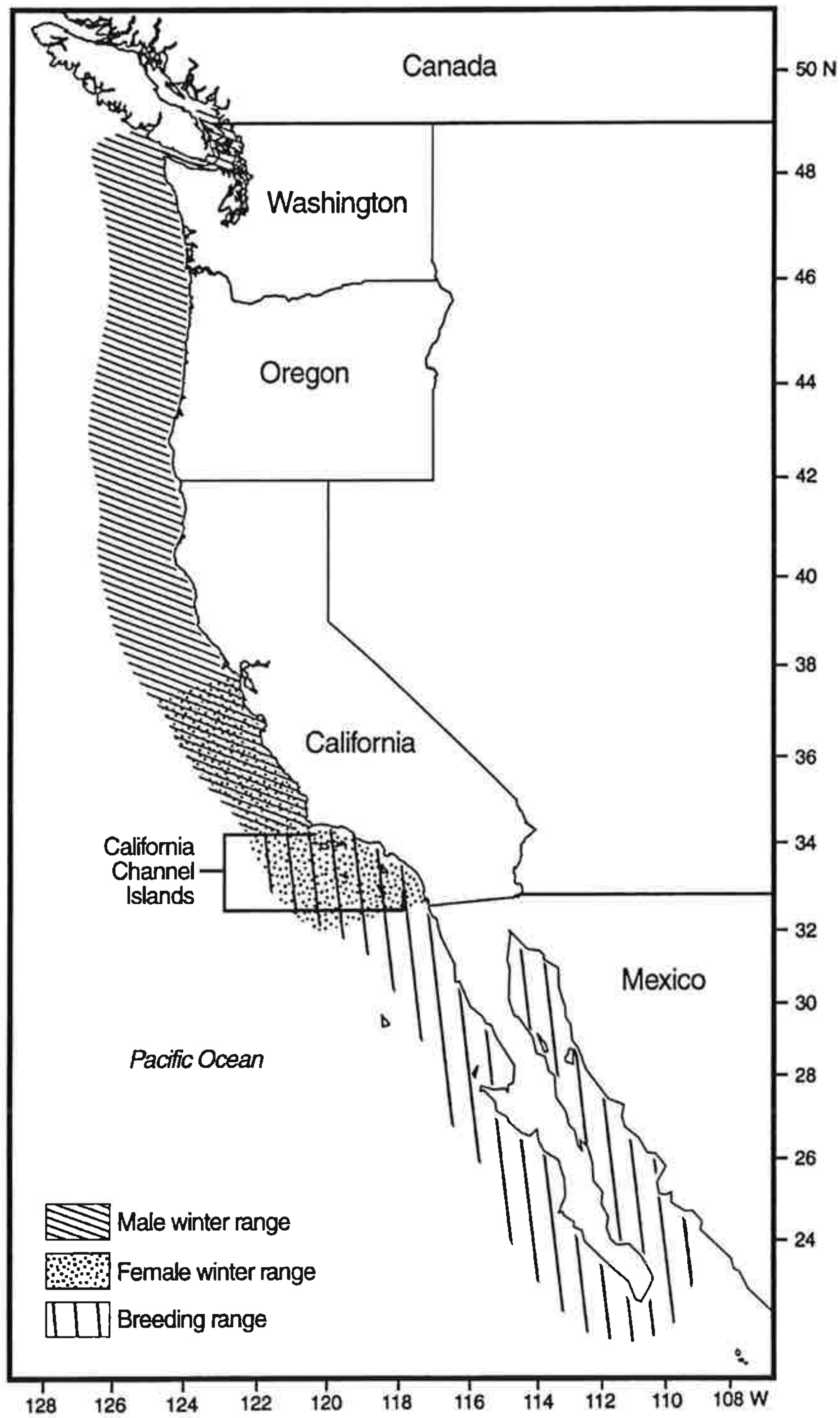
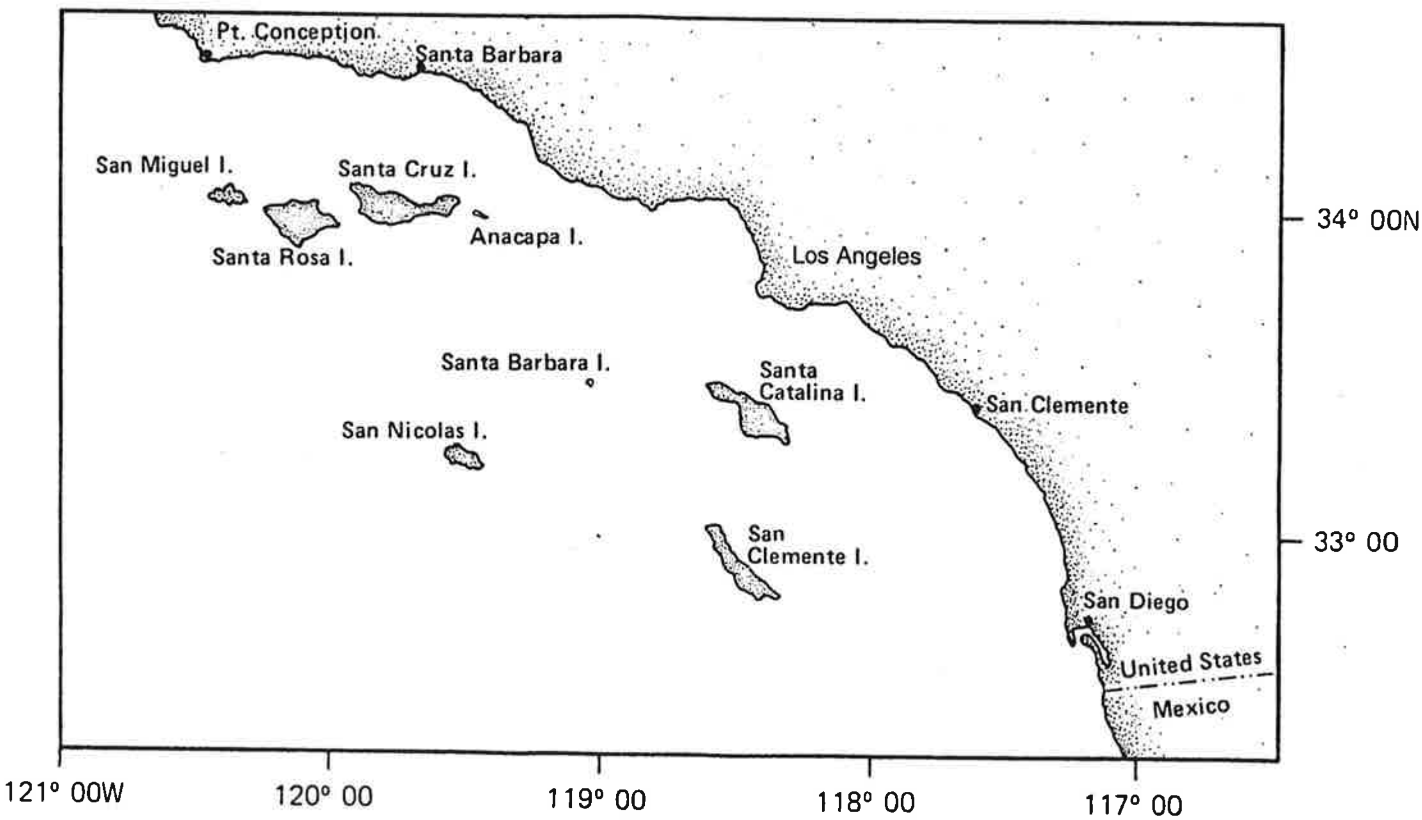


Figure 2. Haulout area map



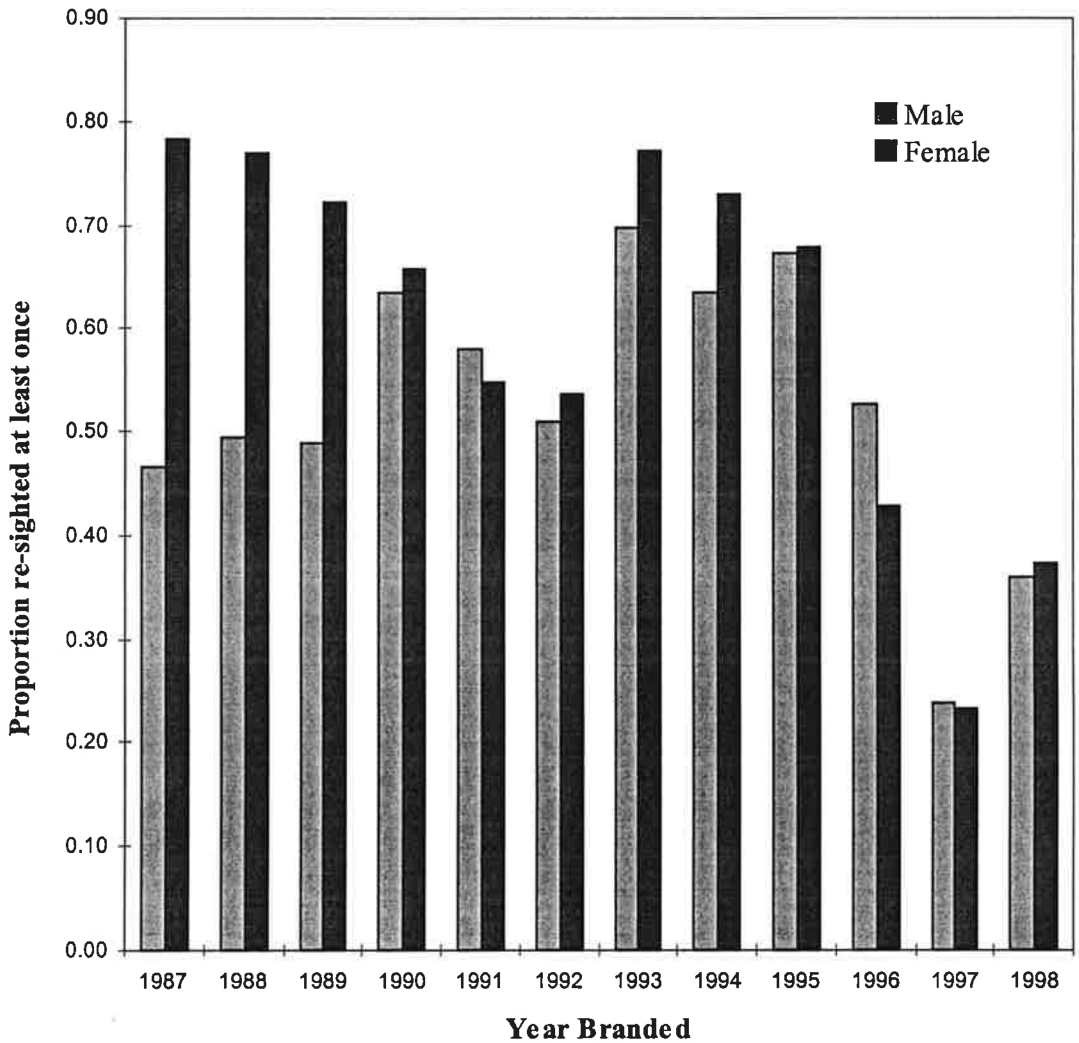
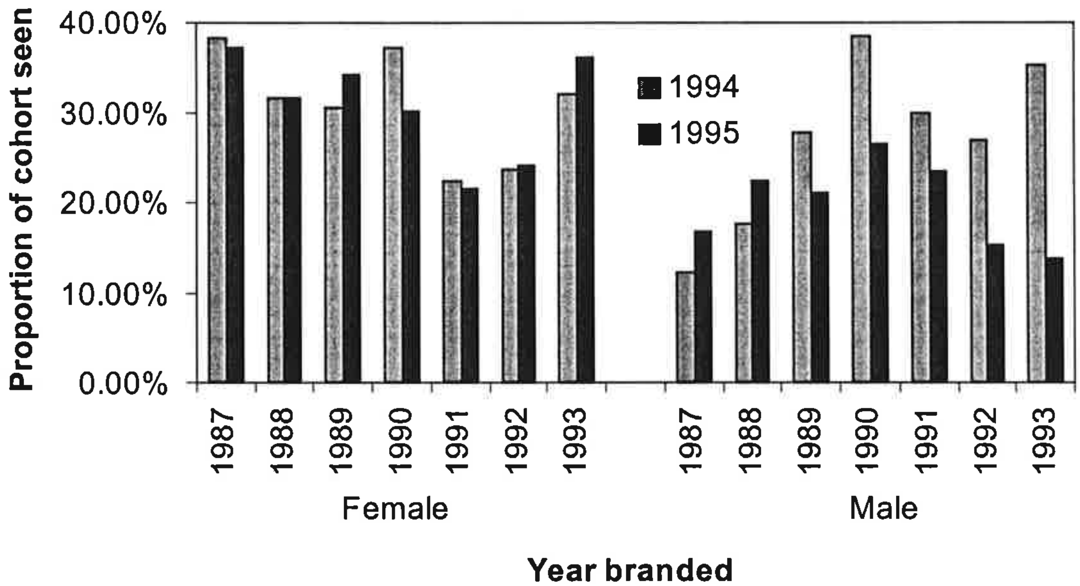
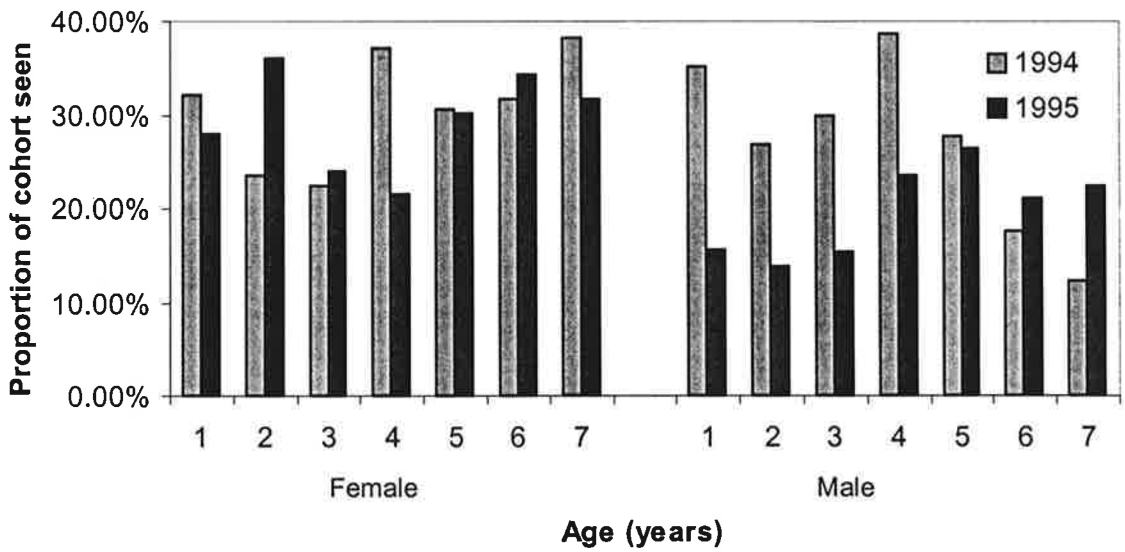


Figure 3. Proportions of male and female branded pup cohorts that were re-sighted at least once during 15 May - 15 August in any year after branding.



a)



b)

Figure 4. Proportion of each branding year cohort seen in 1994 and 1995 (a) and the proportion of each age cohort seen in 1994/1995. Re-sighting was conducted at ANI during 1994 but not 1995. Comparisons of branding year-cohorts across years are slightly influenced by aging of the cohort and comparisons of age-cohorts are influenced by the differential survival of branding year-cohorts (e.g., 2 year old females in 1994 (the 1992 year cohort) had poor survival in comparison to the 1993 cohort seen in 1995).

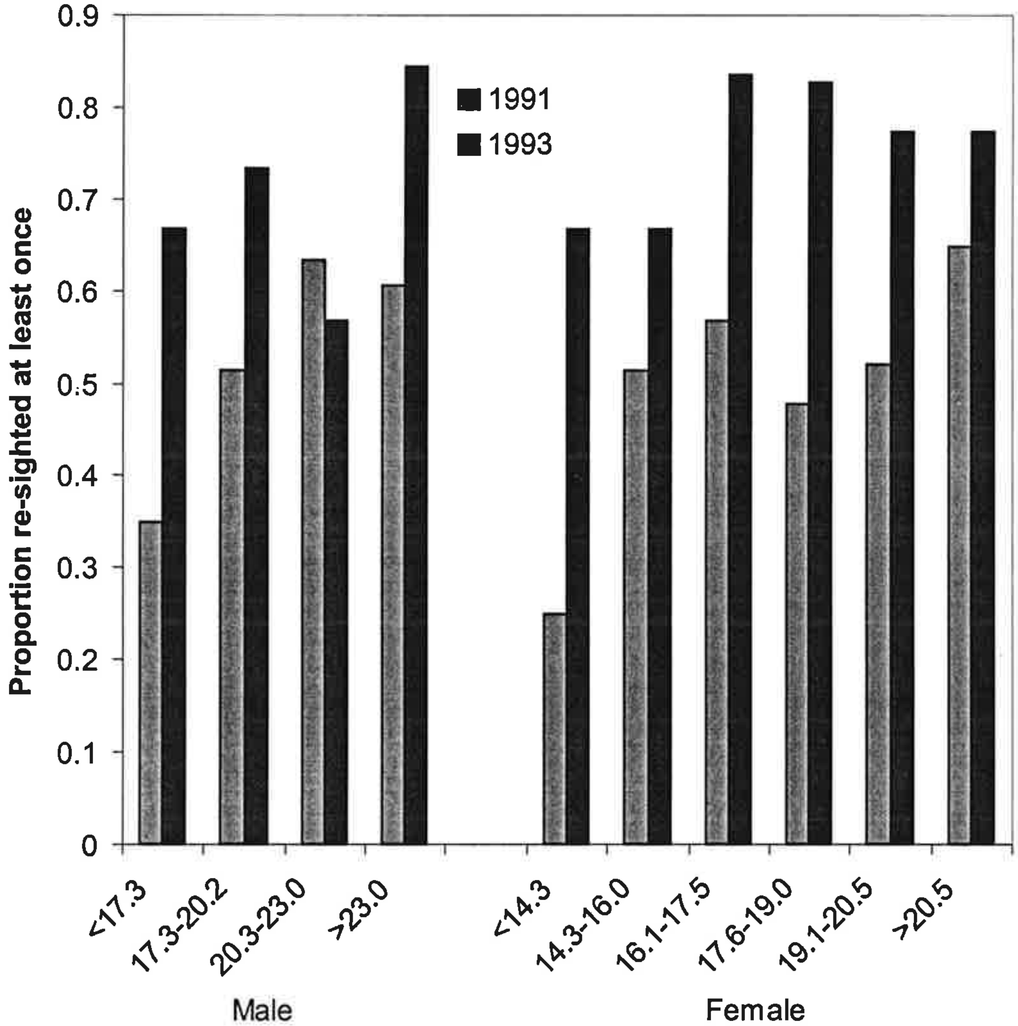


Figure 5. Proportions of the 1991 and 1993 male and female branded pup cohorts classified by weight that were re-sighted at least once during 15 May - 15 August in any year after branding.

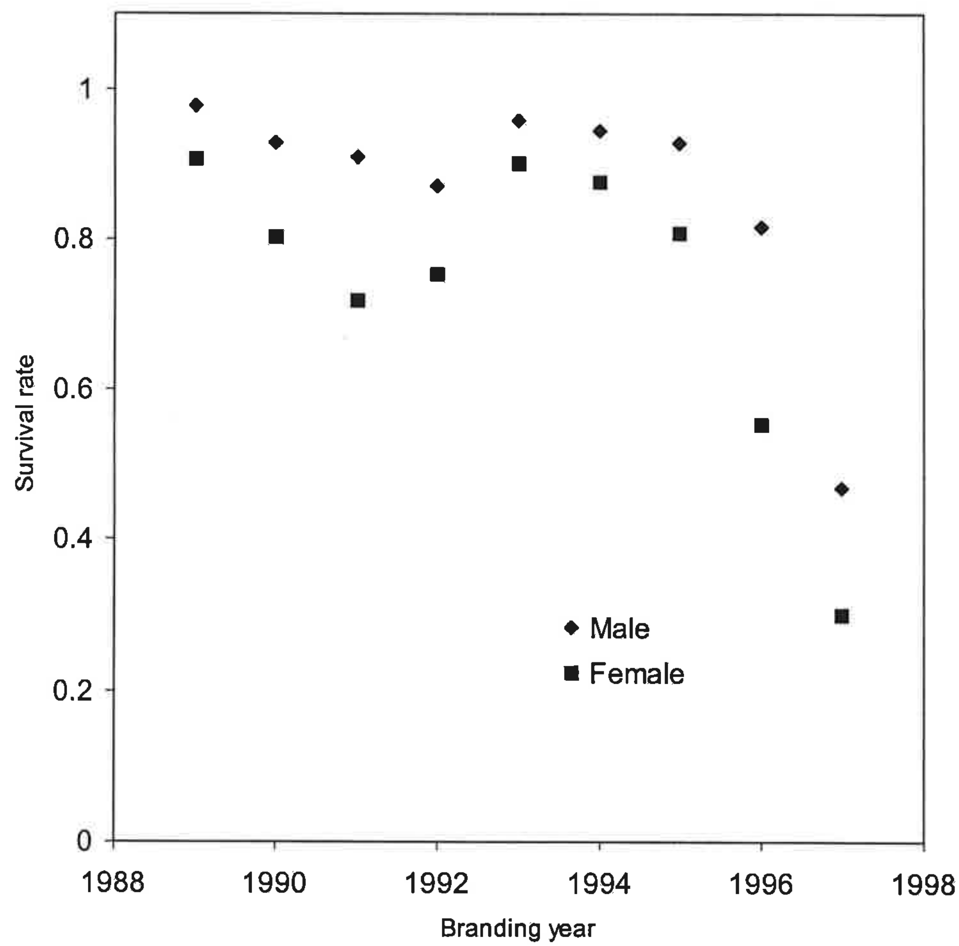
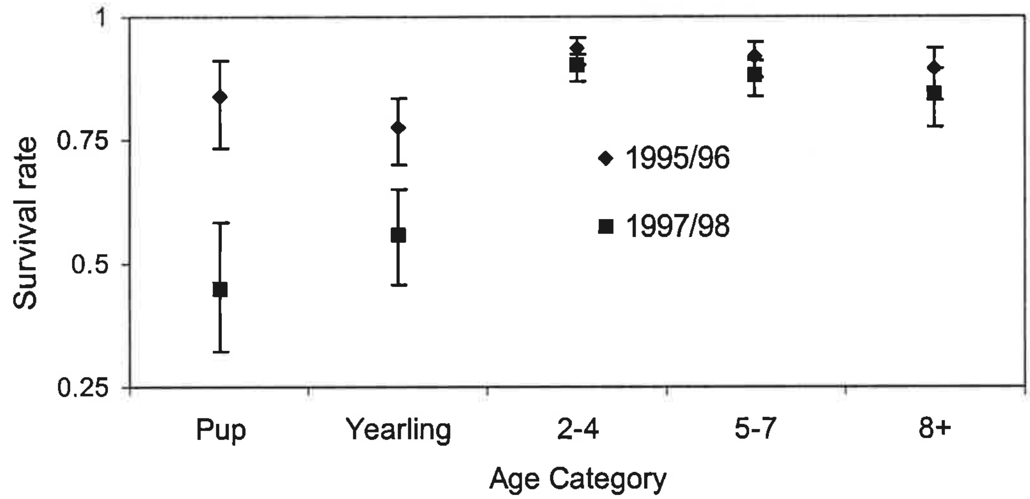
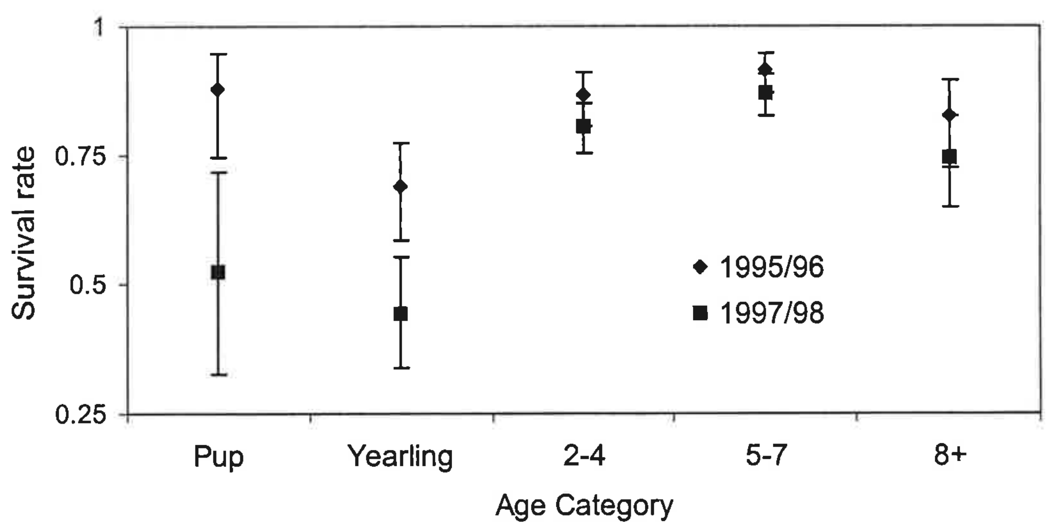


Figure 6. Average survival from branding to first year of pup cohorts branded from 1989-1997. Average was computed by weighting survival rates in each pup-weight group by the proportion of pups in the weight group.



a)



b)

Figure 7. Annual survival rate for female (a) and male (b) California sea lions during a non-El Niño period 1995/96 and an El Niño period of 1997/98. Female pup survival is for the 17.6-19.0 kg weight group and for males the 17.3-20.2 kg weight group.

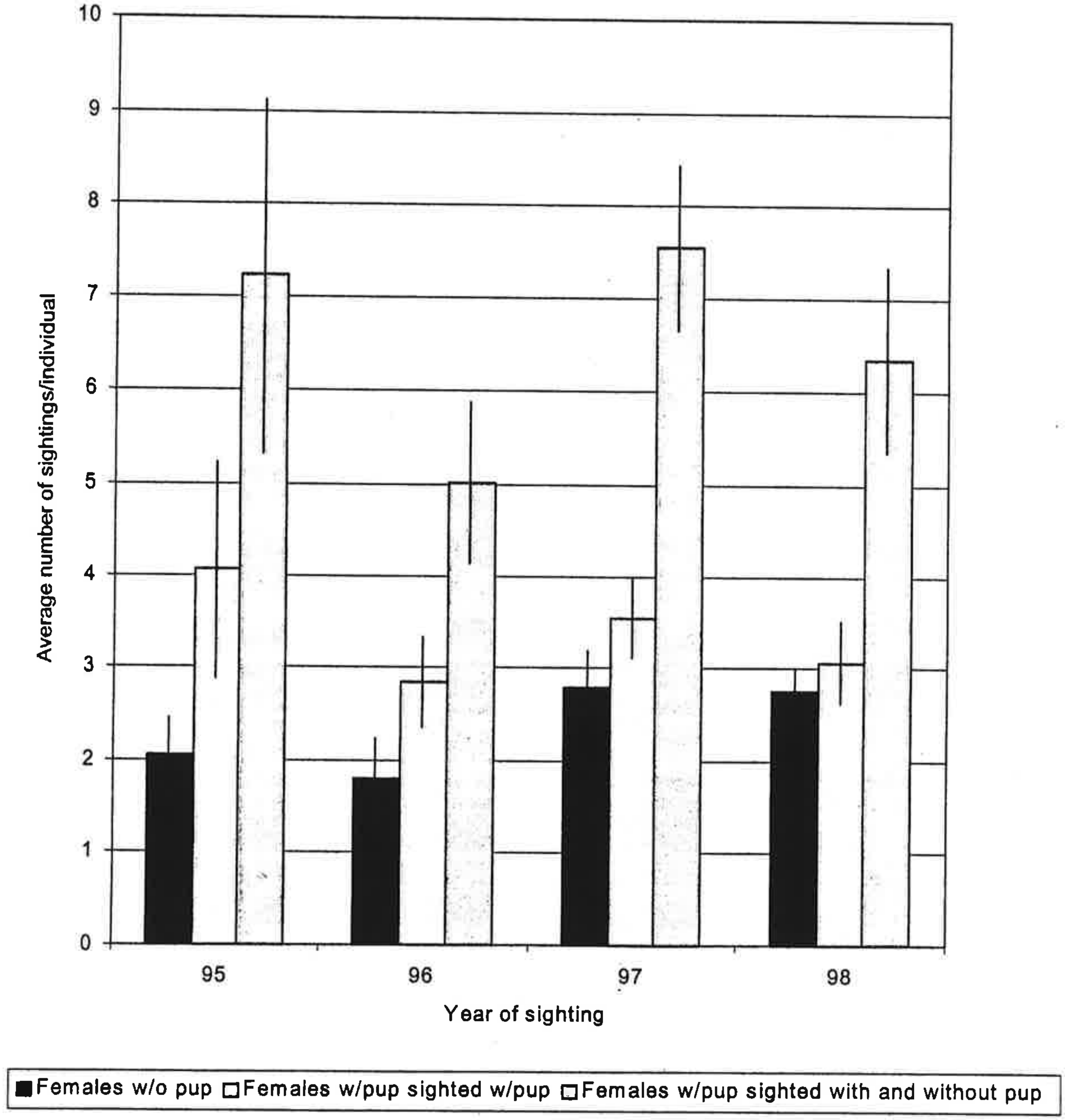


Figure 8. Average number of times (+/- 2 SE) that a female sea lion was seen during the 15 July - 15August season based on their observed association with a pup.

SMALL CETACEAN AERIAL SURVEY OF PRINCE WILLIAM SOUND AND THE WESTERN GULF OF ALASKA IN 1998 AND ABUNDANCE ESTIMATES FOR THE SOUTHEAST ALASKA AND THE GULF OF ALASKA HARBOR PORPOISE STOCKS

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

Abstract

The National Marine Mammal Laboratory (NMML) conducted an aerial survey for small cetaceans from 27 May to 28 July 1998 in Prince William Sound, the western Gulf of Alaska from Cape Suckling to the west side of Kodiak Island (out to the 1829 m (1,000 fm) depth contour), and Shelikof Strait. A total of 9,486 km were surveyed in a Dehavilland Twin Otter at 152.5 m (500 ft) altitude and 185 km/hr (100 kts). Primary observers searched through bubble windows on the left and right sides of the aircraft and reported sightings to a computer operator. To estimate a perception bias correction factor for this study, an independent observer was added at a belly window position to determine the number of animals in the immediate vicinity of the trackline that were missed by the primary observers. There were 83 sightings of harbor porpoise (114 individuals) and 70 Dall's porpoise (122 individuals). No Pacific white-sided dolphins were seen. The 1997 survey data from southeastern Alaska to Cape Suckling were combined with the 1998 survey data to estimate a perception bias correction factor of 2.14 (CV = 0.154). The program DISTANCE was used with the perception bias correction factor and an availability correction factor of 2.96 to produce an abundance estimate of 21,451 (CV = 0.309) for the Gulf of Alaska harbor porpoise stock. Cook Inlet was not included in these surveys; instead, an abundance estimate was produced from harbor porpoise sightings made during a NMML beluga whale survey there (156, CV = 0.645) to make a total Gulf of Alaska stock estimate of 22,951 (CV=0.297, N_{min} = 17,960). The Gulf of Alaska estimate was significantly higher than the previous estimate of 8,497, most likely due to a difference in the area and habitat surveyed. Using the same analysis, the abundance of the Southeast Alaska stock of harbor porpoise, from the 1997 survey, was estimated at 11,337 (CV = 0.265; N_{min} = 9,106). The Southeast Alaska estimate was not significantly different from the previous estimate of 10,301.

Introduction

In 1991 - 1993, the National Marine Mammal Laboratory conducted aerial and vessel surveys to produce a minimum abundance estimate for harbor porpoise (*Phocoena phocoena*) in waters extending from southeastern Alaska to Bristol Bay (Dahlheim et al. in press). A second series of aerial surveys was initiated in 1997 to update the abundance estimate for harbor porpoise and to produce an abundance estimate for Dall's porpoise (*Phocoenoides dalli*) and other small cetaceans in Alaskan waters. The Alaska coastal waters were split into three regions corresponding to the stock boundaries for harbor porpoise. The 1997 survey included the inland waters of southeastern Alaska and the eastern Gulf of Alaska from Dixon Entrance to Cape Suckling (Waite and Hobbs 1998). The 1998 survey included Prince William Sound, the Gulf of Alaska from Cape Suckling to Unimak Pass, and Shelikof Strait (reported here). The 1999 survey covered Bristol Bay in the Bering Sea and will be reported on next year.

Harbor porpoise, Dall's porpoise, and the Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) are the only small cetaceans, other than beluga whales (*Delphinapterus leucas*), commonly found in Alaskan waters. Three harbor porpoise stocks are recognized in Alaska: Southeast Alaska, Gulf of Alaska, and the Bering Sea. The population estimates for these stocks were reported in Hill and DeMaster (1998) as: 10,301, 8,497, and 10,946, respectively. These estimates were based on the aforementioned surveys 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). Known fishery takes do not currently exceed the PBR, but a reliable estimate of human-caused mortality is unavailable due to the lack of fishery 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 harbor porpoise surveys in 1991 - 1993 will become unreliable for stock assessment purposes by the year 1999.

Dall's porpoise occur in both pelagic and coastal waters in Alaska and are considered to be one continuous stock. A corrected population estimate of 83,400 was reported in Hill and DeMaster (1998), 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 Alaskan 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 of 931,000 was made by Buckland et al. (1993b), though this may be an overestimate because no vessel attraction correction factor was applied.

The current study (1997-99) will provide new abundance estimates for each stock of harbor porpoise, and Dall's porpoise. Although the previous harbor porpoise surveys (1991-1993) used a vessel platform for the inside waters of Southeast Alaska (Dahlheim et al. 1992, 1993, 1994), the current survey was conducted entirely from aircraft. However, a concurrent vessel survey in a selected portion of southeastern Alaska and a calibration study with the survey vessel. We report here the results from the second year of surveys (1998) and abundance estimates for surveys conducted in 1997 and 1998.

Methods

Survey Design

Four series of sawtooth lines were designed for the offshore waters between Prince William Sound and Unimak Pass (along the east and south side of Kodiak Island; Fig.1). Each line consisted of two strata. The first strata ("short" sawtooth) went from shore out to 28 km (15 nm) or the 91 m (50 fm) depth contour, whichever was furthest from shore. The second strata ("long" sawtooth) went out to the 1829 m (1,000 fm) depth contour. The base of each sawtooth was approximately 74 km (40 nm) wide. Each series consisted of a pattern of two short sawtooths and one long sawtooth. The start location for each line was chosen as a random number between 0 and 40, based on the number of nautical miles west from Cape Suckling. A similar pattern of tracklines was designed for Shelikof Strait (74 km widths), which zigzagged between the Alaska Peninsula and Kodiak Island. Inlets and bays were surveyed based on their size. Half of the inlets and bays 6 - 11 km (3 - 6 nm) wide and a quarter less than 6 km (3 nm) wide were included. All major passages were also included. Surveys in Prince William Sound consisted of two lines; one covering the central waters and one along the coast with extensions into randomly selected inlets. The study area was stratified into regions based on geographical features and depth (inshore waters, offshore out to 91 m (50 fm) depth contour, and from the 91 m (50 fm) depth contour to the 1,829 m (1,000 fm) depth contour).

Survey Methods

A Dehavilland Twin Otter (NOAA) was used as the survey platform. Line-transect surveys were flown at an altitude of 152.5 m (500 ft) and a speed of 185 km/hr (100 kts). To estimate a perception bias correction factor for this study, an independent observer was added at a belly window position to determine the number of animals in the immediate vicinity of the trackline that were missed by the primary observers. Five observers rotated through 40-minute shifts in positions at the right and left side bubble windows (primary observers), a belly window, a computer, 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 aircraft 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. Environmental conditions included percent cloud cover, sea state (Beaufort scale), visibility (an overall determination from excellent to unacceptable of how each observer felt they could see a porpoise), and glare (no glare, minor glare, bad glare, or reflective glare) experienced by each observer. When a sighting was made, the observer called out "mark" when the animal location crossed the beam line of the plane. The observer used an inclinometer to obtain the distance (vertical angle) of the animal from the plane. At the "mark", the recorder hit the appropriate computer key corresponding to the observer's position; this recorded the time and position from the GPS unit. The observer then reported the species, vertical 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 any environmental changes that occurred along a trackline. The two primary observers searched through bubble windows which allowed each to see slightly more 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 of the primary observers. Belly window sightings included species, number of animals, and position seen in the belly window defined by six vertical zones across the window.

Analysis

The 1997 survey data (Waite and Hobbs 1998) were combined with the 1998 survey data to estimate perception bias from comparisons of the belly window and primary observer sightings. Sightings were considered matches (sightings of the same group seen by both observers), if they occurred within 5 sec, were not greater than 10° angular distance, and met other conditions such as similar group size. Two experienced reviewers checked the matches independently and then discussed differences until both agreed on the results. Matched sightings were used to estimate an empirical average distance from the trackline for each sighting zone at the belly window, based on the quantifiable distances given from the side windows. Matched sightings also provided an estimate of probabilities of species misidentification. Probabilities were assumed to fit a binomial model and were estimated by maximum likelihood. Observations by belly window observers with less than 95% reliability were not included in the analysis. Matched and unmatched sightings within 50 m of the trackline were analyzed using logistic regression with an offset (cf. Buckland et al. 1993a) to estimate perception bias for the primary observers.

The line-transect analysis program DISTANCE (Laake et al. 1993) was used to estimate the abundance of harbor porpoise in each stock separately. Only data from primary observers were used. The average distance of sightings from the trackline by strata were used to identify significant covariates. Visibility levels, glare types, percent cloud cover, sea state (Beaufort scale), and individual observers were considered as possible covariates. Sightings were then stratified accordingly. Distances were pooled into 50 m bins to remove bias from angle estimation rounding and allow application of the perception bias estimate. Densities, which included the correction factor for perception bias, were estimated for the regions individually. Inlets that were not surveyed were grouped into regional areas (southeastern Alaska, Prince William Sound, Kenai Peninsula, Alaska Peninsula, and Kodiak Island). Density estimates produced for surveyed inlets from the corresponding areas were then used to extrapolate abundance estimates for the unsurveyed inlets. An abundance estimate was also extrapolated for a portion of Frederick Sound in southeastern Alaska that was not surveyed based on two adjoining surveyed portions. All regions and unsurveyed inlets were then combined to estimate an uncorrected (for availability) abundance for each stock . An appropriate correction factor for availability bias (2.96; CV = 0.180) (Laake et al. 1997) was applied to the observed abundance estimates to produce the complete abundance estimate for each stock. The correction used in the previous surveys (3.1) from Calambokidis *et al.* (1993) was not used since it incorporated both visibility and perception bias.

Cook Inlet was not included in these surveys, but was surveyed concurrently in 1998 for beluga whales by a separate NMML aerial team (Rugh et al. 1999). The aircraft used was an Aero Commander with bubble windows, although the windows were smaller than the Twin Otter bubble windows, and the observers could not see directly below the plane. Survey methods were similar, except that the survey was conducted at an altitude of 244 m and the primary focus was to find beluga whales. The search effort, therefore, was not concentrated close to the trackline where harbor porpoise are typically seen. NMML has conducted these beluga whale surveys each year since 1993. All harbor porpoise sightings from the offshore transects in the beluga surveys from 1993 to 1999 (with a known distance from the trackline) were used to estimate the strip width for harbor porpoise in the beluga surveys. The tracklines and sightings from 1998 only were used to estimate the abundance of harbor porpoise in Cook Inlet for that year. This abundance estimate was then corrected for availability bias and added to the abundance estimate from the Gulf of Alaska survey to produce a complete estimate for that stock.

A similar analysis is planned for Dall's porpoise but will include the 1999 survey data as well. Only one sighting of Pacific white-sided dolphins was made in 1997 and 1998 surveys, so a similar analysis is not possible for this species.

Results

The line-transect aerial survey was conducted 27 May to 28 July 1998 in Prince William Sound, the western Gulf of Alaska (from Cape Suckling to the west side of Kodiak Island), and Shelikof Strait (Fig. 1). Gaps in the survey effort occurred due to inclement weather primarily off the Kenai Peninsula and the southern side of the Alaska Peninsula west of Kodiak Island. A total of 9,486 km were surveyed on effort. Sightings locations of harbor porpoise (83 sightings, 114 individuals) and Dall's porpoise (70 sightings, 122 individuals) are shown in Figures 2 and 3. No Pacific white-sided dolphins were seen in 1998. Numbers of all marine mammals sighted during the surveys are shown in Table 1 (these include sightings from all observer positions with double counts removed). Eight harbor porpoise were sighted during the Cook Inlet beluga whales survey in 1998.

Harbor porpoise abundance estimates were made for each region within the 1997 (Waite and Hobbs 1998) and the 1998 study areas. Estimates from regions within each stock area were then combined to produce an overall abundance for each stock (Table 2). No significant variation in mean sighting distance from the trackline resulted from stratification by individual observer, visibility level, glare type, percent cloud cover, and sea state. Inexperienced observers at the belly window were found to have low reliability (<95%) for distinguishing among harbor porpoise, Dall's porpoise, and harbor seal, therefore, these data were not included in the analysis. A total of 62 potential matches between primary observers and belly window observers were used to estimate a perception bias of 0.47, yielding a correction factor of 2.14 (CV = 0.154). A correction factor of 2.96 (CV = 0.180) (Laake et al. 1997) was applied to account for availability bias. The full correction for visibility bias was then 6.32 (= 2.96/0.47; CV = 0.237). Approximately 5% of the study areas were unsurveyed, primarily inlets. Density estimates for these unsurveyed areas were extrapolated from similar surveyed areas in the same regional area (Table 3). The abundance estimate for the Southeast Alaska stock of harbor porpoise was 11,337 (CV = 0.265; N_{min} = 9,106, Table 2) and is not significantly different from the 1993 estimate. The abundance of Gulf of Alaska stock, which includes the Cook Inlet harbor porpoise abundance estimate, was 22,951 (CV = 0.297; N_{min} = 17,960, Table 2). This estimate is significantly different from the 1991 - 1993 estimate of 8,497 (t-test, natural log of means, $p<0.01$).

Discussion

The abundance estimates for the Southeast Alaska harbor porpoise stock did not change significantly from the 1993 estimate (10,301 porpoise, Hill and DeMaster 1998) to the 1997 estimate (11,337 porpoise). The estimated abundance from the earlier surveys was from a combination of vessel surveys in the inside waters of southeastern Alaska and aerial surveys offshore. However, the 1997 survey used an aerial platform for both inside and offshore waters. Different correction factors appropriate for the different survey platforms were applied to the earlier survey estimates, and the vessel surveys were conducted in different seasons than the 1997 aerial survey. The 1998 also surveyed further offshore than the earlier surveys. For these reasons, the two abundance estimates may not be entirely comparable. In 1997, a vessel survey was conducted in Glacier Bay and Icy Strait, which included a calibration experiment with the aerial platform. Analysis of these data is in progress. Two methods of comparison will be used:

1) abundance estimates will be compared between the 1997 aerial survey and the 1997 vessel survey conducted in the Glacier Bay/Icy Strait region. These two surveys were close in time (aerial: 28, 29, 30 May; vessel: 31 May to 5 June), so it may be assumed that there was insignificant immigration and emigration between surveys, 2) analysis of the calibration experiment will provide a correction for missed porpoise.

The abundance estimates for the Gulf of Alaska harbor porpoise stock changed significantly from the 1991 - 1993 estimate (8,497, Hill and DeMaster 1998) to the 1998 preliminary estimate 22,951. This represents an annual increase of 20% over 5 years. There may have been a real increase in the population, although an increase at this large scale is considered unlikely. Alternatively, differences in the areas and habitats surveyed most likely account for the difference in abundance estimates. The 1991 - 1993 survey included offshore waters of Prince William Sound, Kodiak Island (and Shelikof Strait) and the Alaska Peninsula only. It did not include bays, channels, or inlets. Although harbor porpoise occur in both nearshore and offshore waters, concentrations of animals tend to occur more often in nearshore waters, sometimes in bays and inlets. Also, the study area in the 1998 survey covered areas offshore of Kodiak Island and Prince William Sound to the 1829 m (1000 fm) depth contour (>100 nm offshore) while the earlier survey only flew 30 nm offshore, and the 1998 survey included offshore of the Kenai Peninsula to the 91 m (50 fm) depth contour which was not covered at all in the earlier survey. Harbor porpoise were found over shelf areas in some of these offshore regions. Including these nearshore and offshore water features in the 1998 survey resulted in an abundance estimate representing a larger area of harbor porpoise habitat for the Gulf of Alaska stock.

A basic assumption in line-transect theory is that all animals are seen on the trackline. However, this assumption is violated in marine mammal surveys because animals are not available to be seen while diving (availability bias) and because animals are missed due to environmental conditions or because observers do not always perceive 100% of the available sighting cues (perception bias; Marsh and Sinclair 1989). Correction factors for availability bias in aerial surveys of harbor porpoise were estimated at 2.96 (CV=0.180) (Laake et al. 1997) from Puget Sound, Washington, and 3.2 (Barlow et al. 1988) from the west coast of the continental United States. A correction factor for a combination of both perception and availability bias was estimated at 3.1 (CV = 0.171) from the Puget Sound study (Calambokidis et al. 1993). We estimated a perception bias for this study (2.14) with the independent belly window observer, and so only needed an additional correction for availability bias. The correction factor of 3.2 of Barlow et al. (1988) includes untested assumptions regarding observer behavior and visibility of harbor porpoise during surfacing intervals which, although reasonable, are not required in the treatment of Laake et al. (1997). The correction of 2.96 for availability bias, therefore, was used for the two harbor porpoise stocks in this study.

Stratification by observer or environmental condition was not considered necessary for this data set because significant differences in the mean sighting distances were not found. This can be explained in part by the relatively narrow estimated strip widths for harbor porpoise (1997, 0.194 km; 1998, 0.155 km). Preliminary analysis of Dall's porpoise data from these two years of surveys, with a larger estimated strip width of 0.255 km, do show significant variation in mean sighting distance for several of these stratification schemes. Also, survey effort was typically terminated when environmental conditions were considered poor, so little data from extreme conditions are available.

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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.

Buckland, S. T., J. M. Breiwick. K. L. Cattanach, and J. L. Laake. 1993a. Estimated population size of the California gray whale. Mar. Mammal Sci. 9(3):235-249.

Buckland, S. T., K. L. Cattanach, and R. C. Hobbs. 1993b. 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. 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 pp.

Dahlheim, M., A. York, J. Waite, and R. Towell. 1994. Abundance and distribution of harbor porpoise (*Phocoena phocoena*) in Southeast Alaska, and the offshore waters off Dixon Entrance to Prince William Sound, 1993. Annual Report for 1993 to the Office of Protected Resources, NMFS, NOAA, 1335 East-West Highway, Silver Springs, MD 20910, 52 pp.

Dahlheim, M., A. York, J. Waite, and R. Towell. 1993. Abundance and distribution of harbor porpoise (*Phocoena phocoena*) in Southeast Alaska, Kodiak Island and the south side of the Alaska Peninsula, 1992. Annual rept. to the Office of Protected Resources, NMFS, NOAA, 1335 East-West Highway, Silver Springs, MD 20910, 52 pp.

Dahlheim, M., A. York, J. Waite, and C. Goebel-Diaz. 1992. Abundance and distribution of harbor porpoise (*Phocoena phocoena*) in Southeast Alaska, Cook Inlet and Bristol Bay, Alaska, 1991. Annual rept. to the Office of Protected Resources, NMFS, NOAA, 1335

East-West Highway, Silver Springs, MD 20910, 54 pp.

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., and D. P. DeMaster. 1998. Alaska marine mammal stock assessments, 1998. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-97, 166 pp.

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 report to the MMPA Assessment Program, 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 pp.

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. Wildl. Manage. 61(1):63-75.

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.

Marsh, H., and D. F. Sinclair. 1989. Correcting for visibility bias in strip transect aerial surveys of aquatic fauna. J. Wildl. Manage. 53(4):1017-1024.

Rugh, D.J., Hobbs, R.C., Shelden, K.E.W., Mahoney, B.A., and Litzky, L.K. 1999. Surveys of beluga whales in Cook Inlet, Alaska, June 1998. Paper SC/51/SM11 presented to the Int. Whale Comm. Scientific Committee, May 1999 (unpublished).

Turnock, B. J., and T. J. Quinn. II 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 pp.

Waite, J. M., and R. C. Hobbs. 1998. Small Cetacean aerial and vessel survey in Southeast

Alaska and the eastern Gulf of Alaska, 1997. Annual Report for 1997 to Office of Protected Resources, NMFS, NOAA, 1335 East-West Highway, Silver Springs, MD 20910, 13 pp.

Table 1. Marine mammal sightings made during the 1998 survey. Numbers in parentheses are sightings made incidental to the systematic effort.

Species	Number of sightings	Number of animals
Harbor porpoise (*Phocoena phocoena*)	83 (12)	114 (15)
Dall's porpoise (*Phocoenoides dalli*)	70 (14)	122 (36)
Killer whale (*Orcinus orca*)	13 (1)	30 (10)
Cuviers beaked whale (*Ziphius cavirostris*)	1	6
Sperm whale (*Physeter macrocephalus*)	(2)	(3)
Fin whale (*Balaenoptera physalus*)	24 (19)	37 (37)
Humpback whale (*Megaptera novaeangliae*)	47 (30)	75 (45)
Northern right whale (*Eubalaena glacialis*)	(1)	(1)
unidentified dolphin/porpoise	14 (3)	16 (5)
unidentified large whale	30 (31)	46 (63)
Harbor seal (*Phoca vitulina*)	25 (5)	40 (20)
Steller sea lion (*Eumetopias jubatus*)	20 (3)	77 (48)
Northern fur seal (*Callorhinus ursinus*)	1	1
unidentified pinniped	8 (1)	10 (2)

Table 2. Abundance estimates for the stocks of harbor porpoise in Southeast Alaska and Gulf of Alaska in 1997 and 1998, respectively.

	Southeast Alaska stock		Gulf of Alaska stock		Cook Inlet Survey	
	Estimate	CV	Estimate	CV	Estimate	CV
Study area (km^2)	106087		119182		18948	
Total trackline (km)	9844		9486		1355	
Sightings	111		68		7	
g(0) Correction	2.14	0.034	2.14	0.034	1	
Effective strip width (km)	0.194	0.014	0.150	0.087	0.476	0.371
Average group size	1.18	0.041	1.34	0.046	1.20	0.046
Average density of sightings	0.028	0.204	0.045	0.247	0.007	0.644
Average density of porpoise	0.033	0.207	0.061	0.252	0.008	0.645
Observed abundance	3550	0.207	7247	0.252	156	0.645
Extrapolated area (km^2)	6539		4722			
Abundance in extrapolated area	280	0.398	351	0.557		
Total uncorrected abundance	3830	0.194	7754	0.237		
Correction for availability	2.96	0.180	2.96	0.180		
Total abundance	11337	0.265	22951	0.297		
N_{min}	9106		17960			
Lower 95% confidence limit (Log-normal distribution)	6807		12969			
Upper 95% confidence limit (Log-normal distribution)	18880		40615			

Table 3. Abundance estimates of inlets and channels not surveyed based on densities in similar surveyed areas.

	SE Alaska Inlets	Frederick Sound (portion)	SE Alaska Total	Kenai Peninsula	Kodiak Island	Alaska Peninsula	Prince William Sound	Gulf of Alaska Total
Number surveyed	32	2	34	3	9	2	5	19
Area studied (km^2)	4792	2564	7356	439	2782	202	4188	7611
Weighted average density	0.041	0.073		0.142	0.189	0.000	0.000	
Weighted SD of density	0.139	0.054		0.089	0.350	0.000	0.000	
Weighted CV of density	3.412	0.744		0.627	1.850			
Number not surveyed	326	1	327	15	17	21	9	62
Area not surveyed	6135	404	6539	662	1356	1617	1087	4722
Abundance in unsurveyed inlets	250	29	280	94	257	0	0	351
SE of Abundance	109	22	111	25	194	0	0	195
CV of Abundance	0.436	0.744	0.398	0.265	0.755			0.557

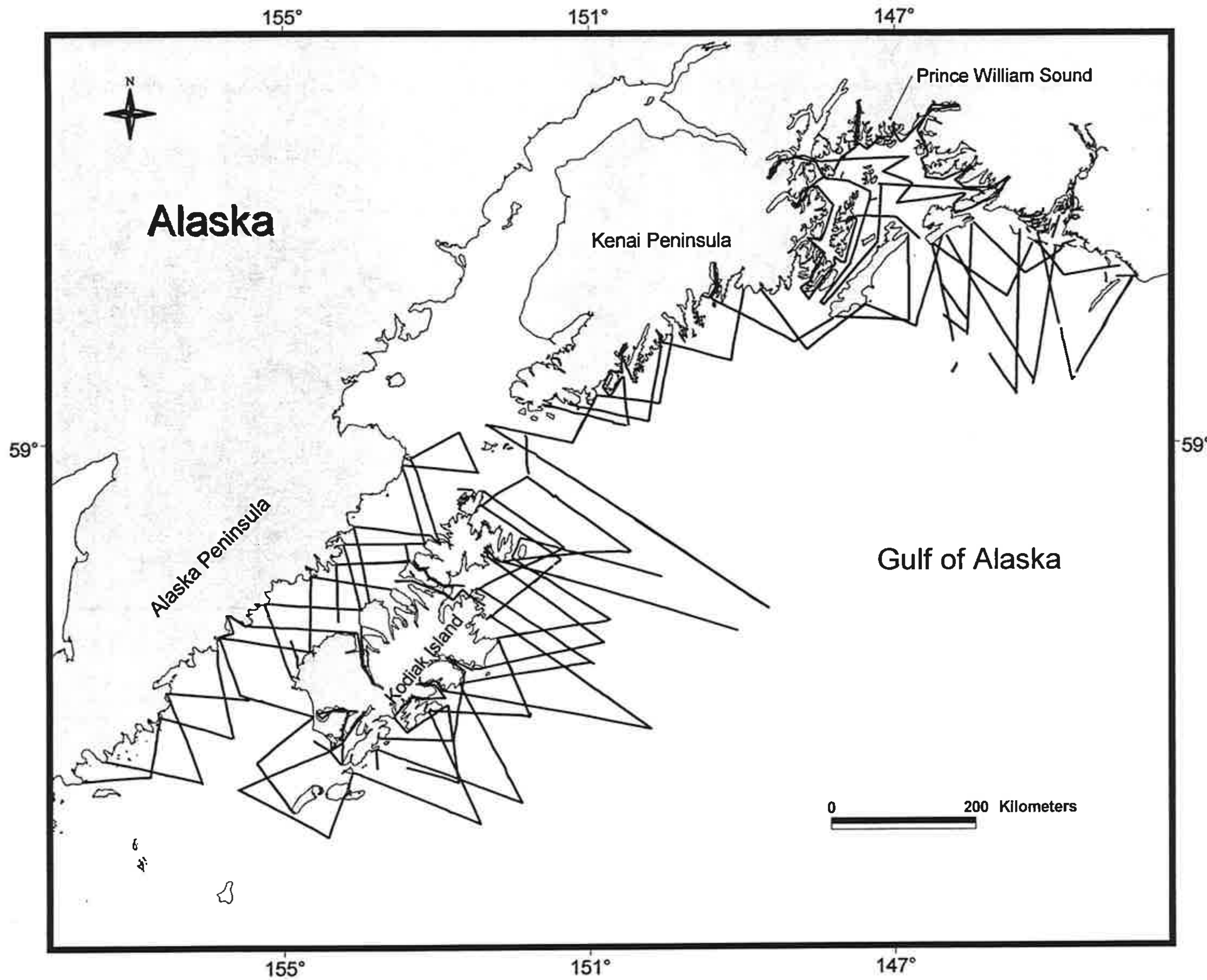

Figure 1. Aerial survey tracklines completed during the 1998 small cetacean survey.

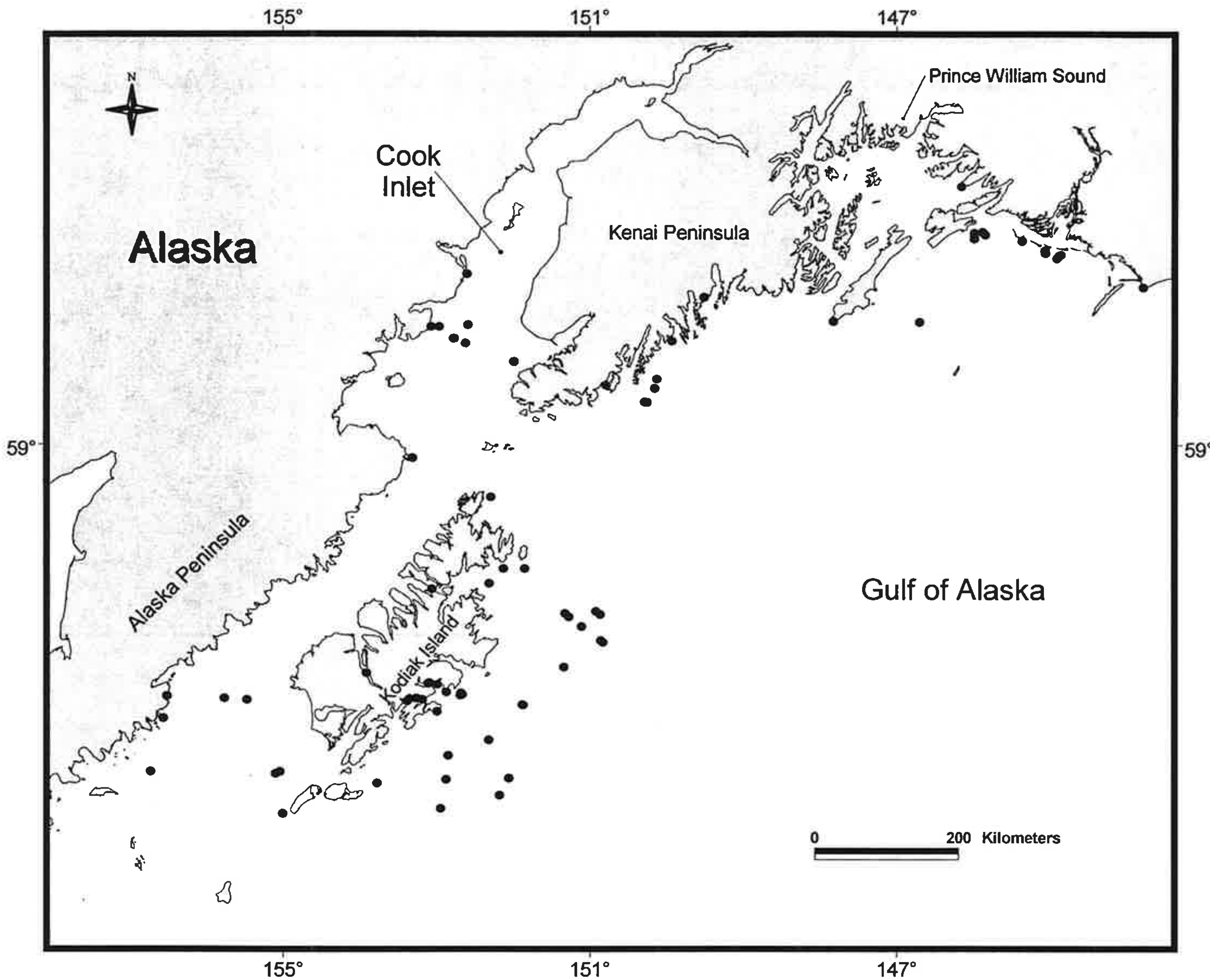

Figure 2. Harbor porpoise sightings made during the 1998 aerial survey. Sightings in Cook Inlet were made during the NMML 1998 beluga whale survey.

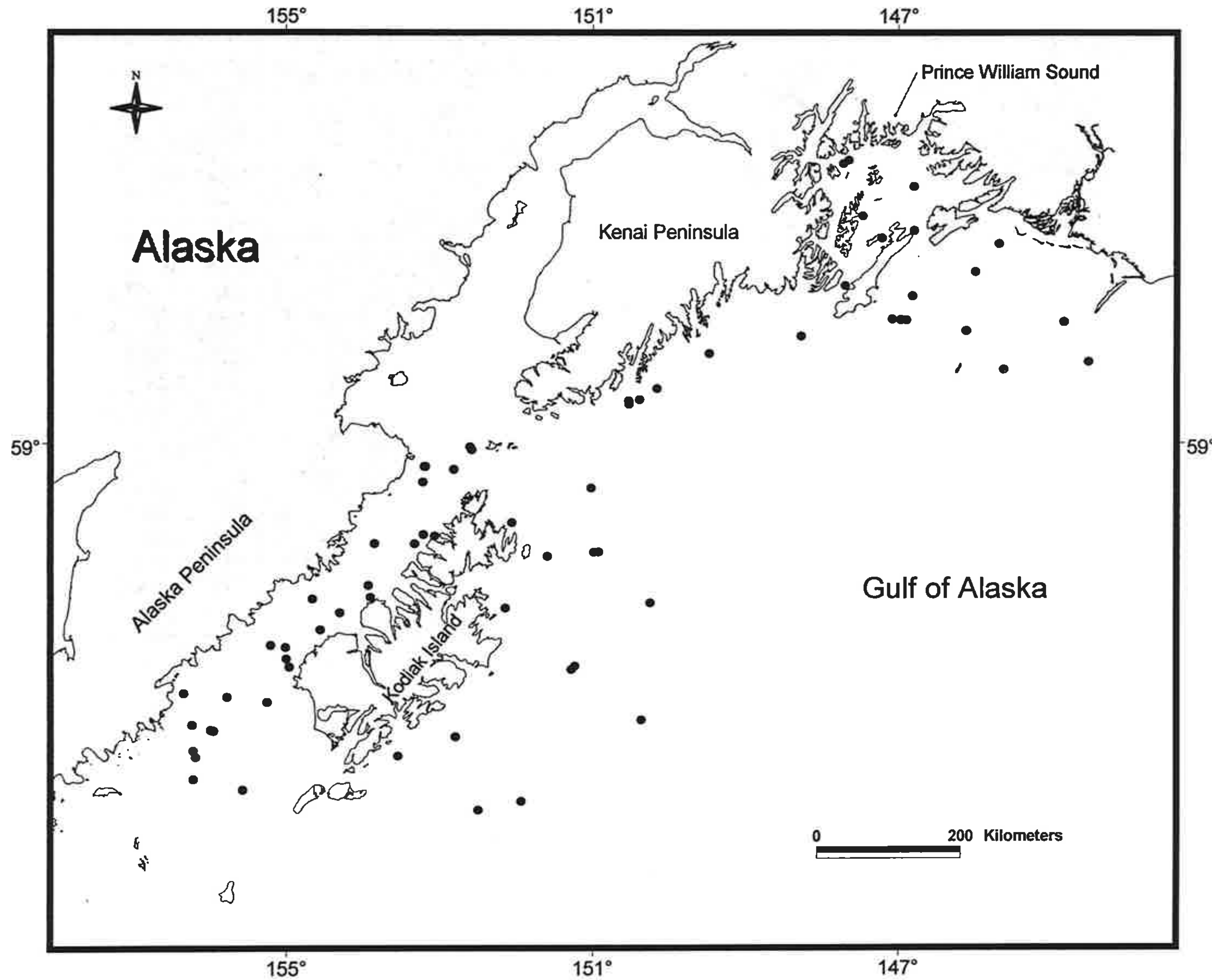

Figure 3. Dall's porpoise sightings made during the 1998 aerial survey.

A PRELIMINARY EVALUATION OF THE RELATIONSHIP BETWEEN SMALL CETACEAN TAG DESIGN AND ATTACHMENT DURATIONS: A BIOENGINEERING APPROACH

M. Bradley Hanson and Wenhong Xu

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

Abstract

Only recently have dorsal fin-mounted small cetacean telemetry tags begun to consistently remain attached for extended periods of up to several months. Although reasons for successes and failures have in many cases remained unclear (due to a paucity of re-sights following signal loss), several observations have documented the structural failure of the tag saddle, attachment pins, or dorsal fin tissue. All materials, including biological tissues, have inherent strength characteristics such that structural failures are a function of the mechanical properties of these components and the loads to which they are subjected. In several cases, dorsal fin tissue has been observed to degenerate at the pin sites, likely from pressure caused by tag drag, allowing pin out-migration and tag loss. A finite element analysis was conducted to examine load distributions in a harbor porpoise dorsal fin for the three most commonly deployed tag configurations (front-mount, single side-mount, and paired side-mount). Material properties for saddles and pins were based on published values and those of the dorsal fin were determined by mechanical testing. Load cases were developed using drag data from wind tunnel testing (simulating velocity phases during typical dive cycles of a free-ranging harbor porpoise collected by Time Depth Recorder(TDR)) and two yaw positions to approximate loads during turns. Although the front-mount tag produced only slightly greater drag compared to the single side-mount (at typical swim speeds and zero yaw), it generated greater drag and higher stress concentrations in the tissue at the pin sites in a yawed state, possibly accounting for the generally shorter attachment durations suspected for front-mounts. The paired side-mount configuration, despite having a similar total drag load than the single side-mount, had substantially lower stress concentrations at the pin sites in both yaw positions. This lower stress may have promoted extended attachment durations (7+ months), exceeding many of the multi-month attachment durations of the single side-mount.

Introduction

Although small cetaceans have been tagged for over 35 years with a variety of telemetry devices, this technique has yet to gain its place as a standard research tool for these species, as it has for pinnipeds, many fish, as well as terrestrial mammals. Part of the reason this technique has likely not been fully embraced by small cetacean researchers is due to premature signal loss. Although some recent studies have made progress in attaining multi-month deployments, a substantial amount of variability still remains and the underlying reasons for these "successes" remains unclear. An inherent problem to improving this technique has been a general lack of resights following signal loss which has limited researchers ability to ascertain the sources of the failures. As a result, tag/attachment design schemes are based on a limited understanding of the factors influencing the attachment longevity. Although the number of animals resighted following signal loss has been very limited, those observed have provided some valuable information on the associated failure modes. One cause of tag loss that was documented early on, was degeneration of the dorsal fin tissue allowing pin out-migration and was suggested to be a result of pressure necrosis (Irvine et al. 1979). This type of necrosis represents a structural breakdown of the tissue as a result of extended periods of load concentrations that occlude blood flow (Levy 1962) in the tissue adjacent to the pins that secure the tag. However, it is important to note that tag attachments are essentially percutaneous devices experiencing dynamic loads in an aquatic environment such that others factors could be associated with tissue breakdown. For percutaneous devices, tissue degeneration might be expected to occur at these sites; 1) as a foreign body response due to the interaction of the pinning material and adjacent tissue (von Recum and Park 1981), 2) from infection due to a bacterial invasion of the wound (von Recum and Park 1981), 3) due to pressure necrosis, from chronic stress concentrations which occlude blood flow (Levy 1962), or 4) due to mechanical stresses disrupting the healing process (von Recum and Park 1981).

Biocompatibilty of the pinning materials with marine mammal skin has been examined in implant studies conducted on captive animals (Geraci and Smith 1990). Because most of the test materials stimulated a foreign body response and were readily rejected, it was suggested that the constant exposure of open wounds to the non-sterile aquatic environment allowed 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 as the attachment pins for a killer whale tag (4.5+ months, Erickson 1978). In addition, infections have typically not been observed at pin out-migration sites in studies using free-ranging animals (Irvine et al. 1982, Martin and da Silva 1998). The lack of observed infections may be associated with the saline content of seawater or robust immune systems of the animal. These results suggest that a tissue's response to loading stress (caused by the additional drag of the tag or other loads) may be of greater influence on tag retention than pin biocompatibility or infection.

Dorsal fin tissue is biomaterial with inherent strength characteristics. Like the performance of any material, its failure will be related to the magnitude and frequency of the loads its experiences. Dorsal fins are more elastic than the pins and tag saddles that are typically attached to them, such that the mismatch in their material properties likely results in stress concentrations in the tissue surrounding the attachment site. For a given load regime the stress distribution within the fin will be a function of the structural composition of the tissue and the attachment scheme's configuration, which is dependent on the position of the tag on the fin and the number, diameter, and location of pins. If the stress is sufficient to occlude blood flow, pressure necrosis and tissue degradation will ensue. While observations of tissue degradation have typically been attributed to pressure necrosis (Irvine et al. 1982, Martin and da Silva 1998, Orr et al. 1998), it is unknown if the pressure that these, or any other tags cause, is sufficient to occlude blood flow. Tissue degradation due to mechanical stresses disrupting the tissue healing will be a function of the dynamic movement of the tag. The frequency and magnitude of these movements, besides being dependent on the swimming and diving behavior of the animal, are also likely a function of the position of the tag and the number and arrangement of the pins. Quantifying the frequency and magnitude of swimming and diving behavior in free-ranging small cetaceans has only recently been accomplished with time-depth recorders, although these data are currently limited to depth and velocity (Hanson and Baird unpubl. data) and thus lack heading information. The variety of positions tags have been placed on the fin (leading edge, or one side, or both sides), as well as the various number of pins used (one to six) and arrangements (straight vs. X pattern), indicates a general lack of understanding of this factor by researchers and confounds an assessment of each aspect's influence.

Little information is available on the loads different tag/attachment configurations create in the fin under normal animal behavior. An initial attempt to relate tag load to duration of attachment looked at the proportional drag increase for a given tag design on a model porpoise tested in a wind tunnel relative to the design's typical duration of attachment (Hanson et al. 1998a). Although this approach was the first to quantify the total load that a tag generates and demonstrated that wind tunnel data appeared to be suitable for explaining some observed differences in observed attachment longevity, it could not explain all the observed differences suggesting that a more sophisticated model was required.

Finite element analysis (FEA) is a routinely used computer-based modeling procedure which allows the mechanical analysis of the an engineered structure. It can be used to approximate numeric solutions for the mechanical deformation and stresses on a structure exposed to external forces within the constraints of the physical laws that underlie force equilibrium. Using this technique to evaluate the stress distribution that various tag configurations create in the tissue of a dorsal fin requires the division of the fin's component parts into small, polygonal finite elements that together, fit the actual geometry. The tag components (transmitter, saddle, attachment pins) are similarly defined. Together, these elements represent the mesh of the finite element model where the intersections of the vertices of the adjacent elements are defined as the nodes. The material properties (the stress behavior under strain) of each material component of the model is assigned to the appropriate element. These material properties are obtained from mechanical testing of these components. For commonly available materials, published values of their specifications are readily available. Other materials, such as dorsal fin tissue, need to be tested on a uniaxial or biaxial tester. Boundary conditions are specified to fix a portion of the model so that it remains in place rather than moving as a rigid body when the load cases of interest are applied. The nodal displacements are then solved for and estimates of the associated stresses are calculated and displayed graphically.

This report describes the development of a three-dimensional finite element model of a harbor porpoise dorsal fin with the three most commonly used telemetry tag placements subjected to loads that are expected to occur during normal swimming. This is the first model of its kind and thus represents a preliminary attempt to quantify the stresses dorsal fin tissues experience for these different tag/attachment configurations for comparison to their attachment longevities.

Methods

Geometries

A fiberglass model of the dorsal fin was made from a mold taken from a carcass of a 1.54 m adult male harbor porpoise killed incidental to commercial fishing operations in Washington State to define the fin's external geometry. X, y, and z coordinates were measured relative to the base of the fin along a plane at its insertion point on the body. The external geometry of the fin was determined by tracing the outline of the base and side of the fin on grid paper to provide the x and y coordinates and the thickness of the fin was measured every 6 mm back from the leading edge on a series of lines spaced 6 mm up from the base. These values were input into a data base.

Dorsal fins are an appendage primarily composed of connective tissue (Felts 1966, Elsner et al. 1974), primarily collagen fibers (Parry and Craig 1980), and its vascularization serves an important thermoregulatory role for internal reproductive organs (Rommel et al. 1992, 1993). The structural integrity of the fin is provided by the connective tissue which composes a vertically oriented ligamentous layer below the skin and surrounds a core in which the fibers are arranged as a matrix (Elsner et al. 1974). Consequently, three layers were defined; the dermis, vertical sheath, and central matrix, and measurements of the thickness of each these components were made from the formalin preserved fin of a 170 cm long adult female harbor porpoise. Thickness of the internal layers were made 10 mm up from the base of the fin near the posterior end of the fin (overall thickness 1.8 cm, dermis 0.3 cm, and vertical sheath 0.1 cm), mid-fin (overall thickness 2.3 cm, dermis 0.3 cm, and vertical sheath 0.15 cm), and near the posterior end of the fin (overall thickness 0.8 cm, dermis 0.25 cm, and vertical sheath 0.05 cm). Measurements were also made 2.5 cm down from the tip at a point where the overall thickness was 1.0 cm (dermis 0.2 cm, vertical sheath 0.05 cm). Thicknesses were extrapolated for component thickness between these two locations and coordinates were input relative to the external geometry of the fin. The three tag designs used in the analysis were based on dimensions of a front of the dorsal fin mounted and a single-side mounted configurations of Telonics ST-10 transmitters used by Read and Westgate (1997), and a pair of side mounted tags which included a ST-10 and VHF transmitters in a streamlined urethane saddle used by Hanson (unpubl. data). Pin diameters were 8 mm for the front mount tag and 6.4 mm for both side mounts. All coordinates were entered into ABAQUS structural analysis software (Hibbitt, Karlsson & Sorensen, Inc.,Pawtucket, RI, Version, 5.8).

A finite element mesh of composed of 2368 eight node isoparametric brick elements (ABAQUS element type C3D8R) were used to complete all the component layers of the dorsal fin. The top 2.5 cm of the fin was excluded to minimize the number of elements in order to reduce file size and model processing time. Within the brick elements where pins were located wedge elements were used. The reduced element type was selected because the dorsal fin is a soft tissue. The front mount tag was constructed of six node isoparametric cylindrical elements (C3D6) and the saddle was constructed of eight node brick elements (C3D8R) totaling 288 elements. For the single and paired side mounts eight node brick elements (C3D8R) were used, with a number of elements totaling 554 and 1108 respectively. Each of the three pins was constructed of a total of 112 six node cylindrical elements. An example of a complete finite element model (FEM) with a side-mount tag is presented in Figure 1.

Boundary Conditions

All the nodes on the base of the dorsal fin model were set to zero displacement because no movement is expected where the base is connected to he body. The contacts used were; tag and fin, pin and fin, and fin and tag. No interface elements were used to model these surfaces do to a high degree of complexity. Instead, equations were used to constrain the displacement.

Material Properties

Young's modulus (E) characterizes the stress/strain relationship (stiffness) of materials. It is determined by calculating the slope of a stress/strain diagram of the material as measured when subjected to tension or compression. Because no data existed for the material properties of dorsal fin component layers these were measured experimentally under uniaxial tension. Three regions have been described for the stress/strain curves of soft biological tissues; pre-transition, transition and post-transition (Duck 1990). Relatively large elongation for small increases in applied loads occur with initial loading, the pre-transition region, whereas less elongation occurs for the same stress increase in the post-transition area. Tag attachments subjected to normal loads associated with swimming and diving are expected to be in the pre-transition range (Hanson unpubl. data). The Young's modulus for dermis was determined (approximated based on slope of the initial 2% of the stress/displacement plot) to be 0.82 N/mm^2; vertical sheath, 4.8 N/mm^2; and central matrix, 0.44 N/mm^2.

Because the degree to which a deformable body contracts laterally as it elongates when put under tension is a function of its material properties, the ratio of the change in length relative to original length and the change in radius divided by its original radius (Poisson's ratio, ν) must be incorporated in the model. Biological tissues are generally considered to be incompressible and thus are typically assigned values between 0.45 and 0.49. A Poisson's ratio of 0.45 was used in this study based on its use in another study which also had tissue with a high collagen content (mitral valve, Kunzelman et al. 1993)).

Load Cases

Five load phases associated with surfacing/diving pattens have been identified based on analyses of time-depth recorder (TDR) data (which included a velocity meter) deployed on a free-ranging harbor porpoise (Hanson unpubl. data). These general features include: 1) air/water transition, 2) early dive acceleration, 3) mid dive stabilization, 4) late dive deceleration, 5) water/air transition. A preliminary analysis of a four hour subset of a 39 hour TDR record indicated a mean velocity of 6.6 km/h for all phases combined (Hanson unpubl. data). Because the flow to the velocity turbine is likely disrupted by the suction cup that is located in front, the velocity meter requires calibration in order to correct the speed. An analyses of velocity meter readings compared to rate of change of the depth pressure sensor indicated that the velocity meter was likely under reporting the true velocity by at least 15% (S. Blackwell, pers. com.). Correction for this yields a mean swim velocity of 7.6 km/h. This speed in sea water corresponds to a dynamic pressure of approximately 8q for data collected on life-size porpoise model in a wind tunnel. The load each tag design generated was determined by subtracting the baseline load of the porpoise model by itself from the load of the porpoise and the tag design.

Results

Of primary interest were the compressive stresses that develop at the pin/tissue interface. The material property testing had determined that the vertical sheath is the primary load bearing component, being about 5 times stronger than the dermis and 10 times stronger than the central matrix. As a result, it sustained the highest compressive stresses of the three primary layers. Consequently, for each tag design and load case the compressive stress on the tissue at the pin/tissue interface was recorded.

At the average simulated swim speed and zero yaw the front mount generated the highest compressive stress (2.72 mN/mm^2) of the three tags (Table 1). This was about 30% higher than the single side mount, and 135% higher than the paired side mount. Similarly, the front mount created the greatest tissue load (6.78 mN/mm^2) at 10 degree yaw. This was about 125% greater than the single side mount and about 730 % greater than the paired side mount. An example of the stress contours generated by a side mount tag is illustrated in Figure 2. None of these forces were great enough to cause a failure in the material properties of the saddle or pin materials.

Two studies have used front and side mount configured tags but have deployed them on very different species (harbor porpoise, Westgate and Read 1998, boto, Martin and da Silva 1998) and a third study has exclusively used paired side mounts on harbor and Dall's porpoise and bottlenose dolphin (Hanson et al 1998a, Hanson unpubl. data, Hanson et al. 1999, Hohn, Hansen and Hanson unpubl. data). In the first two studies, both found that the single side mounts had substantially longer attachment longevities compared to tags mounted on the front (harbor porpoise, front-mount average attachment duration = 14 days, n=5, side-mount average duration = 106 days, n=9, Westgate and Read 1998, boto, front-mount average attachment duration= 46 days, n=24, side mount= 117 days, n=10, Martin and da Silva 1998). In the study that used paired side mounts minimum deployments of 142, 148+, and 149+ days (+ indicates tags are still active at time of publication) have achieved for Dall's porpoise (Hanson et al. 1998a, Hanson unpubl.), 215 days for a harbor porpoise (Hanson et al. 1999), and 180 days for a bottlenose dolphin (Hohn, Hansen, and Hanson unpubl data).

Discussion

While the results of this study are preliminary, they appear to indicate that tag designs that generate greater pressure concentrations in the tissue are those that will remain attached shorter durations, as inferred by signal loss. It is interesting to note that although the drag from the front mount was only about 10 % of the single side mount at average swim speed (Hanson et al. 1998b), it appeared to create about 30% greater pressure, despite have larger diameter pins (7.8 mm vs 6.25 mm). It is interesting to note that the paired side mount developed about the same drag as the single side mount at average swim speed (despite having a greater cross-sectional frontal area, Hanson unpubl. data), likely achieved by streamlining (Hanson 1998). However, it only generated about half the stress of the single side mount. While both the single side mount and paired side mount appear to be capable of yielding multi-month attachments, short transmitter battery life and resights have limited a complete evaluation of the full potential of these systems. Side mounts have been known to provide up to 290 day attachments (and possibly longer) since the transmitters were only designed with a six month service life (Martin and da Silva 1998). To date, most of the transmitters on paired side mounts have not been designed to function more than 6 months. The relatively small pin migration (approximately 3 cm) observed on a harbor porpoise 203 days after deployment with a tag that was known to have been subjected to rubbing shows promise for long-term attachment durations of this configuration (Hanson et al. 1999). However, based on relative levels of stress, the paired side mount might be expected to out perform the single side mount. Although sample size is small, the paired side mount has provided several consistently long deployments.

Based on only the level of stress, these results potentially suggest that pressure necrosis, the occlusion of capillary blood flow for an extended duration (Levy 1962), may be leading to faster tissue degeneration, and consequent pin out-migration. Although it remains unclear if this is actually occurring but some evidence suggests that it is not. The observed pressure levels for all tags are less than the minimum level observed to cause pressure necrosis in human skin, about 6.9 mN/mm^2 (Brand 1976). The extent to which the morphology of the dorsal fin tissue may differ from human skin with respect to blood flow under pressure is unknown but given the similarity of the fine structure of many mammalian tissues this may be of similar magnitude. Likely more important are the potential effects of the simplifying assumptions inherent to FEMs and accuracy of the input data given that the model presented is a first attempt to quantify the load concentrations. Primary assumptions for FEMs include that the materials behave linearly, are isotropic and homogenous. Biological materials are typically non-linear and anisotropic but for low levels of stress being experienced in this case, these factors may not be of significance. Although gross examination of the major components suggest no major variations in component structure, histological studies of dorsal fin tissue are being undertaken to compare different regions. The accuracy of some of the input data need to be verified. In the case of dorsal fin material properties, although the tissue used was from an area that pins typically penetrate these estimates were made from a single test. Consequently additional tests, preferably using a biaxial tester, need to be made using tissues from a variety of sites in the fin. The calibration of TDR velocity data are ongoing and the other 35 hours of data need to be included to gain the most accurate picture of porpoise velocity during dives. The wind tunnel data which translate these velocity data into loads for each tag appear to have minimal variability at middle to upper velocities but the lower velocities are subject to the influence of limitations of drag balance resolution (Hanson et al 1998b). Potential techniques to improve tag drag data include using a more sensitive drag balance on models of only the fins (and tags) in a smaller tunnel, suction cup-attaching tags to captive animals and determining tag drag through deceleration glides, or taking a numerical approach using computational fluid dynamics (CFD). The extent to which yaw data from the wind tunnel simulates the loads of turning animals is unclear. Data on frequency and magnitude of turns by free-ranging animals is a major gap in developing a "load budget" but may be possible to obtain using recently developed TDRs that include an electronic compass. Alternatively, underwater video of porpoises turning may allow determination of the magnitude of the turns. In particular, the frequency of changes in heading and velocity are necessary to assess the potential of the alternate explanation for tissue breakdown; dynamic loading results in mechanical disruption of the healing process.

Observations of free-ranging animals underwater near the surface clearly indicate that changes in heading occur frequently. However, it is currently unclear whether these changes are of sufficient magnitude to result in a mechanical disruption of the healing process. The lower magnitude changes are likely due to the attachment system better stabilizing the tags relative to the applied forces. The substantial increase in loads that front mount and single side mount both experience between zero degree yaw and 10 degree yaw is likely due to the development of a moment load. This load component is lacking in the paired side mount due to its symmetrical design such that stress appears to decrease, with smallest relative change from the zero degree state. The front mount develops this load while turning whereas the single side mount would be expected to experience moment load at zero yaw. However, the paired side mount's symmetrical configuration likely eliminates moment load, likely reducing total stress as well as minimizing the proportional increase in stress when yawed. The urethane used for the saddle on the paired side mount has material properties closer to a dorsal fin than the thermoplastic or polycarbonate materials typically used for saddles which may reduce stress concentrations in the tissue, similar to stress reduction regions in percutaneous devices suggested by Grosse-Siestrup and Affeld (1984). These results suggest that tissue degeneration from mechanical disruption of the healing process would be more likely to occur with the front mount which appears to correspond to its shorter attachment duration. It also suggests that the paired side mount may yield a longer duration of attachment than a single side mount. Additional FEM analyses are required to better investigate the locations of the pressure changes. These analyses need to be tied with field studies that include dedicated resight effort utilizing single and paired side mount tags with greater battery life. Such field studies would also help increase the understanding of the sources of variability in signal (i.e., attachment) duration. Of particular interest are those deployments of only a few weeks duration when it would seem unlikely that the transmitter or tissue had failed. Attachments have been documented to fail during these periods (Read and Westgate 1997, Hanson unpubl. data) and based on resights it is likely that this was due to rubbing behavior. Estimating the magnitude of this behavior might be possible based on the published maximum power outputs for a given species as an input to the FEM in order to determine what part of the attachment system fails. Although determining the frequency of such activities is likely to be extremely difficult, even if these loads may be an important source of mechanical disruption to the healing process. This highlights the need to try to incorporate a tag design/attachment procedure that results in a fit with minimal discomfort.

This study was the first attempt to evaluate tag attachment performance by quantitatively estimating the loads the different designs generate in the tissues. Although it is clear that numerous refinements and several additional analyses are needed to the FEM, the application of this technique will likely be the most viable approach to determining the factors having the greatest influence on tag attachment if combined with field studies that can evaluate the attachments by obtaining resight data.

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Citations

Brand, P.W. 1976. Pressure Sores - The problem. Pp. 19-23, in R.M. Kenedi, J.M. Cowden, and J.T. Scales (eds.), Bedsore Biomechanics. University Park Press, London.

Duck, F. A. 1990. Physical properties of tissue. Academic Press, San Diego, CA.

Elsner, R., J. Pirie, D.D. Kenney, and S. Schemmer. 1974. Functional circulatory anatomy of cetacean appendages. Pp. 143-159, In: R, J. Harrison, ed., Functional anatomy of marine mammals. Vol. 2. Academic Press, London.

Erickson, A. W. 1978. Population studies of killer whales (*Orcinus orca*) in the Pacific Northwest: A radio-marking and tracking study of killer whales. 34 pp. U.S. Dep. Commer., Natl. Tech. Inform. Serv., Rep. No. PB-285615. Available from NTIS, 5285 Port Royal Road, Springfield, VA 22167.

Felts, W. J. L. 1966. Some functional and structural characteristics of cetacean flippers and flukes. Pp.255-276, In Whales, dolphins and porpoises, K. S. Norris, (ed.). University of California Press, Berkeley.

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: Advances in research on the beluga whale, *Dephinapterus leucas*, T.G. Smith, D.J. St. Aubin, and J. R, Geraci, (eds.). Can. Bull. Fish. Aq. Sci. 224.

Grosse-Siestrup, C., and K. Affeld. 1984. Design criteria for percutaneous devices. J. Biomed. Mat. Res. 18:357-382.

Hanson, M.B. 1998. Design considerations for telemetry tags for small cetaceans. Pp. 37-49, in P.S. Hill and D.P. DeMaster (eds.), Marine Mammal Protection Act and Endangered Species Act implementation program 1997. AFSC Processed Rep. 98-10. Available Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE, BIN C15700, Seattle WA 98115-0070.

Hanson, M.B., Baird, R.W., and DeLong, R.L. 1998a. Short-term movements of tagged Dall's porpoise in Haro Strait, Washington. Pp. 111-119, in P.S. Hill and D.P. DeMaster (eds.), Marine Mammal Protection Act and Endangered Species Act implementation program 1997. AFSC Processed Rep. 98-10. Available Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE, BIN C15700, Seattle WA 98115-0070.

Hanson, M.B., Westgate, A.J., and Read A. J. 1998b. Evaluation of small cetacean tags by measuring drag in wind tunnels. Pp. 51-62, in P.S. Hill and D.P. DeMaster (eds.), Marine Mammal Protection Act and Endangered Species Act implementation program 1997. AFSC Processed Rep. 98-10. Available Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE, BIN C15700, Seattle WA 98115-0070.

Hanson, M.B., Baird, R.W., and DeLong, R.L. 1999. Movements of a tagged harbor porpoise in inland Washington waters from June 1998 to January 1999. Pp. 85-95, in D.P. DeMaster (eds.), Marine Mammal Protection Act and Endangered Species Act implementation program 1998. AFSC Processed Rep. 98-XX. Available Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE, BIN C15700, Seattle WA 98115-0070.

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.

Irvine, A. B., M.D. Scott, R. S. Wells, J.H. Kaufmann, 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. U.S. Dep. Commer., Natl. Tech. Inform. Serv., Rep. No. PB298042. Available from NTIS, 5285 Port Royal Road, Springfield, VA 22167.

Kunzelman, K.S, R.P.M. Cochran, C. Chuong, W. S. Ring, E. D. Verrier and R. D. Eberhart. 1993. Finite element analysis of the mitral valve. J. Heart Valve Dis. 2:326-340

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

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.

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. Mamm. Sci.. 14(4):829-834.

Parry, D.A. D., and A. S. Craig. 1980. Collagen fibrils during development and maturation on their contribution to the mechanical attributes of connective tissue. Pp. 2-23, In Fibrous proteins: Scientific, Industrial and Medical aspects, Vol. II, D.A.D. Parry and L.K. Creamer, eds. Academic Press, New York.

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. Anat. Rec. 232:150-156.

Rommel, S. A. , D. A. Pabst, and W. A. McLellan.. 1993. Functional morphology of the vascular plexus associated withe the cetacean uterus. Anat. Rec. 237:538-546.

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

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.

Table 1. Estimated compressional stress levels (mN/mm^2) at pin/tissue interface in the vertical heath of a harbor porpoise dorsal fin for an average simulated swim velocity of 7.6 km/h

	Tag Configuration		
	Front mount	Single side mount	Paired side mount
0° yaw	2.72	2.09	1.15
10° yaw	6.78	3.01	0.8

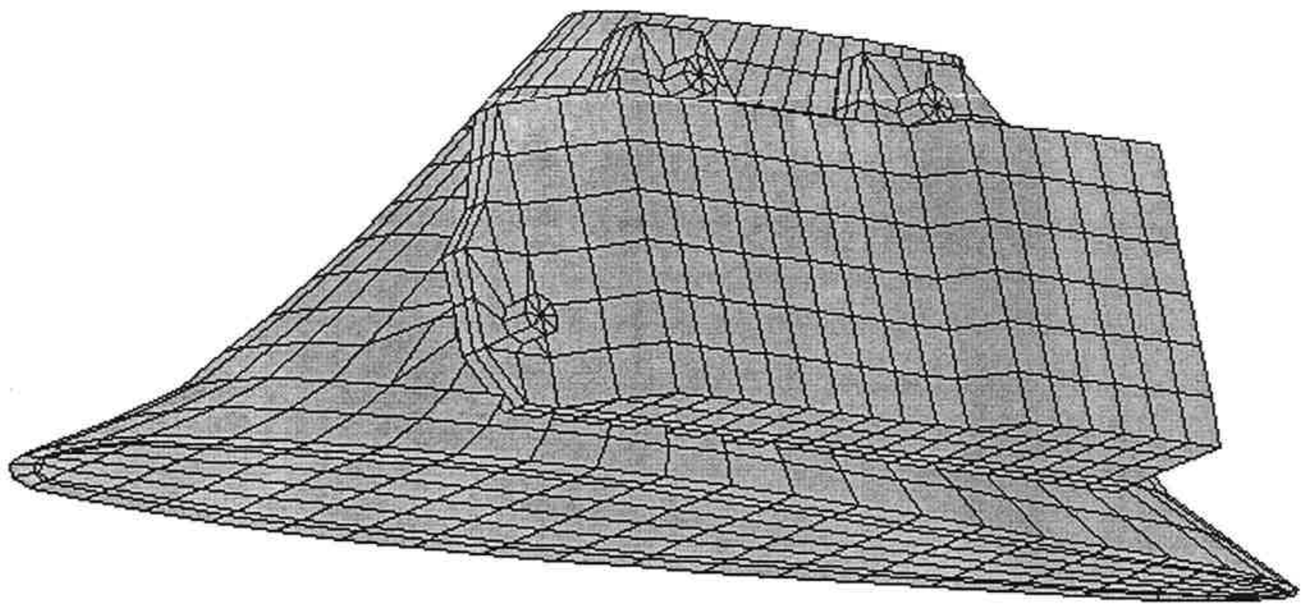

Figure 1. Finite element model geometry of a harbor porpoise dorsal fin with one of the three tag designs analyzed, the single side mount.

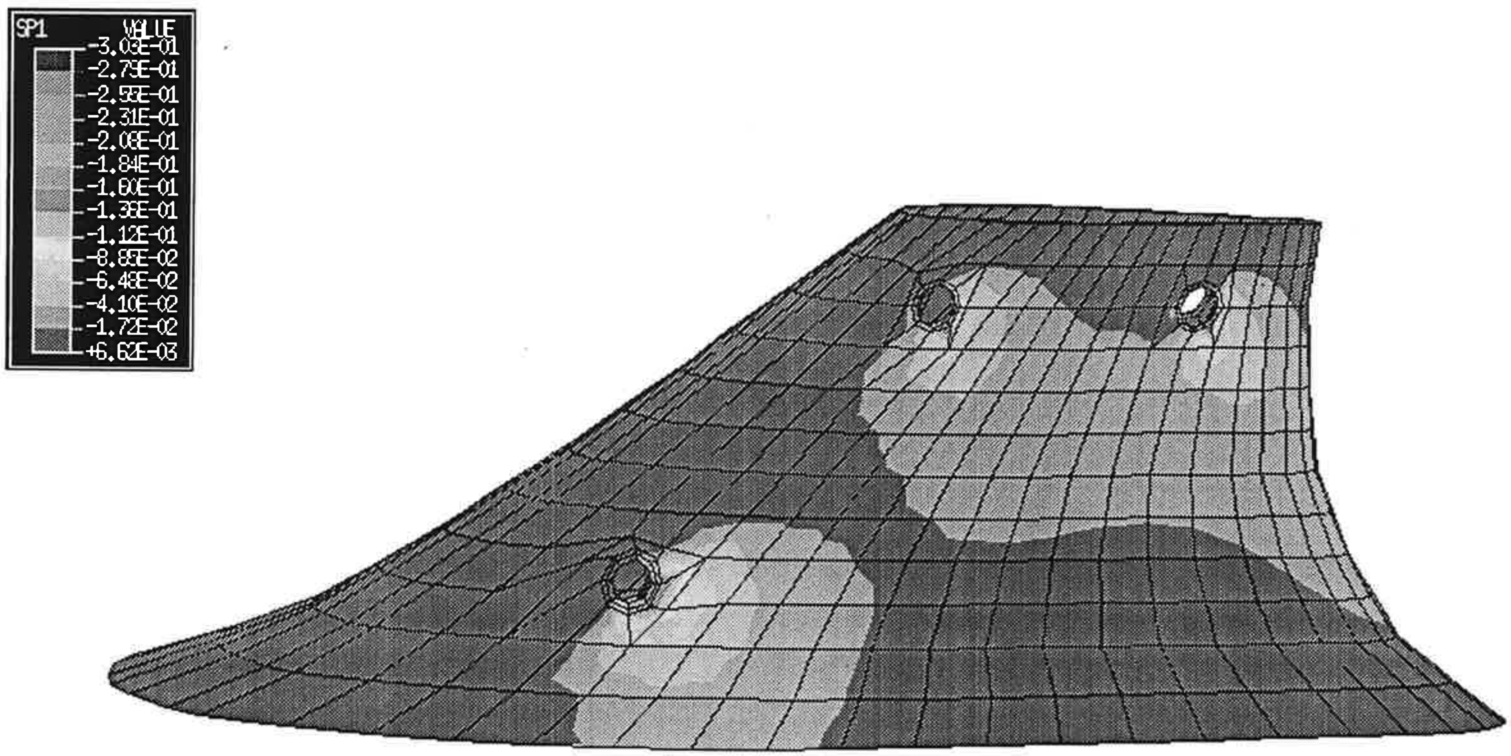

Figure 2. Finite element model compressional stress distribution contours. Only the vertical sheath is illustrated for a single side mount tag at average simulated swim speed and zero yaw.

FIELD REPORT OF THE 1997/98 STUDY OF THE EASTERN NORTH PACIFIC STOCK OF GRAY WHALES DURING THEIR SOUTHBOUND MIGRATION

David J. Rugh, Rod C. Hobbs,
Robyn P. Angliss, Lisa S. Baraff, Cynthia D'Vincent, Scott Hill, Marcia M. Muto,
Melissa A. Scillia, Kim E.W. Shelden, and Janice M. Waite.

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Pt Way N.E.
Seattle, Washington 98115-0070

Abstract

Systematic counts of eastern North Pacific gray whales (*Eschrichtius robustus*) were conducted from 13 December 1997 to 2 February 1998 at Granite Canyon, California, and from 11 to 24 February at two alternate sites nearby in Point Lobos State Park. This study was the final census conducted during the five-year period following the removal of the Eastern North Pacific stock of gray whales from the ESA List of Endangered and Threatened Wildlife. The counts were made at the same research station used most years since 1975 by the National Marine Mammal Laboratory. Basic counting methods were similar to those used in previous surveys. In addition, high-powered binoculars provided an indication of the limits of the observers' sighting range; a thermal sensor compared day and night passage rates; and observer counting performances were compared. A total of 2,318 pods (3,634 whales) were counted during 435 hrs of standard watch when visibility was recorded as fair to excellent. Data were analyzed using the same procedures applied previous years except for a modification to account for differential sightability by pod size. The calculated population abundance was 26,653 whales (CV = 10.06%; 95% log-normal confidence interval = 21,878 to 32,427). The timing of the 1997/98 migration was nearly 4 days later than the median date for the past 18 years (15 Jan), and – except for the 1993/94 season – it was the latest migration on record.

Introduction

The eastern North Pacific stock of gray whales has a predictable migration which has allowed researchers to conduct counts at regular intervals (Reilly 1984; Rugh et al. 1999a). Each year, from mid-December to mid-February, gray whales migrate south past the Granite Canyon research station near Carmel, California, a site used by the National Marine Mammal Laboratory (NMML) most seasons since 1975. Convenient access to this site and the narrowness of the whales' migratory corridor in this area have permitted an efficient counting process that has been repeated through many seasons (listed in Shelden et al. In press).

In recent years, the counting procedure has been tested in several ways: 1) aerial surveys documented the offshore distribution of sightings near Granite Canyon (Reilly et al. 1983; Withrow et al. 1994; Shelden and Laake In press); 2) high-powered binoculars provided an estimate of how many whales were missed as a function of distance (Rugh et al. 1995; In press); 3) thermal sensors provided records of day and night passage rates (Donahue et al. 1995; Perryman et al. 1999); 4) paired, independent counts allowed for estimates of whales missed within the viewing range (Rugh et al. 1990; 1993); 5) aircraft circling over whale groups provided accurate group counts to calibrate against estimates made by shore-based observers (Reilly 1981; Laake et al. 1994); 6) video tapes collected by thermal sensors provided a precise way to examine group sizes (DeAngelis et al. 1997); and 7) concentrated searches helped track selected whale pods through the viewing area, providing data which could be used to estimate errors in the standard counting procedures (Lerczak 1997; Rugh et al. 1997).

The objective of the 1997/98 study was to estimate abundance of the Eastern North Pacific stock of gray whales based on standardized, systematic counts of gray whales passing the research station during the southbound migration. The basic counting effort was comparable to previous seasons to allow for inter-year trend analysis (e.g., Buckland and Breiwick In press). In addition, supportive studies were done to follow-up on analysis of parameters listed above.

This study is the final field report in the five years following the removal of this stock of gray whales from the List of Endangered and Threatened Wildlife in June 1994 (Federal Register 58 FR 3121). Results of this research provided the primary information pertinent to the review of the status of this stock (Rugh et al. 1999b).

Methods

Survey effort

Systematic counts of gray whales were conducted from 13 December 1997 to 24 February 1998. Most of the study occurred at the Granite Canyon research station, 13 km south of Carmel, California, the site used by the NMML most years since 1975. However, unusually heavy storms (during an El Niño year) washed out the road to the research site on 2 February, and the road was not open to the public again until 7 May. By 11 February the weather abated enough to allow observers a chance to resume the search. But, because there was no access to Granite Canyon, the observations were made at *ad hoc* sites in Point Lobos State Park, 7 km south of Carmel. Two sites were used during the final two weeks of the survey (11-24 February); however, no exact altitudes were recorded for the sites (approximately 6 and 25 m high, respectively), and they did not provide protection from the elements, so it is unclear how comparable the results are to data collected from the Granite Canyon site.

At Granite Canyon, observation sheds set on the seaward edge of a 20.5 m high bluff provided desk space and some protection from the elements and helped observers focus on the viewing area. Although the field of view covered over 150°, observers generally focused on an area 40-50° north of an imaginary line perpendicular to the coastline (at 241° magnetic), referred to as the standard azimuth. A total of 10 people took part in the shore-based counts (see list of authors). All of the observers had previous experience in cetacean surveys, including one to many seasons of gray whale counts at Granite Canyon. As in previous seasons, 3 three-hour standard- watch shifts covered the 9 daylight hours from 0730 to 1630. Observers were rotated such that each observer had approximately equal amounts of time in each of the three shifts, and each observer was paired with as many other observers as practical.

Counting protocol

Standard watch procedures were the same as in previous surveys (Rugh *et al.* 1990; 1993; Laake et al. 1994). With each initial sighting of a whale pod, the time, horizontal bearing, and vertical angle were recorded. These data were collected again, along with an estimated pod size, when the whales were near the standard azimuth. Magnetic compasses in the binoculars provided the horizontal bearings ($\pm 2°$), and 14 reticle marks in the binoculars provided vertical angles relative to the horizon. Analysis of whale arrival time was based on the calculated time each pod crossed the standard azimuth (detailed in Rugh *et al.* 1993). In addition to whale sightings, observers recorded start and end of systematic search effort, visibility (subjectively categorized from 1 to 6, i.e., excellent to useless), sea state (Beaufort scale), and wind direction.

Paired, independent counts

A second, parallel watch was conducted whenever possible to provide an independent sighting record, allowing for comparisons between pairs of observers. Methods are described in detail in Rugh et al. (1990; 1993). Observers did not cue on each other's sightings because they were visually blocked from each other by the walls of the observation sheds, and radios or surf noise prevented them from hearing each other. Records from the "south shed" were used for the standard counts; the "north shed" was used only for paired, independent counts by a second observer. Observers were given at least a 1.5 hours rest before and after each standard watch.

High-powered binocular test

A high-powered binocular (25-power) was fix-mounted in a dedicated observation shed. It was aimed exactly on the standard azimuth and included the horizon in the outer viewing perimeter. Data were collected on a tape recorder, and, except for looking briefly at a clock, the observers never had to look away from the field of view during a watch period. Data included time, vertical reticle of a sighting, horizontal sector, number of whales, and direction headed. Location data were later converted to distance from shore, and the sighting records were compared to records from the standard watch. Details of the research protocol are explained in Rugh et al. (In press). Effort on this fixed binocular was divided into 45-minute shifts and ran from 0730 to 1630. Observers had a minimum of 45 minutes of rest between shifts.

Tracking test

During 7-23 January 1998, NMML continued the test of the research protocol used to count gray whales, a test first run in January 1997 (Rugh et al. 1997). This test provided: 1) an evaluation of pod-size estimates made by observers on the standard census; 2) information on the accuracy of north/south sighting linkages made within each observer's record on the standard watch; and 3) documentation of other parameters relevant to the matching algorithm used to compare counters. While the standard counts were being conducted, a team of two trackers selected whale pods for study (through a quasi-randomization process that minimized biases toward large groups relatively close to shore). Each selected pod was tracked through the field of view with effort concentrated on accurately determining group size. One observer used 7x50 binoculars to follow the group while the other observer recorded sighting times and locations, using a gridded map to plot the trackline of the respective whale group. Each track was given a quality rating based on the observers' confidence that they had followed the same animals during the entire track, and each group size was given a quality rating based on the observers' confidence in the estimation. After the records were collected, it was determined which whale groups were also seen by observers on the standard watch, so that group size and related parameters could be compared.

Thermal sensor

Paired thermal sensors have been operated concurrent to the shore-based visual surveys of gray whales most days in January from 1994-98, as weather allowed, in a study by Wayne Perryman (Southwest Fisheries Science Center, NMFS). The primary objective was to test the assumption of equal travel rates by gray whales during day and night (e.g., Donahue et al. 1995 and Perryman et al. 1999). An additional objective was to compare the sighting rates and pod-size estimates obtained from the two counting methods: thermal sensors vs observers on the standard watch (e.g., DeAngelis et al. 1997). Results from 1994-96 are summarized in Perryman et al. (1999). A thermal sensor operated most days 5-24 January 1998. Results from the 1998 season will be provided in a separate document at a later date.

Abundance analysis

Analytical techniques followed methods described in Buckland et al. (1993) and Breiwick and Hobbs (1996). This approach estimates the population abundance by multiplying correction factors for pod-size estimation bias, pods missed during a standard watch, pods passing when no watch was in effect, and diel variations in travel rates. Aspects of this method were developed for earlier abundance estimates conducted by Reilly et al. (1983), Breiwick et al. (1988), Laake et al. (1994), and Hobbs et al. (In press). The 1997/98 calculations were modified to account for differential sightability by pod size. This adjustment to the analysis has little impact on the abundance estimate, but it nearly doubles the CV, primarily due to including the covariance components of the variance of total whales passing during watch periods and variances in pod size corrections. This suggests that the CV(N) has been underestimated for prior surveys.

The systematic counts of southbound whales made from the "south shed" (northbound whales were excluded from this analysis) were used to estimate the total number of whales passing the site during usable watch periods. The total number of whales passing during a watch period was then multiplied by a correction for whales passing when no watch was in effect (including periods with poor visibility) and differences in diurnal/nocturnal travel rates. Details of the analytical procedures used for the estimate of abundance of gray whales in 1997/98 are presented in Hobbs and Rugh (1999).

Results and Discussion

Watch Effort

A total of 507.4 hours of survey effort occurred during the 66 days on which standard watches were conducted from 13 December 1997 to 24 February 1998. This survey covered the entire duration of the southbound migration through central California. There was a total of 435.3 hours of watch in usable effort (visibility 1-4) in the standard watch, and 72.1 hours when visibility was too poor (>4) to be included in the analysis. No effort was conducted from 3-10 February due to unusually violent storm activity that washed away the road to the research station. From 11-24 February the effort was continued at two sites in Point Lobos State Park.

Visibility

The average encounter rate of pods per hour in excellent to fair viewing conditions (visibilities 1 through 4) was 5.33 (SE = 0.26) and dropped off significantly to 3.40 pods per hour (SE = 0.33, p =<0.001) in poor and useless conditions (visibilities 5 and 6) (Table 1). Visibility 4 (fair) was thus selected as the threshold value for usable effort periods. The parameters for visibilities 1 and 2 were very similar to each other, as were the parameters for visibilities 3 and 4; however, visibilities 1 and 2 were significantly different from 3 and 4. So the analysis treated these as two visibility categories: visibilities 1 and 2 versus 3 and 4. Visibilities 5 and 6 were not included in the abundance analysis; they were treated as periods without observational effort.

Observation shed affect

Although the observation sheds were constructed to resemble each other enough that there was no apparent advantage in using one versus the other, there appeared to be an influence on sighting rates in 1997/98, unlike previous years. The south observation site had a slight but significant disadvantage relative to the north shed (coefficient -0.41; Table 2). The observers in the two sheds were only 4 m apart and had a difference in altitude of <0.09 m. Since neither significantly blocked the view of the other, and observers were rotated between the sheds, it is unclear where this influence came from.

Wind speed

Because the visibility of whales is often influenced by the wind, observers recorded wind force in the proximity of the whale corridor in terms of the Beaufort scale rather than using an anemometer at the research station. Local gusts on the coastal bluffs or around buildings strongly influenced the wind near the shore-based observers. A negative wind affect on whale counts was least in Beaufort 1 conditions (nearly windless), increasing to an asymptote at Beaufort 4. Higher Beaufort values were associated with larger waves which make whales rise higher when surfacing. This reverses the intuitive correlation between higher Beaufort conditions and lowered sighting rates. Whales make increased surface disturbances as they come up for air in rough seas, making them more visible to observers.

Wind direction

Wind direction parallel and perpendicular to the coast were included as the sine and cosine of the recorded wind direction (N, NE, E, etc.) subtracted from the azimuth bearing (241° magnetic). Each of these values was included as a second-order polynomial to allow for non-linear responses to wind direction. This influence of wind direction on sighting rates is most probably a function of visibility, and– to some extent– is included in the visibility affect.

Pod size

Average estimated pod-size was 1.57 (SE = 0.02) during usable effort periods. Pod size effect appeared linear up to pod sizes of four where it became highly variable due to small sample sizes (see Hobbs and Rugh 1999). Consequently, pod-size effect was truncated at a pod-size of four and treated as a linear effect in the abundance analysis. Pod-size corrections were based on bias estimates calculated in Laake et al. (1994) with separate corrections for each recorded pod size of 1, 2, 3, and >3 whales (Table 3).

The tracking test resulted in 219 track records collected during 14 days in January 1997 and 17 days in January 1998. Of these tracks, 74% were considered excellent to fair records (track qualities 1-3). The remaining records (track qualities 4 to 6) were compromised by visibility, high densities of whale pods in the area, or other factors that made it difficult to follow the focal pod. The final analysis will provide an indication of the consistency that can be expected within the records of shore-based observers counting gray whales, quantifying this dimension of error within the abundance calculations and correcting for over- or under-estimations in group sizes (Rugh et al. 1997).

Sighting rates

The mean sighting rate for fair or better visibility during 15-19 January 1998 was 11.5 pods/hr. This allows comparisons of sighting rates to other years when counts were done only in January, as in 1995. The sighting rate in 1998 was similar to rates seen in 1994 (11 pods/hr) and 1995 (10.7 pods/hr) but higher than the rate in 1996 (9.1 pods/hr).

The more whales there are in the viewing area, the more likely it is that whales will be missed because: 1) high sighting densities, such as >20 pods/hr, will increase the likelihood of false linkages between whale groups, and 2) an increase in sightings means observers spend more time recording entries. When looking away from the viewing area, observers may miss surfacings or confuse whale groups during subsequent observations (thus the tracking test, explained earlier). The most proficient effort would be an observer dedicated to scanning the viewing area and never looking down during a watch while another person records entries and acts as an auxiliary observer. However, this fully dedicated observer would potentially still miss some pods, making it necessary to conduct the double-count effort with two teams of two observers each. With this in mind, there is little to be gained from the marginally higher sighting rate of a fully dedicated observer. Also, to maintain compatibility of the south shed records to previous years, the research protocol must maintain the fundamental procedure of observers operating alone and hand-writing their data entries.

Distance offshore

In 1997/98, the mean offshore distance of pod sightings when visibility was fair or better was 1.21 nm (2.25 km; SD = 0.72nm; Fig. 1). This is equivalent to the mean offshore distance (1.21 nm offshore) found during aerial surveys in January 1996 (Shelden and Laake In press). When corrected for differential sightability by pod size and distance, the mean offshore distance was 1.26 nm (2.32 km; SD = 0.70 nm). The mean offshore distance per whale was 1.31 nm (2.42 km; SD = 0.64 nm). When corrected for differential sightability by pod size and distance, the mean offshore distance per whale was 1.30 nm (2.40 km; SD =0.72).

Aerial surveys have documented the offshore distribution of gray whales in the vicinity of Granite Canyon for several years (Shelden and Laake In press). Because few whales (1.28%) have been found beyond 3 nm, no corrections are necessary for whales passing the site too far seaward of the shore-based observers viewing area. The paired, independent counts of shore-based observers are considered an adequate representation of the drop-off in sighting rates as a function of distance from shore. Also, high-powered binoculars, fixed in place, have been used to examine the distance to gray whale sightings to measure significant changes in the median offshore distribution of sightings between years. To date, these data have not indicated any dramatic change in the gray whale's offshore distribution in 1997/98 relative to other years.

Paired, independent counts

A total of 1,331 pods were recorded during periods of fair or better (<5) visibility when pairs of observers were conducting counts independently. Of these, 922 were seen by both observers, 189 were seen by only the south observer, and 220 were seen by only the north observer. There was a variety of sighting rates among the observers (Table 2), such that nearly every observer had a different correction factor. All of the sighting rates were treated relative to the one observer (#1) who had the most experience conducting whale counts; therefore, observer #1 had a covariate value of 0.00. Distance also influenced sighting rates relative to each observer (Table 2). This was probably a function of where individual observer's tended to focus their search effort.

Significant correction factors

Significant effects were detectable for: 1) visibility, 2) observation site (south vs north shed), 3) sea state (Beaufort condition), 4) wind direction, 5) pod size, 6) sighting rates (pods per hour), 7) distance offshore, and 8) observer (Table 2). Interactions between these parameters were found only between observers and distance offshore when a restrictive criterion approach was used. The resultant model was applied to the primary observer data to estimate a correction for pods missed by observers. The mean corrected pod size (based on calculations used in Laake et al. 1994) was 2.36 (CV = 10.00%). The correction factor for whales passing when no watches were in effect was 3.73 (CV = 0.41%; Table 3).

Thermal sensors

Conclusions from the 1994-96 study using thermal sensors (Perryman et al. 1999) showed that through January there were larger diurnal pod sizes ($\bar{x}$ = 1.75 + 0.280 by day; $\bar{x}$ = 1.63 + 0.232 by night) and greater diurnal offshore distances ($\bar{x}$ = 2.30 + 0.328 km by day; $\bar{x}$ = 2.03 + 0.356 by night) but no diel variation in surfacing interval. The nocturnal migration rate (average number of whales passing per hour) was higher than the diurnal rate (correction factor = 1.02, S.E. = 0.023; Table 3), but no diel variation in swimming speed was found.

Abundance estimate

During the standard watch, a total of 2,591 southbound pods was recorded, of which 2,318 pods (3,634 whales) were seen when visibility was fair or better. The estimated number of whales passing during watch periods was 7,002 (CV = 9.48%). The total number of whales passing Granite Canyon during the 1997/98 southbound migration was estimated to be 26,635 (CV = 10.06%; 95% log-normal confidence interval = 21,878 to 32,427; Table 3).

The abundance calculated for 1997/98 was not significantly larger than the previous estimates from 1987/88, 1993/94, and 1995/96, but it was significantly larger than the estimate from 1992/93 (Table 4). Variations in estimates may in part be due to undocumented vagaries in sampling, or they may be due to differences in the proportion of the gray whale population that migrates as far south as central California each year, passing the observation site. The weather was severe enough in 1998 that watch effort was suspended for nine days (which has rarely occurred for even a single day in other years), and new sites were used when access to Granite Canyon was lost. The unwatched period and potential differences between the new sites and Granite Canyon could have led to biases that can not be fully appraised without conducting similar efforts at both sites.

Timing of the migration

Daily sighting rates (Fig. 2) showed the southbound migration was nearly symmetrical around a peak on 18 January 1998 (SE = 0.18), or day 49.4 when day 1 = 1 December 1997. Standard deviation was 12.4 days (SE = 0.13). Sighting rates were low (<1/hr) from 13-24 December, rising to nearly 14/hr in mid-January, and then dropping until mid-February when the migration reversed and became northbound. The timing of the 1997/98 migration was nearly 4 days later than the median date (15 Jan, or day 45.9) for the past 18 years, and– except for the 1993/94 season– it was the latest migration on record (Rugh et al. 1999a).

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Citations

Breiwick, J.M., and R.C. Hobbs. 1996. Preliminary documentation of gray whale abundance estimation procedures. Unpubl doc. SC/48/AS2 submitted to Sci. Comm. of Int. Whal. Commn. 5 pp.

Breiwick, J., Rugh, D., Withrow, D., Dahlheim, M., and Buckland, S. 1988. Preliminary population estimate of gray whales during the 1987/88 southward migration. Unpubl. doc. SC/40/PS12 submitted to Sci. Comm. of Int. Whal. Commn. 21 pp.

Buckland, S.T., and Breiwick, J.M. In press. Estimated trends in abundance of California gray whales from shore counts, 1967/68 to 1995/96. J. Cetacean Res. Manage. Special Issue 2.

Buckland, S.T., Breiwick, J.M., Cattanach, K.L., and Laake, J.L. 1993. Estimated population size of the California gray whale. Mar. Mammal Sci. 9(3):235-249.

DeAngelis, M.T., T. Martin, and W.L. Perryman. 1997. Pod size estimates studied through thermal sensors. Contract rept. to Natl. Mar. Mammal Lab, NMFS, NOAA, 7600 Sand Pt Way NE, Seattle, WA 98115. 7 pp.

Donahue, M.A., W.L. Perryman, and J.L. Laake. 1995. Measurements of California gray whale day/night migration patterns with infrared sensors. Abstract in the Eleventh Biennial Conf. on the Biol. of Mar. Mammals, Dec. 1995.

Hobbs, R.C., and Rugh, D.J. 1999. The abundance of gray whales in the 1997/98 southbound migration in the eastern North Pacific. Unpubl. doc. SC/51/AS10 submitted to Int. Whal. Comm. 16 pp.

Hobbs, R.C., D.J. Rugh, J.M. Waite, J.M. Breiwick and D.P. DeMaster. In press. The abundance of gray whales in the 1995/96 southbound migration in the eastern North Pacific. J. Cetacean Res. Manage. Special Issue 2.

Laake, J.L., Rugh, D.J., Lerczak, J.A. and Buckland, S.T. 1994. Preliminary estimates of population size of gray whales from the 1992/93 and 1993/94 shore-based surveys. Unpubl. doc. SC/46/AS7 submitted to Int. Whal. Comm. 13 pp.

Lerczak, J.A. 1997. The swimming behavior of gray whales during their southbound migration past the Granite Canyon, CA, survey station. Contract report to Natl. Mar. Mammal Lab., NMFS, NOAA, DOC. 24 pp.

Perryman, W.L., M.A. Donahue, J.L. Laake, and T.E. Martin. 1999. Diel variation in migration rates of eastern Pacific gray whales measured with thermal imaging sensors. Mar. Mammal Sci. 15(2):426-445.

Reilly, S.B. 1981. Population assessment and population dynamics of the California gray whale (*Eschrichtius robustus*). Mar. Mammal Sci. 6(2):109-120.

Reilly, S.B. 1984. Assessing gray whale abundance: a review. pp 203-23. In: M.L. Jones, S.L. Swartz and S. Leatherwood (eds.) *The Gray Whale (Eschrichtius robustus)*. Academic Press, Orlando, FL xxiv +600 pp.

Reilly, S.B., Rice, D.W., and Wolman, A.A. 1983. Population assessment of the gray whale, *Eschrichtius robustus*, from California shore censuses, 1967-80. Fish. Bull.U.S. 81(2):267-281.

Rugh, D.J., Ferrero, R.C., and Dahlheim, M.E. 1990. Inter-observer count discrepancies in a shore-based census of gray whales (*Eschrichtius robustus*). Mar. Mammal Sci. 6(2):109-120.

Rugh, D.J., Breiwick, J.M., Dahlheim, M.E., and Boucher, G.C. 1993. A comparison of independent, concurrent sighting records from a shore-based count of gray whales. Wildl. Soc. Bull. 21:427-37.

Rugh, D.J., J.A. Lerczak, and J.L. Laake. 1995. Using 25X binoculars to study the offshore distribution of gray whales migrating past a shore station. Unpubl. doc. SC/47/AS5 submitted to Sci. Comm. of Int. Whal. Commn. 13 pp.

Rugh, D.J., R.C. Hobbs, J.A. Lerczak, L.S. Baraff, J.M. Waite, C. D'Vincent, P.S. Hill, and M.M. Muto. 1997. An assessment of gray whale counts made by shore-based observers. Unpubl. manuscript., annual rept. to MMPA/ESA.

Rugh, D.J., Shelden, K.E.W., and Schulman-Janiger, A. 1999a. Timing of the southbound migration of gray whales in 1998/99. Unpubl. doc. SC/51/AS11 submitted to Sci. Comm. of Int. Whal. Commn. 11 pp.

Rugh, D.J., M.M. Muto, S.E. Moore, and D.P. DeMaster. 1999b. Status review of the Eastern North Pacific stock of gray whales. NOAA Tech. Memo. NMFS-AFSC-103. 96 pp.

Rugh, D.J., J.A. Lerczak, R.C. Hobbs, J.M. Waite, and J.L. Laake. In press. Evaluation of high-powered binoculars to detect inter-year changes in the offshore distribution of gray whales. J. Cetacean Res. Manage. Special Issue 2.

Shelden, K.E.W., and J.L. Laake. In press. Comparison of the offshore distribution of southbound migrating gray whales from aerial survey data collected off Granite Canyon, California, 1979-96. J. Cetacean Res. Manage. Special Issue 2.

Shelden, K.E.W., D.J. Rugh, and S.A. Boeve. In press. Gray whale calf sightings collected during southbound gray whale migrations, 1952-95. J. Cetacean Res. Manage. Special Issue 2.

Withrow, D.E., Laake, J.L. and Shelden, K.E.W. 1994. Offshore distribution of gray whales along the central California coast during the 1993-94 southbound migration. Unpubl. doc. SC/46/AS8 submitted to Sci. Comm. of Int. Whal. Comm. 9 pp.

Table 1. Rates of sightings of gray whale pods as a function of visibility throughout the research season. "Early/late effort" is time spent by observers on watch before 0730 and after 1630. Abundance analysis included only sightings that were recorded between 0730 and 1630.

Visibilities	Visibility Code	Number of pods	Hours of Effort	Pods/hr	S.E.
Excellent	1	37	3.0	12.33	3.21
Very Good	2	273	41.8	6.53	1.13
Good	3	625	136.2	4.59	0.43
Fair	4	1383	254.3	5.44	0.33
Poor	5	219	64.3	3.40	0.33
Unacceptable	6	9	7.8	1.15	0.45
Early/late effort		45	9.7		
All Effort		2546	507.4	5.02	0.22
Usable Effort	1 - 4	2318	435.3	5.33	0.26

Table 2. Covariates and fitted parameters used to model the probability of detecting groups of gray whales migrating through the viewing range of shore-based observers at Granite Canyon in central California, 13 December 1997 to 24 February 1998.

Variables	Coefficient values	S.E.	Observer /distance	S.E.
Intercept	0.46	0.56		
Visibility	-0.81	0.23		
Observation site	-0.41	0.15		
Sea state	2.53	0.57		
Wind direction	0.60	0.18		
Wind direction^2	-0.63	0.23		
Pod size	0.29	0.08		
Sighting rate	-0.07	0.02		
Distance offshore	2.69	0.42		
Distance^2	-0.76	0.11		
Observer 1	0.00	0.00	0.00	0.00
Observer 2	-0.63	0.67	0.12	0.50
Observer 3	0.64	0.68	-0.17	0.42
Observer 4	-0.30	0.61	-0.19	0.40
Observer 5	0.41	0.60	-1.03	0.43
Observer 6	0.41	0.45	-0.60	0.30
Observer 7	-2.73	1.01	2.32	0.95
Observer 8	-0.61	0.58	0.11	0.39
Observer 9	0.16	0.54	-1.02	0.36
Observer 10	1.11	1.13	-1.02	0.99

Table 3. Intermediate parameters used to estimate the abundance of the eastern North Pacific stock of gray whales during the 1997/98 southbound migration.

Parameter	Estimate	S.E.	CV
Total number of whale groups recorded by the primary observer during watch periods	2,318		
Total number of groups (estimated)	2,965	73.5	3.17%
Mean recorded group size	1.57	0.02	1.38%
Corrected mean group size (Laake et al. 1994)	2.36	0.24	10.00%
Estimated number of whales passing during watch periods	7,002	664	9.48%
Correction for whales passing outside of watch periods	3.73	0.02	0.41%
Estimated total whales (without night travel correction)	26,113	2,561	9.81%
Correction for night travel	1.02	0.023	2.25%
Total number of whales	**26,635**	2,681	10.06%
lower bound	21,878		
upper bound	32,427		

Table 4. Recent abundance estimates of the eastern North Pacific stock of gray whales.

Season	Abundance	CV	95% CI	Source
1987/88	21,296	6.05%	18,900-24,000	Buckland et al. 1993
1992/93	17,674	5.87%	15,800-19,800	Laake et al. 1994
1993/94	23,109	5.42%	20,800-25,700	Laake et al. 1994
1995/96	22,263	9.25%	18,700-26,500	Hobbs et al. In press
1997/98	26,635	10.06%	21,878-32,427	Hobbs and Rugh 1999

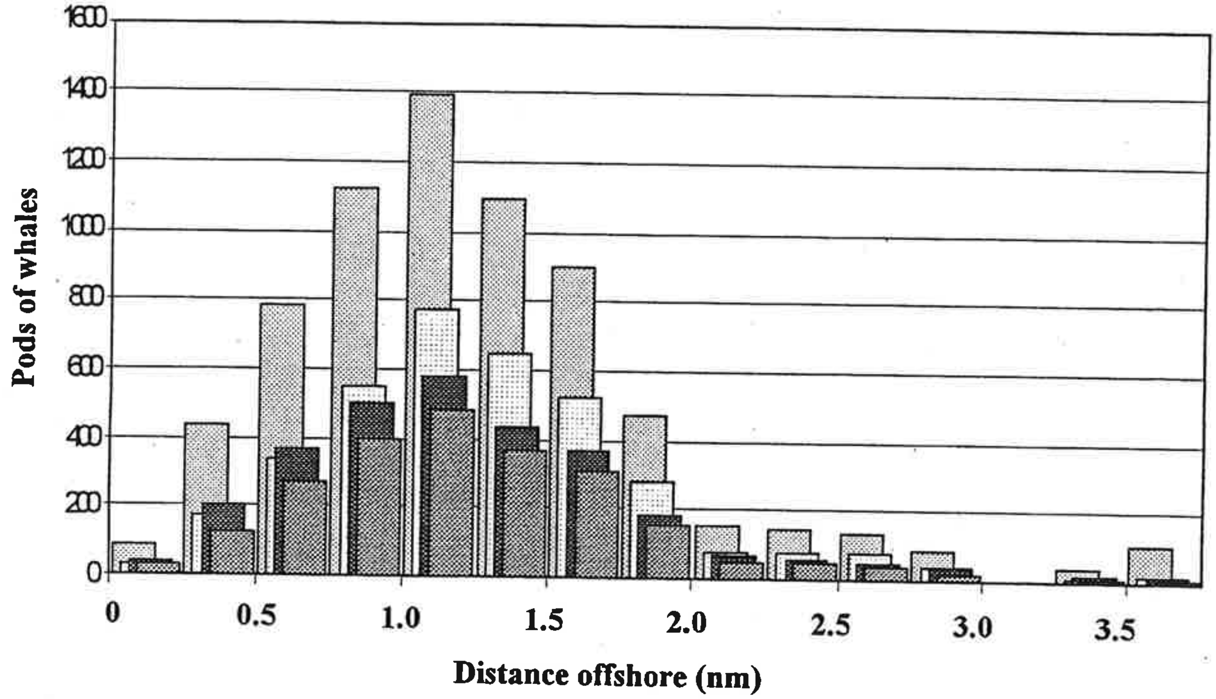

Figure 1. Offshore distribution of standard watch sightings of gray whales between 13 December 1997 and 24 February 1998 during the southbound migration past Granite Canyon, California. Only effort periods with visibility <5 were included.

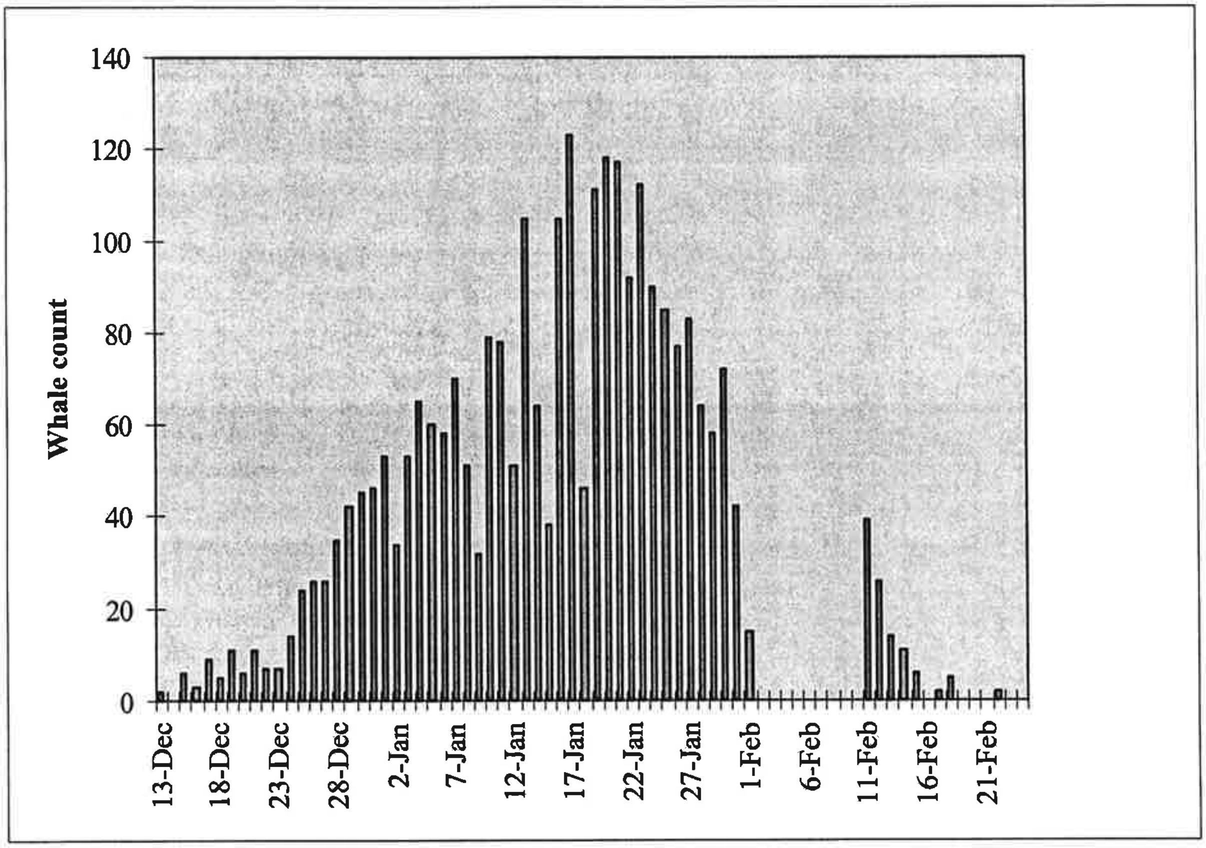

Figure 2. Sighting rates of gray whales in the standard watch periods 13 December 1997 to 24 February 1997 during the southbound migration past Granite Canyon, California. Only effort periods with visibility <5 were included.

MOVEMENTS OF A TAGGED HARBOR PORPOISE IN INLAND WASHINGTON WATERS FROM JUNE 1998 TO JANUARY 1999

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
Current address:
Pacific Whale Foundation
101 North Kihei Road
Kihei, Hawaii
96753

Abstract

Movements of cetaceans tagged with telemetry packages can provide important information for assessing stock structure and habitat use. Harbor porpoises (*Phocoena phocoena*) are common in the inland waters of Washington State, but little is known about the biology of this species in the region. On 16 June 1998, two harbor porpoises were live-captured using a modified gillnet. One of the animals was safely released a few minutes after capture and the other was retained for tagging. While this capture technique has been used on this species before, the use of a hydraulic net reel increased the efficiency of the process as a well as increasing safety for the animals. The animal retained had a pair of hydrodynamically efficient transmitters (satellite/VHF) attached to its dorsal fin. Due to a malfunction of the saltwater switch, the signals from the satellite transmitter were received for only 57 days and did not provide any high quality locations. The VHF transmitter, despite a broken antenna, allowed the porpoise to be relocated on 76 days through 17 January 1999, a period of 215 days, the longest duration of monitoring for an individual of this species by telemetry. Although the porpoise was captured off Pt. Doughty, Orcas Island, within the next two weeks it made several trips into the southern Strait of Georgia, appearing to remain in that area until it was last relocated on 17 January, again near Pt. Doughty. The majority of locations were confined to a 65 km^2 region over the deepest waters of the southern Strait of Georgia (200 m). Although the core portion of this animal's home range was relatively small, it moved extensively within the area. The confined movements of this porpoise has important implications for stock structure subdivision, and suggests the need for additional monitoring (due to its close proximity to increasingly urbanized areas). Dive data collected with suction-cup attached time-depth recorders confirm that porpoises make use of deep waters in this basin.

Introduction

A fundamental component of population assessment under the Marine Mammal Protection Act is identifying stocks. Stock discrimination has been an ongoing effort for several U.S. small cetacean populations (e.g., eastern North Pacific harbor porpoise, Barlow et al. 1997, western North Atlantic harbor porpoise, and southeastern United States/Gulf of Mexico bottlenose dolphins, Blaylock et al. 1995). Populations can be subdivided based on information on distribution and movements, population trends, or differences in morphology, genetics, contaminants, 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.

Numerous harbor porpoise have been tagged with VHF or satellite-linked transmitters in the western North Atlantic (see Read and Gaskin 1985, Read and Westgate 1997), providing important information on the movements of this species in the region. Harbor porpoise are common in Washington's coastal and inland waters (Everitt et al. 1980), yet little is known about their movements (see Flaherty and Stark 1982). The purpose of this study was to refine a previously used system for capturing free-ranging harbor porpoises (Osmek in prep.a.), to deploy hydrodynamically efficient tags with a six-month service life (Hanson 1998), to evaluate tag design and attachment system, as well as to monitor movements of harbor porpoise from the inland Washington stock.

Methods

From 8-12 June and 15-19 June 1998, areas where harbor porpoises have commonly been observed in the San Juan Islands, Washington state were searched for concentrations of porpoise. When porpoises were located, a specially designed gillnet was deployed from a 6.1 m vessel with 175 hp outboard that had been outfitted to retrieve the net over the bow onto a hydraulic-powered reel. The net used measured 182 m in length and 9.1m deep, and was constructed of 30.5 cm (12") stretched mesh monofilament gillnet. The 1 cm corkline was equipped with white BL-S floats spaced every 1.1 m. The lead line used was the lightest commercially available, weighing 360 g/m (30lbs/100 fms). The net was set as a drift gillnet with one end attached to the reel, a 4.2 m inflatable with a 15hp outboard engine was used to check and, if necessary, disentangle the net to hang properly. Depending on the conditions of the tidal currents, the net orientation was kept linear by either occasionally backing the deployment boat or tying the 7.2 m tracking vessel off at the end opposite the deployment vessel. The net was only deployed in Beaufort sea states 0-2.

The corkline was closely monitored for areas that where submerged or bunching corks that might indicate an entanglement. The 4.2 m inflatable was used to investigate any potential entanglements. This boat was equipped with a 10 cm thick open cell pad on the deck to serve as the processing platform for captured animals. This method of processing was similar to a method previously used during the capture of a harbor porpoise on the outer Washington coast (Osmek et al. in prep.a). It provides non-rigid support for the porpoise and retains water on their flippers and flukes (that has been poured over them to keep their skin moist), which aids in maintaining thermoregulation.

Captured porpoises were fitted with a pair of streamlined tags that were attached to the dorsal fin. The satellite transmitter (PTT) was a Telonics ST-10 powered by two 2/3A cells and the VHF transmitter was powered by a AA battery and was pulsed at 150 ppm. The expected service life of the PTT was approximately 3 months and the VHF transmitter was expected to last a minimum of 150 days. The VHF 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 was potted in a urethane fairing that also doubled as the attachment saddle (Hanson 1998). The dimensions of the PTT/VHF tags were approximately 19.1 cm long, 7.7 cm wide, and 2.8 cm high, and the total weight of each unit was approximately 264g and 192 g for the PTT and VHF transmitter respectively. 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 about 20% more drag for a pair of these tags attached to a harbor porpoise model in a wind tunnel at typical swim speeds (Hanson unpubl data).

Both tags were attached with three 6.4 mm diameter surgical grade titanium pins, threaded on both ends with a 6.4 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 nylon lock 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. The porpoise also had a suction-cup attached time-depth recorder tags placed on it prior to release (see Baird and Hanson 1998; Baird 1998).

The tagged animal was initially followed for several hours to monitor condition, and on subsequent days was located opportunistically while other capture operations were conducted. Relocations were then made almost daily during the first two weeks following release, 1-2 times per week through mid-November, and approximately every two weeks until mid-January. Respiration data were also collected opportunistically, by monitoring a radio receiver 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

Weather permitted net deployment on five of the ten days of field operations. A total of 14 sets were made totaling 15.5 hours of soak time. Average soak time was 1.2 hrs (SD=0.5) with an average of 11.2 (SD=4.5) minutes to deploy the net and an average of 8.6 minutes (SD=3.7) to retrieve it.

Two harbor porpoises were captured near Pt. Doughty, Orcas Island simultaneously on 16 June. One porpoise (a 163 cm female) was retained for tagging, and the other (sub-adult male) was released immediately, unmarked. Both animals appeared to be in good health, the tag attachment was accomplished in 34 minutes and the animal was immediately released.

The satellite transmitter only provided intermittent uplinks and positions for 57 days due to a saltwater switch malfunction. However, the VHF transmitter allowed relocation over the 215 days the transmitter functioned. This is the longest time period an instrumented harbor porpoise has been tracked. Relocation of the porpoise was attempted on 80 days and was successful on 75 of these occasions. This was accomplished despite the strength of the VHF signal being substantially reduced due to the loss of the rigid wire antenna about two weeks after tagging. Antenna loss likely occurred from the porpoise rubbing the tag on the sea bottom. From sea level, reception range decreased from approximately five miles to one mile, while from an aircraft at approximately 600 m in altitude, the range decreased from twelve miles to six miles. Based on aerial searches in the absence of sea level signal reception, the lack of signal reception from sea level was likely due to an inadequate boat search of the area, rather than a large scale movement by the porpoise. Signal loss in late January was most likely due to the transmitter battery reaching the end of its service, rather than tag loss. The transmitter was only warranted for 150 days of service and when the porpoise was last observed (203 days after tag deployment), the tag had migrated approximately 3.0 cm posteriorly, such that it would have been unlikely to come off within the next month.

The porpoise was found in the northern President Channel or southern Strait of Georgia area up though 14 July, but for the next six months it was always located in the southern Strait of Georgia (Fig. 1). Only on the last location on 17 January was the porpoise found back in northern President Channel. It is interesting to note that not only are the majority of the initial daily locations (86%) in the southern Strait of Georgia, 65% are located inside or within approximately 0.5km of the 200 m depth contour, an area encompassing only about 65 km^2 (Fig. 1).

The porpoise was tracked from the boat for 200.6 hours on 68 days. The porpoise was located an average of only 5.3 km (SD=3.7) from the initial location of the previous tracking day, with a maximum distance of 18.2 km. Although her locations were concentrated, she nonetheless moved extensively within that range. As an example, a track of her movements between approximately 1300 and 1700 on 4 October is illustrated in Figure 2. During this period the porpoise moved a total of 9.6 km at an average rate of 2.4 km/hour. During these tracking periods other porpoise were commonly observed with (within one body length) or in the close vicinity (within 500 m) of the tagged porpoise.

Surfacing data were collected on 34 days throughout the tracking period. Analyses of all these data have not been completed, but an example of the respiration pattern information is presented using 1.9 hours of data collected on 23 June. During this period the porpoise surfaced 348 times. The distribution of dive times was bimodal, with no dive durations between 0.25 and 1.34 minutes. Two hundred and ninety-five dives were shorter than 0.25 minutes, and 53 dives were longer than 1.34 minutes. The mean was 2.0 minutes for the long duration dives and 0.10 minutes for short duration dives. Approximately 4.7% of the animal's time was spent at the surface. This porpoise occasionally exhibited a high degree of " logging" behavior; after a long dive, rather than take several dives in between the initial surfacing she would remain at the surface for extended periods. However, this behavior was only observed in sea surface conditions of Beaufort 0 or 1.

The suction cup-mounted recorder remained attached for 38.7 hours. During this period there were 931 dives that exceeded 30 seconds, 31% were between two and 10 m (Fig. 3). The deepest dive was to 170 m.

Discussion

The bow deployment of the gillnet using a hydraulic net reel greatly improved the efficiency of capture operations. In particular, deployment and retrieval times in this study were only of a fraction of the durations when working with a similar sized net by hand (12-26 minutes deployment, 40-75 minutes retrieval, Osmek et al. in prep.a.). Due to the substantial possibility of multiple animal entanglements during a single set, prompt retrieval likely enhances the safety of entangled animals.

Movement data for individual harbor porpoises in Washington waters, as well as all other areas of the eastern North Pacific, are extremely limited. Photo-identification of this species in the San Juan Island area only yielded resights of three individuals, two of which were resighted twice (Flaherty and Stark 1982). Resights occurred from 8.3 to 33.5 km from the pervious location. The resight that occurred 8.3 km from the previous location is of particular note because it occurred in January, six months after the previous sighting. These data also suggest very limited movements, both within and between seasons for inland water harbor porpoise. The only other tagging of a harbor porpoise in this region occurred on the outer Washington coast in 1995. Although that porpoise was tracked for only three weeks its movements were greater than that of the porpoise in this study, moving at least 80 km in a north-south direction along the coast (Osmek et al. in prep.b.). The porpoise in this study also covered considerably less distance than instrumented porpoises in the northwest Atlantic Ocean or North Sea where movements of approximately 75-400 km (Westgate and Read 1998) and 800 km (Teilmann et al. 1998) have been reported, respectively. Unlike the large scale seasonal movements that appear to occur in the northwest Atlantic Ocean or North Sea populations, the only net seasonal movement for this tagged porpoise appeared to be to the north, into the southern Strait of Georgia. The regular observations of other porpoises with, and in the vicinity of, the tagged porpoise during the three seasons this study covered, suggests that this strong site fidelity is likely shared by a substantial proportion of this population. While the year-round presence of harbor porpoise in the San Juan Island area has been documented (Everitt et al. 1980, Flaherty and Stark 1982), their regular occurrence in the southern Strait of Georgia appears to have been overlooked.

The confined range exhibited by the tagged porpoise is of particular interest relative to ongoing stock structure analyses. Recent genetic analyses suggest that greater structure exists within the inland Washington stock, and is particularly restricted for females (S. Chivers, SWFSC pers. comm.). The limited movements of this tagged animal appear to support these findings. Although the genetic analyses suggest that there is a separation in the region of the San Juan Islands, no precise boundary has been defined. Movement data from this animal suggest that an extremely localized stock could exist in the northern region of the San Juan Islands and may be separate from animals in the adjacent inland waters of British Columbia. Given the close proximity of porpoises in this region to the Fraser River plume, which carries runoff from the increasing urbanized lower Fraser River valley, closer monitoring of this population's distribution, abundance, and contaminant burden levels should be undertaken.

The preliminary analysis of surfacing data from the VHF signals demonstrates that it can provide a substantial amount of detailed information on the at-surface patterns of a porpoise. A thorough analysis of the entire data set has the potential to provide insights into variations that may exist as daily or seasonal patterns, or are associated with other possible covariates, that would be of importance in developing correction factors for animals missed during surveys because they are not at the surface.

The summary dive data collected by the TDR in this study are remarkably similar to those collected from porpoises in the northwest Atlantic Ocean (Westgate and Read 1998), but deeper than porpoises in Japan (Otani et al. 1998). The maximum depth this porpoise attained was only less than two of seven porpoises in the northwest Atlantic Ocean (Westgate and Read 1998), slightly deeper than that of North Sea porpoises (166 m, Teilman et al. 1998), and substantially deeper than porpoises in Japan (98.6 m, Otani et al. 1998). The maximum dive depth observed for the porpoise in this study was likely constrained by limited sample size and the maximum depth of the region (being about 200m).

Acknowledgments

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Citations

Baird, R.W. 1998. Studying diving behavior of whales and dolphins using suction-cup attached tags. Whalewatcher 32(1):3-7.

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. 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. Available Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE, BIN C15700, Seattle WA 98115-0070.

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 pp.

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 pp.

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 pp.

Flaherty, C., and S. Stark. 1982. Harbor porpoise (*Phocoena phocoena*) assessment in "Washington Sound". Final Rept. for subcontract 80-ABA-3584 to the National Marine Mammal Lab., Seattle, WA.

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.

Osmek, S. D., M. B. Hanson, and R. L. DeLong. In prep.a. A capture technique for free-ranging harbor porpoises.

Osmek, S. D., M. B. Hanson, and R. L. DeLong. In prep.b. Movements of a tagged harbor porpoise on the outer coast of Washington State.

Otani, S., Y. Naito, A. Kawamura, M. Kawasaki, S. Nishiwaki, and A. Kato. 1998. Diving behavior and performance of harbor porpoises, *Phocoena phocoena*, in Funka Bay, Hokkaido, Japan. Mar. Mamm. Sci. 14(2):209-220.

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.

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.

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.

Teilmann, J., F. Larsen, and G. Desportes. 1998. Remote sensing of harbor porpoise behavior in relation to gillnetting activity in Danish waters. Abstract, World Marine Mammal Conference, Monaco, 20-24 January, 1998.

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.

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.

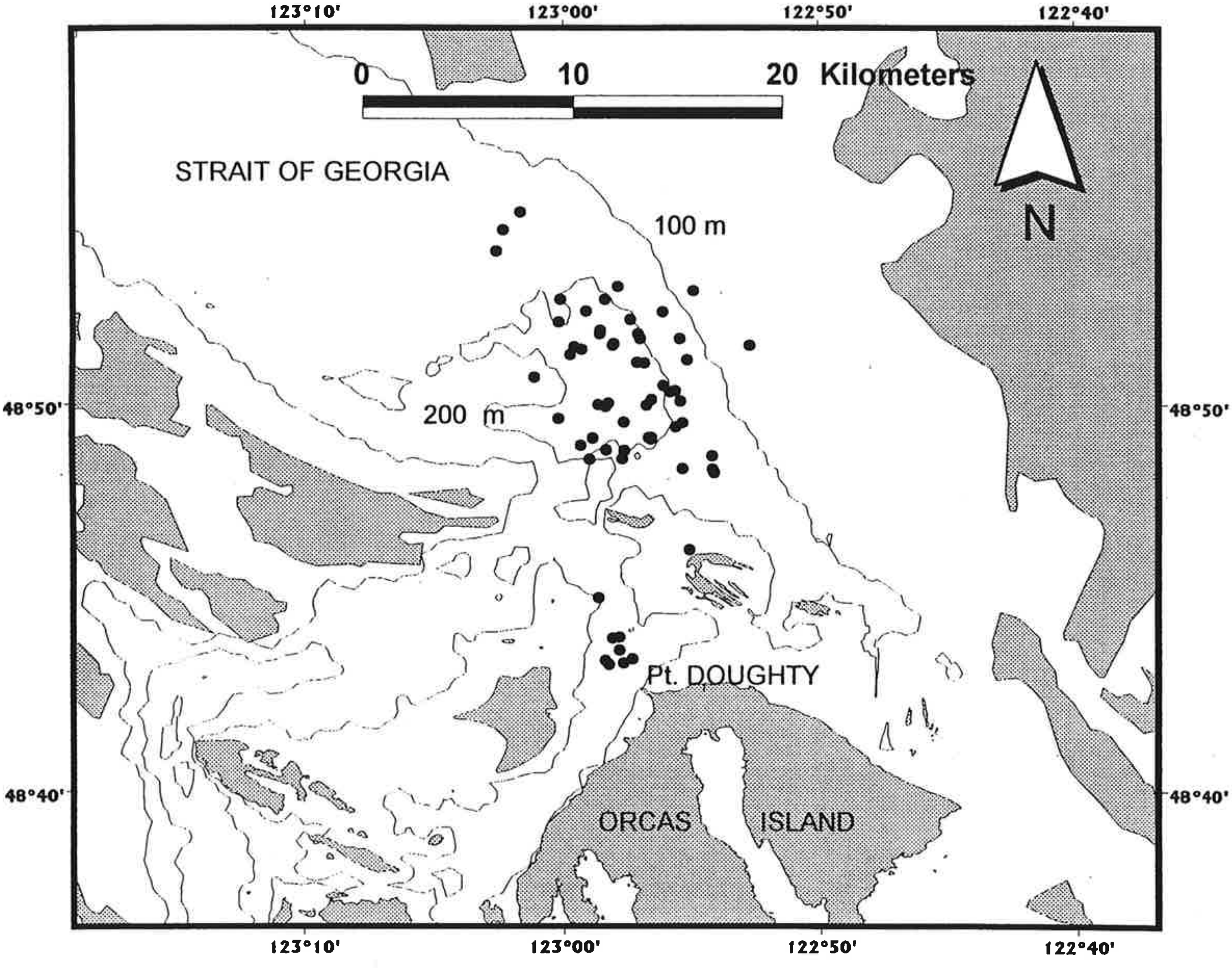

Figure 1. Initial tracking locations of a radio-tagged harbor porpoise monitored from 16 June 1998 to 17 January 1999 in inland Washington waters.

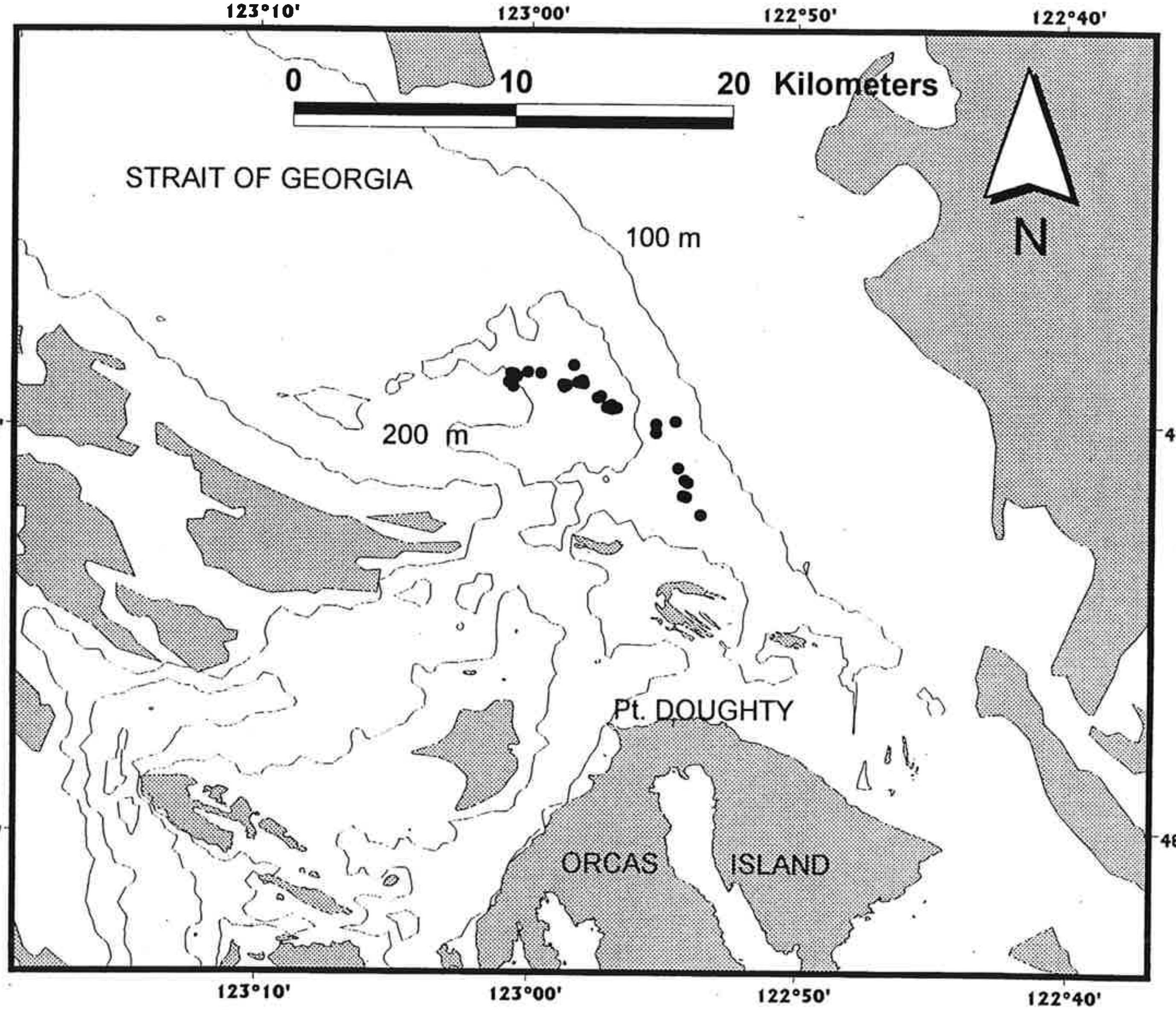

Figure 2. Detailed tracking locations of a radio-tagged harbor porpoise from 1300 to 1700 on 4 October 1998 in inland Washington waters.

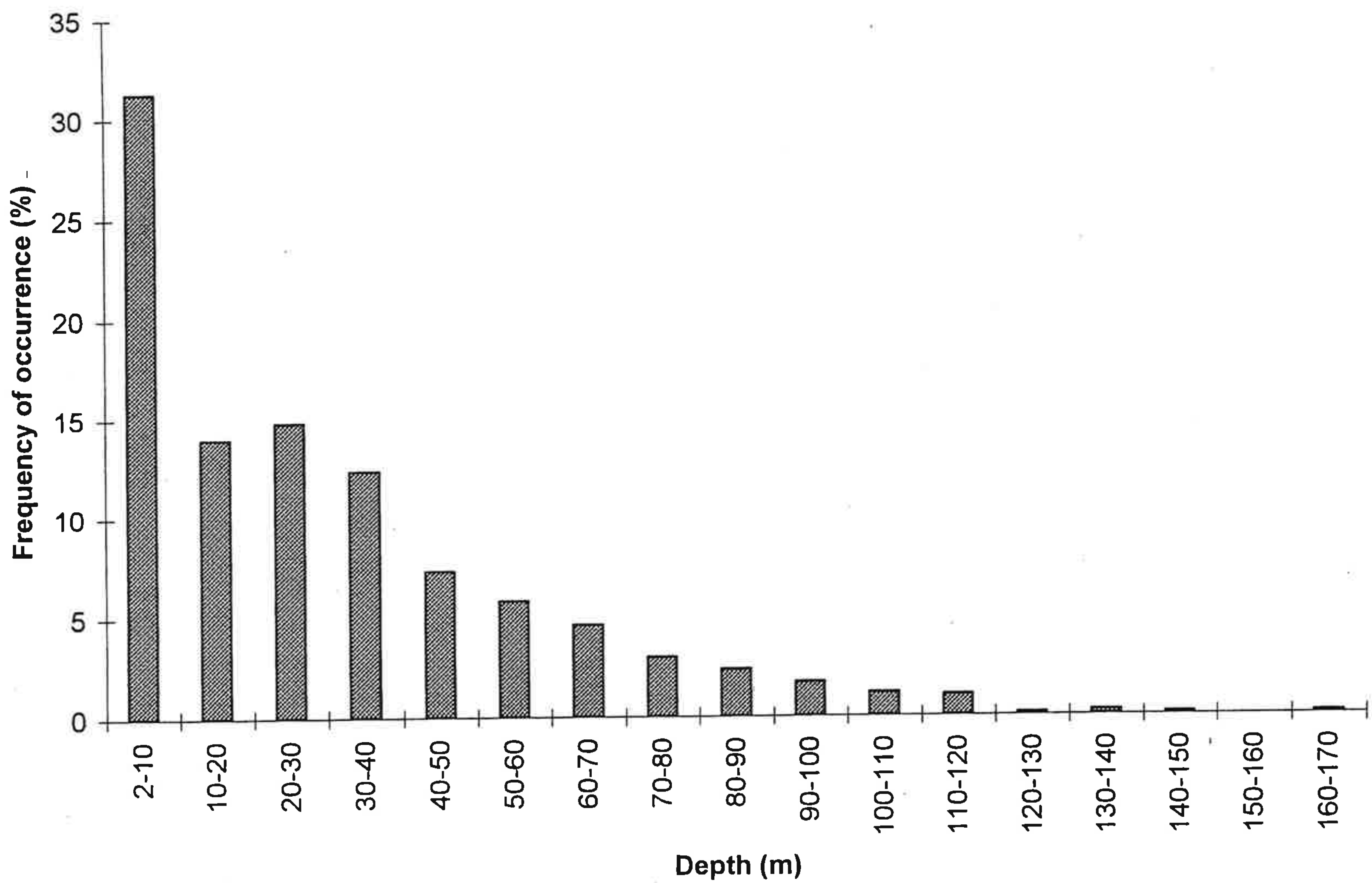

Figure 3. Frequency distribution of maximum dive depths from a tagged harbor porpoise in inland Washington waters.

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

Jeffrey L. Laake, Patrick J. Gearin, and R.L. DeLong

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

Abstract

Harbor porpoise entanglement and mortality has decreased in the Makah set gillnet fishery in northern Washington through the use of acoustic devices (pingers). During 1996, observations of harbor porpoise in the vicinity of the gillnets have demonstrated that porpoise were less likely to approach nets when pingers were attached. The possibility of habituation to the pingers was tested in 1997 with continual usage of pingers for 45 days. An increase in entanglement and decreased displacement of porpoise was observed during the latter half of the study. However, the 1997 results were somewhat equivocal because insufficient numbers of porpoise were observed prior to deployment of the nets . To further evaluate the question of habituation, we conducted another experiment from 7 July - 11 August 1998. Observations of porpoise distribution were conducted during 7-22 July prior to deployment of a mock net (without monofilament webbing) with attached pingers. Observations were conducted for 20 days after pinger deployment. Twelve percent (SE = 1.5%) of the sightings were within 125 m of the net prior to deployment of the pingers. The percentage decreased to 0.5% (SE = 0.5%) during the first 10 days of pinger usage and then increased to 4.1% (SE = 1.0%) during the second 10 days of pinger usage. We interpreted these significant shifts in distribution as evidence that pingers displace porpoise but the displacement lessens through time due to habituation. Our conclusion that porpoise habituated to pingers should not be construed to apply to usage of pingers in other fisheries. Habituation was more likely to occur in this experiment because the net locations were not changed.

Introduction

Experimental field tests of pingers in the Makah tribal fishery in northern Washington during 1995 and 1996 demonstrated dramatic decreases in the incidental mortality of harbor porpoise (Gearin et al. 1999) and observations of harbor porpoise during the field tests showed that harbor porpoise were less likely to approach within 125 m of the net when pingers were attached (Laake et al. 1998a). In 1997, further tests and observations were conducted to assess whether pingers would remain effective when they were used continually (Laake et al. 1998b). During the first 22 days of the 1997 study, only 1 porpoise was entangled during 88 net days (22 days with 4 nets), and during the latter 23 days, 11 porpoise were entangled in nine of the 92 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 study. The increased mortality was supported by observations of harbor porpoise which demonstrated that their closest approach distance to the net decreased during the second-half of the experiment. However, unfortunately very few harbor porpoise were observed prior to deployment of the nets and they were all observed to the north of the northernmost net. Thus, the trend in approach distance and mortality could be explained by a general southward shift of the harbor porpoise distribution.

During all of the observation work from 1995-1997 the major concentration of porpoise sightings was always in the northern part of the bay (Laake et al. 1998a, Laake et al. 1998b). Due to the timing of the fishing season, we were unable to observe sufficiently prior to deploying fishing nets and could not be entirely certain that the observed porpoise distribution was an effect of the pingers or reflected a habitat preference. In 1998, the Makah fishery did not operate and we were able to observe porpoise distribution without nets and pingers and then introduce a net with pingers to examine whether porpoise would become habituated to the pingers.

Methods

The study was conducted in the Spike Rock Fishery Area along the west coast of the Olympic Peninsula, Washington (Laake et al. 1998a). Observations were conducted during 7 July to 11 August 1998 from an exposed bluff site (48°16'39"N, 124°40'48"W) northeast of Shi Shi Beach (Fig. 1). The same site was used during most of the 1997 study (Laake et al. 1998b). A team of 2 persons conducted 30 minute systematic watches of the field of view. One person would observe and the other would record data. Observer and recorder positions were swapped after each 30 minute scan and a 30 minute break was usually taken every 2 hours. The observer scanned the entire field of view (Fig. 1) with 7x50 binoculars starting from either the left or right side of the field of view. Upon completion of the scan the observer would start a new scan at the beginning (either left or right) and did not alternate directions. To achieve a balance of coverage across the entire field of view, one observer would always scan left to right and the other right to left. The observers attempted to maintain a constant scan rate but the number of completed scans during the 30 minute watch varied from 3 to 5. During the watch the visibility conditions were subjectively rated on a scale of 1-5 with 1 being ideal. Observations were 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.

The binoculars had a 5.44° optical field of view with 14 vertical reticle marks (17' per reticle mark) and an internal magnetic compass provided 360° bearings, accurate to within 3°. For each observed group of harbor porpoise, we recorded the group size and 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 from the GPS latitude and longitude of the observation site we computed the latitude and longitude of the observation.

Observations were conducted from 7 - 16 July prior to deployment of a mock net at 1700 on 16 July 1998. The mock net was identical to the fishing nets used in previous experiments

(Laake et al. 1998a) except that the monofilament webbing was removed. Observations were continued from 17 - 22 July with the net in place prior to deployment of 11 pingers that were attached at 1700 on 22 July. As in previous studies (Laake et al. 1998a), the pingers were 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 1m. The nets were checked weekly and any defective pingers were replaced. Observations were continued from 23 July to 11 August with the pingers in place.

A theodolite was used to get daily (unless precluded by fog) readings of the position of the buoys attached to either end of the mock net. From the vertical and horizontal theodolite measurements, the latitude and longitude of the net buoys were computed using the known position of the observation site (Laake et al. 1998a). The closest observed approach distance of the porpoise was computed as the distance between the net (defined as the line between the buoy positions) and the position of the porpoise sighting.

We used a Wilcoxson rank sum test to compare the daily minimum approach distance between three periods: I. 7-22 July, observation prior to pinger deployment, II. 23 July - 1 August, the first 10 days of pinger usage, and III. 2-11 August, the second 10 days of pinger usage. We restricted the test to days in which 5 or more porpoise were sighted to reduce variability. We also compared the proportion of observations within 125 m of the net (Laake et al. 1998a) which provides a more sensitive measure of exposure to entanglement. To reduce the effects of varying visibility we compared the proportion within 125 m of the number seen within 1 km of the net. We fit four generalized linear models (GLM) using a binomial distribution and logit link and different restrictions on proportions within each of the three experimental periods: 1) $p_1=p_2=p_3$, 2) p_1, $p_2=p_3$, 3)p_1, p_2, p_3, and 4) p_2, $p_1=p_3$. The first model assumes no pinger effect, the second assumes a pinger effect which remains constant, the third model assumes a pinger effect that changes during the final period, and the fourth assumes the pinger effect only lasts during the period II. We used a likelihood ratio to test for a pinger effect, Model 1 vs 2 and for habituation, Model 2 vs 3 and Model 3 vs 4.

Results

Prior to deployment of the pingers, 50.9 hours of observation were conducted and 532 porpoise groups were sighted (Table 1, Fig. 2). During the first 10 days of pinger use, 248 porpoise groups were sighted during 39 hours of observation(Table 1, Fig. 3), and in the second 10 days, 399 porpoise groups were sighted during 38.4 hours of observation (Table 1, Fig. 4). There were differences in visibility between periods (Table 2), but they were not too disparate. However, the effect of visibility was evident in a significant negative correlation ($r = -0.615$, $P = 0.04$) between average visibility and average distance observed from the net in period I. The correlation was substantially reduced and non-significant ($r = -0.008$, $P = 0.96$) by restricting to sightings seen within 1 km of the net.

The daily minimum closest approach distances (Table 1) were significantly greater in period II than period I ($P = 0.02$), but the differences were not significant between periods II and III ($P=0.07$) nor between periods I and III ($P = 0.20$). The proportion of harbor porpoise sightings within 125 m of the net was best described by Model 3 with separate probabilities for each period (p_1, p_2, p_3) (Table 3). The probability decreased from period I to II when pingers were attached and increased again during period III but it was not equivalent to p_1, which implied a continuing but reduced affect of the pingers on porpoise distribution through time.

Discussion

After 3 years of observing harbor porpoise and monitoring entanglement in nets (Laake et al. 1998a, Laake et al. 1999b, and Gearin et al. 1999), for this setnet fishery we believe it is reasonable to conclude the following:

1) Harbor porpoise mortality was reduced when pingers were attached to nets because harbor porpoise were less likely to approach nets within 125 m.

2) With continual use of pingers, porpoise began to approach the nets and entanglement increased.

3) There was evidence of habituation during the 45 days of pinger usage in 1997 and 20 days in 1998. The displacement of porpoise weakened through time, but the effect of the pingers was still evident. Even though the entanglement did increase in the latter part of the 1997 fishery, the mortality was still lower than in nets without pingers.

A comparison of the porpoise distribution maps from 1996, 1997 and 1998 show similarities but striking differences. During the 1996 study (Laake et al. 1998a) , at least two of the 4 nets were equipped with pingers at all times and during 1997 all 4 nets were equipped with pingers throughout the study. In both years, porpoise were infrequently seen in the southern half of the bay even though visibility conditions were often excellent and porpoise were frequently seen at the same distance to the north. During 1998, prior to deploying the pingers harbor porpoise were seen throughout the bay and historical observations (NMML unpubl. data) reflect the same pattern. These comparisons support the finding that displacement is the mechanism for entanglement reduction and suggest that porpoise may be displaced on a larger scale depending on the orientation of the nets with pingers and the habitat usage patterns of the porpoise.

In our study we have assumed that the same group(s) of porpoise remain in the general area to obtain continual exposure to the pingers. We feel this is a reasonable assumption because porpoise were seen several miles to the north on several occasions when few or no porpoise were seen from the observation site. We believe the porpoise shift up and down the coast following prey aggregations. If we did not demonstrate habituation of porpoise we would not have been able to conclude that habituation could not occur because it could have been argued that the same porpoise never encountered the pingers more than once or so infrequently that habituation was unlikely. Regardless of the mechanism, it would have been preferable if no apparent signs of habituation would have been observed. Given our observations of increased entanglement and a reduction in displacement we believe the only reasonable explanation is habituation due to constant exposure. Even though the effectiveness of the pingers was reduced with continual usage, the pingers continued to displace porpoise and maintained entanglement rates below levels without pingers.

Our conclusion that porpoise habituated to pingers should not be construed to apply to usage of pingers in other fisheries. Because we do not understand the mechanism for habituation nor the amount or frequency of exposure that leads to habituation, it would not be wise to conclude that habituation would occur in situations where the exposure would be different. In particular, our nets remained at the same location throughout the experiment. If setnets are moved or drift nets are employed, the frequency and level of exposure to the pingers would vary and habituation may or may not occur. Also, the pinger we employed produced a constant sound which may be more susceptible to habituation. Experiments with captive porpoise and field studies in different fisheries and with different pingers should be conducted to investigate further the problem of habituation.

Acknowledgments

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Citations

Gearin, P.J., M.E. Gosho, J. Laake, L. Cooke, R.L. DeLong, and K. M. Hughes. 1999. Experimental testing of acoustic alarms (pingers) to reduce bycatch of harbor porpoise (*Phocoena phocoena*) in Washington state. Inter. Whal. Comm. Unpubl. scientific document SC/51/SM13.

Laake, J., D. Rugh, and L. Baraff. 1998a. 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, 40pp.

Laake, J.L., P.J. Gearin, M.E. Gosho, and R.L. DeLong. 1998b. Evaluation of harbor porpoise habituation to pingers in a set gillnet fishery, 121-126. In P.S. Hill, B. Jones, and D.P. DeMaster (editors) Marine Mammal Protection Act and Endangered Species Act Inplementation Program 1997. U. S. Dep. Commer., AFSC Processed Rep. 98-10, 246pp.

Table 1. Hours of search effort and number of observed sightings of harbor porpoise groups surfacing when visibility was classified as fair or better. Dates with no search effort were excluded. Daily minimum approach distance is listed for all days with five or more sightings.

Date	Sightings			Effort (hours)	Minimum approach distance (m)
	All	Within 1 km of net	Within 125 m of net		
7/7/98	17	17	1	3.0	107.2
7/8/98	35	35	2	6.0	93.9
7/9/98	184	91	16	5.5	1.6
7/10/98	84	69	5	6.8	32.0
7/12/98	2	1	0	3.9	-
7/13/98	58	52	9	3.5	18.4
7/15/98	26	24	0	5.1	262.1
7/16/98	0	0	0	2.5	-
7/18/98	35	28	5	3.5	0.2
7/19/98	24	21	1	3.2	86.3
7/20/98	1	1	0	2.0	-
7/21/98	66	65	16	6.0	16.0
7/24/98	32	27	0	7.0	131.5
7/26/98	21	21	0	5.5	237.6
7/27/98	27	22	0	4.0	246.9
7/28/98	3	3	0	0.5	-
7/29/98	5	4	0	6.0	224.9
7/30/98	72	53	0	7.0	261.5
7/31/98	82	69	1	5.0	69.3
8/1/98	6	6	0	4.0	140.6
8/3/98	151	129	6	6.0	2.2
8/4/98	68	59	2	5.5	94.7
8/5/98	16	16	0	3.2	173.6
8/6/98	26	24	1	5.0	112.4
8/7/98	31	29	0	6.5	185.8
8/8/98	50	46	3	6.0	31.0
8/9/98	30	29	3	4.5	73.4
8/11/98	27	20	0	1.8	199.9
Total	1179	961	71	128.4	-

Table 2. Percentages of effort by visibility for each period.

Period	Visibility			
	Excellent	Very Good	Good	Fair
Before pingers	13.7%	17.3%	47.9%	21.0%
First 10 days	3.8%	64.1%	28.2%	3.8%
Second 10 days	0.0%	41.6%	47.1%	11.3%

Table 3. Summary results for generalized linear models of the proportion of sightings seen with 125 m of those seen within 1 km. Each likelihood ratio test had 1 degree of freedom.

Model	p_1	p_2	p_3	df	Deviance	Likelihood ratio test
1	0.069	0.069	0.069	26	71.08	
2	0.120	0.028	0.028	25	36.58	1 vs. 2: $\chi^2 = 34.5$, $P < 0.001$
3	0.120	0.005	0.041	24	28.47	2 vs. 3: $\chi^2 = 8.1$, $P = 0.004$
4	0.085	0.005	0.085	25	46.08	4 vs. 3: $\chi^2 = 17.6$, $P < 0.001$

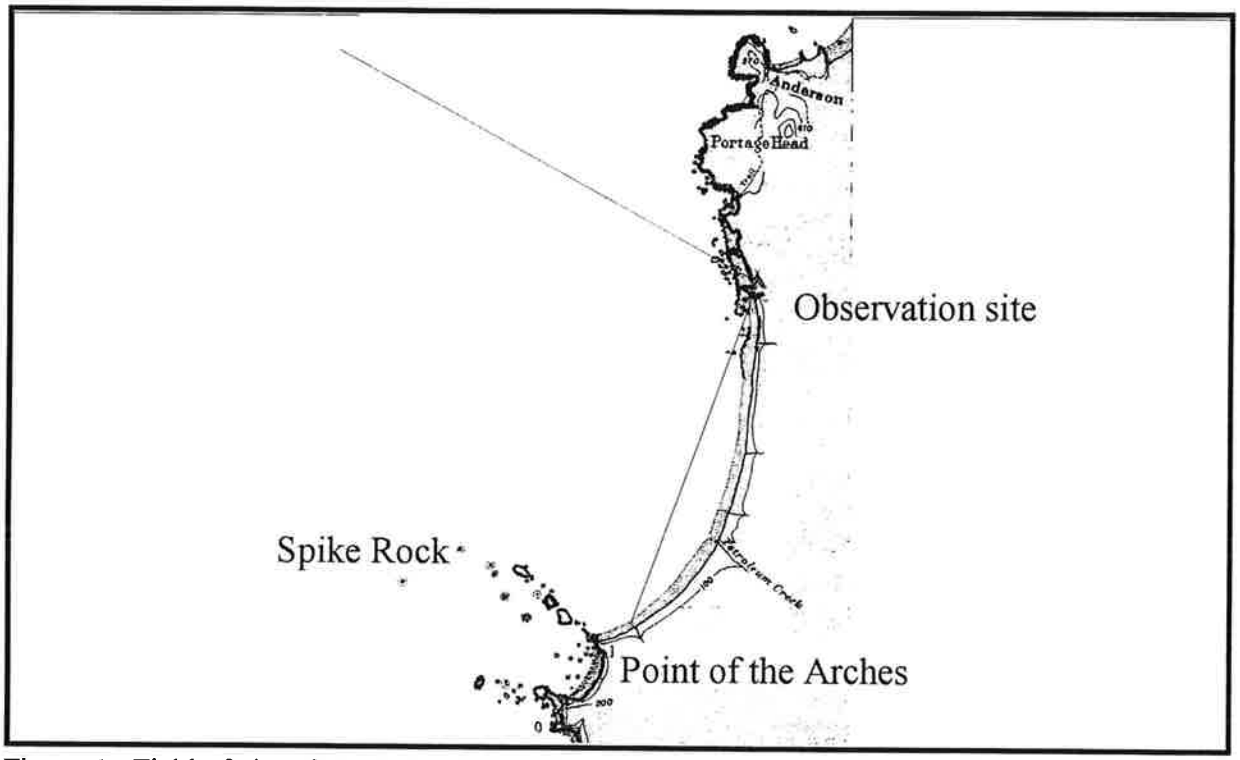

Figure 1. Field of view from 1998 observation site which was also used in 1997.

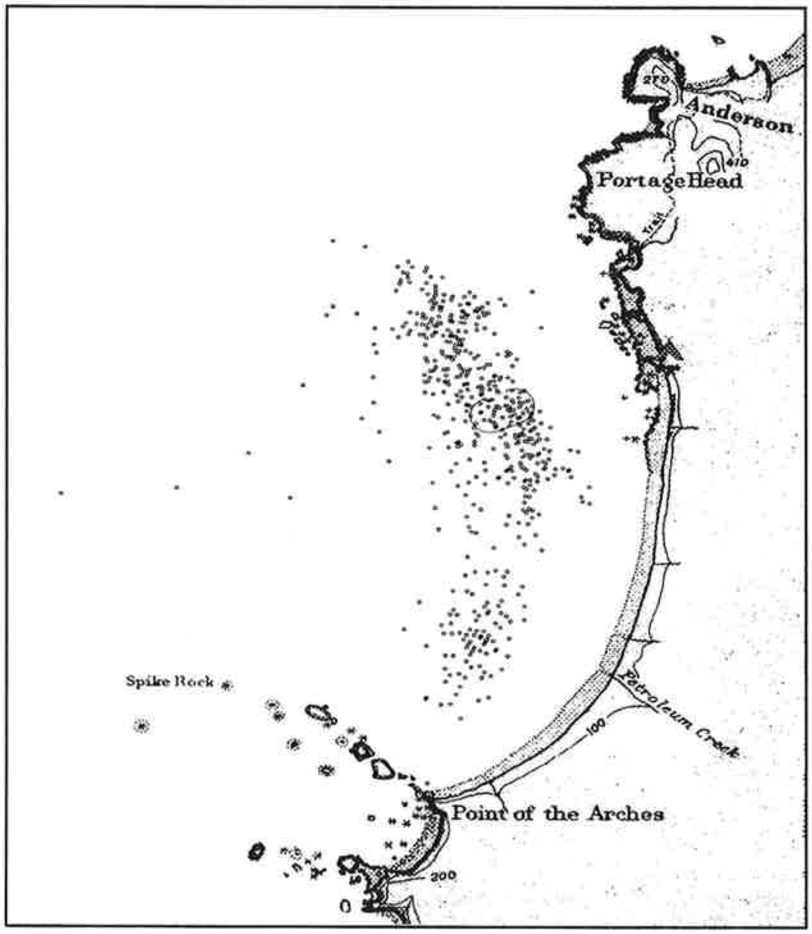

Figure 2. Distribution of harbor porpoise sightings during period I (7-21 July 1998) prior to deployment of the pingers. The circular track marks a buffer of 125 m around the position of the mock net.

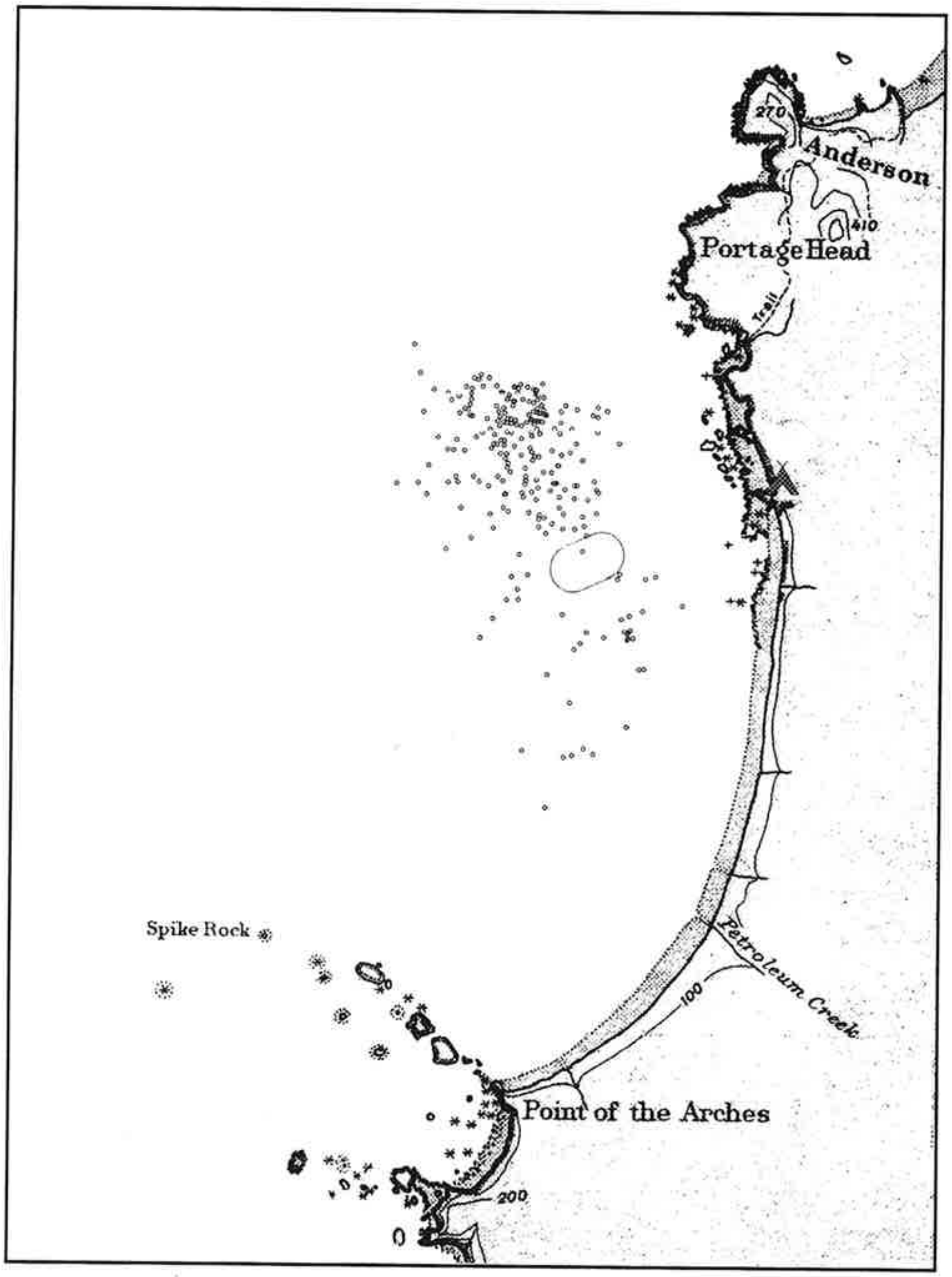

Figure 3. Distribution of harbor porpoise sightings during period II (22 July - 1 August 1998), the first 10 days of pinger usage. The circular track marks a buffer of 125 m around the position of the mock net.

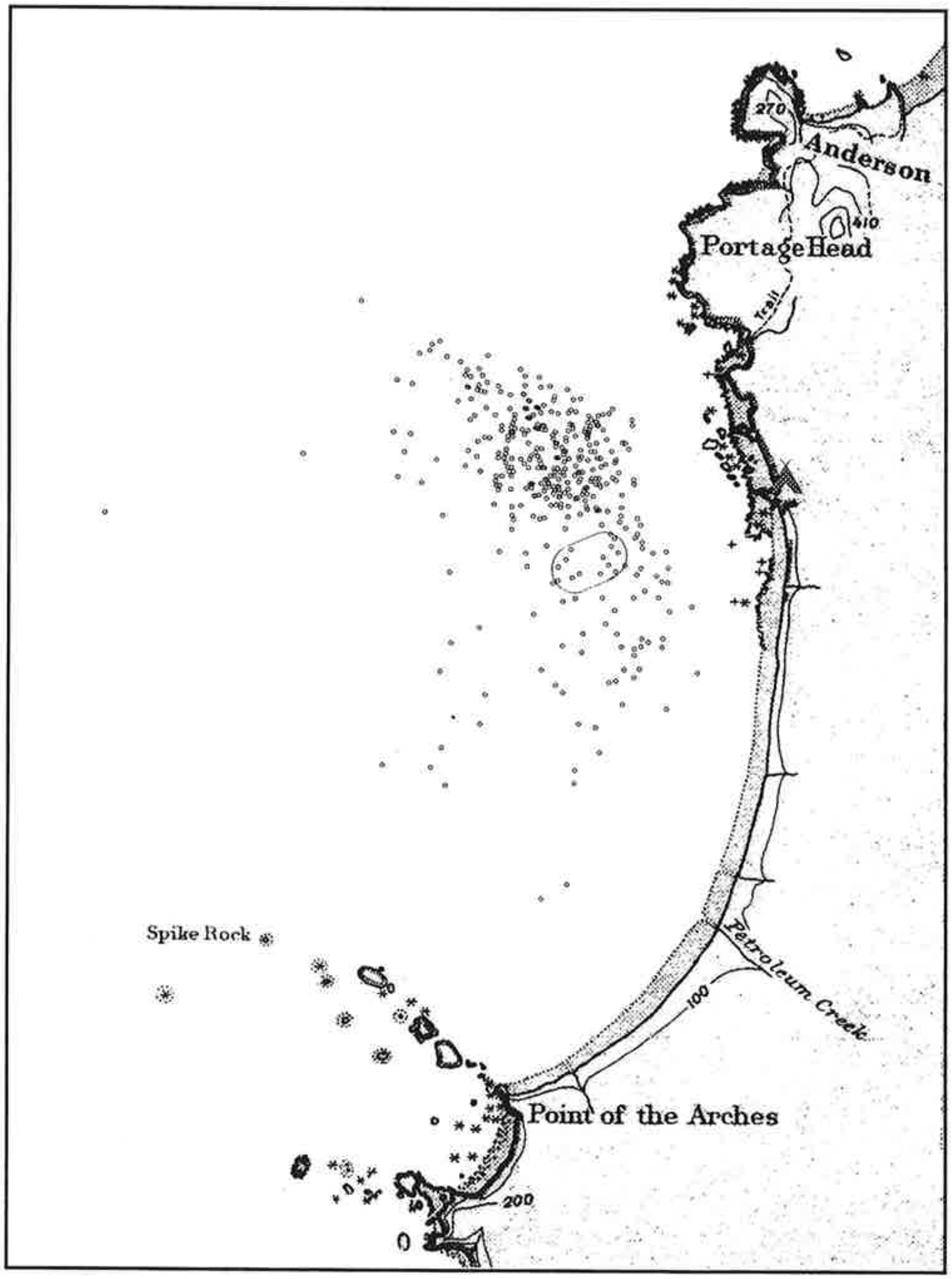

Figure 4. Distribution of harbor porpoise sightings during period III (2-11 August 1998), the second 10 days of pinger usage. The circular track marks a buffer of 125 m around the position of the mock net.

ACOUSTIC ALARMS AND PACIFIC HERRING (*CLUPEA PALLASI*)

Kirt M. Hughes, Larry L. Lehman, Patrick J. Gearin, Jeffrey L. Laake, Robert L. DeLong, and Merrill E. Gosho.

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

Abstract

Acoustic alarm (pingers) effects on Pacific herring, *Clupea pallasi*, were explored by direct observation of herring and experimental control-treatment differences in herring distribution and catch rates. Inactive and active pingers which produced a broad band signal centered at about 3 kHz and a second peak at about 20 kHz (source levels were 121.7 - 124.7 dB re 1 μPa @ 1m) were placed into a pen containing herring and also among free-swimming herring at Neah Bay in northwest Washington State. Herring responded equally to both inactive and active pingers with an initial startle reaction followed by a resumption of normal swimming behavior in close proximity (0.2m) to the pinger. We attached pingers on a sample of gill-net sets that were fished for herring in Neah Bay from 13 July- 12 August 1998. Sonar was used to determine the distribution of herring in the vicinity of one of the gill-nets being fished alternately with active and inactive pingers. The sonar distributions did not suggest an aversive reaction relative to the alarms. Likewise, the occurrence of herring catch in the gill-nets was not significantly different between control and alarmed sets.

Introduction

An experimental evaluation of the effectiveness of acoustic alarms (pingers) to reduce harbor porpoise (*Phocoena phocoena*) entanglement in the New England sink net fishery (Krause et al. 1997) led to observations of reduced catches of Atlantic herring (*Clupea harengus*) in nets with pingers attached. This observation called into question the mechanism by which pingers functioned to lower catch rates of harbor porpoise in the fishery. Do the pingers reduce harbor porpoise entanglement by alerting or repelling porpoise from the nets or do they actually function by repelling harbor porpoise prey (i.e., herring)? Atlantic herring are the primary prey of harbor porpoise in the Gulf of Maine (Recchia and Read 1988). Pacific herring (*Clupea pallasi*) are also known to be the primary prey of harbor porpoise in the Northern Washington Marine Setnet fishery (Gearin et al. 1994) considered in this study.

Herring, a clupeiform fish, are known to possess the ability to hear at frequencies higher than many other teleost fishes (Enger 1967 and Schwartz and Greer 1984). Olsen (1976) observed that Atlantic herring, *Clupea harengus*, exhibited a directional avoidance response to frequencies from 0.03 - 5 kHz when the sound source was a distance of 22.5m to 30m from the herring. For frequencies greater than 10 kHz no responses were noted. Habituation to the signal was reported by Olsen (1976). Enger (1967) reported nervous responses to pure tone sound from 0.03 - 4 kHz with sound pressure as high as 35dB. Responses were noted for frequencies above 6 kHz, however 66% of the herring in the study had no response to frequencies above 0.5 kHz. In all situations a visible response was only elicited with sound pressure levels 20 - 30 dB above background levels. In a study of Pacific herring, it was shown that frequencies to 1 kHz elicited a strong response (Schwartz and Greer 1984) yet the herring habituated to common underwater sounds. Other clupeid fishes of the genus *Alosa* were also found to respond to high frequency sound (Nestler et al. 1992 and Mann et al. 1997). Blueback herring, *Alosa aestivalis,* responded to 110 - 140 kHz frequencies with sound pressure levels above 180dB (Mann et al. 1997).

In a attempt to determine how acoustic alarms might affect Pacific herring we conducted observational studies of herring reactions to pingers, a small mesh herring gill-net fishery, and utilized sonar to evaluate the distribution of small bait-fish, specifically herring. A pilot study was conducted in 1997 (Hughes et al. 1998), followed by a more extensive and rigorous study in 1998; the results of which are reported here.

Methods

Acoustic Alarms

The pingers are based on the Lien model (Fullilove 1994), with some modifications (Gearin et al. 1996). Each pinger was made of a section of black ABS pipe 15 - 18cm (6-7in.) in length and 5.1cm (2.0in.) in diameter. One end was fitted with a solid cap that housed the alarm (a piezo-buzzer, Radio Shack®, catalog #273-068); the other end was a threaded cap allowing the four nine-volt batteries that power the alarm to be easily replaced. Three of the alarms were tested in the marine environment of Puget Sound to determine their signal strength and source levels (Gearin et al. 1996). The alarms produced a broad band signal centered at about 3 kHz and a second peak at about 20 kHz. The source levels were 121.7 - 124.7 dB re 1 μPa @ 1 m. In air at a distance of 30cm, the minimum source levels were 90 dB, according to manufacturer specifications.

Observation Study

We observed the reaction of herring held in net pens and free-swimming herring to active and inactive pingers. Pingers were introduced to a net pen containing Pacific herring at the Edmonds Marina in the waters of Puget Sound. The net pen was rectangular; 7m long, 4.5m wide by 3m deep. Approximately 5000-7000 herring were caught in the wild eight days prior to the test and placed in the pen. The medium-sized herring ranged in length from150-225mm (standard length measured from the anterior tip of the lower jaw to the posterior extent of the hypural plates in the caudal region). Pingers were suspended in the water by a small line 1.5m below the surface. In the first test an inactive pinger was placed in the water, the response of the herring was observed for 15 minutes. This procedure was then repeated three more times alternately using active and inactive pingers.

We also observed the reaction of free-swimming herring to pingers from an observation deck several meters above the water at Neah Bay. Inactive and active pingers were alternately lowered into schools of free swimming herring for 15 minute periods. The initial reactions of the herring to the pingers and subsequent responses were observed.

Catch Rate Study

In an attempt to determine the effect of acoustic alarms on free swimming Pacific herring we fished small mesh gill-nets in the harbor of Neah Bay, Washington. The Neah Bay harbor, 48° 25' N; 124° 36' W, is protected by a man-made breakwater on the northern side facing the Strait of Juan de Fuca. During the 1998 field season all nets were deployed on 13 July 1998 and removed from the study site on 12 August 1998; fishing effort with net #3 however was discontinued on 4 August 1998 (Table 1).

Two monofilament nylon nets with stretched mesh sizes of 3.2cm (1.25in.) and 5.1cm (2.0in.) were used in the study. Both nets were 50 fathoms in length; composed of a corkline, a 25 fathom section of 3.2cm mesh, a 25 fathom section of 5.1cm mesh, and a leadline. The nets were checked daily; on average, twenty four hours from the previous day, the catch was examined and recorded. The nets were fished in generally the same manner as the marine set-net fishery of the Makah tribe (Gearin 1994). Each end of the leadline was anchored to the substrate. A buoy was attached to each end of the corkline. The nets fished vertically at mid-water. Nets were alternately fished with pingers (alarm) and without pingers (control) for varying periods of time. Pingers were attached with nylon ties to the corkline at 22m (12.0fms) intervals with the first and last at each end of the net. We compared catch rates as, catch per unit of effort (CPUE) of nets fished with pingers versus nets fished without pingers. We used a chi-square contingency test to compare the distribution of number of herring caught in sets with and without pingers. For purposes of our study one "net day" (ND) is equivalent to 50 fathoms of net being fished for twenty four hours.

Sonar Surveys

In an attempt to determine how herring were distributed in the vicinity of the net during control versus alarm conditions, transects were run perpendicular to net #1 using sonar at the predicted high and low tides during daylight hours. A Lowrance model X65, with a transducer frequency of 192 kHz and beam width of 20° was used to quantify fish along the transects. Additionally a speed, temperature and distance log Lowrance model ST-TBK, was used to allow boat operator to maintain a speed of between 2.5 and 4.0 knots along the transects. There were six transects running perpendicular to the net; the first and last were at the ends of the net and there was 18.3m between adjacent transects. The beam width of the transducer over an average bottom depth of 10.4m provided a view of the bottom 3.6m wide. The screen resolution allowed the observer to count individual sonar hits (fish), when larger aggregations were apparent the observer estimated the number of fish present. Each transect was separated into four 25m sections on each side of the net. The sum of all fish in a 25m section was determined. Counts of fish in each section were totaled by control or alarm and grouped by the distance from the net.

We used a chi-square test to compare the distributions although we recognized that observations of fish were not independent events.

Results

Observations

When the inactive pinger was introduced, herring moved quickly away from the pinger to a distance of about 1.5m. Two minutes after the pinger was introduced the herring had moved to a distance about 0.3m from the pinger and after five minutes the distance was reduced to near 0.2m. When the active pinger was introduced the reactions were nearly identical. In all of the trials, we observed an initial startle response followed by resumption of a normal polarized swimming pattern of the herring school. Free swimming herring in Neah Bay harbor also exhibited an initial startle response as the pinger was lowered into the water but within a few minutes they appeared to ignore both active and inactive pingers alike.

Catch Data

During the test fishery, 1633 herring were caught; including 1039 from control nets in 44.1 ND and 594 from alarmed nets in 24.3 ND (Table 2). The CPUE values for control nets were 23.6 herring per ND compared to 24.4 per ND for alarmed nets. The herring caught ranged from SL=114 -249mm. Daily catch per net ranged from 0-520 herring (Table 3). There was no significant difference ($\chi^2 = 1.66$, df = 1, P=0.196) between the catch rates of nets with pingers compared to those without.

Transect Surveys

Transect surveys began on 14 July 1999, the last day was 5 August 1999, a total of forty-two surveys were conducted. A significant difference was found between distributions during control and alarm periods (χ^2=10.54, df=3, P=0.0145)(Fig. 1); however, we believe the significance is an artifact of the non-independence created by schooling behavior. Most of the chi-square contribution resulted from the small differences in the 0-25 m bin, but the effect is opposite of a predicted alarm effect, with a greater than expected percentage seen closer to the net during alarm periods. Inference about herring behavior from sonar assumes that all of the fish are herring which seems reasonable in this case because 98.6% of the fish caught in the nets were herring.

Discussion

Observations of both net pen herring and free swimming herring suggest that herring are not reacting to the sound of the pinger as much as the physical presence of the unit in the water. Our 1998 catch data and sonar transect data support these observations. An initial catch rate study conducted in 1997 (NMML unpubl. data) suggested that catch was lower when alarms were attached to the nets; however, the deployment of alarms on nets was not well balanced in time or between nets. Most of the 1997 fishing with alarms was conducted after fishing with control nets. It is quite possible that fishing with control nets artificially lowered the catch rates during the alarm periods because of removal of the fish. Although, the deployment of the alarm and control periods for the 1998 study was not perfectly balanced, we believe it was balanced sufficiently for a valid test.

Laake et al. (1998) demonstrated that harbor porpoise were less likely to approach nets within 125m of a net if pingers were attached. Based on the results of our tests with herring, we do not believe this behavior is related to a reaction of herring to the alarms.

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Citations

Enger, P. S. 1967. Herring and hearing. Comp. Biochem. Physiol. 22: 527-538.

Fullilove, J. 1994. How to make a gillnet "Pinger". National Fisherman. 75(1):29-30.

Gearin, P. J., S. R. Melin, R. L. DeLong, H. Kajimura, M. A. Johnson. 1994. Harbor Porpoise Interactions With a Chinook Salmon Set-Net Fishery in Washington State. Rep. Int. Whal. Commn (Special Issue 15), 1994.

Gearin, P. J., M. E. Gosho, L. Cooke, R. DeLong, and J. Laake. 1996. Acoustic Alarm experiment in the 1995 Northern Washington Marine Setnet Fishery: Methods to Reduce By-catch of Harbor Porpoise. Rep. Int. Whal. Commn. SC/48/SM10.

Kraus, S. D., A. J. Read, A. Solow, K. Baldwin, T. Spradlin, E. Anderson, and J. Williamson. 1997. Nature. Vol. 388:525.

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 pp.

Mann, D. A., Z. Lu, and A. N. Popper, 1997. A clupeid fish can detect ultrasound. Nature. Vol. 389:341.

Nestler, J. M., G. R. Ploskey, J. Pickens, J. Menezes, and C. Schilt. 1992. Responses of blueback herring to high-frequency sound and implications for reducing entrainment at hydro-power dams. N. Am. J. Fish. Mgnt. Vol. 12, no. 4 pp. 667-683.

Olsen, K.: Evidence for localization of sound by fish in schools. In: Sound Reception in Fish. Schuijf, A., Hawkins, A. D. (eds.). Amsterdam: Elsevier, 1976, pp. 257-270.

Recchia, C. A. and A. J. Read. 1988. Stomach contents of harbour porpoises, *Phocoena phocoena*, from the Bay of Fundy. Can. J. Zool. 67(9):2140-6.

Swartz, A. L., and G. L. Greer. 1984. Responses of Pacific herring, *Clupea harengus pallasi*, to some underwater sounds. Can. J. Fish. Aquat. Sci. 41: 1183-1192.

Table 1. Net characteristics and locations for herring catch rate study in Neah Bay.

	Net # 1	Net # 2	Net # 3
Date of set	14-Jul-98	14-Jul-98	14-Jul-98
Date of pull	12-Aug-98	12-Aug-98	4-Aug-98
Net length (fms)	50	50	19
Mesh size	3.2cm(1.25")/5.1cm (2.0")	3.2cm(1.25")/5.1cm (2.0")	4.4cm(1.75")
Depth of water	10.4m (34.0')	7.9m (26.0')	5.49m (18.0')
Latitude	48 22.555'N;	48 22.500'N;	48 22.411'N;
Longitude	124 36.907'W	124 36.214'W	124 35.618'W

Table 2. Summary statistics of catch, effort and CPUE (number of herring caught per day standardized for a 50 fathom net).

Net Days Fished		Net # 1	Net # 2	Net # 3	**TOTAL**
	Control	16.0	22.0	6.1	44.1
	Alarm	14.0	8.0	2.3	24.3
	TOTAL	30.0	30.0	8.4	68.4
Herring catch					
	Control	714	321	4	1039
	Alarm	584	9	1	594
CPUE herring / net day					
	Control	23.6 herring / net day			
	Alarm	24.4 herring / net day			

Table 3. Number of herring caught in each net and status (C=control, A=Alarm) of each net.

	Net 1		Net 2		Net 3	
Date	Pinger	Catch	Pinger	Catch	Pinger	Catch
14-Jul-98	C	89	C	3	C	0
15-Jul-98	C	31	C	2	A	0
16-Jul-98	C	5	C	30	A	0
17-Jul-98	A	436	C	88	C	0
18-Jul-98	A	17	C	107	C	0
19-Jul-98	C	5	C	3	A	0
20-Jul-98	C	0	C	0	A	0
21-Jul-98	A	0	C	0	C	1
22-Jul-98	A	22	C	4	C	2
23-Jul-98	C	8	C	103	A	0
24-Jul-98	C	29	C	34	A	1
25-Jul-98	A	0	C	2	C	0
26-Jul-98	A	2	C	0	C	1
27-Jul-98	C	140	A	0	C	0
28-Jul-98	C	3	A	0	C	0
29-Jul-98	A	1	C	0	C	0
30-Jul-98	A	0	C	3	C	0
31-Jul-98	C	0	A	8	C	0
1-Aug-98	C	0	A	0	C	0
2-Aug-98	A	0	C	1	C	0
3-Aug-98	A	1	C	0	C	0
4-Aug-98	C	2	A	1	C	0
5-Aug-98	C	2	A	0		
6-Aug-98	A	1	C	4		
7-Aug-98	A	2	C	0		
8-Aug-98	C	0	A	0		
9-Aug-98	C	0	A	0		
10-Aug-98	A	5	C	18		
11-Aug-98	A	97	C	275		
12-Aug-98	C	520	A	18		

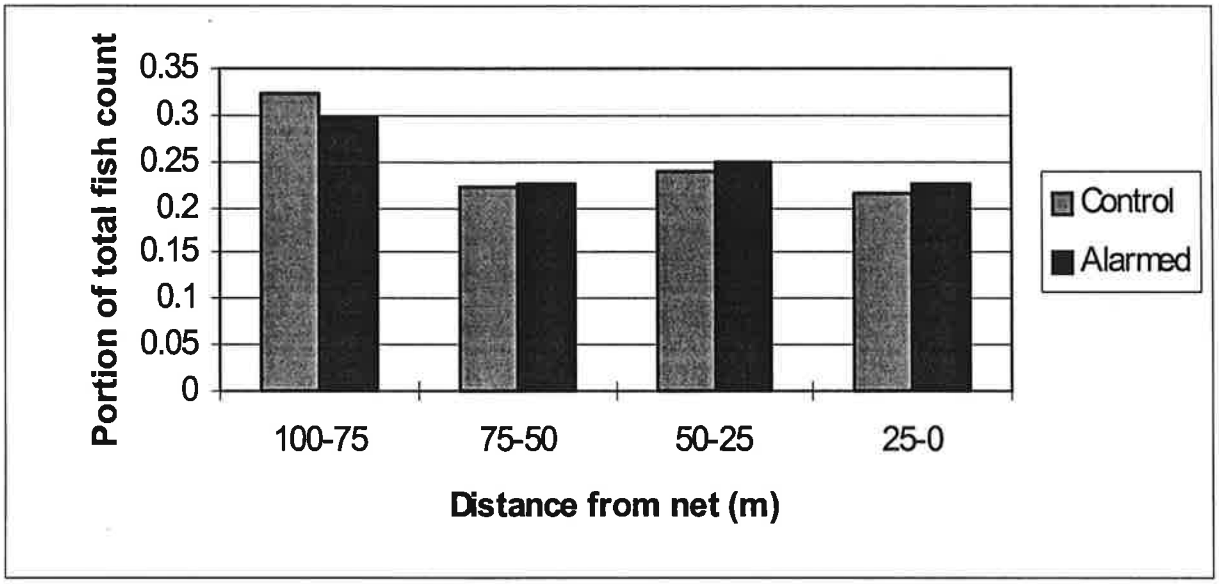


Figure 1. Proportion of fish counted in each distance bin from the net during alarm and control periods.

ABUNDANCE AND DISTRIBUTION OF HARBOR SEALS (*PHOCA VITULINA RICHARDSI*) FOR SOUTHERN SOUTHEAST ALASKA FROM FREDERICK SOUND TO THE U.S./CANADA BORDER IN 1998

David E. Withrow, Jack C. Cesarone, and John L. Bengtson

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

Abstract

Minimum population estimates were obtained for harbor seals, *Phoca vitulina richardsi*, in the southern portion of Southeast Alaska during August 1998. The mean number of seals counted was 26,106 (95% confidence interval between 24,964 and 27,248). The CV of the mean was equal to 2.23%. Comparisons were made between similar surveys conducted in September of 1993. The 1993 surveys covered the entire Southeast Alaska region while the 1997 surveys censused the northern portion from Kayak Island to Frederick Sound and the present surveys ranged from Frederick Sound south to the U.S./Canada border. More survey aircraft and observers were utilized in both the 1997 and 1998 studies and area coverage was much more complete. Observers more precisely delineated the location of sites in 1997 and 1998 than in 1993. Observers recorded seals at 428 sites in 1998. There were 199 sites which compared directly to 148 sites in 1993. Of these sites in common, 8,791 seals were observed in 1993 and 15,473 were observed in 1998. There were 10,633 seals found at 229 new sites during the 1998 surveys. Possible explanations for the increased number of seals observed include: more complete area coverage, surveys conducted earlier when more seals are expected to haul out, the population growth is real and/or seals are immigrating from other areas.

Introduction

Declines in harbor seal, *Phoca vitulina richardsi*, 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 to 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 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: southeastern Alaska, the Gulf of Alaska (from Prince William Sound to the Shumigan 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 SE Alaska 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 [Bristol Bay, Prince William Sound, and Copper River Delta], Loughlin 1993 [Gulf of Alaska and Prince William Sound], Loughlin 1994 [southeastern 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), the Gulf of Alaska was censused in 1996 (Withrow and Loughlin 1997), and the northern portion of SE Alaska was surveyed in 1997 (Withrow and Cesarone 1998) . This paper describes the results of our census efforts in the southern portion of SE Alaska in 1998.

Methods

Study Area

The study in 1998 consisted of eight aerial surveys in six areas (Areas 8-13; Fig. 1). Areas1-7 were censused in 1997. All surveys were conducted from August 18-27, 1998 (Table 1). Dana Seagars surveyed Area 8 from southern Fredrick Sound down Chatham Strait to northern Sumner Strait including Coronation Island and the western shore of Kupreanof Island. John Jansen surveyed Area 9, Fredrick Sound to Clarence Strait including northern Sumner Strait. Kaya Brix surveyed Area 10, the northwestern shore of Prince of Wales Island from Sumner Strait to the mouth of Trocadero Bay. John Bengston surveyed Area 11 from southern Sumner Strait south to the Cleveland Peninsula including Etolin and Wrangell Island. Robin Westlake surveyed Area 12, southwestern shore of Prince of Wales Island from southern Suemez Island to Cape Chacon. Peter Olesiuk and David Withrow each surveyed a portion of Area 13, Clarence Strait from the Cleveland Peninsula to Dixon Entrance including Revillagigedo, Annette, McFarland and Percy Islands including Portland Canal. Una Swain also censused a portion of Area 13. She surveyed the ADF&G trend routes along southeast Prince of Wales Island, the southern tip of the Cleveland Peninsula, the Behm Canal, and Mary Island.

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 the greatest numbers at and around the time of low tide. Aerial surveys were arranged and timed such that terrestrial haul-out 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 haul-out sites as well as all known haul-out sites.

Subsequently, four to seven repetitive photographic counts were conducted for each major haul-out 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 animals (Loughlin 1992, 1993; Pitcher 1989, 1990; Withrow and Loughlin 1995b).

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. Jansen and Seagars flew out of Petersburg. Brix, Bengtson, Westlake, Olesiuk, Swain, and Withrow used Ketchikan as their base of operations.

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) 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 1998) 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.

Results

Area 8. (*Seagars; southern Fredrick Sound down Chatham Strait to northern Sumner Strait including Coronation Island and the western shore of Kupreanof Island*)
This area contained 60 individual sites. Two to six replicate counts were recorded for each site during the 8 day survey window. The maximum count of 7,232 harbor seals was obtained by combining the maximum count for each area regardless of day censused. The sum of means was $\bar{x}$ = 4,314 harbor seals (SD = 182.52), with a CV = 4.23% (Table 2, Fig. 2).

Area 9. *(Jansen; Fredrick Sound to Clarence Strait including northern Sumner Strait)*
This area contained 56 individual sites. Two to seven replicate counts were recorded for each site during the 8 day survey window. The maximum count of 6,950 harbor seals was obtained by combining the maximum count for each area regardless of day censused. The sum of means was $\bar{x}$ = 3,052 harbor seals (SD = 208.60), with a CV = 6.83% (Table 3, Fig. 3).

Area 10. (*Brix; northwestern shore of Prince of Wales Island from Sumner Strait to the mouth of Trocadero Bay*)
This area contained 46 individual sites. One to three replicate counts were recorded for each site during the 8 day survey window. The maximum count of 4,343 harbor seals was obtained by combining the maximum count for each area regardless of day censused. The sum of means was $\bar{x}$ = 3,469 harbor seals (SD = 252.39), with a CV =7.28% (Table 4, Fig. 4).

Area 11. (*Bengtson; southern Sumner Strait south to the Cleveland Peninsula including Etolin and Wrangell Island*)
This area contained 38 individual sites. One to seven replicate counts were recorded for each site during the 8 day survey window. The maximum count of 3,969 harbor seals was obtained by combining the maximum count for each area regardless of day censused. The sum of means was $\bar{x}$ = 2,576 harbor seals (SD =159.94), with a CV = 6.21% (Table 5, Fig. 5).

Area 12. (*Westlake; southwestern shore of Prince of Wales Island from southern Suemez Island to Cape Chacon*)
This area contained 63 individual sites. One to five replicate counts were recorded for each site during the 8 day survey window. The maximum count of 4,679 harbor seals was obtained by combining the maximum count for each area regardless of day censused. The sum of means was $\bar{x}$ = 3,021 harbor seals (SD = 212.05), with a CV = 7.02% (Table 6, Fig. 6).

Area 13 (*Olesiuk & Withrow; Clarence Strait from the Cleveland Peninsula to Dixon Entrance including Revillagigedo and Annette Islands and Portland Canal*)
This area contained 98 individual sites. One to four replicate counts were recorded for each site during the 8 day survey window. The maximum count of 5,827 harbor seals was obtained by combining the maximum count for each area regardless of day censused. The sum of means was $\bar{x}$ = 4,252 harbor seals (SD = 216.91), with a CV = 5.10% (Table 7, Fig. 7).

Area 13 (*Swain; ADF&G trend routes along southeast Prince of Wales Island, the southern tip of the Cleveland Peninsula, the Behm Canal, and Mary Island*)
This area is primarily the ADF&G Ketchikan Trend Route plus several additional surrounding locations for a total of 63 individual sites. One to eight replicate counts were recorded for each site during the 8 day survey window. The maximum count of 9,323 harbor seals was obtained by combining the maximum count for each area regardless of day censused. The sum of means was $\bar{x}$ = 5,421 harbor seals (SD = 284.07), with a CV = 5.24% (Table 8, Fig. 8).

Estimated Population Size for the southern portion of Southeast (all areas combined)
The entire region from Frederick Sound to the U.S./Canada border contained 428 individual sites. (Only sites where seals were observed at least once in August 1998 are included). One to

eight replicate counts were recorded for each site during the 10 day survey window. The maximum count of 42,323 harbor seals was obtained by combining the maximum count for each area regardless of day censused. The sum of means was $\overline{x}$ = 26,106 harbor seals (SD = 582.08), with a CV = 2.23% (Table 9).

1998 and 1993 Comparisons

Site locations in 1998 were compared with those from 1993. Exact positions (latitude and longitude) were not recorded in 1993, which complicated the cross-match procedure. In addition, observers in 1998 were encouraged to delineate positions as precisely as possible. For example, in 1998, 4-6 sites might have been identified for an area which was delineated as a single site in 1993. Observers recorded seals at 428 sites in 1998. There were 199 sites in common with 148 sites from 1993. Observers recorded 8,791 seals in 1993 and 15,473 seals in 1998 at these same sites. There were 229 new sites discovered in 1998 containing 10,633 seals.

Discussion

The 1998 harbor seal census surveys were conducted in a similar manner to those of 1993 (Loughlin 1994). We used eight aircraft, each with an experienced observer, to cover the survey area (Figs.1-8). 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 1998 were long, but allowed sufficient coverage and that all areas could be censused within 2 hours of either side of low tide.

The 1993 surveys were handicapped with logistical requirements to conduct ten concurrent surveys using ten different aircraft and observers. These surveys were conducted between 12-20 September. We decided to split SE Alaska in half and survey the northern section in 1997 and the southern section in 1998. This allowed us to better utilize the resources 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 18-27 August 1998, 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. In 1997, we surveyed in August, and resurveyed one of the routes again in September. This proved very useful and concluded that indeed August was the better month to conduct surveys. In addition, weather is generally much worse in September.

Observers counted seals at 199 sites in 1998 which directly compared to 148 sites in 1993. They recorded 8,791 seals in 1993 and 15,473 seals in 1998 at these same sites. There were 229 new sites discovered in 1998 containing 10,633 seals.

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 (Pers. Com., Peter Olesiuk, Canadian Department of Fisheries and Oceans)

Our over-all population estimate, without corrections for seals in the water and not present at the time census counts were made, is 26,106 with a 95% confidence interval between 24,964 and 27,248. The coefficient of variation is a low 2.23 (Table 9), but this is in part due to the large number of sites (n=428) and large number of replicates (n=1,598).

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, U.S. Fish and Wildlife Service, and the Canadian Department of Fisheries and Oceans all provided experienced observers. Anne York provided analytical advice.

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. Report.27 pp. Available National Marine Mammal Laboratory, 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. Report. 25 pp. Available National Marine Mammal Laboratory, 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. Report. 42 pp. Available National Marine Mammal Laboratory, 7600 Sand Point Way, Seattle, WA.

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

Pitcher, K. W. 1990. Major decline in number of harbor seals, *Phoca vitulina richardsi*, on Tugidak Island, Gulf of Alaska. Mar. Mamm. 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 Commerce, 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 Marine Mammal Assessment Program (MMAP), NOAA, Office of Protected Resources, Silver Spring, Maryland. May 1995 39 pp.

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. 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 J.C. Cesarone. 1998. Abundance and distribution of harbor seals (*Phoca vitulina richardsi*) for northern Southeast Alaska from Kayak Island to Frederick Sound in 1997. Annual report to the MMPA Assessment Program, Office of Protected Resources, NMFS, NOAA, 1335 East-West Highway, Silver Spring, MD 20910

Table and Figure captions

Table 1. Area numbers, survey route locations, observers, affiliations, and dates for harbor seal surveys in southern southeast Alaska in 1998.

Table 2. The number of seals counted at each site for Area 8. [Seagars] (southern Fredrick Sound down Chatham Strait to northern Sumner Strait including Coronation Island and the western shore of Kupreanof Island)

Table 3. The number of seals counted at each site for Area 9. [Jansen] (Fredrick Sound to Clarence Strait including northern Sumner Strait)

Table 4. The number of seals counted at each site for Area 10. [Brix] (northwestern shore of Prince of Wales Island from Sumner Strait to the mouth of Trocadero Bay)

Table 5. The number of seals counted at each site for Area 11. [Bengtson] (southern Sumner Strait south to the Cleveland Peninsula including Etolin and Wrangell Island)

Table 6. The number of seals counted at each site for Area 12. [Westlake] (southwestern shore of Prince of Wales Island from southern Suemez Island to Cape Chacon)

Table 7. The number of seals counted at each site for Area 13. [Olesiuk & Withrow] (Clarence Strait from the Cleveland Peninsula to Dixon Entrance including Revillagigedo, Annette, McFarland and Percy Islands, and Portland Canal)

Table 8. The number of seals counted at each site for Area 13. [Swain] (ADF&G trend routes along southeast Prince of Wales Island, the southern tip of the Cleveland Peninsula, the Behm Canal, and Mary Island)

Table 9. Summary statistics for all areas.

Figure 1. Survey areas for 1997 (1-7) and 1998 (8-13).

Figure 2. Survey Area 8. [Seagars] (southern Fredrick Sound down Chatham Strait to northern Sumner Strait including Coronation Island and the western shore of Kupreanof Island)

Figure 3. Survey Area 9. [Jansen] (Fredrick Sound to Clarence Strait including northern Sumner Strait)

Figure 4. Survey Area 10. [Brix] (northwestern shore of Prince of Wales Island from Sumner Strait to the mouth of Trocadero Bay)

Figure 5. Survey Area 11. [Bengtson] (southern Sumner Strait south to the Cleveland Peninsula including Etolin and Wrangell Island)

Figure 6. Survey Area 12. [Westlake-Storey] (southwestern shore of Prince of Wales Island from southern Suemez Island to Cape Chacon)

Figure 7. Survey Area 13. [Olesiuk, Withrow, & Swain] (ADF&G trend routes along southeast Prince of Wales Island, the southern tip of the Cleveland Peninsula, the Behm Canal, and Mary Island)

Figure 8. Survey Area 13. [Olesiuk & Withrow] (Clarence Strait from the Cleveland Peninsula to Dixon Entrance including Revillagigedo, Annette, McFarland and Percy Islands, and Portland Canal)

Table 1. Area numbers, survey route locations, observers, affiliations, and dates for harbor seal surveys in southern southeast Alaska in 1998.

Survey area	Observer	Affiliation	Dates
Area 8 southern Fredrick Sound down Chatham Strait to northern Sumner Strait including Coronation Island and the western shore of Kupreanof Island	Dana Seagars	USF&WS	8/18/97 - 8/26/98
Area 9 Fredrick Sound to Clarence Strait including northern Sumner Strait	John Jansen	NMFS/NMML	8/18/97 - 8/26/98
Area 10 northwestern shore of Prince of Wales Island from Sumner Strait to the mouth of Trocadero Bay	Kaja Brix	NMFS/R	8/19/97 - 8/26/98
Area 11 southern Sumner Strait south to the Cleveland Peninsula including Etolin and Wrangell Island	John Bengtson	NMFS/NMML	8/19/98 - 8/25/98
Area 12 southwestern shore of Prince of Wales Island from southern Suemez Island to Cape Chacon	Robin Westlake-Storey	NMFS/SWFSC	8/19/97 - 8/26/98
Area 13 ADF&G trend routes along southeast Prince of Wales Island, the southern tip of the Cleveland Peninsula, the Behm Canal, and Mary Island	Una Swain	ADF&G	8/19/97 - 8/26/98
Area 13 Clarence Strait from the Cleveland Peninsula to Dixon Entrance including Revillagigedo and Annette Islands	Peter Olesiuk	DFO	8/19/97 - 8/27/98
Area 13 McFarland and Percy Islands, + Portland Canal	Dave Withrow	NMFS/NMML	8/25/97 - 8/27/98

ADF&G	Alaska Department of Fish and Game
DFO	Canadian Department of Fisheries and Oceans
NMFS/NMML	National Marine Fisheries Service, (National Marine Mammal Laboratory)
NMFS/R	National Marine Fisheries Service, (Regional Office)
NMFS/SWFSC	National Marine Fisheries Service, (Southwest Fisheries Science Center)
USF&WS	US Fish and Wildlife Sevice

Table 2. The number of seals counted at each site for Area 8. [Seagars]

(southern Fredrick Sound down Chatham Strait to northern Sumner Strait including Coronation Island and the western shore of Kupreanof Island)

LOCODE	Location	Type	Latitude	Longitude	MAX	MEAN	08/18/99	08/19/99	08/20/99	08/21/99	08/23/98	08/24/98	08/26/98
449	Trouble I.	R	56.459	133.678	24	9	5	15		24		0	0
450	Keku Strait-ESE of Meadow I.		56.487	133.686	68	40		60		68		30	0
451	W. of Skiff I.	R/C	56.535	133.708	424	158	424	47				106	56
452	E. of Monte Carlo I. group	R	56.537	133.708	108	47	108	0		41		0	87
453	Monte Carlo group 1	R	56.547	133.792	60	20		60		0			0
454	Monte Carlo group 2	R	56.539	133.755	34	10	34	0		0			6
455	Monte Carlo group 3	R/S	56.522	133.768	166	90	112	25		61		84	166
456	Monte Carlo group 4	R	56.523	133.779	50	13		50		0		0	0
457	Monte Carlo group 5	R	56.535	133.798	53	26	53			14		28	8
458	S. Threemile Arm	R	56.560	133.820	146	90		100		146		108	6
459	NW of Conclusion I.	R	56.503	133.848	2	0	2	0		0		0	0
460	SE Conclusion	R	56.460	133.779	25	14		25		0		9	20
461	Islets NW of Sumner I.	R	56.432	133.992	75	48	63	45		45		75	12
462	NNE of Sumner I.	R	56.415	133.784	8	2		8		0		0	0
463	Strait I./Mariposa Reef	R	56.393	133.857	160	114	46	130		156		160	80
464	Islets SE of Sumner	R	56.401	133.782	73	60	73	60		68		67	31
465	S. coast of Sumner	R	56.395	133.798	95	49	8	60		95		66	15
466	W. of Sumner I.	R	56.424	133.860	56	49	51	48		38		56	50
467	NW Pt. Beauclerc	R	56.301	133.850	60	22	2	0		25		60	25
468	Beauclerc I.	R	56.256	133.860	302	237	302	258		282		150	192
469	Islet N. of Pt. Amelius	R	56.212	133.880	21	5		0		0		21	0
470	Amelius group	R	56.178	133.869	127	61	127	20		56		71	30
471	Islet S. of Louise Cove	R	56.176	133.883	38	11	18	0		0		38	0
472	Islets S. of Amelius group	R	56.136	133.903	732	499	412	509		732		435	408
473	E. of Pt. St. Albans	R	56.096	133.932	75	15	75	0		0		0	0
474	Islets S. of Pt. St. Albans	R	56.074	133.988	154	104		65		154		145	50
475	E. Affleck Canal	R	56.164	134.046	131	60	20	34		131		82	33
476	N. Affleck Canal	R	56.201	134.201	90	34	15	0		0		63	90
477	Kell Bay Islets	R	56.085	134.135	140	91	25	40		124		140	127
478	North Island	R	56.068	134.104	49	35	35	0		49		45	47
479	N. Fairway Island	R	56.041	134.060	150	59	150	0		40		44	61
480	S. Fairway Island	R	56.028	134.054	50	35	50	40		42		23	19
481	Middle Spanish I. W.	R	55.969	134.121	77	51	75	35	25	77	42		
482	S. Spanish I. W.	R	55.941	134.144	174	109	55	120	72	110	174		123
483	Middle Spanish I. E.	R	55.953	134.116	60	46		30	49	60	33		60
484	N. Spanish I. E.	R	55.983	134.098	68	44	30	31	53	68	54		30
485	Cora Pt. to Helm Pt.	R	55.911	134.116	70	42		9	35	70	60		34
486	Windy Bay	R	55.877	134.333	300	206	90	128	252	216	247		300
487	Egg Harbor	R/C	55.933	134.332	40	25		19	30	22	13		40
488	Gish Bay	R	55.918	134.193	50	26	6	33	10	38	50		17
489	Table Bay	R	56.165	134.265	25	14			12	10	12	25	10
490	Harris Cove	R	56.332	134.297	87	60			81	0	70	87	63
491	N. Gedney Harbor	R	56.392	134.251	239	164		39	105	202	222	239	174
492	Windfall I.	R	56.444	134.259	25	19			25	21	16	18	13
493	Outer Tebenkof Bay	R	56.463	134.232	45	29			15	24	38	45	25
494	Davis Rock/Troller I.	R	56.491	134.238	96	53			43	65	96	51	12
495	Inner Tebenkof Bay 1	R	56.458	134.138	47	32			40	0	31	47	43
496	Inner Tebenkof Bay 2	R	56.429	134.146	69	45			36	69		31	44
497	Tebenkof Bay-3 Islets	R	56.418	134.100	294	212			165	229	294	158	212

Table 2 - continued

498	Pt. Ellis	R	56.563	134.328	286	151		128	76	138	286	123	157
499	N. Bay of Pillars	R	56.610	134.315	332	177		51	74	15	280	312	332
500	Security Bay	R	56.827	134.308	132	63		48	0	0	65	131	132
501	Saginaw Bay	R/S	56.863	134.175	133	69		47	0	0	131	101	133
502	N. Keku Islets	R	56.931	134.129	152	107		94	72	31	147	152	145
503	Port Camden	R/S	56.729	133.924	47	29			21	27	47	25	23
504	S. of Horseshoe I.	R	56.786	133.734	318	201		151	0	124	306	306	318
505	Outer Reid Bay	R	56.387	133.850	50	23				50		18	0
506	Hare I.	S	56.858	133.971	192	151				129	150	192	132
507	Inner Camden	R	56.669	133.961	53	51					53		49
508	N. of Table Bay	R	56.221	134.268	25	13					13	25	0
				totals	7232	4314	2466	2662	1291	4186	2930	4192	4240

MAX	MEAN
7232	4314

95 % Confidence Interval	
3955 =LOW	4674 =HIGH

CV	SD
4.23	182.52

Table 3. The number of seals counted at each site for Area 9. [Jansen]

(Fredrick Sound to Clarence Strait including northern Sumner Strait)

LOCODE	Location	Type	Latitude	Longitude	MAX	MEAN	08/18/98	08/19/98	08/20/98	08/21/98	08/23/98	08/24/98	08/25/98	08/26/98
574	Turnabout I./W. rocks	R	57.120	134.011	147	91	48	21	94	147	86	127		113
575	Storm I.-Bird Rock	R	57.208	133.584	161	84	161	57	9	142	109	3		105
576	Farragut Bay-W. Bay	R	57.132	133.239	148	110	116	46	80	104	148	142		135
577	Farragut Bay-Francis Anchorage	S	57.148	133.160	80	42	76	0	0	80	76	0		60
578	Farragut Bay-NE Read I.	R	57.133	133.206	125	18	125	0	0	0	0	0		0
579	Baird Glacier	S	57.084	132.820	131	30	10	3	0	131	64	0		4
580	Rookery I.-Duncan Canal	C	56.693	133.206	166	78	67		0	0	80	166		154
581	S. Woewodski I.-W. of marker	R	56.507	133.020	183	135	155	20	104		172	173		183
582	SE of Mitchell Pt.-W. rocks	R	56.437	133.189	208	91	80	208	157		48	48		7
583	Outer Totem Bay-W. rocks	R	56.463	133.390	55	19	46	31	55	0	0	0		0
584	W. of Shingle I.	R	56.427	133.426	115	57	115	70	88	34	40	37		12
585	E. of Yellow I.-E.	R	56.428	133.469	173	104	173	81	127	74	121	88		66
586	E. of Yellow I.-mid.	R	56.427	133.492	207	33	207	7	20	0	0	0		0
587	Vichnefski Rock-marker rock	R	56.437	133.015	269	144	181	83	269	0	79	188		207
588	NW of Big Level I.-outer rock	R	56.444	133.099	47	9		47	0	0	0	5		0
589	SE of Mitchell Pt.-E. rock	R	56.428	133.162	170	38		5	50	0	0	0		170
590	N. of Shingle I.	R	56.455	133.359	8	1		8	0	0	0	0		0
591	E. of Yellow I.-W.	R	56.425	133.503	229	93		169	0	0	0	162		229
592	S. of Yellow I.	R	56.423	133.548	10	3		10	0	3	0	0		5
593	Pt. Barrie	R	56.429	133.637	45	22		36	45	0	0	40		9
594	Bushy I. E.	R	56.270	132.953	191	113		137	0	52		184		191
595	Shrubby I.-SW	R	56.214	133.017	342	71		13	342	0		0		0
596	Echo I. off S. end	R	56.227	133.033	404	169		218	0	165		404		57
597	West I.-marker rock	R	56.193	133.019	238	131		77	237	103		238		0
598	Blashke I.-NW rocks	R	56.162	132.974	252	78		33	252	43		61		0
599	Rose I.-Rose Rocks	R	56.087	132.876	25	6		6	0	0		25		0
600	Seal Rock	R	56.074	132.834	7	1		7	0	0		0		0
601	Triplets I.-Deichman Rock	R	56.065	132.823	164	98		78	0	123		164		126
602	Blashke I.-S.	R	56.103	132.849	208	56		30	208	43		0		0
603	Blashke I.-NE rocks	R	56.150	132.885	200	55		25	0	200		25		25
604	Key Reef-marker rock	R	56.160	132.827	109	77		97	109	88		89		3
605	Nesbitt Reef	R	56.226	132.871	210	140		140	210	191		160		0
606	Le Conte Bay	I	56.821	132.397	1085	489		300	450	440	1085	270	508	368
607	Grief I.-N.	R	56.614	133.063	77	30			35	0	0	37		77
608	NW of Big Level I.-inner rocks	R	56.475	133.085	30	15			14	0	0	30		30
609	Outer Totem Bay-E. rocks	R	56.463	133.382	57	43				8	57	56		52
610	S. of Shigle I.	R	56.457	133.361	3	1			3	0	0	0		0
611	Tide I.	R	56.281	133.066	52	13			52	0		0		0
613	Bushy I. NE	R	56.269	132.952	106	27			106	0		0		0
614	Bushy I. NW	R	56.277	133.004	10	3			10	0		0		0
615	Farragut Bay-E. Bay	R	57.133	133.211	71	26			10	3	71	8		39
616	Stop I.-Portage Bay	S	56.960	133.298	17	7				12	0	0		17
617	N. Kupreanof I.-near Bohemian range	R	57.039	133.505	37	20				9	0	34		37
618	N. Kupreanof I. 1	R	57.065	133.675	16	6				3	4	0		16

Table 3 - continued

619	N. Kupreanof I.-Turn mountain	R	57.089	133.828	12	8				10	0	12		10
620	W. Pinta Rocks-E. of marker	R	57.083	134.003	33	22				11	23	21		33
621	Pt. Highland-E.	R	57.135	133.425	14	6				11	14	0		0
622	Coney I.-nearby sand flat	S	56.687	132.632	8	4				8				0
623	White Rocks	R	56.478	133.033	3	1		3	0	0	0	0		0
624	Pt. Highland-W.	R	57.157	133.474	9	6					9	0		8
625	Portage I.	R	57.016	133.351	12	6					6	0		12
626	E Pinta Rocks	R	57.087	133.975	5	3						5		0
627	Pt. Vandeput-E.	R	57.017	132.978	164	54	164	69	44	14	43	0		47
628	Pt. Vandeput-W.	R	57.015	132.995	24	13					24	0		14
629	Pt. Vandeput-central	R	57.017	132.984	65	48						30		65
630	N. Kupreanof I. 2	R	57.084	133.769	13	8					11	0		13

totals	6950	3052	1724	2135	3180	2252	2370	3032	508	2699

MAX	MEAN
6950	3052

95 % Confidence Interval			
2642	=LOW	3463	=HIGH

CV	SD
6.83	208.6

Table 4. The number of seals counted at each site for Area 10. [Brix]

(northwestern shore of Prince of Wales Island from Sumner Strait to the mouth of Trocadero Bay)

LOCODE	Location	Type	Latitude	Longitude	MAX	MEAN	8/19/98	8/20/98	8/21/98	8/23/98	8/24/98	8/25/98	8/26/98
315	Cape Bartolome	R	55.233	133.615	27	17	4	19		27			
316	Cabras I.	R	55.349	133.390	20	16	10	18		20			
317	NE St. Ignace I.	R	55.432	133.394	0	0	0	0		0			
318	NW St. Ignace I.	R	55.443	133.449	75	38		75		0			
319	Port Real Marina	R	55.443	133.427	139	70		0		139			
320	NW Pt. Amargura	R	55.479	133.421	57	46	26	56		57			
321	Gaviota I.	R	55.398	133.671	71	60		48		71			
322	E Noyes I.	R	55.495	133.602	16	8		0		16			
323	NW Lulu I.	R	55.517	133.551	44	23	6	20		44			
324	Pt. Animas-San Fernando I.	R	55.531	133.480	32	28		31		20		32	
325	Palisade Pt.-San Fernando I.	R	55.569	133.378	6	6						6	
326	Pt. Sta Rosalia-San Fernando I.	R	55.570	133.449	21	16				21		11	
327	NE San Fernando I.	R	55.537	133.281	15	9				3		15	
328	Abbess I.	R/S	55.563	133.188	250	197				250		144	
329	Blanquizal I.	R	55.624	133.415	14	14						14	
330	Culebra I.	R	55.673	133.450	82	66			50			82	
331	Warm Chuck Inlet	R	55.742	133.445	119	97			75			119	
332	Nossuk Bay	R	55.716	133.339	28	27			26			28	
333	S. Tukekan I.	R	55.775	133.273	223	219			223			214	
334	S. of Naukati Bay	R	55.814	133.177	50	28			50			6	
335	NE of Tuxekan I./Tuxekan Passage	R	55.880	133.263	47	46			47			44	
336	N Tuxekan I.	R	55.917	133.285	8	7			6			8	
337	Hub Rock	R	55.943	133.302	50	46			50			41	
338	N El Capitan I.	R	55.978	133.307	368	270			172			368	
339	NW El Capitan I.	R	55.959	133.350	87	87						87	
340	SW El Capitan I.	R	55.916	133.366	121	116			121			111	
341	Cap I.	R	55.894	133.337	0	0			0				
342	Hoot I.	R	55.913	133.424	21	16			10			21	
343	S. Marble I.	R	55.943	133.495	121	118			114			121	
344	N. Marble I.	R	55.997	133.456	95	48			0			95	
345	Eagle I.	R	55.863	133.479	202	183			155			202	193
346	Port Alice area	R	55.836	133.627	39	20			7			15	39
347	Cosmos Pass	R	55.885	133.689	211	173					140	211	169
348	E Warren I.	R	55.896	133.844	10	6					10		1
349	Pt. Hardscrabble	R	55.991	133.787	99	61					99		22
350	N. Pt. Hardscrabble	R	56.019	133.754	65	65							65
351	Ruins Pt.	R	56.083	133.673	170	139					170		108
352	Shipley Bay	R	56.096	133.614	95	95							95
353	Bluff I.	R	56.111	133.687	30	30					30		
354	Kosciusko I./NW penninsula	R	56.145	133.634	91	52					13		91
355	Hamilton I.	R	56.153	133.549	150	135					150		119
356	NW Prince of Wales I.	R/S	56.185	133.617	365	309					365		252
357	Labouchere Bay	R	56.293	133.680	67	59					50		67
358	Anguilla I.	R	55.683	133.616	64	38					45	6	64
359	St. Joseph I.	R	55.594	133.724	85	85							85
360	San Lorenzo I.	R	55.611	133.580	71	54					71	57	35

Table 4 - continued

361	Wood I./Twin I.	R	55.676	133.707	89	55					31	46	89
362	Emerald I.	R/S	55.736	133.679	233	176					70	225	233
				totals	**4343**	**3469**	**46**	**267**	**1106**	**668**	**1244**	**2329**	**1727**

MAX	MEAN
4343	3469

95 % Confidence Interval			
2963	=LOW	3975	=HIGH

CV	SD
7.28	252.39

Table 5. The number of seals counted at each site for Area 11. [Bengtson]

(southern Sumner Strait south to the Cleveland Peninsula including Etolin and Wrangell Island)

LOCODE	Location	Type	Latitude	Longitude	MAX	MEAN	08/19/99	08/20/99	08/21/99	08/22/99	08/23/99	08/24/99	08/25/99
632	East Vixen	R	55.814	132.066	25	14			17	0	25	19	8
633	West Vixen	R	55.840	132.091	35	23		13			14	35	30
634	Westerly I.	R	55.903	132.158	93	74		72	74	57	86	93	64
635	S. Bronson	R	55.920	132.166	58	19		27	0	2	0	58	24
636	Bronson Light	R	55.933	132.117	105	80		78	55	105	70	74	96
637	Deer Light	R	56.007	132.090	156	125		93	152	139	100	112	156
638	Niblack	R	56.020	132.112	117	89		72	55	106	105	81	117
639	Bold	R	56.052	132.144	18	5		18	10	3	0	1	0
640	Blanche	R	56.085	132.087	24	11	1	14	11	2	6	17	24
641	Anan	R	56.196	131.932	46	27		46		20		15	27
642	Neptune	R	56.345	132.005	71	41			19	25	71	46	44
643	S. Madan	R	56.392	132.181	22	8			3	1	15	22	0
644	N. Madan	R	56.402	132.183	23	12			23	8	1	17	12
645	Village	R	56.203	132.291	95	85		88		81	78	95	84
646	Zimovia	R	56.331	132.358	25	11		12		0	6	13	25
647	Woronkofoski	R	56.366	132.573	1	0			1	0	0		
648	Quiet		56.243	132.632	23	17		14	13	18	20	15	23
649	Harrington	R	56.169	132.723	73	52		55	42	35	48	73	60
650	W. Buster	R	56.333	133.436	9	6		6			9	2	5
651	E. Buster	R	56.339	133.394	59	28		16			11	24	59
652	Eye Opener	R	56.384	133.276	5	5							5
653	Colpoys		56.335	133.214	32	9		32			0	3	0
654	Bay		56.324	133.157	245	138		245			90		80
655	W. Rookery	R	56.313	133.115	908	629		795			908	462	350
657	Thorne	R	56.107	132.990	39	21		12		26	39	8	18
658	Beck		56.037	132.872	48	36		31		48	44	27	30
659	Deichman	R	56.059	132.834	213	177		162		107	213	202	200
660	Luck	R	55.970	132.721	92	69	92	44		52	68	66	89
661	Lincoln	R	56.057	132.688	62	47	62		48	50	56	28	35
662	N. Rocky	R	56.051	132.601	46	28			10	46	40	2	42
663	Mid Rocky	R	56.043	132.588	258	148	258		103	103	157	126	139
664	E. Rocky	R	56.048	132.570	208	118	89		61	208	197	77	77
665	S. Rocky	R	56.036	132.590	156	73	28		70	76	156	43	62
666	McHenry		56.011	132.415	7	2			2	0	0	7	0
667	Range	R	55.995	132.473	285	208	102		229	260	240	129	285
668	Double	RP	55.948	132.447	16	8			12	16	0	11	0
669	Center	R	55.928	132.433	192	100	61		97	154	192	39	57
670	Ship		55.601	132.203	79	36	8					20	79
				totals	3969	2576	701	1945	1107	1748	3065	2062	2406

MAX	MEAN
3969	2576

95 % Confidence Interval			
2260	=LOW	2892	=HIGH

CV	SD
6.21	159.94

Table 6. The number of seals counted at each site for Area 12. [Westlake]

(southwestern shore of Prince of Wales Island from southern Suemez Island to Cape Chacon)

LOCODE	Location	Type	Latitude	Longitude	MAX	MEAN	08/19/99	08/20/99	08/21/99	08/22/99	08/23/99	08/24/99	08/25/99	08/26/98
509	Chichagof Bay	R	55.009	131.982	25	12	7			25		9		5
510	Kendrick Bay	R	54.875	132.017	120	81	45			67		90		120
511	S. Kendrick Bay	R	54.843	131.974	12	12	12							11
512	Stone Rock	R	54.739	131.470	16	11	7			6		13		16
513	Pt. Marsh	R	54.720	132.322	65	41	38			65		23		38
514	S. Leading Pt.	R	54.781	132.349	75	27	5			75		0		
515	S. Round I.	R	54.778	132.483	30	11	30			0		2		
516	N. Round I.	R	54.796	132.471	85	41	85			0		38		
517	Middle Barrier I.	R	54.800	132.417	32	21		9				32		
518	Barrier I.	R	54.779	132.442	205	103		36		162		205		8
519	W. Barrier I. 1	R	54.820	132.456	75	58		29		75		71		
520	W. Barrier I. 2	R	54.797	132.463	150	63		150		24		14		
521	NW Barrier I.	R	54.794	132.483	53	34		53				22		26
522	N. Leading Pt.	R	54,849	132.346	71	32		21		0		37		71
523	Wallace Rock	R	54.867	132.383	63	63		63						
524	N. Wallace Rock	R	54.880	132.413	105	91		76		105				
525	W. Wallace Rock	R	54.881	132.457	122	122		122						
526	Outer Kassa Pt.	R	54.899	132.516	15	9		13		0		15		6
527	S. Blanket I.	R	55.103	132.697	50	38		12		37	45		50	44
528	Meares I.	R	55.263	133.151	18	13		11			16		18	7
529	Millar Rocks	R	55.200	133.260	58	46		12	55		58		57	46
530	Upper Trocadero Bay	R	55.353	132.900	44	13		5			0		44	3
531	Lower Trocadero Bay	R	55.386	133.101	58	30		58			23		38	0
532	Port Refugio Entrance	R	55.310	133.298	75	48		27			75		40	48
533	NE Suemez I.	R	55.351	133.353	34	25		34			15			
534	South Rocks	R	54.782	132.604	47	30			47	12				
535	Datzkoo I.	R	54.728	132.677	190	86			43		190		26	
536	McLeod Bay	R	54.707	132.668	55	31			39		0		55	
537	Cape Muzon E.	R	54.660	132.691	27	20			12		22		27	
538	Cape Muzon W.	R	54.665	132.736	8	8			8				8	
539	S. Liscome Pt.	R	54.687	132.849	5	2			5		0		0	
540	Ritter Pt. Bay	R	54.865	133.022	64	40			64		35		20	
541	Waterfall Bay	R	54.940	133.150	90	64			90		47		55	
542	N. Welcome Pt.	R	54.993	133.160	64	32			8		64		23	
543	Lookout Pt.	R	55.114	133.240	66	51			35		66		53	
544	Hook Arm	R/S	55.127	133.170	55	35			20		45		18	55
545	Outer Hook Arm	R	55.112	133.204	6	2			6		0		0	0
546	Foul Bay	R	55.240	133.081	16	8			15		16		0	0
547	Sentinels	R	55.176	133.015	209	119			74	140	93		77	209
548	N. McFarland I.	R	55.082	132.900	173	129			11	134	166		173	159
549	Baldy Bay Reef	R	55.038	132.985	102	83			85	94	78		102	56
550	S. Grand I.	R	54.961	132.887	211	95			18	96		211	56	
551	N. Grand I.	R/S	54.991	132.893	270	135			94	60	202	50	270	
552	Bird Rock	R	54.882	132.448	160	117			125	131	70	100		160
553	Klakas Bay	R	54.883	132.416	335	222				101		229		335
554	Cape Chacon	R	54.692	132.044	25	15				10		25		11

Table 6 - continued

555	Ingraham Bay	R	54.974	131.977	27	23				15		27		27
556	S. Corlies I.	R	55.113	132.929	85	53				45	42		41	85
557	W. Goat I.	R	55.202	132.946	58	34				30	0		58	49
558	Natzuhini Bay	R/C/W	55.253	132.869	66	52				38			66	52
559	SE Sukkwan I.	R	55.018	132.687	55	44				43	55		46	32
560	Daykoo I.	R	54.710	132.681	0	0							0	
561	Wolk Harbor	R	54.684	132.789	18	15					18		12	
562	Mid. Trocadero Bay	R	55.378	133.021	46	35					33		46	27
563	E. Grand I.	R/S	54.961	132.769	285	215					285	135	224	
564	Brownson Bay	R	54.717	132.239	13	7						13		0
565	Outer Hessa Inlet	R	54.785	132.344	72	69						65		72
566	S. Barrier I.	R	54.768	132.424	34	34						34		
567	Hawkan Narrows	R	54.871	132.830	5	5						5		
568	Outer Port Bazan	R	54.801	132.981	8	8							8	
569	N. Blanket I.	R	55.169	132.779	31	25							18	31
571	Biscuit Lagoon	R	54.897	132.309	6	6								6
572	Hassiah Inlet	R	54.984	132.580	30	30								30
573	N. Hassiah Inlet	R	55.0155	132.5661	6	6								6
				totals	4679	3021	229	731	854	1590	1759	1465	1729	1851

MAX	MEAN
4679	3021

95 % Confidence Interval			
2602	=LOW	3440	=HIGH

CV	SD
7.02	212.05

Table 7. The number of seals counted at each site for Area 13. [Olesiuk & Withrow]

(Clarence Strait from the Cleveland Peninsula to Dixon Entrance including Revillagigedo, Annette, McFarland and Percy Islands, and Portland Canal)

LOCODE	Location	Type	Latitude	Longitude	MAX	MEAN	08/19/98	08/20/98	08/21/98	08/22/98	08/23/98	08/24/98	08/25/98	08/26/98	08/27/98
363	Tatoosh I.	R	55.528	131.843	67	44	26					40		67	
364	Back I.	R	55.538	131.771	10	4	3					0		10	
365	W. Traitors Cove	R	55.697	131.699	150	105	70					96		150	
366	Traitors Cove	R	55.696	131.677	5	2	5					0		0	
367	E. Traitors Cove	R	55.734	131.600	70	50	70					68		12	
368	Neets Bay	R	55.794	131.543	132	109	95					99		132	
369	Clam I.	R	55.780	131.612	50	47	45					50		45	
370	Shrimp Bay	R	55.847	131.503	95	64	39					58		95	
371	Hose Pt.	R	55.972	131.197	61	45						29		61	
372	Fire Pt.	R	55.936	131.162	33	23						33		12	
373	Unuk R.	S	56.051	131.120	134	67						134		0	
374	Square I.	R	55.858	131.825	86	74		52				84		86	
375	W. Spacious Bay	R	55.861	131.902	23	15		22				23		0	
376	Port Stewart	R	55.720	131.851	68	46		28				68		42	
377	Thomas I.	G	55.621	131.945	39	29		39				18			
378	S. Thomas I.	R	55.613	131.952	450	339		330				238		450	
379	Bull I.	R	55.499	131.475	94	58			94			60		20	
380	N. Osten I.	R	55.422	131.322	119	99			88			90		119	
381	Snipe I.	R	55.362	131.254	122	82			73			50		122	
382	W. Mop Pt.	R	55.390	131.268	92	70			92			70		48	
383	Streets I.	R	55.474	132.137	58	49		58					41		48
384	E. Spacious Bay	R	55.879	131.797	36	31		36						26	
385	Ship I.	R	55.595	132.204	127	64		28					127		37
386	W. Grindall I.	R	55.440	132.152	25	22		25					23		18
387	Walden Rocks	R	55.267	131.607	24	21		24	22				16		20
388	Blank Inlet	R	55.278	131.670	16	14		16					16		9
389	NE Bronaugh I.	R	55.120	131.740	41	22		22					41		3
390	SE Bronaugh I.	R	55.120	131.706	123	101		123					84		95
391	SW Bronaugh I.	R	55.108	131.736	56	44		50					25		56
392	NW Bronaugh I.	R	55.128	131.749	33	16		33					16		0
393	SW Gravina I.	R	55.208	131.835	28	26			25				24		28
394	NW Gravina I.	R	55.299	131.863	12	6			6				0		12
395	Vallenar Bay	R/G	55.382	131.870	67	45			29				40		67
396	Reef Point	R	55.245	131.474	77	65			50				68		77
397	NW Lewis I.	R	55.193	131.375	76	64			70				76		46
398	W Walker I.	R	55.187	131.347	124	63			16				124		50
399	Kwain Bay	R	55.092	131.362	56	39			27				56	40	34
400	NE Annette Pt.	R	55.033	131.344	45	16			4				0		45
401	SW Hemlock I.	R	55.152	131.595	98	77			56				98		
402	N. Driest Pt.	R	55.189	131.598	23	12			23				0		
403	W. Driest Pt.	R	55.184	131.601	161	92			65				49		161
404	N Island Pt.	R	55.493	131.325	12	10			7					12	
405	Fripo I.	R	55.027	131.205	55	37			27				30	55	
406	E. Duck I.	R	54.987	131.225	40	32				40			31	25	
407	Duke Pt.	R	54.924	131.192	18	10				10			1	18	
408	N. East I.	R	54.887	131.189	49	41				39			49	34	

Table 7 - continued

409	East I.	R	54.870	131.197	40	28				40			23	20	
410	S. East I.	R	54.865	131.209	13	11				11			13	10	
411	E. Kelp I.	R	54.871	131.230	4	4				4					
412	Yellow Rocks	R	54.786	132.383	29	13				4			7	29	
413	Barren I.	R	54.744	131.355	10	6				10			1		
414	S. Kelp I.	R	54.861	131.251	9	5				9			0		
415	SE Kelp I.	R	54.860	131.297	13	9				9			13	4	
416	Vancouver I.	R	54.857	131.371	39	30				34			18	39	
417	Sister I.	R	54.849	131.289	9	9				9					
418	SE Cape Northumberland	R	54.850	131.328	59	34				37			5	59	
419	Bee Rocks	R	54.879	131.563	4	2				4			0		
420	S. Pt. White	R	54.907	131.471	27	23				22			19	27	
421	Ryus Bay	R	54.970	131.440	81	29				7			0	81	
422	Tamgas Reef	R	54.985	131.418	77	31				77			16	0	
423	Marten Arm	S	55.137	130.558	85	43				85				0	
424	S. Boca De Quadra	R	55.157	130.700	31	16				16			31	0	
425	W. Hotspur I.	R	54.972	131.550	48	39					48		30		
426	W. Werlick I.	R	54.958	131.533	38	27					16			38	
427	E. Werlick I.	R	54.965	131.507	14	11					7		14		
428	SE Percy I.	R	54.952	131.542	59	39					13		59	45	
429	N. Cow I.	R	54.971	131.584	152	69					28		26	152	
430	W. Percy I.	R	54.959	131.586	148	88					148		95	20	
431	E. Percy I.	R	54.955	131.568	82	38					82		33	0	
432	Fleece Rock	R	54.727	130.798	20	13					20				5
433	N. Lord I.	S/G	54.750	130.790	528	508					528				488
434	N. Fillmore Inlet	R	54.919	130.461	8	8									8
435	Fillmore Inlet	R	54.887	130.508	47	47					47				
436	N. Willard Inlet	R	54.962	130.644	26	18					26				9
437	Willard Inlet	R	54.867	130.682	22	18					22				13
438	Tongass Reef	R	54.785	130.748	32	31					32				30
439	Nakat Inlet	R	54.949	130.751	38	35					32				38
440	S. DeLong I.	R	54.954	130.982	118	72					118				26
441	Vixen Bay	R	55.048	130.784	28	14							28	0	
442	Mink Bay	R	55.053	130.707	32	28							23	32	
443	Middle Boca De Quadra	R	55.209	130.596	49	49								49	
444	N. Boca De Quadra	R	55.289	130.525	46	46								46	
445	Middle Marten Arm	R	55.127	130.620	72	72								72	
446	Kestrel I.	R	55.108	130.797	31	31								31	
447	E. Pt. Davidson	R	54.999	131.580	27	27			27						
448	Gilanta Rocks	R	54.812	130.936	4	4									4
734	S. Club Rocks		54.809	131.360	17	16							14	17	
736	W. of Dog I.		54.860	131.357	6	4							6	1	
737	N. Tamgas Reef		54.999	131.397	0	0								0	
738	Sealed Passage area		54.940	131.567	18	18								18	
739	Danger Passage		55.052	131.221	11	11								11	

740	East I. Area		54.868	131.204	26	26								26	
741	S. of Male Point	R	54.783	130.574	35	35									35
742	Logan Point	R	55.281	129.966	32	32									32
743	Glacier Point	R	55.827	130.089	19	19									19
744	N. of River Point	R	55.612	130.136	30	30									30
745	Pirie Point	R	55.503	130.106	1	1									1
746	Dogfish Bay	R	55.078	130.199	29	29									29
747	Fillmore Inlet		54.897	130.471	24	24									24
				totals	5827	4252	353	886	801	467	1167	1308	1509	2508	1597

MAX	MEAN
5827	4252

95 % Confidence Interval	
3824 =LOW	4681 =HIGH

CV	SD
5.10	216.91

Table 8. The number of seals counted at each site for Area 13. [Swain]

(ADF&G trend routes along southeast Prince of Wales Island, the southern tip of the Cleveland Peninsula, the Behm Canal, and Mary Island)

LOCODE	Location	Type	Latitude	Longitude	MAX	MEAN	08/19/99	08/20/99	08/21/99	08/22/99	08/23/99	08/24/99	08/25/99	08/26/98
671	Hog Rocks	R	55.177	131.290	67	50	62	29	38	47	67	44	62	
672	Whale I.	R	55.022	131.183	138	100	138	47	97	77	124	97	120	
673	Snail Rock	R	55.037	131.054	58	51	39	47	58		58			
674	White Reef	R	55.065	131.027	741	449	630	417	741	403	547	476	245	130
675	Slate I.	R	55.097	131.043	1239	181	0	0	0	1239	0	29	0	
676	Alava Bay	R	55.223	131.142	42	13	0	42	10					0
677	Roe Pt.	R	55.248	130.998	74	45	37	32	66	46	31	74	31	
678	Rudyerd I.	R	55.294	131.034	128	79			128	29		68		89
679	Carp I.	R	55.500	130.880	17	5	8	9	17	0	0	0	0	
680	Smeaton I.	R	55.346	130.977	17	13			6			17	15	
681	Bakewell Arm	R	55.320	130.691	116	88	116		98					50
682	Winstanley	R	55.411	130.900	0	0	0	0	0	0	0	0	0	
683	Entrance I.	R	55.767	130.920	4	2					4	0	1	
684	New Eddy Proper	R	55.504	130.947	57	22	0		7	46		57	0	
685	N. Eddystone	R	55.516	130.923	653	361	653	235	331	209		320	419	
686	Snip I.	R	55.694	130.978	22	6	0	22		0	0			
687	Channel I.	R	55.751	130.949	756	384	756	351	389	214	389	301	285	
688	Eagle I.	R/S	55.846	132.300	669	521	532	488	534	492	669	426	504	
689	W. Tolstoi I.	R	55.547	132.452	111	101	111	104	103	104	110	97	81	
690	Daisy	R	55.471	132.299	182	128	55	128	135	146	180	182	68	
691	Kasaan I.	R	55.486	132.363	344	238	160	221		238	233	229	344	
692	Karta Bay	R/C/S	55.594	132.517	105	72	51	105		101	41	76		57
693	SE Hollis	R	55.474	132.599	127	121						127		114
694	E. Hollis	R	55.510	132.540	11	6						11		1
695	Skowl Pt. Light	R	55.427	132.274	41	29	16		36	41			23	28
696	S. Skowl Pt.	R	55.005	132.077	14	10	13		14	14			0	
697	W. Skowl Pt.	R	55.418	132.301	42	36	24		37	39			42	
698	McKenzie	R	55.414	132.359	183	115	183	116	90	103	96	112	108	
699	Polk Inlet	R	55.422	132.409	133	126					128	115	127	133
700	Spiral Cove	R	55.381	132.226	33	14			33	0	0			22
701	Troller's Cove	R	55.375	132.218	49	23				3	41		49	0
702	Island Pt.	R	55.353	132.162	13	8	1	8	6	11	13	9	11	
703	N. Clover Bay	R	55.329	132.144	58	45	35	43	46	46	42	58	46	
704	Clover Bay	R	55.302	132.130	107	89	45	93	82	107	102	96	99	
705	Skin I.	R	55.295	132.082	41	28	30	3	38	41	40	28	14	
706	Cholmondeley Sound	R	55.255	132.099	202	121	58	170	140	202	86	19	169	
707	Lancaster	R	55.237	132.070	172	33	24	0	19	3	16	172	0	
708	Dora Bay	R	55.220	132.173	211	132	28	174	140	161	143	65	211	
709	S. Arm Cholmondeley Sound	R	55.151	132.344	90	52					59	5	52	90
710	Sunny Cove	R	55.247	132.253	23	13	0	16	12		23	12	17	
711	N. Halibut Creek	R	55.252	131.997	29	23					18	22	29	
712	Wedge-Chasina	R	55.181	131.966	93	47			42	93	74	0	24	
713	Port Halliday	R	55.080	132.065	4	2			4	0	0		2	
714	N. Arm Moira	R	55.106	132.119	53	27		0	25		43		53	12
715	Egg I.	R	55.059	132.058	74	48			27	47	47		46	74
716	Dickman Bay	R	54.997	132.221	111	50			34		111		54	1

Table 8 - continued

717	W. Arm Moira	R	54.991	132.211	47	24		39	34		0		47	0
718	S. Arm Moira	R	54.979	132.156	4	1			4		0		0	0
719	East S. Arm Moira	R	54.999	132.146	160	41			4		0		0	160
720	Moira Rock	R	55.086	132.001	65	46			39	41	65		38	49
721	W. Polk Inlet	R	55.426	132.449	91	91								91
722	W. Patterson I.	R	55.406	132.213	16	16								16
723	E. Patterson I.	R	55.402	132.177	119	119								119
724	High I.	R	55.394	132.163	4	4								4
725	S. Patterson I.	R	55.399	132.202	18	18								18
726	Black I.	R	55.217	131.133	56	22						10	56	0
727	Hollis	R	55.488	132.615	37	19						37		0
728	Head W Arm Cholmondeley	R	55.214	132.242	117	111						117	105	
729	W. Arm Cholmondeley	R	55.400	132.467	83	28						0	0	83
730	Wedge	R	55.141	131.960	328	276		252	290	323	312	119	308	328
731	Moria Sound	R	55.016	132.074	423	289		327	253	353	338	114	423	213
732	Mid Moria	R	55.043	132.024	100	79			85	100	79	22	95	94
733	White Rock	R	55.055	132.000	201	136		170	157	201	129	58	102	
				totals	9323	5421	3805	3688	4449	5320	4458	3821	4525	1976

MAX	MEAN
9323	5421

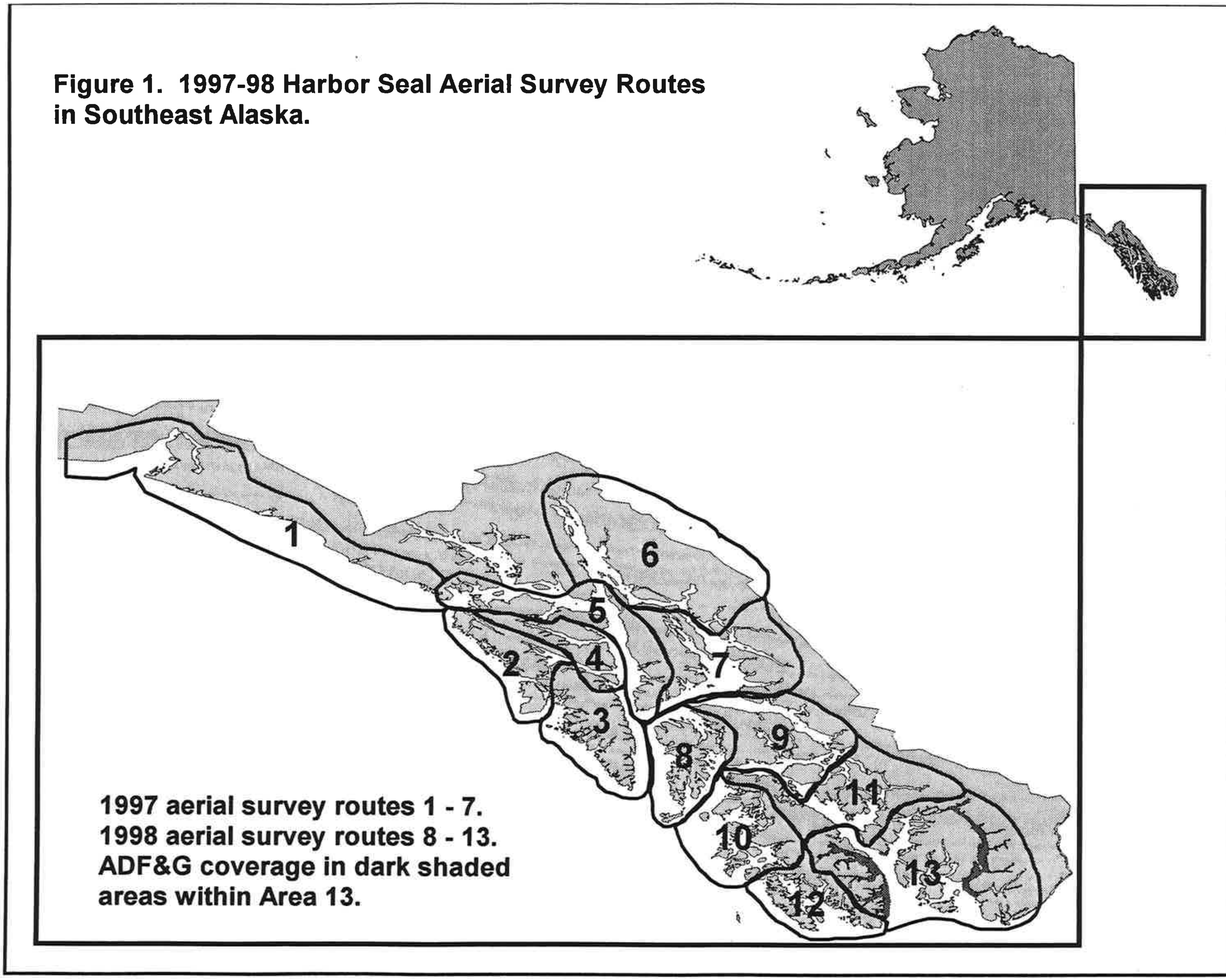
95 % Confidence Interval			
4862	=LOW	5981	=HIGH

CV	SD
5.24	284.07

Table 9. Summary statistics for all areas.

		MAX	MEAN	95 % Confidence Interval				CV	SD
Area 8	Seagars	7232	4314	3955	=LOW	4674	=HIGH	4.23	182.52
Area 9	Jansen	6950	3052	2642	=LOW	3463	=HIGH	6.83	208.60
Area 10	Brix	4343	3469	2963	=LOW	3975	=HIGH	7.28	252.39
Area 11	Bengtson	3969	2576	2260	=LOW	2892	=HIGH	6.21	159.94
Area 12	Westlake	4679	3021	2602	=LOW	3440	=HIGH	7.02	212.05
Area 13	Olesiuk & Withrow	5827	4252	3824	=LOW	4681	=HIGH	5.10	216.91
Area 13	Swain	9323	5421	4862	=LOW	5981	=HIGH	5.24	284.07
	Totals =	42,323	**26,106**	24,964	=LOW	27,248	=HIGH	2.23	582.08

Figure 1. 1997-98 Harbor Seal Aerial Survey Routes in Southeast Alaska.



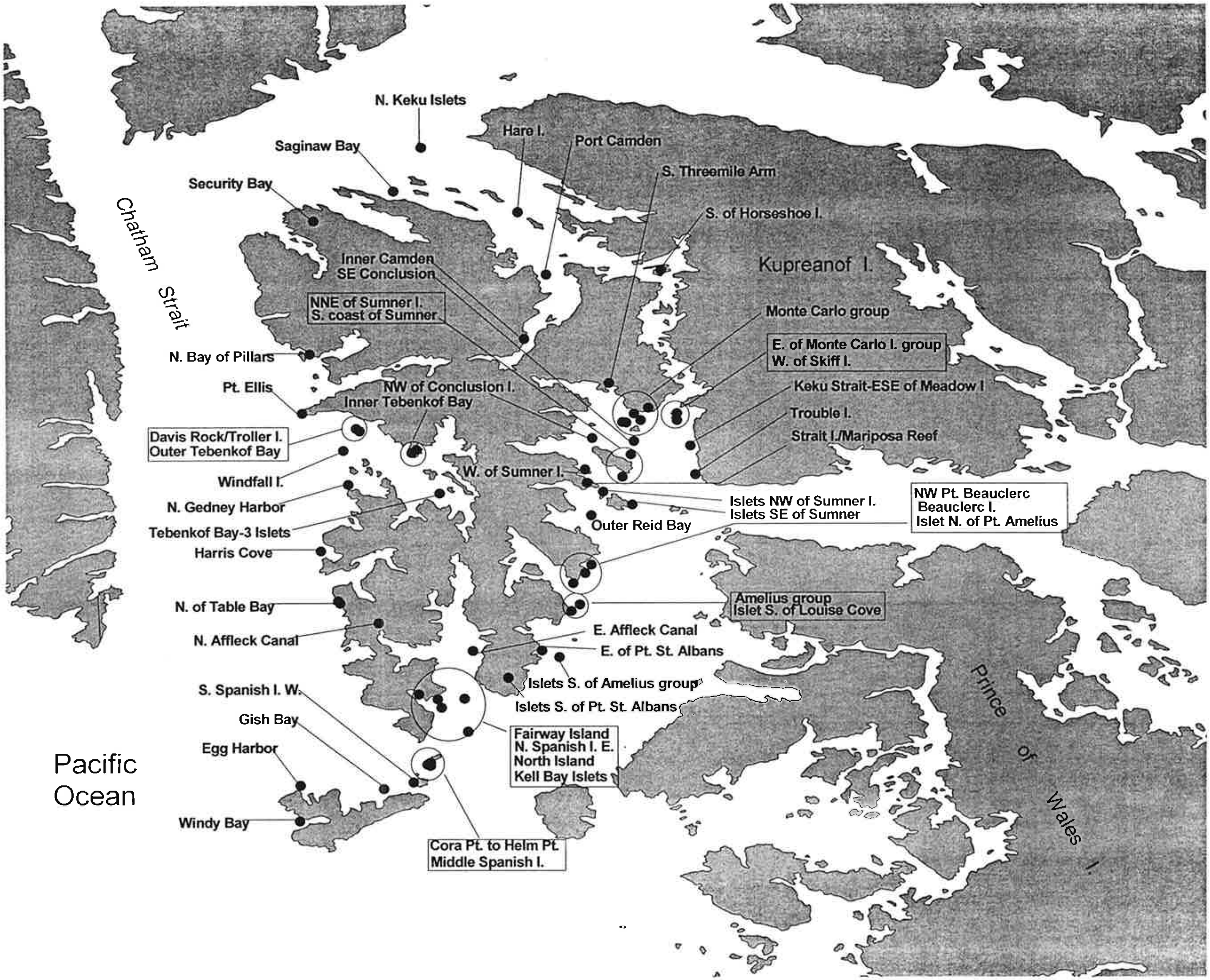


Figure 2. Survey Area 8. [Seagars] (southern Fredrick Sound down Chatham Strait to northern Sumner Strait including Coronation Island and the western shore of Kupreanof Island)

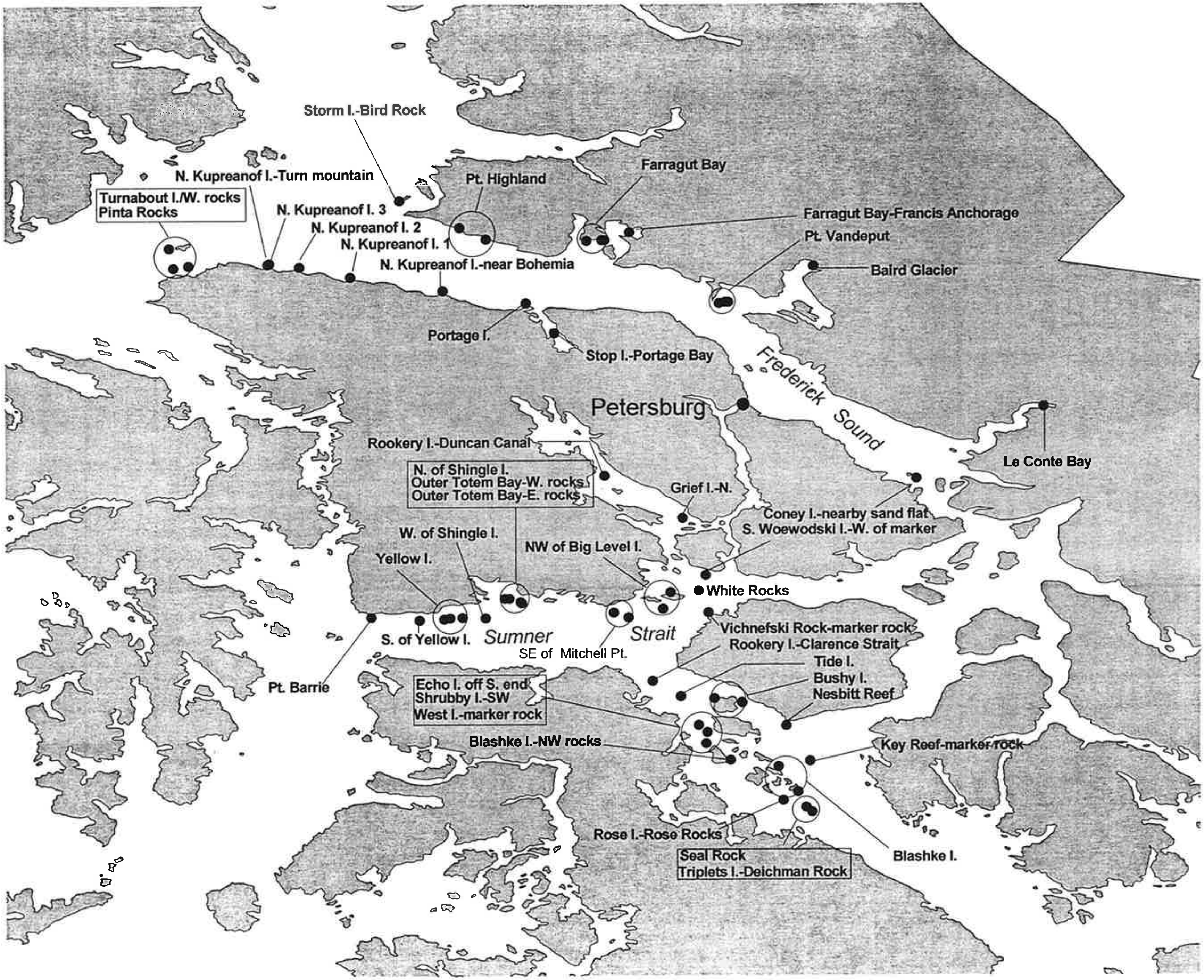


Figure 3. Survey Area 9. [Jansen] (Fredrick Sound to Clarence Strait including northern Sumner Strait)

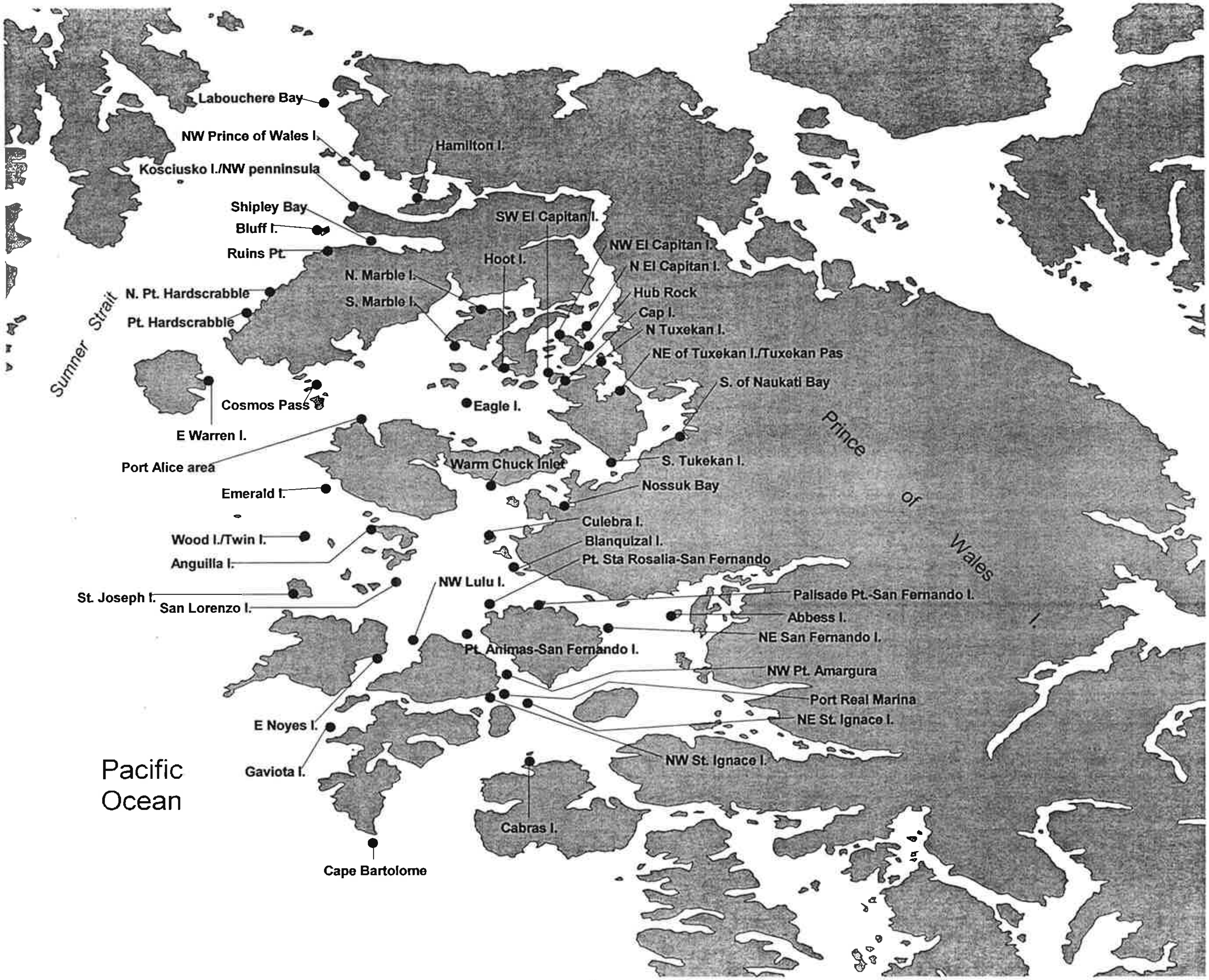


Figure 4. Survey Area 10. [Brix] (northwestern shore of Prince of Wales Island from southern Suemez Island to Cape Chacon)

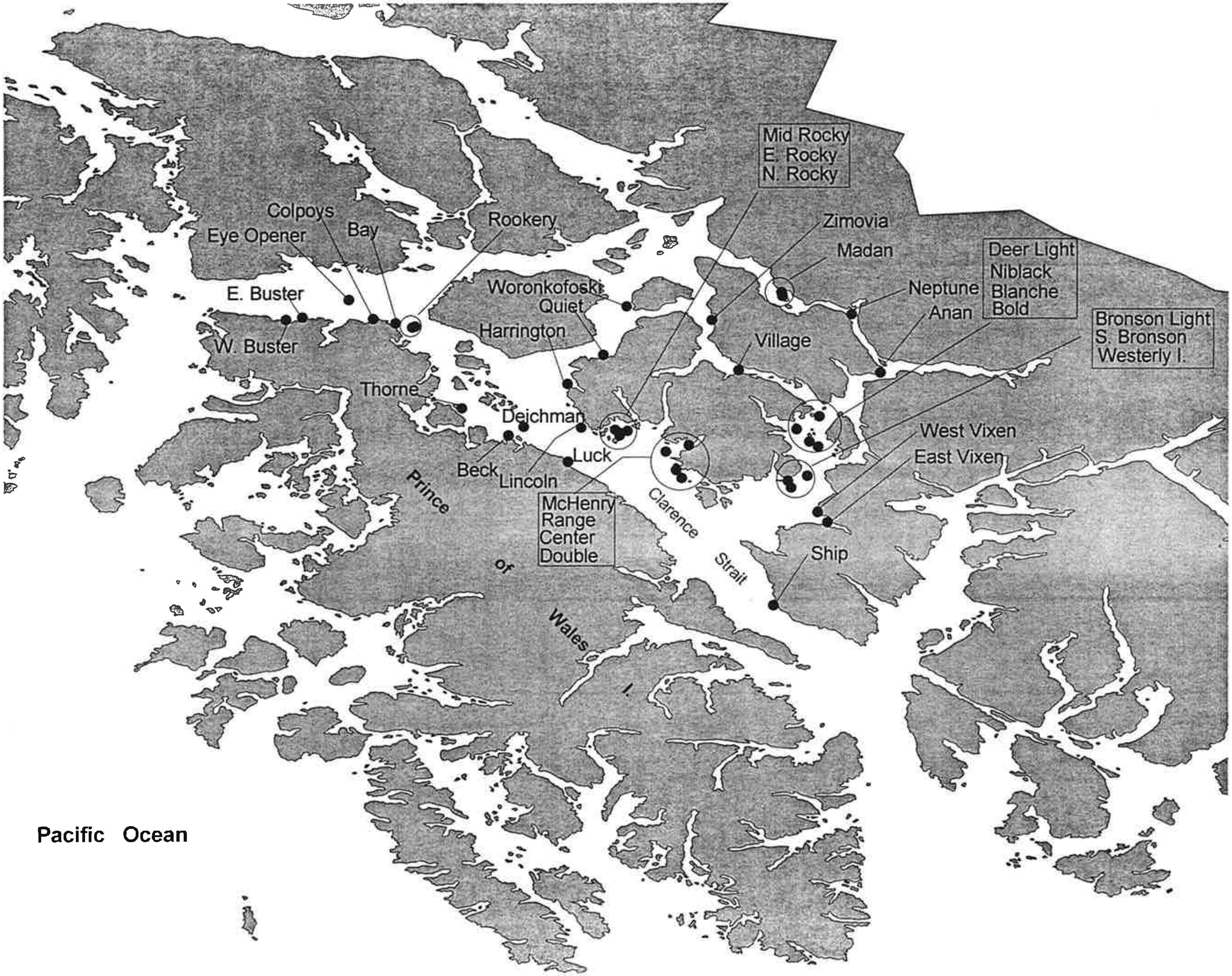


Figure 5. Survey Area 11. [Bengston] (southern Sumner Strait south to the Cleveland Peninsula including Etolin and Wrangell Island)

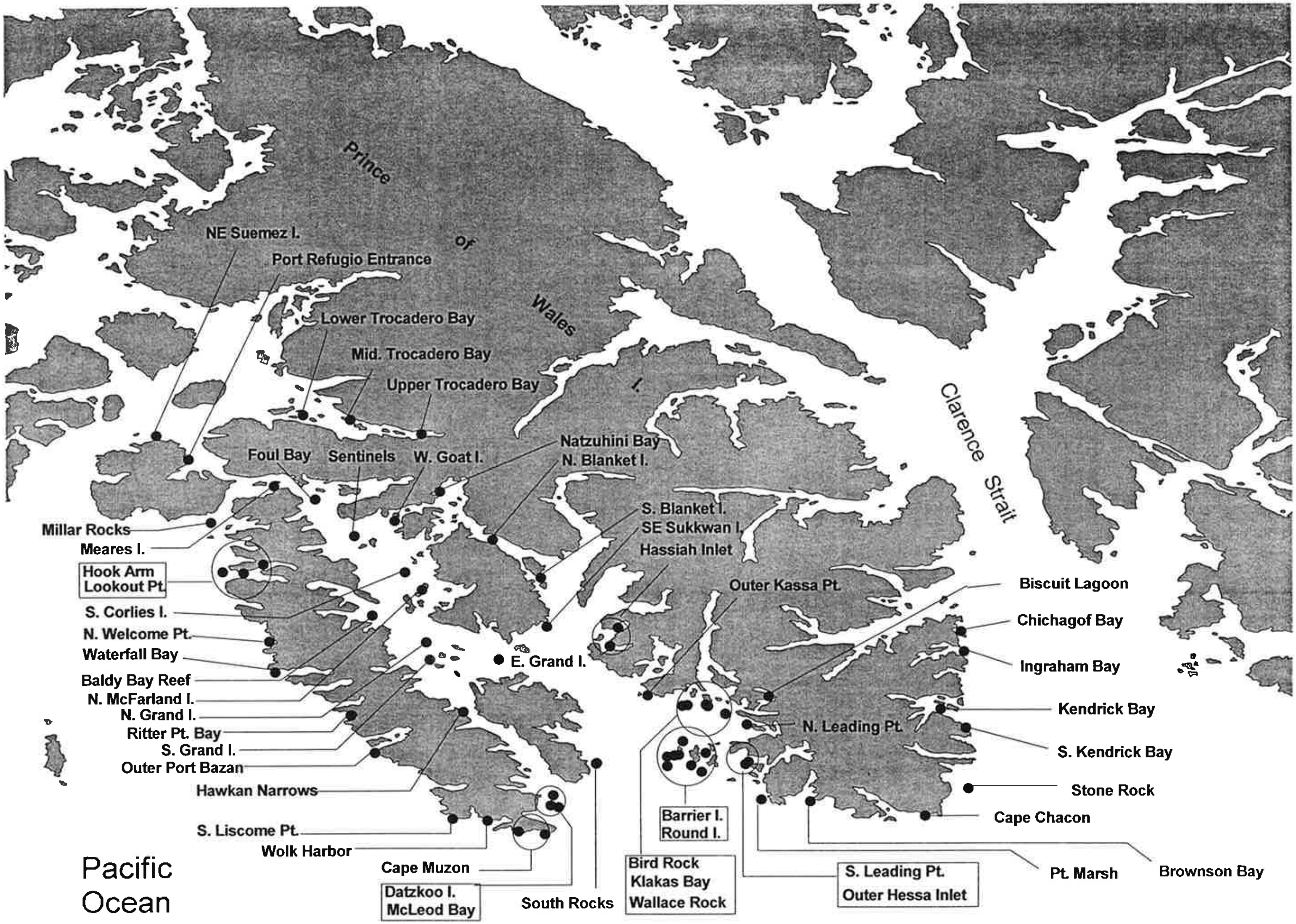


Figure 6. Survey Area 12. [Westlake-Storey] (southwestern shore of Prince of Wales Island from Suemez Island to Chichagof Bay)

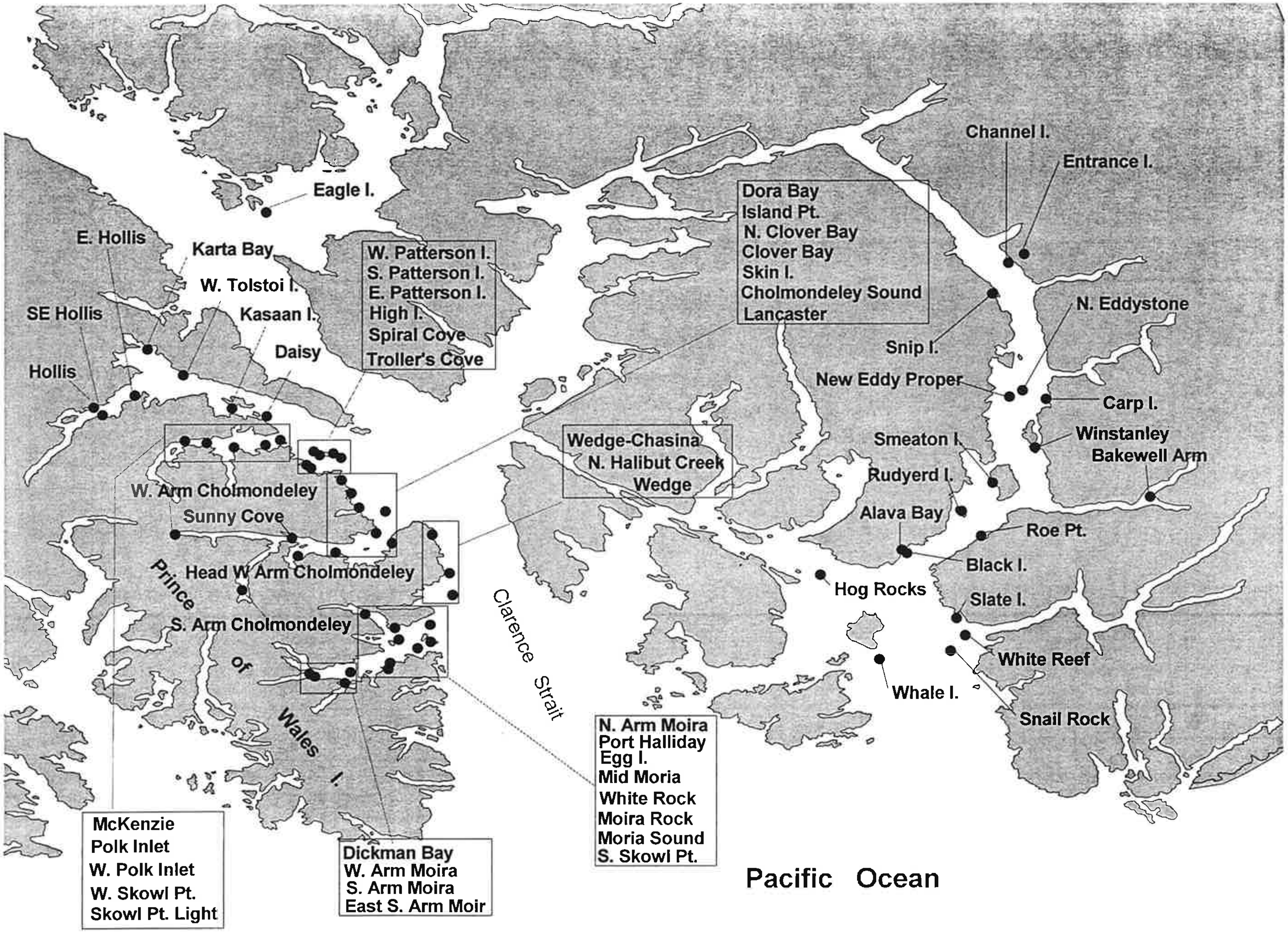


Figure 7. Survey Area 13. [Swain] (ADF&G trend routes along southeast Prince of Wales Island, the southern tip of the Cleveland Peninsula, the Behm Canal, and Mary Island)

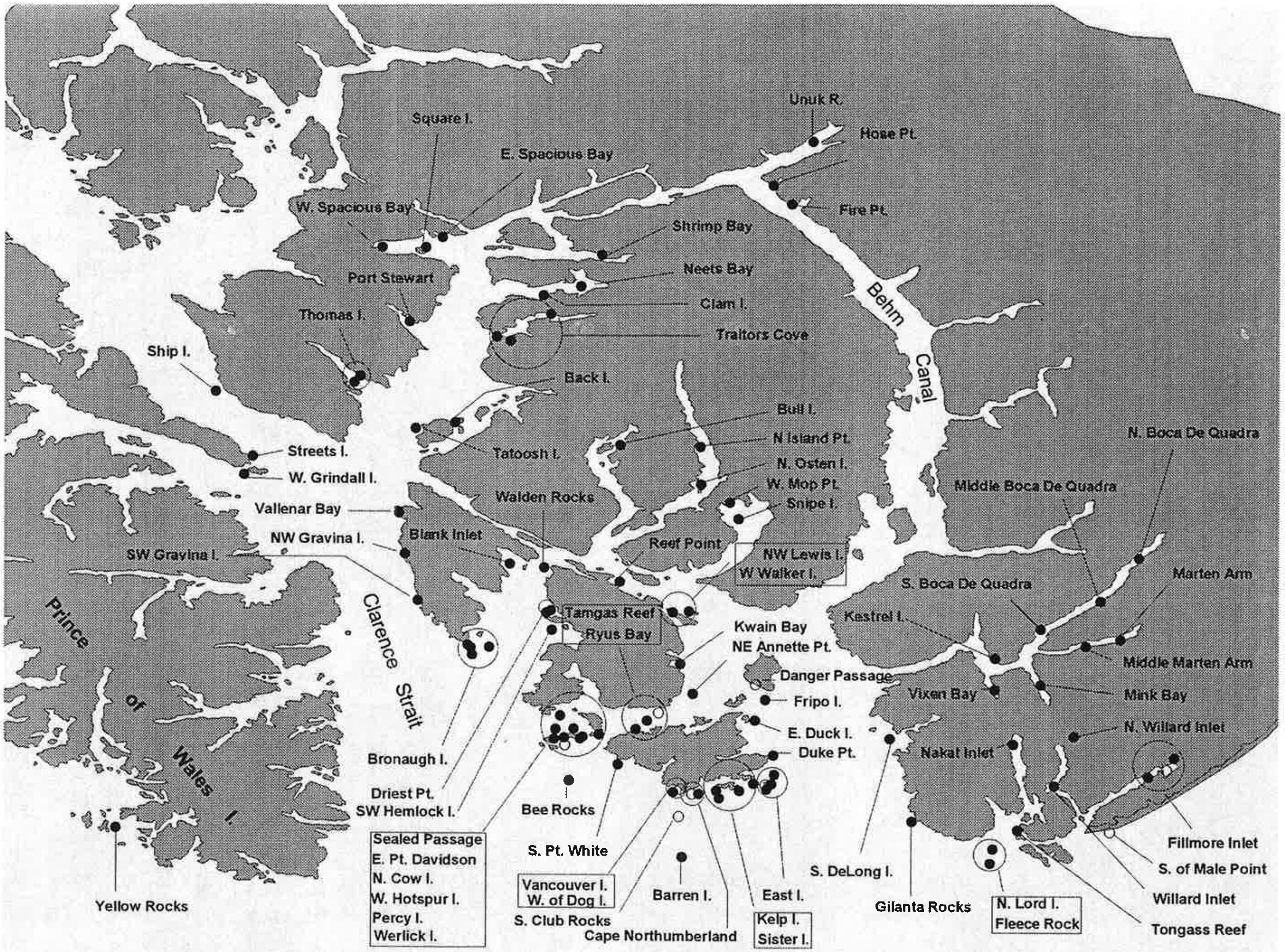


Figure 8. Survey Area 13. [Olesiuk {solid} and Withrow {open}] (Clarence Strait from the Cleveland Peninsula to Dixon Entrance including Revillagigedo, Annette, McFarland, and Percy Islands, and Portland Canal)

FOOD HABITS OF HARBOR SEALS (*PHOCA VITULINA*) AT THE UMPQUA RIVER DURING 1997 AND 1998

Anthony Orr, Adria Banks, Steve Mellman, and Harriet Huber

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

Abstract

The concurrent rise in harbor seal (*Phoca vitulina*) abundance in Oregon and the decline of many salmonids ultimately listed under the Endangered Species Act (ESA) has made estimating harbor seal consumption of ESA-listed salmonids vital in assessing their impact on the recovery of endangered species. In July 1996, National Marine Fisheries Service (NMFS) listed Umpqua River sea-run cutthroat trout (*Oncorhynchus clarkii*) as endangered under the ESA. As part of a larger study to appraise the effect of predation on salmonid stocks, National Marine Mammal Laboratory (NMML) staff began collecting harbor seal food habits data at the Umpqua River, Oregon.

From September to December 1997, predation surveys were conducted at two sites on the lower Umpqua River and one site on the lower Siltcoos River where harbor seals were known or suspected to feed on salmonids. Unless weather intervened, predation surveys were conducted for a minimum of 100 continuous minutes. Fifteen minute distribution surveys were conducted at nine upriver sites on the Umpqua to determine additional areas where predation on salmonids may occur. Weather conditions, visibility, percent cloud cover, predation activity, and maximum number of seals in the area were recorded every 15 (distribution surveys) to 20 min (predation surveys). Predation surveys were conducted for a total of 3,555 min, during which no predation events were observed. However, two predation events were recorded during non-observation effort. Distribution surveys were conducted for a total of 3,065 min. Hourly encounter rate was calculated by dividing harbor seal sightings by total effort at each site. These values were greatest at Brandy Bar and lowest at Dump Station.

During 1997 and 1998, fecal samples were collected from two haul-out sites in the Umpqua River at low tides. Boat-based counts of harbor seals were made prior to each scat collection. Highest mean counts were during August 1998 and lowest mean counts occurred during December 1997. Number of seals hauled out ranged from 2 to 424.

From 15 September to 1 December 1997, scats were collected approximately every other day during low tide cycles. From March through October 1998, scat collections occurred every two weeks. Scats were processed, and prey hard parts stored in vials. Prey were identified to the lowest possible taxon. To date, identification of 1998 samples is incomplete. Identification of cephalopods, cartilaginous fish, and teleost fish (using otoliths) has been finished. Skeletal remains have been used to identify salmonids only.

Minimum number of individuals (MNI) for fish was estimated using the greater number of either right or left otoliths or diagnostic skeletal elements. If there were unknown-side otoliths, their total was divided by two and added to the side with the greatest number of otoliths. For cephalopods,

MNI was estimated using the greater number of upper or lower beaks. A count of one was assigned to prey taxa for which enumeration by diagnostic hard parts was not possible.

Of the 148 scats collected during 1997, 120 (81%) contained prey remains. Of the 582 scats retrieved during 1998, 553 (95%) had prey parts that could be identified, 27 (5%) contained no prey remains, and one sample had unidentifiable remains. Most (80%) prey remains were identified to at least genus; and at least 25 species corresponding to at least 22 families were represented in the harbor seal diet during both years. In addition, the percent of samples containing otoliths, beaks, and cartilaginous remains was comparable between years.

Prey taxa were analyzed using percent frequency of occurrence (%FO), the frequency with which a given prey taxon appears in all fecal samples, and relative abundance (%RA), the MNI of each prey taxon divided by the total number of prey taxa found in all fecal samples. During 1997, the most frequently occurring prey consumed by harbor seals were unidentified flatfish (37.5%), unidentified fish (30%), rex sole (*Errex zachirus*; 29.2%), Pacific staghorn sculpin (*Leptocottus armatus*; 25.8%), and Pacific hake (*Merluccius productus*; 25.8%). The most abundant prey, however, were Pacific sand lance (*Ammodytes hexapteras*; 25.8%), shiner surfperch (*Cymatogaster aggregata*; 13.5%), smelts (Osmerid spp.; 6.4%), Pacific staghorn sculpin (8.1%), and rex sole (5.5%). The high occurrence of unidentified fish may be reduced when these samples are reexamined later this year.

During 1998, the most commonly occurring identifiable prey of seals were lampreys (*Lampetra* spp.; 23.0%), Pacific herring (*Clupea pallasi*; 10.8%), rex sole (10.6%), English sole (*Parophrys vetulus*; 9.4%), and Pacific hake (8.1%). The most abundant prey were Pacific sand lance (16.7%), shiner surfperch (11.6%), lampreys (10.4%), rex sole (6.8%), and Pacific herring (5.7%). These values may change as identification of bone from 1998 samples is completed.

Salmonids (*Oncorhynchus* spp.) did not rank in the top ten most frequently occurring or abundant prey found in fecal samples collected during either year. During 1997, salmon were retrieved from 14 scats (11.7%), of which 4 were determined to be of adult age/size class, and the remaining were considered juveniles. Two of the 10 samples that contained juveniles had chinook salmon (*O. tshawytscha*) otoliths. During 1998, no salmon otoliths were found, but 12 scats (<2%) collected during spring and fall contained salmon bone.

Introduction

The number of harbor seals in Oregon has increased an average of 6-7% each year between 1978 and 1998, although, in recent years, numbers appear to be leveling off at about 8,000 seals (Brown and Kohlmann 1998). Predation by harbor seals on salmonids in Oregon has been documented in the past (Beach et al. 1985, Brown 1980, Harvey 1988, Brown et al. 1995, Riemer and Brown 1997). With decreasing salmonid populations and the listing of more salmonids as endangered under the ESA, documenting the incidence of predation by pinnipeds and estimating the consumption of ESA-listed salmonids becomes important in assessing the impact of pinniped predation on recovery of listed species. Salmonids present in the Umpqua River, Oregon are spring and fall chinook (*Oncorhynchus tshawytscha*), coho (*O. kisutch*), steelhead (*O. mykiss*) and cutthroat trout (*O. clarkii*). In July 1996, NMFS listed Umpqua River sea-run cutthroat trout as endangered under the ESA. As part of a larger study to assess the impact of harbor seal predation on the recovery of ESA-listed salmonids, NMML began collecting harbor seal food habits data at the Umpqua River in September 1997.

About 300 to 400 harbor seals are resident year round in the estuary of the Umpqua River. Harbor seals have not previously been recorded as feeding on cutthroat trout in the Umpqua River. We began our food habits study during fall 1997 to coincide with the presence of returning adult anadromous cutthroat trout in the estuary. During 1998, we began scat collection in the spring to coincide with the departure of adult and juvenile cutthroat from the estuary.

In April 1999, the reevaluation of the status of the Umpqua River cutthroat trout evolutionary significant unit (ESU) was completed. NMFS proposed that the Umpqua River basin cutthroat be removed from the ESA list because it identified those fish as part of the larger Oregon Coast ESU, which extends from south of the Columbia River to Cape Blanco, Oregon. This Oregon Coast ESU has been declared a "candidate" species, which NMFS will continue to monitor. The delisting will be finalized in 2000 by the U.S. Fish and Wildlife Service that maintains the government's endangered species list. The status review did not completely resolve the Umpqua River ESU boundary question; it is possible, as more information becomes available, that smaller ESUs within the Oregon Coast ESU may also be recognized.

Methods

Predation and distribution surveys

From September to December 1997, predation surveys were conducted at sites where harbor seals were known or suspected to feed on salmonids. Surveys were conducted at Half Moon Bay and Windy Cove, which are man-made coves on the southern side of the Umpqua River within 1.5 km of the mouth, to document foraging behavior. To determine additional areas where predation on salmonids may occur, land-based distribution surveys were conducted weekly from Highways 101 and 38 at 9 sites along the river from Reedsport up to river mile 20 during all tidal periods. Total number of seals identified was divided by total effort at each site to calculate hourly encounter rate. In addition to surveys on the Umpqua River, weekly surveys were conducted at a location at the mouth of the Siltcoos River (20 miles north of the Umpqua) to document harbor seal predation on coho salmon. Located in southern Lane County, OR, the Siltcoos River had a coho salmon population of approximately 6,265 fish during 1996 (Loynes pers. comm., Oregon Department of Fish and Wildlife).

All surveys were land-based. The surveyor scanned the river to a distance of approximately 200 to 400 m using binoculars and a spotting scope. Unless weather intervened, predation surveys were conducted for a minimum of 100 continuous minutes at a total of three areas on the lower Umpqua and Siltcoos Rivers, and for 15 min at upriver distribution-survey sites on the Umpqua. Weather conditions, visibility, percent cloud cover, predation activity, and maximum number of seals in the area were recorded every 15 (distribution surveys) to 20 min (predation surveys).

Harbor seal abundance estimates and scat collection

During 1997 and 1998, scat samples were collected from two haulout sites in the Umpqua River. Both sites were sand bars located within 5 km of the river's mouth and within 1.5 km of each other on opposite banks. Prior to each scat collection, boat-based counts of harbor seals were made from a distance of approximately 100 to 200 m from each haulout.

To maximize sample size, harbor seal scats were collected every other day from 15 September to 1 December 1997 during the daytime low tide, weather permitting. Collection trips were conducted during consecutive days when haulout sites were inaccessible for several days due to adverse weather conditions. Feces were assumed to comprise a single scat if they were in close proximity to one another and appeared to have a similar consistency. Scats were collected, placed in individual Whirl-paks, frozen, and later processed at the Oregon Institute of Marine Biology, Charleston, OR.

From March through October 1998, attempts were made to pick a minimum of 50 scats every two weeks at low tides. Scats (and one spewing) were collected, placed in individual Whirl-paks, transported to NMML (Seattle, WA), and frozen for later processing.

Scat processing and analysis

Sub-samples (2.5 to 5 g) were taken from each scat, placed in a 56-g Whirl-pak, and refrozen for later genetic analysis. The remaining material was thawed, rinsed in nested sieves (1.0 mm, 0.71 mm, and 0.5 mm in 1997; 1.4 mm, 1.0 mm, and 0.5 mm in 1998), and all fish remains were dried and stored in glass vials. Statoliths and beaks were stored in 70% isopropyl or ethyl alcohol. The spewing was processed using the same protocol as scats.

Prey were identified to the lowest possible taxon using sagittal otoliths, skeletal elements (teeth, vertebrae, cranial bones, etc.), cartilaginous remains, statoliths, and beaks. To date, identification of 1998 samples is incomplete. Identification of cephalopods, cartilaginous fish, and teleost fish (using otoliths) has been finished. Skeletal remains have been used to identify salmonids only.

Prey remains were compared to the NMML reference collection and voucher samples verified by Pacific ID (Victoria, British Columbia). Prey categorization included "unidentified taxa", items that were clearly distinct from known taxa but were unfamiliar to identifiers, and "unidentifiable" prey items, which included extremely eroded or fragmented prey material and general structures such as lenses or statoliths. Otoliths and beaks were separated by side (left, right, or unknown for otoliths and upper, lower, or unknown for beaks) and enumerated.

Prey taxa were analyzed using percent frequency of occurrence (%FO), the frequency with which a given prey taxon appears in all fecal samples, and relative abundance (%RA), the minimum number of individuals (MNI) of each prey taxon divided by the total number of prey taxa found in all fecal samples. Minimum number of individuals for fish was estimated using the greater number of either right or left otoliths or diagnostic skeletal elements. If there were unknown-side otoliths, their total was divided by two and added to the side with the greatest number of otoliths. For cephalopods, MNI was estimated using the greater number of upper or lower beaks. A count of one was assigned to prey taxa for which enumeration by diagnostic hard parts was not possible.

Results

Predation surveys

A total of 3,555 min were spent looking for harbor seal predation on salmonids at three locations (Table 1). No predation events were observed. However, two predation events were recorded during non-observation effort. The first event occurred on 17 September 1997. A harbor seal surfaced near the center of Half Moon Bay, moved toward the south edge of the cove, and dove and surfaced repeatedly for 30 min consuming a coho salmon. The second event occurred on 2 October 1997 at Brandy Bar (river mile 14). Two harbor seals were observed diving and surfacing in the area. One seal surfaced with a small salmonid in its mouth. The seal dove and surfaced repeatedly for 15 min until the fish was consumed.

Distribution surveys

Surveys were conducted for a total of 3,065 min. Encounter rate was highest at Brandy Bar and lowest at Dump station (Table 2).

Population surveys

The mean number of harbor seals at the Umpqua River fluctuated during 1997 and 1998. Highest mean counts were during August 1998 and lowest mean counts occurred during December 1997. Number of seals hauled out ranged from 2 to 424 (Fig. 1).

Fecal samples

Fecal samples of harbor seals collected at the Umpqua River during 1997 and 1998 predominately contained remains that were identifiable. Of the 148 scats collected during 1997, 81% (n=120) had identifiable remains, the remaining did not contain any prey remains (blanks; Table 3). Of the 582 feces retrieved during 1998, 95% (n=553) had prey parts that could be identified, 5% (n=27) were blank, and one sample had unidentifiable remains. In both years, the percent of samples containing otoliths, beaks, and cartilaginous remains was comparable (Table 4).

Approximately half (48%) of the samples collected during 1997 had two or three taxa present (Fig. 2). During 1998, however, over two-thirds (68%) of the scats had only one or two prey taxa identified. Because bone identification (except for salmonids) is not yet complete, we expect 1998 taxa richness values to change as bone identification is completed. Species that have less robust otoliths, e.g. Pacific hake (*Merluccius productus*), may be under represented in 1998 data.

Most (80%) prey remains were identified to at least genus during both years (Fig. 3). At least 25 species (23 fish, 2 cephalopod), corresponding to at least 22 families (20 fish, 2 cephalopod), were represented in the harbor seal diet during both years (Table 5).

The most frequently occurring prey consumed by harbor seals during 1997 were unidentified flatfish (37.5%), unidentified fish (30%), Rex sole (*Errex zachirus*; 29.2%), Pacific staghorn sculpin (*Leptocottus armatus*; 25.8%), and Pacific hake (25.8%). The most abundant prey, however, were Pacific sand lance (*Ammodytes hexapteras*; 25.8%), Shiner surfperch (*Cymatogaster aggregata*; 13.5%), smelts (6.4%), Pacific staghorn sculpin (8.1%), and Rex sole (5.5%; Table 6). The high occurrence of unidentified fish may be reduced when these samples are reexamined in the coming year.

The most commonly occurring identifiable prey of seals during 1998 were lampreys (*Lampetra* spp.; 23.0%), Pacific herring (*Clupea pallasi*; 10.8%), Rex sole (10.6%), English sole (*Parophrys vetulus*; 9.4%), and Pacific hake (8.1%). The most abundant prey were Pacific sand lance (16.7%), Shiner surfperch (11.6%), lamprey (10.4%), Rex sole (6.8%), and Pacific herring (5.7%; Table 6). These values may change as 1998 identification is completed.

Salmonids (*Oncorhynchus* spp.) did not rank in the top ten most frequently occurring or abundant prey found in fecal samples collected during either year (Table 6). During 1997, salmon were retrieved from 14 scats (11.7%), of which 4 were determined using bones to be of adult age/size class, and the remaining were considered juveniles. Two of the 10 samples that contained juveniles had chinook otoliths. During 1998, no salmon otoliths were found, but 12 scat samples (<2%) collected during spring and fall contained salmon bone. Age, size, or species has not yet been determined. Currently, salmon remains are being separated into age and size classes, and subsamples are being sent for genetic analysis for species identification. Work remains to be done and there potentially may be a change in %FO and %RA of several species.

Acknowledgements

The 1997 field effort was conducted by S. Mellman in 1998 scat collection and harbor seal counts were conducted by L. Lehman, M. Gosho, K. Hughes, S. Melin and R. DeLong. The U.S. Coast Guard Umpqua River Station provided boat storage and a location for keeping a chest freezer during the 1997 field season. The original study sight was identified during surveys conducted by J. Scordino, R. Brown and R. DeLong.

Literature Cited

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. NWAFC Processed Rep. 85-03. 316 p. Available Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE, BIN C15700, Seattle, WA 98115-0070.

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. Jefferies. 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. 16 p.

Brown, R.F., and S.G. Kohlmann. 1998. Trends in abundance and current status of the Pacific harbor seal (*Phoca vitulina richardsi*) in Oregon: 1977-1998. ODFW Wildlife Diversity Program Tech. Rept. 98-6-01. 16 p.

Harvey, J.T. 1988. Population dynamics, annual food consumption, movements and dive behaviors of harbor seals, *Phoca viulina richardsi*, in Oregon. Ph.D. Thesis. Oregon State University. 177 p.

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. Rept. 97-6-02. 34 p.

Table 1. Location and date of harbor seal predation observations at the Umpqua River, Oregon during 1997.

LOCATION	DATE	OBSERVATION EFFORT	PREDATION/SPP.
Siltcoos River	10/2/97	200	0
	10/12/97	300	0
	10/21/97	400	0
	10/28/97	400	0
	11/4/97	400	0
	11/12/97	300	0
	11/25/97	200	0
Half Moon Bay	9/23/97	55	0
	9/29/97	100	0
	10/6/97	100	0
	10/12/97	100	0
	10/13/97	100	0
	10/14/97	100	0
	10/20/97	120	0
	10/22/97	100	0
	10/24/97	80	0
	10/27/97	100	0
Windy Cove	9/23/97	100	0
	9/25/97	100	0
	9/29/97	200	0
Total Observation Effort		**3555**	

Table 2. Total number of harbor seal sightings observed during all distribution surveys (*P.v.* sightings) at each site along the Umpqua River during 1997. All sightings are of single individuals except those indicated by parentheses. For example (2) represents one sighting of two individuals. Hourly encounter rate was calculated by dividing *P.v.* sightings by total effort at each site.

SITE	RIVER MILE (approx.)	*P.v.* SIGHTINGS	TOTAL EFFORT (min)	ENCOUNTER RATE
Scottsburg Park	20	3	355	0.5
Mill Creek	18	6	355	1.0
Steel Pier	16	7	355	1.2
Brandy Bar	14	5, (2), (3)	365	1.6
Dean Creek	12	4	355	0.7
Elk viewpoint	10	3, (2)	355	0.8
Dump Station	9	2	355	0.3
101 Upriver	8	2, (2)	300	0.8
101 Downriver	8	2	270	0.4
Totals		**43**	**3065**	

Table 3. Summary of the number of prey remains retrieved from harbor seal fecal samples collected at the Umpqua River, Oregon during 1997 and 1998. Seasons were defined as follows: fall (samples collected after 15 July), summer (samples collected 15 May to 15 July) and spring (samples collected prior to 15 July). Asterisk (*) indicates that samples collected includes one spewing.

Season	**Collection date**	**# samples collected**	**with identifiable remains**	**with unidentifiable remains**	**with no prey remains**
fall 97	9/16-23/97	29	27	0	2
	9/27-10/6/97	8	5	0	3
	10/12-24/97	38	31	0	7
	10/31-11/10/97	27	21	0	6
	11/12-25/97	46	36	0	10
spring 98	3/24-25/98	34	31	1	2
	4/13-15/98	71	64	0	7
	4/26-27/98	53	49	0	4
	5/13-14/98	45	41	0	4
summer 98	5/27-28/98	13	12	0	1
	6/11-12/98	39*	38	0	1
fall 98	8/5-6/98	144	143	0	1
	8/19-20/98	115	112	0	3
	9/6-9/98	34	31	0	3
	9/19-21/98	13	13	0	0
	10/7-8/98	20	19	0	1
Total 97		**148**	**120**	**0**	**28**
Total 98		**581**	**553**	**1**	**27**

Table 4. Summary of the percentages of samples containing otoliths, beaks and cartilaginous remains collected at the Umpqua River, Oregon during 1997 and 1998. Parentheses indicate number of samples.

	1997	**1998**
% with fish otoliths	44 (53)	53 (296)
% with cephalopod beaks	5 (6)	6 (37)
% with cartilaginous remains	28 (34)	29 (164)

Table 5. Species and families of prey found in harbor seal fecal samples collected at the Umpqua River, Oregon during 1997 and 1998. Cross (†) indicates species found only during 1997. Asterisk (*) indicates species found only during 1998.

SPECIES	FAMILY	COMMON NAME
Fishes		
Alosa sapidissima	Clupeidae	American shad
Ammodytes hexapterus	Ammodytidae	Pacific sand lance
*Chilara taylori**	Ophidiidae	Spotted cuskeel
Citharichthys sordidus	Bothidae	Pacific sanddab
Clupea pallasii	Clupeidae	Pacific herring
Cymatogaster aggregata	Embiotocidae	Shiner surfperch
Engraulis mordax	Engraulididae	Northern anchovy
*Eopsetta jordani**	Pleuronectidae	Petrale sole
Eptatretus stoutii	Myxinidae	Pacific hagfish
Errex zachirus	Pleuronectidae	Rex sole
Gasteroseus aculeatus†	Gasterosteidae	Three-spine sticleback
*Isopsetta isolepis**	Pleuronectidae	Butter sole
Lampetra ayresii	Petromyzontidae	River lamprey
Lampetra tridentata	Petromyzontidae	Pacific lamprey
Leptocottus armatus	Cottidae	Pacific staghorn sculpin
*Lyopsetta exilis**	Pleuronectidae	Slender sole
Merluccius productus	Gadidae	Pacific hake
Microgadus porximus	Gadidae	Pacific tomcod
Microstomus pacificus	Pleuronectidae	Dover sole
Oncorhynchus spp.	Salmonidae	Salmon
Ophiodon elongatus†	Hexagrammidae	Lingcod
Osmerid spp.	Osmeridae	Smelt
Parophrys vetulus	Pleuronectidae	English sole
Pholid spp.	Pholididae	Gunnel
Platicthys stellatus	Pleuronectidae	Starry flounder
Rajid spp.*	Rajidae	Skate
*Sardinops sagax**	Clupeidae	Pacific sardine
Scomber japonicus	Scombridae	Pacific mackerel
Sebastes spp.	Scorpaenidae	Rockfish
*Trichodon trichodon**	Trichodontidae	Pacific sandfish
Cephalopods		
Loligo opalescens	Loliginidae	Market squid
Octopus rubescens	Octopodidae	

Table 6. Percent frequency of occurrence (%FO) and relative abundance (%RA) of prey taxa retrieved from harbor seal fecal samples collected at the Umpqua River, Oregon during 1997 and 1998. Parentheses indicate minimum number.

	1997		1998	
PREY TAXA	%FO		%FO	%RA
Unidentified flatfish	37.5 (45)	5.3 (42)	2.3 (13)	0.6 (13)
Unidentified fish	30.0 (36)	4.6 (37)	3.6 (20)	1.0 (20)
Errex zachirus	29.2 (35)	5.5 (44)	10.6 (59)	6.8 (141)
Leptocottus armatus	25.8 (31)	8.1 (65)	5.0 (28)	2.8 (57)
Merluccius productus	25.8 (31)	3.9 (31)	8.1 (45)	3.4 (70)
Eptatretus spp.	16.7 (20)	2.5 (20)	5.2 (29)	3.1 (64)
Clupea pallasi	15.8 (19)	2.8 (22)	10.8 (60)	5.7 (118)
Microgadus proximus	15.0 (18)	2.6 (21)	3.1 (17)	1.3 (27)
Osmerid spp.	14.2 (17)	6.4 (51)	6.8 (38)	5.8 (120)
Cymatogaster aggregata	12.5 (15)	13.5 (108)	7.0 (39)	11.6 (234)
Oncorhynchus spp.	11.7 (14)	2.1 (17)	2.2 (12)	0.6 (12)
Sebastes spp.	11.7 (14)	1.8 (14)	0.4 (2)	0.2 (4)
Lampetra spp.	10.8 (13)	1.6 (13)	23.0 (128)	10.4 (215)
Platichthys stellatus	10.0 (12)	2.3 (18)	1.3 (7)	0.7 (14)
Parophrys vetulus	10.0 (12)	4.8 (38)	9.4 (52)	5.4 (111)
Ammodytes hexapteras	5.8 (7)	25.8 (206)	1.3 (7)	16.7 (344)
Pholididae	5.8 (7)	0.9 (7)	---	---
Cephalopods	5.0 (6)	0.8 (6)	---	---
Cottid spp.	5.0 (6)	0.9 (7)	0.9 (5)	0.4 (8)
Clupeid spp.	4.2 (5)	0.6 (5)	2.0 (11)	1.1 (22)
Unidentified elasmobranchs	4.2 (5)	0.6 (5)	---	---
Citharichthys sordidus	3.3 (4)	1.4 (11)	1.3 (7)	0.5 (10)
Engraulis mordax	2.5 (3)	0.4 (3)	0.2 (1)	0.1 (1)
Microstomus pacificus	2.5 (3)	0.4 (3)	3.2 (18)	1.5 (30)
Alosa sapidissima	1.7 (2)	0.3 (2)	0.9 (5)	0.2 (5)
Scomber japonicus	1.7 (2)	0.3 (2)	---	---
Gasterosteus aculeatus	0.8 (1)	0.1 (1)	---	---
Ophiodon elongatus	0.8 (1)	0.1 (1)	---	---
Chilara taylori	---	---	0.7 (4)	0.3 (6)
Citharichthys spp.	---	---	0.4 (2)	0.2 (4)
Embiotocid spp.	---	---	0.2 (1)	0.2 (5)
Eopsetta jordani	---	---	0.2 (1)	0.1 (1)
Isopsetta isolepis	---	---	2.2 (12)	0.8 (17)
Loligo opalescens	---	---	0.9 (5)	0.5 (10)
Lyopsetta exilis	---	---	5.0 (28)	2.1 (44)
Unidentifiable remains	---	---	13.9 (77)	5.5 (113)
Octopus rubescens	---	---	5.4 (30)	2.5 (51)
Pleuronectid spp.	---	---	6.5 (36)	3.3 (68)
Rajid spp.	---	---	0.2 (1)	0.1 (1)
Sardinops sagax	---	---	5.2 (29)	4.0 (83)
Scorpaenid spp.	---	---	0.4 (2)	0.1 (2)
Trichodon trichodon	---	---	0.2 (1)	0.1 (1)
Unidentified cartilaginous	---	---	2.5 (14)	0.7 (14)
Unidentified other	---	---		0.1 (1)

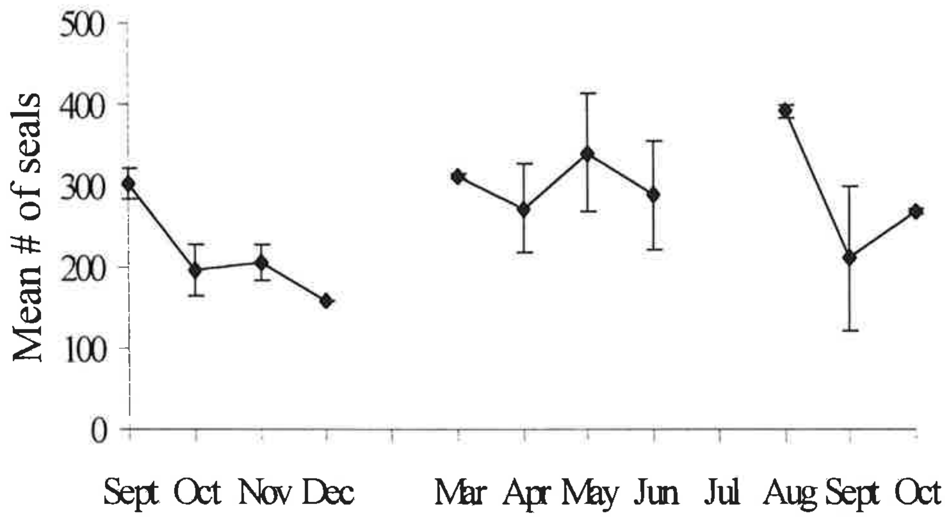


Figure 1. Monthly mean number of harbor seals at the Umpqua River from surveys conducted during 1997 and 1998. Vertical bars indicate one standard error.

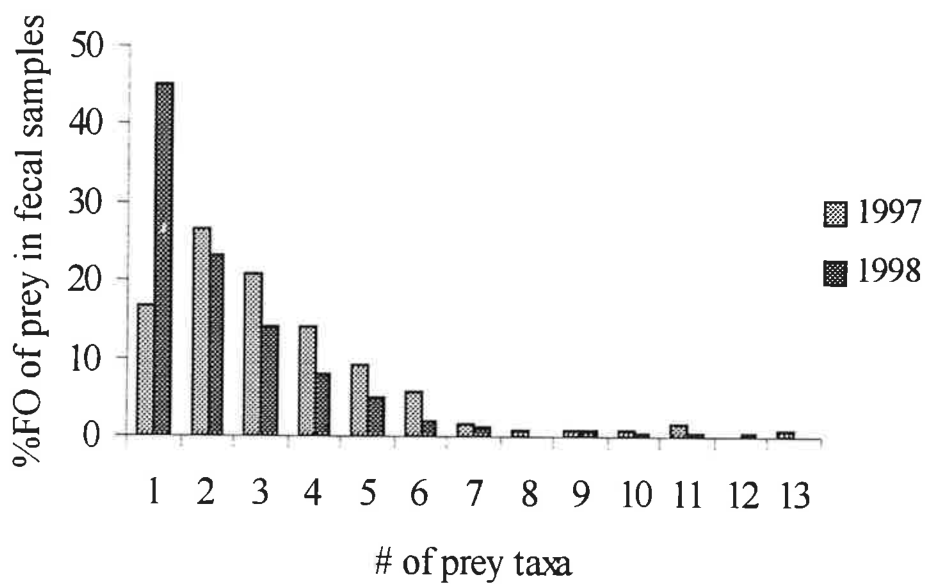


Figure 2. Frequency of occurrence of single and multiple prey taxa found in harbor seal fecal samples collected at the Umpqua River, Oregon during 1997 and 1998.

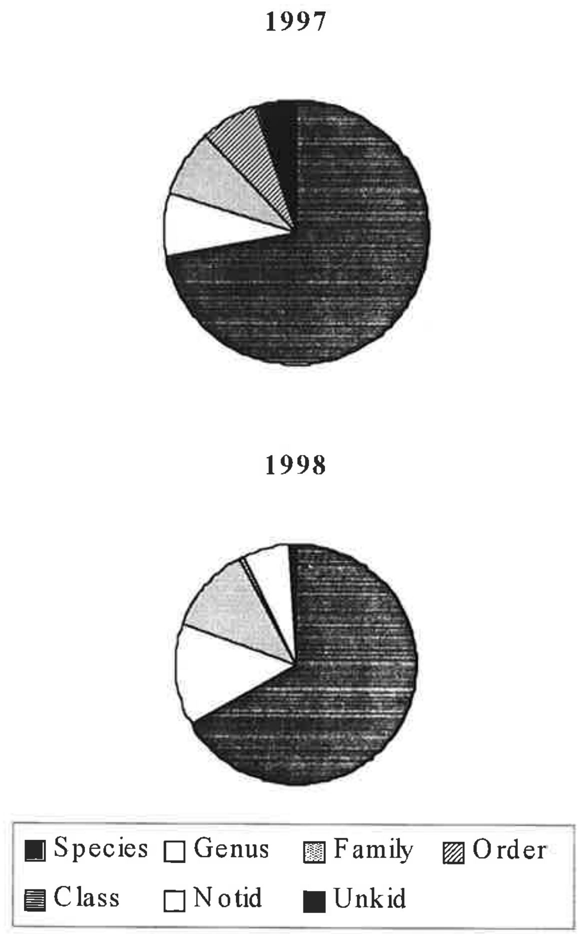


Figure 3. Percentages of prey remains identified to the lowest possible taxonomic level from harbor seal fecal samples collected at the Umpqua River, Oregon during 1997 and 1998.

REPORT ON WASHINGTON HARBOR SEAL OSP WORKSHOPS

Steven Jeffries [1], Jeffrey Laake [2], Harriet Huber [2], and Robert DeLong [2]

[1] Marine Mammal Investigations
Washington Department of Fish and Wildlife
7801 Phillips Road, S.W.
Tacoma, WA 98498

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

Abstract

In 1998, two workshops were convened to bring together biologists collecting survey data on harbor seals and statisticians familiar with population dynamics to discuss survey procedure, available data, and to develop a plan for analysis. The first workshop was held on 14 May 1998 with a report produced in November 1998 which contained a summary of discussion and a preliminary analysis that suggested the number of harbor seals on the Washington coast was stabilizing. In the second workshop, held in 1-3 December 1998, participants explored the compatibility of Washington and British Columbia inland water survey data, described potential Optimum Sustainable Population (OSP) assessment methods, conducted further analyses of the data, and identified remaining analysis issues. The major points of discussion at both workshops and some preliminary results are provided in this report.

Introduction

Harbor seals are the most abundant pinniped in the Pacific Northwest, with about 10,000 resident in Oregon and about 35,000 resident in Washington. Historical levels of abundance are unknown, but numbers were severely reduced by bounty hunters under a state-financed program which considered harbor seals to be predators in direct competition with commercial and sport fishermen. The bounty program was terminated in 1960 and the harbor seal population in Washington state was estimated as 2,000-3,000 animals in the early 1970s (Newby 1973). Since the Marine Mammal Protection Act (MMPA) was passed in 1972 and the bounty program ceased, harbor seal numbers in the Pacific Northwest have increased. Systematic surveys of coastal Washington started in 1978 and of the Washington inland waters in 1983.

Coastal surveys in Washington document an increase in harbor seals since 1978 and an apparent leveling of counts since the early 1990s. Counts in the Washington inland waters are still increasing. The 1997 estimate for the Washington coastal stock is 18,152 seals (95% CI= 15,793 to 20,863) and for the Washington inland waters stock is 16,056 seals (95% CI= 14,067 to 18,325). These estimates are based on mean counts of 11,864 seals for the coast, 10, 494 for the inland stock and a correction factor of 1.53 to account for seals in the water during surveys. The increasing harbor seal population combined with decreasing salmonid populations and the perceived connection between the two indicate a need for managers to assess the present status of harbor seals.

Survey Methodology and Data

Political boundaries/stocks

Washington and Oregon Departments of Fish and Wildlife manage harbor seals by state boundaries, National Marine Fisheries Service (NMFS) manages harbor seals by stock boundaries. At least two stocks are identified in Washington state: the coastal stock and the inland stock. The dividing line within the state is arbitrarily defined as a line north of Cape Flattery across the Strait of Juan de Fuca (Fig. 1). The inland stock is composed of seals in the Strait of Juan de Fuca, San Juan Islands, Eastern Bays, Puget Sound and Hood Canal. The coastal stock includes seals on the outer Olympic Peninsula coast, the Washington coastal estuaries of Grays Harbor and Willapa Bay as well as all seals in Oregon (Fig. 1). The northern boundary of the coastal stock is arbitrarily defined as the U.S./Canada border, the southern boundary as the Oregon/California border. Washington stocks are separated because of differences in cranial morphology, pupping phenology, and genetics (Temte 1986, Temte 1991, Huber et al. 1995, Lamont et al. 1996). No radio-tagged seals from the inland stock have been observed on the coast or vice versa.

Survey methods

Harbor seal surveys in Washington are flown when maximum numbers are assumed to be onshore; seals in the water are not counted. The only age classes distinguishable from the air are pups and non-pups; pups are identified by color, size, and proximity to an adult female. When on sand,pups are fairly easy to identify; but more difficult to distinguish when on rocky substrate, particularly on overcast days. Surveys were flown between 1.5 to 2 hours before low tide to 1.5 to 2 hours after low tide in a single engine plane at 700 to 800 ft altitude at 80 knots. All known sites were surveyed and new sites were looked for on each census. Consistency in data collection was very high; about 80% of pupping season surveys were flown by one observer, the others were flown by a second observer. Data collected during surveys included date, time, location, visual estimate of seal numbers and photographs of all sites with more than 25 seals. Photographs were taken with an SLR camera with 70-210 mm lens, using 200 or 400 ASA Ektachrome film, shot at 500 to 1000 of a second to compensate for the movement of the plane. Evidence of recent disturbance (haul marks on the beach or many seals milling in the water) was also noted. At least 2-3 surveys were scheduled for each region for each year. Sometimes surveys were canceled because of weather. Surveys were flown in late May/mid June for the coastal stock and August/early September for the inland stock. Differences in pupping phenology among survey regions were taken into account in order to survey as close as possible (tides permitting) to the time when the peak number of pups would be present.

Pupping phenology

For harbor seals along the coast in Washington and Oregon, most pups are born between mid-May and Mid-June. For harbor seals in the inland waters of Washington and Canada, most pups are born in July and August.

Harbor seal haul-out behavior

Haul-out behavior of harbor seals varies with season; in general, the highest number of seals are on land during the pupping and molt season, the lowest numbers during the winter. Other variables which can affect haulout behavior are tide, weather, time of day, and disturbance. Most haulout areas in Washington have the most space available at low tide; in some places, the haulout area is completely covered by water at high tide. Some areas such as floating docks or other man-made structures are available at all tides. Only one region, Hood Canal, is a high tide haulout (because of steep banks, the seals can only reach the haulout area when the tide is high). Highest numbers are on land when low tides occur in mid-morning. Rainy or stormy weather can cause seals to leave haulouts. At no time is the entire population on shore (Jeffries 1985). A correction factor to account for seals in the water during surveys was developed for Washington and Oregon during the pupping season (correction factor = 1.53; Huber 1995). Haul-out behavior is also influenced by age, sex, and reproductive condition. During pupping season surveys, adult females and nursing pups spent 90 to 100% of their time on shore. Females nurse pups for 4 to 6 weeks. After weaning, pups spend an increased amount of time in the water and haulout only infrequently. The molt period occurs 6 to 8 weeks after the pupping season. Seals undergoing molt spend a higher proportion of time on shore. Adult females molt first, then adult males, so that as the molt period progresses, the age/sex structure of hauled out seals changes (Thompson and Rothery 1987).

Molt vs. pupping surveys

Harbor seal surveys are flown by different researchers at different times because of local constraints. Surveys are flown in Washington, Oregon and British Columbia during the pupping season to track annual pup production and to avoid bad weather and inappropriate tides in the fall. Molt season for the Washington/British Columbia inland seals is in October/November when the lowest tides occur during darkness and the weather is apt to be windy and rainy. Surveys are flown in Alaska during molt season to avoid foggy weather in June. Surveys are flown in California in June (between the pupping season and the molt season) to avoid spring storms and wind and the influx of human disturbance on the beaches in later summer.

Survey Regions

There are about 320 harbor seal haul-out sites in Washington State. Washington survey regions are depicted in Fig. 1. Seals on the Columbia River are included in Oregon data and seals on the northern side of the Strait of Juan de Fuca and the Gulf Islands are included in Canadian data. The total number of seals (including pups) and the number of pups present at each site were counted from slides. The number of seals counted at each haul-out site was summarized into 7 Survey Regions (Coastal Estuaries; Outer Olympic Peninsula, Strait of Juan de Fuca, San Juan Islands, Eastern Bays, southern Puget Sound and Hood Canal). A complete survey of each region was attempted in one day; if this was impossible because of weather or disturbance, surveys from 2 or 3 days were sometimes combined. To obtain a number for annual counts, mean counts from all survey regions were combined. In some years, because of bad weather or disturbance on the haulout or incomplete surveys, there was no count for one or more survey regions and consequently no annual count for the year. Surveys with low counts (due to disturbance or weather) or surveys outside the survey window were discarded.

Compatibility of Washington and British Columbia inland waters surveys
In comparing data from Washington and British Columbia inland water surveys, there are basic similarities: surveys were flown at low tide during the pupping season; counts are of the total number of seals including pups; and surveys were conducted with one to two primary observers throughout the time series. In Boundary Bay, the only haulout where both groups surveyed the same area, there was less than 5% difference between counts in the two data sets. Dissimilarities include 1) separation of pups and non-pups in Washington data, but not in the British Columbia data; 2) multiple surveys each year in Washington, only one survey per year in BC (every 2 years since 1988); 3) BC data include a correction factor for counts to account for timing of the survey in relation to tide height and rising or falling tide; 4) some parts of the BC coast have never been surveyed; part of the Strait of Juan de Fuca has been surveyed only twice in 15 years; 5) imputation of missing data is not always the same (BC uses the missing area as a proportion of the region; Washington uses an estimate of the missing area based on previous and subsequent surveys of the area). In general, the strength of the BC data lies in the length of the time series, while the strength of the Washington data is in its precision, the result of repeated surveys in each year. There are weaknesses in both data sets. Washington has no surveys before 1975 and incomplete surveys to 1983. BC surveys began in 1973, there are no surveys 1977 to 1981, incomplete surveys 1982 to 1986, and the survey schedule is now every two years starting in 1988. A later analysis may join inland water data from Washington and BC including a reanalysis differentiating pups and non-pups from survey photos in British Columbia.

Analysis Methods

In Washington, harbor seals are recovering from a dramatically reduced population. For the last 2 to 3 decades, there has been little or no harvest and seal numbers have increased substantially. Monitoring growth by conducting aerial surveys since 1975 has enabled estimation of maximum net productivity level (MNPL) for these harbor seal stocks and an assessment of whether the stocks are at optimum sustainable population (OSP) size (i.e., above MNPL). Two types of analysis techniques were discussed during the workshop: 1) dynamic esponse analysis, and 2) fitting population growth models.

Dynamic Response Analysis
Dynamic response analysis (DRA) (Goodman 1988) was developed as a simple non-parametric assessment of whether a recovering population is above or below MNPL by examining the curvature of the population trajectory. A second-order polynomial regression is fitted to sections of the population trajectory. A positive second order coefficient means the trajectory is concave upwards (Fig. 2a), a negative second order coefficient means the trajectory is concave downwards (Fig. 2b), and if the quadratic coefficient is not significantly different from zero, either a linear or constant trajectory is implied (Fig. 2c). If a second-order polynomial is fitted to

intervals of a logistic growth curve, the sign of the quadratic coefficient will change from zero, to positive, to zero, to negative and finally back to zero (Fig. 3). The population has exceeded its MNPL at points at and above where the sign is negative.

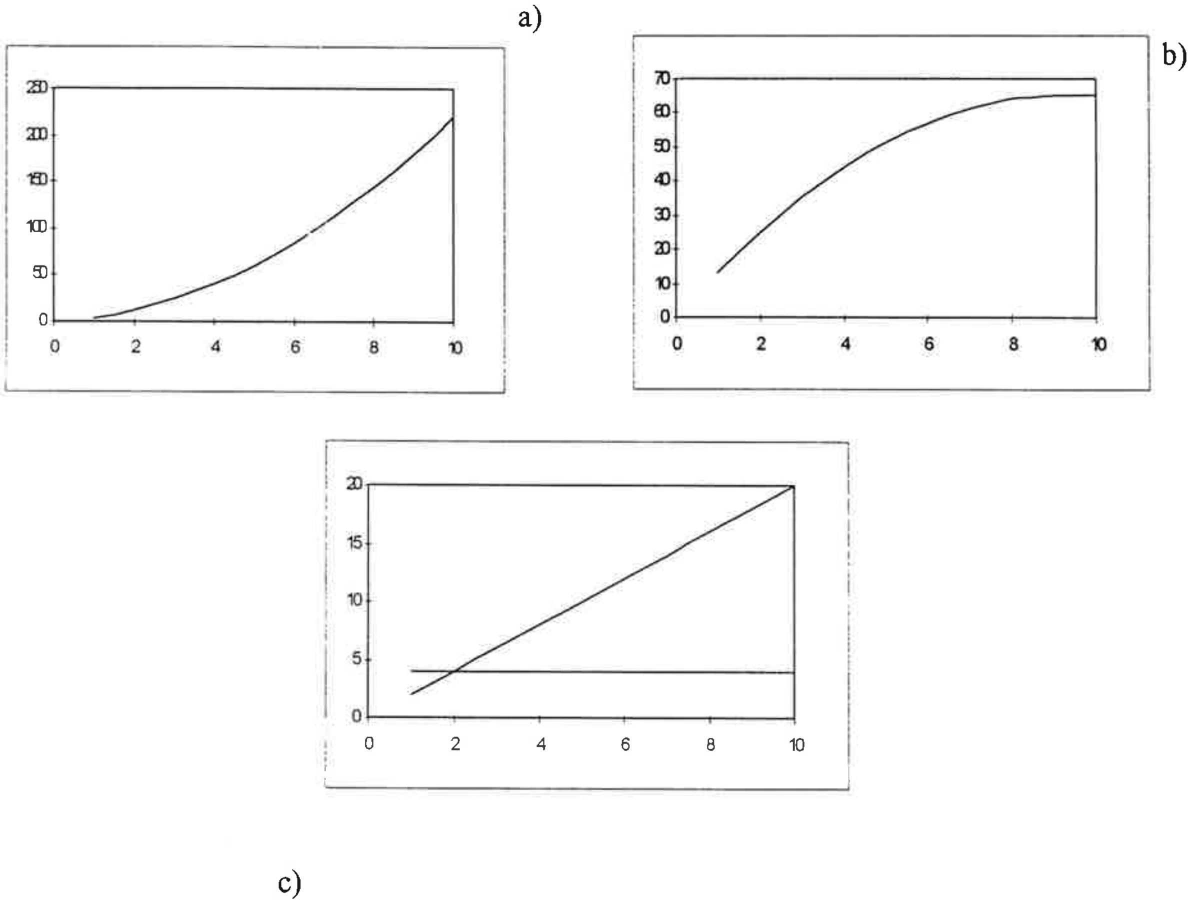


Figure 2. Population trajectory when the second-order polynomial coefficient is positive (a), negative (b) and zero (c).

Variability in the counts will manifest itself in the second-order coefficients. The second-order coefficients will be variable and potentially the standard errors of the parameters will be so large that most or all of the coefficients may not be significantly different from zero. To overcome this variability Boveng et al. (1988) suggested the following:

1) fitting the regressions to overlapping sets of time intervals (with *k* points) by moving the interval one step which adds a more recent estimate and discards the oldest,

2) repeating this process increasing *k* from 4 (the smallest possible) to *n* (the number of estimates - the largest possible)

3) choosing the smallest *k* such that the signs of the coefficients are consistent with the logistic growth model and positive and negative coefficients are statistically different from zero.

The Washington coastal surveys of harbor seals from 1980-1997 were used in a DRA using the approach of Boveng et al. (1988). For intervals of k=4 to k=7 surveys, Figure 4 shows the quadratic coefficients and their 95% confidence interval plotted at the mid-point of the

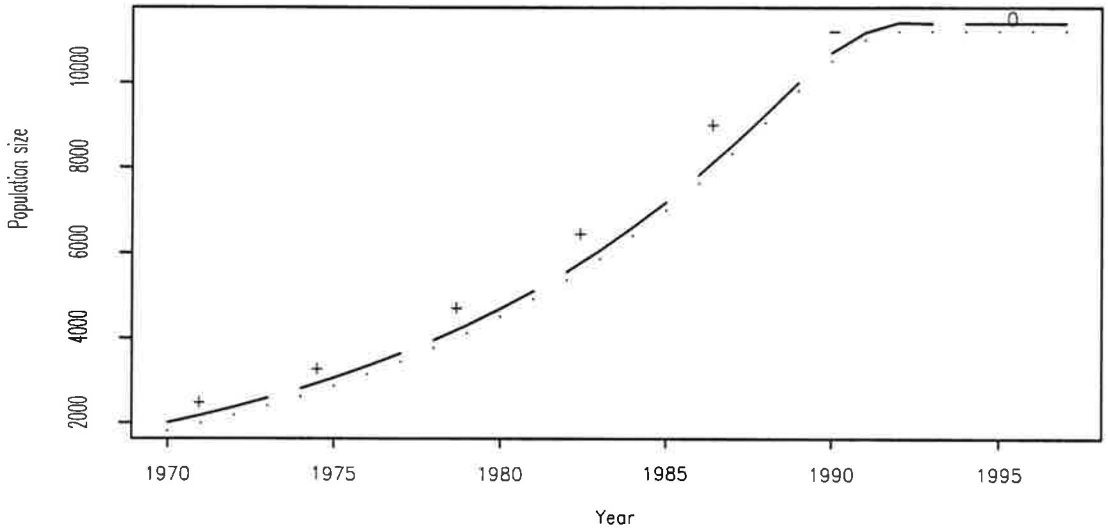


Figure 3. Example growth curve and sign of the second-order polynomial coefficient for non-overlapping intervals.

interval for the survey data and a dashed line showing the quadratic coefficients from a generalized logistic model fitted to the survey data. None of these intervals satisfy the criteria of Boveng et al. (1988) to demonstrate a response. When all 13 surveys are used, the quadratic coefficient is negative and is significantly different from zero. However, when any lesser number of intervals are used, the strict criteria of statistical significance is not satisfied. This implies that the coastal stock is above MNPL.

The DRA concept requires as little as possible from the data without a presumed growth model. While this is a desirable goal, unless the survey data are very precise, the population has exhibited a large change in size and a large number of surveys have been conducted, the assessment is likely to be incorrect (Gerrodette 1988). Additionally, the outcome of DRA is simply a qualitative decision whether the population is above or below MNPL. No estimate of MNPL or further understanding of the population dynamics can be achieved with this technique. To develop quantitative assessments, the count data must be fitted to population growth models, which was the subject of most of the workshop discussion.

Population Growth Models

Two simple non-age structured deterministic population growth models were considered during the workshop: exponential and generalized logistic. These models are discrete in nature with an annual time step to represent the annual pulse-breeding. In each case, the population size (N_t) in year t is expressed in terms of the population size (N_{t-1}) in year t-1 plus growth (new individuals), which is some fraction of N_{t-1}. Exponential growth assumes the population grows without limit at a constant annual rate (R_{max}):

$$N_t = N_{t-1} + N_{t-1}R_{max} \qquad (1)$$

Clearly, the exponential model is unrealistic but can be used as a null model to test for density dependence. In the generalized logistic growth model (Fig. 5), the rate of increase is a function of the population size relative to the maximum population size K (carrying capacity):

$$N_t = N_{t-1} + N_{t-1}R_{\max}\left[1-\left(\frac{N_{t-1}}{K}\right)^z\right] \tag{2}$$

Annual net production is simply the difference in consecutive population sizes:

$$N_t - N_{t-1} = N_{t-1}R_{\max}\left[1-\left(\frac{N_{t-1}}{K}\right)^z\right] \tag{3}$$

and maximum net productivity level (MNPL) is the value of N which maximizes (3). As N_t/K ranges between 0 and 1, the realized per capita growth rate values range between R_{max} and 0:

$$\frac{N_t - N_{t-1}}{N_{t-1}} = R_{\max}\left[1-\left(\frac{N_{t-1}}{K}\right)^z\right] \tag{4}$$

The shape of the growth curve (Fig. 5) and the per capita production curve is governed by the exponent z (Fig. 6), which determines the density dependent effect and the position of MNPL relative to K (Fig. 7). If $z=1$, per capita production is a linear function of N and MNPL/ K = 0.5. If $z>1$, per capita production is a concave (downwards) non-linear function of N and MNPL/ K > 0.5 and if $z<1$, per capita production is a convex (concave upwards) non-linear function of N and MNPL/ K < 0.5. An approximate relationship between MNPL/K and z (Polachek 1982) shown in Figure 8 is given by:

$$MNPL\ /\ K \approx (z+1)^{-1/z} \tag{5}$$

An examination of Figures 5-7 and 9 provides the following insights to help understand the generalized logistic and its parameters:

1) The density dependence exponent z will always be poorly estimated without extremely precise abundance estimates. This is evident by examining Fig. 5 which shows that doubling the z exponent from 5 to 11 made an inconsequential change to the growth curve.

2) If R_{max} is constant as z increases, the peak of the production curve increases (i.e., greater production) as well as shifting to the right.

3) R_{max} and z are negatively correlated in the model (i.e., to achieve the same growth with a lower z, R_{max} must increase (Fig. 9).

4) The correlation between R_{max} and z is lessened by observing the population over a wide-range of growth. Without very precise data, it would be difficult to discriminate between the 2 models in Figure 9 if the population was observed from year 10 and beyond. However, if it was observed from year 0, the parameters would be more easily determined.

Growth Model Fitting

Fitting the growth models to data involves finding parameter values which provide the "best fit" to the data. The "best fit" depends on the assumed statistical model for the observed data. The population models are deterministic (i.e., given the parameter values, the population size in year N_t determines the size in year N_{t+1}) but the observed count C_t of the population represents some unknown and variable fraction of N_t :

$$C_t = N_t p_t \tag{6}$$

If we assume that p_t is a normal random variable with expectation p and variance s^2 , the statistical model for the counts can be expressed as:

$$C_t = N_t(p+\delta_t) = N_t p + N_t \delta_t = N_t p + \varepsilon_t \tag{7}$$

where the distribution for δ_t is N(0, s^2) and the distribution for $\varepsilon_t = N_t\ \delta_t$ is N(0,$s^2 N_t^{\ 2}$). Thus, the coefficient of variation (c) of the errors ε_t is constant:

$$c = CV(\varepsilon_t) = \frac{sN_t}{pN_t} = \frac{s}{p} \tag{8}$$

An estimate of p cannot be obtained from the count data and requires additional data (e.g., radio-tagging to obtain proportion ashore). If an estimate of p is available, it can be included in the model or it can be set to 1 in the model and used to scale K upward. Henceforth, p will be ignored in the discussion. The preliminary analysis in the first workshop report used a constant variance model. In most cases, the error structure will not affect the fit substantially. However, as outlined above the constant cv model is most appropriate.

Following these assumptions the statistical model is:

$$C_t = N_t + \varepsilon_t \tag{9}$$

where N_t , the population size at time t is specified by the generalized logistic and ε_t are independent normal errors with zero expectation and constant cv. The parameters of the growth model are R_{max}, K, z, and an intercept N_0, which is an initial population size for some arbitrarily chosen time designated as t=0. If k counts are conducted at times $t_1,t_2,\ldots,t_k$, the log-likelihood ignoring constants is:

$$\ln L = -k\ln(c) - \frac{1}{2c^2}\sum_{i=1}^{k}\left[\frac{C_{t_i} - N_{t_i}}{N_{t_i}}\right]^2 \tag{10}$$

The maximum likelihood estimator (MLE) for c, can be derived by setting the partial derivative of (10) with respect to c:

$$\frac{\partial \ln L}{\partial c} = -\frac{k}{c} + \frac{1}{c^3}\sum_{i=1}^{k}\left[\frac{C_{t_i} - N_{t_i}}{N_{t_i}}\right]^2 \tag{11}$$

equal to zero, to obtain:

$$\hat{c}^2 = \frac{1}{k}\sum_{i=1}^{k}\left[\frac{C_{t_i} - N_{t_i}}{N_{t_i}}\right]^2 \tag{12}$$

Replacing $\hat{c}$ into (10), and ignoring constant terms yields the log-likelihood for the parameters of the growth model:

$$\ln L = -\frac{k}{2}\ln\left(\sum_{i=1}^{k}\left[\frac{C_{t_i} - N_{t_i}}{N_{t_i}}\right]^2\right) \tag{13}$$

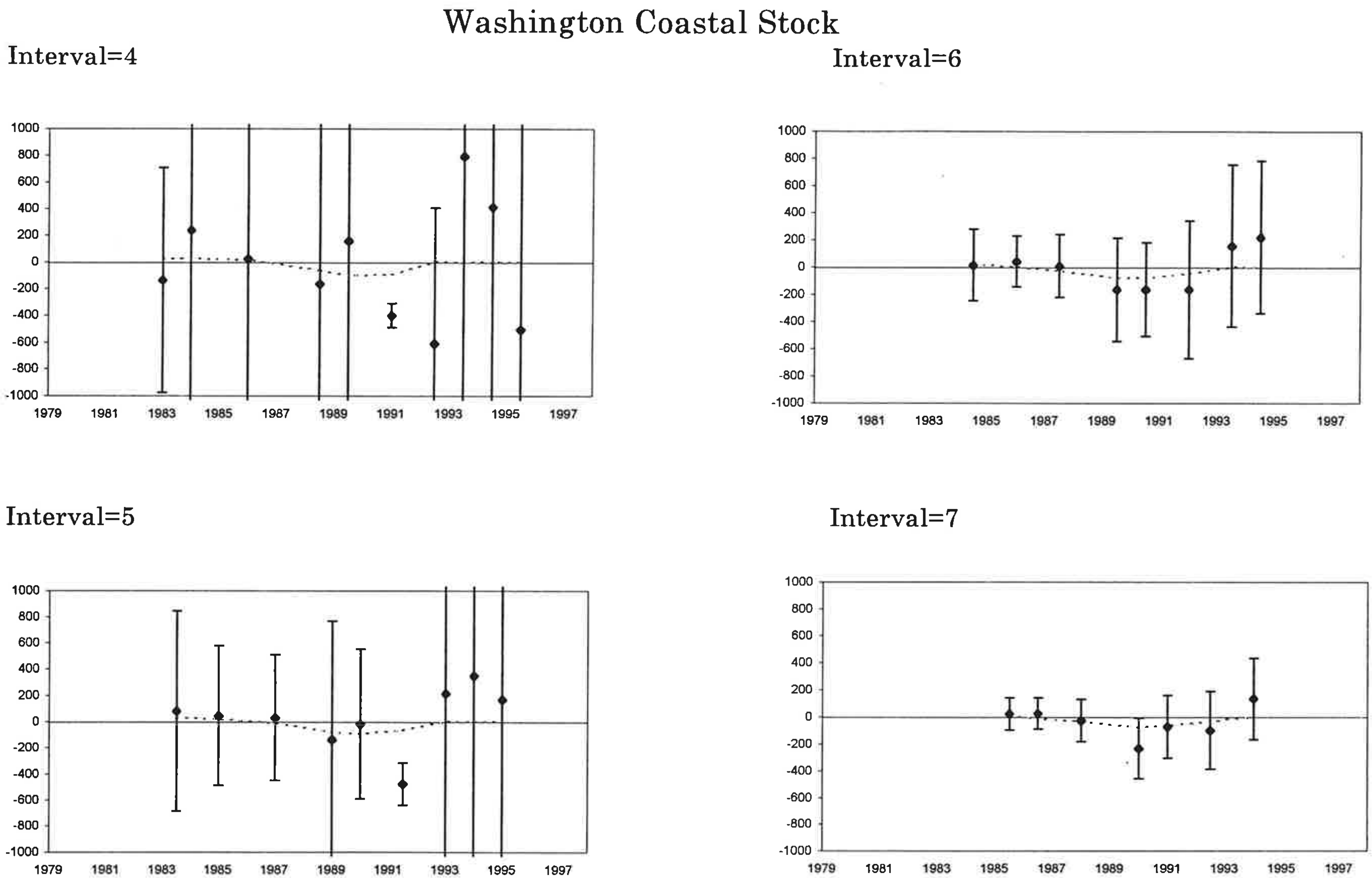


Figure 4. Quadratic coefficients and their 95% confidence interval plotted at the mid-point of the interval for the survey data and a dashed line showing the quadratic coefficients from a generalized logistic model fitted to the survey data for intervals of k=4 to k=7 surveys of the Washington coastal harbor seals.

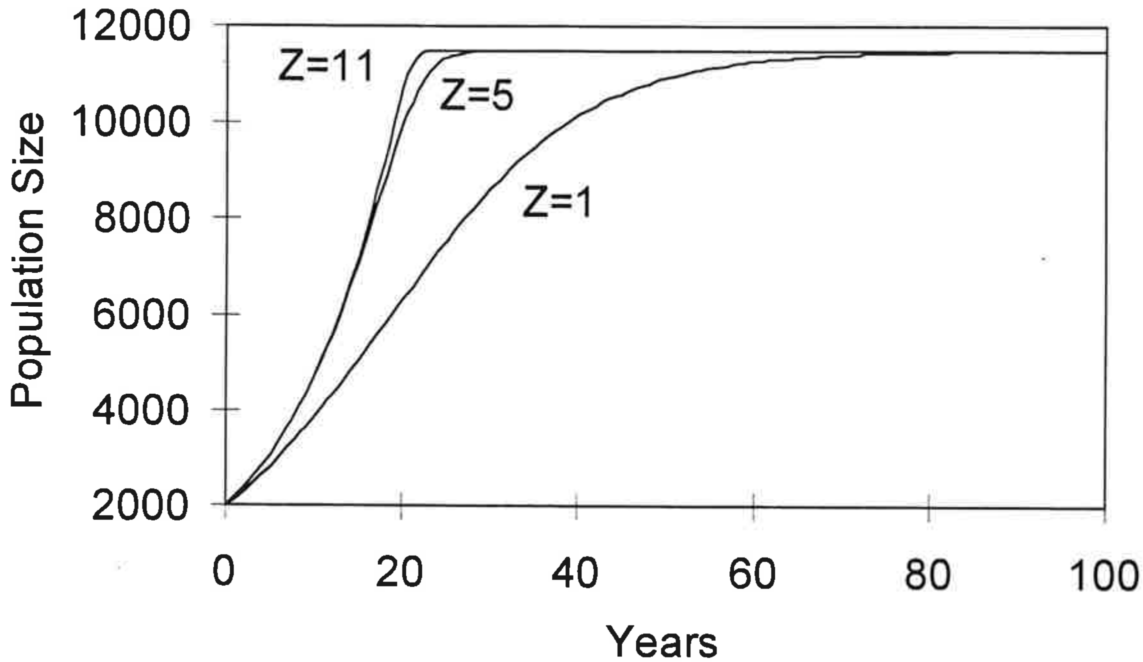


Figure 5. Examples of logistic growth models for z=1,5, and 11.

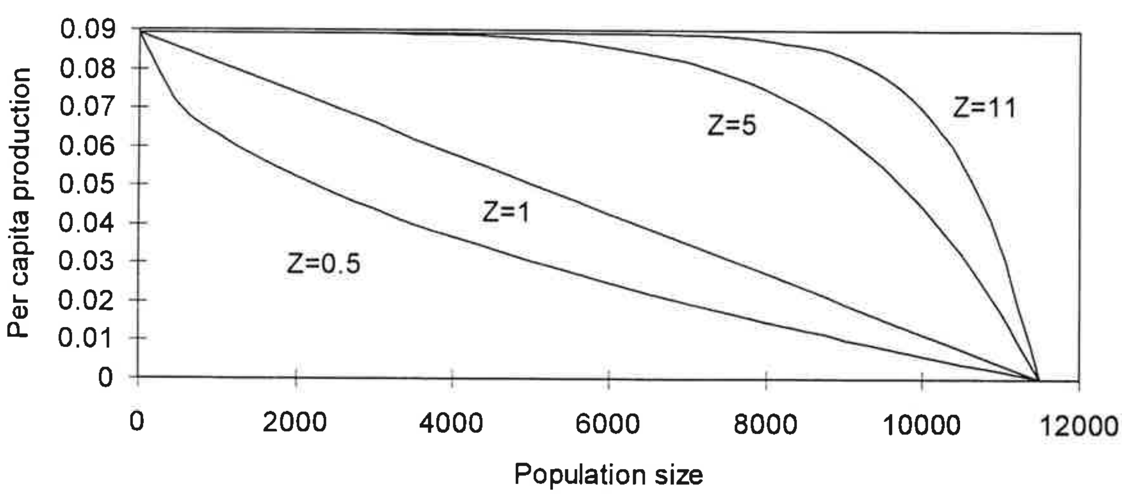


Figure 6. Examples of per capita production for logistic growth model with z=0.5,1,5, and 11.

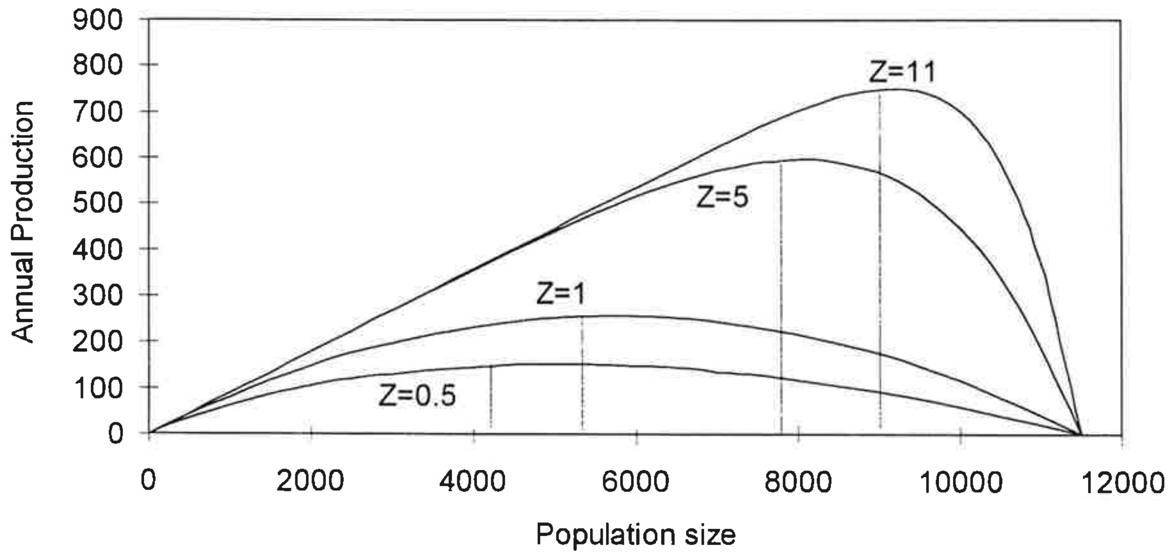


Figure 7. Examples of annual net production for logistic growth model with z=0.5,1,5, and 11. MNPL (peak of the production curve) indicated by vertical bar.

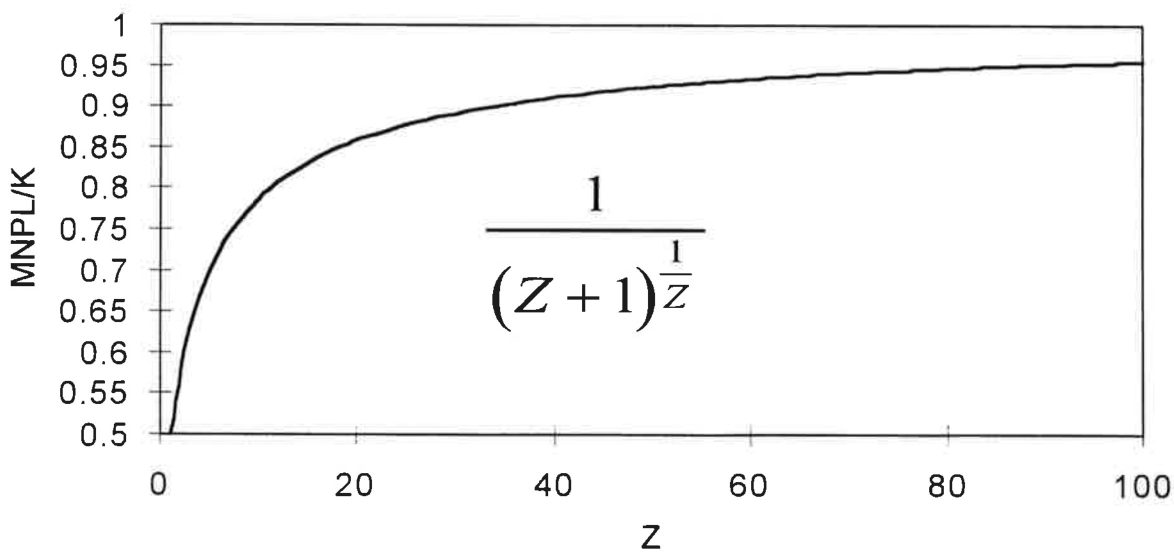


Figure 8. Approximation relating MNPL/K and value of z in generalized logistic growth model.

Maximizing (13) is equivalent to minimizing the sum of squared proportional residuals:

$$\sum_{i=1}^{k}\left[\frac{C_{t_i} - N_{t_i}}{N_{t_i}}\right]^2 \tag{14}$$

If a constant variance model is assumed, parameter MLEs are obtained by minimizing the residual sum of squares (RSS) with respect to the parameters:

$$\sum_{i=1}^{k}(C_{t_i} - N_{t_i})^2 \tag{15}$$

The assumption of normal errors is probably reasonable as long as p is not close to 0 or 1 and c^2 is sufficiently small such that there is little area in the tails of the distribution which exceed 1 or less than 0. A more complex alternative model could be constructed by assuming p_t follows a Beta distribution which is bounded between 0 and 1, and C_t follows a binomial distribution with parameters N_t and p_t (or normal approximation).

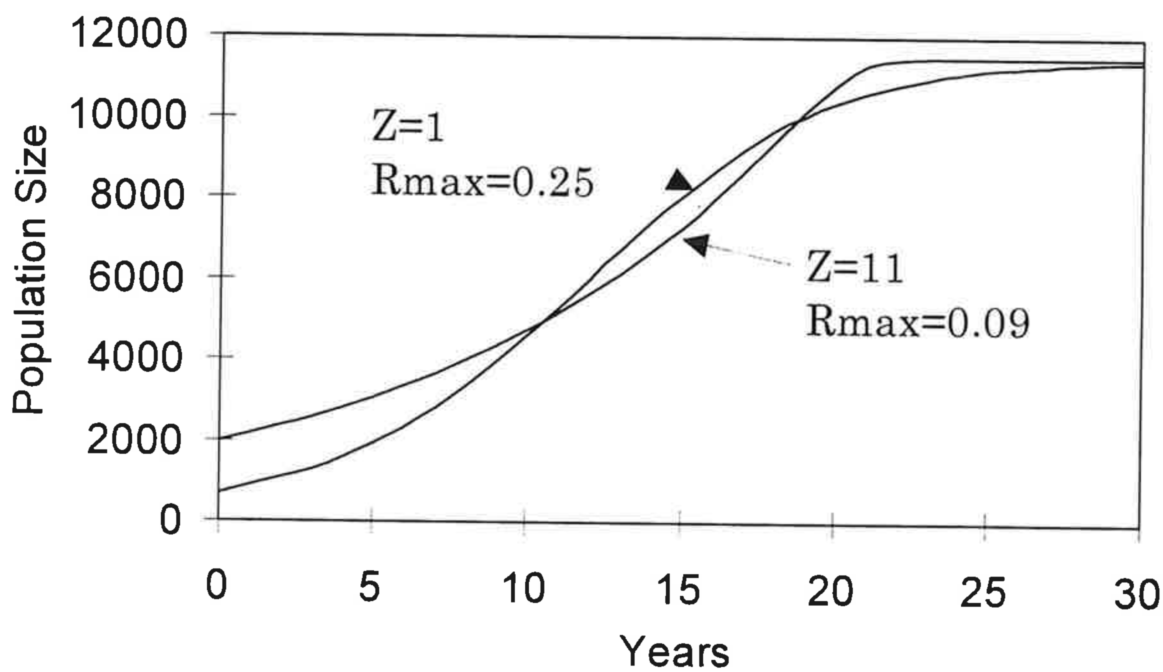


Figure 9. Two similar growth curves achieved by choosing different values for z and R_{max}.

The parameter estimates can be obtained by using an optimization search algorithm (e.g., Newton-Raphson) that finds the values which maximize (13) or likewise minimize (14). A computer program (GenLogistic) was written to find the parameter MLEs. Variance and confidence intervals for the parameters and related quantities (e.g., MNPL/K) can be obtained using: 1) large-sample theory variances (i.e., inverse of the information matrix) and an assumed distribution, 2) profile likelihood intervals, or 3) parametric bootstrap.

One of the complications in the harbor seal data is missing counts. While it is not necessary to have a count for each year, ideally for any one year the defined range should be counted completely. However, in certain instances some portions of the range are not counted due to bad weather, logistical problems or lack of funding. Or in other instances, the surveys were begun in one region and then expanded into other regions over time. For example, in Washington, Grays Harbor and Willapa Bay were surveyed as early as 1975 but the surveys of the Olympic coast region were not begun until 1980. A simple solution is to limit the counts to years in which seals were counted in all regions. However, this solution wastes valuable data and severely restricts the time frame of the surveys.

Two other alternatives are: 1) impute (i.e., assign) the missing values based on the model and the collected data, and fit the growth curve for the entire region using the observed and imputed missing values or 2) fit separate growth curves for each region using the counts that are available for each region. The first method has the advantage of directly providing parameter estimates for the entire defined population, but the disadvantage is the need to devise an unbiased method of imputing the missing values. Fitting separate growth models to the regions only uses the observed data and allows variation in the number of replicate counts between regions but may require more parameters which apply to the regions and not the entire population. Random movement between regions will create additional variation in the counts and directed movement (i.e., permanent emigration/immigration) will be reflected in the parameters of the region growth models. The latter provides information about spatial dynamics of population growth but complicates the interpretation for the entire population. Imputation methods are probably worth exploring but we have focused on the region approach to handle missing counts and unequal replication.

Fitting separate growth models to r regions concurrently requires maximizing the sum of the regional log-likelihoods (13):

$$\ln L = -\frac{1}{2}\sum_{j=1}^{r} k_j \ln\left(\sum_{i=1}^{k_j}\left[\frac{C_{t_{ij}} - N_{t_{ij}}}{N_{t_{ij}}}\right]^2\right) \qquad (16)$$

where k_j is the number of surveys in the j^{th} region. Because the predicted abundance for survey i in region j($N_{t_{ij}}$) may be determined by unique regional parameters, the number of estimated parameters expands substantially. However, in many instances it will be reasonable that some of the parameters can be held constant for some or all of the regions. For example, z will be poorly estimated in general and it is unlikely that the data will support estimating a different z for each region. Also, R_{max} may be constant for each region unless there is a strong movement component. However, K and N_0 are unlikely to be constant across regions because of differences in region size and habitat quality. GenLogistic can fit separate growth models simultaneously to several regions and some or all parameters can be held in common for the regions. To choose the most appropriate model, GenLogistic outputs the model Akaike Information Criterion, AIC = -2 * LnL + 2 * number of parameters. One strategy for model selection is to choose the most parsimonious model (fewest number of parameters that adequately explains data) by selecting the model with minimum AIC (Burnham and Anderson 1998).

Given a set of regional growth models, the next step is to combine them to be able to describe and interpret the growth for the entire stock or population. Obviously, for any year the predicted abundance for all of the regions is simply the sum of the predictions for each region and the same holds for K and N_0. However, estimates of z and R_{max} for the stock/population are not directly obtainable unless they are held equivalent among regions. Equivalents can be obtained by fitting a generalized logistic to the series of summed predicted abundances. However, alternative approaches need to be developed so adequate variances can be constructed for the case when z and R_{max} vary by region.

Preliminary Analysis

The aerial survey data from the coast of Washington and the inland waters of Washington and British Columbia were assembled for the second workshop. We present a preliminary analysis of the Washington data in which we fit exponential and generalized logistic growth models to the counts of all seals (pups and non-pups). Because the analysis was based on the uncorrected counts, the estimated carrying capacity (K) and initial population size (N_0) represent the population that was ashore during a survey. To get estimates of the true population size, K and N_0 the estimates would have to be scaled by an estimate of the proportion ashore (eq 6). Analysis of the British Columbia data have been included in a working assessment document prepared by Olesiuk (Department of Fisheries and Oceans, Canada).

Coastal Washington

As managed by NMFS, harbor seals that inhabit the outer coast of Washington are part of a stock that includes seals in Oregon (including the Columbia River southward to the California border). The aerial survey data from Oregon were not available during the meeting, so we limited the analysis to seals that inhabit the Washington coast which includes two regions: the Washington coastal estuaries (Grays Harbor and Willapa Bay) and the Olympic coast which includes the northern coast between the estuaries and Cape Flattery at the tip of the Olympic Peninsula. The coastal estuaries were the focus of early studies so aerial counts were made starting in 1975. Aerial surveys of the Olympic coast did not begin until 1980.

If we limited the analysis to those years in which the entire coast was surveyed, only 13 years would be available beginning in 1980 with unequal replication of counts within the regions. Therefore, we partitioned the analysis and simultaneously fitted separate growth models for the two regions, as described above. We examined reduced parameter models that assumed the rate of increase R_{max} was constant for both regions and the density dependent exponent z was constant in the logistic model. The generalized logistic model with constant R_{max} and z was clearly the best model (Table 1). The large discrepancy in AIC between the exponential and logistic models provides strong evidence for a density dependent response in population growth.

As expected, the regional initial population sizes and carrying capacities were estimated with reasonable precision, whereas lesser precision was achieved for R_{max} and z (Table 2). The 95-percentile bootstrap intervals and the profile intervals agreed quite well. The 1970 initial population size in the coastal estuaries is consistent with the 800 seals reported by Newby (1973) for 1971-1972. Likewise, the predicted 1970 initial population size for the outer coast is similar to the anecdotal estimate of 100+ seals reported by Newby (1973). The growth curves for seals along the Washington coast demonstrate the apparent slowing of growth as the numbers approach the current carrying capacity (Figure 9a-c). The predicted population size for 1997 as a proportion of K was 0.99 (bootstrap 95% CI: 0.97 - 1.00) and the ratio of the 1997 predicted population size to MNPL was 1.83 (bootstrap 95% CI: 1.34 - 1.99). This latter ratio is > 1 when the population is above MNPL (i.e., within OSP). Thus, seals along the Washington coast were within OSP in 1997.

Table 1. Model selection results for coastal Washington. The shading indicates the model with minimum AIC.

Model	k	LnL	AIC
Exponential			
All vary by region	4	-24.58	57.16
Regional N_0; Constant R_{max}	3	-24.76	55.52
Generalized Logistic			
All vary by region	8	-1.04	18.09
Regional N_0, K R_{max}; Constant z	7	-1.71	17.42
Regional N_0, K z; Constant R_{max};	7	-1.78	17.56
Regional N_0, K; Constant z, R_{max};	6	-1.88	15.77

Inland Washington waters

As managed by NMFS, the Washington inland stock includes all harbor seals in U.S. waters east of a line extending north-south between Cape Flattery on the Olympic Peninsula and Bonilla Point on Vancouver Island. The coastline within the Washington inland stock has been divided into 5 regions: Strait of Juan de Fuca, Eastern Bays, San Juan Islands, Hood Canal and southern Puget Sound (Fig. 1). In the Strait, seals were typically counted in the eastern portion of the strait (east of Port Angeles), but the western portion, which does not provide many suitable haulouts, was excluded. Seals were counted in each of the 5 regions at various times since 1978. The counts from 1978 were obtained from Calambokidis et al. (1979).

Table 2. Generalized logistic parameter estimates, bootstrap standard errors and percentile confidence interval (1000 replicates), and profile likelihood intervals for counts of all seals on Washington coast.

Parameter	Region	Estimate	Bootstrap SE	Bootstrap 95% CI	Profile interval
N_0	Coastal estuaries	689	147	481 - 1014	454 - 1075
	Olympic coast	288	87	158 - 482	151 - 500
	All	977	219	659-1494	
K	Coastal estuaries	7638	386	7109 - 8619	6971 - 8667
	Olympic coast	4031	247	3676 - 4635	3596 - 4676
	All	11669	519	11046-13056	
R_{max}	Both	0.20	0.05	0.13 - 0.28	0.12 - 0.29
z	Both	1.487	1.64	1.00 - 7.26	1.00 - 6.26
c	Coastal estuaries	0.169	-		-
	Olympic coast	0.154	-		-

If we limited the analysis to those years in which the entire inland waters were surveyed, only 5 years would be available beginning in 1991 with unequal replication of counts within the regions. Therefore, we partitioned the analysis and simultaneously fitted separate growth models for the five regions, as described above. We examined reduced parameter models that assumed the rate of increase R_{max} was constant for both regions and the density dependent exponent z was constant in the logistic model. The generalized logistic model with constant R_{max} and z was the best model (Table 3). The discrepancy in AIC between the exponential and logistic models provides some evidence for a density dependent response in population growth.

Table 3. Model selection results for Washington inland waters. The shading indicates the model with minimum AIC.

Model	k	LnL	AIC
Exponential			
All vary by region	10	42.36	-64.73
Regional N_0; Constant R_{max}	6	16.88	-21.77
Generalized Logistic			
All vary by region	20	47.81	-55.63
Regional N_0, K R_{max}; Constant z	16	47.47	-62.94
Regional N_0, K z; Constant R_{max};	16	47.10	-62.21
Regional N_0, K; Constant z, R_{max};	12	46.75	-69.50

As expected and as shown above for the coastal stock, the regional initial population sizes and carrying capacities were estimated with reasonable precision, whereas lesser precision was achieved for R_{max} and z (Table 4). Only the 95-percentile bootstrap intervals were computed for the inland stock. The early 1970 population estimates from Newby (1973) (Table 4) were in general agreement with the confidence intervals for the initial sizes. Newby's estimate for the Eastern Bays did not include Boundary Bay, so it is lower than the predicted interval as expected. It is unclear why Newby's San Juan Island estimate is lower than the predicted interval.

The growth curves for seals in the inland Washington stock suggest a possible slowing of growth as the numbers approach the current carrying capacity (Fig. 11a-e). The rate of growth in 1997 varies between the 5 regions varies because some regions are closer to their predicted K. The predicted size of the inland stock for 1997 as a proportion of K was 0.70 (bootstrap 95% CI: 0.36 - 0.94) and the ratio of the 1997 predicted population size to MNPL was 1.40 (bootstrap 95% CI: 0.69 - 1.71). This latter ratio is > 1 when the population is above MNPL (i.e., within OSP). Thus, because the confidence interval includes 1, we cannot say with certainty that the Washington inland stock coast was within OSP in 1997.

Remaining Analysis Issues

During the workshop, several analysis issues were identified that needed further examination. We outline these issues here but do not attempt to address them in any detail.

Counts vs. abundance estimates

Our preliminary analysis used the count data without any attempt to adjust the counts to represent total seal abundance. As mentioned previously, with a measure of the average proportion ashore p, the initial size N_0 and K can be scaled to represent the appropriate values for the stock/population. However, the proportion ashore during a survey will depend on the tide state and the timing relative to peak pupping, and possibly other factors (Frost et al. In press). At the very least, variability in p will result in variability in the counts, which is reflected in the precision of the parameters of the growth model.

However, the bigger concern is the possibility of a trend in p which would result in biased parameter estimates. A trend in p could occur if over the 2+ decades of surveys, the survey timing changed relative to any of the factors that affect p in such manner to induce a trend. One such possibility is the timing of the surveys relative to peak pupping or tides. In the Olympic region of coastal Washington many of the early surveys were done in early June until it was discovered that the peak of pupping occurred about the third week of June. Likewise, some of the early surveys by DFO in the Straits of Georgia were often conducted at sub-optimal tides, whereas the later surveys were more strictly controlled. Both will induce a positive bias in R_{max}. However, the bias can be eliminated or reduced by either adjusting the counts directly from measurement of p as a function of tide or timing or as a relative adjustment to an estimated peak (e.g., peak pupping, low tide etc) by incorporating covariates into the model (Frost et al. In press). A trend in p could also be induced if the seals spend more or less time ashore as the population increased. The most plausible scenario would be a decrease in the time ashore because more time foraging may be required as the population increases and food resources decrease. Direct measurement of p over time (e.g., deployment of radio-tags) is the only way to circumvent this potential bias. Any use of haul-out correction factors ($1/p$) must consider the differences resulting from sex and age. In particular, we would expect pups and females with pups to spend much more time ashore than either juveniles, barren females, or males. These differences complicate the use of haul-out corrections

Missing Data

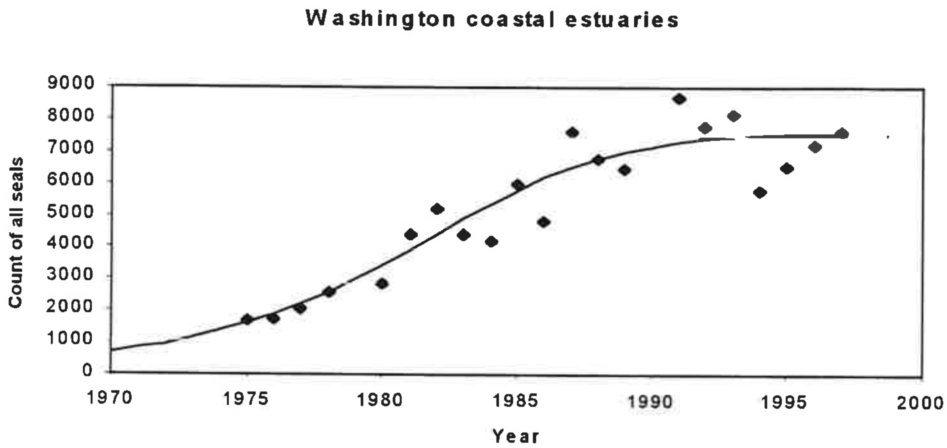
Unfortunately, not all of the seal haul-outs were counted in each year. In our preliminary analysis we have dealt with the missing data by regionally stratifying the haul-out locations and treating each region as an independent unit. This is a reasonable approach as long as there is not a large amount of movement between regions. Alternative methods for imputing missing data should be explored.

Model Structure

Our preliminary analysis is useful, but it is truly just a beginning point for a more thorough analysis that could be conducted with these data. In particular, alternative model structures should be examined that explore: 1) the beta-binomial or similar error model, 2) a stochastic growth model, and 3) a stage-structured (pup, non-pup) growth model. While we do not expect that our conclusions would change under these alternative models, we would potentially increase our understanding of harbor seal population dynamics.

Acknowledgments

We acknowledge and thank the other participants of the workshop (Peter Boveng, Jeff Breiwick, Peter Olesiuk, John Pierce, Paul Wade, and Dave Withrow) for their input and ideas which are summarized in this report.



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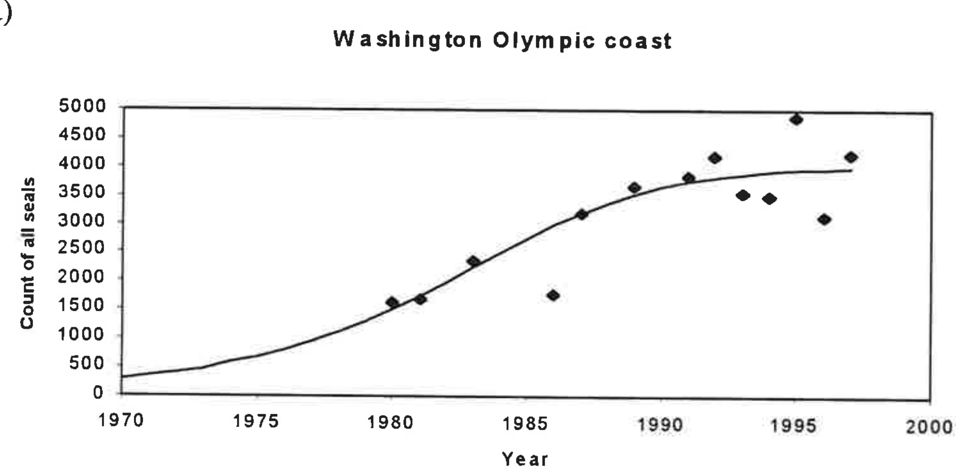

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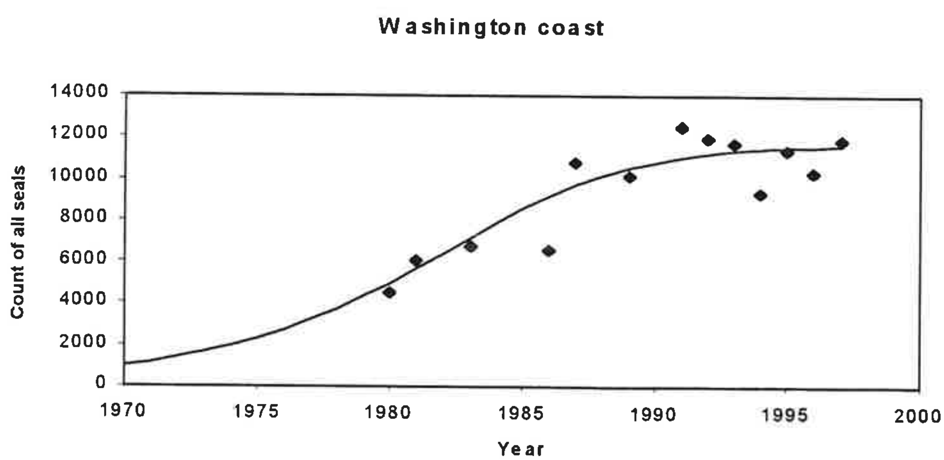
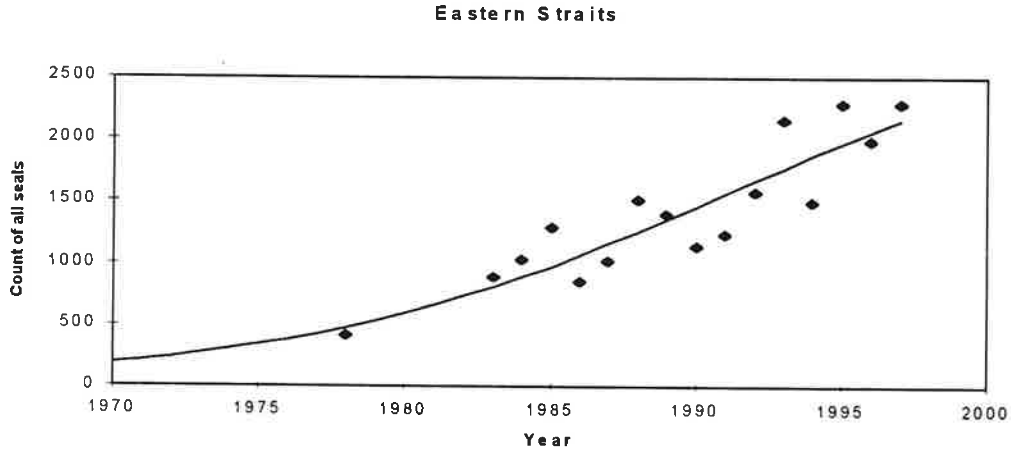


(c)

Figure 10. Fitted generalized logistic growth curves for coastal estuaries (a), Olympic coast (b), and the total of both regions (c). In (c) counts are only shown for years in which both regions were counted.

Table 4. Generalized logistic parameter estimates, bootstrap standard errors and percentile confidence interval (1000 replicates) for counts of all seals in Washington inland waters. The 1970-72 estimates were obtained from Newby (1973).

Parameter	Region	Estimate	Bootstrap SE	Bootstrap 95% CI	1970-72 estimate
N_0	Eastern Strait	189	38	130 - 277	150
	Eastern Bays	457	77	294 - 600	290
	San Juan Islands	363	74	250 - 538	160
	Hood Canal	713	225	193 - 982	-
	Southern Puget Sound	166	29	111 - 225	210
	All	1888	300	1173 - 2302	
K	Eastern Straits	3057	882	2125 - 5311	
	Eastern Bays	2542	171	2177 - 2838	
	San Juan Islands	9154	5145	5623 - 24281	
	Hood Canal	954	99	861 - 1230	
	Southern Puget Sound	1272	173	1027 - 1647	
	All	16979	5937	12185 - 34072	
R_{max}	All	0.14	0.02	0.095 - 0.172	
z	All	1.00	0.75	1.00 - 3.45	
c	Eastern Straits	0.200	-	-	
	Eastern Bays	0.072	-	-	
	San Juan Islands	0.107	-	-	
	Hood Canal	0.243	-	-	
	Southern Puget Sound	0.140	-	-	



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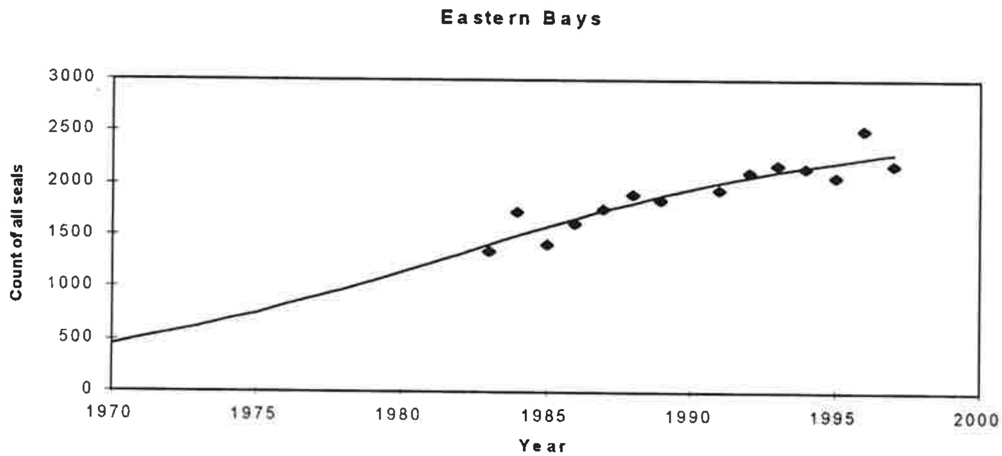

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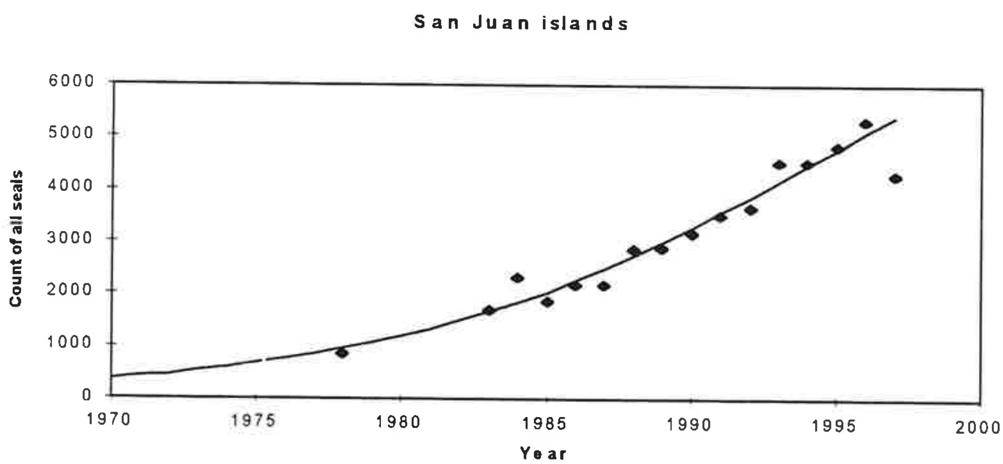
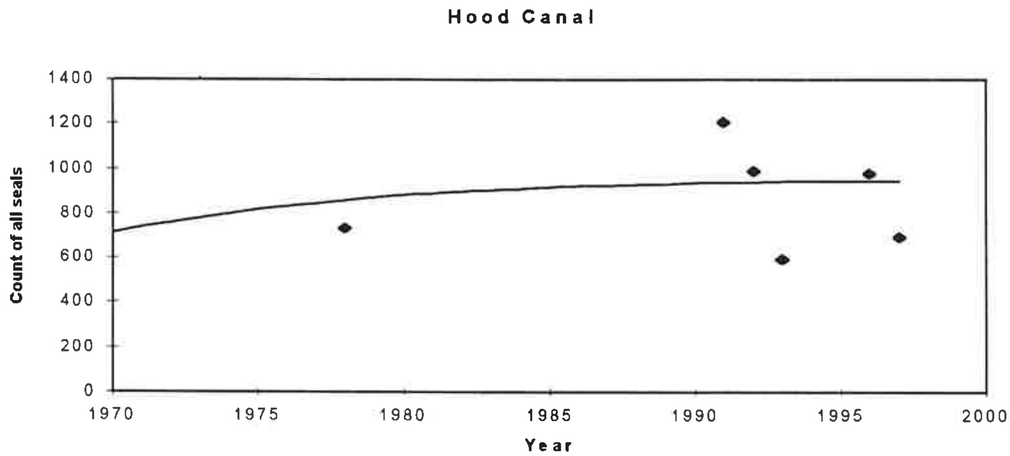


c)

Figure 11. Fitted generalized logistic growth curves for Eastern Strait (a), Eastern Bays (b), San Juan Islands (c), Hood Canal (d), southern Puget Sound (e) and the entire inland stock (f). In (f) counts are only shown for years in which both regions were counted.



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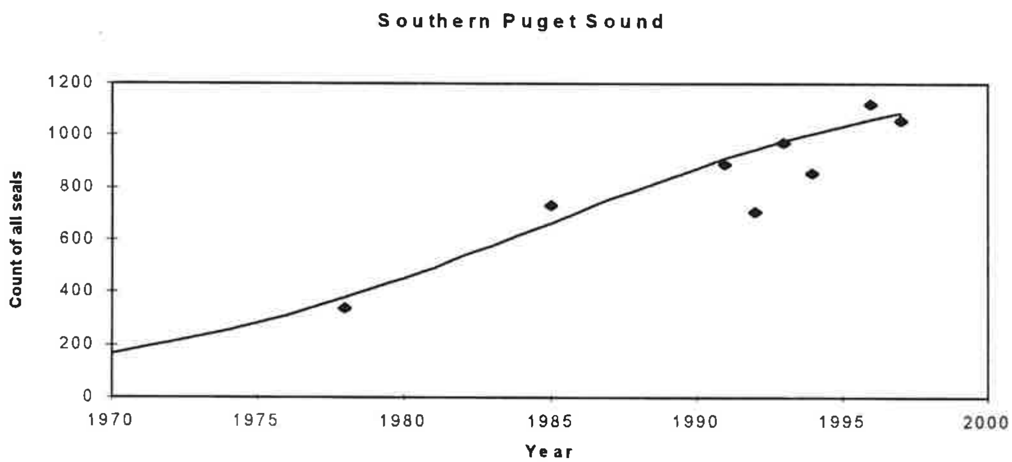

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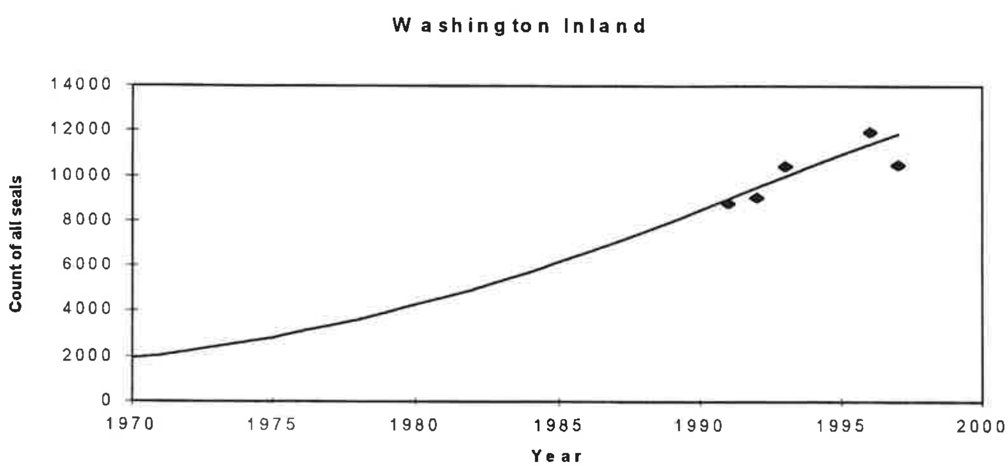


f)

Figure 11 (cont).

Citations

Boveng, P., D.P. DeMaster, and B.S. Stewart. 1988. Dynamic response analysis. III. A consistency filter and application to four northern elephant seal colonies. Marine Mammal Science 4:210-222.

Burnham, K.P. and D.R. Anderson. 1998. Model selection and inference: a practical information-theoretic approach. Springer-Verlag, New York. 353p.

Calambokidis, J.A., R. D. Everitt, J.C. Cubbage, and S. D. Carter. 1979. Harbor seal census for the inland waters of Washington, 1977-1978. Murrelet 60:110-112.

Gerodette, T. 1988. Dynamic response analysis. II. Evaluation of dynamic response analysis in a simulated no-harvest case. Marine Mammal Science 4:196-209.

Frost, K. J., L. F. Lowry, and J. M. VerHoef. In press. Monitoring the trend of harbor seals in Prince William Sound, Alaska after the Exxon Valdez oil spill. Marine Mammal Science.

Goodman, D. 1988. Dynamic response analysis. I. Qualitative estimate of stock status relative to maximum net productivity level from observed dynamics. Marine Mammal Science 4:183-195.

Huber, H. R. 1995. Correction factor to estimate abundance of harbor seals in Washington, 1991-1993. Unpubl. M.S. thesis. University of Washington. Seattle. 53pp.

Huber, H. R., S. J. Jeffries, R. D. Brown, and R. L. DeLong. 1995. Harbor seal stocks in Washington and Oregon: evidence from pupping phenology, tagging, and genetics studies. Abstract, Northwest Vertebrate Society Symposium, Orcas Island, WA, 23-25 March 1995.

Jeffries, S.J. 1985. Occurrence and distribution patterns of marine mammals in the Columbia River and adjacent coastal waters of northern Oregon and Washington. In: Marine mammals and their interactions with fisheries of the Columbia River and adjacent waters, 1980-1982. NWAFC Processed Report 85-04. Available Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE, BIN C15700 Seattle, WA.

Lamont, M. G. et al. 1996. Genetic substructure of Pacific harbor seals (*Phoca vitulina richardsi*) of Washington, Oregon, and California. Marine Mammal Science.

Newby, T. 1973. Changes in the Washington state harbor seal population, 1942-1972. The Murrelet 1:4-6.

Polachek. T. 1982. Local stability and maximum bet productivity levels for a simple model of porpoise population sizes. U.S. Dep. Commer., NOAA Tech. Memo. NOAA-TM-NMFS-SWFC-17.

Temte, J. L. 1986. Photoperiod and the timing of pupping in the Pacific harbor seal (*Phoca vitulina richardsi*) with notes on reproduction in northern fur seals and Dall porpoises. Unpubl. M. S. thesis, Oregon State University, Corvallis, Oregon.

Temte, J. L. 1991. Population differentiation of the Pacific harbor seal: cranial morphometry parallels birth timing. Abstract, Ninth Biennial Marine Mammal Conference, Chicago, December 5-9, 1991.

Thompson, P., and P. Rothery. 1987. Age and sex differences in the timing of moult in the common seal, *Phoca vitulina*. Zoolological Society of London 212:597-603.

AN ESTIMATE OF THE PROPORTION OF HARBOR SEALS MISSED DURING AERIAL SURVEYS OVER GLACIAL ICE IN ALASKA.

David E. Withrow and Jack C. Cesarone

National Marine Mammal Laboratory
Alaska Fisheries Science Center
7600 Sand Point Way; C15700
Seattle, Washington 98115

Abstract

An unknown, but substantial number of harbor seals haul out on ice calved from glaciers in Alaska. Little is known about these seals, because of their isolation and the difficulty of capturing them. During 1997 and 1998, we developed new techniques that allowed us to capture 19 seals and tag them with VHF transmitters at several glacial sites in Kenai Fjords National Park, Alaska. The aim of our study was to estimate the proportion of seals not present on the ice (and therefore not counted) during molt-season aerial surveys. Data-logging receivers positioned near the ice concentrations, recorded presence and absence of seals every 20 minutes. Date and time of day were important covariates that strongly influenced haulout behavior, as were, to a lesser extent, wind direction, speed, and tidal state. In late August and early September 1998, eight replicate aerial surveys were flown over Aialik and Pedersen Glaciers in the Kenai. The average proportion of tagged seals hauled out during these surveys was 52%. Therefore, raw counts from aerial surveys should be multiplied by the reciprocal of this value, 1.92. This estimate is similar to previous values of 1.74 and 1.90 developed for seals hauling out on rocky and sandy substrates, respectively.

Introduction

Harbor seals inhabit temperate and sub-arctic coastal and estuarine waters from Baja California north to Cape Newenham, Alaska, and the Pribilof Islands. Harbor seals haul out on rocks, reefs, beaches, and drifting glacial ice. They are considered non-migratory, however tide, weather, time of day, season and food availability all contribute to their haulout patterns.

There are two annual peaks in haulout behavior, one during May/June (pupping) and the other during August/September (molt) when maximum numbers occur on land. In Alaska, the greatest number of seals haul out during the molt period and our aerial census surveys take place during this time period.

Harbor seals are censused from aircraft by photographing those on land during the molt period (August/September). An unknown, but substantial number of harbor seals haul out on ice calved from glaciers in Alaska. This paper reports on the fifth year of a multi-year study to determine a correction factor to estimate the relative proportion of seals not hauled out (on ice) and thus not counted during the surveys. This correction factor will then be applied to minimum population estimates to determine a more accurate estimate of harbor seal abundance in Alaska.

Previous correction factor studies

In 1994, we conducted the first correction factor study on rocky substrate in southeast Alaska (Withrow and Loughlin 1995). Our primary haulout site was a small rocky island (54°57.83 N, 132°46.78 W) with a few gravel beaches exposed only at low tide. These gravel beaches were preferred areas, but ample rocky haulout space remained, even during the highest tidal conditions. The mean percent number of tagged seals hauled out each day during low tide was 58%. This resulted in a correction factor of 1.7. We stated that this correction should be applied only to those areas similar in geography and phenology.

In 1995 and 1996, we chose a sand-bar substrate, which was completely submerged during high tide near Cordova, Alaska adjacent to Prince William Sound. We worked primarily in Hawkin's Cutoff (60°27.052 N, 146°19.577 W) in 1995. During the normal molt census surveys, the weather was marginal, at best. The mean percent number of tagged seals hauled out was only 40% and the resulting correction factor was 2.5 (Withrow & Loughlin 1996). The Alaska Department of Fish and Game (ADF&G) recorded the presence of our seals during their aerial surveys two weeks earlier, under much more favorable conditions. The ADF&G surveys also covered most of Prince William Sound whereas our surveys were concentrated primarily within 40-50km of the tagging location. During this time period, the mean percent number of tagged seals hauled out was 67%, resulting in a correction factor of 1.5. We stated the correction factor values of 1.5 and 2.5 probably represent the extremes with 1.5 being our best choice, but collected earlier than other NMML molt surveys. For at least Prince William Sound and perhaps for other areas, the ADF&G have found that surveys conducted in mid August yield higher counts than surveys conducted later in August or early September (Frost et al. 1996). The 2.5 correction factor may at least suggest an upper bound and may give us a better indication of possible count adjustments, if molt census surveys were conducted under similar marginal weather conditions.

For 1996, we repeated our efforts in the Cordova area in order to reduce the variance and increase the precision of the 1995 correction factor estimates. Eleven replicate aerial surveys were flown and the mean percent number of tagged seals hauled out each day was 53%. This yielded a correction factor of 1.90, almost exactly midway between the two extremes observed in 1995.

Methods

Ice captures

Harbor seals were captured using entangling gill nets set amidst floating ice. The nets were constructed of a multi-filament, translucent fiber dyed a light blue or green. We experimented with both a 6 and 8 filament twist in order to access how visible each type was to swimming seals. (Momoi Net Supply, Japan, #s AK6-50 [color #SH-1) and MST-50 [color # SH-29]). Each net panel measured 30m long and 3.7m deep with 30cm stretched mesh openings and was hung at a 2:1 ratio. The float line was strung with either individual floats or hollow core floating line (2.54 cm dia.). A relatively light (0.07kg/m) lead line was sufficient to keep the net hanging straight in the water. Panels could be set separately or strung together.

The net was deployed from a slow moving boat which, depending on conditions, was either a 6m Boston Whaler or a 3 m white Zodiac powered by a quiet electric motor. The later allowed closer approaches to hauled seals but restricted the amount of net that could be deployed. Early in the project we attempted to disguise the zodiac and its crew by covering both with a white canvas tarp during approaches. In most cases the net was set as close as possible to the largest number of hauled seals.

The type and duration of each set was adjusted according to the amount of ice cover and, to a lesser extent, the prevailing weather. Sets were not possible in the thickest ice (>70% cover) and were most successful in moderate ice cover (approx. 50% cover). We assumed that the ice helped to disguise the floating net and planned our sets to take advantage of favorable ice cover. Whenever possible, the net was set in open leads between ice packs to avoid tangling it at the surface. Drifting pieces of ice would sometimes foul in the float line and, if not watched closely, could disguise the telltale movements that signaled a tangled animal below. At frequent intervals the net would be retrieved, cleared of ice, and reset.

Onshore processing

All seals were physically restrained during handling and tagging; no chemical sedation was required. Seals were initially given an external examination which included recording mass, standard length, sex, age class, stage of molt, and noting any external scars, wounds, or parasites. Approximately 50 cc of blood was drawn from the extradural intervertebral vein to assess health and condition. On some animals, a whisker was taken for stable carbon isotope analysis. The seals were then tagged on the hind flipper with a Temple cattle-ear tag (1 x 1.5 x 5.0 cm) with a VHF transmitter attached (Advanced Telemetry Systems Inc. model 201, 166 MHZ). Weight of the tag and transmitter was approximately 25 gr. A small 0.7 cm diameter biopsy punch was taken from the left rear flipper (used for mitochondrial DNA studies) and the Temple tag was clipped in place through this small hole. A small plastic, orange, All Flex tag (1.5 x 4.5 cm) was clipped to the right rear flipper. Seals were released immediately after tagging. A list of radio frequencies used, animal identification numbers, samples taken, and other information appear in Table 1.

During tagging, the stage of molt for each seal was estimated. The categories were pre-molt, early mid-molt, mid-molt, late mid-molt, and post molt. These categories were assigned a numerical value: pre-molt received a value of 1, early mid-molt a value of 2, mid-molt a value of 3, late mid-molt a value of 4, and post molt a value of 5. Males and females were then scored and a mean value determined to estimate the average stage of molt during the tagging period. Mean molt stages were also estimated for age classes (adult, sub-adult, yearling, and pup).

DCC procedure

On 18 August, an ATS data collection computer system (DCC, receiver, antenna, and marine battery) was placed on the cliff to the west of Pedersen Glacier (59° 53.692 N, 149° 52.116 W) and another system was placed on Squab Island (59° 56.003 N, 149° 42.833W) just south of Aialik Glacier. Seal haulout information was collected every 20 minutes, 24 hours a day, until the unit's batteries failed (presumably because of freezing temperatures) on September 30th. The units were recovered in early October.

Aerial surveys

Aerial surveys were flown from 22 August to 3 September after release of the transmitter-equipped seals to determine the proportion of seals not present on the ice (and therefore not counted) during molt-season surveys. We utilized a single engine Cessna 185 equipped with floats for our daily surveys which were conducted as close to low tide as possible. Flights covered Pedersen and Aialik Glaciers and surrounding areas from the McCarty Fiord to Cape Resurrection (Fig. 1). Two antennae were mounted on the wing struts, one pointing forward and to the left and the other pointing forward and to the right. An ATS receiver equipped with an A/B/Both switch was used to determine which side of the aircraft the seals were located. The observer determined the location of and photographed all seals hauled out including the presence or absence of all tagged seals.

Results and Discussion

Correction Factor Analysis

Many census studies for harbor seals are designed to determine a minimum population estimate for the particular area of interest. It is unknown how these minimum estimates correlate with the true size of the population. Withrow and Loughlin (1995), provided a table of earlier tagging studies, most of which suffered from small sample sizes and were not designed specifically to correct census estimates. Boveng (1988) formulated a best guess correction factor of 1.4 to 2.0 for the number of harbor seals along the U. S. west coast. Huber et al. (1992) calculated correction factors ranging from 1.5 to 1.8 for the counted population during pupping in Oregon and Washington. Withrow and Loughlin (1995) calculated a correction factor of 1.74 for harbor seals in southeast Alaska, hauled out on rocky outcroppings and islands not completely covered by water at high tide. Withrow and Loughlin (1997) also calculated a correction factor of 1.90 for seals in Orca Inlet (Prince William Sound) using sand bars as their primary haulout substrate.

In this study, a total of 19 seals were captured and equipped with transmitters. Of these, 9 were males and 10 were females which were comprised of 8 adults, 7 sub adults, 3 yearlings, and 1 pup (Table 1). Eighteen of the 19 tagged seals were relocated from the air during molt census surveys from 22 August to 3 September. Figure 1 shows the study area where seals hauled out, including the capture locations (Pedersen and Aialik Glaciers) and the aerial coverage area from McCarty Fjord to Cape Resurrection.

The daily mean number of tagged seals hauled out was calculated by dividing the number of seals hauled out by the number of seals detected during the aerial surveys. The mean number of tagged seals hauled out each day during the August/September surveys was 9.4 (range 6-13) (Table 2). The daily percentage of tagged seals hauled out ranged from 33% to 72%. These percentages were then summed and a mean calculated to determine the mean percent hauled out during each survey period. Our surveys were conducted during the same period (22 August to 3 September) and tidal cycle as our assessment surveys. The resulting value for the mean percent number of harbor seals hauled out was 52% (75 total seals/18 tagged seals sighted at least once). A correction factor of 1.92 was computed by taking the reciprocal of 52%. The CV of the mean is 23.47%. The 95% confidence interval for the mean percent number of seals hauled out is between 23.2% and 81.0%. Counts from assessment surveys, collected during the same time period and for seals exhibiting similar haulout behavior (using ice haulouts), can be multiplied by the 1.92 correction factor for a better estimate of the total number of harbor seals present.

Haulout Behavior Data

Many researchers have noted that seals haul out in greatest numbers in the absence of high winds, heavy rains and/or disturbance (Fisher 1952, Bishop 1967, Knudtson 1974, Johnson 1976, Calambokidis et al. 1978, Streveler 1979, Allen et al. 1980, Everitt and Braham 1980, Sullivan 1980). Tidal influences are greatest on gently sloping substrates, such as tide flats, where minor tidal changes affect large surface areas (Hoover-Miller 1994).

Tide height was a primary factor in determining haulout behavior for seals hauling out on rocky (Withrow and Loughlin 1996) and sandy (Withrow and Loughlin 1997) substrates. For seals using ice haulouts, tide was not expected to greatly influence seal haulout patterns. This was basically true except that Pedersen Glacier has receded to such a point that seals need to traverse an outflow stream in order to get to and from the glacier. The stream shallows up at several points and seals only appear to transit when the stream is higher (when tides are at the higher stages).

Time of day, however was an important factor. Greatest numbers of seals were hauled out between 12:00 and 19:00 hours at Pedersen Glacier (Fig. 2) with a peak between 12:00 and 14:00 (N=913 seal hours hauled out). At Aialik Glacier (Fig. 3), most seals hauled out between 10:00 and 19:00 with peak numbers between 10:00 and 13:00 (N=133 seal hours hauled out). It's not clear why the two glacial areas differ slightly, but the tidal effect in Pedersen may be a component. Haulout patterns for each seal are plotted by 1 hour time blocks by day. These data are located in the appendix of this paper. Survey period ranged from August 18 to September 26, 1998. One VHF receiver and data collection computer (DCC) were placed near each glacier to record the haulout data. All seals were instrumented with flipper tags and three seals also received stronger back mounted units to examine potential tag loss. Some seals moved between glaciers, but primarily most stayed at the glacier where they were originally captured. Most seals appeared to prefer Pedersen Glacier over Aialik Glacier in 1998. The opposite pattern was observed in 1997. Strong winds were more frequent at Aialik Glacier, calving was also more frequent, and the resulting flow sizes were usually smaller in 1998 than in 1997. There was also substantial tour boat traffic at Aialik Glacier and little disturbance at Pedersen Glacier.

Molt Phenology

Thompson and Rothery (1987) noted that females completed their molt an average of 7 days earlier than immature males and 19 days earlier than mature males. In southeast Alaska, we also noticed that females were further along in the molting process than were most males (Withrow and Loughlin 1995). Male seals spent more time hauled out (27.1%) on average than did females (9.7%) or pups (7.0%).

In Orca Inlet (sandy substrate) Withrow and Loughlin (1996) used an arbitrary 5 point molt scale scoring system discussed earlier (Table 1). Females showed a slight tenancy to molt sooner with a mean score of 3.9 compared to males with a mean score of 3.8. When seals were combined by age class, there was also very little difference. Adult seals had a mean value of 3.9, sub-adult 3.8 and the 2 yearlings averaged 4.0 There was no obvious difference in the percent time hauled out between the sexes.

For the ice-associated seals around Aialik and Pedersen Glaciers, results were similar. The scores were slightly different, but the ranking between the groupings were comparable. Females had a mean score of 3.3 (higher number signifies further along in molting process) and males 2.7. Adults (score of 3.5) in general were further along than both sub-adults (2.9) and yearlings (2.3).

Conclusion

A correction factor of 1.92 reflects the proportion of seals not hauled out during molt assessment surveys, for seals utilizing ice haulouts at glaciers along the Kenai Peninsula (in 1998). Again, we stress that this correction should only be applied to those areas similar in geography, phenology, and censused during similar time periods. Seals in other geographic areas or other types of haulout sites, may behave quite differently. Caution should be exercised initially so that this correction factor is not applied too broadly. Our future work will focus on conducting correction factor studies in the same areas as our range-wide harbor seal assessment surveys.

Citations

Allen, S.G., D.G. Ainley, and G.W. Page. 1980. Haulout patterns of harbour seals in Bolinas Lagoon, California. Final rep. for MMC contract MM8AC012. Marine Mammal Commission, Washington D.C. 31 pp. (Natl. Tech. Inf. Serv., PB80-176910).

Bishop, R.H. 1967. Reproduction, age determination and behavior of the harbor seal, *Phoca vitulina* L., in the Gulf of Alaska. M.S. Thesis, Univ. Fairbanks, Alaska. 121 pp.

Boveng, P. 1988. Status of the Pacific harbor seal population on the U. S. west coast. Dept. Commerce, NMFS, SWFC Admin. Rept. LJ-88-06. 43 pp.

Calambokidis, J., K. Bowman, S. Carter, J. Cubbage, P. Dawson, T. Fleischner, J. Skidmore, and B. Taylor. 1978. Chloridated hydrocarbon concentrations and the ecology and behavior of harbor seals in Washington State waters. Unpubl. Manscr., Evergreen State College, Olympia, Wash. 121 pp.

Everitt, R.D., and H.W. Braham. 1980. Aerial surveys of Pacific harbor seals in the southerneastern Bering Sea. Northwest Sci. 54:281-288.

Fisher, H.D. 1952. The status of the harbour seal in British Columbia, with particular reference to the Skeena River. Fish. Res. Board Can. Bull. 93. 58 pp.

Frost, K.J., L.F. Lowry, R.J. Small, and S.J. Iverson. 1996. Monitoring, habitat use, and trophic interactions of harbor seals in Prince William Sound, Alaska. 1996 State-Federal Natural Resource Restoration Study No. 93064. 133 pp.

Hoover-Miller, A.A. 1994. Harbor seal (*Phoca vitulina*) biology and management in Alaska. Contract number T75134749. Marine Mammal Commission, Washington D.C. 45 pp

Huber, H., S. Jeffries, R. Brown, and R. DeLong. 1992. Abundance of harbor seals (*Phoca vitulina richardsi*) in Washington and Oregon, 1992. Annual report to the Marine Mammal Assessment Program (MMAP), NOAA, Office of Protected Resources, Silver Spring, Maryland. 19 pp.

Johnson, B.W. 1976. Studies on the northernmost colonies of Pacific harbor seals, *Phoca vitulina richardsi*, in the eastern Bering Sea. Unpubl. Manuscr., Alaska Dep. Fish and Game, Fairbanks. 67 pp.

Knudtson, P.M. 1974. Mother-pup behavior within a pupping colony of harbor seals *Phoca vitulina richardsi* in Humboldt Bay, California. M.S. Thesis, Humboldt State Univ., Arcata, CA. 42 pp.

Strevler, G.P. 1979. Distribution, population ecology and impact susceptibility of the harbor seal in Glacier Bay, Alaska. Processed rep., Natl. Park Serv., Juneau, Alaska. 49 pp.

Sullivan, R.M. 1980. Seasonal occurrence and haulout use in pinnipeds along Humboldt County, California. J. Mammal. 61:754-759.

Thompson P., and P. Rothery. 1987. Age and sex differences in the timing of moult in the common seal, *Phoca vitulina*. J. Zool. (Lond.) 212:597-603.

Withrow D.E., and T.R. Loughlin. 1995. Haulout behavior and method to estimate the proportion of harbor seals missed during molt census surveys in Alaska. Annual report to the Marine Mammal Assessment Program (MMAP), NOAA, Office of Protected Resources, Silver Spring, Maryland. May 1995 39 pp.

Withrow D.E., and T.R. Loughlin. 1996. Haulout behavior and a correction factor estimate for the proportion of harbor seals missed during molt census surveys near Cordova, Alaska. Annual report to the Marine Mammal Assessment Program (MMAP), NOAA, Office of Protected Resources, Silver Spring, Maryland. November 1996. 28 pp.

Withrow, D.E. and T.R. Loughlin. 1997. A correction factor estimate for the proportion of harbor seals missed on sand bar haulouts during molt census surveys in 1996 near

Cordova, Alaska. Annual report to the MMPA Assessment Program, Office of Protected Resources, NMFS, NOAA, 1335 East-West Highway, Silver Spring, MD 20910 16 pp.

Table 1. Harbor Seals tagged near Pedersen and Aialik Glaciers, August 1998 and stages of molt for seal sex/age classes.

Aialik Glacier Lat. 59 56.717 and Long. 149 44.474
Pedersen Glacier Lat. 59 53.358 and Long. 149 47.189

ID	ORANGE	SEX	AGE	DATE	FREQ	Location
98A2	1112	F	A	8/5/98	166.198	Pedersen
98A5	1115	F	A	8/7/98	166.161	Pedersen
98A7	1117	F	A	8/8/98	166.260	Aialik
98A11	1121	F	A	8/10/98	166.381	Pedersen
98A16	1126	F	A	8/15/98	166.579	Pedersen
98A14	1124	M	A	8/12/98	166.520	Pedersen
98A17	1127	M	A	8/16/98	166.621	Pedersen
98A19	1129	M	A	8/18/98	166.639	Pedersen
98A15	1125	F	P	8/15/98	166.563	Pedersen
98A4	1114	F	SA	8/7/98	166.142	Pedersen
98A12	1122	F	SA	8/12/98	166.442	Pedersen
98A1	1111	M	SA	8/5/98	166.180	Pedersen
98A3	1113	M	SA	8/7/98	166.100	Pedersen
98A6	1116	M	SA	8/8/98	166.222	Pedersen
98A8	1118	M	SA	8/9/98	166.302	Aialik
98A10	1120	M	SA	8/10/98	166.320	Aialik
98A9	1119	F	Y	8/9/98	166.341	Aialik
98A13	1123	F	Y	8/12/98	166.483	Pedersen
98A18	1128	M	Y	8/17/98	166.661	Pedersen

Molt Stage Codes	
1	pre
2	early mid
3	mid
4	late mid
5	post

Seal Sex/Age	Molt Stage Code Mean
females	3.3
males	2.7
adults	3.5
sub-adults	2.9
yearling	2.3

Table 2. Correction Factor estimate for ice-associated harbor seals

Harbor seals sighted during aerial assessment surveys.
"1" indicates seal was present and hauled out on ice,
"blank" indicated seal was not present.

Seal ID	Date								Count
Frequency	8/22/98	8/26/98	8/27/98	8/28/98	8/29/98	9/2/98	9/2/98	9/3/98	
166.100	1	1		1		1	1	1	6
166.142		1		1	1	1	1		5
166.161	1	1	1	1	1	1	1	1	8
166.180				1	1		1		3
166.198			1	1	1				3
166.222									0
166.260		1	1						2
166.302						1			1
166.320	1	1	1	1			1	1	6
166.341		1	1		1	1	1		5
166.381	1	1					1		3
166.442	1	1						1	3
166.483		1		1		1	1		4
166.520	1		1	1	1	1	1	1	7
166.563				1	1				2
166.579	1			1	1	1	1		5
166.621	1				1	1	1	1	5
166.639	1			1		1	1		4
166.661	1						1	1	3
sub-total	10	9	6	11	9	10	13	7	75
proportion hauled out	0.56	0.50	0.33	0.61	0.50	0.56	0.72	0.39	0.52

Correction Factor = 1.92

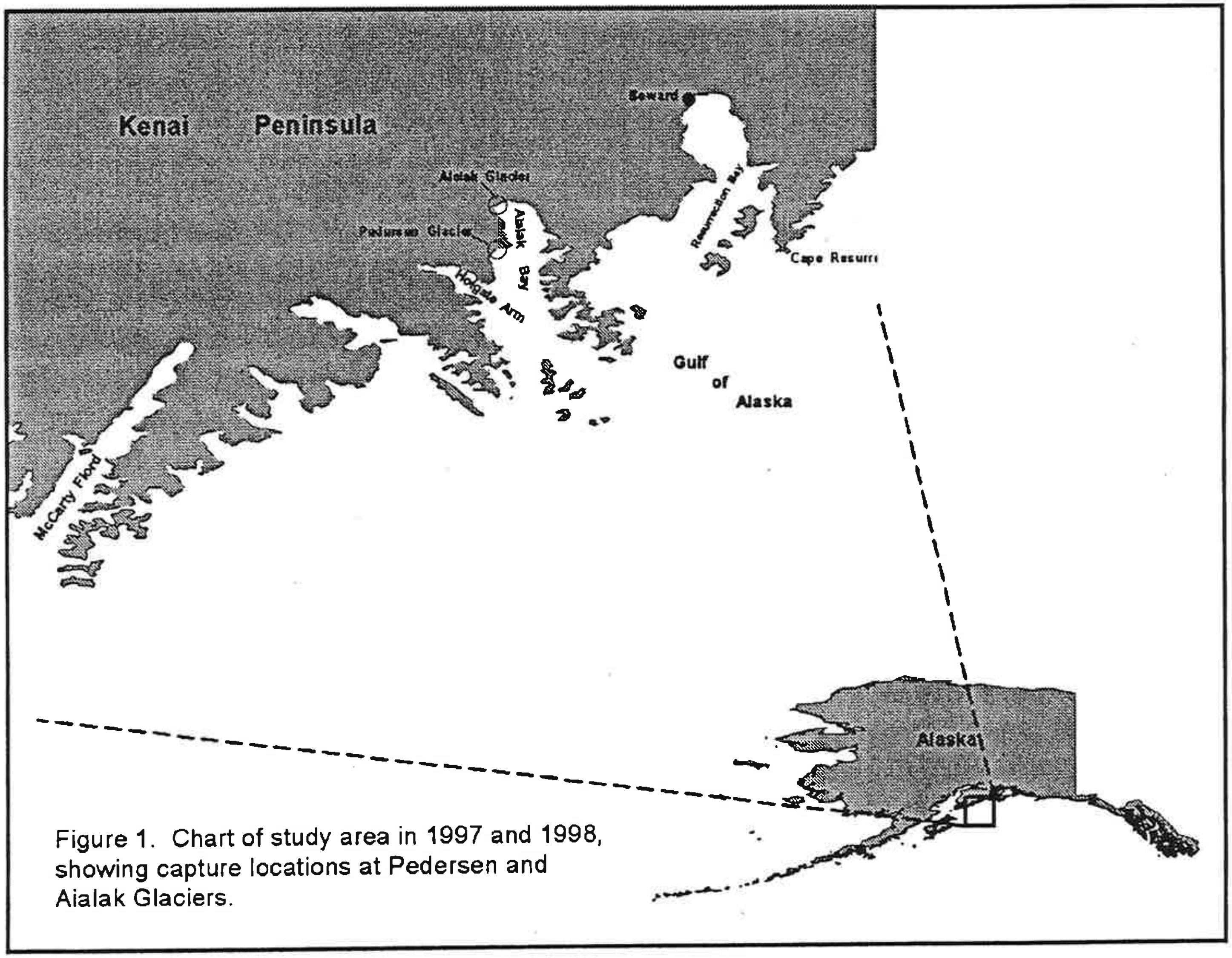


Figure 1. Chart of study area in 1997 and 1998, showing capture locations at Pedersen and Aialak Glaciers.

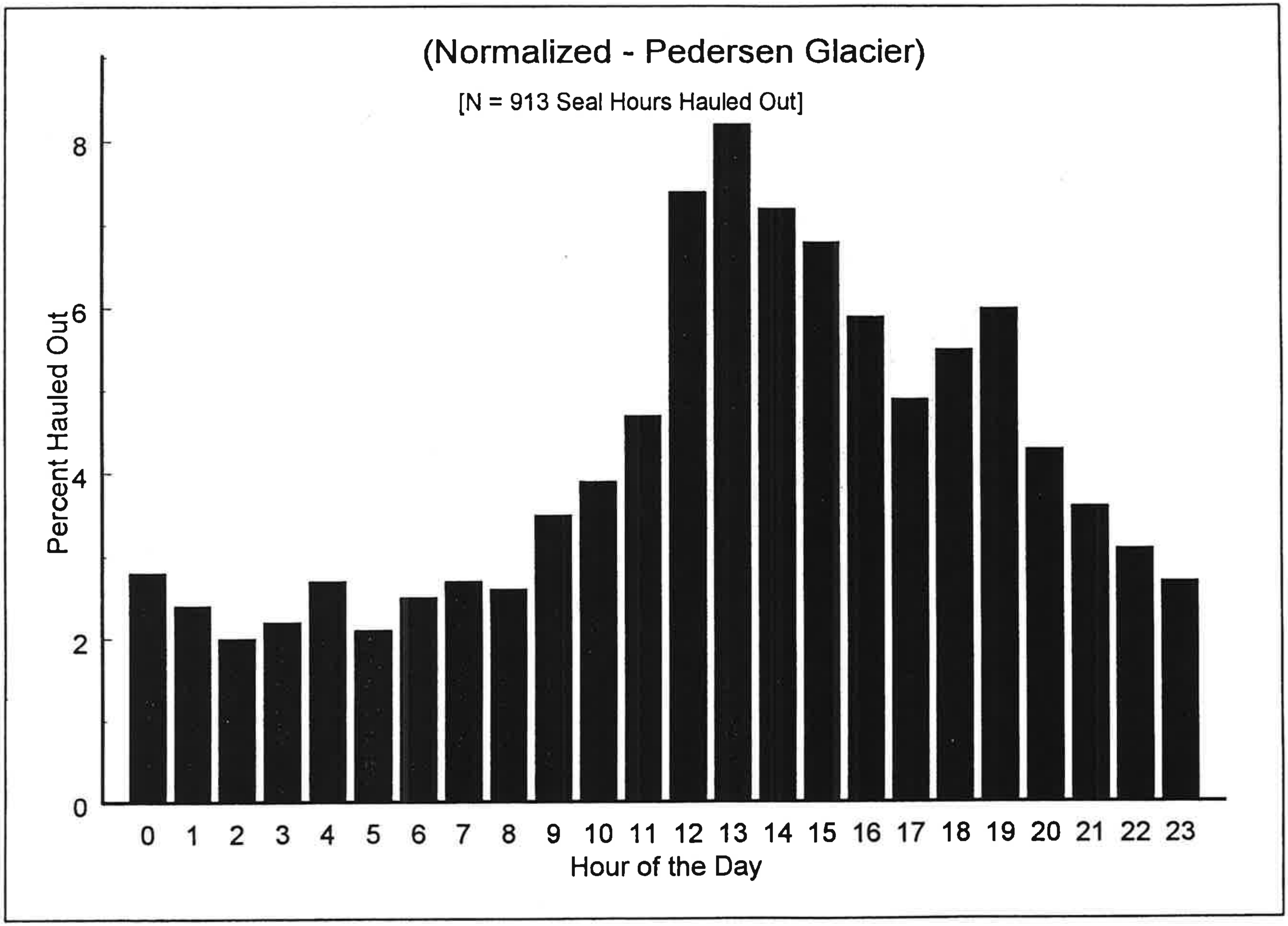


Figure 2. Percent of Seals Hauled Out by Hour of the Day.

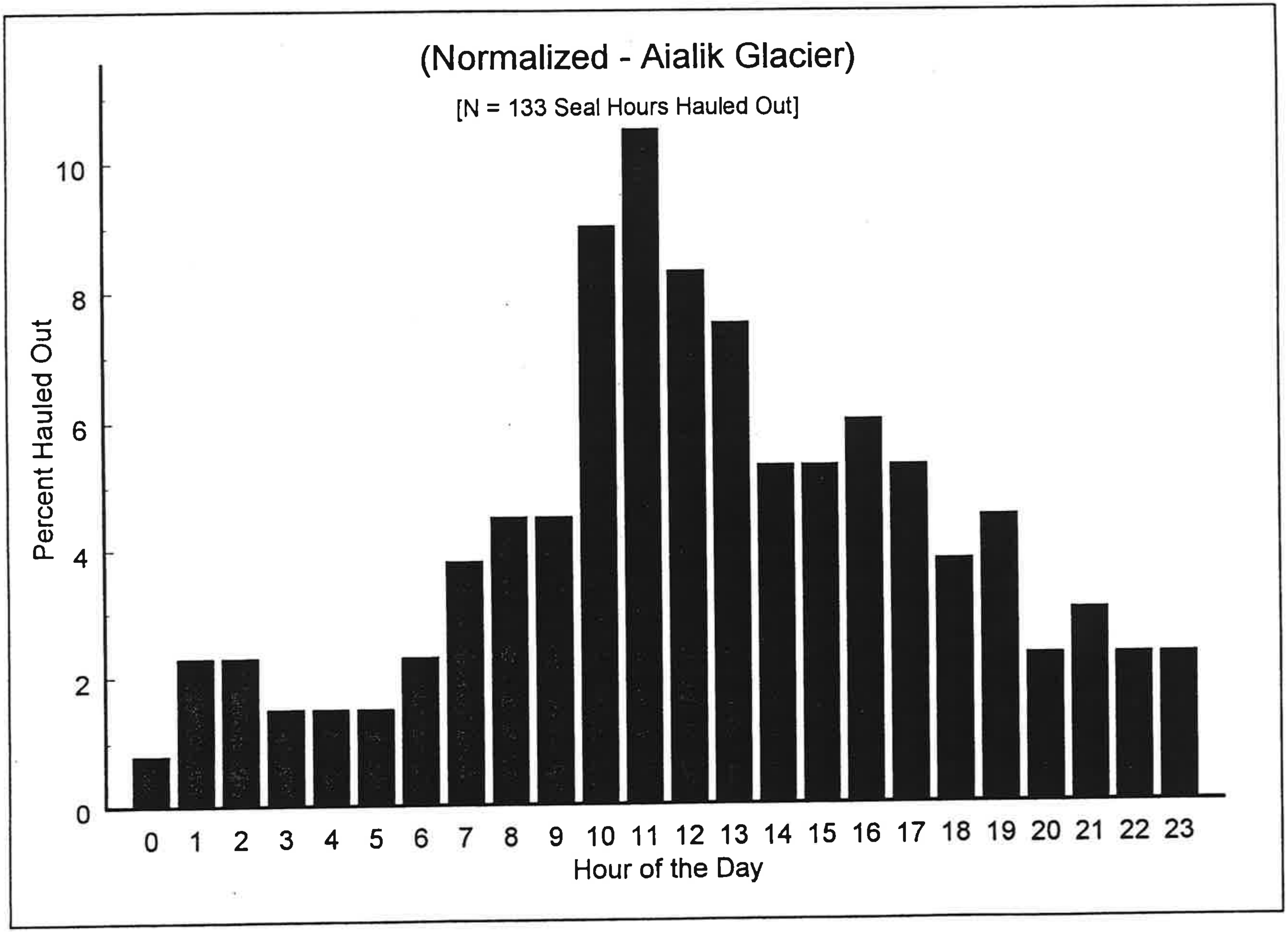
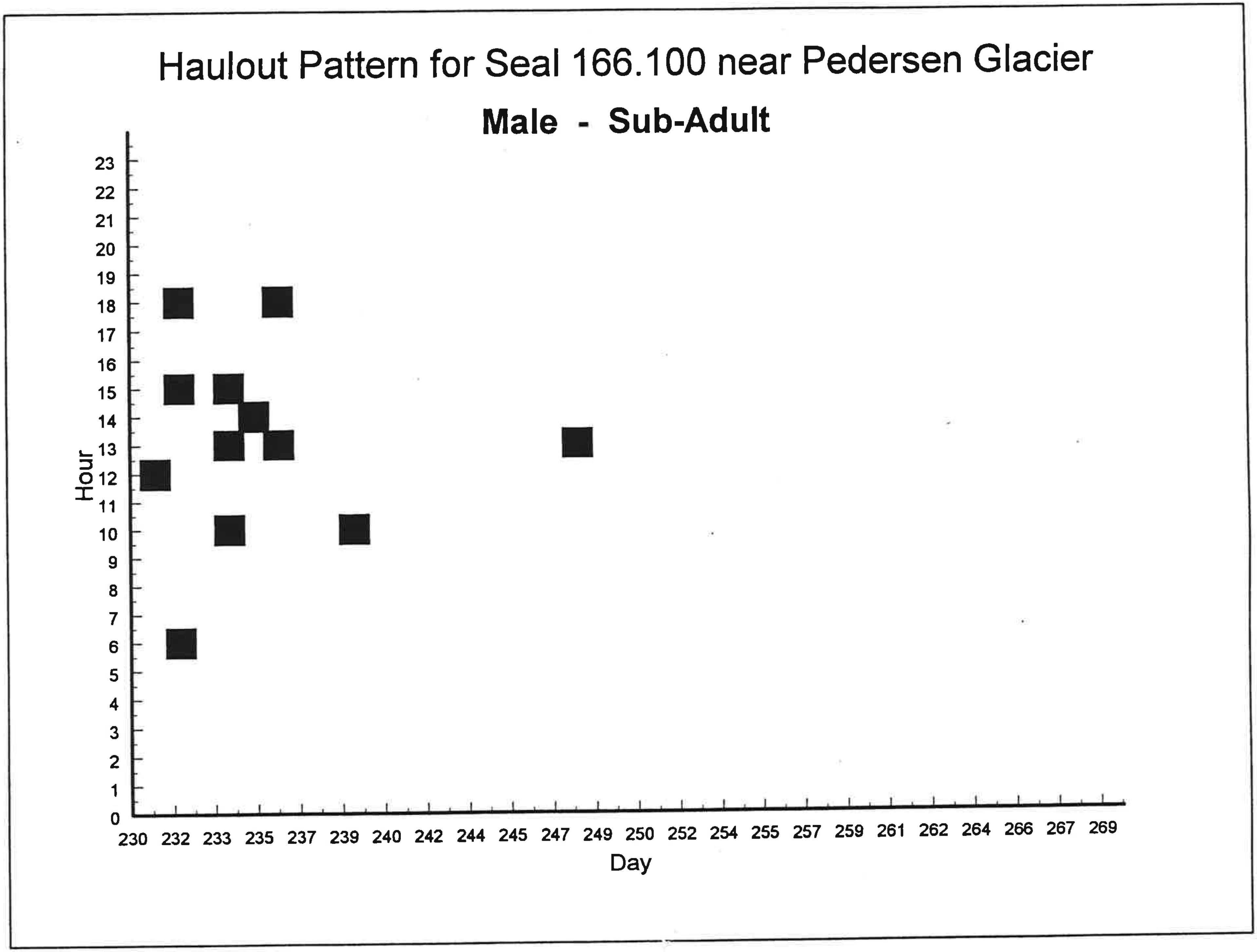
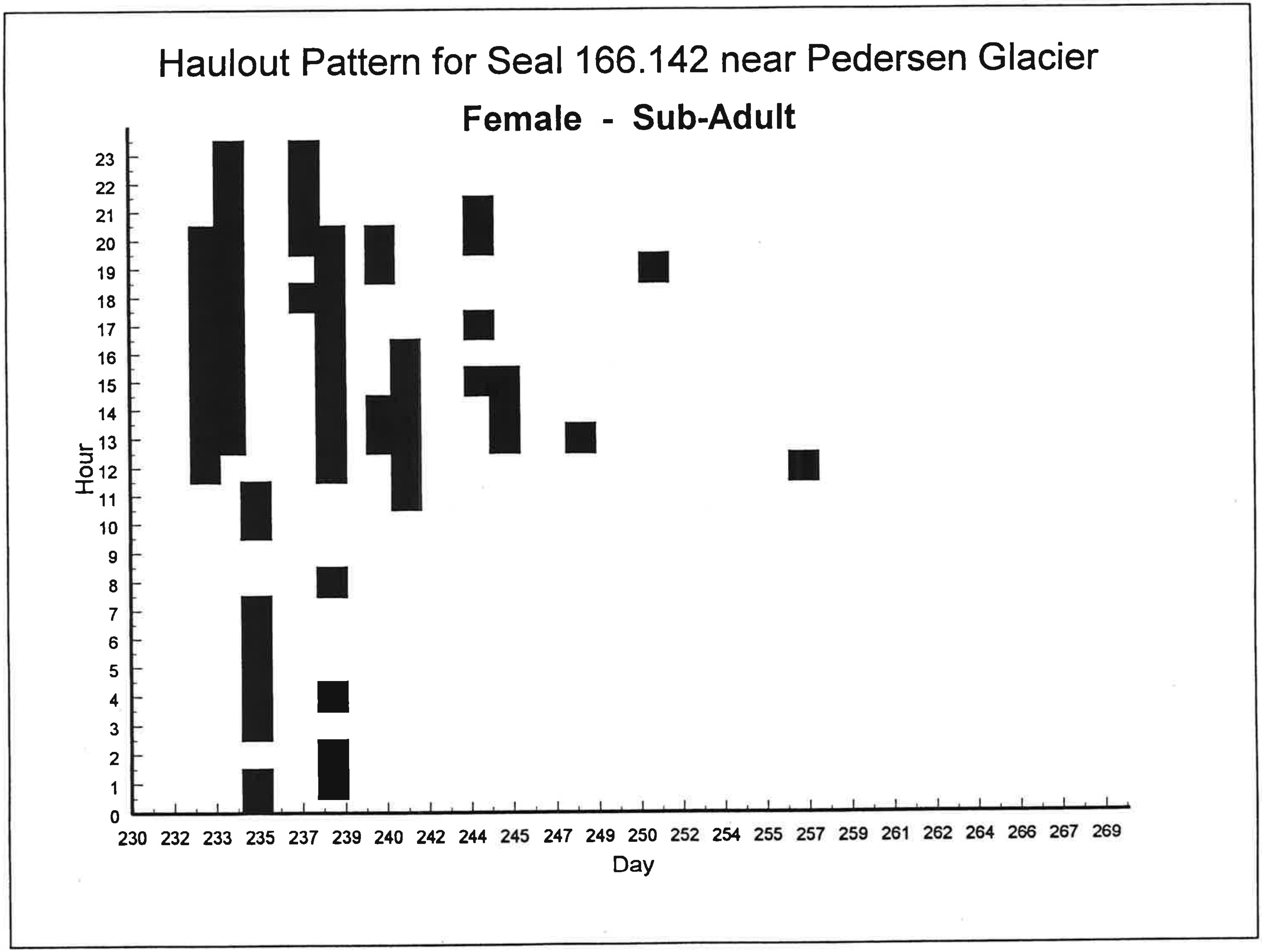


Figure 3. Percent of Seals Hauled Out by Hour of the Day.

Appendix

Haulout patterns for all seals by 1 hour time blocks by day, recorded by remote VHF receivers and data collection computers (DCCs). One station was placed near Pedersen Glacier and the other on Squab Island near Aialik Glacier. Day is the day of the year (often referred to as Julian Day; day 230 = August 18 and day 269 = September 26.). Seal number is the VHF tag frequency. Three seals were also instrumented with stronger back (as addition to flipper) mounted tags to look at possible tag loss. **(Therefore seal 166.161 = 164.854; seal 166.260 = 164.734; and seal 166.320 = 164.833).**


Haulout Pattern for Seal 166.100 near Pedersen Glacier
Male - Sub-Adult
Hour
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Day
230 232 233 235 237 239 240 242 244 245 247 249 250 252 254 255 257 259 261 262 264 266 267 269


Haulout Pattern for Seal 166.142 near Pedersen Glacier
Female - Sub-Adult
Hour
23
22
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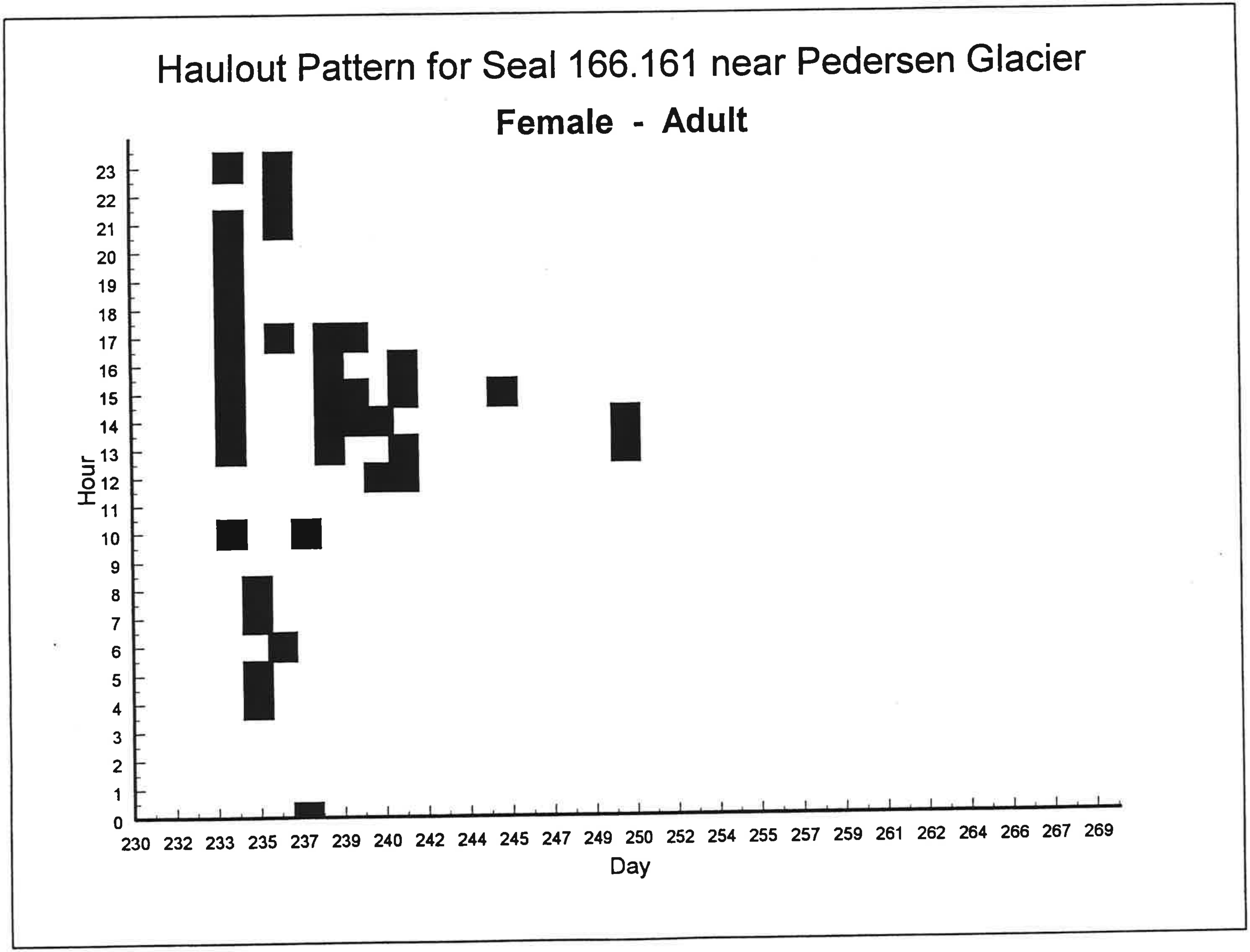
230 232 233 235 237 239 240 242 244 245 247 249 250 252 254 255 257 259 261 262 264 266 267 269
Day


Haulout Pattern for Seal 166.161 near Pedersen Glacier
Female - Adult
Hour
23
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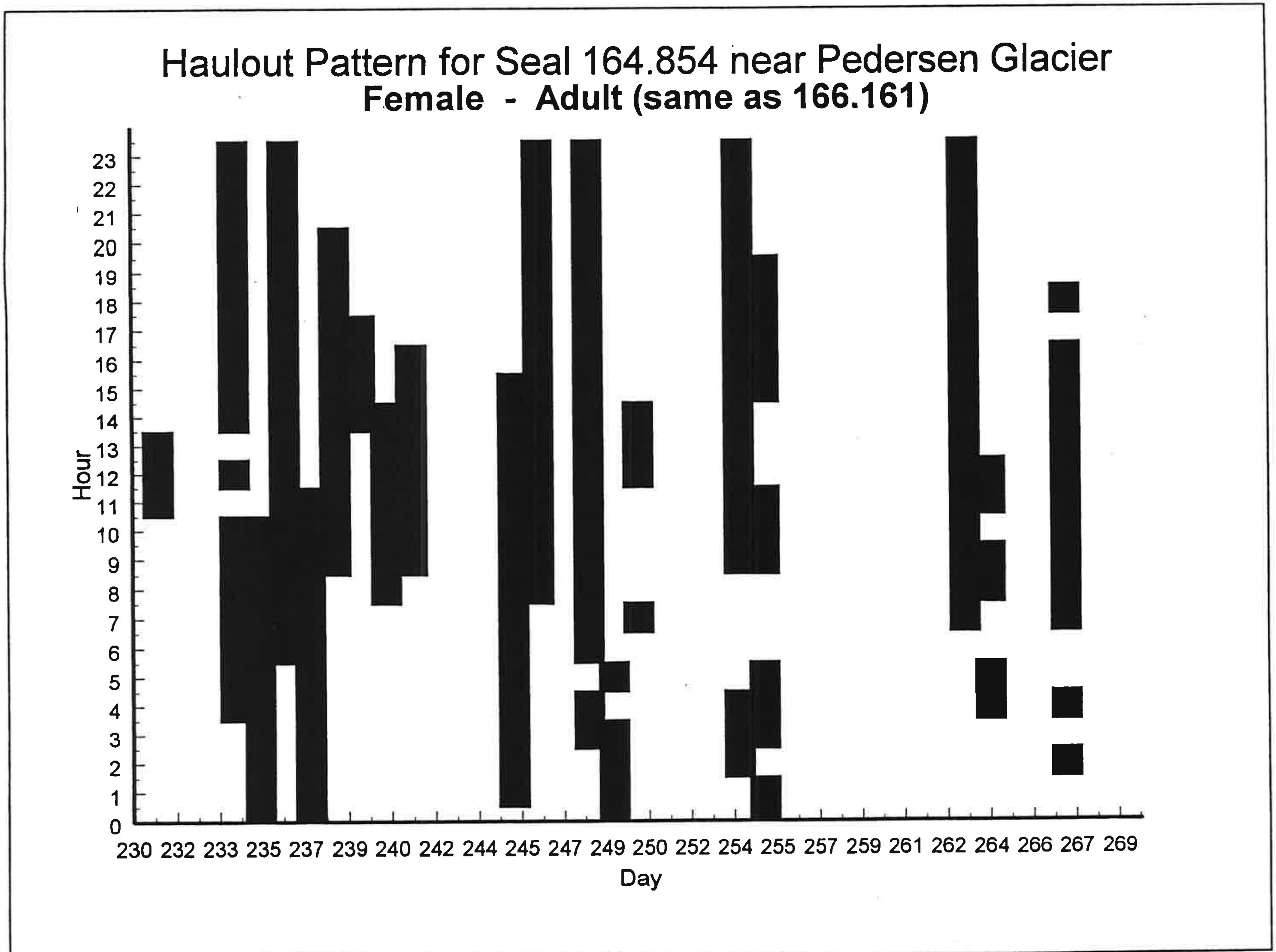
230 232 233 235 237 239 240 242 244 245 247 249 250 252 254 255 257 259 261 262 264 266 267 269
Day


Haulout Pattern for Seal 164.854 near Pedersen Glacier
Female - Adult (same as 166.161)
Hour
0
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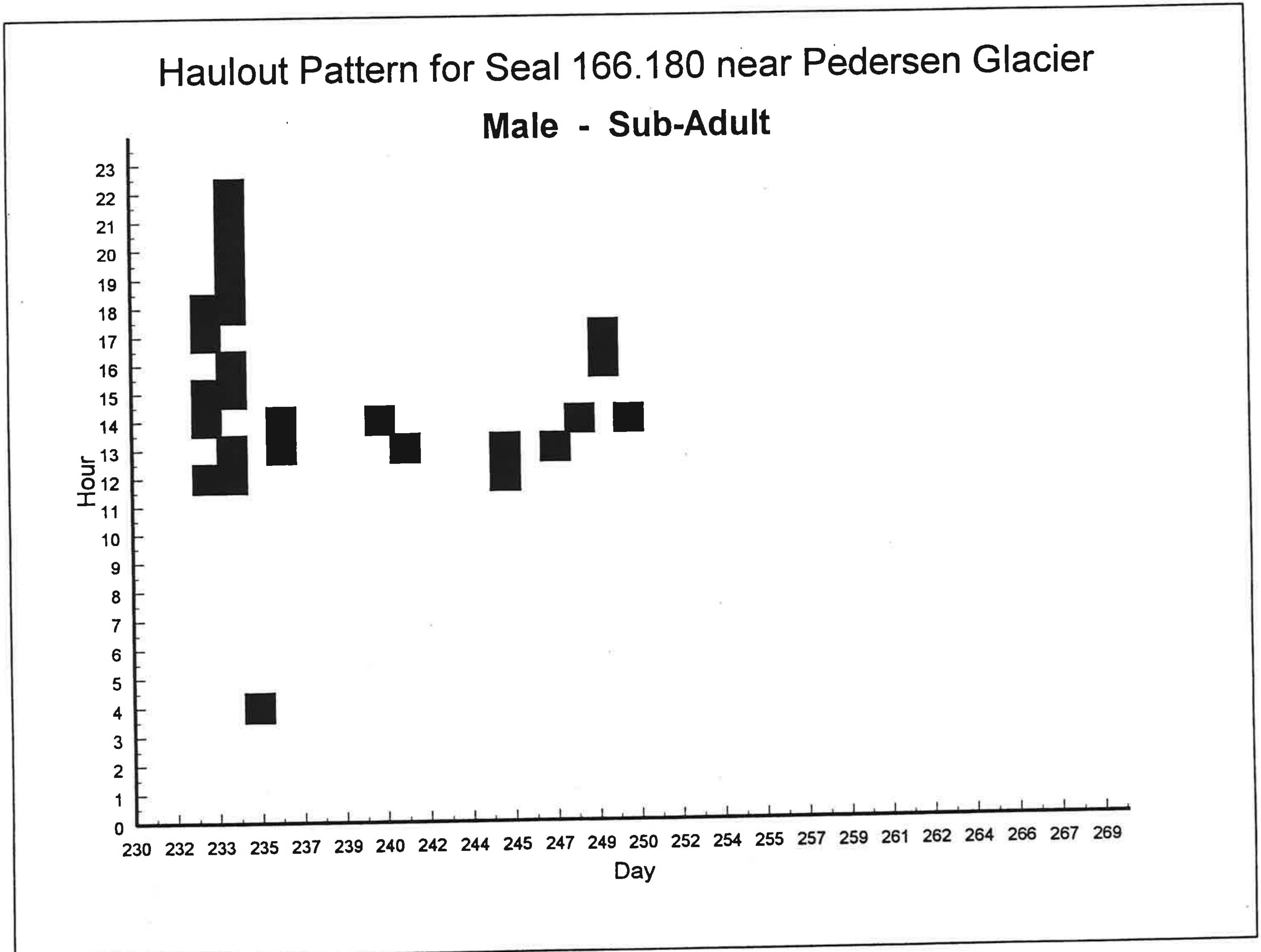
22
23
Day
230 232 233 235 237 239 240 242 244 245 247 249 250 252 254 255 257 259 261 262 264 266 267 269


Haulout Pattern for Seal 166.180 near Pedersen Glacier
Male - Sub-Adult
Hour
23
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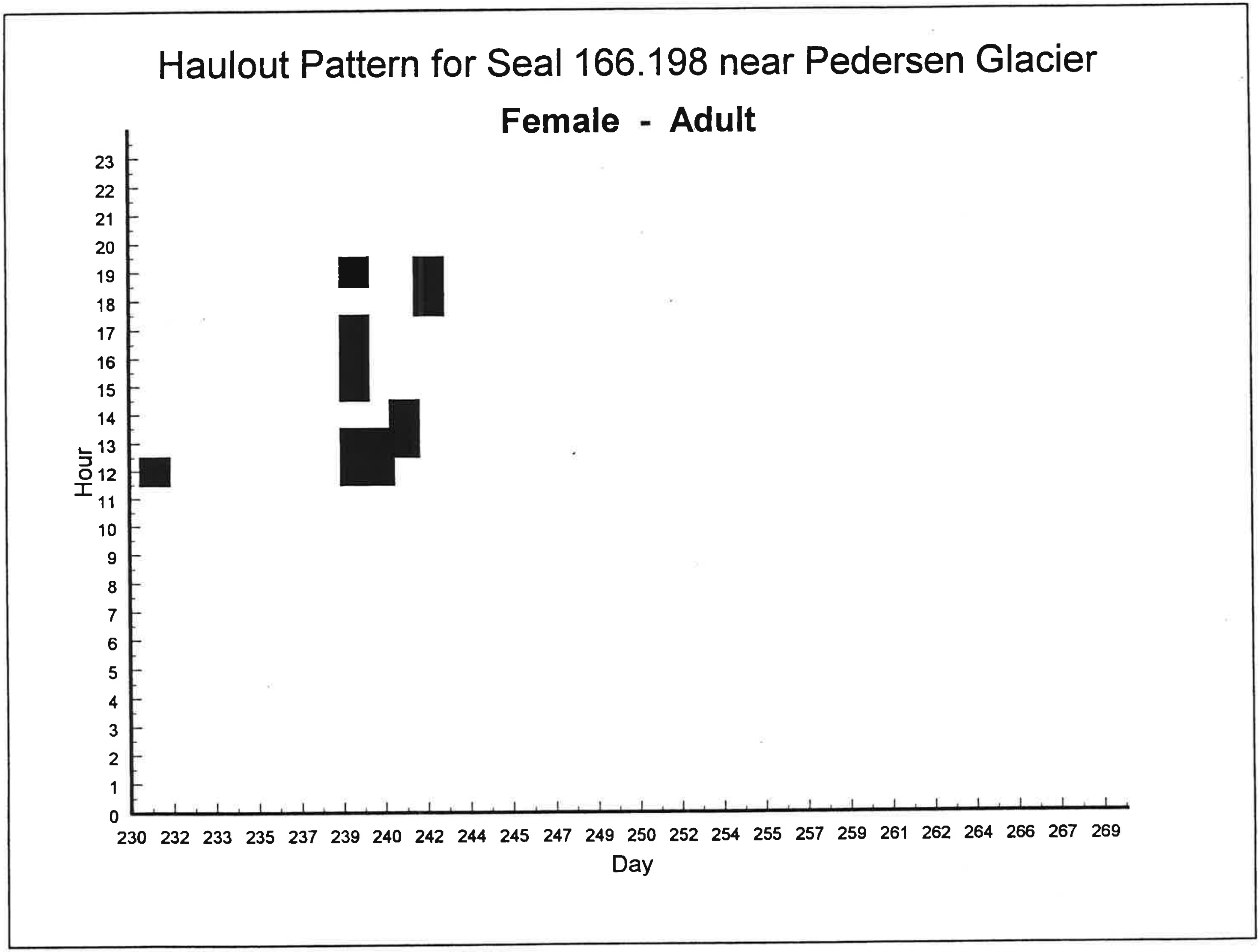
0
230 232 233 235 237 239 240 242 244 245 247 249 250 252 254 255 257 259 261 262 264 266 267 269
Day



Haulout Pattern for Seal 166.198 near Pedersen Glacier
Female - Adult
Hour
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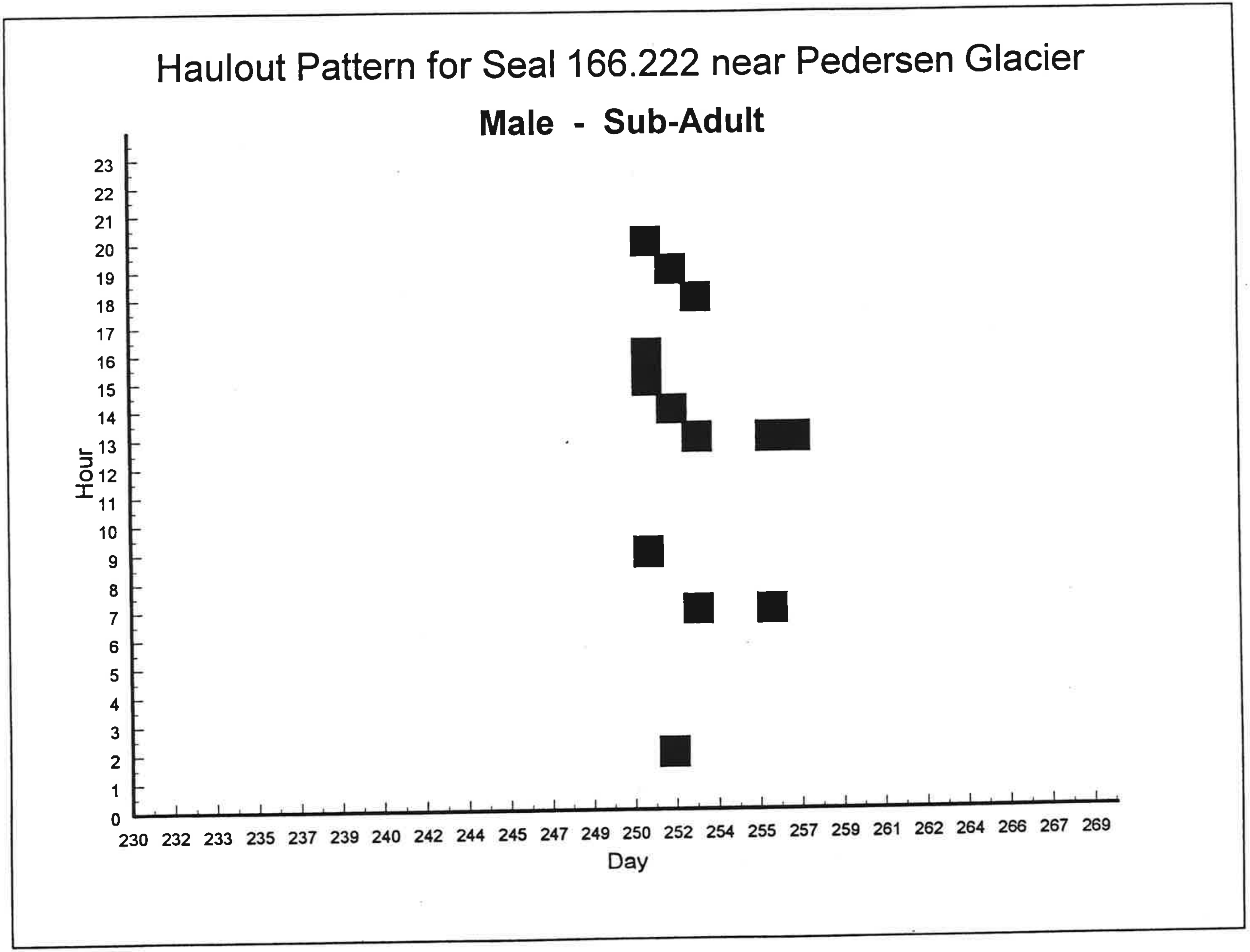
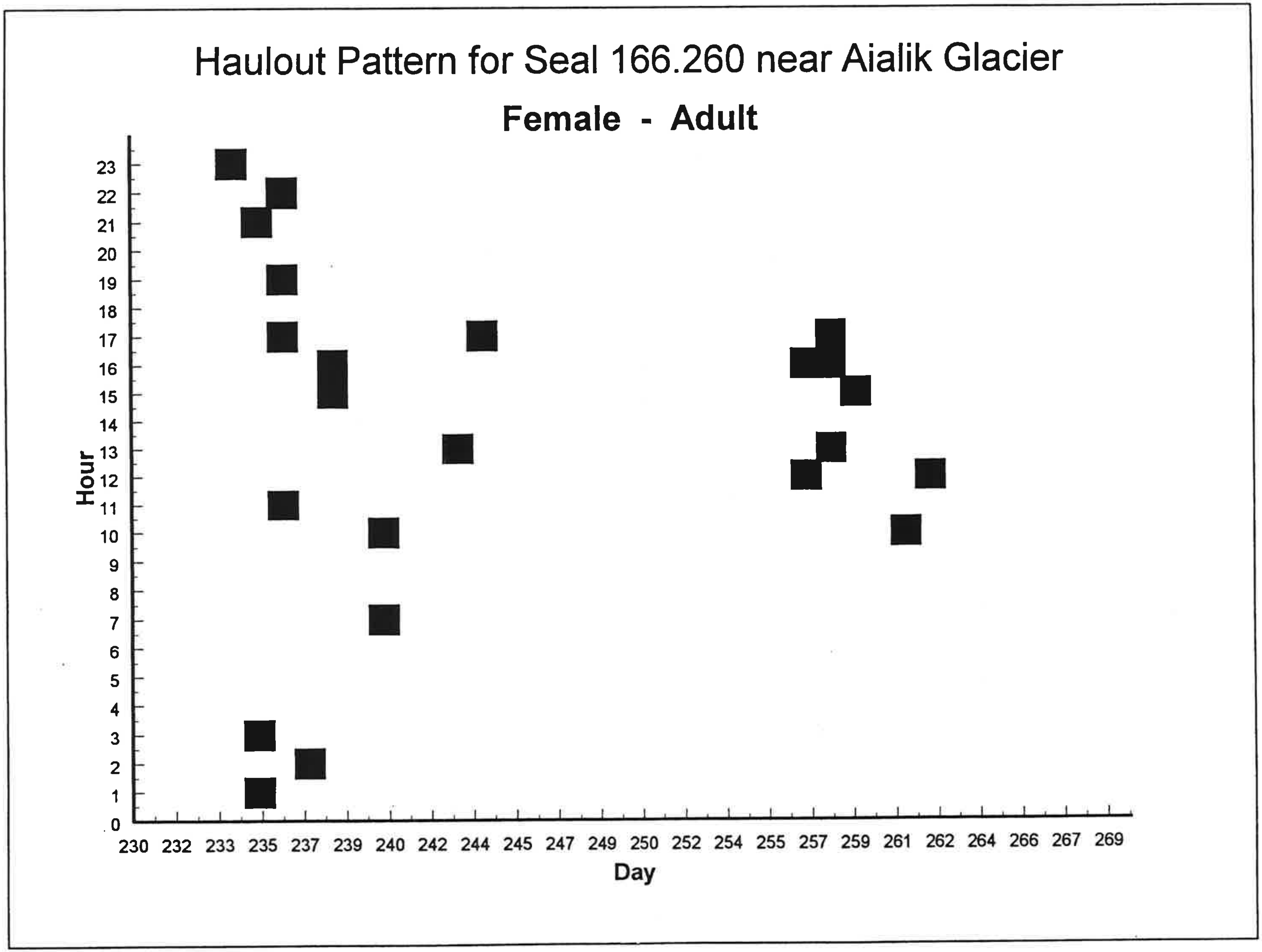
230 232 233 235 237 239 240 242 244 245 247 249 250 252 254 255 257 259 261 262 264 266 267 269
Day


Haulout Pattern for Seal 166.222 near Pedersen Glacier
Male - Sub-Adult
Hour
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
230 232 233 235 237 239 240 242 244 245 247 249 250 252 254 255 257 259 261 262 264 266 267 269
Day


Haulout Pattern for Seal 166.260 near Aialik Glacier
Female - Adult
Hour
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10
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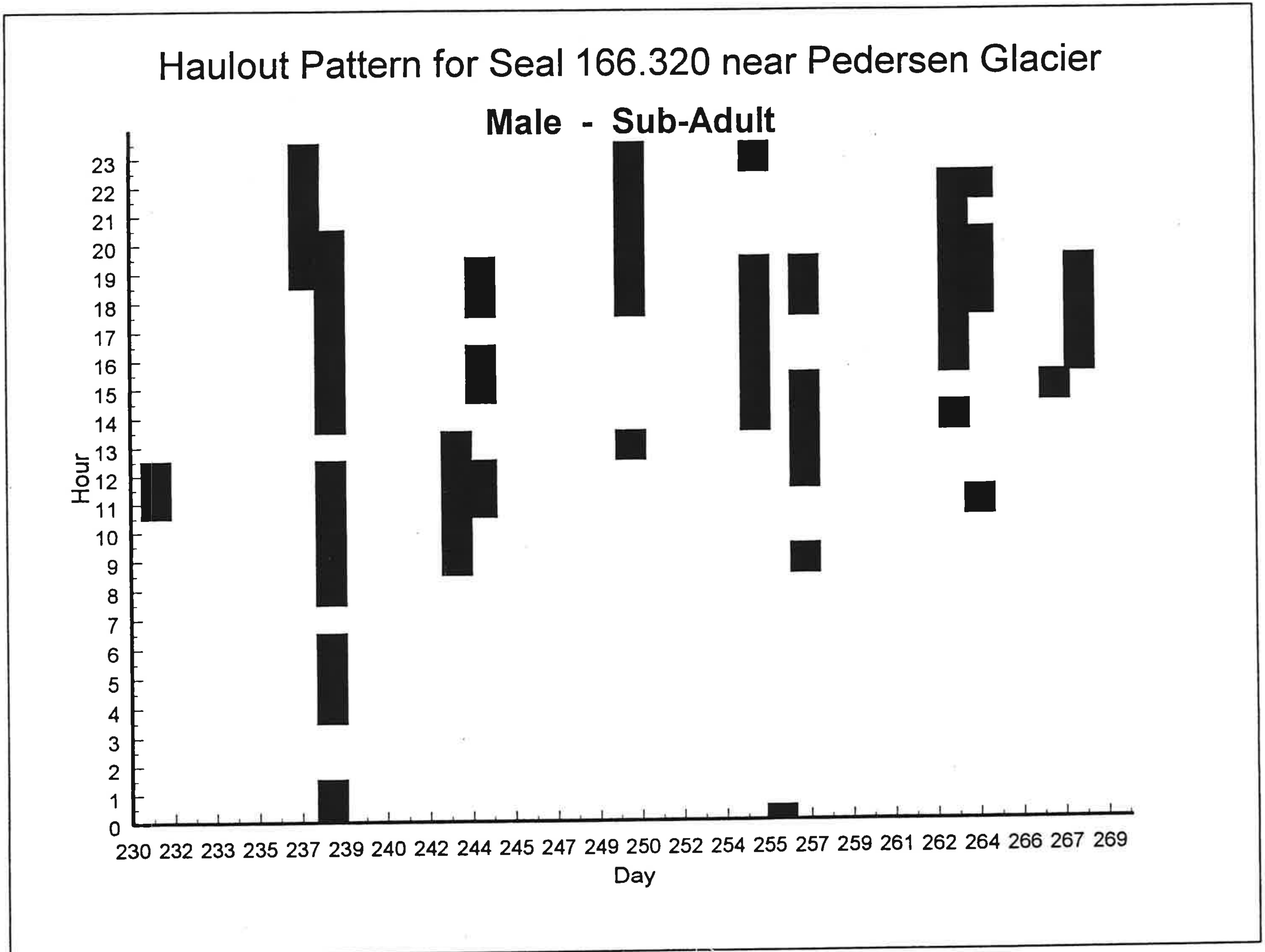
230 232 233 235 237 239 240 242 244 245 247 249 250 252 254 255 257 259 261 262 264 266 267 269
Day


Haulout Pattern for Seal 166.320 near Pedersen Glacier
Male - Sub-Adult
Hour
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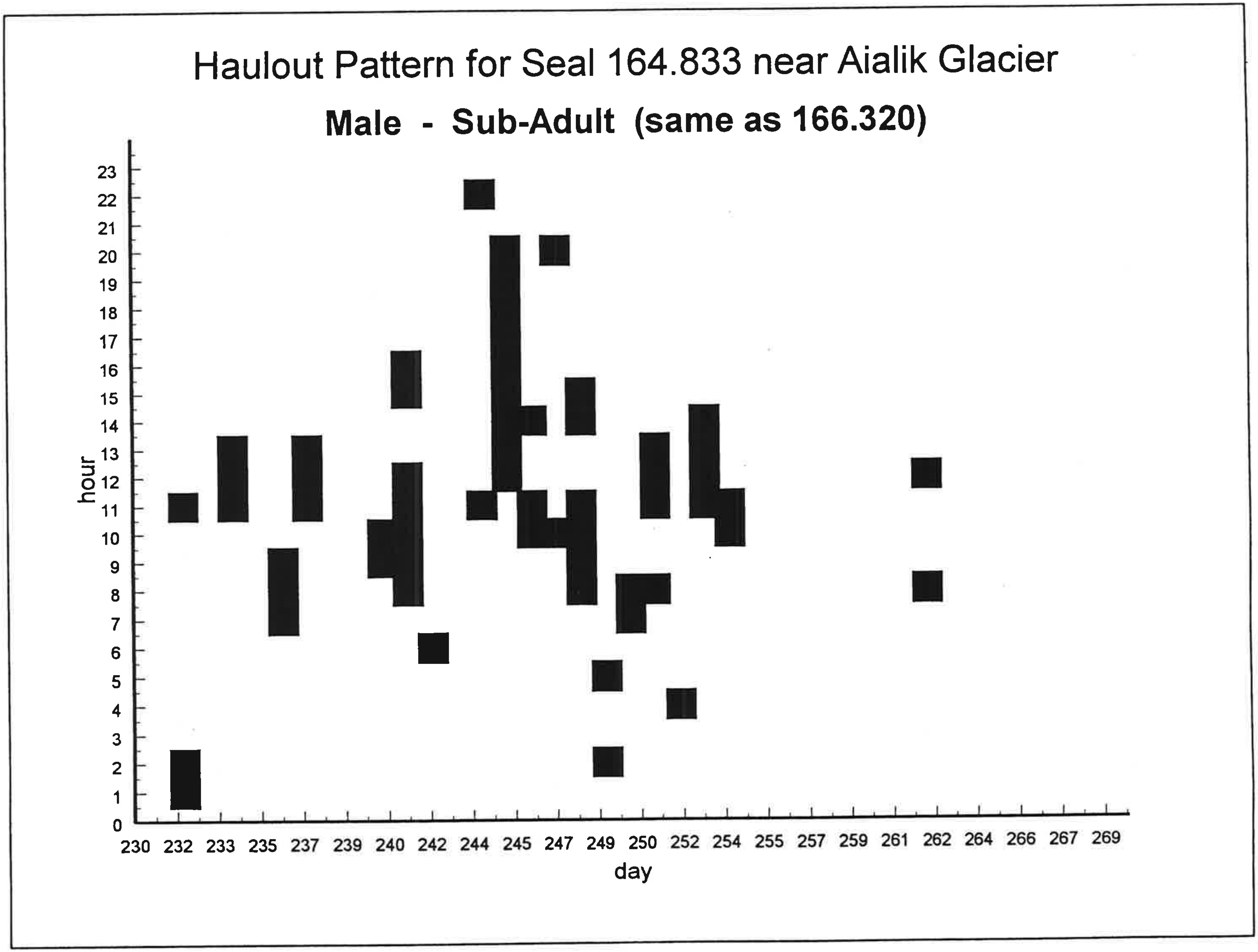
230 232 233 235 237 239 240 242 244 245 247 249 250 252 254 255 257 259 261 262 264 266 267 269
Day


Haulout Pattern for Seal 164.833 near Aialik Glacier
Male - Sub-Adult (same as 166.320)
hour
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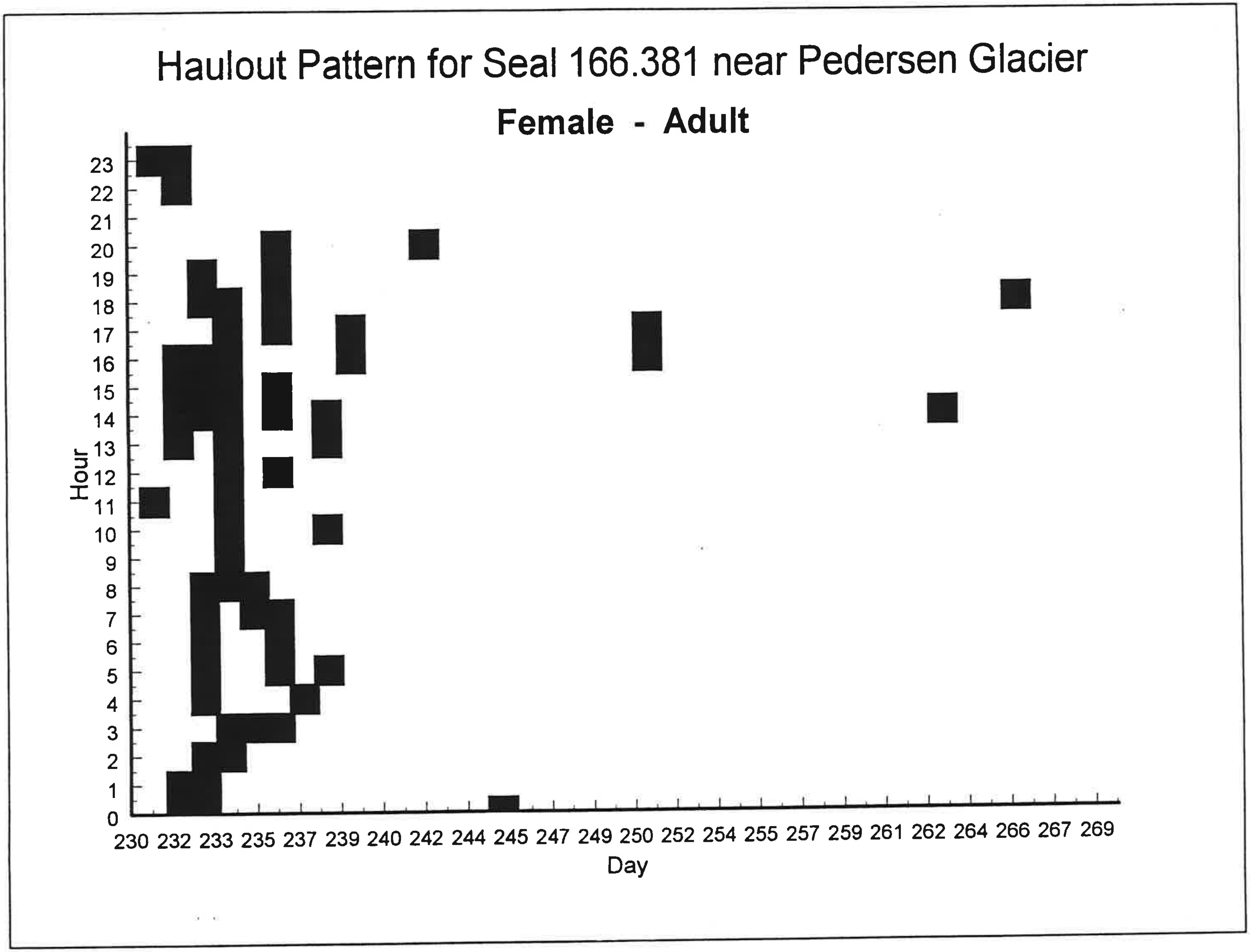
day



Haulout Pattern for Seal 166.381 near Pedersen Glacier
Female - Adult
Hour
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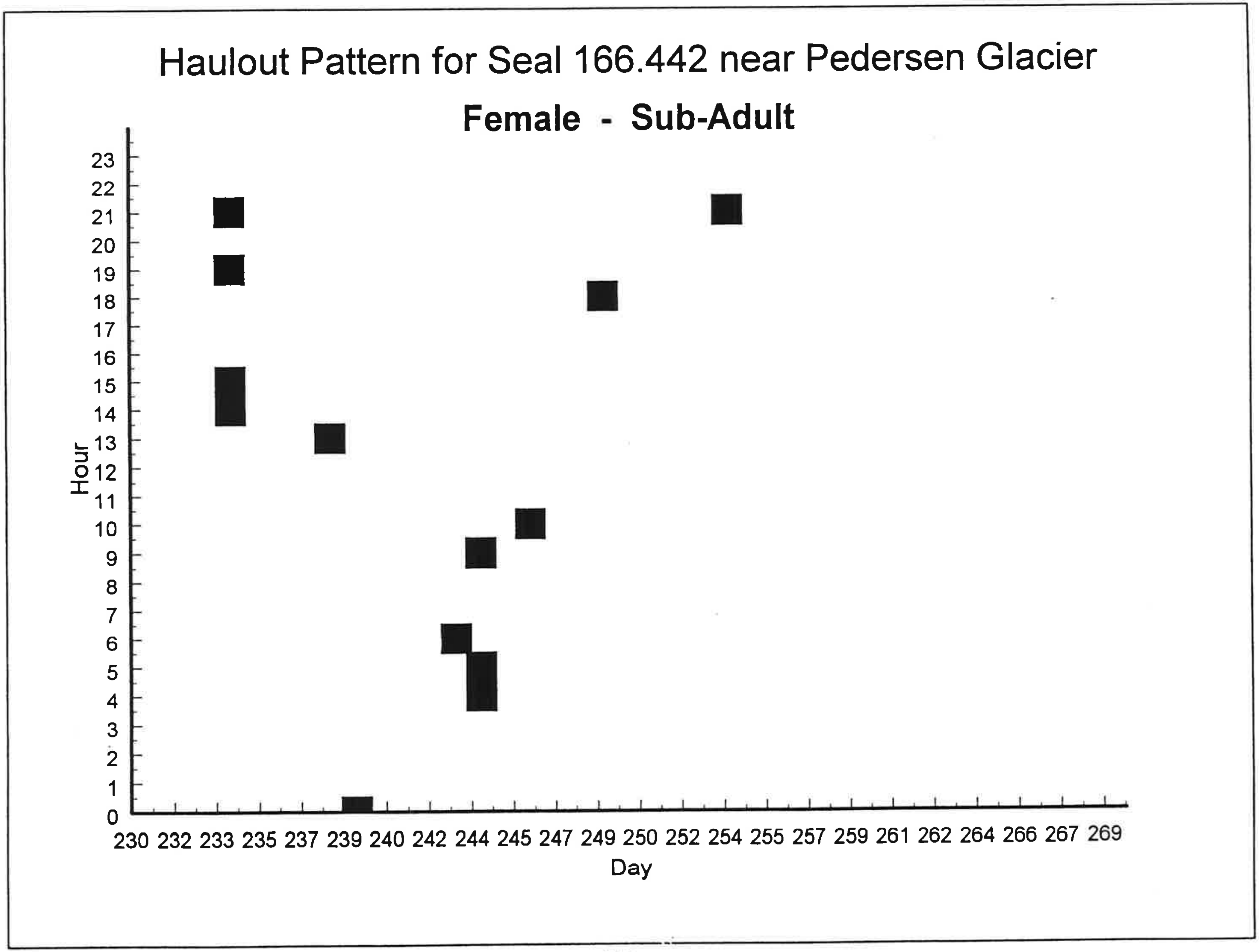
Day


Haulout Pattern for Seal 166.442 near Pedersen Glacier
Female - Sub-Adult
Hour
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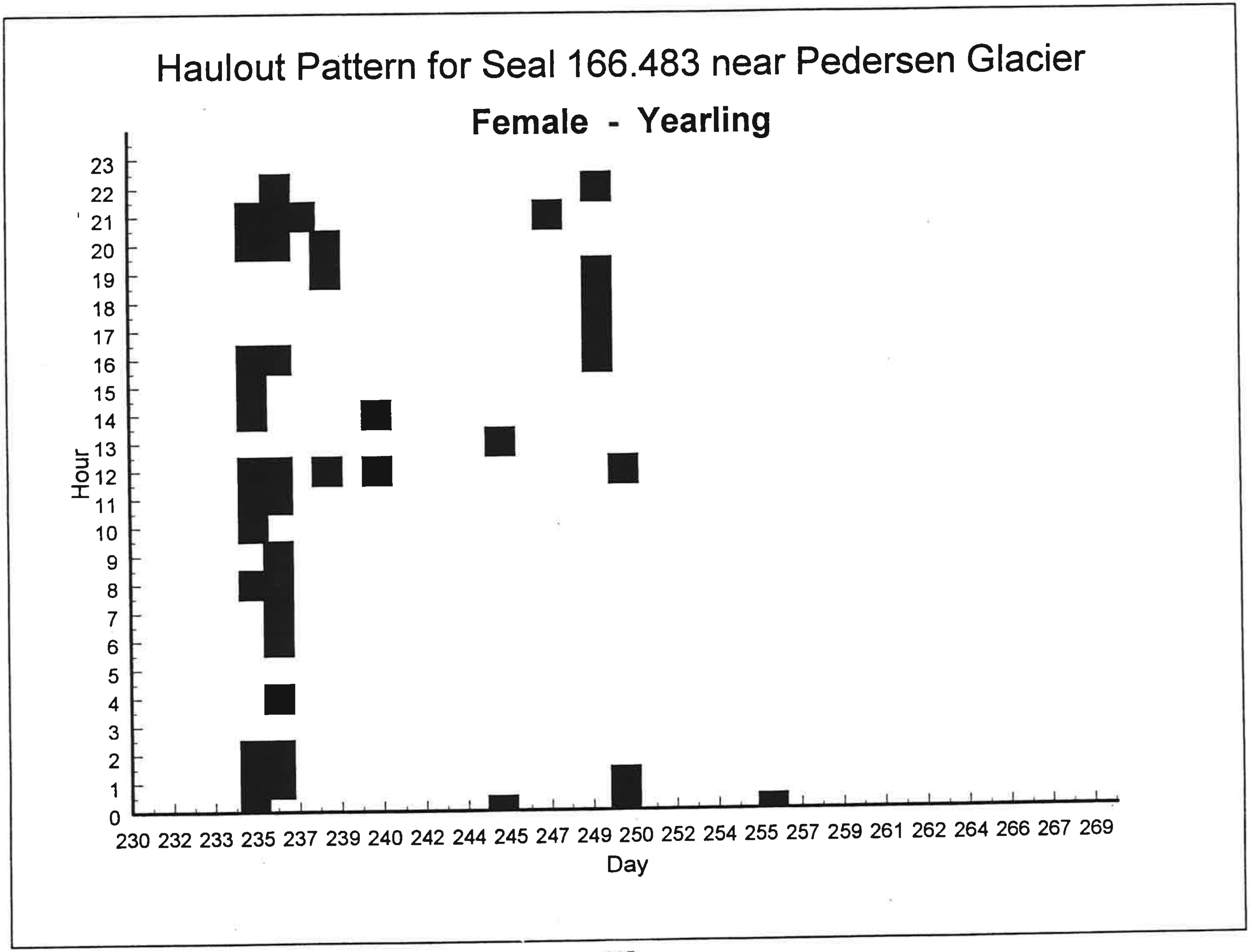
Day



Haulout Pattern for Seal 166.483 near Pedersen Glacier
Female - Yearling
Hour
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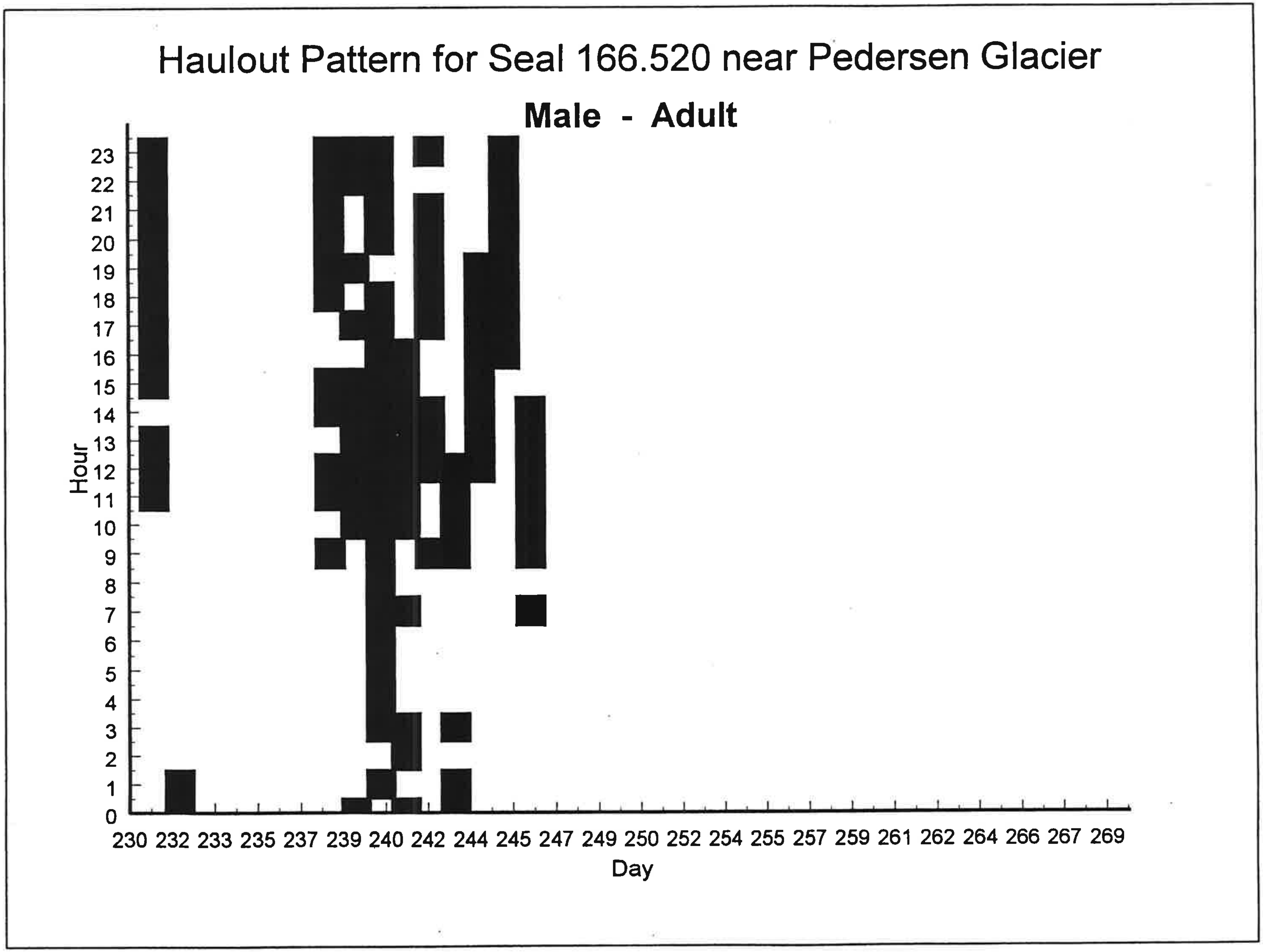
Day


Haulout Pattern for Seal 166.520 near Pedersen Glacier
Male - Adult
Hour
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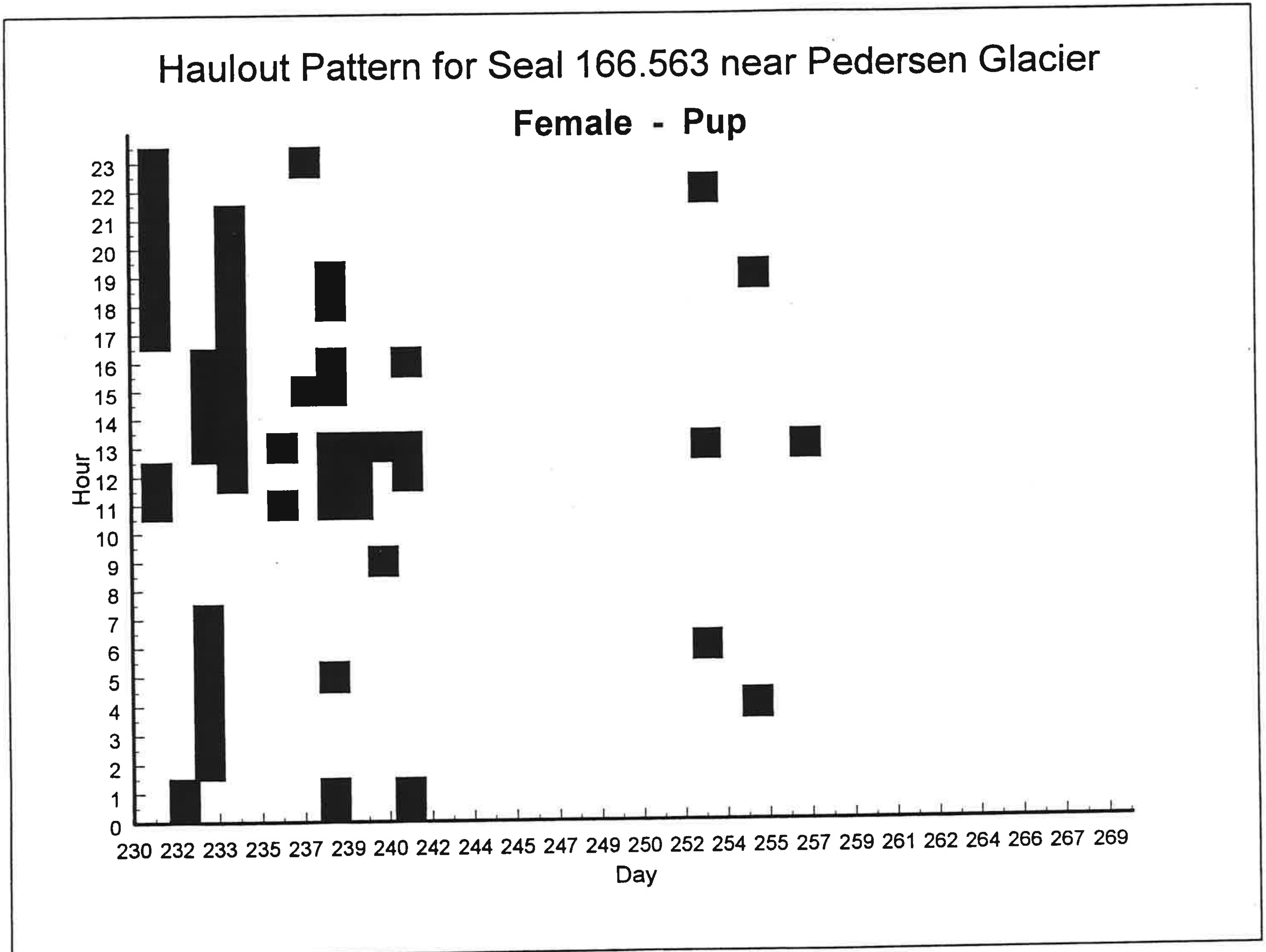
Day


Haulout Pattern for Seal 166.563 near Pedersen Glacier
Female - Pup
Hour
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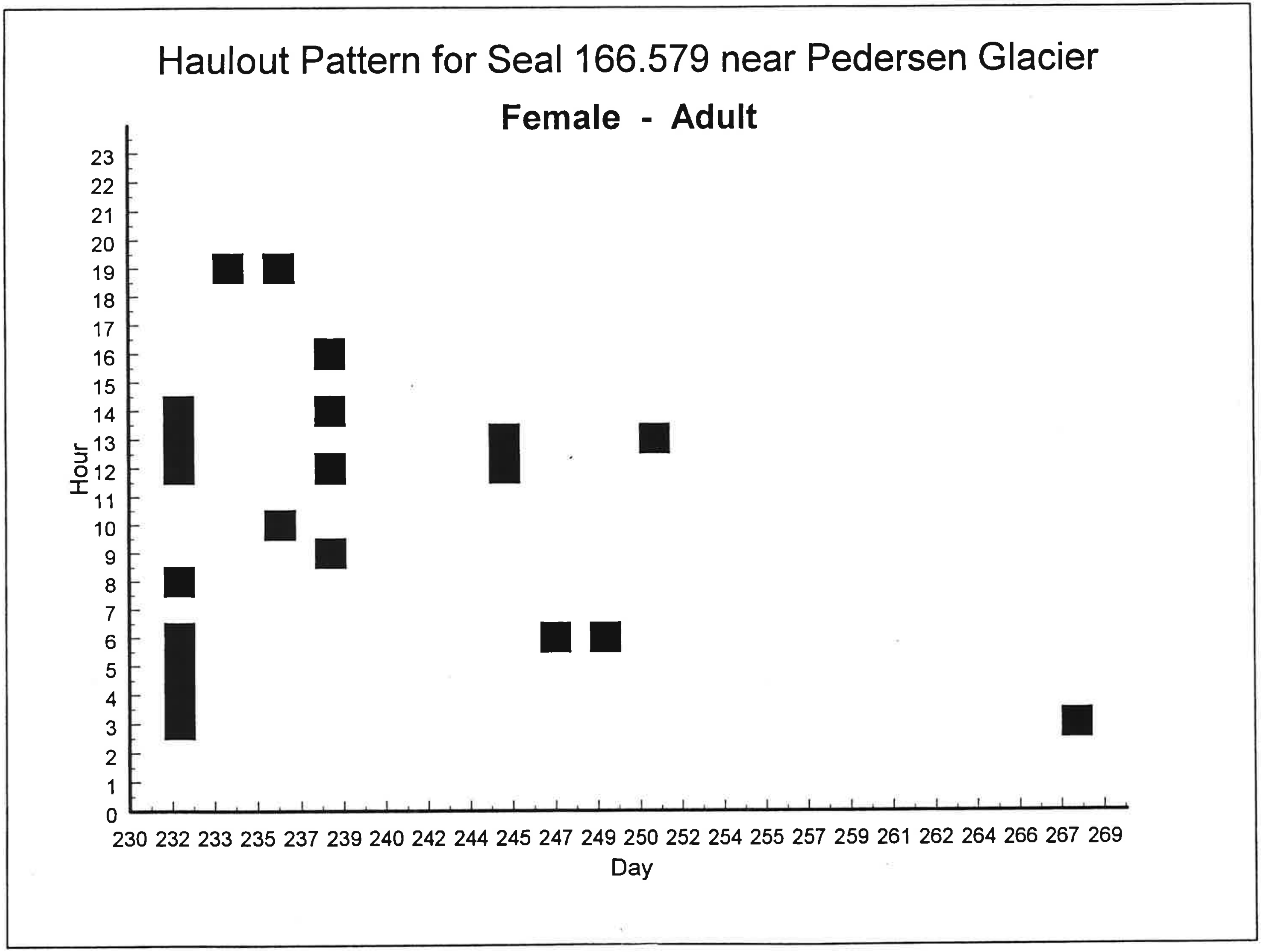
Day


Haulout Pattern for Seal 166.579 near Pedersen Glacier
Female - Adult
Hour
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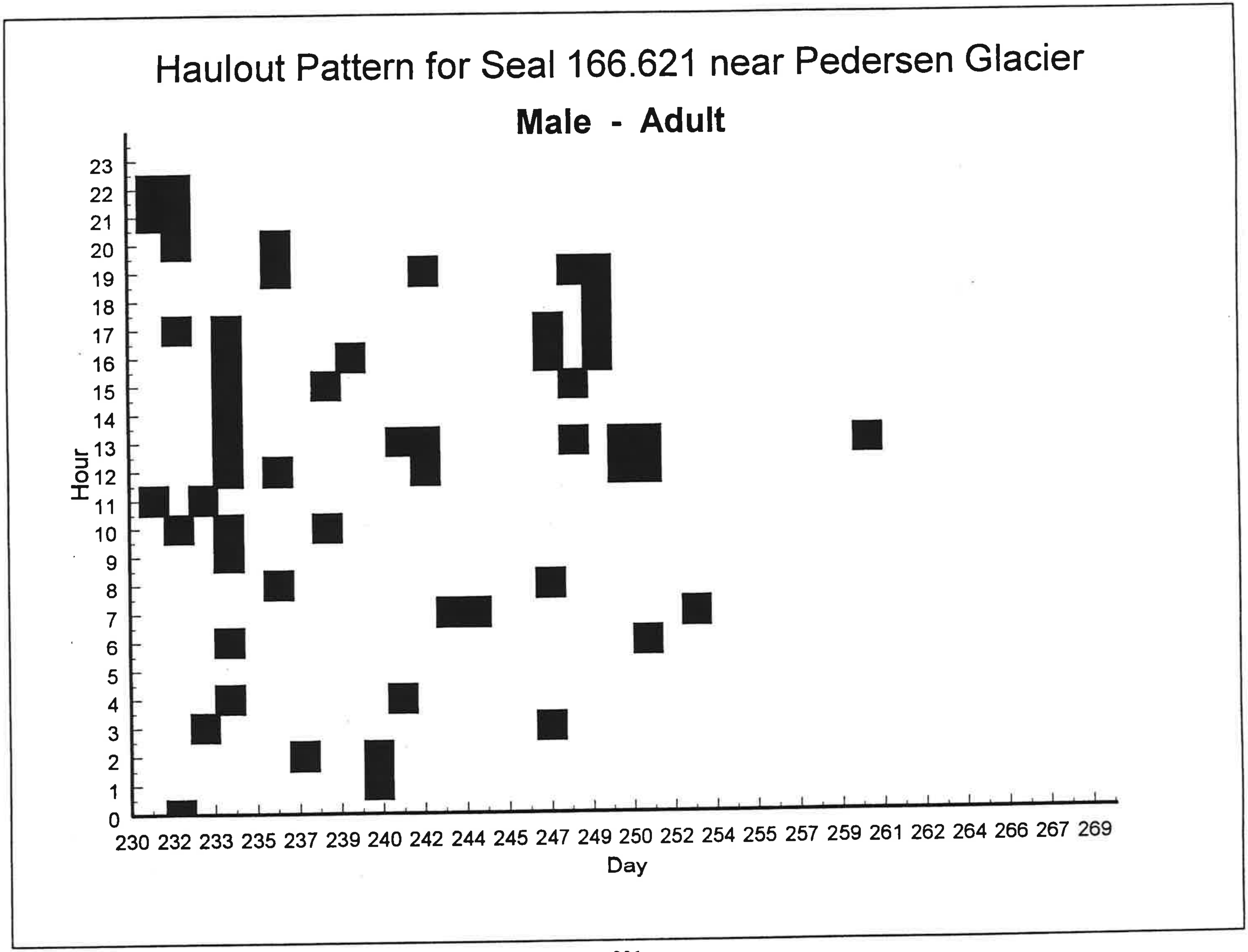
Day



Haulout Pattern for Seal 166.621 near Pedersen Glacier
Male - Adult
Hour
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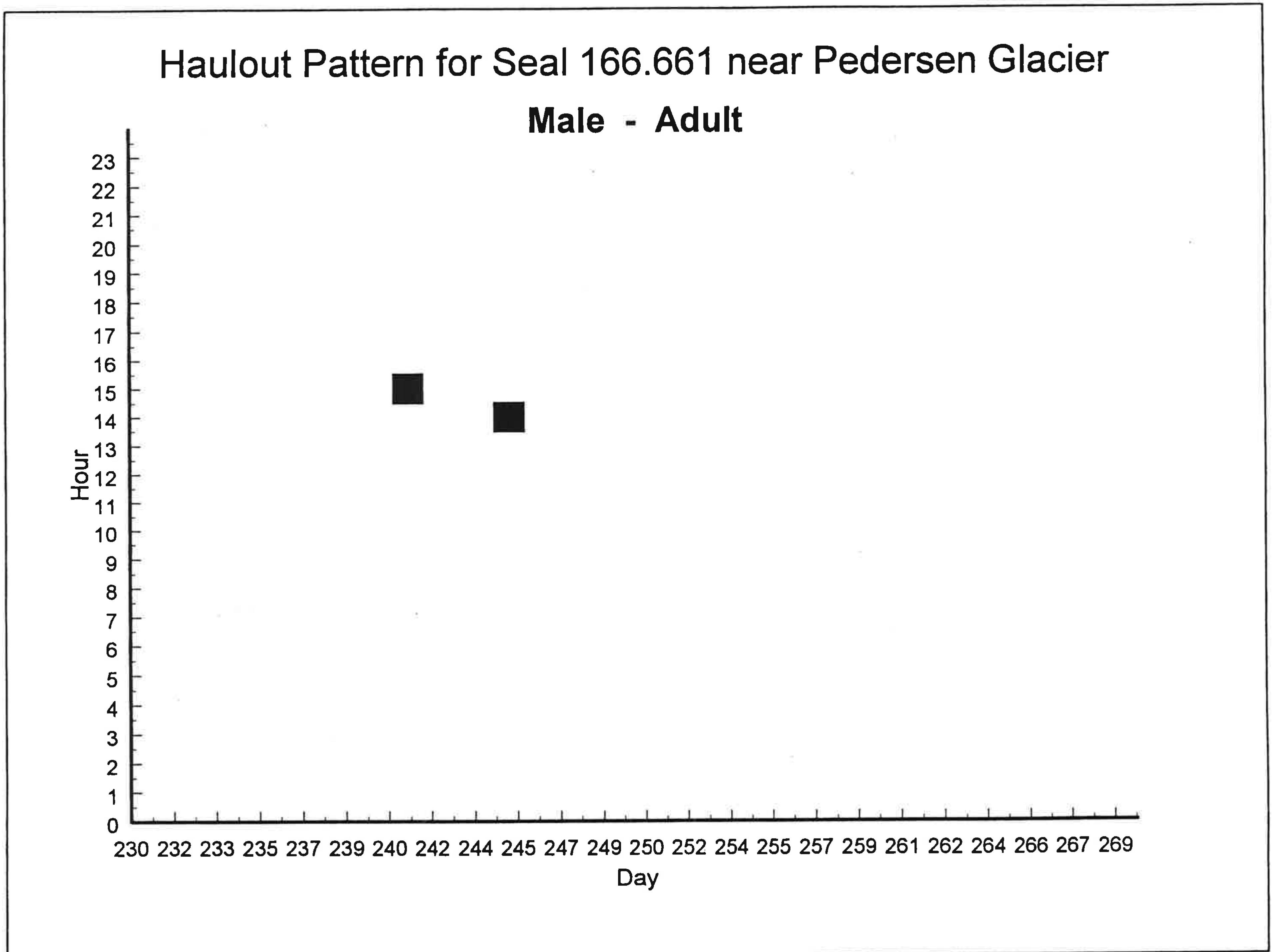
230 232 233 235 237 239 240 242 244 245 247 249 250 252 254 255 257 259 261 262 264 266 267 269
Day



Haulout Pattern for Seal 166.661 near Pedersen Glacier
Male - Adult
Hour
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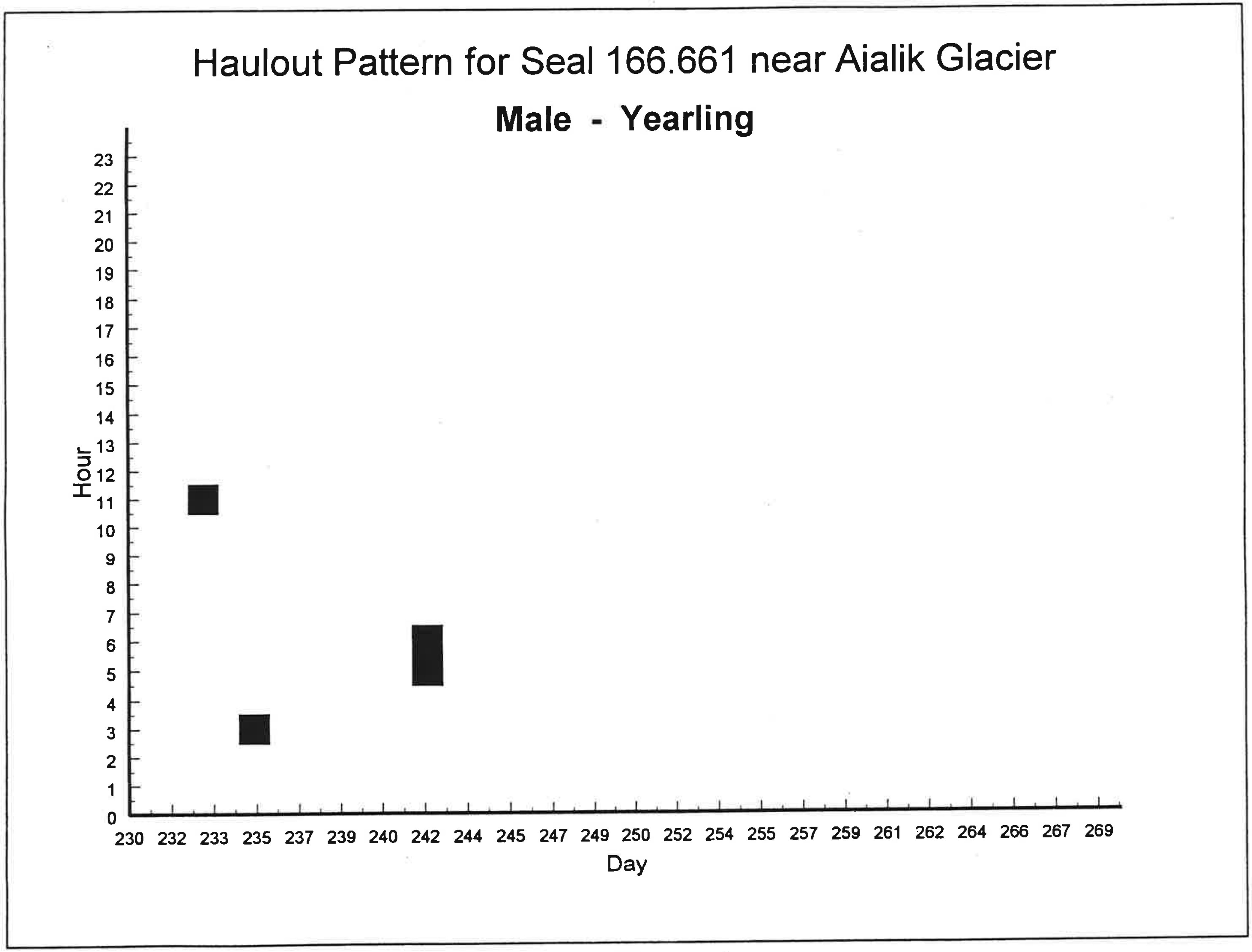
Day



Haulout Pattern for Seal 166.661 near Aialik Glacier
Male - Yearling
Hour
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230 232 233 235 237 239 240 242 244 245 247 249 250 252 254 255 257 259 261 262 264 266 267 269
Day

UPDATE ON THE NORTH PACIFIC HUMPBACK WHALE FLUKE PHOTOGRAPH COLLECTION, AUGUST 1999

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

Starting in 1985, the National Marine Mammal Laboratory (NMML) has been developing and curating a collection of humpback whale 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 25,000 photographs by 1999, 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 only when there are at least 2 photographs of a particular individual whale in the database. As of August 1999, there were 25,489 fluke photographs in the database: 13,206 fluke photographs with a NMMLID (3,151 unique NMMLID numbers) and 12,283 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, while others may be unmatchable due to 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 3. Matches so far confirm strong links between Hawaii and Alaska, and between Mexico (mainland and Baja) and California. Wintering areas have long been assumed to be segregated, with a low rate of exchange between them. However, there is a surprisingly strong link between Hawaii and offshore Mexico (Revillagigedos). However, 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.

Long-Term Sighting Histories

In the past year, NMML was asked to archive and curate the humpback whale fluke photograph collection of Charles Jurasz, the Alaska researcher who began the systematic collection of humpback fluke photographs in 1967. The Jurasz collection comprises 1,113 fluke photographs taken from 1968-1981, and has lengthened the long-term sighting histories of whales by at least 8 years, and increased sample sizes from the late 1960s and early 1970s.

With the addition of the Jurasz photographs, there are now more than 1,077 individual whales which have been seen over a period of at least 5 years. Of those 1,077 individuals, 423 were seen over at least a 10 or more year span, 169 were seen over at least a 15 or more year span, and 28 whales were seen at least over a 20 or more year time span (Fig. 1). The whale with the longest sighting history in the database is NMMLID 169, who was first photographed by C. Jurasz in Alaska in 1968, and photographed as recently as 1998 in Alaska by F. Sharpe and J. Straley (Mizroch and Harkness 1998).

Life History Parameter Workshops

Chris 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. A draft of that paper was distributed at the International Whaling Commission (IWC) Scientific Committee meeting this year, and a review of the draft by the co-authors is underway.

Testing the Effectiveness of the Matching System

Matching success of the computer system had not been measured since the database numbered 12,000 photos in 1991. This year we initiated a test of matching success rate with a database at roughly 25,000 photos. The database was stratified by photographic quality code, and a random draw was conducted of approximately 0.5 percent of the database for each photo quality code (quality 1 (excellent): 15 photos, quality 2 (moderate or good): 80 photos; quality 3 (poor): 30 photos). Results of matching the quality 1 photos were presented at IWC (Mizroch and Harkness 1999), and testing of the other quality codes has just been completed and will be presented in the final draft of the paper. In 10 of 15 cases, the first match was found in the top 0.27% of the database (fewer than 70 photos evaluated). In all 15 cases, the first match was found in the top 3.1% of the database. On the average, the first match was found in the top 0.5% of the database (approximately 130 photographs) (SD=0.0079).

Citations

Gabriele, C. G., Straley, J. M., Mizroch, S. A., Baker, C. S., Glockner-Ferrari D., Ferrari, M. J., von Ziegesar, O., Darling, J., Cerchio, S., Craig, A., Quinn II, T. J., Herman, L. H., McSweeney, D., and Jacobsen, J. In review. Calf mortality in central North Pacific humpback whales.

Mizroch, S. A., and S. A. D. Harkness. 1998. Long term match of a North Pacific humpback whale. Marine Mammal Society Newsletter 6:7-8 pp.

Mizroch, S. A. ānd S. A. D. Harkness. 1999. A test of computer-assisted matching using the

North Pacific Humpback Whale Fluke Photograph Collection, April 1999. Presented as a working paper to the International Whaling Commission Scientific Committee.

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

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	G. 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	R. Baird
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

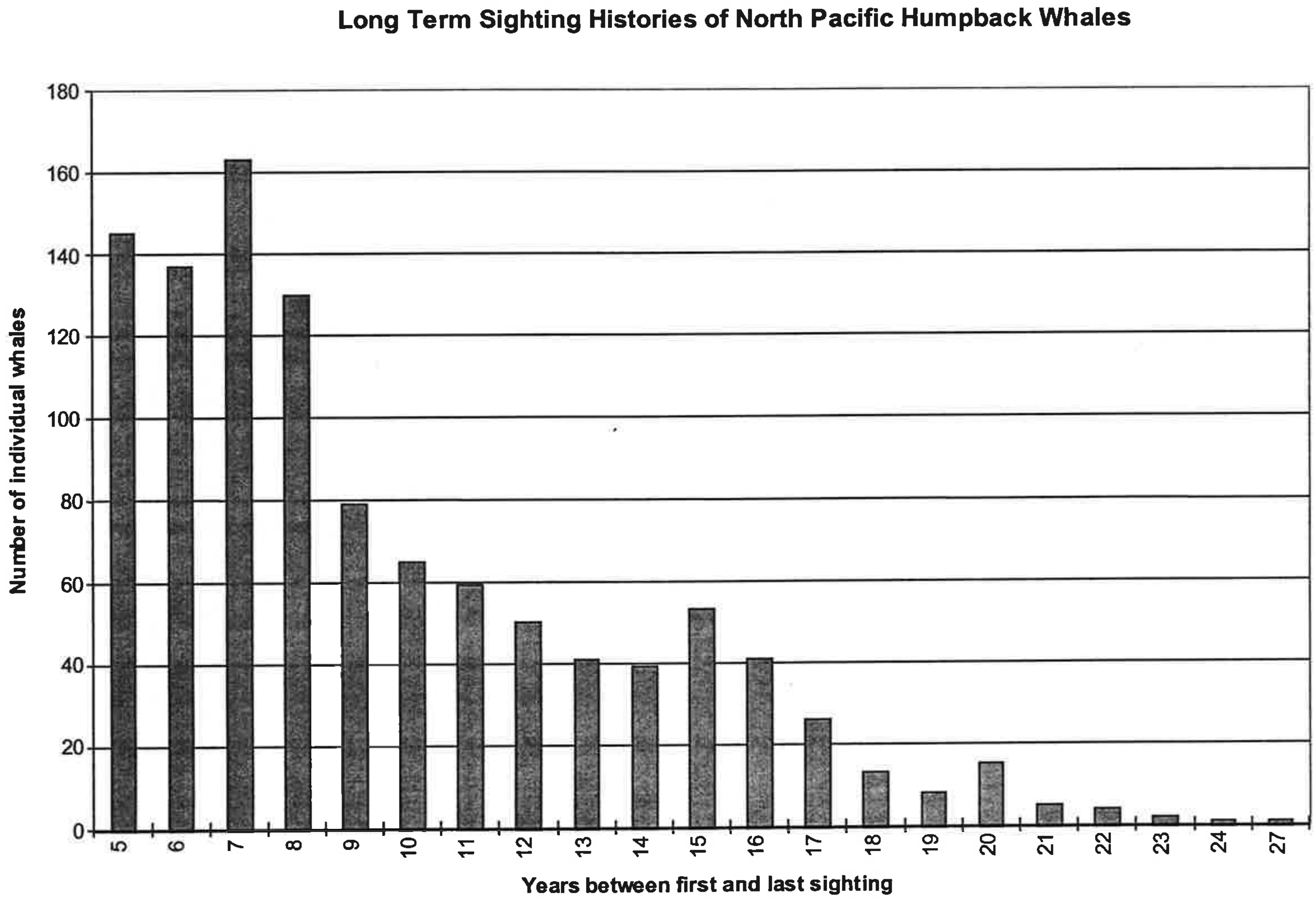
Table 2. Number of humpback whale photographs in the database, by area and year.

Year	*Alaska*	*California*	*Canada*	*Colombia*	*Hawaii*	*Japan*	*Mexico*	*Ogasawara*	*Okinawa*	*Oregon*	*Washington*	*Total*
1966							1					1
1968	10											10
1969	4											4
1970	2											2
1972	29											29
1973	13											13
1974	50											50
1975	37				3							40
1976	66				68							134
1977	269		2		27							298
1978	271				68		84					423
1979	322				121		27					470
1980	600	3			513		68					1,184
1981	365				793		20				5	1,183
1982	194		1		311							506
1983	124	10	1		410		8					553
1984	375		1		310		10					696
1985	226	2	8		355		10					601
1986	522	96	4	1	866		107					1,596
1987	369	93	2		828		107	8				1,407
1988	259	111	16		1,362		164	19				1,931
1989	247	55	14	41	1,106		316	70	2			1,851
1990	143	115	13		971		247	105	17	23	1	1,635
1991	485	265	18		953	18	307					2,046
1992	898	398	28		891	15	180			5		2,415
1993	308	255	48		1,217	17	96					1,941
1994	575	242	1		415	37	82				13	1,365
1995	619	318			614	33	82				43	1,709
1996	28	41			939		117					1,125
1997	2				1		129					132
Total	7,412	2,004	157	42	13,142	120	2,162	202	19	28	62	25,350

Table 3. 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	934	1	6	392	-	5	8	9	-	-
California	1	521	2	1	-	28	60	1	18	4
Canada	6	2	49	22	-	4	3	2	-	9
Hawaii	392	1	22	1834	2	8	-	23	1	-
Japan - Ogasawara		-	-	2	6	-	-	-	-	-
Mexico - Baja	5	28	4	8	-	131	32	17	2	3
Mexico - Mainland	8	60	3	-	-	32	109	9	7	2
Mexico - Revillagigedos	9	1	2	23	-	17	9	132	-	1
Oregon	-	18	-	1	-	2	7	-	21	-
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.



INCORPORATING TRADITIONAL KNOWLEDGE INTO TESTABLE HYPOTHESES OF ARCTIC ICE SEAL ECOLOGY

John L. Bengtson[1] and Henry Huntington[2]

[1]National Marine Mammal Laboratory
Alaska Fisheries Science Center
National Marine Fisheries Service, NOAA
7600 Sand Point Way NE
Seattle, Washington 98115, U.S.A.

and

[2]Huntington Consulting
P.O. Box 773564
Eagle River, Alaska 99577

Abstract

This project gathered traditional ecological knowledge (TEK) about Arctic ice seals (i.e., ringed, bearded, spotted, and ribbon seals) inhabiting eastern Norton Sound and Norton Bay, Alaska. The main activities included interviewing Alaska Native hunters and elders from the three Norton Sound communities of Elim, Shaktoolik, and Koyuk to document the TEK about ice seals that has been developed over many generations. The documentation of this knowledge was prepared in the form of maps and a written report, which will also be translated into an Alaska Native language to ensure that the information is widely available not only to the research and management communities, but also as a permanent reference to the Alaska Natives.

Introduction

Seals are an important subsistence resource for communities in coastal Alaska. They are used for food, including seal oil, and for clothing and other materials. In Norton Bay, hunters recognize six types of seals: ringed seals, bearded seals, spotted seals, ribbon seals, *qairaliq* seals, and *iigliq* seals. The latter two do not appear to have English or scientific names. To hunters in Norton Bay, they are distinct types of seals, with their own habits, appearance, and distribution, which are described below. In addition to these six, fur seals and sea lions are seen on rare occasions.

The purpose of this study was to document TEK about seals in the Norton Bay area. There were several reasons for doing so. First, it provided an opportunity for the area's hunters and elders to record their knowledge of the distribution, abundance, and natural history of seals and any changes that have occurred in the region. Such information is useful in better understanding the region's seal populations and in perpetuating the legacy of knowledge gathered over many generations. Second, it allowed local residents to express their views on the status of seal populations, so that their understanding and perspective is taken into account in research and management involving seals. Third, it provided an opportunity for collaboration between residents of seal hunting communities and scientists and wildlife managers. Such collaboration is an essential component of understanding the resources and making sure they continue to thrive in order to provide for future generations. Finally, documenting local knowledge can support local management efforts, such as those of the Elim-Shaktoolik-Koyuk Marine Mammal Commission.

This report describes what elders and hunters in the Norton Bay area know about seals. It is intended to be an accurate record of information gathered in a research workshop held in Shaktoolik, Alaska, February 1-5, 1999.

Insights into species' ecology provide scientists with essential perspectives with which to evaluate the stock assessments required by the Marine Mammal Protection Act. Relevant topics for ice seals include seasonal movements, distribution patterns, and habitat selection, especially in terms of assessing potential stock structure and designing aerial surveys for the purpose of estimating abundance. Studies addressing these topics will be most effective if they are focused on testable hypotheses that have been developed using all sources of relevant information.

One significant, though mostly under-utilized, source of information is the TEK of Alaska Native hunters. Such knowledge, based upon individual experiences evaluated in terms of the information passed on from other hunters and one's elders, can form a coherent perspective of the ecology of local regions. The TEK for a specific area is comprised of information integrated by hunters who have been active in that region for extended periods, and who routinely stake their livelihood on its accuracy and utility. For scientists, TEK can serve an important role in developing experimental designs and scientifically testable hypotheses for research on species for which there is relatively little scientific information.

Methods

Ice seal TEK was gathered during semi-directive group interviews in a workshop context, following the methodology used by Huntington and Mymrin (1996) in this region for the beluga whale project. The main data gathering and review portions of this project was accomplished in two phases: 1) group interviews, in which hunters shared their knowledge of ice seals, and 2) a review session in which hunters reviewed, commented, and refined the draft maps and text prepared from the group interviews. This methodology allows for integrating a broad range of ecological factors (e.g., ice, currents, fish, killer whales) relating to seal distribution, behavior, and abundance. The participants in the workshops were experienced ice seal hunters and skin sewers from the Elim-Shaktoolik-Koyuk area.

In a semi-directive interview format (for a full discussion of this method in the context of traditional ecological knowledge, see Huntington and Mymrin 1996, and Huntington 1998), participants were guided in the discussions by the interviewer, but the direction and scope of the workshop are allowed to flow with the participants' thoughts. There was no fixed questionnaire, nor a pre-set limit on the time for discussions or the topics that must be covered.

For the workshop in this study, we had a number of topics that we wanted to cover, though the order in which they were covered did not matter. We initiated discussions with a general question, such as "What types of seals do you see in this area?" The resulting discussion led to a number of other topics, interwoven with each other, and covering the majority of the topics on our list. If the discussion faltered, or if we were not clear on a point, we would ask further questions. The workshop was more of a discussion or an extended conversation.

To record spatial information, mylar or acetate sheets on top of printed maps were used, recording locations with permanent ink markers, and writing notes alongside. The geographic information was entered into a GIS using ArcInfo software. The maps produced in the final report were created by exporting the GIS coverages into CorelDraw for annotation and printing.

Based on the initial round of interviews, a draft report was prepared for review by the participants in the study. This review, which included a review workshop held in Elim on May 25, 1999, was an opportunity to correct any factual errors, to add information that had been missed in the initial interviews, and to make sure that the report did not contain material that might harm the interests of residents of the area.

The project was intended to cover the areas in and around Norton Bay in which seals are seen and hunted on a regular basis. The project was not intended to cover areas outside the Elim-Shaktoolik-Koyuk region.

Results

Norton Bay residents recognize six types of seals that are commonly seen in the region. Four of these—ringed seals, bearded seals, spotted seals, and ribbon seals—are species known to science. Whether the two other types of seals known in Norton Bay—locally called *qairaliq* and *iigliq*—are known to science, and if so by what names, is unclear at this time. For the purposes of this project, all six types of seals were described separately. In addition to these commonly-seen seals, fur seals and sea lions are seen infrequently. The participants in the study had a number of other observations related to seals and the marine environment in the Norton Bay area. The following paragraphs provide several brief examples of the types of traditional knowledge relevant to the various species of seals in the Norton Bay area.

Ringed seals

Ringed seals are found in Norton Bay all year, and are most abundant from September to June, or from just before freeze-up until break-up. Most ringed seals go north with the ice in spring, but some stay in the region in summer. If the wind keeps the ice in Norton Bay until it melts, more seals will remain in the area in summer since they will have remained with the ice. If the ice is blown out of the bay before it melts, many of these seals will migrate north. Most of the seals that leave the area return with the fall herring run before freeze-up. In fall, during freeze-up, ringed seals push the fresh ice up to create hummocks through which they can breathe. The hummocks are not open all the way, but have only a small hole through which the air can come in. Ringed seals maintain a network of such holes to get from safe areas under the ice out to open water for feeding. They will maintain the holes all winter. In winter, male ringed seals travel around, but females stay in one area to make dens and have pups. There are fewer ringed seal now than there were 20 years ago. They are still abundant in the spring, but there are fewer in the fall. In 1998, in two separate cases, ringed seals were taken that appeared normal but that yielded very light, clear seal oil that tasted odd and was regarded as unfit to eat. One person who ate meat from one of these seals became ill, perhaps as a result of the meat. The cause of this anomaly is not known, and it had not been seen before.

Bearded seals

Bearded seals are found in the Norton Bay area year round. Their abundance is greatest in the winter months from freeze-up to break-up. At this time of year, they are found along the ice edge. In spring, most bearded seals will move northwards with the ice, but some stay in the area all summer.

The ones that stay all summer include young bearded seal that go up rivers and stay there for the summer, living alone and occasionally hauling out on the riverbank. When the ice begins to form in fall, these seals return to the salt water for the winter. Bearded seals have been seen as far as 50 miles up the Koyuk River. Another group, composed of large adults, stays out in the deeper water off Norton Bay all summer. They tend to be black and to have thin blubber that is darker in color than that of other bearded seals. Their blubber makes excellent seal oil, but their skins are so thick they can only be used as a cutting surface. These seals are regarded as a separate type of bearded seal.

Typically, bearded seals are found in areas where invertebrates are common, such as at Besboro Island and Cape Denbigh. Bearded seals eat clams, shrimp, crabs, mussels, and other bottom foods. They also eat fish. Bearded seals have pups on the floating ice in May and June, when the brant fly north and the ice begins to break up. The females will help their pups shed the lanugo (fluffy, soft fur of the newborn), rolling it into a ball and leaving it on top of the ice where the pup was born.

Spotted seals

Spotted seals migrate through the Norton Bay area in spring and fall, though some will remain in the region all summer. In spring, spotted seals tend to be out on the pack ice, beyond easy hunting range, and so are not seen as often as in fall when they migrate into the area before freeze-up, at the same time as the returning bearded and ringed seals. Spotted seals often travel in large groups. Spotted seals are common on the north end of Besboro Island in summer, hauling out on a point of land that is near the waterline. Spotted seals will also haul out on rocks near Cape Darby in spring and in fall, during the migration. Spotted seals that are present in summer often bother commercial fishermen by eating the heads of silver salmon. They do not eat the bodies nor do they eat chum salmon. Spotted seals do not get caught in the fishing nets. In fall, spotted seals are often seen in particular places in Norton Bay. In 1952, a year of very late freeze-up, hunters saw spotted seals in open water near the beach on the east side of the bay, near Cottonwood. They were thought to be feeding on herring, swimming in towards shore to chase the fish into the shallows. In spring, spotted seals feed on spawning herring, and can be seen with herring eggs stuck to their whiskers and fur. They swim through the herring school with their mouths open, trying to catch fish. Usually in spring, spotted seals arrive with their pups already able to travel with them. They usually arrive in May and June, though one was taken by a Shaktoolik hunter in March, which was regarded as an anomaly.

Huntington, Henry P., and Nikolai I. Mymrin. 1996. Traditional ecological knowledge of beluga whales: an indigenous knowledge pilot project in the Chukchi and northern Bering Seas. Final Report. Anchorage: Inuit Circumpolar Conference. 88pp.

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. Other studies will appear in peer-reviewed journals.

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 August 24-28 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 September 9-20 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 were collected from two sites 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 pp.

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.

GENETIC IDENTIFICATION OF SALMONID BONE FROM PINNIPED FOOD HABITS SAMPLES

Harriet Huber[1], Linda Park[2], Eric LaHood[2], Greg Mackey[2], and Maureen Purcell[2]

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

[2]Conservation Biology Division
Northwest Fisheries Science Center, NMFS, NOAA
2725 Montlake Blvd. East
Seattle, Washington 98112

Abstract

To assess pinniped predation on salmonids from scat where only salmonid bones are present, the National Marine Mammal Laboratory (NMML) and the Conservation Biology Molecular Genetics Laboratory (CBMGL) collaborated on a study to develop molecular genetics techniques to identify salmonid bones to species. To date, CBMGL has been successful in isolating DNA from salmonid bone which has passed through a harbor seal digestive tract and in identifying salmonid species through direct sequencing of the control region (D-loop) of mtDNA and using RFLP (Restriction fragment length polymorphism) analysis on mitochondrial gene ND3. At the Umpqua River, Oregon, 673 scat samples were collected in 1997 and 1998 to assess harbor seal predation on endangered cutthroat trout. Thirty of the scat samples (4%) had some evidence of salmonid predation. Two samples contained both bones and otoliths and 28 samples contained only salmonid bones. Analysis is not yet complete. To date, from 1 to 9 bones in each scat sample have been processed; 71 % of the processed bones/teeth (53/76) have been identified to species. At least one bone or tooth has been identified as coho, chinook or steelhead from the 24 scats (80%) processed so far. No cutthroat have been identified yet. In most samples, only one salmonid species was identified; in 2 samples with juvenile fish, 2 species were found. In the samples where otoliths were present, the bone and otolith identification agreed. At present, the cost of direct sequencing is $20 per bone; analysis of 12 to 24 bones takes about a week. Work is continuing on finding a quicker species assay and on the feasibility of using microsatellites from nuclear DNA to identify salmonid stocks or Evolutionary Significant Units (ESU).

Introduction

Since the passage of the Marine Mammal Protection Act in 1972, the number of harbor seals and California sea lions in Washington, Oregon, and California has increased by 5 to 7% each year. During the same time, the number of salmonid stocks listed as endangered has also increased. Consequently, the question of what impact increasing pinniped populations are having on endangered salmonids has intensified in importance.

For many years, pinniped food habits studies relied on identification of otoliths in scat to determine what prey had been consumed. For most fish, otoliths permit identification to species level and also age class/size of fish. However, with some large salmonids, heads may not be consumed; consequently, otoliths are not present in scat. In addition, salmonid otoliths are fragile; as a result, frequently the otoliths that are present are worn or damaged and therefore not possible to identify to species or to age class. In more recent food habits studies, identification of diagnostic bones has been used to determine prey species when otoliths were not available. Even with this method, problems may occur because the diagnostic bones for salmonids are useful in identification only as far as family.

In 1994, National Marine Mammal Laboratory (NMML) began a study to determine the effect of pinniped predation on ESA listed salmonids, focusing on harbor seal predation on spring chinook (adults and smolt) in the Columbia River. From 1994 to 1997, 1,694 scat samples were collected from seals on the Columbia River. In 1997, NMML began an investigation of harbor seal predation on endangered cutthroat trout at the Umpqua River, Oregon where 120 scat samples were collected in 1997 and 553 samples were collected in 1998. From the Columbia and Umpqua Rivers, 218 samples contained remains from salmonids, but only 24 % of these samples contained identifiable otoliths. Ream et al. (1998) did developmental work on determining prey from bones found in Steller sea lion scat. Because of this, NMML began a collaborative study with the Conservation Biology Molecular Genetics Laboratory (CBMGL) to develop techniques to isolate mtDNA from salmonid bones and to genetically identify the species of salmonid represented by bone where otoliths were not available or where timing of runs could not be used to differentiate between species.

Methods

Because bone samples are destroyed in processing, the feasibility of isolating DNA from salmonid bones was tested first on bones that had been digested in the laboratory with trypsin (a digestive enzyme), then on bones collected from a captive harbor seal feeding study (where the species of salmonid eaten was known) before study samples were processed.
To isolate the DNA, salmonid bones were prepared by soaking in dilute (10%) bleach solution and then rinsed. The bone samples were then powdered, digested using Proteinase-K, and phenol extracted (Honda et al. 1994). DNA was run out on agarose gels to determine overall quality and quantified fluorometrically. CBMGL amplified the mtDNA D-loop region using PCR. The products were cleaned and sequenced using radio-labeled neucleotides. The sequences were compared with known sequences from west coast salmonids (Shedlock et al. 1992). DNA extracted from digested bone is degraded, consequently the retrievable fragments are only 200-300 bp long compared to ~1100 bp for the entire D-loop region, thus it was necessary to find a smaller diagnostic area to distinguish species from each other (Table 1).

Direct sequencing of samples is expensive and labor intensive. We are currently in the process of developing a faster method of identification. Two genes, ND3 and ATPase 6, have been used to construct robust phylogenies of Pacific salmon (Domanico and Phillips 1995). The authors also reported little intraspecific variation from wide geographic locations. CBMGL sequenced a portion of the ND3 gene in cutthroat, chinook, coho, and steelhead and aligned it to the published sequences of these species, as well as chum, pink, and sockeye salmon. In a small 100 base pair stretch of DNA, there were enough fixed sequence variants to confidently distinguish all species. This 100 base pair stretch was sequenced in twenty bone samples and all samples were easily identified to species. ND3 appears quite promising for RFLP (restriction fragment length polymorphism) analysis as only a single nucleotide has been found to be polymorphic within a species. We are currently investigating RFLP and the other non-sequencing based assays using both the ND3 and ATPase 6 genes.

Results

DNA was successfully extracted from salmonid bones from trypsined fish, from bones from a harbor seal captive feeding study and from bones in harbor seal scat. Salmonid bone or teeth from 27 scat samples collected from the Umpqua River between September and November 1997 and April to October 1998 have been processed so far (Table 2). Each scat had from 1 to more than 100 salmonid bones present. DNA was successfully extracted from vertebrae, gill rakers and teeth which are the salmonid hard parts most commonly found in harbor seal scat. To date, 76 bones/teeth have been processed (1 to 9 bones/teeth from 27 of the 30 scat samples). Of these, DNA was successfully amplified from 53 (70%). Bones/teeth from 24 samples have been identified to species (Table 2). The samples described as 'unidentified' will be reprocessed. The species identified include steelhead, chinook and coho; no cutthroat have yet been found. In most samples only one salmonid species was present, however, in two samples containing juvenile fish had two species, one contained chinook and coho; the other contained coho and steelhead. In both scat samples where otoliths were present, bone and otolith identification agreed.

We also processed 5 harbor seal scat samples containing salmonid bones from the Ozette River, Washington where there is concern about harbor seal predation on endangered sockeye. In those samples we found only coho and chinook. There was no evidence of sockeye predation.

At present, the cost for direct sequencing is approximately $20 per bone and the processing time is approximately 12 to 24 bone samples per week.

Conclusions and further questions

So, far this pilot project has been successful in isolating DNA, in identifying salmonid species and in determining areas where a perceived problem of pinniped predation on an endangered salmonoid has turned out to be unwarranted. As a pilot project, questions of interpretation and direction for further study remain. Each scat sample contains a varying number of salmonid bones, some as few as one, some more than 100 bones. How many bones should be sampled from each scat sample to detect if more than one salmonid species is present? It is suggested that if <10 bones are present, sample all bones and if > 100 bones are present, sample 20 bones. Under this sampling regime, if two species are present and the species in lower abundance is represented by about 15% of the bones, the probability of missing that species is less than 0.05.

Is it possible to determine the minimum number of individuals genetically from bone DNA? This could be done using microsatellites, but, because all bones would have to be tested, it may be too expensive to do for more than a few samples. In this case, it is easier to determine if the DNA is from more than one individual than if it is from the same individual.

What is the potential for identifying stocks or ESUs? The Columbia River has many stocks of salmonids, many of which are ESA-listed. The ability to identify salmonid bone to stock or ESU would provide great insight into the potential impacts of pinniped predation on the recovery of listed ESUs. It is probable that this can be done using microsatellites, but questions remain, which loci should be looked at and how many loci should be investigated?

What is the potential for differentiating between wild and hatchery salmonids? This might be better done with scales or otoliths which can detect the feeding regimes of hatchery raised smolt. Few scales are found in harbor seal scat, more are found in sea lion scat.

Literature Cited

Domanico, M. J. and R. B. Phillips (1995). Phylogenetic analysis of Pacific salmon (*genus Oncorhynchus*) based on mitochondrial DNA sequence data. Mol. Phylogenet. Evol. 4(4): 366-371.

Honda, Katsuya. Eiko Sugiyama, Akira Tsuchikane, Yoshihiko Katsuyama, and Noriyoshi Harashima. 1994. Nested amplification of COL2A1 3' variable region in skeletal remains. Jpn. J. Legal Med. 48 (3): 156-160.

Ream, R.R., T.R. Loughlin, P. Bentzen, and R. L. Merrick. 1998. Fecal DNA: Steller sea lions and their prey. Abstract, World Marine Mammal Conference. Monaco, 20-24 January 1998. p 111.

Shedlock, A.M., J.D. Parker, D. A. Crispin, T.W. Pietsch, and G. Burmer. 1992. Evolution of the salmonid mitochrondrial control region. Mol. Phylog. Evol. 1(3):179-192.

Table 1. MtDNA sequences for 6 salmonid species, similarities in neucleotides are shown in dark type, differences are in light type.

		10	20	30	40	50
Coho	1	TGTTAAACCC	CTAAACCAGG	AAGTCTCAAA	TCAGCATGAT	ATTTTTTATA
Chinook	1	TGTTAAACCC	CTAAACCAGG	AAGTTTCAAA	TCAGCATGAT	ATTTTTTATA
Cutthroat	1	TGTTAAACCC	CTAAACCAGG	A[illegible]GTATC[illegible]AA	TCAGCAATAT	-TTTTT-GTA
Steelhead	1	TGTTAAACCC	CTAAACCAGG	AAGTCTCAAA	TCAGCGTAAT	ATTTTT-ATA
Chum	1	TGTTAAACCC	CTAAACCAGG	AAGTCTCAAA	TCAGCGTAAT	ATTTTT-ATA
Pink	1	TGTTAAACCC	CTAAACCAGG	AAGTCTCAAA	TCAGCGTAAT	ATTTTT-GTA

		60	70	80	90	100
Coho	51	TACATTAATA	AACTTTTGGT	GCACTTT[illegible]TA	GCATTTGGCA	CCGACAGCGC
Chinook	51	TACATTAATA	AACTTTTAGT	GCACTTTATA	GCATTTGGCA	CCGACAGCGC
Cutthroat	51	TACATTAATA	AACTTTTG-T	GCACTTTATA	GCATTTGGCA	CCGACA[illegible]CGC
Steelhead	51	TACATTAATG	AACTTTTGAT	GCACTTT--A	GCATTTGGCA	CCGACAGCGC
Chum	51	TACATTAATA	AACTTTTGAT	GCACTTTATA	GCATTTGGCA	CCGACA[illegible]CGC
Pink	51	TACATTAATG	AACTTTTGAT	GCACTTTATA	GCATTTGGCA	CCGACAGCGC

		110	120	130	140	150
Coho	101	TGTAATGCAT	ACACTTTCAT	AATTAAAGTA	T-ACATTAAT	AAACTTTTCG
Chinook	101	TGTAATGCGT	ACACTTTCAT	AATTAAAGTA	T-ACATTAAT	AAACTTT[illegible]CG
Cutthroat	101	TGTGGTGCGT	ACACTTTCAT	AATTAAAGTA	TTACATTAAT	AAACTTTTCG
Steelhead	101	TGTAATGCGT	ACACTTTCAT	AA[illegible]TAAAGTA	TTACATTAAT	AAACTTTTCG
Chum	101	TGTAATGCGT	AT[illegible]ATTTCAT	AATTAAAGTA	T[illegible]ACATTAAT	AAACTTTTCG
Pink	101	TGTAATGCGT	ACATTTTCAT	AATTAAAGTA	TTACATTAAT	AAACTTTTCG

		160	170	180	190	200
Coho	151	ATCC-CTTAG	[illegible]AGCACCACG	GCACCGGACA	GCACTGTTAT	AGACACTATT
Chinook	151	ATCC-CCTAG	[illegible]AACACCAT-	----------	----------	--------TT
Cutthroat	151	GCCCCCTTCG	TAGCATC-TG	GCACCG-ACA	ACACTGATAT	TAATACCATT
Steelhead	151	ACCCACTTTG	TAGCACC-TA	GC[illegible]CCG-ACA	ACGCTGTTAT	CAATGCCATT
Chum	151	TCCC-CTTTC	[illegible]CACACT-CA	GCACCGGACA	ACGCTATTAT	CAGCGCCATT
Pink	151	GCCCA-TTTT	[illegible]CACGCC-CG	GCACCG[illegible]A[illegible]A	ACGCTGTCAT	CA[illegible]CGCCATT

		210	220	230	240	250
Coho	201	TCCACCCCCC	AGCCCACTGC	TGG-CGTA--	....	....
Chinook	201	TCC-CCGCCT	[illegible]ACCCACTGC	TGGACGTA--	....	....
Cutthroat	201	TCCAC-GCAC	[illegible]ACCCACTGC	TAGACGTA--	....	....
Steelhead	201	TCCAC-GCAC	AGCCCGCCGC	T-GACGTA--	....	....
Chum	201	TTC-CCGCAC	[illegible]GCCC-CTGC	TCG-CGTA--	-----.....	....
Pink	201	TTA-CTGCAC	AGCCG-CTGC	TGG-CGTAGC	TTAAC	

Table 2. Summary of genetic analysis of salmonid bone from Umpqua River harbor seal scat samples, September to November 1997 and April to October 1998. Samples marked "unidentified" will be reprocessed.

Sample #	Date	Sample Description	Number processed	Number amplified	Number sequenced	Species
0001-97	9/16/97	1 bone, no vert	1	1	0	unidentified
0003-97	9/16/97	5-6 bone fragments	6	5	5	chinook
0014-97	9/22/97	tooth, bone	5	3	3	chinook
0058-97	10/17/97	vertebra	1	1	1	chinook
0059-97	10/17/97	114 bones, otoliths	9	3	3	chinook
0060-97	10/17/97	bone fragments	6	2	2	chinook
0066-97	10/20/97	3 vertebrae	3	2	3	coho
0078-97	10/31/97	109 bones; otoliths	4	4	4	chinook
0079-97	10/31/97	tooth, bone	2	2	2	chinook
0087-97	11/09/97	teeth, bone	4	3	3	chinook
0090-97	11/09/97	vertebrae	5	3	3	coho
0132-97	11/24/97	bone	2	2	2	coho
0133-97	11/24/97	bone	7	7	5	coho
0134-97	11/24/97	bone	1	1	0	unidentified
0187-98	8/20/98	bone	1	1	1	coho
0188-98	8/20/98	teeth, bone	3	2	2	coho, steelhead
0290-98	8/19/98	1 vertebra	1	1	1	chinook
0303-98	10/7/98	vertebrae fragments	0	0	0	unidentified
0315-98	10/7/98	vertebrae fragments	0	0	0	unidentified
0320-98	9/19/98	teeth, bones	1	1	1	chinook
0325-98	9/18/98	vertebrae fragments	0	0	0	unidentified
0416-98	8/6/98	vertebrae	1	1	1	coho
0423-98	8/6/98	1 vertebra	1	1	1	chinook
0446-98	8/6/98	vertebrae	2	2	2	chinook
0457-98	8/6/98	teeth, bone	1	1	1	chinook
0618-98	4/15/98	bone	3	2	2	chinook, coho
0623-98	4/15/98	bone	1	1	1	chinook
0662-98	4/13/98	1 tooth	1	0	0	unidentified
0703-98	5/14/98	vertebrae	3	3	3	coho
0707-98	5/14/98	vertebrae	1	1	1	coho
Totals			76	56	53	

WASHINGTON STATE PINNIPED DIET STUDIES 1983-1998.

Patrick J. Gearin[1], Kirt M. Hughes[1], Lawrence L. Lehman[1], Robert L. DeLong[1],
Steven J. Jeffries[2] and Merrill E. Gosho[1]

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

[2] Marine Mammal Investigations
Washington Department of Fish and Wildlife
7801 Phillips Road, S.W.
Tacoma, WA 98498

Abstract

For the years 1983 through 1998, a large amount of food habits data was collected for California sea lions, *Zalophus californianus*, and harbor seals, *Phoca vitulina,* in Washington State from scat (fecal) samples and from stomachs. Much of the data however, was not analyzed due to other priorities. Recent funding by NMFS allowed for completing the processing of these food habits samples and initiation of the analysis and reporting of the data. During the last year, over 2,700 scat samples and 200 stomach content samples from California sea lions and harbor seals have been cleaned, sorted, and prepared for prey identification. Prey identifications have been completed for 1,029 scat samples from sea lions and harbor seals. Recent analysis of prey identified from California sea lions scats from 1988 and 1989 indicates that the order of frequency of occurrence for the top five prey was the same for both years. The primary prey in order of frequency were; Pacific whiting, *Merluccius productus*, Spiny dogfish, *Squalus acanthias*, Pacific salmon, (Salmonidae), walleye pollock, *Theragra chalcogramma*, and Pacific herring, *Clupea pallasi*. Three of the top five species (Pacific herring, Pacific whiting, and walleye pollock) are among those currently under review as candidate species for Endangered Species Act (ESA) listing in Washington. In addition, some salmon stocks (ranked third in frequency) have recently been listed under the ESA. Further analysis of these food habits data may provide information on the relationships of these depressed stocks to pinniped predation.

Introduction

There is currently little information on the diet and general food habits of California sea lions (*Zalophus californianus*) and harbor seals (*Phoca vitulina)* within Washington State. A recent document by the National Marine Fisheries Service (NMFS) summarizes available information in Washington for both species of predator (NMFS, 1997). More detailed information however, is needed in light of the current status of various fish stocks throughout Puget Sound and Hood Canal. The recent listings of Puget Sound chinook salmon, *Oncorhynchus tshawytscha,* and summer chum salmon, *Oncorhynchus keta*, in Hood Canal as threatened under the Endangered Species Act (ESA) require the initiation of recovery plans which assess potential threats to the recovery of these stocks (NMFS, March, 1999a). In addition, seven non-salmon ESA candidate species are under review in Puget Sound for listing, including; Pacific herring, *Clupea pallasi*, Pacific whiting, *Merluccius productus*, walleye pollock, *Theragra chalcogramma*, Pacific cod, *Gadus macrocephalus*, brown rockfish, *Sebastes auriculatus*, copper rockfish, *Sebastes caurinus*, and quillback rockfish, *Sebastes maliger* (NMFS, June, 1999).

This study entails the analysis of scat and stomach contents from California sea lions collected from 1986 through 1998 (Table 1) and harbor seals collected from 1983 through 1998 (Table 2) in Washington State. This report will update the progress of the prey identifications completed for California sea lions scats collected in 1988 and 1989 and further processing of scats and stomachs from sea lions and harbor seals.

Materials and Methods

Scat Collections and Diet Assessment

Scats from California sea lions and harbor seals were collected opportunistically at haulout sites in Washington. California sea lion collection sites in Puget Sound were at Everett, Edmonds, Shilshole Bay, and Toliva Shoals. On the outer coast scats were collected at East Bodelteh Island, Carroll Island, Sea lion rock, and Tatoosh Island. Harbor seal collection sites in Puget Sound were at Everett, Gertrude Island, and the Nisqually River Delta. In the Strait of Juan de Fuca and on the outer coast scats were collected at Dungeness Spit, Protection Island, Cooke rock, East Bodelteh Island, Father and Son Rock, and Tatoosh Island. Scats were frozen after collection and later thawed to be processed and identified at the National Marine Mammal Laboratory (NMML) in Seattle. The scats were emulsified in a solution of water and mild liquid detergent for one or more days and then rinsed through a series of nested metal sieves with mesh sizes of 1.4 mm, 0.71 mm and 0.5 mm. The contents, once sieved, were sorted and prey hard parts such as fish otoliths and bones, and cephalopod beaks and statoliths were recovered. The prey hard parts were then examined with a dissecting microscope with an ocular micrometer magnification from 6.4X to 32X. Otoliths were identified to the lowest taxa possible, counted left and right, measured and categorized according to relative condition. Prey identifications from fish bone were made using vertebrae, gill rakers, otic capsules, teeth and mouthparts or other distinctive diagnostic features. Two measures of relative prey importance were calculated from the scat contents; frequency of occurrence (FO) and minimum number of prey (N_{min}). The FO was calculated as a percentage based on the occurrence of any given prey taxa in the total number of scat samples which contained identifiable prey components. The N_{min} was calculated as the minimum number of individual prey (e.g., herring and squid) represented in each scat sample. The N_{min} was determined by using diagnostic features such as otoliths, squid beaks, vertebrae identified to that taxa. For example, when a scat contained ten left and nine right otoliths from Pacific herring, the N_{min} for that sample for herring was ten. Squid beaks recovered were treated in a similar manner. If certain bony elements were recovered which could be identified but not quantified and no otoliths or squid beaks were recovered then the N_{min} was considered to be one. Fish size was estimated using species specific regressions which convert otolith length to fish length and mass as described in Harvey et al., (1995, in press). The length frequencies of walleye pollock consumed by sea lions during 1988-89 were estimated by measuring otoliths recovered from the scats. A correction factor (1.273) to account for degradation of the otoliths by digestion was used (J. Harvey, pers, comm.) and the corrected otolith lengths were then plugged in to a regression to convert otolith length to fish standard length.

Stomachs were collected from dead beach stranded California sea lions and harbor seals or those incidentally taken during a fishery. Collections were made at various sites throughout Washington. Once collected, stomachs were frozen, later thawed, weighed, contents removed, and inner stomach lining rinsed to recover remaining contents. The stomach was then re-weighed to determine the mass of contents. Volume of contents was determined by water displacement. Stomach contents were then processed and identified in the same manner as scat contents.

Results

California Sea Lion

From 1986 through 1998, 2,264 scats from California sea lions were collected primarily from Puget Sound haulout sites (Table 1). All of the California sea lion scats have been cleaned, processed and dried for identification. To date, 850 scats from 1986-1989 have been analyzed and prey components identified, quantified and measured (Table 1). Stomachs from 100 California sea lions were collected from 1987-1998 from beach stranded animals or sea lions incidentally taken in fisheries. All the stomachs have been cleaned and the contents sorted and mass and volume of contents has been determined. The identifications of prey from the stomachs still needs to be completed.

Harbor Seal

Harbor seal scat and stomach contents were collected opportunistically in Washington since 1983. A total of 470 harbor seal scat samples were collected from eight different haul out sites (Table 2). All of these samples have been processed which includes cleaning, sieving and rough sorting of components. Prey identifications, frequency and numerical proportion of prey has been completed for 179 of the samples (Table 2). Approximately 100 harbor seal stomachs were collected in Washington from 1988-1997. Most of the samples (95) were from harbor seals collected from incidentally caught animals in commercial fisheries and the remainder were from beach stranded animals. All of the stomachs have been cleaned and the contents sieved and rough sorted. Stomach content mass and volume has been determined. The stomachs collected were primarily from young seals less than 3 years of age, so a straight forward comparison to scat contents will not be made. The stomach contents data will be reported in a separate section of a future report. The prey identifications and numerical proportions of prey for each sample will be completed and reported by location and date in the final report.

1988-1989 California Sea Lion Scat Analysis

In 1988, 342 California sea lion scats were collected from Puget Sound from Everett (163), Shilshole Bay (154), Edmonds (24), and miscellaneous south Puget Sound locations (3). Identifiable prey components were identified in 300 of the total scats examined so n=300 was used for determining frequency of occurrence. The frequency of occurrence of prey for 1988 is shown in Table 3. At least 19 prey categories were identified from the 1988 scat samples with Pacific whiting (hake) ranking number one in frequency at 81% (Fig. 1, Table 3). Other important prey during 1988 were Spiny dogfish (25%), Salmonidae (18%), Walleye pollock (15.7%), Pacific herring (13%) and market squid (11.7%). During 1989, 273 scats were collected from Puget Sound from Everett and Shilshole Bay. Of this total, identifiable prey was found in 220 scat samples, so n=220 for frequency calculations. The prey for 1989 was very similar to the 1988 prey, with the first five major prey taxa being the same in both years (Fig. 2, Table 3). Pacific whiting (83%), spiny dogfish (19.5%), Salmonidae (12.3%), walleye pollock (9.5%), Pacific herring (8.6%) and market squid (3.6%) were the dominant prey for 1989. The only major differences between 1988 and 1989 was the frequency of market squid which was over 3 times greater in 1988 than in 1989 and of salmonidae which was about 1.5 times greater in 1988. This fact may be a result of the larger number of scats collected at Shilshole Bay in 1988 where squid and salmon were more prevalent. Although few salmonid otoliths were recovered in the scats, steelhead was identified in one sample from 1988 and at least 2 chinook salmon were identified from 1989. The remainder of salmonid identifications were made from salmon bone.

Size of Pacific Whiting

The mean estimated lengths for each year were 1988 (33.2 cm) and 1989 (36.0 cm.) (Figure 3). The estimated range of lengths were from 8.8 to 62.5 cm. There was no significant difference in lengths of Pacific whiting consumed between 1988 and 1989 (t-test, $p = 0.084452$). These data indicate that for both years, sea lions were feeding primarily on age 2 and 3 year old fish (Figure 3).

Summary and Discussion

The data resulting from the analysis of the harbor seal and California sea lion scat and stomach contents will provide an extensive amount of baseline information for these marine predators for the years 1983-1998. These data may be useful in constructing food consumption estimates for the 2 species and providing further information on the relationships of marine predators to their prey. Factors such as size of prey consumed can be estimated and these data can be compared between years to determine if shifts in prey selection have occurred. Comparisons between sea lion and harbor seal diet can also be made to evaluate potential competition or resource partitioning by the 2 species. These data may also provide further information on the potential impacts of predation on depressed fish stocks.

Citations

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

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 ecosystems of Washington, Oregon, and California. U.S. Dep. Comm., NOAA Tech. Memo. NMFS-NWFSC-28, 172 pp.

National Marine Fisheries Service. 1999a. Federal Register/ Vol. 64, No. 56 and 57,/ March 24 and 25, 1999., p. 14308 and 14508.

National Marine Fisheries Service. 1999b. Federal Register/Vol. 64. No. 118/ June 21, 1999, p. 33037.

Table 1. California sea lion scat collections from Washington State from 1986-1998.

Year	Number collected	Number sorted	Identified[1]
1986	100	100	100
1987	135	135	135
1988	342	342	342
1989	273	273	273
1990	135	135	0
1991	108	108	0
1994	362	362	0
1995	267	267	0
1996	93	93	0
1997	252	252	0
1998	197	197	0
Totals	**2264**	**2264**	**850**

[1] Prey components have been identified, measured, and quantified.

Table 2. Harbor seal scat collections in Washington State 1983-97.

Date	Location	Number Collected	Status
1983	Gertrude Island	12	sorted
1983	Dungeness Spit	20	sorted
3/10/88	Nisqually River	21	ID'd
9/26/91	Protection Is.	11	sorted
1989	Everett	112	ID'd
1995	Everett	46	ID'd
1996	Everett	69	sorted
1997	Everett	112	sorted
Total Everett		**339**	**339 sorted**
8/11/94	Father and Son	8	sorted
8/19/94	Cooke Rock	11	sorted
1996	Tatoosh Island	35	sorted
1997	Tatoosh Island	14	sorted
North Coast Total		**67**	**67 sorted**
Total all areas		**470**	**179 ID'd**

Table 3. Percent frequency occurrence of prey remains found in California sea lion scats from Washington State.

1988 Prey species	% FO	1989 Prey species	% FO
Pacific whiting	81.3	Pacific whiting	83.2
Spiny dogfish	25.3	Spiny dogfish	19.5
Salmonidae[1]	18.0	Salmonidae[2]	12.3
Walleye Pollock	15.7	Walleye Pollock	9.5
Pacific herring	13.0	Pacific herring	8.6
Loligo	11.7	Clupeidae	5.5
Gadidae	5.3	Loligo	3.6
Clupeidae	3.0	Shiner surfperch	2.7
Plainfin midshipman	2.0	Pile surfperch	1.4
Pacific tomcod	2.0	Plainfin midshipman	1.4
American Shad	1.7	Gadidae	1.4
Pacific cod	1.0	American Shad	0.9
Surfperch	0.7	Surfperch	0.9
Shiner surfperch	0.7	Undet Cephalopd	0.9
Raja spp	0.7	Pacific lamprey	0.9
Cottid sp	0.3	Pacific tomcod	0.9
Pacific lamprey	0.3	Raja spp	0.5
Pacific Mackerel	0.3	Ling cod	0.5
Petrale sole	0.3	Cottidae	0.5
		Pacific cod	0.5

[1]One sample from 1988 was identified to steelhead.
[2]Two samples from 1989 were identified to chinook salmon.

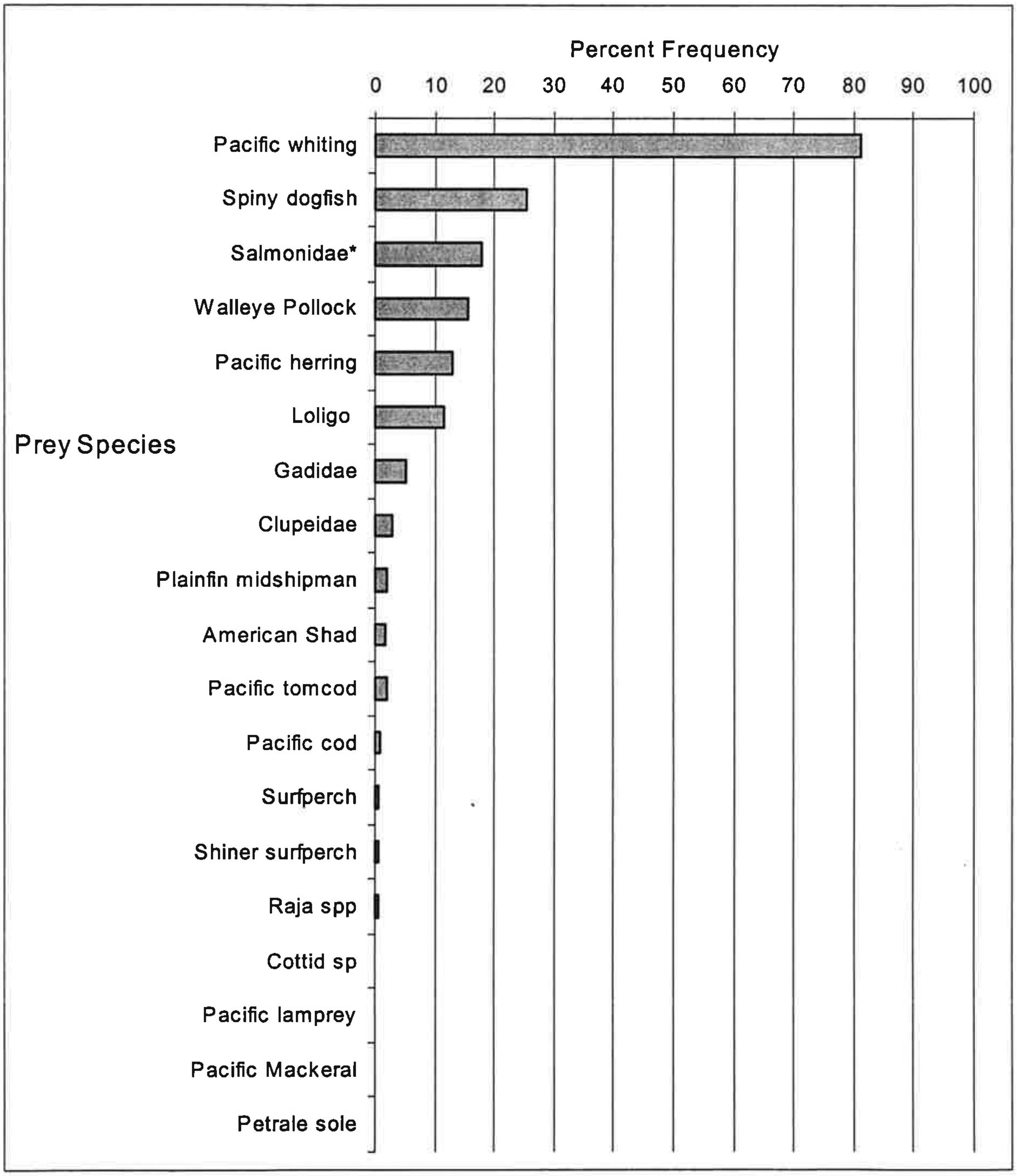


Figure 1. Frequency of prey identified from California sea lion scats collected during 1988 (n=300). Cottid sp. through Petrale sole have FO=0.3% therefore are difficult to interpolate. *indicates one sample was identified to steelhead and the remainder to *Oncorhynchus spp*.

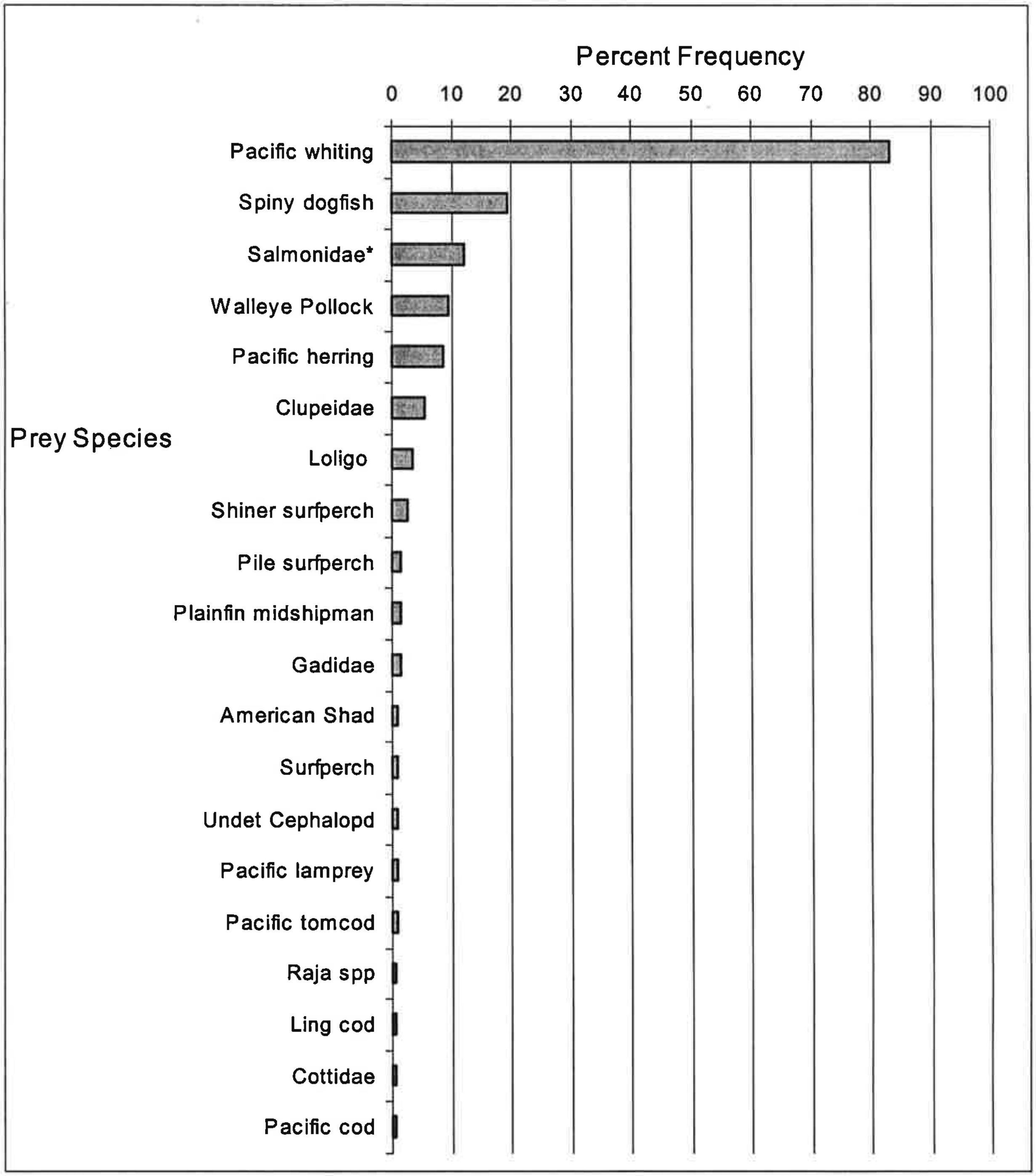


Figure 2. Frequency of prey identified from California sea lion scats collected during 1988 (n=300). *indicates two samples were identified to chinook salmon and the remainder to *Oncorhynchus spp*.

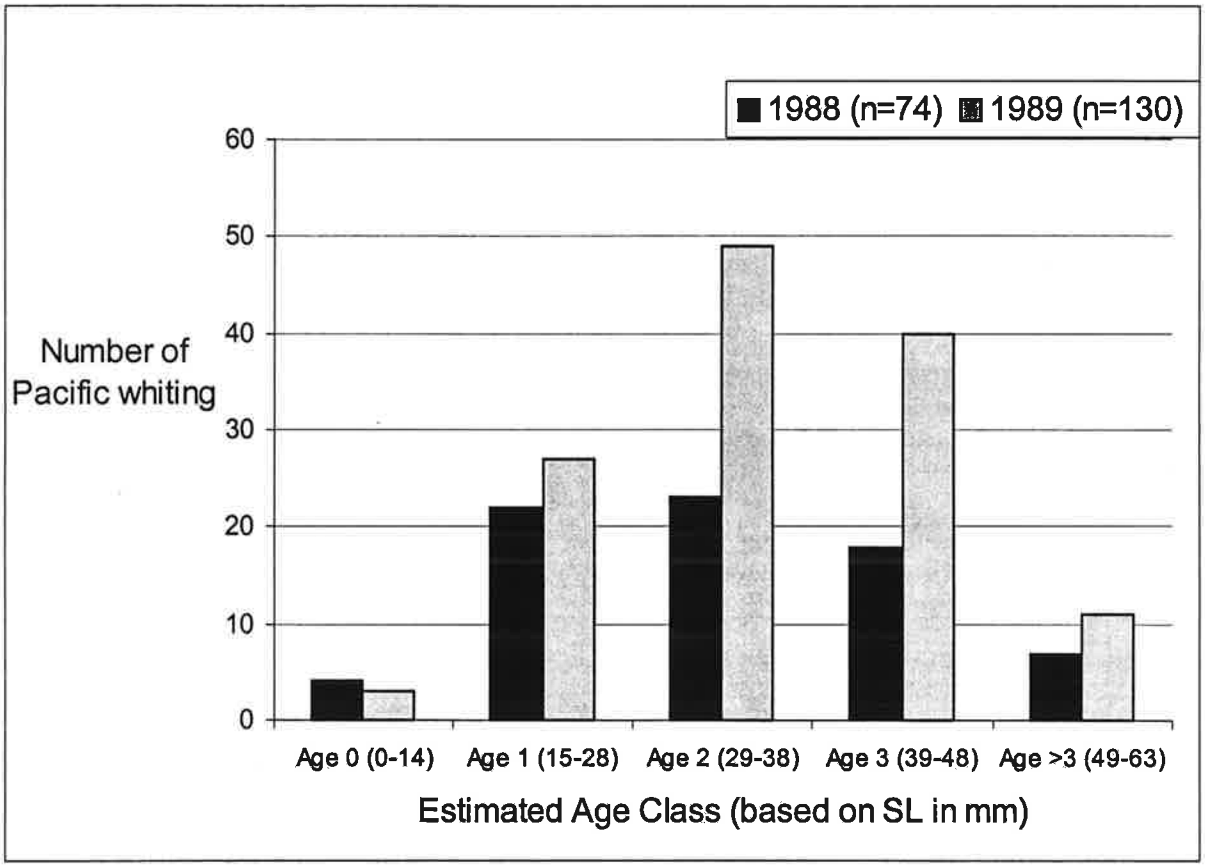


Figure 3. Estimated age class structure of Pacific whiting consumed by California sea lions. For 1988 the mean SL=33.2 mm the range SL=8.8-62.5 mm and 1989 the mean SL=36.0 mm and the range SL=10.3-56.0 mm.

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) 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 longline sets were completed in rough bottom near Buldir, Kasatochi to sample large fish and their prey. Oceanographic data were collected via a continuously operated thermosalinograph and conductivity-temperature-density (CTD) casts (n=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 3 sites in Alaskan 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 3 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 eight Orcas 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 had 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 17-18 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 21-23 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 had arrived with gusto and 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 scientific party disembarked on 24 March.

Methods

Hydroacoustic surveys

Acoustic data were collected along a series of parallel transects within a 10 nm radius of the three sites (Buldir, Kasatochi and Ugamak). Transect spacing was around 3 nm. The vessel generally operated at 10 kts 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 ships 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 kts. 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 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 I. 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 Pacific 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 NMFS REFM Food Habits Lab in Seattle.

Oceanographic data

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*), a 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 longline 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 ship board 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).

			START			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

FATTY ACID PROFILES OF STELLER SEA LIONS AND NORTH PACIFIC OCEAN FORAGE FISHES

Thomas R. Loughlin[1], and Stanley D.Rice[2]

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

[2]Auke Bay Laboratory
National Marine Fisheries Service, NOAA
11305 Glacier Highway
Juneau, Alaska 99801

Introduction

Application of fatty acid techniques to diet analyses for Steller sea lions and other North Pacific Ocean (NPO) predators has been slowed by several factors. The most important may be that only one North American laboratory performs fatty acid (FA) analyses on marine mammal tissues (Dr. S. Iverson, Dalhousie University) and its research has been focused on North Atlantic Ocean phocids. Similar information is unavailable for NPO prey and predator species. In addition to developing baseline values for prey FA profiles, potential spatial or age-based variability in prey FA profiles must be assessed because the potential for considerable variation exists. Techniques for predator tissue collection (i.e., where and how to collect) require further development.

This study was designed to address these factors through a three-year collaborative effort between the National Marine Mammal Laboratory (NMML) and the Auke Bay Laboratory (ABL) of the NMFS/AFSC. Year-one was used for development of sampling techniques (by darting); and to assess variability in prey FA profiles in northern fur seals. Years two and three will then be used to develop FA profiles for major marine mammal prey in the NPO and to assess variability in FA profiles of marine mammal using Steller sea lions as a test subject. A significant by-product of this research will be the development of a capability within the NMFS for marine mammal FA analyses.

1997/98 Results

Fur seal blubber was collected in 1997 during the annual harvest on St. Paul Island. Blubber samples were collected from 16 males and 3 females, and each individual was sampled in 3 locations: neck, pelvis and shoulder.

Lipid class composition and fatty acid content of these samples is being examined to test the following hypotheses:

1. Lipid content of blubber samples taken from any one location are representative of the content found in the entire blubber layer.

2. Lipid content of females does not differ from content of males.

3. Energy content does not vary among locations in a seal's blubber.

4. Thickness of the blubber layer is an accurate predictor of surplus energy in individual seals.

The fur seal samples were subdivided into 171 blubber sections which represent three sections of blubber taken from each of the three body locations sampled from each of the 19 seals. The first section represents a portion of the entire blubber layer in a sample, while the remaining two represent samples of the distal and proximal layers. The latter two samples were prepared by dissecting the blubber layer away from the dermis and cutting the resulting section into halves along a line parallel to the dermis. The resulting section closest to the dermis was sectioned into halves again and the half found closest to the dermis retained and considered the distal layer. A similar procedure was used to select a layer of blubber closest to the interior layer of the animal, this is the proximal sample. Small sections of each of the four layers was retained in a third sample, representing the entire layer. Prior to dissection, the breadth of the blubber layer was measured with calipers at the point of greatest thickness.

Blubber sample analysis is ongoing. No results are available at present. However, blubber samples will be processed to determine the lipid class composition and fatty acid content of the triglyceride component. Lipid extractions, analysis of class composition, esterification of triglyceride FA and GC/MS analysis will follow standard procedures developed by ABL.

Statistical analysis to test the first hypothesis will follow the procedures of Grahl-Nielsen and Mjaavatten (1992). After characterizing the FA composition of the triglycerides in the samples of whole blubber a model will be constructed by principle components analysis (PCA). This set of samples is referred to as the training set, and the PCA identifies a coordinate system that accounts for the greatest amount of variation with the fewest number of coordinates. Then a model can be constructed that describes the whole blubber in terms of its location in this coordinate system and a frequency distribution for the distances between the model centroid and each of the individuals. These distances are defined by the relative standard deviations (RSD) for each of the samples in the training set and they are assumed to follow a known distribution (Wold and Sjostrom 1977), so that a 95% confidence limit for the distances can be calculated and defined as RSD_{max}. Thus, the probability of committing a Type I error when excluding a sample with unknown origin from the model is < 5% when the sample's RSD > RSD_{max}. Similar models will be constructed for the samples taken from each of the other body locations. The distances between the centroids for each of the sampling strata will then be compared and identified as similar or different on the basis of the probability of committing a Type I error. Whole blubber samples will used to examine the second hypothesis by comparing the distance between male and female centroids.

The last two hypotheses will be examined by the general linear model. For the third hypothesis, the proportion of triglyceride (TAG) found in a sample's total lipid will be related to the location of the sample by thefollowing model:

$$\text{Percent TAG} = \text{location} + \text{position(location)}$$

where location refers to either neck, pelvis or shoulder and position refers to either distal or proximal samples nested within the position. The fourth hypothesis will be examined by regressing the proportion of TAG found in a sample of whole blubber against the greatest thickness of the blubber layer prior to dissection.

Citations

Grahl-Nielsen, O., and O. Mjaavatten. 1992. Discrimination of striped bass stocks: A new method based on chemometry of the fatty acid profile in heart tissue. Trans. Am. Fish. Soc. 121:307-314.

Wold, S., and M. Sjöström. 1977. SIMCA: a method for analyzing chemical data in terms of similarity and analogy. Amer. Chem. Soc. Symposium Series 52:243-282.

INVESTIGATIONS OF MARINE MAMMAL INTERACTIONS WITH LAKE OZETTE SOCKEYE SALMON, *ONCORHYNCHUS NERKA*, 1998

Patrick J. Gearin[1], Kirt M. Hughes[1], Lawrence L. Lehman[1], Lawrence Cooke[2], Robert L. DeLong, and Merrill E. Gosho[1]

[1] National Marine Mammal Laboratory
Alaska Fisheries Science Center
7600 Sand Point Way, NE
Seattle, WA 98115
and
[2]Makah Tribe, Makah Fisheries Management Division
P.O. Box 115
Neah Bay, WA 98357

Abstract

In anticipation of the listing of Lake Ozette sockeye salmon, *Oncorhynchus nerka*, as threatened under the Endangered Species Act in March, 1999, we initiated a study in 1998 in cooperation with the Makah Tribe and National Park Service to investigate the interactions between marine mammal predators and the Lake Ozette sockeye salmon run.

Abundance and distribution of harbor seals, *Phoca vitulina*, and California, *Zalophus californianus*, and Steller, *Eumetopias jubatus*, sea lions was determined by aerial and vessel surveys from May through August during the timing of the sockeye run. Harbor seal numbers within 5.5 km of the Ozette River mouth ranged from 950 to 1,393 individuals. Steller sea lion numbers ranged from 404 to 1,016 individuals and California sea lions from 0 to 541 within approximately 18.5 km of the Ozette River mouth. Food habits of the four species of predator were determined by collection and analysis of scat (fecal) samples. Salmonid frequencies in the scat samples were; harbor seals (1.5%), Steller sea lions (1.6%), California sea lions (11.8%) and river otters (17.5%). Sockeye salmon remains were not found in scats from harbor seals, of the five samples which contained salmon, 2 were coho salmon and 3 were chinook salmon. The final prey identifications of salmonids have not been completed for the other predators and will utilize DNA analysis to determine salmonid species identifications. The surveys by boat , from shore, and by snorkel dive methods in Lake Ozette and the Ozette River did not result in direct observations of predation on sockeye salmon. Harbor seals were frequently observed in the lower Ozette River and exhibited foraging behavior. River otters were observed in the upper and lower Ozette River. Steller or California sea lions were not observed in either the Ozette River or in Lake Ozette. This finding plus the lack of evidence from the scat sampling suggest that interactions between sea lions and Lake Ozette sockeye are probably minimal. Both harbor seals and river otters were observed frequently in the vicinity of the sockeye weir on the upper Ozette River and both species were observed passing through the weir while carrying sockeye salmon into Lake Ozette. Predator scars on fish observed at the sockeye weir (3.4%) provide further evidence that both otters and harbor seals are predating Lake Ozette sockeye. Future research on

mammalian predators should focus on river otters and harbor seals with the objectives being to determine where the predation occurs and to what extent it may impact the recovery of Lake Ozette sockeye.

Introduction

The Lake Ozette sockeye salmon, *Oncorhynchus nerka*, was listed as threatened under the Endangered Species Act in March, 1999 by the National Marine Fisheries Service (NMFS, 1999). The Lake Ozette Evolutionary Significant Unit (ESU) contains a small endemic run of sockeye salmon which travel from the Pacific Ocean through the Ozette River to spawning grounds in Lake Ozette (Figs. 1 and 2). The Makah Indian tribe through the Makah Fisheries Management Division maintains a fish weir on the upper Ozette River which is used to estimate total sockeye escapement. The fish weir has been operated seasonally (May-July) since 1977 in order to count adult sockeye passing into Lake Ozette.

The Lake Ozette sockeye run appears to have declined considerably since the late 1940s when some reports suggest as many as 17,000 fish were harvested (Jacobs et al. 1996). Total run sizes during this period however, are unknown and based on unsubstantiated harvest estimates (Dlugokenski et al. 1981). Early escapement estimates in 1924 and 1925 counted 3,251 and 6,343 sockeye respectively at a counting weir in the Ozette River (Kemmerich 1945). The average estimated run size from 1977 to 1995 was 951 fish, with a low of 263 in 1990 and a high peak of 2,191 in 1988 (Makah Fisheries data in: Jacobs et al. 1996). The majority of adult sockeye spawn in Lake Ozette at two lakeshore sites and a few may also spawn at Umbrella Creek, a large tributary that flows into the northern part of the lake (Jacobs et al. 1996).

Considerable efforts have been made in past years to determine the cause(s) of the apparent decline in Lake Ozette sockeye (Dlugokenski et al. 1981, Blum 1988, Beauchamp et al. 1993, Jacobs et al. 1996), however few proximal causes have been determined. Possible causes as noted in past studies include; habitat degradation due to excessive logging, over harvest, competition, and predation. Restoration of the Lake Ozette sockeye run is of considerable importance in light of the recent NMFS ESA listing as well as for continued survival of this unique stock.

Little information is available concerning the potential impact of pinniped predation on the Lake Ozette sockeye. Harbor seals, *Phoca vitulina*, have been observed in Lake Ozette and pinniped bites marks have been noted on returning sockeye salmon adults (Larry Cooke, pers. comm. March, 1998). The area around Cape Alava has large numbers of pinnipeds during certain times of year. Harbor seal densities at Cape Alava are some of the highest on the outer Washington coast with peak counts during May and June of over 1,000 animals. California sea lions, *Zalophus californianus*, and Steller sea lions, *Eumetopias jubatus*, are also seasonally abundant in the Cape Alava area. Most of the pinniped haulout sites in the Cape Alava area are in close proximity (1-3 km) to the Ozette River. Another species of aquatic predator which is locally abundant in the area is the river otter, *Lutra canadensis*, which is common both in the Ozette River and in Lake Ozette. The combination of pinniped abundance and proximity to the Ozette River makes it likely that predation interactions occur in this area. For this reason, we initiated a study during the spring of 1998 to investigate the interactions between pinnipeds and the Lake Ozette sockeye run.

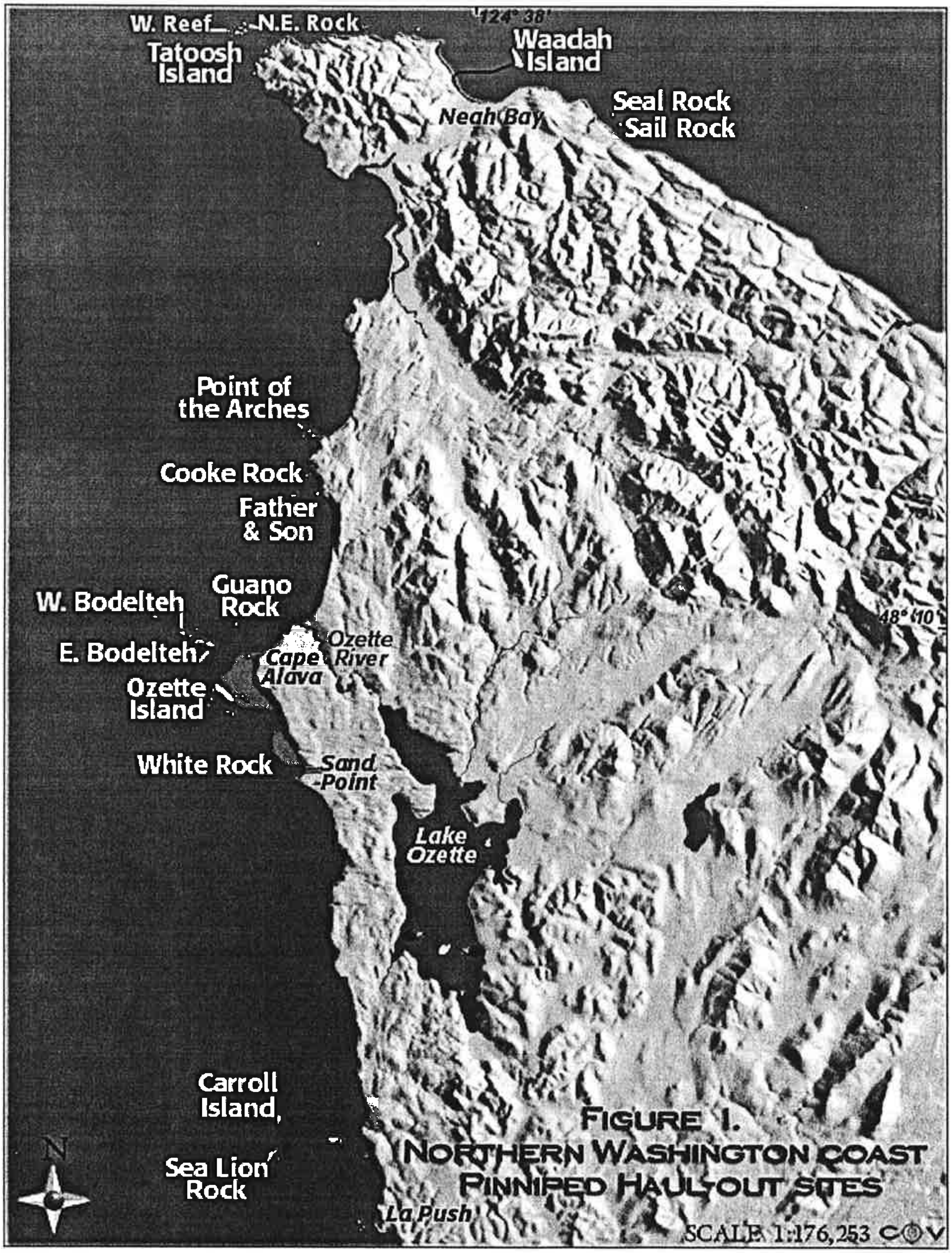


Figure 1. Ozette study site region.

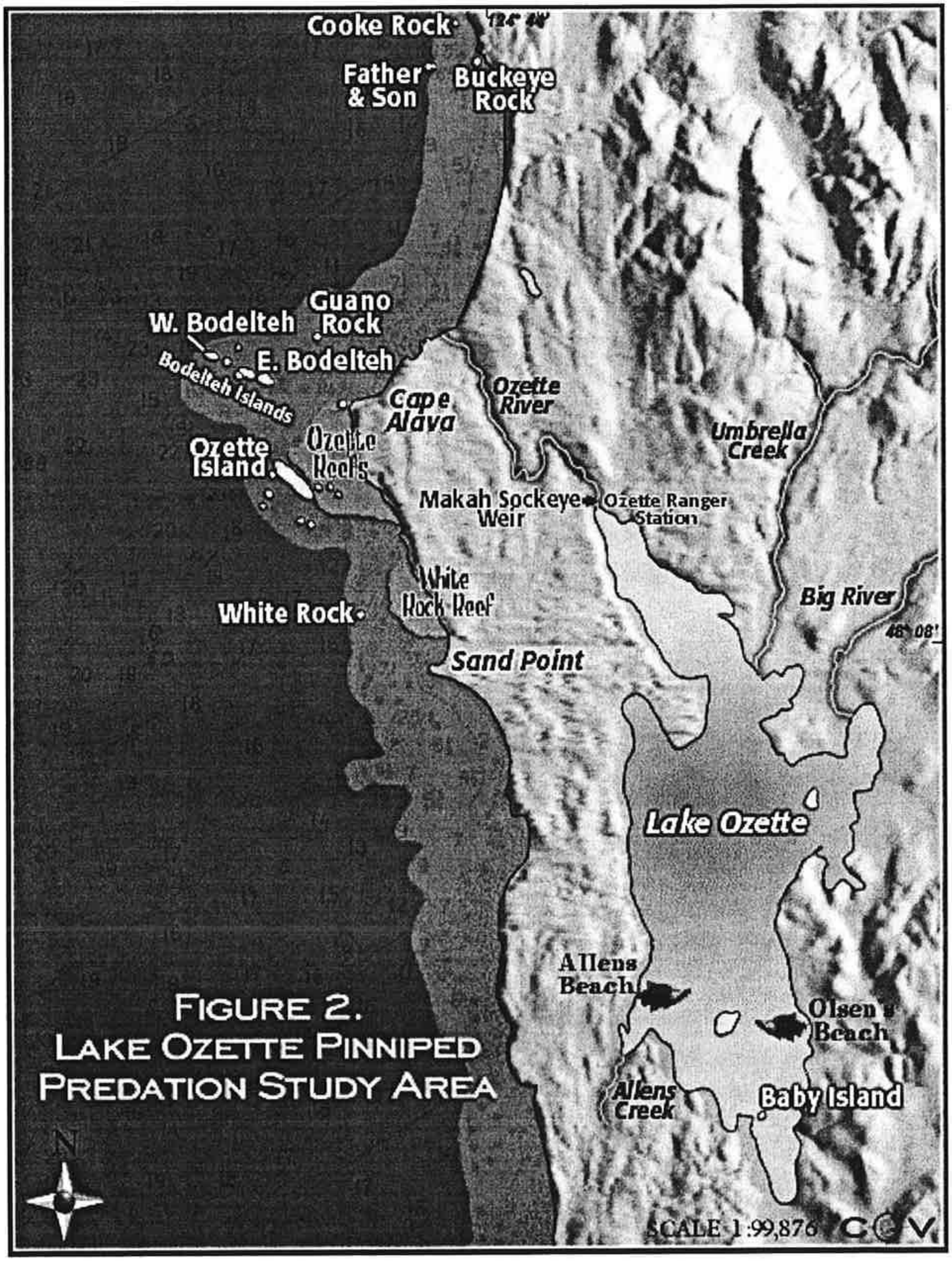


Figure 2. Lake Ozette Sockeye salmon/ pinniped interaction study sites.

The objectives of the research were to; determine the abundance and distribution of pinnipeds in the vicinity of the Ozette River and Lake Ozette, collect and analyze pinniped scats collected in the vicinity and quantify salmonid occurrence, conduct surveys in Lake Ozette and the Ozette River to record the presence of pinniped predators including their abundance, behavior and foraging activity, and collect data related to scarring of sockeye salmon by pinniped predators.

Materials and Methods

Recognizing the importance of obtaining accurate sockeye escapement estimates, we assisted the Makah Tribe in helping to set up the sockeye weir in early May. In addition, we provided some initial funding to help purchase and install a new time lapse video camera system at the sockeye weir. This video camera system enabled us to obtain information from the Tribe on the occurrence of predators and the level of predator scars on fish passing through the weir.

Research on pinniped abundance, diet, and distribution was timed to correspond to the passage of sockeye salmon into Lake Ozette which occurs primarily from May through July (Fig. 3).

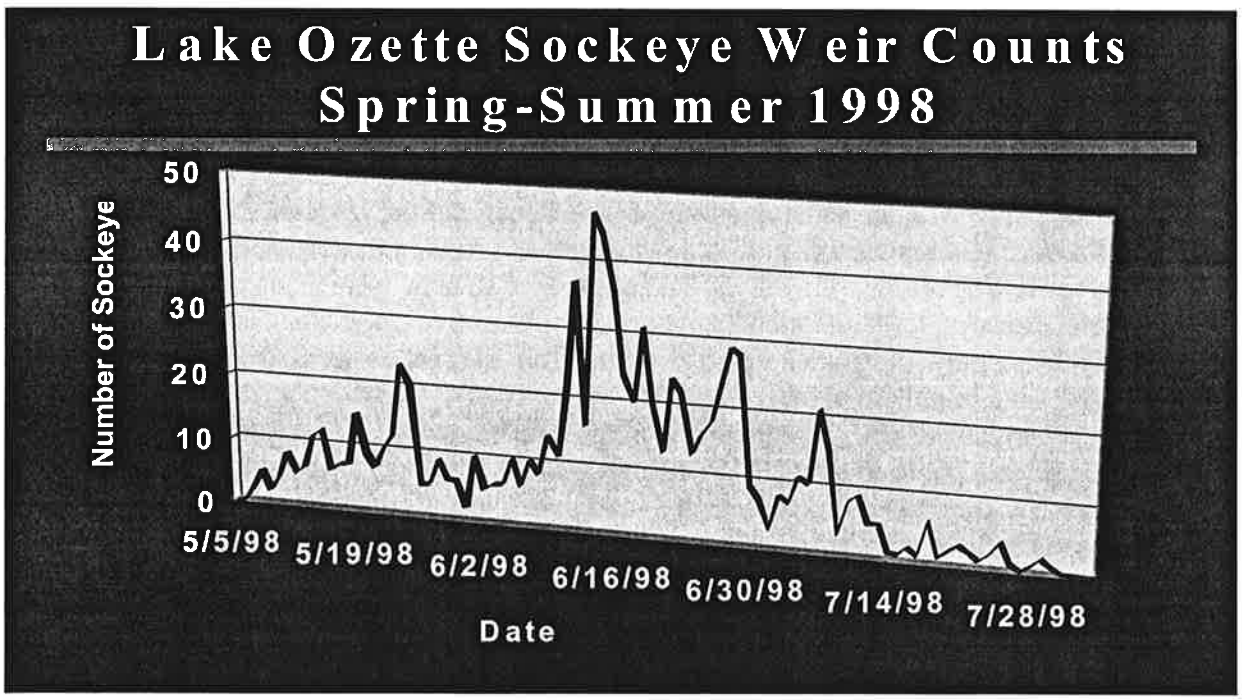


Figure 3. Lake Ozette Sockeye salmon weir counts during 1998 (data from Makah Fisheries Management Division).

Pinniped Abundance and Distribution

The abundance and distribution of harbor seals and sea lions was determined by conducting aerial and vessel surveys in the area. Four aerial surveys were flown in the vicinity of the Ozette River during May through June 1998. Aerial surveys were flown during low tide cycles to optimize the counts of harbor seals and sea lions. Aerial photographs were taken of major groups of pinnipeds and slides were projected and images were counted. The harbor seal sites surveyed were those within 3 nm (5.5 km) of the Ozette River mouth in order to access the abundance of animals in close proximity to the river mouth and potentially to Lake Ozette. Eight main harbor seal haulout sites within this area were surveyed during each survey (Table 1, Fig. 2).

For both California and Steller sea lions, the area surveyed was larger, reflecting their more dispersed distribution in the region. Sea lion sites surveyed were within approximately 10 nm (18.5 km) of the river mouth, ranging from Tatoosh Island to Sea Lion Rock (Fig. 2). Sea lion sites surveyed within this region were grouped into four main haulout complexes which included; Tatoosh Island, Cape Alava, Carroll Island, and Sea Lion Rock. These complexes include about 12 different haulout sites. In addition to aerial surveys, vessel surveys were conducted opportunistically from May-October during scat collection trips.

Scat Collections and Diet Assessment

Harbor seal scats were collected between 6 May and 30 July from haulout sites within 5.5 km of the Ozette River mouth including; East Bodelteh Island, Ozette Reefs, Father and Son Rock, and Cooke Rock (Fig. 2). Sea lion scats from both California and Steller sea lions were collected between May and July from the Bodelteh Islands, Guano Rock and Sea Lion Rock haulout sites (Fig. 2). Scats were frozen after collection and later thawed and cleaned and sorted at the National Marine Mammal Laboratory (NMML) in Seattle. The scats were emulsified in a solution of water and mild liquid detergent for 1-4 days and then rinsed through a series of nested metal sieves with mesh sizes of 1.4 mm, 0.71 mm and 0.5 mm. The contents, once sieved, were sorted and prey hard parts such as fish otoliths, bones, and cephalopod beaks and statoliths were recovered. The prey hard parts were later examined at the NMML food habits laboratory under a dissecting microscope with an ocular micrometer magnification from 6.4X to 32X. Otoliths were identified to the lowest taxa possible, counted left and right, measured and categorized according to relative condition. Prey identifications from fish bone were made using vertebrae, gill rakers, otic capsules, teeth and mouthparts or other distinctive diagnostic features. Two measures of relative prey importance were calculated from the scat contents; frequency of occurrence (FO) and minimum number of prey (Nmin). The FO was calculated as a percentage based on the occurrence of any given prey taxa in the total number of scat samples which contained identifiable prey components. The Nmin was calculated as the minimum number of individual prey (i.e. herring, smelt) represented in each scat sample. The Nmin was determined by using diagnostic features such as otoliths, squid beaks, vertebrae or others which were identified to that taxa. For example, when a scat contained 10 left and 9 right otoliths from Pacific herring, the Nmin for that sample for herring was 10. Similarly, if 10 upper and 9 lower squid beaks were recovered, the Nmin for squid was 10. If certain bony elements were recovered which could be identified but not quantified and no otoliths or squid beaks were recovered than the Nmin was considered one. The size of fish prey was estimated using formulas species specific which convert otolith length to fish length and mass as described in Harvey et al., (1995, in press). The minimum number of salmonid prey was determined from the scat samples and where possible an estimate of size was made. Salmonid bone from harbor seal and river otter scats were analyzed by the Conservation Biological and Molecular Genetics Laboratory (CBMGL) of the Northwest Fisheries Science Center of NMFS. The lab extracted DNA from the fish bone, amplified it using PCR techniques and identified salmonid species by direct sequencing of mitochondrial DNA (mtDNA).

Ozette River Observations

Periodic observations were conducted in the Ozette River by either floating the river in a small inflatable raft, swimming the river in wetsuits and mask and snorkel gear, or from shore based observation sites. Objectives were to record the distribution and abundance of pinnipeds, their foraging behavior and the occurrence of salmonids.

Land based observations were conducted at the mouth of the Ozette River on 3-5 June, 18 June, 30 June-2 July, and from 21-22 July from about two hours before until two hours after day time high tides. Observations were made from two locations; one on the east and west side of the beach crest. The station on the west side surveyed the southern extent of the river mouth and a significant portion of the surf zone north of the river towards Duk point. The station to the east of the beach crest surveyed all portions of the river visible east of the beach crest (encompassing about 125 m of river).

Small boat surveys on the lower Ozette River were conducted on 20 May, and 3-5 June. A 3 m long inflatable raft with ten observers was used. The surveys began at the mouth of the river, proceeded upriver approximately 1.5 miles to the first large logjam and then returned downstream to the mouth.

Two snorkel dive surveys were conducted, one on 17 June which encompassed the entire stretch of river from the sockeye weir to the mouth (Fig. 2), and one on the upper 1 mile of river on 29 June.

Lake Ozette predator and spawning ground surveys

Vessel surveys were conducted at Lake Ozette on June 4 and on December 8 and 9, 1998. Vessel surveys were conducted a distance of 100-150 m from shore and followed the contour of the lake. On June 4 and December 9, Big River was surveyed from the mouth to upriver about 0.75 miles. Spawning areas were surveyed by snorkel dive surveys on December 8 and 9. Two divers were deployed at Olsen's Beach, Allens Beach, Baby Island, and near Allens Creek. At Olsen's Beach, the area was surveyed each direction about 150 m north and south of the dock. Divers swam parallel to the beach, in transects at depths of 1.5, 2.5 and 3.5 m, scanning each direction 1-2 m. At Allens Beach, the site was surveyed about 125 m north and south of the thermograph using transects in depths of 1.5, 2.5, and 3.5 m. The entire shoreline of Baby Island was surveyed by swimming around the island at a depth of 2-3 m. At Allens Creek the area was surveyed from the mouth of the creek to the north about 100 m. Sockeye which were observed were counted and their condition was noted. Redds were counted and the measurements of their physical characteristics were noted (water depth, diameter, etc.).

Results

Pinniped Abundance and Distribution

<u>Harbor seals</u>

Total counts of harbor seals ranged from 621 to 911 during the four aerial surveys conducted (Table 1). These counts however only represent minimum numbers of seals in the area since a certain percentage are foraging or in the water and thus unavailable to be counted.

Huber (1995) developed a correction factor to account for missing animals by tagging seals with radio transmitters and determining the percent in the water versus hauled out. The correction factor developed was from the Grays Harbor area during the peak pupping season. Therefore, we assumed the percentages were similar on the northern Washington coast, we used the correction factor of Huber (1995) of 1.53 to generate an estimate of true abundance for the area (Table 1). The corrected abundance of harbor seals in the region ranged from 950 to 1,393.

Table 1. Counts of harbor seals from aerial surveys on the northern Washington coast near Cape Alava/Ozette area. Surveys within 3 nm (5.5 km) of the Ozette River mouth, May 5 - June 30, 1998.

Location	5/5/98	5/29/98	6/15/98	6/30/98
Cooke Rock	100(0)	80(0)	62(1)	49(3)
Father and Son	17(0)	9(0)	12(0)	40(1)
E. of Father & Son	0	0	28(0)	14(1)
East Bodelteh Island	96(1)	98(8)	272(19)	321(26)
Ozette Island area	58(0)	61(0)	70(8)	146(8)
Ozette Reefs	198(0)	389(5)	296(15)	33(4)
East White Rock	152(0)	82(0)	148(9)	27(6)
Sand Point area	0	2(0)	23(1)	40(4)
Total	621(1)	721(13)	911(53)	670(53)
Corrected abundance[1]	950	1,103	1,393	1,025

Note- numbers in parentheses ( ) indicate pup counts.
[1] Correction factor 0f 1.53 from Huber (1995).

Steller sea lions

Steller sea lions were counted during the four aerial surveys from May 5 through June 30 and also during six vessel surveys from July 28 through October 4 (Table 2). Steller numbers ranged between 359 to 1,016 with peak counts during May and low counts in June. These counts reflect the movement patterns of Steller sea lions in the region. Steller numbers tend to be lowest during June when animals return to breeding rookeries in Oregon or British Columbia and increase through the summer thereafter in response to aggregations of Pacific whiting nearby (Gearin et al. 1999).

Table 2. Counts of Steller sea lions on the northern Washington coast within 10 nm (18.5 km) of the Ozette River from aerial and vessel surveys between May 5 - October 4, 1998.

Date	Tatoosh Island	Cape Alava	Carroll Island	Sea Lion Rock[1]	Total
5/5/98	56	268	503	189	1016
5/29/98	16	57	351	174	598
6/15/98	0	46	195	167	408
6/30/98	12	1	189	15	217
7/28/98	136	45	223	0	404
7/30/98	180	15	322	0	517
8/24/98	116	175	193	62	546
8/31/98	32	177	262	0	471
9/21/98	128	355	18	5	506
10/4/98	83	303	137	3	526

[1] Sea Lion Rock is a "new" haulout site located 0.6 km south of Carroll Island.

California sea lions

California sea lions were counted during the four aerial surveys and also during six vessel surveys. The counts ranged between 0 and 541 sea lions during the period with peak numbers observed during early May (Table 3). Numbers of California sea lions declined dramatically after the first week in May and were near zero during June and most of July. The numbers began to increase again in late August. California sea lions are migratory in the area of northern Washington and generally just pass through the area on their way to and from the rookeries in southern California. In the Spring, peak numbers occur during April and May as the animals move south and in the Fall, peak numbers occur during October through December as animals move back north. On November 3, 1998, 1,200 California sea lions were counted on East Bodelteh Island but by January 5, 1999, the number had declined to 50.

Table 3. Counts of California sea lions on the northern Washington coast within 10 nm (18.5 km) of the Ozette River from aerial and vessel surveys between 5 May - October 4, 1998.

Date	Tatoosh Island	Cape Alava	Carroll Island	Sea Lion Rock	Total
5/5/98	91	193	122	135	541
5/29/98	36	4	31	55	126
6/15/98	0	0	0	0	0
6/30/98	0	0	0	0	0
7/28/98	0	0	0	0	0
7/30/98	4	1	0	0	5
8/24/98	0	0	0	103	103
8/31/98	0	14	5	0	19
9/21/98	2	8	22	2	34
10/4/98	1	49	297	1	348

River otter

No abundance estimates for river otters in the Ozette River were made, nor do past estimates exist. Few river otters were observed during day light surveys in Lake Ozette or the Ozette River but river otters are expected to be primarily nocturnal or forage during dawn/dusk periods so they were unlikely to be seen during our surveys. River otters were reported frequently by the sockeye weir observers and were apparently very active in the vicinity of the weir at night. As many as 3-4 otters were observed near the weir at one time. Otters were captured by video tape passing through the weir at least 82 times between 7 May through 2 July (Makah Fisheries, unpubl. data). Snorkel dive surveys and river bank surveys from the weir down river 200-300 m yielded many signs of river otters including tracks and scat piles along both sides of the river. Based on these observations, it is likely that an otter den is present near the sockeye weir. River otters were also observed in the lower mile of the Ozette River, so they are certainly distributed along the entire length of river. The Ozette River appears to be ideal river otter habitat with muddy cut banks and fallen timber along the entire stretch making for good denning and slide sites. The river also is essentially impassable to vessels except for the lower 1-2 miles which reduces human disturbance. The river contains large amounts of suitable prey such as crayfish, mussels, trout and squawfish (see section on river observations). River otters, like other mustelids are territorial and their densities within the Ozette River region are probably strongly influenced by this behavior. Given that the Ozette River appears to be ideal otter habitat, it is likely that maximum densities occur throughout.

Pinniped Scat Collection and Diet

Scats were collected from four species of marine predator in and near the Ozette River from May through July. For a summary of scat collections by date, location, and species, see Appendix 1, Tables 1-4. Harbor seal scats were collected from four primary haulout sites, each within 5.5 km of the mouth of the Ozette River. A total of 347 harbor seal scats were collected from May through July (Table 4). Steller sea lion scats were collected from four haulout sites, each within 18.5 km of the Ozette River mouth. A total of 124 Steller sea lion scats were collected (Table 4). We collected only 21 California sea lion scats during the study primarily because the number of California sea lions declined rapidly in the area after the first week in May (see Table 3). Forty-six scats were collected at East Bodelteh Island from what we refer to as "mixed" sea lions where Steller and California sea lions were hauled out together (Table 4). We collected 40 scats from river otters from riverbank locations along the upper Ozette River (Table 4). Most of the otter scats were collected within 200 m of the sockeye fish weir.

Table 4. Scats collected from four species of predators in and near the Ozette River during 1998.

Species	Time series	Number
Harbor seal	5/6/98-7/30/98	347
California sea lion	5/6/98-5/6/98	21
Steller sea lion	5/6/98-7/29/98	124
Mixed sea lion[1]	5/6/98-5/19/98	46
River otter	6/4/98-6/29/98	40
Total		**578**

[1] Mixed sea lion scat from haulouts where Steller and California sea lions were hauled out together.

Scat Contents and Prey Identification

Harbor seal

Of the 347 harbor seal scats collected, 330 contained identifiable prey so the number for calculating frequency of occurrence was n=330. The harbor seal scats contained at least 37 different prey categories as is typical of the diverse diet of harbor seals in other areas (Fig. 4, Appendix 1, Table 5). Salmonids were very low in frequency of occurrence from the samples examined and were found in only 1.5% or 5 of the total scats. No salmonid otoliths were recovered in these scats, the identifications were made using mtDNA extracted from salmonid bone. The five samples examined were identified as coho salmon (2) and chinook salmon (3). No sockeye salmon was identified from the samples. The primary prey of harbor seals was Pacific tomcod (FO=41.2%) and osmerids (smelts, FO=30.9%). Clupeids, including Pacific herring, Pacific sardine, and American shad, were also important (Fig. 4). The pleuronectids also occurred in high frequencies, especially English sole.

Steller sea lion

Of the 124 Steller sea lion scats collected during the study, identifiable prey was found in all of the samples (n=124). Only two (1.6%) contained salmonid remains (Fig. 5). Two of these samples contained salmonid bone which was not identifiable to species. One of the samples contained a single otolith from a chinook salmon, *Oncorhynchus tshawytscha*. The primary prey based on FO of Steller sea lions from the samples was Pacific whiting which was found in 88% of the scats (Fig. 5, Appendix 1, Table 6). Spiny dogfish (24.2%), starry flounder (16.1%), skates (Family Rajidae, 14.5%), Pacific herring (11.3%) and Pacific sardine (5.7%) were also common prey found in the samples.

California sea lion

Of the 21 California sea lion scats collected, 17 contained identifiable prey (n=17). The primary prey based on FO was Pacific whiting (82.4%). Spiny dogfish, Pacific sardine and Pacific mackerel each were found in 23.5%. Salmonids were found in 11.8% of the scats. All of the salmonid remains were identified from bone (Fig. 6, Appendix 1, Table 7).

Mixed sea lion scats

Forty-six scats were collected from haulout sites which contained both Steller and California sea lions and identifiable prey was recovered from all (n=46). The primary prey based on FO from these samples was Pacific whiting and Pacific herring, each found in 56.5% of the samples (Fig. 7, Appendix 1, Table 8). Salmonid bone was found in 30.4% of the samples, but no otoliths were recovered.

River otter

Forty river otter scats were collected and identifiable prey was found in all samples (n=40). The primary prey as determined by FO was crayfish (82.5%), Northern squawfish (47.5%), sculpins (Family Cottidae) (45%), freshwater mussels (40%), and small rodents (30%) (Fig. 8, Appendix 1, Table 9). Salmonid bone or otoliths were found in 17.5% of the samples. Salmonid otoliths were recovered in two scats which included one chinook salmon otolith in one sample and three coho salmon otoliths in one sample. DNA was extracted from samples of bones from 11 scats and preliminary sequencing indicates that two samples contained bone from chinook salmon and one contained bone from coho salmon (data from CBMGL). Crayfish were identified and enumerated from either claw parts or from gastroliths, a calcified structure found in some crayfish when calcium is resorbed from the old exoskeleton after molting. Gastroliths were found in 17 (51.5%) of the scats which contained crayfish parts and their numbers ranged from 0 to 12. Northern squawfish were identified from either otoliths (four were recovered) or more commonly from the distinctive milky colored bone. Sculpins (Family Cottidae) were identified from otoliths (11 recovered) or from bone. The mammal bone recovered could not be identified to species but most appeared to be from small rodents. Much of the fish and mammal bone recovered was chewed and broken making species level identification difficult. Mammal bone consisted primarily of the remnants of broken femurs, humeri and other long bones and their epiphyses and in one instance the jaw parts from a microtine type rodent (probably a meadow mouse or vole). Insect remains consisted of leg sections from a grasshopper (Order

Orthoptera), and wing parts from dragonflies (Order Odonata). Spider (Arachnida) parts were recovered in one sample.

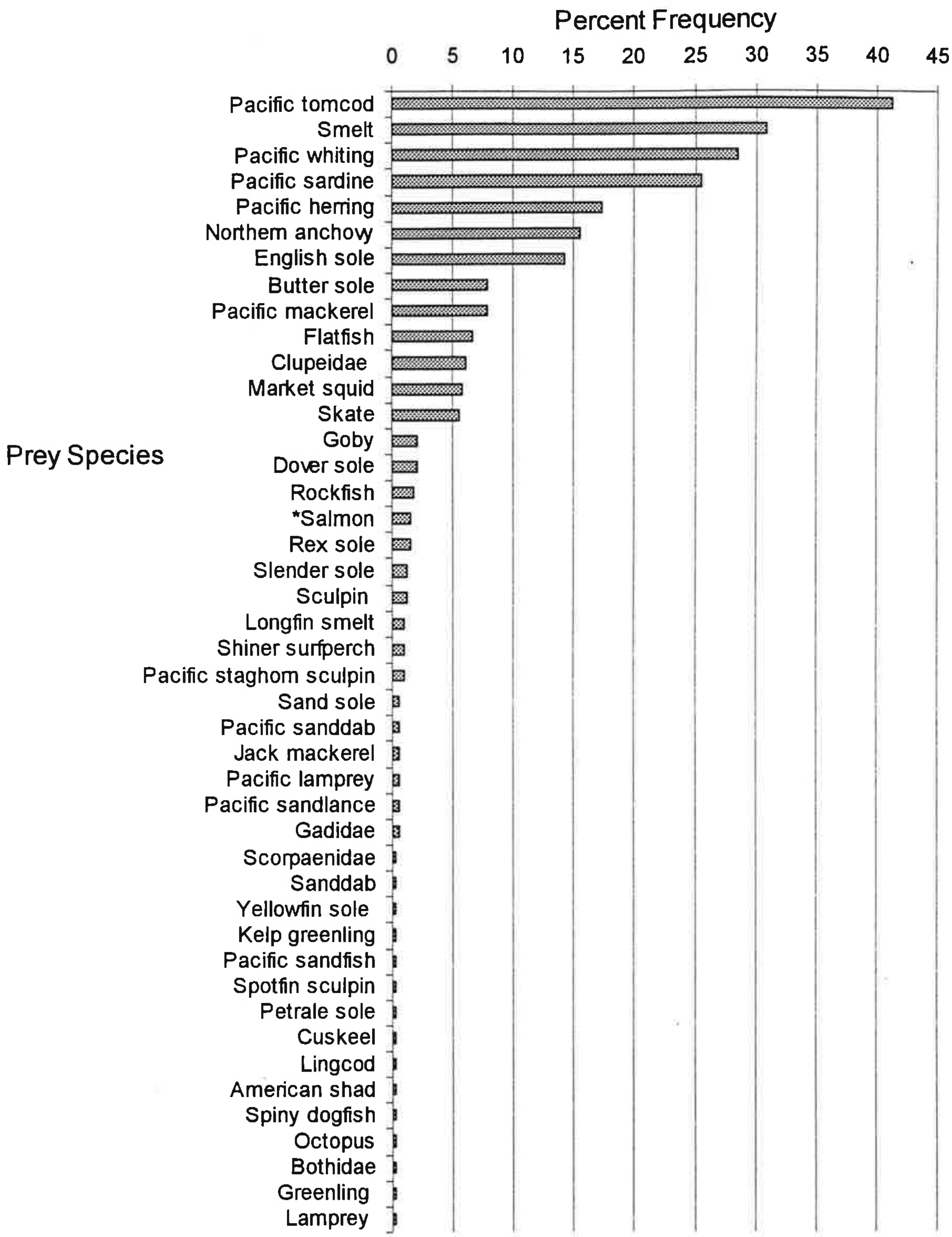


Figure 4. Frequency of harbor seal prey identified from scat collected near the Ozette River(n=330). * Total frequency for salmon includes 2 samples with coho (FO=0.6; Nmin=2) and 3 samples with chinook salmon (FO=0.9; Nmin=3).

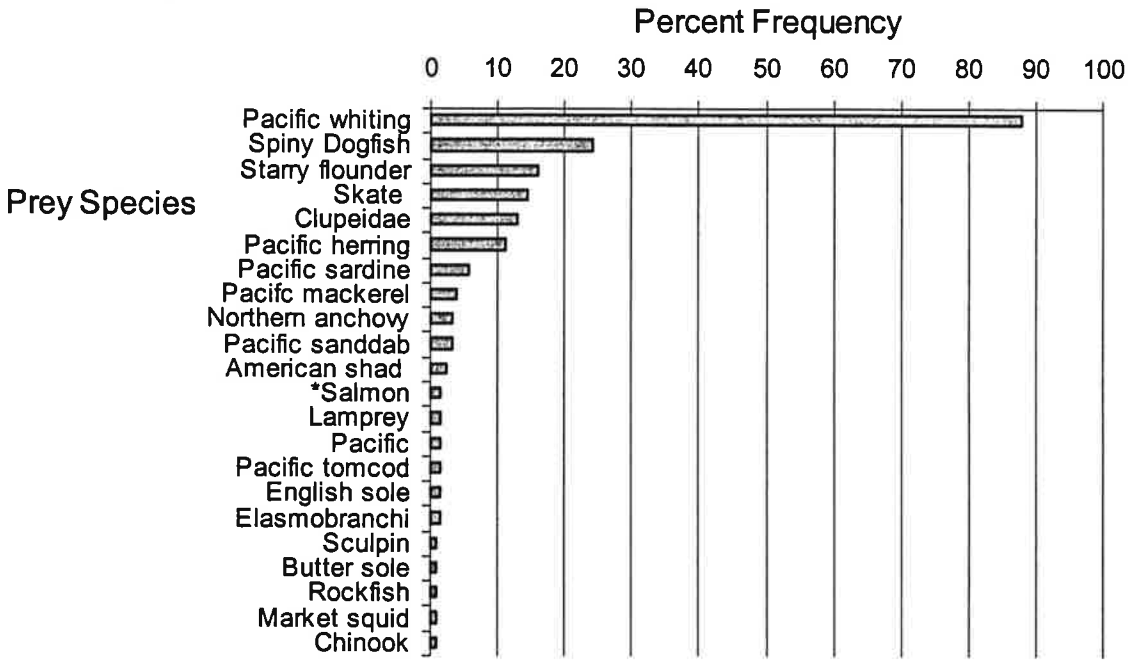


Figure 5. Frequency of prey identified from Steller sea lion scats collected during 1998 (n=124). * indicates total frequency for salmon includes chinook salmon.

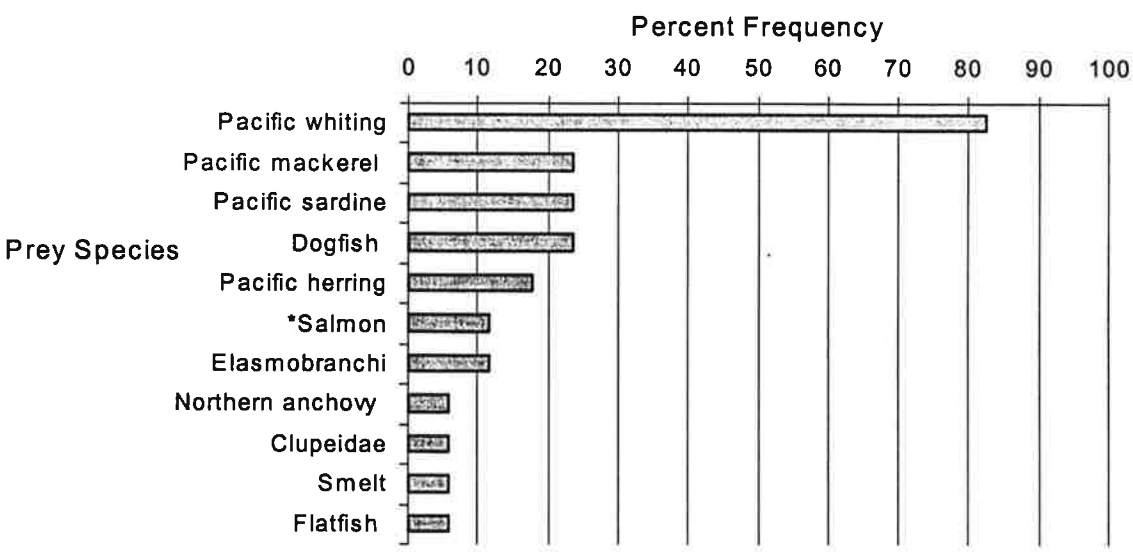


Figure 6. Frequency of prey identified from California sea lion scats collected during 1998 (n=17). *indicates no salmonids were identified to species for these samples.

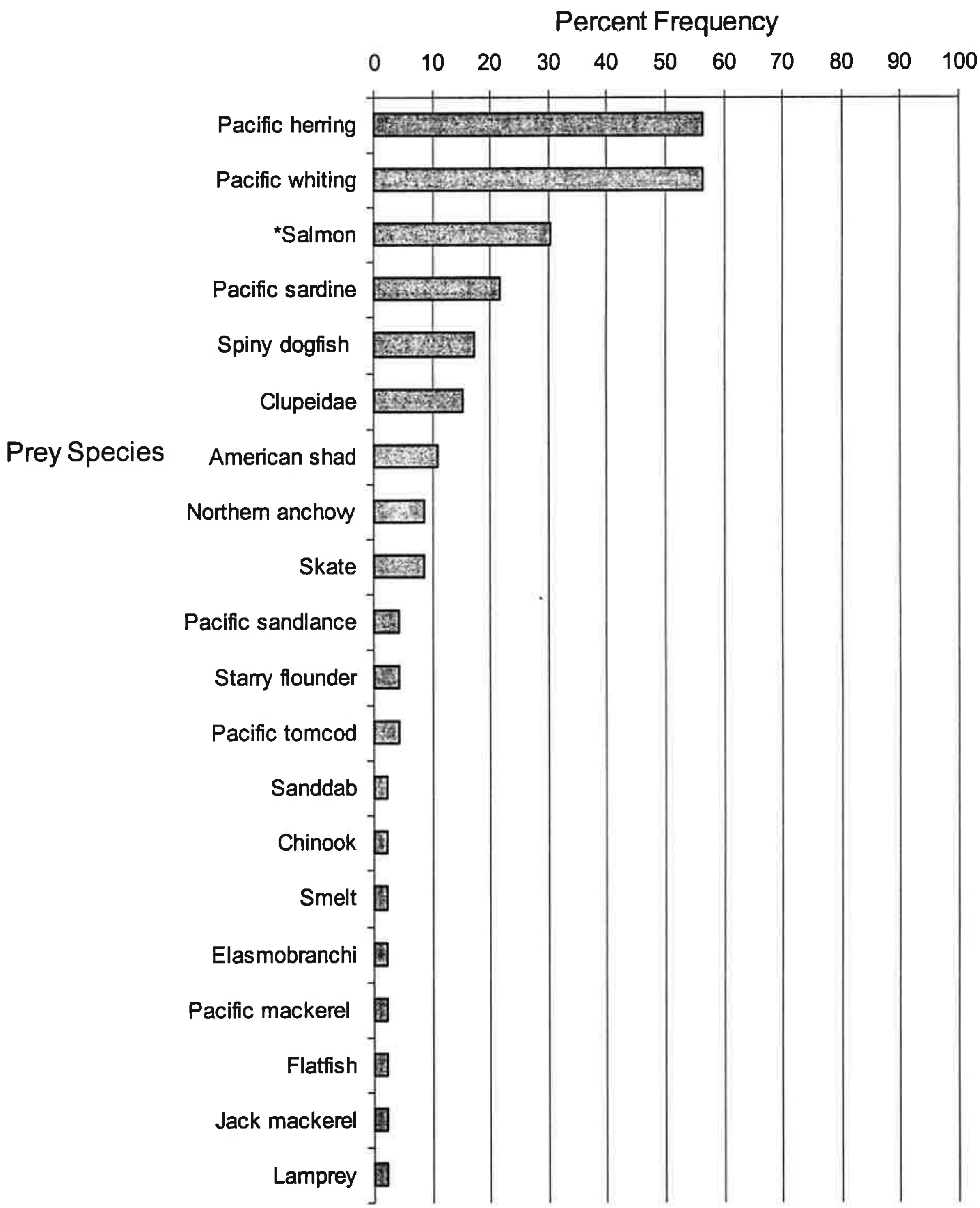


Figure 7. Frequency of prey identified from mixed sea lion scats (Steller sea lion and California sea lions) collected during 1998 (n=46). *indicates total frequency for salmon includes chinook salmon.

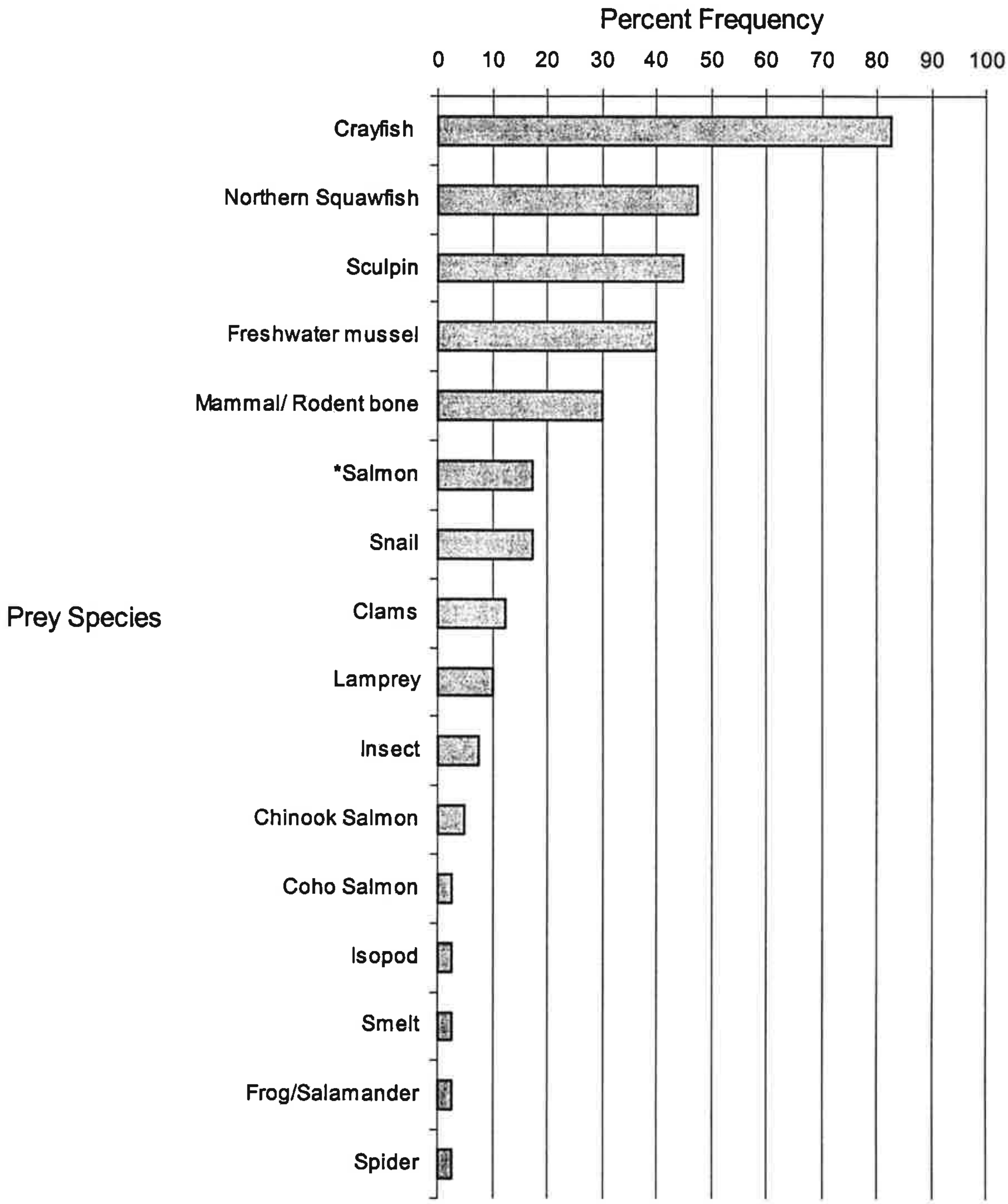


Figure 8. Frequency of prey identified from river otter scats collected at the Ozette river during 1998 (n=40). * indicates total frequency for salmon includes chinook and coho salmon.

Ozette River and Ozette Lake Observations

Land based river observations

Observations of the river from the beach crest on the east and west sides of the river focused on the distribution, abundance and foraging activity of potential sockeye predators during high tide cycles. The Ozette River is not accessible to seals or salmon during low tides since it becomes bar bound at these times. Observations totaling 37.6 hours over 9 days were conducted between June 3 through July 22 (Table 5). Harbor seals were observed during 9 of 12 surveys over the period, with as many as 5-6 seals observed during any one time. Seals were observed within the river on 6 of 12 surveys conducted. Harbor seals were also observed on 8 of 12 surveys at the mouth of the river in the surf-zone. The seals were generally first sighted beyond the surf-zone and cautiously moved into the river. The seals offshore behavior was unclear from the beach crest. Although an observer, while traveling into the river, noted that the seals' appear to exhibit foraging behavior. No more than three seals were seen in the river at any one time. During the two hour period before the high tide the seals moved between the ocean and the river. Behavior of each seal was similar upon entering the river. The seals, would pause in the deep pool at the southeastern end of the beach crest when entering or leaving the river. Although the seals appeared to exhibit foraging behavior in this area, no actual feeding by seals was observed. Separating the deep pool from the first glide of the river is a short riffle, (4 m in length). Depth through this riffle is effected by tidal height, when tidal height exceeds 1.5 m above mean low the riffle disappears. The first glide of the river, 300 m in length and 1 to 3 m deep, is tidally influenced. When seals were in the river, they exhibited two types of feeding behavior. One technique was to move from pool, through riffle into the glide where they would remain for up to 30 minutes, making several short dives. The second technique was characterized by the seals moving from the pool through the riffle into the glide, then back to the lower pool without surfacing. Movement into the river was not observed when there were campers on the beach crest. As the tide began to ebb, the seals moved back to the ocean, often remaining in the surf-zone and beyond.

Table 5. Land based observations at Ozette River mouth during 1998.

DATE	Hours Observed	Seals Present			Seal Time in River in minutes
		in river	off mouth	minimum	
3 June 1998; 1800	3.75	3	3	3	1 P.v. 120; 2 P.v. 60
4 June 1998; 0800	3.25	1	3-4	3-4	1 P.v. 66
4 June 1998; 1920	2.5	2	4	4	1 P.v. 54; 1 P.v. 11
5 June 1998; 0800	2.0	1	0	1	1 P.v. 60
18 June 1998; 0730	4.0	0	4-5	4-5	

DATE	Hours Observed	Seals Present			Seal Time in River in minutes
		in river	off mouth	minimum	
30 June 1998; 1600	3.0	0	2	2	
1 July 1998; 0530	4.0	0	0	0	
1 July 1998; 1700	4.25	0	1	1	
2 July 1998; 0600	2.5	0	1	1	
21 July 1998; 1055	3.1	0	0	0	
21 July 1998; 1900	2.75	2	2	2	1 P.v. 25*; 1 P.v. 15*
22 July 1998; 1154	2.5	0	0	0	

* 2 P.v.'s were still up river at end on observation period (observation period terminated due to darkness).

The presence of sea otters and various bird species were noted (Appendix 2, Table 1). Sea otters were observed on all surveys, always beyond the surf-zone and appeared to be feeding. Cormorants and rhinoceros auklets were observed feeding in and beyond the surf zone. Western gulls were observed splashing in the surf zone, but only appeared to be bathing. Bald eagles were observed atop the trees on the south side of the river mouth. A juvenile bald eagle was seen on the river bank. Belted kingfishers and mergansers were each seen feeding in the river on small fish on the east side of the beach crest.

Adult sockeye were observed just below the weir, as well as off the south tip of the beach crest. Juvenile sockeye (fry) were also observed on the east side of the beach crest, within 1 m from shore.

Water based river observations

Six surveys were conducted on the Ozette River between 20 May and 29 June. Four surveys were conducted in the lower 1.5-2 miles of river using the inflatable boat and 2 snorkel dive surveys were conducted, one in the upper 1.5 miles and one in the entire stretch of river from the weir to the mouth. For survey purposes the river was divided into three sections, based on generalized characteristics; upper (first one and one-half mile from lake), middle (middle three miles), and lower (last one and one-half miles to the ocean). Each section is described in detail below.

The upper section of the river is easily passable for swimmers in wetsuits. The dominant substrate ranges from small gravel to small cobble. The river in this section is composed mainly of riffles and small pools. Depths range from 0.25 m to as much as 2 m in the deeper pools. Small woody debris is abundant within this section, primarily small limbs and branches with 15-30 cm diameter trees found sporadically. The stream bank is diverse, ranging from steep banks with over hangs to gradual slopes. Numerous game trails leading up from the river into the forest were noted. This upper section contained relatively abundant numbers and species of fish, including squawfish, sculpins, cutthroat trout, and sockeye salmon.

The middle section is slow moving and characterized by numerous massive logjams interspersed by slow moving glides. The dominant substrate is bivalves, with large cobble and increasing amounts of sand and silt. In some sections, freshwater mussels literally cover large expanses of river bottom stretching from bank to bank. The river is made up of larger pools and deeper riffles than the upper section, with numerous glides. Depths range from 0.25 to 2.5 m. Woody debris is abundant in this section, with large logs (one-half to one and a quarter meter diameter) creating greater than ten massive logjams. The stream bank is similar to the upper section, including the presence of game trails. The ichthyofauna of this section is comprised primarily of squawfish and sculpin, however, the survey effort focused under water was somewhat less than in the upper section.

The lower section is tidally influenced at least three-quarters of a mile from the ocean. Depths range from 0.25 to 2.5 m. The substrate is similar to the upper section with small gravel and cobble yet the silt load is greater due to the abundance of large glides. There are many large boulder erratics as well as large stumps. The large woody debris of this sections is generally submerged. There are three large log jams ending about 1.5 mile from the river mouth. The fish observed in this section include; salmonid fry, sculpins, adult sockeye and squawfish.

Adult sockeye salmon were observed in the upper and lower sections of river during boat and dive surveys. School sizes ranged from 2 to 15 fish. Harbor seals or river otters were not observed during the boat or dive surveys in the Ozette River.

Lake Ozette boat surveys

Three vessel surveys were conducted in Lake Ozette to look for harbor seals or other predators on 4 June, and on 8 and 9 December. On June 4, the perimeter of the Lake was surveyed and also up Big River for 0.5 -0.75 miles. No seals or other predators were observed on this survey. On December 8, we surveyed from the sockeye fish weir to the south as far as Baby Island and then ran back north along the east side of the lake to Olsen's Beach. From there, we cut across the Lake to the west side near Allens Slough and surveyed north past Rocky Point to the entrance to Big River. We entered Big River and surveyed upriver for about 0.5 miles. The river was flooded and visibility through the water was poor. No seals or other predators were observed in the river or lake during the survey. On December 9, the entire perimeter of the lake was surveyed again but no seals or other predators were observed. A resident of Lake Ozette reported to us that 2-3 harbor seals had been observed in the lake over the last several weeks, near Rocky Point.

Spawning ground surveys

Spawning ground surveys were conducted on 8 and 9 December using divers in wetsuits and mask and snorkel gear. On 8 December, biologists from the Makah Tribe were collecting sockeye for brood stock at Olsen's Beach so we did not survey this area. The water level was very high at Lake Ozette during the surveys due to high runoff conditions in the area. Two divers entered the water at Allens Beach at the center of the spawning beds, marked with a stake and a thermograph. One diver headed north about 100 m, the other south 100 m, looking for any signs of spawning sockeye. No signs of spawning were noted on the north side. On the south side, 8-12 sockeye were counted, sex and condition however were not noted. Three redds were observed in this area. The redds had no fish associated with them and were at a depth of about 3.0 m. The sockeye in the area were milling around at depths of about 3.1 m and some digging had occurred, (their caudal region had already turned white). Lake level seemed to be up about 2-3 m from the summer shoreline and associated vegetation. Visibility from the surface was about 4-5 m.

On 9 December, the spawning ground surveys started at Olsen's Beach. Beginning at the dock, divers surveyed about 125 m to the north and south. Two transects depths in each direction were surveyed, 2 m and 3.5 m, looking laterally about 1 m to each side. Visibility was good to a depth of about 4-5 m. No sockeye or redds were found on the south transect. Substrate on the south side was primarily muddy with a high load of silt at the prime spawning depths with cobble along the shoreline. Additionally, large patches of grass were noted on the south side. Two male carcasses were observed and collected from the south. The fish were measured and otoliths were collected. To the north, nine sockeye were seen, five males and four females. Of these fish all the males were considered ripe. One female was spent, two were ripe and one was green. All but one of the fish showed signs of spawning activity, (white caudal area from digging). Five redds were identified at depths of 2.42 m, 2.17 m, 2.26 m, 2.66 m and 2.84 m, with two of the redds covered. The sockeye were milling around in the shallows, and only one male was guarding a redd. The area to the north where the sockeye were located was marked by a flag and was the same area fished for brood stock on the previous day. Surface substrate on the north side was predominantly sand in the shallows (<2.5 m), with cobble about 0.05 m below that. As depth increased, surface substrate turned to cobble, with a thin layer of silt covering everything. The condition of the fish suggests that the majority of the spawning at that site was finished. Four carcasses were collected on the north side, two males and two females, which were measured and otoliths collected.

After completing the survey of Olsen's Beach we ran the boat south to Baby Island. Two divers entered the water and surveyed the entire shore of the island at a depth of 2-3 m. No sockeye were seen. The substrate on the south side of the island was suitable for spawning and the north side was predominantly bedrock. The survey continued along the shore to Allens Slough. At Allens slough at the mouth of the creek, two divers entered water and surveyed to the north. The area adjacent to the mouth of the slough had a high mud and silt load, however gravel suitable for spawning was found about 35 m from the mouth. No sockeye were observed so the survey continued north to Allens Beach.

At Allens Beach, two divers entered the water at the thermograph stake and surveyed about 125 m to the north and south. Transects were conducted swimming parallel to the shore at varying depths, 1.5 m, 2.5 m and 3.5 m, and scanning 1 m to the left and right. On the south side, 22 sockeye were counted, most milling around within 1 m from the bottom. Ten males and eight females were noted, of these the males were considered ripe. Six females were ripe and two were green. Eleven redds were counted with fish in the area but none of them were actively guarding redds. Most dig sites were at a depth of 3.05 m, and within 10 m from the stake. Gravel on the south transect was ideal for spawning. Going from the shore out, surface substrate gradually increased in size, from pea gravel to cobble. The shallow substrate had very small amounts of silt on them, with the deeper areas having a slightly heavier load. The redd sites had uniform gravel to depth. From the condition of the sockeye, spawning had not occurred but may have begun by the end of the year. No sockeye were present to the north of the stake. The substrate on the north side was similar to that on the south side with a slightly greater slope. No harbor seals were seen during the spawning ground surveys, and no schools of fish other than sockeye were seen on the spawning grounds.

Summary and Discussion

The investigations of predator distribution and abundance near the Ozette River in 1998 confirmed that large numbers of potential predators occur within close proximity to the Ozette River and therefore potentially to Lake Ozette sockeye salmon. Harbor seals numbered in excess of 1,000 individuals within 5.5 km of the river mouth and both California and Steller sea lions were seasonally abundant with combined numbers exceeding 1,500 individuals during early May. These observations confirm both the spatial and temporal overlap of potential predators to Lake Ozette sockeye. Neither California nor Steller sea lions were observed or reported in the Ozette River or in Lake Ozette during the period when sockeye transit the river from May through early August, suggesting that overlap of these two predators is probably minimal. Harbor seals and river otters however were both common and appeared to occur frequently in the Ozette River during the period that sockeye were transiting the river. Harbor seals were observed in the lower river on five of nine days surveyed and at the river mouth on eight of nine days and exhibited foraging behavior in these areas, although they were not observed preying on sockeye. Although we did not observe harbor seals in Lake Ozette during our limited survey efforts, they were reported by local residents and National Park Service personnel as having been in the Lake in both May, June and December. Harbor seals were captured by video passing through the sockeye weir into Lake Ozette at least eight times during the season and were observed eating a sockeye salmon at least once. These observations suggest that although harbor seals are not abundant within the Ozette watershed, that small numbers are commonly observed there during the sockeye run. This is a cause for concern given the small size of the sockeye population because even a small number of seals could potentially consume a significant number of fish. River otters were observed in both the upper and lower Ozette River during the season. Weir observers and the video camera noted otters passing through the sockeye weir at least 82 times and as many as 3-4 otters were observed at night in the vicinity of the weir (Makah Fisheries, unpubl. Data). River otters were also captured carrying sockeye salmon through the weir from the river into the Lake. This is also a cause for concern because river otters are very adept predators and are fully capable of preying on sockeye salmon in the narrow and shallow water conditions in the upper river. A subsample of 705 sockeye examined from video tapes from 7 May through 2 July showed predator scars on at least 3.4% of the fish.

The investigations of diet through collection and examination of scat material did not yield any evidence of predation on sockeye salmon by these predators. However this finding must be viewed cautiously when making conclusions about potential impacts, because the methodology may not have been sufficient to detect these predation events. Given the small estimated population size of the 1998 sockeye run (1,406) and the fact that the run is protracted over 3-4 months it is unlikely that scat sampling would yield significant percentages of sockeye salmon. Analyses using DNA have been completed for the salmonid bone samples from harbor seals yet these did not indicate that sockeye salmon were consumed. Further analysis of the bone samples from scats of river otters and sea lions using DNA techniques may provide information on the identity of the salmonid bone recovered in the 1998 samples. Even if these analyses document sockeye salmon predation, it is unlikely to indicate any significant level of impact due to the low salmonid frequencies from the samples. The 1998 scat sampling results do provide a good baseline of information about the generalized food habits of these predators in the Ozette/Cape Alava area. These results demonstrate that overall on a large scale that sockeye salmon and salmonids in general are not primary prey. Given the findings, or lack of findings from the scat sampling in 1998 we would not recommend further scat sampling from harbor seals or sea lions as a means to document sockeye salmon interactions. Scat sampling from river otters in the Ozette River however may be more beneficial due to the high degree of spatial and temporal overlap of otters and sockeye salmon.

The observations conducted in the Ozette River and Lake Ozette indicate that both harbor seals and river otters frequent these areas. Neither species of predator was observed in Lake Ozette during out limited surveys but they were observed and reported there by other sources; including the Makah Tribal sockeye weir observers and by Lake Ozette residents. Harbor seals were observed consistently in the lower Ozette River and exhibited foraging behavior in this area. These findings suggest that interactions between harbor seals and sockeye salmon could occur in this area. Interactions could also occur in the central or upper Ozette River but our survey effort there was minimal. We did not observe harbor seals or river otters near the spawning grounds during our December surveys, however there were only two surveys during the spawning period.

Further research is needed to focus efforts on interactions between harbor seals, river otters and the Lake Ozette sockeye. We recommend that intensive survey effort be conducted during the 1999 season at the lower Ozette River to determine if predation occurs there and to what extent harbor seals utilize this area. The surveys should occur in June during the peak of sockeye passage into Lake Ozette. We also recommend that survey efforts increase on the upper Ozette River near the sockeye weir to document any interactions. Vessel surveys in Lake Ozette should also increase to at least 2 per month to record any activity of seals or otters in the lake. Finally, a key piece of information needs to be analyzed and quantified regarding the predator scars observed on Lake Ozette sockeye. These data need to be analyzed to determine if they are caused by harbor seals, sea lions or river otters. This information can then help determine where the predation occurs and how best to quantify the effects.

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Citations

Beauchamp, D.A., M.G. LaRiviere, and G.L. Thomas. 1993. Evaluation of competition and predation as limits to juvenile sockeye salmon production in Lake Ozette, Washington. Final Rept. to Makah Tribe, Makah Fish. Manag. Division, Neah Bay, WA. 67 pp.

Blum, J.P. 1988. Assessment of Factors Affecting Sockeye Salmon (*Oncorhynchus nerka*) Production in Ozette Lake, WA. M.S. Thesis, Univ. of Washington, Seattle, WA, 107 pp.

Cooke, L., V. Cooke, M. Crewson, M. Haggerty, J. Hinton and E. Johnson. 1999. Escapement estimate for Lake Ozette sockeye salmon during 1998. Makah Fisheries Management Report 99-1, P.O. Box 119, Neah Bay, WA. 98357, 12 pp.

Dlugokenski, C.E., W.H. Bradshaw, and S.R. Hager. 1981. An Investigation of the Limiting Factors to Lake Ozette sockeye salmon production and a plan for their restoration. U.S. Fish and Wildlife Service, Fisheries Assistance Office, Olympia, WA., 59 pp.

Gearin, P.J., S.J. Jeffries, S. Riemer, L.L. Lehman, K.M. Hughes, and L. Cooke. 1999. Prey of Steller sea lions, *Eumetopias jubatus,* in Washington State. In: Abstracts of the Marine Mammal Society 13th Biennial Conference, Nov. 29-Dec. 3, 1999. Wailea, Maui, Hawaii.

Harvey, J. T., Loughlin, T. R., Perez, M. A., and Oxman, D. S. 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. 48 pp.

Huber, H. R. 1995. Correction factor to estimate abundance of harbor seals in Washington, 1991-1993. M.S. thesis. Univ. of Washington Seattle, WA. 53pp.

Jacobs, R., Larson, G., Meyer, J., Currence, N., Hinton, J., Adkison, M., Burgner, R., Geiger, H., and Lestelle, L. 1996. The Sockeye Salmon *Oncorhynchus nerka* Population in Lake Ozette, Washington, USA. U.S. Dept. of Interior, NPS, Tech. Rept. NPS/CCSOSU/NRTR-96-04. 110 pp.

Kemmerich, J. 1945. A review of artificial propagation and transplantation of the sockeye salmon of the Puget Sound area in the State of Washington conducted by the federal government from 1868 to 1945. U.S. Fish and Wildlife Service, Unpub. ms. 116 pp.

LaRiviere, R.G. 1991. Lake Ozette sockeye salmon studies: Adult weir operations, 1988-1990. Makah Tribe Project Rept. 91-1. Makah Fisheries Management Department, P.O. Box 115, Neah Bay, WA. 98357.

National Marine Fisheries Service (NMFS). 1999. Endangered and Threatened Species: Threatened Status for Ozette Lake Sockeye Salmon in Washington. Federal Register/Vol. 64, No. 57/March 25, 1999/Rules and Regulations. Pp. 4528-14536.

Appendix 1

Table 1. Harbor seal scat collections, Ozette project, 1998.

Date	Location	Number
5/6/98	E. Bodelteh	32
5/7/98	Father & Son	6
5/7/98	Cooke Rock	22
5/7/98	NE Ozette Rock	2
5/19/98	E. Bodelteh	50
6/1/98	E. Bodelteh	42
6/3/98	E. Bodelteh	6
6/3/98	Cooke Rock	8
6/5/98	Cooke Rock	4
6/16/98	E. Bodelteh	30
6/18/98	E. Bodelteh	16
7/2/98	E. Bodelteh	36
7/2/98	Father & Son	18*
7/16/98	E. Bodelteh	10
7/22/98	E. Bodelteh	29
7/28/98	Cooke Rock	16
7/28/98	Father & Son	13
7/30/98	Father & Son	5
Total		**347**

* Two of the samples were blanks with no contents.

Appendix 1

Table 2. Steller sea lion scats collected for the Ozette sockeye project during 1998.

Date	Location	Number
5/6/98	Sea Lion Rock	15
6/3/98	West Bodelteh	30
7/28/98	Carroll Island	20
7/28/98	Sea Lion Rock	13
7/28/98	West Bodelteh	23
7/29/98	Tatoosh Island	23
Total		**124**

Table 3. California sea lion and mixed[1] sea lion scats collected for the Ozette project during 1998.

Date	Location	Number
5/6/98	Sea Lion Rock	6
5/6/98	Sea Lion Rock	15
5/6/98	East Bodelteh	30[1]
5/19/98	East Bodelteh	15[1]
Total		**66**

[1] Mixed sea lions = collections in areas where Steller and California sea lions were hauled out together.

Table 4. River Otter scats collected from the Ozette River, 1998.

Date	Location	Number
6/4/98	Near sockeye weir	13
6/17/98	upper 1 mile	6
6/29/98	upper 2 miles	21
Total		**40**

Appendix 1.

Table 5. Prey remains from harbor seals scats on the outer coast of Washington, 1998 (n=330).

Prey species	Scientific name	% Frequency	Nmin* $_{total}$
Pacific tomcod	*Microgadus proximus*	41.2	
Smelt	*Osmeridae spp*	30.9	
Pacific whiting	*Merluccius productus*	28.5	
Pacific sardine	*Sardinops sagax*	25.5	
Pacific herring	*Clupea pallasi*	17.3	
Northern anchovy	*Engraulis mordax*	15.5	
English sole	*Parophrys vetulus*	14.2	
Butter sole	*Isopsetta isolepis*	7.9	
Pacific mackerel	*Scomber japonicus*	7.9	
Flatfish	*Pleuronectiformes spp*	6.7	
Clupeidae	*Clupeidae spp*	6.1	
Market squid	*Loligo opalescens*	5.8	
Skate	*Rajidae spp*	5.5	
Goby	*Gobiidae spp*	2.1	
Dover sole	*Microstomas pacificus*	2.1	
Rockfish	*Sebastes spp*	1.8	
Rex sole	*Glyptocephalus zachirus*	1.5	
Slender sole	*Lyopsetta exilis*	1.2	
Sculpin	*Cottidae spp*	1.2	
Salmon[1]	*Salmonidae spp*	1.5	
Longfin smelt	*Spirinchus thaleichthys*	0.9	
Shiner surfperch	*Cymatogaster aggregata*	0.9	
Pacific staghorn sculpin	*Leptocottus armatus*	0.9	
Sand sole	*Psettichthys melanosticus*	0.6	
Pacific sanddab	*Citharichthys sordidus*	0.6	
Jack mackerel	*Trachurus symmetricus*	0.6	
Pacific lamprey	*Lampetra tridentata*	0.6	
Pacific sandlance	*Ammodytes hexapterus*	0.6	
Gadidae	*Gadidae spp*	0.6	
Scorpaenidae	*Scorpaenidae spp*	0.3	
Sanddab	*Citharichthys spp*	0.3	
Yellowfin sole	*Limanda aspera*	0.3	
Kelp greenling	*Hexagrammos decagrammus*	0.3	
Pacific sandfish	*Trichodon trichodon*	0.3	
Spotfin sculpin	*Icelinus tenuis*	0.3	
Petrale sole	*Eopsetta jordani*	0.3	
Cuskeel	*Ophidiidae spp*	0.3	
Lingcod	*Ophiodon elongatus*	0.3	
American shad	*Alosa sapidissima*	0.3	
Spiny dogfish	*Squalus acanthias*	0.3	
Octopus	*Octopus spp*	0.3	
Bothidae	*Bothidae spp*	0.3	
Greenling	*Hexagrammidae spp*	0.3	
Lamprey	*Petromyzontidae spp*	0.3	

[1]Total frequency for salmon includes 2 samples with Coho (FO=0.6; Nmin=2) and 3 samples with Chinook salmon (FO=0.9; Nmin=3). *Nmin calculation for these samples has not yet been completed.

Appendix 1

Table 6. Prey remains from Steller sea lion scats on the Washington coast, 1998 (n=124).

Species	Scientific name	% Frequency	$Nmin_{total}$
Pacific whiting	*Merrluccius productus*	87.9	116
Spiny Dogfish	*Squalus acanthias*	24.2	30
Starry flounder	*Platichthys stellatus*	16.1	21
Skate	*Rajidae spp*	14.5	19
Clupeidae	*Clupeidae spp*	12.9	19
Pacific herring	*Clupea pallasi*	11.3	46
Pacific sardine	*Sardinops sagax*	5.7	18
Pacific mackerel	*Scomber japonicus*	4	5
Northern anchovy	*Engraulis mordax*	3.2	18
Pacific sanddab	*Citharichthys sordidus*	3.2	13
American shad	*Alosa sapidissima*	2.4	3
Salmon[2]	*Salmonidae spp*	1.6	2
Lamprey	*Lampetra spp*	1.6	2
Pacific sandlance	*Ammodytes hexapterus*	1.6	3
Pacific tomcod	*Microgadus proximus*	1.6	2
English sole	*Parophrys vetulus*	1.6	2
Elasmobranchi	*Elasmobranchi spp*	1.6	2
Sculpin	*Cottidae spp*	0.8	1
Butter sole	*Isopsetta isolepis*	0.8	1
Rockfish	*Sebastes spp*	0.8	1
Market squid	*Loligo opalescens*	0.8	1
Chinook	*Oncorhynchus tshawytscha*	0.8	1

[2]Total frequency for salmon includes Chinook salmon.

Table 7. Prey remains from California sea lion scats on the outer Washington coast, May 1998 (n=17).

Prey species	Scientific name	% Frequency	$Nmin_{total}$
Pacific whiting	*Merluccius productus*	82.4	14
Pacific mackerel	*Scomber japonicus*	23.5	4
Pacific sardine	*Sardinops sagax*	23.5	5
Dogfish	*Squalus acanthias*	23.5	4
Pacific herring	*Clupea pallasi*	17.7	12
Salmon[3]	*Salmonidae spp*	11.8	2
Elasmobranchi	*Elasmobranchi spp*	11.8	2
Northern anchovy	*Engraulis mordax*	5.9	1
Clupeidae	*Clupeidae spp*	5.9	1
Smelt	*Osmeridae spp*	5.9	1
Flatfish	*Pleuronectiformes spp*	5.9	1

[3]Salmon were not identified to species for these samples.

Appendix 1

Table 8. Prey remains from mixed scats (Steller sea lions and California sea lions) on the outer Washington coast, 1998 (n=46).

Prey species	Scientific name	% Frequency	Nmin $_{total}$
Pacific herring	*Clupea pallasi*	56.5	87
Pacific whiting	*Merluccius productus*	56.5	38
Salmon[4]	*Salmonidae spp*	30.4	14
Pacific sardine	*Sardinops sagax*	21.7	21
Spiny dogfish	*Sqaulus acanthias*	17.4	7
Clupeidae	*Clupeidae spp*	15.2	13
American shad	*Alosa sapidissima*	10.9	3
Northern anchovy	*Engraulis mordax*	8.7	10
Skate	*Rajidae spp*	8.7	4
Pacific sandlance	*Ammodytes hexapterus*	4.3	2
Starry flounder	*Platichthys stellatus*	4.3	2
Pacific tomcod	*Microgadus proximus*	4.3	3
Sanddab	*Citharichthys spp*	2.2	1
Chinook	*Oncorhynchus tshawytscha*	2.2	1
Smelt	*Osmeridae spp*	2.2	1
Elasmobranchii	*Elasmobranchii spp*	2.2	2
Pacific mackerel	*Scomber japonicus*	2.2	1
Flatfish	*Pleuronectiformes spp*	2.2	1
Jack mackerel	*Trachurus symmetricus*	2.2	1
Lamprey	*Lampetra spp*	2.2	3

[4]Total frequency for salmon includes Chinook salmon

Table 9. Prey remains from river otter scats from the Ozette River, June 1998 (n=40).

Prey species	Scientific name	% Frequency	Nmin $_{total}$
Crayfish	*Pacifasticus lineasticus*	82.5	47
Northern Squawfish	*Ptychocheilus oregonensis*	47.5	19
Sculpin	*Cottidae spp*	45.0	23
Freshwater mussel		40.0	16
Mammal/ Rodent bone	*Mammalia/Rodentia*	30.0	12
Salmon[5]	*Salmonidae spp*	17.5	8
Snail	*Gastropoda spp*	17.5	10
Clams	*Bivalvia spp*	12.5	5
Lamprey	*Lampetra spp*	10.0	4
Insect	*Arthropoda spp*	7.5	3
Chinook salmon	*Oncorhynchus tshawytscha*	5.0	2
Coho salmon	*Oncorhynchus kisutch*	2.5	2
Isopod	*Isopoda spp*	2.5	1
Smelt	*Osmeridae spp*	2.5	1
Frog/Salamander	Amphibia	2.5	1
Spider	Arachnida	2.5	1

[5]Total frequency for salmon includes 2 samples with Chinook and 1 sample with Coho salmon.

Appendix 2

Table 1. Species observed in and along the Ozette River during NMML boat, shore based, and dive surveys in 1998.

Species (FISH)	Distribution along river (upper, middle, lower)
Northern Squawfish, *Ptychocheilus oregonensis*	upper, middle
Sculpin, *Cottus sp.*	upper, middle, lower
Trout, Cutthroat or Rainbow, *Oncorhynchus sp.*	upper, middle
Sockeye salmon, *Oncorhynchus nerka*	upper, lower
Salmon (Coho or Chinook), *Oncorhynchus. sp.*	upper
Pacific lamprey, *Lampetra tridentata*	upper
Species (OTHER)	
Harbor seal, *Phoca vitulina*	lower
Mergansers, *Common / Hooded, Mergus sp, / Lophodytes sp.*	lower
Bald eagle, *Haliaetus leucocephalus alascanus*	lower
Crawfish, *Pacifasticus lineasticus*	upper, middle
Belted kingfisher, *Ceryle alcyon*	upper, middle, lower
Elk (Wapiti), *Cervus canadensis*	middle
River otter, *Lutra canadensis*	upper
Black-tail deer, *Odocoileus hemionus columbianus*	upper, middle, lower
Racoon, *Procyon lotor*	upper, middle, lower
Coyote, *Canis latrans*	lower
Freshwater mussel	upper, middle, lower