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Marine Mammal Protection Act and Endangered Species Act Implementation Program 1999

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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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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 17 papers, is a compilation of studies carried out with fiscal year 1999 (FY99) 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.

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MMPA/ESA Implementation Program
Report for 1999

Reporting Center: National Marine Mammal Laboratory
Alaska Fisheries Science Center

Administrative Office: Office of Protected Resources
National Marine Fisheries Service

AERIAL SURVEYS OF BELUGA WHALES IN COOK INLET, ALASKA, JUNE 1999

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Abstract

The National Marine Fisheries Service (NMFS) conducted an aerial survey of the beluga whale population in Cook Inlet, Alaska, during 8-14 June 1999. The 41.5 hr survey was flown in a twin-engine, high-wing aircraft at an altitude of 244 m (800 ft) and speed of 185 km/hr (100 kt) along a trackline 1.4 km from shore, consistent with annual surveys flown each year since 1993. The flights in 1999 included one or more surveys of coastal areas around nearly the entire Inlet and 1,790 km of transects across the Inlet. Paired, independent observers searched on the coastal (left) side of the plane, where virtually all sightings occur, while a single observer and a computer operator/data recorder were on the right side. In addition, each day a different visitor observed from the left side. After finding beluga groups, a series of aerial passes were made to allow at least two pairs of primary observers to make four or more counts of each group. Inter-day counts ranged from 75 to160 belugas near the Susitna River (between the Beluga and Little Susitna Rivers), 13 to 43 in Knik Arm, and 17 to 30 in Chickaloon Bay, but no belugas were found in lower Cook Inlet. The sum of the aerial estimates (using median counts from each site, not corrected for missed whales) ranged from 197 to 221 whales, depending on observer. The index count for 1999 is 217, which is slightly higher than the index counts for 1998 (193) but lower than all index counts by NMFS observers between 1993-97.

Introduction

Beluga whales (*Delphinapterus leucas*) are distributed around most of Alaska from Yakutat Bay 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 (Laidre et al. in prep.). Beluga whales in Cook Inlet are very concentrated in a few river mouths during parts of the year

(Rugh et al. in prep.). 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 NMFS National Marine Mammal Laboratory (NMML) and Alaska Regional Office have conducted annual aerial surveys to study the distribution and abundance of beluga whales in Cook Inlet each June/July since 1993 (Withrow et al. 1994; Rugh et al. 1995, 1996, 1997a, 1997b, 1999) in cooperation with the Alaska Beluga Whale Commission (ABWC) and the Cook Inlet Marine Mammal Council (CIMMC). A letter from the Alaska Regional Scientific Review Group (ASRG) to S. Pennoyer, NMFS, dated 13 May 1997, strongly urged NMFS to continue these surveys every year. Aerial surveys are proven to be the most efficient method for collecting distribution and abundance data for beluga whales in Cook Inlet (Klinkhart 1966; Calkins et al. 1975; Murray and Fay 1979; Calkins 1984). The most recent studies have been some of the most thorough and intensive (Rugh et al. in prep.).

Methods

The survey aircraft, an Aero Commander 680 FL (*N7UP*), has twin-engines, high-wings, 10-hr flying capability, and is equipped with seating for five passengers and one pilot. There are bubble windows at each of the four 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 a portable global positioning system (GPS) interfaced with the laptop 386 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.

There was an attempt to synchronize flight timings with low tides in the upper Inlet. This was primarily to minimize the effective survey area (at low tide, large areas of mudflats are exposed that would otherwise have to be surveyed). However, 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.

Coastal surveys were conducted on a trackline approximately 1.4 km offshore. The objective was to search nearshore, shallow waters where beluga whales are typically seen in summer (Rugh et al. in prep.). 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, systematic 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). In 1999, this sawtooth pattern was offset from the previous years to reduce resampling among years.

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 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 survey protocol was the independence of the observers on the left (i.e., 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 counting passes by flying a criss-cross pattern over the group, recording starts and stops of group perimeters.

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 (four passes for each of two pairs of observers on the left side of the aircraft), there were typically eight or more separate counting opportunities per whale 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. Count records 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.

A digital video camera was operated on each counting pass. Both the digital video and the Hi-8mm video used in previous seasons were run simultaneously in one test to allow for comparisons of the two cameras. Later, the images will be studied in the laboratory, and counts of whales will be compared to the infield counts (Hobbs and Waite in prep.). Analysis of both the aerial counts and counts from the video tapes are detailed in Hobbs et al. (in prep.) for 1994-98 data.

Results

A total of 41.5 hr of aerial surveys were flown around Cook Inlet 8-14 June 1999. All of these surveys (12 flights ranging from 1.6 to 5.3 hr) were based out of Anchorage, with refueling stops in Kenai and Homer. Systematic search effort was conducted for 22.1 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 1.5 hr (6.6% of the total flight time) when the left-front observer considered the visibility poor or worse. All of the primary observers who flew with this project in 1998 returned in 1999.

On 8 June, a test flight was conducted to be sure all onboard systems were operational. In addition, the group of whales at the Little Susitna River was circled for aerial photography (to collect images that will provide ratios of dark to light animals) and tests with dual video cameras (to compare a new digital video camera to the Hi-8mm camera used during the past several years).

On 9, 12, and 13 June, surveys were made around upper Cook Inlet, north of the East and West Forelands. High winds prevented surveys in Turnagain Arm except on 12 June. Excellent sighting conditions and thorough coverage made 12 June the primary survey day for upper Cook Inlet in 1999. On 10, 11, and 14 June, the lower Inlet and offshore waters were surveyed. Although the lower Inlet is usually surveyed in two days, unforecasted high winds in the lower Inlet on 11 June required an additional survey flight on 14 June. The composite of these aerial surveys provided a thorough coverage of most of the coast of Cook Inlet for all waters within approximately 3 km of shore (Fig. 1). In addition, there were 1,790 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 tracklines covered roughly 6,200 sq km, which is approximately 31% of the surface area of Cook Inlet; however, these surveys covered virtually all of the coastal areas except the southwesternmost corner of the lower Inlet. Most of upper Cook Inlet was surveyed three times, in particular the Susitna Delta where large groups of beluga whales have usually been found.

Counts of beluga whales are shown in Table 1, and sighting locations are shown in Figure 1. These counts are the medians of each primary observers' counts on multiple passes over a group. Ideal counting conditions and thorough coverage of the upper Inlet occurred on 12 June. Therefore, only the counts made on that date are used in summary calculations (which is consistent with methods used in the past). The sum of the observers' counts ranged from 197 to 221, depending on observer, with a median index count of 217. 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.). The median index of counts in 1999 (217) is higher than in 1998 (193) but lower than in previous years (Table 2).

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, described here as the Susitna Delta, or in Knik Arm and Chickaloon Bay (Fig. 1). 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 July or later and are very likely associated with the migration of anadromous fish, particularly eulachon (*Thaleichthys pacificus*) (Calkins 1984; 1989) and several species of Pacific salmon. Only 0-4% of the annual sightings of belugas have occurred in lower Cook Inlet since 1993 (Table 2), but historically many whales were seen in the lower Inlet (Rugh et al. in prep.). Prior to 1996, small groups of belugas were observed in the lower Inlet (such as in Kachemak and Redoubt Bays), but only single or dead whales have been seen south of North Foreland since then, and none were seen in the lower Inlet in 1999. Although the southwesternmost part of the lower Inlet was not surveyed in 1999 due to high winds or fog and rain, this area has never had beluga whales during any surveys in the past. Many sea otters, harbor porpoise, harbor seals, and some other cetaceans (e.g., humpback, gray, and minke whales) were seen in the lower Inlet, so the lack of beluga sightings may not be a function of visibility. In fact, on virtually every day of this survey a sighting was made of a beluga group near the Little Susitna River, even in windy conditions while the aircraft was doing an approach into Anchorage International Airport.

The uncorrected sum of median estimates made from the June 1999 aerial observations in Cook Inlet was 217 beluga whales. Using the same procedure of summarizing median estimates from the highest seasonal counts at each site 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. The average abundance estimate for the period 1994-98 is 505 beluga whales (SE = 81, CV = 0.16; Hobbs et al. in prep.), including corrections for whales missed within the viewing range of observers and whales missed because they were beneath the surface. Although there appears to be a decline in abundance estimates through this 5-year period, the trend is not statistically significant.

The rise in the abundance index in 1999 might at first be interpreted as a rise in the true abundance (perhaps as a function of the moratorium on the hunt in 1999); however, the precision of the index is not good enough to be a true reflection of such a small change (24 whales). The abundance estimate for 1998 (347 beluga whales) had a CV of 0.29 (Hobbs et al. in prep.); therefore, a large change in counts would be necessary to show a statistically significant difference. Note that as beluga group density decreases, aerial counts become more accurate, reducing the sensitivity to a downward trend in abundance. As of yet there is no clear evidence that the Cook Inlet beluga population has changed in size when compared to the 1998 abundance estimate of 347 whales (Hobbs et al. in prep).

Acknowledgments

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Table 1. Summary of counts of beluga whales made during aerial surveys of Cook Inlet in June 1999. Medians from primary 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		10-11 June		12 June		13-14 June		1999
	median	high	median	high	median	high	median	high	Highest medians
Turnagain Arm (East of Chickaloon Bay)	---	---	---	---	0	0	---	---	0
Chickaloon Bay/ Pt. Possession	17	30	---	---	**29**	39	---	---	29
Pt. Possession to East Foreland	0	0	0	0	**1**	1	0	0	1
Mid-Inlet east of Trading Bay	---	---	0	0	---	---	0	0	0
East Foreland to Homer	---	---	0	0	---	---	---	---	0
Kachemak Bay	---	---	0	0	---	---	---	---	0
W side of lower Cook Inlet	---	---	0	0	---	---	0	0	0
Redoubt Bay	---	---	0	0	---	---	0	0	0
Trading Bay	0	0	---	---	0	0	0	0	0
Susitna Delta (N Foreland to Pt. Mackenzie	89	105	75	96	**160**	221	109	181	160
Fire Island	---	---	---	---	0	0	---	---	0
Knik Arm	43	51	---	---	**27**	39	14	27	27*

Total = 217

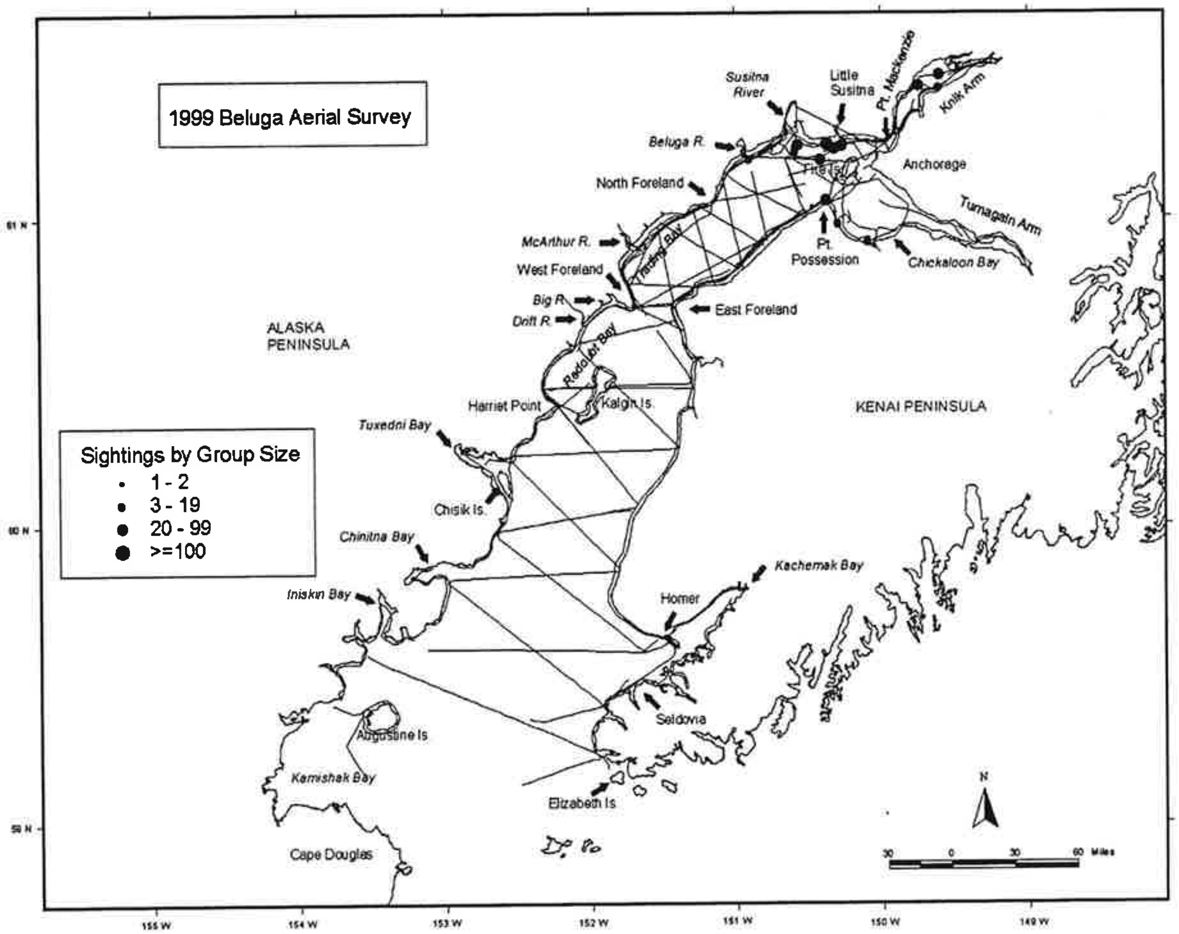
*Use high count of Knik Arm plus Susitna counts, allowing that whales may move between these two areas.

Table 2. Summary of beluga whale sightings made during aerial surveys of Cook Inlet in June or July 1993-99. 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
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
1999	June 8-14	**217**	0	74	26

Figure Caption

Fig. 1. Aerial survey tracklines and beluga groups seen 8-14 June 1999 during aerial surveys of Cook Inlet.



1999 COOK INLET BELUGA TAGGING PROJECT FIELD REPORT

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Introduction

This report summarizes the 1999 beluga whale capture and satellite tagging project in Cook Inlet, Alaska. The study was conducted 24 May - 3 June by a team of biologists from NMML, NMFS Anchorage Office of Protected Resources, NMFS Southwest Fisheries Science Center, and two Alaskan Native beluga whale hunters from Anchorage. For the first time in over 5 years of testing alternative capture techniques in Upper Cook Inlet, beluga whales were successfully captured and one adult male was equipped with a satellite/VHF tag package.

The beluga whales in Cook Inlet are considered a separate stock from those located elsewhere in Alaskan waters (O'Corry-Crowe et al. 1997, Frost and Lowry 1990). The most recent estimate of the Cook Inlet beluga population is 347 animals (Hobbs et al. 1999), approximately 47% lower than the 1994 estimate. Prior to 1999, subsistence harvests exceeded 30 animals per year (Hill and DeMaster 1998) although hunting is currently suspended.

Determination of current population status represents a high priority mission for NMFS, the achievement of which is contingent on both the completion of annual aerial surveys and the development of correction factors to account for animals below the surface at the time of survey. Thus, the objective of the 1999 tagging project was to capture one or more beluga whales and equip them with satellite/VHF telemetry tags to allow real time and remote collection of dive and surfacing interval data. In addition, satellite location and dive data can provide valuable information on distribution and movement patterns during spring and summer.

Beluga whale tagging in Cook Inlet was first attempted in 1994 when VHF transmitters, affixed to suction cups, were applied to free ranging animals by jab stick (Lerczak 1995). No effort was made, at that time, to capture animals or to attach more durable tag packages. The VHF transmitters yielded some, albeit limited (owing to the short-term nature of the suction cup form of attachment), surfacing data.

In 1995, suction cup tags were again deployed, and a significant, but unsuccessful, attempt was also made to capture and equip belugas with satellite tags (Waite et al. 1996). The capture method involved jumping from a small boat next to a surfacing beluga while slipping a hoop net over the animal's head. As demonstrated in earlier work in the Canadian High Arctic (Smith and Martin 1994), when done in water shallow enough for a diver to easily touch bottom, beluga whales can be quickly brought under control. However, the turbid waters of Upper Cook Inlet severely limited the researcher's ability to track and closely approach whales. Likewise, water depth could not be judged with certainty to ensure a safe jump. The evasive behavior of the Cook Inlet beluga whales, combined with minimal water clarity, confounded all attempts to use the jump capture-method.

In 1997, a third season of tagging work was initiated. Based on observations from previous years and recommendations from beluga whale researchers in Canada, an alternative capture method using large-mesh gillnets and several small boats was used (Hill et al. 1998). The objective was to deploy a gillnet ahead of the beluga whales and subsequently drive them into the net.

In retrospect, this approach was not entirely appropriate for the highly elusive whales in Cook Inlet. Despite nearly three weeks of effort, no beluga whales could be driven into the capture net long enough to become entangled. On 14 occasions, the net was set ahead of individual beluga whales and each time the animals simply reversed direction, evaded the small boats then stayed well away from the immediate capture area.

Although the 1997 tagging project failed to capture a single beluga whale, three critical observations were made which ultimately provided the basis for success in 1999. First, more whales could be encountered close to the mouths of the Big and Little Susitna Rivers in shallow water if the field work occurred earlier, during the peaks of the chinook salmon and eulachon runs. In 1997, as these runs declined in early June, the belugas became much more dispersed and less predictable. Second, entanglement in large-mesh gillnets could work, but only if the target animal was fully encircled with no opportunity to double back to open water. Third, in order to accomplish full encirclement, more net would be required and deployment would need to occur at very high speed.

Methods

As in 1997, the wide deltas at the mouths of the Big and Little Susitna Rivers were chosen as the study area based on consistent presence of beluga whales in that area during late spring and early summer (Hill et al. 1998). A field camp was established on the east side of Big Island at the mouth of the Big Susitna River from 24 May to 3 June 1999. Provided winds did not preclude small boat use, a crew of seven biologists and two Native hunters searched for beluga whales during each high tide occurring in daylight. The shallow channels of the Big Susitna River adjacent to the field camp were generally navigable approximately 2 hours before to 2 hours after high slack tide water, thus defining the typical capture effort window. A total of four boats were used, including a 20' Boston whaler carrying the capture net, a 17' Avon, a 16' Zodiak and a 22' aluminum Munson.

The overall capture strategy entailed searching for belugas in shallow waters between the Big Susitna River delta and the mouth of the Little Susitna River. Once whales were located, the hunters would then isolate an individual animal and drive it into water approximately 2 m deep to facilitate tracking and to ensure that the capture net could reach the bottom. When a target animal was moving consistently ahead of the hunter's boat, the net boat was brought into position to the left, and just astern of the hunters' boat. A drag buoy, attached to approximately 150 m of 0.3 m braided mesh net (4 m deep), was then deployed. Immediately, the net boat accelerated to approximately 25 kt, overtook the target animal and executed a tight clockwise turn back to the point of initial deployment. The goal was to have net set around the beluga, with the hunter's boat also encircled in the process.

As the animal attempted escape, it eventually contacted the gillnet, pushing the mesh and floatline into a "v" shaped channel that progressively closed in around it. Once entangled, the animal was tended by personnel in one or more of the nearby boats. Ultimately a hoop net was slipped over the animal's head, and a tail loop placed around its caudal peduncle.

Tag attachment was achieved by boring 1 cm diameter holes through the whale's dorsal ridge such that they aligned with holes in each of four saddle straps glued to the tag. This technique is similar to that reported by Martin and Smith (1992). Nylon bolts (30 cm long) were passed through each hole and attached on either side of the straps. A total of four bolts were thus installed. The tags, built by Wildlife Computers, Redmond Washington, measured 18 cm x 9 cm x 3 cm and weighed about 500 g (complete tag specifications are contained in the reference manual provided by the manufacturer; Wildlife Computers 1994).

Results

Unlike the 1997 effort, better camp placement and more favorable weather conditions allowed the crew to maximize the number of possible capture attempts and to avoid the dangers associated with operating in the upper reaches of the Little Susitna River channel. Of 18 possible high tides occurring in daylight, 12 were worked, 2 were not worked due to winds (5/25 AM, 5/29 AM), and 4 were not worked because of logistical considerations (5/26 AM, 5/31 PM, 6/1 PM and 6/2 PM).

Searches for belugas conducted during the 12 high tides resulted in 12 encounters with groups of 50 - 100 whales. Each of these encounters were followed by capture attempts on individuals in a portion of the total group. Eleven sets were made, in which four belugas were entangled to varying degrees (Table 1). That is, one whale broke free during handling (5/28), one immature (gray) female was captured, measured and released (5/31), one adult broke free at the start of handling (5/31), and one adult male was captured and tagged (5/31).

As hoped, the belugas were consistently found near the river mouths in shallow water throughout the field season. The animals appeared to be feeding, presumably on either chinook salmon or eulachon. Encounters in or near the mouth of the Little Susitna River were most common. Although wary and evasive, the animals were found well onto tidal shallows which reduced their ability to avoid capture by moving into deep water.

Belugas were captured in 3 of 11 sets completed. Three of the unsuccessful sets failed because the net was not quickly or completely closed, and two were ineffective sets from a river bank (see 31 May below for details). In the remaining three, technical difficulties with the net deployment system (i.e., snagging of the net on the deployment stanchion and its subsequent collapse in the high speed tight turns) were responsible for failures.

With respect to logistics, the establishment and dismantlement of the field camp occurred on 5/24 and 6/3, respectively. The team and personal gear were transported by boat, while fuel, water, food and all other equipment were flown in by helicopter sling load. The use of helicopters to move most of the equipment and supply volume in this way proved to be very cost effective since at least 2 days of small boat freight runs to and from Anchorage were avoided, allowing more time for capture efforts.

The following provides details for each day in the field (the field team was in place on the evening of 24 May).

25 May - Weather during the morning high tide was too windy to attempt small boat travel. By the afternoon, the winds had subsided and the crew departed camp at about 1430. A group of approximately 100 belugas were found 2 km up the Little Susitna River. Moving slowly downstream, the boats were used to drive the animals out of the river to the adjacent shallows where attempts were made to isolate an individual in shallow water. At this point, no Native hunters were working with the team. After nearly an hour of unsuccessful attempts to position an animal, the decision was made to begin the trip back to camp, although the tide had already dropped too low to make reaching it certain.

At approximately 2100, the Boston Whaler went hard aground on a sand bar while the other two shallower draft boats reached the shoreline on the west channel of the Big Susitna River, but stranded 5 km from camp. After several hours, two team members walked/drove the Zodiak from shore through the maze of channels out to the Boston Whaler, then brought the remaining team members back to the rest of the group onshore. The team built a fire and spent the night awaiting the incoming tide. The team reached camp at about 0500 the following morning. The late return trip on the ebbing tide the previous night eliminated the crew's ability to work the morning high tide due to fatigue and limited time available to refuel the boats. A total of 50 whales were taken by harassment during pursuit; none were captured.

26 May - The crew remained in camp and prepared the boats for the afternoon high tide. By 1500, however, the winds had risen too high to work. Instead, a watch was established on an adjacent island (Delta) in the event that belugas moved into the main channel of the Big Susitna River. No belugas were sighted or harassed.

27 May - Winds continued in the morning with marginal sighting conditions. A group of about 50 whales were encountered, but could not be moved to a suitable capture location. No sets were made. Likewise, during the afternoon high tide, conditions were marginal and no whales were found. A total of 50 whales were taken by harassment.

28 May - Weather during the morning high tide was clear and calm; the team was on the water by 0500. No whales were seen between the Big Susitna River and the shoreline 3 km north of the Little Susitna River and the crew returned to camp.

At about 1830, the team headed out on the evening high tide, meeting up with the two Native hunters, Korke and Rusty Dimmick. Together, we traveled approximately 4 km toward the Little Susitna River before encountering a group of 50 whales well into the shallows. Attempts were made for approximately 0.5 hr to position an animal for capture, resulting in a total of 50 takes by harassment. Eventually, a large white adult was singled out of the group and a set was made. With about one-half of the net deployed, however, the webbing snagged on the corner of the stanchion, tearing it out of the stern mounts. The stanchion stayed in the stern of the boat, however, and the remaining net was paid out over the aft starboard side by hand.

Despite the mishap, the beluga remained in the net and was forming a "v" channel as it tried to escape to deeper water. The Zodiak crew reached the animal and maneuvered into position to affix a tail loop. The team members had hands on the animal's flukes and caudal peduncle and were just seconds from slipping the tail loop on, when the beluga broke free; the net had slipped over its back. Instead of becoming well wrapped, the whale had been pushing against the taut webbing, which, at 0.3 m, was not wide enough to securely entangle its head. Upon return to camp, the net stanchion was repaired. A total of 50 belugas were taken by harassment and 1 was captured, handled briefly but lost.

29 May - The winds were blowing too hard in the morning to go out. In the afternoon, the winds moderated enough to search for belugas, but none were seen. Sighting conditions were marginal with steady rain.

30 May - Weather during the morning high tide was favorable, allowing departure by 0600. Whales were quickly spotted midway between the Big and Little Susitna Rivers, well into the shallows. From the group of about 75 belugas, three different individuals were singled out for capture in three separate capture attempts. In each case, major difficulties were again encountered with the net deployment system. In the tight, high speed turns, the net was snagging on the starboard corner of the net stanchion. Although whales were in good position for capture each time, only a portion of the net was out prior to the stanchion collapses, and complete encirclement was not achieved. Upon return to camp, several modifications were made to the deployment gear, including:

a) re-stacking of the net with the lead line on the starboard side of the net box so that it would be on the extreme inside of the turn,

b) the net box was tipped 15° aft to facilitate the net's travel up to the stanchion,

c) the stanchion itself was lowered about 0.6 m to reduce the vertical distance required for the net to travel before exiting, and

d) the starboard extension on the top of the stanchion was padded, and its width to starboard extended by approximately 0.2 m using a deflated soccer ball and duct tape to minimize snagging as the webbing rounded the stanchion corner.

In addition, two badly torn net panels were replaced, and several tears repaired.

By late afternoon, the boats and crew were ready to attempt captures once again. Whales were found in approximately the same area as in the morning. A group of about 75 animals were worked twice. Each time, a single animal was maneuvered into capture position and a set was made. Given the difficulties with the net deployment earlier in the day, the evening sets were made more slowly to allow close monitoring of the gear. The modifications greatly reduced the nets tendency to snag, suggesting that future sets could once again be attempted at high speed. Given the moderated speed during the two evening sets, however, no animals were captured as they escaped prior to full encirclement. A total of 150 belugas were taken by harassment; none were captured.

May 31 - Weather conditions were good for the morning high tide and the crew departed camp at 0530. A group of about 100 belugas were found 2 km up the Little Susitna River. Given the lack of success experienced earlier in the project when we attempted to move whales out of the river and onto adjacent shallows, a different net deployment was tried. One end of the net was anchored to the beach on the inside of the last bend of the river and deployed upstream along a shallow bar, thus forming a beach seine into which animals could be driven as they swam downstream. Most animals avoided the net, opting to swim closer to the opposite riverbank, but at least five whales approached the seine, with one eventually entering it and becoming entangled. The animal was a grey, sub-adult female, too small to tag. The animal was measured and subsequently released less than 10 minutes after capture. Upon release she quickly rejoined the main group.

The team reformed and followed the same group of whales into the shallows west of the Little Susitna River. At 1030 an unsuccessful set was made on a single white adult that escaped before a full encirclement could be achieved. The set was made at full speed with no deployment problems. At 1130 a portion of the same group was again located in the shallows and the boats positioned for capture. A full encirclement was achieved, capturing two animals. One was well entangled, and tended by the hunter's boat. The second animal was forming a "v" channel when approached by the Zodiak. Adjacent to the animal, the Zodiak tangled in the net, requiring several minutes to be cut free. In the meantime, the second beluga broke free of the net and swam to deep water. The first animal, still well entangled was then tail looped and its head slipped into a hoop net. The net panel entangling the animal was unsewn from the net and used to help secure the animal at the surface alongside the hunter's boat. The rest of the net was brought back aboard the Boston Whaler to be repaired and re-stacked later. The animal was slowly moved inshore along side the hunter's boat until waist deep water was reached. The animal, a white to grayish-white male measuring 370 cm was in good condition. It continued efforts to swim until the tide dropped enough for it to rest on the bottom, but otherwise did not show much response to the tag attachment. Vocalizations, however, were energetic and continuous. Tag number 25850 (with a VHF transmitter (167.423) was attached to the dorsal hump following the previously described standard procedure. Two 17" identification bands, DL 00142 and DL 00141 were fitted to the right and left flippers, respectively. The field number RCF 400 was assigned to the animal for entry onto a NMML standard cetacean life history record.

Given the capture location (61°13.81' N 150°17.26' W) well onto the tidal flats and the time required to complete the tag attachment, both the capture team and beluga were stranded through the low tide period. During the stranding period, the animal was located in a shallow channel which was eventually dug out into a 0.4 m deep water-filled depression around the animal. Throughout the low tide, the animal was kept wet and its condition was monitored constantly. By 1830, the incoming tide had reached the animal. It began moving toward deeper water vigorously, even before fully re-floated. Within 10 minutes the whale had reached the edge of the deep water and began a regular shallow diving pattern. It immediately rejoined a group of about 75 whales milling about adjacent to the edge of the tidal flats in deep water.

The satellite tag was functioning normally at the time of release, and continued to transmit dive and location data until 17 September, 1999, 112 days after capture. A total of 150 whales were taken by harassment and three were captured.

June 1 - Due to fuel supply constraints, only one tide per day could be worked during the last two days of the project. Weather was good for the morning tide and the crew was on the water by 0700. However, no whales were located.

June 2 - The weather remained clear and the morning tide was chosen for the last capture attempt. A group of about 100 whales was located 2 km up the Little Susitna River. The whale tagged the previous day was seen in the group, swimming normally with the package securely in place. Two beach sets, similar to the one described on 31 May were attempted, but no whales approached the net. A total of 50 whales were taken by harassment and none were captured.

Discussion

The beluga tagging project in 1999 resulted in the collection of valuable data for dive correction factor estimation and demonstrated the feasibility of capturing belugas in Upper Cook Inlet for the first time. The requisite equipment, personnel, logistic and methodological components identified thus far provide a firm foundation for success in future capture efforts. Moreover, refinements to the technique, particularly with regard to net deployment and net construction can now be made to enhance our ability to confidently and safely capture and handle these animals.

Subsequent to the tag deployment, NMFS researchers monitored the animal via the onboard VHF transmitter and collected over 10 hr of surfacing interval data, beyond that which will be provided by the satellite PTT. These collections significantly increase the data available for analyses of surfacing and sightability. Future tagging work remains important, however, as the sample of tagged animals from which to examine diving behavior needs to be increased, and should include the broadest possible range of age and sex strata.

In addition, given the limited satellite tag life expectancy (i.e., perhaps up to 4 months), information on fall and winter movements and distribution are unlikely to result from tagging in May or June. Consequently, an expansion of the tagging project to include capture efforts in late summer or fall should be considered.

Prior to consideration of future capture work in Cook Inlet, additional net deployment trials should be completed to allow proper modification of the net deployment stanchion. Several of the field modifications suggest the direction to be taken to develop a design that will operate smoothly in high speed turns. This work can be completed during the fall and winter of 2000 in lake Washington.

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Table 1. Capture work summary for the 1999 Cook Inlet beluga whale tagging project.

Date	High Tide	Takes by Harassment	# of Sets	# of Belugas Captured	Comments
25 May	AM	-	-	-	winds - no capture effort
	PM	50	0	0	
26 May	AM	-	-	-	out over AM low
	PM	0	0	0	observed from Delta Is.
27 May	AM	50	0	0	
	PM	0	0	0	
28 May	AM	0	0	0	
	PM	50	1	1	
29 May	AM	-	-	-	winds - no capture effort
	PM	0	0	0	
30 May	AM	75	3	0	
	PM	75	2	0	
31 May	AM	150	3	3	RCF 400 tagged
	PM	-	-	-	fuel constrained
1 June	AM	0	0	0	
	PM	-	-	-	fuel constrained
2 June	AM	0	0	0	
	PM	-	-	-	fuel constrained
Total		500	11	4	

AERIAL SURVEYS OF BELUGAS IN NORTHEASTERN BRISTOL BAY, ALASKA, MAY-JUNE 1999

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Abstract

Between 31 May and 4 June 1999, the National Marine Mammal Laboratory (NMML) conducted aerial surveys of the beluga whale population in Bristol Bay, Alaska. The survey design comprised a coastline track 1.4 km from shore in Nushagak and Kvichak Bays, exploration of major rivers (including the Igushik, Snake, Wood, Black Slough, Nushagak, Clark Slough, Kvichak, and Naknek), and offshore transect lines crossing the Kvichak River. The 16 hr survey was flown in a twin-engine, high-wing aircraft at an altitude of 244 m (800 ft) and speed of 185 km/hr (100 kt). Paired, independent observers searched on the coastal (left) side of the plane, where virtually all sightings occurred, while a single observer and a computer operator/data recorder were on the right side. Generally, weather conditions were good during this study, with Beaufort sea states ranging from 2 to 4 and clear or partly cloudy skies. Groups of belugas were found at five primary locations: in the Igushik River, in the Snake River, at Black Slough, near Etolin Point, and in the Kvichak River. The sum of the aerial estimates on 31 May was 150 (median count) and 220 (high count) belugas. On 3 June, the median and high counts were 268 and 337 belugas, respectively. The experiment conducted on 4 June yielded a high count of 98 belugas in the Kvichak River (range: 74-98). Preliminary estimates of group size, corrected for animals that were submerged during a counting pass, were obtained for videotaped passes from 31 May and 3 June, respectively: Igushik River (17 and 28), Snake River (174 and 212), Black Slough (0 and 5), Schooner Channel (0 and 231), and Etolin Point (11 and 39). Small groups (consisting of only one or two animals, n = 3) or dispersed groups (e.g., Kvichak River observations, n = 2) were not videotaped. Correction factors for observer counts, line transects in the Kvichak River, and detection bias (i.e., whales that were missed while at the surface) in video counts are currently under development.

Introduction

Beluga whales, *Delphinapterus leucas*, are distributed throughout seasonally ice-covered Arctic and subarctic waters of the Northern Hemisphere (Hazard 1988). Belugas that occupy Bristol Bay during the summer months represent one of three genetically-distinct stocks found in western Alaska waters (O'Corry-Crowe et al. 1997). The Bristol Bay watershed also supports a substantial Pacific salmon fishery. Depredation of salmon by belugas has long been a concern of fishery participants in this region (Frost et al. 1984). In response to concerns expressed by the fishing community, an aerial survey of Nushagak and Kvichak Bays was undertaken by the National Marine Mammal Laboratory (NMML) prior to the start of the 1999 fishing season.

Aerial surveys of belugas in Bristol Bay have primarily occurred in late June and early July (Lowry and Frost 1999), when belugas are usually most abundant (Frost et al. 1984). Alaska Department of Fish and Game (ADF&G) aerial surveys conducted in 1983, 1993, 1994, and 1999 yielded similar abundance estimates of roughly over 1,100 animals, suggesting that beluga numbers in this region have been stable for the last 17 years (Lowry and Frost 1999, ABWC 1999). A comprehensive review of the literature provided in Lowry and Frost (1999) notes that abundance estimates of approximately 1,000 belugas in Bristol Bay have been reported since 1954.

Methods

The survey design was initially comprised of a coastline track 1.4 km from shore along Nushagak and Kvichak Bay and exploration of major rivers including the Igushik, Snake, Wood, Black Slough, Nushagak, Clark Slough, Kvichak, and Naknek. Surveys were flown in a twin-engine, high-wing aircraft at an altitude of 244 m (800 ft) and speed of 185 km/hr (100 kt). Bubble windows at the left-front and right-front positions provided observers with unobstructed views ahead of and directly beneath the aircraft. The second observer on the coastal side was positioned at a flat window. Paired, independent observers searched on the coastal (left) side of the plane, where virtually all sightings occurred, while a single observer and a computer operator/data recorder were on the right side. This protocol is fully detailed in Rugh et al. (this volume) and Rugh et al. (2000).

The variety of habitat types occupied by beluga groups in Bristol Bay required revision of surveying techniques during the field study. This included adding transect lines crossing the Kvichak River Delta. Offshore transects were not flown in Nushagak and Kvichak Bay because considerable search effort expended during the ADF&G surveys showed virtually all whale sightings would be visible from their coastal track located about 1.2 km from shore (Frost et al. 1986, Frost and Lowry 1990, Lowry and Frost 1999).

A digital-8 video camera recorded each counting pass made over whale groups. Multiple counts and video passes were made over belugas in compact groups using methods developed for beluga groups found in Cook Inlet, Alaska (e.g., Rugh et al. this volume, 2000; Hobbs et al. 2000a, b). Only counts given a grade of A or B were used in the analysis. Counting techniques were modified slightly for belugas found scattered along bends in the Snake River where the airplane was not able to maneuver within the tight confines of each river bend while at the same time providing an adequate field of view for the observers and videographer. Instead, this river was partitioned by river bend and counts and video were obtained for only a single pass along each bend as the aircraft either traversed from the mouth toward the source of the river or vice versa. Line transects were used to count the dispersed group in the mouth of the Kvichak River. To document observer detection rates of belugas during line transect counts, video was obtained on the left side and beneath the aircraft during the 4 June survey. All counts were collected independently and were not reviewed or discussed by the survey team during the study period.

Video recordings were reviewed to evaluate image quality at the end of the field project. Only video passes given the highest rating (good or excellent) were used in the analysis. Video counting methods are detailed in Hobbs et al. (2000b). To account for availability bias (i.e., animals that were submerged during a counting pass), a correction factor was developed using McLaren's (1961) formula. This correction factor, $A_{g.p}$, for each video pass of a beluga group was calculated as:

$$A_{g.p} = \frac{T_1}{T_s + t_{g.p}}$$

where T_1 is the average dive interval of a whale in Bristol Bay (28.5 sec (range: 26-31 sec), for details see Frost et al. (1985)), T_s is the average time a whale is at the surface during a video pass, and $t_{g.p}$ is the time spent counting. Surfacing times were computed only for whales that surfaced and submerged while within the video field of view. Time spent counting (scan time) was defined as the amount of time an object (e.g., landmark or dark patch of water) took to cross the video field of view. Corrections for detection bias (i.e., whales that were missed while at the surface) are currently under development (see examples in Hobbs et al. 2000b). For those groups where video was not obtained or the quality was inadequate, corrected observer counts will be incorporated to provide an abundance estimate for the Bristol Bay population (see Hobbs et al. 2000a). The observer counts for beluga groups presented in this paper have not yet been corrected for observer effects and the effect of encounter rate (group density in whales per second) and the proportion of beluga groups missed (see Hobbs et al. 2000a). Similarly, counts obtained along line transects also need to be corrected for availability and detection biases. Differences in how data were acquired precluded using correction factors developed by ADF&G for their aerial surveys (Lowry and Frost 1999).

Results and Discussion

Aerial surveys of the beluga population in northeastern Bristol Bay were conducted between 31 May and 4 June 1999. Groups of belugas were found at five primary locations: in the Igushik River, in the Snake River, at Black Slough, near Etolin Point, and in the Kvichak River. Complete surveys of Nushagak and Kvichak Bay were conducted on 31 May (Fig. 1) and 3 June (Fig. 2). On 4 June, an experiment to document observer detection rates during line transect surveys was conducted at the Kvichak River (Fig. 3). Rain and low clouds halted the survey on 1 and 2 June, but, in general, weather conditions were good during the 16 hr of survey effort. Beaufort sea states ranged from 2 to 4 and skies were clear or partly cloudy. Low tide was 7 ft. above MLT throughout much of the survey which allowed the whales to travel far up rivers such as the Snake and to disperse along the mudflats in the Kvichak River Delta.

The belugas found in the Kvichak River Delta were far more dispersed than were other groups. On 31 May, seven tracklines spaced at one mile intervals were flown across the river from its mouth to its intersection with the Alagnak River. At this point the Kvichak River narrowed and a single trackline was flown upriver to just past the town of Levelock where water depth appeared too shallow for belugas. Low ceilings and fog precluded using this technique during the second flight (3 June) when only a single trackline was flown between the mouth of the Kvichak River and 6 miles south of Levelock. To test the line transect sampling technique and observer detection rates, a final survey of the Kvichak River was conducted on 4 June. Tracklines traversed as the plane entered the river were videotaped to correct for whales missed by the left front observer (Fig. 3a). Videotape was also obtained through a port in the belly of the aircraft to correct for observations missed beneath the aircraft (Fig. 3b). Correction factors for the line transect data are currently under development.

Counts of beluga groups made by the paired-observers are shown in Table 1. These counts include an overall median for each location that was computed from the medians of each observers' A and B quality counts on multiple passes over beluga groups in that area. Similarly, high counts for each location were calculated by summing the largest number of animals counted on a single pass for each beluga group in that area. The sum of the aerial estimates on 31 May was 150 (median count) and 220 (high count) belugas (Table 1). On 3 June, the median and high counts were 268 and 337 belugas, respectively. The experiment conducted on 4 June yielded a high count of 98 belugas in the Kvichak River (range: 74-98). Total counts were similar to those obtained during ADF&G's aerial surveys in 1983 where 124 to 265 belugas were observed in the Kvichak River and its delta, and 10 to 20 whales were present in rivers in Nushagak Bay between 31 May and 4 June (Frost et al. 1986). Other marine mammal sightings during the NMML survey included 10 walrus (offshore of Egegik Bay) and 6 gray whales (scattered along the shore between Naknek River and Egegik Bay) on 31 May, and 1 gray whale (in Halfmoon Bay) on 3 June.

Counts obtained from video footage are shown in Table 2. Of the 14 groups observed during the survey, 9 were videotaped. Groups were not videotaped if they were small (only one or two animals, n = 3) or dispersed (eg., Kvichak River observations, n = 2). Each video pass was corrected for whales that were submerged during a counting pass (availability bias). Scan times averaged 7.73 sec and ranged from 2.23 sec to 23.97 sec (n = 43). The average time a whale spent at the surface was 2.04 sec (S.D. = 1.04, S.E. = 0.08, n = 159). Correction factors ranged from 1.10 to 5.25 (n = 35). In a few cases, scan time or time at surface could not be derived from a video pass due to a lack of landmarks or because none of the whales in a group completed an entire surfacing within the field of view, respectively (n = 11). When this occurred, and there was only one count for a group (e.g., in the bends of the Snake River), the uncorrected count was used for the estimated group size (Table 2). At this time, comparisons of averaged group size estimates from video (Table 3) to observer counts (Table 1) would be premature as the observer counts have not been corrected for availability bias. A coefficient of variation (CV) for group size has not been estimated at this time.

The fraction of beluga groups that were missed during the survey was estimated from the independent records of the paired-observers. Of the 14 groups total, 10 were available to the paired-observers shoreward (left-side) of the aircraft while 3 were seen by the right observer(s) and 1 was visible from both sides of the aircraft (Table 4). None of the groups were offshore of the trackline (the four sightings to the right of the aircraft occurred as the plane traversed a river mouth). Six of the nine groups (67%) seen by the observer in the left-front position were missed by the second observer(s). The second observer(s) saw five groups of which two (40%) were missed by the front observer. Three of the groups were seen by both left-side observers. In one case, a group was observed by the computer operator and missed by the right-front observer. Group size did not appear to be a factor since observers in left side positions missed very large and very small groups (Table 4). Miss rates were slightly skewed suggesting that seat position or window type (bubble versus flat) may have influenced sightability. However, experience level was also a consideration. Those observers (A and B) with extensive backgrounds in aerial survey techniques and experience searching for belugas missed groups 14% and 25% of the time while less experienced observers (C and D) missed groups 43% and 75% of the time, respectively (Table 4). Logistic regression techniques similar to those presented in Hobbs et al. (2000a) will be used to estimate the likelihood that entire groups were missed during the systematic surveys.

After correction factors have been developed, a total abundance estimate for belugas in Bristol Bay will be calculated from the data presented above. This estimate will be compared to the estimate obtained during the July 1999 survey (ABWC 1999).

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Table 1. Summary of counts of belugas made during aerial surveys of northeastern Bristol Bay in May-June 1999. Medians from paired, independent observers' counts were calculated using aerial passes only where observers considered visibility good or excellent (conditions B or A). An overall median was computed for the beluga group using the median count of each observer. High counts represent the largest number of belugas counted by any observer on any pass. * = counts represent total number of animals observed on line transects. 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 Nushagak and Kvichak Bays.

Location	31 May		3 June		4 June	
	Median	High	Median	High	Median	High
Protection Point to Igushik River[1]	1	1	0	0	---	---
Igushik River[2]	6	25	18	31	---	---
Snake River[3]	57	100	97	113	---	---
Wood River	0	0	0	0	---	---
Black Slough[4]	0	0	7	9	---	---
Nushugak River	0	0	0	0	---	---
Clark Slough	0	0	0	0	---	---
Schooner Channel, Flounder Flat[5]	0	0	110	155	---	---
Etolin Point[6]	10	18	11	14	---	---
Etolin Point to Halfmoon Bay[7]	1	1	0	0	---	---
Kvichak River to Levelock[7]	75*	75*	25*	25*		98*
Naknek River to Egegik Bay	0	0	0	0	---	---
TOTALS	150	220	268	337		

[1] Group 1
[2] Group 2 + 3 (31 May), Group 1 (3 June)
[3] Group 4 + bends (31 May), Group 2 bends (3 June)
[4] Group 3
[5] Group 4 + 5 + 6
[6] Group 5 (31 May), Group 7 (3 June)
[7] Group 6 (31 May), Group 8 (3 June)

Table 2. Counts from digital Hi-8 video tape obtained concurrent to observer counts of belugas in northeastern Bristol Bay, May-June 1999. * = average of Pass 1 & 2 of Group 4.

Date	Group	Pass	Location	Video count	Scan time (sec)	Average time at surface (sec)	Availability correction factor	Estimated group size	Average of group size
31 May	2	2	Igushik R.	1	5.80	no data			17
31 May	2	4	Igushik R.	6	5.20	1.97	3.97	24	
31 May	2	5	Igushik R.	1	4.90	no data			
31 May	2	6	Igushik R.	6	5.57	2.37	3.59	22	
31 May	2	7	Igushik R.	1	5.03	1.40	4.43	4	
31 May	2	8	Igushik R.	5	5.33	2.49	3.64	18	
31 May	4	1	Snake R.	9	8.30	2.21	2.71	24	33*
31 May	4	Bend1	Snake R.	9	4.70	no data	no data	9	9
31 May	4	Bend2	Snake R.	13	23.97	2.00	1.10	14	14
31 May	4	Bend3	Snake R.	7	5.97	2.62	3.32	23	23
31 May	4	Bend5	Snake R.	2	6.00	1.38	3.86	8	8
31 May	4	Bend6	Snake R.	13	9.33	1.58	2.61	34	34
31 May	4	Bend7	Snake R.	4	7.20	1.53	3.26	13	13
31 May	4	2: Bend8	Snake R.	15	8.40	1.81	2.79	42	
31 May	5	2	Etolin Pt.	5	11.03	2.25	2.15	11	11
31 May	5	3	Etolin Pt.	3	4.30	no data			
3 June	1	1	Igushik R.	5	6.07	2.07	3.50	18	28
3 June	1	2	Igushik R.	6	8.00	1.82	2.90	17	
3 June	1	3	Igushik R.	6	8.83	0.85	2.94	18	
3 June	1	4	Igushik R.	5	7.13	1.64	3.25	16	
3 June	1	5	Igushik R.	0	9.27	no data			
3 June	1	6	Igushik R.	16	6.53	2.03	3.33	53	
3 June	1	7	Igushik R.	5	8.53	2.39	2.61	13	
3 June	1	8	Igushik R.	17	6.30	1.85	3.50	59	
3 June	2	Bend1	Snake R.	0	8.00	no data		0	0
3 June	2	Bend2	Snake R.	0	8.83	no data		0	0
3 June	2	Bend3	Snake R.	2	8.70	2.53	2.54	5	5
3 June	2	Bend4	Snake R.	1	17.47	1.73	1.48	1	1
3 June	2	Bend5	Snake R.	16	5.50	1.59	4.02	64	64
3 June	2	Bend6	Snake R.	4	6.53	no data	no data	4	4
3 June	2	Bend7	Snake R.	3	9.83	1.39	2.54	8	8
3 June	2	Bend8	Snake R.	4	5.73	no data	no data	4	4
3 June	2	Bend9	Snake R.	18	5.63	2.17	3.65	66	66
3 June	2	Bend10	Snake R.	6	3.73	1.70	5.25	31	31
3 June	3	2	Black Sl.	4	no data	1.70			5
3 June	3	3	Black Sl.	2	12.43	2.12	1.96	4	
3 June	3	4	Black Sl.	1	8.53	no data			
3 June	3	5	Black Sl.	2	6.23	3.47	2.94	6	
3 June	3	7	Black Sl.	2	10.07	1.43	2.48	5	
3 June	5	1	Schooner Ch.	76	8.37	4.24	2.26	172	172
3 June	5	2	Schooner Ch.	62	7.43	no data			
3 June	6	1	Schooner Ch.	22	6.67	2.42	3.14	69	69
3 June	7	1	Etolin Pt.	14	8.87	1.37	2.78	39	39
3 June	7	2	Etolin Pt.	14	2.23	no data			

Table 3. Averaged group size estimates of belugas in northeastern Bristol Bay, May-June 1999, from videotaped counting passes. Counts have been corrected for whales that were submerged and therefore missed during each counting pass (availability bias). Dashes indicate that the area was surveyed but no whales were seen. Sites are listed in a clockwise order around Nushagak and Kvichak Bays.

Location	31 May	3 June
Protection Point to Igushik River	No video	---
Igushik River[1]	17	28
Snake River[2]	174	212
Wood River	---	---
Black Slough	---	5
Nushugak River	---	---
Clark Slough	---	---
Schooner Channel, Flounder Flat[3]	---	231
Etolin Point	11	39
Etolin Point to Halfmoon Bay	No video	---
Kvichak River to Levelock	No video	No video
Naknek River to Egegik Bay	---	---

[1] Two whales farther upriver were not captured in video on 31 May.
[2] Two whales at the mouth of the river were not videotaped on 3 June; video totals include counts that could not be corrected for availability bias.
[3] Two whales near Ekuk were not videotaped on 3 June.

Table 4. Fraction of beluga groups missed by observers during aerial surveys of northeastern Bristol Bay, Alaska, May-June 1999. Observer seating positions: LF = left front, LC = left center, LR = left rear, RF = right front, and CO = computer operator. * = headsets were not isolated.

Group	Observers						Median group size at 1st sighting (from observer counts)
	A	B	C	D	E	F	
1	CO					RF-missed	1
2		LF-missed	LC-missed	LR			4
3	LF			LR-missed		LC-missed	2
4		RF					9
5			LF	LC-missed			10
6	LF		RF	LC-missed			scattered
1		LC	LF				18
2	LF		LC-missed				2
3					RF		7
4		LF	LC				2
5		LF	LC-missed				65
6	LF*	LC*					43
7	LF-missed	LC					11
8	LF	LC-missed					scattered
Missed	1 of 7	2 of 8	3 of 7	3 of 4	-	-	

Figure 1. Trackline and beluga sightings from the 31 May 1999 aerial survey of northeastern Bristol Bay, Alaska.

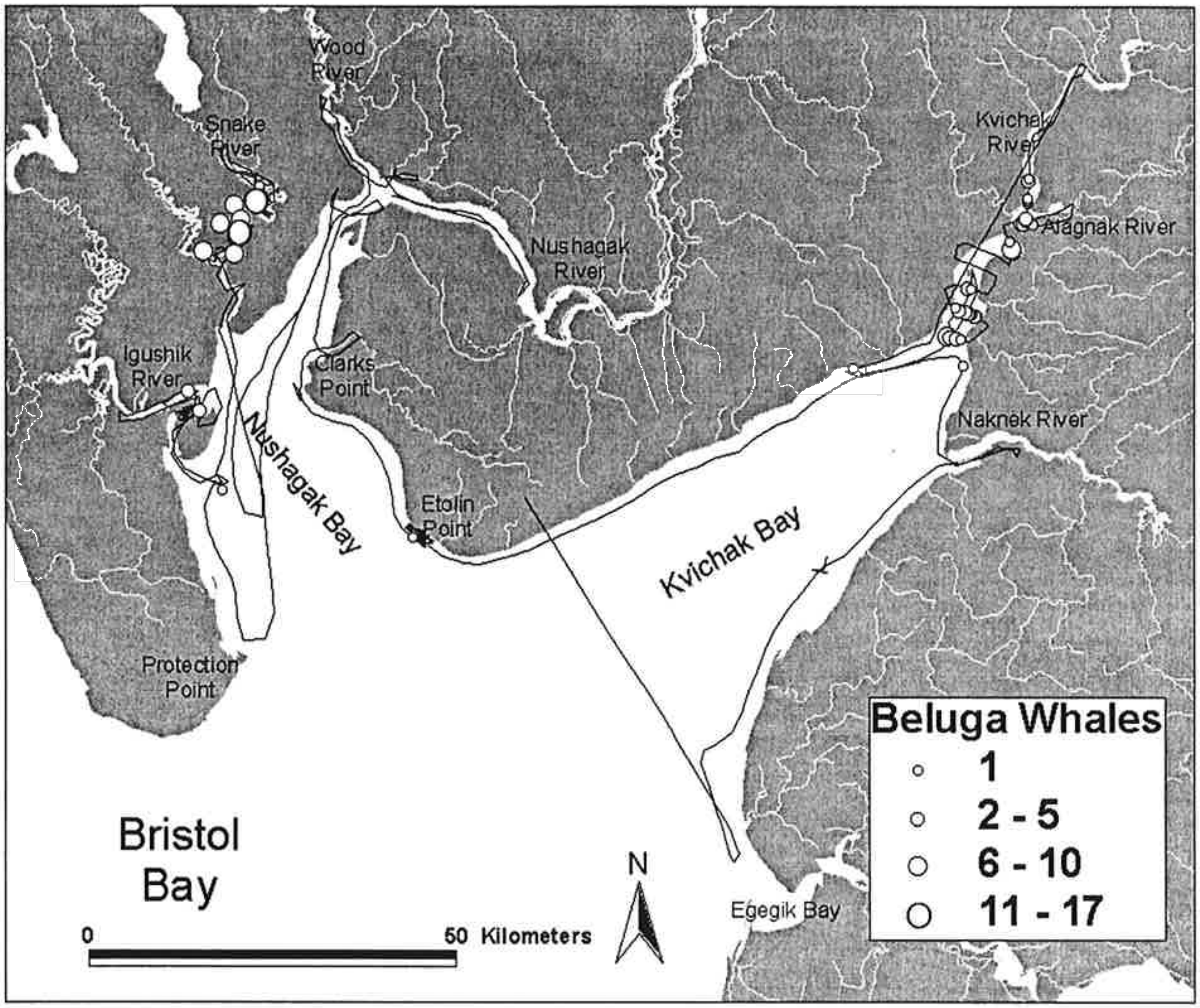


Figure 2. Trackline and beluga sightings from the 3 June 1999 aerial survey of northeastern Bristol Bay, Alaska.

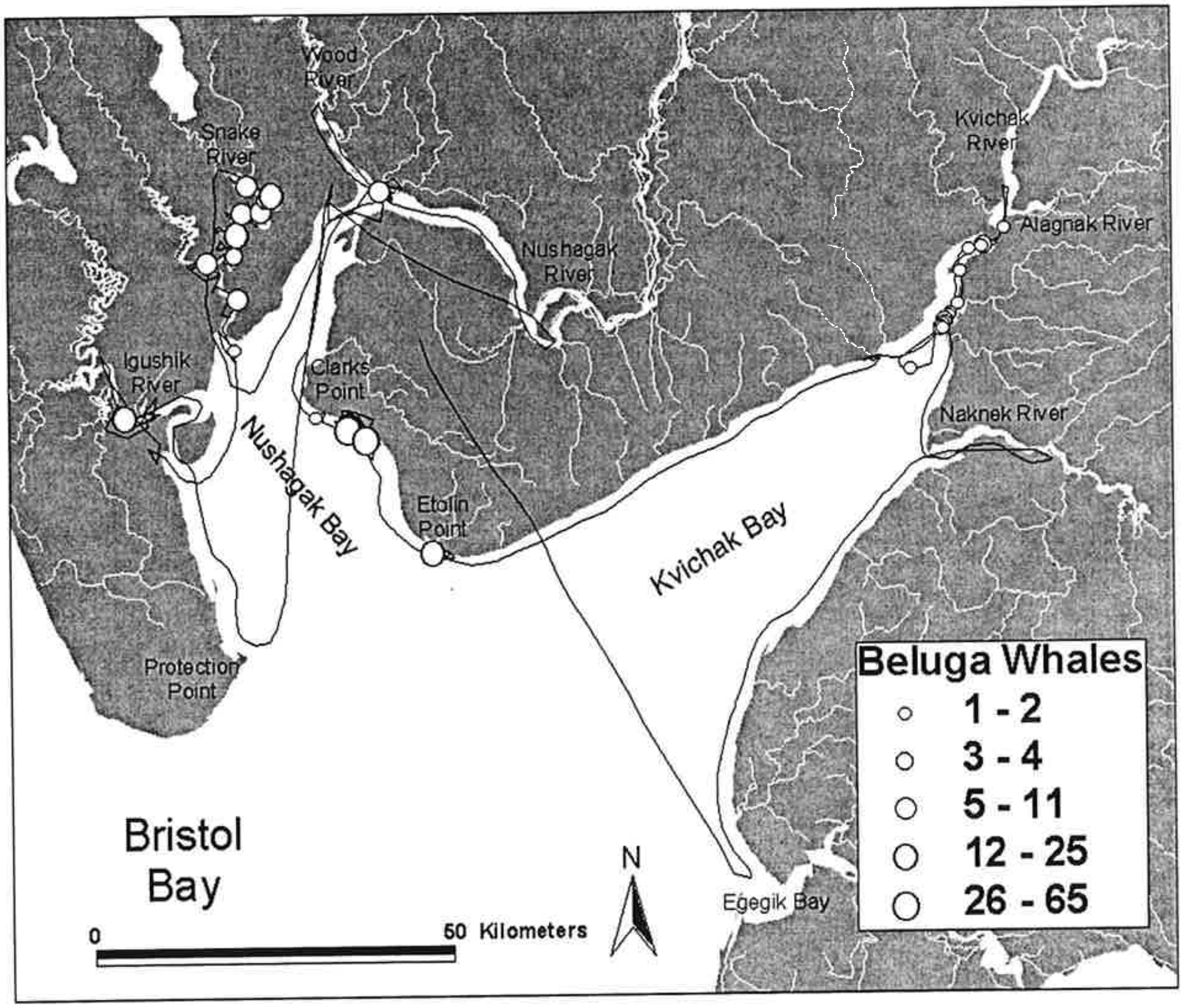
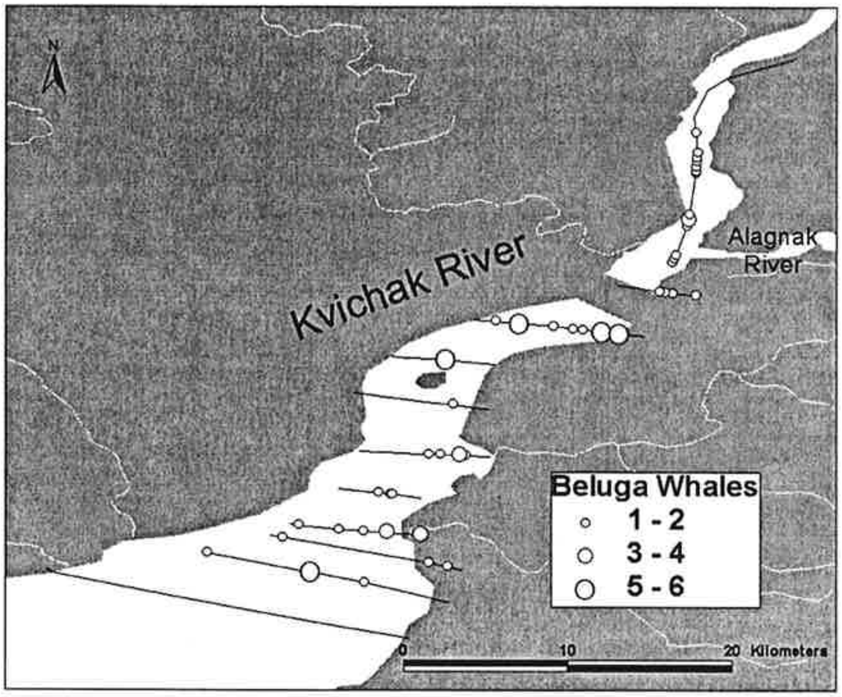
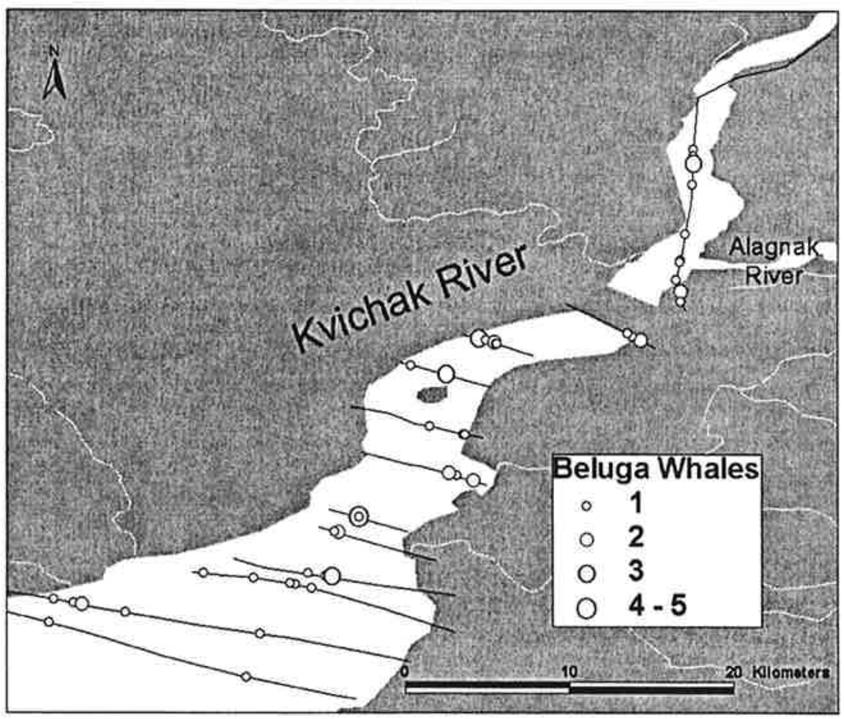


Figure 3. Transects and beluga sightings from the 4 June 1999 aerial survey of the Kvichak River, northeastern Bristol Bay, Alaska. Transects traversing up the river (a) and exiting the river (b) yielded beluga counts of 98 and 74, respectively.

a



b



SURVIVAL RATES OF CALIFORNIA SEA LIONS (*Zalophus californianus*) FROM A BRANDING STUDY AT SAN MIGUEL ISLAND, CALIFORNIA

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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. In this report, we describe results from additional analyses to estimate survival rate using re-sighting data obtained through 1999. We demonstrate the importance of El Niño events on female survival rates and provide survivorship curves for both sexes.

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.

Methods

Branding/Sighting

From 1987 through 1999, 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 at Año Nuevo Island(ANI) during the breeding season (Birch and Ono, unpubl. report). In 1996, the surveys were extended to include Año Nuevo Island, Farallon Island, 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 and allows models to specify time- and individual-specific covariates for re-sighting and survival probabilities.

Covariates are included to reduce the heterogeneity in capture probabilities and to explain the variability in survival. Heterogeneity in capture probabilities can bias estimated survival rates if the appropriate covariate is not included in the model (Pollock et al. 1990). The nature of re-sighting sea lions at specific haulouts guaranteed highly variable sighting probabilities. The probability of re-sighting a particular sea lion was dependent on whether the sea lion used a particular area, how long it remained and various other factors.

Previous analyses (Melin et al. 1997, Melin et al. 1999) have shown that capture probabilities depend on age, sex, and the year of re-sighting; however, those analyses did not consider where the sea lion was re-sighted. Until recently, most of the re-sighting effort at SMI was focused at and around Adams Cove where the pups were initially branded. If most sea lions return to their natal area to breed then we might expect to see an age effect on capture probability and an increase in capture probability after the sea lion began breeding. Or if the sea lions demonstrate fidelity to particular areas on the island regardless of breeding, we would also expect to see an increase in sighting probability for any sea lion that used the area around Adams Cove. We have treated this possible source of heterogeneity in capture probability as a form of trap dependence (Pradel 1993). After a sea lion was "captured/re-sighted" near Adams Cove its probability of future re-sighting was allowed to change. As described by Pradel (1993) this was enabled by switching the sea lion from an initial cohort to a re-sight cohort and treating the removal as a loss-on-capture from the initial cohort. We refer to this as an area effect.

Survival rates have also been shown to vary by age, sex and year and the pup's weight at branding has been shown to affect its first year survival (Melin et al. 1999). Melin et al. (1999) split each pup cohort based on their initial weight and in the analysis they treated each weight grouping as a categorical factor which does not recognize the ordinal nature of binned continuous data. We have modified this approach by dividing each pup cohort by sex into four weight groups with an equal number in each group and then using the median weight of each group in the design matrix to model first-year survival as a continuous function of weight with a logistic link function.

This analysis has several other differences with the analysis of Melin et al. (1999). The age groups were changed to pup, yearling, 2 year, 3-5 year and 6+ year olds to align better with expected behavioral and maturation changes. Two year olds were split off because females typically do not breed until age 3 at the earliest and 2 year olds also use ANI more than 3 or 4 year olds. The analysis was restricted to cohorts branded from 1989-1998 and each sex was analyzed separately. Both of these restrictions were necessary to enable treating the pup weight and area effects with groups. Ideally, both pup weight and area could be used as individual covariates within MARK. However, using MARK with covariates on a large data set was infeasible because of the slow execution time (Note: after the analysis was completed this problem was resolved in a new version). Using the 12 cohorts with 4 weight groups and modeling the area-trap dependence required 72 groups for each sex. Extending the analysis to more cohorts or to analyze female and male data simultaneously would have required more computer memory than was available. As in Melin et al. (1999), we also estimated the product of survival and capture probability in 1999 and did not restrict the model of capture probability to eliminate the confounding between survival and capture probabilities in the final year.

Model goodness of fit was tested using Test 2 and 3 as suggested by Lebreton et al.(1992). Program Release from within MARK was used to compute the test statistics stratified into cohorts based on sex, branding year and area. For each cohort the null hypothesis for the test statistic assumes time-dependent capture and survival probabilities. Thus, the global model for each sex was age*year*area for both survival and capture probability. Unfortunately, the global model is not exactly what we would like to specify. It is more general than needed because we expect that area would affect capture probability but not survival, but also it excludes the effect of pup weight on first year survival because further dividing the groups based on weight would have reduced the sample size within each group even further which would further reduce the power of the Chi-square test. If the global model did not fit we used the total Chi-square divided by the degrees of freedom to estimate the over-dispersion coefficient $\hat{c}$ which was used to adjust parameter standard errors and confidence intervals to reflect additional uncertainty resulting from over-dispersion. We could not use the bootstrapping approach suggested by White et al. (in press) because MARK could not accommodate loss-on-capture events.

We fitted a variety of models that allowed capture probability and survival to vary by age, sex, year, area, and pup weight and pertinent interactions of these main effects. We also considered reduced age models by collapsing the older age groups (i.e., 3-5, 6+ to 3+). 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. 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. To select the most parsimonious model, we used Akaike's information criterion (AICc) or QAICc for over-dispersed data (Burnham and Anderson 1999).

To estimate a mean survival rate, we used a random-effects model (Burnham in press) to describe the annual variation in survival. The resulting parameters are a mean and process variance which describes the amount of variation in true survival after removing sampling variability. We estimated a mean survival rate for each age class used in the model and constructed a mean survivorship curve, S(x), the probability of surviving from branding to age x:

$$S(x) = \prod_{i=1}^{x} \bar{s}_i$$

We constructed a 95% confidence interval for the mean survivorship based on an assumed log-normal distribution for the estimated survival rate (Burnham et al. 1987:213). The lower and upper intervals are S(x)/C and S(x)*C, where C= $\exp[1.96\sqrt{\hat{Var}(\ln[S(x)])}]$ and

$$\hat{Var}(\ln[S(x)] = \sum_{i=1}^{x} \ln\ 1+\frac{\hat{Var}(s_i)}{s_i^2} \quad +2\sum_{i=1}^{x}\sum_{j=1+1}^{x} \ln\ 1+\frac{\hat{Cov}(s_i,s_j)}{s_i s_j}$$

We used z-tests based on the log-normal to compare estimated survival rates:

$$Z = \frac{\ln(s_i)-\ln(s_j)}{\sqrt{\hat{Var}[\ln(s_i)-\ln(s_j)]}}$$

where the variance of the difference of the logarithms includes sampling covariances if appropriate. Back-transformation of the difference in ln(survival) produces a ratio of survival rates and confidence interval.

Results

From the 1989-1998 cohorts, 2,800 female and 1,865 male pups were branded (Table 1-2, Fig. 3). Summaries of the data collected through the 1999 field season were given by Melin et al. (1999), so they are not repeated here.

The global model for females did not fit the data (Table 3) which suggested that either additional sources of heterogeneity remained or the data were over-dispersed. We treated the lack of fit as over-dispersion and used an estimated $\hat{c} = 1.6$ (=319.1/200). In contrast, the global model for males did fit adequately (Table 4), so we did not adjust for over-dispersion.

The same model was selected for both males and females (Tables 5-6). Capture probability varied by age and year and the annual variation differed between age classes (i.e., interaction between age and year). Sea lions seen at Area 1, were subsequently more likely to be seen on future occasions and this area effect increased with age (Figs. 4-5). The large increase in capture probability in 1994 resulted from expansion of the survey effort at SMI and the beginning of dedicated survey effort at ANI. The subsequent decline in capture probability in 1995, particularly for young males, occurred because ANI was not surveyed that year. The capture probability was highly correlated with the total number of days sampled at SMI and ANI (Fig. 6, Table 7). Each linear regression was significant ($P<0.03$ in each case) (Fig. 7) which suggests that more parsimonious models may be constructed by modeling capture probability as a function of sampling effort.

Survival varied by age for four age classes (pup, yearling, 2 year old and 3+ year old) and the annual variation pattern was different for the age classes (i.e., interaction between age and year). Pup survival from branding to 1 year old was dependent on their weight at branding (Fig. 8). To compute an average survival rate over years we used the survival rate for the median weight group in each year. The average male pup survival was significantly greater than female pup survival (Table 8) if the 1997/1998 El Niño was excluded but including those years increased the variability in the estimated averages such that a difference was no longer supported. Yearling survival rates were quite similar for both sexes, but survival for 2 year old females was significantly greater than males (Fig. 9, Table 8). Likewise, 3+ year old survival was greater for females although it fell short of being strictly significant ($p = 0.056$). The mean survivorship curves reflect these differences with the curves crossing at age 3 (Fig. 10).

The two El Niño events of January 1992 through December 1993 and May 1997 through December 1998 affected pup weights and survival. The average female pup weight for the 1992, 1993, 1997 and 1998 cohorts was 15.95 kg (SE = 0.70) which was significantly lower ($t = 3.22$, $p = 0.018$) than the average weight of 18.68 kg (SE = 0.49) for non-El Niño year cohorts from 1987-1999. Likewise, the male pup weights of 18.11kg (SE = 0.90) for the El Niño years and 21.76 kg(SE = 0.57) for the non-El Niño years were significantly different ($t = 3.44$, $p = 0.014$). Because pup weight affected first-year survival, we expected reductions in pup weights during El Niño years would reduce survival. For female pups the survival rate for the median weight was smaller and the difference was not significant (Fig. 11). In addition to reducing pup weights, El Niño events may create less favorable conditions for foraging which can reduce survival for pups of similar weight. For each weight category, females had significantly higher survival rates in non-El Niño years (Fig. 12). Thus, even if pup weights had not shifted in El Niño years, survival would have declined in female pups presumably because of poor foraging success. For males, the differences within weight categories were again smaller than females and they were not significantly different from unity.

Discussion

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.

Acknowledgments

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Citations

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Table 1. Number of female pups branded in each cohort stratified by weight (kg) category.

Cohort	<15.1	15.1-17.4	17.5-19.7	>19.7	Total
1989	2	7	14	85	108
1990	24	47	70	104	245
1991	27	44	63	125	259
1992	104	71	29	25	229
1993	49	96	117	79	341
1994	89	122	104	51	366
1995	36	69	133	88	326
1996	24	82	95	112	313
1997	175	75	42	21	313
1998	173	72	38	17	300
Total	703	685	705	707	2800

Table 2. Number of male pups branded in each cohort stratified by weight (kg) category.

Cohort	<17.3	17.3-20.3	20.4-23.0	>23.0	Total
1989	0	8	14	68	90
1990	32	40	86	96	254
1991	20	35	79	104	238
1992	106	80	47	28	261
1993	24	46	43	32	145
1994	27	54	33	20	134
1995	14	58	50	52	174
1996	16	48	65	55	184
1997	106	50	24	5	185
1998	124	44	25	7	200
Total	469	463	466	467	1865

Table 3. Goodness-of-fit test statistics (Test 2+3) for each cohort of female pups stratified by initial release and subsequent re-sighting at area 1 which includes Adams Cove and surrounding areas. The 1997 and 1998 cohorts do not provide information on lack of fit because they are fitted exactly.

	First release			Re-sighted at area 1		
Cohort	X^2	df	p	X^2	df	p
1989	11.6	14	0.638	33.1	21	0.045
1990	18.7	21	0.604	36.9	21	0.017
1991	36.1	20	0.015	24.5	17	0.106
1992	36.0	17	0.005	15.1	13	0.301
1993	29.7	17	0.029	38.2	10	0.000
1994	24.4	11	0.011	10.5	7	0.162
1995	1.0	5	0.963	1.9	4	0.754
1996	1.4	2	0.497			
Total	158.9	107	0.001	160.2	93	0.000

Table 4. Goodness-of-fit test statistics (Test 2+3) for each cohort of male pups. See Table 3 for description.

	First release			Re-sighted at area 1		
Cohort	X^2	df	p	X^2	df	p
1989	3.7	4	0.448	14.8	17	0.609
1990	11.1	22	0.973	27.4	19	0.095
1991	12.8	18	0.803	8.0	13	0.844
1992	8.9	15	0.882	11.4	13	0.577
1993	19.2	13	0.117	2.8	9	0.971
1994	10.4	7	0.167	8.7	6	0.191
1995	7.0	6	0.321	0.4	6	0.998
1996	6.5	2	0.038			
Total	79.6	87	0.700	73.5	83	0.762

Table 5. QAICc values for models of female capture-recapture data. Age(4) represents reduced age models with age classified in 4 levels (0,1,2,3+) and age(3) with 3 levels (0,1,2+).

Survival	Capture Probability					
	age	age+year	age+year+area	age+year+age*area	age*year+age*area	age(3)*year+age(3)*area
age	8910.0	8573.4	8498.2	8497.2	8420.4	
age+pupwt	8899.2	8555.3	8481.3	8480.3	8406.8	
age+pupwt+year	8873.9	8453.2	8388.5	8389.2	8375.5	
age*year + pupwt	8836.5	8434.1	8366.3	8367.4	8363.8	8364.2
age*year + pupwt*year					8371.2	
age(4)*year + pupwt					8352.1	8359.2
age(3)*year + pupwt					8356.0	

Table 6. AICc values for models of male capture-recapture data. Age(4) represents reduced age models with age classified in 4 levels (0,1,2,3+) and age(3) with 3 levels (0,1,2+).

Survival	Capture Probability					
	age	age+year	age+year+area	age+year+age*area	age*year+age*area	age(3)*year+age(3)*area
age	9302.7	8873.0	8782.6	8771.1	8735.0	
age+pupwt	9286.9	8844.9	8755.9	8744.1	8712.0	
age+pupwt+year	9235.1	8815.0	8729.5	8717.9	8702.3	8713.4
age*year + pupwt	9086.8	8803.7	8715.0	8703.5	8702.2	
age*year + pupwt*year					8712.9	
age(4)*year + pupwt					8700.9	8711.1
age(3)*year + pupwt					8707.3	

Table 7. Correlations between number of days sampled and capture probability for each group.

		Female	Male
Initial	Yearling	0.84	0.84
	2 yr old	0.78	0.87
	3-5 yr old	0.82	0.88
	6+ yr old	0.98	0.97
Resight	2 yr old	0.79	0.87
	3-5 yr old	0.85	0.87
	6+ yr old	0.99	0.99

Table 8. Mean survival rates by age and sex and Z-statistics for differences between male and female rates.

	Male		Female		Z
	Estimate	SE	Estimate	SE	
Pup	0.840	0.076	0.741	0.071	-0.96
Pup*	0.963	0.027	0.864	0.027	-2.58
Yearling	0.765	0.056	0.799	0.056	0.43
2 yr old	0.780	0.038	0.919	0.027	2.86
3+ yr old	0.895	0.010	0.942	0.023	1.91

* Excludes 1997/1998 El Niño

Figure 1. Coastal map

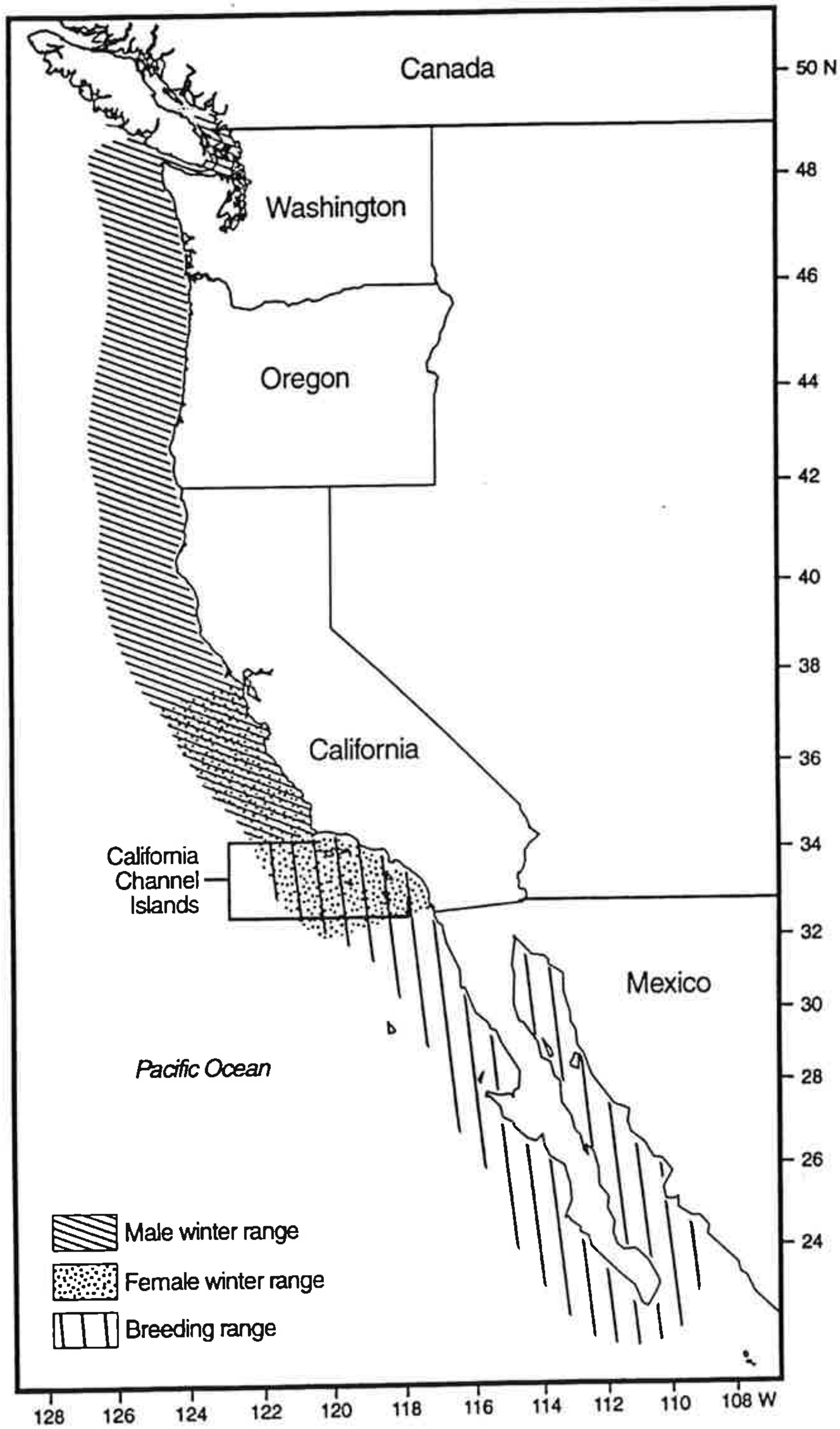
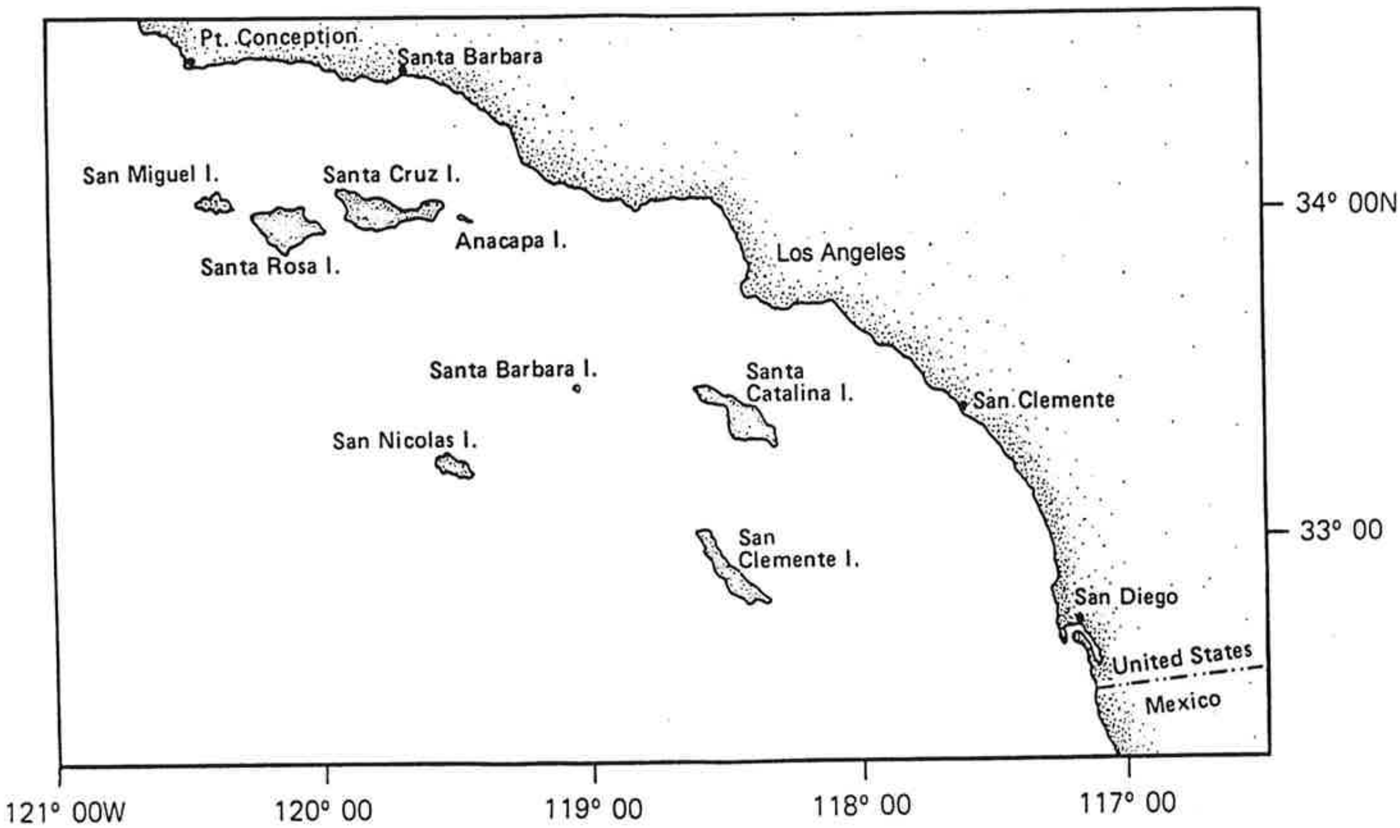
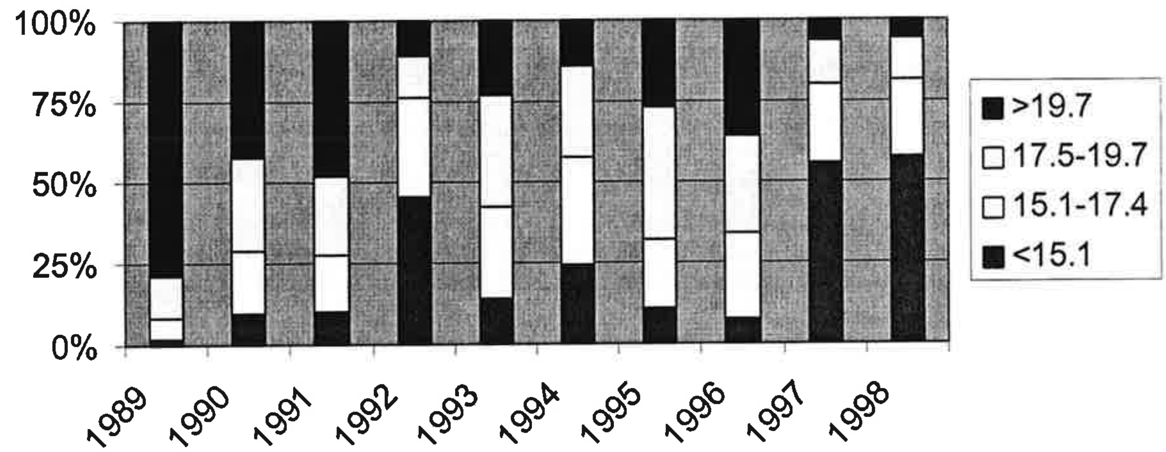


Figure 2. Haulout map



a)



b)

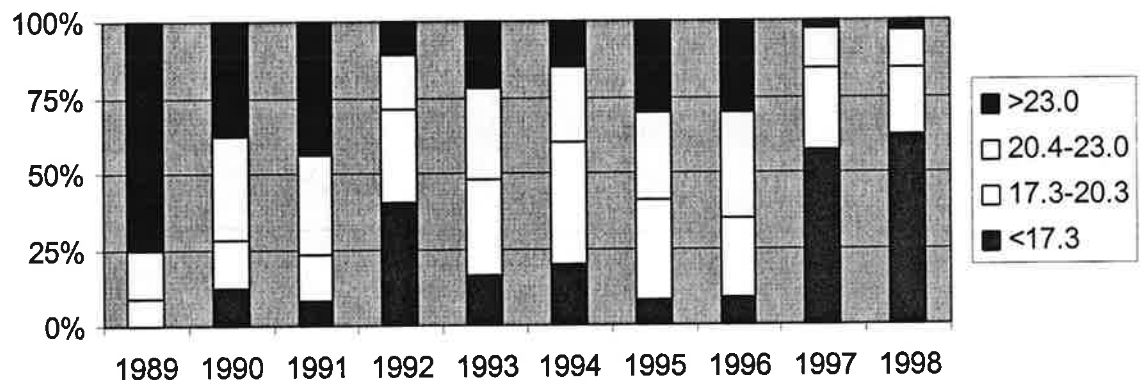
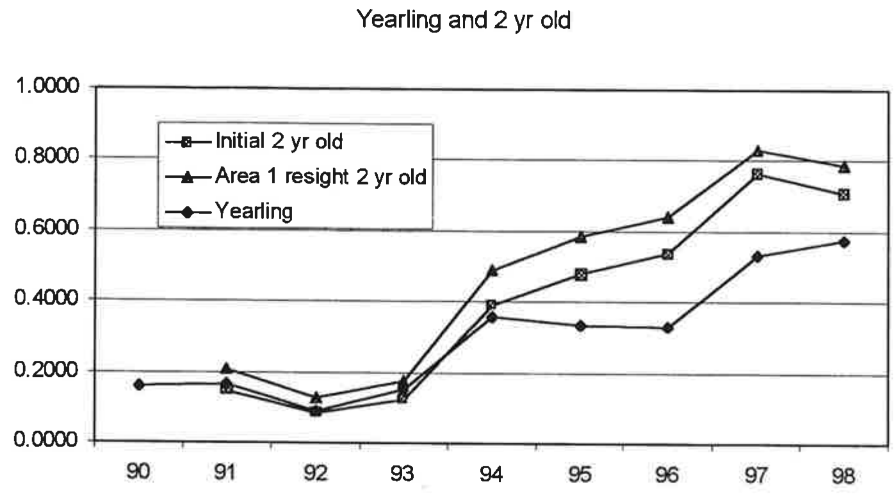
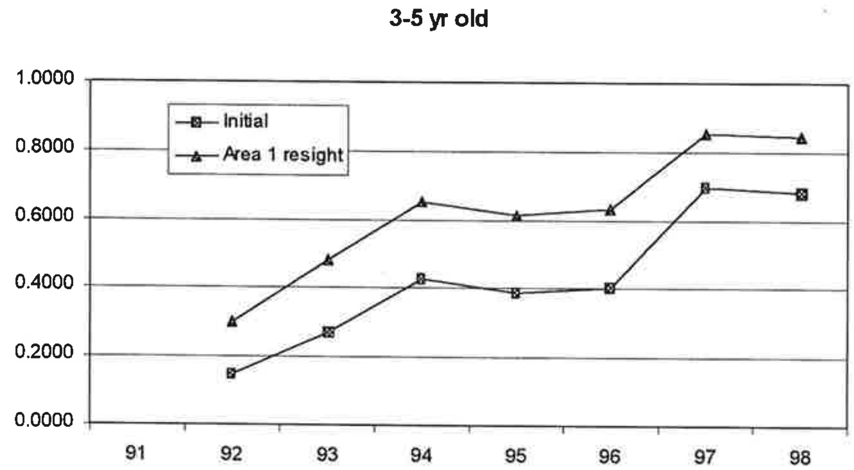


Figure 3. Proportions of pups in each weight category at branding for the 1989-1998 cohorts of females (a) and males (b).





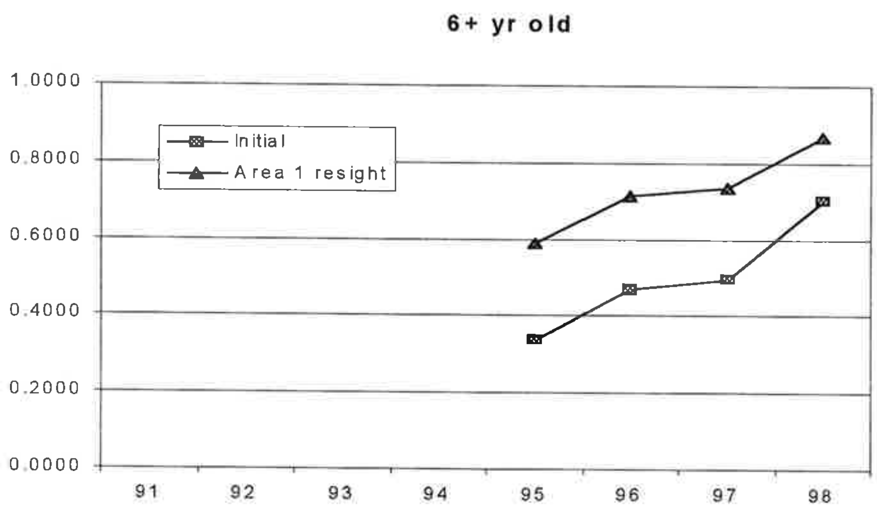


Figure 4. Capture probabilities for female sea lions prior (Initial) and subsequent (Area 1 re-sight) to being sighted in area 1. Yearling sea lions cannot be seen on any prior occasion in area 1.

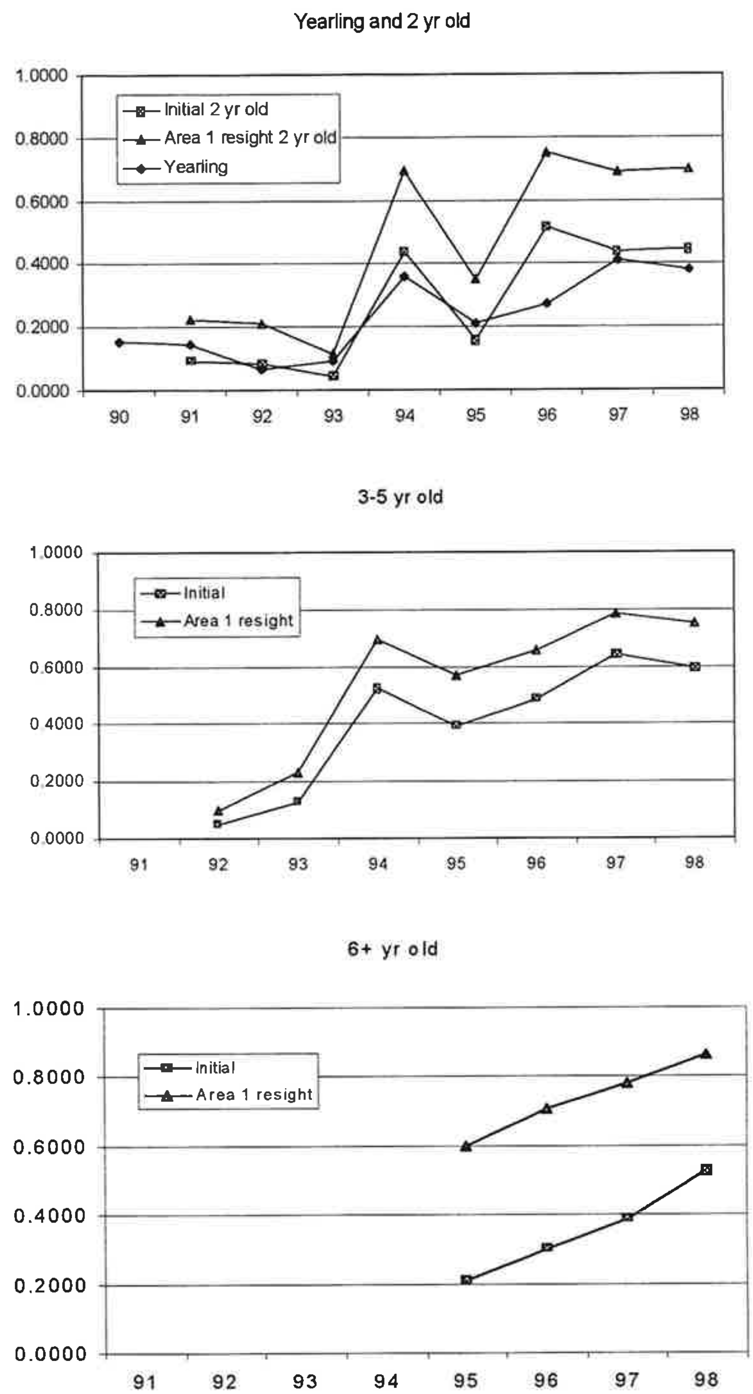


Figure 5. Capture probabilities for male sea lions prior (Initial) and subsequent (Area 1 re-sight) to being sighted in area 1. Yearling sea lions cannot be seen on any prior occasion in area 1.

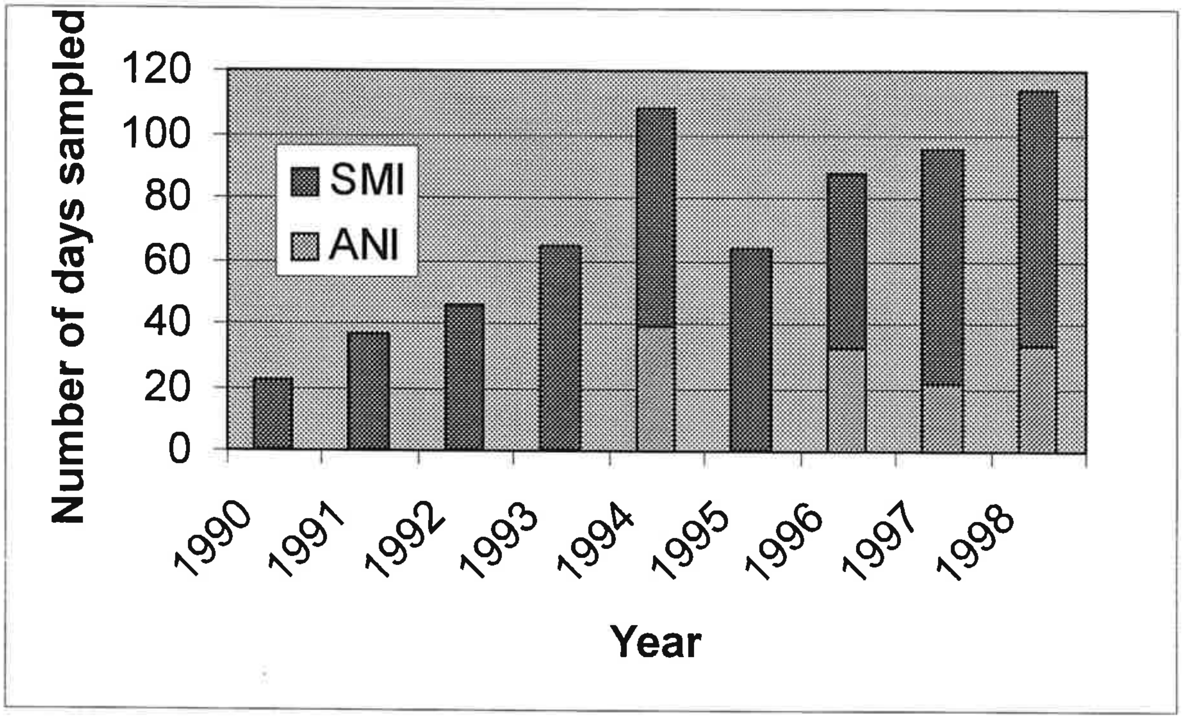


Figure 6. Number of days sampled at ANI and SMI in each year.

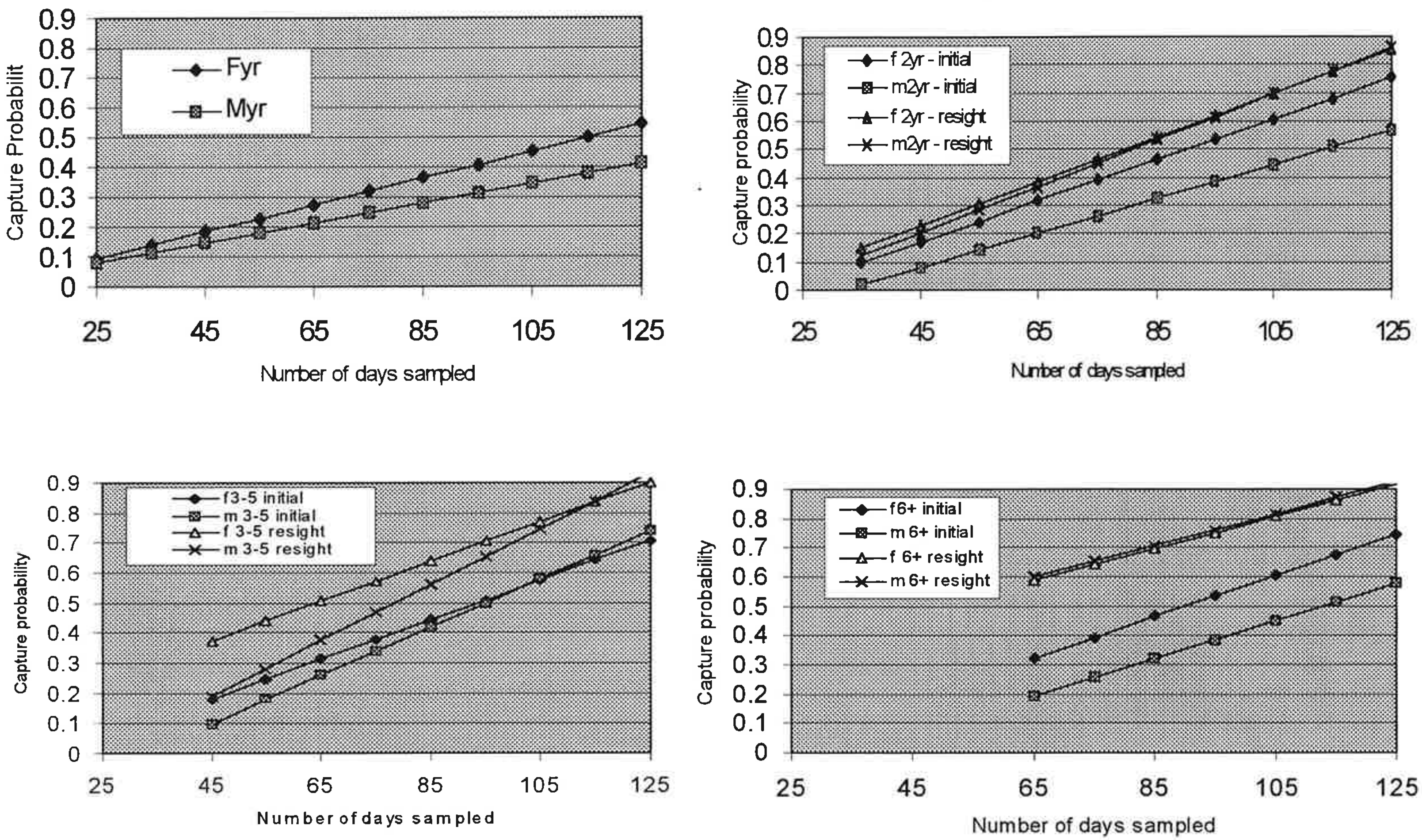
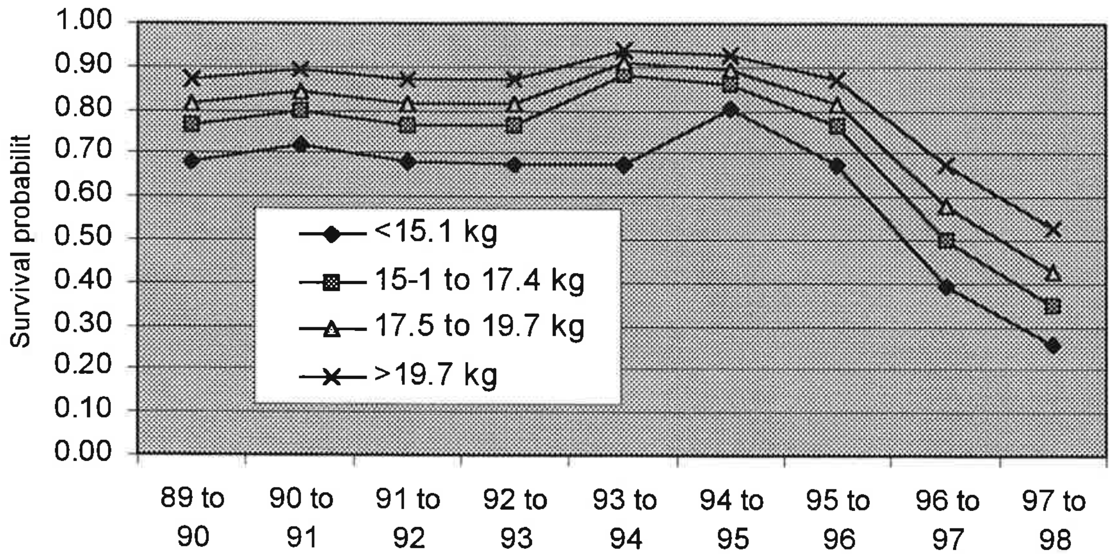


Figure 7. Regression equations of capture probability against total number of days sampled at ANI and SMI.

a)



b)

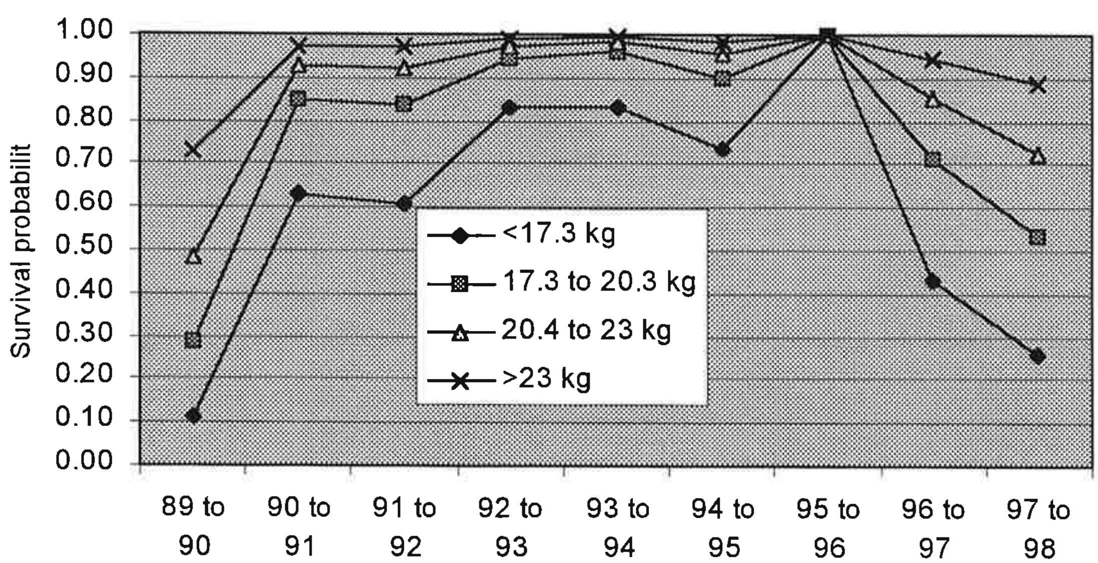
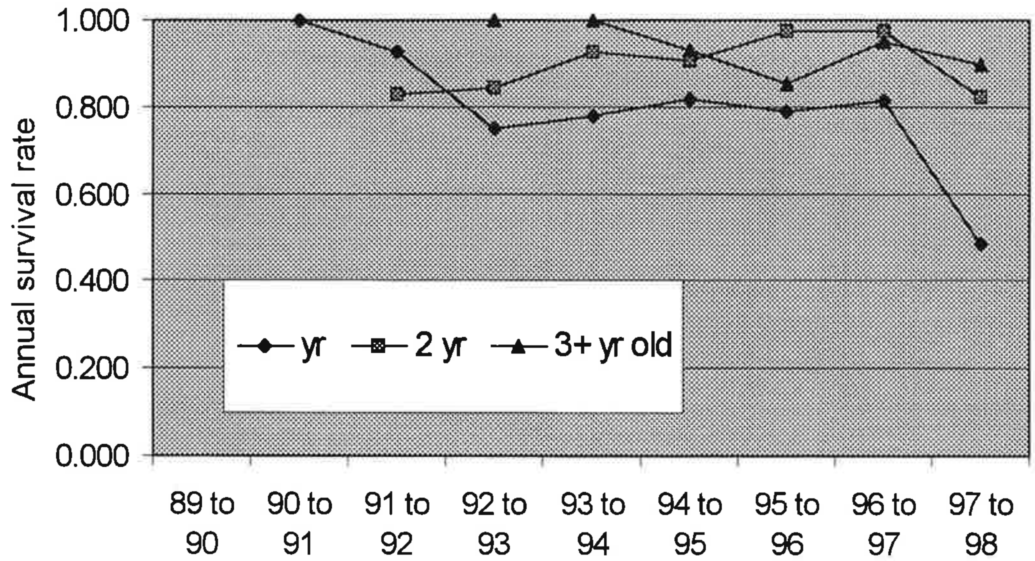


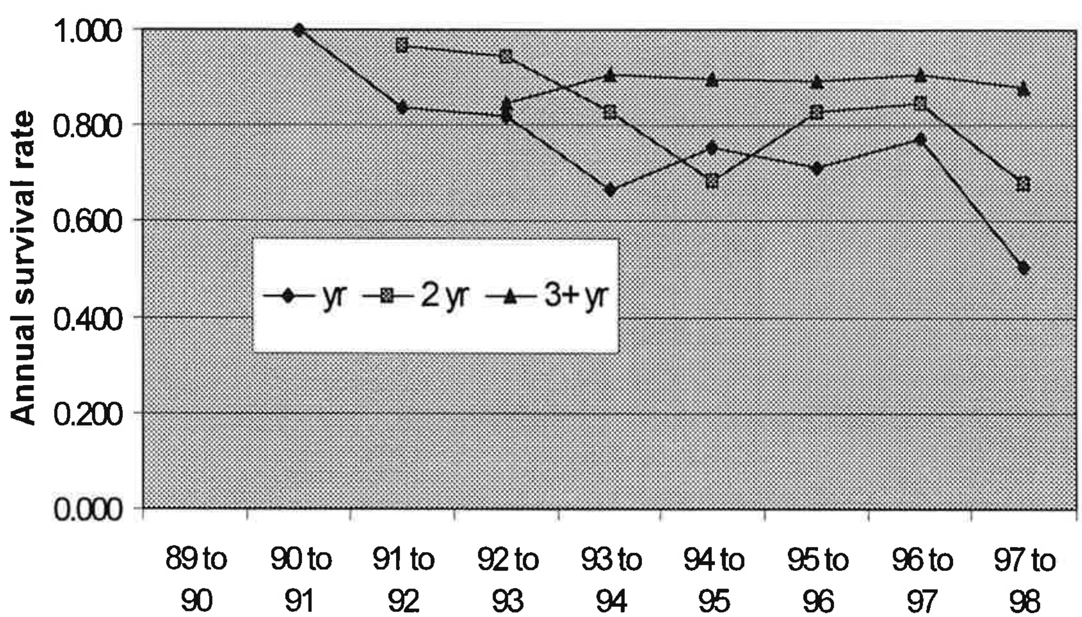
Figure 8. Survival rate from branding to age 1 of female (a) and male (b) pups divided into weight categories.

a)



1.000
0.800
0.600
0.400
0.200
0.000
Annual survival rate
yr
2 yr
3+ yr old
89 to 90
90 to 91
91 to 92
92 to 93
93 to 94
94 to 95
95 to 96
96 to 97
97 to 98

b)



1.000
0.800
0.600
0.400
0.200
0.000
Annual survival rate
yr
2 yr
3+ yr
89 to 90
90 to 91
91 to 92
92 to 93
93 to 94
94 to 95
95 to 96
96 to 97
97 to 98

Figure 9.

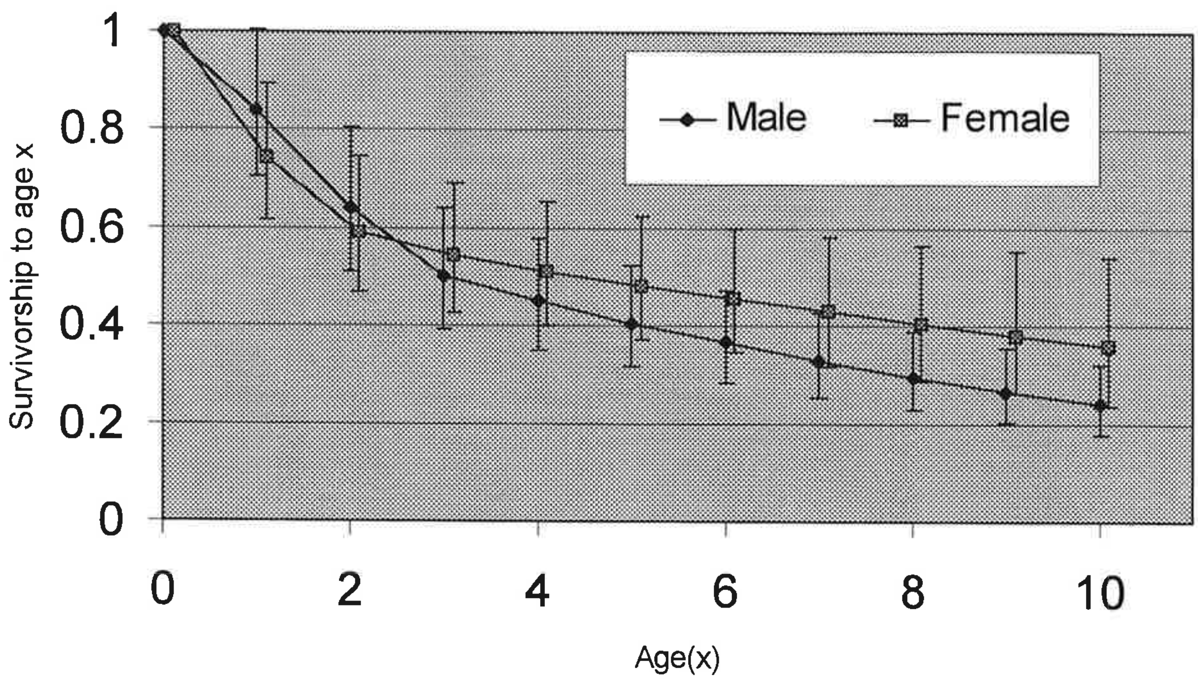
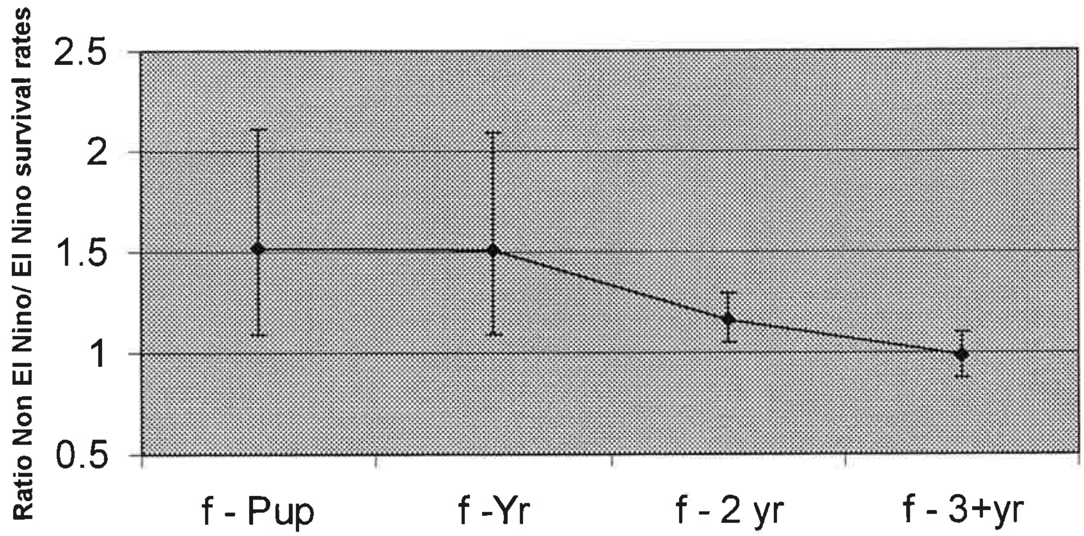


Figure 10. Average survivorship curves and 95% confidence intervals for male and female California sea lions from branding to age x.

a)



b)

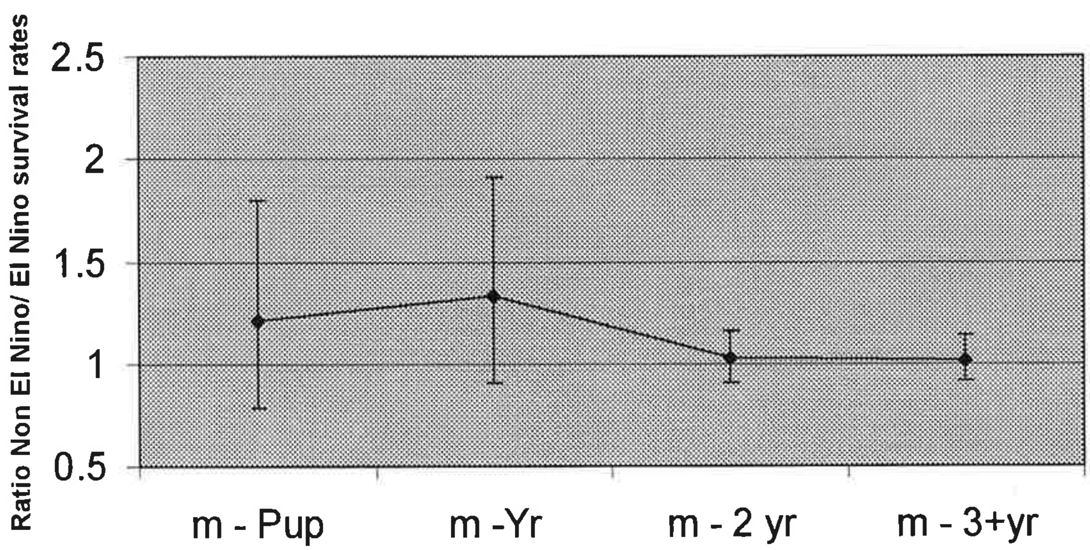
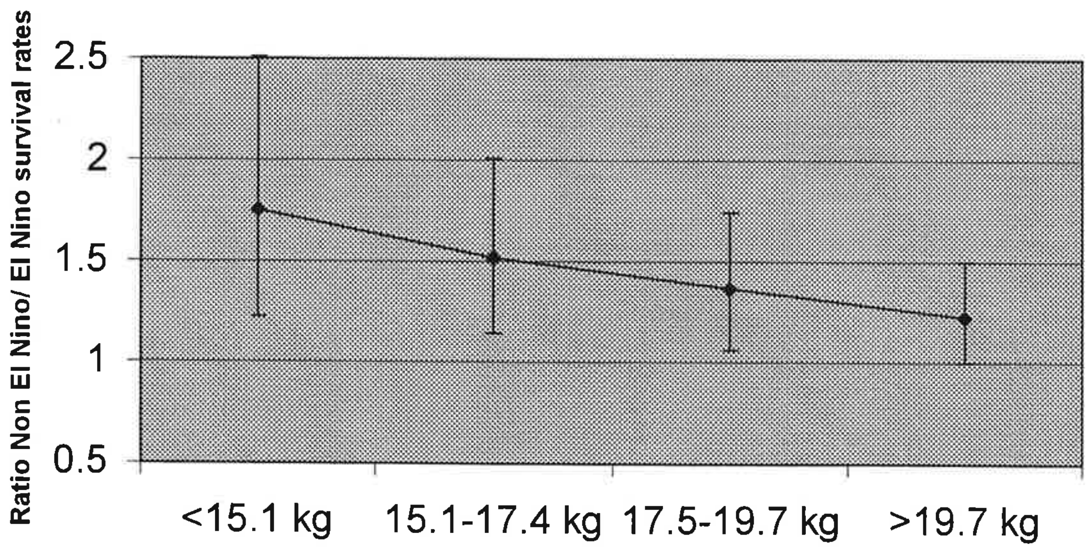


Figure 11. Ratio of survival rates in non-El Niño and El Niño years for females (a) and males pups(b) within each age category. Pup survival is computed using the annual survival rates of the median pup weight category in each year. For pups, survival to 1992, 1993, 1997 and 1998 are included in the El Niño years. For non-pups, a response would not be expected in a short time period (3-6 months) so 1992 and 1997 were included in the non-El Niño years.

a)



b)

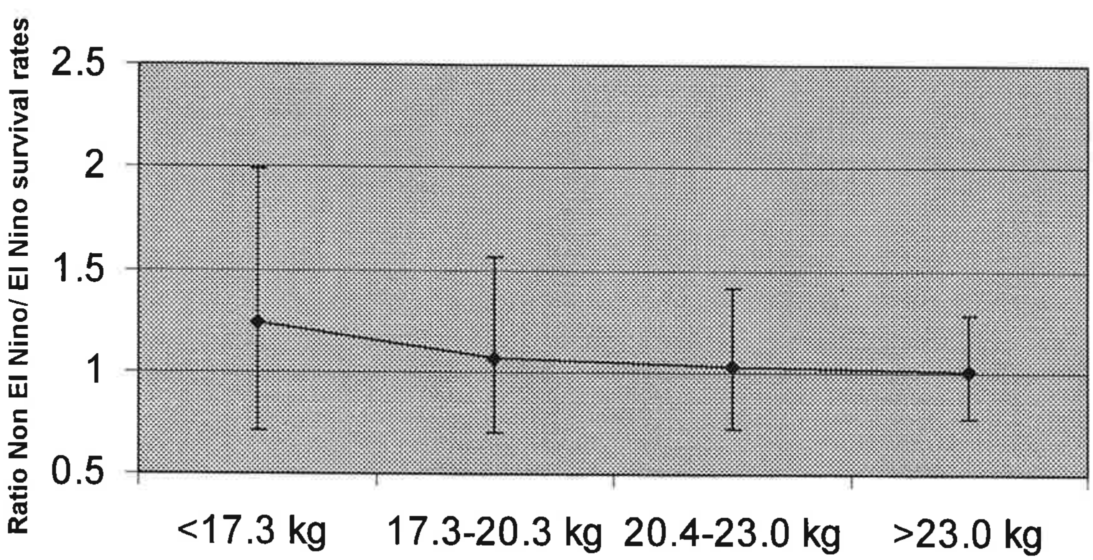


Figure 12. Ratio of survival rates in non-El Niño and El Niño years for female pups (a) and male pups(b) within each weight group.

NORTH PACIFIC RIGHT WHALE AND BOWHEAD WHALE HABITAT STUDY: R/V *ALPHA HELIX* AND CCG *LAURIER* CRUISES, JULY 1999

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Abstract

Provisional summer habitat studies were conducted on northern right whales in the eastern Bering Sea and bowhead whales in the Alaskan Beaufort Sea. Project objectives for the right whale study were to: (a) collect and interpret observations on the physical and biological features in the vicinity of right whale aggregations in the South Eastern Bering Sea, using the R/V *Alpha Helix* and (b) compare these data with habitat information from the area where right whales have historically been reported. Four right whales were seen in the eastern Bering Sea during aerial surveys and their positions were used to derive two transect lines for habitat and prey studies from the R/V *Alpha Helix*. Zooplankton samples from these tows have been analyzed by researchers at University of Alaska-Fairbanks, with the results to be summarized in a forthcoming technical report. Objectives for the bowhead study were to survey the Beaufort Sea slope for cetaceans (bowhead and white whales) using the Canadian Coast Guard Icebreaker (CCGI) *Sir Wilfrid Laurier* as a platform of opportunity, in conjunction with other NSF-funded oceanographic research. Extensive sea ice caused sampling along the slope to be canceled. Eight bowhead whales were seen on 25 July 1999 near Barrow, Alaska: two during a search conducted from a helicopter and six from the ship's bridge. This was an atypical time of year for bowheads to be seen near Barrow.

Introduction

A research program on North Pacific right whales (*Balaena glacialis*) was initiated by scientists at the NMFS/Southwest Fisheries Science Center (SWFSC) laboratory in summer 1998, based on repeated sightings of northern right whales in the eastern Bering Sea each July since 1996. In 1999, the SWFSC research program consisted of photo-identification and biopsy sampling, from an aircraft and a US Coast Guard cutter platform (LeDuc et al. 2000). The NMML joined this research in 1999 to coordinate habitat studies with scientists from University of California-Irvine and University of Alaska-Fairbanks, working aboard the R/V *Alpha Helix*. The goal was to sample hydrographic and biological features in the vicinity of northern right whales and to compare these data with habitat summaries for areas where right whales historically occurred.

Bowhead whales (*Balaena mysticetus*) and white whales (*Delphinapterus leucas*) have been suggested as good 'indicator species' of Arctic climate change (Tynan and DeMaster, 1997), but for this to be true models must be developed that integrate cetacean habitat selection with a suite of oceanographic features. Opportunities to simultaneously sample cetacean distribution and concomitant oceanography have been few in the Arctic, and always at a local scale (e.g., Moore et al. 1995). It appeared that the 1999 cruise of the Canadian Coast Guard Icebreaker (CCGI) *Sir Wilfrid Laurier* would provide a unique opportunity to survey the Beaufort sea slope for cetaceans coincident with hydrographic sampling (Fig. 1). The slope is potentially important summer habitat both for beluga and bowhead whales (Moore et al. in press) but has been under-sampled to date.

Methods

Two supplemental hydrographic survey track lines were added to the Alpha Helix cruise instructions in July 1999, based upon real-time locations of northern right whales in the eastern Bering Sea. Zooplankton tows were taken along those two transect lines, and in nearby areas of the Bering Sea (K. Coyle, pers. commun. 15 September 2000). Additional details of zooplankton and hydrographic sampling methods will be provided in the up-coming technical report (Coyle et al. in prep).

One scientist from the NMML (S. Moore) met the CCGI *Laurier* in Barrow, Alaska and disembarked in Prudhoe Bay, Alaska on 20-27 July 1999. Extensive sea ice resulted in the postponement of the planned mooring and conductivity temperature and depth (CTD) work, and departure of U.S., Canadian and Japanese oceanographers on 22 July. The ship remained in the Barrow area until 25 July, waiting for wind conditions to induce sea ice movement offshore. On 25 July, the decision was made to begin a crossing of the Alaskan Beaufort Sea, along the only available route near shore. Prior to departure from Barrow, a two-hour aerial survey of the Barrow Canyon area was conducted by helicopter and a watch for cetaceans from the ship's bridge using naked eye and handheld 25X binoculars was initiated.

Results and Discussion

Northern Right Whales

Aerial surveys for northern right whales and other cetaceans were conducted from 5-17 July 1999 out of Dillingham, Alaska. Four right whales were seen, two near 56°30'N, 163°20'W and two near 57°00'N, 164°10'W/164°30'W, respectively. The first two right whales were among an aggregation of fin and humpback whales that extended west from 163°00'W to about 163°30'W longitude between 56°30'N and 56°40'N. The other two sightings were near, but not among fin whales. Based upon the locations of the right whales, and several other clusters of fin whales, two transect lines were derived for hydrographic and prey sampling from the *R/V Alpha Helix*. Each line extended northeast from roughly 56°10'N, 164°5.0'W to 57°00'N, 162°50'W and from 56°30'N, 165°00'W to 57°20'N, 163°30'W. The coordinates for these two transects were faxed to the *Alpha Helix* cruise leader (G. Hunt) on 14 July 1999. Results of the hydrographic and zooplankton sampling have been analyzed by a UA-Fairbanks biologist (Ken Coyle) and will be summarized in a forthcoming technical report (Coyle et al. in prep).

Bowhead Whales

Vessel and helicopter surveys for Arctic cetaceans were conducted from 20-27 July 1999 from the CCGI *Sir Wilfrid Laurier.* Extensive sea ice resulted in the postponement of mooring and CTD work planned for the Beaufort Sea slope, so survey of this habitat could not be conducted. On 25 July, prior to departure from Barrow, AK, a two-hour aerial survey of the Barrow Canyon area was conducted by helicopter and a watch for marine mammals from the ship's bridge was initiated. Eight bowhead whales were seen during this search: two from the helicopter and six from the ship. Bowheads were seen near: 71°30'N, 155°40'W to 155°54'W; two whales and near 71°26'N, 156°23'W; six whales. Two gray whales were also seen on 25 July, just north of Dease Inlet (71°14.7'N, 155°22.1'W) in 50% ice cover. These two whales appeared to be juveniles (small) and initially tried to out-run the ship. Although ice conditions curtailed plans to survey the Beaufort Sea slope, it is noteworthy that bowhead whales were seen near Barrow in July, a time of year when the Bering-Chukchi-Beaufort stock is expected to be in the Canadian Arctic. However, the sightings reported here fall within the time frame of those summarized in Moore (1992) and are in keeping with suggestions by Russian scientists that the Barrow Canyon is a focal feeding area for bowheads and that they "move on" from there only when zooplankton concentrations disperse (Melnikov et al. 1998).

Citations

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Moore, S.E. 1992. Summer records of bowhead whales in the northeastern Chukchi Sea. Arctic 45(4): 398-400.

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Moore, S.E., J.C. George, K.O. Coyle, and T.J. Weingartner. 1995. Bowhead whales along the Chukotka coast in autumn. Arctic. 48(2): 155-160.

Tynan, C.T., and D.P. DeMaster. 1997. Observations and predictions of Arctic climate change: potential effects on marine mammals. Arctic 50(4): 308-322.

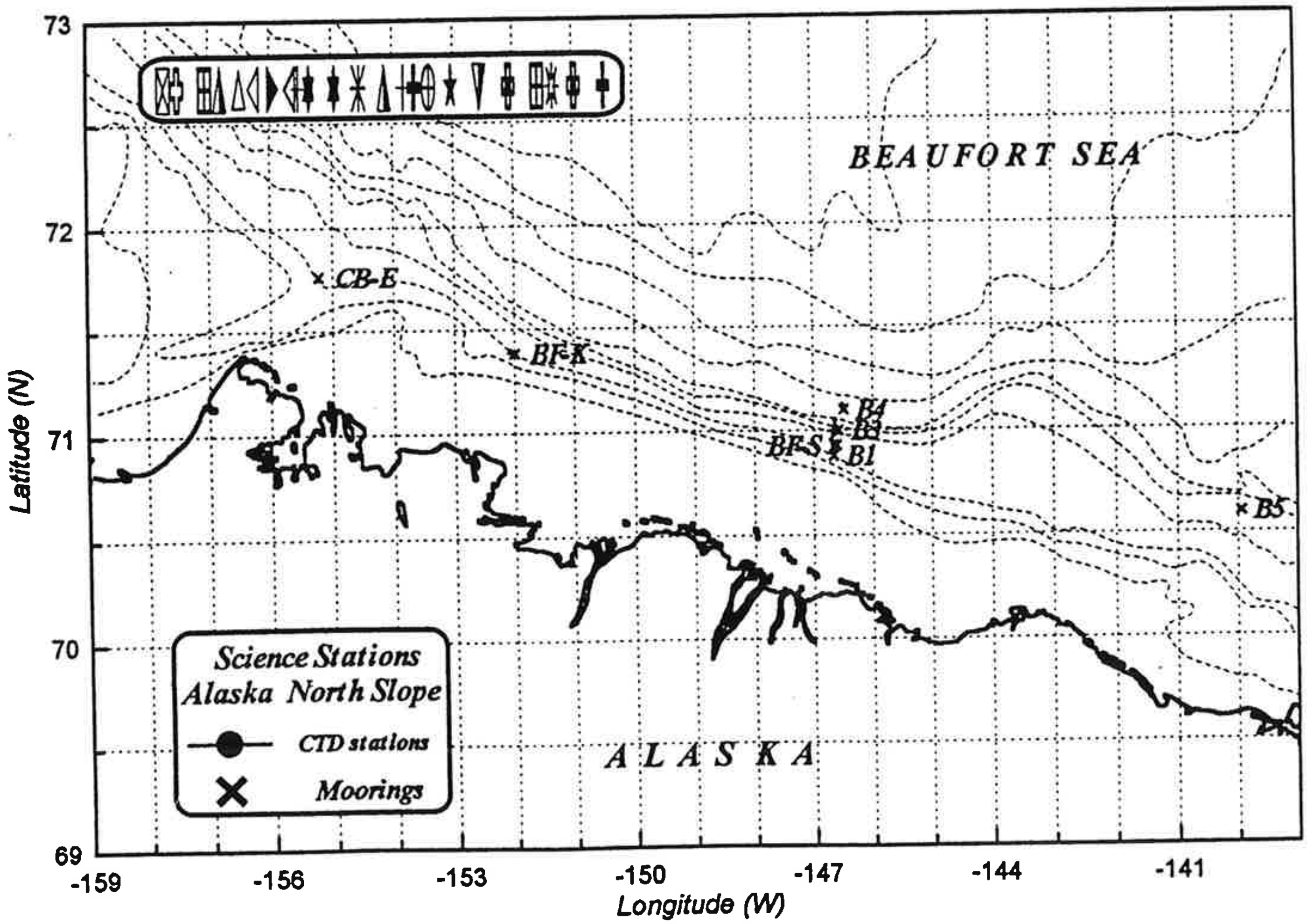

Figure 1. Planned CTD stations and mooring sites for the July 1999 portion of the CCGI *Sir Wilfrid Laurier* cruise. Sites along the Beaufort Sea slope could not be approached due to extensive sea ice.

PROVISIONAL ESTIMATES OF MYSTICETE WHALE ABUNDANCE ON THE CENTRAL BERING SEA SHELF, 1999

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Abstract

Visual surveys for cetaceans were conducted along transect lines in the central Bering Sea in association with commercial fisheries research from 5 July through 5 August 1999. A total of 6,043 km of survey effort was completed, with over 125 sightings of single or groups of mysticete whales. Most sightings (60%) were of fin whales, with sightings clustered along the outer Bering Sea shelf break, primarily near the 200m isobath. In addition, there were 27 sightings of minke whales and 17 sightings of humpback whales. Minke whales were primarily distributed along the upper slope in water 100-200m deep, while humpbacks clustered along the eastern Aleutian Islands and near the U.S./Russian Convention Line southwest of St. Lawrence Island. Provisional abundance estimates for fin, humpback and minke whales were: 4,951 (95% CI = 2,833-8,653); 1,175 (95% CI = 197-7,009) and 936 (95% CI = 473-1,852), respectively. These three species were the only ones for which sufficient on-effort sightings were available to estimate abundance. Sei whales, a gray whale, and a pair of northern right whales were also seen. Although right whales have been seen in this area before, some behavioral details are provided here because observations of these whales remain quite rare.

Introduction

There have been few broad-scale surveys for whales in the central Bering Sea that were not associated with commercial whaling (e.g., Wada 1981), such that many contemporary references to mysticete whale distribution and abundance there relies on catch records (e.g., Springer et al. 1996, 1999; Tynan, 1999). Northern right whales (*Eubalaena glacialis*), fin whales (*Balaenoptera physalus*), and humpback whales (*Megaptera novaeangliae*) were harvested predominantly south of the Aleutian Islands in the North Pacific, but takes were also substantive in the central Bering Sea (Miyashita et al. 1995; Nasu, 1974). From 1966-1990, minke whale (*Balaeanoptera acutorostrata*) sighting rates from whaling or whaling-support vessels were highest in the western Pacific and Sea of Okhotsk, with comparatively few whales reported for the central Bering Sea (Miyashita et al. 1995). For lack of broad-scale surveys, it has been impossible to determine if populations of mysticete whales are recovering from the commercial harvests of the 20th century, and whether they play an important role in the ecology of the Bering Sea (Livingston 1993).

An exceptional sighting of a small group of northern right whales was made during fishery research in the eastern Bering Sea in July 1996 (Goddard and Rugh, 1998). This sighting precipitated efforts to put marine mammal observers onboard a fishery research vessel in summer 1997. This opportunistic survey proved successful, as northern right whales were sighted and photographed in the anomalous coccolithophore (*Emiliania huxleyi*) bloom prevalent in the eastern Bering Sea that year (Tynan 1998; Vance et al. 1998). In 1999, scientists from the Alaska Fisheries Science Center/Resource Assessment and Conservation Engineering (AFSC/RACE) Division conducted another in a series of acoustic-trawl surveys for walleye pollock (*Theragra chalcogramma*) on the Bering Sea shelf. Biologists from the AFSC/National Marine Mammal Laboratory (NMML) were able to join the second leg of that cruise and conduct a visual survey along the lines RACE had developed for the pollock assessment. This opportunity provided a means to assess the central Bering Sea shelf for mysticete whales, with provisional results of that effort reported here.

Methods

Visual Survey Protocol

A line-transect survey for cetaceans was conducted from the flying bridge of the NOAA ship *Miller Freeman* (215 ft), while the ship was in transit between trawling sites over the central Bering Sea shelf (Fig. 1). The survey design consisted of north-south transect lines spaced 20 nmi apart (except in the "Horseshoe" area where spacing was 10 nmi) and proceeded from east to west starting at longitude 171°26'W and ending at longitude 178°55'W. The vessel maintained a speed of 10-11 knots between trawling sites. Effort began and ended with available light (0730 - 2230 hours local time). Except for observer rotation, standard line-transect survey protocol was adopted (Barlow 1988). When weather conditions permitted (i.e., dry, visibility $\gtrsim$1 km), two primary observers maintained a continuous watch for marine mammals at starboard and port stations on the flying bridge using 25x150 power binoculars (Fig. 1: on-effort). Observer eye height was 12 m above the water line. A data recorder, stationed between the primary observers, searched by scanning both sides of the ship with naked eye and using 7x50 hand held binoculars. In poor weather (i.e., rain, visibility $\lesssim$1 km), or areas of patchy dense fog, one observer maintained watch using hand held binoculars from the bridge (Fig 1: bridge-effort). Survey effort was suspended whenever visual conditions deteriorated completely and while RACE biologists conducted fishing operations (Fig. 1: off-effort).

Data Collection, Oceanographic Correlates and Analysis

Variables related to marine mammal survey effort were recorded on a laptop computer and updated whenever conditions changed (Table 1). At 5-minute intervals, the program automatically updated fields of time, date, latitude, longitude and other variables if they remained unchanged. Environmental and oceanographic data were obtained from instruments maintained by the fishery scientists. Along-track measurements of water temperature, salinity and chlorophyll 'a' were recorded at 5-minute intervals from the ship's flow-through system, which sampled seawater at about 3 m depth. Wind direction and speed, vessel heading and vessel speed were also recorded every 5 minutes. A bongo tow net system (60 cm bongo frame with 505µm mesh nets and a 40 kg lead weight) was deployed from the ship's starboard winch to collect samples in the vicinity of right whales and in the coccolithophore bloom. The contents of the tow were roughly identified and stored for future identification.

Mysticete whale abundance was estimated using standard line transect analysis for species with 10 or more on-effort sightings. Bridge-effort and off-effort sightings were not used for abundance estimation, but were plotted to depict species' distribution. Effective strip width, observed density, and abundance were estimated using the program DISTANCE (Laake et al. 1993). Sighting distances were truncated in increments of 0.5 km to avoid gaps of 1 km or greater in the distribution of sightings from the trackline.

Results

The cruise began and ended in Dutch Harbor, Alaska and extended from 5 July through 5 August 1999. Although the acoustic trawl effort for pollock began on transect line 19 (56°20'N, 171°26'W) and ended with transect line 29 (60°65.9'N, 178°91.68'W), survey effort for marine mammals began on transit to and from these way points. The entire track of the marine mammal survey, including transect lines 19-29, the Horseshoe area, and transits to and from Dutch Harbor, covered 6,043 km (Fig. 1). Of the total track, 2,354 km (39%) was surveyed on-effort, 2,017 km (33%) was conducted by one person on the bridge in marginal weather conditions (i.e., bridge-effort), with the remaining 1,672 km (28%) of track line covered while observers were off-effort.

Mysticete Whale Distribution and Abundance

There were a total of 125 mysticete whale sightings during the cruise, the majority (60%) were, fin whales (Table 2). Fin whale sightings were clustered along the outer Bering Sea shelf break, primarily near the 200 m isobath (Fig. 2). Overall, there were 75 fin whale sightings, 58 of which were on-effort, and therefore used to estimate abundance (Table 3). Using a truncation distance of 5 km, the estimated abundance of fin whales was 4,951 (95% CI = 2,833-8,653).

There were 27 sightings of minke whales and 17 sightings of humpback whales during the cruise. Minke whales were distributed along the upper slope in water 100 m to 200 m deep, while humpbacks clustered along the eastern Aleutian Islands and near the U.S./Russian Convention Line southwest of St. Lawrence Island (Fig. 3). Twenty of the minke whale sightings, and 10 of the humpback sightings were on-effort, and used to estimate abundance (Table 3). Using truncation distances of 2.5 km and 3 km, respectively, estimated abundance of minke whales was 936 (95% CI = 473-1,852); estimated abundance of humpback whales was 1,175 (95% CI = 197-7,009). Confidence in the humpback whale estimate is especially low (CV = 1.13), due largely to the paucity of on-effort sightings.

There were four sightings of six sei whales (*Balaenoptera borealis*) during the cruise; three sightings of five sei whales near minke whale sightings southeast of Pervenets Canyon shoreward of the 200 m isobath, and a lone sei whale north of there near the 100 m isobath (Fig. 3). In addition, there were single sightings each of a gray whale (*Eschrichtius robustus*) near St. Matthew Island (60°35.19'N, 173°24.17'W), and a pair of Northern right whales (*Eubalaena glacialis*) in the eastern Bering Sea (56°58.33'N, 163°27.64'W; Fig. 3). Although right whales have been seen in this area before, some additional details of this sighting are provided because observations of these whales remain rare.

Northern Right Whale Observations

On 31 July 1999, an extensive coccolithophore bloom was observed during a ten-hour, eastbound transit beginning at approximately 1230 local time (57°21.78'N and 166°28.07'W; Fig. 1). The vessel was in the bloom at least until sunset, approximately 2245 local time (56°52.12'N and 163°32.92'W). Two northern right whales were initially sighted with naked eye near the horizon, breaching at least five times. Species identification was confirmed with hand held, and subsequently 25X binoculars. The pair was near the only right whale sighting on Leg 1 of the *Miller Freeman* cruise (conducted in June 1999) and, as in 1997, the whales were well within the coccolithophore bloom (Tynan 1998). The right whales were approximately 5 km (2-3 mile) from four fin whales, and in the vicinity of right whale sightings made by researchers conducting aerial, vessel, and acoustic surveys from 8-18 July 1999, just 10 days prior to this sighting (R. LeDuc pers. commun.).

The right whales remained within one body length of each other throughout the approximately one hour observation period and did not appear to respond adversely to the vessel. In fact, they approached and swam across the bow, passing within 250 m of the ship (Fig. 4). Observed behaviors included breaching, close contact, rolling to extend a pectoral fin in the air, a fluke-up dive, shallow dives of short duration (1-5 minute down time average) and slow-swimming in tandem, but not synchronous diving. Both whales appeared healthy and robust, were similar in length (roughly 12-14 m) and girth, and were free of fishery gear-interaction scars or other human or natural caused markings. Oddly, both animals lacked white-colored callosities typically associated with right whales. Instead, their raised callosity patches were a darker, rust-colored hue.

Water depth at the whales' location was 70.6 m, water temperature was 8.6° C, chlorophyll 'a' reading was 0.578 and salinity was 31.753 psu. Shortly after photographing the whales, two bongo nets (505-µm mesh) were deployed and a tow taken near the bottom and within the coccolithophore bloom. During the tow, the whale remained within about 2 km (1 nmi) of the vessel. Samples from both nets collected from a bottom depth 70-71 m included jelly fish (50-220 grams, discarded) and larval pollock (preserved in 2-32 ounce jars; 2 gms frozen for MACE/Bailey).

Oceanographic Correlates

Throughout the cruise, there often was a positive correlation between mysticete whale aggregations and concentrations of zooplankton, euphausiids, pollock and other fish observed on the echosounder by the Midwater Assessment Conservation Engineering (MACE) scientists. Elevated chlorophyll 'a' readings were also noted during these observations. Although not yet fully analyzed, a few observations, especially those on the middle shelf along the 200 m contour and adjacent to canyons are summarized here.

On 14 July 1999 (line 21: 62°59.95' N, 173°58.75'W), large aggregations of 3-5 inch arctic cod (*Boreogadus saida*) occurred simultaneously with an aggregation of humpback whales, killer whales *(Orcinus orca*) and approximately 20 species of sea birds, pomerine jaegers being the dominant species. As daybreak allowed better visibility, an interesting event involving five killer whales and a single humpback whale was in progress. Within a 2-minute period, the killer whales surrounded and then closed on the humpback whale at which point the humpback grew increasingly agitated with tail-slaps becoming more frequent and forceful. Unfortunately, the vessel then left the area so observers were unable to determine the outcome of the killer whale/humpback whale interaction.

On 16 July 1999 (line 22: 57°14.97'N and 173°18.55'W), the MACE echosounder detected over 25 miles of zooplankton and euphausiids echosign near Zemchug Canyon (bottom depth 135-150 m), including 4-5 mile intervals of strong fish echo within the longer stretch of zooplankton. Concurrently, marine mammal observers documented aggregations of fin whales, Dall's porpoise, short-tailed shearwaters, fork-tailed storm petrels, Leach's storm petrels, long-tailed jaegers, and Laysan albatross.

On 26 July 1999 (line 26: 58°39.38'N and 176°50.17'W), the MACE echosounder detected similar prey aggregations near Pervenents Canyon (bottom depth 150-200 m), where dense pollock schools at times occupied the entire water column. Aggregations of fin whales and several groups of minke and sei whales were documented, with all species lunge-feeding at the surface. The whales were accompanied by thousands of seabirds. Dominant bird species included short-tailed shearwaters, fork-tailed storm petrels, pomerine jaegers, Laysan albatross and an enormous flock of red phalaropes.

Although off-effort on 27 July (line 27: 59°36.40'N and 177°09.80'W), the observers recorded the largest aggregation of fin whales, more than 100 animals, within a 5-6 mile stretch of dense fish echosign. Surprisingly, there were not many seabirds. Oceanographic readings in the area of the coccolithophore bloom were unique. Peak flourometer and water temperature readings were recorded while transiting through the bloom. Chlorophyll 'a' readings ranged from 0.6 to 0.9, averaging approximately 0.7, and peaking at 0.918. Water temperature ranged from 6.0° to 8.9° C and peaked at 8.9° C. As would be expected on the middle shelf, water depth ranged from 66 to 71m. Marine mammals seen in the coccolithophore bloom included northern fur seals (9), harbor porpoise (nearly 30% of all sightings), fin whales and the pair of right whales (Fig. 3). Birds observed in the area included the glaucous-winged gull, parasitic jaeger, Arctic tern, and possibly an Aleutian tern.

Discussion

The 1999 cruise aboard the NOAA ship *Miller Freeman* provided a valuable opportunity to conduct a line-transect survey for marine mammals in the central Bering Sea, and resulted in sufficient sighting data to support the calculation of provisional abundance estimates for fin, minke and humpback whales. Because the survey covered only a portion of the entire Bering Sea, and because the abundance estimates were not corrected for animals missed on the trackline, animals that were submerged, nor animals that are vessel-attracted or vessel-shy, they must be considered rudimentary estimates of mysticete whale abundance. To emphasize this point, a plot of June/July 1980-99 sightings of the three species was compiled from the National Marine Mammal Laboratory (NMML) Platforms of Opportunity (PoP) database (Fig. 5). Although unrelated to survey effort, the broad distribution of sightings for each species provides a clear indication that whales detected during any one survey will surely under-represent the overall distribution and abundance of mysticete whales in the eastern and central Bering Sea.

Until now, however, there has been no estimate of fin whale abundance in the Bering Sea (Hill and DeMaster 1999). However, Ohsumi and Wada (1974) estimated 14,620 to 18,630 fin whales in the entire North Pacific in the late 1970s. The uncorrected abundance estimate of 4,951 whales (95% CI = 2,833-8,653) reported here indicates that the Bering Sea is an important habitat for fin whales, and it may be the most abundant mysticete whale there. Fin whale sightings were concentrated along the shelf edge and were often associated with dense concentrations of zooplankton and fish. Nasu (1974) reported that fin whales in the Bering Sea were commonly associated with the oceanic front that occurs between water masses at the shelf break, and Springer et al. (1999) also reported fin whale distribution in subarctic North Pacific (based on whaling records) to coincide with zooplankton biomass.

Minke whales in the eastern North Pacific have been separated into two stocks based on behavioral differences: 1) the Alaska stock and 2) the California, Oregon and Washington (C/O/W) stock (Hill and DeMaster, 1999). During the *Miller Freeman* survey, minke whales were distributed throughout the study area, including nearshore regions (e.g., Unimak I.) and the upper shelf, suggesting widespread use of the Bering Sea. While there are reports of minke whale aggregations elsewhere in the Bering Sea, such as along the Chukotka coastline (e.g., Melnikov et al. 2000), there has been no abundance estimate available for the Alaska stock of minke whales in the Bering Sea. Therefore, the estimate of 936 whales (95% CI = 473-1,852), although uncorrected and covering only a small portion of the stock's range, provides a baseline minimum estimate for this population.

Little is known about humpback whales distribution and abundance in the Bering Sea (Perry et al. 1999). Our estimate of 1,175 whales (95% CI = 197-7,009), despite the associated large uncertainty, indicates that humpback whales clearly use the Bering Sea as a summer feeding ground. There are records of humpback aggregations along the Chukotka Peninsula (e.g., Melnikov et al. 1999), so clearly our estimate does not account for all humpbacks in the Bering Sea. Whaling records show that humpback whales were caught in the Bering, mostly north of Unimak Pass (Reeves et al. 1985), where sightings were clustered during our survey. Notably, humpback whales were not seen in the highly productive areas along the shelf edge where fin whales were found, suggesting temporal or spatial separation in foraging, or differences in foraging threshold (Piatt and Methven, 1992), between the two species. It is not clear whether Bering Sea humpback whales all return to the same wintering grounds. Marking studies conducted during years of whaling found humpback whales marked in the Bering Sea moved between both Japanese waters and eastern North Pacific waters (Ohsumi and Masaki, 1975). Thus, more than one stock of humpback whales may be represented in the Bering Sea.

The only northern right whales sighted were observed in the eastern Bering Sea, where they have been seen each summer since 1996 (Goddard and Rugh, 1998). As in 1997, the right whales were seen within a coccolithophore bloom (Tynan 1998). Photographs taken of right whales in 1997 also show "rust-colored" callosities, similar to those photographed in 1999. One explanation for the atypical callosity coloration might be a lack of diatoms in a coccolithophore bloom, which may somehow affect callosity coloration.

The opportunistic survey aboard the NOAA ship *Miller Freeman* provides a snapshot of fundamental information about mysticete whale populations in the central Bering Sea. It appears that substantial numbers of fin whales, minke whales and humpback whales occur in the Bering Sea, and that they occupy somewhat dissimilar habitats there. These provisional abundance estimates provide a baseline for comparison to data we hope to obtain in subsequent surveys. Finally, the observation of northern right whales adds to the increasing information base regarding their behavioral ecology in the Bering Sea.

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Table 1. Summary of cetacean survey data fields.

DATA FIELD	Description
1. Begin/End/Comment	Begin and end effort codes; comments throughout the day
2. Environmental Conditions	Beaufort sea state; swell height and direction; weather (i.e. rain, fog, clear, haze), visibility, sun angle
3. Oceanographic data	Fluorometer reading, salinity, water temperature, wind speed and direction
4. Navigation	Ship's heading and speed
5. Observers	Observer positions
6. Sighting	Time, LAT and LONG, bearing reticle distance species estimated group size (best, high low) observer)

Table 2. Mysticete whale sighting summary.

SPECIES	Total No. Sightings	Total No. Whales	% Total Sightings
Fin whale	75	346	60
Minke whale	27	37	22
Humpback whale	17	39	14
Sei whale	4	6	3
Gray whale	1	1	0.5
N. Right whale	1	2	0.5

Table 3 Abundance estimates of fin, humpback and minke whales

Abundance estimate of fin whales (derived from 58 on-effort sightings).

Parameter	Point Estimate	Standard Error	Percent Coefficient of Variation	95%Confidence Interval Lower Bound	Upper Bound
Number of Sightings	58				
Truncation distance (km)	5.0				
Effective Strip Width (km)	2.6	0.3	10	2.1	3.2
Sightings per km.	0.024	0.006	23	0.016	0.038
Sightings per km^2	0.0046	0.0012	25	0.0029	0.0076
Average pod size	3.1	0.4	14	2.3	4.1
Whales per km^2	0.014	0.004	29	0.008	0.025
Estimated Abundance	4951	1434	29	2833	8653

Abundance estimate of humpback whales (derived from 10 on-effort sightings).

Parameter	Point Estimate	Standard Error	Percent Coefficient of Variation	95%Confidence Interval Lower Bound	Upper Bound
Number of Sightings	10				
Truncation distance (km)	3.0				
Effective Strip Width (km)	1.2	0.5	39	0.5	2.8
Sightings per km.	0.004	0.004	105	0.001	0.023
Sightings per km^2	0.002	0.002	112	0.000	0.011
Average pod size	1.9	0.3	17	1.3	2.8
Whales per km^2	0.003	0.004	113	0.001	0.020
Estimated Abundance	1175	1325	113	197	7009

Abundance estimate of minke whales (derived from 20 on-effort sightings).

Parameter	Point Estimate	Standard Error	Percent Coefficient of Variation	95%Confidence Interval Lower Bound	Upper Bound
Number of Sightings	20				
Truncation distance (km)	2.5				
Effective Strip Width (km)	2.0	0.4	19	1.3	3.0
Sightings per km.	0.0084	0.0019	22	0.0055	0.0130
Sightings per km^2	0.0021	0.0006	30	0.0012	0.0037
Average pod size	1.3	0.3	19	1.0	1.9
Whales per km^2	0.0027	0.0010	35	0.0014	0.0054
Estimated Abundance	936	331	35	473	1852

Figure Captions

Figure 1. Survey track of the NOAA ship *Miller Freeman* in the central Bering Sea shelf. See text for trackline designations: on-effort; bridge-effort and off-effort.

Figure 2. Distribution of 75 sightings representing 346 fin whales.

Figure 3. Distribution of: 27 sightings representing 37 minke whales; 17 sightings representing 39 humpback whales; 4 sightings representing 6 sei whales; and single sightings of a gray whale and a pair of northern right whales.

Figure 4. Surfacing sequence for a pair of right whales as they passed the bow of the NOAA ship *Miller Freeman* on 31 July 1999.

Figure 5. Distribution of fin, minke and humpback whales in the central and eastern Bering Sea from NMML Platforms of Opportunity (PoP) database. Data from opportunistic sightings during June and July, 1980-99.

Figure 1 – Effort map.

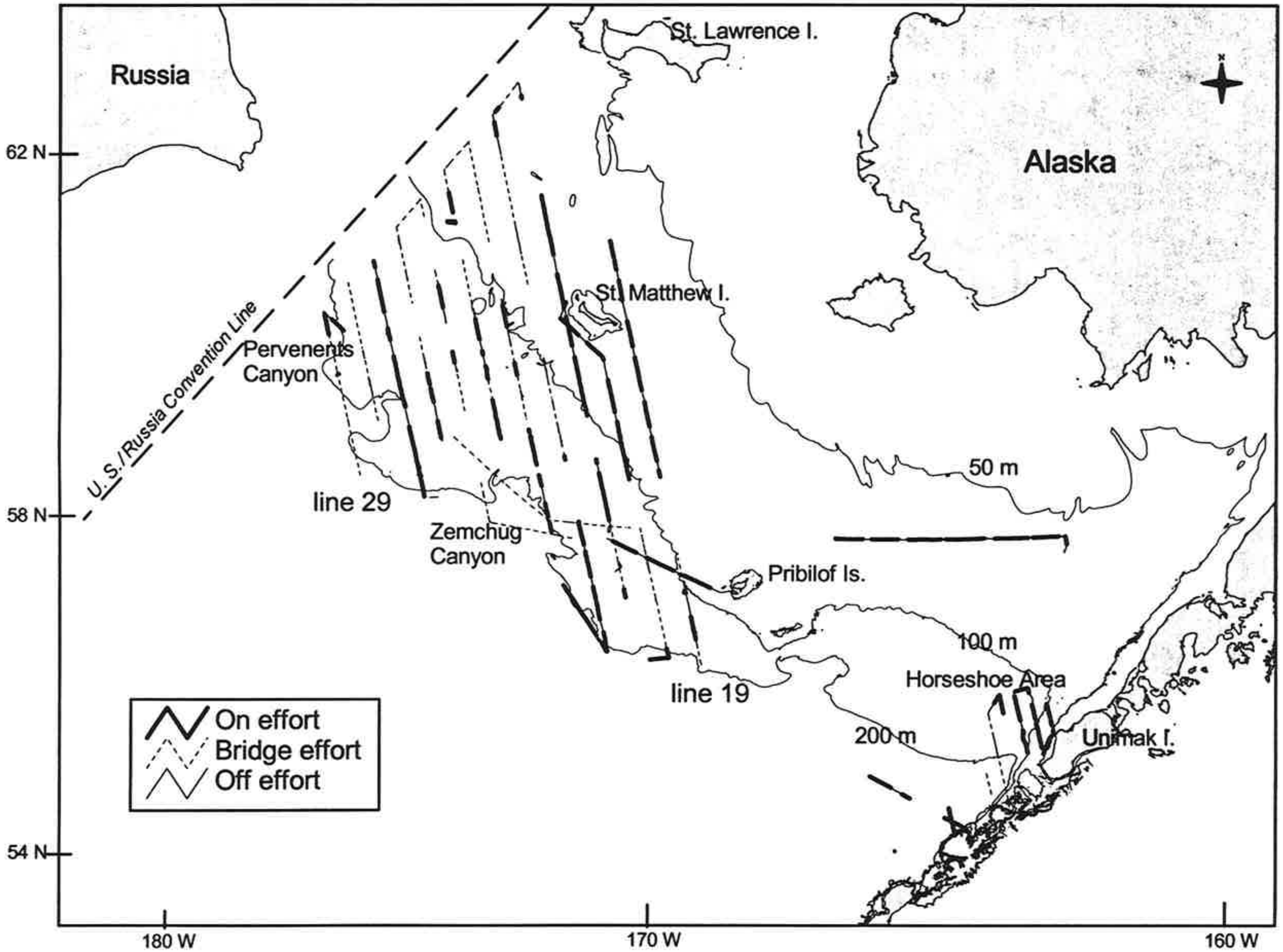


Figure 2. – Fin whale distribution

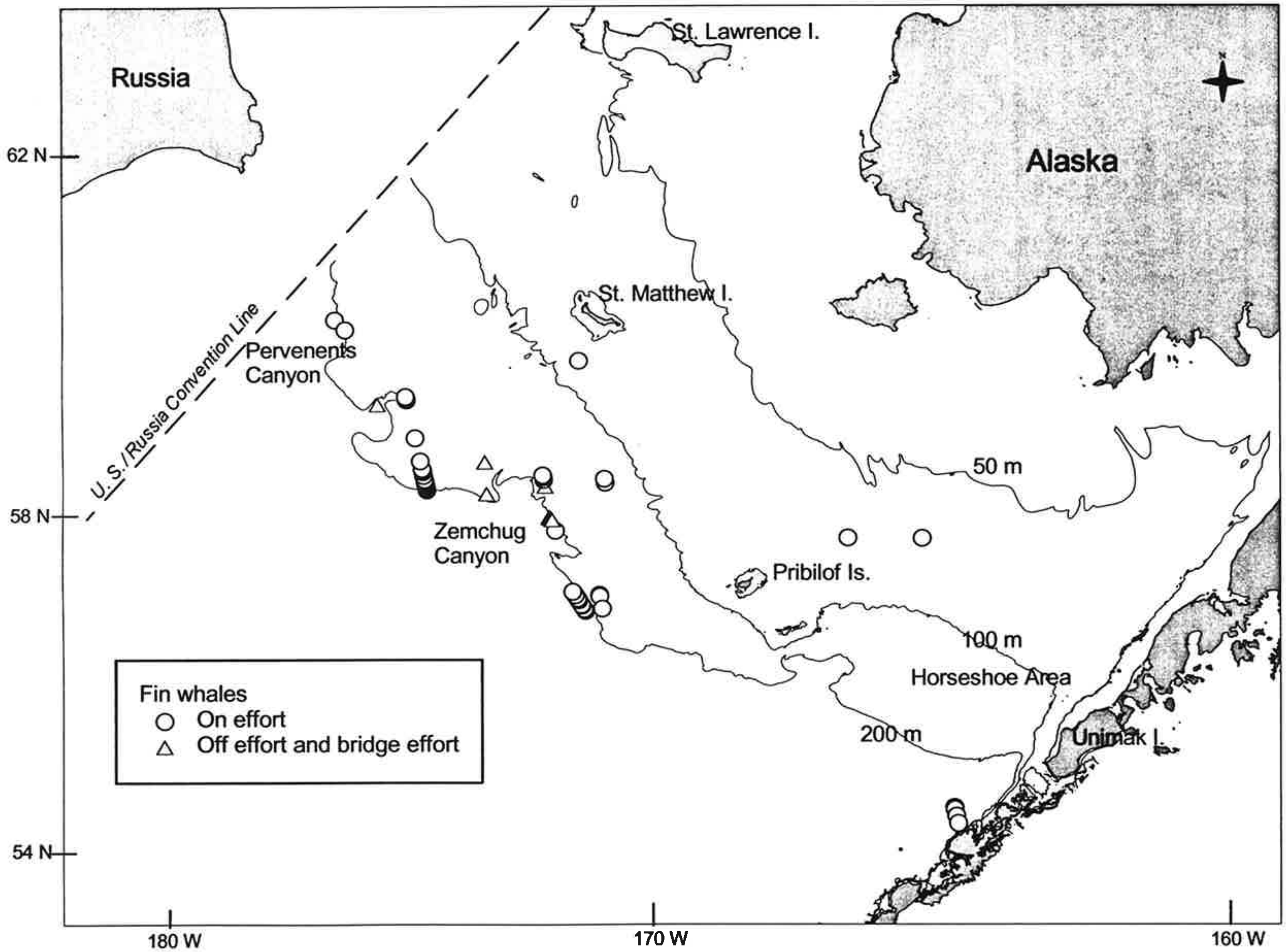


Figure 3. – Right whale, gray whale, humpback whale, minke whale, and sei whale distribution.

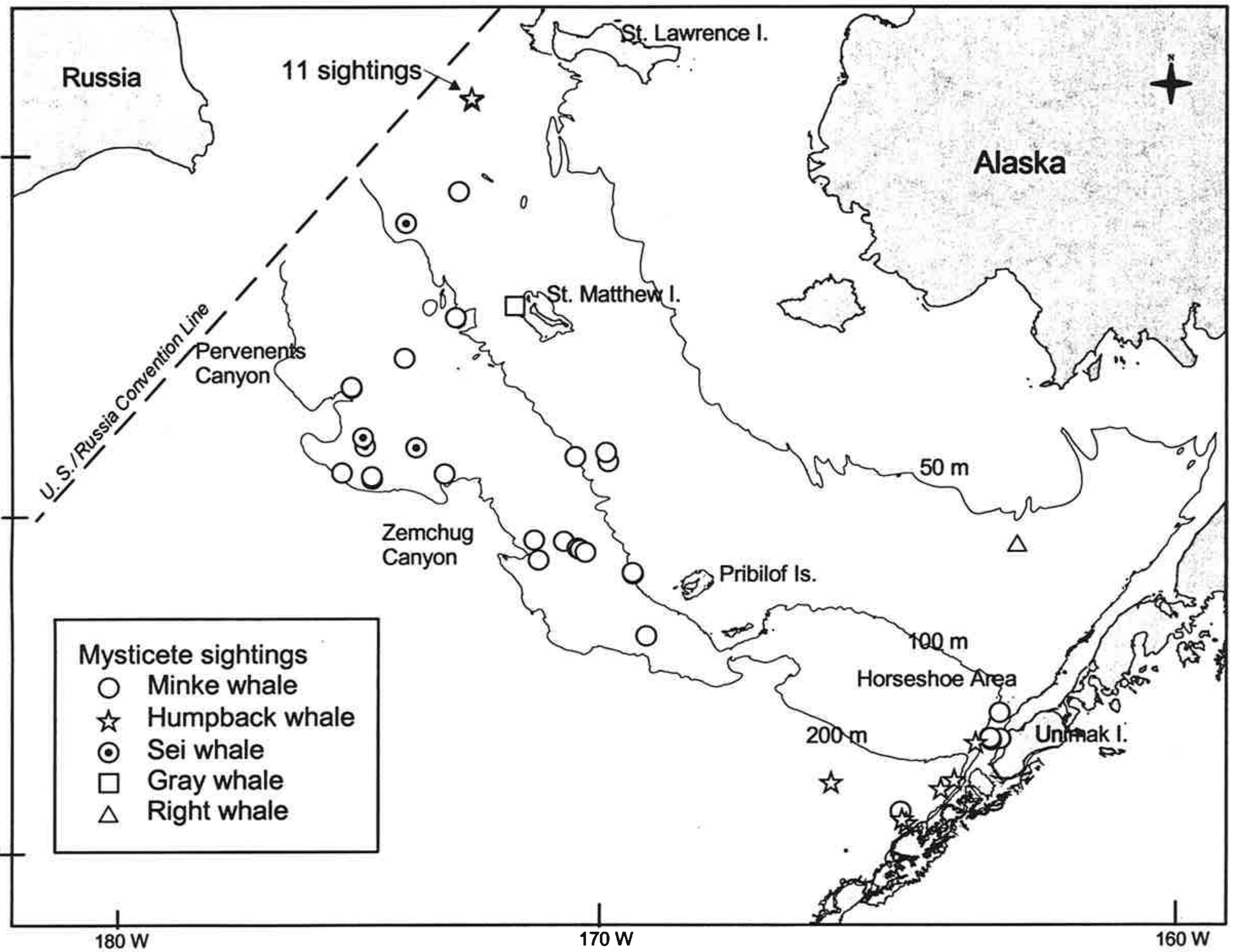
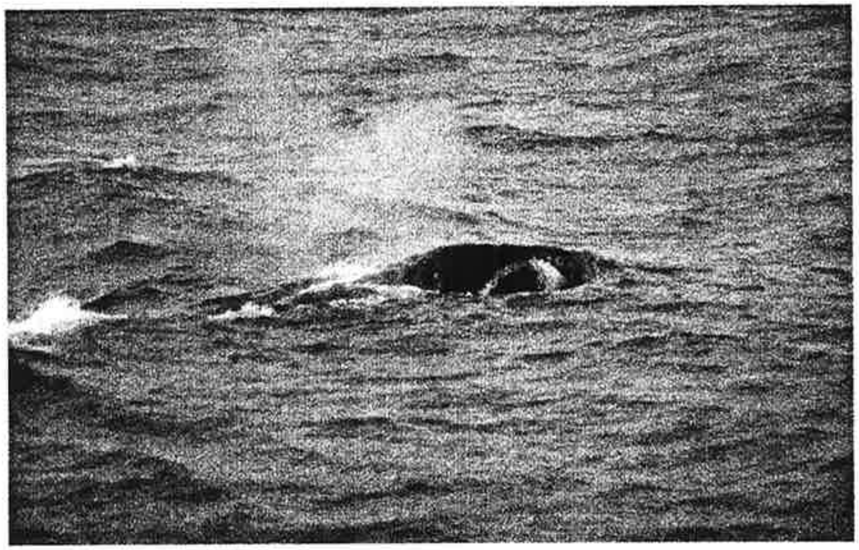
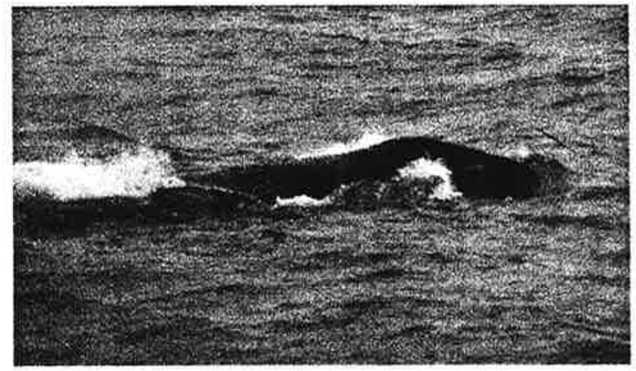


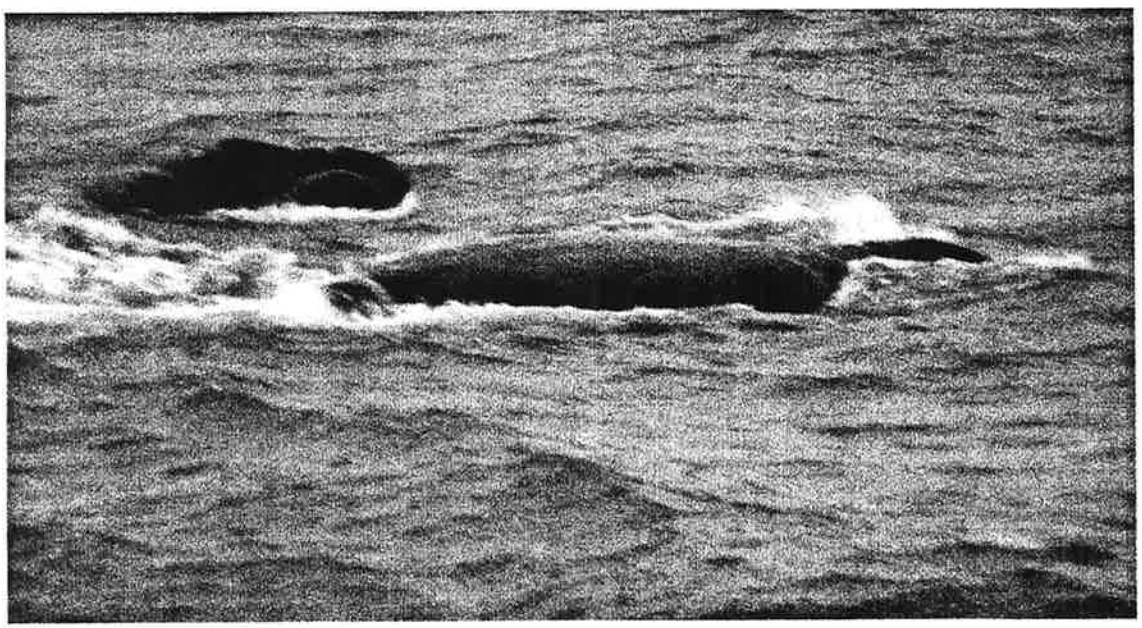
Figure 4.



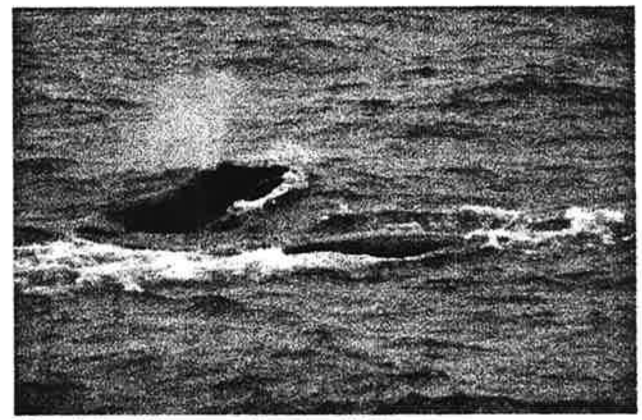
No. 1: V-shaped blow from foreground animal.



No. 2: Foreground animal at peak of surfacing.



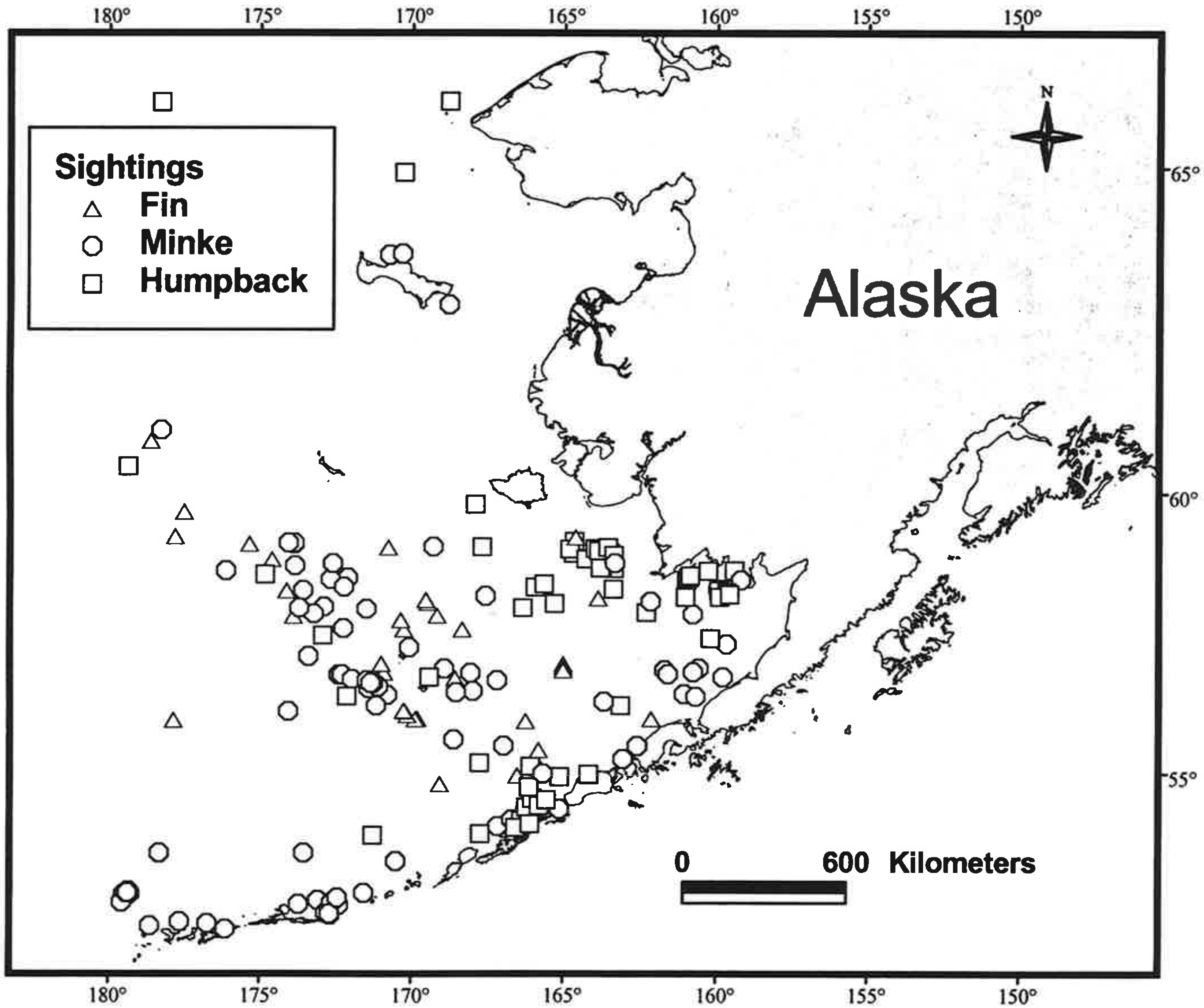
No. 3: Background animal begins to surface.



No. 4: Background animal blows.

No. 5: End of surfacing sequence.

Figure 5.


180°
175°
170°
165°
160°
155°
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Fin
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N
Alaska
0
600 Kilometers

SMALL CETACEAN AERIAL SURVEY OF BRISTOL BAY AND THE SOUTH SIDE OF THE ALASKA PENINSULA IN 1999

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Abstract

The National Marine Mammal Laboratory (NMML) conducted an aerial survey for small cetaceans from 5 June to 4 July 1999 in Bristol Bay and along southwestern Alaska Peninsula (out to the 1829 m (1,000 fm) depth contour). A total of 8,522 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 215 sightings of harbor porpoise (260 individuals), 12 Dall's porpoise (24 individuals), and 16 Pacific whitesided dolphins (170 individuals) while surveying tracklines. Additional cetacean sightings included 12 gray whales (13 individuals), 18 humpback whales (29 individuals), 8 minke whales (13 individuals), and 3 killer whales (11 individuals).

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. 2000). 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 (Waite and Hobbs 1999). The 1999 survey covered Bristol Bay in the Bering Sea and is reported here.

Harbor porpoise, Dall's porpoise, and the Pacific whitesided 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 (1999) 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. 2000), 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 became 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 (1999), using an abundance estimate produced by Hobbs and Lerczak (1993) and a correction for vessel attraction produced by Turnock and Quinn (1991).

The Pacific whitesided 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 whitesided dolphins of 931,000 was made by Buckland et al. (1993), 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. We report here the results from the third year of surveys (1999).

Methods

Survey Design

Two overlapping sawtooth lines were designed along the coastline of Bristol Bay. Both sides of each sawtooth were approximately 37 km with a 46 km base. Large bays were also included in the survey. Vertical lines 18.5 km apart covered the center of Bristol Bay. 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. The study area was stratified into four regions based on geographical features and depth.

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.

Results and Discussion

The line-transect aerial survey was conducted 5 June to 4 July 1999 in Bristol Bay and the west end of the south side of the Alaska Peninsula. A total of 8,522 km were surveyed on effort (Fig. 1). Sightings locations of harbor porpoise (215 sightings, 260 individuals) are shown in Figure 2, and Dall's porpoise (12 sightings, 24 individuals), and Pacific whitesided dolphins (16 sightings, 170 individuals) in Figure 3. 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).

In the final analysis, 1997 - 1999 survey data will be combined to produce one correction factor for animals missed on the trackline (using the independent observer comparison). This will be used to determine an abundance estimate for harbor porpoise (for each stock), Dall's porpoise and Pacific whitesided dolphins (if the sample size allows). Preliminary estimates for harbor porpoise have been reported for the Southeast Alaska and Gulf of Alaska stocks (Waite and Hobbs 1998 and 1999), but the data will be reanalyzed to produce final abundance estimates. The line-transect analysis program DISTANCE (Laake et al. 1993) will be used in this analysis.

Acknowledgments

Funding for this project was provided by Recover Protected Species Program, NMFS, NOAA. We thank Karin Forney, Jim Lerczak, Laura Litzky, Sue Moore, Stephanie Norman, and

Kim Shelden for participating as observers in the 1998 survey. Kim Shelden assisted with data editing. We thank the pilots of the NOAA Twin Otter (LT Michele Finn, LT Phil Hall, LT John Longenecker and LT Mark Moran) for their dedication and excellent handling of the aircraft. This research was conducted under Permit No. 782-1438 issued by the National Marine Fisheries Service.

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Table 1. Marine mammal sightings made during the 1999 survey. Numbers in parentheses are sightings made while off the transect lines (off effort).

Species	Number of sightings	Number of animals
Harbor porpoise (*Phocoena phocoena*)	215 (66)	260 (84)
Dall's porpoise (*Phocoenoides dalli*)	12 (1)	24 (2)
Pacific whitesided dolphin (*Lagenorhynchus obliquidens*)	16 (1)	170 (3)
Beluga whale (*Delphinapterus leucas*)	0 (9)	0 (76)
Killer whale (*Orcinus orca*)	3 (3)	11 (3)
Minke whale (*Balaenoptera acutorostrata*)	8 (3)	13 (3)
Humpback whale (*Megaptera novaeangliae*)	18 (14)	29 (67)
Gray whale (*Eschrichtius robustus*)	12 (14)	13 (18)
unidentified dolphin/porpoise	10 (2)	13 (16)
unidentified large whale	7 (10)	8 (12)
Harbor seal (*Phoca vitulina*)	35 (3)	55 (3)
Steller sea lion (*Eumetopias jubatus*)	18 (2)	24 (2)
Walrus (*Odobenus rosmarus*)	113 (57)	181 (81)
unidentified pinniped	5 (0)	7 (0)

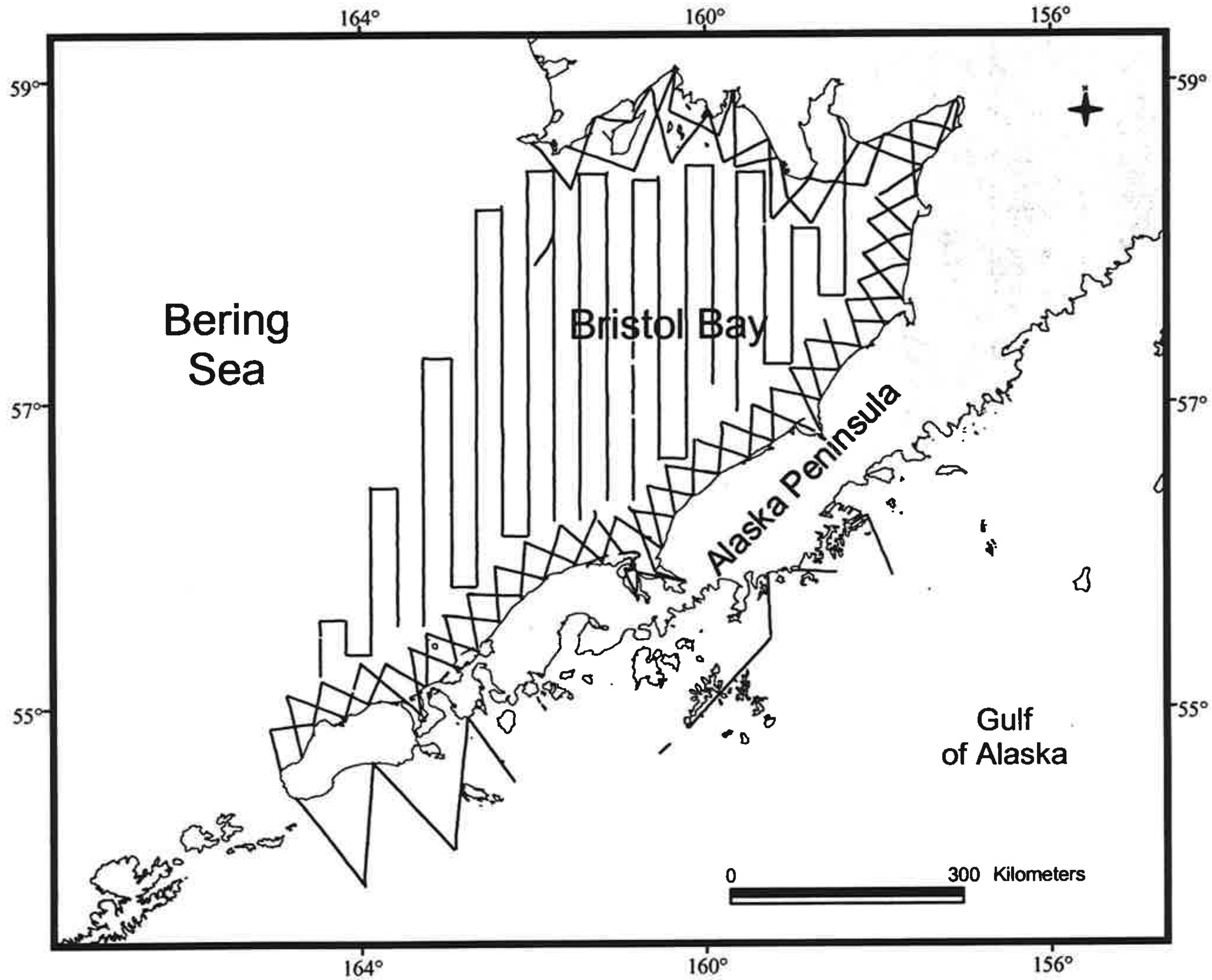

Figure 1. Aerial survey tracklines completed during the 1999 small cetacean survey.

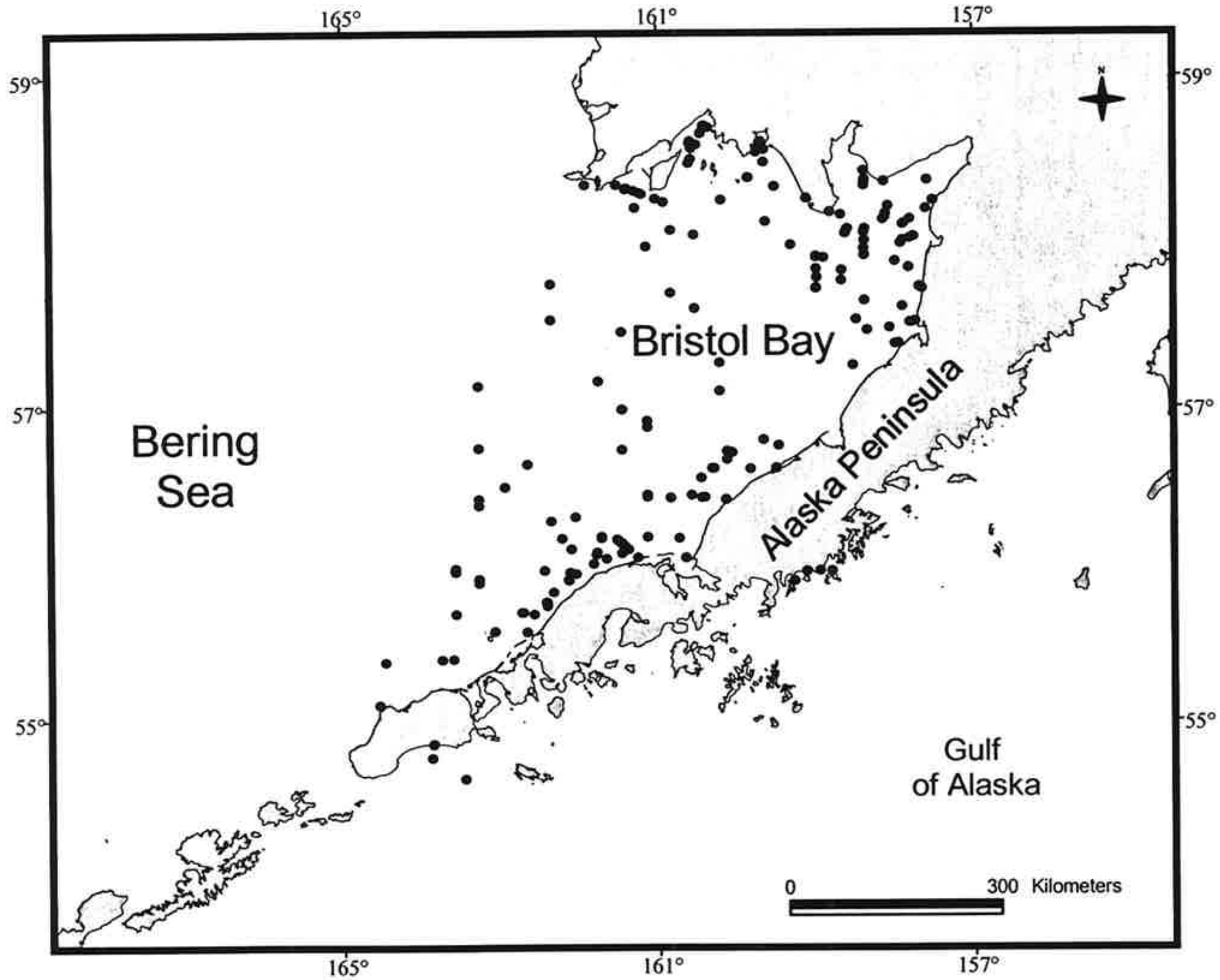

Figure 2. Harbor porpoise sightings during the 1999 small cetacean aerial survey.

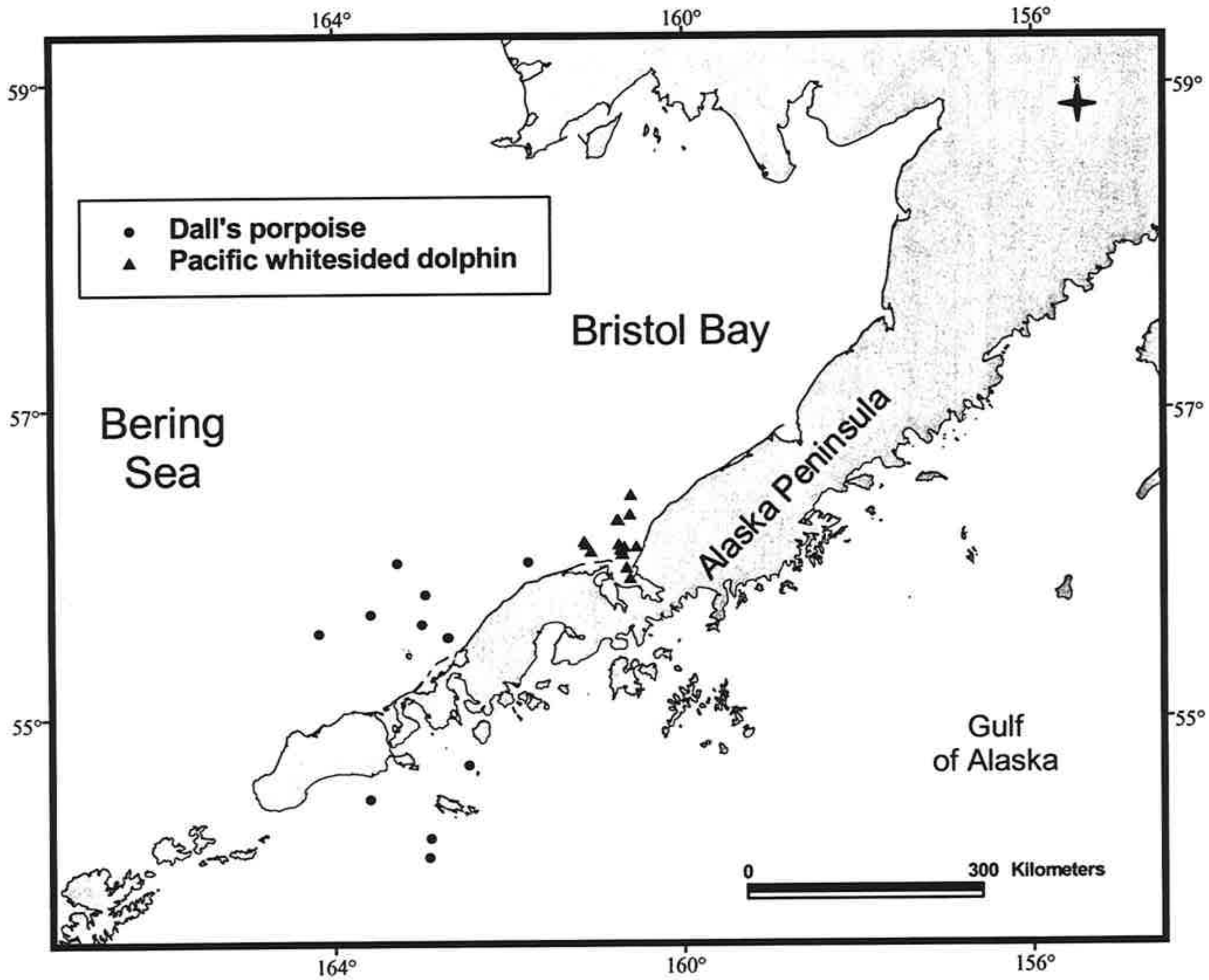

Figure 3. Dall's porpoise and Pacific whitesided dolphin sightings during the 1999 small cetacean aerial survey.

ABUNDANCE AND DISTRIBUTION OF HARBOR SEALS (*Phoca vitulina*) ALONG THE ALEUTIAN ISLANDS DURING 1999

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Abstract

Minimum population estimates were obtained for harbor seals, (*Phoca vitulina)*, in the Aleutian Islands, Alaska, during August molt surveys in 1999. The mean number of seals counted was 3,489 (95% confidence interval between 3,206 and 3,810). The CV of the mean was equal to 4.4%. Comparisons were made between similar surveys conducted in August of 1994 when 2,362 seals were counted (mean values); there were no surveys prior to 1994 that were designed to specifically target harbor seals. With the aid of GPS (global positioning system) receivers on each aircraft, observers were able to more precisely determine the location of seal haul-out sites. In 1999, seals were recorded at 412 sites whereas in 1994, only 232 sites were detected. The two surveys differed in their coverage: the easternmost point in both surveys was Unimak Pass, whereas the westernmost point in 1994 was Kiska Island, in 1999 the survey reached 330 km farther west to Attu Island. Survey conditions (weather and visibility), were better in 1999 than 1994. Enhanced coverage and conditions likely account, at least in part, for the 1,127 increase in seals observed in 1999.

Introduction

Background

Declines in harbor seal, *Phoca vitulina richardsi*, abundance have been observed in several locations throughout Alaska (e.g., Pitcher 1990). 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 marine mammals caught incidental to commercial fisheries, to levels below a zero mortality rate goal. 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 CV of abundance, net productivity rates, and current takes by commercial fisheries and subsistence hunters. The purpose of our study is to provide an estimate of the population size of seals throughout Alaska.

Harbor seals range from throughout coastal Alaska from southern Kuskokwim Bay southward (Frost et al. 1982). We have arbitrarily sub-divided the state into five regions for census purposes: northern southeast Alaska, southern southeast Alaska, the Gulf of Alaska (from Prince William Sound to the Shumagan Islands), the Aleutian Islands, and the north side of the Alaska Peninsula to southern Kuskokwim Bay. These regions roughly follow the putative stock management areas, but logistical constraints were also considered. The National Marine Mammal Laboratory (NMML), with funding from the NMFS Office of Protected Resources, has censused each of these regions twice since 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], Withrow and Loughlin 1996 [Gulf of Alaska], Withrow and Loughlin 1997 [northern southeast Alaska], and Withrow and Cesarone 1998 [southern southeast Alaska]. This report describes the results of the second abundance survey of the Aleutian Islands. Previous to 1994, data on harbor seal abundance (along the Aleutian Islands) were collected incidental to Steller sea lion and sea otter studies. The objective of this study was to derive a minimum population estimate of harbor seals along the Aleutian Islands chain from Unimak Pass to Attu Island.

Methods

Study Area

Aerial surveys were flown from 6 to15 August 1999 from Unimak Pass west to Attu Island. This time of year corresponds to the harbor seal's annual molt period when most animals are thought to be hauled out on land and visible to observers. The study area was subdivided into four sections (Figs. 1-5) such that each section was surveyed by separate observers at about the same time. Table 1 lists the observers, dates and aircraft used to survey each area. All known harbor seal haul-out sites in each area were surveyed.

Survey Methods

Fixed-wing aircraft were used to photograph harbor seals while they were on land. The molt period is the optimal period to obtain minimum population estimates because that is when the greatest number of harbor seals spend the greatest amount of time hauled out (Pitcher and Calkins 1979; Calambokidis et al. 1987). At locations that are affected by tides, harbor seals haul out in greatest numbers at and around the time of low tide. Aerial surveys were timed such that haul-out sites were flown within 2 hours on either side of low tide, when available daylight and weather permitted. At least four repetitive photographic counts were planned for each major haul-out site within each study area over the 2 week survey period. Four or more repetitive surveys are necessary to obtain estimates of coefficient of variation (CV; standard deviation of the counts divided by the mean count) less than 30%. Four to five surveys resulted in the desired results in past harbor seal surveys in Alaska and have proven to be an effective way of counting the maximum number of animals (Loughlin 1992, 1993; Pitcher 1989, 1990).

Harbor seals on land or in the water adjacent to the haul-out sites were photographed with 35 mm cameras with a 70-210 mm or 35-135 mm zoom lens using ASA 200 or 400 color slide film. Transparencies were later projected onto a white background and the number of seals counted. Generally, two counters score the number of seals on the photographs for each site and the arithmetic mean is calculated. This year, one counter scored each slide twice and then took the average count. 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 ten) were counted as the plane passed by (no photographs were taken), while larger groups were circled and photographed.

Most surveys were flown between 100 to 300 m (wind permitting) at about 90 knots. The survey area was divided into four zones with a plane and observer dedicated to each section. Zone 1 included the area from Unimak Pass in the east to Umnak Pass in the west, including the southern shore of Unalaska Island and the northeastern shore of Unalaska Island between Skan Bay and Unalaska Bay (Fig. 2, Table 2). Zone 2 ran from Umnak Pass in the east to Amutka Island in the west, and the northwestern shore of Unalaska Island from Umnak Pass to Skan Bay (Fig. 3, Table 3). Zone 3 included the area from Seguam Island in the east to Kagalaska Island in the west (Fig. 4, Table 4). Zone 4 ran from Adak Island in the east to Attu Island in the west (Fig. 5, Table 5).

Data analysis

The maximum number of animals counted on one day for each zone was accepted as that area's minimum number of seals, which were then summed for a minimum population estimate for the Aleutian Islands. The maximum number for each zone did not occur on the same day, resulting in the possible double counting of some animals if they moved from one area to another. The number of seals moving between areas was assumed to be small considering each area's large geographic size.

The mean and standard deviation (SD) of the mean for each zone 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 to be 1.0 (based on the average maximum of the calculated CVs of the mean multiplied by the count for that site). The variance of the total for the Aleutian Islands 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 sites and that there was no trend in the number of animals ashore over the survey period. The assumption that seals did not move between sites 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

Zone 1

Seagars surveyed from Unimak Pass in the east to Umnak Pass in the west, including the southern shore of Unalaska Island and the northeastern shore of Unalaska Island between Skan Bay and Unalaska Bay. This area contained 102 sites. Seven surveys were flown from 6 to 15 August 1999 resulting in three or more surveys for most sites. The maximum count of 1,479 harbor seals was obtained by combining the maximum count for each area regardless of day censused (Fig. 2, Table 2). The sum of means was x = 1,261 harbor seals (SD = 61.32), with a CV = 4.86% (Table 6).

Zone 2

Jansen surveyed from Umnak Pass in the east to Amutka Island in the west, and the northwestern shore of Unalaska Island from Umnak Pass to Skan Bay. This area contained 92 sites. Eight surveys were flown from 6-15 August 1999 resulting in one to five replicates for each site. The maximum count of 1,209 harbor seals was obtained by combining the maximum count for each area regardless of day censused (Fig. 3, Table 3). The sum of means was x = 690 harbor seals (SD = 65.37), with a CV = 9.47% (Table 6).

Zone 3

Olesiuk surveyed from Seguam Island in the east to Kagalaska Island in the west. This area contained 55 sites. Seven surveys were flown from 6-14 August 1999 resulting in only to four replicates for each site. The maximum count of 589 harbor seals was obtained by combining the maximum count for each area regardless of day censused (Fig. 4, Table 4). The sum of means was x = 457 harbor seals (SD = 40.52), with a CV = 8.87% (Table 6).

Zone 4

Cesarone surveyed from Adak Island in the east to Attu Island in the west. This area contained 134 sites. Five surveys were flown from 7-12 August 1999 resulting in one to two replicates for each site. The maximum count of 1,158 harbor seals was obtained by combining the maximum count for each area regardless of day censused (Fig. 5, Table 5). The sum of means was x = 1,081 harbor seals (SD = 118.02), with a CV = 10.92% (Table 6).

Estimated Population Size for 1999 in the Aleutian Islands

The summary of maximum counts for all 384 sites in all four zones combined was 4,837 harbor seals (Table 6). The sum of mean counts for all areas was 3,508 harbor seals (SD = 153.75) with a CV of 4.4%. The 95% confidence interval about the mean ranged from a low of 3,206 to a high of 3,810 harbor seals. Summary statistics for all four zones and the combined totals are listed in Table 6. A comparisons of means counts between 1999 and 1994 appears in Table 7.

Discussion

Survey conditions in the Aleutian Islands are difficult. Obtaining military clearances for takeoff and landings at the Adak naval facility and Shemya Air Force facility, dealing with landing and weekend restrictions, fuel caches, limited daylight and four high-wing, twin-engine, long range aircrafts all presented logistical challenges. Weather, by far however, was the most significant constraint.

Harbor seals in the Aleutian Islands were not as densely distributed as many other areas in Alaska. Groups typically ranged from one to ten seals and were hauled out on rocky out-croppings and stone beaches. Their low numbers, combined with the fact that proportionally more dark seals are found along the Aleutian Islands than in other areas of the state, (especially when wet) made them difficult to see. Often movement, not the animal, was the initial sighting cue.

Survey conditions (weather, visibility, and logistical constraints) became more limiting as surveys progressed west along the chain. We planned to complete at least four replicate surveys of each site excluding the first reconnaissance survey. This was not possible in most areas. Average number of replicate flights for each area decreased as one moved west (2.8 replicates for Zone 1, 2.2 in Zone 2, 2.0 in Zone 3, and 1.2 in Zone 4). This was due to inclement weather and limits on outward travel distances without reliable access to fuel deposits. During this period, low tide occurred early in the morning and often there was not enough light to census during the falling tide.

In 1994, we estimated the mean number of seals along the Aleutians to be 2,362 (Withrow and Loughlin 1995a). However, due to the conservative nature and extreme difficulty censusing harbor seals in that year, we recommended that the maximum count of 3,437 be utilized for population estimates. A list of counts between the 1994 and 1999 surveys is compared, by Zone, in Table 7. A slight increase was noted in 1999 for zone 1 and a slight decrease for Zone 2. Zones 3 and 4 show significant increases. In 1994 for Zone 4, we were only able to survey as far west as Kiska Island, but in 1999 we were able to census out to Attu Island (Fig. 5). In 1994, 232 individual sites were recorded. Improved weather and visibility, combined with increased coverage, likely account, at least in part, for the 1,127 increase in seals observed in 1999. With the addition of GPS (global positioning system) receivers for all aircraft in 1999, observers delineated 412 sites. There was certainly a tendency in 1999 to split rather than lump the number of sites found, but it appears there was also an increase in the actual number of sites located. For 1999, we suggest the mean count of 3,489 be utilized as the best, unadjusted, estimate for the minimum number of harbor seals along the Aleutian Island chain (in U.S. waters). It should be noted, however that this estimate does not consider necessary adjustments to the aerial survey counts, such as the correction factor adjustment to account for seals in the water and not available for counting (Withrow and Loughlin, 1995b). The actual number of harbor seals present in the Aleutian Islands is certainly much larger than the minimum estimate.

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. Dan Vollum and Allan Williams of Aeroplanes Inc., Adam Hale and Roger Young from Peninsula Airways, and Tom Blaesing and Dave Weintraub from Commander NW piloted our aircrafts. Their expertise and attention to safety were greatly appreciated.

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Table 1. Zone number, city from which surveys originated, name of observer, dates, and aircraft type for harbor seal surveys in the Aleutian Islands during August 1999.

Zone	City	Name	Dates	Aircraft
1	Dutch Harbor	Dana Seagars	6-16 August	Grumman Goose (Piston)
2	Dutch Harbor	John Jansen	6-14 August	Aero Commander (Turbo)
3	Atka Island	Peter Olesiuk	6-14 August	Aero Commander (Turbo)
4	Adak Island	Jack Cesarone	7-12 August	Grumman Goose (Turbine)

Table 2. The number of seals counted at each site for Zone 1. [Seagars]

(from Unimak Pass in the east to Umnak Pass in the west, including the southern shore of Unalaska Island and the northeastern shore of Unalaska Island between Skan Bay and Unalaska Bay)

Location	Substrate	Latitude	Longitude	MAX	MEAN	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug
Aitak I.-NE		54.1861	164.8104	0	7	7									
Aitak I.NW		54.1909	164.8351	0	9	9									
Akun I.-Isle 1	Rock	54.1413	165.6470	10	15		10						15		19
Akun I.-Isle 2	Rock	54.1478	165.6486	18	11		18						15		1
Akun I.-N Akun Bay	Rock	54.2834	165.4968	1	1		1						0		
Akun I.-NW Akun	Rock	54.2750	165.6598	8	5		8						2		
Akun I.-Poa Inlet	Rock	54.1296	165.4979	54	45		54								36
Akun I.-Surf Rocks	Rock	54.1642	165.6308	36	22		36						21		10
Akun I.-Tangik Islet	Rock	54.1461	165.4826	5	14		5						18		19
Akun I.-Trident Bay Inlet	Rock	54.1395	165.5210	7	4		7								0
Akun I.-W Akun	Rock	54.1870	165.6283	5	4		5						3		
Akutan I.-Race Rocks	Rock	54.1337	165.6573	25	40		25								54
Avatanak I.-E Avatanak		54.0554	165.2431	0	3	5									0
Avatanak I.-N Avatanak	Rock	54.0934	165.3035	6	7		6								7
Avatanak I.-NE Avatanak		54.0913	165.2593	0	10	19									0
Avatanak I.-NW Avatanak		54.0822	165.4187	0	8										8
Avatanak I.-S Avatanak		54.0494	165.3165	0	2	6	0								0
Avatanak I.-SW Avatanak		54.0702	165.3954	0	9	5	0								23
Avatanak I.-SW#2	Rock	54.0407	165.4770	4	6		4								8
Avatanak I.-W		54.0707	165.4785	5	5		5								4
Avatanak-94,8	Rock	54.0837	165.3512	0	0		0								
Baby I.-Baby Islands		53.9950	166.0639	230	177				168	230	155	156			
Egg I.		53.8685	166.0417	25	11				0	4		25			16
Kaligagan I.		54.1427	164.9120	49	29	21	49								17
Kaliganan I.-4 islets W of Kaligagan	Rock	54.1428	164.9361	15	20		15								24
Rootok I.-E Rootok	Rock	54.0476	165.4861	15	18	15	15								25
Rootok I.-NE Rootok		54.0517	165.5059	10	10	16	10								5
Rootok I.-NW Rootok	Rock	54.0486	165.5563	4	4		4								3
Rootok I.-SE Rootok	Rock	54.0318	165.5148	0	5	6									3
Rootok I.-SW Rootok	Rock	54.0284	165.5586	2	9	15	2								9
Sedanka I.-entrance N of Cape Sedanka	Rock	53.8549	166.1123	8	4				3	8		5			0
Sedanka I.-inner Signal Rocks		53.7889	166.0894	51	71							51			90
Sedanka I.-S of Biarha Head		53.8241	166.1234	9	5							9			0
Sedanka I.-S Sedanka		53.7297	166.1810	22	19							22			16
Sedanka I.-W of Strait Bay		53.8001	166.2988	1	1				1	1	1	0			
Sednaka I.-Sedanka Pass		53.8446	166.0975	16	10					4		16			11
Tigalda I.-N rock pile 1	Rock	54.1567	164.9573	10	13		10								15
Tigalda I.-N rock pile 2	Rock	54.1393	164.9918	36	30		36								23
Tigalda I.-N Tigalda	Rock	54.1319	165.1410	36	20		36								4
Tigalda I.-NW Kelp Bay		54.1209	165.1662	0	8		0								15
Tigalda I.-old 94-18		54.1176	165.1954	0	5										5
Tigalda I.-W of Derbin Pt.		54.0853	165.1721	0	12	16									8
Tigalda I.-W Tigalda Bay	Rock	54.1191	165.0215	2	15		2								27

Table 2. Zone 1 Seagars

Tigalda-94,11	Rock	54.0718	165.1170	0	0	0									
Tigalda-94,12	Rock	54.1215	164.0887	0	0	0									
Tigalda-94,18	Rock	54.1170	165.1876	0	0		0								
Tigalda-94,58	Rock	54.1179	165.1691	0	0		0								
Tigalda-N rock pile 3	Rock	54.1360	164.9815	18	10		18								2
Ugamak I.-N		54.2193	164.8235	0	2	7	0								0
Umnak/Samalga-94,121	Rock	53.8506	167.1542	0	0	0			0	0					
Unalaska I.-Brundage Head		53.9340	166.2086	22	13	0			8	18	15	22			
Unalaska I.-Cannery Point		53.7169	166.7938	1	0				1	0			0		
Unalaska I.-Cape Prominence	Rock	53.4448	166.7454	18	15							18			11
Unalaska I.-Cape Yanaliuk		53.5334	166.5870	0	2							0			4
Unalaska I.-Cathedral Rocks poor	Rock	53.7373	166.8821	28	16	10			28	21			4		
Unalaska I.-Dushkot I.		53.7584	166.5081	16	13				14	8	16	13			
Unalaska I.-E of Amugul Bay		53.7817	166.3596	4	2				1	4	1	2			
Unalaska I.-E of Bishop Head		53.9746	166.9412	2	1				2	0					
Unalaska I.-E of Reptition Point		53.4495	167.0207	0	7										7
Unalaska I.-E Unalaska Rocks 1		53.9019	166.2167	13	10				10	13	7	8			
Unalaska I.-E Unalaska Rocks 2		53.9155	166.2095	9	5	0			7	4	3	9			
Unalaska I.-Eagle Rock		53.8681	166.3197	1	0				1	0	0	0			
Unalaska I.-Emerald Island	Rock	53.2889	167.5857	55	40							55			24
Unalaska I.-English Bay, N side entranc	Rock	53.9457	166.2491	8	3	1			4	1	8	2			
Unalaska I.-Erskine Bay Islet		53.7370	166.5890	5	3				5	1	3	2			
Unalaska I.-Erskine Point	Rock	53.9845	166.2756	5	4	5			2	5	4	2			
Unalaska I.-Fisherman's Point	Rock	53.9405	166.2259	56	41	36			40	38	35	56			
Unalaska I.-head of Beaver Inlet		53.7342	166.5468	3	2				3	3	2	1			
Unalaska I.-Huddle Rocks	Rock	53.3239	167.3287	15	16							15			16
Unalaska I.-inner Usof Bay		53.5038	166.7700	20	14							20			8
Unalaska I.-Kayak Cape		53.5813	166.5062	30	18							30			6
Unalaska I.-Kesselen Bay Islet	Rock	53.7121	166.5700	22	17				18	22	11	18			
Unalaska I.-Lance Point	Rock	53.3353	167.3034	25	20							25			15
Unalaska I.-Lou170T	Rock	53.6776	166.8322	1	2	6			0	1			0		
Unalaska I.-Makushin Point		53.7564	167.0193	25	11	0			25				8		
Unalaska I.-N Malga Bay		53.9998	166.1772	83	31				83	10	12	18			
Unalaska I.-N of Lamb Point	Rock	53.3206	167.4341	10	10							10			10
Unalaska I.-N Point, Hog I.	Rock	53.9152	166.5635	18	13	20			12	18	0	16			
Unalaska I.-N Portage Bay		53.7329	166.7651	4	2				3	4			0		
Unalaska I.-N Surveyor Bay	Rock	53.2806	167.6078	5	3							5			0
Unalaska I.-NE Unalga		53.9782	166.0879	25	23				18	25	24	23			
Unalaska I.-NW Kalekta Bay	Rock	53.9945	166.3525	8	6	11			4	8	7	2			
Unalaska I.-outer Usof Bay		53.4744	166.7401	20	14							20			7
Unalaska I.-Peter I.		53.6998	166.8409	9	5				9	2			3		
Unalaska I.-Reef Point	Rock	53.4393	166.8188	15	11							15			6
Unalaska I.-Round I.	Rock	53.7682	166.3831	11	8				5	9	8	11			
Unalaska I.-S Konet's Head	Rock	53.2962	167.8257	10	16							10			22
Unalaska I.-S of Deep Bay		53.8794	166.2383	8	4				8	4	3	1			
Unalaska I.-S of Lone Peak		53.2719	167.7525	0	6										6
Unalaska I.-S of Princess Head		53.9825	166.4102	2	1				1	2	0	2			
Unalaska I.-S Unalga		53.9556	166.1323	4	2				3	2	0	4			

Table 2. Zone 1 Seagars

Unalaska I.-SE Kalekta Bay		53.9681	166.3040	2	1	0			2	0	2	0			
Unalaska I.-SE Portage Bay		53.7186	166.7261	8	4					8			0		
Unalaska I.-Spire Rock	Rock	53.4340	166.8966	3	2							3			0
Unalaska I.-SW Udagak Strait		53.7050	166.2616	5	8						2	5			17
Unalaska I.-SW Ugadaga Bay		53.8129	166.4152	4	2				0	3	1	4			
Unalaska I.-SW Unalga		53.9594	166.1882	5	3				1	3	5	3			
Unalaska I.-Tanaskan Bay Islet		53.7225	166.4818	4	3				3	3	4	3			
Unalaska I.-Tower Point		53.4008	167.1659	0	10										10
Unalaska I.-W Agamgik Bay		53.8576	166.3535	18	9				7	18	5	6			
Unalaska I.-W of Gargoyle I.		53.2788	167.5671	0	10										10
Unalaska I.-W of Huddle Rocks	Rock	53.3314	167.3682	12	12							12			12
Unalaska I.-W of Small Bay		53.7904	166.4558	2	2				2	2	2	0			
Unalaska I.-W of Split Top Mtn.		53.9388	166.4423	4	1	0				4	0	0			
Unalaska I.-W Surveyor Bay	Rock	53.2697	167.6117	5	3							5			0
Unalaska I.-West of Pipe	Rock	53.6485	166.8095	20	15	7			5	20			29		
Unalaska I.-Whalebone Cape		53.4849	166.6571	25	21							25			17
Unalaska-94,111	Rock	53.8672	166.0543	0	0	0			0	0					
Unalaska-94,120	Rock	53.9881	166.8179	0	0	0			0	0					
Unalaska-94,98	Rock	54.0048	166.6381	0	0	0				0					
Unalaska-94,99	Rock	53.8000	167.0875	0	0	0			0	0					
Unalga I.-E. Unalga		53.9689	166.0743	3	1				0	0		3			

MAX	MEAN
1,479	1,261

95 % Confidence Interval	
1,140 =LOW	1,382 =HIGH

CV	COUNT	SD
4.86	102	61.32

Table 2. Zone 1 Seagars

Table 3. The number of seals counted for each site for Zone 2. [Jansen]

(from Umnak Pass in the east to Amutka Island in the west, and the northwestern shore of Unalaska Island from Umnak Pass to Skan Bay)

Location	Substrate	Latitude	Longitude	MAX	MEAN	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug
Amukta I. E.	Rock	52.4816	171.2003	4	4							4		
Amukta I. NW.	Rock	52.5246	171.2774	5	5							5		
Amukta I. SE.	Rock	52.4584	171.2234	6	6							6		
Amukta I.-North Pt.	Rock	52.5319	171.2488	5	5							5		
Carlisle I. E.	Rock	52.8933	169.9931	10	5					0		6	10	
Carlisle I. N.1	Rock	52.9266	170.0625	15	11					7		10	15	
Carlisle I. N.2	Rock	52.9239	170.0359	3	2					0		3	2	
Carlisle I. NE.	Rock	52.9168	169.9970	10	4				3	0		10	4	
Carlisle I.-West Cape1	Rock	52.8964	170.1229	17	10					5		9	17	
Carlisle I.-West Cape2	Rock	52.9027	170.1217	6	4					1		6	4	
Chagulak I. N.	Rock	52.5883	171.1529	4	4							4		
Chuginadak I. N.1	Rock	52.8831	169.8100	6	2				1	4	1	0	6	
Chuginadak I. N.2	Rock	52.8851	169.8422	16	10					2	6	15	16	
Chuginadak I. N.3	Rock	52.8936	169.7473	20	11					3	15	20	6	
Chuginadak I.-Applegate Cove	Rock	52.8718	169.8696	4	2							0	4	
Chuginadak I.-Concord Pt.	Rock	52.7868	169.7481	4	4							4		
Chuginadak I.-Corwin Rks	Rock	52.8955	169.6915	25	12				2	1	25	15	15	
Chuginadak I.-East Cape	Rock	52.8192	169.6677	1	1							1		
Chuginadak I.-NE Cape1	Rock	52.8580	169.6668	4	1						4	0	0	
Chuginadak I.-NE Cape2	Rock	52.8691	169.6657	10	4					0	10	4	0	
Chuginadak I.-West Cape1	Rock	52.8336	170.0109	1	0					1		0	0	
Chuginadak I.-West Cape2	Rock	52.8269	170.0071	8	5					0		8	6	
Herbert I. E.	Rock	52.7570	170.0483	4	2					0		4		
Herbert I. W.	Rock	52.7478	170.1781	1	1					1		0		
Herbert I.-North Pt.	Rock	52.7929	170.1123	6	4					6		2		
Herbert I.-NW Pt.	Rock	52.7898	170.1576	4	3					2		4		
Kagamil I. N Cove E	Rock	53.0319	169.7144	15	10				10	6	12	15	8	
Kagamil I. N Cove W	Rock	53.0274	169.7315	50	22				11	25	50	1	25	
Kagamil I. NE.	Rock	53.0241	169.6619	20	6					0	0	5	20	
Kagamil I. S.	Rock	52.9534	169.7460	10	6					10	4	0	10	
Kagamil I. SE.	Rock	52.9653	169.6894	1	0					0	0	0	1	
Kagamil I.-Candlestick Pt.	Rock	53.0250	169.7462	5	2				1	5	0	0	3	
Kagamil I.-East Cape	Rock	53.0062	169.6622	10	5				2	5	10	5	2	
Polivnoi Rk-Umnak Pass	Rock	53.2663	167.9530	1	1	1						0		
Pustoi I.-Umnak Pass	Rock	53.3957	167.8225	24	12		0					24		
Samalga I. N.	Rock	52.7950	169.1962	20	16							12	20	
Samalga I. S.1	Rock	52.7704	169.2016	12	6							0	12	
Samalga I. S.2	Rock	52.7796	169.1870	10	5							0	10	
Samalga I. S.3	Rock	52.7824	169.1797	11	6							0	11	
Samalga I. SW.1	Rock	52.7601	169.2633	60	33							40	0	60
Samalga I. SW.2	Rock	52.7690	169.2565	25	25							25		
Ship Rk E.-Umnak Pass	Rock	53.3740	167.8232	20	10		0					20		
Ship Rk W.-Umnak Pass	Rock	53.3714	167.8332	21	11		21					0		
Uliaga I. E.	Rock	53.0634	169.7351	2	0				2	0	0	0	0	
Umnak I.-Aguliuk Pt.	Rock	53.4778	168.3473	5	2	4			0	0	5		0	
Umnak I.-Amos Pt.	Rock	53.0334	168.4845	2	1		0					2		

Umnak I.-Anangula I.	Rock	53.0035	168.9139	10	10								10	
Umnak I.-Ashishik Pt.	Rock	53.5629	168.0775	10	2	0			0	0	10		0	
Umnak I.-Breadloaf I.	Rock	52.8297	169.0524	7	7								7	
Umnak I.-Broken Pt.	Rock	53.2699	168.4898	12	5				0	4	12		5	
Umnak I.-Cape Aslik	Rock	53.3946	168.3959	4	2				0	4	0		2	
Umnak I.-Cape Sagak	Rock	52.8270	169.0941	5	5								5	
Umnak I.-Cape Starr1	Rock	52.9175	168.9986	50	36							50	22	
Umnak I.-Cape Starr2	Rock	52.9200	169.0080	30	15							0	30	
Umnak I.-Cape Tanak	Rock	53.5642	167.9740	5	1	2			0	0	0		5	
Umnak I.-Eider Rk., Nikolski Bay	Rock	52.9882	168.8770	6	6								6	
Umnak I.-Elbow Hill	Rock	52.8603	169.0107	15	15								15	
Umnak I.-Fox Pt.	Rock	53.5562	168.1178	5	1	0			0	0	5		0	
Umnak I.-Kelp Pt., Nikolski Bay	Rock	52.9720	168.8653	4	4								4	
Umnak I.-Kigul I.	Rock	53.0463	168.4387	4	2		0					4		
Umnak I.-Lookout Cove	Rock	53.0181	168.5678	20	20							20		
Umnak I.-Lookout Cove N.	Rock	53.0302	168.5304	10	10							10		
Umnak I.-N. of Kigul I.	Rock	53.0543	168.4425	20	16		12					20		
Umnak I.-N. of Twin Lava Pt.1	Rock	53.1950	168.7469	3	1				0	0	0		3	
Umnak I.-N. of Twin Lava Pt.2	Rock	53.2071	168.7212	2	1				0	0	0		2	
Umnak I.-Okee Bay	Rock	53.0393	168.8130	10	5				0				10	
Umnak I.-Outer Russian Bay	Rock	53.1316	168.3310	8	6		3					8		
Umnak I.-Pancake Rk.	Rock	52.9347	169.0245	40	28							40	15	
Umnak I.-S. of Russian Bay	Rock	53.1172	168.3925	4	1		0				4	0		
Umnak I.-Steeple Pt.	Rock	53.2761	168.3504	6	2				0	3	0		6	
Umnak I.-SW. of Kigul I.	Rock	53.0387	168.4565	13	8		3					13		
Umnak I.-Teapot Hill	Rock	53.1362	168.8004	12	4				0	0			12	
Umnak I.-Traders Cove, Driftwood B	Rock	52.9567	168.7034	4	3							1		4
Umnak I.-Umnak Lake Bay	Rock	52.9117	168.8522	12	12								12	
Unalaska I.-Aspid Bay	Rock	53.4351	167.4135	10	3	0	0		10	0				
Unalaska I.-Aspid Cape	Rock	53.4525	167.4710	10	5	10	0		0	4			9	
Unalaska I.-Boulder Pt.	Rock	53.3602	167.7529	7	4	0							7	
Unalaska I.-Cape Aspid SE.	Rock	53.4481	167.4572	25	5	0	0		25	0			0	
Unalaska I.-Kashega Pinnacles	Rock	53.4925	167.2266	25	14	0	4		25	25				
Unalaska I.-Kashega Pt.	Rock	53.5213	167.1901	7	2	0	0		7	0				
Unalaska I.-Kismaliuk Bay	Rock	53.4562	167.3094	24	7	0	5		24	0				
Unalaska I.-Kof pt.	Rock	53.6571	167.0556	8	4				8	0				
Unalaska I.-McIver Bight	Rock	53.5035	167.1898	14	8	11	0		7	14				
Unalaska I.-Ranchers Pt.	Rock	53.3942	167.6375	8	4	0							8	
Unalaska I.-Sedanka Pt.1	Rock	53.4785	167.2969	25	18	11				25				
Unalaska I.-Sedanka Pt.2	Rock	53.4941	167.3358	30	15	0	8		20	30				
Unalaska I.-Sedanka Pt.3	Rock	53.4878	167.3263	90	40	0	90		35	35				
Unalaska I.-Spray Cape	Rock	53.6114	167.1670	30	16	0	9		25	30				
Unalaska I.-Station Bay	Rock	53.3843	167.6115	22	11	11	0						22	
Unalaska I.-Wedge Pt.	Rock	53.4507	167.3867	6	2	0	0		6	0				
Yunaska I. N.	Rock	52.7010	170.6393	10	5					0		10		
Yunaska I.-E. Cove	Rock	52.6544	170.5519	5	5							5		
Yunaska I.-S. Anchorage	Rock	52.5974	170.6980	3	3							3		

MAX	MEAN
1,209	690

95 % Confidence Interval			
561	=LOW	819	=HIGH

CV	COUNT	SD
9.47	92	65.368

Table 3. Zone 2 Jansen

Table 4. The number of seals counted for each site for Zone 3. [Olesiuk]

(from Seguam Island in the east to Kagalaska Island in the west)

Location	Substrate	Latitude	Longitude	MAX	MEAN	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug
Amlia I. NE	Rock	52.1343	173.8764	20	11	20				8				6
Amlia I. NW-1	Rock	52.1012	173.2394	5	5									5
Amlia I. NW-2	Rock	52.1067	173.1876	12	12									12
Amlia I. NW-3	Rock	52.1003	173.0756	15	15									15
Amlia I. SE-1	Rock	52.0761	172.9749	5	4						5	3		
Amlia I. SE-2	Rock	52.0573	173.1337	42	34						26	42		35
Amlia I. SE-4	Rock	52.0501	173.2078	20	11						20	6		8
Amlia I. SE-5	Rock	52.0571	173.2728	23	16							9		23
Amlia I. SW-1	Rock	52.0558	173.9027	4	4							4		
Amlia I. SW-2	Rock	52.1007	173.9676	8	8							8		
Amlia I. SW-3	Rock	52.0546	173.1541	1	1									1
Amlia-94,126	Rock	52.1378	173.5212	0	0	0								
Amlia-94,127	Rock	52.0212	173.0003	0	0						0			
Amtagis I.	Rock	52.0190	174.4223	6	4							6		1
Asuksak I. NW	Rock	51.9355	176.1171	2	2					2		2		
Atka I. SW	Rock	52.0021	175.1339	1	1							1		
Atka-94,130	Rock	52.1005	174.0248	0	0			0				0		0
Atka-94,141	Rock	52.2055	174.0407	0	0			0						
Atka-94,145	Rock	52.1000	174.9222	0	0			0						
Atka-94,146	Rock	52.2670	174.0248	0	0	0								
Atka-94,148	Rock	52.2170	174.0376	0	0			0				0		
Aziak I. N	Rock	51.9552	176.1555	4	2					4		0		
Bechevin Bay	Rock	52.0527	175.0584	16	10			10		16		4		
Bechevin Point	Rock	52.0598	175.0334	14	11			8		14		11		
Blue Fox Bay	Rock	52.1048	174.8340	20	15			16		16		8		20
Bugle Point	Rock	52.0334	175.9711	8	7					6		8		
Cape Akuyan N	Rock	52.0264	176.2029	2	2					2		2		
Cape Korovin E	Rock	52.2747	174.3265	1	1									1
Cape Misty	Rock	52.0336	173.8336	6	6									6
Cape Shaw	Rock	52.3061	174.9850	6	6									6
Cape Tadluk	Rock	52.0182	174.7577	18	15							18		11
Cape Utlaug W	Rock	52.0921	174.1715	3	2						3	0		3
Chugul Island E	Rock	51.9392	175.7868	3	3					3				
Chugul Island W	Rock	51.9388	175.8590	18	15					11		18		
Crescent Bay	Rock	52.0236	175.2396	3	3							3		
Egg Bay	Rock	52.1731	174.4264	1	1			1		0		1		1
Explorer Bay E	Rock	52.0365	174.5738	19	13							19		7
Explorer Bay W	Rock	52.0355	174.5918	14	6					0		4		14
Hungry Bay NE	Rock	52.1257	173.7038	5	3	5								0
Hungry Bay NW	Rock	52.1246	173.8221	3	3	3								
Idalug Cape W	Rock	52.1174	173.4381	10	9	7								10
Kagalaska I. E	Rock	51.8098	176.2393	12	10					12		7		
Kagalaska I. S	Rock	51.7337	176.3180	9	5							9		1
Kagalaska I. SW	Rock	51.7253	176.3739	2	2					2				

Kagalaska I. W	Rock	51.7834	176.4065	12	6					0		7		12
Kagalaska-94,135	Rock	51.7336	176.3722	0	0							0		
Kasatochi I. SE	Rock	52.1576	175.4872	4	2			4				0		
Koniuji I. SE	Rock	52.2093	175.1234	15	10			5				9		15
Kuvurof Point	Rock	52.0836	174.9385	6	4			1		4		6		
Little Tanaga I. NE	S	51.8400	176.0502	13	13					13				
Little Tanaga I. NW	Rock	51.8571	176.2209	17	17					16		17		
Oglodak I. SE	Rock	51.9674	175.4242	11	11							11		
Sagchudak I. NE	Rock	52.0199	174.4726	12	7			9				0		12
Salt I. N	Rock	52.1673	174.6229	19	11			19		3		15		7
Seguam-94,123	Rock	52.2388	172.5345	0	0	0								
Sviechnikof Harbor NE	Rock	52.0416	173.3565	9	5							9		0
Sviechnikof Harbor W	Rock	52.0413	173.4584	18	12							18		5
Tagadak I. N	Rock	51.9586	176.0192	13	13					13		13		
Tagalak I. E-1	Rock	51.9550	175.6173	16	14			12				16		
Tagalak I. E-2	Rock	51.9569	175.6404	15	15							15		
Tagalak-94,131	Rock	51.9501	175.5858	0	0			0						
Tanadak I.	Rock	52.0582	172.9557	32	29						25	32		
Turf Point	Rock	52.2503	172.5403	3	3							3		
Umak I. E	Rock	51.8881	175.9852	12	12							12		
Umak I. NE	Rock	51.9019	175.9839	6	4					1		6		
Umak-94,133	Rock	51.9005	175.0924	0	0						0			
Vasilief Bay	Rock	52.0835	174.3363	4	4									4
Wall Bay	Rock	52.1004	174.8721	11	3			2		0		0		11

MAX	MEAN
589	457

95 % Confidence Interval			
376	=LOW	538	=HIGH

CV	COUNT	SD
8.87	55	40.52

Table 4. Zone 3 Olesiuk

Table 5. The number of seals counted for each site for Zone 4. [Cesarone]

(from Adak Island in the east to Attu Island in the west)

Location	Substrate	Latitude	Longitude	MAX	MEAN	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug
Adak I. SW	Rock	51.6513	177.0036	4	4		4							
Agattu I.-E 1	Sand	52.4713	173.7082	1	1						1			
Agattu I.-E 2	Sand	52.4177	173.7031	1	1						1			
Agattu I.-E 3	Rock	52.4001	173.7181	1	1						1			
Agattu I.-N	Rock	52.5007	173.6709	2	2						2			
Agattu I.-NE 1	Rock	52.5074	173.7234	8	8						8			
Agattu I.-NE 2	Rock	52.5080	173.7413	33	33						33			
Agattu I.-SE	Rock	52.3401	173.6431	10	10				10					
Agattu I.-SW 1	Rock	52.3751	173.4931	1	1						1			
Agattu I.-SW 2	Rock	52.3745	173.4597	10	10						10			
Alaid I.-E	Rock	52.7427	173.9394	4	4				4					
Alaid I.-S1	Rock	52.7397	174.0881	3	3						3			
Alaid I.-SE 1	Sand	52.7353	173.9214	13	13				13					
Alaid I.-SE 2	Rock	52.7579	173.9184	11	11						11			
Aliad I.-S2	Sand	52.7429	173.8917	2	2						2			
Aliad I.-SW	Rock	52.7508	173.8597	1	1				1					
Amatignak I.- E	Rock	51.2535	179.0570	20	20							20		
Amatignak I.- NE	Rock	51.2887	179.0752	3	2					3		1		
Amatignak I.- SE	Rock	51.2378	179.0844	2	2							2		
Amchitka I.-N	Rock	51.6364	178.7735	1	1						1			
Amchitka I.-NE	Rock	51.4197	179.2342	14	8					2	14			
Amchitka I.-offshore rocks N	Rock	51.7386	179.2018	1	1					1				
Amchitka I.-S 1	Rock	51.3712	179.1867	13	13					13				
Amchitka I.-S 2	Rock	51.4052	179.1427	14	10					6	14			
Amchitka I.-S 3	Rock	51.4353	179.0840	13	11					9	13			
Amchitka I.-S 4	Rock	51.4415	179.0710	30	30					30				
Amchitka I.-S 5	Rock	51.4555	179.0514	4	4					4				
Amchitka I.-S 6	Rock	51.4695	179.0260	8	8					8				
Amchitka I.-S 7	Rock	51.4918	179.0027	10	10					10				
Amchitka I.-SE	Rock	51.3519	179.2224	13	13						13			
Amchitka I.-SW	Rock	51.5536	178.7893	25	25						25			
Amchitka I.-W	Rock	51.6392	178.6060	12	12						12			
Attu I.- S Abraham Bay	Rock	52.8510	172.7340	4	4						4			
Attu I.-Casco Cove inner	Rock	52.8715	173.2734	6	6				6					
Attu I.-Casco Cove outer	Rock	52.8682	173.3066	11	11				11					
Attu I.-Chirikof Pt. N	Rock	52.8433	173.4259	4	4						4			
Attu I.-Chirikof Pt. S 1	Rock	52.8234	173.4193	14	14						14			
Attu I.-Chirikof Pt. S 2	P	52.8088	173.3254	3	3				3					
Attu I.-Chirikof Pt. S shore	Rock	52.8227	173.3536	4	4				4					
Attu I.-E Abraham Bay	Rock	52.8725	172.7737	1	1						1			
Attu I.-Etienne Bay inner	Rock	52.8751	172.6202	4	4				4					
Attu I.-Etienne Bay outer	Rock	52.9040	172.6352	10	10				10					
Attu I.-Massacre Bay outer	Rock	52.7840	173.2260	29	29						29			
Attu I.-Massacre Bay SW1	Rock	52.8096	173.2083	1	1						1			

Attu I.-Massacre Bay SW2	Rock	52.8063	173.2728	3	3						3			
Attu I.-SW	Rock	52.9022	172.5244	8	8						8			
Attu I.-SW Abraham Bay	Rock	52.8671	172.7094	15	15						15			
Attu I.-Temnac Bay	Rock	52.8211	173.0704	3	3				3					
Bay of Islands-Inner	Rock	51.7862	176.7678	7	7		7							
Bay of Islands-outer 1	Rock	51.8169	176.8408	12	7		2					12		
Bay of Islands-outer 2	Rock	51.8199	176.8670	4	4		4							
Cape Chlanak	Rock	51.7015	177.1677	1	1							1		
Cape Chunu	Rock	51.6511	177.6374	4	4					4				
Cape Chunu-W of	Rock	51.6512	177.6689	11	11							11		
Cape Tusik E	Rock	51.6846	177.2409	1	1							1		
Cape Tusik W	Rock	51.6735	177.2723	5	5							5		
Chuna Bay W	Rock	51.6905	177.6260	21	21							21		
Chunu Bay E	Rock	51.7052	177.3229	11	11							11		
Chunu Bay mid. 1	Rock	51.6877	177.5576	9	8					6		9		
Chunu Bay mid. 2	Rock	51.6892	177.5699	11	11							11		
Clam Lagoon	Sand	51.9211	176.5733	38	38							38		
Clam Lagoon-E side of spit	Rock	51.9364	176.5538	23	23							23		
Clam Lagoon-S end of spit	Rock	51.9058	176.5503	2	2							2		
Eddy Rock	Rock	51.6916	177.7196	11	9					11		7		
Elf I.	Rock	51.7001	176.5193	7	7							7		
Ilak I.	Rock	51.4580	178.2932	2	2							2		
Kanaga I. S	Rock	51.6855	177.3224	8	5					8		1		
Kanaga I.-Adak Strait 1	Rock	51.8212	177.1255	4	4							4		
Kanaga I.-Adak Strait 2	Rock	51.8040	177.1250	4	4							4		
Kanaga I.-Adak Strait 3	Rock	51.7930	177.1218	18	18							18		
Kanaga I.-N shore	Rock	51.7339	177.6336	31	18					31		5		
Kanaga I.-NW tip	Rock	51.7174	177.6882	18	18							18		
Kanaga I.-W of Kanaga Bay	Rock	51.6916	177.2242	12	12							12		
Kanaga I.-W of Ship Rock	Rock	51.7545	177.4564	1	1							1		
Kanaga I.-W shore 1	Rock	51.6865	177.6766	14	14							14		
Kanaga I.-W shore 2	Rock	51.7097	177.6907	15	15							15		
Kanaga Sound	Rock	51.9035	177.3574	10	10							10		
Kavalaga I. E	Rock	51.5504	178.7265	2	2							2		
Kavalaga I. SE	Rock	51.5337	178.7167	6	6							6		
Kavalaga I. W	Rock	51.5743	178.8419	3	3							3		
Kiska I.- W	Rock	51.8710	177.1928	1	1					1	1			
Kiska I.-E 1	Rock	51.9334	177.6175	15	15					15				
Kiska I.-E 2	Rock	52.0069	177.6002	5	5					4	5			
Kiska I.-E 3	Rock	51.9916	177.5739	5	5					5	4			
Kiska I.-NE	Rock	52.0736	177.6898	12	12						12			
Kiska I.-S 1	Rock	51.9068	177.3690	1	1					1				
Kiska I.-S 2	Rock	51.8047	177.3408	9	9					9				
Kiska I.-SW	Rock	51.8724	177.2203	7	7						7			
Little Kiska I.-E offshore rocks 1	Rock	51.9426	177.7667	6	6						6			
Little Sitkin I. SW	Rock	51.9224	178.4528	14	10					14	6			
Little Sitkin I.-S offshore rocks	Rock	51.9012	178.4006	15	15					15				
Little Sitkin I.-S	Rock	51.8933	178.4840	21	21						21			

Table 5. Zone 4 Cesarone

Nizki I.-E	Rock	52.7180	174.0262	16	11				16		6			
Nizki I.-S	Sand	52.7099	173.9913	3	3						3			
Nizki I.-SW	Sand	52.7246	173.9593	2	2				2					
Ogliuga I.-E shore	Rock	51.6064	178.6080	3	3							3		
Ogliuga I.-S offshore rocks	Rock	51.5755	178.6370	2	2							2		
Ogliuga I.-SW shore	Rock	51.5689	178.6674	28	19					9		28		
Ogliuga I.-W offshore rocks	Rock	51.5912	178.6907	3	3					3		2		
Rat I.-E 1	Rock	51.8196	178.2007	25	16					6	25			
Rat I.-E 2	Rock	51.8264	178.1924	1	1						1			
Rat I.-E 3	Rock	51.8341	178.1920	30	30						30			
Rat I.-E offshore rocks	Rock	51.8839	178.0095	11	11					11				
Rat I.-S	Rock	51.7727	178.2927	10	10						10			
Rat I.-SE	Rock	51.7668	178.3576	6	6						6			
Rat I.-SW 1	Rock	51.8226	178.2581	8	8						8			
Rat I.-SW 2	Rock	51.8261	178.2365	2	2					2				
Sea Otter Pass 1	Rock	51.5729	178.7004	4	4							4		
Sea Otter Pass 2	Rock	51.5705	178.7263	7	7							7		
Semisopochnoi I.-S	Rock	51.8722	179.6541	4	4							4		
Semisopochnoi I.-W	Rock	51.9519	179.4690	1	1							1		
Shemya I.-S	Rock	52.7045	174.0919	3	2				3		1			
Shemya I.-SE	Rock	52.7014	174.1342	4	4						4			
Shemya I.-SW	Rock	52.7083	174.0570	1	1						1			
Shoal Pt.	Rock	51.8572	177.0581	2	2							2		
Tag I.	Rock	51.5757	178.5854	4	4							4		
Tanaga I.-Annoy Rock	Rock	51.7065	177.8072	6	6							6		
Tanaga I.-Cape Amagalik	Rock	51.6890	178.1084	40	38					40		36		
Tanaga I.-Lash Bay outer	Rock	51.6530	178.0565	12	12							12		
Tanaga I.-N shore	Rock	51.9179	178.0520	2	2							2		
Tanaga I.-S of Annoy Rock	Rock	51.6754	177.8212	12	12					12				
Tanaga I.-S of Cape Sasmik	Rock	51.5578	177.9009	1	1					1				
Tanaga I.-S shore	Rock	51.6234	178.0032	9	5					1		9		
Tanaga I.-SE shore	Rock	51.6894	177.9083	4	4					4				
Tanaga I.-Tanaga Bay 1	Rock	51.7059	178.0675	8	8							8		
Tanaga I.-Tanaga Bay 2	Rock	51.7007	178.0174	1	1							1		
Tanaga I.-W of Cape Sudak	Rock	51.8343	177.6727	3	3							3		
Three Arm Bay-outer	Rock	51.7427	176.8837	1	1		8					1		
Turret Pt.	Rock	51.6092	176.8088	9	9							9		
Ulak I.-E shore	Rock	51.3667	178.9189	12	12							12		
Ulak I.-N offshore rocks	Rock	51.4560	178.9542	2	2							2		
Ulak I.-N shore	Rock	51.4035	178.9695	4	4					4				
Ulak I.-W shore	Rock	51.3667	179.0045	1	1					1				
Unalga I.-SE	Rock	51.5734	179.0258	6	4					6		1		

MAX	MEAN
1,158	1,081

95 % Confidence Interval	
848 =LOW	1,314 =HIGH

CV	COUNT	SD
10.92	134	118

Table 5. Zone 4 Cesarone

Table 6. Summary statistics for each zone and all zones combined.

Observer	Zone	MAX	MEAN	95 % Confidence Interval =LOW	95 % Confidence Interval =HIGH	CV	COUNT	SD
	All Zones	4,837	3,508	3,206	3,810	4.38	384	153.75
Segars	Zone 1	1,479	1,261	1,140	1,382	4.86	102	61.32055
Jansen	Zone 2	1,209	690	561	819	9.47	92	65.36801
Olesiuk	Zone 3	589	457	376	538	8.87	55	40.52074
Cesarone	Zone 4	1,158	1,081	848	1,314	10.92	134	118.018

Table 7. Mean count comparisons between the 1994 and 1999 surveys.

	1999	1994
Zone 1	1,261	1,091
Zone 2	690	729
Zone 3	457	181
Zone 4	1,081	553
all Zones combined	3,489	2,362

Fig. 1. Aleutian Island 1999 harbor seal aerial survey by zone.

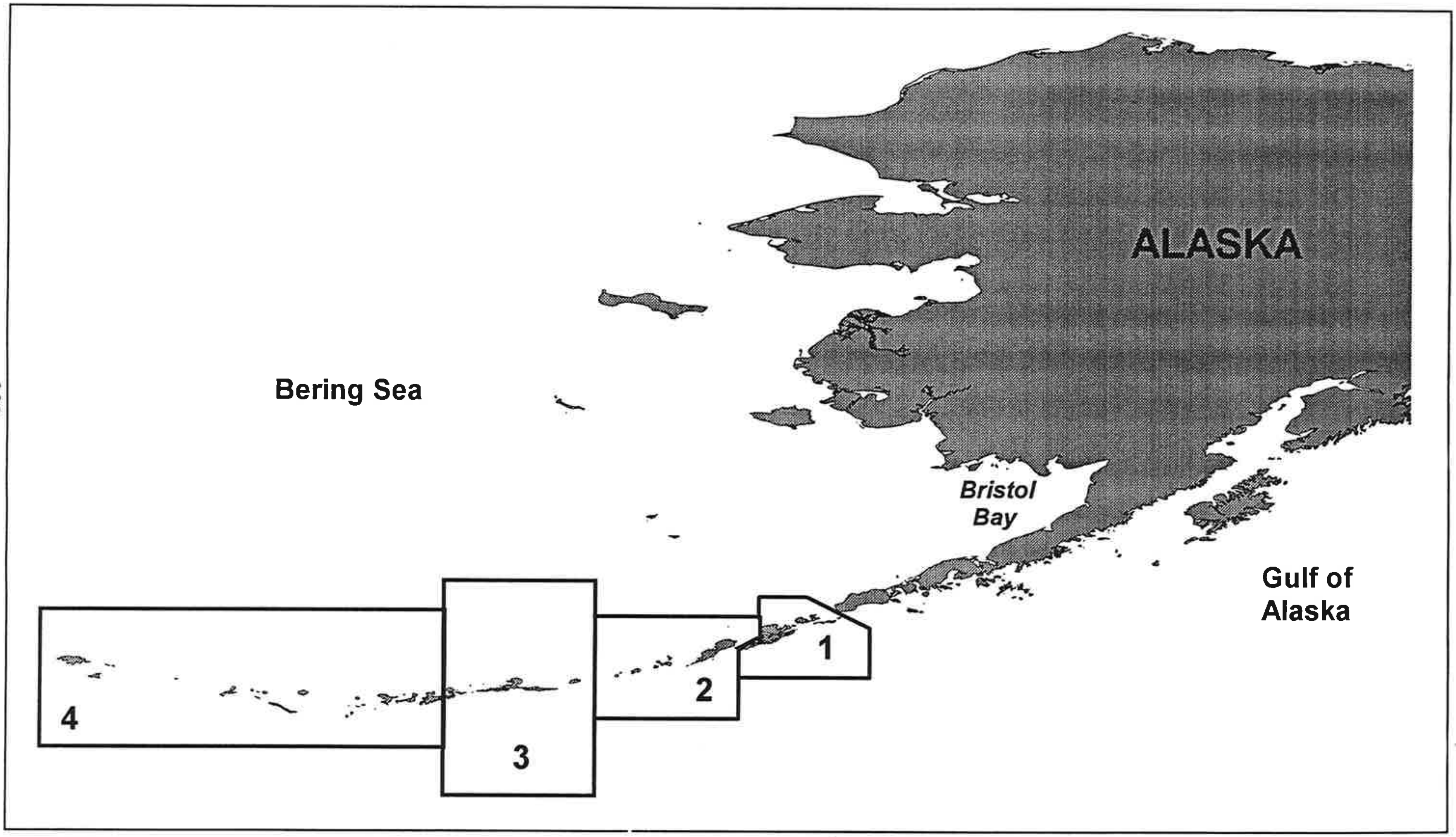


Fig. 2. Zone 1 - Unimak Pass to Umnak Pass including northeastern and southern Unalaska.

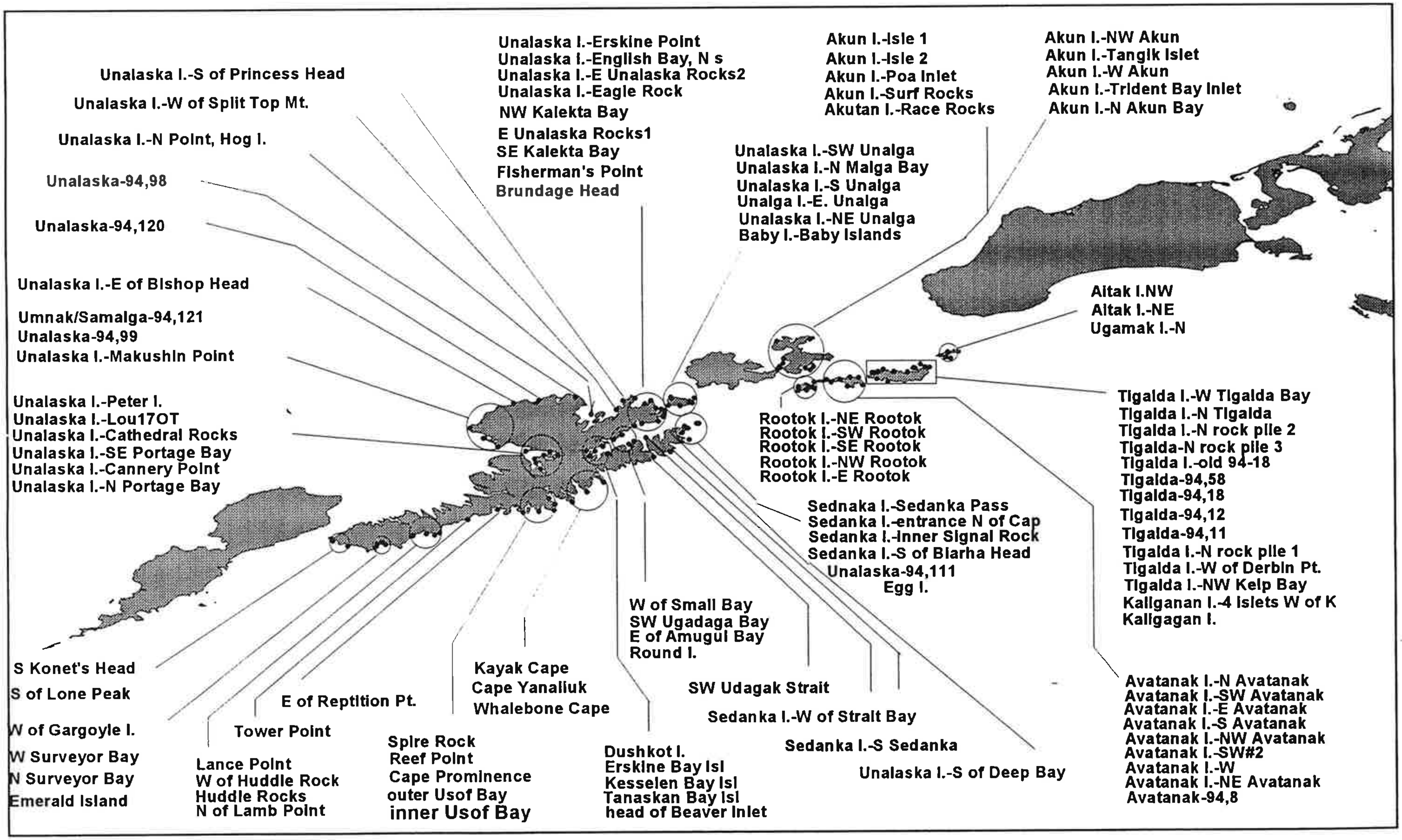


Fig. 3. Zone 2 - Amutka I. to Umnak Pass and northwestern Unalaska I.

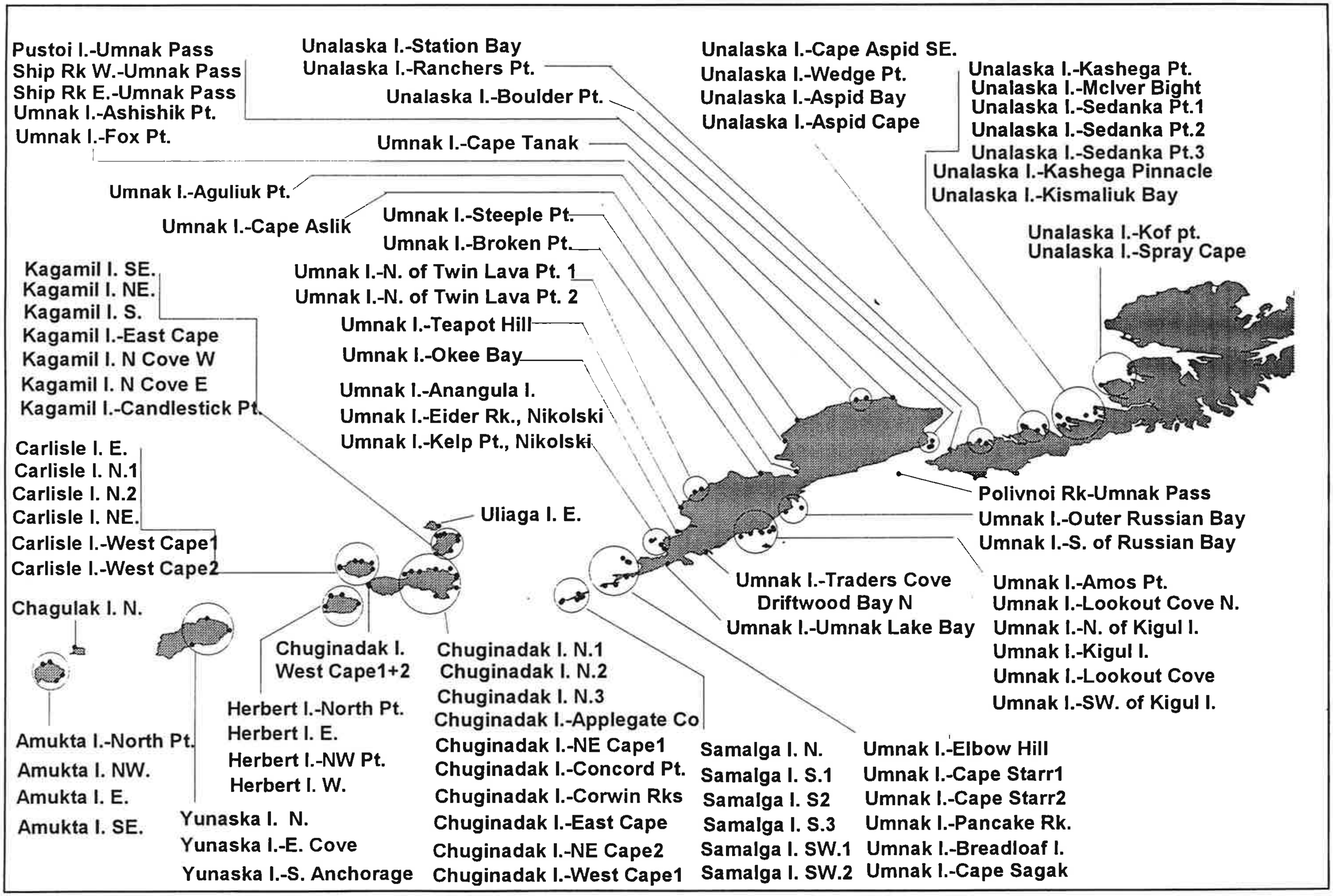


Figure 4. Zone 3 - Seguam I. to Kagalaska I.

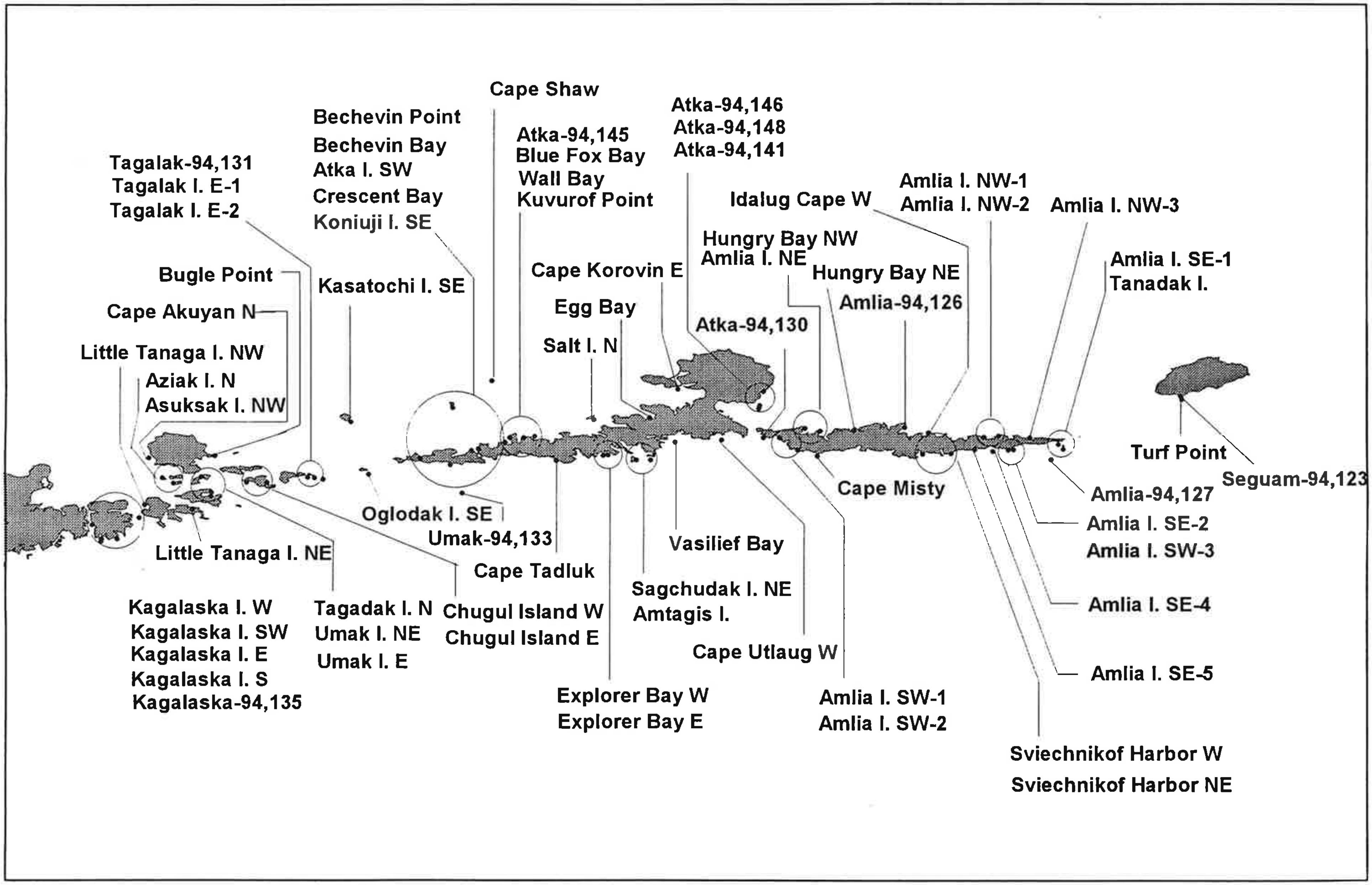


Fig. 5(A). Zone 4(A) - Attu I. to Buldir I.

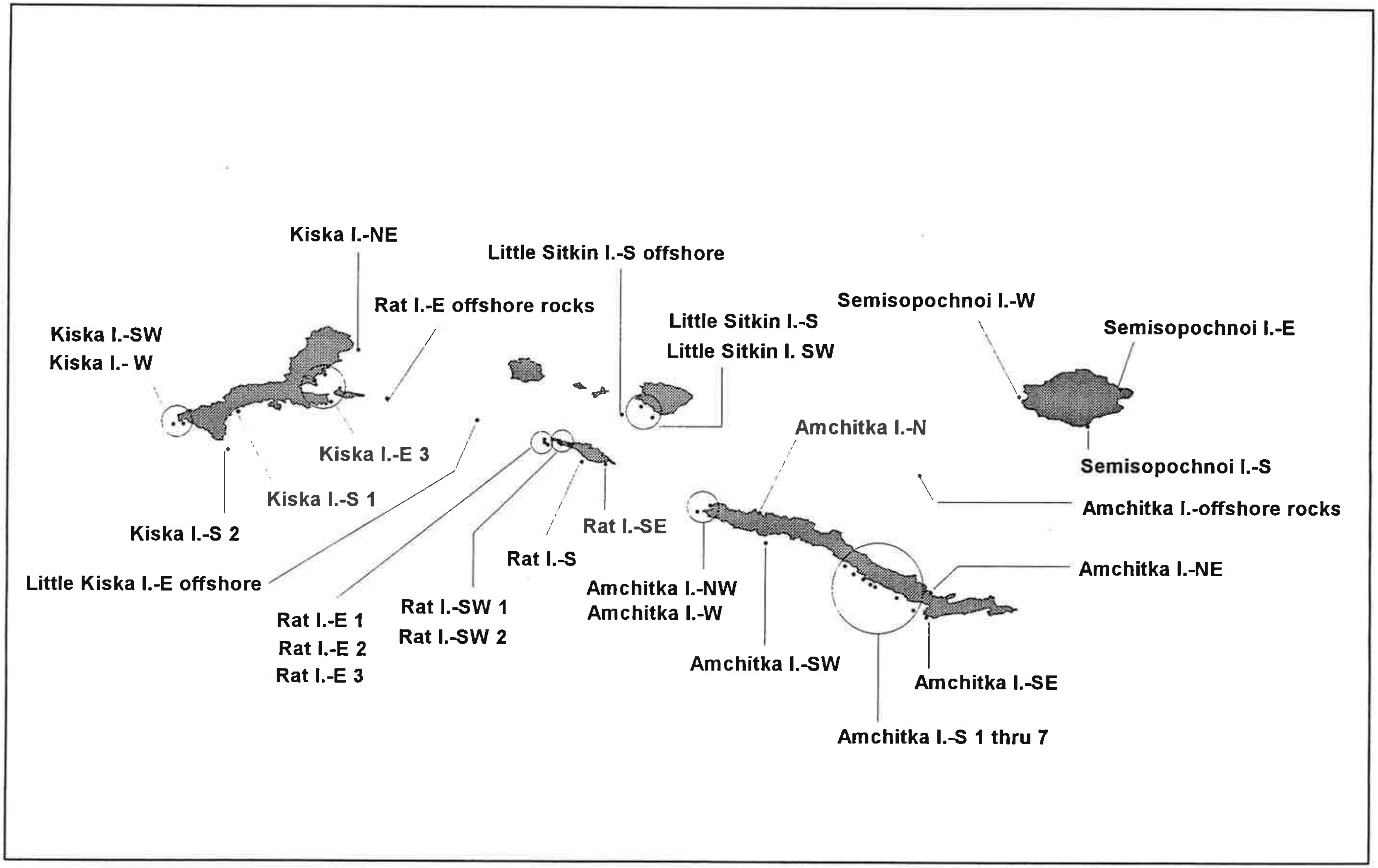


Fig. 5(b). Zone 4(b) - Kiska I. to Semisopochnoi I.

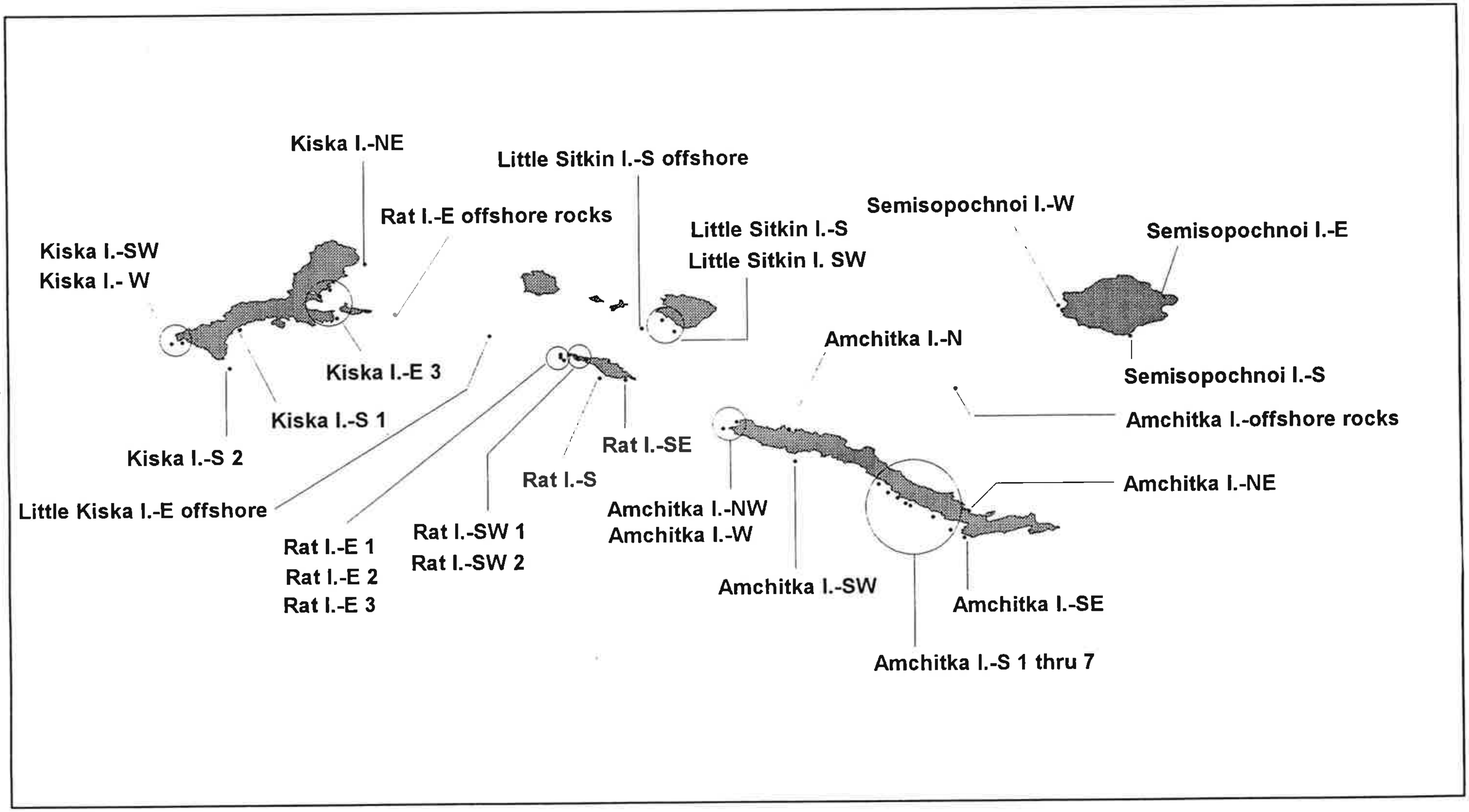
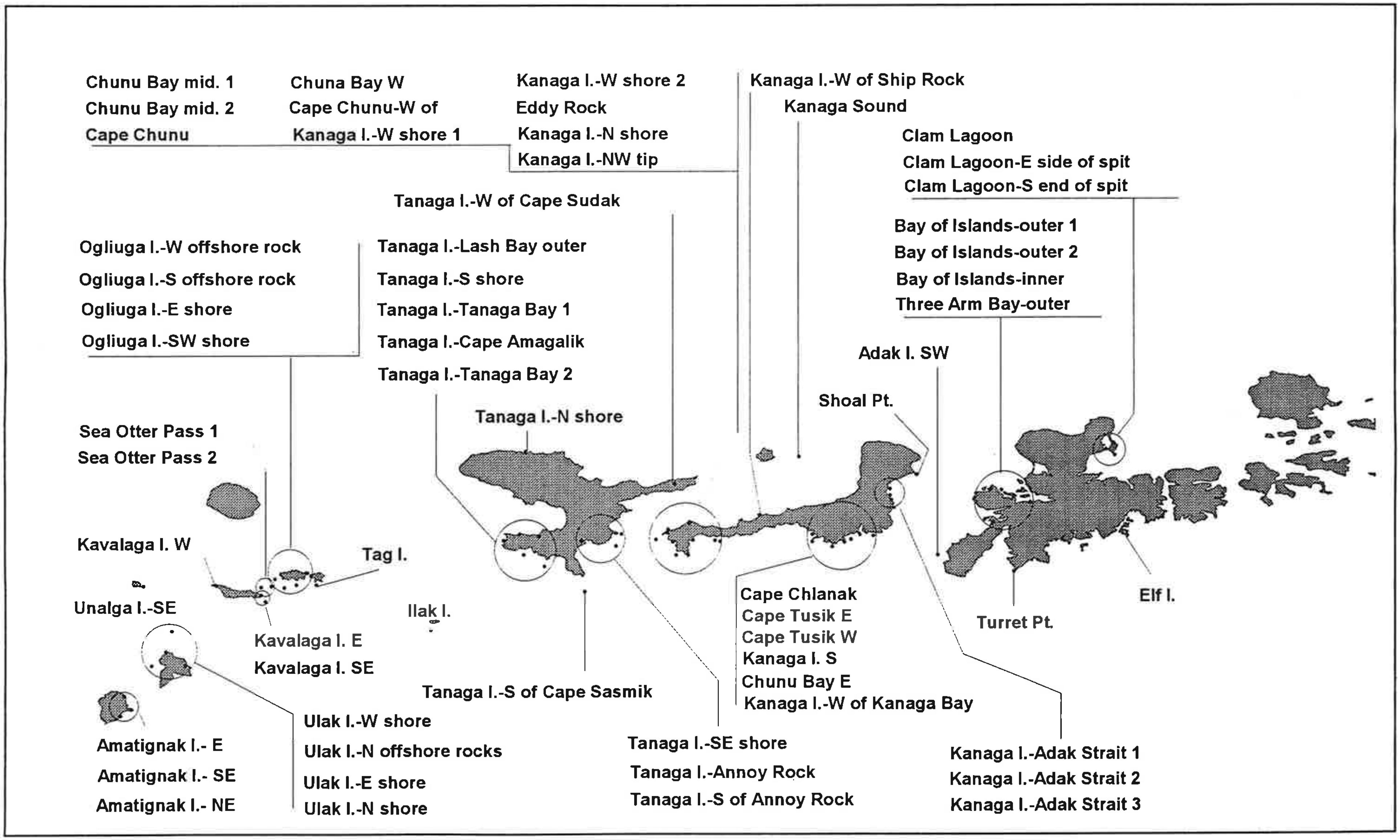


Fig. 5(c). Zone 4 (c) - Amatignak I. to Adak I.



SEROLOGICAL TESTING OF HARBOR SEALS (*Phoca vitulina*) IN WASHINGTON, 1998-1999

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Abstract

In 1986, the Washington Department of Fish and Wildlife began disease screening of harbor seals in Washington which included testing for brucellosis, leptospirosis, influenza, calicivirus, and morbillivirus. All results were negative until 1994 when evidence of harbor seal exposure to leptospirosis and brucellosis was found. To date, all serologic testing for influenza virus, calicivirus and morbillivirus has been negative. From 1994 to 1999, harbor seals from Gertrude Island, Smith/Minor Islands, Hood Canal (inland stock) the Columbia River, Grays Harbor and Willapa Bay (coastal stock) were tested for *Brucella* (n = 713) and *Leptospira* titres (n = 680). Overall, 14% of the population had positive or suspect test results for *Brucella*. Evidence of *Brucella* was significantly higher among yearlings (46%) and subadults (36%) compared to adults (9%) and pups (7%), although weaned pups had significantly higher positive and suspect titres (11%) than nursing pups (4%). There was no difference in proportion of positive and suspect results between seals from the inland stock and the coastal stock. In 1998 and 1999, 22% of seals (67/303) screened for *Leptospira* had suspect titres; only one seal had titres >1:400. As in 1994 to 1997, suspect titres for *Leptospira* were evenly distributed among the age classes.

Introduction

Washington Department of Fish and Wildlife (WDFW) has conducted disease screening of harbor seals *(Phoca vitulina)* in Washington state as part of ongoing research efforts since 1986. These efforts have been funded by WDFW (Puget Sound Ambient Monitoring Program and Marine Mammal Investigations) and by NMFS (Northwest Region, Recover Protected Species, and the National Marine Mammal Laboratory). The various diseases screened for include brucellosis, leptospirosis, influenza, calicivirus and morbillivirus (Lambourn et al. 1998). To date, all serologic testing for influenza virus, calicivirus and morbillivirus has been negative.

Brucellosis

Brucellosis is a contagious bacterial disease described in a number of mammalian species including cattle, bison, swine, sheep, dogs and humans. It is primarily a pathogen of male and female reproductive tracts, characterized by impaired fertility and abortion (Kennedy and Miller 1993).

Infection of marine mammals with *Brucella* bacteria was first described in 1994 (Ross et al.1994). Three different *Brucella* species have been isolated from the internal organs of seven common seals, four harbor porpoise (*Phocoena phocoena)* and one common dolphin (*Delphinus delphis*), one Atlantic whitesided dolphin (*Lagenorhynchus acutus),* two striped dolphins (*Stenella coeruleoalba),* one hooded seal (*Cystophora cristata),* one gray seal (*Halichoerus grypus)* and a European otter (*Lutra lutra)* in the United Kingdom (Foster et al. 1996). In 1994, a *Brucella* was isolated from a bottlenose dolphin (*Tursiops truncatus*) from California (Ewalt et al. 1994). The isolates obtained from the marine mammals have been reported as members of the genus *Brucella,* however they do not match any known *Brucella* species and probably represent new, undescribed strains (Ewalt et al. 1994).

Screening for *Brucella* in harbor seals in Washington began in 1994. From 1994 to 1997, 373 seals were tested in southern Puget Sound, Smith and Minor Islands and the Columbia River (Table 1). Overall, 18% of seals screened had suspect or positive titres for *Brucella*. Yearlings (age 6-18 months) had the highest suspect or positive titres (56%) and subadults (age 18-48 months) had 40% suspect or positive titres. Only 10% of adults (age > 48 months), 8% of nursing pups (age <2 months), and 15% of weaned pups (age 2-6 months) showed suspect or positive titres (Table 1). Of the 50 adult females screened for *Brucella* titres, only one was considered seropositive; she had evidence of a recent abortion. WDFW, with National Veterinary Service Laboratory (NVSL), Ames, IA, has isolated *Brucella* from numerous tissues and body fluids of seven harbor seals from Puget Sound. The *Brucella* species isolated was biochemically similar to a *Brucella* species identified from a seal in the United Kingdom; however, subsequent DNA testing showed these were genetically distinct strains (Lambourn et al. 1998). Brucellosis can have a major impact on the health and reproductive success of terrestrial mammals; it is unknown how these new *Brucella* strains will affect harbor seals and other mammals in Washington.

Leptospirosis

The first report of leptospirosis in a marine mammal was from a California sea lion (*Zalophus californianus*) in 1970 (Vedros et al. 1971). Epizootics in the California sea lion population in the past have been linked to El Niño events. During these warm water events, high numbers of sea lions (primarily 2-8 year old males) have been found stranded on beaches with clinical symptoms which include: lethargy, depression, extreme thirst (often drinking from fresh water sourccs), reluctance to use rear limbs, and renal failure. The causative agent is *Leptospira pomona* or a similar *Leptospira* organism. Leptospirosis is zoonotic and has potential health risks to humans and domestics animals (dogs, cattle, sheep, pigs and horses). It has also been linked to reproductive failure, abortions, and multiple hemorrhagic syndrome in fetuses and neonates in northern fur seals (*Callorhinus ursinus*) as well as California sea lions (Smith et al. 1974; Smith et al. 1978).

In Washington state, harbor seal population screening for *Leptospira* titres was negative from 1986 to 1994. From 1994 to 1997, 27% (103/377) of the seals tested in Washington had suspect titres (< 1:400) primarily to *L. grippotyphosa* (Lambourn et al.1998). In 1997, two adult seals had positive titres (>1:400) against *L. pomona*. One was an adult female from the Columbia River with titres of 1:800; the other, an adult male from outside Washington state (Puntledge River near Courtney, British Columbia), had titres of 1:3200 (Lambourn et al. 1998). In California, in 1996, leptospirosis was first found in two harbor seals infected during captivity at a rehabilitation center (Stamper et al. 1998), and later in a harbor seal infected prior to captivity (Stevens et al. 1999).

Methods

Capture and handling techniques

Most seals were caught using the beach seine technique described in Jeffries et al. (1993). Some additional seals were captured by grabbing individuals by hand. Once captured, seals were placed in individual hoop nets. Length, weight, age, and sex were determined before tagging. Blood for serologic screening was drawn from the extradural intravertebral vein using a vacutainer adapter and an 18 gauge 1½ to 3½ inch needle. For blood collection, serum separator vacutainer tubes were used. Serum was separated as soon as possible after capture, aliquoted into 1-2 ml samples, and frozen (-20° C) pending disease screening.

Serologic screening

Harbor seal serum samples were tested at the Washington Department of Agriculture (WDA), Microbiology Laboratory in Olympia for the presence of antibodies to *Brucella abortus* antigens supplied by NVSL in Ames, IA. Procedures used for testing samples followed standard protocols for *Brucella abortus* testing developed by NVSL. Serum was screened for *Brucella* using the Brucella Buffered Plate Agglutination test antigen (BAPA), the Brucellosis Card test (BBA), Rivanol, and complement fixation(CF) test. Supplemental testing was done on a small number of serum samples using Particle Concentration Fluorescence Immunoassay (PCFIA). Interpretation of results followed standards developed by the U.S. Department of Agriculture. A seal was considered positive when all tests (BAPA, BBA and Rivanol >1:50) were positive. A seal with one or more, but not all, tests positive was considered suspect.

Leptospira screening was conducted at WDA with the micro agglutination test (MAT). The serum was diluted with 0.85% NaCl to 1:100, 1:200, 1:400, 1:800, 1:1600 and 1:3200 and tested for antibodies to *L. pomona, L. hardjo, L. grippotyphosa, L. icterohemorrhagiae* and *L. canicola*. Seals were considered suspect with a titre of <1:400 and positive with titres of >1:400.

Results

In 1998 and 1999, 340 harbor seals from Gertrude Island, Hood Canal, Grays Harbor and

Willapa Bay were screened for *Brucella* exposure and 303 seals from Gertrude Island, Hood Canal and Grays Harbor for *Leptospira* exposure.

Brucellosis

In 1998 and 1999, 174 harbor seals from Gertrude Island (Table 2) and 107 harbor seals from Hood Canal (Table 3) were screened for exposure to *Brucella*. In 1999, 46 seals were screened for *Brucella* exposure in Grays Harbor (Table 4) and 13 pups were screened in Willapa Bay (Table 5). All 13 seal pups captured on June 1999 in Willapa Bay and screened for *Brucella* exposure were negative. In 1998 and 1999, as was true for previous screenings, the age classes with the highest number of suspect and positive titres were the yearlings (age 6-18 months) and subadults (18-48 months). Yearlings showed a 40%, subadults a 33%, adults a 8% and pups a 2% exposure rate.

Overall, from 1994 to 1999, 14% of the screened animals had positive or suspect test results for *Brucella* titres (Table 6). Evidence of *Brucella* exposure was significantly higher among yearlings (46%) and subadults (36%) compared to pups (7%) and adults (9%) ($X^2 = 101.3$, $P < 0.001$). Weaned pups had significantly higher positive and suspect titres (11%) than nursing pups (4%) ($z = 2.39$, $P = 0.01$). There was no difference in proportion of positive or suspect results between seals from the inland stock and the coastal stock ($z = 1.02$, $P > 0.05$).

Leptosirosis

In 1998 and 1999, 161 seals from Gertrude Island (Table 7), 98 seals from Hood Canal (Table 8) and 44 seals from Grays Harbor (Table 9) were screened for *Leptospira* titres. Of the 303 seals screened in all, 67 (22%) had suspect titres (Table 10). There was only one positive titre in an adult male; the proportion of suspect titres were evenly distributed among the age classes (Table 10). The percent of suspect and positive titres was lower in 1998 and 1999 than in 1994 to 1997 (28%) but that may be an artifact of a change in the testing procedure that began mid 1999. This change has eliminated some false positives from the cross reactivity of other bacteria. This has decreased the proportion of suspect titres. Retesting of previous samples is currently underway.

Discussion

Monitoring the status and health of Washington harbor seals is one of the primary research objectives of the WDFW and NMML. Serology from harbor seals captured throughout Washington's marine waters shows evidence of exposure to previously unknown strains of *Brucella* which may pose a significant health risk to other marine mammals and domestic livestock. Because of the prevalence of *Brucella* titres in serum from yearlings and subadults, these age classes will be the focus of screening for evidence of *Brucella* exposure in other geographic areas.

The mechanism for *Brucella* infection in harbor seals is not known, although immunohistochemistry techniques have found positive *Brucella* staining within the uterus and gut of the lungworms (*Parafilaroides* sp.) from two of the harbor seals where a *Brucella* organism was cultured and isolated from lung tissue (Garner et al. 1997). Staining also revealed the intracellular presence of *Brucella* in lymph node tissue, inflamed cells and an abscessed area of the surrounding parenchyma. These results may indicate that lungworms are the source of the infection in harbor seals. An intermediate host of the lungworm, *P. decorum,* is the opaleye perch which is prey of California sea lions in the Southern California Bight. The range of the opaleye perch does not extend into Washington waters. The WDFW, NSVL and Murray Dailey have proposed cooperative studies to identify fish species that are prey of harbor seals which may also be intermediate hosts to *Parafilaroides* sp. in Washington.

The significantly greater presence of *Brucella* titres in weaned pups, yearlings, and subadults may suggest that the infection most commonly begins with harbor seals when they are first foraging on their own rather than being passed on from mother to pup during nursing. After the initial infection, *Brucella* organisms can remain dormant until a seal is immunocompromised by environmental contaminants, disease, or pregnancy, this dormancy may explain the significantly lower *Brucella* titres in adult harbor seals.

The etiology and risks from brucellosis and leptospirosis (Smith et al 1978; Visser et al 1991; Wilkinson 1996) relative to Washington harbor seals remains unknown. However, *Brucella* and *Leptospira* are known to be zoonotic and have caused reproductive failure and disease in domestic livestock and other wildlife species. Research has also shown links between areas of relatively high environmental contamination and failed immune response and disease in harbor seals (Ross et al. 1996). Because *Brucella* and *Leptospira* can also infect and cause a variety of clinical diseases in humans (Gelfand et al. 1989), the presence of *Brucella* and *Leptospira* bacteria in marine mammals harvested by various Native American tribes in the Northwest poses an unknown risk of potential human exposure and infection. Marine mammal biologists, seal rehabilitators and fishermen who have direct contact with pinnipeds may also be at risk of infection.

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Table 1. *Brucella* titres in harbor seals sampled at southern Puget Sound, Smith and Minor Islands, and Columbia River, 1994-1997.

		Negative*		Suspect**		Positive***	
Age class	*n*	Female	Male	Female	Male	Female	Male
Nursing pup	77	41	30	3	3	0	0
Weaned pup	79	29	37	5	4	2	2
Yearling	29	3	11	2	0	4	9
Subadult	50	16	14	5	6	3	6
Adult	138	49	75	0	10	1	3
TOTALS	373	138	167	15	23	10	20

* NEGATIVE = All *Brucella* tests negative.
** SUSPECT TITRES = One or more but not all *Brucella* tests (BAPA, BBA and Rivanol >I:50) positive.
*** POSITIVE TITRES = All *Brucella* tests (BAPA, BBA and Rivanol>I:50) positive.

Table 2. *Brucella* titres in harbor seals from Gertrude Island 1998, 1999.

		Negative*		Suspect**		Positive***	
Age Class	*n*	Female	Male	Female	Male	Female	Male
Pups							
Newborn	11	5	6	0	0	0	0
Nursing	13	7	6	0	0	0	0
Abandoned	10	6	4	0	0	0	0
Weaned	67	35	29	1	1	1	0
Yearling	7	1	0	1	1	3	1
Subadult	7	3	2	0	0	0	2
Adult	59	22	32	0	4	1	0
TOTALS	174	79	79	2	6	5	3

* NEGATIVE = All *Brucella* tests negative.
** SUSPECT TITRES = One or more but not all *Brucella* tests (BAPA, BBA and Rivanol >I:50) positive.
*** POSITIVE TITRES = All *Brucella* tests (BAPA, BBA and Rivanol>I:50) positive.

Table 3. *Brucella* titres in harbor seals from Hood Canal 1998, 1999.

		Negative*		Suspect**		Positive***	
Age Class	*n*	Female	Male	Female	Male	Female	Male
Pups							
Newborn	2	1	1	0	0	0	0
Nursing	36	14	22	0	0	0	0
Abandoned	1	0	1	0	0	0	0
Weaned	1	0	1	0	0	0	0
Yearling	21	9	6	2	0	2	2
Subadult	5	1	3	0	0	1	0
Adult	41	22	17	1	1	0	0
TOTALS	107	47	51	3	1	3	2

* NEGATIVE = All *Brucella* tests negative.
** SUSPECT TITRES = One or more but not all *Brucella* tests (BAPA, BBA and Rivanol >I:50) positive.
*** POSITIVE TITRES = All *Brucella* tests (BAPA, BBA and Rivanol>I:50) positive.

Table 4. *Brucella* titres in harbor seals sampled at Grays Harbor, 1999.

		Negative*		Suspect**		Positive***	
Age Class	*n*	Female	Male	Female	Male	Female	Male
Pups							
Newborn	6	2	3	0	1	0	0
Nursing	9	3	6	0	0	0	0
Abandoned	2	1	1	0	0	0	0
Weaned	4	2	2	0	0	0	0
Yearling	5	2	1	0	1	1	0
Subadult	3	1	1	0	0	1	0
Adult	17	9	5	1	1	0	1
TOTALS	46	20	19	1	3	2	1

* NEGATIVE = All *Brucella* tests negative.
** SUSPECT TITRES = One or more but not all *Brucella* tests (BAPA, BBA and Rivanol >I:50) positive.
*** POSITIVE TITRES = All *Brucella* tests (BAPA, BBA and Rivanol>I:50) positive.

Table 5. *Brucella* titres in harbor seal pups sampled at Willapa Bay, 1999.

Age Class	*n*	Negative*		Suspect**		Positive***	
		Female	Male	Female	Male	Female	Male
Newborn	1	0	1	0	0	0	0
Nursing	12	5	7	0	0	0	0
TOTALS	13	5	8	0	0	0	0

* NEGATIVE = All *Brucella* tests negative.
** SUSPECT TITRES = One or more but not all *Brucella* tests (BAPA, BBA and Rivanol >I:50) positive.
*** POSITIVE TITRES = All *Brucella* tests (BAPA, BBA and Rivanol>I:50) positive.

Table 6. Summary of *Brucella* titres in harbor seals sampled at Gertrude Island, Hood Canal, Smith/Minor Islands, Columbia River, Grays Harbor, and Willapa Bay, 1994-1999.

Age Class	*n*	Negative*		Suspect**		Positive***	
		Female	Male	Female	Male	Female	Male
Nursing pup	180	85	88	3	4	0	0
Weaned pup	151	66	69	6	5	3	2
Yearling	62	15	18	5	2	10	12
Subadult	65	21	20	5	6	5	8
Adult	255	102	129	2	16	2	4
TOTALS	713	289	324	21	33	20	26

* NEGATIVE = All *Brucella* tests negative.
** SUSPECT TITRES = One or more but not all *Brucella* tests (BAPA, BBA and Rivanol >I:50) positive.
*** POSITIVE TITRES = All *Brucella* tests (BAPA, BBA and Rivanol>I:50) positive.

Table 7. *Leptospira* titres in harbor seals sampled at Gertrude Island, 1998, 1999.

		Negative*		Suspect**		Positive***	
Age Class	*n*	Female	Male	Female	Male	Female	Male
Pup	96	46	40	9	4	0	0
Yearling	5	5	1	0	1	0	0
Subadult	7	1	2	2	2	0	0
Adult	53	14	22	3	13	0	1
TOTALS	161	66	65	14	20	0	1

* NEGATIVE = No titres
** SUSPECT = Titres < 1:400
*** POSITIVE = Titres > 1:400

Table 8. *Leptospira* titres in harbor seals sampled at Hood Canal, 1998, 1999.

		Negative*		Suspect**		Positive***	
Age Class	*n*	Female	Male	Female	Male	Female	Male
Pup	37	14	18	2	3	0	0
Yearling	20	10	8	2	0	0	0
Subadult	7	2	5	0	0	0	0
Adult	34	19	11	1	3	0	0
TOTALS	98	45	42	5	6	0	0

* NEGATIVE = No titres
** SUSPECT = Titres < 1:400
*** POSITIVE = Titres > 1:400

Table 9. *Leptospira* titres in harbor seals sampled at Grays Harbor, 1999.

		Negative*		Suspect**		Positive***	
Age Class	*n*	Female	Male	Female	Male	Female	Male
Pup	19	2	9	3	5	0	0
Yearling	5	2	0	1	2	0	0
Subadult	3	0	1	1	1	0	0
Adult	17	6	2	4	5	0	0
TOTALS	44	10	12	9	13	0	0

* NEGATIVE = No titres
** SUSPECT = Titres < 1:400
*** POSITIVE = Titres > 1:400

Table 10. Summary of *Leptospira* titres in harbor seals from Gertrude Island, Hood Canal, and Grays Harbor, 1998, 1999.

		Negative*		Suspect**		Positive***	
Age Class	*n*	Female	Male	Female	Male	Female	Male
Pup	152	62	67	14	12	0	0
Yearling	30	17	9	3	3	0	0
Subadult	17	3	8	3	3	0	0
Adult	104	39	35	8	21	0	1
TOTALS	303	121	119	28	39	0	1

* NEGATIVE = No titres
** SUSPECT = Titres < 1:400
*** POSITIVE = Titres > 1:400

GENETIC IDENTIFICATION OF SALMONID BONE FROM HARBOR SEAL SCAT

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Abstract

Over the last several decades, Pacific harbor seal (*Phoca vitulina richardsi*) populations have been increasing in abundance while one of their major prey items, Pacific salmonids, have been declining. Therefore, understanding the predator-prey relationships between harbor seals and Pacific salmon (*Oncorhynchus* spp.) populations is an important biological and resource management question. Using molecular genetic techniques, DNA was extracted from 146 salmonid bones recovered from harbor seal scat samples and 10 bones from river otter scat. A portion of the mitochondrial genome was successfully amplified via the polymerase chain reaction in 102 of these DNA samples. The fish bones were identified to the species level by either DNA sequencing or restriction enzyme analysis of the mitochondrial DNA. Three mitochondrial regions were explored for usefulness in species identification including the d-loop, a variable region of the 16s ribosomal gene, and a region spanning the cytochrome oxidase III and ND3 genes. Six restriction enzymes were identified in the cytochrome oxidase III/ND3 region that produce haplotype patterns that can distinguish among all seven of the common *Oncorhynchus* species. A screen for restriction enzyme polymorphisms in the cytochrome oxidase III/ND3 region of seven Pacific salmon species across a large geographical area found only one intraspecific haplotype polymorphism.

Introduction

Eighteen stocks of Pacific salmon are listed as threatened or endangered under the U.S. Endangered Species Act and seven more stocks are currently being evaluated for listing. The ecological and economic consequences of these listings are large, so considerable effort has been made to understand and respond to these declining populations. Meanwhile, Pacific harbor seals (*Phoca vitulina richardsi*) on the U.S. West Coast have been increasing an average of 5% to 7% per year as a result of the Marine Mammal Protection Act of 1972, although harbor seal population numbers may be leveling off (Brown and Kohlmann 1998; Jeffries et al. 1999). Salmonid fishes are seasonally important prey for harbor seals, so quantifying and understanding the interactions between these two protected species is important for biologically sound management strategies.

One method of quantifying the contribution of salmonid fishes to the marine mammal diet is through the construction of consumption models (Olesiuk 1993) which require detailed knowledge of the predator's food habits. Although determination of food habits can be done using invasive methods, such as dissecting the stomachs of sacrificed animals (Mohn and Bowen 1996) or lavaging (Harvey and Antonelis 1994), a non-invasive method is much preferred. The non-invasive method most commonly used involves the morphological identification of indigestible parts (e.g., otoliths and bones) from scat samples. Otoliths alone can be used to identify species (Ochoa-Acuna and Francis 1995) but are not always present in scat samples, which can result in an underestimate of the number of species and the number of fish consumed (Boyle et al. 1990, Cottrell et al. 1996, Riemer and Brown 1997). Skeletal remains in scat samples are much more common and generally bones can be identified to the species level, however, with salmonid bones identification is only possible to the family level. Because some salmonid species are threatened or endangered, while others are abundant, it is important to know which species of salmonid is the prey of harbor seals. Given these requirements, this study explored the use of molecular genetic tools for species-level identification of salmonid skeletal remains recovered from Pacific harbor seal scat samples. In addition, we examined a small number of scat samples (n = 10) collected from river otter (*Lutra canadensis*) at Lake Ozette (WA).

Mitochondrial DNA (mtDNA) has been widely employed in systematic studies (reviewed by Avise 1994) making it ideal for animal species identification. In this study, we explored three regions of the mitochondrial genome that have been previously sequenced, partially or entirely, in Pacific salmon. DNA sequencing of these loci provided an unambiguous way to determine species identity; however, sequencing can become prohibitively laborious and costly for a large number of samples. To reduce time and cost, and to facilitate transfer of this technology to a laboratory with more limited facilities, restriction fragment length polymorphism (RFLP) analysis was explored as an alternative to sequencing.

In the first phase of the study, we developed and validated the genetic tools for species identification using frozen or ethanol preserved tissues collected from known species and known populations. In the second phase, we applied these tools to the identification of bone remains. Here we report the methodology associated with these two phases of the project. The salmon and trout bones that were identified in this study using genetics were incorporated into a larger study of the harbor seal diet and will be reported elsewhere (Orr et al. in prep).

Materials and Methods

Marker development and validation

The known tissue samples were collected over the past decade by the Conservation Biology Division (Northwest Fisheries Science Center (NWFSC)/NMFS/NOAA) and maintained either frozen or preserved in ethanol. Control populations were chosen to represent the range of chinook (*Oncorhynchus tshawytsha*), coho (*O. kisutch*), sockeye (*O. nerka*), pink (*O. gobuscha*), and chum salmon(*O. keta*), and steelhead (*O. mykiss*), coastal cutthroat trout (*O. clarki clarki*), and Yellowstone cutthroat trout (*O. clarki bouvieri*) (exact locations are listed in Table 1). Tissues were extracted with either a standard phenol/chloroform extraction (Sambrook et al. 1989) or using DNAeasy 96-well tissue kit (Qiagen; Valencia, CA[1]) following the manufacturer's instruction for tissue preparations.

Three mitochondrial regions were investigated in this study: the d-loop (Shedlock et al. 1992), a region spanning the cytochrome oxidase III (COIII) and ND3 genes (Domanico and Phillips 1995), and the 16s ribosomal gene (Parker and Kornfield 1996). The complete mitochondrial sequence was available from rainbow trout (Genbank: NC_001717; Zardoya et al. 1995). The d-loop (Shedlock et al. 1992) and ND3 (Domanico and Phillips 1995) regions were previously sequenced for all major salmonid species of the Pacific Northwest, and the COIII and 16s sequences were available for chum salmon (COIII: Oohara et al. 1997; 16s: Genbank: AF125512). Primers were either taken directly from these studies or designed from these sequences (Table 2). All primers were cycled with 2.5 mM $MgCl_2$, 0.8 mM dNTPs, 0.04 µM primers, 0.25 U of *Taq* DNA polymerase (Promega; Madison, WI), 20-40 ng of DNA, and cresol red loading buffer (final concentration 2% sucrose and 0.005% cresol red) for 35-45 cycles of 94°C for 45 seconds, 55°C for 45 seconds, and 72°C for 1 minute.

A single individual from each of the following species: chinook salmon (ID), coho salmon (WA), sockeye salmon (ID), chum salmon (WA), pink salmon (WA), steelhead (WA) and a coastal cutthroat trout (WA) were sequenced for both the 16s and COIII/ND3 loci. For DNA sequencing, the PCR products were purified with an Ultrafree MC column (Millipore; Beverly, MA) and resuspended in 20 µL of sterile water. Purified product (1-10 µL depending on band intensity) was sequenced directly using the USB ThermoSequenase cycle sequencing kit (Cleveland, OH) following manufacturer instructions. MACDNASIS (Miraibio Inc.; Alameda, CA) and SEQUENCHER (Gene Codes Corp.; Ann Arbor, MI) were used for sequence alignment and identification of diagnostic restriction enzyme cut sites.

For the restriction enzyme analysis, the unpurified ND3/COIII PCR product was digested in the presence of cresol red loading buffer. Restriction digests were incubated for 6 to 12 hours at 37°C for *Dpn* II, *Sau* 96I, *Fok* I, *Ase* I, at 50° for *Apo* I, and at 60°C for *Bst* NI using the supplied buffers (NEB; Beverly, MA) and 1-5 units of enzyme.

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[1] Reference to trade names throughout this paper does not constitute endorsement by the National Marine Fisheries Service.

Restricted products were electrophoresed in a 4%, 3:1 high-resolution and medium-resolution agarose gel (Continental Laboratory Products; San Diego, CA). Agarose gels were visualized with SYBR Gold following manufacturer's instructions (Molecular Probes; Eugene, OR). The haplotypes were scored with a simple alphabetic system: "A" was uncut (368 basepair (bp) band) and "B" was cut (size differed depending on enzyme). The enzyme *Apo* I has two cut patterns: the "B" haplotype occurs in steelhead salmon with the major band migrating at 300 bp and the "C" haplotype occurs in sockeye, chum, and pink salmon with the major band migrating at 250 bp.

Identification of bone remains

Personnel from the National Marine Mammal Laboratory (NMML) collected and processed harbor seal scat samples from the Umpqua River (OR) and river otter scat samples from Lake Ozette (WA). NMML researchers identified bone remains to either family or species level using morphological characters. From 39 distinct harbor seal scat samples, 146 bones belonging to the genus *Oncorhynchus* were transferred to a laboratory at the Northwest Fisheries Science Center for DNA analysis and identification to species. An additional 10 bones (representing 10 different scat samples) from river otter were also transferred and analyzed.

To prepare samples for DNA extraction, bones were soaked in 10% sodium hypochlorite for 10 minutes. To prevent DNA degradation, bones were rinsed twice in sterile water to remove all traces of the sodium hypochlorite. Bones ranged in weight from 0.1 to 105.6 mg and included teeth, vertebrae, gillrakers, radials and bone fragments (hereafter, all bony parts and teeth will be referred to as "bone"). The bones were decalcified overnight in 0.5M EDTA solution (Hochmeister et al. 1991); fragile or small fragments were not decalcified. The EDTA was removed and the decalcified samples were extracted with the QIAamp tissue extraction kit (Qiagen, Valencia, CA) using the manufacturer's instructions with the following modifications: (1) samples were proteinase K digested overnight or until completely digested, (2) 10 µg/mL yeast t-RNA carrier was added to the extractant before placement on the QiaQuick column, and (3) DNA was eluted in a reduced volume (50-100 µL of Buffer AE). Negative controls containing no tissue were carried through the procedure to verify that the extraction was free of contaminating DNA. Bones from a freshly killed cutthroat trout were used as a positive extraction control.

Bone DNA was not routinely quantified prior to PCR amplification but 5-10 µL of extracted DNA were used in each amplification reaction. When samples failed to amplify, we attempted to quantify the DNA or increased the amount of template in the PCR reaction. Amplification success was determined by electrophoresis through a 2% agarose gel followed by staining with ethidium bromide or SYBR Gold. Species identification was accomplished by sequencing of either the d-loop or the COIII/ND3 locus. RFLP analysis, using five of the six enzymes (*Bst* NI was excluded), was also used to identify species but, enzyme amount was reduced to 0.4-1.0 units and incubation time did not exceed 2 hours.

Results and Discussion

Marker development and validation

To confirm and complete the previous sequencing, the COIII/ND3 and 16s loci were sequenced for all seven species of interest (Figs. 1 and 2). These data have been deposited into Genbank. Sufficient nucleotide variation exists in the d-loop (Shedlock et al., 1992) and in the COIII/ND3 locus (Fig. 1) to distinguish among the Pacific salmon species. A single polymorphism was observed at position 341 between our ND3 sequence and the published ND3 sequence in chinook (Domanico and Phillips, 1995) (Fig. 1). Both the d-loop and COIII/ND3 proved useful for sequence-based identification of bone remains.

Since hundreds of bone samples may be collected for a single study and sequencing is laborious and costly, we sought to find a faster and less expensive method for species identification such as RFLP analysis. Using the MACDNASIS program, we selected six restriction enzyme in the COIII/ND3 PCR fragment (*Dpn* II, *Sau* 96I, *Fok* I, *Ase* I, *Apo* I, and *Bst* NI) that distinguish all the *Oncorhynchus* species (although, *Bst* NI is not actually required for species identification). The COIII/ND3 region was investigated for RFLP analysis because, in contrast to the d-loop, we found no intraspecific variation in our sequencing of the bone. Domanico and Phillips (1995) also reported a lack of intraspecific variation at this locus in their study. To further verify this absence of intraspecific variation and to ensure accurate species identification, samples of known *Oncorhynchus* species from multiple populations spanning a large geographic range were sampled for RFLP polymorphism within each species. No intraspecific polymorphisms were detected among: coho salmon from OR, WA, and British Columbia (BC); sockeye salmon from OR, ID, WA, BC, and Russia; chum salmon from WA, AK, Russia, and Japan; steelhead from CA, OR, WA, and Russia and cutthroat trout from OR, WA, and MT (Tables 1 and 3). A single intraspecific polymorphism was found with the *Dpn* II enzyme between two life history forms of chinook salmon, the fall and spring runs in the Columbia and Snake River Basins (Tables 1 and 3). Spring run chinook salmon from the Snake River and lower Columbia River had the "A" (uncut) haplotype at a frequency of 83% and 91%, respectively, whereas the fall run from the lower Columbia River was fixed for the "B" haplotype. The "B" haplotype was also fixed in all other populations examined (Sacramento River, CA; Puget Sound, WA; and the Frasier River, BC). Despite this *Dpn* II polymorphism, both haplotypes are chinook-specific.

Identification of bone remains

PCR reactions of DNA extracted from bone produced highly variable results. Amplification of bone extractions from a freshly killed cutthroat trout could consistently be amplified. From 146 harbor seal samples extracted, 44 (30%) failed to amplify after repeated attempts using all possible primer sets. This was most likely due to poor initial recovery of DNA from the sample. Among the scat bone samples, there did not appear to be a relationship between bone size and DNA extraction success. The smallest structure we successfully amplified was 0.2 mg (a tooth) and the largest was 21.8 mg (vertebra). In contrast to the 70% success rate in harbor seal, we were only able to amplify 4 of the 10 river otter bones (40% success). Bones from river otter scat were more degraded than bones from harbor seal scat, such that one possible cause of PCR failure could be the morphological misidentification of the bone fragments as an *Oncorhynchus* species. The d-loop and COIII/ND3 primers are likely *Oncorhynchus* specific and will not amplify other vertebrate genera. To test the possibility that the lack of PCR amplification was due to morphological misidentification, we used the 16s primers which are conserved across a broad set of taxa from Platyhelminthes through Chordata (Parker and Kornfield 1996) on all samples that failed to amplify. One of the river otter samples had apparently been morphologically misidentified and had a 100% homology to the published 16s sequence available for northern squawfish (*Ptychocheilus oregonensis*) (Simons and Mayden 1998).

After verifying the specificity of the RFLP analysis for distinguishing among *Oncorhynchus* species, the assay was applied to the bone samples. Restriction enzyme digestion required some modification when applied to the bone. On occasion, the restriction enzyme protocol developed for the fresh tissue generally resulted in degradation of the amplified bone PCR product. Enzyme amount and digestion times were scaled back significantly for the analysis of the bone samples. The *Fok* I enzyme proved the most difficult for the bone samples. This was not unexpected because *Fok* I can cut any two nucleotides if present at a high concentration relative to target or if allowed to digest more than two hours. *Apo* I and *Ase* I can also exhibit non-specific restriction activity if the enzyme is in considerable excess to target. In some cases, only very weak amplification was achieved with the bone samples and it was difficult to get digestion without degradation. While sequencing was the main techniques used for bone identification (n=84), 18 bones were identified using the RFLP technique. Additionally, 14 bones, previously identified by sequencing, were also subjected to RFLP analysis; the two techniques gave matching results. However, further application of the RFLP technique on a larger sample set (data not presented) suggests that the RFLP technique, using SYBR gold, is useful in approximately 60% of the samples and that the remaining samples may require the greater sensitivity of a radioisotope-based assay.

Conclusions

This study focused on the development of tools for the identification of salmonid bone remains recovered from harbor seal and river otter scat. These tools will assist in efforts to better characterize the diet of aquatic mammals and can also be used to address direct management questions in rivers such as the Umpqua River where threatened species occur. The harbor seal's diet in the Umpqua River consisted of non-salmonid fish and chinook, coho and steelhead salmon; no threatened cutthroat trout were observed in the scat samples (Orr et al. in prep). Extraction of DNA from the bones can be done with a commercially available kit with minor modifications. Sequencing or RFLP analyses are both viable methods of identifying the seven common *Oncorhynchus* species. A recently published study also identified restriction enzymes in the cytochrome B gene that distinguish among ten species, including: chum salmon, coho salmon, pink salmon, sockeye salmon, chinook salmon, rainbow trout, Atlantic salmon (*Salmo salar*), brown trout (*Salmo trutta*), Arctic char (*Salvelinus alpinus*), and brook trout (*Salvelinus fontinalis*) (Russell et al. 2000). This study reports fixed RFLP differences among these species but did not confirm the lack of intraspecific variation in a wide geographic survey of each species. Nevertheless, these primers may also prove useful in species identification of bone remains. The techniques established here will be useful for further study of aquatic mammal diets and may have potential for forensic type applications involving the genus *Oncorhynchus*.

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Table 1. Species, sample locations, and sample sizes (n) examined for restriction fragment length polymorphism at the COIII/ND3 locus.

Species	Population	Location	n
Chinook			
	Winter Run	Sacramento River, CA	1
	Fall Run, Abernathy	Lower Columbia, WA	1
	Spring Run, Wind River	Lower Columbia, WA	1
	Spring Run, Grande Ronde	Snake River, ID	1
	Kitsap Penisula, Grovers Creek	Puget Sound, WA	1
	Walker Creek, Upper Frasier	British Columbia	1
Coho			
	Edison Creek, Sixes River	Coastal, OR	1
	Marmot Dam, Sandy River	Willamette River, OR	1
	North Fork, Moclips River	Coastal, WA	1
	Minter Creek	Puget Sound, WA	1
	Yakoun River	British Columbia	7
Sockeye			
	Nehalem Ponds	Coastal, OR	4
	Redfish Lake	Snake River, ID	4
	Lake Ozette	Puget Sound, WA	1
	Lake Wenatchee	Inland, WA	1
	Babine Lake	British Columbia	2
	Alturas Lake	British Columbia	2
	Kamachatka River	Russia	9
Chum			
	Hood Canal	Puget Sound, WA	1
	Frosty Creek	Alaska	1
	Utka River	Russia	9
	Miomote River	Japan	1
Pink			
	Nisqually River	S. Puget Sound, WA	6
	Snohomish River Even Year	N. Puget Sound, WA	1
	Bacon Creek, Skagit River	N. Puget Sound, WA	7
	Hood Canal Hatchery	Hood Canal, WA	9
	Upper Dungeness	Strait of Juan de Fuca,	5
Steelhead			
	Gaviota Creek	CA	4
	Coquille River	Coastal, OR	8
	Upper Tucannon	Snake River, WA	1
	Finney Creek	Puget Sound, WA	1
	Quinalt National Fish Hatchery	Coastal, WA	1
	Tigil River	Kamatchatka , Russia	1
Cutthroat			
	Alsea River	Coastal, OR	2
	Alsea Hatchery	Coastal, OR	3
	Duwamish River	Puget Sound, WA	1
	Yellowstone River[1]	MT	5

[1]Yellowstone cutthroat trout (*O. clarki bouvieri*) is a separate subspecies from the Washington and Oregon coastal cutthroat trout (*O. clarki clarki*).

Table 2. Primer sequences, size of amplified product, and references for mitochondrial loci used in this study.

Locus	Primer Sequences (5'-> 3')	Product Size	Reference
d-loop	P2: tgt taa acc cct aaa cca g P4: gcc gaa tgt aaa gca tct ggt	230	Shedlock et al., 1992
COIII/ Nd3	F: tta caa tcg ctg acg gcg R: gaa aga gat agt ggc tag tac tg	368	Domanico and Phillips, 1995
16sV	F: tac ata aca cga gaa gac c R: gtg att gcg ctg tta tcc	260	Parker and Kornfield, 1997

Table 3. Restriction fragment length polymorphisms of the cytochrome oxidase III and ND3 locus digested with six restriction enzymes. The "A" haplotype does not cut with the enzyme, "B" cuts with the enzyme, and "C" cuts with the enzyme but at a different site than "B".

Species	***Dpn*II**	***Sau*96I**	***Fok*I**	***Ase*I**	***Apo*I**	***Bst*NI**
Chinook	A/B[1]	B	B	A	A	A
Coho	A	A	B	A	A	A
Sockeye	A	A	A	A	C	B
Chum	A	A	A	B	C	A
Pink	B	A	A	B	C	B
Steelhead	A	A	A	B	B	A
Cutthroat	A	A	A	A	A	A

[1]Spring run chinook from the Columbia and Snake Rivers were polymorphic for the *Dpn* II cut site. Spring chinook from the Wind River Hatchery on the lower Columbia River had the "A" haplotype at a frequency of 0.91 (n=12) and spring chinook from the Grande Ronde River of the upper Snake River had the "A" haplotype at a frequency of 0.83 (n=12). All other chinook samples from table 1 (including the fall run chinook from the Columbia River) were fixed for the "B" haplotype.

Figure Legend

Figure 1. Aligned sequences of the 3' region of the cytochrome oxidase III gene (COIII) and the 5' region of the ND3 gene for seven species of the genus *Oncorhynchus*. Sequence identity to chinook salmon is denoted by dots and nucleotide substitutions are indicated. The arrow at basepair 300 indicates the end of the COIII gene and the start of the ND3 gene. Stars above the sequence correspond to restriction enzyme cut sites used in this study. At position 341 in chinook, the R represents an A or G.

Figure 2. Aligned sequences of a variable portion of the 16s gene for seven species of the genus *Oncorhynchus*. Sequence identity to chinook is denoted by dots and nucleotide substitutions are indicated.

Figure 1

```
                            20    DpnII         40                  60
                               ****
Chinook    : TTACAATGCCTGACGGCGTGTACGGCTCTACTTTCTTTGTCGCCACCGGATTCCATGGCC
Coho       : ...................A..........................A.............
Sockeye    : ...................A....................T.....G............T
Chum       : ...................A........C.................A.............
Pink       : ...................A.....A..C...........A.....A.............
Steelhead  : ...................A.......................T..A.............
Cutthroat  : ...........................................T..A.............

                            80     BstNI       100     ApoI/Sau96I 120
                                  *****                  ******   ***
Chinook    : TACACGTGATTATTGGCTCAACCTTTCTAGCCGTTTGCCTTCTGCGACAGGTCCAATACC
Coho       : .......A.....C.............................A.....A..T.......
Sockeye    : .......A.................C..G..............A.....AA.T.......
Chum       : .......A..C..C..............G..T...........A.....AA.T.......
Pink       : .......A..C..C............T.G.....C........A.....AA.T.......
Steelhead  : .......A....................G..............A.....A..T.....T.
Cutthroat  : ....T..A....................G..............A.....A..T.......

               FokI           140                 160                 180
             **********
Chinook    : ACTTTACATCCGAACATCATTTTGGCTTTGAAGCTGCTGCTTGATATTGACACTTTGTAG
Coho       : ............................................................
Sockeye    : ..........T.......................C.........................
Chum       : .T..C.....T.......................C.........................
Pink       : ....C.....T..G....................C.........................
Steelhead  : ..........T.............................C...................
Cutthroat  : ..........T.................................................

                              200                 220                 240

Chinook    : ACGTTGTGTGACTCTTCCTATACGTCTCTATTTACTGATGAGGCTCATAATCTTTCTAGT
Coho       : .......A....................................................
Sockeye    : ......................................................C.....
Chum       : .........................T..................................
Pink       : ............................................................
Steelhead  : .......A..G.................................................
Cutthroat  : .......A....................................................

              AseI            260                 280                 300
             ******                                          End CoIII ->
Chinook    : ATTAACACGTATAAGTGACTTCCAATCACCCGGTCTTGGTTAAAATCCAAGGAAAGATAA
Coho       : ......G.....................................................
Sockeye    : ..C..TGA....................................................
Chum       : .....TTA....................................................
Pink       : .....TTA...CG.................T.............................
Steelhead  : .....T........................C.............................
Cutthroat  : ............................................................

               ApoI         DpnII                 340                 360
              ******        *****
Chinook    : TGAACTTAATTACAACAATCATCACTATTACCATCACATTRTCCGCAGTACTAGCCACTA
Coho       : ............................C.........C.G..T...............G
Sockeye    : ........G.............................C.G...................
Chum       : ......................T.....C...........G...C...............
Pink       : .....C..........G.....T...............C.G...................
Steelhead  : ....T.....C.............................A...................
Cutthroat  : ............................C...........G...................


Chinook    : TTTCTTTC
Coho       : ........
Sockeye    : ........
Chum       : .C......
Pink       : .C......
Steelhead  : ........
Cutthroat  : ........
```

Figure 2

```
                              20                  40                  60
Chinook   : GGAGCTTTAGACACCAGGCAGATCACGTCAAACAACCTTGAATTAACAAGTAAAAACGCAGT
Coho      : ........................................G.....................
Sockeye   : ..............................................................
Chum      : ..........................................C...................
Pink      : ...............C............A...A.............................
Steelhead : ...............................G..............................
Cutthroat : ...............................G..............................

                              80                 100                 120
Chinook   : GACCCCTAGCCCATATGTCTTTGGTTGGGGCGACCGCGGGGGAAAATTAAGCCCCCATGTGG
Coho      : ..............................................................
Sockeye   : ............G.................................................
Chum      : ...............................................A..............
Pink      : ...............................................A..............
Steelhead : ..............................................................
Cutthroat : ....................................T.............C...........

                             140                 160                 180
Chinook   : ATGGGGGCATGCCCCCACAGCCAAGAGCCACAGCTCTAAGCACCAGAATATCTGACCAAAAA
Coho      : ...............T............T...A.............................
Sockeye   : ..............................................................
Chum      : ......................G.....T....................T............
Pink      : ............T.........G.....T..............C..................
Steelhead : ......................G.....T...............................T.
Cutthroat : ......................G.....T..G..............................

                             200                 220
Chinook   : TGATCCGGCAAACGCCGATCAACGGACCGAGTTACCCTAG....
Coho      : ............................................
Sockeye   : ............................................
Chum      : ............................................
Pink      : ..........G.................................
Steelhead : .........G..................................
Cutthroat : ............................................
```

UPDATE ON THE NORTH PACIFIC HUMPBACK WHALE FLUKE PHOTOGRAPH COLLECTION, AUGUST 2000

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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 25,800 photographs by 2000, representing contributions from over 18 research groups, taken from all regions in the North Pacific (Tables 1 and 2).

Matches in The Database

Unique ID numbers (NMMLID) are assigned when there are at least 2 photographs of a particular individual whale in the database. As of August 2000, there were 25,834 fluke photographs in the database: 13,732 fluke photographs with a NMMLID (3,233 unique NMMLID numbers) and 12,109 fluke photographs without a NMMLID. The exact number of individual whales in the database cannot be determined at this time because the database has not yet been thoroughly cross-matched between areas and different research collections. Some of the unmatched photos may be unique whales that have only one photograph in the database, and other photos may be unmatchable due to photo quality.

Preliminary List of Matches Between Areas

In prior years, we have focused on integrating some of the long-term sightings, especially the Jurasz collection from southeastern Alaska, which dates back to 1968. Working with that collection kept our focus on matching Alaskan whales to the entire North Pacific database. This year, our focus shifted to matching whales photographed in Washington State (a fairly small sample of 128 photographs, see Table 2), and whales photographed in Mexican waters (a larger sample, 2,297, see Table 2).

A summary of matches of whales that have been photographed within and between different areas is presented in Table 3. This list is preliminary and does not imply rates of exchange between areas, because the database has not been thoroughly cross-matched within and between areas. However, during the past year, we've picked up some interesting new matches. This year, we found eight new matches between Washington State and Hawaii, our first documentation of movement between those areas. We've also added nine new Canada-Hawaii matches (formerly 22 whales, now 31). We found our first match between mainland Mexico and Hawaii, and we've also added 15 new matches between the Revillagigedos Archipelago and Hawaii (formerly 23 whales, now 38).

We've also added four new Baja California-Alaska matches (formerly 5 whales, now 9), two new mainland Mexico-Alaska matches (formerly 8 whales, now 10), and one new Revillagigedos-Alaska match (formerly 9 whales, now 10).

Life History Parameter Studies

Chris Gabriele of Glacier Bay National Park and Preserve presented results from the paper on estimating calf mortality at the 13th Biennial Conference on the Biology of Marine Mammals in Hawaii in December, 1999. A draft of that paper (Gabriele et al. in prep.) is in final review, and will be submitted to a journal before the end of 2000.

Jan Straley of University of Alaska has begun work on a paper on humpback whales birth intervals.

Sally Mizroch will be submitting a draft paper for review by co-authors on humpback whale adult survival by the end of August 2000.

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 past year we tested matching success rate with a database at over 25,000 photos (Mizroch and Harkness submitted). 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: 15 photos, quality 2: 80 photos; quality 3: 30 photos).

Tests of the system showed that, on average, the first match was found after examining approximately 130 photographs if the photograph quality was excellent or good. If photo quality was poor, the first match was found, on average, after examining approximately 220 photographs. Match success did not appear to be strongly related to whether the tail flukes had especially distinctive markings or pigment patterns (recognition quality). An advantage of computer-assisted matching is the ability to compare new photographs to the entire North Pacific collection, where no bias is introduced based on expectation of resightings within or between specific areas, or based on expectation of behavioral role (e.g., matching "known" females to "known" females).

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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	G. Kaufman
SeaSearch	SeaSearch	C, Jurasz
UABCS	Univ. Autonoma de Baja Calif. Sur	J. Urban
UNAM	Univ. Nacional Autonoma de Mexico	P. Lladron, 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*	*Oregon*	*Panama*	*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	65				90						155
1977	299		2		27						328
1978	267				68		84				419
1979	323				135		27				485
1980	630	4			511		68				1,213
1981	365				792		20			5	1,182
1982	195		1		310						506
1983	124	10	1		410		8				553
1984	375		1		310		10				696
1985	226	2	8		355		10				601
1986	523	96	4	1	866		107				1,597
1987	369	93	2		828	8	107				1,407
1988	259	111	16		1,362	18	164				1,930
1989	247	55	14	41	1,106	72	316				1,851
1990	143	115	13	3	969	122	247	23		1	1,636
1991	503	265	18		953	18	307				2,064
1992	898	398	28	10	890	15	180	5	2		2,426
1993	308	257	48		1,217	17	97				1,944
1994	575	242	88		415	37	82			13	1,452
1995	619	319			614	33	82			42	1,709
1996	28	41			946		252			34	1,301
1997	1				1		129			17	148
1998	1				41					9	51
1999	8									7	15
Total	7,496	2,008	244	55	13,219	340	2,297	28	2	128	25,817

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*	*Japan*	*Baja*	*Mainland*	*Revillagigedos*	*Oregon*	*Washington*
Alaska	953	1	7	406	-	9	10	10	-	-
California	1	521	2	1	-	26	65	1	19	4
Canada	7	2	70	31	-	5	4	2	-	21
Hawaii	406	1	31	1,877	2	7	1	38	1	8
Japan	-	-	-	2	6	-	-	-	-	-
Mexico - Baja	9	26	5	7	-	132	30	25	2	4
Mexico - Mainland	10	65	4	1	-	30	127	12	8	3
Mexico - Revillagigedos	10	1	2	38	-	25	12	172	-	3
Oregon	-	19	-	1	-	2	8	-	21	-
Washington	-	4	21	8	-	4	3	3	-	44

ABUNDANCE AND DISTRIBUTION OF RINGED SEALS (*Phoca hispida*) IN THE COASTAL CHUKCHI SEA, ALASKA, MAY-JUNE 1999

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Abstract

The National Marine Mammal Laboratory (NMML) conducted an aerial survey of the ringed seal population in coastal and offshore Chukchi Sea waters during May-June 1999. The surveys were designed to complement aerial surveys flown by the Alaska Department of Fish and Game (ADFG) in 1985-87 (Frost and Lowry 1988). Survey lines were flown during mid-day (1000-1600 local time) at an altitude of 300 ft (91 m) and a speed of 100 kt (185 km/h) along 20 nmi (37 km) tracklines perpendicular to the shoreline. In addition, 10 lines of 80-100 nmi (148-185 km) were flown far offshore to assess how coastal densities of seals changed as a function of distance from shore. To evaluate the time that ringed seals spent basking on the ice surface, we attached satellite-linked time-depth recorders to three adult ringed seals. Haulout patterns indicated that ringed seals showed a transition to basking behavior in late May, and that seals were generally hauled out between 1000 and 1700 local solar time. Aerial surveys indicated that ringed seals were relatively common in coastal areas, and that densities dropped off as distance from shore increased. The highest densities of ringed seals were found in coastal waters south of Kivalina. Bearded seals were generally more abundant farther from shore, with the exception of high bearded seal numbers observed south of Kivalina.

Introduction

Ringed seals are small phocid seals that are circumpolar and widely distributed, usually associated with areas of seasonal sea ice (McLaren 1958, Smith 1987, Kelly 1988). These seals have historically been important to subsistence hunters in the Arctic, and are also important prey species for polar bears (Stirling and McEwan 1975, Smith 1980); however, knowledge of ringed seal population dynamics is limited, due to the difficulty of assessing populations in ice-covered environments.

Ringed seals overwinter in areas of pack or shorefast sea ice, where they maintain breathing holes through the ice (Smith and Stirling 1975). During the winter, seals dig lairs in the snow surrounding their breathing holes, which they use for resting and for the birth and nursing of their young in March-May (McLaren 1958, Smith and Stirling 1975). Breathing holes and lairs are generally within 1 to 2 km of each other (Kelly and Quakenbush 1990) during the winter when seals' movements are constrained by the location of breathing holes in the fast ice. In late spring, the seals haul out for their annual molt on the surface of the ice near breathing holes or lairs (Smith 1973, Smith and Hammill 1981, Kelly et al. 1986). Increased temperature and day length at this time of year promote higher skin temperatures, which facilitates epidermal growth (Feltz and Fay 1966). Because seals are abundant above the ice and readily visible at this time, conditions are good for conducting aerial surveys of local distribution and abundance of the ringed and bearded seal populations.

Aerial surveys during late April through June, when ringed seals are easily counted on the ice surface, have indicated that ringed seals are distributed from as far south as Bristol Bay, northwards to the Beaufort Sea (Burns and Harbo 1972, Burns et al. 1981). Although ringed seals in the Beaufort Sea have been surveyed in 1996-1999 (Frost et al. 1997, 1998, 1999), seals in the eastern Chukchi Sea had not been assessed since 1985-87 (Frost and Lowry 1988). This paper presents the preliminary results of a ringed seal survey conducted in 1999 in the eastern Chukchi Sea.

Methods

Aerial surveys

Aerial surveys were flown along the northwest coast of Alaska from 23 May-6 June 1999. A team of 4-5 observers flew line transects from the shoreline to 20 nmi (37 km) or 100 nmi (185 km) offshore. To accommodate concerns raised by Alaska Natives hunting bowhead whales, the following aerial survey protocol was used to avoid disturbing bowhead whales and whaling activities near villages. The southern portion of the survey area was flown first, working progressively north to Barrow. A 15 nmi radius "no-fly" zone was maintained around the villages of Wales, Kivalina, Pt. Hope, Wainwright, and Barrow until whaling activities had been concluded. Whaling activities had concluded at Wainwright and Barrow by the time those areas were surveyed.

Survey lines and areas were chosen to correspond to areas surveyed in 1985-87 (Frost and Lowry 1988, Frost et al. 1988) to facilitate comparisons of ringed seal density estimates between their survey and ours (Fig. 1). In each of twelve survey zones from the northern coast of the Seward Peninsula to Barrow, 14 lines of 20 nmi (37 km) were flown at a speed of 90-100 kt (167-185 km/h) and an altitude of 300 feet (91 m) on a course generally perpendicular to the shoreline. In addition, 10 lines of 80-100 nmi (148-185 km) were flown far offshore to assess how coastal densities of seals changed as a function of distance from shore.

Aerial surveys were conducted between 1000 and 1600 local time, to coincide with the time of day when maximal numbers of seals haul out (Burns and Harbo 1972, Smith and Hammill 1981). Weather and ice conditions were recorded by an observer during surveys. In addition, a belly-mounted video camera recorded the ice concentration and characteristics during all survey flights.

Ringed seal capture and satellite tag deployment

Satellite-linked transmitters were deployed on three ringed seals to obtain detailed information on haulout behavior, which could be used to correct aerial survey counts for those seals not hauled out on ice. For this work, we collaborated with Dr. Brendan Kelly (University of Alaska, Fairbanks) at his field site at Reindeer Island from 1 to10 May 1999. Reindeer Island is approximately 6 nmi offshore from Prudhoe Bay, AK, in the sea ice of the Beaufort Sea. To capture ringed seals, subnivean seal lairs in the shorefast sea ice were located using trained dogs, remotely triggered nets were set up, and the breathing holes were continuously monitored in the lairs (Kelly 1996). After capture, satellite-linked time-depth recorders were attached to the seals' fur with epoxy glue. Location and haul-out data were collected from the recorders via the ARGOS satellite system.

Results

Ringed seals were relatively common in most coastal areas (Figs. 2 and 3; Table 1). Ringed seal densities declined as one flew farther offshore, and bearded seals were more common in offshore pack ice habitats. One exception to this general pattern was the higher densities of bearded seals observed within 20 nmi (37 km) of the coastline south of Kivalina, which is an area favored by Alaska Native subsistence hunters targeting bearded seals. Walrus, beluga whales, bowhead whales, and polar bears were also observed throughout the study area. Data analyses of both the sightings data and ice characteristics are underway.

Satellite-linked time-depth recorders deployed on three female adult ringed seals in May 1999 (Table 2) monitored the seals' dive and haul-out behavior through June. The termination of transmissions occurred at about the time when we would have expected the transmitters to fall off of the seals due to the completion of their molt cycle. Haul-out patterns from one ringed seal instrumented in early May indicated that the seal showed an abrupt transition in haulout behavior around 28 May (Figure 4). Presumably, this shift was associated with a change from using subnivean lairs to basking on the ice surface. In early May, while the seal was using subnivean lairs, haul-out periods tended to be scattered throughout the day. After the transition to basking behavior, the seal was generally hauled out between 1000 and 1700 local solar time.

Acknowledgments

We thank Dr. Brendan Kelly and his field crew for sharing their field camp and extensive knowledge of ringed seals, and for helping us with instrumentation of seals. Dave Weintraub of Commander NW, Ltd., is thanked for his capable piloting skills on the aerial survey, and the staff of the U.S. Fish and Wildlife Service's Selawik National Wildlife Refuge for logistical assistance in Kotzebue. Ronda Hinz was a tremendous help in data processing and assisting with density estimates.

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Table 1. Densities and estimated abundance for ringed seals in coastal (within 20 nm of shore) and offshore (20-100 nm from shore) Chukchi Sea waters, May-June 1999. "South" refers to the area north of Shishmaref, and "north" refers to the area north of Cape Lisburne. Note that estimated abundances have not yet been adjusted for seals that had not hauled out during surveys.

Survey Zone	Density (seals/nm^2)	Estimated abundance (seals)
C0	6.41	12127
C1	8.92	17143
C2 & T1	12.59	127710
C4 & C5	9.52	40246
C6	1.33	2583
B1	1.16	2282
Offshore area- south	1.67	21569
Offshore area- north	1.42	23670

Table 2. Ringed seals instrumented with satellite-linked time depth recorders at Reindeer Island, Beaufort Sea, May 1999.

Instrument number	Sex	Weight (kg)	Date of deployment	Date of last transmission
99-098	F	50.0	6 May 1999	28 June 1999
99-099	F	54.5	23 May 1999	27 June 1999
99-100	F	52.3	24 May 1999	15 June 1999

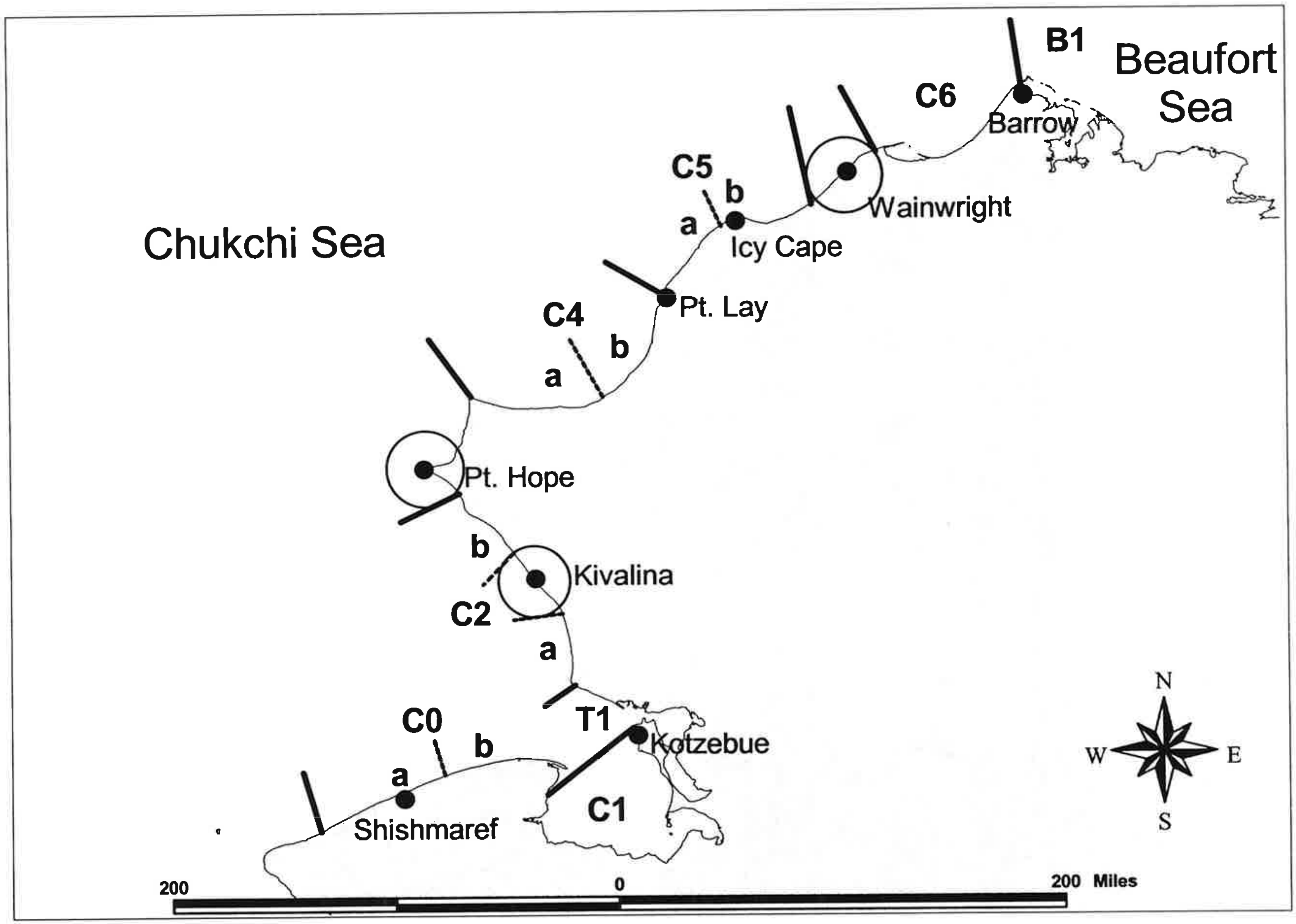
Figure Captions

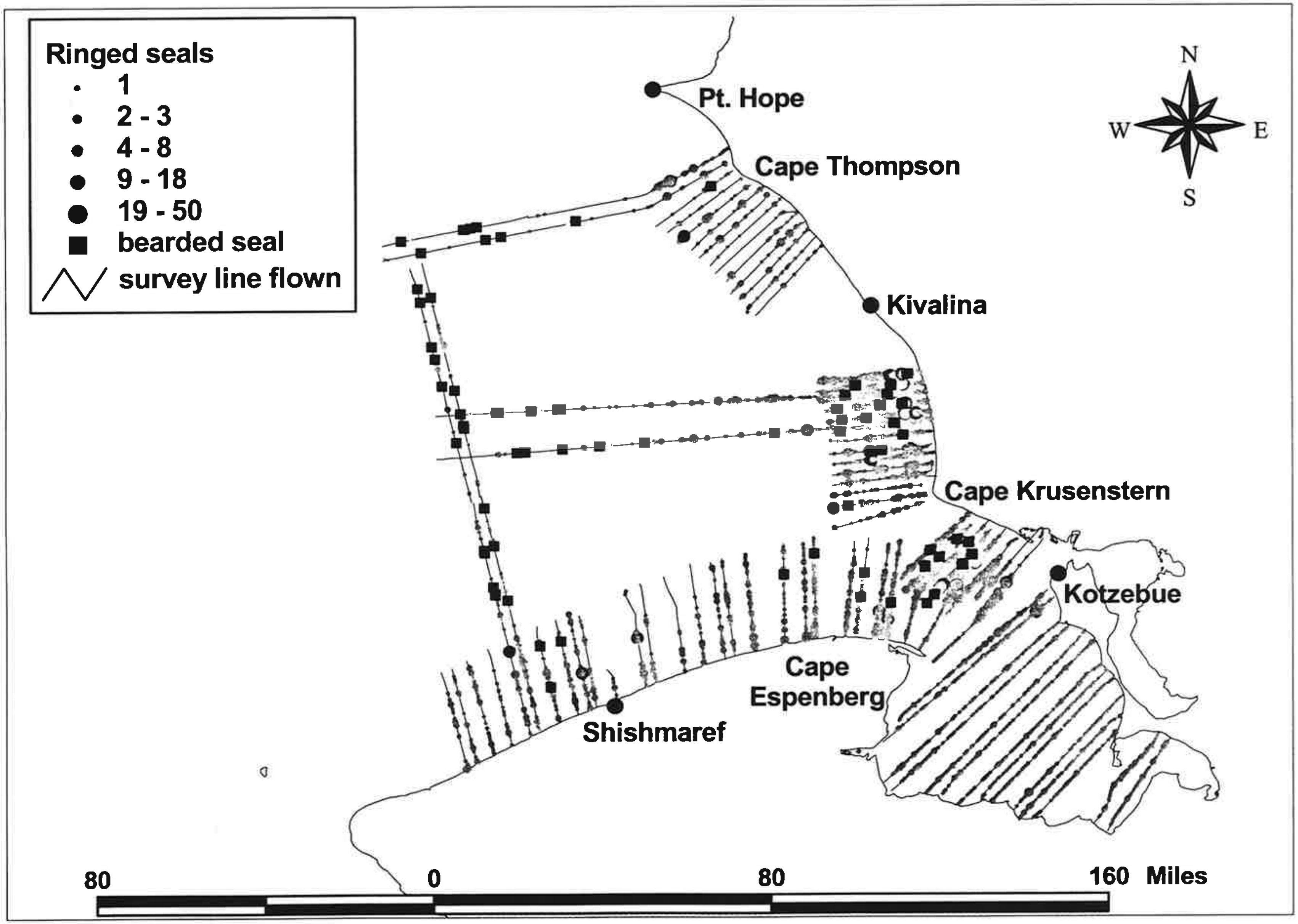
Figure 1. Zones for ringed seal aerial surveys in the eastern coastal Chukchi Sea, May-June 1999. Circles indicate 15 nm radius "no-fly" zones around whaling villages.

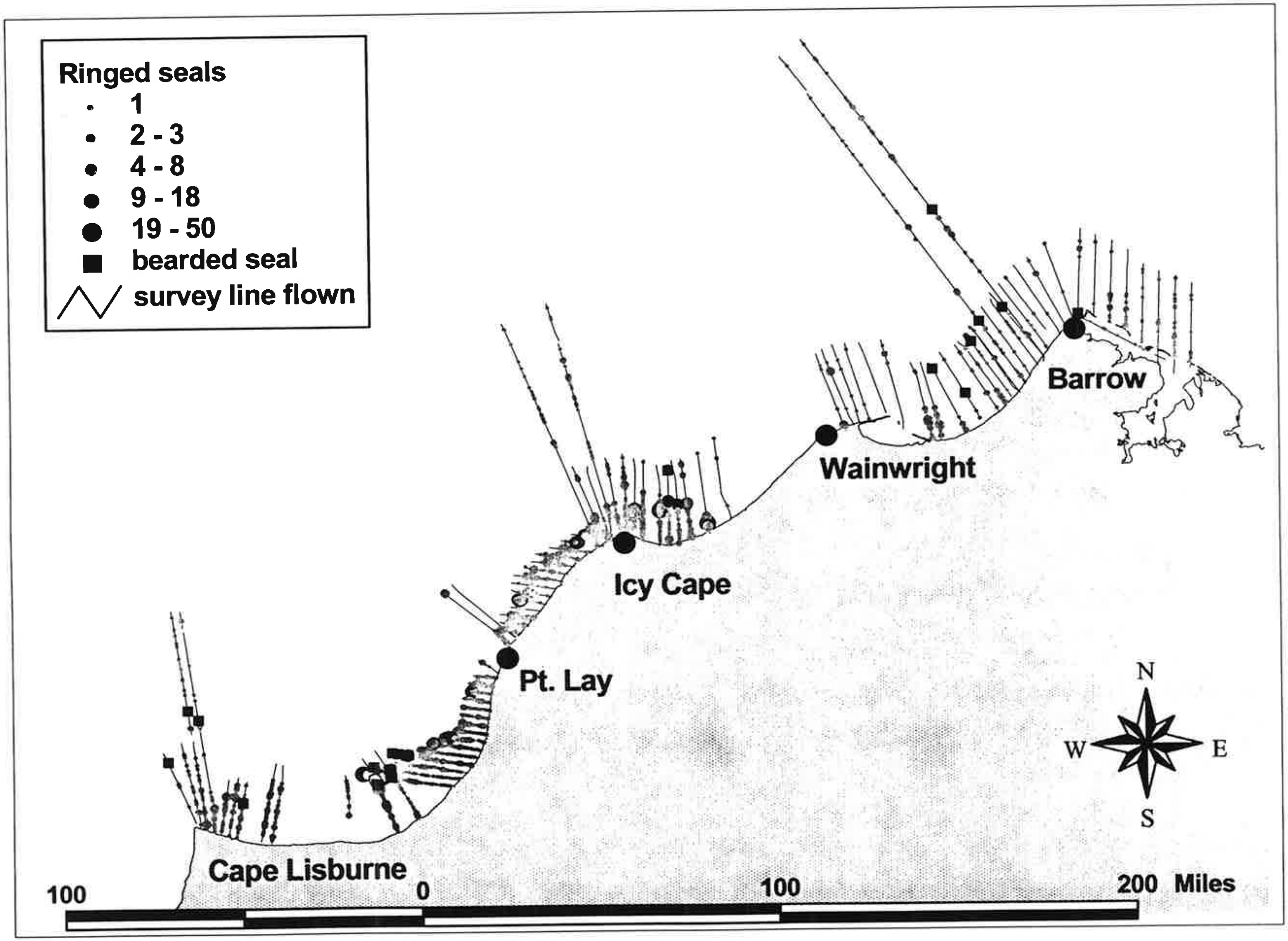
Figure 2. Observations of ringed and bearded seals along the southern part of the Chukchi Sea study area, Ikpek Lagoon to Point Hope, May 1999.

Figure 3. Observations of ringed and bearded seals along the northern part of the Chukchi Sea study area, Point Hope to Barrow, May-June 1999.

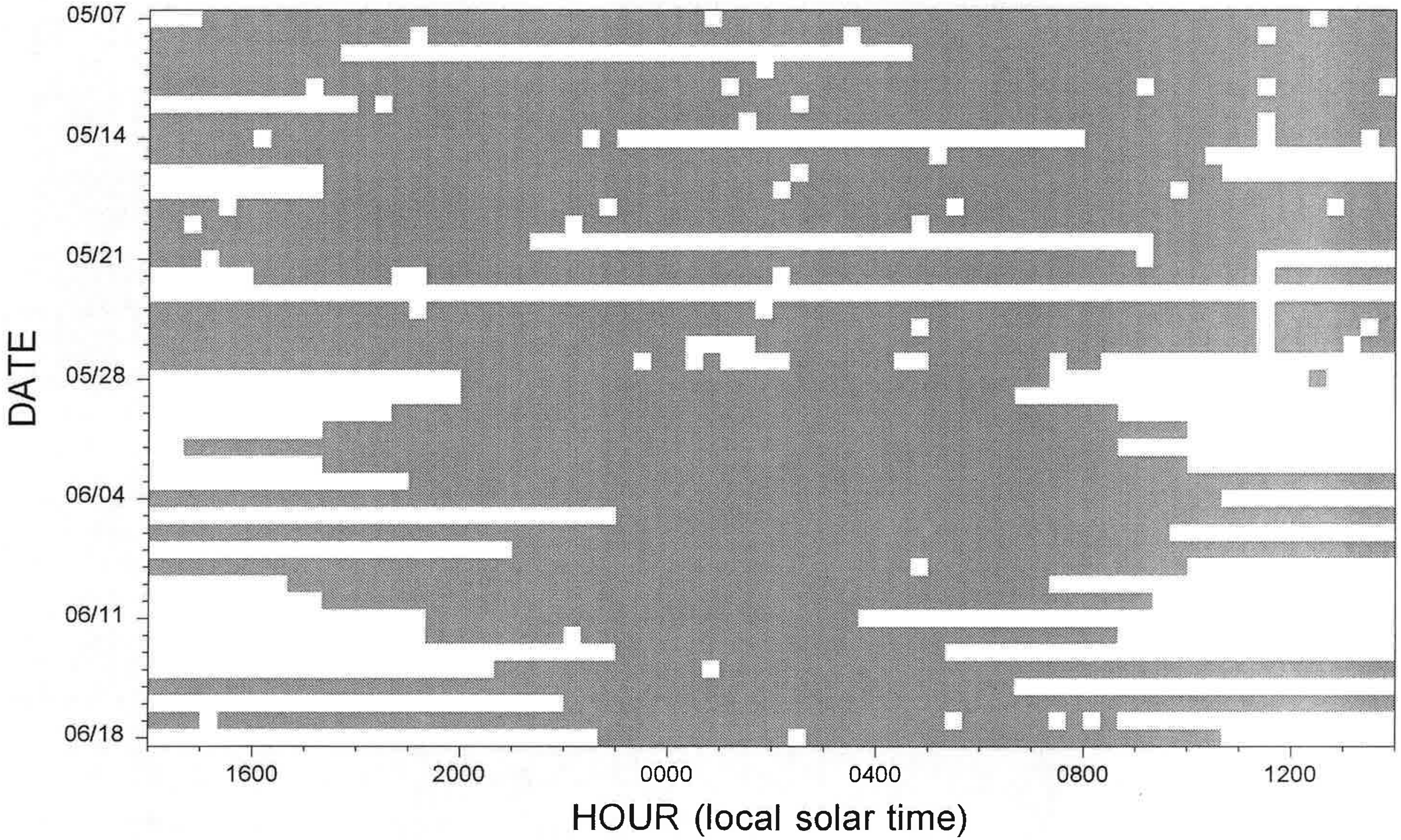
Figure 4. Ringed seal haulout patterns (in white) showing transition from using lairs under snow to basking on ice surface, around 28 May 1999.


B1
Beaufort Sea
C6
Barrow
C5
b
a
Wainwright
Icy Cape
Chukchi Sea
Pt. Lay
C4
b
a
Pt. Hope
b
Kivalina
C2
a
T1
Kotzebue
C0
b
a
Shishmaref
C1
N
W
E
S
200
0
200 Miles


Ringed seals
1
2 - 3
4 - 8
9 - 18
19 - 50
bearded seal
survey line flown
Pt. Hope
Cape Thompson
Kivalina
Cape Krusenstern
Kotzebue
Cape Espenberg
Shishmaref
N
S
W
E
80
0
80
160 Miles


Ringed seals
1
2 - 3
4 - 8
9 - 18
19 - 50
bearded seal
survey line flown
Barrow
Wainwright
Icy Cape
Pt. Lay
Cape Lisburne
N
S
W
E
100
0
100
200 Miles

RINGED SEAL HAULOUT PATTERNS (IN WHITE) SHOWING TRANSITION FROM USING LAIRS UNDER SNOW TO BASKING ON ICE SURFACE, AROUND 28 MAY



MORTALITY ESTIMATION AND HARVEST MONITORING OF ARCTIC ICE SEALS

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Abstract

Although the four ice-associated seal species (ringed, bearded, ribbon, and spotted seals) in the Bering, Chukchi and Beaufort Seas are important to subsistence hunters in Alaska, knowledge of their genetic discreteness, trends in abundance, life history status, and age structure is limited. Harvest information and biological specimens from Native Alaskan hunters can provide data for assessing life history status, contaminant load, stock structure, and population dynamics of these species. Samples of ice seal teeth, blubber and liver, reproductive organs, and skin were collected from the 1999 autumn subsistence hunt, and shipped to research laboratories for analysis. In addition, household interviews were conducted in the autumn of 2000 to assess the number and species of seals harvested.

Introduction

Four species of ice-associated seals inhabit the Bering, Chukchi, and Beaufort Seas: ringed, *Phoca hispida*; bearded, *Erignathus barbatus*; ribbon, *Phoca fasciata*; and spotted seals, *Phoca largha*. Despite the fact that these seals are important resources for Native Alaskans, as well as key ecological components of Arctic marine ecosystems, relatively little is known of the seals' genetic discreteness, trends in abundance, life history status, or age structure. As apex predators, these seals are at or near the top of the food web, and consequently often concentrate a variety of contaminants (e.g., heavy metals, organochlorines) that are potentially harmful to the human populations that consume these seals. In addition, the distributions of these seals (and therefore their availability to subsistence hunters) are highly sensitive to suitable sea ice conditions, and as such, may be particularly vulnerable to climatic change. Reductions in extent of Arctic sea ice, coincident with warming trends, have already occurred, and may indicate the onset of long-term polar warming predicted by climatic models.

Obtaining harvest information and biological specimen materials from ice seals can allow scientists to learn a considerable amount about the life history status, contaminant loads, and changes in trends of seal populations. Because of their wide distribution and extended seasonal movements, Arctic ice seals represent apex predators that integrate environmental conditions throughout the Bering and Chukchi Seas on broad spatial and temporal scales. Seasonal and inter-annual changes in the physical and biological environmental conditions encountered by seals throughout this zone are likely to influence the seals' diet, behavior, and physical condition. In particular, one would expect that if broad ecological shifts occurred, such changes would be reflected in these seals' life history parameters (e.g., diet, growth rates, reproductive condition). The life history parameters of ice seals may provide an additional source of information on how physical and biological features of the Bering and Chukchi Seas ecosystem have changed and affected these ice-dwelling predators. Contaminants analyses can be conducted on blubber and organs (e.g., liver) to help clarify the extent of potential risks to human health posed by eating harvested seals. Furthermore, because these seals are relatively long-lived, their hard tissues (i.e., teeth) offer researchers a chronological record that can be used to investigate inter-decadal changes within the ecosystem.

The objectives of this project are to: 1) assess the annual mortality levels of Alaska ice seals (ringed, bearded, spotted, and ribbon seals) taken in subsistence harvests, and 2) collect and analyze biological specimen material from harvested seals to begin assessing the age structure and reproductive status of seals taken, as well as evaluating the stock structure of ice seals through genetic analyses.

Methods

Tissue sampling

An Alaska Department of Fish and Game (ADFG) marine mammal biologist traveled to Shishmaref and Gambell in autumn 1999 to coordinate the sampling effort in cooperation with Alaska Native hunters. Alaska Native hunters were requested to procure samples of ice seal teeth (for age estimation), blubber and liver (for contaminants analyses), reproductive organs (for reproductive status), and skin (for genetics) from the 1999 autumn subsistence hunt. The Alaska Nanuuq ("Polar Bear") Commission and the Eskimo Walrus Commission assisted in facilitating contacts with relevant Alaska Native hunters so that arrangements could be made to gather harvest information and to obtain specimen material (note: hunters belonging to the Alaska Nanuuq Commission are also involved in hunting ice seals). Biological specimen material was collected and prepared for shipment according to scientific protocols provided by the National Marine Mammal Laboratory (NMML) (following consultations with Alaska Native hunters and collaborators at the ADFG, the NOAA/BRD Alaska Marine Mammal Tissue Archival Project (AMMTAP), and the NOAA Marine Mammal Health and Stranding Response Program). From these collections, teeth were provided to NMML staff; stomach contents will be analyzed by ADFG; and reproductive tracts were preserved and archived for future analysis.

Household interviews

To supplement specimen collection, household interviews were undertaken in the autumn of 2000. These interviews consisted of visiting each household in a village and asking a brief series of questions (e.g., about 10 minutes) concerning how many seals, what species, etc. were taken by that household during the autumn harvest. Estimates of struck and lost seals were also solicited. In addition to questions about seals harvested, the occupants of the household were asked what information they are most interested in concerning seals. Their responses will assist biologists in ensuring that future ice seal research includes a focus on issues of most concern to Alaska Native constituents.

Results

Plans were set in place for a system to monitor subsistence harvests of ice seals at all the main hunting villages located in areas under the jurisdiction of the North Slope Borough (Kaktovik to Kivalina), the Maniilaq Association (Kotzebue area), and Kawerak Inc. (Shishmaref to Norton Sound, including St. Lawrence Island). Unfortunately, as steps were taken to implement these plans, it became apparent that the personnel resources available were insufficient to cover as wide an area as had been desired for all of this project's original objectives (i.e., collecting specimen material and estimates of the numbers of seals harvested).

Good tissue samples were obtained from Shishmaref (n = 29), including 19 ringed seals and 10 spotted seals. Due to unexpected changes in the availability of the harvest monitor in Gambell, it was only possible to obtain samples from 5 seals (3 bearded seals, 1 ringed seal, and 1 ribbon seal). These tissue samples have been curated and shipped to ADFG (stomachs, reproductive tracts), NMML (teeth), and NMFS' Southwest Fisheries Science Center (genetics samples) for analysis. NMML's tooth samples have been thin-sectioned and examined by microscope to estimate ages of harvested seals. Contracts have been set in place to support a specimen collector in Barrow (and again in Shishmaref) in the autumn of 2000.

In regard to gathering information on the numbers of ice seals harvested, household interviews of Native subsistence hunters were conducted during the autumn of 2000. At present, the results of those surveys are still being consolidated into a report by the contractors. When completed, those results should provide an estimate of the take level and composition of subsistence harvests of ice seals undertaken from the Bering Strait north and east to the Canadian border.

NORTHERN FUR SEAL STUDIES CONDUCTED ON THE PRIBILOF ISLANDS AND BOGOSLOF ISLAND, 1999

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Introduction

In 1999, studies of northern fur seals (*Callorhinus ursinus*) were carried out on the Pribilof Islands, Alaska during July to September, and on Bogoslof Island during the month of July. Areas of research included subsistence harvest tissue collections, adult male counts, analysis of pup production data from the 1998 census, offspring condition, prey selection, incidence of entanglement, pup mortality and disease, as well as special studies of juvenile male 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 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 1,291 sub-adult male seals were taken in the subsistence harvest by St. Paul Island residents in 1999. One female and one bull seal were accidentally killed on St. Paul Island. On St. George Island, 193 sub-adult male seals were taken in the subsistence harvest in 1999. Tooth samples were obtained from approximately 20% of the 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 9 to 16 July 1999. A total of 3,767 harem and 7,589 idle adult male seals, also referred to as bulls, were counted on St. Paul Island. On St. George Island, a total of 1,052 harem and 916 idle adult male seals were counted from 11 to16 July. The counts of territorial males with females on St. Paul for 1999 showed a marked decrease compared to 1998 (approximately 20% lower). This is the 6th year in succession we have seen this trend (mean = -3.1% per year, via regression estimate). For St. George the territorial males with females were down by 17%, consistent with the decline on St. Paul.

Number of Pups Born on St. Paul Island

The number of fur seal pups was estimated on seven sample rookeries in August 1998 using the shearing-sampling method. Sample rookeries were chosen from the rookeries not selected in 1996, the first year we returned to sub-sampling rookeries (following the protocol described in York and Towell, 1997). The total number of pups alive at the time of sampling was determined for each of the sampled rookeries using a Peterson estimate (York and Towell, 1996). The total number of pups alive at the time of sampling on all rookeries was estimated by multiplying the total number of breeding males from all rookeries by a jackknife ratio of pups to breeding males on the seven sample rookeries (York and Kozloff 1987; York and Towell, 1997). The total number of dead pups was estimated from the mortality rate on the sampled rookeries. The total number of pups born was estimated by summing the estimates of live and dead pups. Variances of numbers of pups and mortality rates were estimated following York and Kozloff (1987) and York and Towell (1997); in addition, bootstrap variances of the parameters based on 2,000 replicates were also obtained.

The estimate for the total number of pups alive on St. Paul Island at the time of marking in 1998 was 174,091. The empirical standard error was 6,017; the bootstrapped standard error was slightly larger (6,267). The number of dead pups was estimated to be 5,058 (2,258 counted on sample rookeries and 2,800 estimated on the other rookeries; the estimated mortality rate for late August was 2.82% (SE = 0.06%). The estimate of the total number of pups born on St. Paul Island in 1998 is 179,149 (SE = 6,193); the standard error accounts for variance in the estimation of both live and dead pups (York and Towell, 1996). The approximate 95% confidence interval of pups born in 1998 was computed by multiplying the standard deviation of the jackknife ratio of pups to breeding males (e.g., York and Kozloff 1987) by 2.365 (the 97.5 percentile of Student's t-distribution with 7 degrees of freedom) and was 179,149 ± (2.365 X 6,193), or 179,149 ± 14,646, or (164,503 - 193,795). The bootstrapped median estimate of the total number of pups born (179,232) is similar to the above, as is the standard error (6,550), and 95% confidence interval (164,542 - 188,462) based on 2,000 replications of the estimation process.

The above total does not include the pups on Sea Lion Rock. The last direct census of fur seals pups on Sea Lion Rock (1994) estimated 12,891 pups born (12,589 = live, 302 = dead). If we add this number to the St. Paul estimate calculated above, total pup production on St. Paul Island was 192,040; this value is comparable to years when a census was done on Sea Lion Rock. The total estimated number of pups born in on St. Paul Island in 1998 was not significantly different ($P = 0.82$) from 1996, but was significantly less than the estimate in 1994 ($P < 0.01$).

Number of Pups Born on St. George Island

The number of pups born on St. George Island was estimated from a shearing-sampling study conducted on all rookeries. The most recent estimate of pup production prior to this study was obtained in 1996. From 8 to 10 August, a total of 3,144 pups were shear-marked on St. George Island. The ratio of marked to unmarked pups on each rookery was determined by two researchers on two occasions: once from 13 to 14 August and again from 17 to 23 August.

Counts of dead pups were made from 18 to 21 August 1998. The estimate of the number alive was calculated similarly to the method described for St. George Island for 1994 (York and Towell 1996) with the ratio of marked to unmarked pups determined by two researchers only. The estimated total number of pups alive on St. George Island at the time of marking was 21,638 (SE = 222). The total number of dead pups was 452 and the estimated mortality rate was 2.05%. The total number of pups born on St. George Island and the approximate 95% confidence interval was 22,090 ± (2.447 X 222), or 22,090 ± 543, or 21,547 - 22,633. The bootstrapped median estimate was similar (22,135); the standard error (388) and 95% confidence interval was somewhat larger (21,426 - 22,894).

The 1998 estimate of pups born on St. George Island is significantly less ($P < 0.01$) than the number of pups born in 1996, but the estimate is not significantly different ($P = 0.22$) than the estimate of the number of pups born in 1994. The 1996 estimate of the number of pups born on St. George Island was the highest since 1985, when over 28,000 pups were born.

Estimate of Total Stock Size

Crude estimates of the total fur seal abundance have been presented in the past (Loughlin et al. 1994). These estimates were calculated by multiplying the average number of pups born over the past 3 censuses by a correction factor of 4.47. That correction factor was derived from estimates of survival and fecundity (Loughlin et al. 1994) from data collected at sea during 1958-1974. Therefore, a strong assumption built into the estimate is that these vital rates are still valid. Since we cannot verify these assumptions, the estimate must be viewed only as a rough approximation. The estimate of the total stock for the Pribilof Islands population in 1998 is about 973,000 fur seals. The total stock size for the United States, which includes the Pribilof, Bogoslof, and San Miguel, (CA) populations, is about 1,004,000 fur seals.

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 24-25 August 1999, a total of 1,081 pups (462 female, 619 male) were weighed and measured on St. Paul Island. The mean weight of male and female pups was 8.89 kg (SD = 1.65 kg) and 7.73 kg (SD = 1.44 kg), respectively. The mean length of male pups was 74.3 cm (SD = 4.53 cm) and for females the mean length was 71.66 cm (SD = 4.44 cm).

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 24-25 1999, a total of 34 scats were collected on St. Paul Island. An additional 37 scats were collected from juvenile male haul-out sites on Bogoslof Island on 31 July 1999. 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 1999, the St. Paul Island Tribal Government continued a study of juvenile and adult male fur seal entanglement during the subsistence harvest. Researchers also 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.

Nine subsistence harvest surveys were conducted on St. Paul Island during July and early August of 1999. Observers sampled 2,350 male seals of all age groups combined on St. Paul Island. Six entangled juvenile and adult male seals were captured, examined, and the debris was removed during harvest surveys. The rate of entanglement was 0.26% (6/2,350) on St. Paul Island. Two adult female fur seals were observed entangled out of 22,820 females surveyed during bull counts on St. Paul Island. The rate of entanglement among females was calculated at 0.009% for entangled females. The 1999 data are comparable to the observed rate of "entangled" and "entangled and scarred" females combined from 1992 to 1998.

Pup Mortality and Disease

On St. Paul Island, dead pups were collected from two sites on a daily basis from 5 July to 12 August 1999. A total of 110 dead pups (49 females and 61 males) were collected and necropsied. Tissues for toxicological and disease studies were collected from 39 pups. A detailed contract report prepared by Wildlife Pathology International regarding disease surveillance in 1999 is available at NMML.

Foraging Studies

In 1997, a total of fifteen 3-5 year old juvenile male fur seals were tracked during foraging trips to sea with satellite and radio transmitters during foraging studies on St. Paul Island. Four of these males were instrumented with a time-depth recorder in addition to the satellite and radio transmitter. Fecal material (in the form of scat or enema) was collected when possible from males captured during 1998, for detailed prey analysis. Preliminary information from radio and satellite telemetry indicated that, during 1998, juvenile male northern fur seals on St. Paul Island made foraging trips averaging 17 days in duration and traveled an average of 490 km maximum distance from their initial haul-out site.

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INVESTIGATIONS OF PINNIPED INTERACTIONS WITH LAKE OZETTE SOCKEYE SALMON, *Oncorhynchus nerka*, 1999

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Abstract

Lake Ozette sockeye salmon, *Oncorhynchus nerka*, were listed as threatened under the U.S. Endangered Species Act in March 1999. The reasons for the apparent decline of Lake Ozette sockeye salmon are unknown but possible causes include destruction of spawning habitat, overharvesting, and predation by marine mammals or other fish predators. We initiated a research project in the Spring of 1998 in cooperation with the Makah Indian Tribe and the National Park Service (NPS) to investigate the interactions between Lake Ozette sockeye salmon and marine or aquatic mammalian predators. The results of the 1998 research were reported in Gearin et al. (1999). Research on interactions between pinnipeds and Ozette sockeye salmon were continued in 1999, focusing on observations of predator distribution and activity in the lower Ozette River, Lake Ozette surveys and summaries of videotape documentation of predation activity and scarring rates. During 1999, no predation on sockeye salmon by harbor seals or river otters was observed during 22 days of observations at the lower Ozette River. Harbor seals and river otters though were commonly observed foraging in the lower river. Harbor seals were only observed during two of ten Lake Ozette surveys conducted from August 30, 1999 through January 31, 2000. Harbor seals were observed by Makah and NPS personnel near the lakeside sockeye spawning grounds on at least six days during their dive surveys. Sockeye salmon carcasses were noted on the bottom during one survey which appeared to have been eaten by seals.

Data from video and weir observers observed river otters carrying sockeye salmon in their mouths ten times during the season and harbor seals five times. Data from the videotapes

indicated that at least 10% of the fish passing through the weir had predator scars consistent with pinniped marks.

Introduction

Lake Ozette sockeye salmon, *Oncorhynchus nerka*, were listed as threatened under the U.S. Endangered Species Act in March 1999 by the National Marine Fisheries Service (NMFS, March 1999). The Lake Ozette Evolutionary Significance 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 salmon escapement.

The Lake Ozette sockeye salmon 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). The average estimated run size from 1977 to 1995 was 951 fish, with lows of 263 in 1990 and high peaks of 2,191 in 1988 (Makah Fisheries data in: Jacobs et al. 1996). The majority of adult sockeye salmon 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, overharvesting, competition, and predation.

A study was initiated in the spring of 1998 to investigate the interactions between pinnipeds and Lake Ozette sockeye salmon Gearin et al. (1999). Harbor seals, *Phoca vitulina*, California sea lions, *Zalophus californianus*, and Steller sea lions, *Eumetopias jubatus*, are all seasonally abundant in close proximity (1-3 km) to the mouth of the Ozette River. The river otter, *Lutra canadensis*, is also common both in the Ozette River and in Lake Ozette. Food habits studies of these predators in 1998 did not reveal evidence of predation on sockeye salmon from scat samples collected at nearby haul-out sites. However direct evidence of predation by harbor seals and river otters was documented by the Makah Tribe on videotape at the fish weir. In 1998, river otters were observed on videotape 82 times passing through the opening in the weir and at least eight times with sockeye salmon in their grasp. Harbor seals were observed passing through the weir at least eight times and on one occasion with a sockeye salmon in it's mouth. The videotapes also indicated that upwards of 15%-20% of the fish passing through the weir had predator scars indicative of pinniped predation activities.

This report summarizes the results of investigations of pinniped interactions with Lake Ozette sockeye salmon during 1999. The efforts during 1999 focused primarily on conducting surveys in Lake Ozette during the spawning season and intensive land-based surveys for predation activity in the lower Ozette River during the peak timing of the sockeye salmon migration into Lake Ozette.

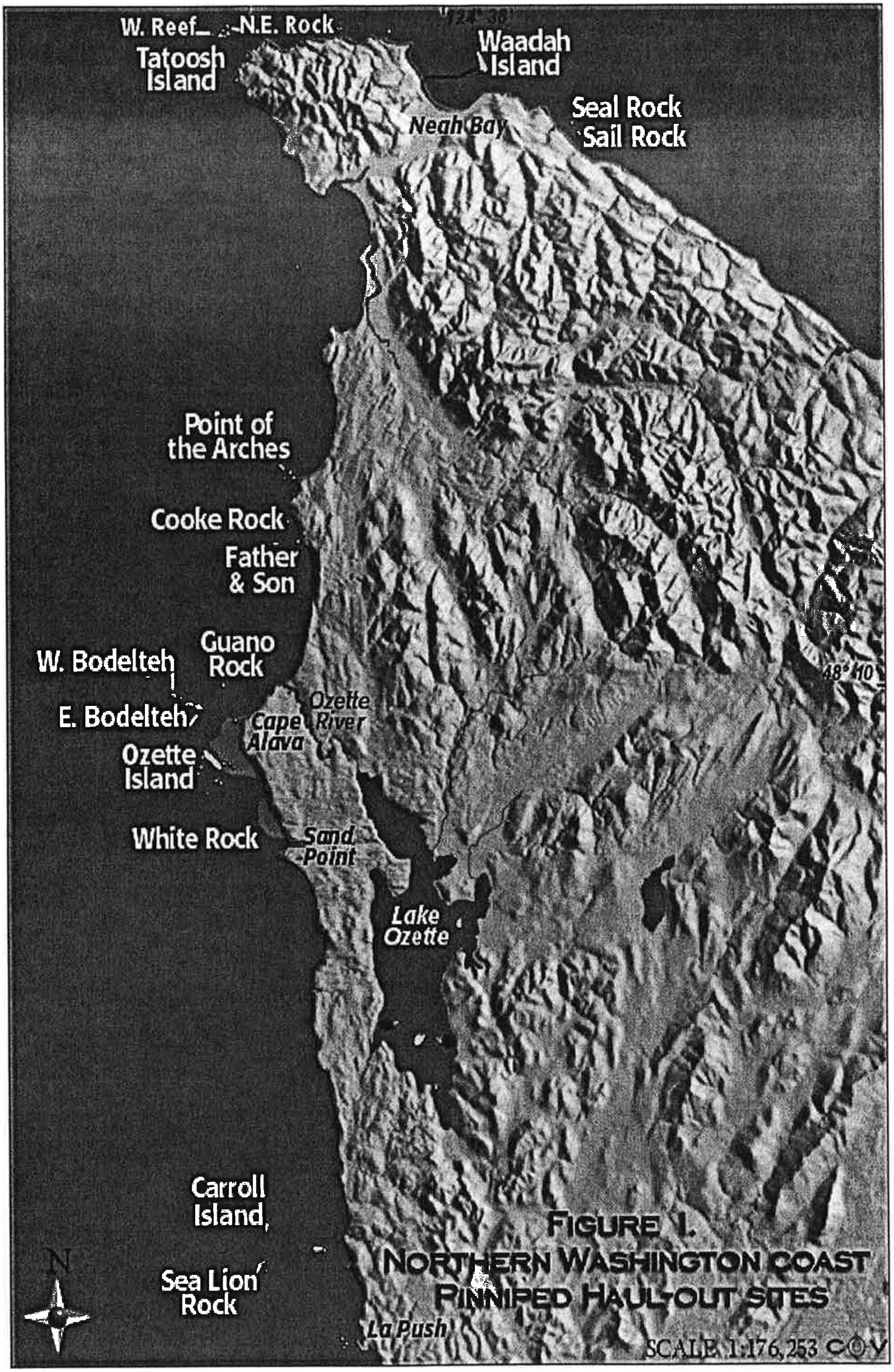

Figure 1. Ozette study site region.

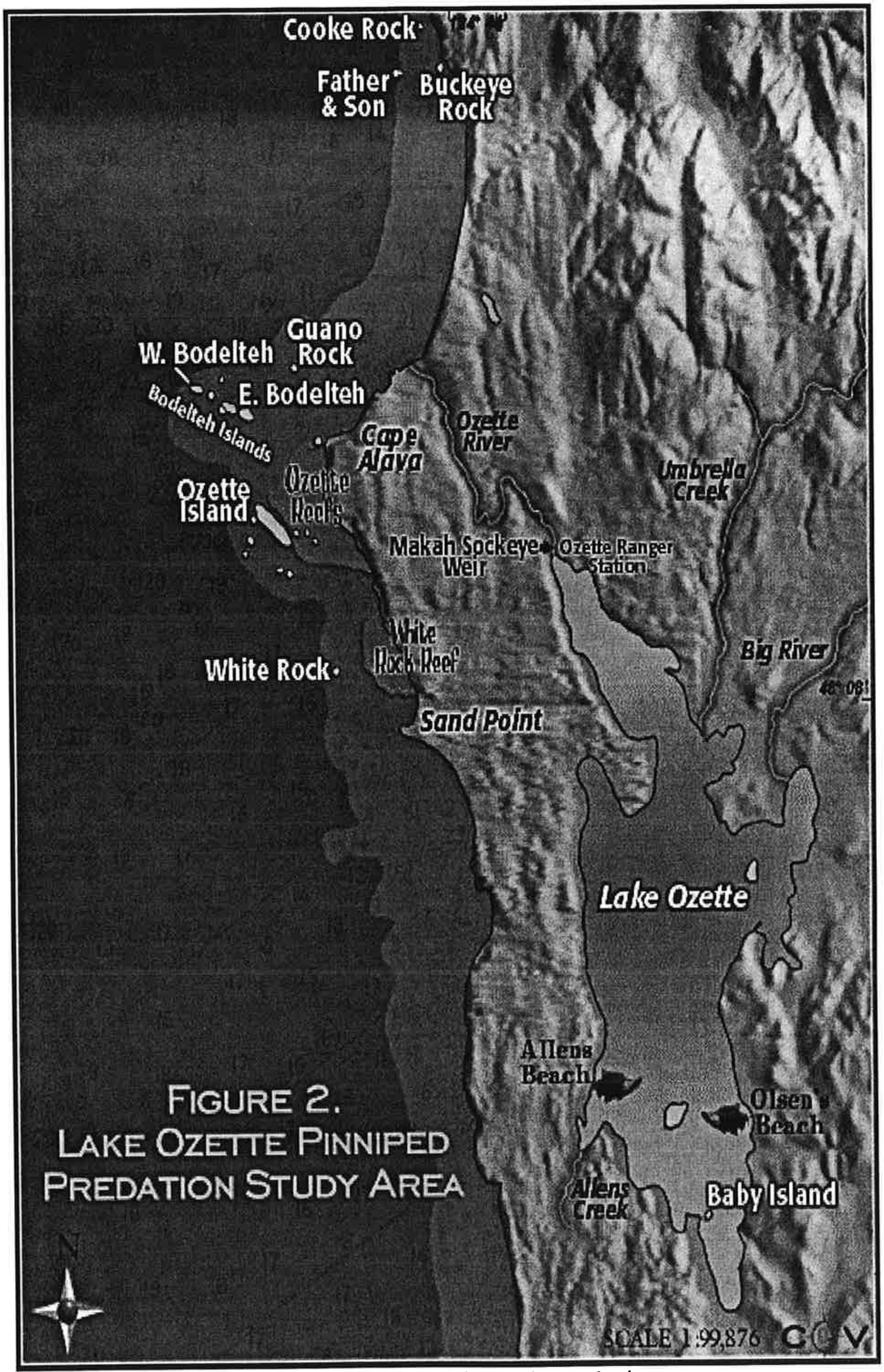

Figure 2. Lake Ozette Sockeye salmon/ pinniped interaction study sites.

Materials and Methods

Ozette River Observations

Land-based observations were conducted at the mouth of the Ozette River from 8-29 June. Observations were made from two locations; one from a 5 m high blind at the mouth of the river on the north side and one about 300 m upriver from a surface level blind. The station at the mouth of the river surveyed the lower river from the surf zone to about 200 m upstream. All high tide cycles were surveyed both day and night from 2 hours before high tide to 3 hours after the tide. A monocular night vision scope was used during nighttime tides. The field of view using the monocular scope was limited to about a 10 m wide span and a distance of roughly 100 m out from the blind. By swinging the scope back and forth though and scanning the river up and down stream, most of the river and surf zone could be covered. It's possible that seals could have been missed during the scans but unlikely that predation activity which created ripples or splashes would have been missed. We did observe racoons, deer, and otters swimming in the river during the nocturnal observations with the night vision scope, suggesting that seals would have been seen if present. Observations were also made on a random sample of low tide periods during night and day. The presence of harbor seals or river otters and their activity was recorded.

Lake Ozette predator and spawning ground surveys

Vessel surveys were conducted at Lake Ozette between 24 June 1999 and 31 January 2000 to record the presence and distribution of harbor seals or river otters. Vessel surveys were conducted at 100-150 m from the shore and followed the contour of the lake. At Olsen's and Allen's beaches, the two main spawning sites, the vessel paused for 20-30 minutes to scan for predators. Spawning areas were surveyed by snorkel and scuba dive surveys by the Makah Tribe and NPS on a weekly basis after November 15th. The results of the these surveys are only reported here as they relate to harbor seal activity.

Video tape documentation at the sockeye weir

The Ozette sockeye weir was deployed from May 1 through September 15, 1999. A time-lapse video system was deployed from May through August 1999 to record the passage of sockeye and interactions with predators. The video system documented the passage of harbor seals and river otters through the fish weir and enabled a minimum calculation of predator scarring rates as fish traveled through the weir opening. The fish scarring rates are considered a minimum estimate because fish were only photographed on the left side as they passed through the weir and because the light level and angle of fish passing through did not enable a fine enough image to determine with complete accuracy all potential predator scars.

Results

Ozette River observations

Observations of the lower river from the blinds focused on the distribution, abundance and foraging activity of potential sockeye salmon predators during high tide cycles. The Ozette River is not accessible to seals or salmon during low tides since it is blocked by a sand bar at this time. From 8-29 June, a total of 278 hours of observations was made from the lower river blind site (Table 1). High tide observations during this interval totaled 198 hours. In addition, 99 hours of observations were made during high tide cycles at the upriver blind. A random sample of low tide observations were also made both during the day and night, totaling 62 hours. Harbor seals were observed in the river or in the surf zone at the river mouth during 12 of the 22 observation days and during 18 of the 35 high tide cycles covered. Seals were not observed during any of the low tide observations. Generally, only one harbor seal was observed at a time, but at least two were observed during five different days (Table 1). Harbor seals were not observed to predate any sockeye but they did exhibit foraging behavior in the river as determined by their diving and swimming activity. On two days seals were observed chasing sockeye salmon in the pool below the lower blind. The seals were generally first sighted beyond the surf-zone and cautiously moved into the river. The presence of hikers or campers on the beach crest appeared to keep seals from entering the river. During the 2 hour period before the high tide the seals moved between the surf zone and the river, and in most cases had either exited the river or moved further upstream out of view by several hours after the high tide.

River otters were observed in the lower river during 10 of the 22 days observed and during 13 of the high tide cycles observed. On 12 of the tide cycles when otters were observed, only a single animal was seen. On one occasion, three otters were observed. River otters were observed in the river during both high and low tide cycles and were not observed in the ocean surf zone. Otters were observed foraging frequently in the lower river and actually eating prey at least 27 times. Prey appeared to be small fish such as sculpins, starry flounder, and other small flatfishes. River otters were not observed predating or chasing sockeye salmon during the period.

Other potential predators of sockeye observed on the lower river were; cormorants, mergansers, kingfishers, bald eagles and raccoons. None of these were observed to either chase or kill sockeye salmon during the period.

Adult sockeye salmon were observed splashing and finning in the lower river during most of the high tide cycles observed. The first deep pool at the mouth of the river just around the bend from the entrance appeared to be an area where sockeye salmon would pause and hold for a few minutes before proceeding upstream. This pool was also an area where seals and otters foraged when present in the river.

Table 1. Observations conducted at the lower Ozette River from 8-29 June, 1999.

Date	span	total hours	harbor seal	river otter
6/8/99	0500-1300	8	1	1
6/8/99	1745-2245	5	0	0
6/9/99	0615-1115	5	0	0
6/9/99	1830-2330	5	0	0
6/10/99	0715-2400	16.75	2	0
6/11/99	0000-1330	13.5	1	1
6/11/99	2020-2400	3.5	2	0
6/12/99	0000-0115	1.25	0	0

6/12/99	0915-2400	14.75	0	3
6/13/99	0000-0200	2	0	0
6/13/99	0900-1530	6.5	1	0
6/13/99	2100-2400	3	0	0
6/14/99	0000-0300	3	0	0
6/14/99	1115-1615	5	2	0
6/14/99	2245-2400	1.25	0	0
6/15/99	0000-0345	3.75	0	0
6/15/99	1215-1715	5	0	1
6/16/99	0045-1800	16.75	1	0
6/17/99	0030-1845	18.25	1	1
6/18/99	0115-0615	5	0	0
6/18/99	1445-2400	8.75	1	0
6/19/99	0000-0730	7.5	0	1
6/19/99	1530-2030	5	0	0
6/20/99	0315-0815	5	1	0
6/20/99	1630-2130	5	1	0
6/21/99	0430-0930	5	0	0
6/21/99	1715-2215	5	1	0
6/22/99	0530-1030	5	1	1
6/22/99	1800-2300	5	2	0
6/23/99	0630-2345	17.25	1	1
6/24/99	0730-2015	12.75	0	1
6/25/99	0815-2400	15.75	2	1
6/26/99	0000-0100	1	0	0
6/26/99	0915-1415	5	0	0
6/26/99	2045-2400	2.75	0	0
6/27/99	0000-1500	15	0	0

6/27/99	2130-2400	2.5	0	0
6/28/99	0000-0230	2.5	0	0
6/28/99	1030-1530	5	0	0
6/28/99	2200-2400	2	0	0
6/29/00	0000-0300	3	0	0
Totals			278 hours	

Lake Ozette predator and spawning ground surveys

Ten vessel surveys were conducted in Lake Ozette to look for harbor seals or other predators between 24 June 1999 and 31 January 2000. Beginning on 30 August, surveys were conducted on average every 2 weeks. Harbor seals were observed in Lake Ozette on only 2 of the surveys, both sightings were of single animals. One seal was observed on 13 January in the northwest portion of the lake and one on 31 January off Ranier Landing. Spawning ground surveys using divers were conducted by the Makah Tribe and NPS every 7-10 days from November 15 through mid-January. Harbor seals were observed on at least six days near Olsen's Beach or Allen's Beach. On one occasion, 4-5 sockeye salmon heads and frames were found by divers on the bottom off Olsen's Beach. The sockeye salmon carcasses appeared to have been eaten by predators according to divers.

Videotape documentation at the sockeye weir

The time-lapse camera recorded instances of river otters and harbor seals passing through the opening of the weir and also chasing or carrying fish through the weir in May through July, 1999. River otters were observed near the weir at least 274 times, and on 14 occasions they were chasing sockeye salmon through the weir. River otters were observed carrying sockeye salmon through the weir at least ten times. River otters were observed consistently around the weir between May 4 and July 22, 1999. Observers also documented seven instances of predation by otters within 150m of the weir.

Harbor seals were observed passing through the weir at least 20 times and were observed preying on 5 sockeye salmon on 5 different days. All of the harbor seal activity was from May 9-16. Harbor seals were not observed near the weir after mid-May.

Preliminary viewing of the videotapes indicated that at least 10% of the sockeye salmon passing through the weir had predator scars consistent with either harbor seal or river otter marks. Different marks included; deep laccrations or bite marks, claw marks, tail rakes, "golden arches" type marks and deep teeth marks. Since only one side of the fish is generally seen on the tape, a true scarring rate could not be determined. In addition, the light conditions influence the clarity of the picture and often make it difficult to determine how fresh or deep a mark was. A subsample of tapes is being reviewed where picture clarity is good to determine a final scarring rate. These data will be reported in a later report.

Summary and Recommendations

The standard methods for documenting interactions between pinnipeds and salmonids such as prey analysis and observational studies have not yielded evidence of significant impact by pinnipeds on Lake Ozette sockeye salmon. Prey studies in 1998 (Gearin et al. 1999) on four species of aquatic predator did not yield evidence of predation on sockeye salmon nor did intensive observations during 1999 on the lower Ozette River. Observations and video tape data however from the weir on the upper Ozette River indicate that both harbor seals and river otters prey on sockeye salmon and frequently pass through the weir pursuing fish. Additional observations in 1999 on the spawning grounds during dive surveys indicate that seals are commonly observed near the spawning beaches and may be preying on spawning sockeye salmon. The videotapes also suggest that predator scarring rates are at least 10% although this percentage may be an underestimate as stated earlier. Sea lions have not been observed in the Ozette River or Lake Ozette during the sockeye salmon migration or spawning times suggesting that these species are not currently involved in interactions at least not in the river or lake. Harbor seals appear to be in low abundance in the Ozette River and Lake Ozette. They are not known to haul-out in these areas and at most only 3-4 have been observed at any one time. River otters may be more abundant in the drainage than harbor seals and are present there year round. Given the relatively small size of the Lake Ozette sockeye salmon run, the level of observed predation by river otters and harbor seals is a concern for the future health of this run. Future studies should focus on determining the level of this predation, where and when it is occurring and record the numbers of predators in the system. A better estimate of predator scarring rates should be made in order to determine where the marks are occurring and by which predators. This may require the capture and examination of sockeye salmon at both the upper and lower rivers to record the change in scarring rates as fish migrate up river. Intensive observations should also be conducted near the fish weir to document predation activities and at the spawning grounds to determine if seals prey on spawning sockeye salmon.

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WINTER STELLER SEA LION PREY AND FORAGING STUDIES, (CRUISE SMMOCI-991) 2-25 MARCH 1999

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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 (Kiska, Kasatochi and Ugamak) in Alaska waters during 2-25 March 1999. A total of 401 km of transects were completed as part of the basic surveys. Strong echo sign was rarely seen during the day, and only on a few occasions at night. Preliminary biomass estimates suggest that the midwater biomass was greatest at Ugamak Island and declined to the west. No midwater trawls or longline sets were conducted due to rough weather. Oceanographic data were collected via a continuously operated thermosalinograph and conductivity-temperature-density (CTD) casts (n = 56) conducted during the cruise. Sea surface temperature was typically around 2°-4° C. Twenty-nine 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, northern fulmars, and glaucous winged gulls; distinctly different from the species assemblage observed during summer surveys. No killer whales were seen; however, Dall's porpoise and a minke whale were observed during the survey. No pinnipeds were seen at sea; however, Steller sea lion counts were made at a number of rookeries and haul-out sites and 234 scat samples were collected. Five young of the year sea lion pups were captured on three occasions on Kiska Island and Seguam Island. Blood was successfully drawn from all five animals and total length and girth measurements were taken. Attempts were initially made to weigh the pups but because of uneven terrain and difficulties with slings these weights were unsuccessful.

Introduction

Scientists from the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USF&WS), aboard the USF&WS vessel *M/V Tiĝlax̂* conducted a hydroacoustic - midwater trawl survey for Steller sea lion prey at three sites in Alaskan waters during 2-25 March 1999 for a total of 23 sea days. The area of operations included the Kiska, Kasatochi and Ugamak rookeries and waters surrounding these sites.

The principal objectives of the cruise were to 1) collect scat samples at rookeries and haulouts in the region. 2) conduct hydroacoustic - midwater trawl surveys around Kiska, Kasatochi, and Ugamak Islands to compare to surveys conducted during the past 3) capture juvenile sea lions and obtain measurements and collect blood samples at sites when feasible. 4) conduct exploratory SCUBA operations near shore to assess sites for future capture of young sea lions. Secondary objectives included tag and brand resights, sighting surveys of marine mammals and seabirds during hydroacoustic surveys and counts of sea lions by age and sex.

Cruise Narrative

The cruise began at Adak, Alaska on 2 March 1999 on the *M/V Tiĝlax̂* with the scientific party boarding at that time. Departure from Adak was prompt, and within an hour of arrival on the island. After departure, the vessel proceeded to Kiska arriving on 3 March to stormy weather (SE wind at 50 kts). The vessel anchored in Kiska Harbor for the remainder of the day. On 4 March the vessel departed Kiska Harbor to attempt prey assessment hydroacoustic surveys; however, stormy weather on the south side of the island prevented the surveys. The vessel then proceeded around to the north side of the island to look for animals at Dark Cove and Sirius Point. There were no animals at Sirius Point and the weather at Dark Cove was too rough and the visibility too low to enter the Cove. Hydroacoustic surveys began late in the afternoon on the south side of Kiska and continued until weather prevented surveys from continuing. On 5 March a shore party was able to land at Dark Cove and travel overland to Cape St. Stephens where a net capture of a female pup was accomplished, associated measurements and samples were taken, and scats were collected.

On 6-7 March several attempts were made to continue hydroacoustic transects at Kiska with limited success, 4 out of 10 transects were completed, 8 CTDs and no trawls or longlines were conducted. Shore parties landed at Gertrude Island and at Wolf Point on Kiska, scats were collected (n = 18 and n = 29), resightings of several pups with red flipper tags (#1115, 1157, 1162 and 1134 (right only)) were made, but captures were either unsuccessful or conditions were not suitable. Kiska transects were then resumed until weather conditions became too rough to continue.

Due to deteriorating weather conditions at Kiska, (SE wind at 50 kts; 28 ft. seas), the vessel departed the area traveling east toward Amchitka Island. A shore party landed at the rocks off Chitka Point (10) for scat collections. Fog, wind, and the shallow reef at East Cape prevented getting around the south side of cape for a count or shore landing; however, there were no animals seen on the north side of the cape. Weather reports for the Delarof Islands were bad (SE wind at 50 kts) and due to the lack of safe anchorage in that area the vessel continued on to Kanaga.

Wind direction switched from SE to NE and weather conditions had deteriorated enough before reaching Kanaga that the vessel anchored at Tanaga (traveling into a NE wind of 50 kts all night). Travel to Kanaga was not possible, therefore the vessel headed to the Bay of Waterfalls at Adak Island on 9-10 March. Lake Point, Adak was too rough to go ashore but a count was made from the vessel, despite poor visibility at times, caused by blowing snow.

The vessel then moved on to Kasatochi and conducted hydroacoustic transects from 10-15 March, between storms. Ten hydroacoustic transects were completed, 28 CTDs, and scats (n = 20) were collected. Periodic light echo "sign" was seen on 15 March during transects, however, trawls were not conducted due to rough weather and potentially hazardous working conditions on the trawl deck (SE wind at 40 kts; 20 ft seas). The vessel then proceeded on to Seguam Island.

On 16 March a shore party collected scats (n = 44) and captured three pups at Seguam Island. Blood samples were taken from all three pups and one pup with a red flipper tag (no number seen) was resighted. There were approximately 50 pups present among the 200 animals onshore. Animal behavior and future underwater capture techniques were evaluated while conducting dive operations. Divers (McAllister, Erickson and Pepper) entered the water and spooked the animals off the rocks and into the water; however, it appeared that the animals avoided the divers.

From 17-18 March the vessel proceeded east towards the Ugamak and Unimak Pass area. Counts were made at Unalaska, Akun and Tanginak before arrival at Ugamak on 18 March, when night transects began. Hydroacoustic transects were conducted through the late afternoon on 19 March until the weather became too rough to continue (NW winds of 35-40 kts). On 21 March weather conditions subsided and transects were resumed, completing 9 out of 10 transects, 20 CTDs. A large storm was approaching and the vessel left the Unimak Pass area later that day per the Captain's orders (forecast SE wind of 70 kts with 50 ft seas). One Neuston surface tow was conducted to verify acoustic sign but no captures, scat collections, trawls or longlines were made at Aiktak/Ugamak due to rough weather.

Between 22-24 March the vessel proceeded eastward stopping at Jude Island to count, capture, and collect scats and also at Chowiet and Latax Rocks to count and collect scats. On 24 March at 2330 hours the vessel arrived in Homer to end the trip.

Methods

Hydroacoustic surveys

Acoustic data were collected along a series of parallel transects within a 10 nmi radius of the three sites (Kiska, Kasatochi and Ugamak). Transect spacing was around 3 nmi. The vessel generally operated at 10 kts during the survey. Data were collected using the vessel's BioSonics 102 echo sounder system, with hull mounted (4 m deep) 38 and 120 kHz transducer, operated in a multiplexing mode. Attempts were made to survey all legs once during daylight hours, however rough weather hampered completion of 2 out of 3 survey sites. The central three transects were also surveyed at night at all three sites. Settings for the 102 Echosounder were: 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 operated in multiplexing mode to obtain separate estimates of total biomass and large target (fish) biomass. All data was echo integrated in real time using BioSonics ESP software running on the ship's computer.

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

Seabird and marine mammal sighting surveys

During hydroacoustic daylight transects, members of the scientific party also conducted sighting surveys of marine mammals and seabirds from the vessel's flying bridge. Standard USF&WS seabird sighting protocols were observed (Gould and Forsell 1989). Two observers conducted sighting transects --one observer and one recorder. The 90° area from amidships to the bow (usually to port unless weather or glare interfered) was observed continuously. Marine mammals and seabirds were recorded by species and number.

Oceanographic data

A continuous thermosalinograph record was generally maintained throughout all hydroacoustic transects using the ship's Seabird Seacat SBE 21 thermosalinograph, however the program malfunctioned at the beginning of the trip and no thermosalinograph record was available for this trip. A portable CTD (the ship's Seabird Seacat SBE-19 Profiler) was deployed at the beginning and end of each transect to obtain salinity and temperature profiles for the entire water column.

Results

Hydroacoustic surveys

A total of 401 km of transects were run as part of the basic surveys conducted at the three sites: 276 km during the day and 125 km at night. At Kiska, Kasatochi, and Ugamak, 40%, 100%,and 90% (respectively) the transects were completed.

A strong echo sign was rarely seen at any site during the day and on few occasions at night. At those sites where nighttime transects were run (Kiska, Kasatochi, and Ugamak Islands) faint scattered sign of zooplankton and fish were observed during daylight hours at Kasatochi and Ugamak. A neuston tow on a vertical layer of strong signal return at Ugamak showed it was composed of larval fish and worms. Rough weather prevented midwater trawling on sign at all sites.

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

Trawls

No midwater trawls were made with the herring trawl due to rough weather.

Longline sets

No longline sets were made due to rough weather.

Oceanographic data

56 CTD casts were made during the period. These data remain to be analyzed. Continuous sea surface temperature (SST) were obtained from virtually all transects from the ship's thermometer. SST was typically around 2°-4° C. The thermosalinograph malfunctioned during the entire trip therefore salinity measurements are not available.

Marine mammal and seabird sighting surveys

Sighting surveys were conducted at all locations where hydroacoustics transects were performed. Twenty-nine hours of sighting surveys were obtained simultaneous to the hydroacoustic surveys. The most common species observed were common and thick-billed murres, crested auklets, northern fulmars, 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 analyzed by the USF&WS.

Sighting records of marine mammals were maintained throughout the cruise. Marine mammal species sighted include a Minke whale (*Balaenoptera acutororostrata*) and Dall's porpoise (*Phocoenoides dalli).* No killer whales (*Orcinus orca*) were seen during the trip. No pinnipeds were seen at sea. However, Steller sea lions were seen onshore and counts were made at the sites listed in Table 3.

Conclusions

The cruise was moderately successful even though rough weather conditions were more prevalent than in past trips. The vessel and crew performed admirably during periods of stormy weather. Thus, the vessel continues to provide an excellent platform for winter work.

The ship's BioSonics 102 hydroacoustic 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.

Midwater trawling was not conducted during this trip due to rough weather and dangerous conditions on the vessels back deck during the few times when acoustic sign was encountered. As large storms were frequent throughout the trip, effort was prioritized to finish transect lines over conducting trawls in areas of no acoustic return. Even with this prioritization of effort only one site (Kasatochi) was able to be surveyed to completion. The longline gear was not deployed at any sites due to rough weather conditions.

Seabird and marine mammal sighting surveys were conducted at all locations where hydroacoustics transects were performed--Kiska, Kasatochi, and Ugamak Islands. Twenty-nine hours of sightings were obtained. Direct entry of data into a shipboard GIS (D-Log program) has increased the speed of data entry and analysis for sighting surveys. 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 in the numbers of crested auklets sighted.

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Table 1.-- Itinerary and activities for March 1999 cruise (SMMOCI-99-1)

Date	Location	Activity	Comments
02 March	Adak	Scientific party arrive	
02 March	Adak	Vessel departs	
03 March	Kiska	Arrive at Kiska, anchor for night	Storm SE 50
04 March	Kiska	Transit around N. side; began transects	Too rough to continue transects
05 March	Kiska	Dark Cove; skiff to shore, scats (3), fetus (1), & capture (1 pup)	Blowing snow, occasional white-out conditions
06 March	Kiska	Gertrude scats (18); Anchor Little Kiska Head	Storm SE 50; 28 ft. seas
07 March	Kiska	Transit N.side Kiska transects, Wolf Point scats (29)	Weather subsiding W 30; 4 ft.seas, 18 ft. swell Lots of young animals; red tags (1115, 1157, 1162, 1134 (rt. only))
08 March	Amchitka	Transit to Amchitka; scats @ Chitka Point	SW 40 - SE 45 - SW 50 Storm approaching SE 50 in Delarofs
09 March	Tanaga; transit to Adak	Anchor Tanaga Bay, depart for Kanaga	Storm NE 50-70
10 March	Adak	Too rough @ Lk. Point; depart for Kasatochi	Low visibility, blowing snow. Weather improving
11 March	Kasatochi	Day & night transects	
12 March	Kasatochi	Transects & Kasatochi scats (20), Kagalaska scats (21)	Touch & go at Adak for parts

Date	Location	Activity	Comments
13 March	Kasatochi	Transects; anchor @ Atka	Storm SW 35 - W 55
14 March	Kasatochi	Anchor @ Atka	WSW 38-40; 20 ft. seas
15 March	Kasatochi	Transects; depart for Seguam	W 25; 10 ft. seas, big swell. Storm approaching, SE 40; 20 ft. seas
16 March	Seguam	Scats (44); captures (3 pups); divers recon	Sun! Weather forecast: SE 60-70; 35 ft. seas
17 March	Transit to Unalaska		SE 40-50; 5 ft seas to SE 60-70; 16 ft.
18 March	Ugamak	Night transects	SE 30
19 March	Ugamak/Aiktak	Day transects	Weather deteriorating to NW 35-40
20 March	Ugamak/Aiktak	Drive by Aiktak/Ugamak for scats, captures - too rough	Waves breaking over top of Aiktak. Winds @ anchor to 99 mph
21 March	Ugamak/Aiktak	Transects; Neuston tow; anchor @ Tigalda Bay; depart across Unimak Pass	Flat Calm in am; storms forecast SE 70; 55 ft seas
22 March	Jude	Scats (31); capture (1 pup)	
23 March	Chowiet	Scats (33); depart for Latax Rocks	Sunny weather; 10 Harbor seals
24 March	Latax Rocks	Scats (25); depart for Homer	Weather deteriorating; arrive @ Homer 2330 hrs.
25 March	Homer	Scientific party (except Chumbley & Kurle) depart	End of Cruise
26 March	Homer	Chumbley & Kurle depart	Gear shipment/scat shipment

Table 2.--Scientific personnel involved with March 1999 cruise (SMMOCI-991).

Name	Sex/nationality	Position	Organization
K. Chumbley	F/USA	Party Chief	NMFS
R. Ream	M/USA	Asst. Party Chief	NMFS
C. Kurle	F/USA	Wildlife Biologist	NMFS
J. Thomason	M/USA	Wildlife Biologist	Contract employee
P. Browne	F/USA	Wildlife Biologist	Contract employee
C. Gburski	M/USA	Wildlife Biologist	Contract employee
D. Dragoo	M/USA	Seabird biologist	USF&WS
T. Bittner	F/USA	Seabird biologist	USF&WS

Table 3. Counts of Steller sea lions March 1999

site	hour	day	month	year	count	comments
Kiska/C.St.Stephen	1400	5	March	1999	75	3 scats; 1 fetus
Kiska - Twin Rocks	0845	6	March	1999	15	SE 50
Kiska/Gertrude Cove	1000	6	March	1999	35	collected 18 scats
Kiska - Wolf Point	1100	6	March	1999	40	1 capture; Lots of young animals, 4 tag resights; 29 scats
Tanadak	1030	8	March	1999	140	SW 40 - SE 45 - SE 50
Rat/Krysi Point	1130	8	March	1999	50	rough estimate - large breakers, low vis.
Amchitka - Bird Is.	1430	8	March	1999	0	
Amchitka - Chitka Pt.	1625	8	March	1999	19	10 scats
Amchitka - East Cape	1930	8	March	1999	--	Too rough to get around Cape; forecast: SE 35 to W 55; 30 ft. seas
Adak - Lake Point	0950	10	March	1999	302	Blowing snow; too rough to get ashore
Kanaga/North Cape	1240	10	March	1999	50	
Kasatochi	1100	12	March	1999	42	20 scats
Kagalaska	1525	12	March	1999	46	21 scats
Seguam/Turf Point	1600	16	March	1999	200	about 50 pups; 3 captures; 1 tag resight; 44 scats
Seguam - Moundhill Pt.	1725	16	March	1999	6	All males
Akutan - Bishop Pt.	1115	18	March	1999	0	
Akun - Billingshead	1300	18	March	1999	125-150	Forecast: NW 60
Tanginak	1750	18	March	1999	50	
Aiktak/Ugamak Bay	0830	21	March	1999	207	Forecast: SE 70; too rough to go ashore
Omega	1130	22	March	1999	11	
Jude	1200	22	March	1999	247	31 scats
Chowiet	0930	23	March	1999	34	33 scats; 10 Harbor seals
Chirikof	1530	23	March	1999	10	Big onshore swell
Latax Rocks	1320	24	March	1999	57	25 scats

Table 4. Prey Survey Transects During 2-25 March 1999 Cruise (SMMOCI 99-1)

Site	Hydroacoustic Transects - Winter 1998															
Transect	Date	Time (GMT)	Lat.	Begin Long.	SST	Salinity	CTD No.	Time (GMT)	Lat.	End Long.	SST.	Salinity	CTD No.	Trawl No.	Files Hydro	Files T-S
KI-1	5-Mar	0215	51 58	176 57	3.4		0	0353	51 58	177 20	3.4		1		KI1	
KI-2	5-Mar	0449	51 55	177 13	3.4		2	0556	51 55	176 56	3.4		3		KI2	
KI-2N	5-Mar	0814	51 55	176 56			4	0920	51 55	177 13			5		KI2N	
KI-3	7-Mar	0331	51 52	176 56	3.4		6	0420	51 52	177 09	3.4		7		KI3	
KA-1	11-Mar	1837	52 06	175 45	3.5		01	1935	52 14	175 45	3.3		02		KA1	KA1
KA-2	11-Mar	2041	52 18	175 40	3.4		03	2219	52 02	175 40	3.5		04		KA2	KA2
KA-3	11-Mar	2257	52 01	175 35			05	0108	52 19	175 35	3.4		06		KA3	KA3
KA-4N	12-Mar	0204	52 20	175 30	3.4		07	0252	52 12	175 30	3.6		08		KA4N	KA4N
KA-4S	12-Mar	0412	52 09	175 30	3.5		09	0506	52 00	175 30	3.5		10		KA4S	KA4S
KA-3N	12-Mar	0809	52 01	175 35	3.5		11	1000	52 19	175 35	3.6		12		KA3	KA3N
KA4NN	12-Mar	1057	52 20	175 30	3.5		13	1146	52 12	175 30	3.5		14		KA4NN	
KA4SN	12-Mar	1236	52 09	175 30	3.7		15	1335	52 00	175 30	3.7		16		KA4SN	
KA5N	12-Mar	1413	52 01	175 25	3.7		17	1556	52 19	175 25	3.4		18		KA5N	
KA-5	12-Mar	1830	52 19	175 25	3.3		19	1932	52 10	175 25	3.6		20		KA5	KA5
	13-Mar	2222	52 10	175 25	3.6		00	2300	52 06	175 25	3.6		01		KA5	KA5
	15-Mar	1916	52 06	175 25	3.3		02	1949	52 01	175 25	3.4		03		KA5	KA5
KA-6	15-Mar	2026	52 02	175 20	3.4		04	2213	52 18	175 20	3.3		05		KA6	KA6
KA-7	15-Mar	2314	52 14	175 15	3.3		06	0004	52 06	175 15			075		KA7	KA7
UG3N	19-Mar	0812	54 16	165 03	2.8		00	0958	54 16	164 31	1.9		01		UG3N	UG3
UG4EN	19-Mar	1042	54 13	164 30	1.9		02	1136	54 13	164 45	2.3		03		UG4EN	UG4E
UG4WN	19-Mar	1214	54 13	164 51	2.3		04	1256	54 13	165 04	2.9		05		UG4WN	UG4W
UG5N	19-Mar	1336	54 10	165 03	2.7		06	1550	54 10	164 31	2.0		07		UG5N	UG5
UG6	19-Mar	1847	54 07	164 54	2.5		08	1959	54 07	164 34	2.1		09		UG6	UG6
UG7	19-Mar	2047	54 04	164 40	1.9		10	2141	54 04	164 54	2.6		11		UG7	UG7
UG5	19-Mar	2316	54 10	165 03	2.8		12	0126	54 10	164 31	1.9		13		UG5	UG5
UG4E	21-Mar	1725	54 13	164 30	1.5		14	1815	54 13	164 45	1.9		15		UG4E	UG4E
UG4W	21-Mar	1932	54 13	164 51	2.2		16	1953	54 13	164 56			17	N01	UG4W	UG4W
UG3	21-Mar	2132	54 16	165 03	2.3		18	2311	54 16	164 13	1.9		19		UG3	UG3
UG2	21-Mar	2352	54 19	164 34	1.5		20	0122	54 19	165 00			21		UG2	UG2

Table 5.--Trawls and long line sets made during 2 - 25 March 1999 cruise (SMMOCI-99-1).

Station	Tow#	Date	Start time	Latitude	Longitude	End time	Latitude	Longitude	Area	Gear	Depth (m)
1	N01	3/21/98	1003	54.12.8	164.54.0	10:18:00	54.12.7	164.55.15	Ugamak	Nueston	48-52

FATTY ACID PROFILES OF STELLER SEA LIONS AND NORTH PACIFIC OCEAN FORAGE FISHES, A PILOT STUDY USING NORTHERN FUR SEALS

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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 laboratory in North America 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.

This study was designed to address these factors through a 3-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 and collection of northern fur seal tissues for preliminary testing. Year-two was used to develop FA profiles for blubber collected from St. Paul Island, Alaska juvenile male and female northern fur seals from three body locations and two depths to assess the best body areas from which to collect tissue on an otariid. Year-three will be used to develop FA profiles for northern fur seal prey and for fur seals from St. George Island, Alaska. A significant by-product of this research will be the development of a capability within the NMFS for marine mammal FA analyses and its application to Steller sea lions.

Methods

Fur seal blubber was collected in 1997 during the annual harvest on the Pribilof Islands. Blubber samples were collected from 16 juvenile males and 3 females on St. Paul Island and from 18 juvenile males on St. George Island. Each animal was sampled in three locations: neck, pelvis and shoulder. All samples were subsequently cut in half, and surface and deep layer blubber analysis was performed on all tissues. Utilizing the 164 blubber samples from animals from St. Paul Island, all lipids were initially extracted using a modification of Folch's method as outlined in Christie (1989). The non-polar lipid composition of the samples were then analyzed with high performance liquid chromatography (the HPLC method; see Christie, 1989), and the fatty acid composition was determined using a gas chromatograph equipped with a mass selective detector (GC/MS).

Statistical analysis was used to compare fatty acid and non-polar lipid contents between sexes and blubber layers, and among body locations and individuals. Differences in the non-polar lipid content of the entire blubber layer and between the three body locations were examined using analysis of variance (ANOVA). Statistical analysis to compare fatty acid compositions of blubber from St. Paul Island animals followed the procedures of Grahl-Nielsen (1999) using soft independent modeling by class analogy (SIMCA) (Wold and Sjöström 1977) with SIMCA-P version 8.0 from Umetrics AB[1]. SIMCA is a multivariate technique based on principal components analysis (PCA). In addition, fatty acid compositions will be analyzed following the procedures of Smith et al. (1997; 1999) using classification and regression tree analysis (CART).

1998/99 Results

Data interpretation and statistical analysis of blubber from northern fur seals on St. Paul Island has begun, and will continue in the year 2000 with the addition of the St. George Island animals and the prey items. Preliminary results indicate no difference between different areas or depths sampled. In addition, both juvenile male and female samples show a high level of wax esters and a high level of non-extractable dry weight in the blubber indicating that fur seal fat is high in protein.

Little in the way of results were available by the end of FY 1999. However, shortly into FY 2000, preliminary results were available. These results indicated that non-polar lipid content was highly variable among individuals and between sexes. The samples from females may have been overly influenced by the inclusion of a post-parturient female (female C) whose non-polar lipid content was especially low. Non-polar lipid content also varied with body location of sampled blubber in the juvenile males, with pelvic samples having the highest content and shoulder samples containing the lowest content. Pelvic samples were the best overall indicators of overall mean non-polar lipid content for individuals. There were no differences in non-polar lipids between inner and outer layers of blubber.

All juvenile males had unique fatty acid compositions, and the PCA models successfully discriminated between samples from different individuals 100% of the time. Female C had a distinct fatty acid composition from the two nulliparous females and all of the juvenile males. Juvenile males and the two nulliparous females overlapped in their fatty acid compositions, with only neck samples correctly classifying the sexes separately. The PCA models indicated that neck, shoulder and pelvic samples had fatty acid compositions that were not distinguishable from each other. However, when a model was built using the fatty acid compositions of the inner and outer layers of a particular set of samples (i.e., neck), and the corresponding set of entire blubber layers was applied to that model, the PCA model correctly identified the sample location 100% (neck) and 93.8% (shoulder and pelvis) of the time. Thus, a model for a particular tissue correctly described that particular tissue very well. Finally, the models indicated that there was no difference in fatty acid compositions between outer and inner blubber layers.

Non-polar lipid and fatty acid compositions of 95 prey items collected in 1997 in the Bering Sea and blubber from animals collected on St. George Island is underway with expected completion within the year 2000.

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Citations

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