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Outer Continental Shelf Environmental Assessment Program

Final Reports of Principal Investigators

Volume 37

March 1986

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service
Office of Oceanography and Marine Assessment
Ocean Assessments Division
Alaska Office

U.S. DEPARTMENT OF THE INTERIOR
Minerals Management Service
OCS Study, MMS 86-0021

"Outer Continental Shelf Environmental Assessment Program Final Reports of Principal Investigators" ("OCSEAP Final Reports") continues the series entitled "Environmental Assessment of the Alaskan Continental Shelf Final Reports of Principal Investigators."

It is suggested that sections of this publication be cited as follows:

Brueggeman, J. J., and R. A. Grotefendt. 1984. Seal/sea lion and walrus surveys of the Navarin Basin, Alaska. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. 37:1-229

Cummings, W. C., D. V. Holliday, and B. J. Lee. 1984. Potential impacts of man-made noise on ringed seals: vocalizations and reactions. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. 37:95-230

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Schneider, K. B. 1976. Distribution and abundance of sea otters in southwestern Bristol Bay. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. 37:627-694

OCSEAP Final Reports are published by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of Oceanography and Marine Assessment, Ocean Assessments Division, Alaska Office, Anchorage, and primarily funded by the Minerals Management Service, U.S. Department of the Interior, through interagency agreement.

Requests for receipt of OCSEAP Final Reports on a continuing basis should be addressed to:

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P. O. Box 56
Anchorage, AK 99513

OUTER CONTINENTAL SHELF
ENVIRONMENTAL ASSESSMENT PROGRAM

FINAL REPORTS OF PRINCIPAL INVESTIGATORS

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Anchorage, Alaska

The facts, conclusions, and issues appearing in these reports are based on research results of the Outer Continental Shelf Environmental Assessment Program (OCSEAP), which is managed by the National Oceanic and Atmospheric Administration, U.S. Department of Commerce, and funded (wholly or in part) by the Minerals Management Service, U.S. Department of the Interior, through an Interagency Agreement.

Content of these reports has not been altered from that submitted by the Principal Investigators. In some instances, minor grammatical, spelling, and punctuation errors have been corrected to improve readability; some figures, charts, and tables have been enhanced to improve clarity in reproduction.

Outer Continental Shelf Environmental Assessment Program

Final Reports of Principal Investigators

VOLUME 37 MARCH 1986

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SEAL/SEA LION AND WALRUS SURVEYS OF THE NAVARIN BASIN

by

J. J. Brueggeman and R.A. Grotefendt
Envirosphere Company

Final Report
Outer Continental Shelf Environmental Assessment Program
Research Unit 625

1984

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ABSTRACT

Seal, seal lion, and walrus distribution, habitat use, and density were examined in the 54,000 nm^2 Navarin Basin planning unit of the northcentral Bering Sea during four seasons distributed between 1982 and 1983. Vessel and helicopter surveys were conducted along systematic tracklines distributed over the outer continental shelf, slope, and rise encompassing the Basin. The survey design was modified during winter when pack ice covered approximately half of the Basin in order to thoroughly survey the marginal ice front. During the surveys seven species of pinnipeds were observed over almost 5,500 nm of aerial and 2,600 nm of vessel surveys. Approximately 90 percent of the 1,852 animals observed were recorded during the winter survey when pinnipeds haul out on the ice. Over 75 percent of the 1,670 animals recorded during winter were walruses (52 percent) and northern sea lions (24 percent). Of the 310 seals recorded in winter, 78 percent were spotted seals, followed by ribbon and a few bearded, ringed, and fur seals in decreasing order of abundance. Walruses were primarily encountered deep in the ice front, while sea lions concentrated along the edge. Ribbon and spotted seals were intermediate in location between those two species, although distributions among species overlapped. Walruses were predominantly found in the eastern half of the ice front, sea lions and spotted seals in the western half, and ribbon seals in the center. Ice conditions utilized by these species differed, but sea lions, spotted seals, and ribbon seals generally inhabited areas of broken ice containing small floes, compared to walruses that utilized areas of thin ice surrounded by heavier pack ice. Densities of these species were estimated from the strip transect procedure and included 15.4 animals per 100 nm^2 for walrus, 6.09 for spotted seals, 2.45 for sea lions, and 0.95 for ribbon seals. Too few of the other species were sighted to analyze. None of the estimates account for submerged animals. The survey results verify that all seven of the pinniped species indigenous to the Bering Sea winter in the marginal ice front of the Navarin Basin, and at least the four most common species partition their use of the ice front, thus probably reducing interspecific competition. Density estimates of pinnipeds using the Basin were generally lower than in traditional concentration areas such as the St. Lawrence Island vicinity, Gulf of Anadyr, and Bristol Bay for each species except for ribbon seals which were higher. A similar analysis was not possible to do for pinnipeds encountered during the spring, summer, and fall seasons because of the few animals observed; however, most of the animals encountered were recorded during spring using bands of fringe ice where they bear their young. The only newborns observed during winter were walruses which occurred at a time of the year earlier than has been previously reported in the literature.

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INTRODUCTION

Information on pinniped use of the northcentral Bering Sea is limited. Most information is derived from studies in the eastern (Kenyon 1960; Burns 1970; Kenyon 1972; Fay 1974; Burns and Harbo 1977; and Fay 1982) and to a lesser degree the western (Tikhomirov 1964; Shustov 1965; and Kosygin 1966) Bering Sea during spring when pinnipeds haul out on the pack ice. While these and other surveys (Braham et al. unpublished) have entered into the central Bering Sea, very little effort has been devoted to the northcentral Bering Sea ice front. Even less effort has been given to this area during ice free seasons (Consiglieri and Bouchet 1981). Studies of marine mammals in the northcentral Bering Sea, particularly during winter, have been few primarily because of its remoteness, high logistical costs to access it, and harsh weather.

The results of these published studies identify that seven species of pinnipeds inhabit the northcentral Bering Sea seasonally: northern fur seal (Callorhinus ursinus); northern sea lion (Eumetopias jubatus); Pacific walrus (Odobenus rosmarus); and the spotted (Phoca largha), bearded (Erignathus barbatus), ribbon (Phoca fasciata), and ringed (Phoca hispida) seals (Burns and Harbo 1977). Pinnipeds are most abundant during winter and spring when pack ice provides a platform for resting, breeding, birthing, and molting. Most species migrate either passively on the ice as it retreats northward or actively (swimming) to the Chukchi Sea to summer, except for spotted seals, sea lions, and fur seals which move to coastal areas of the Bering Sea. Varying sex and age components of these pinniped populations adopt a pelagic existence in the Bering Sea during the ice free seasons. The densities and movement patterns of pinnipeds in the northcentral Bering Sea, however, are poorly known.

Determination of these population characteristics is particularly important since the Navarin Basin planning unit (hereafter referred to as the Navarin Basin) in the northcentral Bering Sea is scheduled for oil and gas development in 1984. Because development may alter habitats of these animals, the Outer Continental Shelf Lands Act of 1953 as amended in 1978 requires that baseline studies be done to assess potential impacts to the populations. In accordance to these requirements, the Minerals Management Service funded the Outer Continental Shelf Environmental Assessment Program (OCSEAP) to support studies to:

1. Assess winter habitat use of the Navarin Basin by cetaceans, emphasizing the seasonal population size and distribution of bowhead whales relative to ice and other environmental parameters;

2. Identify and enumerate the endangered species of whales in the Basin during the ice free period, assess habitat use, and correlate their temporal and spatial distribution with environmental parameters; and

3. Document sightings of other species of marine mammals observed during the surveys, and provide estimates of their abundance and distribution within the region.

Objective 3 is addressed in this report. The report examines pinniped abundance and distribution in the Basin during the spring (May-June), summer (July-August), fall (October-November), and winter (February-March). Because of the difficulty in detecting and identifying pinnipeds in open water, the report concentrates on winter when pinnipeds hauled out on the ice and were most visible to survey. The other two objectives are addressed in an earlier report.

ACKNOWLEDGMENTS

We thank the field team of Dr. A. Erickson, Dr. T. Newby, J. Joyce, J. Hartley, B. Troutman, and W. Everett. Dr. D. Chapman, Dr. T. Quinn, and R. Fairbanks provided advice on statistical procedures.
Dr. T. Loughlin and M. Athey reviewed the report. Logistical support

was provided by the staffs of the NOAA ship SURVEYOR and the U.S.C.G. icebreaker POLAR SEA. Without the support of these people, organizations, and personnel of both the Minerals Management Service and Outer Continental Shelf Environmental Assessment Program, the accomplishments of this study would never have been realized.

STUDY AREA

The Navarin Basin is located in the northcentral Bering Sea, approximately 200 nautical miles (nm) off the coast of Alaska (Figure 1). It covers over 54,000 nm^2, an area approaching the size of the State of Michigan, and is bounded by the U.S.-U.S.S.R. Convention Line to the west, 174°W longitude to the east, and latitudes 63°N and 58°N to the north and south. Water depth in the Basin ranges from about 44 m on the outer continental shelf to over 3000 m outside the shelf. The shelf comprises approximately half of the area in the Basin, while the continental slope and rise comprise 36 percent and 14 percent, respectively. The study area was extended to 171°W longitude during the winter survey period (Figure 2).

The climate of the study area features harsh environmental conditions that promote the seasonal development of sea ice (Figure 3). Environmental conditions typically consist of cold temperatures, high wind speeds, low visibility, and extreme ranges in day length (Brower et al. 1977). Average annual air temperature and wind speed are 0°C and 14 kt, and visibility <2 nm persists approximately 14 percent of the time during the year. Sea ice persists in the Navarin Basin from December through June and ice coverage is greatest from February through April (Potocsky 1975). It seldom extends south of the outer continental shelf and is typically <1 m thick. Breakup of the ice begins in mid-April, and the Basin is generally ice-free by late June.

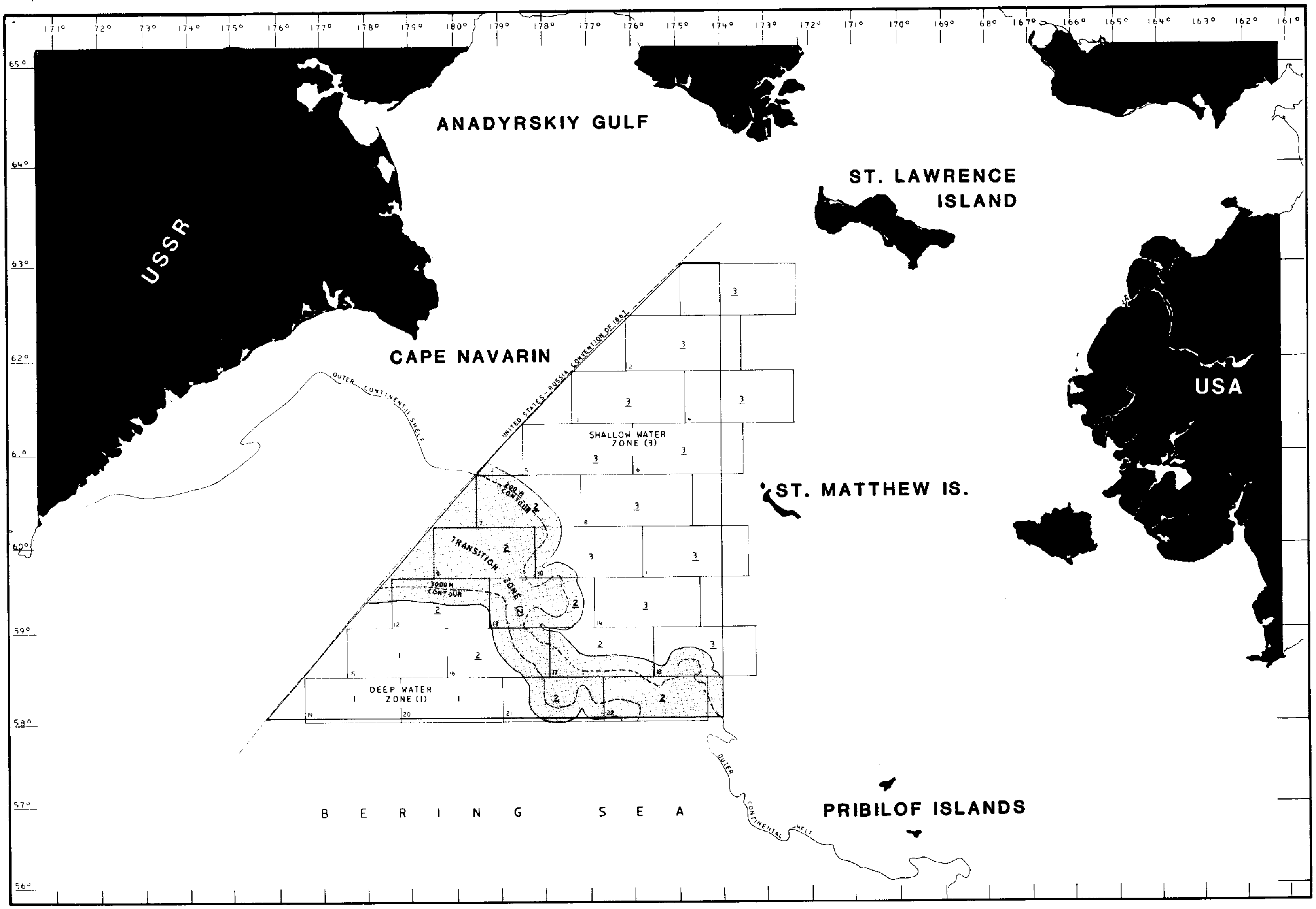

FIGURE 1 STUDY AREA AND SAMPLING DESIGN IN THE NAVARIN BASIN FOR SPRING THROUGH FALL SURVEY PERIOD, 1982.

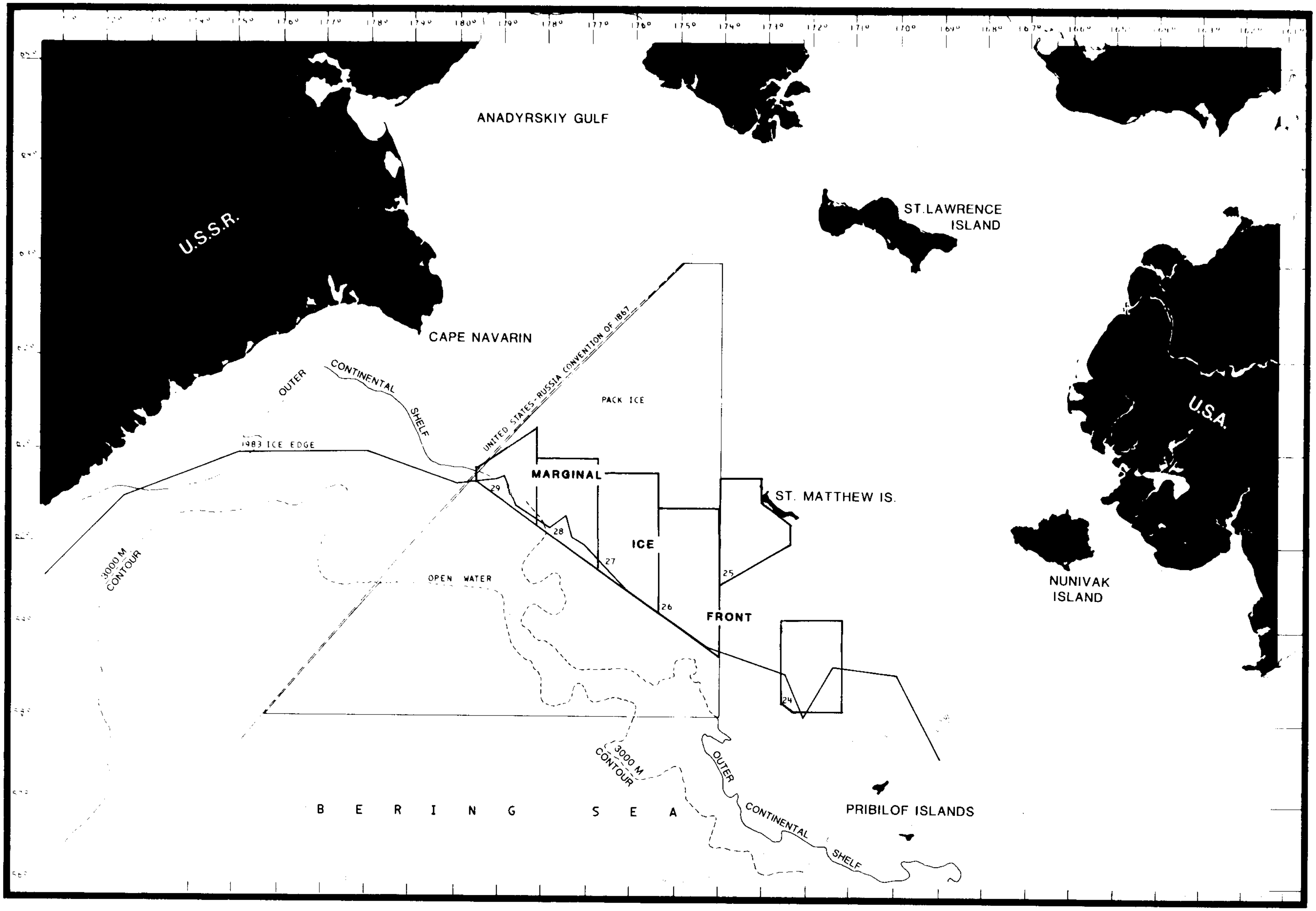

Figure 2 STUDY AREA AND SAMPLING DESIGN IN THE NAVARIN BASIN DURING WINTER SURVEY PERIOD

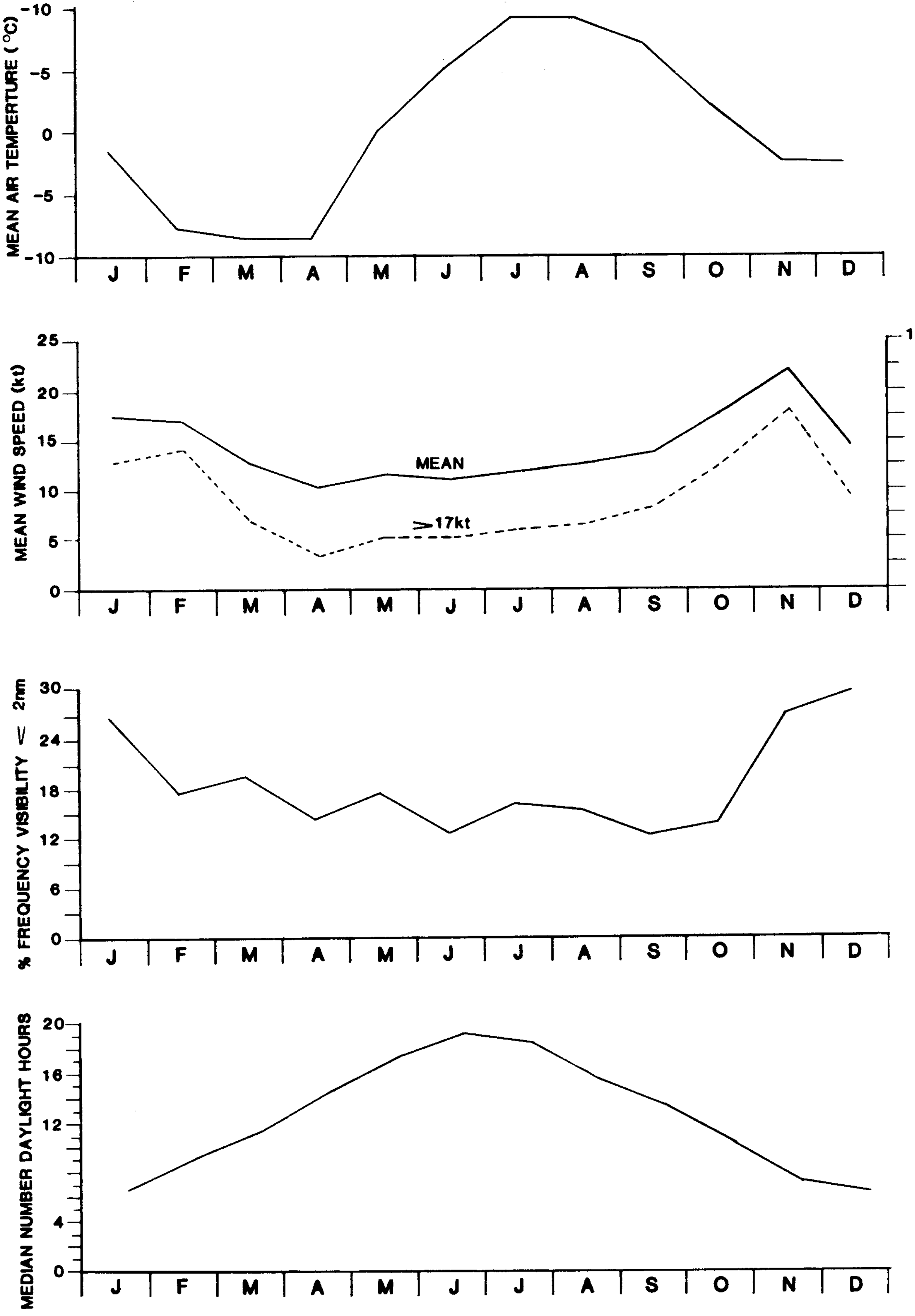

FIGURE 3 HISTORIC ENVIRONMENTAL CONDITIONS OF THE NORTH CENTRAL BERING SEA (BROWER ET AL. 1977).

METHODS

Two sampling designs were developed for aerial and vessel surveys of marine mammals in the Navarin Basin. One design was for surveys during the ice-free period from late spring to early fall. This design was modified for surveys during the late winter-to-early spring when sea ice was in the Basin.

ICE-FREE PERIOD - SPRING, SUMMER, AND FALL

The Basin was stratified into three survey zones (Figure 1). The shallow water zone coincided with the outer continental shelf, while the transition and deep water zones corresponded to the outer continental slope and rise, respectively. The former zone was the area northeast of a point 10 nm northeast of the 200 m contour line, and the latter zone was the area southwest of a point 10 nm southwest of the 3000 m contour line. The area between these points was the transition zone, which featured the greatest topographic relief. The Basin was stratified in this manner to account for distributional differences of marine mammals relative to major changes in water depth. Moreover, areas of potential petroleum development in the Basin may be closely linked to the feasibility of extracting petroleum in various water depths.

Twenty-two sampling units were distributed over the three zones (Figure 1). The shallow water zone contained 11 units, the transition zone eight units, and the deep water zone three units. Each unit was approximately 34 nm by 72 nm and comprised about 2,450 nm^2. Nine transect lines, 30 nm long, were equidistantly spaced every 8 nm, corresponding to the longitude lines in each sampling unit (Figure 4). This configuration provided thorough coverage of a sampling unit and prevented double surveying of adjacent lines or units.

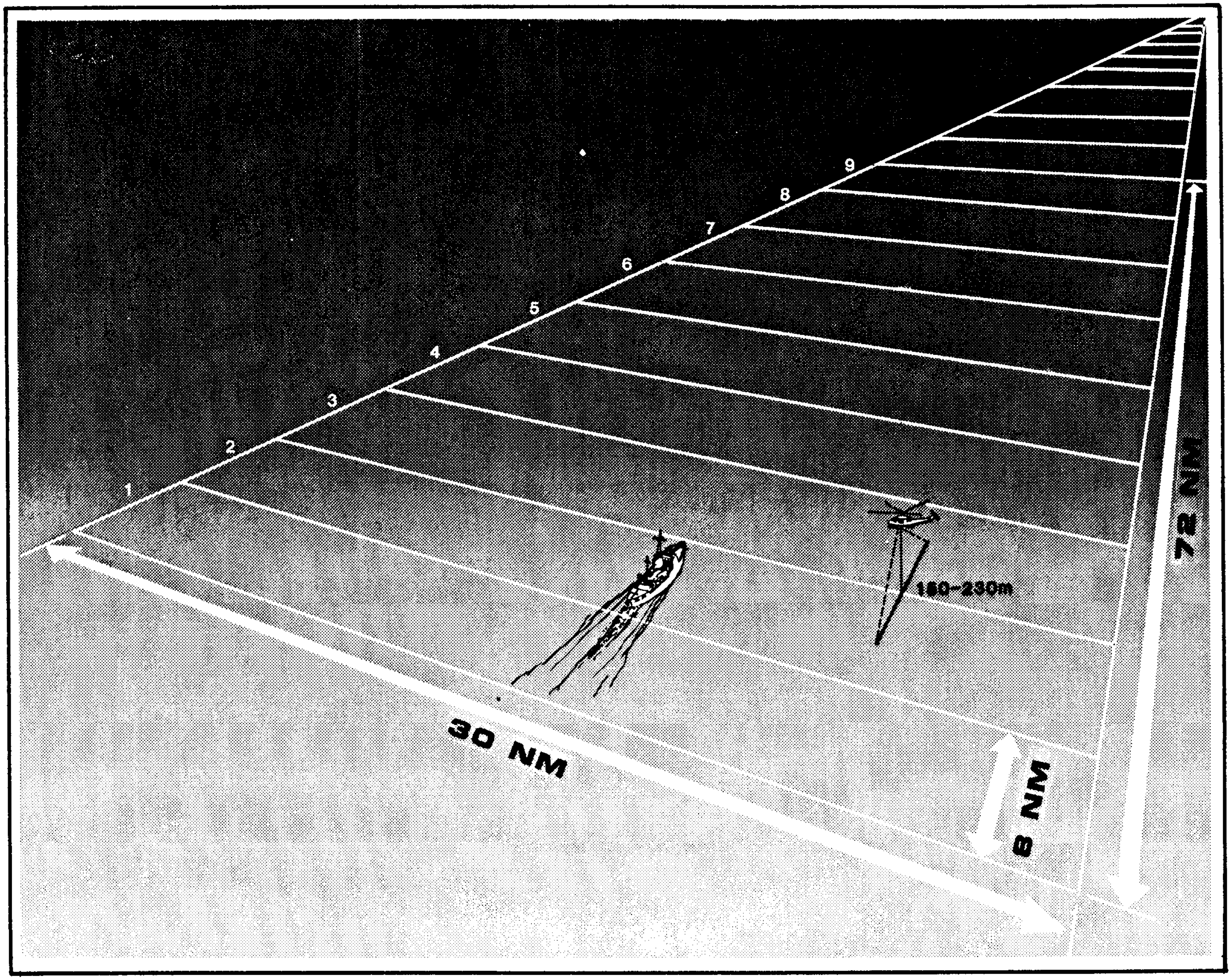

Figure 4 TRACKLINE ORIENTATION OF AERIAL AND VESSEL SURVEYS DURING SPRING THROUGH FALL PERIOD.

Aerial and vessel surveys were conducted along the transect lines of randomly selected sampling units (Figure 4). Survey effort in a given zone was allocated in proportion to the relative amount of area in each zone. Consequently, we attempted to allocate 50 percent of the survey effort in the shallow water zone, 36 percent in the transition zone, and 14 percent in the deep water zone. This approach assumed that marine mammals were distributed in proportion to the amount of area available in each zone; an assumption that was the best available at the initiation of the study from the marine mammal literature for the Basin.

Aerial surveys were conducted from a UH1M helicopter based on the NOAA ship SURVEYOR. Surveys were flown at altitudes of 150-230 m and at speeds of 65-75 kt. Two observers, one positioned in the co-pilot's seat and one in the right-aft section of the helicopter, provided data on marine mammals and environmental conditions to a data recorder; all data were recorded on computer-ready-forms. Data collected on marine mammals during a survey were number, species, vertical angle when an animal was perpendicular to the trackline, group size, time, and position. Environmental conditions including visibility (Appendix Table 1), Beaufort Wind Scale (Appendix Table 2), air temperature, and glare were evaluated at the start of each transect line surveyed, or whenever the conditions changed. Vertical angles were taken with clinometers and positions were recorded from a GNS-500 every 3 nm along a transect line. The pilot was responsible for providing positions of the aircraft to the data recorder, maintaining a constant altitude and airspeed, and when possible, searching for marine mammals.

When the wind speed was greater than a Beaufort 4, the visibility <2 nm, or the ceiling below 150 m, vessel surveys were conducted along the transect lines in place of aerial surveys. Surveys were performed from the flying bridge, approximately 18 m above the water, and at a vessel speed of 12 kt. Two observers, individually stationed on the port and starboard sides of the vessel, recorded marine mammal and environmental data on the same variables described for the aerial surveys. Radial angles, instead of vertical angles, were taken with a sighting board or 10 minute surveyors transit and animal distances from the vessel were estimated by observers who generally had substantial experience with this estimation procedure. Water depth was recorded every 3 nm. Vessel surveys were terminated when wind speed exceeded a Beaufort 6.

Vessel surveys were also conducted in conjunction with the aerial surveys (Figure 4). The ship travelled an east-west route along the mid-latitudinal points of the north-south transect lines. One observer, positioned on the flying bridge, recorded marine mammals encountered along the trackline. The use of the ship during the aerial surveys was for the purpose of collecting distributional information on marine mammals and providing safeguards to the helicopter crew.

SEASONAL ICE PERIOD - WINTER

During the seasonal ice period, the Basin was stratified into three zones identified as the open water, marginal ice front, and heavy pack ice zones (Figure 2). The former zone occurred entirely in open water, while the heavy pack ice zone was primarily in areas of 90 to 100 percent ice coverage; the marginal ice front zone was intermediate between these two strata and consisted chiefly of 10 to 90 percent ice coverage. The size of each zone varied according to the movement of the sea ice during the course of the study. Although this stratification procedure was developed, the open water was not surveyed because of persistent high seas, nor was the heavy pack ice surveyed since the ice-breaker had difficulty penetrating the dense, and at times thick, pack ice. Consequently, the entire survey effort was devoted to the marginal ice zone, where the largest number and greatest diversity of marine mammals were expected to be found (Burns et al. 1981, Brueggeman 1982).

Six sampling units were equidistantly distributed across the marginal ice front between longitudes 171°12'W and 179°36'W (Figure 2). The survey area extended beyond the boundaries of the Basin in order to increase coverage of the front. Although each unit was 36 nm wide, the north and south boundaries varied since they corresponded to the edge of the ice and the start of heavy pack ice; boundaries that are governed by wind and currents. The average sampling unit size was 2,730 nm^2, with a range of 1,474 to 3,731 nm^2.

Aerial and vessel surveys were conducted along seven paired transect lines established in each sampling unit (Figure 5). The paired transect lines were spaced every 4 nm and corresponded to the longitude lines. Individual transect lines comprising each pair were separated by 2 nm and extended 30 nm into the pack ice from the interface of the marginal ice front with the open water; the exact length of the transect lines varied depending on ice conditions and a combination of logistical factors influencing opportunities for surveys.

Aerial surveys were conducted from two Sikorsky H-52-A helicopters based on the U.S. Coast Guard icebreaker POLAR SEA (Figure 5). The helicopters flew transect lines parallel to each other or singly at speeds of 65-75 kt and at altitudes of 150-230 m. Observer and data collection procedures were largely the same as those for aerial surveys during the ice-free period. The only difference was that navigation was determined from Loran-C systems on each helicopter, and ice thickness, size, and concentration were visually evaluated every 3 nm along the transect line by the observer occupying the copilot's seat in each helicopter; ice characteristics were evaluated by the same two observers for every survey to maintain data consistency (Appendix Table 3 defines ice characteristics). Single helicopter surveys were flown along the transect lines when one helicopter was inoperable. Under these circumstances, the Coast Guard restricted the helicopter range to 8 nm from the ship. To maximize the use of a single helicopter, the ship travelled a predetermined course, while the helicopter flew a

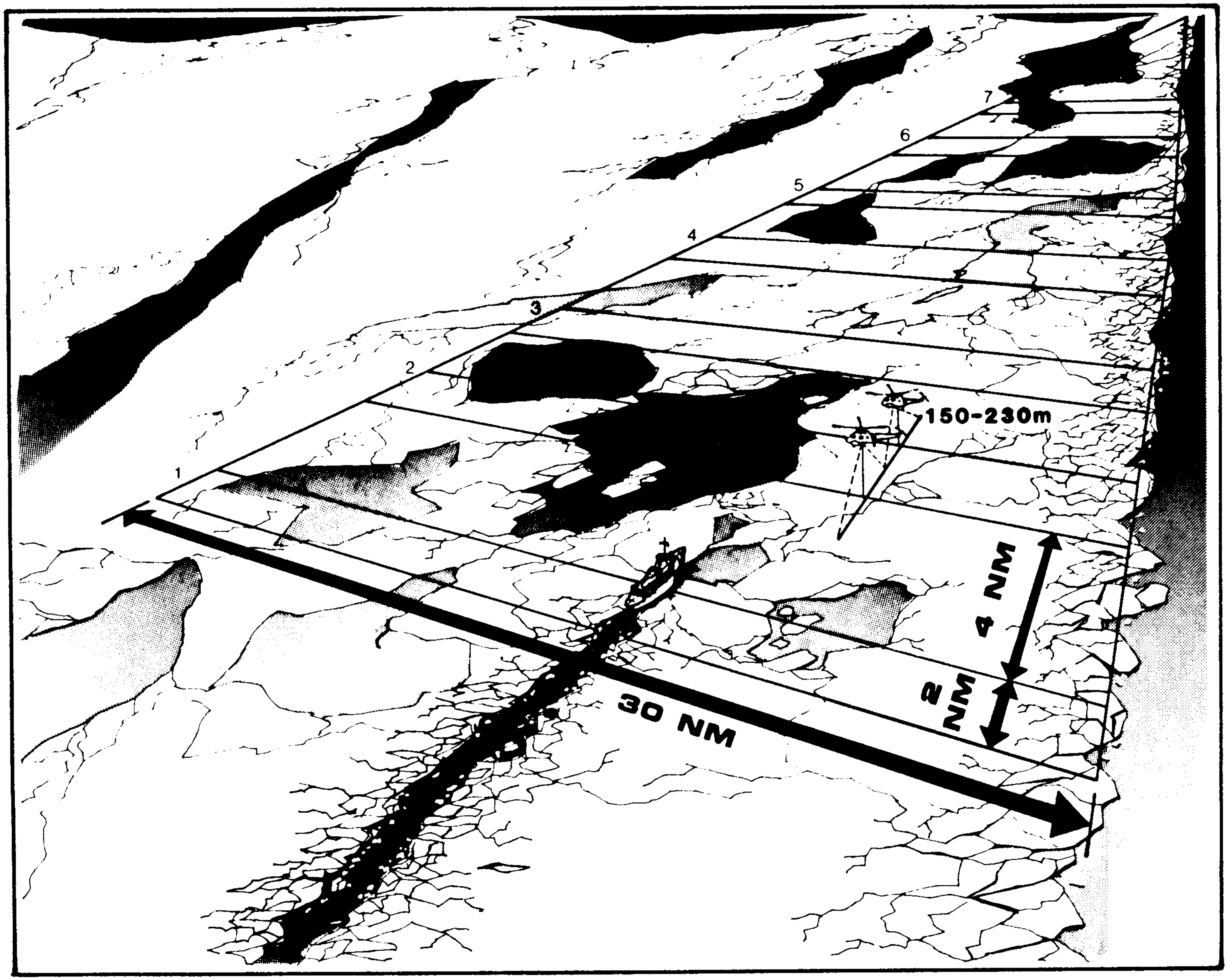

FIGURE 5 TRACKLINE ORIENTATION OF AERIAL AND VESSEL SURVEYS DURING WINTER, 1983.

transect line 8 nm both north and south of the ship. A similar vessel travel pattern was followed during the two-helicopter surveys but the aircraft travelled longer distances from the ship.

When winds exceeded 25 kt, ceiling was below 91 m, visibility was <2 nm, or both helicopters were inoperable, vessel surveys were conducted along the transect lines in place of aerial surveys. Vessel surveys followed the same data collection procedures as described for the ice free period surveys except for the location of the observers and the angle measurement to an observed animal. Observations of marine mammals were made from the loft-conning tower, 34 m above the water. Each observer recorded all marine mammals occurring in a 90° arc on either side of the bow of the ship for the port and starboard sides. Angles to animals were taken in combination with a sighting board for the radial angle and a clinometer for the vertical angle. This approach provided an accurate way of determining animal distances from the ship. Vessel surveys were also conducted during aerial surveys if survey team members were available to observe when one helicopter was inoperable; data collected during these surveys were used to describe marine mammal distribution and species composition.

DATA ANALYSIS

Standard statistical procedures were used in the data analysis. Population estimates were derived from the strip-transect method (Eberhardt 1978). The strip-transect method involves calculating abundance from the density of animals in a survey strip. Although this method assumes that all animals in the designated strip are counted, confirmation of this assumption is impossible and probably violated for marine mammals. However, this method provided the best relative index of pinniped abundance for this study.

Estimates of the density and abundance of pinnipeds and associated variances were calculated from methods described by Estes and Gilbert (1978) for strip-transect analysis. Density and abundance were calculated by summing the sampling unit estimates for the Navarin Basin.

The estimator has the following form:

Estimated density is:

$$D_i = \Sigma\ y_i / \Sigma\ x_i$$

where D_i = the density of pinnipeds per nm^2 for a sampling unit
y_i = the number of pinnipeds in the i^{th} transect strip, and
x_i = the area of the i^{th} transect strip

Estimated variance of D_i is:

$$S^2_{D_i} = \Sigma\ (y_i^2 / x_i) - D\ \ y_i\ \Sigma / (n-1)(\Sigma\ x_i)$$

where n = number of transects

Estimated abundance for a unit is:

$$T_i = D_i\ A_i$$

where: T_i = abundance of pinnipeds in a sampling unit, and
A_i = total area of that sampling unit

Estimated abundance for all zones is

$$T = \Sigma\ T$$

Estimated variance of T is:

$$V(T) = A\ (A - \Sigma\ x_i)\ S^2_{D_i}$$

The 95 percent confidence interval for T is:

$$T \pm 1.96 \sqrt{V(T)}$$

Pinniped abundance was estimated from systematic aerial and vessel surveys. Estimates were made from animal observations occurring in a strip width of 0.5 nm (0.25 nm per side of the trackline) for the winter surveys. This strip width best fit the observed distribution of perpendicular distances of pinnipeds from the transect line. Other investigators (Burns and Harbo 1977, Braham et al. unpublished) have found this strip width to be suitable for estimating pinniped population sizes. The number of pinniped observations recorded from the two survey platforms did not indicate an observation bias for either side of the aircraft or vessel, so the observations for the two sides were treated equally in estimating abundance. No density estimates were made for pinniped populations during the ice free season because of the difficulties of accurately counting pinnipeds in open water.

Other statistical procedures used in the analysis were Chi-square goodness-of-fit for testing animal abundance among units, animal use of ice types, and interaction of time of day and wind chill on haul out patterns of pinnipeds. This procedure tests the hypothesis that animals are uniformly distributed in space or time. Significant animal occurrence in a particular ice type was identified by procedures developed by Nue et al. (1974). Analysis of variance was applied to data delineating species distance from the ice edge. All tests were performed at the 0.05 level of significance.

RESULTS

Four hundred and fifty groups of pinnipeds representing seven species and 1,852 individuals were observed during four seasonal surveys of the Navarin Basin (Table 1). Over 50 percent of the animals were walruses, while northern sea lions comprised approximately another 25 percent. Spotted seals were the most abundant seal species encountered, followed by ribbon, bearded, ringed, and fur seals. Approximately 90 percent of the pinnipeds were recorded during the winter survey period (February-March), when pinnipeds haul out on pack ice and are most visible. Conversely, counts made during the other three seasons were generally much lower because of the low visibility of pinnipeds in open water. More animals were recorded during spring than summer or fall, however, because bands of remnant ice (Burns et al. 1980) in the northern third of the Basin provided a platform for pinnipeds to haul out on. Over 75 percent of the animals recorded for all four seasons were observed during aerial surveys, which accounted for 69 percent of the 8,057 nm censused.

ICE FREE PERIOD

Ten percent of the pinnipeds recorded in the Basin were observed during the spring through fall seasons (Table 1). The greatest number and highest diversity of species were recorded in the spring, primarily on remnant ice. Walruses and sea lions comprised over 70 percent of the 161 pinnipeds encountered during this time, while 41 ribbon, spotted, and bearded seals were recorded. Mean group sizes were largest for walruses (5.6±2.4 standard error) and smallest for bearded seals (1.0±0.0); mean sizes of northern sea lion (4.3±1.2), spotted seal (1.2±0.1), and ribbon seal (1.0±0.04) groups were intermediate (Figure 6). During the summer and fall seasons, 17 fur seals and 4 northern sea lions were observed primarily as singles. Most of the animals were observed from the vessel in open water, compared to the spring when almost all of the animals were observed from the helicopter on ice. A total of 5,647 nm were surveyed from vessel and helicopter

TABLE 1

NUMBER OF SEALS, SEA LIONS, AND WALRUSES RECORDED DURING THE FOUR SEASONAL SURVEYS OF THE NAVARIN BASIN, 11 MAY-10 JUNE, 20 JULY-19 AUGUST, 29 OCTOBER-12 NOVEMBER 1982, AND 19 FEBRUARY-18 MARCH 1983

	Spring				Summer				Fall				Winter				Total			
		No. Individuals				No. Individuals				No. Individuals				No. Individuals				No. Individuals		
Species	No. Groups	Aerial	Vessel	Total	No. Groups	Aerial	Vessel	Total	No. Groups	Aerial	Vessel	Total	No. Groups	Aerial	Vessel	Total	No. Groups	Aerial	Vessel	Total
Spotted seal	13	14	1	15	-[a]	-	-	-	-	-	-	-	42	225	16	241	55	239	17	256
Ribbon seal	21	22	-	22	-	-	-	-	-	-	-	-	22	46	12	58	43	68	12	80
Bearded seal	4	4	-	4	-	-	-	-	-	-	-	-	8	6	2	8	12	10	2	12
Ringed seal	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	2	2	2	-	2
Fur seal	-	-	-	-	9	-	10	10	6	-	7	7	1	1	-	1	16	1	17	18
Northern sea lion	11	42	5	47	4	2	2	4	-	-	-	-	69	361	45	406	84	405	52	457
Walrus	12	65	2	67	-	-	-	-	-	-	-	-	147	574	294	868	159	639	296	935
Unidentified pinniped	3	-	6	6	-	-	-	-	-	-	-	-	73	72	14	86	79	72	20	92
TOTAL	67	147	14	161	13	2	12	14	6	-	7	7	364	1287	383	1670	450	1436	416	1852

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[a] Dash (-) signifies no animals were observed.

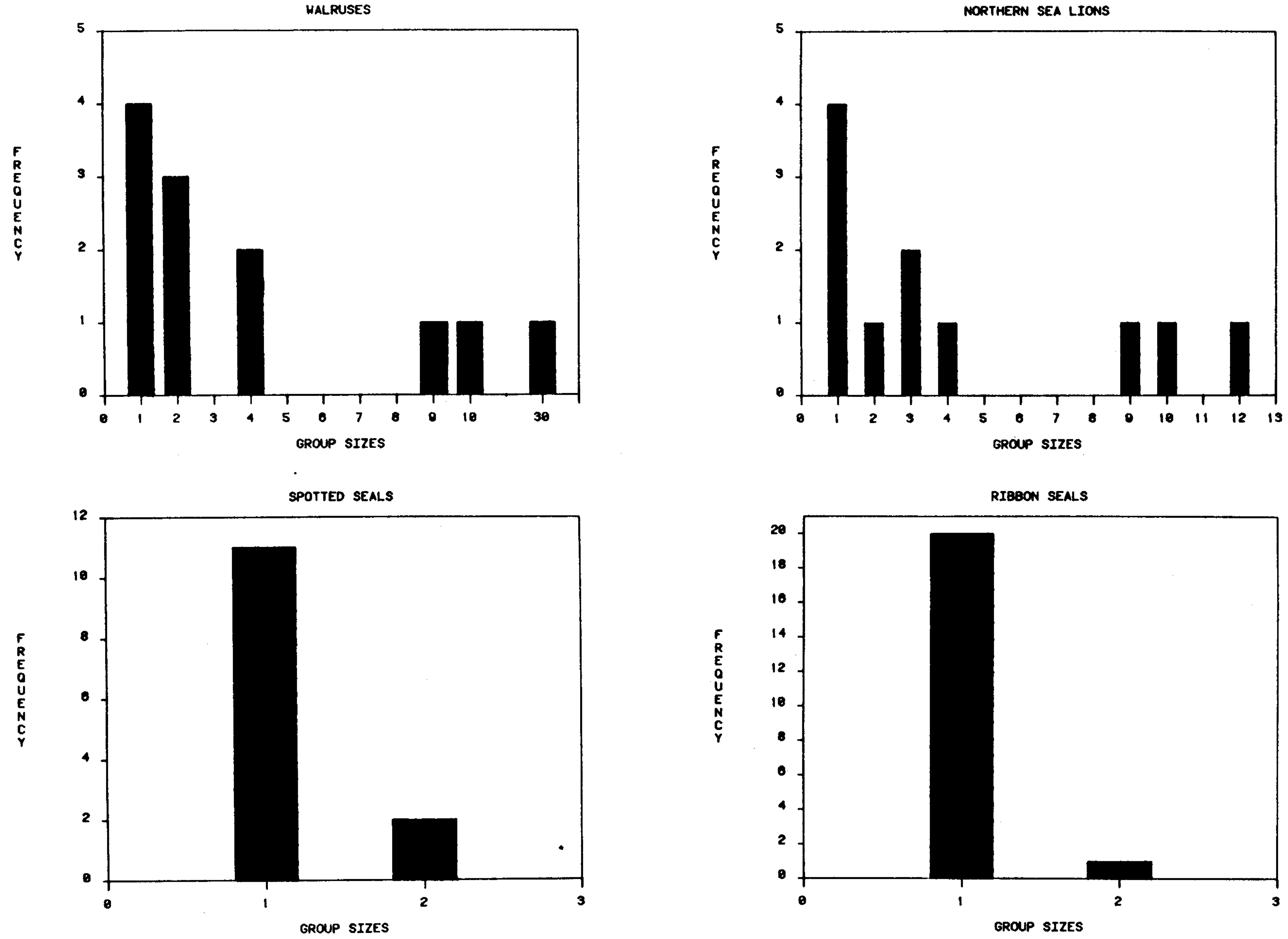

FIGURE 6 FREQUENCY DISTRIBUTION OF GROUP SIZES FOR THE FOUR MOST COMMON SPECIES OF PINNIPEDS OBSERVED IN THE NAVARIN BASIN DURING SPRING 1982.

over these three seasons (Appendix Figures 1-6 illustrate the locations of the survey tracklines and animals).

SEASONAL ICE PERIOD

Composition and Relative Abundance

The seven species of pinnipeds found in the Bering Sea were observed in the marginal ice front of the Navarin Basin during the winter survey (Table 2, Figure 7). Over 75 percent of the 1,670 animals recorded along the 2,410 nm censused were walruses (52 percent) and northern sea lions (24 percent). Of the 310 seals encountered, 78 percent were spotted seals, followed by ribbon, bearded, ringed, and fur seals in their order of decreasing relative abundance. Eighty-six animals, primarily seals, were not identified to species because most of them were briefly seen in the water. Approximately 65 percent of the pinnipeds were recorded during aerial surveys, which represented 68 percent of the total survey effort. (Appendix Figures 7-11 illustrate the locations of the survey tracklines and animals.)

Group sizes of pinnipeds were quite variable (Figure 8). Average group sizes were largest for walruses (6.9±1.4 standard error) and smallest for ribbon seals (1.3±0.2). Spotted seals and northern sea lions were recorded in groups averaging 6.3±3.6 and 5.9±0.8 animals, respectively. Spotted seal groups were the most variable, occasionally occurring in large but loose aggregations, while ribbon seal group sizes were consistently small. Although the large groups of walruses typically associated with the spring (Fay 1981; Brueggeman unpubl. data) were not observed, group sizes of the other pinnipeds were similar to those reported by Burns and Harbo (1977). The sex or age composition of the groups was not determined but eight newborn walruses were observed primarily with single adults, presumably their mothers. The newborns were recorded between 25 February and 7 March, inclusively. The earliest previously recorded birth date of walruses was 15 April (Fay 1981). No other species of newborn seals were observed because

TABLE 2

NUMBER OF SEALS, SEA LIONS, AND WALRUSES OBSERVED DURING THE WINTER AERIAL AND VESSEL SURVEYS OF THE NAVARIN BASIN, 19 FEBRUARY-18 MARCH 1983

Sampling Unit	Trackline distance surveyed			Spotted seal		Ribbon seal		Bearded seal		Ringed seal		N. fur seal		N. sea lion		N. Pacific walrus		Unidentified pinniped		Total	
	Aerial (%)	Vessel (%)	Total (nm)	No. Groups	No. Indiv.	No. Groups	No. Indiv.	No. Groups	No. Indiv.	No. Groups	No. Indiv.	No. Groups	No. Indiv.	No. Groups	No. Indiv.	No. Groups	No. Indiv.	No. Groups	No. Indiv.	No. Groups	No. Indiv.
24	0	100	147	2	4	-[a]	-	1	1	-	-	-	-	3	7	25[c]	42	7	12	38	66
25	82	18	462	1[b]	1	5	5	-	-	-	-	-	-	-[b]	-	43[c]	198	17	18	66	222
26	71	29	613	4[b]	15	12[c]	45	6	6	-	-	-	-	8[b]	26	64[c]	556	24	26	118	674
27	83	17	482	4	37	3[b]	6	-	-	-	-	1	1	10	34	5[b]	33	3	3	26	114
28	80	20	466	3[b]	3	2[b]	2	-	-	-	-	-	-	36	324	-[b]	-	7	7	48	336
29	23	77	240	28[c]	181	-[b]	-	1	1	2	2	-	-	12	15	10	39	15	20	68	258
TOTAL	68	32	2410	42	241	22	58	8	8	2	2	1	1	69	406	147	868	73	86	364	1670

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[a] Dash (-) signifies no animals.
[b] Significantly fewer observed than expected ($p<0.05$).
[c] Significantly more observed than expected ($p<0.05$).

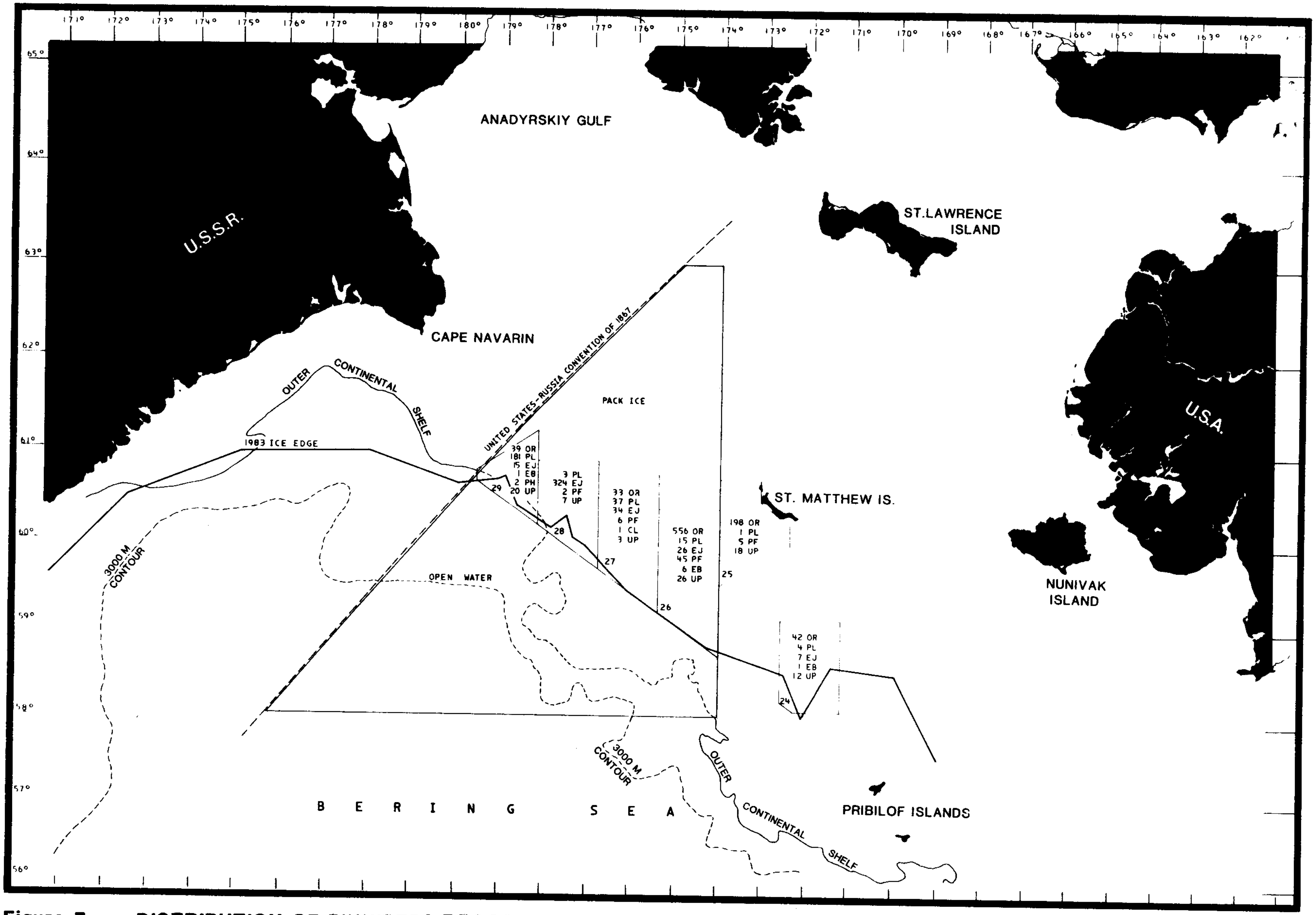

Figure 7 DISTRIBUTION OF PINNIPEDS RECORDED IN NAVARIN BASIN DURING WINTER, FEBRUARY 19–MARCH 18, 1983. (See Figures 7 Through 11 and Table 4 in Appendices for Specific Locations of Survey Tracklines and Animals.)

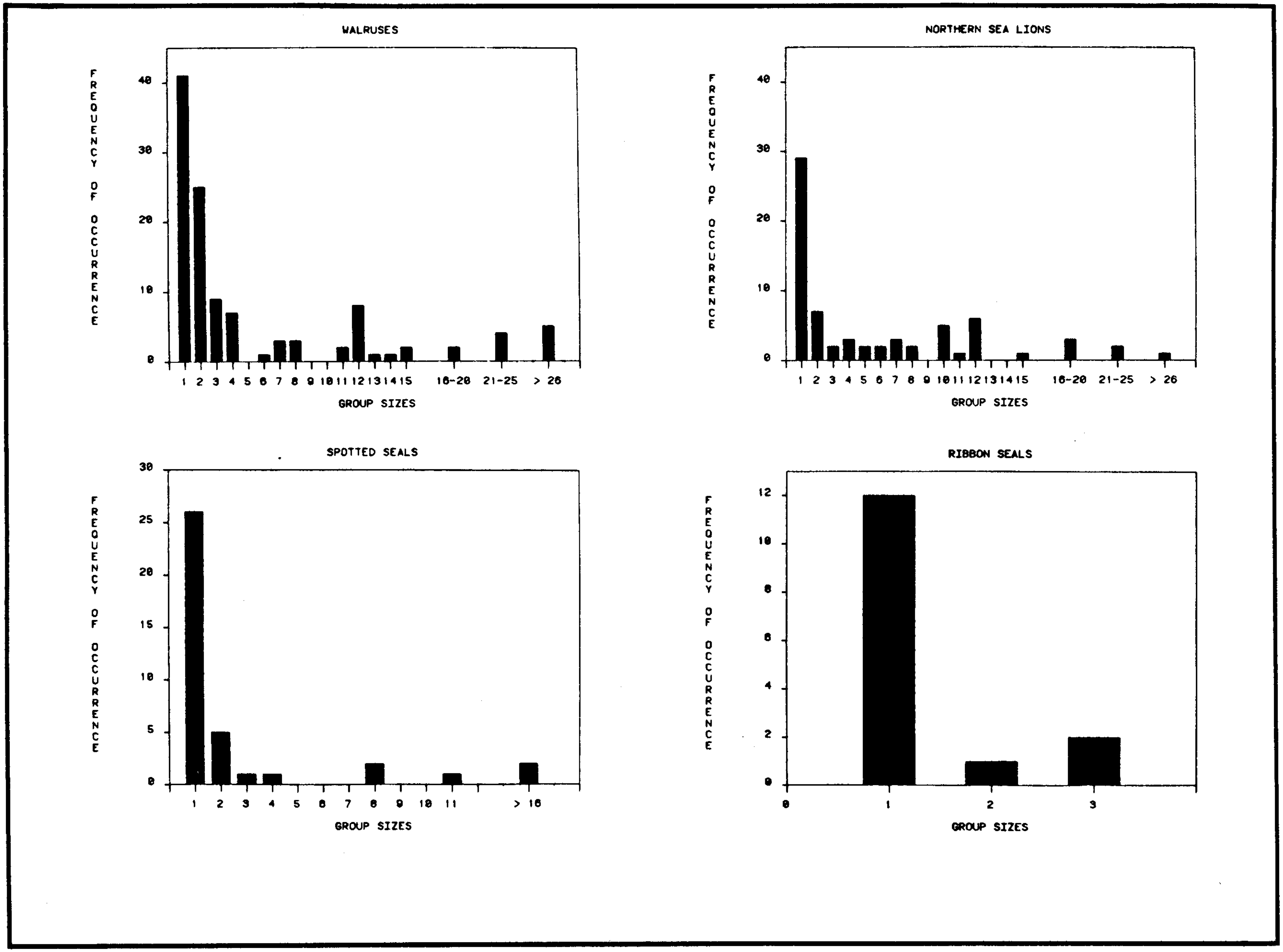

FIGURE 8 FREQUENCY DISTRIBUTION OF GROUP SIZES FOR THE FOUR MOST COMMON SPECIES OF PINNIPEDS OBSERVED IN THE MARGINAL ICE FRONT DURING WINTER, 1983.

birthing periods of ice seals occurred after completion of our surveys and sea lions or fur seals birth on land outside the Basin. Group characteristics of the other species were not examined because too few animals were recorded, and only animals observed on the ice were included for the four species analyzed.

Distribution

Pinnipeds differed in their spatial distribution across the ice front and from the ice edge or open water (Figure 9). Spotted seals were the most widely distributed species in the ice front. They occurred in every unit, but were especially abundant in unit 29, where observed numbers significantly ($P<0.05$) exceeded expected numbers (Appendix Table 5). Ribbon seals, the most narrowly distributed species, occurred in the four units centrally located in the ice front. They were particularly abundant in unit 26, where the number observed was significantly ($P<0.05$) greater than the expected. Although walruses and northern sea lions were encountered in 5 of the 6 units, the distribution of each species spanned the entire front. Walrus use was significantly ($P<0.05$) greater than expected in the three eastern units, as was sea lion use ($P<0.05$) in unit 28 of the front. Although there were too few observations of the other species to assess distribution, bearded seals were sporadically observed across the entire ice front. These results identify that pinnipeds were widespread in the ice front, and furthermore certain areas were preferentially used by each species, which generally did not overlap.

In addition to having specific distribution patterns across the ice front, pinnipeds were differentially spaced from the ice edge (Figure 10). The average distance from the ice edge was significantly different ($P<0.05$; 3,274 df; $F=149.40$) among northern sea lions, walruses, spotted seals, and ribbon seals. Northern sea lions were closest (12.5 nm±0.8 standard error) and walruses farthest (67.4 nm±1.9) from the ice edge. Distributed between these two species were the spotted (30.5 nm±2.7) and ribbon (60.5 nm±4.2) seals, although

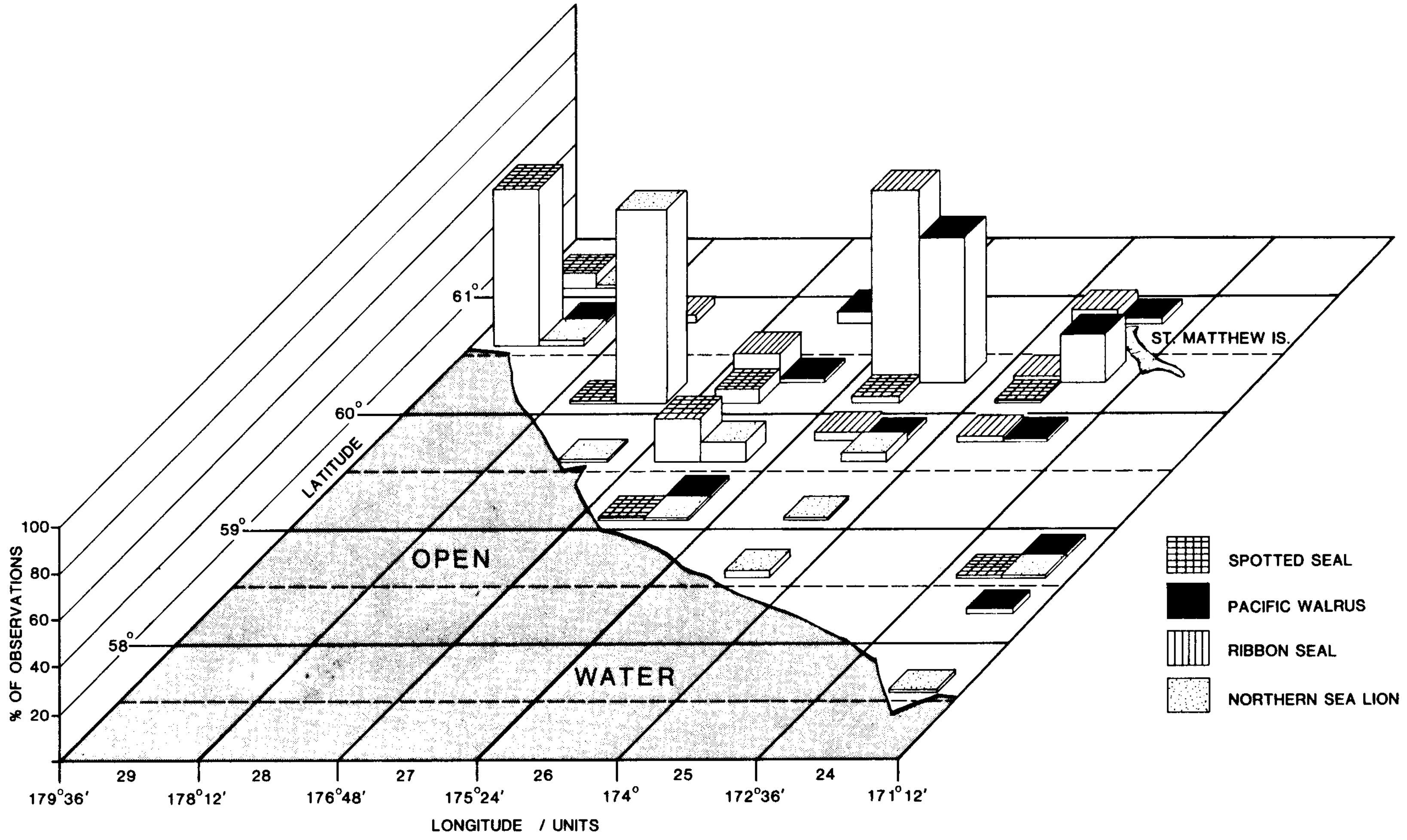

FIGURE 9 DISTRIBUTION OF THE FOUR MOST COMMON PINNIPEDS OBSERVED IN THE MARGINAL ICE FRONT DURING WINTER, 1983.

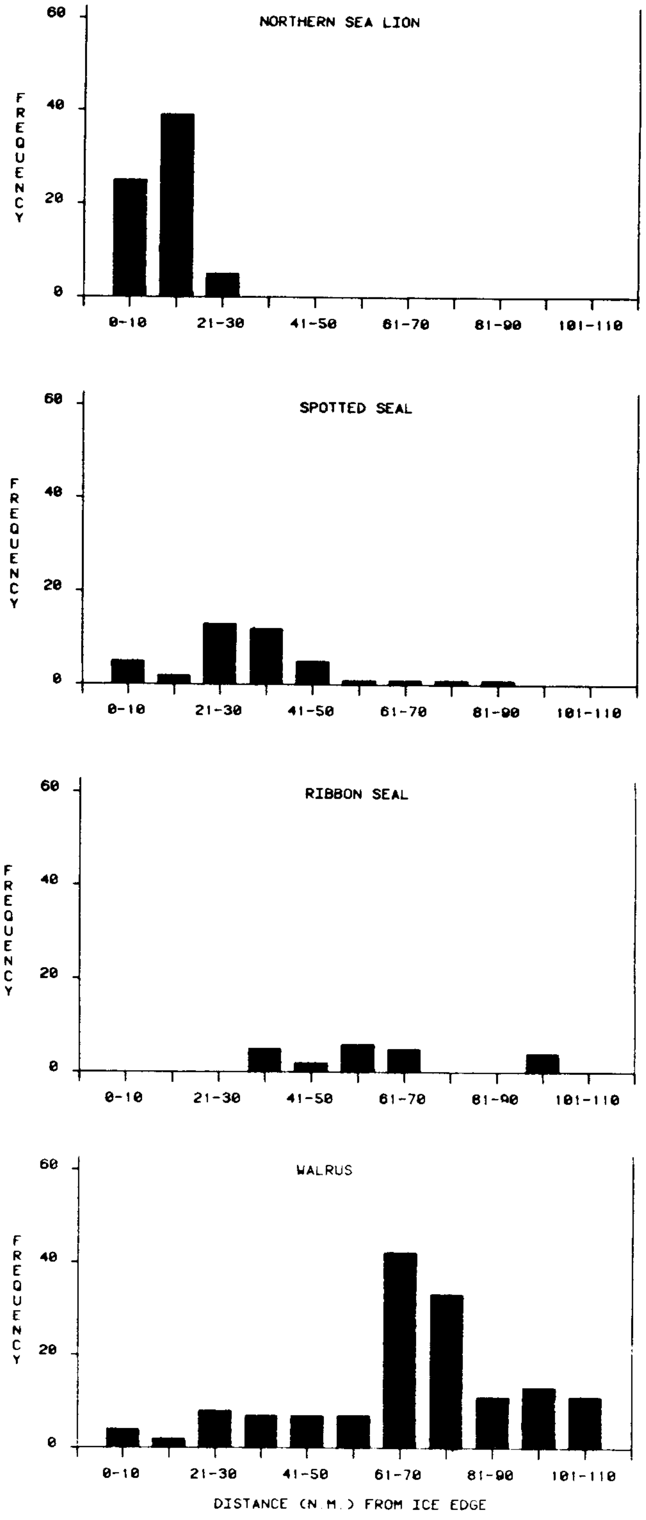

FIGURE 10 DISTANCE FREQUENCIES OF NORTHERN SEA LIONS ,SPOTTED SEALS, RIBBON SEALS,AND WALRUSES INTO THE PACK ICE FROM THE EDGE OF MARGINAL ICE FRONT DURING WINTER 1983.

ribbon seals were considerably deeper into the pack ice. Walruses were found over the greatest range of distances and sea lions the narrowest range, suggesting that while each species concentrated at certain distances from the edge, the adaptability of sea lions to penetrate into the pack ice may be more limited than for walruses or the other pinniped species examined. Too few sightings were recorded of the other species to analyze.

Ice Characterization and Use

The spatial distribution of pinnipeds is influenced by ice. Ice provides pinnipeds a platform for birthing, breeding, and molting (Burns et al. 1981). Pinnipeds may select certain ice conditions to accomplish these biological events. In order to evaluate the role of ice in the life cycle of pinnipeds, measurements were made of ice coverage, floe size, and ice thickness. A description of these ice conditions and their use by pinnipeds is provided below.

Ice coverage in the Basin was more extensive than average (Figure 11). The approximate ice edge, which was located south of the 1954-70, 16 year mean (Potocsky 1975), followed the outer continental slope. This resulted in pack ice covering approximately half of the Navarin Basin. The marginal ice front, a zone of transition between the irregular southern margin of the main pack ice and the heavier consolidated pack ice (Burns et al. 1981), ranged between 30 and 100 nm in width in the study area. Ice coverage in the marginal ice front was 76 percent during the winter survey (Table 3). Pack ice coverage increased from 68 percent in the most western unit (29) to approximately 80 percent in the eastern units (24, 25). One-way ANOVA (following arcsine transformation) indicated that ice coverage among units was significantly different ($P<0.001$; 5,837 df; $F=14.78$). Ice in the western units was more broken and featured relatively large proportions of area in the lower ice concentration and floe size classes but the ice was thick. Conversely, ice in the eastern units was relatively

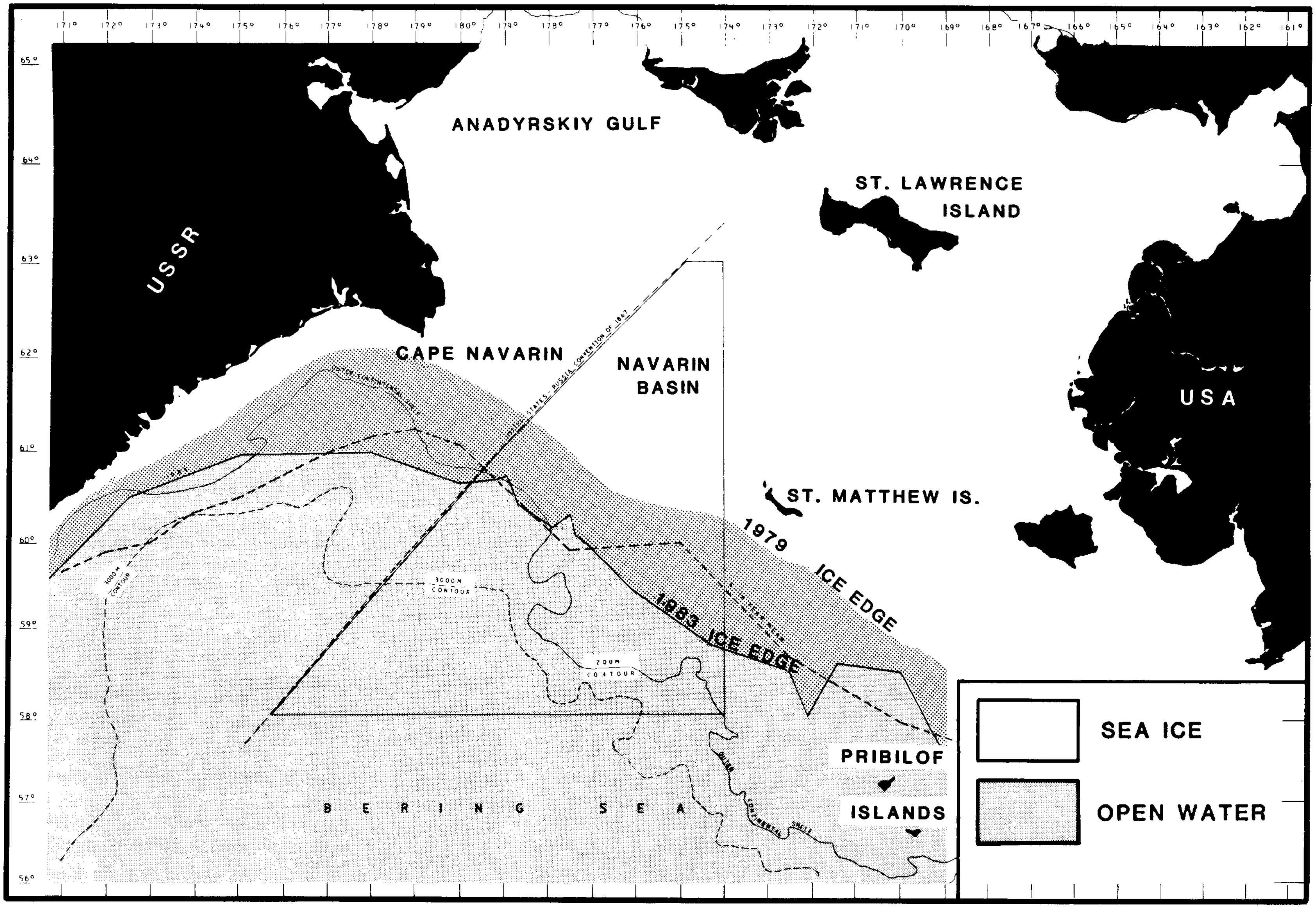

Figure 11 APPROXIMATE LOCATION OF ICE EDGE DURING 1979 AND 1983 STUDY PERIODS COMPARED TO A 5-16 YEAR MEAN (Potocsky 1975) IN THE BERING SEA.

TABLE 3

ICE CHARACTERISTICS OF STUDY AREA, 19 FEBRUARY - 18 MARCH 1983[a/]

Sampling unit	Percent area coverage of ice	Percent area (nm^2) coverage of each ice concentration category					Percent area coverage of each ice size category[b/]				Percent area coverage of each ice thickness category			Total area surveyed (nm^2)
		0-20	21-40	41-60	61-80	81-100	Grease-slush	Pancake-small	Medium-large	Vast-giant	New	Young	First year	
24	79.0	2.0	7.1	15.1	25.3	50.5	4.8	4.5	5.6	85.1	19.1	11.7	69.2	73.4
25	80.5	0.6	4.5	12.8	35.7	46.4	17.3	0.0	8.8	73.9	28.2	45.6	26.2	231.2
26	78.5	2.0	3.8	19.4	25.9	48.9	17.1	5.2	15.7	62.0	17.9	55.6	26.5	306.4
27	71.5	9.3	3.9	21.9	23.8	41.1	2.7	59.2	20.0	18.1	1.9	30.3	67.8	240.9
28	75.7	3.0	3.5	18.1	38.4	37.0	4.1	24.0	30.8	41.1	0.6	29.5	69.9	233.0
29	68.2	11.7	13.5	12.2	24.2	38.4	3.9	40.2	15.8	40.1	1.7	35.0	63.3	119.9
TOTAL	75.9	4.4	5.1	17.3	29.6	43.6	10.0	21.0	17.4	51.6	11.8	38.8	49.4	1204.8

[a/] Ice characteristics are defined in Appendix Table B-3.

[b/] Ice size was calculated as a proportion of total ice coverage.

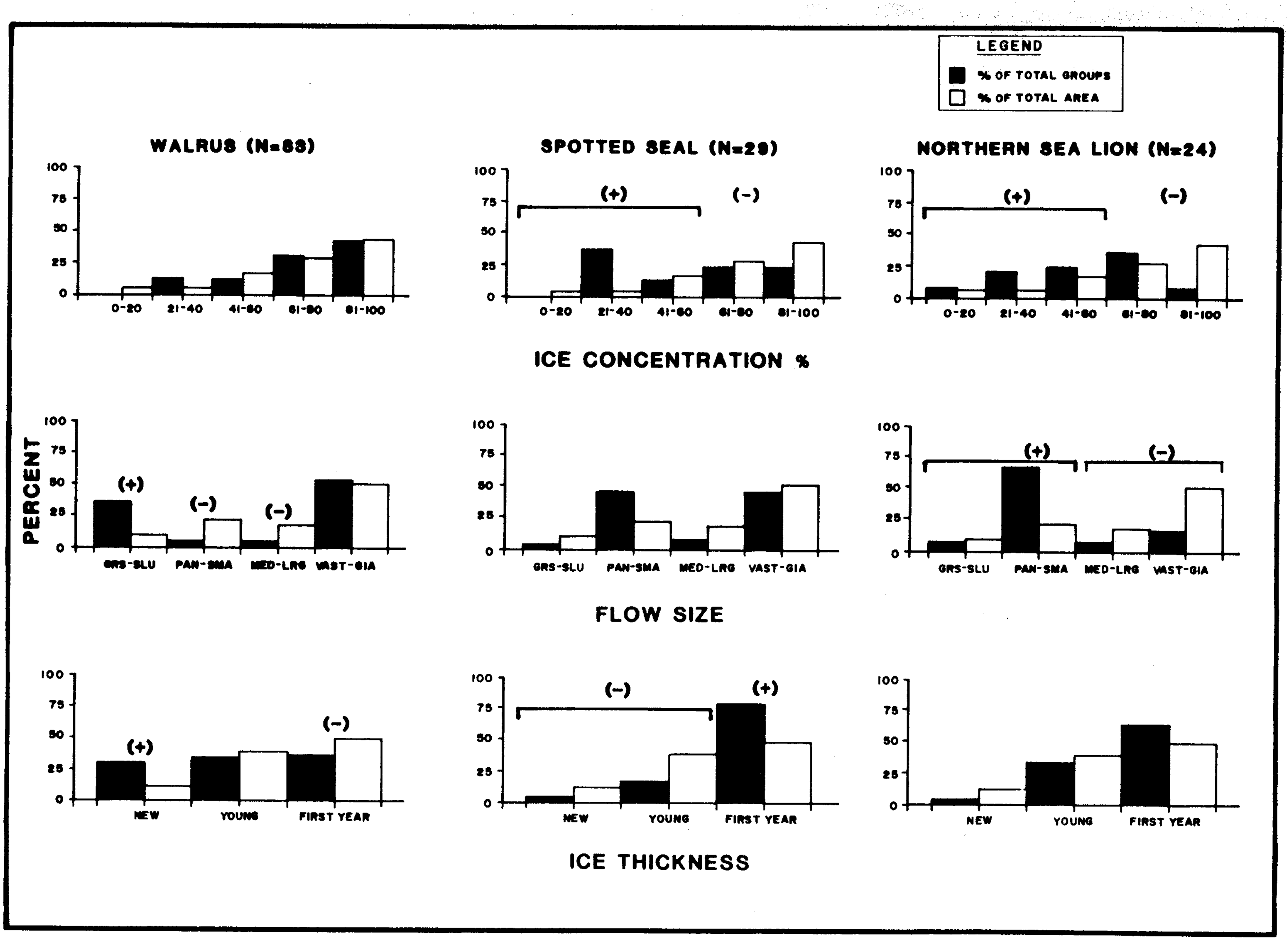

FIGURE 12 PERCENT OCCURRENCE OF PINNIPEDS RELATIVE TO PERCENT AVAILABILITY OF ICE TYPES IN THE MARGINAL ICE FRONT : PLUS (+) SIGNIFIES SIGNIFICANT PREFERENCE, MINUS (-) SIGNIFIES SIGNIFICANT AVOIDANCE, BRACKET (┌─┐) SIGNIFIES POOLED DATA.

thin but more concentrated, as evidenced by the presence of large amounts of areas in the higher ice concentration and floe size classes.

Pinnipeds occurred in a variety of ice conditions (Figure 12). Chi-square analysis (Appendix Table 6) identified that walruses preferred ($P<0.05$) areas of new ice and grease to slush floes, but indiscriminately ($P>0.05$) used areas of 20 to 100 percent ice coverage. Seventy-five percent of the animals, however, were recorded in the higher ice coverage areas (60 to 100 percent). Significantly fewer ($P<0.05$) walruses were associated with the intermediate floe sizes (pancake to large floes) and first year ice. Northern sea lions used areas of different ice thickness in proportion to their availability, but they were more abundant than expected ($P<0.05$) in areas with grease to small floes (pooled) and 0 to 60 percent ice coverage (pooled); use was particularly high in the areas with pancake to small floes (pooling of certain ice classes was necessary to obtain sample sizes sufficient to perform Chi-square analysis for sea lions and spotted seals). Conversely, areas of high ice coverage (80-100 percent) and large floe sizes (medium to giant) received significantly ($P<0.05$) low use by sea lions. Spotted seal occurrence in ice was most similar to northern sea lions. Areas of 20 to 60 percent (pooled) ice coverage and first year ice were preferred ($P<0.05$) by spotted seals, while they occurred in areas of new and young ice (pooled) and 81 to 100 percent ice coverage in numbers significantly ($P<0.05$) less than expected. Although there was no significant ($P>0.05$) seal use of specific floe sizes, they were most abundant in areas with pancake to small floes. Similar comparisons for the other pinniped species were not made because sample sizes were insufficient for analysis. These results suggest that while the species examined displayed wide use of pack ice, each species generally tended to have preferences and avoidances for particular ice conditions in the areas surveyed.

Density

Density estimates of pinnipeds may be influenced by environmental conditions at the time of survey. Withrow (1982), Everitt and Jeffries (1979), and others have shown that harbor seals and northern sea lions have definite haul out patterns correlated to time of day. Surveys conducted at off times produce biased estimates of density. Since ice related pinnipeds may also show a similar pattern to time of day and be further influenced by wind chill during winter, we examined the influence of these environmental factors on our counts. Counts may also be influenced by vessel or helicopter noises; however, most of the animals we observed were counted before they reacted to the survey platforms.

The number of pinnipeds we observed on the ice was influenced by wind chill and possibly by time of day (Table 4). Seals as a group were observed on the ice in significantly ($P<0.05$) lower numbers during wind chill conditions colder than -30°C, while sea lions and walruses did not significantly ($P>0.05$) respond to wind chills reaching -50°C. Conversely, time of day did not significantly ($P>0.05$) influence number of seals seen on the ice but it was significantly ($P<0.05$) associated with sea lion and walrus counts. There was, however, no recognizable trend, suggesting sample size may have been too small or these species have no predictable haul out patterns during the winter season. Because of the effect of wind chill on seal counts, density estimates were derived for seals and areas surveyed under wind chills warmer than -30°C for all times of day, while sea lion and walrus densities were calculated without concern to wind chill or time of day.

The stratified estimated density of pinnipeds in the marginal ice front was 27.33 animals per 100 nm^2, representing an estimated 4,477 seals, sea lions, and walruses (Tables 5, 6). Walrus and spotted seal estimated densities were over 75 percent greater than for the other species. Walrus densities were highest in the eastern half of the ice front while spotted seals densities were highest in the western half of

TABLE 4

CHI-SQUARE GOODNESS-OF-FIT TEST COMPARING HAUL OUT PATTERNS OF SEALS (SPOTTED, RIBBON, BEARDED, AND RINGED SEALS), SEA LIONS, AND WALRUSES TO TIME OF DAY AND WIND CHILL

		Seals		Sea lions		Walruses	
Time interval*	Distance surveyed (nm)	Observed number groups	Expected number groups	Observed number groups	Expected number groups	Observed number groups	Expected number groups
0800-1000	648	4	9.9	6	11.0	5	18.7
1000-1200	935	15	14.2	37	15.9	13	27.1
1200-1400	973	13	14.8	13	16.5	29	28.2
1400-1600	727	15	11.1	3	12.4	16	21.0
1600-1800	580	10	8.8	8	9.9	33	16.8
1800-1900	77	3	1.2	0	1.3	18	2.2
Total	3940	60	60.0 $x^2=8.01$ $p>0.10$	67	67.0 $x^2=39.81$ $p<0.001$	114	114.0 $x^2=147.68$ $p<0.001$

		Seals		Sea lions		Walruses	
Wind chill interval (°C)	Distance surveyed (nm)	Observed number groups	Expected number groups	Observed number groups	Expected number groups	Observed number groups	Expected number groups
-10 to -19	355	15	5.4	8	6.5	4	10.3
-20 to -29	1311	35	20.0	16	24.0	44	37.9
-30 to -39	1999	10	34.6	43	36.5	61	57.8
-40 to -49	275	—	—	—	—	5	8.0
Total	3940	60	60.0 $x^2=42.89$ $p<0.001$	67	67.0 $x^2=4.17$ $p>0.10$	114	114.0 $x^2=6.14$ $p>0.10$

TABLE 5

ESTIMATED DENSITY (per 100 nm^2) OF SEALS, SEA LIONS, AND WALRUSES IN THE MARGINAL ICE FRONT OF THE NAVARIN BASIN DURING WINTER, FEBRUARY-MARCH 1983

Sampling unit	Total area (nm^2)	Area coverage: Aerial		Area coverage: Vessel		Area coverage: Total		Spotted seal		Ribbon seal		Bearded seal		Unidentified pinniped		Northern sea lion		Pacific walrus		Total	
		%[a]	%[b]	%[a]	%[b]	%[a]	%[b]	No.[c]	Den.	No.[c]	Den.	No.[c]	Den.	No.[c]	Den.	No.[c]	Den.	No.[c]	Den.	No.[c]	Den.
24	2924	0.00	0.00	0.09	2.51	0.09	2.51	-[d]	-	-	-	-	-	-	-	-	-	12	16.33	12	16.33
25	2381	0.71	7.98	0.00	1.73	0.71	9.71	-	-	-	-	-	-	-	-	-	-	60	25.95	60	25.95
26	3731	2.43	5.81	0.78	2.40	3.21	8.21	4	3.34	2	1.67	-	-	6	5.02	12	3.92	70	22.85	94	36.80
27	3429	5.83	5.84	0.66	1.19	6.49	7.03	34	15.27	6	2.70	-	-	2	0.90	1	0.42	31	12.87	74	32.16
28	2443	1.86	7.69	0.84	1.94	2.70	9.63	-	-	-	-	-	-	3	4.55	21	8.93	-	-	24	13.48
29	1474	1.91	1.91	5.26	6.27	7.17	8.18	25	23.65	-	-	1	0.95	4	3.78	2	1.66	11	9.12	43	39.16
Total	16,382	2.32	5.02	0.93	2.35	3.25	7.37	63	6.09	8	0.95	1	0.09	15	2.35	36	2.45	184	15.40	307	27.33
Unstratified								63	11.83	8	1.50	1	0.19	15	2.81	36	2.98	184	15.24	307	34.55

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[a] Percent area surveyed for seals and unidentified pinnipeds during wind chill conditions warmer than -30°C.
[b] Percent area surveyed for sea lions and walruses.
[c] Number of animals in strip.
[d] Dash (-) signifies no animals.

TABLE 6

ESTIMATED ABUNDANCES AND 95% CONFIDENCE INTERVALS FOR SEALS, SEA LIONS, AND WALRUSES IN THE MARGINAL ICE FRONT OF THE NAVARIN BASIN DURING WINTER, FEBRUARY-MARCH 1983[a]

Sampling unit	Spotted seal	Ribbon seal	Bearded seal	Unid. seal	Northern sea lion	Pacific walrus	Total
24	- [b]	-	-	-	-	477	477
25	-	-	-	-	-	618	618
26	125	62	-	187	146	853	1373
27	524	93	-	31	14	441	1103
28	-	-	-	111	218	-	329
29	349	-	14	56	24	134	577
Total	998±861	155±199	14±19	385±336	402±396	2523±2050	4477
Unstratified	1938±1474	246±253	31±50	460±371	488±468	2497±1827	5660

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[a] Abundance was calculated for animals in the survey strip during acceptable wind chill conditions. Numbers were derived by multiplying the estimated density times the unit area (Table 5).

[b] Dash (-) signifies no animals.

the front. Density estimates for the other species ranged between 0.09 for bearded seals and 2.45 animals per 100 nm^2 for northern sea lions. Estimated densities for these species in the ice front were difficult to evaluate because of small sample sizes, except for sea lions, which were most dense in the western third of the front. In general, pinniped densities were highest in the portion of the ice front corresponding to the Navarin Basin proper (units 26-29). Indices of abundance for the pinnipeds in the marginal ice front were estimated at 2,523 walruses, 998 spotted seals, 402 northern sea lions, 155 ribbon, and 14 bearded seals. These estimates were based on a survey coverage of 7.4 percent for sea lions and walruses and 3.3 percent for seals. Since they do not account for animals in the water or missed, the estimates should be considered conservative and as an index and not an absolute value of abundance. Confidence intervals around the estimates were wide because of small sample sizes.

DISCUSSION

Pinnipeds inhabited the Navarin Basin yearlong. Use was greatest during the winter and spring when most pinnipeds are driven from more northern latitudes by the pack ice. The pack ice, particularly during spring, provides pinnipeds a platform for resting, birthing, and molting. During the summer and fall when use of the Basin was lowest, the majority of pinnipeds had migrated northward or to coastal areas except for ribbon seals that probably summered over the shelf break (Burns 1970, 1981a). Although no ribbon seals were recorded in the Basin during these seasons, they may have been present but missed because phocid detection and identification in open water were difficult. The few sea lions and fur seals recorded were probably non-breeding animals since these species occupy rookeries throughout the summer. Because of the low numbers of animals observed during the summer and fall and the limited survey effort of the fringe ice where pinnipeds almost entirely occurred in the spring, the discussion will concentrate on the winter survey results which we were able to more thoroughly analyze. Since these results do not reflect the peak period pinnipeds haul out on ice, biases may exist among interspecific comparisons, but the data represent a first detailed description of pinniped use of the central Bering Sea ice front during late winter and early spring.

During the winter survey period, walruses, sea lions, spotted seals, and ribbon seals partitioned their distributions in the pack ice. Walruses, although widespread, occurred principally deep in the pack ice in the eastern half of the ice front. They preferred areas of thin and grease-slush ice, avoided areas of thick ice and intermediate floe sizes, and displayed no association with ice concentration. Correspondingly, the eastern half of the front featured areas containing the highest proportion of grease-slush ice and new ice of the areas surveyed. Braham et al. (unpublished) reported qualitative evidence that walrus use was greater deeper in the pack than along the front. Furthermore, Fay (1981) reported that the northcentral concentration area (St. Lawrence Island vicinity) of walruses lies in an area of relatively thin, broken ice, surrounded by areas of heavier, more consolidated pack ice, and that walrus were conspicuously absent in areas of heavy ice. Walruses appear to select ice conditions that allow easy entry into shallow water feeding areas from haul out sites.

Sea lions, conversely, were very narrowly distributed in the ice front near the ice edge in the western third of the front (unit 28). They preferred areas of grease to small floes (particularly pancake to small floes) and 0 to 60 percent ice coverage, avoided areas of high ice concentration and medium-giant floes, and exhibited no association with ice thickness. These conditions closely describe areas near the ice edge (Burns et al. 1981), and partially agree with ice conditions in unit 28, which featured somewhat lower proportions of area in high ice concentrations and larger floes than elsewhere in the front. Burns and Harbo (1977) also reported that sea lions haul out mainly on small floes at the extreme southern edge of the front or within a few miles of it, but are likely to be encountered at any location along the front. Consequently, sea lions appear to be poorly adapted to inhabiting the deeper pack ice.

Spotted seals, like walruses, were widespread but primarily occurred at locations from the ice edge that were intermediate to walruses and sea lions, and were predominantly in the westernmost unit of the front. They preferred areas of moderate ice coverage (20-60 percent and particularly 20-40 percent) and thick ice (first year), but avoided thin to moderately thick ice. They indiscriminately used ice floe sizes, although the highest proportion of seals was in the pancake to small flow size class. Correspondingly, the unit they occupied in greatest numbers was most similar to the ice condition they preferred. Spotted seals, according to Burns and Harbo (1977) are most abundant in the front, utilizing small floes near the southern terminus of the pack, generally within 30 miles of the open ocean, but are also encountered deeper in the pack where currents or wind keep the ice thin. Since spotted seals, like sea lions, do not maintain breathing holes in ice, they inhabit areas of pack ice where there is persistent open water.

Also intermediate in location to walruses and sea lions, but deeper than spotted seals from the ice edge, were ribbon seals. They primarily occurred in the central section (unit 26) of the front which partially overlapped areas of high walrus use. Too few sightings were made to determine ice use, but Burns and Harbo (1977) reported that ribbon seals usually haul out on relatively thick, clear, rough, snow covered ice floes in the ice front, most often located between 20 and 50 miles north of the ice edge. The ribbon seals we observed were in somewhat similar ice conditions to these, but on the average they were deeper in the pack ice. Too few bearded and ringed seals were observed to evaluate their distribution patterns; these species primarily occur deep in the pack ice largely beyond the areas we surveyed (Burns and Frost 1979; Burns et al. 1981).

Consequently, the distribution of pinnipeds was influenced by sea ice. While ringed seals, and to a lesser degree bearded seals maintain breathing holes in ice, the other species of pinnipeds do not. This precludes sea lions, spotted seals, and ribbon seals from occupying areas deep in the pack ice. Walruses, however, because of their much larger size, can inhabit areas of heavier pack ice than these species but not to the degree of ringed seals. Consequently, sea lions, spotted, and ribbon seals occurred chiefly in areas of broken ice toward the edge of the ice front where smaller floes were prevalent because of the influence of wave action from the open water. In addition, smaller floes provided the greatest amount of edge for these animals to use during haul out periods. Walruses, however, were deeper in the ice but generally near broken ice where openings were available for them to enter the water.

Food availability is undoubtedly another important factor influencing the distribution of pinnipeds in the ice front (Burns et al. 1981; Lowry et al. 1982; Lowry and Frost 1981) but predator-prey studies were beyond the scope of our project. The Pacific walrus, a benthic feeder, preys primarily on bivalve mollusks (Musculus sp., Nucula sp., and Mya truncata sp.) which comprise over 80 percent of their diet (Fay 1982). Spotted and ribbon seals and sea lions all have overlapping prey species with the predominant species being walleye pollock (Gol'tsev 1971; Lowry et al. 1979; Frost and Lowry 1980; Burns et al. 1981; Burns 1981a; Lowry et al. 1982; Bukhtiyarov et al. in prep.;). Other major prey of these species are Arctic cod, saffron cod, capelin, rainbow smelt, sandlance, greenling, sculpins, herring, cephalopods, and shrimp (Lowry et al. 1981, 1982). Sea lions also feed on squid and octopus, species principally associated with the outer continental slope. The availability and distribution of these various prey species, while poorly known north of the slope, are widespread and within the areas occupied by the four pinnipeds (Umeda and Bakkala 1983). Walruses mainly occurred in the shallow water considerably north of the front where access to benthic invertebrates was easiest. Spotted and ribbon seal locations were difficult to interpret since their prey is quite diverse and widely distributed on the shelf. Their distribution may be more a function of the suitability of ice conditions, but this cannot be verified until better information is available on site specific distribution of prey species. A similar problem is associated with evaluating sea lion distribution; however, since sea lions' prey include several species primarily found near the slope, the narrow distribution of sea lions along the edge of the front may in part be related to access to the slope. It is obvious that food is important in the distribution of pinnipeds since it provides the fuel for maintenance and reproduction. Ice, however, is also important since it provides the platform for conducting reproductive events and molting as well as being a barrier to movement. Consequently, distribution of pinnipeds in the marginal ice front is interrelated to ice conditions and prey availability.

Other factors affecting the observed distribution of pinnipeds in the ice front were unclear but the value of partitioning space has been clearly documented. Habitat partitioning reduces competition among consumers for limited resources. This strategy has been reviewed (Schoener 1974) and documented for birds (Cody 1968), mammals (Koplin and Hoffman 1968; Singer 1978; Dueser and Shugart 1979;) and other organisms. In our studies, walruses and sea lions utilized different habitats and distinct feeding strategies. Spotted seals and sea lions also used different habitats, although they prey on many of the same species, but food habits are not completely overlapping. The greatest overlap occurred between the spotted and ribbon seals for a food resource and between ribbon seals and walruses for space. Because ribbon seals prey on species different from walruses, these two species coexisted without competing. Competition between ribbon and spotted seals, however, was reduced through geographical separation. Although prey availability appears to be high on the shelf, the species studied still displayed a partitioning of habitats suggesting that other factors (behavior, etc.) probably play an important role in determining their distributions.

Estimated densities of pinnipeds in the marginal ice front varied from those reported by other investigators (Table 7). Density comparisons, however, must be viewed with caution for several reasons: data collection and analysis procedures differed among investigators; other surveys coincided with peak haul out periods whereas our surveys occurred before that time; there may be considerable variation in densities between years. Pups were excluded from the densities reported by Burns and Harbo (1977) to make comparisons with our data more compatible; it was not possible to also do this with Braham et al. (unpublished) data. Despite these concerns, density comparisons describe the relative importance of the ice front in the Navarin Basin to pinnipeds. We found that walrus densities were almost triple those previously reported for the ice front in the southcentral Bering Sea or Navarin Basin, but were similar for spotted seals. Spotted seal and walrus densities were, however, five times lower in the study area than reported for known areas of highest density (walrus in Bristol Bay and northern Bering Sea, spotted seals in southeastern Bering Sea) for these two species. Bearded seal densities were also much lower than

TABLE 7

COMPARISON OF PINNIPED DENSITIES (PER NM^2) REPORTED FOR THE CURRENT STUDY TO THOSE REPORTED BY OTHER INVESTIGATORS

Location[a]	Source	Pacific walrus	Northern sea lion	Spotted seal	Ribbon seal	Bearded seal
Navarin Basin	Current study	0.152	0.030	0.120	0.015	0.002
Southcentral Bering Sea	Burns and Harbo (1977)	0.058	-	0.194	-	-
Southeastern Bering Sea	Burns and Harbo (1977)	0.118	-	0.614	-	-
Southeastern Bering Sea	Braham et al. (unpublished)	0.82	-	0.370	0.006	0.083
Bristol Bay	Burns and Harbo (1977)	0.740	-	0.084	-	-
Northern Bering Sea	Braham et al. (unpublished)	2.77	-	-	<0.001	0.141

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[a] Southeastern Bering Sea = 160° to 168°W, south of 61°N; Northern Bering Sea = St. Lawrence Island vicinity; Southeastern Bering Sea = 163°W to 169°W; Southcentral Bering Sea = 169°W to 180°W; Bristol Bay = 157°W to 163°W; Navarin Basin = 171°W to 180°W.

reported elsewhere in the pack ice, particularly when compared to areas deeper in the pack ice of the northern Bering Sea than we surveyed, which is where this species normally occurs. Conversely, ribbon seal densities were higher in the Basin than in the southeastern or northern Bering Sea, which has been reported to hold true for the western Bering Sea in general (Braham et al. unpublished). Availability of data for additional comparisons of densities in different geographic areas of the pack ice for ribbon and bearded seals was quite limited since few surveys have been conducted in their habitats. Similarly, no comparisons of sea lion densities were possible because our studies document the first density estimates of this species in the marginal ice front. In summary, our results indicate that the marginal ice front in the Navarin Basin supports lower densities of walrus, spotted, and bearded seals than in their prime areas of use while ribbon seal densities were higher in the Basin than eastward in the front; comparisons of sea lion densities were not possible.

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APPENDIX A

APPENDIX A

APPENDIX TABLE 1
DEFINITION OF SURFACE VISIBILITY CATEGORIES USED DURING AERIAL AND VESSEL SURVEYS[a]

Category	Definition
Excellent	Surface of water calm, a high overcast solid enough to prevent sun glare. Beaufort = 0, visibility greater than 5 km. Marine mammals will appear black against a uniform gray background.
Very good	May be a light surface ripple on the surface or slightly uneven lighting, but still relatively easy to distinguish animals at a distance. Beaufort = 1 or 2, visibility greater than 5 km.
Good	May be a light chop, some sun glare or dark shadows in part of survey track. Beaufort less than or equal to 3, visibility less than or equal to 5 km. Animals up close (300 m or less) can still be detected and fairly readily identified.
Fair	Choppy waves with some slight whitecapping, sun glare or dark shadows in 50 percent or less of the survey track. Beaufort less than or equal to 4, visibility less than or equal to 1 km.
Poor	Wind in excess of 15 kt, waves over 2 ft with whitecaps, sun glare may occur in over 50 percent of the survey track. Beaufort less than or equal to 5, visibility less than or equal to 500 m. Animals may be missed unless within 100 m of the survey trackline, identification difficult except for larger species.
Unacceptable	Wind in excess of 25 kt; waves over 3 ft high with pronounced whitecapping. Sun glare may or may not be present. Beaufort greater than or equal to 6 or visibility less than or equal to 300 m. Detection of any marine mammal unlikely unless observer is looking directly at the place where it surfaces. Identification very difficult due to improbability of seeing animal more than once.

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[a] Surface visibility classification was taken from the National Marine Fisheries Service's Platform of Opportunities Program (Consiglieri and Bouchet 1981).

APPENDIX TABLE 2

DESCRIPTION OF BEAUFORT WIND SCALE USED DURING AERIAL AND VESSEL SURVEYS [a/]

Scale	Sea Condition	Wave Height (ft)	Wind Speed (kt)
0	Smooth and mirrorlike	0	0-1
1	Scale-like ripples without foam crests	1	1-3
2	Small short wavelets; crests glass appearance and not breaking	2	4-6
3	Large wavelets; some crests break, foam of glassy appearance; occasional white form crests	3	7-10
4	Small waves become longer; fairly frequent white foam crests	4	11-16
5	Moderate waves more pronounced long form; many white foam crests; there may be some spray	6	17-21
6	Large waves form; white foam crests extensive; may be spray	10	22-27
7	Sea heaves; white foam from breaking waves brown in streaks in direction of wind; spindrift	14	28-33
8	Moderately high waves of greater lengths; edges of crests break into sprindrifts; foam blown in well-marked streaks	18	28-33

[a/] Beaufort wind scale was taken from Consiglieri and Bouchet (1981).

APPENDIX TABLE 3

SEA ICE CLASSIFICATION USED DURING AERIAL AND VESSEL SURVEYS[a]

Category	Description
Ice thickness	
New ice	less than or equal to 10 cm
Young ice	10-30 cm
1st year ice	greater than or equal to 30 cm
Ice type	
Grease ice	A later stage of freezing than frazile ice (fine spicules or plates of ice suspended in water) when the crystals have coagulated to form a soupy layer on the surface. Grease ice reflects little light, giving the sea a matt appearance.
Slush	Snow which is saturated and mixed with water on ice surfaces, or as a viscous floating mass in water after a heavy snowfall.
Pancake ice	Predominately circular pieces of ice from 30 cm-3 m in diameter, and up to about 10 cm in thickness, with raised rims due to the pieces striking against one another.
Floes	Any relatively flat piece of ice 10 m or more across.
Small floe	less than 10 m across
Medium floe	10-30 m across
Large floe	30-100 m across
Vast floe	100-200 m across
Giant floe	greater than 200 m across
Ice Concentration	The ratio of tenths of the sea surface actually covered by ice to the total area of sea surface, both ice-covered and ice-free, at a specific location or over a defined area.

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[a] Ice descriptions were taken from the World Meteorological Organization (1970). Ice floe sizes were modified from the World Meteorological Organization according to definitions of National Oceanic and Atmospheric Administration.

APPENDIX TABLE 4
RECORD OF PINNIPEDS ENCOUNTERED IN THE NAVARIN BASIN DURING THE FOUR SURVEY SEASONS, MAY-JUNE, JULY-AUGUST, OCTOBER-NOVEMBER, 1982 AND FEBRUARY-MARCH 1983

SPRING SURVEY

Date	Species[a]	Number	Location
5/21/82	PF	1	59° 54'N, 174° 39'W
5/21/82	PL	1	60° 7'N, 174° 34'W
5/21/82	EB	1	60° 6'N, 174° 34'W
5/21/82	PF	1	60° 6'N, 174° 34'W
5/21/82	PF	1	60° 6'N, 174° 34'W
5/21/82	PF	1	60° 6'N, 174° 34'W
5/21/82	EB	1	60° 6'N, 174° 34'W
5/21/82	PF	1	60° 6'N, 174° 34'W
5/21/82	PL	1	60° 4'N, 174° 34'W
5/21/82	PL	1	60° 4'N, 174° 34'W
5/21/82	PF	1	60° 4'N, 174° 34'W
5/21/82	OR	1	59° 55'N, 174° 37'W
5/21/82	OR	9	59° 55'N, 174° 15'W
5/21/82	OR	2	59° 55'N, 174° 15'W
5/21/82	OR	2	59° 54'N, 174° 34'W
5/21/82	OR	4	59° 55'N, 174° 18'W
5/21/82	PL	1	59° 56'N, 174° 18'W
5/21/82	PF	1	59° 58'N, 174° 18'W
5/21/82	OR	1	60° 00'N, 174° 18'W
5/21/82	OR	30	60° 00'N, 174° 18'W
5/21/82	PF	1	60° 7'N, 174° 18'W
5/21/82	EJ	2	60° 7'N, 174° 18'W
5/21/82	PF	1	60° 7'N, 174° 18'W
5/21/82	PL	1	60° 7'N, 174° 18'W
5/21/82	PL	1	60° 7'N, 174° 18'W
5/21/82	PF	1	60° 7'N, 174° 18'W
5/21/82	PF	1	60° 7'N, 174° 18'W
5/21/82	PL	1	60° 8'N, 174° 18'W
5/21/82	PL	1	60° 8'N, 174° 18'W
5/21/82	PL	1	60° 10'N, 174° 18'W
5/21/82	PF	1	60° 10'N, 174° 2'W
5/21/82	PF	1	60° 10'N, 174° 2'W
5/21/82	PF	1	60° 7'N, 174° 2'W

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[a] EJ = northern sea lion, CL = northern fur seal, PL = spotted seal, EB = bearded seal, PF = ribbon seal, OR = Pacific walrus

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RECORD OF PINNIPEDS ENCOUNTERED IN THE NAVARIN BASIN DURING THE FOUR SURVEY SEASONS, MAY-JUNE, JULY-AUGUST, OCTOBER-NOVEMBER, 1982 AND FEBRUARY-MARCH 1983

Date	Species[a]	Number	Location
	SPRING SURVEY (Continued)		
5/21/82	PF	1	60° 7'N, 174° 2'W
5/21/82	OR	1	60° 5'N, 174° 2'W
5/21/82	OR	4	59° 59'N, 173° 46'W
5/21/82	OR	10	59° 59'N, 173° 46'W
5/21/82	EJ	9	60° 1'N, 173° 46'W
5/21/82	OR	1	60° 1'N, 173° 46'W
5/21/82	PL	2	60° 2'N, 173° 46'W
5/21/82	PF	2	60° 3'N, 173° 46'W
5/21/82	PF	1	60° 5'N, 173° 46'W
5/21/82	PL	1	60° 7'N, 173° 46'W
5/21/82	PF	1	60° 7'N, 173° 46'W
5/21/82	EB	1	60° 8'N, 173° 46'W
5/21/82	EJ	1	60° 10'N, 173° 44'W
5/21/82	PF	1	60° 5'N, 173° 30'W
5/21/82	PL	2	60° 5'N, 173° 30'W
5/21/82	EJ	10	60° 1'N, 173° 30'W
5/21/82	EJ	12	60° 1'N, 173° 30'W
5/21/82	EJ	3	60° 1'N, 173° 30'W
5/21/82	EJ	4	60° 1'N, 173° 30'W
5/21/82	EB	1	60° 1'N, 173° 30'W
5/23/82	PF	1	60° 43'N, 175° 20'W
5/23/82	PF	1	60° 43'N, 175° 20'W
5/23/82	EJ	1	60° 41'N, 175° 20'W
5/21/82	UP	1	59° 55'N, 174° 48'W
5/21/82	UP	4	59° 55'N, 174° 43'W
5/21/82	OR	2	59° 54'N, 174° 40'W
5/21/82	UP	1	59° 54'N, 174° 39'W
5/27/82	PL	1	60° 37'N, 174° 46'W
5/27/82	EJ	3	60° 41'N, 174° 46'W
5/27/82	EJ	1	60° 42'N, 174° 46'W
	SUMMER SURVEY		
7/28/82	EJ	2	60° 48'N, 178° 22'W
7/26/82	EJ	2	60° 53'N, 175° 1'W
7/29/82	CL	1	59° 46'N, 179° 8'W
8/04/82	CL	1	59° 52'N, 173° 30'W
8/07/82	CL	2	58° 26'N, 174° 39'W
8/07/82	CL	1	58° 19'N, 174° 39'W
8/07/82	CL	1	58° 18'N, 174° 39'W
8/07/82	CL	1	58° 16'N, 174° 39'W

APPENDIX TABLE 4
RECORD OF PINNIPEDS ENCOUNTERED IN THE NAVARIN BASIN DURING THE FOUR SURVEY SEASONS, MAY-JUNE, JULY-AUGUST, OCTOBER-NOVEMBER, 1982 AND FEBRUARY-MARCH 1983

Date	Species[a]	Number	Location
SUMMER SURVEY (Continued)			
8/07/82	CL	1	58° 8'N, 174° 39'W
8/08/82	CL	1	58° 10'N, 174° 54'W
8/08/82	CL	1	58° 15'N, 174° 54'W
FALL SURVEY			
11/6/82	CL	1	61° 03'N, 175° 33'W
11/6/82	CL	1	61° 03'N, 175° 24'W
11/10/82	CL	1	59° 55'N, 173° 38'W
11/10/82	CL	2	59° 55'N, 173° 53'W
11/10/82	CL	1	59° 55'N, 174° 47'W
11/10/82	CL	1	59° 55'N, 175° 28'W
WINTER SURVEY			
02/21/83	PL	3	58° 36'N, 171° 25'W
02/21/83	OR	1	58° 10'N, 171° 32'W
02/21/83	UP	1	58° 27'N, 171° 43'W
02/21/83	UP	3	58° 25'N, 171° 48'W
02/21/83	OR	4	58° 22'N, 171° 48'W
02/21/83	OR	3	58° 22'N, 171° 48'W
02/21/83	OR	1	58° 20'N, 171° 48'W
02/21/83	OR	1	58° 19'N, 171° 48'W
02/22/83	OR	2	58° 10'N, 171° 48'W
02/22/83	OR	2	58° 08'N, 171° 48'W
02/22/83	UP	1	58° 03'N, 171° 48'W
02/22/83	EJ	1	57° 59'N, 172° 05'W
02/22/83	UP	1	58° 07'N, 172° 11'W
02/22/83	EB	1	58° 14'N, 172° 17'W
02/23/83	UP	4	58° 27'N, 172° 32'W
02/23/83	EJ	1	58° 31'N, 172° 32'W
02/23/83	EJ	5	58° 31'N, 172° 32'W
02/23/83	OR	1	58° 39'N, 172° 33'W
02/23/83	UP	1	58° 45'N, 172° 32'W
02/23/83	UP	1	58° 48'N, 172° 32'W
02/23/83	OR	1	58° 51'N, 172° 33'W
02/23/83	OR	1	58° 53'N, 172° 32'W
02/23/83	OR	2	58° 58'N, 172° 32'W
02/23/83	OR	2	58° 58'N, 172° 32'W
02/23/83	OR	2	58° 58'N, 172° 32'W

APPENDIX TABLE 4
RECORD OF PINNIPEDS ENCOUNTERED IN THE NAVARIN BASIN DURING THE FOUR SURVEY SEASONS, MAY-JUNE, JULY-AUGUST, OCTOBER-NOVEMBER, 1982 AND FEBRUARY-MARCH 1983

Date	Species[a]	Number	Location
	WINTER SURVEY (Continued)		
02/24/83	EJ	2	59° 33'N, 176° 12'W
02/24/83	CL	1	59° 33'N, 176° 10'W
02/24/83	EJ	4	59° 32'N, 176° 04'W
02/24/83	UP	1	59° 44'N, 175° 54'W
02/24/83	PL	1	59° 54'N, 175° 52'W
02/25/83	EJ	1	59° 29'N, 176° 04'W
02/25/83	EJ	1	59° 28'N, 176° 04'W
02/25/83	OR	2	59° 28'N, 176° 04'W
02/25/83	EJ	4	59° 29'N, 176° 03'W
02/25/83	PL	1	59° 31'N, 176° 03'W
02/25/83	PL	34	59° 31'N, 176° 03'W
02/26/83	PL	1	60° 07'N, 177° 27'W
02/26/83	EJ	1	60° 16'N, 177° 34'W
02/26/83	UP	1	60° 18'N, 177° 41'W
02/26/83	EJ	1	60° 19'N, 177° 41'W
02/26/83	UP	1	60° 27'N, 177° 42'W
02/26/83	EJ	1	60° 21'N, 177° 52'W
02/27/83	PL	1	60° 35'N, 178° 13'W
02/28/83	PL	1	60° 54'N, 178° 14'W
02/28/83	PL	1	60° 54'N, 178° 15'W
02/28/83	PL	1	60° 55'N, 178° 17'W
02/28/83	OR	4	60° 55'N, 178° 18'W
02/28/83	PL	1	60° 55'N, 178° 19'W
02/28/83	PL	1	60° 55'N, 178° 19'W
02/28/83	PL	1	60° 55'N, 178° 19'W
02/28/83	PL	1	60° 55'N, 178° 19'W
02/28/83	PL	1	60° 55'N, 178° 19'W
02/28/83	PL	1	60° 56'N, 178° 21'W
02/28/83	PL	1	60° 57'N, 178° 23'W
02/28/83	OR	2	61° 02'N, 178° 19'W
02/28/83	UP	1	61° 01'N, 178° 17'W
02/28/83	UP	1	61° 01'N, 178° 17'W
02/28/83	OR	1	61° 04'N, 178° 16'W
02/28/83	UP	1	61° 05'N, 178° 16'W
02/28/83	OR	1	61° 11'N, 178° 20'W
02/28/83	PL	2	61° 13'N, 178° 25'W
02/28/83	OR	1	61° 12'N, 178° 27'W
02/28/83	PL	1	61° 12'N, 178° 29'W
02/28/83	PH	1	61° 11'N, 178° 30'W
02/28/83	UP	1	61° 11'N, 178° 30'W
02/28/83	OR	1	61° 04'N, 178° 40'W
02/28/83	OR	1	61° 04'N, 178° 40'W

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APPENDIX TABLE 4
RECORD OF PINNIPEDS ENCOUNTERED IN THE NAVARIN BASIN DURING THE FOUR SURVEY SEASONS, MAY-JUNE, JULY-AUGUST, OCTOBER-NOVEMBER, 1982 AND FEBRUARY-MARCH 1983

Date	Species[a]	Number	Location
	WINTER SURVEY (Continued)		
02/28/83	OR	23	61° 01'N, 178° 41'W
02/28/83	PL	1	61° 01'N, 178° 41'W
02/28/83	OR	2	61° 01'N, 178° 41'W
02/28/83	PH	1	61° 01'N, 178° 35'W
03/01/83	UP	1	61° 00'N, 178° 30'W
03/01/83	PL	1	60° 59'N, 178° 28'W
03/01/83	OR	3	60° 56'N, 178° 28'W
03/01/83	EB	1	60° 39'N, 178° 28'W
03/02/83	PL	1	60° 41'N, 178° 51'W
03/02/83	UP	1	60° 43'N, 178° 51'W
03/02/83	PL	1	60° 55'N, 178° 54'W
03/02/83	PL	2	60° 56'N, 178° 52'W
03/02/83	PL	1	60° 56'N, 178° 52'W
03/02/83	PL	2	60° 56'N, 178° 52'W
03/02/83	PL	35	60° 58'N, 178° 53'W
03/02/83	PL	99	60° 58'N, 178° 53'W
03/02/83	UP	4	61° 00'N, 178° 52'W
03/02/83	UP	1	61° 00'N, 178° 52'W
03/02/83	UP	1	61° 00'N, 178° 58'W
03/02/83	PL	4	61° 01'N, 179° 02'W
03/02/83	PL	8	61° 01'N, 179° 02'W
03/02/83	PL	2	61° 01'N, 179° 02'W
03/02/83	PL	8	60° 59'N, 179° 04'W
03/02/83	UP	1	60° 58'N, 179° 04'W
03/02/83	PL	1	60° 55'N, 179° 04'W
03/02/83	UP	1	60° 55'N, 179° 04'W
03/03/83	EJ	1	60° 44'N, 179° 04'W
03/03/83	UP	2	60° 44'N, 179° 04'W
03/03/83	EJ	1	60° 44'N, 179° 04'W
03/03/83	EJ	1	60° 44'N, 179° 04'W
03/03/83	EJ	1	60° 43'N, 179° 05'W
03/03/83	EJ	1	60° 41'N, 179° 15'W
03/03/83	EJ	1	60° 41'N, 179° 15'W
03/03/83	EJ	2	60° 44'N, 179° 16'W
03/03/83	EJ	1	60° 49'N, 179° 16'W
03/03/83	UP	1	60° 47'N, 179° 24'W
03/03/83	UP	2	60° 49'N, 179° 24'W
03/03/83	PL	1	60° 49'N, 179° 15'W
03/03/83	EJ	2	60° 47'N, 179° 14'W
03/03/83	EJ	1	60° 51'N, 179° 18'W

APPENDIX TABLE 4
RECORD OF PINNIPEDS ENCOUNTERED IN THE NAVARIN BASIN DURING THE FOUR SURVEY SEASONS, MAY-JUNE, JULY-AUGUST, OCTOBER-NOVEMBER, 1982 AND FEBRUARY-MARCH 1983

Date	Species[a]	Number	Location
	<u>WINTER SURVEY</u> (Continued)		
03/03/83	EJ	2	60° 47'N, 178° 51'W
03/03/83	EJ	1	61° 00'N, 178° 38'W
03/03/83	UP	1	60° 58'N, 178° 36'W
03/04/83	EJ	4	60° 18'N, 177° 37'W
03/04/83	EJ	10	60° 20'N, 177° 37'W
03/04/83	EJ	10	60° 18'N, 177° 26'W
03/04/83	EJ	35	60° 18'N, 177° 26'W
03/04/83	EJ	25	60° 18'N, 177° 24'W
03/04/83	EJ	12	60° 18'N, 177° 24'W
03/04/83	EJ	10	60° 18'N, 177° 24'W
03/04/83	EJ	25	60° 20'N, 177° 25'W
03/04/83	EJ	12	60° 20'N, 177° 25'W
03/04/83	EJ	1	60° 20'N, 177° 25'W
03/04/83	EJ	8	60° 19'N, 177° 28'W
03/04/83	EJ	8	60° 17'N, 177° 24'W
03/04/83	EJ	7	60° 17'N, 177° 24'W
03/04/83	EJ	12	60° 17'N, 177° 24'W
03/04/83	EJ	11	60° 16'N, 177° 23'W
03/04/83	EJ	19	60° 16'N, 177° 23'W
03/04/83	EJ	18	60° 15'N, 177° 23'W
03/04/83	EJ	10	60° 13'N, 177° 22'W
03/04/83	EJ	12	60° 13'N, 177° 22'W
03/04/83	EJ	16	60° 11'N, 177° 21'W
03/04/83	EJ	2	60° 08'N, 177° 19'W
03/04/83	EJ	2	60° 05'N, 177° 15'W
03/04/83	PL	1	60° 30'N, 177° 20'W
03/04/83	PL	1	60° 27'N, 177° 20'W
03/04/83	EJ	7	60° 15'N, 177° 20'W
03/04/83	EJ	1	60° 13'N, 177° 20'W
03/04/83	EJ	1	60° 11'N, 177° 20'W
03/04/83	EJ	15	60° 09'N, 177° 16'W
03/04/83	EJ	1	60° 09'N, 177° 20'W
03/04/83	EJ	5	60° 09'N, 177° 16'W
03/04/83	EJ	7	60° 09'N, 177° 20'W
03/04/83	EJ	12	60° 09'N, 177° 20'W
03/04/83	EJ	1	60° 27'N, 177° 16'W
03/04/83	UP	1	60° 30'N, 177° 16'W
03/04/83	EJ	1	60° 05'N, 177° 08'W
03/04/83	EJ	1	59° 57'N, 176° 58'W
03/04/83	UP	1	60° 24'N, 176° 52'W
03/04/83	OR	15	60° 47'N, 176° 44'W
03/04/83	OR	13	60° 47'N, 176° 44'W

APPENDIX TABLE 4
RECORD OF PINNIPEDS ENCOUNTERED IN THE NAVARIN BASIN DURING THE FOUR SURVEY SEASONS, MAY-JUNE, JULY-AUGUST, OCTOBER-NOVEMBER, 1982 AND FEBRUARY-MARCH 1983

Date	Species[a/]	Number	Location
	WINTER SURVEY (Continued)		
03/04/83	OR	1	60° 43'N, 176° 44'W
03/04/83	UP	1	60° 39'N, 176° 44'W
03/04/83	PF	1	60° 25'N, 176° 44'W
03/04/83	PF	2	60° 26'N, 176° 40'W
03/04/83	PF	3	60° 26'N, 176° 40'W
03/04/83	PF	1	60° 38'N, 177° 05'W
03/04/83	PF	1	60° 37'N, 177° 09'W
03/04/83	UP	1	60° 52'N, 177° 16'W
03/04/83	UP	1	60° 53'N, 177° 16'W
03/04/83	UP	1	60° 56'N, 177° 08'W
03/05/83	EJ	3	59° 37'N, 176° 08'W
03/05/83	EJ	1	59° 33'N, 175° 52'W
03/05/83	EJ	6	59° 42'N, 175° 44'W
03/05/83	EJ	10	59° 42'N, 175° 44'W
03/05/83	EJ	2	59° 32'N, 175° 51'W
03/05/83	UP	1	59° 55'N, 175° 32'W
03/05/83	EJ	12	59° 35'N, 175° 20'W
03/05/83	OR	1	59° 45'N, 175° 20'W
03/05/83	PL	2	60° 09'N, 175° 20'W
03/05/83	OR	1	60° 05'N, 175° 23'W
03/05/83	PL	11	60° 04'N, 175° 25'W
03/05/83	EB	1	60° 04'N, 175° 25'W
03/06/83	PF	1	59° 56'N, 174° 53'W
03/06/83	PF	1	60° 07'N, 174° 52'W
03/06/83	UP	1	60° 16'N, 174° 44'W
03/06/83	OR	2	60° 23'N, 174° 44'W
03/06/83	OR	1	60° 22'N, 174° 48'W
03/06/83	UP	1	60° 22'N, 174° 48'W
03/06/83	OR	1	60° 22'N, 174° 50'W
03/06/83	UP	1	60° 22'N, 174° 51'W
03/06/83	UP	1	60° 20'N, 175° 05'W
03/06/83	OR	1	60° 19'N, 175° 05'W
03/06/83	UP	1	60° 19'N, 175° 05'W
03/06/83	UP	1	60° 16'N, 175° 04'W
03/06/83	UP	1	60° 11'N, 175° 04'W
03/06/83	UP	1	60° 11'N, 175° 04'W
03/06/83	PL	1	60° 10'N, 175° 06'W
03/06/83	OR	1	60° 10'N, 175° 06'W
03/06/83	UP	1	60° 09'N, 175° 06'W

APPENDIX TABLE 4

RECORD OF PINNIPEDS ENCOUNTERED IN THE NAVARIN BASIN DURING THE FOUR SURVEY SEASONS, MAY-JUNE, JULY-AUGUST, OCTOBER-NOVEMBER, 1982 AND FEBRUARY-MARCH 1983

Date	Species[a]	Number	Location
	WINTER SURVEY (Continued)		
03/07/83	PL	1	60° 23'N, 175° 08'W
03/07/83	OR	1	60° 26'N, 175° 10'W
03/07/83	UP	1	60° 26'N, 175° 08'W
03/07/83	PF	1	60° 23'N, 175° 06'W
03/07/83	OR	1	60° 23'N, 175° 05'W
03/07/83	OR	1	60° 23'N, 175° 00'W
03/07/83	OR	1	60° 23'N, 174° 58'W
03/07/83	OR	3	60° 22'N, 174° 56'W
03/07/83	OR	2	60° 21'N, 174° 56'W
03/07/83	OR	1	60° 21'N, 174° 56'W
03/07/83	OR	1	60° 21'N, 174° 56'W
03/07/83	OR	3	60° 21'N, 174° 56'W
03/07/83	OR	2	60° 21'N, 174° 56'W
03/07/83	OR	1	60° 20'N, 174° 56'W
03/07/83	OR	15	60° 20'N, 174° 56'W
03/07/83	OR	8	60° 20'N, 174° 56'W
03/07/83	OR	3	60° 20'N, 174° 56'W
03/07/83	OR	1	60° 20'N, 174° 56'W
03/07/83	OR	8	60° 19'N, 174° 56'W
03/07/83	OR	1	60° 19'N, 174° 56'W
03/07/83	OR	2	60° 19'N, 174° 56'W
03/07/83	OR	7	60° 19'N, 174° 56'W
03/07/83	OR	2	60° 19'N, 174° 56'W
03/07/83	OR	2	60° 19'N, 174° 56'W
03/07/83	OR	4	60° 19'N, 174° 56'W
03/07/83	OR	11	60° 19'N, 174° 56'W
03/07/83	OR	12	60° 19'N, 174° 56'W
03/07/83	OR	2	60° 19'N, 174° 56'W
03/07/83	PF	1	60° 17'N, 174° 56'W
03/08/83	PF	1	59° 53'N, 174° 28'W
03/08/83	EJ	1	59° 27'N, 174° 40'W
03/08/83	UP	1	59° 26'N, 174° 49'W
03/09/83	EJ	1	58° 59'N, 174° 32'W
03/09/83	EJ	3	58° 57'N, 174° 32'W
03/09/83	EJ	6	58° 56'N, 174° 32'W
03/09/83	EJ	1	58° 53'N, 174° 31'W
03/09/83	UP	1	58° 57'N, 174° 16'W
03/09/83	EJ	1	59° 04'N, 174° 16'W
03/09/83	EJ	1	59° 09'N, 174° 14'W
03/10/83	UP	1	60° 16'N, 173° 06'W
03/10/83	OR	1	60° 28'N, 173° 08'W

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APPENDIX TABLE 4
RECORD OF PINNIPEDS ENCOUNTERED IN THE NAVARIN BASIN DURING THE FOUR SURVEY SEASONS, MAY-JUNE, JULY-AUGUST, OCTOBER-NOVEMBER, 1982 AND FEBRUARY-MARCH 1983

Date	Species[a]	Number	Location
	WINTER SURVEY (Continued)		
03/10/83	OR	1	60° 28'N, 173° 08'W
03/10/83	OR	3	60° 28'N, 173° 08'W
03/10/83	OR	1	60° 27'N, 173° 08'W
03/10/83	UP	1	60° 27'N, 173° 08'W
03/10/83	UP	1	60° 23'N, 173° 09'W
03/10/83	UP	1	60° 18'N, 173° 08'W
03/10/83	UP	1	60° 17'N, 173° 08'W
03/10/83	PF	1	60° 15'N, 173° 07'W
03/10/83	UP	1	60° 14'N, 173° 06'W
03/10/83	UP	1	60° 11'N, 173° 07'W
03/10/83	UP	2	60° 08'N, 173° 08'W
03/10/83	UP	1	60° 06'N, 173° 08'W
03/10/83	UP	1	60° 02'N, 173° 08'W
03/10/83	UP	1	60° 01'N, 172° 56'W
03/10/83	UP	1	60° 04'N, 172° 56'W
03/10/83	PL	1	60° 06'N, 172° 56'W
03/10/83	UP	1	60° 08'N, 172° 56'W
03/11/83	UP	1	60° 19'N, 172° 52'W
03/11/83	OR	3	60° 19'N, 172° 52'W
03/11/83	OR	1	60° 14'N, 172° 35'W
03/11/83	OR	1	60° 15'N, 172° 34'W
03/11/83	OR	1	60° 15'N, 172° 34'W
03/11/83	OR	3	60° 16'N, 172° 33'W
03/11/83	OR	1	60° 16'N, 172° 33'W
03/11/83	OR	2	60° 16'N, 172° 32'W
03/11/83	OR	1	60° 16'N, 172° 32'W
03/11/83	OR	3	60° 16'N, 172° 32'W
03/11/83	OR	1	60° 09'N, 172° 32'W
03/11/83	PL	1	60° 04'N, 172° 28'W
03/11/83	OR	3	60° 05'N, 172° 29'W
03/11/83	OR	1	60° 05'N, 172° 29'W
03/12/83	OR	1	60° 34'N, 173° 37'W
03/12/83	OR	2	60° 33'N, 173° 42'W
03/12/83	OR	1	60° 31'N, 173° 44'W
03/12/83	OR	1	60° 29'N, 173° 46'W
03/12/83	OR	1	60° 25'N, 173° 44'W
03/12/83	OR	2	60° 26'N, 173° 47'W
03/12/83	OR	6	60° 25'N, 173° 48'W
03/12/83	OR	3	60° 24'N, 173° 48'W
03/12/83	OR	15	60° 23'N, 173° 52'W
03/12/83	OR	1	60° 17'N, 173° 54'W

APPENDIX TABLE 4
RECORD OF PINNIPEDS ENCOUNTERED IN THE NAVARIN BASIN DURING THE FOUR SURVEY SEASONS, MAY-JUNE, JULY-AUGUST, OCTOBER-NOVEMBER, 1982 AND FEBRUARY-MARCH 1983

Date	Species[a]	Number	Location
	<u>WINTER SURVEY</u> (Continued)		
03/12/83	OR	1	60° 17'N, 173° 54'W
03/12/83	OR	1	60° 20'N, 173° 54'W
03/12/83	OR	5	60° 18'N, 173° 55'W
03/12/83	OR	1	60° 14'N, 173° 54'W
03/12/83	UP	1	60° 14'N, 173° 54'W
03/12/83	OR	5	60° 17'N, 173° 56'W
03/12/83	OR	4	60° 15'N, 173° 53'W
03/12/83	OR	3	60° 15'N, 173° 53'W
03/12/83	OR	2	60° 22'N, 173° 56'W
03/12/83	OR	1	60° 18'N, 173° 56'W
03/12/83	UP	1	60° 16'N, 173° 56'W
03/12/83	OR	12	60° 16'N, 174° 08'W
03/12/83	PF	4	60° 07'N, 174° 08'W
03/12/83	PF	24	60° 02'N, 174° 13'W
03/12/83	OR	2	60° 01'N, 174° 16'W
03/12/83	UP	1	60° 01'N, 174° 18'W
03/12/83	EB	1	60° 00'N, 174° 19'W
03/12/83	OR	1	59° 59'N, 174° 23'W
03/12/83	UP	1	59° 59'N, 174° 23'W
03/12/83	UP	1	59° 59'N, 174° 23'W
03/12/83	OR	2	60° 03'N, 174° 28'W
03/12/83	EB	1	59° 59'N, 174° 26'W
03/12/83	EB	1	59° 59'N, 174° 29'W
03/12/83	UP	1	60° 00'N, 174° 31'W
03/12/83	UP	2	60° 01'N, 174° 31'W
03/13/83	PF	4	60° 10'N, 174° 38'W
03/13/83	PF	1	60° 10'N, 174° 38'W
03/13/83	PF	3	60° 12'N, 174° 23'W
03/13/83	OR	1	60° 19'N, 174° 32'W
03/13/83	OR	2	60° 17'N, 174° 28'W
03/13/83	UP	2	60° 08'N, 174° 29'W
03/13/83	OR	1	60° 07'N, 174° 27'W
03/13/83	OR	1	60° 12'N, 174° 21'W
03/13/83	EB	1	60° 12'N, 174° 21'W
03/13/83	OR	23	60° 11'N, 174° 20'W
03/13/83	OR	37	60° 11'N, 174° 20'W
03/13/83	OR	2	60° 17'N, 174° 20'W
03/13/83	OR	16	60° 16'N, 174° 20'W
03/13/83	OR	12	60° 17'N, 174° 20'W
03/13/83	OR	2	60° 17'N, 174° 20'W
03/13/83	PF	3	60° 11'N, 174° 15'W

APPENDIX TABLE 4
RECORD OF PINNIPEDS ENCOUNTERED IN THE NAVARIN BASIN DURING THE FOUR SURVEY SEASONS, MAY-JUNE, JULY-AUGUST, OCTOBER-NOVEMBER, 1982 AND FEBRUARY-MARCH 1983

Date	Species[a/]	Number	Location
		WINTER SURVEY (Continued)	
03/13/83	OR	12	60° 13'N, 174° 09'W
03/13/83	OR	11	60° 13'N, 174° 09'W
03/13/83	OR	4	60° 13'N, 174° 09'W
03/13/83	OR	3	60° 13'N, 174° 09'W
03/13/83	PF	1	60° 08'N, 174° 04'W
03/13/83	OR	42	60° 13'N, 174° 10'W
03/13/83	OR	4	60° 12'N, 174° 08'W
03/13/83	OR	6	60° 21'N, 174° 07'W
03/13/83	OR	1	60° 21'N, 174° 08'W
03/13/83	OR	35	60° 18'N, 174° 08'W
03/13/83	OR	38	60° 15'N, 174° 03'W
03/13/83	OR	7	60° 15'N, 174° 08'W
03/13/83	OR	99	60° 15'N, 174° 03'W
03/13/83	OR	3	60° 12'N, 174° 08'W
03/13/83	OR	23	60° 16'N, 174° 06'W
03/13/83	OR	36	60° 16'N, 174° 06'W
03/13/83	OR	22	60° 17'N, 173° 55'W
03/13/83	OR	14	60° 17'N, 173° 55'W
03/13/83	OR	1	60° 16'N, 173° 52'W
03/13/83	OR	2	60° 17'N, 173° 45'W
03/13/83	OR	2	60° 16'N, 174° 01'W
03/13/83	OR	12	60° 16'N, 174° 01'W
03/13/83	OR	1	60° 16'N, 173° 58'W
03/13/83	OR	12	60° 16'N, 173° 55'W
03/13/83	OR	12	60° 17'N, 173° 53'W
03/13/83	OR	3	60° 17'N, 173° 53'W
03/13/83	OR	8	60° 20'N, 173° 35'W
03/13/83	OR	20	60° 19'N, 173° 20'W
03/13/83	OR	7	60° 20'N, 173° 20'W
03/14/83	OR	1	60° 35'N, 173° 44'W
03/14/83	OR	4	60° 35'N, 173° 44'W
03/14/83	UP	1	60° 26'N, 173° 40'W
03/14/83	OR	6	60° 40'N, 173° 41'W
03/14/83	PF	1	60° 38'N, 173° 53'W
03/14/83	PF	1	60° 38'N, 173° 53'W
03/14/83	PF	1	60° 38'N, 173° 53'W
03/14/83	OR	1	60° 26'N, 173° 49'W
03/15/83	OR	12	60° 01'N, 173° 20'W
03/15/83	OR	1	59° 59'N, 173° 20'W
03/15/83	OR	2	59° 53'N, 173° 25'W
03/15/83	OR	4	59° 58'N, 173° 32'W

APPENDIX TABLE 4
RECORD OF PINNIPEDS ENCOUNTERED IN THE NAVARIN BASIN DURING THE FOUR SURVEY SEASONS, MAY-JUNE, JULY-AUGUST, OCTOBER-NOVEMBER, 1982 AND FEBRUARY-MARCH 1983

Date	Species[a]	Number	Location
	WINTER SURVEY (Continued)		
03/15/83	PF	1	59° 47'N, 173° 48'W
03/15/83	UP	1	59° 49'N, 174° 08'W
03/15/83	UP	1	59° 47'N, 174° 08'W
03/15/83	UP	1	59° 37'N, 174° 20'W
03/15/83	EB	1	59° 46'N, 174° 26'W
03/15/83	UP	1	59° 35'N, 174° 42'W
03/15/83	UP	1	59° 36'N, 174° 47'W
03/15/83	UP	1	59° 36'N, 174° 52'W
03/16/83	OR	1	60° 43'N, 175° 22'W
03/16/83	PL	1	60° 26'N, 176° 02'W
03/16/83	OR	2	60° 25'N, 176° 03'W

APPENDIX TABLE 5

CHI-SQUARE ANALYSES OF PINNIPED OCCURRENCE IN SAMPLING UNITS OF THE MARGINAL ICE FRONT

Sampling unit	Distance surveyed (nm)	Proportion of total distance	Walrus				Northern sea lion			
			No. obs.	No. exp.	Prop. obs.	95 confidence interval	No. obs.	No. exp.	Prop. obs.	95 confidence interval
24	147	0.061	25	9.0	0.170	$0.088 \le P \le 0.252$ a/	3	4.2	0.043	$-0.021 \le P \le 0.107$
25	462	0.192	43	28.2	0.293	$0.194 \le P \le 0.392$ a/	0	13.2	0.000	b/
26	613	0.254	64	37.4	0.435	$0.327 \le P \le 0.543$ a/	8	17.6	0.116	$0.014 \le P \le 0.218$ b/
27	482	0.200	5	29.4	0.034	$-0.005 \le P \le 0.073$ b/	10	13.8	0.145	$0.033 \le P \le 0.257$
28	466	0.193	0	28.4	0.000	b/	36	13.3	0.522	$0.364 \le P \le 0.680$ a/
29	240	0.100	10	14.6	0.068	$0.013 < P < 0.123$	12	6.9	0.174	$0.054 < P < 0.294$
Total	2,410	1.000	147	147.0	1.000	$x^2 = 105.23$	69	69.0	1.000	$x^2 = 62.34$

Sampling unit	Distance surveyed (nm)	Proportion of total distance	Spotted seal				Ribbon seal			
			No. obs.	No. exp.	Prop. obs.	95 confidence interval	No. obs.	No. exp.	Prop. obs.	95 confidence interval
24	147	0.061	2				0	5.5	0.227	$0.027 \le P \le 0.427$
25	462	0.192	1	11.7	0.072	$-0.309 \le P \le 0.175$ b/	5			
26	613	0.254	4	10.7	0.095	$-0.022 \le P \le 0.212$ b/	12	5.6	0.546	$0.308 \le P \le 0.784$ a/
27	482	0.200	4	8.4	0.095	$-0.022 \le P \le 0.212$	3			
28	466	0.193	3	8.1	0.071	$-0.031 \le P \le 0.173$ b/	2	10.9	0.227	$0.027 \le P \le 0.427$ b/
29	240	0.100	28	4.1	0.667	$0.479 < P < 0.855$ a/	0			
Total	2,410	1.000	42	42.0	1.000	$x^2 = 155.39$	22	22.0	1.000	$x^2 = 10.55$

---

a/ Significant preference.

b/ Significant avoidance.

APPENDIX TABLE 6

CHI-SQUARE ANALYSIS OF PACIFIC WALRUS OCCURRENCE IN DIFFERENT ICE CONCENTRATION, SIZE, AND THICKNESS CATEGORIES

Ice Concentration Category	Area (nm^2)	Proportion of total area	Number observed	Number expected	Proportion observed	95 confidence interval
0-20	53	0.045	0	4	0.000	$0.039 \leq P \leq 0.225$
21-40	62	0.051	11	4	0.132	
41-60	208	0.173	10	14	0.121	$0.032 \leq P \leq 0.210$
61-80	357	0.296	26	25	0.313	$0.186 \leq P \leq 0.440$
81-100	525	0.436	36	36	0.434	$0.298 \leq P \leq 0.570$
Total	1,205	1.000	83	83	1.000	$x^2 = 2.31$

Ice Size Category	Area (nm^2)	Proportion of total area	Number observed	Number expected	Proportion observed	95 confidence interval
Grease-slush	91	0.100	30	8	0.361	$0.230 \leq P \leq 0.493$[a]
Pan-small	192	0.210	4	18	0.048	$-0.011 \leq P \leq 0.107$[b]
Med-large	159	0.174	4	15	0.048	$-0.011 \leq P \leq 0.107$[b]
Vast-giant	472	0.516	45	42	0.542	$0.406 \leq P \leq 0.679$
Total	914	1.000	83	83	1.000	$x^2 = 79.67$

Ice Thickness Category	Area (nm^2)	Proportion of total area	Number observed	Number expected	Proportion observed	95 confidence interval
New (<10 cm)	142	0.118	25	10	0.301	$0.180 \leq P \leq 0.422$[a]
Young (10-30cm)	468	0.388	28	32	0.338	$0.214 \leq P \leq 0.462$
First year (>30 cm)	595	0.494	30	41	0.361	$0.235 \leq P \leq 0.487$[b]
Total	1205	1.000	83	83	1.000	$x^2 = 25.95$

---

[a] Significant preference.

[b] Significant avoidance.

APPENDIX TABLE 6 (Continued)

CHI-SQUARE ANALYSIS OF NORTHERN SEA LION OCCURRENCE IN DIFFERENT ICE CONCENTRATION, SIZE, AND THICKNESS CATEGORIES

Ice Concentration Category	Area (nm^2)	Proportion of total area	Number observed	Number expected	Proportion observed	95 confidence interval
0-20	53	0.045	2	1	0.083	$0.298 \le P \le 0.785$ a/
21-40	62	0.051	5	1	0.208	
41-60	208	0.173	6	4	0.250	
61-80	357	0.294	9	7	0.375	$0.138 \le P \le 0.612$
81-100	525	0.437	2	11	0.083	$-0.052 < P < 0.218$ b/
Total	1,205	1.000	24	24	1.000	$x^2 = 16.10$

Ice Size Category	Area (nm^2)	Proportion of total area	Number observed	Number expected	Proportion observed	95 confidence interval
Grease-slush	91	0.100	2	3	0.083	$0.552 \le P \le 0.948$ a/
Pan-small	192	0.210	16	5	0.667	
Med-large	159	0.174	2	4	0.083	$0.052 < P < 0.448$ b/
Vast-giant	472	0.516	4	12	0.167	
Total	914	1.000	24	24	1.000	$x^2 = 18.75$

Ice Thickness Category	Area (nm^2)	Proportion of total area	Number observed	Number expected	Proportion observed	95 confidence interval
New (<10 cm)	142	0.118	1	3	0.042	$0.154 \le P \le 0.596$
Young (10-30 cm)	468	0.388	8	9	0.333	
First year (>30 cm)	595	0.494	15	12	0.625	$0.404 < P < 0.846$
Total	1,205	1.000	24	24	1.000	$x^2 = 1.50$

---

a/ Significant preference.

b/ Significant avoidance.

APPENDIX TABLE 6 (Continued)

CHI-SQUARE ANALYSIS OF SPOTTED SEAL OCCURRENCE IN DIFFERENT ICE CONCENTRATION, SIZE, AND THICKNESS CATEGORIES

Ice Concentration Category	Area (nm^2)	Proportion of total area	Number observed	Number expected	Proportion observed	95 confidence interval
0-20	53	0.045	0	1	0.000	
21-40	62	0.051	11	1	0.380	$0.296 \leq P \leq 0.740$a/
41-60	208	0.173	4	5	0.138	
61-80	357	0.294	7	9	0.241	$0.024 \leq P \leq 0.431$
81-100	525	0.437	7	13	0.241	$0.024 \leq P \leq 0.431$b/
Total	1,205	1.000	29	29	1.000	$x^2 = 12.36$

Ice Size Category	Area (nm^2)	Proportion of total area	Number observed	Number expected	Proportion observed	95 confidence interval
Grease-slush	91	0.100	1	3	0.034	
Pan-small	192	0.210	13	6	0.448	$0.260 \leq P \leq 0.705$
Med-large	159	0.174	2	5	0.069	$-0.044 \leq P \leq 0.182$
Vast-giant	472	0.516	13	15	0.448	$0.227 \leq P \leq 0.670$
Total	914	1.000	29	29	1.000	$x^2 = 4.84$

Ice Thickness Category	Area (nm^2)	Proportion of total area	Number observed	Number expected	Proportion observed	95 confidence interval
New (<10 cm)	142	0.118	1	4	0.035	$0.038 \leq P \leq 0.376$b/
Young (10-30cm)	468	0.388	5	11	0.172	
First year (>30 cm)	595	0.494	23	14	0.793	$0.624 \leq P \leq 0.962$a/
Total	1,205	1.000	29	29	1.000	$x^2 = 11.19$

a/ Significant preference.

b/ Significant avoidance.

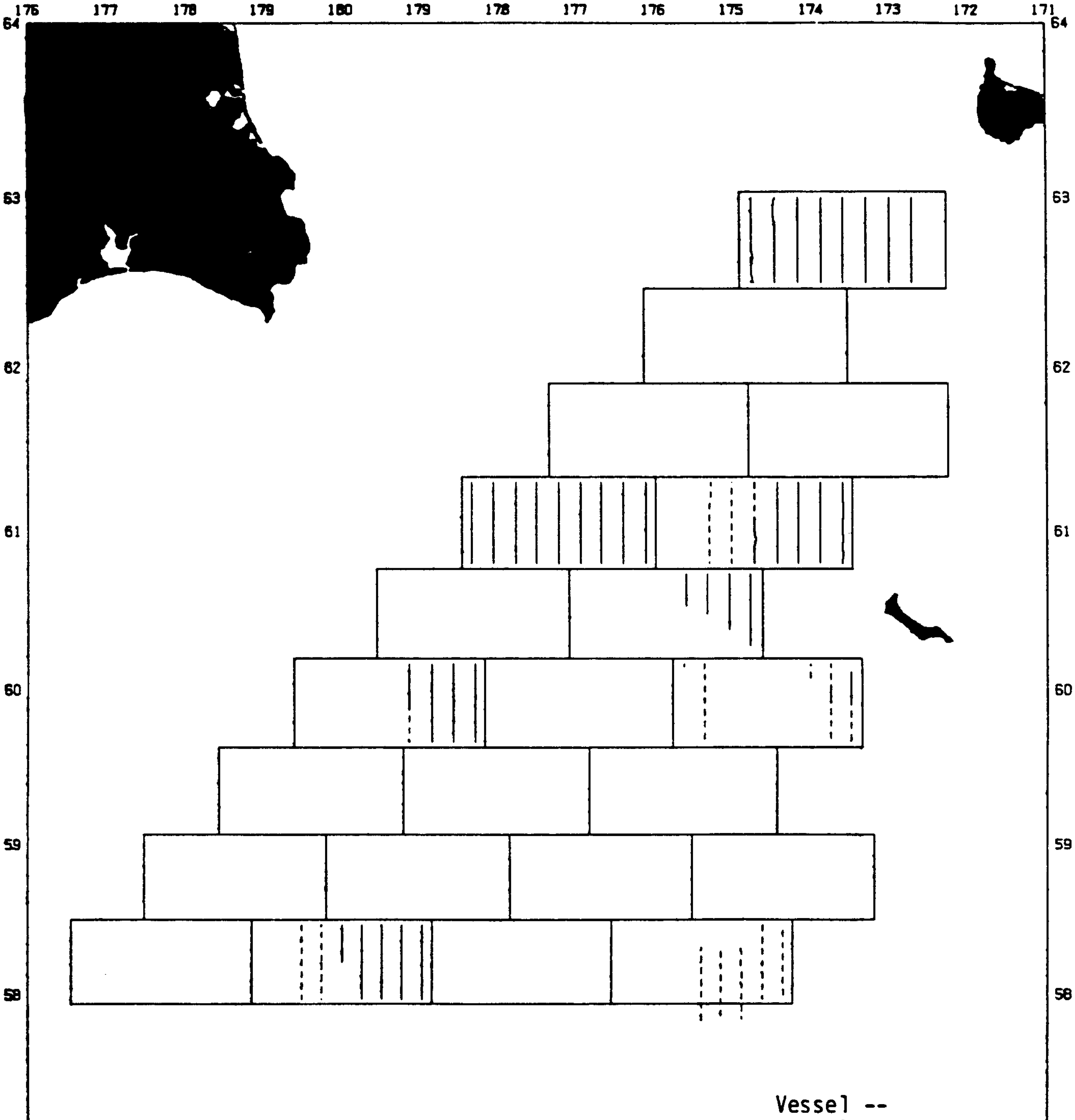


FIGURE 1 LOCATION OF AERIAL AND VESSEL TRACKLINES SURVEYED IN THE NAVARIN BASIN DURING SPRING, MAY - JUNE, 1982.

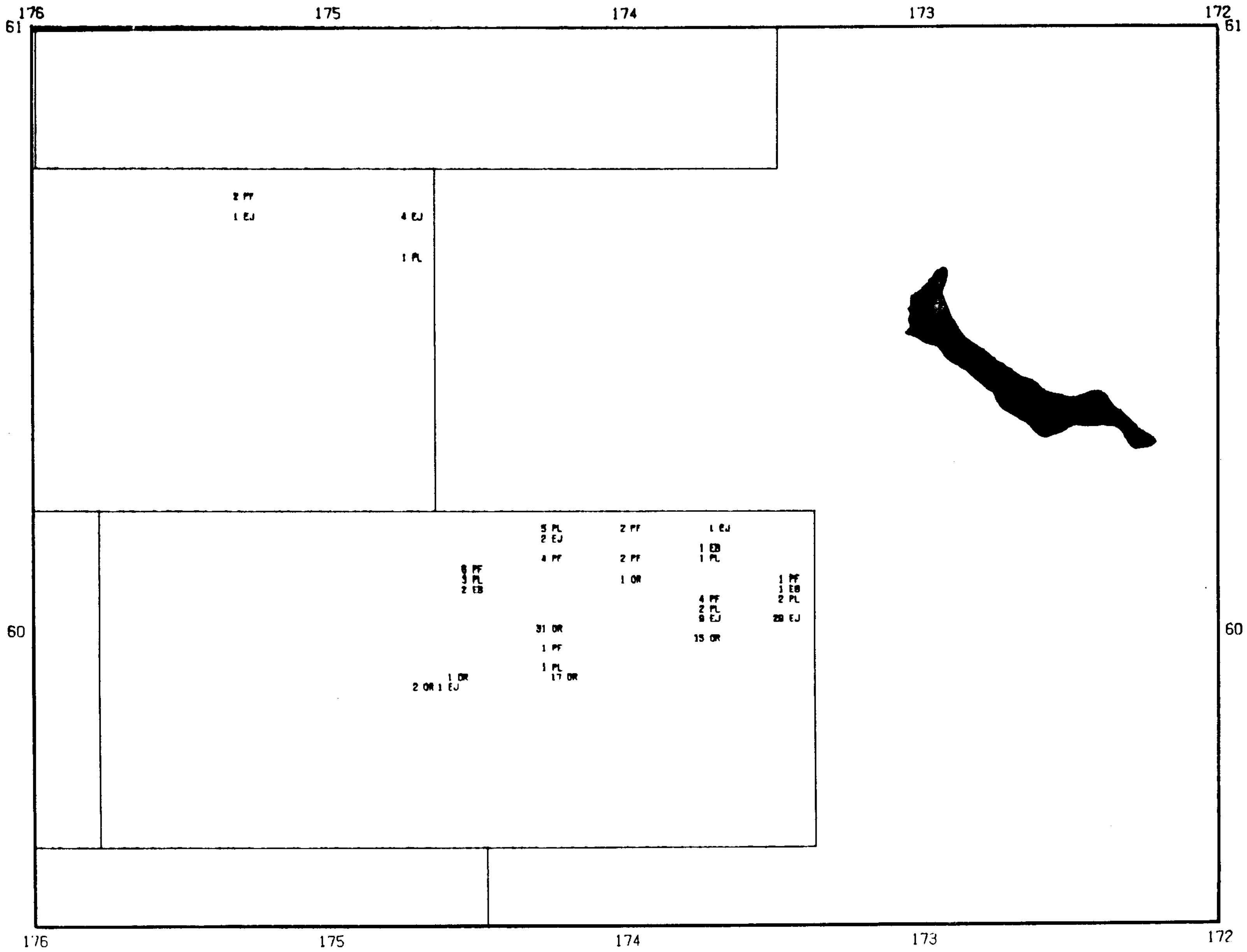


Figure 2 LOCATION OF PINNIPEDS OBSERVED IN THE NAVARIN BASIN DURING THE SPRING SURVEY, MAY-JUNE 1982. (Abbreviations are defined in Appendix Table 4).

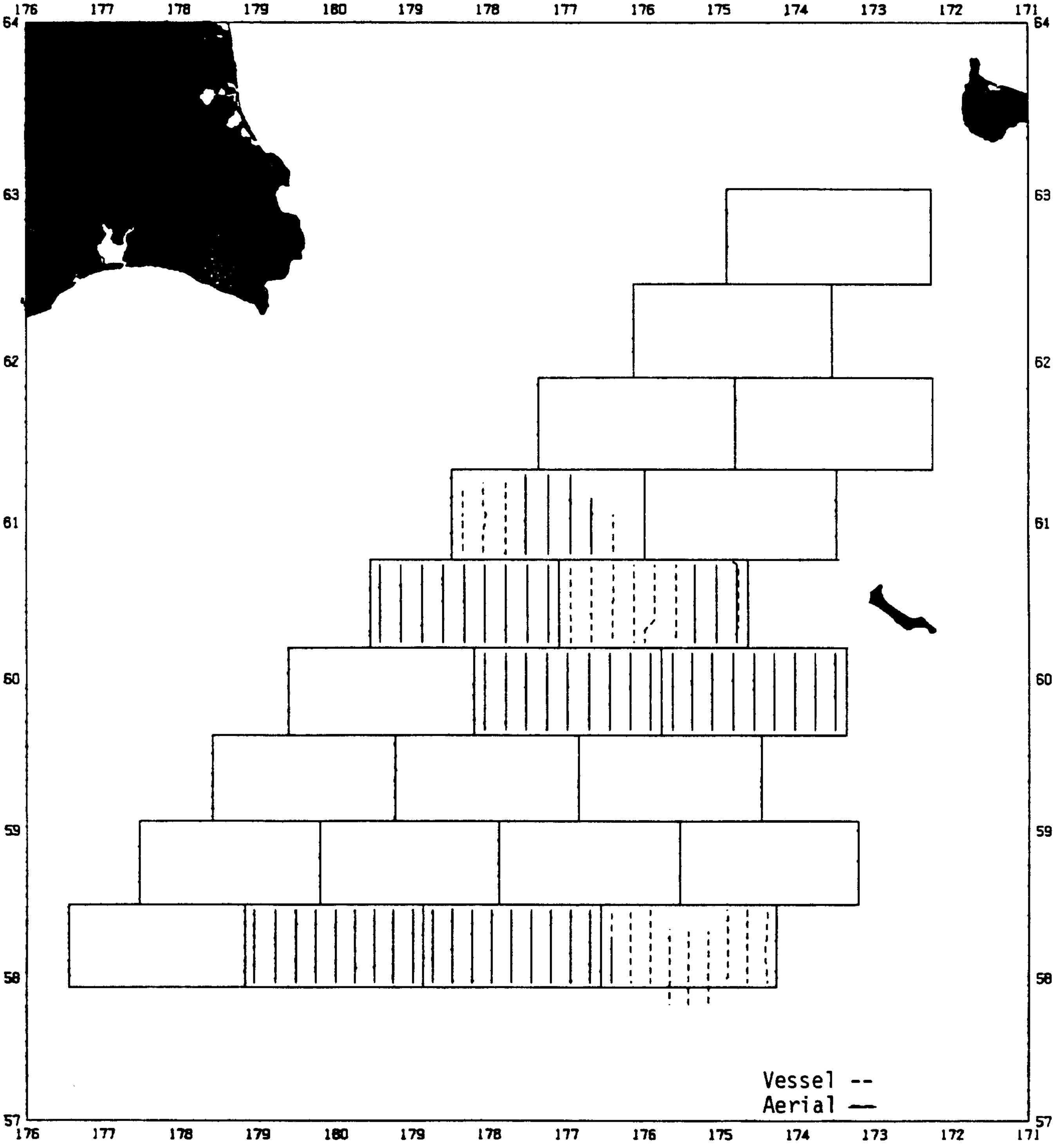


FIGURE 3 LOCATION OF AERIAL AND VESSEL TRACKLINES SURVEYED IN THE NAVARIN BASIN DURING SUMMER, JULY – AUGUST, 1982.

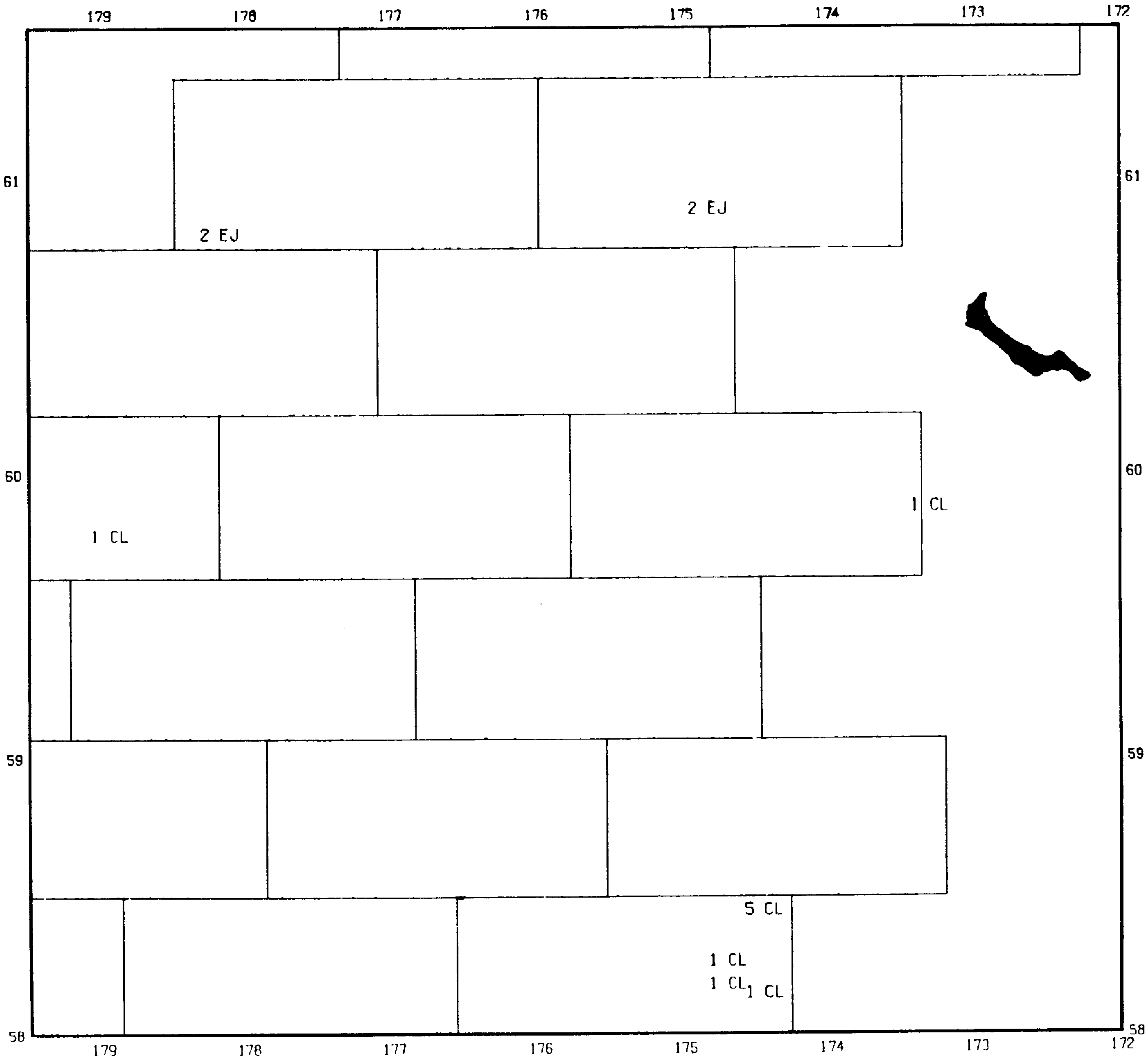


Figure 4 LOCATION OF PINNIPEDS OBSERVED IN THE NAVARIN BASIN DURING THE SUMMER SURVEYS, JULY-AUGUST 1982. (Abbreviations are defined in Appendix Table 4).

FIGURE 5 LOCATION OF AERIAL AND VESSEL TRACKLINES SURVEYED IN THE NAVARIN BASIN DURING FALL, OCTOBER - NOVEMBER, 1982.

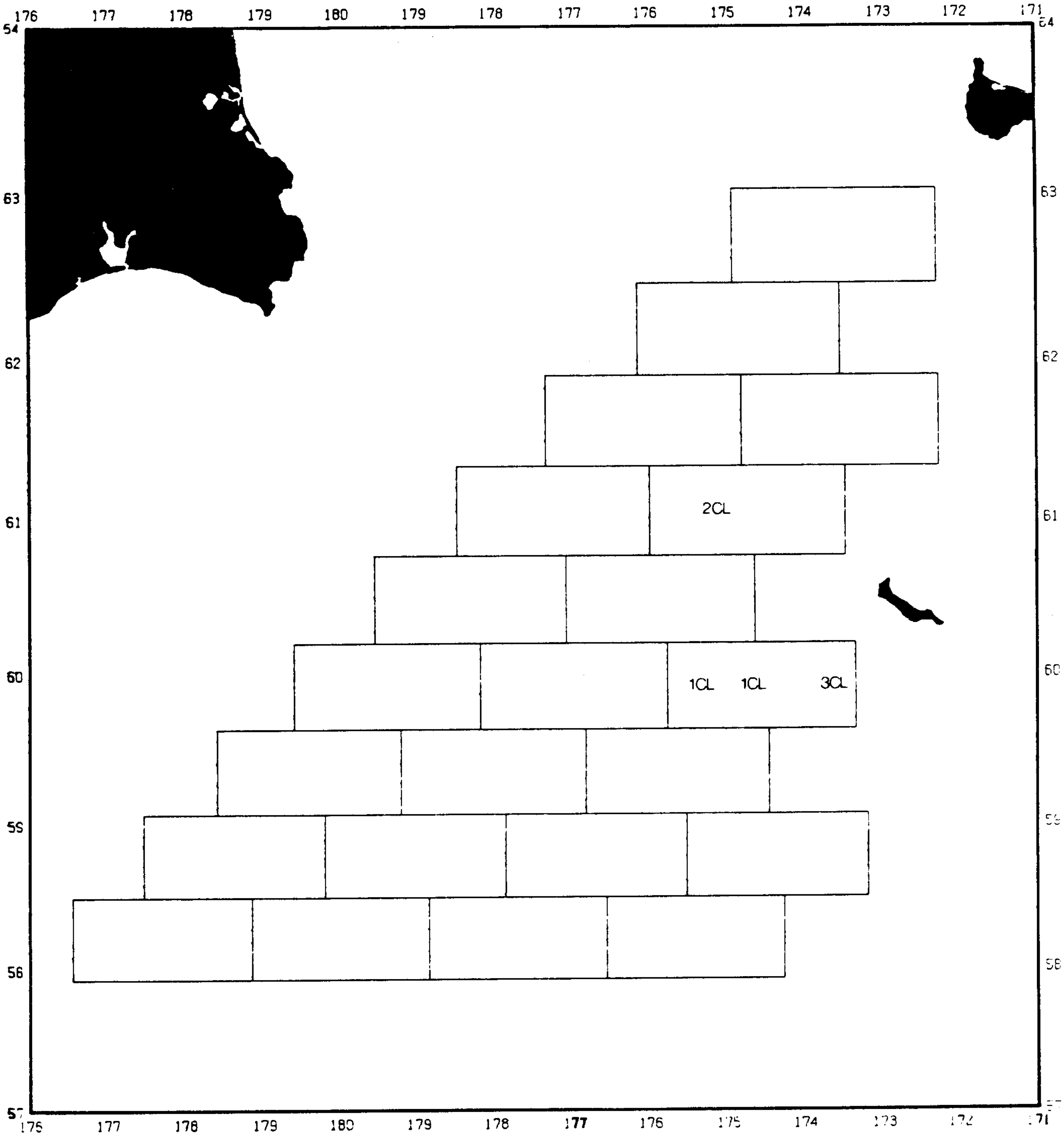


Figure 6 LOCATION OF PINNIPEDS OBSERVED IN THE NAVARIN BASIN DURING THE FALL SURVEYS, OCTOBER-NOVEMBER 1982. (Abbreviations are defined in Appendix Table 4).

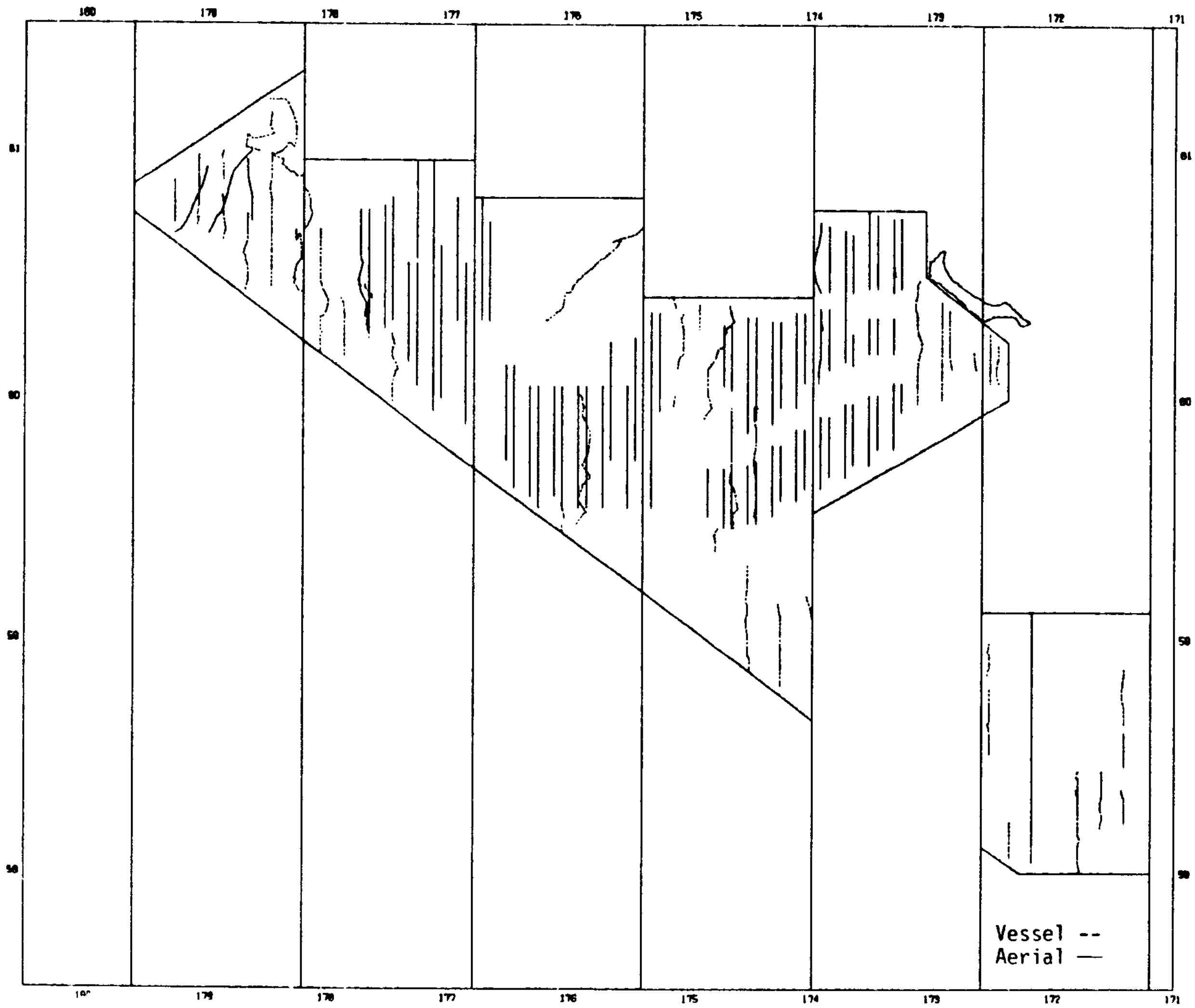


FIGURE 7 LOCATION OF AERIAL AND VESSEL TRACKLINES SURVEYED IN THE NAVARIN BASIN DURING WINTER, FEBRUARY - MARCH, 1983.

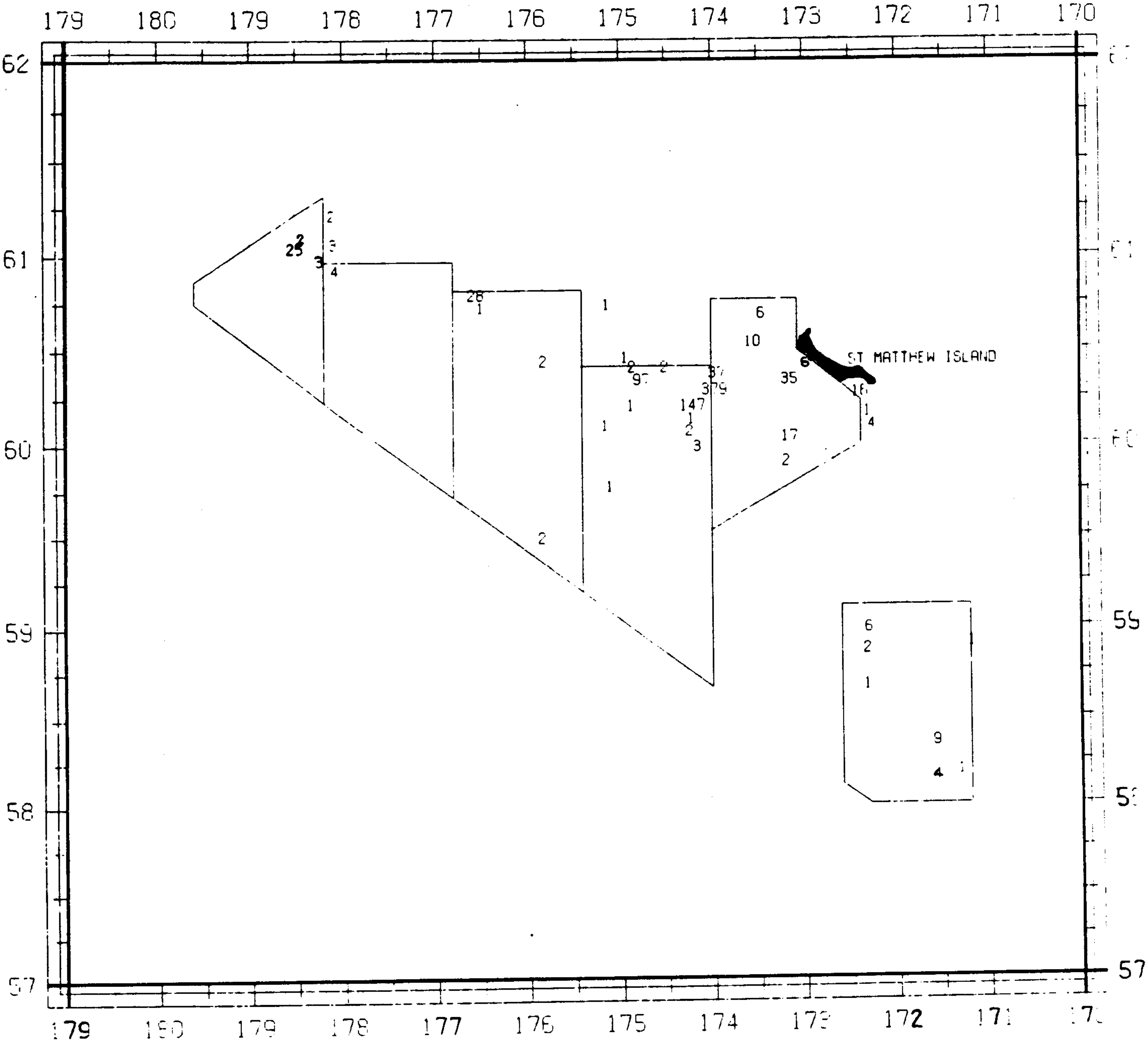
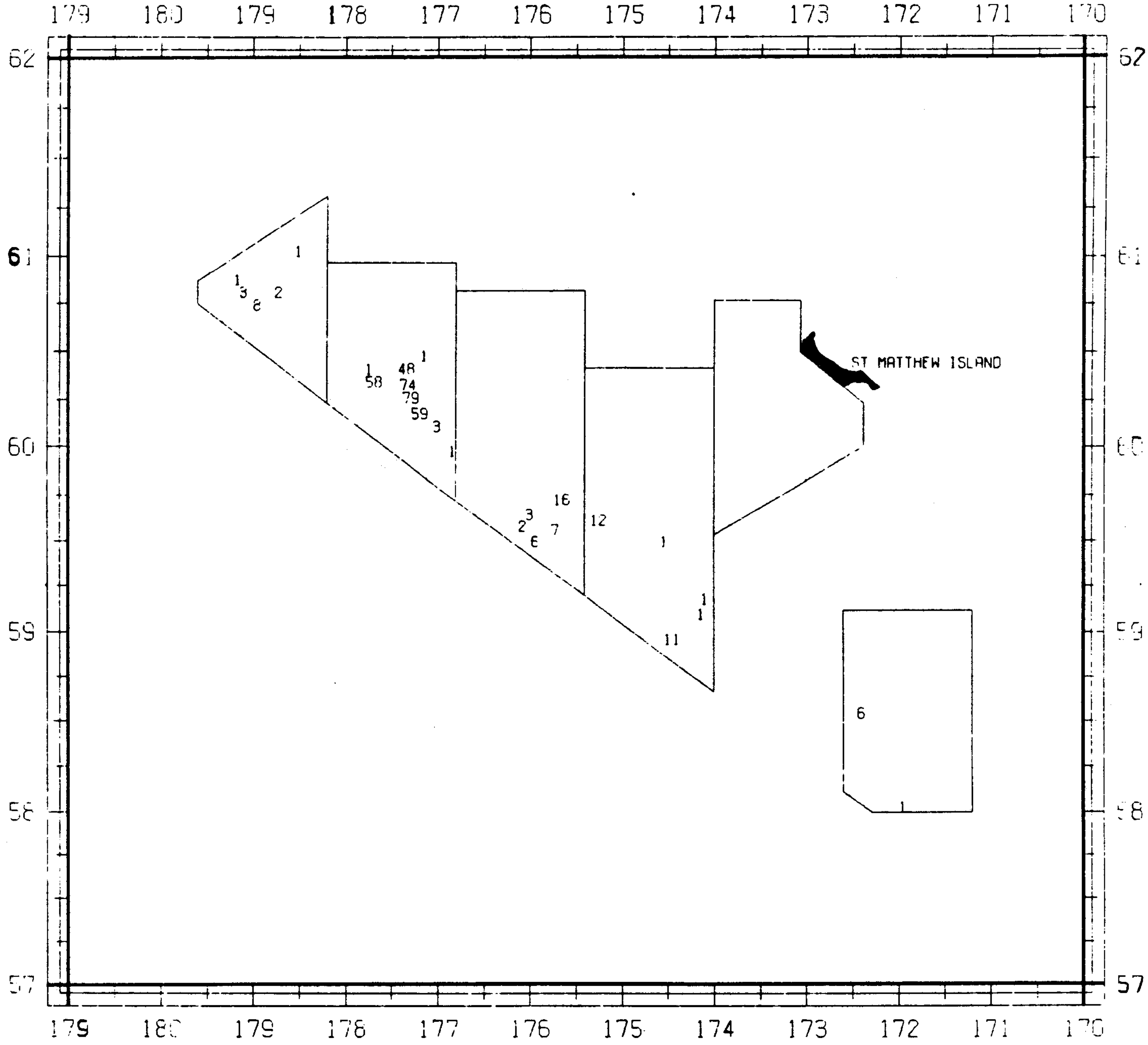


Figure 8 LOCATION OF WALRUSES OBSERVED IN THE NAVARIN BASIN DURING THE WINTER SURVEYS, FEBRUARY-MARCH 1983.



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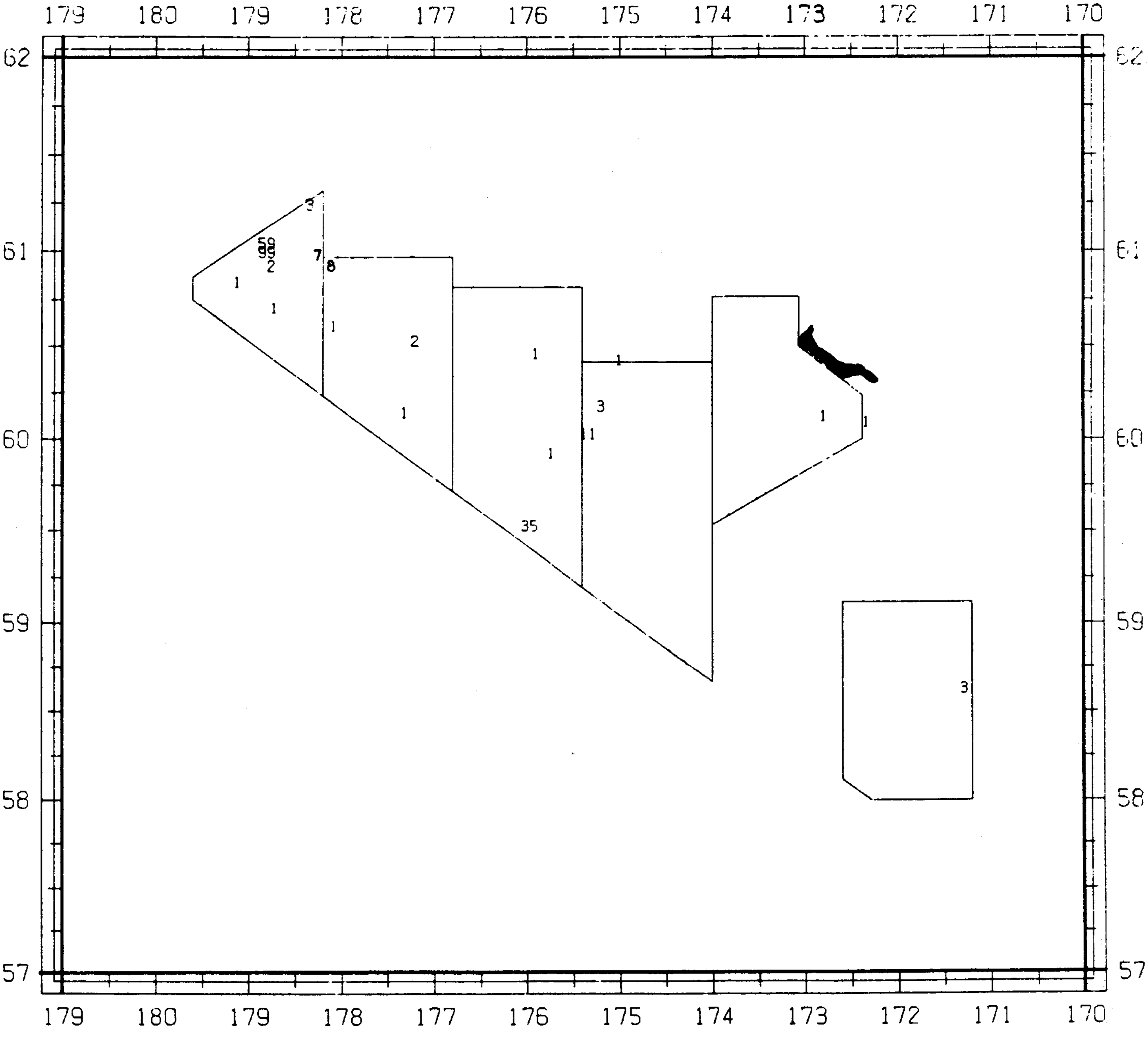

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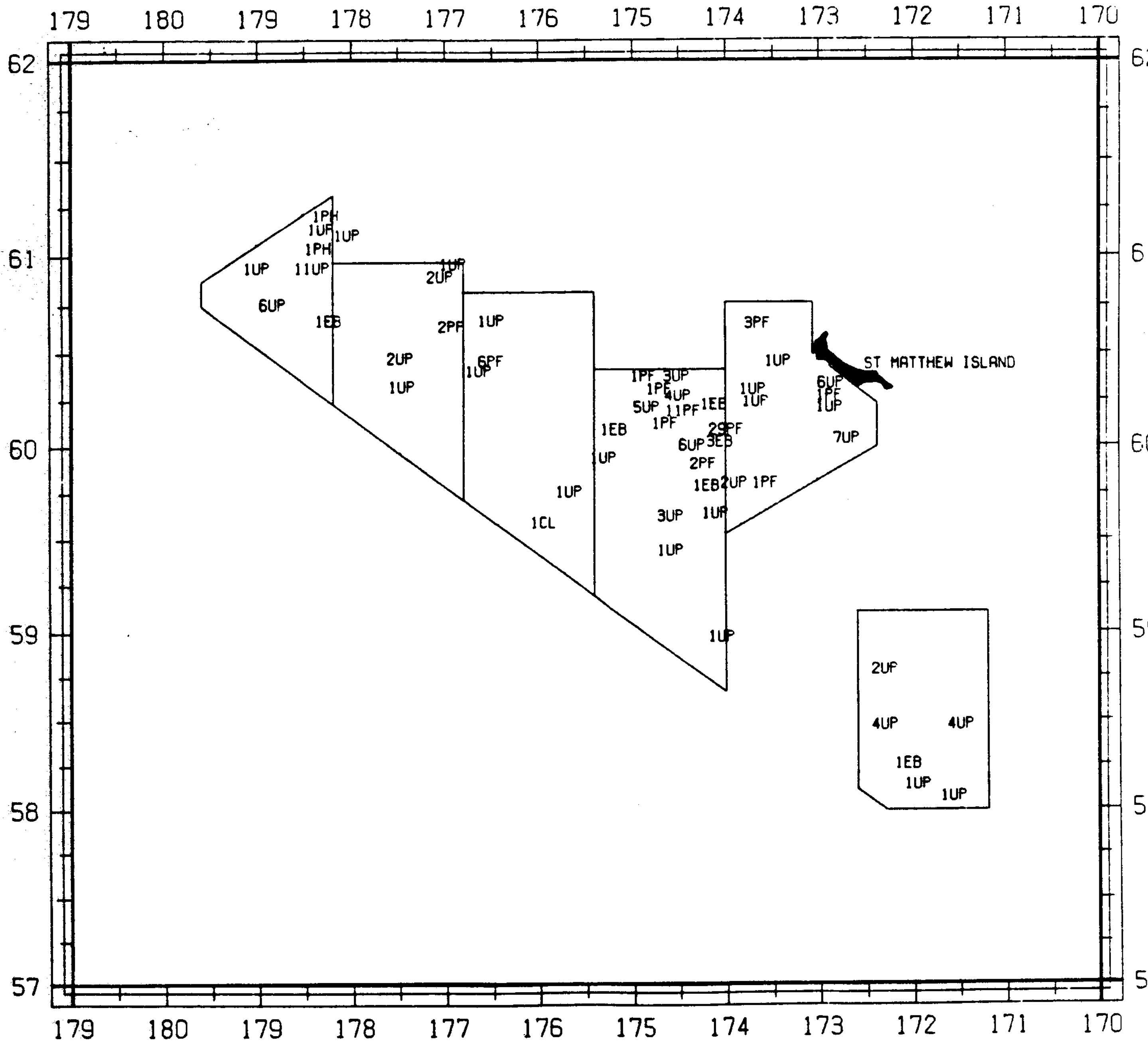

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POTENTIAL IMPACTS
OF MAN-MADE NOISE ON RINGED SEALS:
VOCALIZATIONS AND REACTIONS

by

William C. Cummings
Oceanographic Consultants

D. V. Holliday
B. J. Lee
Tracor, Inc.

Final Report
Outer Continental Shelf Environmental Assessment Program
Research Unit 636

December 1984

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I. EXECUTIVE SUMMARY

This is a report of studies related to possible impacts of man-made noise on the ringed seal (Phoca hispida), with emphasis on seal vocalizations and noises associated with near-shore geophysical exploration. The research was supported by the Minerals Management Service through interagency agreement with the National Oceanic and Atmospheric Administration, Office of Oceanography and Marine Services, Juneau, Alaska, as part of the Outer Continental Shelf Environmental Assessment Program under Contract 83-ABC-00065. It was conducted in Kotzebue Sound, Alaska, during March and April 1984.

The study area was typical of that used or planned for offshore seismic exploration. It was covered with first-year landfast ice, deformed with ridges, hummocks, and refrozen fractures, in a shallow-water area found to be inhabited with ringed seals. Surprisingly, there was evidence that at least two bearded seals (Erignathus barbatus) also resided there. A bearded seal pup was found in a lair, and very distant bearded seal trills were recorded on two occasions. The major task was to characterize the types of ringed seal sounds in this location by means of long-term field recordings, and to determine their frequency of occurrence as a possible clue to any changes in sound production resulting from the artificial introduction of "industrial" underwater noise.

The field activities centered on a precisely located 3-hydrophone array, which resulted in not only a very large number of recorded hours, but some localizations of sounds and sound source levels (intensity). Data were also obtained from outlying hydrophones, including a recording 192 km away. Not counting duplications on recordings of up to six hydrophones at once, we recorded and monitored 245 hrs of data, comprising nearly 25,000 biological sounds.

Ringed seal sounds were of comparatively low source level. Located seal and ice sounds originated mostly in areas of active ice, i.e., refrozen fractures or ridges, at distances up to 0.6 km. The frequency of occurrence of vocalizations dramatically increased over the study, presumably as breeding and parental activity increased. Ice scratching occurred mostly at two times of the day, and the occurrence of vocalizations also showed dependence on time of day. More vocalizations occurred during daylight hours. There were more vocalizations during periods of low windspeed, perhaps the effect of decreased aural masking by wind generated noise for the human listener. The number of scratches was not correlated with windspeed or temperature. The number of vocalizations increased during lower temperatures. Temperature and windspeed were not statistically correlated.

The rubs, squeaks, and quacking barks recorded by us appear to be very similar to ringed seal sounds described by Stirling and coworkers.

The results of underwater noise playback had to be considered in light of an overlying long-term natural increase in sound production. Consequently, comparable periods were kept reasonably short. Two comparisons before and after playback (6 and 23 hrs) of recorded "industrial" noise showed no statistical difference in sound production. Two other periods of comparison before and after (10 and 72 hrs) showed that sound production increased after playbacks, possibly related to an expected overall heightening of breeding and parental activity as the season progressed. There is a possibility that noise unassociated with our activity intensified ringed seal sound production based on the initialization of certain vocalizations by distant sources of low frequency pulses supposedly of man-made origin.

Recommendations basically involve the need for more research with narrower focusing, i.e., sound propagation, attenuation and modeling studies, and more controlled experimentation. Based upon this study, there was no evidence that petro-exploratory industrial noise reduced the occurrence of sound production of ringed seals. In some instances, it could have increased sound production. For example, a different kind of noise (low frequency pulsing believed to be of man-made origin) incited ringed seals to produce rub, squeak and quacking bark sounds. Since the source levels of ringed seal sounds were relatively low, there could have been a potential indirect effect from acoustical masking.

Compared to other pinnipeds, ringed seals did not produce many vocalizations under the circumstances of this study. Consequently, future research that is intended to utilize vocal sound production as indices to population enumeration, distribution or behavior may, of necessity, be limited. On the other hand, ice scratching sounds were very common, and they could possibly be used for these purposes.

II. INTRODUCTION AND BACKGROUND

A. The Problem

Ringed seals, Phoca hispida, are extremely abundant in Arctic Polar regions. Of all the marine mammals of this region, this species is the most numerous and widespread, being circumpolar in distribution (King, 1964). In recent years there has been a large-scale development of hydrocarbon energy sources in the near- and on-shore regions of Arctic Alaska. Associated with industrial activities involving exploration, development, and production, are increased levels of man-made noise and vibration (Malme and Miawski, 1979; Holliday et al., 1980, 1983, 1984; Cummings et al., 1981(6 references); Cummings & Holliday, 1983(3 references); Green, 1981; Ljundblad, 1983; Turl, 1982; LGL, 1981). Please refer to J. Acoust. Soc. Am., Suppl 1, Vols. 70, 74 for abstracts of other reports on man-made underwater noise based on work outside of the Alaskan Arctic region.

Airborne noise and vibration from petro-industrial activities may be of potential impact on Arctic wildlife; in particular, the ringed seal. OCSEAP has expressed concern that noisy activities could adversely affect the bioacoustical behavior of ringed seals, especially during the sensitive period of their life cycle as pups or mothers in early spring reproductive activities. A major source of noise in certain of Alaska's coastal ice regions is associated with on-ice geophysical exploration wherein low frequency sound is used to detect deposits of hydrocarbons in the underlying strata. Added to the noise from seismic profiling itself, are numerous other noise sources such as bulldozers, tank trucks, ice drilling rigs, and transport vehicles.

In addition to possible lair abandonment or displacement (ASA, 1980), the effects of man-made noise may be manifested as changes in the vocal behavior that presumably is important to the animals' welfare. For example, sound production in birds and fish has been shown to cease in the presence of loud man-made noise. There is also an indication that the frequency of occurrence of gray whale sounds is affected by man-made noise (Malme et al., 1983, 1984). The sound production of ringed seals could possibly be affected, but before any changes could be detected in their vocal behavior, a ground truth data base must be established. Thus, the main purpose of this research was to study the ringed seal's vocal activities, first, in a relatively undisturbed situation, and second, when the animals were exposed to possibly disturbing man-made noise. Hopefully, the work would yield information on apparent behavioral roles of vocalizations.

The Alaska office of OCSEAP and the Alaska Eskimo Whaling Commission (AEWC) contracted with Oceanographic Consultants and Tracor in 1981 for the purpose of developing an underwater sound localization system for ringed seal studies and for measurement of Vibroseis®[1] seismic profiling noise. The results of that work are described in a report by Cummings, et al. (1981). In 1983, OCSEAP supported our studies on acoustic and vibration measurements related to possible disturbance of ringed seals off Prudhoe Bay (Holliday et al., 1984). The present study was funded via a prime contract with Tracor, Inc., and a subcontract to Oceanographic Consultants.

B. The Ringed Seal and Its Bioacoustics

Although ringed seals are circumpolar in distribution, significantly large numbers occur on or very near landfast ice during the winter months (King, 1964). They are an important species to Inuit cultures because of their abundance and use for food, shelter, clothing, and artifacts (D. Brice-Bennett, Inuit Tapirisat of Canada, pers. communication).

Male and female ringed seals grow to about the same size (90 kg, 1.4 m) and may live to be over 40 years of age. The pups are born during a period from about mid-March to mid-April. Birth takes place in a natural ice cave or in a lair excavated by the mother where an access

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[1] The use of trade names or model numbers in this report does not imply endorsement.

hole is kept open. Other holes are kept open only for the purpose of breathing. Ringed seal pups are greatly dependent upon their mothers for nourishment, and they nurse for about eight weeks (Scheffer, 1958; McLaren, 1958; Burns and Eley, 1976).

Ringed seals feed on crustaceans and small fish. Their enemies include killer whales, polar bears, Arctic foxes, man, and pathogens (King, 1964).

Smith and Stirling (1975) described the wide variety of lairs as being composed of two general types. They also described the process by which they are constructed. One type, the birth lair, probably originates with the other, the haul-out lair. Birth lairs may have tunnels, whereas haul-out lairs generally are a single chamber. Lairs provide thermal insulation and a hiding place from polar bears and foxes. The reported lair sizes varied from 45 - 65 cm high, 196 - 355 cm long, and 135 - 227 cm wide. These authors indicated that populations may be limited by the amount of suitable breeding ice.

The hearing capabilities of seals were given an early review by Mohl (1968). Terhune and Ronald (1975a, 1975b, 1976) reported on the hearing of ringed seals and the following is mostly based upon their work. There is virtually no quantitative information on the sensitivity of seals to vibrational energy (displacement of the medium vs hearing).

We can assume that the audiogram of ringed seals is U-shaped; however, due to technical difficulties in producing uniform low-frequency sound fields at known received levels in small underwater enclosures, hearing sensitivity below about 1 kHz has not been measured. However, ringed seals do produce (and presumably hear) sound below 1 kHz (Cummings et al., 1981). Terhune and Ronald reported a fairly uniform sensitivity (± 7 dB) from 1 to 45 kHz, with increases of about 60 dB/octave above that frequency to 90 kHz. Thresholds below 45 kHz are about -30 to -20 dB re 1 μbar (70 to 80 dB re 1 μPa). Critical ratios vary between 30 ± 5.4 dB (at 4 kHz) to 35 ± 4.5 dB (at 32 kHz). Critical bandwidths over these frequencies vary from 1 to 3.16 kHz. They concluded that the loss of both sensitivity and pitch discrimination effectively places the upper limit of useful hearing at 90 kHz. On this basis, ringed seals are capable of hearing noise spectra above 1 kHz that is associated with gas and oil exploration on the ice. It would be difficult to predict the masking effect of this noise on their own sounds without more research.

Most animals produce a lexicon of sounds which may occur in well-defined patterns. Examples are the long, involved repetitions of humpback (Payne) and bowhead whale (Ljungblad et al., 1982; Cummings et al., 1983) sounds, or the rhythmical sounds of wild porpoises. We (Holliday et al., 1980) have shown that bearded seal calls off Barrow, Alaska, occurred in a diurnal pattern. The ability to recognize patterns implies categorization and recognition of the components, which can be described in physical terms such as frequency, temporal, and amplitude characteristics.

Very little information has been published on ringed seal sounds. Stirling (1973) described barks, yelps, high-pitched growls, and chirps of ringed seals that extended up to a maximum of about 6 kHz. Cummings et al. (1981) presented some spectra of ringed seal sounds: a gargle-type with peak energy at 1 kHz, a rub that extended from about 0.7 - 2.6 kHz, a bubbling sound thought to have been produced from an underwater exhalation, .05 - 11 kHz, and a scratching sound from a ringed seal working on its breathing or access hole, or in the lair above, 0.5 - 3 kHz. Stirling, et al. (1983), observed that ringed seal vocalizations were more frequent in late April than earlier in the season or in late June, and that the sounds have the potential of being useful for information on distribution and abundance. Their sonagrams indicated considerable low frequency energy in the ringed seal's sounds, below 500 Hz.

Although the behavioral significance of these sounds is unknown, we may assume that some sounds involve inter-animal communications. Likely functions of the signals doubtlessly are associated with courtship, parent-offspring, food finding, and territorial behavior. Based upon what is known of the importance of sound production in other species, it could be assumed, a priori, that ringed seal sound production is a requirement for survival in the natural environment.

To our knowledge, man-made noise had not previously been experimentally played back to ringed seals. Watkins and Schevill (1968) used playbacks to Weddell seals that consisted of the seals' sounds. They reported varied responses and described an apparent learning to ignore. Cummings played back killer whale sounds and random noise to California sea lions off Catalina Island and in the Gulf of California in an unsuccessful attempt to displace them from fishing operations (unpublished). There either was no apparent reaction or the seals appeared to be attracted to the underwater transducer. P. Shaughnessy had much the same results in experiments for the same purpose with fur seals and sea lions in South Africa (pers. communication). On the other hand, Dr. Bruce Mate and co-workers, Oregon State University, have experienced success with underwater playback of noise to harbor seals in the attempt to reduce their predation upon salmon in a restricted area (personal communication). Schusterman and Moore (1981) stressed the importance of individual and group behavioral variability of response to noise.

C. Acoustic Environment

Most models involving the reception of acoustic energy will include three basic parameters, the received level (RL), total propagation losses (TL), and the source level (SL). Thus RL will depend upon the degradation of the propagated sound (TL) and the power of that sound at its source (SL). The most simplified expression of this relationship is:

$$RL = SL - TL \qquad \text{(eq. 1)}$$

where all three variables are given in decibels (dB). As used in this report,

$$dB = 20 \log_{10}(P_1/P_0) \qquad \text{(eq. 2)}$$

where P_1 signifies measured acoustic pressure and P_0 signifies a reference of the pressure measurement, herein defined as 1 μPa (one micropascal). While the dB may seem to be a very indirect method of indicating acoustic levels, it is used by convention because the normal range in pressure units may be in the millions. Since the dB is actually a multiple of a logarithm, its unit is much more manageable in acoustic measurements than the unwieldy large numbers encountered in the direct measurement of pressure, the physical stimulus perceived by the ear.

Also by convention, the term "signal" as applied here denotes the sound of interest, e.g., the warning bark of a seal, whereas the background or accompanying sound may be termed "noise". In most applications, it is the reseacher's arbitrary choice to define sound(s) as signal or noise. In practice, this choice usually does not depend upon aural pleasure or discrimination.

At first glance of eq. 1, it may appear that the loudness of a received level (RL) to a listener will depend upon its magnitude, source level, and total propagation loss. While all three variables are involved in auditory perception, given a satisfactory receiver, the ultimate limitation involves signal to noise ratio (S/N) usually given in dB. In other words, regardless of the signal's received level, audibility (recognition) will depend upon the ratio of its level to an equivalent or nearly equivalent frequency band of noise. Remembering that dB basically is a logarithmic quantity, if the signal and noise are of equal level, S/N = 0. The reader is referred to Urick (1967, 1975, 1983) for discussions of these principles, and there are numerous other references.

The measurement and physical characteristics of petro-industrial and natural background (ambient) noise are of paramount importance in any basic understanding of how this noise may affect marine mammals. In a given model it is conceivable that the RL of man-made noise may be less than that of the natural noise such that it may not be the most important limiting factor in masking of an important biological signal. Or the reverse may be true, in which case the level of man-made noise may be the dominant factor in making an important signal inaudible.

Aside from aspects of the basic sonar equation (eq. 1) that relate to masking and detection, there are possible behavioral responses to man-made noise. In other words, if a signal is audible in the presence of the noise, will it elicit a behavioral response that affects the animal's welfare? For example, in the presence of offensive man-made noise an animal may flee its accustomed location to experience the consequences of a new location. Moreover, if the received noise is sufficiently high and of critical duration and frequency, it could possibly cause physical or psychological impairment, either temporary or permanent. Given the necessary parameters of detection, but lacking those responsible for any direct or indirect harm, in all probability the animal will learn to ignore a given noise source, a process sometimes called acclimation. Acclimation can occur even though a noise may be of some indirect harm.

No one study of acoustics and bioacoustics can sufficiently address all of these items, especially over short-term study periods. Instead, each project must focus on certain priorities. The ultimate objective is a mosaic of facts that will provide management with a sufficient scientific basis for effective decision making.

III. OBJECTIVES

The present study had three main objectives as follows:

(1) Determine vocalization characteristics and patterns for ringed seals in the southern Chukchi Sea region during the study period.

(2) Determine any bioacoustical responses of ringed seals to taped playbacks of man-made noise associated with seismic activities.

(3) Describe any apparent roles of vocalization in reproduction and pupping behavior.

All three goals involve important information for the decisions required before and during offshore oil and gas development. First, to determine if man-made noise affects the sound production of ringed seals, vocalization characteristics and any patterns of vocalization for this species must be known under undisturbed ("normal") conditions. Since winter seismic profiling occurs during the active reproductive season, and it can be assumed that vocalization is part of the reproductive behavior, the resulting man-made noise may possibly affect vocalization and the behavioral role of reproduction-related sounds. Secondly, it would be very useful to determine the apparent reproductive roles of vocalization. Finally, the purposeful introduction of previously recorded man-made noise may indicate bioacoustic responses by the seals that may be indicative of what to expect in the presence of noisy on-ice operations.

IV. METHODS

A. Study Period, Personnel, Location

The technical preparation for this study began on 16 January 1984. This basically consisted of design, purchase, fabrication and testing of the sensing and sound projecting instrumentation as specified in our proposal. A special effort was made to calibrate the receiving transducers in San Diego. The projectors had already been calibrated.

The field personnel were divided into two teams, each consisting of three people. D. V. Holliday headed the first team which was responsible for setting up the ice camp, the initial installation of hydrophones, and the initial recordings near the camp. The second team, headed by W. C. Cummings, reinstalled some of the equipment, completed the recordings, conducted the noise playback experiment, and disassembled the camp. The first team departed for Kotzebue on 18 March, returning on 30-31 March. The second team departed on 29 March and returned on 15 April 1984. Field work was undertaken by:

Team I	D. V. Holliday, Tracor, Inc., San Diego, CA C. F. Greenlaw, Tracor, Inc., Philomath, OR B. Narimatzu, Tracor, Inc., Silverdale, WA
Team II	W. C. Cummings, Oceanographic Consultants, San Diego, CA D. E. Bonnett, Tracor, Inc., Silverdale, WA C. T. Lee, Tracor, Inc., San Diego, CA

Our camp was located on landfast ice at the entrance to Kotzebue Sound (66^{0} 41.1' N, 162^{0} 55.9' W, Fig. 1), a site about 28 km southwest of the village of Kotzebue. The nominal thickness of ice in this region was 2 m. Snow cover was light. The area was moderately ridged, landfast first year ice with hummocks and fractures. The bottom in this location is flat, the depth being about 14.5 m to the top of the flat ice. The camp was occupied from 22 March-13 April 1984. The period of 19-21 March

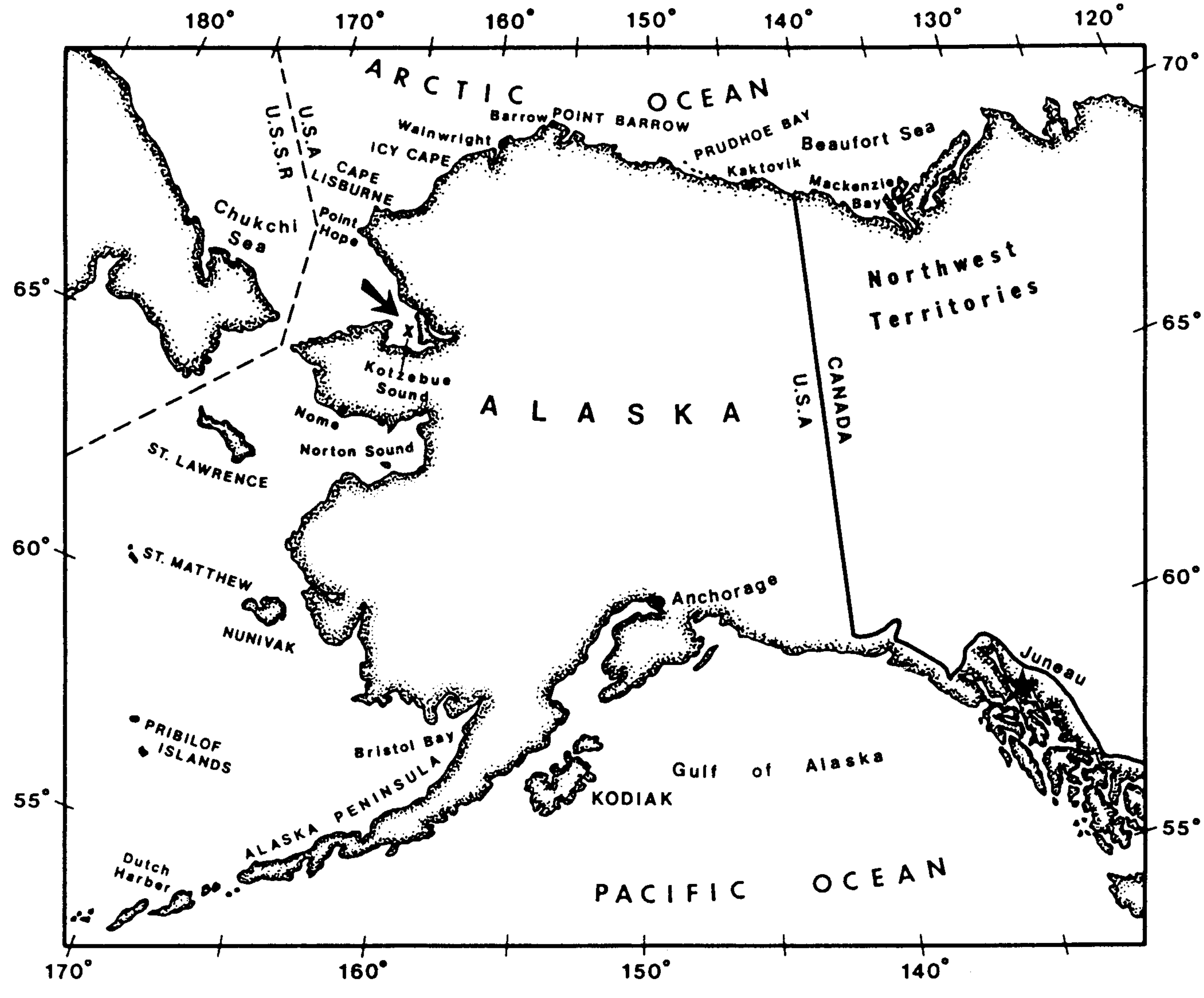


Figure 1. Study site (arrow) at the offshore edge of Kotzebue Sound, Alaska.

was spent assembling snowmachines, readying the field instrumentation, and locating ringed seals. The latter task, of considerable importance to the project, was undertaken by J. Burns (Alaska Department of Fish and Game), B. Kelly (University of Alaska) and associates working with trained dogs. Within a 5.6 km radius of camp, 21 locations were marked signifying breathing holes, and active or abandoned lairs.

Transportation and shipping to and from the base of our operations at Kotzebue were furnished by a NOAA helicopter and crew. Snowmachines were used for local transportation of personnel and gear near the study site, although we also walked long distances to minimize disturbance to the seals.

B. Sensors, Telemetry, Sound Speed

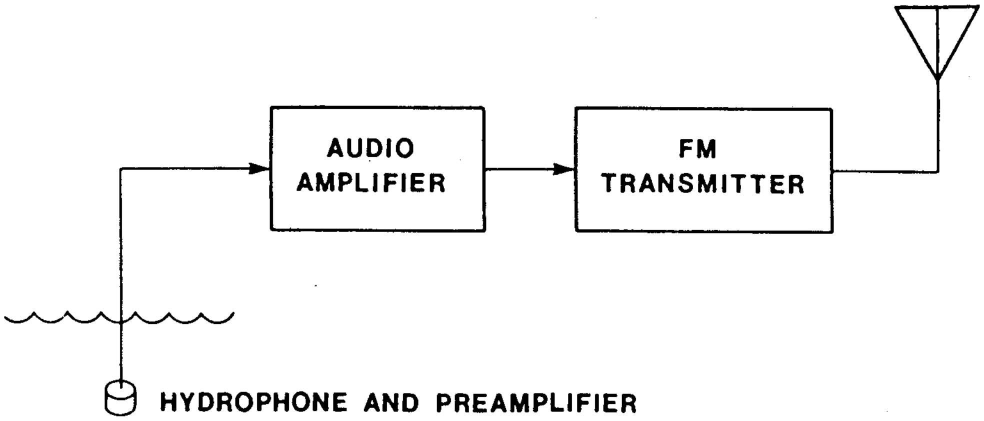
Underwater sound was received with hydrophones (Wilcoxon H-505, InterOcean R-130, and sonobuoys AN/SQQ-57A) placed through holes drilled in the ice. PVC pipe casings and antifreeze were used to prevent loss of the Wilcoxon hydrophones due to freezing. Besides being an antifreeze mechanism, the pipe casings also isolated the hydrophone cable from vibrations due to stress relief (cracking) in the ice. These vibrations can interfere with measurements if the ice is allowed to freeze around the cable. The InterOcean hydrophones were used while being attended, thus they were recoverable. However, the sonobuoy sensing units and cables had to be sacrificed.

When certain of the measurements were made at frequencies greater than 15 kHz, a portable recorder (Nagra 4-SJ) was connected directly to the hydrophone and a portable, wideband amplifier in the field. One recording channel was "hard-wired" to a hydrophone via coaxial cable. Appropriate amplifiers and line drivers were provided to prevent signal loss, and the entire system was calibrated as a unit. For other work, telemetry was provided by transmitters from modified AN/SQQ-57A sonobuoys. Considerable modification of these sonobuoys was necessary in order to dismantle the normal air eject mode, provide for long-term operation with large (105 amp/hr) 12V storage batteries, and provide for additional matched, variable gain amplification (Fig. 2). Just prior to the field work, all three types of hydrophones were calibrated at the U.S. Navy calibration facility in San Diego (TRANSDEC). The design of the instrument was such that these calibrations would not be expected to change due to water temperature changes between this facility and Kotzebue. All of the instrumentation exposed to outside temperatures was tested in a laboratory freezer during the period of preparation.

Three of the hydrophones were installed in a triangular array set up about 1 nm SW of our camp (Fig. 3). These were designated hydrophones A, B, and C, their separation being 118.9, 99, and 108.2 m, respectively. Hydrophone A, installed through a pipe casing, was cable-connected to our camp, a distance of 1.8 km. B and C (sonobuoys) were received at the camp by radio telemetry. Another sonobuoy (D) was installed about 3.7 km SW of the triangular hydrophone array. About 2.8 km NW of the triangular array, a bearded seal pup was found in an active lair consisting of a natural opening between ice blocks. The animal was identified by J. Burns. Here we installed a sonobuoy hydrophone as a microphone, above the water's surface. This location was designated as E, the "bearded seal lair".

A sixth sonobuoy (F) was used as a microphone in an active lair about 1.4 km NW of the camp. A seventh sonobuoy (G) was installed about 5.6 km N of the camp and 25 m from an access hole that was being used by a ringed seal and its pup. There was no den at G, and the seal hole was made through a refrozen fracture. We located this hole and two others in the general vicinity simply by scanning the area with binoculars on a comparatively warm, bright, sunny day. This fracture extended for miles and contained numerous breathing and access holes. The eighth recording location (H) was situated 192 km W of Kotzebue. Here we drilled a 1 m hole through a refrozen polynya and deployed a cable-connected InterOcean hydrophone for two recording sessions lasting two hours. This far offshore site was an area of active ice. It was not possible to record there for a longer period because of the environmental limitations placed upon both airplane and personnel. Locations of all recording and playback sites are summarized in Fig. 3.

TELEMETRY UNIT



AN/SSQ-57A (MODIFIED)

Modifications:

- Remove rotor assembly
- Disarm antenna eject
- Extend antenna cable
- Remove seawater batteries
- Modify for external power
- Disable automatic transmitter cutoff timer
- Remove dissolving plug/paint/seal case

Hydrophone response: 1Hz to 10KHz (flat)

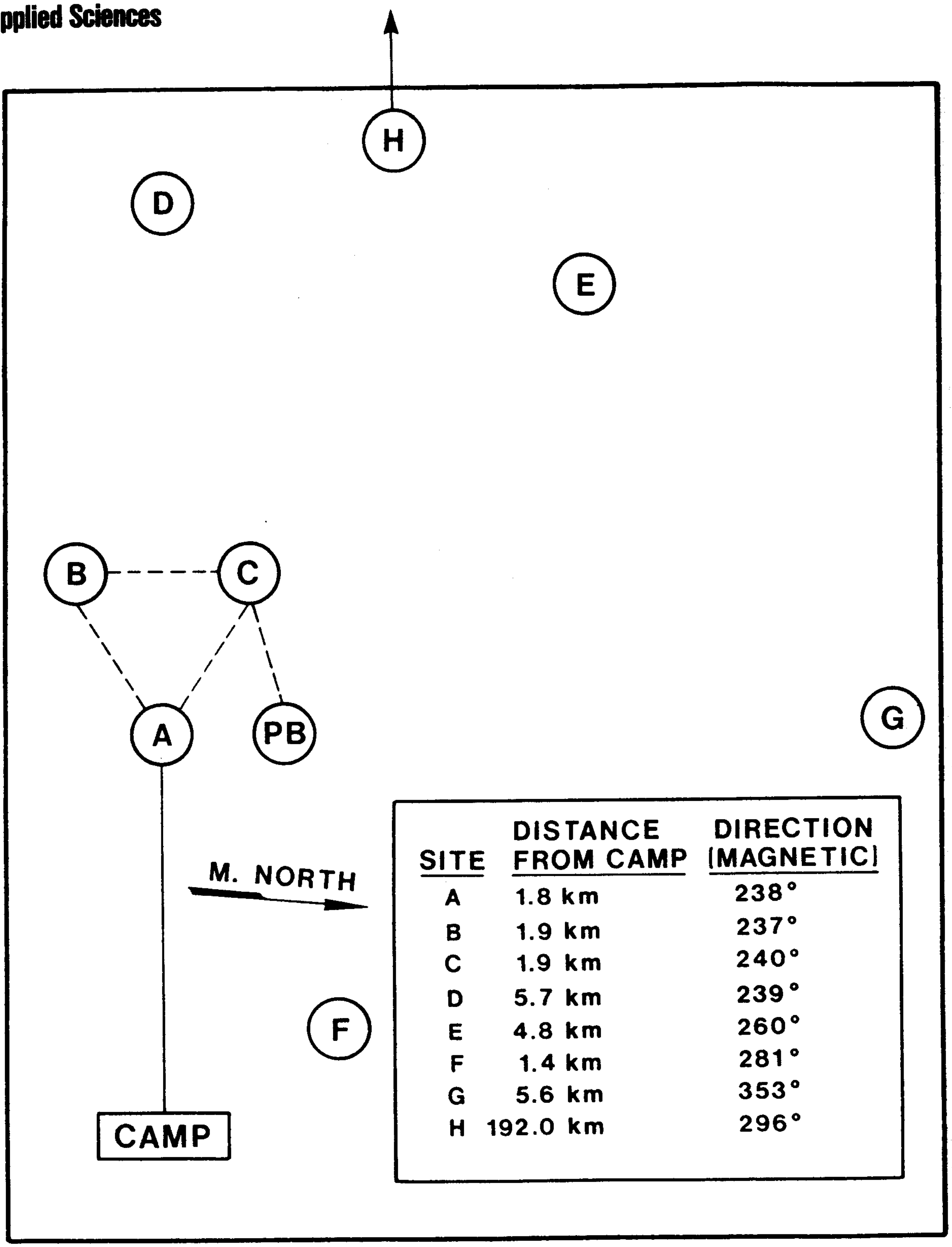
System telemetry response: 5Hz to 20KHz (useful range)

Number of channels: 31

RF telemetry: 162.25 to 173.5 MHz

RF power: 1 watt

Figure 2. Schematic, modifications, and specifications of the telemetry units.



SITE	DISTANCE FROM CAMP	DIRECTION (MAGNETIC)
A	1.8 km	238°
B	1.9 km	237°
C	1.9 km	240°
D	5.7 km	239°
E	4.8 km	260°
F	1.4 km	281°
G	5.6 km	353°
H	192.0 km	296°

Figure 3. Sketch of recording site layout with distances and directions from camp (drawing not to scale).

Supporting data collected during the period of field work included measurements of windspeed and direction, air temperature, light, and underwater sound speed profiles.

C. Recording

To allow for seal location, site preparation, and dismantling, the actual data recordings and sound playback took place 25 March to 11 April 1984. During this period of time 209 hrs were recorded from the triangular array on magnetic tape, most of which included sounds from all three hydrophones recorded simultaneously. In other words, one hour of recording from the triangular array may have consisted of 1 to 3 channels, usually 3. In addition, there were 36 hrs of recordings from the other sensors (D-H) for a total of 245 hrs (Fig. 4). Recordings for long-term monitoring and localization were made with a 4-channel instrumentation recorder (Nagra T). Some long-term monitoring from the remote sensors was also done with uncalibrated recorders (GE, Mod. 3-5105F) for the purpose of determining the frequency of occurrence of sound production. Short-term calibrated recordings were made with a 3-channel instrumentation recorder (Nagra 4-SJ).

D. Playback

A series of playback sessions was undertaken in the area of the triangular array. The underwater sound projector (Navy Type J-9) was lowered to half depth through a large hole chiseled through 2 m of ice at a location 26.2 m from A and 99.5 m from C (Fig. 5). Peak source levels were 135 to 140 dB re 1 μPa, 1 m. Dimensions of the ice opening were 0.75 x 1 m.

Playback data were rerecorded from field recordings taken in prior years, in addition to alternating random noise and a 1 kHz tone. We used a 25-min continuous series of Vibroseis sweeps alternated with 14 min of noise associated with Vibroseis operations (operating bulldozer, drilling,

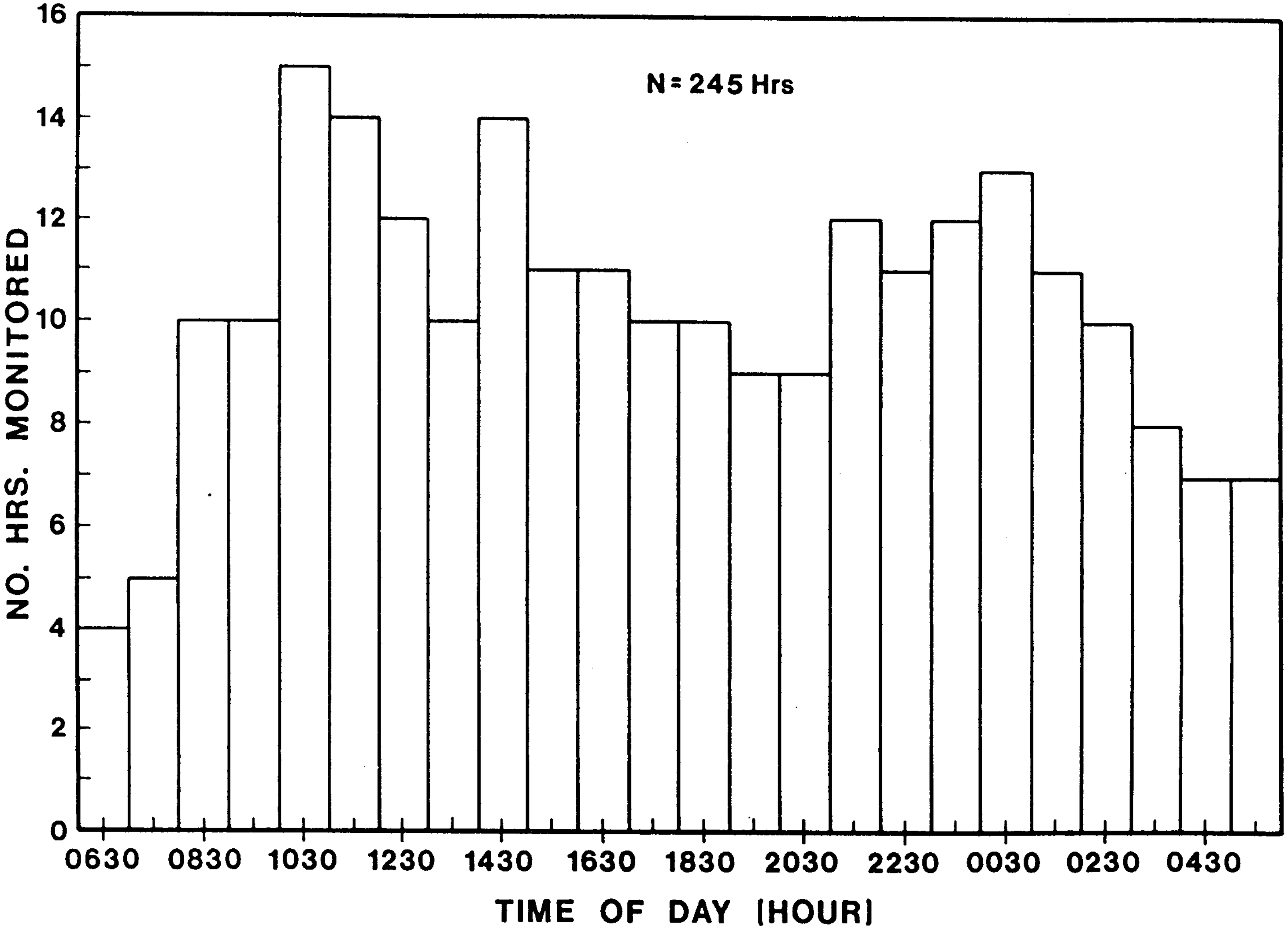


Figure 4. Histogram showing pooled monitoring (recording) effort.

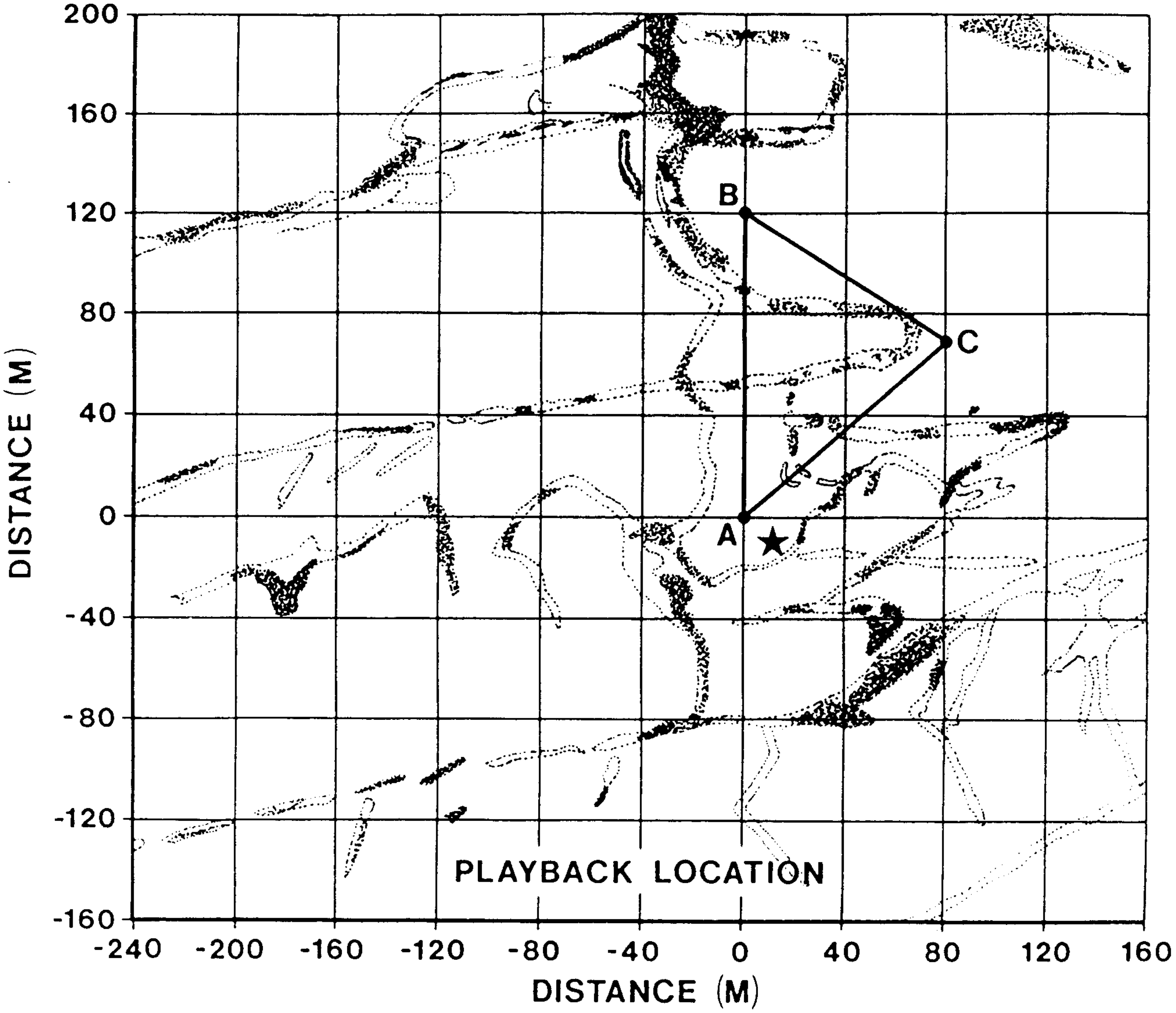


Figure 5. Orientation of the playback location (star) in relation to the triangular array of hydrophones. Surface topography (ridges, refrozen fractures, etc.) as reconstructed from surface measurements and aerial photographs is stippled. Heaviest stippling indicates surface relief of about 2 to 3 m.

movement of heavy track vehicles and personnel, etc.), Figs. 6 and 7. We also used 40 min of random noise alternated with 45 min of 1 kHz tones. Ten minute silent control periods were allowed between adjacent playback sessions. The total duration of playbacks was 14 hrs, 35 min, scheduled as shown in Table 1, with inclusive short, silent control periods.

Playbacks were undertaken on 5, 6 and 8 April, with portions of the recordings at other times being used as controls. Continuous recording was underway during both playback and the interspersed silent control periods. The experimental design was to allow time for recordings of ringed seal sounds before and after playbacks.

E. Analysis

Five basic types of analysis were utilized in this study: 1) waveform and spectrum analyses, 2) determination of the rates of sound production (frequency of occurrence), 3) correlation, 4) sound localization, and 5) source level determination.

Waveform Analysis

Individual vocalizations or other sounds can be characterized by duration (time), level (power), and frequency (analogous to pitch). The last two parameters often change within an individual vocalization, and the first may be variable between sounds.

It is useful to convey the characteristics of a sound by plotting sound pressure level or some proportional quantity, such as a voltage from a pressure sensor, versus time, a technique that primarily utilizes the time domain. This type of display (Fig. 8) conveys at a glance the duration and complexity of a waveform in terms of level and frequency over the sound's duration. A close examination will reveal average and peak pressure levels, and variations (if any) of level and frequency.

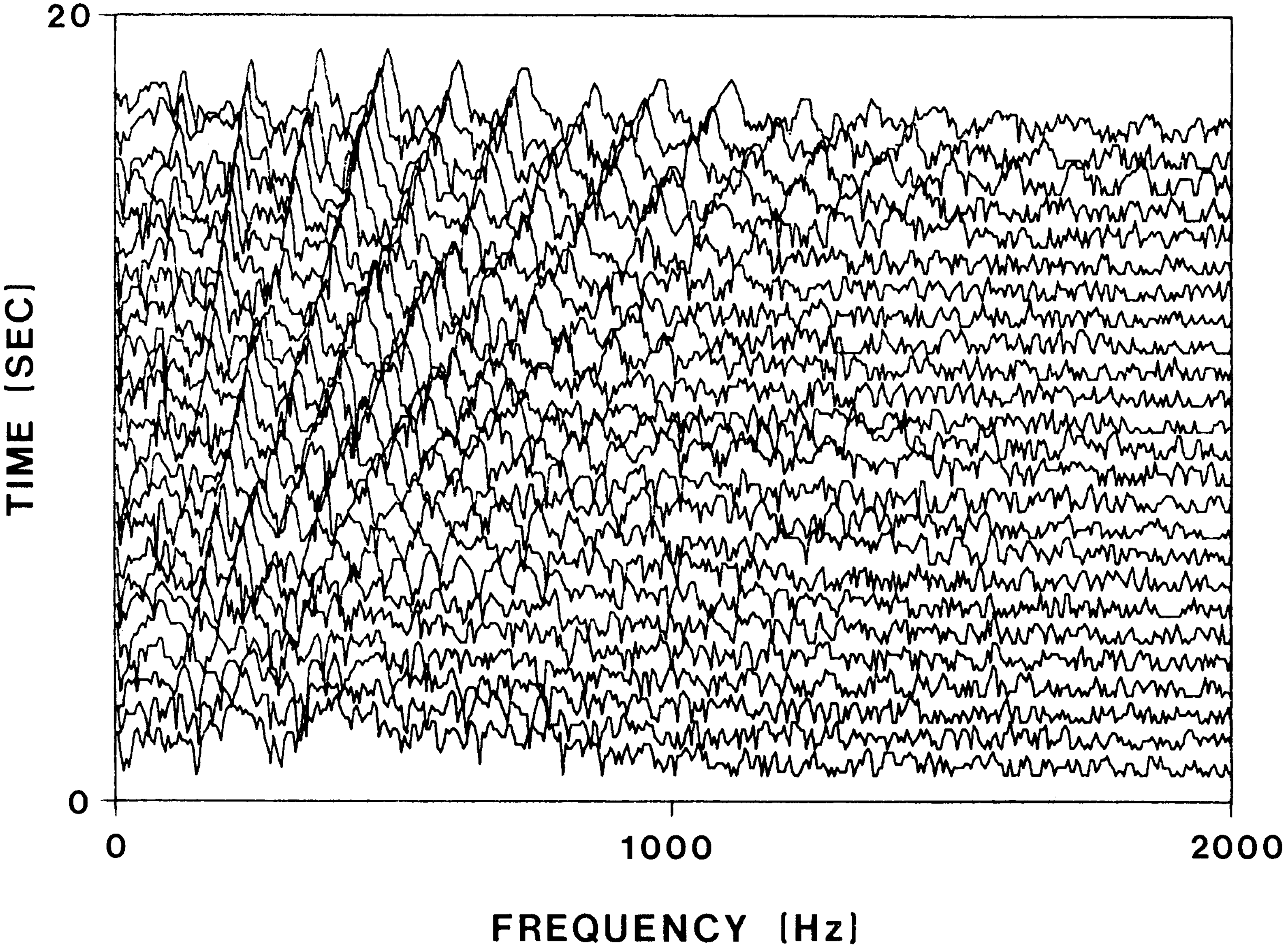
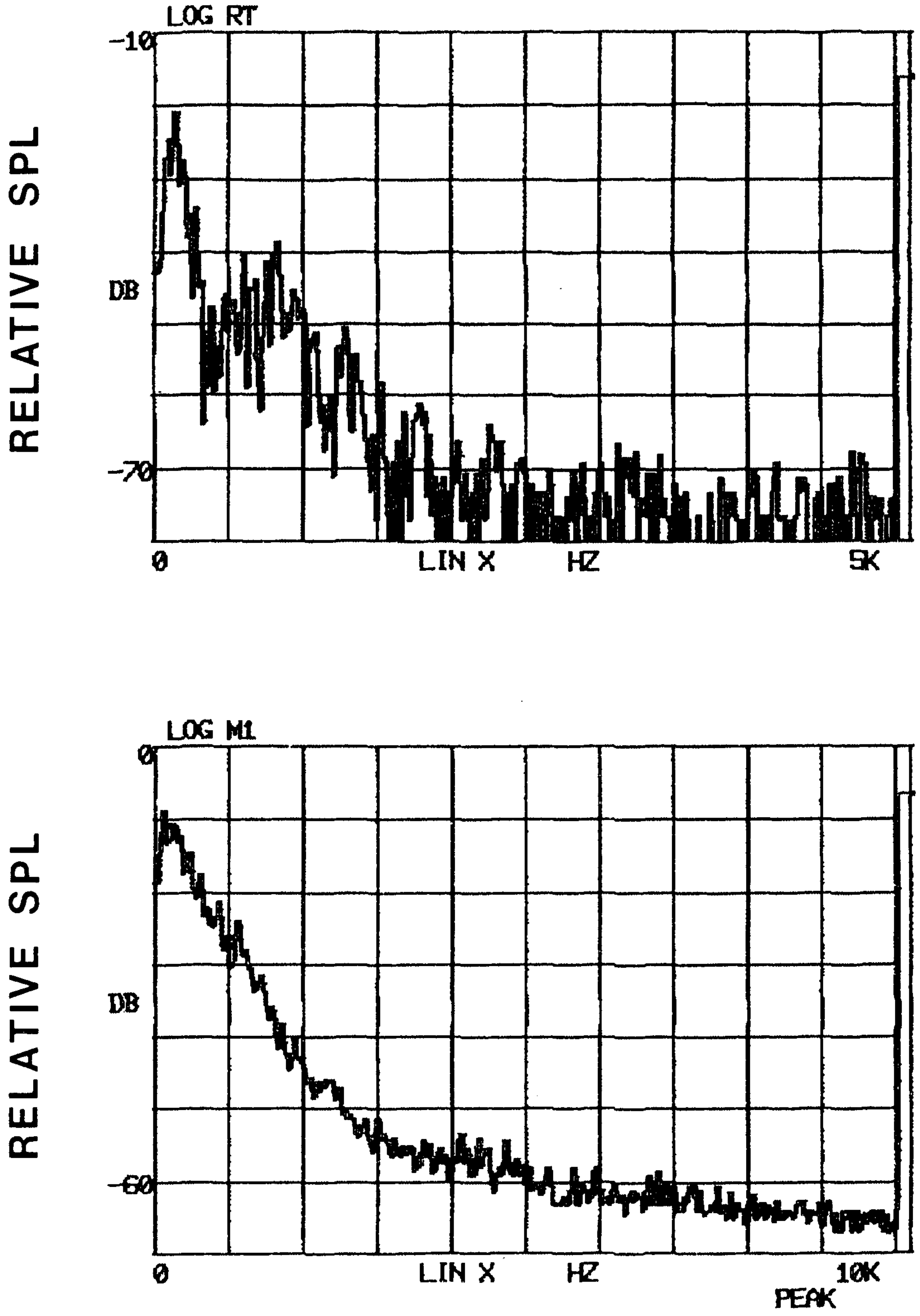


Figure 6. Waterfall display (time history) of Vibroseis and associated industrial noise playback, recorded on the triangular array, showing the fundamental and up to the 11th harmonic, analyzing filter bandwidth, 7.5 Hz.



SPL = Sound Pressure Level

Figure 7. Instantaneous spectra (upper) and 15 sec duration of peak hold spectra (lower) of seismic exploration convoy noise playback consisting of D-6 cat scraping ice, drill, and trucks. Analyzing filter bandwidth 18.8 Hz and 37.5 Hz, respectively.

Table 1. Playback schedule of previously recorded underwater man-made noise, Kotzebue Sound, 1984.

	5 APRIL	6 APRIL	7 APRIL	8 APRIL
Bulldozer and Vibroseis	1544-2202 hrs	none	none	1652-2027 hrs
Random and 1 kHz	none	1351-1833 hrs	none	none

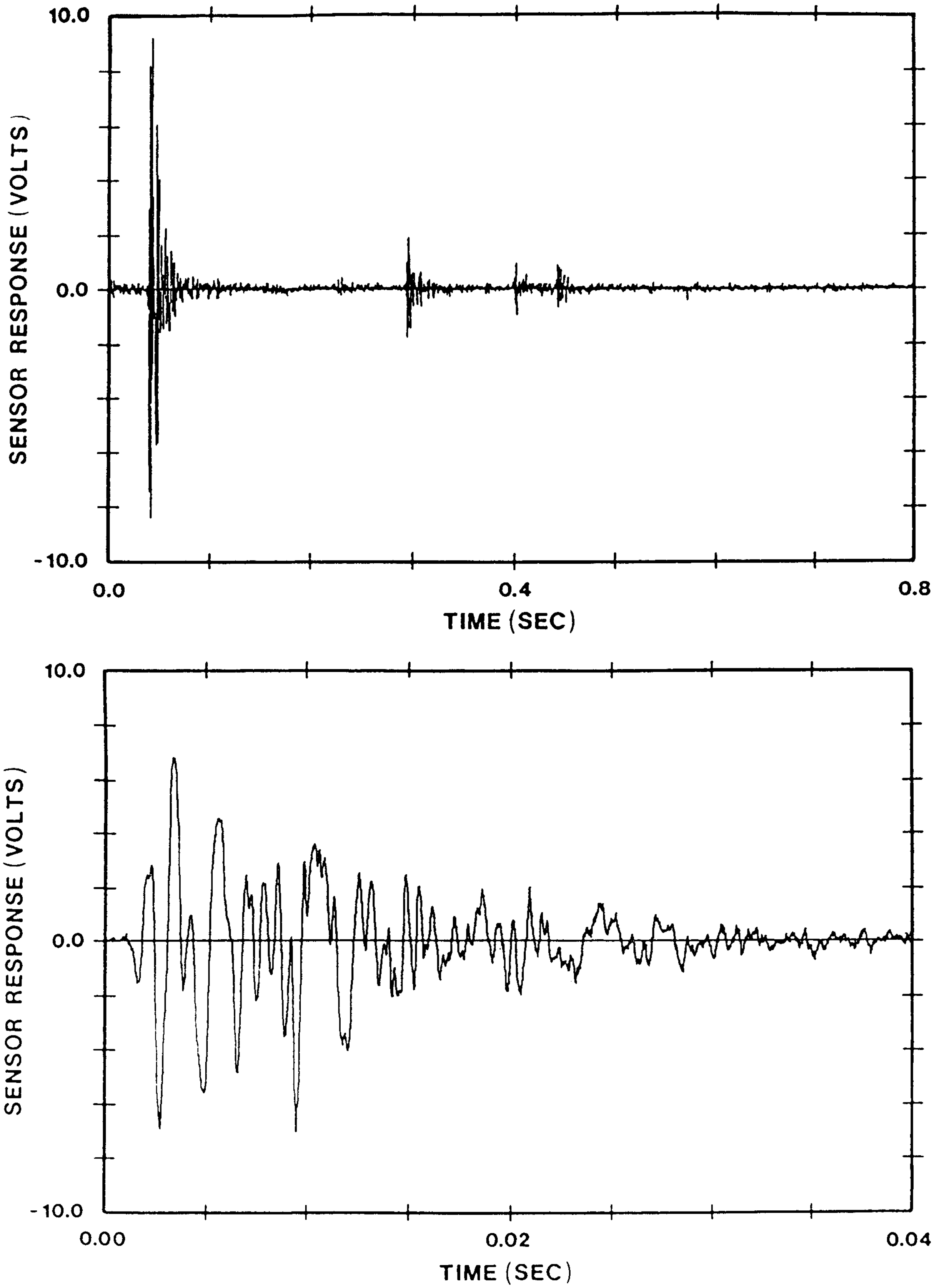


Figure 8. Voltage plotted as a function of time for a transient sound due to ice cracking (upper). Another transient (lower) is displayed with a time scale that is 200 times faster than the waveform in the upper figure.

Some sounds consist of multiple parts separated in time. Such an example appears in Fig. 8 (upper), where the voltage from a hydrophone is plotted versus time. The sound was ice cracking, a common Arctic sound of stress relief produced by differential expansion and contraction of ice with ambient temperature changes. Four distinct arrivals of this sound and several less intense events are displayed. Peak and average pressure levels are calculated by means of calibration between voltage and sound pressure. Sound pressure level decreases after the initial transient for each of the four large signals. These sounds are described as pulses with sharp leading edges and exponentially decaying trailing edges or "tails".

Expanding the time base reveals additional detail in the pressure-time history of a sound (Fig. 8, lower). The signal envelope builds quickly to a peak and then decays relatively slowly over a total time of about 30 ms (milliseconds). The times at which the voltage (pressure) is zero are zero-crossings. If these are evenly spaced in time, the signal is defined as "narrowband", otherwise it is "broadband". Narrowband signals have a restricted frequency range. Wideband signals, including many transients, contain many different frequencies.

Spectrum Analysis

Spectrum analysis emphasizes the frequency domain of signals rather than their explicit temporal behavior. However, time and frequency domains are mathematically related and a unique transformation exists between them, i.e., the Fourier transform. If the variable, x, is a function of time, t, then the Fourier spectrum F, a function of frequency, f, i.e., F(f) is given by:

$$F(f) = \lim_{T \to \infty} \int_{-T}^{T} x(t)\, e^{-j2\pi ft}\, dt \qquad \text{(eq. 3)}$$

We often use the power spectral density, (f), of the waveform x(t) which is defined as:

$$\Phi(f) = \lim_{T \to \infty} E \left\{ \frac{2 \cdot |F(f)|^2}{T} \right\} \qquad \text{(eq. 4)}$$

Here E represents the expectation operator and must be invoked only in the event the signal has a stochastic component. The symbol T represents time. As in most analyses done on modern computer systems, we implement these functions with the Fast Fourier Transform (FFT) algorithm (also see Bendat and Piersol, 1966; Otnes and Enochson, 1972; Anderson, 1971, and Middleton, 1960).

The power spectral density of an ice-cracking transient is displayed in Fig. 9. The curve represents the power in a 1 Hz (Hertz) band at frequencies over the analysis range, here 2 kHz. The power is distributed widely over the band, with maxima at about 10 Hz and near 900 Hz. Spectrum levels are approximately -43 dB for each peak. This electrical power spectral level corresponds, through the calibration constants for the measurement system, to a sound pressure spectrum level of 79dB re 1 μPa in the water.

Sound Frequency of Occurrence

One of our objectives was to report any differences in sound frequency occurrence over time. If present, such a trend may be a means of inferring changes in behavior. Many animals exhibit diurnal patterns in activity that are often indications of related behavior. Sound production is also known to be part of the reproductive behavior in many species. Our field period was explicitly chosen by the sponsor to begin before the pupping season for the ringed seal and to end after the season was well underway.

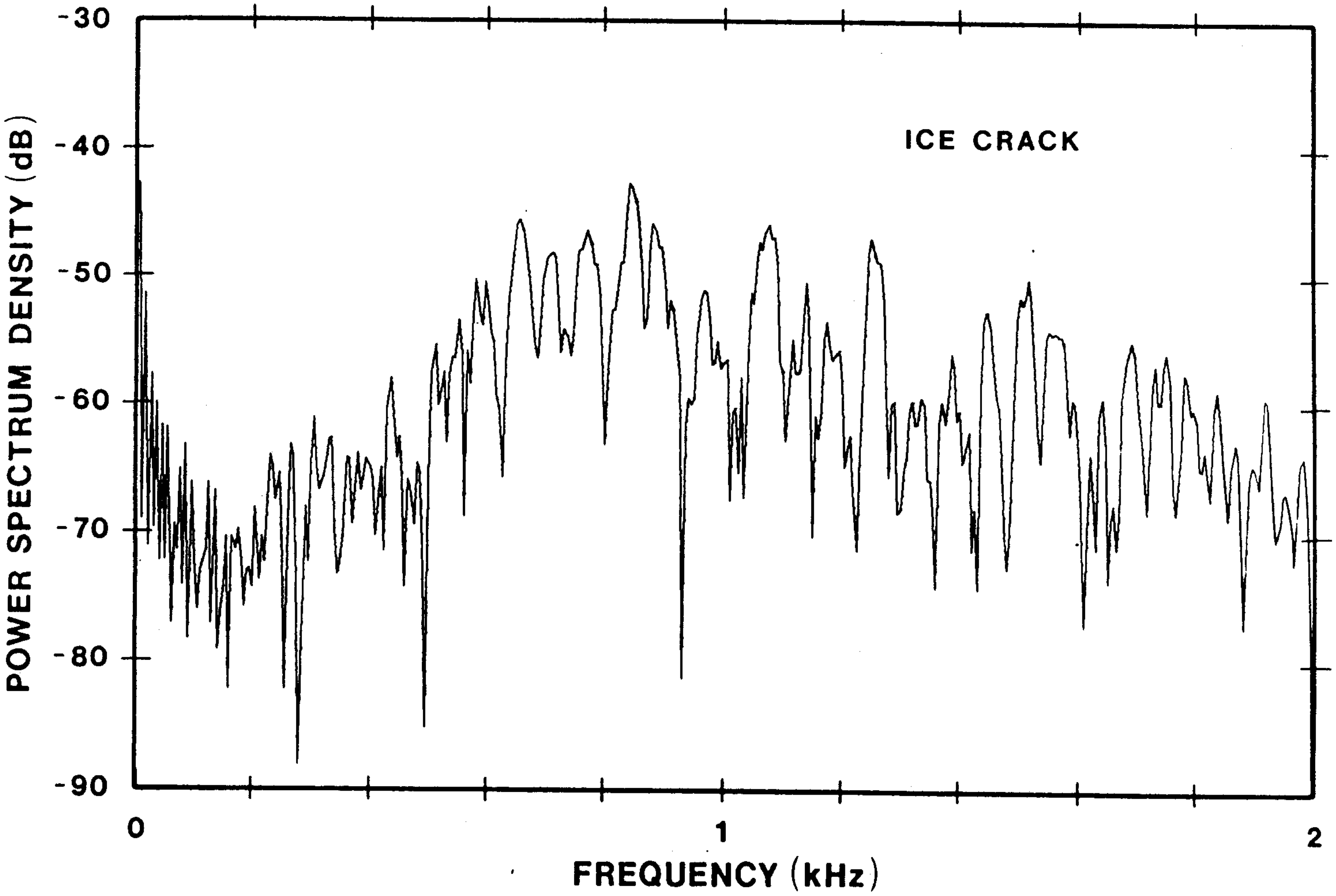


Figure 9. Relative power spectrum density of an ice-cracking sound.

In view of these and other possible temporal dependencies, we monitored all recordings, logging each occurrence of animal sound by type and accumulating totals in fifteen-minute periods. These data were then stored in a computer file for subsequent analysis, e.g., the frequency of occurrence for barks, scratches, squeaks, rubs, etc. The total numbers of animal sounds were also accumulated and plotted. Names of sound categories were mostly derived from their aural appearance, i.e., rub, quacking bark, etc., which does not imply the mechanism of sound production.

Correlations

Correlation analyses between environmental measurements and rates of sound production were undertaken using two techniques, graphical means and statistical calculation. For example, we calculated simple regression equations and coefficients of determination, and we applied the chi-squared and Student's t tests. As explained below, cross-correlation between two or more arrivals of the same sound was used in the localization procedure to determine the geographical origin of sound sources.

Localizations

A single, omnidirectional hydrophone can be used to detect a sound, provided the level of the sound at the hydrophone is sufficiently high relative to background sounds, i.e., above 0 dB signal-to-noise ratio. By itself, such a hydrophone cannot be used to determine either the distance to the sound source or the direction from which the sound originated. However, with two sensors of this type, separated in the horizontal plane by a known distance, one can solve an equation to determine that the sound came from one of two possible directions (bearings). In practice, there usually is not sufficient information to resolve this ambiguity. However, by adding one additional hydrophone, not co-linear with the other two, one can calculate, not only the direction to the sound source, but also the distance.

Our technique for doing this was developed and tested for under-ice localization in an OCSEAP project off Prudhoe Bay in 1981. The procedure and results are fully documented (Cummings, et al., 1981). Basically, this involves measuring the difference in arrival times of the sound of interest at each hydrophone, generally the same method of triangulation as used in related disciplines, such as optical tracking.

In past efforts (also see Cummings, et al., 1983), we used the time of the initial arrival of the sound at each hydrophone to determine the time delay between hydrophones. This is relatively simple in the case of sounds with sharp leading edges or ones that have propagated over similar paths. It is considerably more difficult if the leading edge of the sound envelope is ambiguous, or if the waveforms differ on each hydrophone due to propagation perturbations. The optimal solution to determining the time delay at two sensors is by cross-correlation. The cross-correlation function, $R(\tau)$, is a function of the time delay, τ, between signals on two time functions, $x(t)$ and $x(t+\tau)$. The correlation function is defined as:

$$R(\tau) = \int_{-\infty}^{\infty} x(t)\, x(t+\tau)\, dt \qquad \text{(eq. 5)}$$

The remainder of this discussion utilizes a transient sound from cracking ice recorded on our triangular hydrophone array to illustrate the localization procedure. The identical procedure was employed to localize the animal sounds.

Three hydrophones (designated A, B, C) were positioned at a location 1.8 km from the ice camp. The geometry of the hydrophone locations and the surrounding ridge and refrozen fracture structure are illustrated in Fig. 10. The hydrophones were all located at a depth of 8 m from the ice surface in 14 m of water under 2 m of ice. The hydrophone signal from location A was transmitted, after amplification near the site, via a

1829 m coaxial cable (RG-174/U). Signals from hydrophones at locations B and C were telemetered to the ice camp, and all three sensor outputs were recorded simultaneously on a Nagra T recorder.

Plots of the voltage at hydrophones A and C (Fig. 11, upper) reveal that the signal at hydrophone C arrived about 72 ms later than at hydrophone A (ΔAC). Because of slight differences in propagation path losses and ambient noise, it is very difficult to measure the delay more accurately from this type display. The mathematically optimal manner for obtaining a more accurate estimate of the delay between the two signals is to compute the cross-correlation function (eq. 5). The result of that calculation (Fig. 11, lower) is a waveform with a distinct peak at the delay between the two signals, 72.27 ms. In the firmware implementation of the cross-correlator, provision is made to set a cursor on the peak, providing a direct digital display of the delay. A similar measurement of the delay between the sound arriving at hydrophones A and B resulted in $\Delta AB = 52.93$ ms.

A computer algorithm was used to calculate the parabolic curve labeled $\Delta AB = +52.93$ ms in Fig. 10. This was based on an average measured sound speed of 1437 ± 1 m/sec. A sound originating at any position on this curve would arrive at hydrophone B, 52.93 ms later than at A. Similarly, the curve labeled $\Delta AC = 72.27$ ms represents the locus of points from which a sound would reach hydrophone C, 72.27 ms later than at A. The intersection of these two curves is the location of the ice cracking sound. The coordinates, with respect to hydrophone A, are $x = 218.2$ m and $y = -126.1$ m. This corresponds to a range of $R = 252$ m and a bearing of $\theta = 240^{0}$, relative to location A and line A-B. Therefore, this particular sound originated on a discontinuous, linear ice ridge with relatively low, ca 1 m, relief (Fig. 10).

This procedure was used to localize additional ice-related sounds and a number of animal sounds. Our objective was principally to obtain a distance to the source of the sound in order to determine its source

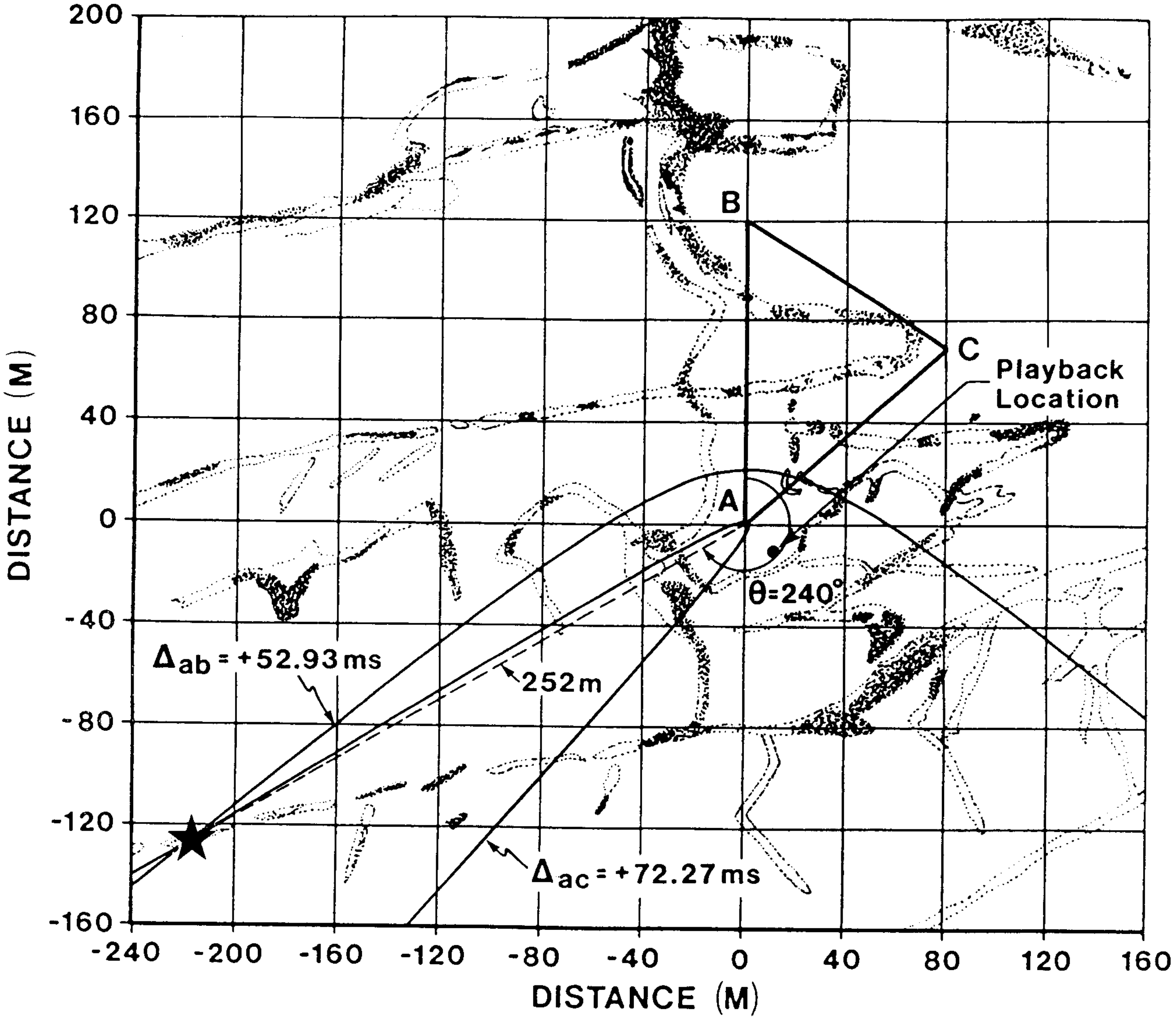


Figure 10. Sensor locations (A,B,C), ice ridges (stippled), triangular array, and the intersection of two parabolas (star) based on the indicated sound arrival time differences.

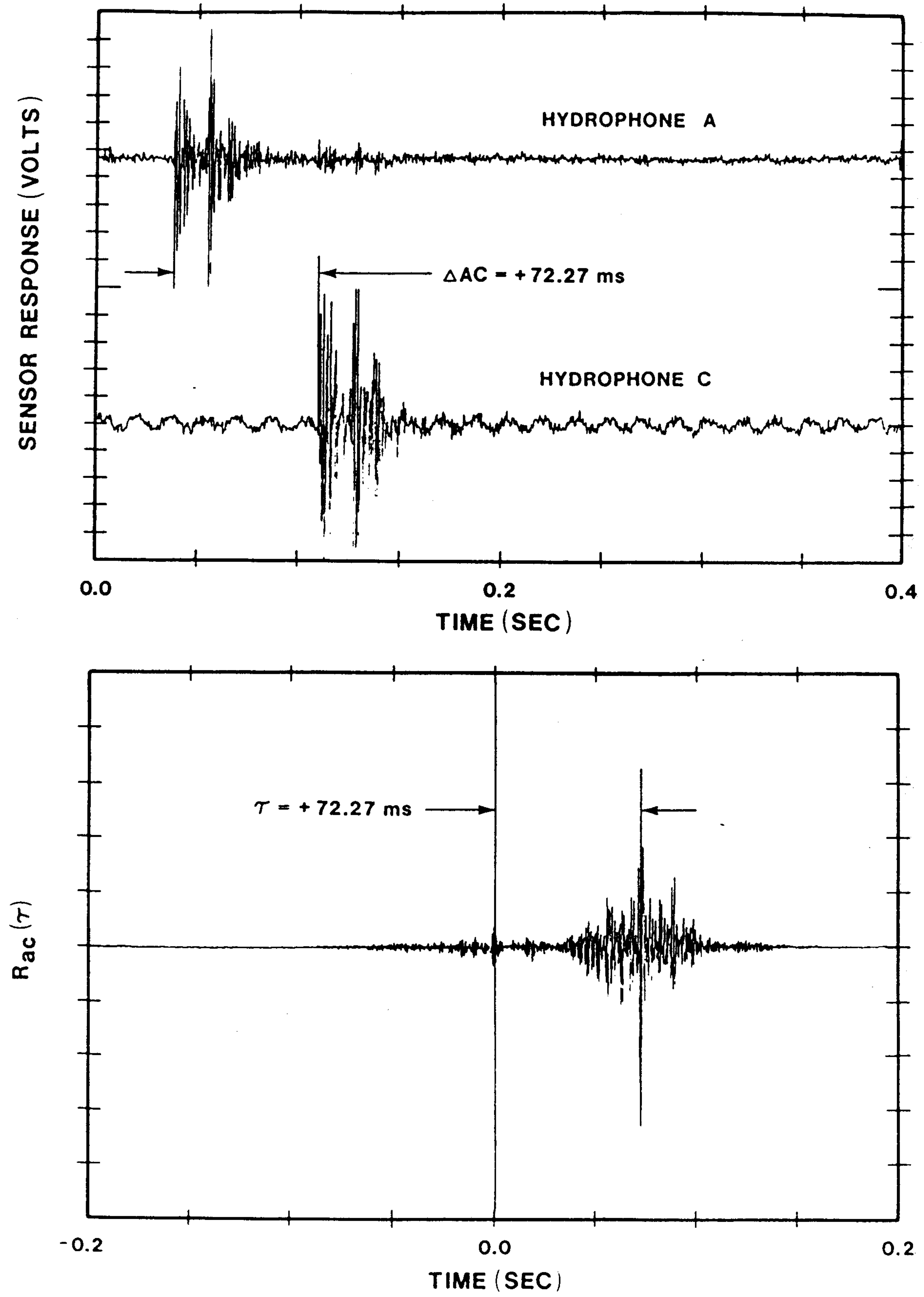


Figure 11. Arrivals of the same ice cracking transient sound at hydrophones A and C (upper) and their cross correlation function used to determine the arrival time difference, 72.27 ms (lower).

level in dB at a standard distance from the point of origin. Also, we wanted to look for any spatial clustering or association with ice surface features.

Source Level Determination

We define source level as the measure of the level or intensity of a sound. This quantity is defined as 10 times the common logarithm of the ratio of the intensity of the source, on its acoustic axis (if any), to the intensity of a plane wave with a root mean square pressure of one micropascal (μPa), referenced at a distance of 1 m from the source.

An absolute measure of the sound intensity at a known distance is required to measure source level. To our knowledge, this measurement has not been done in the case of pinnipeds in the wild. Knowledge of source level (SL, eq. 1) is required to quantify potential masking or other impact on a species from the addition of man-made noise to the environment. Thus, we carefully calibrated the instrumentation used to localize sounds with the triangular array of hydrophones.

V. RESULTS

A. Ringed Seal Sounds

A total of 24,373 individual animal sounds was recorded. Except for one bearded seal pup in a lair (location E), ringed seals were the only pinnipeds seen in the study area. It is possible that a small portion of the vocalizations could have been from bearded seals, based on the fact that some very weak bearded seal trills were heard over two days during our recordings in the Sound. They were powerful and numerous on the offshore recording, 192 km distance.

We recognized 16 different categories of seal sounds. Most of the recorded sounds were scratches that were produced as the seals either clawed at their access or breathing holes to maintain the openings in the ice, or maintained their lairs. Eleven percent were rub sounds. Not considering scratching sounds, rubs were the most common of those sounds thought to be produced as vocalizations. A total of 4.2% of the sounds were squeaks. Quacking barks accounted for only 3.2% of the sounds, but they were outstanding vocalizations when present. Crackles were 1.1% of the total. A listing of the sound categories, including their percentage of occurrence, appears in Table 2.

Although totals are given for the three hydrophones comprising the triangular array and we frequently heard the same sound there on all three sensors, each occurrence was only counted once in these tabulations. About 70 percent of all the scratches came from location E where we had installed a hydrophone in an active lair that was occupied by a bearded seal pup and, presumably, an attending adult. Infrequent sounds, for which the percentage of occurrence is not given in Table 2, together amounted to 0.6% of the total number of seal sounds. Only the common sound categories are included in the following descriptions.

Table 2. Listing of ringed seal sound categories and their occurrence as to location and proportion.

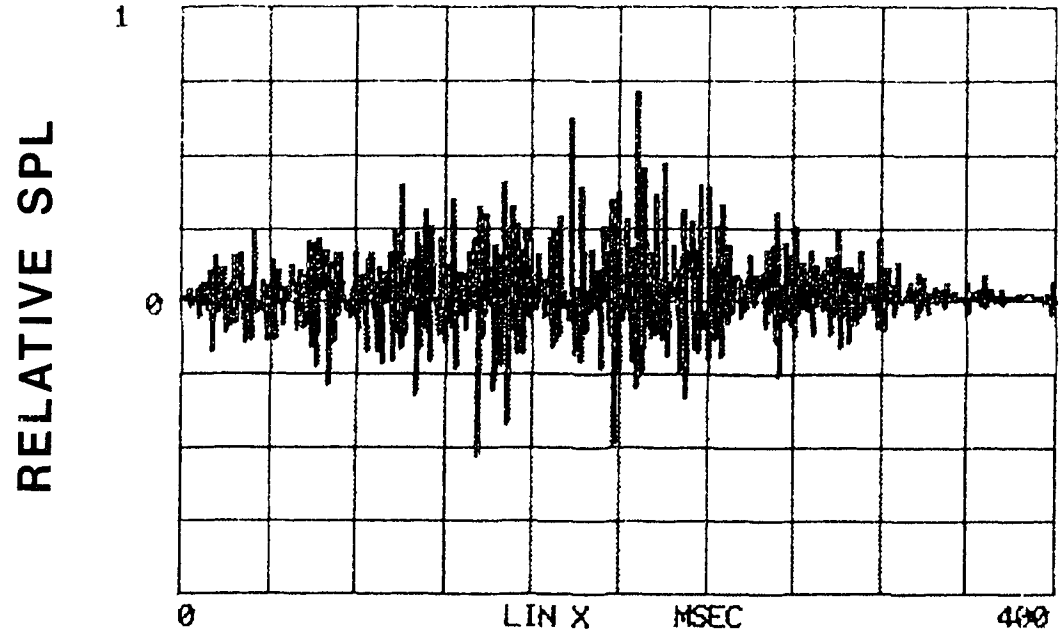
SOUND	TRIANGLE ONLY	OTHER SENSORS	TOTAL SOUNDS	%
Scratch	5,024	14,702	19,726	80.9
Rub	1,734	958	2,692	11.0
Squeak	1,027	5	1,032	4.2
Quacking bark	534	2	536	2.2
Crackle	0	274	274	1.1
Belch	14	0	14	
Bubbling	0	2	2	
Buzz	1	0	1	
Cry	8	0	8	
Crunch	0	3	3	
Growl	4	0	4	
Grunt	1	0	1	
Knocking	1	47	48	
Roar	23	0	23	
Snort	6	0	6	
Splash	1	0	1	
Explosive	2	0	2	
			24,373	

Scratches

We recorded a total of 19,726 scratches, representing 81% of all seal sounds recorded during the study period. Scratching sounds typically were 40-500 msec in duration (Fig. 12, upper) with peak frequencies of 1000-6000 Hz (Fig. 12, lower). Nearby scratching sounds, that were less affected by high frequency attenuation losses, contained energy up to 10 kHz, but for the most part the recorded sounds were below 6 kHz. The high frequency content and the peak frequency usually decreased over the duration of each scratch (Fig. 13). Scratches were a series of broadband transients that occurred at intervals of 400-600 msec (Figs. 14, 15). Aural characteristics were like strokes of sandpaper across a hard surface. Source spectrum levels for two scratches are given in Figs. 16 and 17. Peak source spectrum level was 102 dB re 1 μPa, 1 m, for one and 98 dB for the other. A detailed analysis was done of the occurrence of these sounds (see B., Frequency of Occurrence, Scratches, below).

Rubs

A total of 2,692 rub sounds was recorded during the study. This represented 58% of all the vocalizations recorded at the array (excluding scratches). Rubs were the most common of all ringed seal vocalizations. We recorded as many as 239 rub sounds in 8 hrs of recording and as many as 92 in 15 min, i.e., 9 April. This description was used because the sound so clearly resembled the rubbing of one's wet finger tips over a shiny hard surface, such as glass or the waxed surface of an automobile. Peak sound pressures of rub sounds occurred between 0.5 and 2 kHz, with most of the sounds' energy below 4 kHz (Figs. 18 and 19). The waveform of one rubbing sound and the cross-correlation are shown in Fig. 20. Durations of rub sounds fell in the interval from 80-300 ms, and the peak source spectrum level was about 95 dB re 1 μPa (Fig. 21).



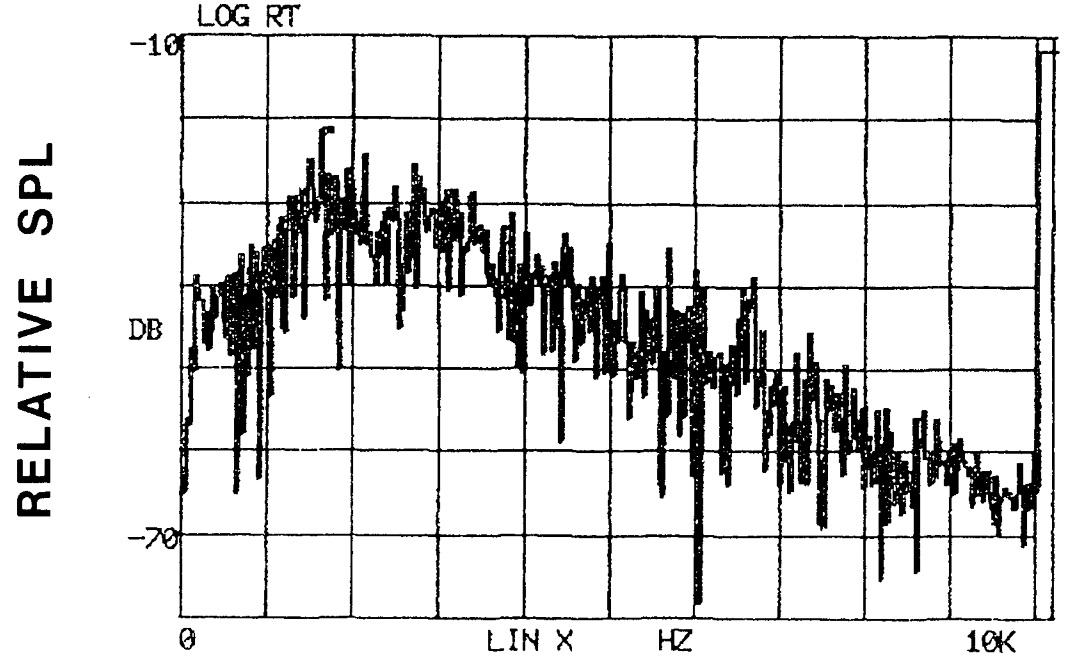


Figure 12. Waveform (upper) and spectrum (lower) of a single scratch sound, 30 March 1984. Analyzing filter bandwidth was 3.75 Hz (upper) and 37.5 Hz (lower).

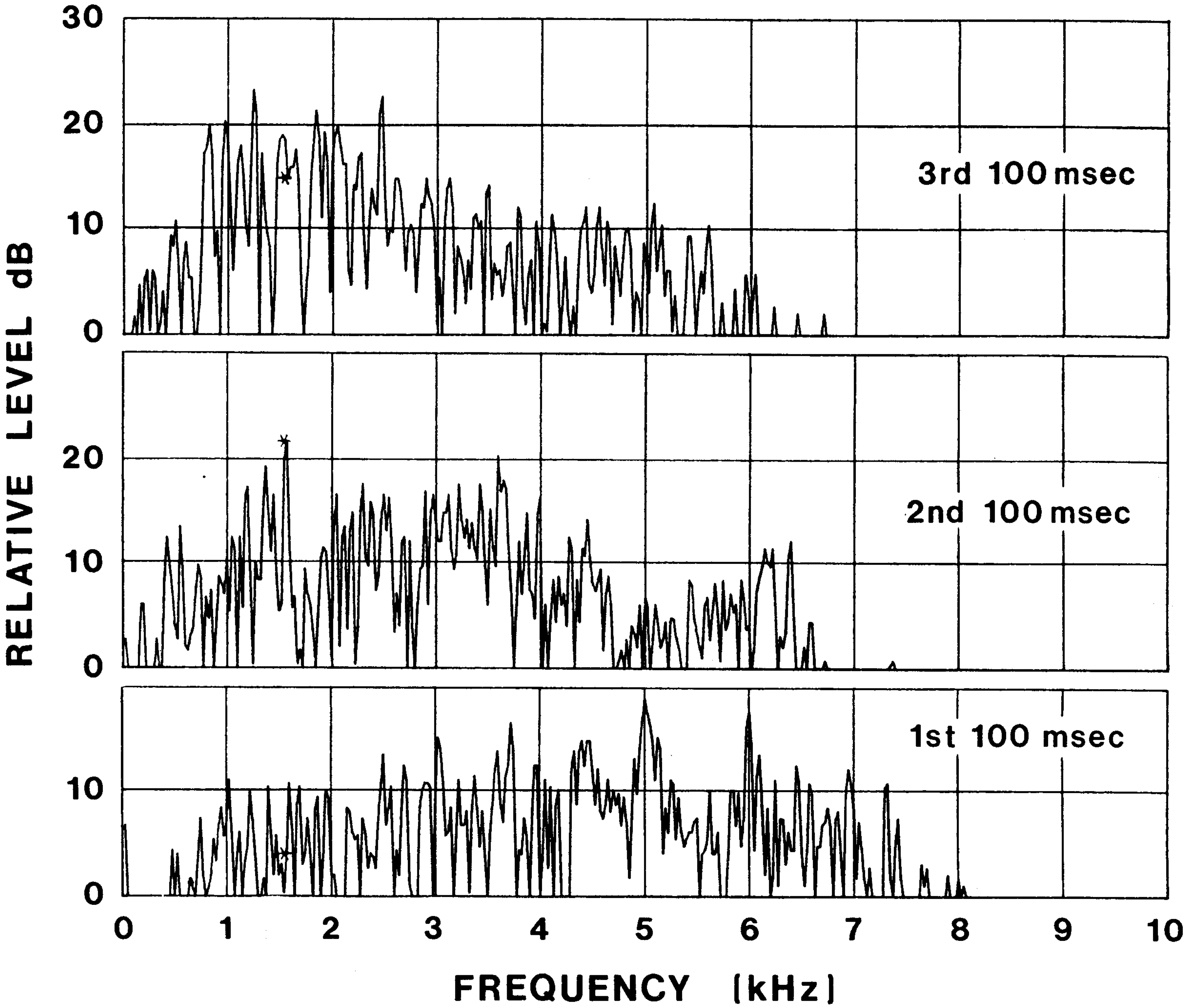


Figure 13. Spectra of a single scratch sound divided into 100 msec intervals showing a decrease in the high frequency content and the peak frequency with time, analyzing filter bandwidth, 37.5 Hz.

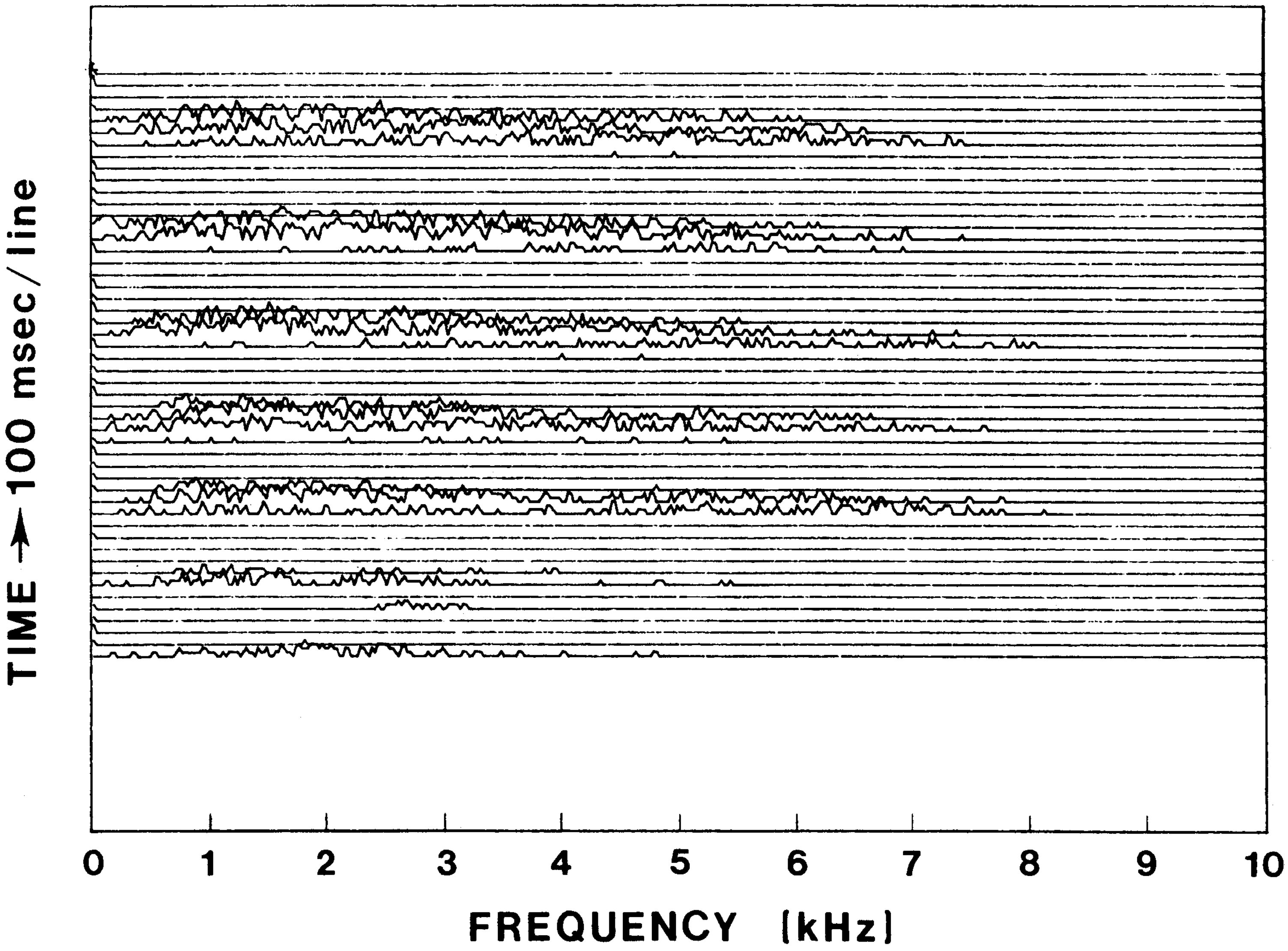


Figure 14. Time history spectra of six scratches in a bout, analyzing filter bandwidth, 37.5 Hz.

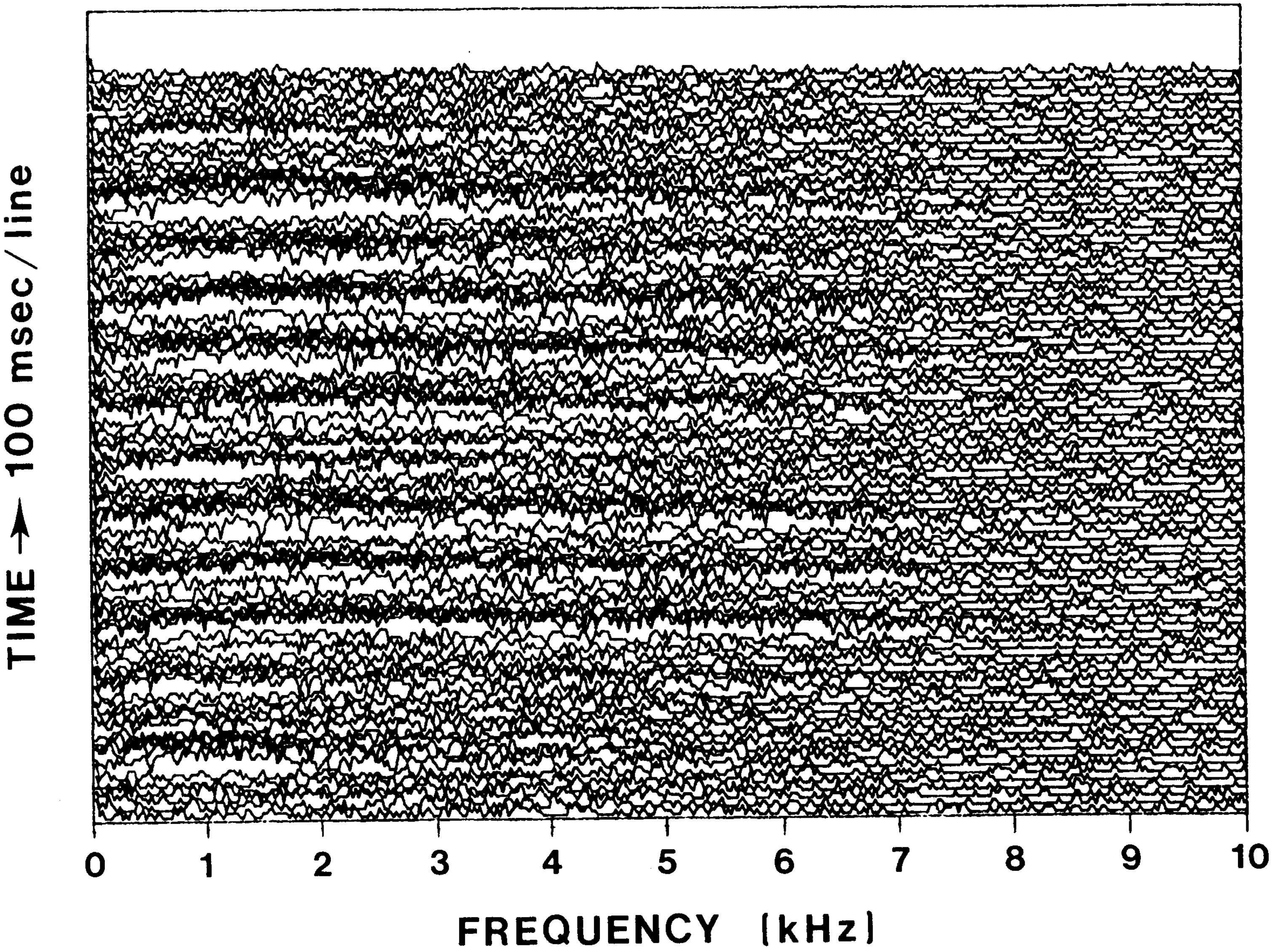


Figure 15. Time history spectra of entire scratch bout consisting of 12 individual scratches, analyzing filter bandwidth, 37.5 Hz.

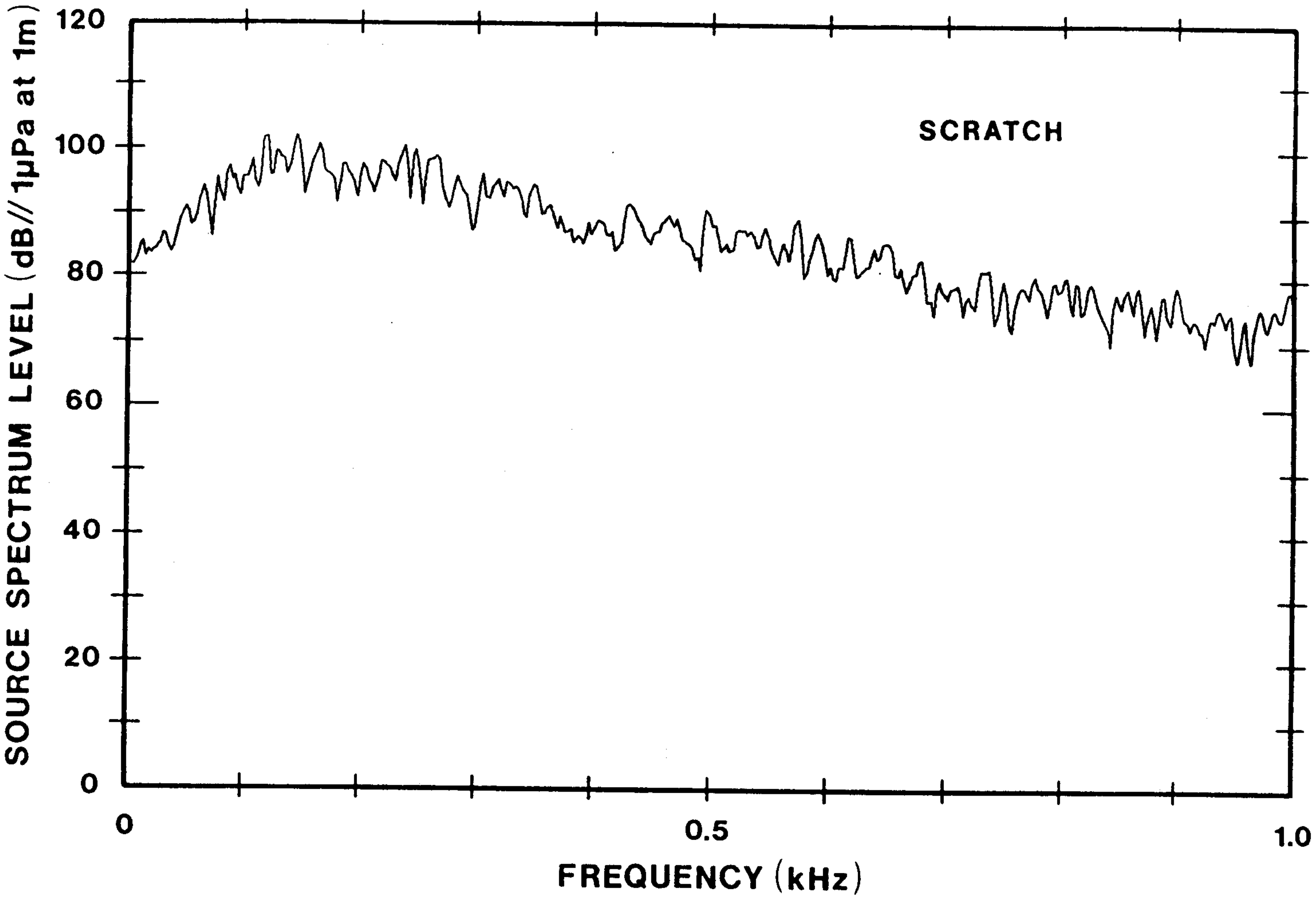


Figure 16. Source spectrum level (0-1 kHz) of a single scratch sound recorded from the triangular array, 28 March 1984, analyzing filter bandwidth, 3.75 Hz. The sound was localized with the array.

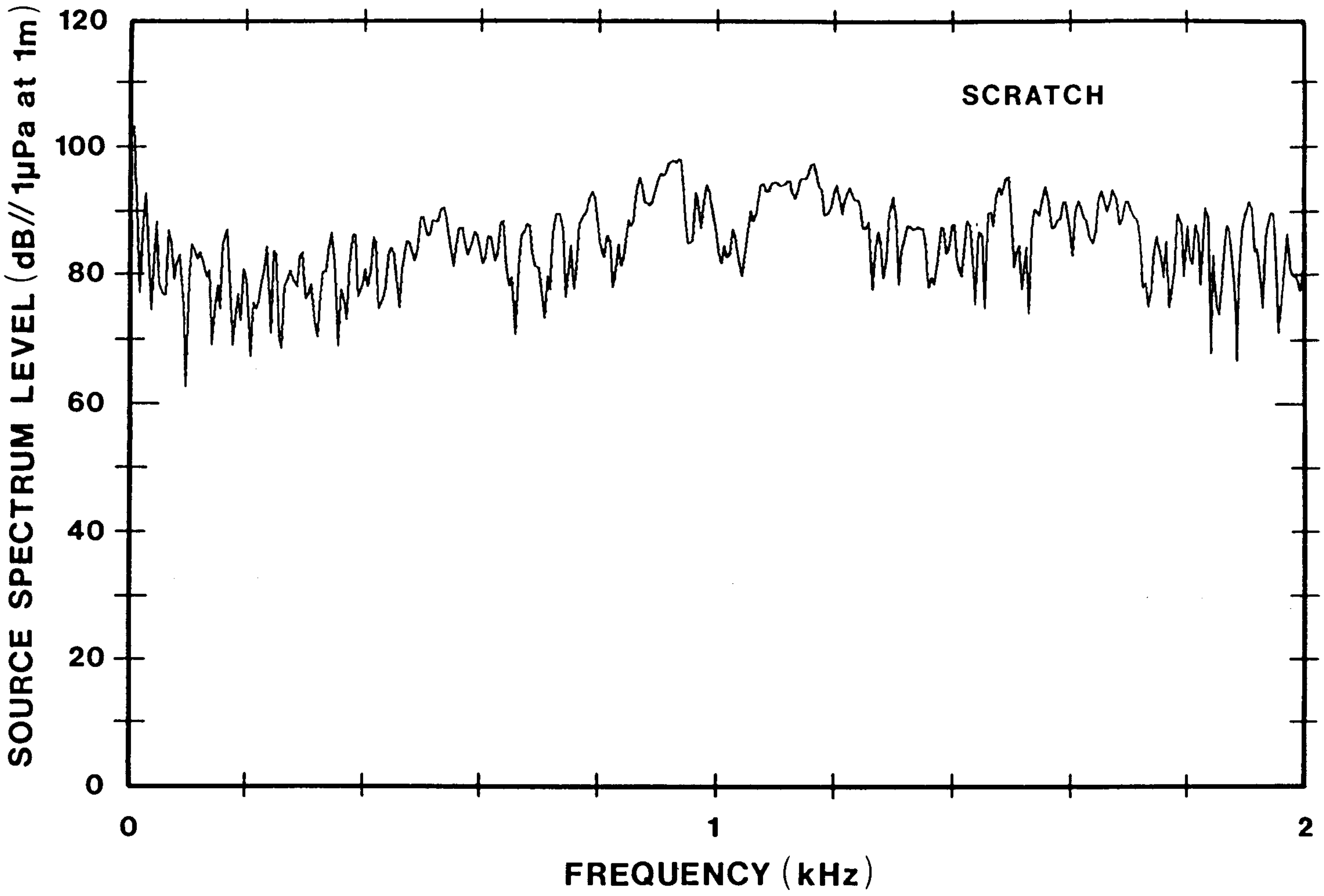


Figure 17. Source spectrum level (0-2 kHz) of another single scratch sound recorded from the triangular array, 28 March 1984, analyzing filter bandwidth, 7.5 Hz. The sound was localized with the array.

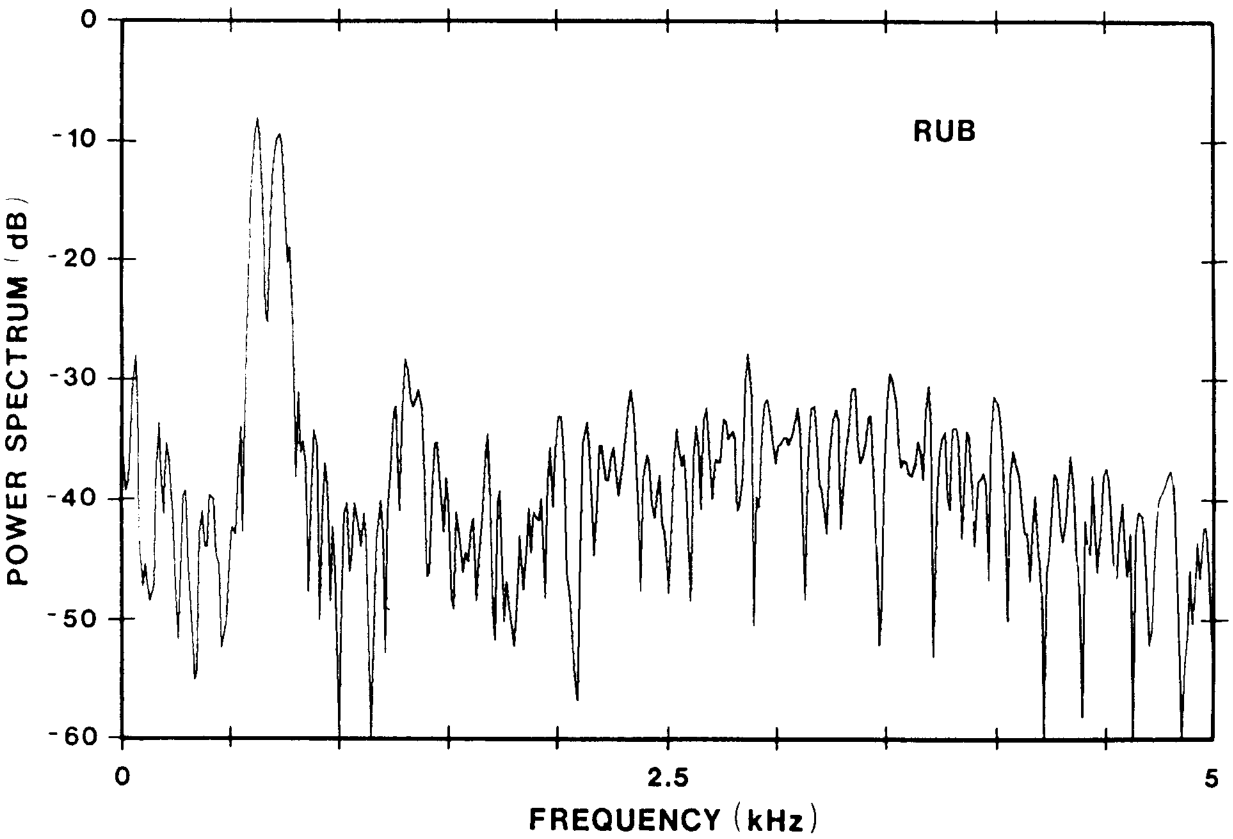


Figure 18. Power spectral density of a rub sound recorded at the triangular array, analyzing filter bandwidth, 18.75 Hz.

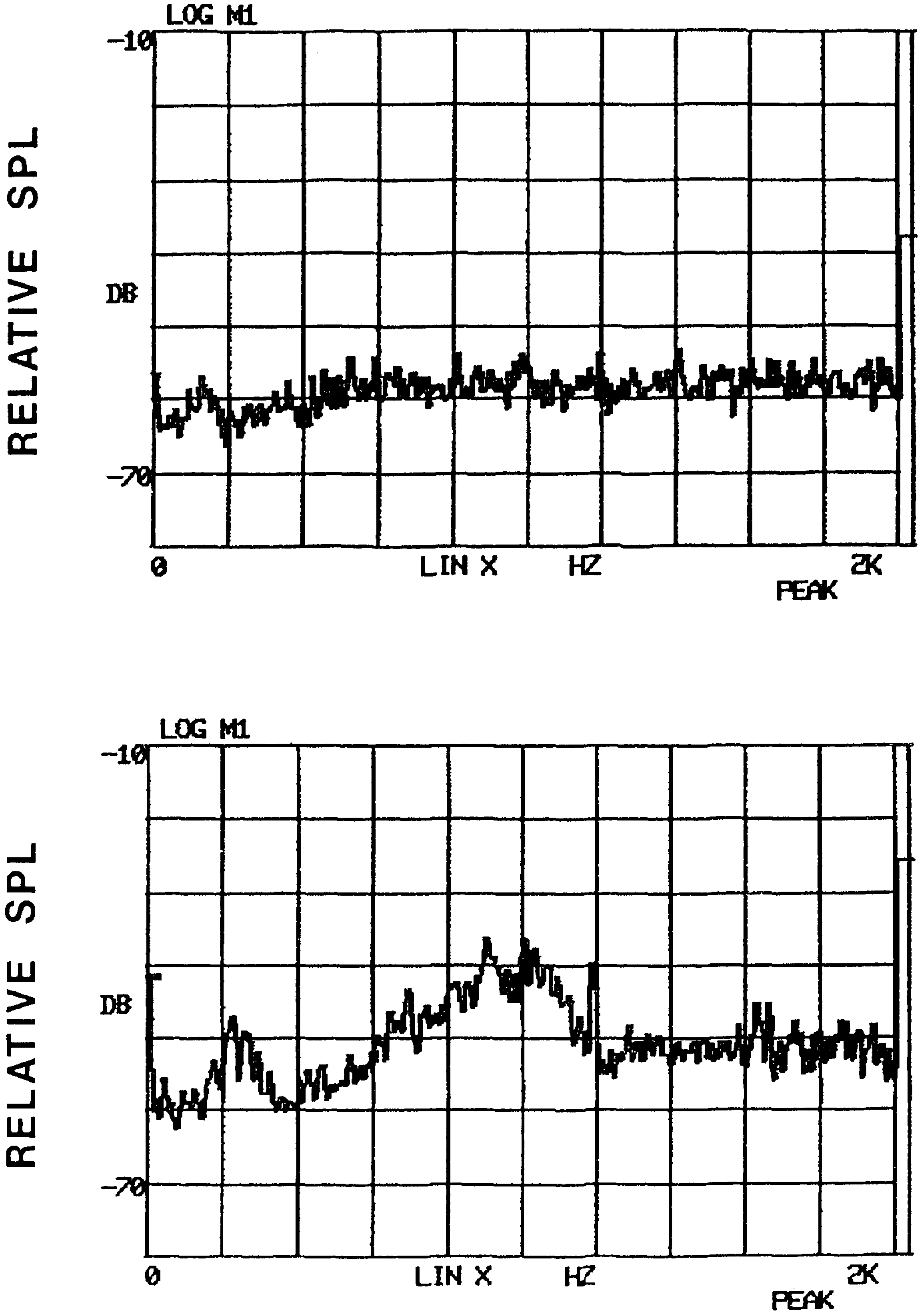


Figure 19. Ambient spectrum (upper) and the additive spectra of 12 rubs (lower) showing most of the energy is in the first 2 kHz with the peak at about 1 kHz, analyzing filter bandwidth, 7.5 Hz.

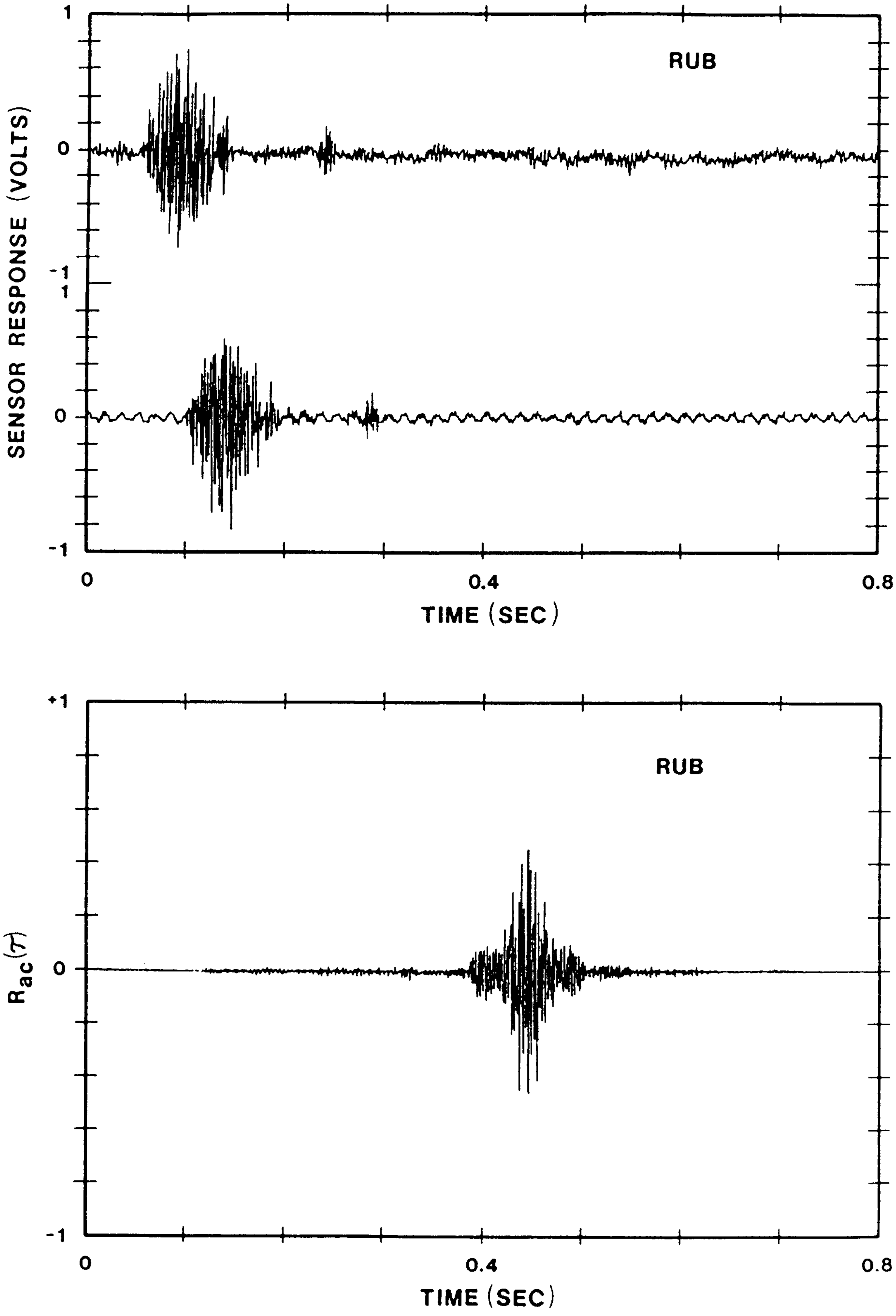


Figure 20. Waveforms of the arrivals of a rub sound at hydrophones A and C, in the triangular array (upper) and the cross correlation function of same (lower) showing the arrival time difference to be 46.88 ms.

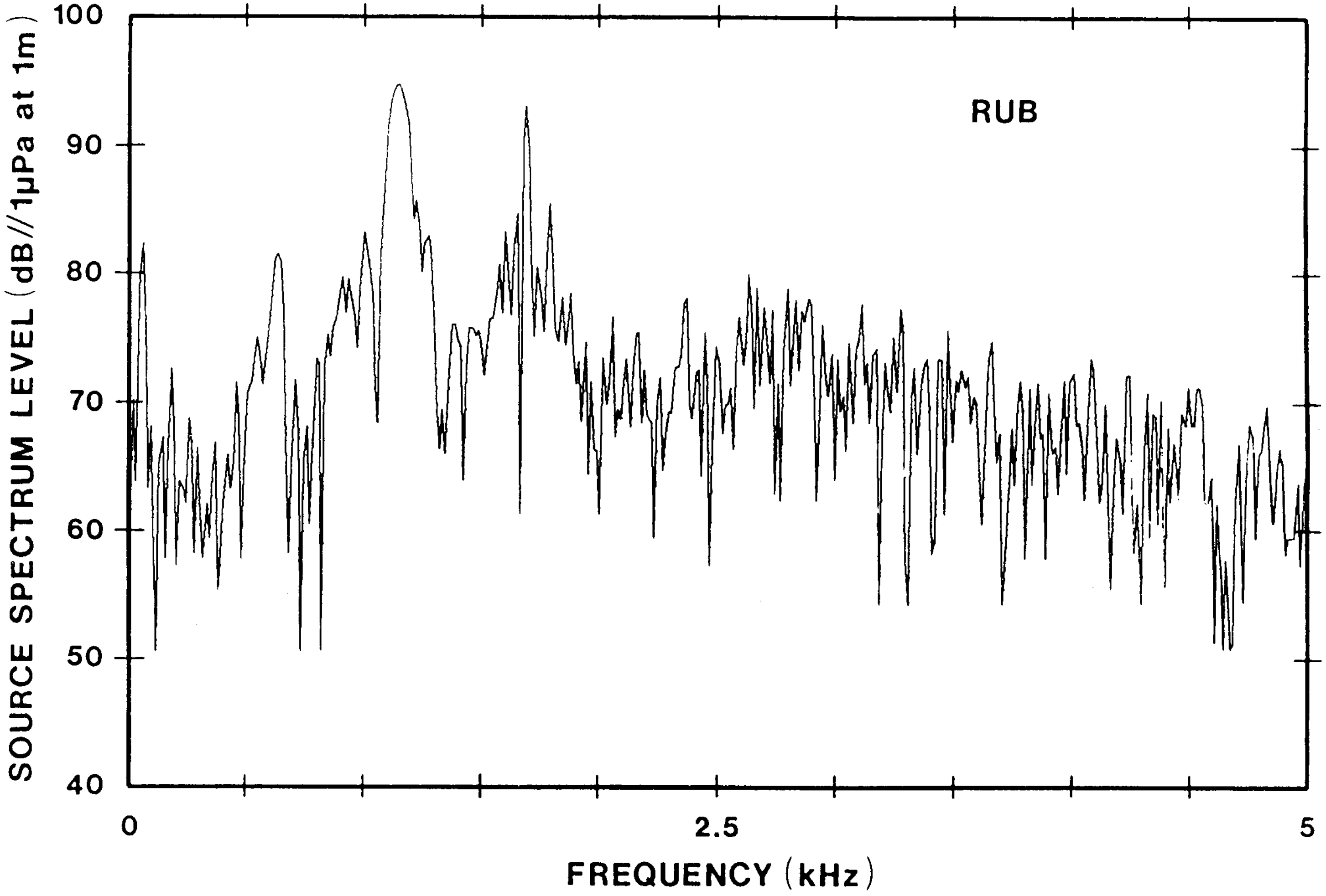


Figure 21. Source spectrum level of a rub sound recorded from the triangular array. The sound was localized with the array. Analyzing filter bandwidth, 18.75 Hz.

Squeaks

These sounds, recorded 1,032 times, were the second most common vocalization (excluding scratches). This represented 4.2% of all sounds or 22.2% of vocalization. Aurally, squeaks were like rubs but generally shorter in duration and higher in frequency. Spectra for two squeaks are given in Fig. 22.

The source spectrum level of a squeak is given in Fig. 23. This sound peaked at 112 dB re 1 μPa, 1 m.

Quacking Barks

Quacking bark sounds strongly resembled vocalizations of ducks. They accounted for 2.2% of the total number of sounds recorded from ringed seals at the triangular array, or 11.5% of the vocalizations (excluding scratches). These sounds normally were produced in volleys of two to five sounds. The waveforms and cross correlation function of a two-element quacking bark appear in Fig. 24. Durations ranged from 30-120 ms with the peak frequencies occurring at 400-1500 Hz. Components of quacking bark sounds were found up to 5 kHz, but most of the energy was less than 2 kHz. The fundamental frequency was typically at about 90 Hz (Figs. 25 - 27). A good example of how the propagation path can affect the spectrum of sounds appears in Fig. 27, lower, where the energy at 0.2 kHz is subdued as received from hydrophone A, compared to C. The source spectrum level of a quacking bark is given in Fig. 28. It peaked at 130 dB re 1 μPa, 1 m.

B. Frequency of Occurrence

Long-term (triangle)

Based on a histogram of the frequency of occurrence of recorded ringed seal vocalizations at the triangle, excluding scratches, the rate of sound production increased over the period of our recordings (Fig. 29).

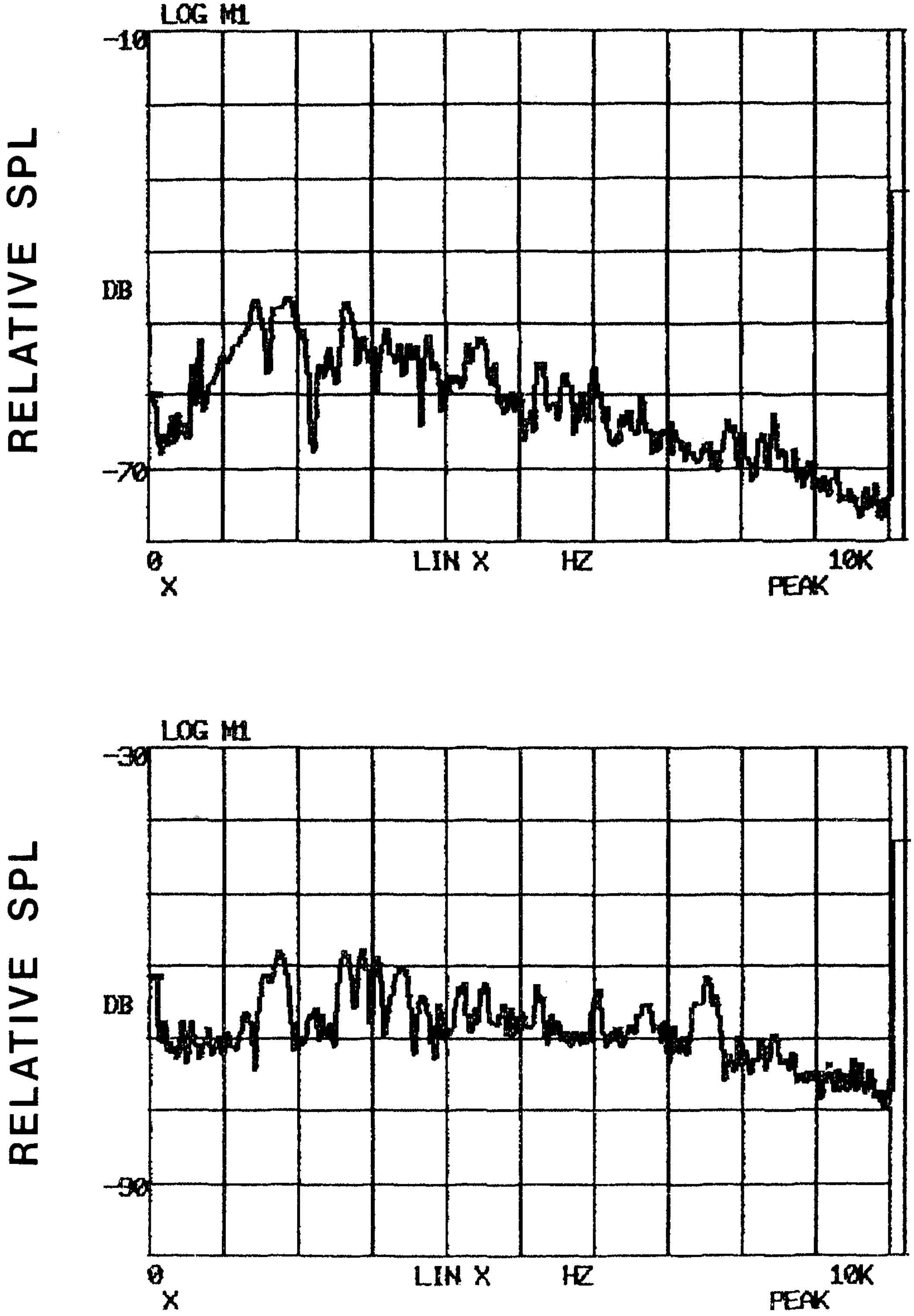


Figure 22. Spectra of a high S/N ratio squeak (upper) and one of low S/N (lower), analyzing filter bandwidth, 37.5 Hz.

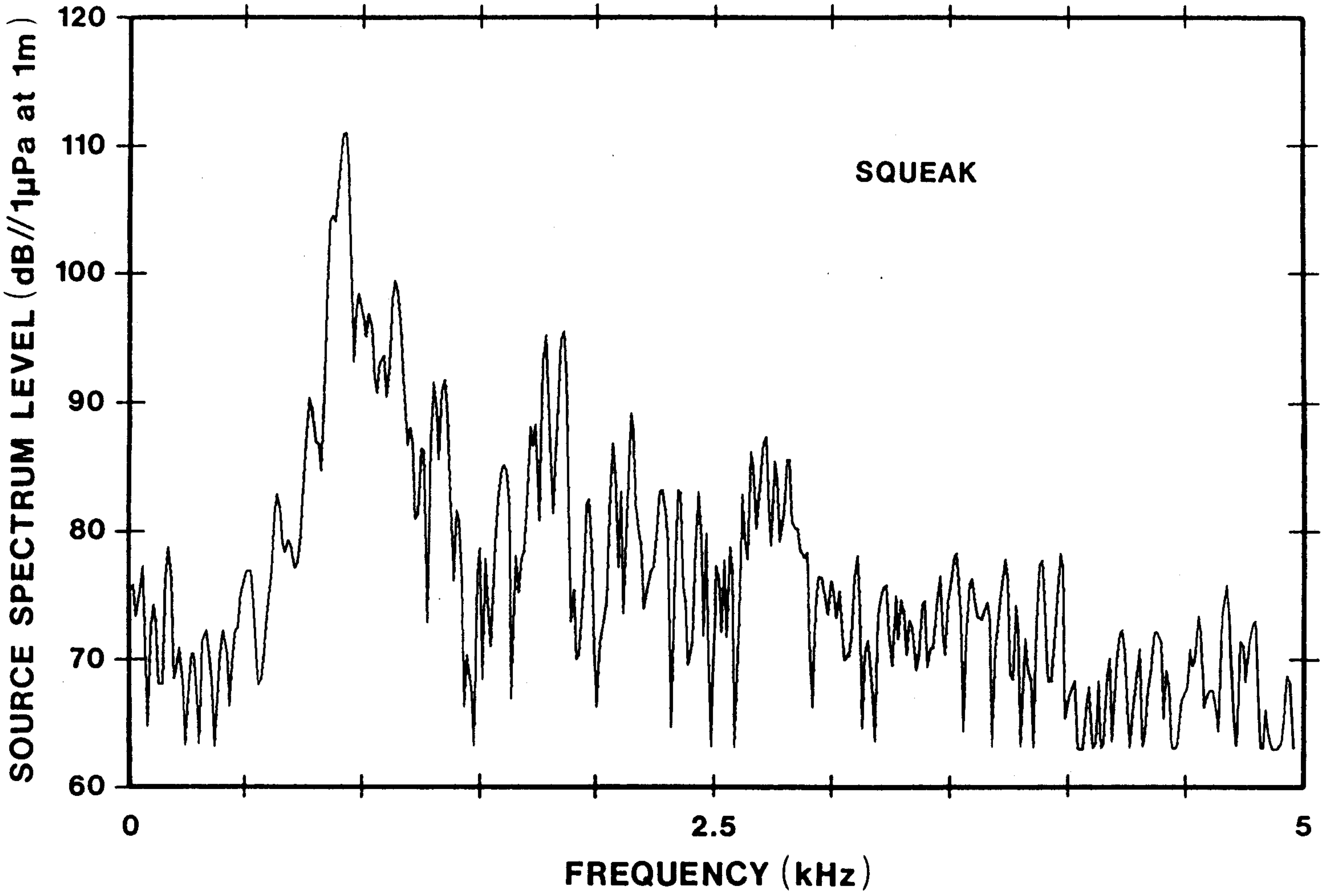


Figure 23. Source spectrum level of a squeak recorded and located from the triangular array. Analyzing filter bandwidth, 18.75 Hz.

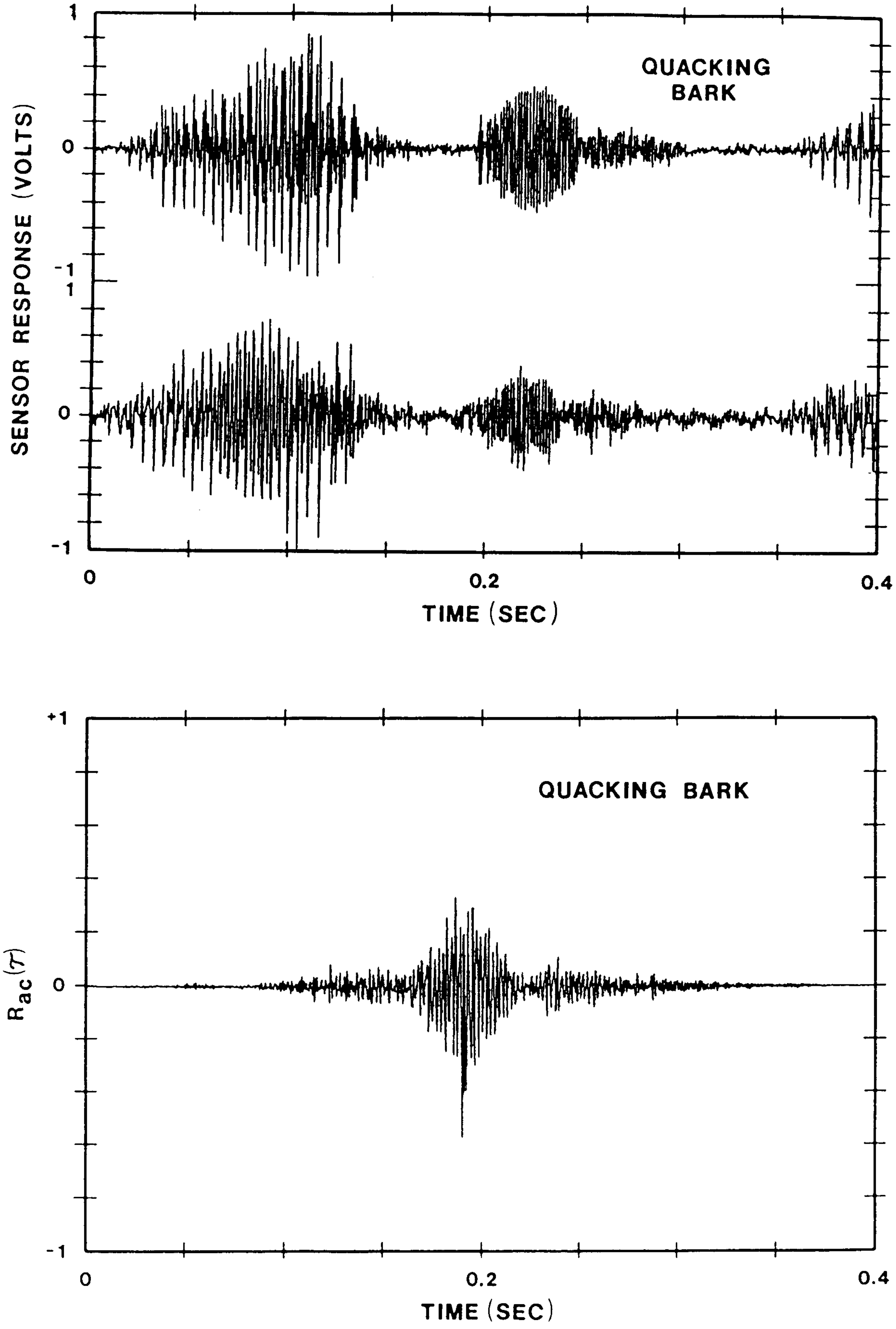


Figure 24. Waveforms of the arrivals of a two-element quacking bark sound at two hydrophones in the triangular array (upper) and the cross correlation function of same (lower) showing the arrival time difference to be 8.98 ms.

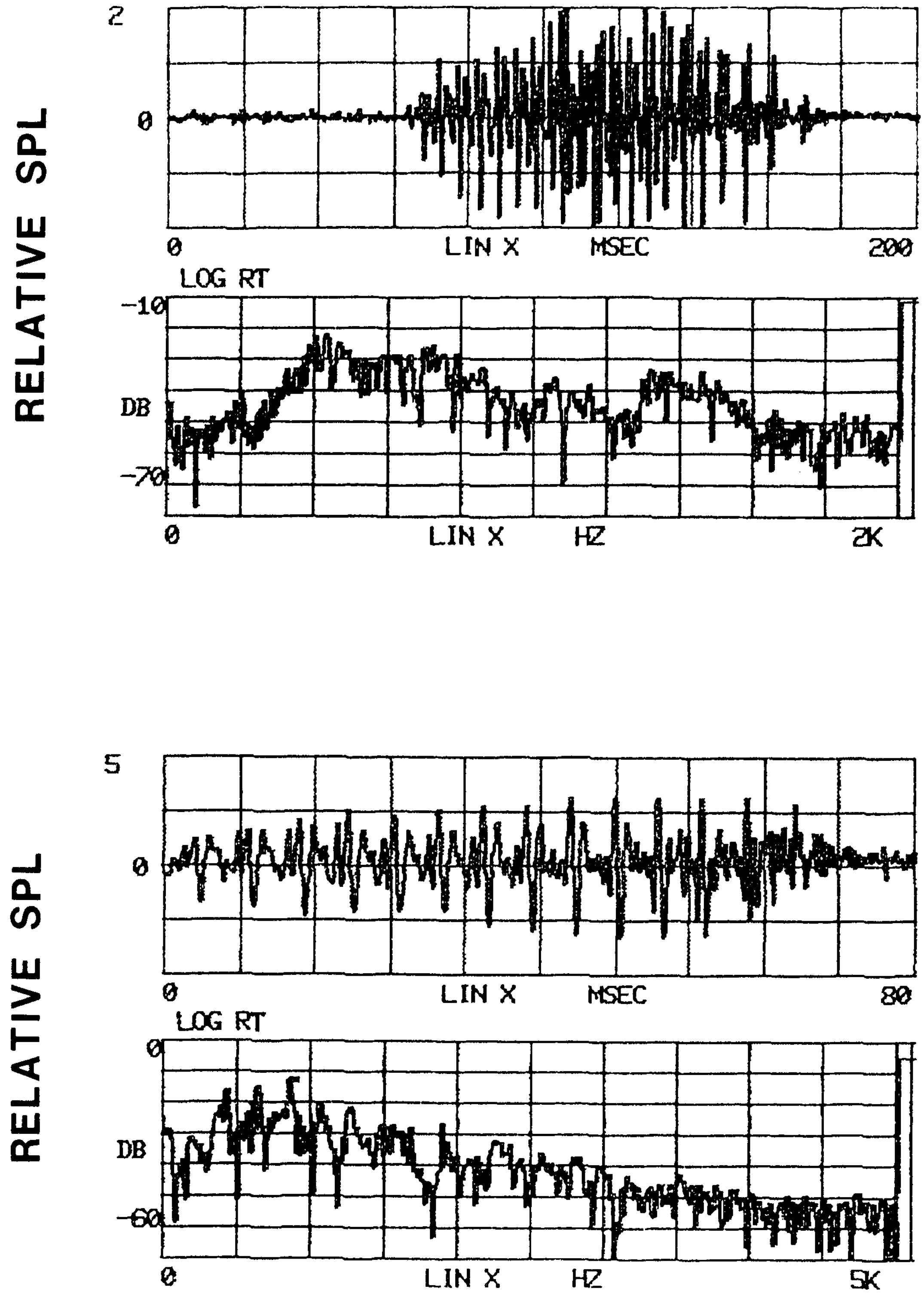


Figure 25. Waveform and spectrum of a single quacking bark (upper), and the same of another quacking bark (lower), stretching out the time scale for more detail of the waveform. Analyzing filter bandwidth, 7.5 Hz (above), 18.75 Hz (below).

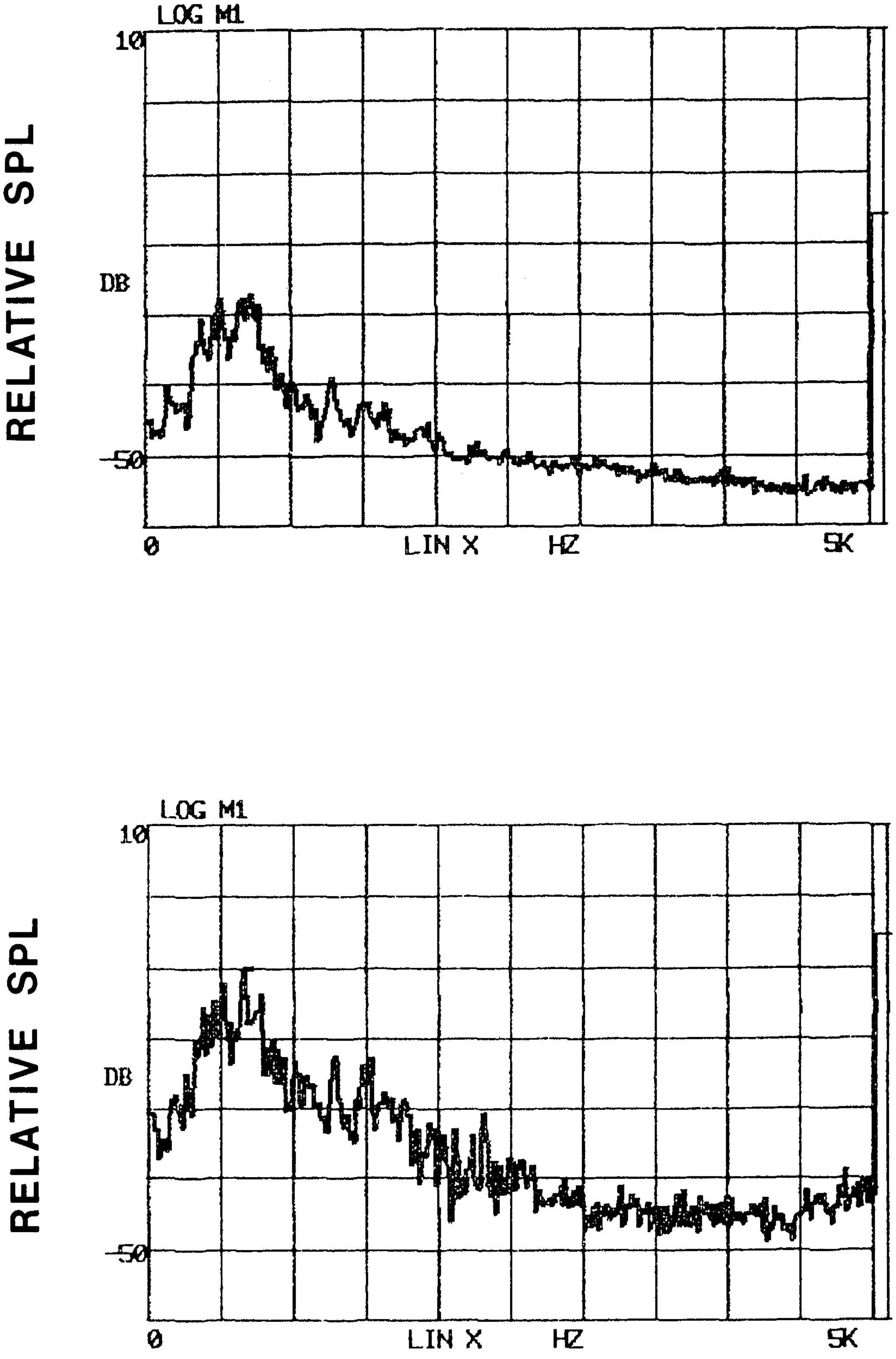


Figure 26. Addition of peak spectra over eight consecutive quacking barks (upper) and the exponential average of the same (lower). Duration, 3.09 sec, analyzing filter bandwidth, 18.75 Hz.

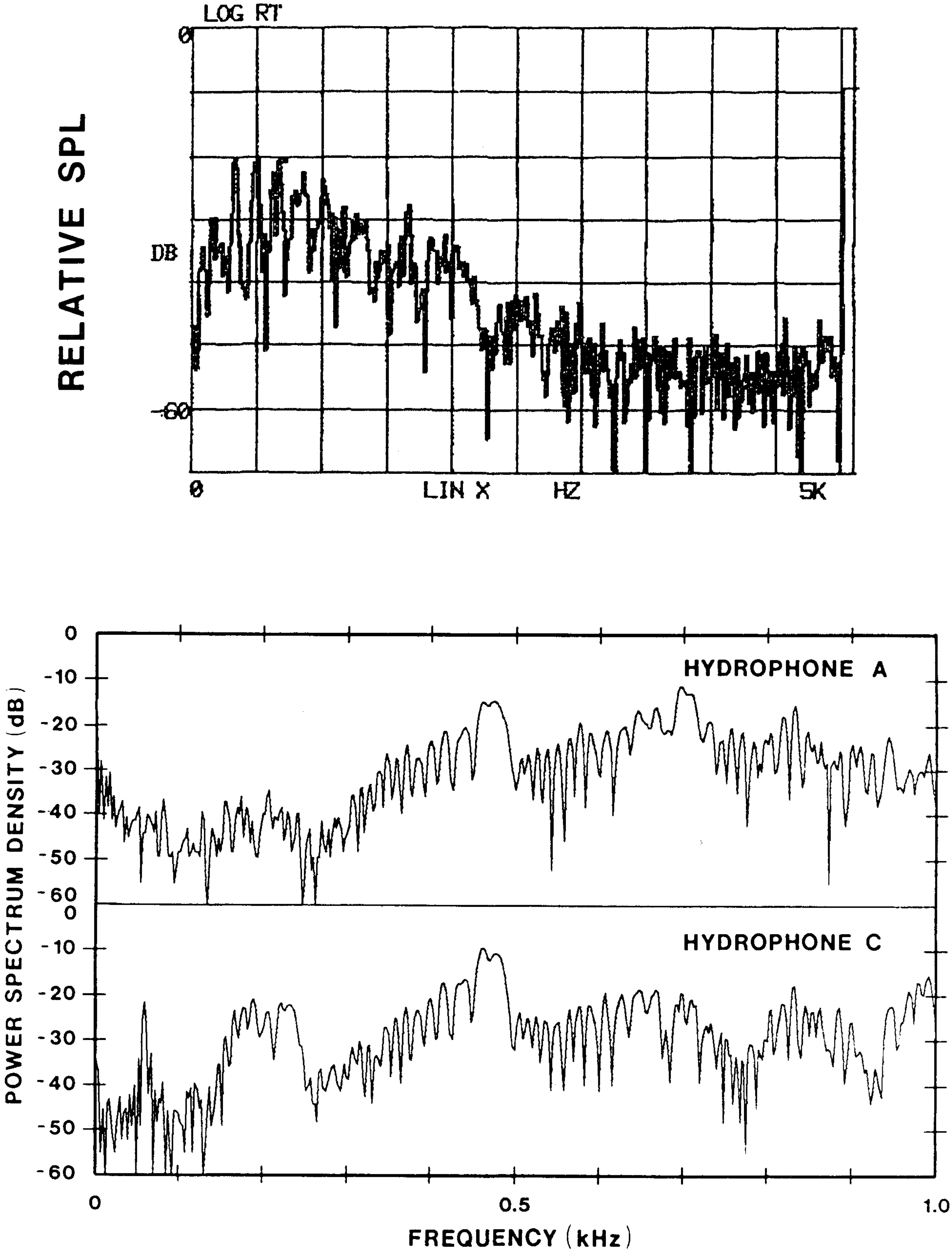


Figure 27. Spectrum of a single quacking bark analyzed at peak amplitude (upper), analyzing filter bandwidth, 18.75 Hz. Power spectral densities (0-1 kHz) of the arrival of a quacking bark at two hydrophones in the triangular array, analyzing filter bandwidth, 3.7 Hz.

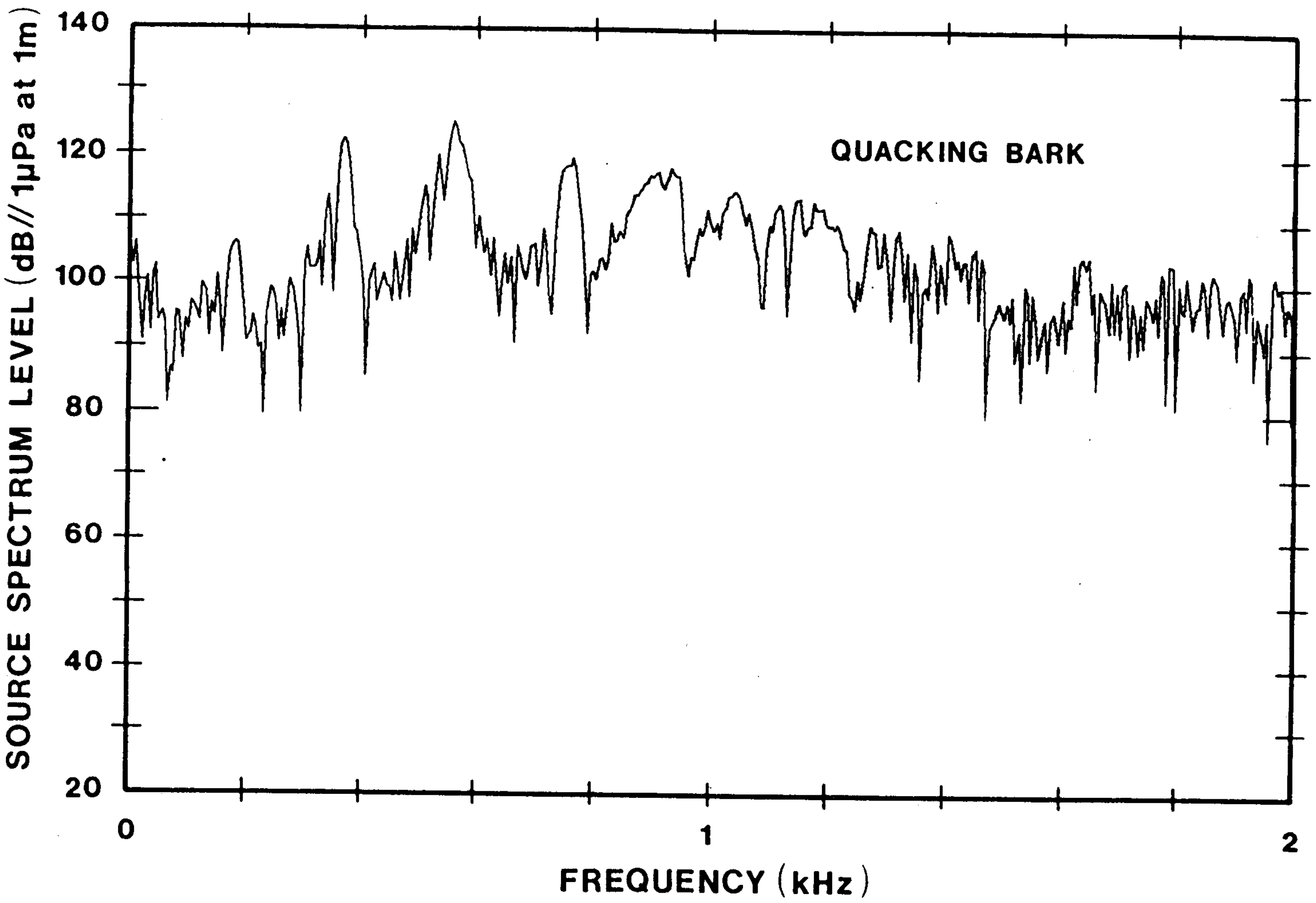


Figure 28. Source spectrum level of a quacking bark recorded and located with the triangular array. Analyzing filter bandwidth, 7.5 Hz.

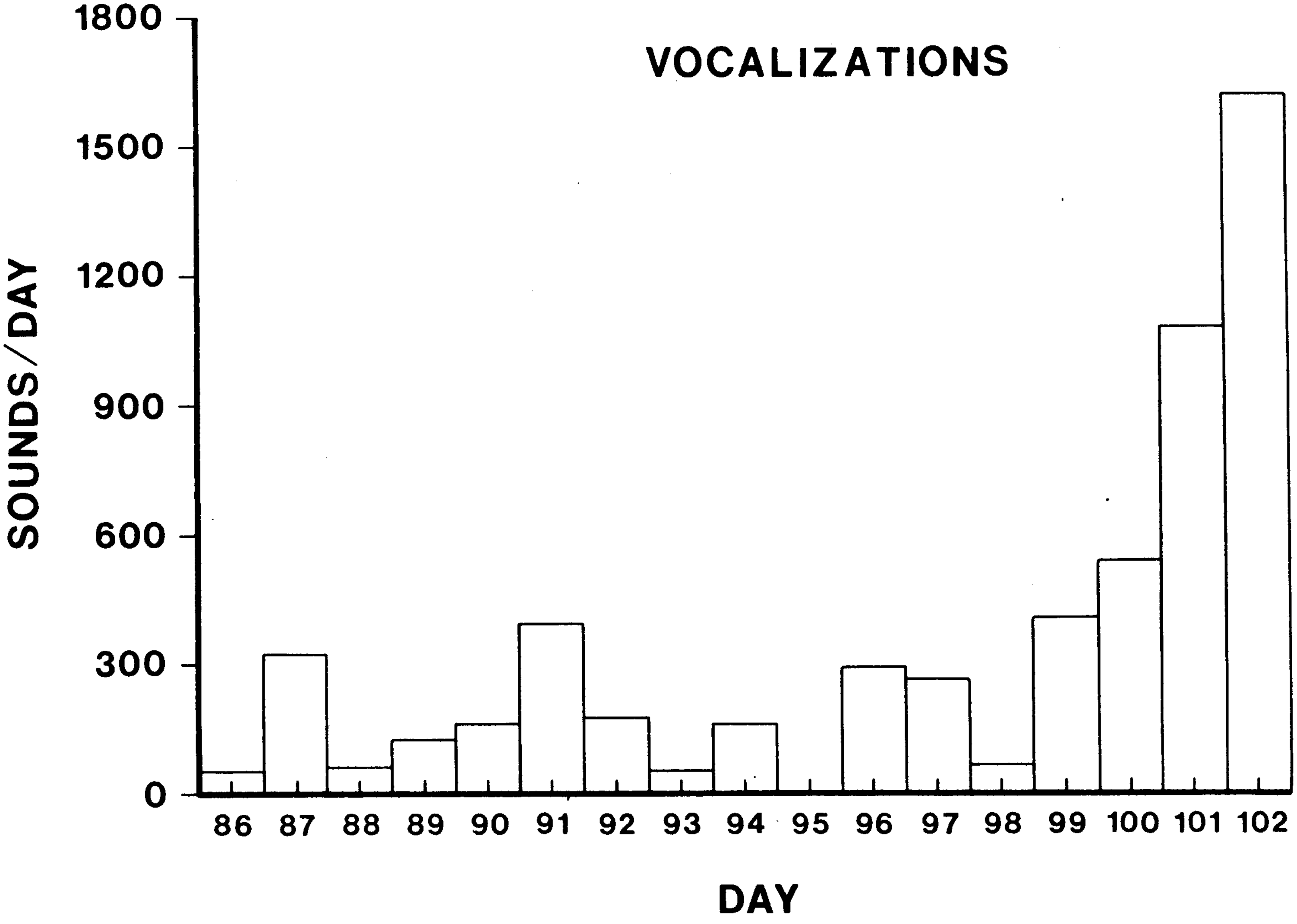


Figure 29. Histogram showing the long-term increase in the rate of ringed seal vocalizations from the array (sounds, excluding scratches) over the recording period beginning with Julian day 86 (26 March 1984). The data were normalized for unequal recording times each day (see text).

There appeared to be a rapid increase in sound production beginning 5 April 1984. It was necessary to normalize these data because of unequal recording effort between days. The data were analyzed by counting the number of all vocalizations from the triangular array in all categories per hour of recording in each day, and extrapolating by multiplying the average number of sounds per hour by 24, the hours in each day represented.

The long-term occurrences of the most prominent and frequent ringed seal sounds are shown in Figs. 30 and 31. The increase in sound production (bar heights, not numbers of bars) can readily be seen in the case of rubs, squeaks, and barks; however, the occurrence of scratches appeared to diminish over the recording period (Fig. 31, lower). These data were normalized for unequal recording durations since they were plotted as the number of sounds/hr. The total numbers of sounds, including scratches, were also plotted as a histogram in terms of sounds/hr, but the trend toward increasing sound production rates was obscured by the pattern of scratch occurrences (Fig. 32).

The occurrences of ten other sound categories recorded from the triangle were plotted as histograms using the computerized file of their counts, but the total numbers of sounds were too low and infrequent to depict as histograms. Instead, these infrequent ringed seal sound categories are tabulated (Table 3). This table can be referenced for the relative total frequency of occurrence for these sounds.

Long-term (other sensors, D, E, F, G)

The occurrence of ringed seal sounds at the remote hydrophones generally was too infrequent to detect long-term changes. A single exception was the occurrence of scratches at E, discussed below under "Scratches". These hydrophones were installed and disassembled at random times over the entire recording period of 25 March-11 April. If one of them ceased to function, or the bioacoustic activity was nil for 24 hrs or more, we discontinued the station. Usable sensors were sometimes moved to other locations where we noted activity, e.g., to location G where a ringed seal mother and pup were spotted sunning themselves near a newly opened access hole in a refrozen fracture.

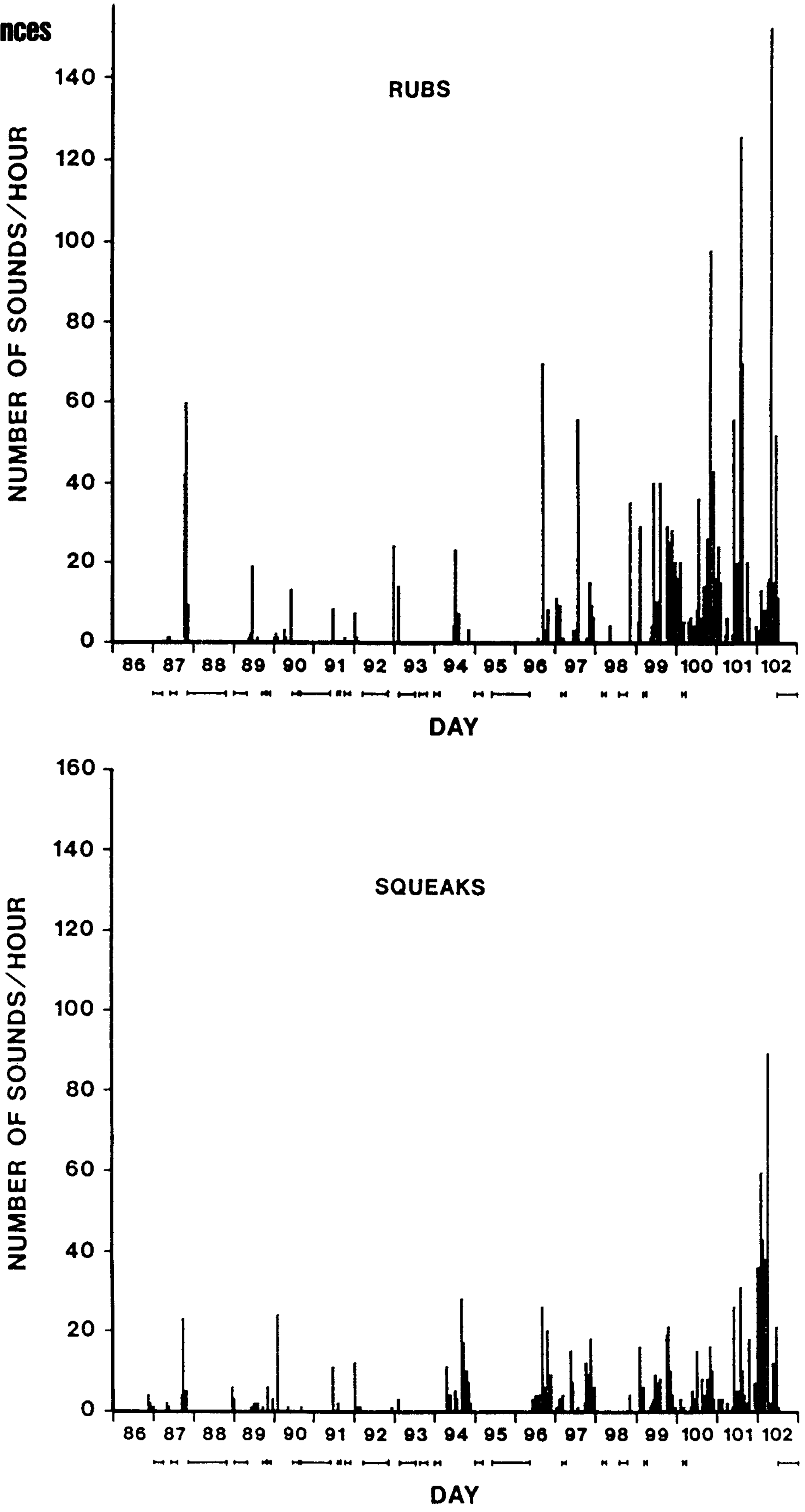
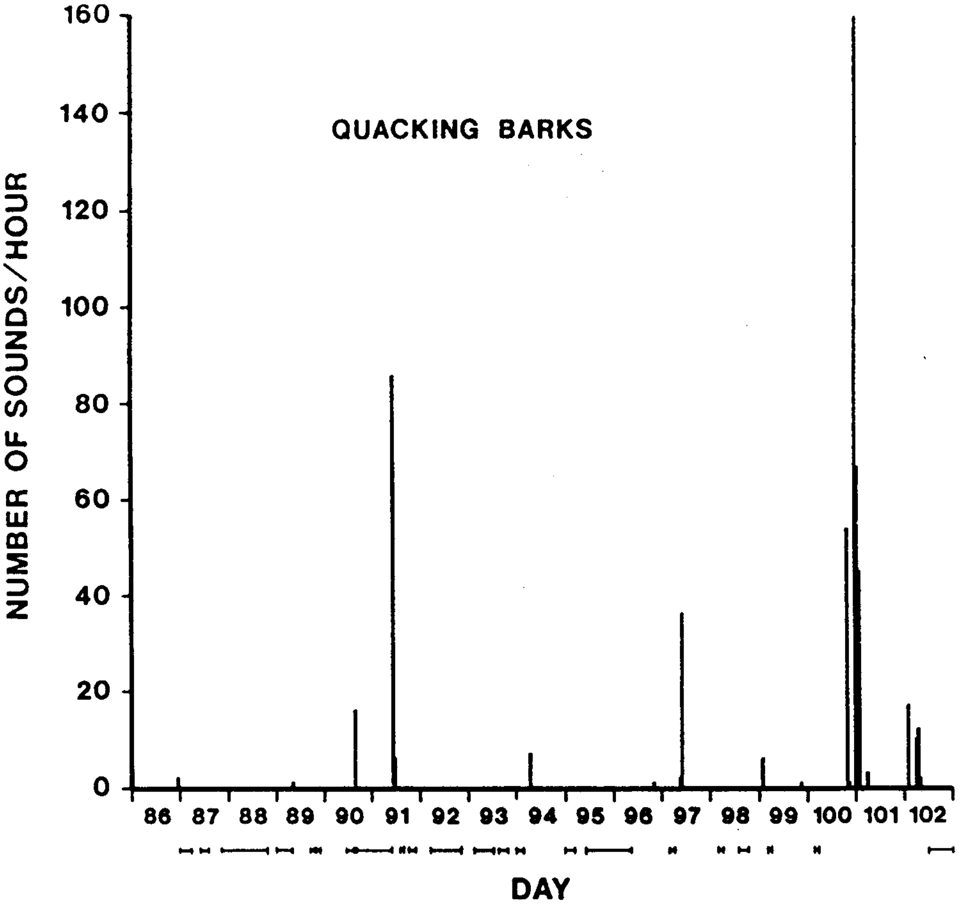


Figure 30. Histograms showing the long-term increase in the rate of rub (upper) and squeak (lower) sounds from ringed seals over the recording period beginning with Julian day 86 (26 March 1984). Periods marked by underlying bars were not recorded.



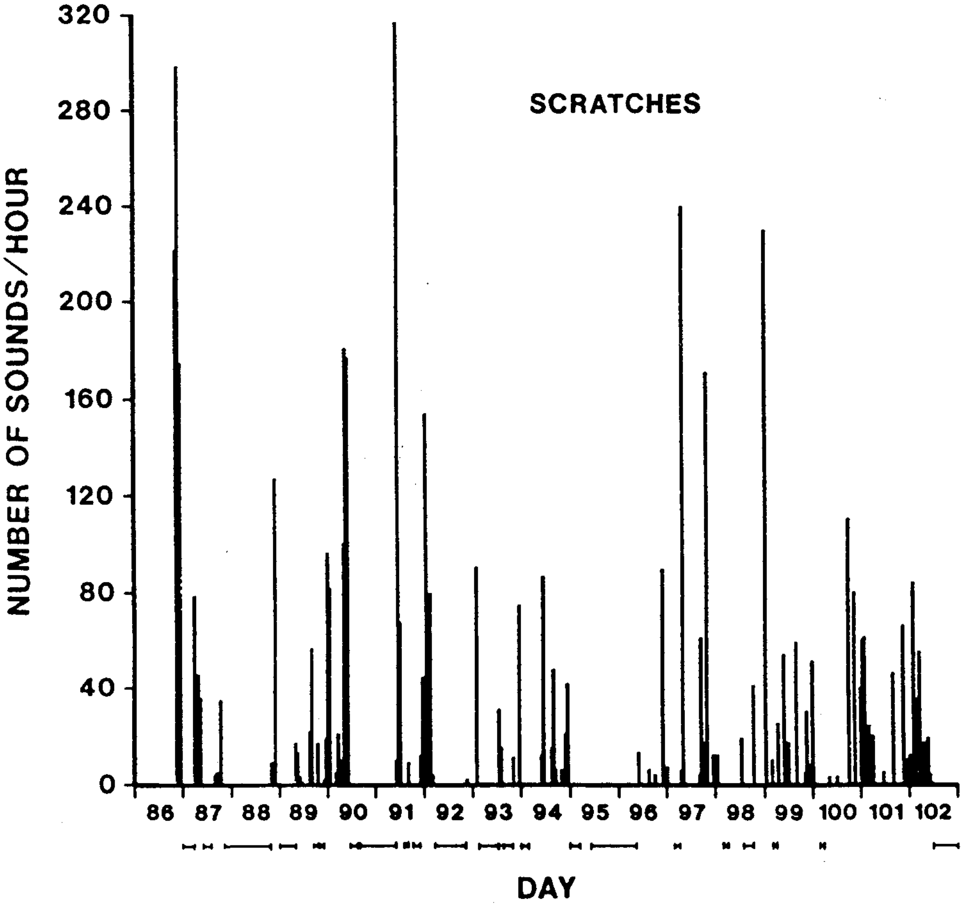


Figure 31. Histograms showing the long-term occurrence of ringed seal sound production rates of quacking barks (upper) and scratches (lower) over the recording period beginning with Julian day 86 (26 March 1984). Periods marked by underlying bars were not recorded.

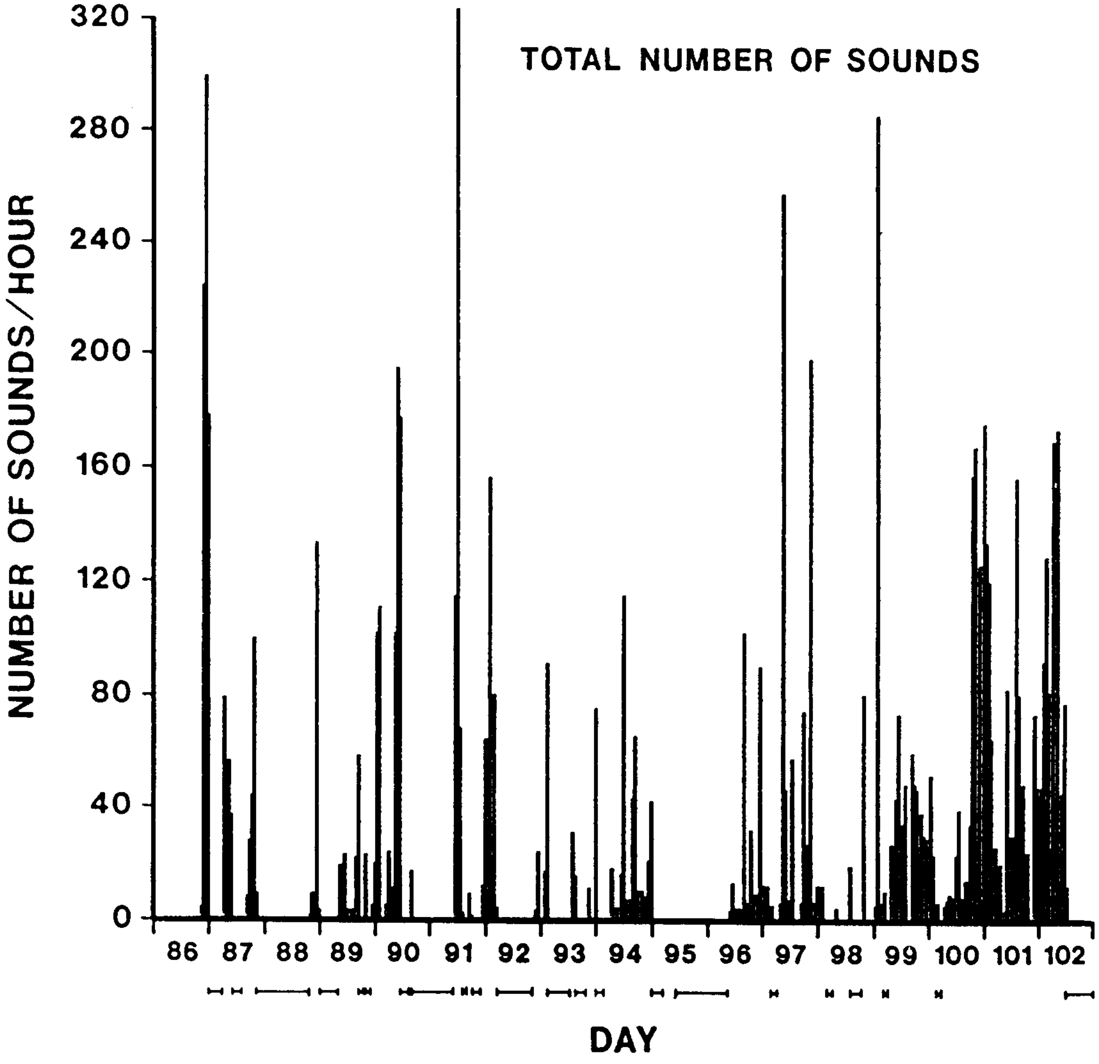


Figure 32. Histogram of pooled data involving all sound categories at the triangle, including scratches, recorded over the entire period beginning with Julian day 86 (26 March 1984).

Table 3. Occurrence of infrequent ringed seal vocalization categories from the triangular array period, 25 Mar-17 Apr 1984.

SOUND CATEGORY	DATES OF OCCURRENCE, '84	NUMBER OF SOUNDS PER HOUR[1]
Cries	27 Mar	8
Belches	30 Mar	1
	31 Mar	8
	6 Apr	4
Roar	9 Apr	22
Buzz	3 Apr	1
Knocking	29 Mar	1
Splash	9 Apr	1
Grunt	28 Mar	1
Snort	30 Mar	4
Explosive	30 Mar	1, 3, 1
Growl	17 Apr	4

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[1] Denotes number of sounds that occurred during a recorded hour over which there was at least one occurrence.

The occurrences of six different sound categories are listed in Table 4 according to remote hydrophone locations D-G (also see Fig. 3). With the exception of 14,702 scratches (14,589 of which came from location E) and 597 rubs (location E), relatively few sounds were recorded from these other hydrophones outside of the triangular array.

Diurnal (triangle)

The data were searched for evidence of diurnal (daily) patterns of ringed seal sound production. This was done mostly by studying the frequency of sound occurrence plots resulting from data recorded at the triangular array of hydrophones. First, we pooled all of the sound categories (scratches included), adding all occurrences during recorded hours over a 24 hr period. Since the recording level of effort varied between hours of the day (comparing day to day), it was necessary to normalize summed data by dividing the total number of sounds by the number of days for which a given hour was recorded. The results (Fig. 33) suggested a bimodal distribution peaked at about 1100 and 0130 hrs.

We then searched the frequencies per category and determined that the bimodality, or apparent diurnal periodicity, was basically due to the occurrence of scratches (Fig. 34). In both Figs. 33 and 34, the lower distributions are smoothed versions of the upper distributions obtained by a moving average of 3. The occurrence of scratches peaked at 1030 and 2330 hrs (Fig. 34, lower).

Fig. 35 resulted from removing the scratching sounds and plotting the pooled data for vocalizations. Although it appears that the frequency of occurrence of seal vocalizations may be independent of the hour of the 24-hr day (averaged data for the triangular array), a statistical analysis showed there was some dependency (chi square = 38.8 > 35.2 (.05) 23 deg freedom). In the same way the raw data showed dependence (chi square = 127.95 > 35.17 (.05) 23 deg freedom).

Table 4. Occurrence of ringed seal sounds at sensors other than from the triangular array during the recording period, 25 March-11 April 84.

SENSOR	SOUND CATEGORY	NO. SOUNDS PER HR[1]	RESPECTIVE DATES (J)
D	Rubs	2,3	86,88
"	Scratches	2	88
E	Rubs	114,83,400	89,89,89
"	Scratches	See Fig. 38	
"	Squeaks	1,1,1,2	88,89,89,93
"	Crackle	104,2	96,96
"	Crunch	3	93
"	Knocking	9,9,2,8,21	93,93,95,96,96
F	Scratches	52	89
G	Rubs	21,13	96,96
"	Scratches	59	96
"	Crackle	120,43,3	95,95,96

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[1] Denotes number of sounds that occurred during a recorded hour (included are the respectively listed Julian (J) dates, next column) over which there was at least one occurrence.

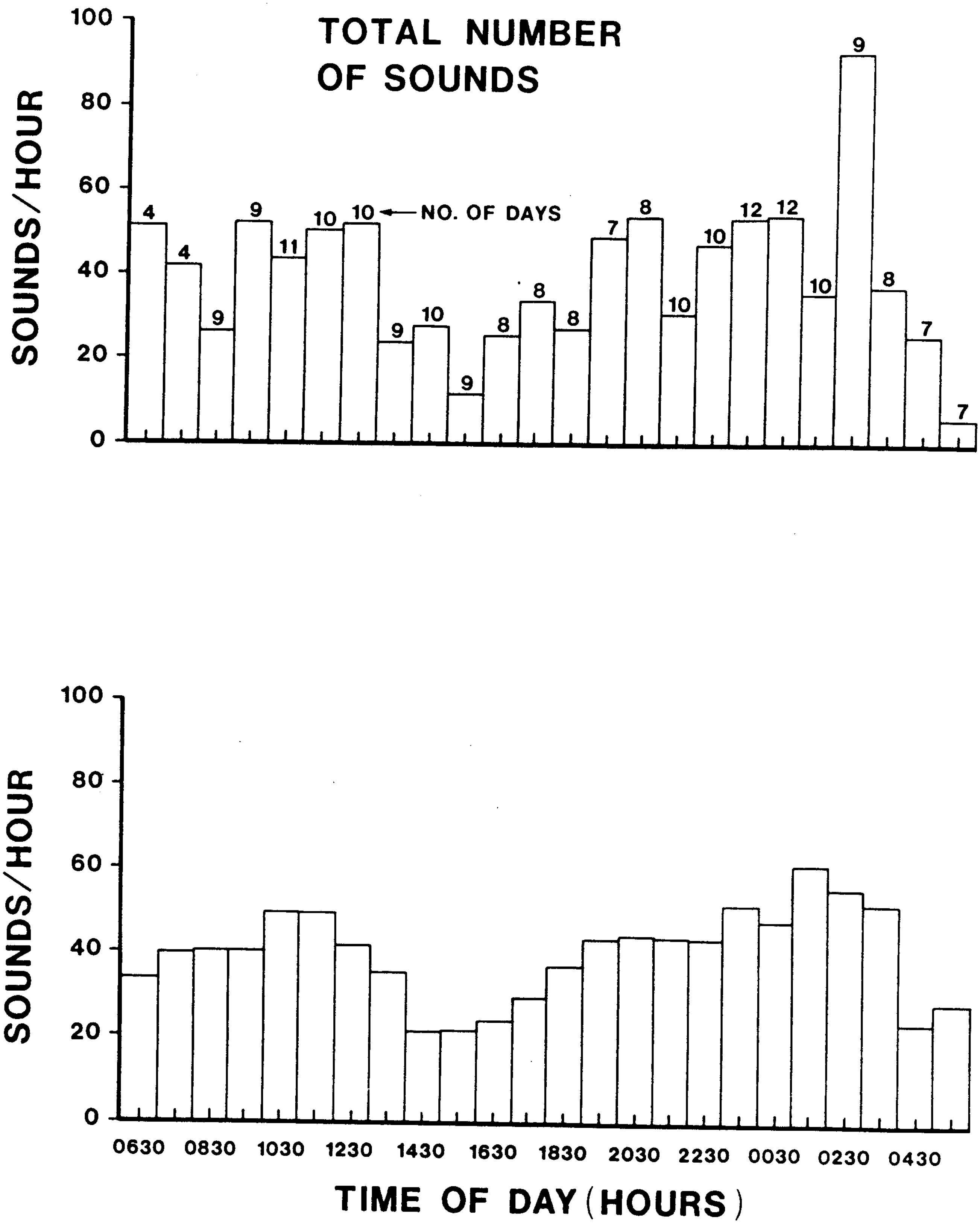

Figure 33. Histograms showing the hourly occurrence of all ringed seal sounds from the triangular array, pooled over the number of days indicated and normalized for unequal numbers of recordings (upper) and the same data smoothed by a moving average of 3 (lower).

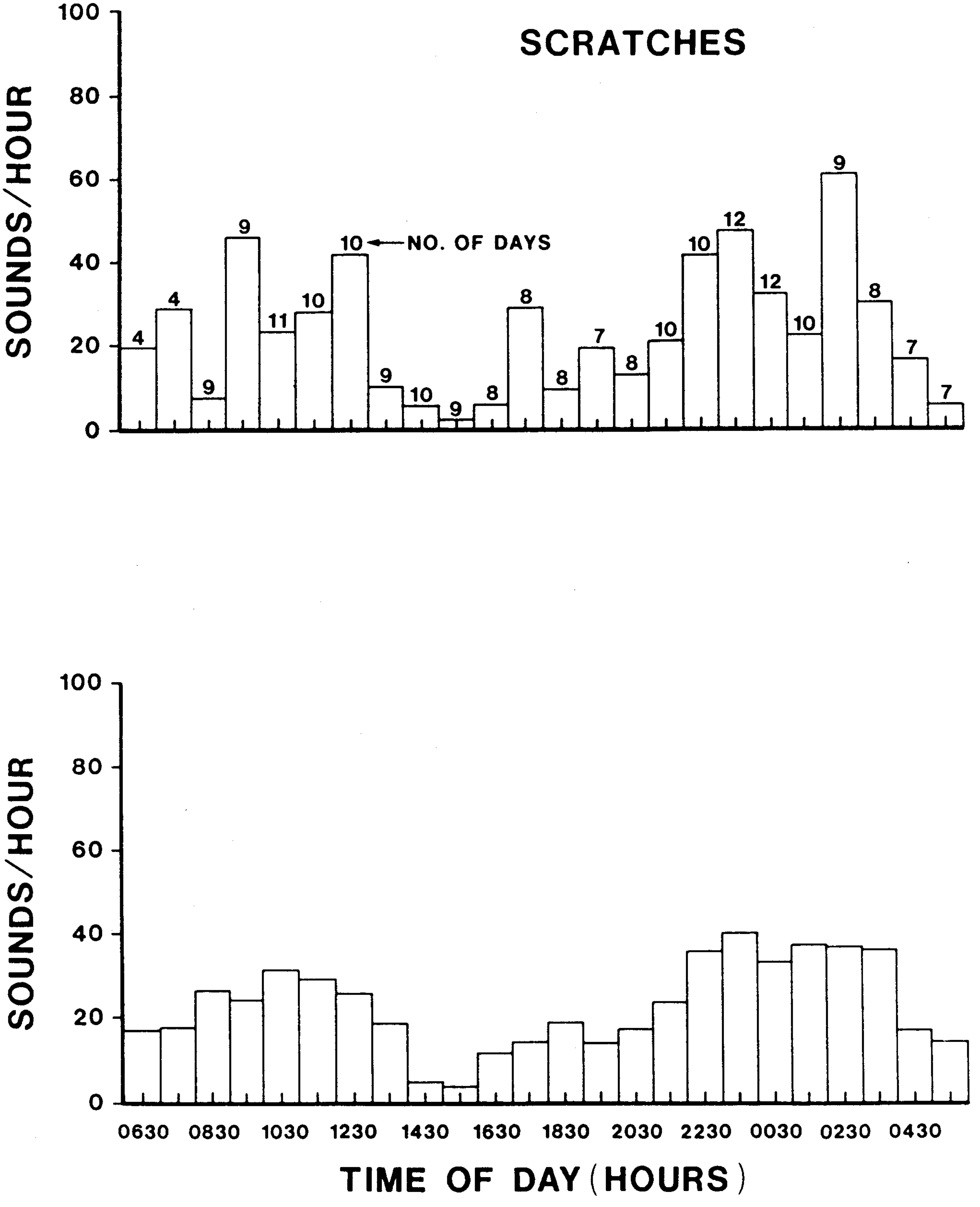

Figure 34. Histograms showing the hourly occurrence of all ringed seal scratches from the triangular array, pooled over the number of days indicated and normalized for unequal numbers of recordings (upper) and the same data smoothed by a moving average of 3 (lower).

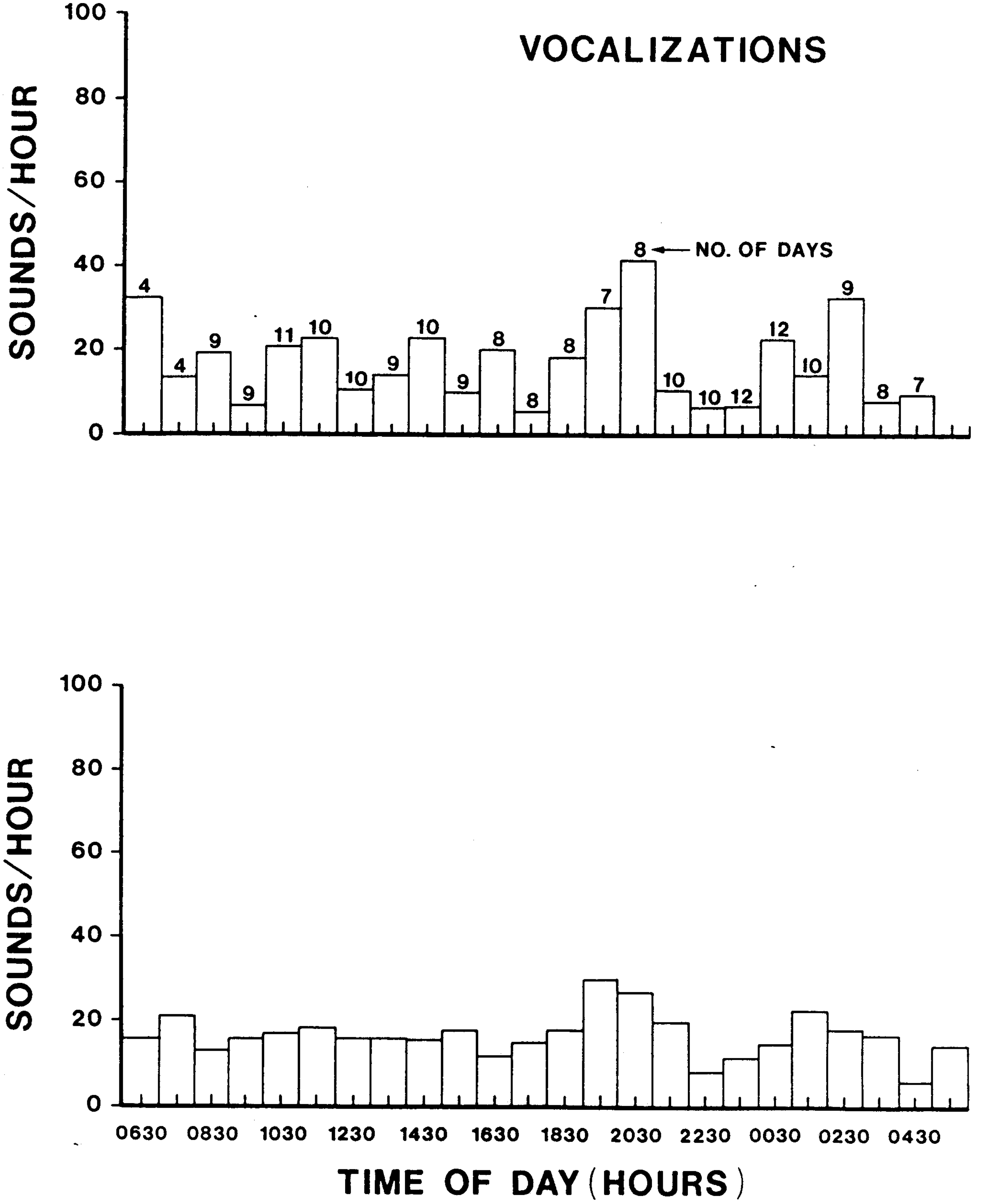

Figure 35. Histograms showing the hourly occurrence of all ringed seal vocalizations from the triangular array, pooled over the number of days indicated and normalized for unequal numbers of recordings (upper) and the same data smoothed by a moving average of 3 (lower).

A Fast Fourier Transform (FFT) was then produced to illustrate the frequency of occurrence (Fig. 36). This indicated possible periodicities of 2 and about 7 hours in the occurrence of pooled data consisting of 3,359 sounds. Figs. 33 to 36 pertain only to data from the triangular array, which were not duplicated, i.e., only the occurrences on one hydrophone (nearly always A) entered these data even though all three hydrophones were recorded simultaneously.

Scratches

Since scratches were so numerous and they were associated with known types of behavior (breathing hole, access hole, or lair building/ maintenance), a study was made of their frequency of occurrence.

Individual scratches occurred in bouts that consisted of 1-126 sounds (mode 4; median 11). Bouts were defined as groupings of scratches separated by at least 3 sec. The frequency of occurrence of given numbers of individual scratches per bout is shown in Fig 37. They comprised a skewed curve that appears to have three peaks centered on 4, 11, and 27 sounds per bout. By far the commonest number of scratches per bout was 6 or less.

A total of 310 bouts was recorded from the triangular array, 26 March to 11 April. Single bouts from a single seal lasted as long as 101 sec, and as many as 34 bouts from more than one seal occurred over a period of 2 hrs. Although only one bout may have been heard in a given time period, bouts generally occurred in series (one group of scratches after another) with a long pause, e.g., 1 min, between series. We never heard scratching from two locations at the same time, although on 26 March, a series from one location was immediately followed by another elsewhere.

On 29 March, we started to record from site E where a hydrophone had been buried in snow and ice at the periphery of an active lair. The lair contained a seal pup which, surprisingly, turned out to be a bearded seal (identified by John Burns, Alaska Department of Fish and Game). The most common sound recorded at this location was scratching. The frequency of

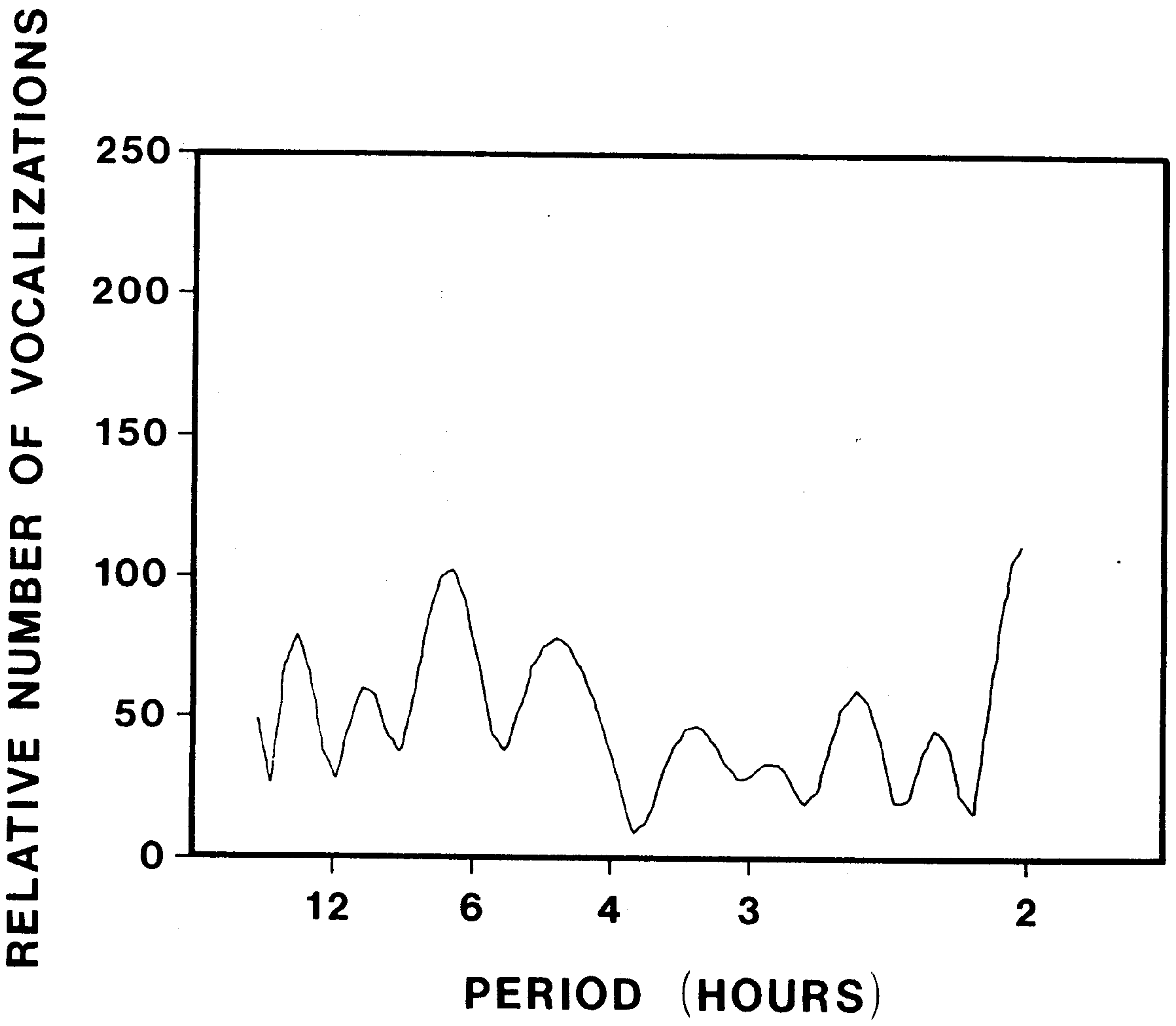

Figure 36. Fast Fourier Transform (FFT) of the frequency of occurrence of ringed seal vocalizations (sounds, excluding scratches) showing two possible periodicities of about 7 and 2 hours (from pooled data of 3,359 vocalizations at the triangle).

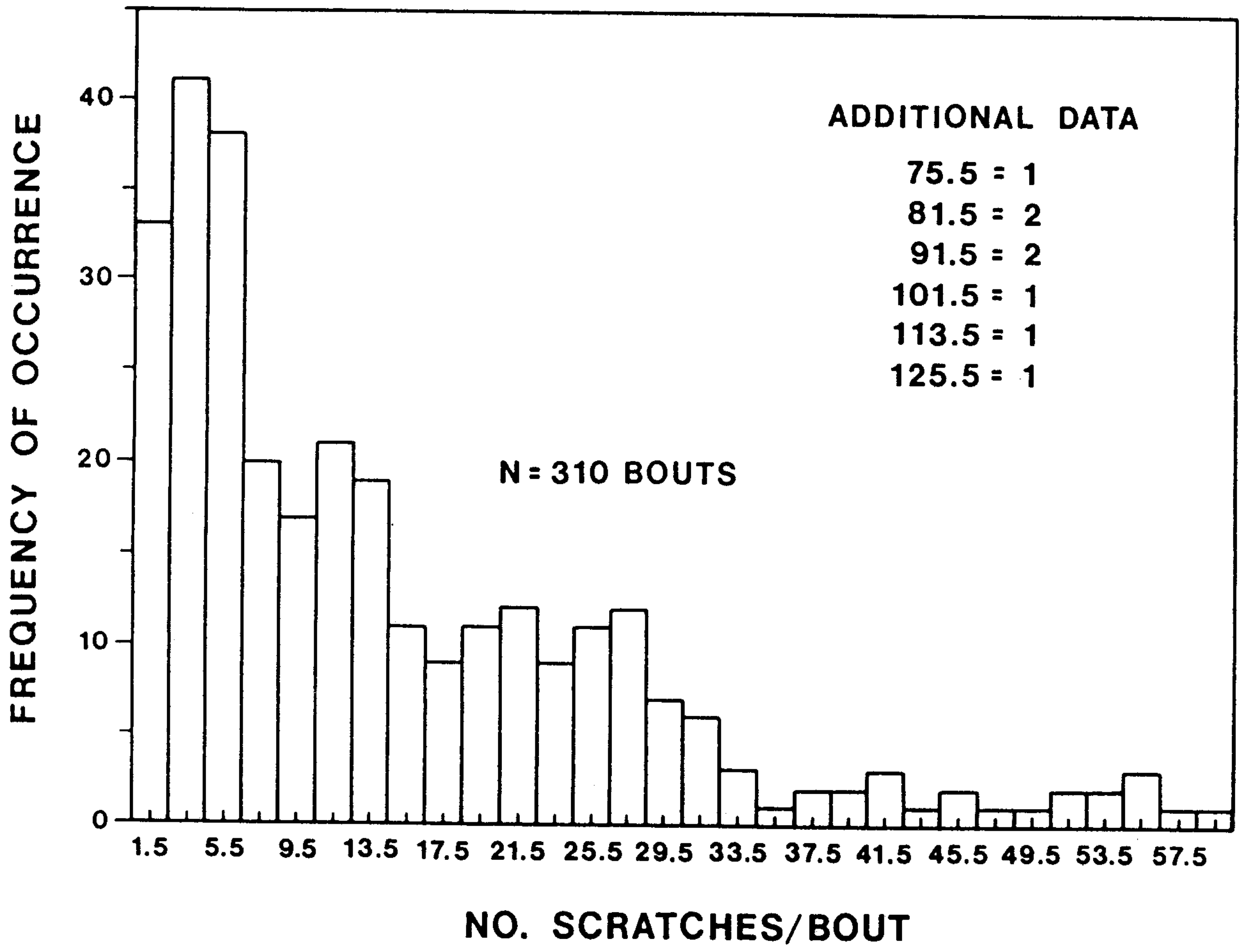

Figure 37. Number (frequency) of ringed seal scratches per bout, including 310 bouts, recorded from the triangular array over the recording period, 25 March-11 April 1984.

occurrence of these sounds was plotted over 56 hrs of recording, sampled over 10 days, 29 March-7 April (Fig. 38). The number of scratches peaked on the third day of recording (31 March) and then decreased until no more were heard after 5 April. At their peak, as many as 4,388 scratches were noted in one hour's time, beginning at 1205 hrs, 31 March.

On 9 April, the hydrophone signal was virtually absent from location E. The S/N ratio and the character of the noise indicated that the useful battery power had run out. Upon our inspection of the lair and the hydrophone, the pup was found frozen into the refrozen access hole with the top of its head and back just above the surface of the ice. We removed the transducer, battery, and transmitter. The site was inspected on 15 April and nothing had changed.

There were very noticeable changes in the acoustical characteristics of individual scratch sounds within bouts that presumably were caused by scratching different forms of ice in different ways. This occurred in virtually all bouts, regardless of location.

Physical Factors and Sound Production

Four environmental factors were measured in the conduct of this research: ambient surface light, windspeed, ambient air temperature, and underwater sound speed. We measured light, wind, and temperature because of the possibility that they may have been associated with the frequency of occurrence of ringed seal sounds. Underwater sound speed was needed for sound source localization (see METHODS).

Light - The relationship of light intensity (μWatts/cm^2) and time of day was first plotted for each of 16 days, with individual datum points at the times of measurement. As reported by the local weather broadcasters over this period of time, daylight periods lengthened by an average of 10 min/day. Pooled light measurements appeared as a strong modal curve which peaked at about 1400 hrs (local time), Fig. 39. The

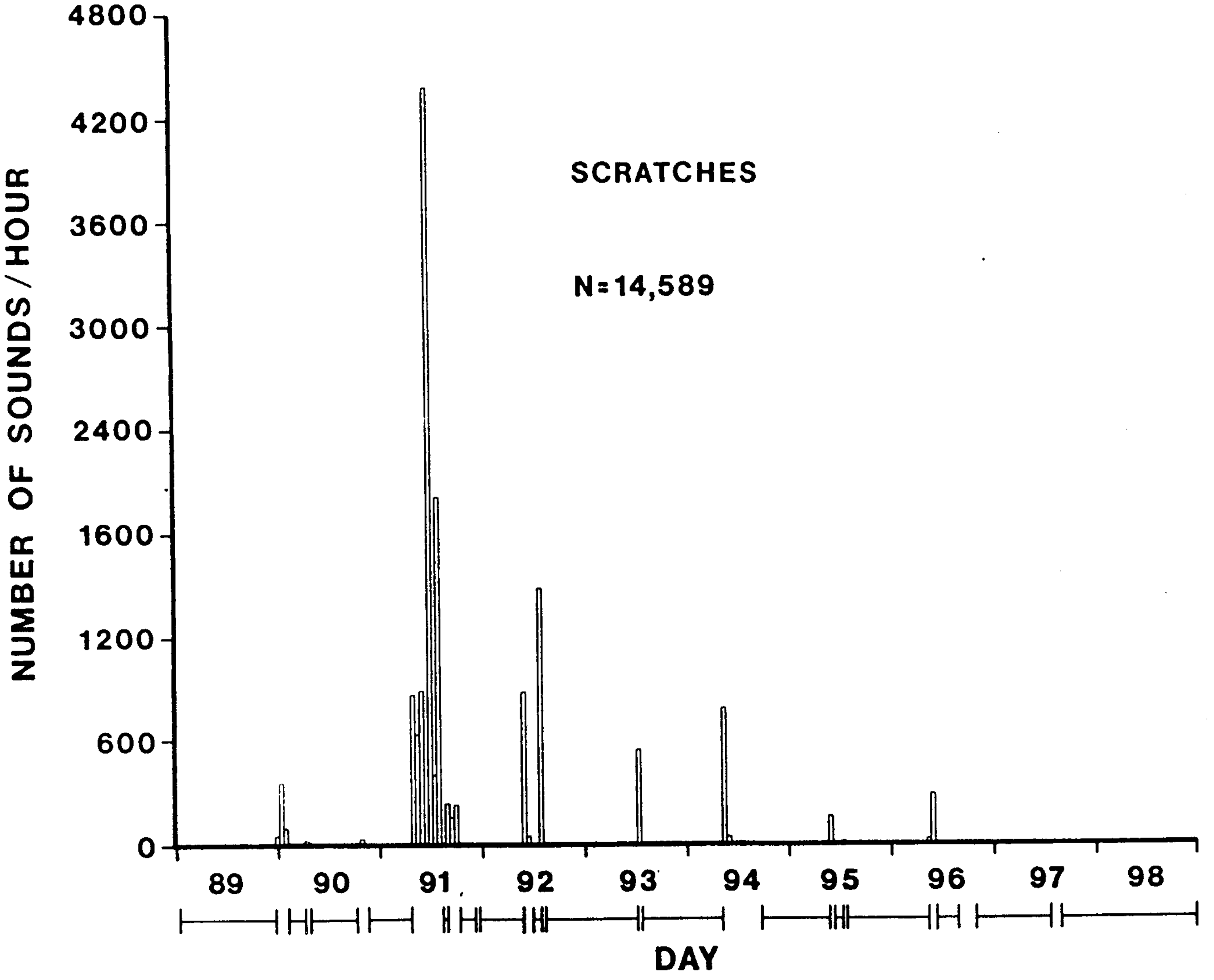

Figure 38. Occurrence of scratching sounds as recorded during 56 hrs over 10 days from the lair at site E, which contained a bearded seal pup, Julian days 89 to 98 (29 March-7 April 84).

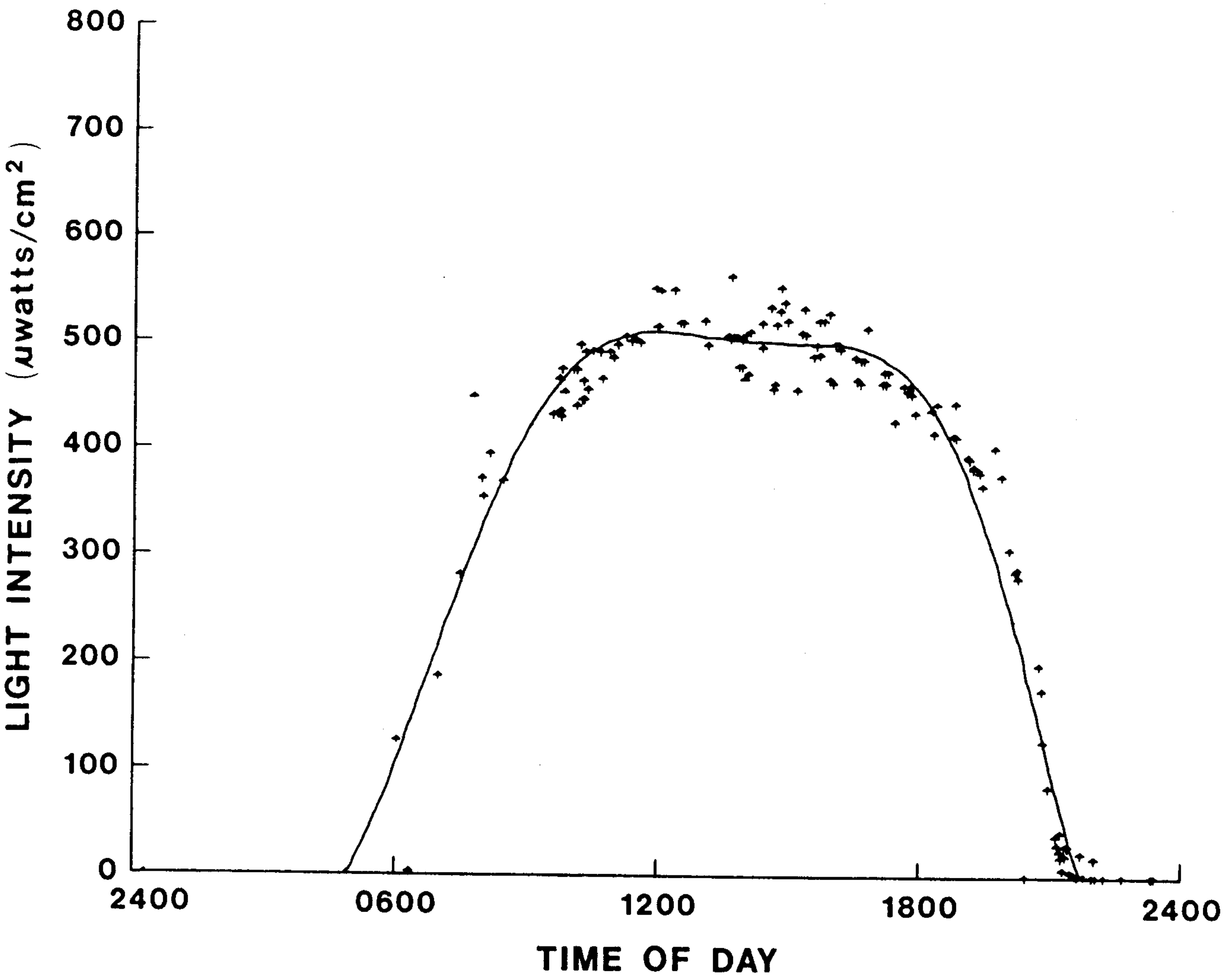

Figure 39. The total of 141 ambient light measurements vs time of day pooled over the recording time period, 25 March-10 April 84.

highest measurements varied from about 450-570 μWatts/cm^2, which occurred over the time period 0930-1800 hrs, depending upon overcast conditions. Our photometer was sensitive enough for measurements from about 0600-2130 hrs on the shortest day.

When the pooled sound data (excluding scratching), i.e., Fig. 35, were divided into light vs dark hours (averaging 0600-2100, 2100-0600 hrs), it was found that more vocalizations/hr appeared during the light hours (chi square = 5.0 > 3.8 (.05) 1 deg freedom). We have already shown that there was some dependency of the number of seal vocalizations/hr on time of day (Frequency of Occurrence, Diurnal).

Using the average light intensity values during times of the day (fitted line, Fig. 39) and the number of seal vocalizations/15 min period that occurred during times of measurable light, we examined the association of the two variables. Based on 901 pairs of observations, light and numbers of sounds were not statistically correlated ($r = .014 < .062$ (.05)).

Windspeed - The range, mean, and values of windspeed (mph) over 210 measurements on days of recording are given in Fig. 40. The tabulated and graphed values, ranging from calm to 45 mph (mean 11.3, SD 9.6), appear in the Appendix. There was a significant negative correlation between the number of ringed seal vocalizations and windspeed, based upon counts of sounds in the 15-min period following each windspeed measurement ($r = |-0.185| > 0.114$ (.05) 210 N). In other words, more vocalizations/hr were counted during low windspeeds. Over the above stated range of windspeeds, vocalizations/15-min period ranged from 0 to 183 (mean 8.4, SD 23.8).

The number of scratches/15-min period was not correlated with windspeed ($r = .0027 < 0.114$ (.05) 210 N) where scratches in the first 15-min period were counted directly after windspeed measurements. In this set of data, the number of scratches ranged from 0 to 96 (mean 4.9, SD 13.9). The range mean and standard deviation for windspeeds were the same as those in the association with vocalizations.

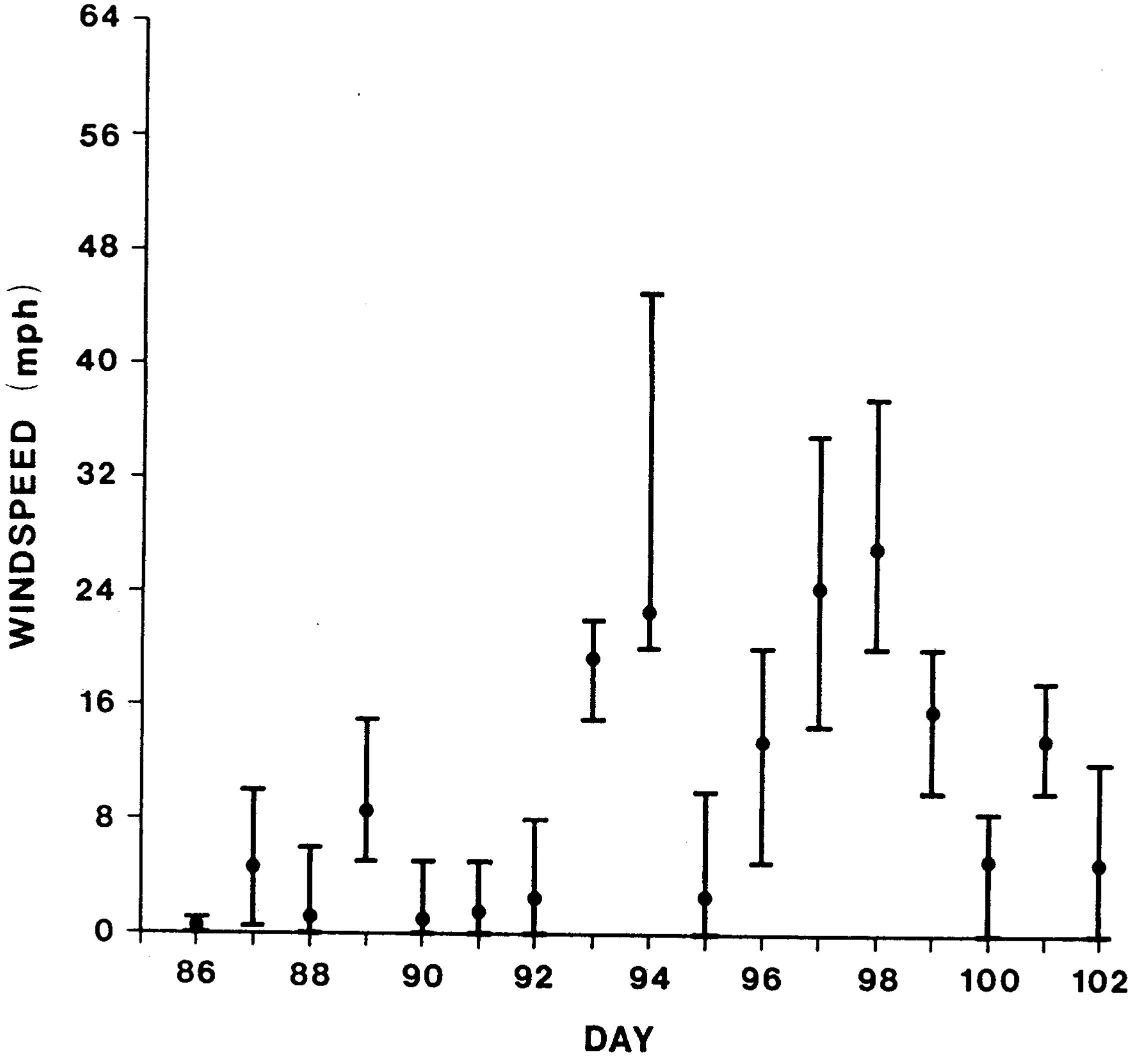

Figure 40. Range, mean and values of windspeeds measured on recording days (N = 210).

Temperature - The range and means of 210 temperature readings on the days of recording are given in Fig. 41. Tabulated temperature data, ranging from -37 to 10°C appear in the Appendix. Temperature variations over 2 April are shown in Fig. 42. As with most days, minima occurred during the hours of darkness, maxima at about 1330 hrs. The number of vocalizations/15-min period following each temperature measurement was significantly negatively correlated with temperature ($r = |-0.17| > 0.114$ (.05) 210 N). There were more vocalizations/15-min period during lower temperatures. The range, mean, and standard deviation for vocalization/15-min period were the same as this comparison with windspeed since the same set of vocalization data was used (range 0-183, mean 8.4, SD 23.8).

Because the number of vocalizations was negatively correlated with both windspeed and temperature, we wanted to examine the association between these two environmental factors. Using 198 pairs (recorded simultaneously) of the two variables noted throughout the recording period, it was determined that they were not statistically correlated ($r = .085 < 0.117$ (.05) 196 deg freedom).

The number of scratches/15-min period following temperature measurements was not significantly correlated with temperature ($r = |-0.036| < 0.114$ (.05) 210 N). The range, mean, and standard deviation of the number of scratches in this set of data were the same as in the comparison between windspeed and scratches (0-96, 4.9, 13.9, respectively).

Underwater sound speed - A set of measurements of underwater sound speed appears in Fig. 43. As described above, this parameter was needed for the localization work. The values were fairly uniform from the surface (in the ice hole and just below) to the bottom of the water column, as would be expected in such shallow water. The average value of 1437 m/sec was used in the localizations.

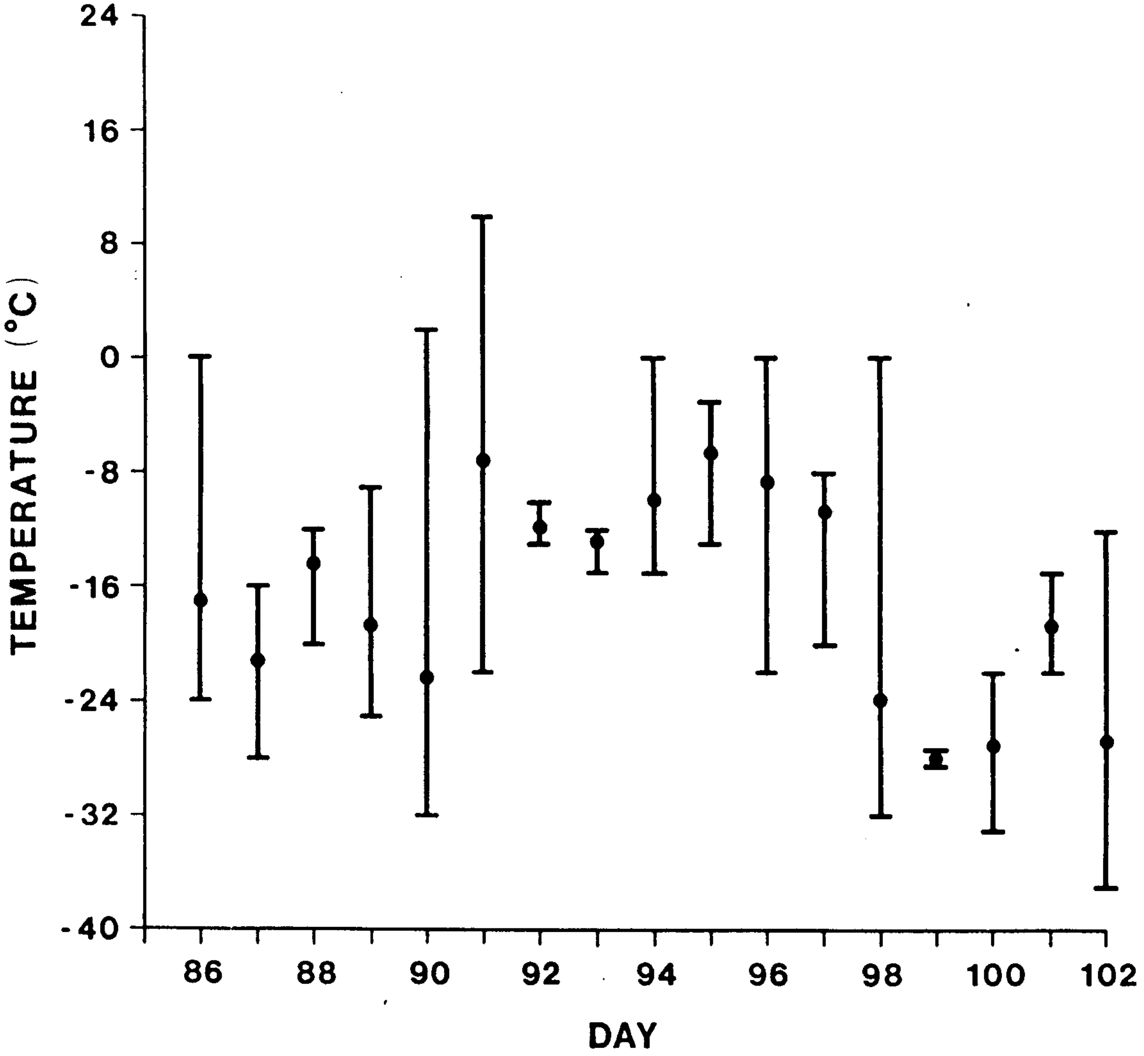

Figure 41. Range and means of temperature readings taken on recording days (N = 210).

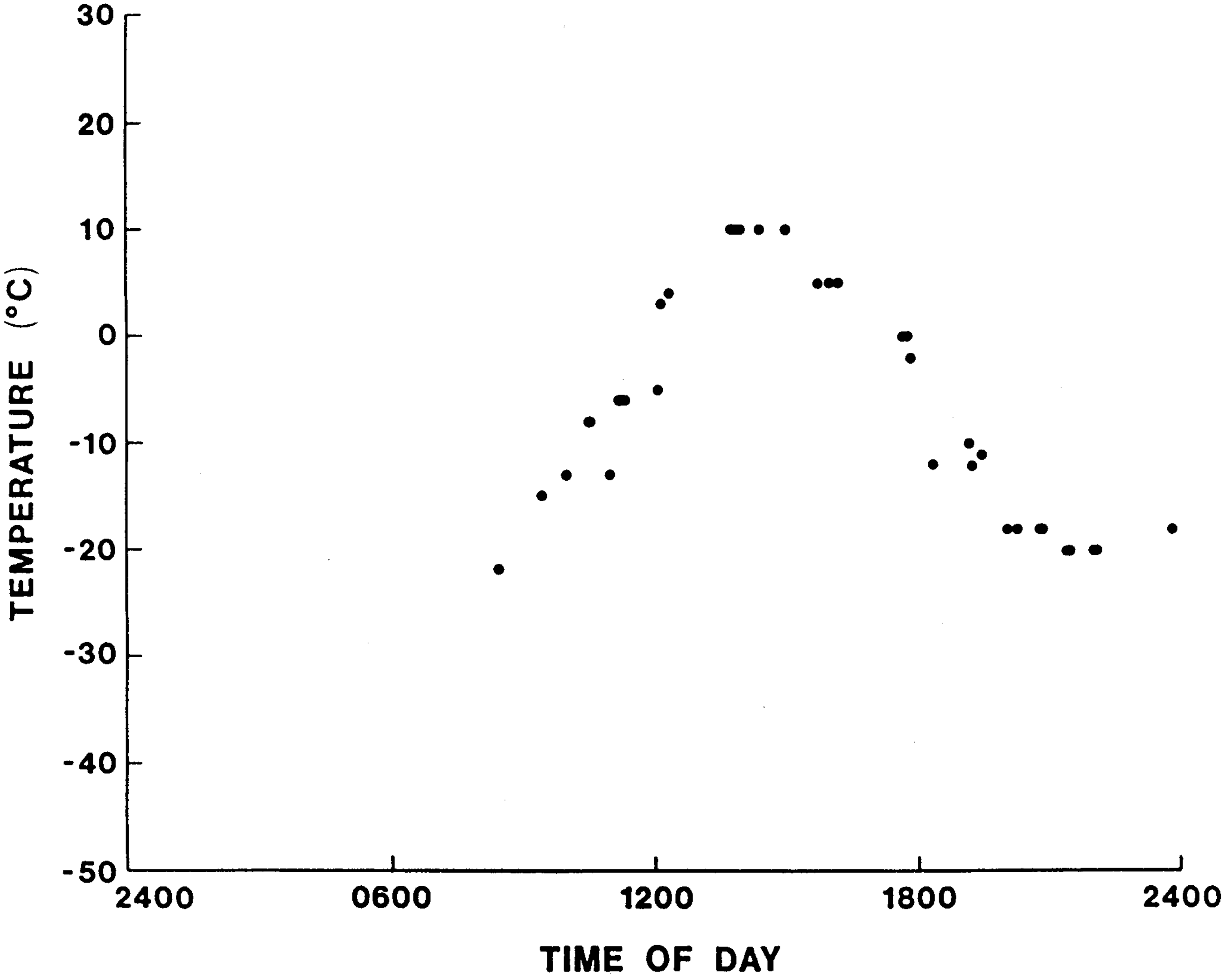

Figure 42. The range of ambient temperature readings taken during 2 April 84.

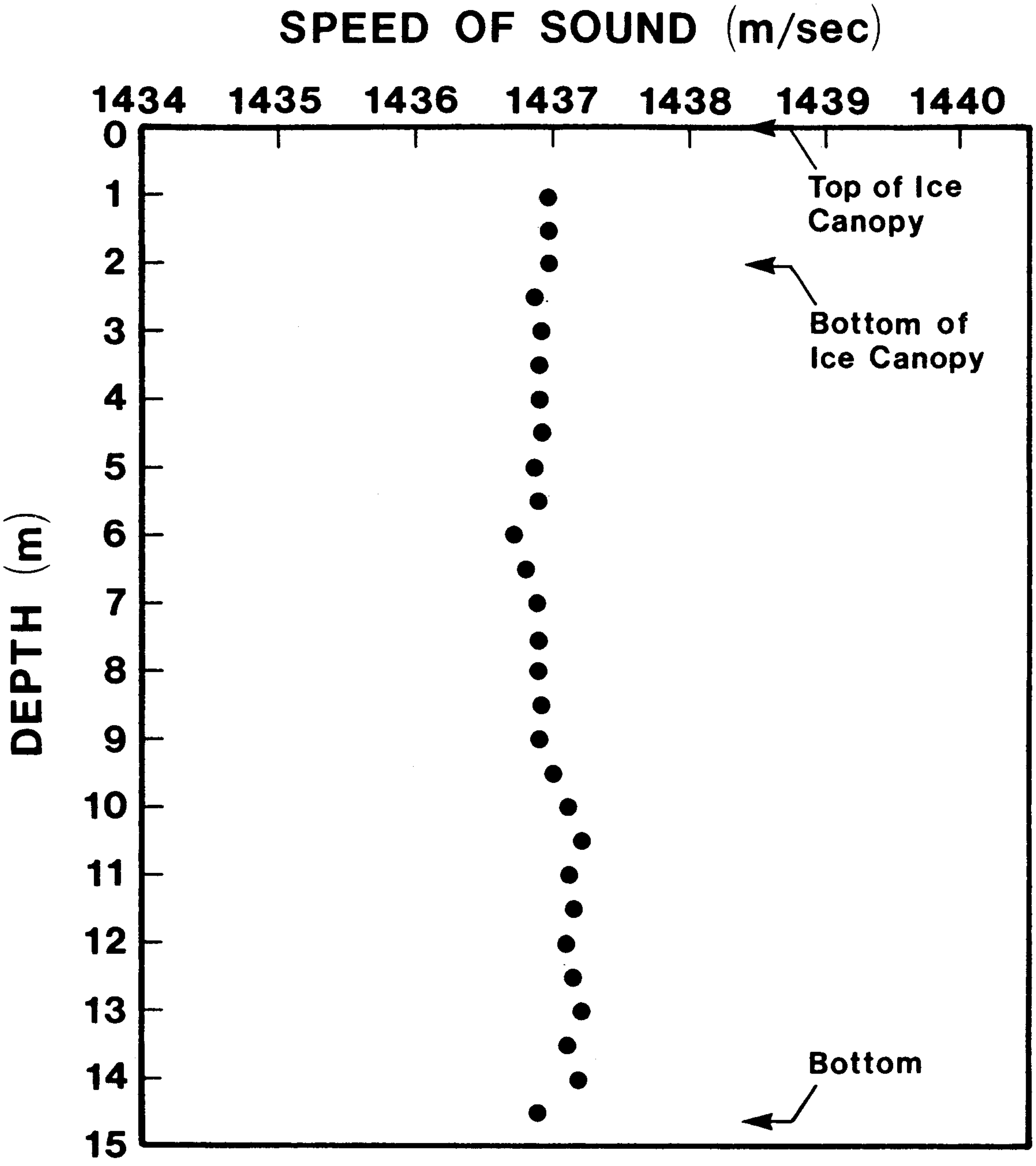

Figure 43. Speed of underwater sound vs depth as measured in Kotzebue Sound at the study site, 25 March 1984. The upper three measurements were in seawater in the drilled hole.

C. Other Recorded Sounds

Low frequency pulses

On more than 36 occasions during the overall recording period, a series of low frequency pulses (LFP) was recorded. These signals occurred in trains of varying total duration from 3 to 16 sec. The pulse-pulse interval was about 95 ms, and the fundamental frequency within a pulse was about 106 Hz (Fig. 44). The amplitude varied between pulses, but the received signal-to-noise ratio of a train was typically 26 dB. The temporal onset of the pulse train was very slow vs an abrupt off ramp.

LFP's originated from an offshore direction, but we were unable to localize them due to the limited size of the hydrophone array. They appeared to be of man-made origin, but we do not know the specific source of these curious sounds.

The onset of LFP's was rapidly followed by a series of ringed seal vocalizations consisting of quacking barks, squeaks and rubs on 31 of the 36 noted occurrences. The vocalizations occurred during the LFP trains, and they decreased when the trains stopped.

Water

Occasionally, we recorded dripping on the water's surface. Aurally, the sounds closely resembled those from pouring a small amount of water from a cup on the surface of a large volume of water. They were broadband sounds extending up to 10 kHz. The waveform of part of such a series of dripping sounds and the spectrum of another appear in Figs. 45 and 46. We have recorded these sounds before near Prudhoe Bay and Barrow.

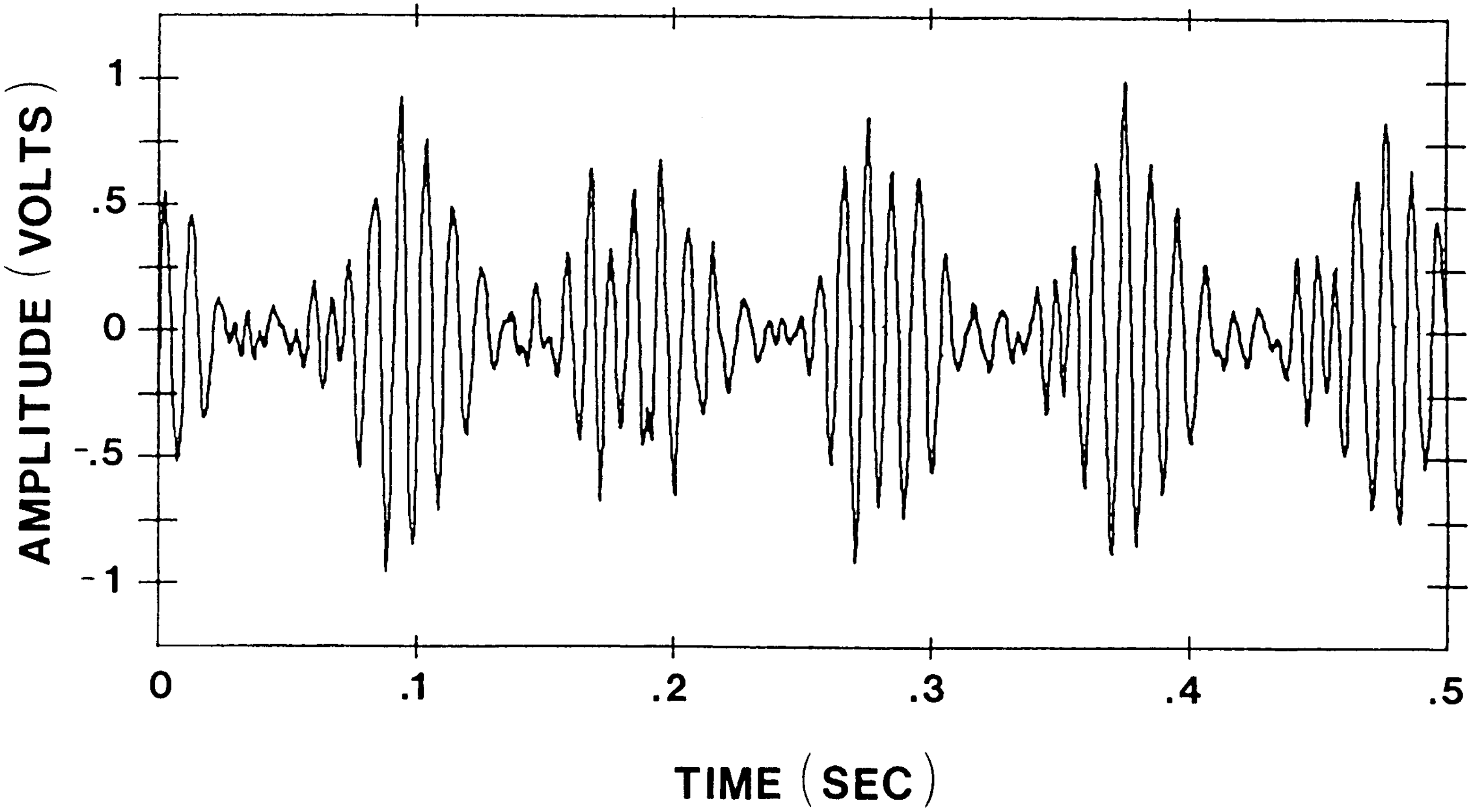

Figure 44. Waveform of a section of a Low Frequency Pulse train showing nearly five pulses.

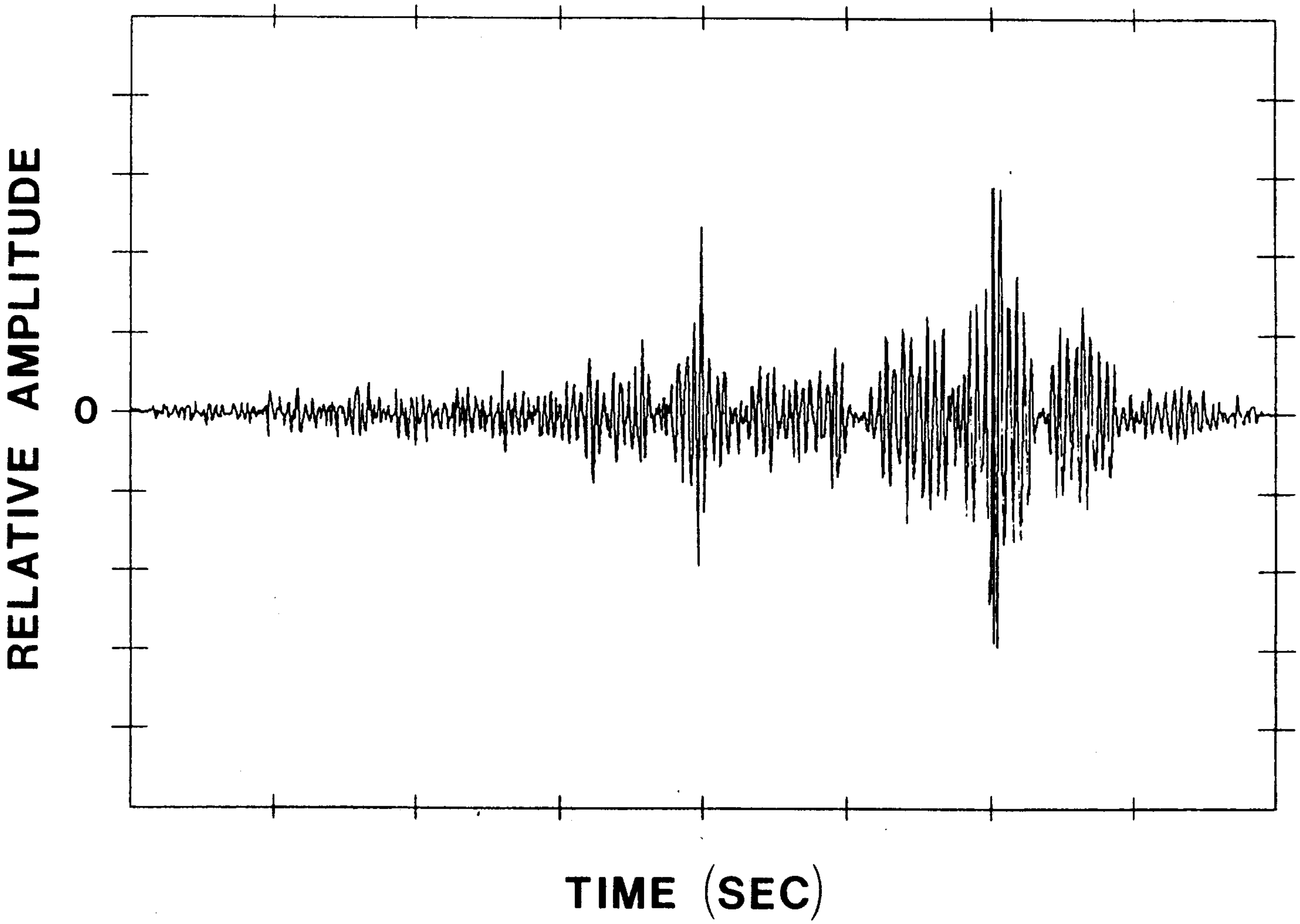

Figure 45. Waveform of water dripping sounds recorded from the triangular array.

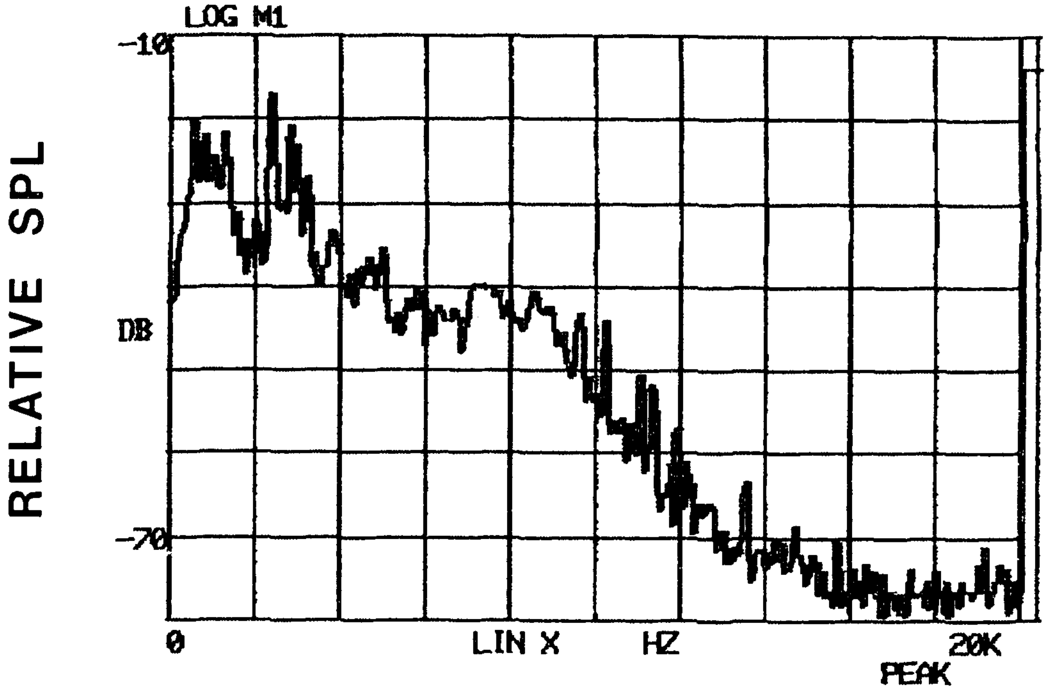

Figure 46. Peak spectrum of water dripping noise recorded from hydrophone A, 6 sec duration, analyzing filter bandwidth, 75 Hz.

Ice

During times of drastic temperature reduction, especially when the temperature dropped to around -30°C for a day or two, we experienced very active ice sounds that resembled sharp cracks followed by reverberation. A particularly active period was 6, 7, 8 April. Fig. 8 exemplifies the waveforms of ice cracking sounds, as does Fig. 11 which shows the arrivals of an ice cracking sound at separate hydrophones, A and C, and their cross-correlation function. Onsets of these sounds were always very fast and followed by a much slower decay rate.

Peak spectra of an ice cracking sound are given in Fig. 47. The source spectrum level of an ice cracking sound is displayed versus frequency (Fig. 48). The spectrum was previously shown in terms of power spectrum density (Fig. 9). The level given by the curve is the source level at the indicated frequency in a 1 Hz frequency band relative to 1 μPa at 1 m. Figs. 9, 47, 48 show that the frequency region of highest energy is 500-1500 Hz.

The positions of nine ice cracking locations are given in Fig. 55. All were associated with active areas of ice as revealed by their locations at ridges or refrozen cracks.

Chukchi Sea

Our purpose in recording from this site (192 km offshore of the triangular array) was to compare the bioacoustic activity there with what was being recorded in Kotzebue Sound. We saw only one open fracture on the way out to this offshore site, at about one-half the distance. The fracture, judged to be about 4 m wide, ran parallel to the International Date Line. Although limited flight time and fuel precluded further exploration, we could see several seals hauled out along the fracture's edge. These were mostly bearded and some ringed seals, including pups. When we did reach the intended recording site, the recording time was also limited because it was not possible to shut down the engine of our single engine plane for any longer than about two hours in such cold.

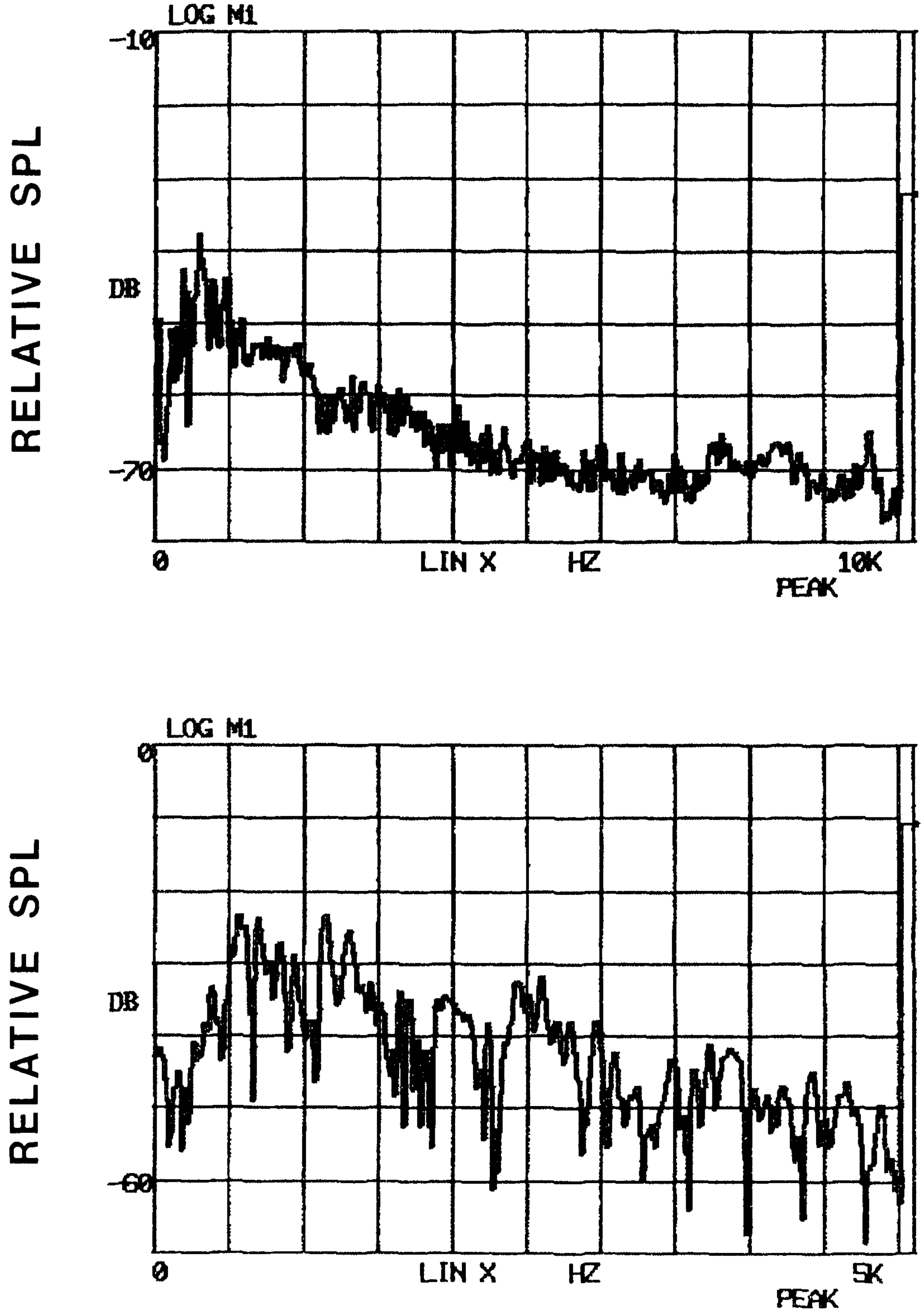

Figure 47. Peak spectra of ice cracking sound over two different bandwidths, 2151 hrs, 7 April 1984, analyzing filter bandwidth, 37.5 Hz, upper, 18.8 Hz, lower.

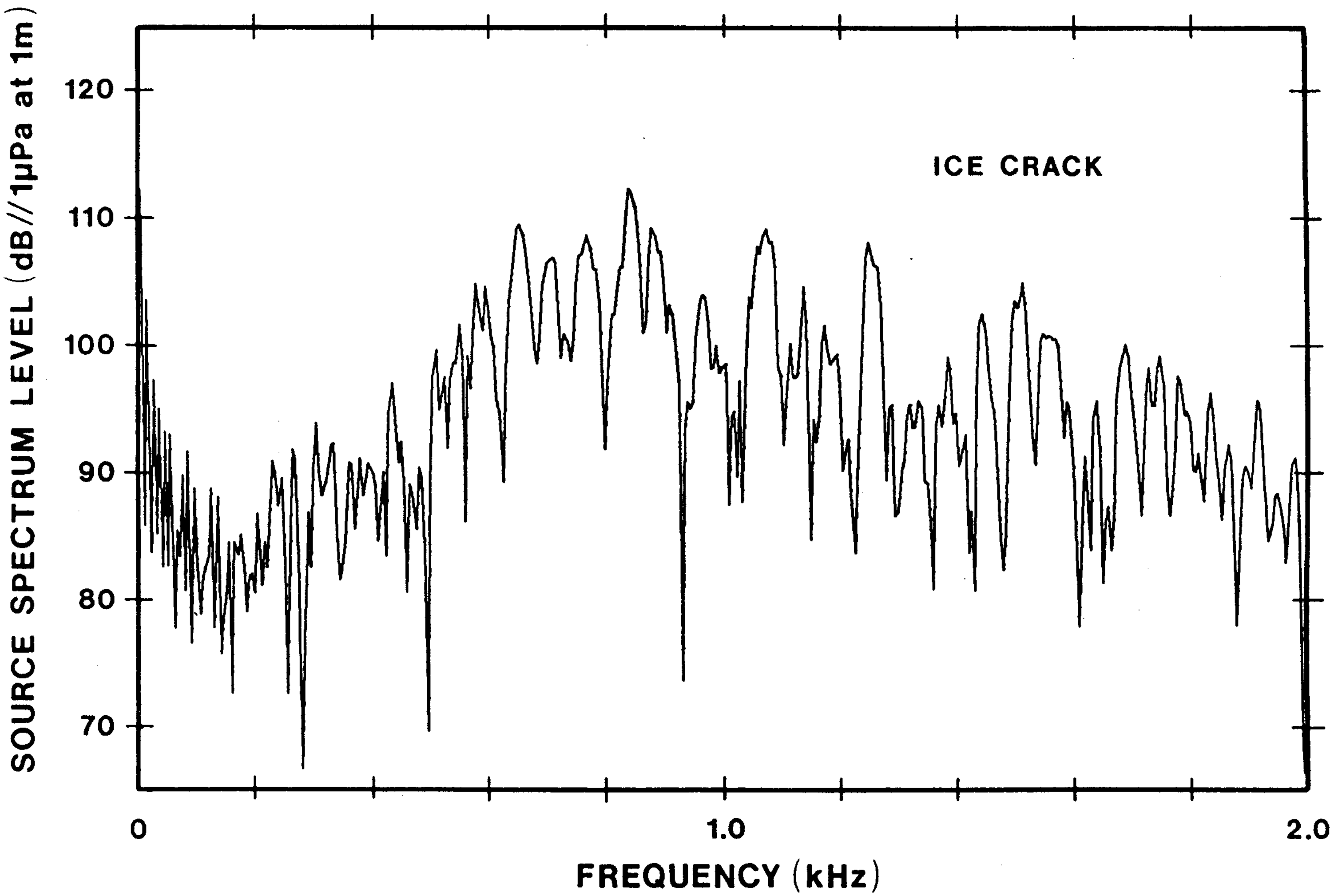

Figure 48. Source spectrum level (per Hz) of an ice cracking transient sound from a low ice ridge 500 m from the hydrophone, Kotzebue Sound.

By far, the predominate sound in this region of the Chukchi Sea was bearded seal trills. The spectra (Fig. 49) were just like those from our previous recordings of bearded seals off Barrow. We also recorded ringed seal rubs and quacking barks in the Chukchi Sea. As evidenced by the wide refrozen polynya that we recorded under and the neighboring high ridges and cracks, this was an area of active ice which appeared to be a shear zone. The water was 44 m deep at this location.

D. Localization

The triangular array of hydrophones was designed for determining where ringed seal sounds originated (see METHODS). Cross correlation functions yielded the sound arrival time differences used in the localization algorithm. Table 5 lists the true bearings of located sounds and their ranges from hydrophone A. As seen in this table, the located sounds originated from as far away as 711 m, as in the case of ice cracking sounds. Located seal scratches were 55-88 m distance; rubs, 19-158 m; squeaks, 82-89 m; and quacking barks, 17-107 m.

The localizations for several sound categories are given in Figs. 50 through 53. All of the located seal sounds appear in Fig. 54 and the ice sounds are in Fig. 55.

E. Response to Playback

A comparison was made of the frequency of occurrence of a total of 2,947 ringed seal vocalizations over test periods before and after noise playbacks. This involved monitoring 148.5 hrs of recordings. (See METHODS for a description of the noise sources.) In addition to expected constraints imposed by recording and playback schedules, the rationale for choice of test periods included "acclimation" sessions following playbacks. These consisted of 6 hrs of quiet after the first playback of seismic exploration and related noise, and 23 hrs of quiet after the playback of random and 1 kHz noise.

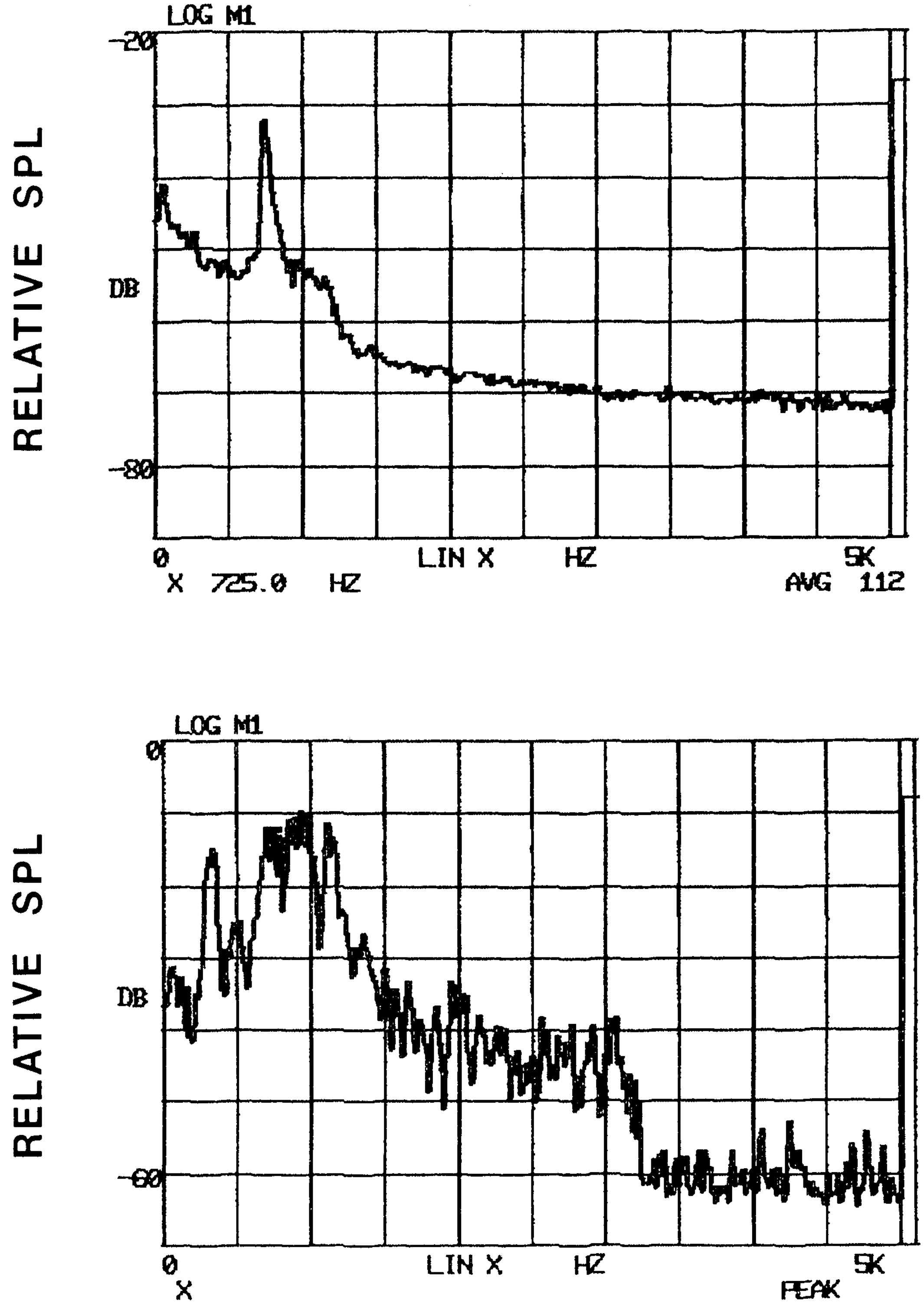

Figure 49. Spectra of Chukchi Sea recordings. Averaged spectra showing peak at 725 Hz from bearded seal trill (upper) and peak hold spectra over 10 sec duration (lower) containing multiple bearded seal trills and ringed seal barks, analyzing filter bandwidth, 12.5 Hz.

Table 5. Compilation of bearings and range of some sounds selected for localization, referenced to hydrophone A.

SOUND CATEGORY	BEARING (^{o}T) ^{o}T = True bearing degrees.	RANGE (M)
Scratches	66.2	55
"	19.9	61
"	42.8	79
"	30.9	71
"	43.0	83
"	41.7	81
"	41.3	80
"	354.6	88
"	354.5	88
Rub	14.3	158
"	108.9	146
"	152.8	23
"	353.4	90
"	271.8	21
"	273.9	19
"	355.1	88
Squeak	42.6	82
"	355.6	89
Quacking bark	0.5	105
"	351.1	107
"	358.9	106
"	5.3	86
"	351.8	106
"	289.3	17
Ice crack	26.8	221
"	240.0	252
"	28.2	390
"	171.9	711
"	100.3	76

Table 5, continued

SOUND CATEGORY	BEARING (^{o}T)	RANGE (M)
Ice crack (cont'd)		
"	174.5	597
"	287.2	586
"	265.7	147
"	166.0	143
"	169.7	136
"	4.7	111
"	91.1	8
Ice knock	12.2	69

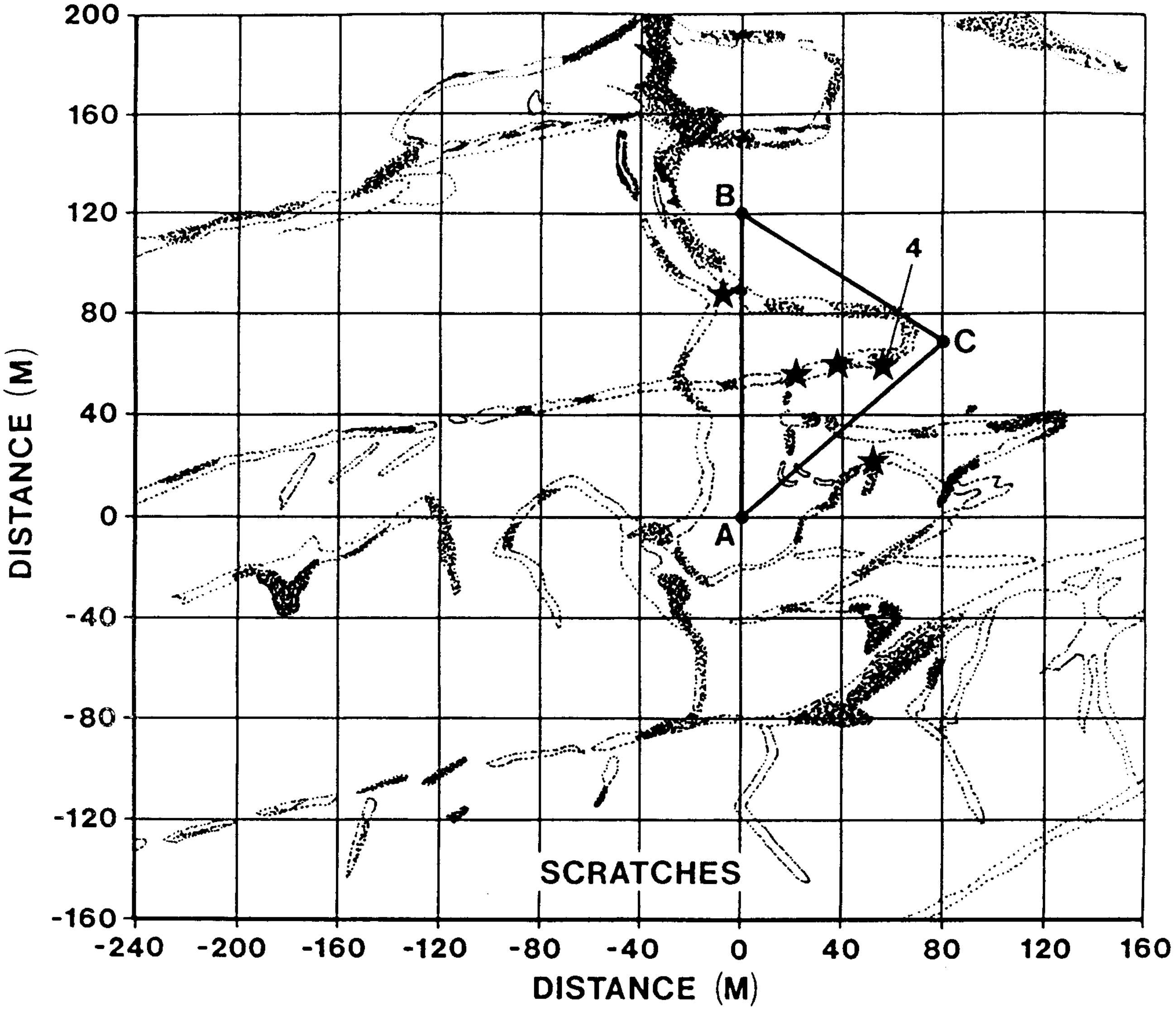

Figure 50. Positions (shown as stars) of eight scratching sound sources from ringed seals in or near the triangular hydrophone array. The number "4" indicates four sound sources.

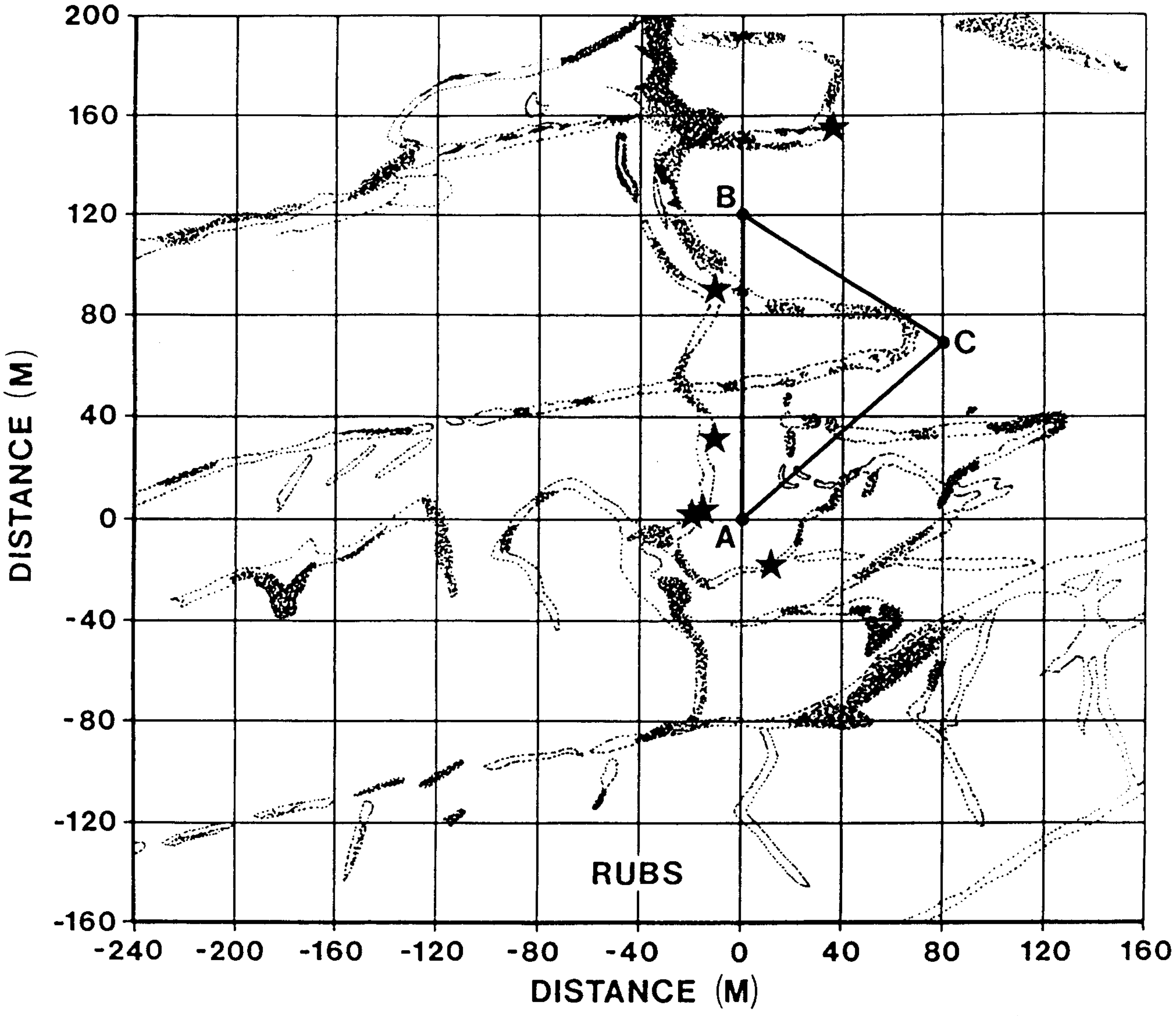

Figure 51. Positions (shown as stars) of five rub sound sources from ringed seals near the triangular array.

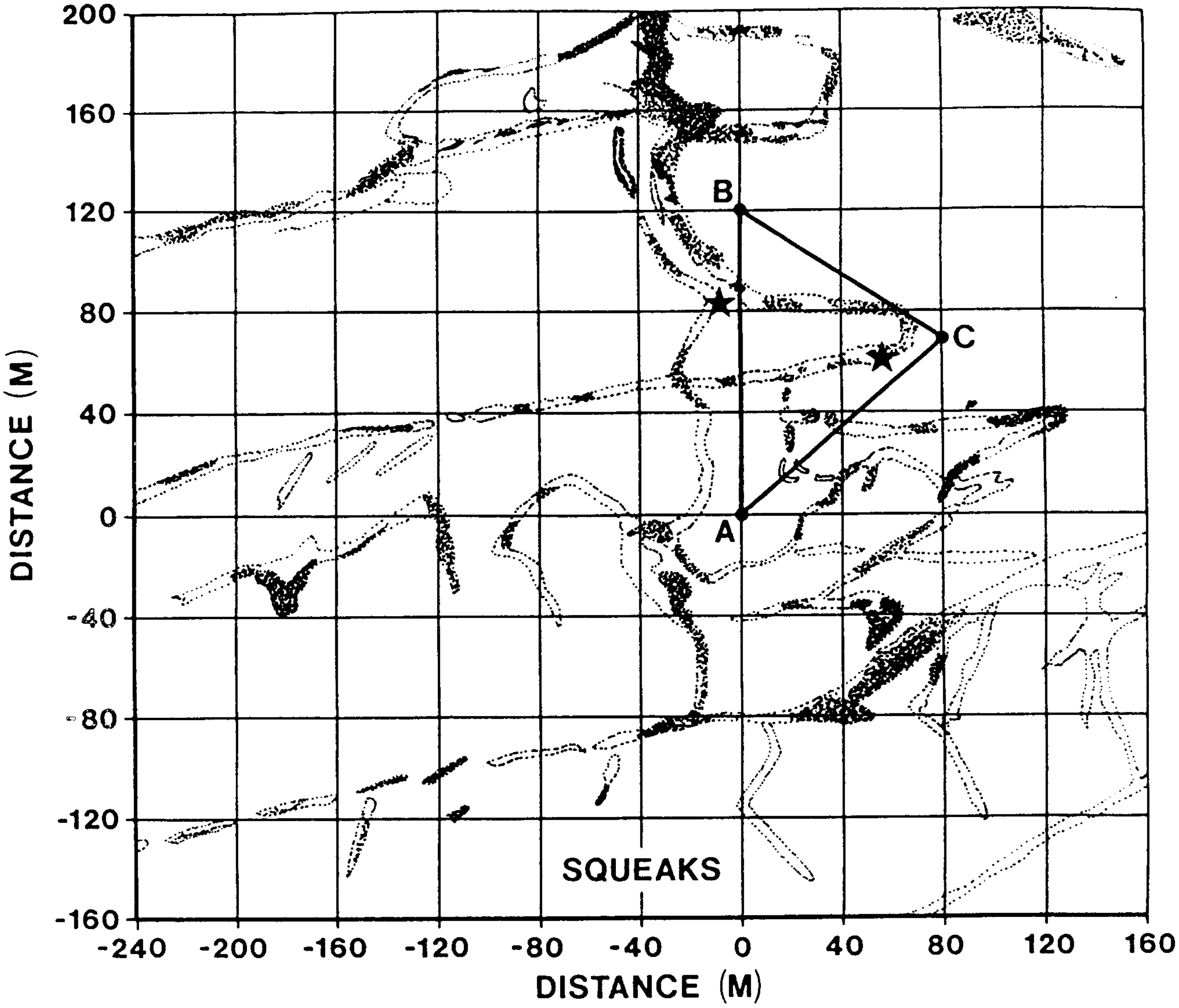

Figure 92. Positions (shown as stars) of two squeak sound sources from ringed seals in or near the triangular array.

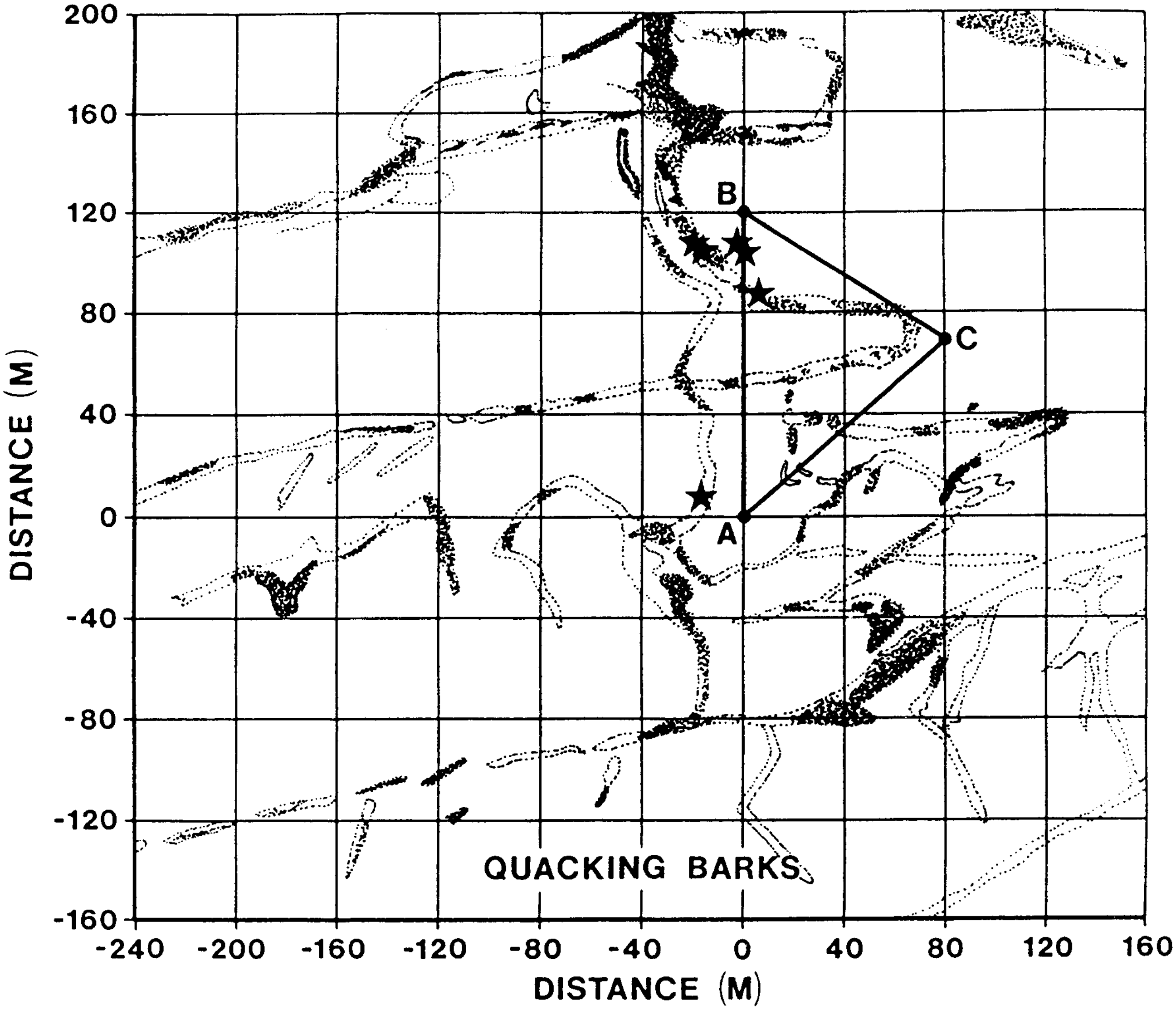

Figure 53. Positions (shown as stars) of six quacking bark sound sources from ringed seals in or near the triangular array.

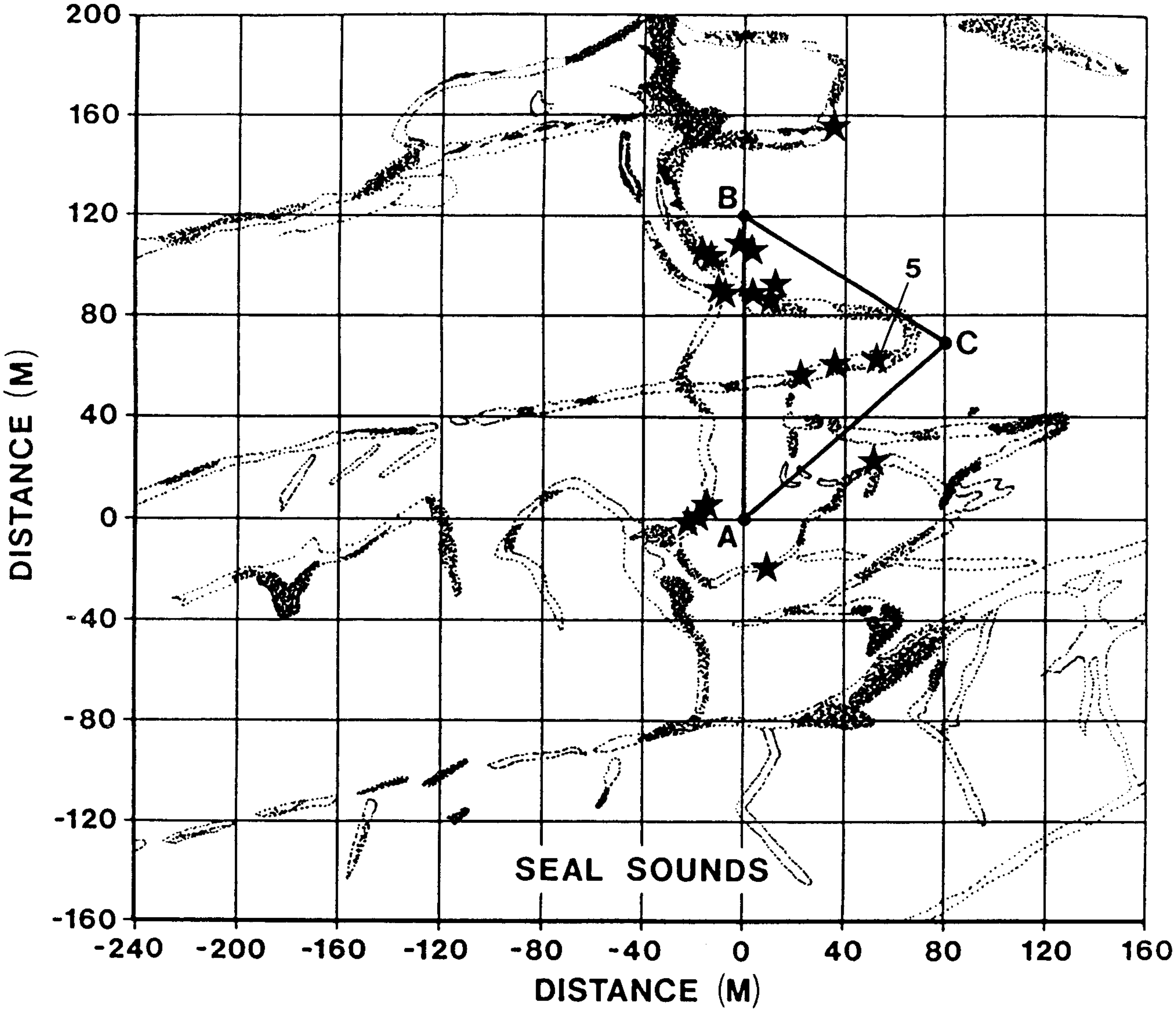

Figure 54. Positions (shown as stars) of all of the localized seal sound sources in or near the triangular array. The number "5" indicates five sound sources at one position.

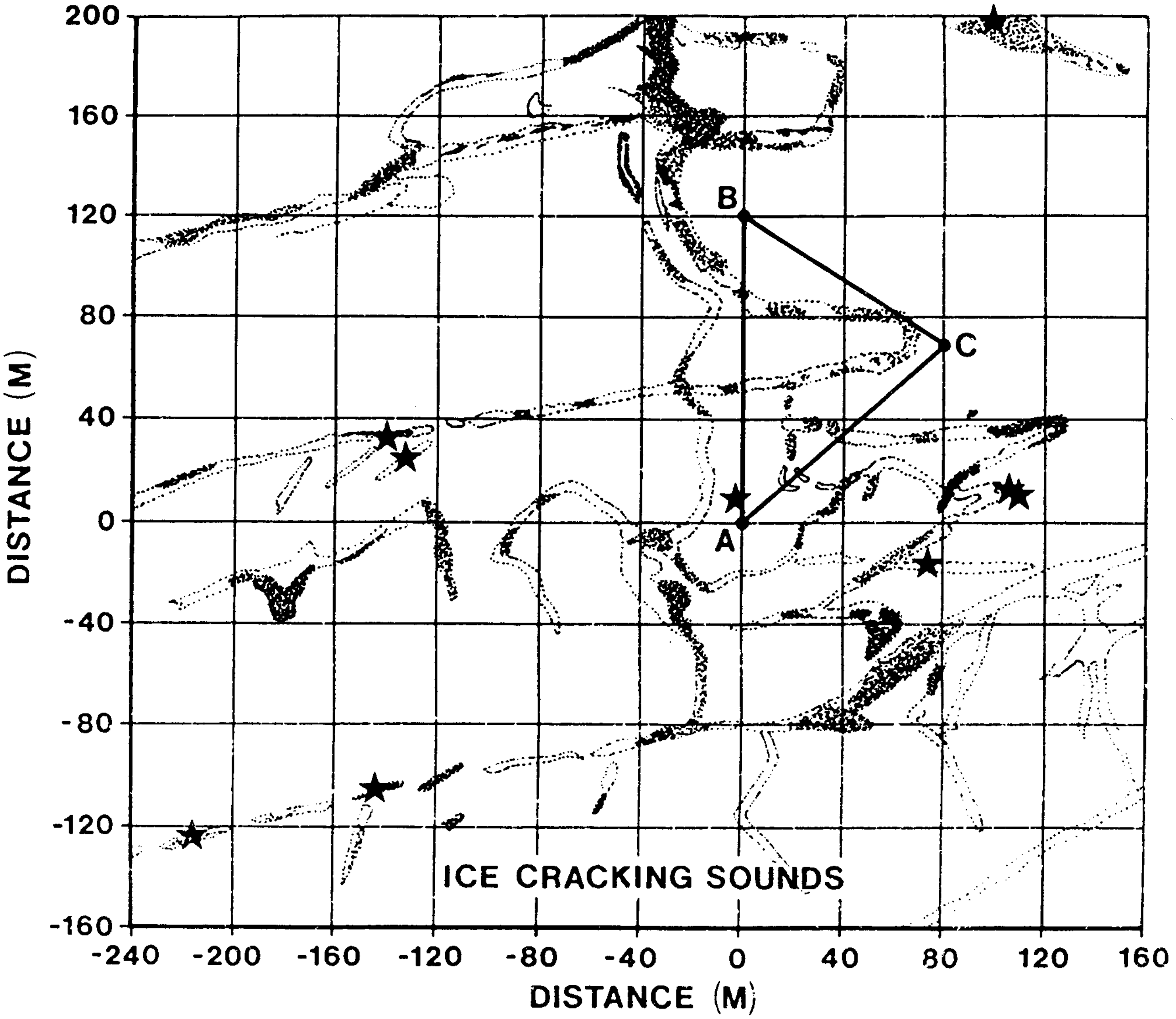

Figure 55. Positions of nine ice cracking sound sources (stars) near the triangular array.

Although vocalizations could be detected during recordings of playback, they could not be accurately counted during these periods because the introduced noise served as a very effective aural masker.

The distributions of the number of sounds/15 min vs number of observations are presented for the designated time periods before and after the given playback periods (Figs. 56 through 59). It was clear that these data could not survive a test of normality required for a parametric statistical test, thus the nonparametric statistic of chi square was used in a single classification test of independence. The data were appropriately grouped to avoid categories containing less than five observations each (Dixon and Massey, 1957; Cochran, 1954, 1963), except for one set of four observations of $\geqq 3$ sounds before Test II, an acceptable allowance (Zar, 1974). The data bases for these tests are tabulated (Table 6).

Data base units were defined as follows: SOUND, the discrete acoustical event counted, e.g., a rub or a quacking bark; SET, a 15-min period during which sounds were counted; CATEGORY, grouped and ungrouped units consisting of the number of sets (15-min periods) per test having a given number of sounds, the same categories being used before playback (defined as the "expected" quantity in the chi square calculation) and after playback (defined as the "observed" in the chi square calculation).

The results of these tests showed that in two cases (Test II, 6 hrs before and 6 hrs after the first playbacks of industrial noise, and Test IV, 23 hrs before and 23 hrs after the second playbacks of industrial noise) there was no significant difference in the occurrence of ringed seal vocalizations before and after playbacks (chi square $0.76 < 3.84$ (.05) 1 deg freedom; chi square $8.99 < 9.49$ (.05) 4 deg freedom, respectively). In the other two cases (Test I, 3 days before and 3 days after all playbacks, and Test III, 10 hrs before and 10 hrs after the playbacks of random and 1 kHz noise) the null hypothesis of no significant difference in the occurrence of ringed seal vocalizations was rejected (chi square $594.82 > 7.82$ (.05) 3 deg freedom; chi square $7.59 > 5.99$ (.05) 2 deg freedom, respectively). Results of these statistical tests are summarized in Table 7.

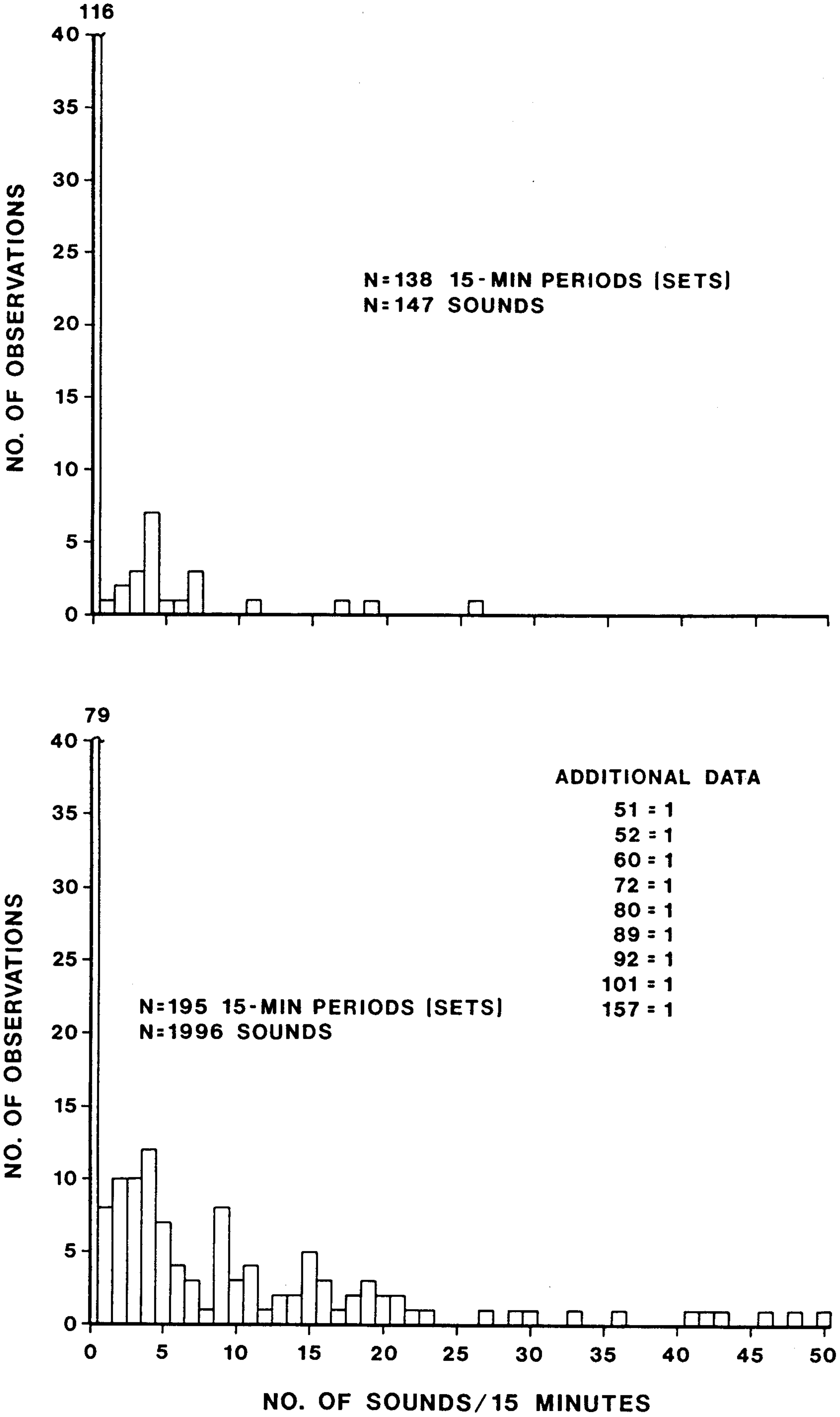

Figure 56. Distribution of numbers of ringed seal vocalizations/ 15 min periods over 72 hrs before any playback of man-made noise (upper) and 72 hrs after all playbacks (lower).

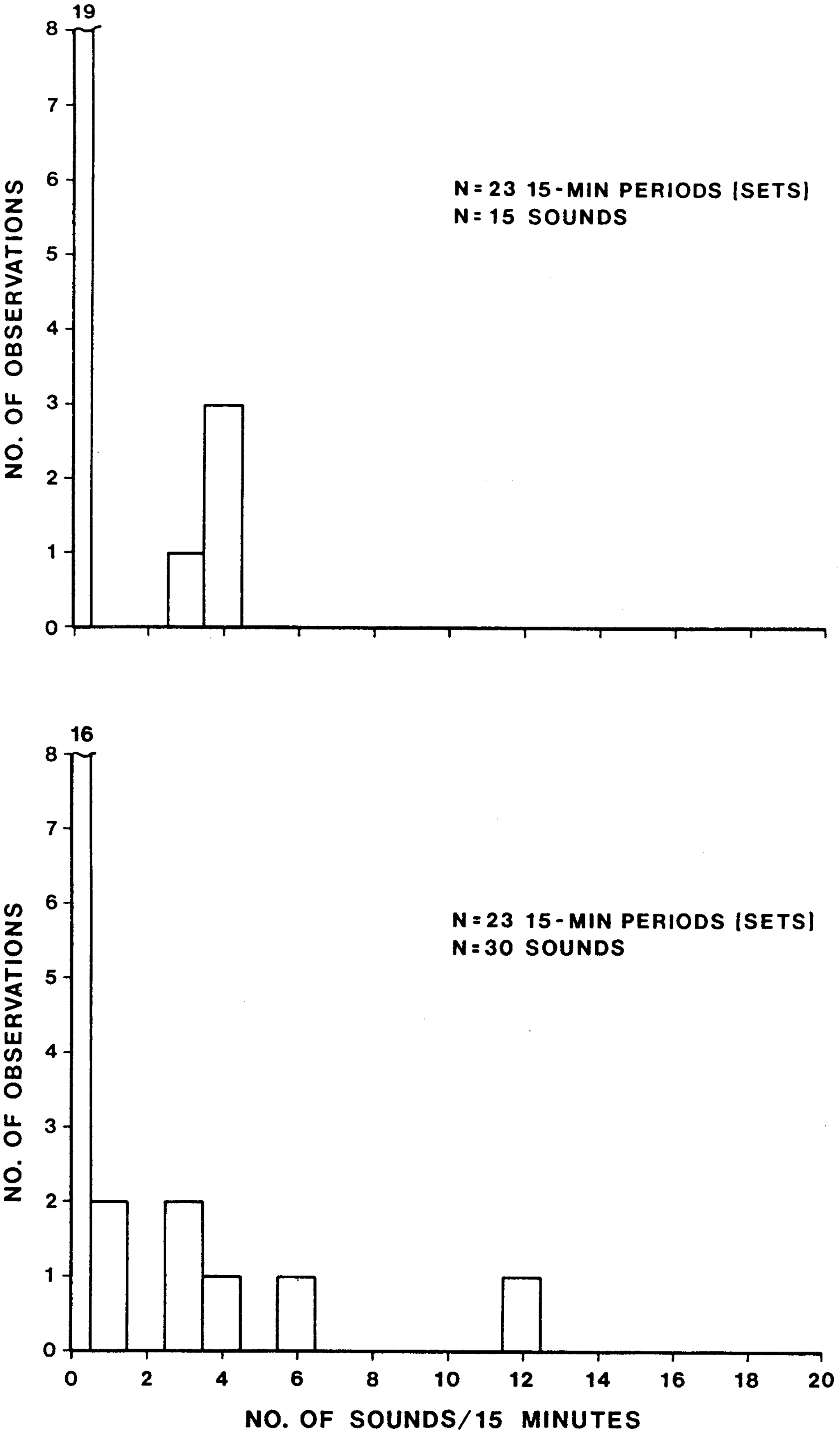

Figure 57. Distribution of numbers of ringed seal vocalizations/ 15 min periods over 6 hrs before playback of Vibroseis and related noise (upper) and 6 hrs after (lower).

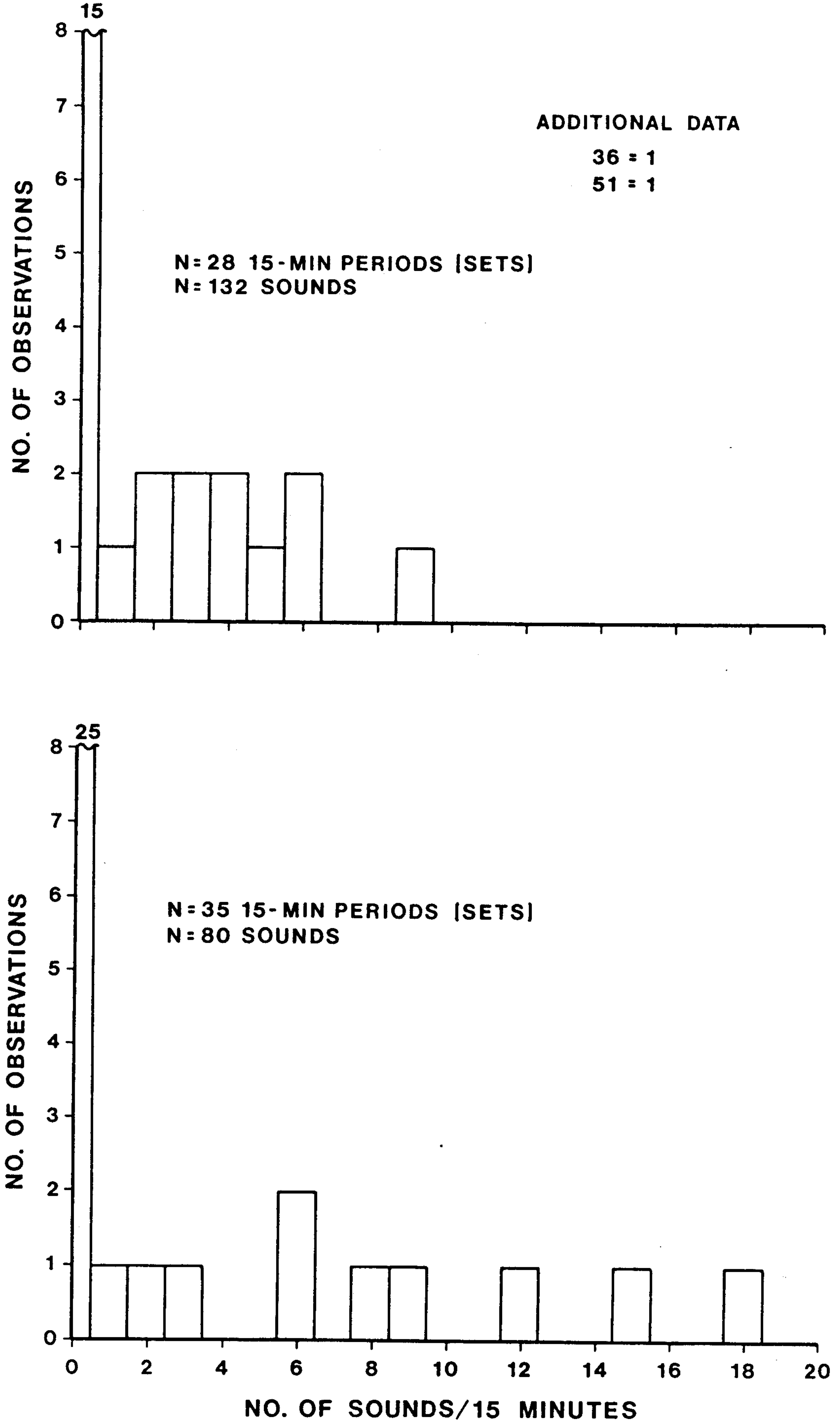

Figure 58. Distribution of numbers of ringed seal vocalizations/15 min periods over 10 hrs before playback of random and 1 kHz noise (upper) and 10 hrs after (lower).

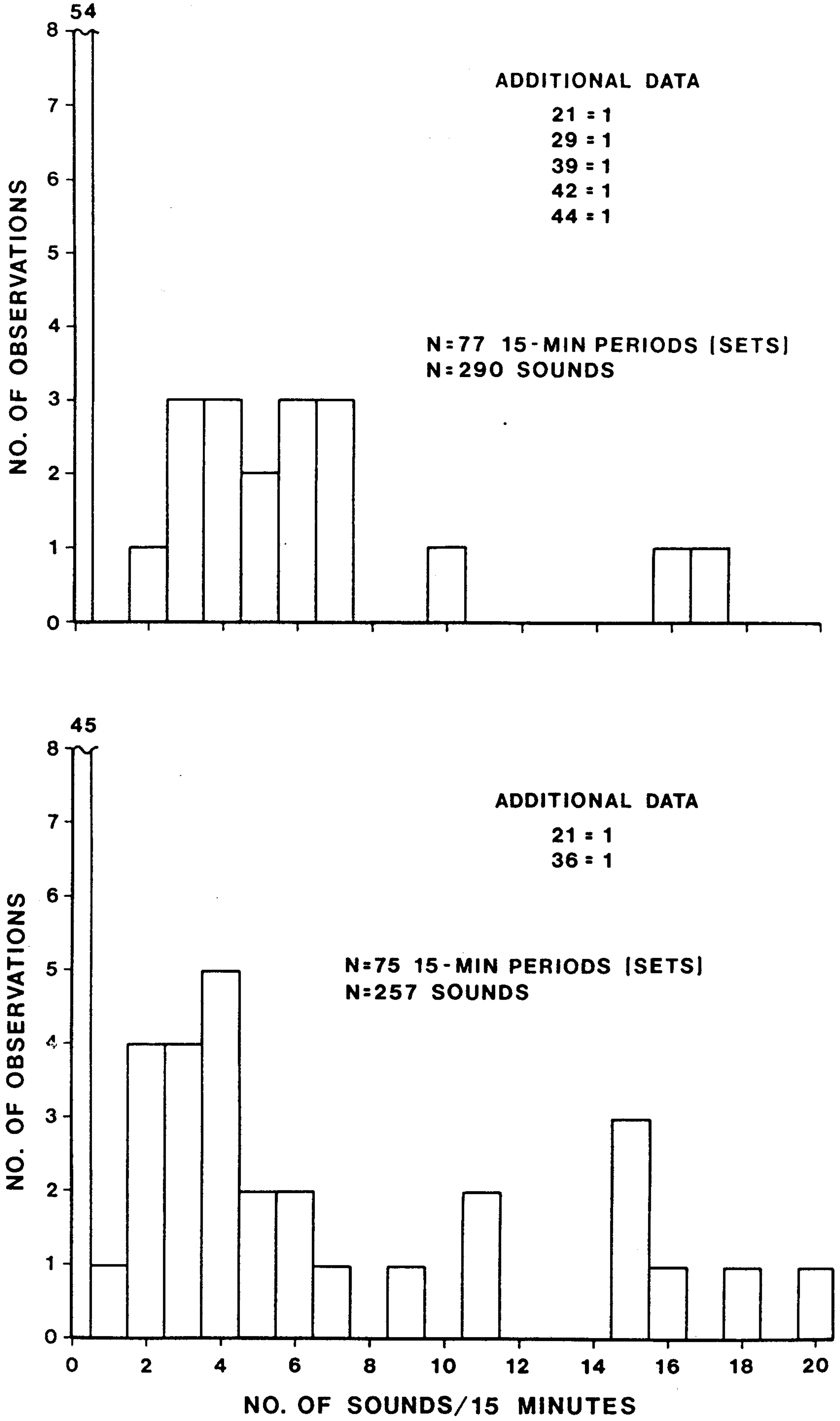

Figure 59. Distribution of numbers of ringed seal vocalizations/ 15 min periods over 23 hrs before third playback (Vibroseis and related noise, upper) and 23 hrs after (lower).

Table 6. Data base for chi square tests of independence.

TEST I

THREE DAYS BEFORE/AFTER ALL PLAYBACK OF NOISE (INDUSTRIAL, RANDOM, 1 KHZ)

EXPECTED (BEFORE)		OBSERVED (AFTER)	
Categories (No. Sounds)	Sets (15-min Periods)	Categories (No. Sounds)	Sets (Observations)
0	116	0	79
1-3	6	1-3	28
4	7	4	12
≧5	9	≧5	76
Σ147[1]	Σ138	Σ1996[1]	Σ195

TEST II

6 HRS BEFORE/AFTER FIRST PLAYBACK OF INDUSTRIAL NOISE[2]

EXPECTED (BEFORE)		OBSERVED (AFTER)	
Categories (No. Sounds)	Sets (Observations)	Categories (No. Sounds)	Sets (Observations)
0-2	19	0-2	18
≧3	4	≧3	5
Σ15	Σ24	Σ30	Σ23

TEST III

10 HRS BEFORE/AFTER FIRST PLAYBACK OF RANDOM AND 1 KHZ NOISE

EXPECTED (BEFORE)		OBSERVED (AFTER)	
Categories (No. Sounds)	Sets (Observations)	Categories (No. Sounds)	Sets (Observations)
0	15	0	25
1-3	5	1-3	3
≧4	8	≧4	7
Σ132	Σ28	Σ80	Σ35

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[1] These sums represent the actual number of sounds in the two sides of each test.

[2] Yates correction for continuity applied since d.f. = 1, Test II.

Table 6. Continued

TEST IV

23 HRS BEFORE THIRD PLAYBACK (INDUSTRIAL NOISE)

EXPECTED (BEFORE)		OBSERVED (AFTER)	
Categories (No. Sounds)	Sets (Observations)	Categories (No. Sounds)	Sets (Observations)
0-1	54	0-1	46
2-4	7	2-4	13
5-6	5	5-6	4
7-16	5	7-16	8
≧ 17	6	≧ 17	4
Σ 290	Σ 77	Σ 251	Σ 75

Table 7. Summary of chi square single classification tests of independence for the occurrence of ringed seal vocalizations before and after designated playback experiments.

TEST	NOISE	PLAYBACK DURATION(HRS)	MONITOR DURATION(HRS) BEFORE	MONITOR DURATION(HRS) AFTER	x^2	DEG FREEDOM	$x^2(.05)$	NO SIGNIFICANT DIFFERENCE
I	All	14.6	72	72	594.82	3	7.82	REJECT
II	Industrial	6.3	6	6	0.76	1	3.84	ACCEPT
III	Random, 1kHz	4.7	10	10	7.59	2	5.99	REJECT
IV	Industrial	3.6	23	23	8.99	4	9.49	ACCEPT

F. Vocalization Roles

The last of our research objectives for this study was to describe any apparent roles of ringed seal vocalizations. Our understanding from John Burns (ADFG) and the sponsors was that reproductive behavior e.g., pupping, at this location, would increase over the assigned study period. The noted increase in the frequency of occurrence of vocalizations (Fig. 29), especially the commonly occurring rubs, squeaks, and quacking barks, would indicate that these sounds may be an integral part of the reproductive behavior. However, the only recorded seal sound category known to be associated with a particular overt behavior was scratching, which was not a vocalization and which showed no apparent positive correlation with heightening of the breeding season (Fig. 31, lower).

VI. DISCUSSION AND SUMMARY

A. Ringed Seal Sounds

Considering that scratching comprised about 80% of the recorded seal sounds, the relatively small remainder (4,631) indicated that ringed seals did not produce many vocalizations during this study, compared with other pinnipeds. We believe this is a significant finding in view of the 245 hrs of recordings, not including the summation of recording effort during simultaneous multi-channel data accession. On the other hand, we do not know the population density within the maximum acoustical detection range (MADR) for these sounds.

In order of decreasing frequency of occurrence, the major vocalization sound categories were rubs, squeaks, and quacking barks. Most of the energy of these sounds was below 4 kHz, and source levels of located sounds ranged from 95 to 130 dB re 1 μPa, 1 m. All were of a transient nature, but they often appeared in short volleys.

Compared with other marine mammal sounds, e.g., large and small whales and other pinnipeds, ringed seal vocalization source levels are not very impressive. The MADR in the natural environment that prevailed during this research probably did not exceed 1 km. Low source level implies two consequences of importance to this study. First, their vocalizations would be of limited use in a population enumeration study because the radius of coverage (MADR) would be comparatively small. Moreover, their sound production is relatively infrequent. Second, masking by man-made or other noise would be more easily facilitated, i.e., vocalizations would be more susceptible to acoustic noise masking.

Scratching (presumably for hole or lair maintenance/building) was a very common activity. Detectable sound energy extended up to 10 kHz, with peak frequencies from 1-4 kHz. These were broadband signals that numbered nearly 20,000 during the study. The source level measured about 100 dB re 1 μPa, 1 m, with implications similar to those of vocalizations except the masking of these sounds by noise may not be as important, behaviorally, as with vocalizations. Since scratches are so common, they could possibly be of great utility in assessing distribution or relative abundance, unlike vocalizations.

In terms of frequency (Hz) and duration of "yelps" and "barks" described by Stirling (1973) and Stirling et al. (1983), it appears that those sounds and the rubs, squeaks, and quacking barks of our study are very similar. For the reasons given, in our opinion, with the major exception of scratches, the ringed seal sounds recorded by us probably would not have been very useful as a tool for studying distribution or abundance (see Stirling et al., 1983). Those researchers also noted an increase in sound production (late April) as pupping increased.

B. Frequency of Occurrence

The rate of ringed seal vocalizations increased markedly in the area of our operation, beginning about 5 April 1984. Sounds after this date became more prevalent each day, with the overall effect being a six-fold increase/day. We believe that this reflects an increase of breeding activity expected for this period.

In the search for any notable diurnal (daily) periodicity of ringed seal sound production, it first appeared that sonic activity was bimodal (1100 and 0130 hrs). However, by studying the occurrence of individual sounds, the bimodality was found to be the result of scratching periodicity about these times. Vocalization frequency was only slightly dependent upon time of day, with possible periodicities of 2 and about 7-hr cycles as revealed by FFT. More vocalizations occurred during the daylight hours compared to darkness.

Scratching occurred in bouts of 1-126 sounds (mode 4, median 11). Scratching bouts were up to 101 sec in duration and as many as 34 bouts were recorded in two hours. Bouts occurred in series.

Physical Factors and Sound Production

Measurements were made of four physical factors: ambient surface light, windspeed, ambient air temperature, and underwater sound speed. We studied the possible association of the first three with ringed seal sound occurrences, and sound speed (mean of 1437 m/sec) was needed for localization of sounds.

The pooled light measurements varied from 450-570 μWatts/cm^2 (0930-1800 hrs) and peaked at about 1400 hrs. Dividing the days into light and dark periods (0600-2100 and 2100-0600 hrs) statistically more vocalizations appeared during the light hours.

When all data during the measurable (light) hours were considered, there was not a statistical correlation between light measurements and vocalization sound counts. On the other hand, more ringed seal vocalizations/hr occurred during the light hours, as compared with dark hours.

There was a significant negative correlation between the number of vocalizations and windspeed. However, this probably is not of biological significance because high windspeeds acoustically masked the presence of the sounds. Conversely, vocalizations were more apparent during lower windspeeds (lower ambient noise).

There was a statistical negative correlation between temperature and vocalization sound production. Surprisingly, the occurrence of scratching sounds was not correlated with temperature. We fully expected more scratching with lower temperatures. The fact that we did not find this relationship may have been due to the fact that the water temperature remained the same, the surface of the holes received protection from the wind and perhaps some insulation from the overlying snow and/or ice, and it was below freezing for virtually the entire duration of the study. On a longer term basis, with ambient temperatures ranging from nearly -40^{0} to 15^{0}C above freezing, one would expect such a correlation, especially during break-up.

Since the number of vocalizations was negatively correlated with both windspeed and temperature, we looked at the possible association between these two environmental variables over the duration of the study. They were not statistically correlated, thus there was indication of an indirect effect between temperature and sound production. We did notice that seals were up, presumably sunning themselves on the ice during the warmest days, which may explain why the number of underwater sounds was less during higher temperatures. As indicated, higher winds increase ambient noise and thus produce more masking of the seal sounds. These two findings, at least in part, may be responsible for the above noted negative correlation.

Sound Speed and Propagation

Under winter conditions, in water as shallow as 15 m such as at our study site, the classical models of propagation (e.g., Urick, 1983) do not apply. The situation in shallow water is compounded by the contiguity of under-ice and sea bottom boundaries, and the relative size of the ice keels and hummocks (WMO, 1970) in comparison to the water depth.

Although it is also frought with complexity, deep water under-ice propagation is normally characterized by significant upward refraction, as the result of a positive sound velocity profile gradient, and wavelength-related downward reflection, from the undersurface of the ice canopy (Welsh et al., 1984). Our sound speed measurements, taken for a representation of the on-site conditions (i.e., 1437 m/sec) needed for sound localization, indicated a very slight positive gradient, beginning at about 9.5 m. For an indication of the importance of the location and depth of the sound source and receiver in shallow ice-covered water, the reader is referred to an account of our OCSEAP supported, brief study of sound propagation in 10 m of water at Prudhoe Bay (Cummings et al., 1981).

C. Other Recorded Sounds

Outstanding underwater sounds, other than seal vocalizations and scratches, consisted of our playbacks of "industrial", random and 1 kHz noise, ice and water sounds.

Ice cracking sounds were most prevalent during periods of steadily decreasing temperature. They are best described as thermal cracking from tensile stresses in the ice structure that are associated with falling air temperatures. Others (e.g., Milne, 1972; Dyer et al., 1984; Welsh et al., 1984) have described such sounds, but we may have been the first to localize the sounds and report source levels.

Another sound, originating on the ice, is that from blowing snow grains. Under conditions of high (>25 mph) winds, the broadband noise contribution from this source often masked nearly all seal vocalizations. Such noise intensity is not dependent upon snow grain size, but a flow, and it increases as the cube of windspeed (Milne, 1974).

We believe the recorded water sounds may have been from one or more of three sources: seals hauling out and shedded water dripping back into the access holes, water dripping back after being uplifted with moving ice, and the release of free brine found in small amounts in the ice structure.

The noise characteristics of the playbacks are described in detail in our previous reports of the noise recorded in the presence of on-ice seismic profiling.

Mainly because of its periodicity, regularity in waveform, and source direction (from the Chukchi sea), it appears that the low frequency pulses are of unknown man-made origin. At least, we do not know the origin. The important significance of these sounds is that they invariably caused ringed seals to immediately respond with a session of quacking barks, rubs, and squeaks which dissipated with the cessation of LFP's. Playbacks of these sounds may be a useful interrogation.

D. Localization

Using samples of the most prevalent sounds recorded from the hydrophone array, we located 8 scratch, 5 rub, 2 squeak, 6 quacking bark, and 9 ice crack sounds. Ranges from the reference hydrophone were 8-586 m, and nearly all of the located sounds came from ridges or refrozen fractures.

The association of seal and ice sound locations and these ice features is reasonable. It would be a decided advantage for the seal to frequent ridged ice because the uneven upward surface is more conducive to safe and effective lairs as a result of drifted snow and natural interstices. Refrozen fractures would normally hold thinner new ice, a definite advantage in constructing or maintaining access or breathing holes. The seals would be inclined to continue to use an access hole that had previously been in the open water of a fracture, even when it became refrozen. We located two open access holes and numerous breathing holes in a long refrozen fracture, 4 km north of camp. A common cause of ice cracking is thermally stress-induced, such as the result of progressive coolings. This is precisely what happened at our study site on 7 April when the prevailing noise was ice cracking, an event very likely to occur in ridged or new ice. Ice cracking was not continuous; instead, it consisted of sharp impulses of variable occurrence.

We made no attempt to utilize a statistically significant sample, mainly because the localization effort was not part of the contract. However, the proximity of localized ringed seal sounds (17-158 m) and their relatively low source level indicated that the other recorded sounds also were from nearby animals.

E. Response to Playback

Using three noise playback sessions totalling 14.5 hrs and counting nearly 3000 vocalization sounds over 148.5 hrs of monitoring, we found no statistical evidence that the introduced noise caused any reduction in ringed seal sounds. There was no statistically significant difference in the number of vocalizations before and after each of two sessions of "industrial" noise playback. There was a statistically significant increase in sound production from before to after the four days of the playback experiments, and there was a statistically significant increase from before to after the playback of random and 1 kHz noise. Although the noise levels of playbacks were of sufficient power and appropriate frequency spread to effectively mask many seal vocalizations, the louder sounds could be distinguished, even during playback.

The overall increase in ringed seal vocalization sound production, presumably as breeding activity heightened, appeared to dominate the frequency of occurrence in sound production. An exception to this overall effect may have been the increase noted in the 10 hrs before and 10 hrs after the 4.7 hrs playback of random and 1 kHz noise. We say this because the total monitoring and playback period was just a little more than 24 hrs--perhaps not enough to reflect the longer trend of increase. On the other hand, this day occurred at the beginning of the upward trend in sound production and could have reflected such a difference. A detailed trend analysis during this one day was not practical because of the relatively low number of sounds. On the basis of normalized data, there were nearly six times as many sounds in the latter eight days (which included the playback period) as in the first nine days.

The onset of low frequency pulses, thought to be of man-made origin, resulted in the immediate production of quacking barks, squeaks and rubs. We have no knowledge as to the source or purpose of these pulses that could have been produced by some kind of impulse mechanism hundreds of kilometers away. During periods of elevated natural ambient noise and low level pulses, it was difficult to aurally discern the pulses, but their presence, betrayed by the sudden appearance of barking, squeaks and rubs, could be confirmed using acoustic signal processing. We do not know the behavioral significance of these bioacoustical outbursts, nor even if the long-term upward trend in ringed seal vocalizations may not have been related to our own playbacks of man-made noise. It was not possible to separate the possible factors after only one season of field data. For certain, the noise playbacks did not elicit immediate ringed seal sound production, as did the occurrence of low frequency pulses. *A priori*, we are inclined to believe that the upward trend of sound production during the last eight days of our recordings was probably due to increased breeding activity or some other natural behavior, and not a manifestation of the noise playbacks.

F. Vocalization Roles

Although we apparently had several seals in the study site, sound production was not characterized by any kind of chorusing. In fact, there appeared to be no interchanges of vocalizations on the recordings.

The primary purpose of scratching is not to make sounds, but these sounds could have a behavioral role, such as signals of territoriality.

The sharp and steady increase in the number of vocalizations over the second half of our field work probably was a manifestation of heightened breeding activity and parental care.

VII. RECOMMENDATIONS

(1) Vocalizations among ringed seals, in the behavioral environment and season of the present study, are not very numerous compared with the biological sounds of many other marine mammals, including other pinnipeds. Vocalizations, per se, in the location and circumstances of this study, would probably not be very useful indices to ringed seal population size, relative abundance, population trends, distribution, or many behavioral activities. This does not imply that sound production in ringed seals may not be as significant in this species in terms of a necessary overt behavior. Scratching, on the other hand, is a very common and identifiable sound. It could very well be used as an index to several useful parameters.

(2) We recommend that an intensive acoustical study be made of underwater sound propagation and attenuation (overall loss) in an area highly populated with ringed seals and typical of sites undergoing on-ice petrochemical exploration. Frequencies (Hz) must be representative of both ringed seal vocalizations (this study) and industrial noise (our previous studies). There is a severe lack of data in such shallow areas because the geophysical industry is not interested in water column properties or the higher frequencies (kHz) and the U.S. Navy would consider the typical near-shore ringed seal habitat as being too shallow for viable Anti-Submarine Warfare operations.

(3) Based on the above parameters, the ringed seal audiogram, and what is now known of vocalization source level, a model should be developed under the framework of the basic sonar equation (eq. 1). The purpose of this model would be to predict a zone (area) of possible influence using both stochastic and deterministic approaches.

(4) The presently described recordings were made in a relatively small area at a specific time of year. Some recording effort should be undertaken at other times and locations, during which on-ice seismic exploration may be undertaken. Animal sound production is an overt manifestation of behavior and, consequently, is affected by seasonal and geographic variation.

(5) We recommend that a method be developed for experimentation on ringed seals under a semi-controllable situation involving their natural or acclimatized behavior and possible effects of man-made noise. For many reasons, this may be too difficult to achieve in the field.

VIII. ACKNOWLEDGEMENTS

We thank Dr. M. J. Hameedi, Dr. S. Zimmerman, L. Jarvela, G. Oliver, G. Lapine, and our helicopter pilots and crews (National Oceanographic and Atmospheric Administration) for administrative and logistic support; D. E. Bonnett, C. T. Lee, B. Narimatzu, and C. F. Greenlaw for their valuable preparatory and field support; S. Guinto for assisting with the analysis; Nelson and Johnny Walker for fixed wing flights and other invaluable assistance and logistics; J. C. Cummings for assisting with provisioning from San Diego and Fairbanks; P. Larson for home base preparations, and R. Hawley, T. Rydlinski, and R. Perez for helping to produce the report. We are indebted to all these people without whom the work could not have been undertaken.

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X APPENDIX

Temperature and Windspeed Records

JULIAN DATE	TIME	TEMP (°C)	WINDSPEED (MPH)
86	836	.0	.0
86	2126	-22.0	1.0
86	2238	-24.0	.0
86	2330	-22.0	.0
87	22	-22.0	1.0
87	112	-21.0	1.0
87	744	-28.0	2.0
87	839	-28.0	.5
87	934	-27.0	1.0
87	1028	-26.0	5.5
87	1122	-25.0	5.0
87	1215	-20.0	5.0
87	1450	-19.0	4.5
87	1544	-16.0	4.0
87	1636	-19.0	7.0
87	1731	-17.0	10.0
87	1825	-17.0	6.0
87	1900	-17.0	3.5
87	2014	-18.0	7.0
87	2105	-19.0	10.0
87	2200	-20.0	5.0
88	1045	-20.0	.0
88	2020	———	3.0
88	2052	-12.0	.0
88	2120	-13.0	.0
88	2141	-15.0	3.0
88	2216	-13.0	.0
88	2235	-13.0	.0
88	2250	-14.0	.0
88	2320	-14.0	.0
88	2325	-14.0	.0
88	2353	-16.0	6.0
89	950	-22.0	7.0
89	956	-22.0	7.0
89	1032	-21.0	7.0
89	1100	-20.0	6.0
89	1117	-20.0	7.0
89	1149	-19.0	6.0
89	1152	-19.0	12.5
89	1432	-12.0	15.0

APPENDIX (Continued)

JULIAN DATE	TIME	TEMP (°C)	WINDSPEED (MPH)
89	1500	-17.8	6.0
89	1526	-17.0	5.5
89	1531	-17.0	7.5
89	1603	-9.0	12.0
89	1622	-14.0	15.0
89	1718	-15.0	15.0
89	2028	-23.0	7.5
89	2322	-25.0	5.0
89	2342	-23.0	5.0
90	12	-23.0	.0
90	13	-23.0	.0
90	17	-23.0	5.0
90	37	-23.0	.0
90	47	-23.0	4.5
90	110	-23.0	.0
90	114	-24.0	.0
90	156	-24.0	.0
90	702	-32.0	.0
90	707	-32.0	.0
90	750	-25.0	.0
90	811	-27.0	2.0
90	946	-23.0	.0
90	1125	-19.0	.0
90	1607	2.0	4.0
90	1913	-16.0	2.0
90	2018	-20.0	.0
90	2207	-24.0	.0
91	829	-22.0	.0
91	927	-15.0	.0
91	1100	-13.0	.0
91	1001	-13.0	.0
91	1032	-8.0	5.0
91	1033	-8.0	5.0
91	1112	-6.0	——
91	1116	-6.0	3.0
91	1119	-6.0	3.0
91	1205	-5.0	2.0
91	1210	3.0	5.0
91	1221	4.0	4.0
91	1345	10.0	.0
91	1350	10.0	.0

APPENDIX (Continued)

JULIAN DATE	TIME	TEMP (°C)	WINDSPEED (MPH)
91	1357	10.0	.0
91	1425	10.0	.0
91	1500	10.0	.0
91	1544	5.0	.0
91	1600	5.0	3.0
91	1612	5.0	.0
91	1739	.0	.0
91	1745	.0	.0
91	1750	-2.0	.0
91	1821	-12.0	.0
91	1910	-10.0	2.0
91	1915	-12.0	2.0
91	1928	-11.0	2.0
91	2005	-18.0	5.0
91	2016	-18.0	3.0
91	2047	-18.0	.0
91	2051	-18.0	.0
91	2123	-20.0	2.0
91	2126	-20.0	2.0
91	2128	-20.0	2.0
91	2200	-20.0	2.0
91	2204	-20.0	2.0
91	2347	-18.0	.0
92	953	-13.0	.0
92	1025	-12.0	2.0
92	1402	-10.0	.0
92	2203	-12.0	8.0
93	1340	-12.0	20.0
93	1408	-12.0	22.0
93	1536	-15.0	20.0
93	2051	-12.0	15.0
94	506	-15.0	30.0
94	947	-15.0	20.0
94	1010	-12.0	20.0
94	1042	-12.0	20.0
94	1055	-12.0	20.0
94	1106	.0	45.0
94	1125	-12.0	20.0
94	1130	-12.0	20.0
94	1200	.0	30.0
94	1203	.0	30.0

APPENDIX (Continued)

JULIAN DATE	TIME	TEMP (°C)	WINDSPEED (MPH)
94	1232	.0	23.0
94	1236	.0	28.0
94	1306	-12.0	20.0
94	1310	-10.0	20.0
94	1425	-12.0	20.0
94	1445	-10.0	20.0
94	1520	-10.0	20.0
94	1525	-10.0	20.0
94	1605	-10.0	20.0
94	1610	-10.0	20.0
94	1633	-12.0	20.0
94	1641	-10.0	20.0
94	1645	-13.0	20.0
94	1713	-13.0	20.0
94	1718	-13.0	20.0
94	1747	-13.0	23.0
94	1750	-13.0	23.0
94	1945	-15.0	20.0
95	436	-13.0	10.0
95	1005	-8.0	.0
95	1010	-8.0	.0
95	1015	-8.0	.0
95	1352	-3.0	4.0
95	1356	-3.0	4.0
95	1755	-3.0	.0
96	937	——	10.0
96	945	-18.0	10.0
96	948	-18.0	10.0
96	1017	-17.0	20.0
96	1020	-17.0	20.0
96	1540	.0	10.0
96	1558	.0	20.0
96	1602	.0	20.0
96	1635	.0	20.0
96	1640	.0	15.0
96	1710	-3.0	13.5
96	1714	.0	13.5
96	1743	-7.0	20.0
96	1746	-7.0	20.0
96	1317	-8.0	15.0
96	1819	-8.0	15.0

APPENDIX (Continued)

JULIAN DATE	TIME	TEMP (°C)	WINDSPEED (MPH)
96	1542	-9.0	6.0
96	1851	-9.0	8.0
96	1908	-10.0	6.0
96	1921	-11.0	9.0
96	1924	-11.0	9.0
96	2321	-22.0	5.0
97	748	-15.0	14.5
97	1121	-20.0	18.5
97	1400	-8.0	30.0
97	1405	-8.0	30.0
97	1440	-8.0	20.0
97	1442	-8.0	22.5
97	1513	-8.0	27.5
97	1727	-11.0	20.0
97	2241	-10.0	35.0
98	612	-25.0	37.5
98	1456	-25.0	27.5
98	1523	-25.0	27.5
98	1558	-25.0	27.5
98	1954	-30.0	22.5
98	2145	-32.0	20.0
98	2325	-30.0	27.5
99	1158	-28.0	20.0
99	1759	-28.0	17.0
99	2330	-28.0	10.0
100	748	-33.0	8.5
100	1437	-22.0	7.5
100	1350	-23.0	5.0
100	2205	-30.0	.0
101	1205	-20.0	10.0
101	1224	-20.0	10.0
101	1342	-15.0	14.0
101	1451	-16.5	17.5
101	1650	-22.0	17.0
102	153	-37.0	12.0
102	604	-33.0	5.0
102	1022	-25.0	.0
102	1550	-12.0	.0

MODERN POPULATIONS, MIGRATIONS, DEMOGRAPHY, TROPHICS, AND HISTORICAL STATUS OF THE PACIFIC WALRUS

by

Francis H. Fay

with

Brendan P. Kelly, Pauline H. Gehnrich, John L. Sease,
and A. Anne Hoover

Institute of Marine Science
University of Alaska

Final Report
Outer Continental Shelf Environmental Assessment Program
Research Unit 611

September 1984

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ABSTRACT

The Pacific walrus population probably was not greatly affected by the incursions of the Russian merchant companies in the 18th and early 19th centuries, because their catches were mostly small and mainly of adult males. But it was severely depleted at least three times after the purchase of Alaska from Russia, first by the Yankee whalers between 1868 and 1880, when they took at least 130,000 animals, mainly adult females. The second depletion was by the American "arctic traders" in the beginning of the 20th century, when they extirpated most of the herds summering in the Bering Sea and greatly reduced those in the Chukchi, as well. The third depletion was by Soviet sealers in the 1930's to 50's, when they took at least 140,000 animals and again brought the population to a low level. The depletion by the Yankee whalers was perhaps the most devastating of the three, because it struck quickly and intensively at a stationary population, made up mainly of old, unproductive animals. It had recovered only partially by the time the traders began their taking, but by then it was broadly based in young, productive animals, hence more adaptive and resilient than before. Following the traders, it probably nearly recovered to its 18th century size before the Soviets began their intensive catching. Although they removed nearly as large a number of animals as the whalers had, the youthful, resilient population was better able to withstand and compensate for the increased mortality. Recovery from that third depletion took about 25 years, and the population apparently reached its new maximum in the late 1970's. It now contains a large proportion of old animals, whose productivity is low and has been lowered still further by a high rate of fetal abortion, possibly attributable to malnutrition, an infectious agent, or a combination of those factors. Its recruitment has been very poor in recent years, due to high postnatal mortality of calves. With such low recruitment and with steeply rising catches in both Alaska and Chukotka, the population probably is in a decline again at present.

Pacific walruses currently inhabit nearly all of their pre-19th century range. Apparently, nearly all of the adult males now summer in the Bering Sea, while all of the females and young summer in the Chukchi. In autumn, the males and females evidently meet in the Bering Strait region, before moving into their wintering-breeding areas in the Bering Sea. In the breeding areas, the adult males evidently eat little or no food during the rut. The adult females apparently eat little during the summer, possible associated with their annual molt. Animals in the western Chukchi Sea in summer appear to be as dependent on polychaetes and ringed seals as they are on mollusks.

Walruses are more easily disturbed by odors than by sight or sound of man and his machinery. Herds of females and young in the eastern Chukchi Sea in summer are likely to be affected by man-made disturbance, mainly through separation of calves from their mothers.

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ACKNOWLEDGEMENTS

For allowing us to use or mention their unpublished data, we are especially grateful to D. Soric, A. Thomas, and D. Wynn of Marineland, Palos Verdes, California, to J. R. Bockstoce of the Whaling Museum, New Bedford, Massachusetts, and D. B. Botkin of the University of California at Santa Barbara, California, to A. W. Smith and D. E. Skilling of Oregon State University to D. Roseneau and A. Springer of LGL Ltd., to R. D. Guthrie, S. W. Stoker, L. L. Renner, S.J., and D. L. Klein of the University of Alaska-Fairbanks, to J. W. Brooks, J. J. Burns, D. G. Calkins, S. J. Harbo, L. F. Lowry, R. R. Nelson, K. Pitcher, K. Schneider, and T. Smith of the Alaska Department of Fish and Game, to V. N. Crosby, A. DeGange, D. Irons, A. M. Johnson, R. D. Jones, K. W. Kenyon, W. Sholes, A. Sowls, A. Thayer, and S. H. Thompson of the U. S. Fish and Wildlife Service, to Yu. A. Bukhtiyarov, G. A. Fedoseev, and V. N. Gol'tsev of the Magadan Section of the Pacific Research Institute of Fisheries and Oceanography (MoTINRO), to L. A. Popov and A. A. Kibal'chich of the Marine Mammal Laboratory, All-Union Institute of Fisheries and Oceanography (VNIRO) in Moscow, and to the walrus hunters of St. Lawrence Island, Bering Sea, especially A. Akeya, T. Antoghame, L. Kulukhon, and V. K. Slwooko.

Many of the data used in the historical analysis were made available to us by the Alaska Department of Fish and Game, the U. S. Fish and Wildlife Service, the Alaskan Eskimo Walrus Commission, and the North Pacific Fisheries Management Council. Apart from the logistic support provided for this study by the OCSEA Program, we were accommodated also on several joint research cruises via Soviet vessels through Area V, Project 6 (Marine Mammals) of the US-USSR Agreement on Cooperation in the Field of Environmental Protection, and we were assisted in various helpful ways by the North Slope Borough, the Eskimo Walrus Commission, the Alaska Department of Public Safety, and Alaska Department of Fish and Game while in Nome and Barrow.

We sincerely thank also the following friends and colleagues, who worked with us on various aspects of this and related projects, for their very considerable help: A. Akeya, Y. A. Bukhtiyarov, J. J. Burns, R. H. Day, B. A. Fay, K. J. Frost, M. Iya, A. M. Johnson, A. A. Kibal'chich, K. Lourie, L. F. Lowry, C. McCumby, E. H. Miller, R. V. Miller, R. R. Nelson, L. A. Popov, G. C. Ray, D. Rugh, L. M. Shults, L. M. Smith, A. G. Somov, S. W. Stoker, J. Taggart, D. Wartzok, J. Wongitillin, and C. Zabel.

We also thank the officers and crews of the CGC POLAR STAR, ZRS ZVYAGINO, ZRS ZYKOVO, K/S ENTUZIAST, N/S OCEANOGRAPHER and R/V RESOLUTION for their patience, assistance, and warm hospitality, during our visits aboard their ships.

INTRODUCTION

General Nature and Scope of Study

The Pacific walrus population inhabits the waters over the entire continental shelf of the Bering and Chukchi seas. That population is a natural resource of paramount economic importance to coastal people of both Chukotka and Alaska, and for that reason, it has been under intensive study by management biologists of the Soviet Union and the United States for more than 50 years. Much has been learned about walruses in that time, but many important problems still remain unsolved.

The goal of this project has been to contribute further information on the subjects of (1) dynamics of the Pacific walrus population, especially from an historical aspect, (2) the current seasonal distribution and movements of the various parts of that population, (3) the principal kinds of foods eaten by the animals in different parts of their range and in different seasons of the year, and (4) the reactions of walruses to man-made disturbances. Those topics were selected as most relevant and most likely to yield information that would meet the needs of agencies and organizations concerned with potential effects of offshore oil and gas development on the walruses of the Bering-Chukchi region. Our general approach to each of those topics was as follows:

Population Dynamics

The Pacific walrus population has a long history of fluctuations in numbers at the hands of man. That history is moderately well documented but in a widely scattered scientific and semipopular literature, as well as in unpublished reports, government files, private journals, and field notes. We contributed some new information to that and undertook a compilation and synthesis of the earlier information, feeling that a better understanding of the status of the population in the past would help to develop a clearer perspective of the present and future. The lessons of history appeared to be particularly valuable as contributions to the basis for predicting the course ahead and for identifying convenient means for monitoring the population along that course.

Distribution and Movements

The overall distribution of the Pacific walrus, as currently understood (Fay, 1982; Fedoseev, 1982), indicates that virtually the entire population resides in the Bering Sea in winter, principally in a large ice-generating area to the south of the Chukchi Peninsula and St. Lawrence Island, and in another such area that extends from south of Nunivak Island into Bristol Bay. In spring, all of the females and young migrate northward, into the Chukchi Sea, leaving most of the adult males behind in the

Bering Sea, where they spend the summer. The locations of most of the major concentrations of walruses in each month from March to September have been delineated, but the distribution during November and December, when the most intensive feeding may take place, and in January and February, during the mating season, have not been documented adequately. The fall migration corridors are virtually unknown; even the spring migration corridors are poorly known except in the Bering Strait region, and for that reason, the principal calving areas have not been defined. Our thrust has been to contribute to filling as many of those gaps as possible and to encourage the governmental agencies on both sides of the International Date Line to contribute, as well.

Complementary to description of the distribution and main migration routes is the need to determine the sex and age compositon of the animals inhabiting each area in each season. That information will indicate which segments of the population are likely to be impacted the most. It also could be useful in contributing to knowledge of the composition of the population at large and its natural mortality and productivity.

Feeding

The feeding habits of walruses in the Bering-Chukchi region had been documented principally from stomach contents of animals taken in the spring in the area from St. Lawrence Island to Bering Strait (Fay et al., 1977; Lowry and Frost, 1981). Only fragmentary data, most of them qualitative, were available from other seasons and other areas (Nikulin, 1941; Brooks, 1954; Tikhomirov, 1964b; Krylov, 1971). The implication of those qualitative reports was that the diet varies greatly in relation to season, region, sex, and age (Fay, 1982).

In general, walruses appear to feed mainly on mollusks, some of which could be severely impacted by environmental pollution (Kelly, 1980). A growing body of evidence suggests that other kinds of invertebrates may be at least equally important as food in some parts of the walrus' range or important as alternate prey when mollusks are unavailable. We sought to obtain more substantive information on those points by investigating the feeding habits of Pacific walruses in as many seasons and different parts of their range as feasible. The risk of impact of offshore oil development on their food supply will remain inadequately known until such information is available.

Response to Disturbance

The reaction of walruses to man and his machines can be described generally as "escape response" and attributed to visual, auditory, and olfactory cues (Loughrey, 1959). The severity of the effects, as we perceive them, range from no reaction at all, to fright, flight, or at worst, death, depending on the circumstances. All walruses do not respond in the same way, and the responses of an individual may vary in different times and places. In some instances, the animals may even be attracted, rather than repelled by human presence. Many factors appear to play a part in the severity of the response, including sex and age of the animals, the size and location of the group (on ice, in water, on land), their distance from the disturbance, and the kind and intensity of the disturbing factor. The reactions of walruses to disturbance by man have not been well documented; even uncritical anecdotal accounts are scarce. We strove to obtain a better understanding of the immediate effects of disturbance and to search for evidence to confirm or deny the suspicions of potential long-term impacts from chronic disturbance.

Relevance to Problems of Petroleum Development

All of the proposed OCS oil lease areas on the Bering-Chukchi shelf lie within the known range of the Pacific walrus population (Fig. 1). Development of some of those may impinge on major mating areas in winter, migration corridors and calving areas in spring, nursery areas in summer, and migration and feeding areas in autumn. Oil transport routes could impinge on all of those habitats, year-round. Because the population is large at present, concern for its preservation is minimal, even though the animals are practically confined to the shelf and wholly dependent on its benthic resources. We expect that some impact on the population by oil development is inevitable. To judge the probability and potential for that impact and devise the means to mitigate it, better understanding of the population and its habitat requirements is needed.

Objectives

Our specific objectives in this project have been to contribute to better understanding of:

1) the history of the population, especially as regards its fluctuations in size and structure and the attendant circumstances at the time of those fluctuations,

2) the current seasonal distribution of the population, ideally in terms of sex/age composition, with emphasis on identifying the principal times and places in which mating, birth, and feeding take place,

3) the seasonal and regional feeding habits of the animals, and

4) the effects on walruses of disturbance by man.

For various reasons, we could not address all of those objectives as fully as we desired in this project, but we did obtain much of the informa-

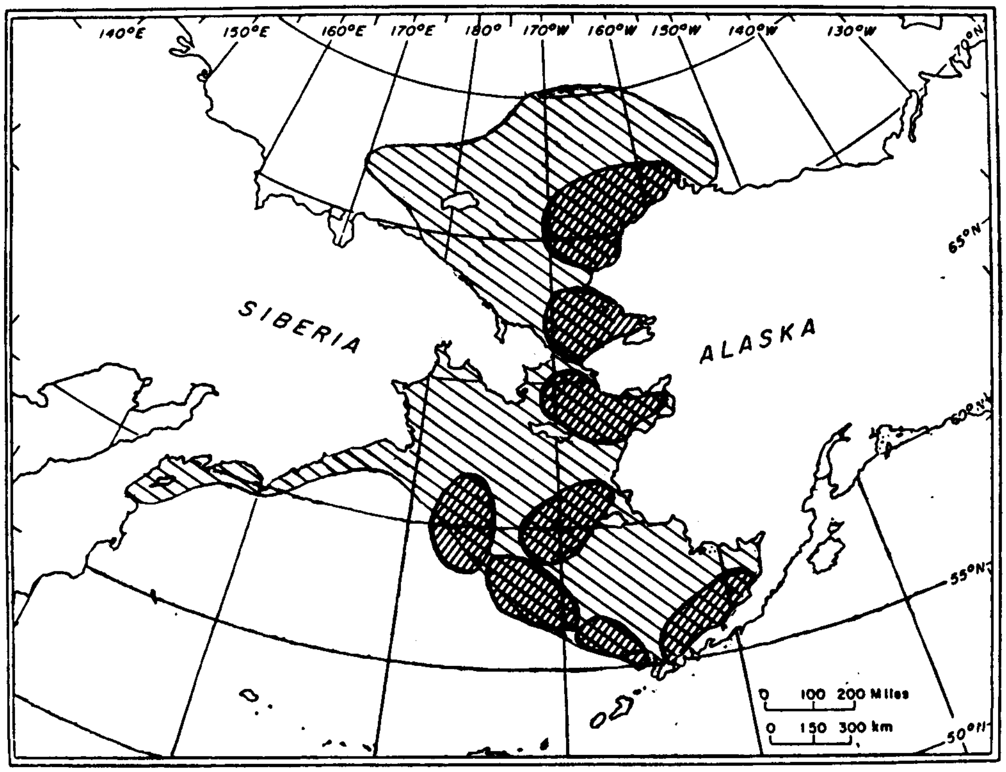

Figure 1. The range of the Pacific walrus population (\\\\) relative to actual and proposed oil lease areas (///////) on the western Alaskan outer continental shelf.

tion that we sought, through it and a series of complimentary projects that were funded by other agencies and organizations. This report is a synopsis of the current state of knowledge, based on the results from all of those, as well as on previous work by us and others.

STUDY AREA

The study area was the entire range of the Pacific walrus population on the continental shelf of the Bering and Chukchi seas, within the 100-m isobath (Fay, 1982). In this and associated projects, we sampled in the pack ice of the Bering and Chukchi seas (Navarin, St. Matthew, Norton, and Hope basins) in May and June 1980 via the CGC POLAR STAR, in the southeastern Bering Sea (St. George and North Aleutian Shelf lease areas) in February and March of 1981 via the Soviet vessel ZRS ZVYAGINO, in Bristol Bay (North Aleutian Shelf) in April to November 1980 and January to May 1981 via chartered aircraft and the State of Alaska's R/V RESOLUTION, in the eastern Chukchi Sea (Barrow Arch lease area) in July and September of 1981 via the CGC POLAR STAR and N/S OCEANOGRAPHER, respectively, and in the eastern and western Chukchi Sea in July and August of 1982 via the Soviet vessel K/S ENTUZIAST. We also sampled on the Punuk Islands, Bering Sea (Norton lease area) during the autumn of 1981 and summer of 1982, and in the central and western Chukchi Sea, adjacent to the Barrow Arch lease area, in the summer of 1983 via the Soviet vessel ZRS ZYKOVO. We also obtained information for this project from study of walruses in captivity at Marineland, California, during 1981 and 1982, and in conjunction with the Alaskan Eskimo Walrus Commission's and U. S. Fish and Wildlife Service's joint program of harvest monitoring in 1980 and 1982.

SOURCES, METHODS, AND RATIONALE OF DATA COLLECTION

History of the Population

Historical information from the 18th, 19th, and first half of the 20th century was extracted mainly from published sources in both Russian and American literature and from some unpublished reviews of those sources. In addition, distributional data from the ships' logs of the 19th-century Yankee whalers were provided by J. R. Bockstoce and D. B. Botkin. Much of the more recent information, from 1950 to 1983, also was extracted from publications and unpublished reports; a large part of it was derived from files of the Alaska Department of Fish and Game (ADF&G) and the P.I.'s files from previous work for the Arctic Institute of North America, the U. S. Public Health Service, the Alaska Sea Grant Program, the U. S. Fish and Wildlife Service (USFWS), the U. S. Marine Mammal Commission, and University of Alaska-Fairbanks. Results from aerial censuses of the walrus population from 1960 to 1980 were from unpublished reports provided by the USFWS and from published and unpublished accounts from the Magadan Section, Pacific Research Institute of Fisheries and Oceanography (MoTINRO), in the

Soviet Union. The methods employed in the harvest sampling and censuses already have been described in detail by Fay (1955, 1958), Kenyon (1960a, 1972), Harbo (1961), Fedoseev (1962), Burns (1965), Gol'tsev (1972, 1975a), Fay et al. (1977), Estes and Gilbert (1978), Fay and Lowry (1981), Fedoseev (1981), Fay and Stoker (1982a,b), and Johnson et al. (1982).

Distribution and Composition

Distributional information, new since Fay's (1982) compilation, was acquired partly from other OCSEAP and MMS investigators and partly by personnel of this and related projects during observation from ships and aircraft. For the most part, that information consisted of sightings along the flight or cruise tracks, with notation of time (for estimation of position), group size and location (i.e., on ice, on shore, in water), and when feasible, composition of the group by sex and approximate age. Animals were regarded as being in a "group" when they were separated from others by at most one body length (after Estes and Gilbert, 1978). Behavioral information about mating, calving, feeding, and responses to disturbance often was obtained in conjunction with those sightings. Since we operated in this project mainly from ships of opportunity, we usually had no control over timing and little control over location of the cruise tracks.

Specific efforts to obtain compositional data from the present population were conducted during five cruises in the Chukchi Sea in 1981 to 1983. The first compositional survey, in July 1981 via the icebreaker CGC POLAR STAR, was designed to cover a 65-km-wide band along the southern part of the pack ice between Point Barrow, Alaska and 169°W longitude. That coverage included about 90 percent of the walrus habitat in the eastern Chukchi Sea identified by Estes and Gilbert (1978) and by Johnson et al. (1982) from aerial surveys of the region. In the first week of the 2-week cruise, we explored as much of that band as possible from east to west, via ship and helicopter, to locate the main concentrations of walruses and to determine whether there was any geographical segregation by sex. On our return eastward in the second week of the cruise, we allocated most of our time to compositional sampling in the areas where the animals had been found to be concentrated. This was followed 2 months later by the second compositional survey in the same area, via the N/S OCEANOGRAPHER. That survey was done as an adjunct to other projects and only in the ice edge, since the ship is not an icebreaker.

The third and fourth compositional surveys were conducted in July and August 1982 via the Soviet vessel K/S ENTUZIAST. Again, because the ship was not an icebreaker, it was limited to working in the edge of the pack. The ship's mission was primarily to search for whales, but we were permitted to survey for walruses, as well, along the entire ice edge from Cape

Schmidt, Chukotka to Barrow, Alaska. We did that twice, each time with a different set of observers. The fifth survey was conducted in August 1983 via the Soviet ship ZRS ZYKOVO. This also was in the edge of the pack but covered only a small part of the distributional area in the western Chukchi Sea, near Cape Schmidt.

On each of those surveys, most of the groups of walruses were observed from the ship; during the first survey, a few were observed from small boats. Once located, each group of walruses generally was approached by the ship upwind at speeds of 2 to 3 kt, to a minimal distance of about 100 to 200 m. During the approach, one observer using a 16-36X "zoom" spotting scope identified the sex and age of each of the animals in the group. A second observer, who was the recorder, counted the number of animals in the group and, when possible, assisted the first observer with the classifications. In some instances, a third observer took photographs of each group, using a 35-mm SLR camera, equipped usually with a 70- to 200-mm zoom telescopic lens. Our rationale in combining visual and photographic methods was that the photos would provide back-up documentation and would allow us to examine the feasibility of using photography alone for future compositional surveys.

Our classification of individuals to age was based on size and shape of the tusks, relative to breadth and depth of the snout. The classes were defined by a set of outline drawings that were traced from photographs depicting front and side views of the head. The scale of those sketches was based on the tusk length data obtained by Fay (1982) and on data gathered more recently by us concerning the length of the tusks and the width and depth of the snout (Table 1). For the classes that lacked data on snout dimensions, we simply estimated by extrapolation from the available data in the other classes, as well as by comparing dimensions among animals shown in the photos. Obviously, the data base of snout dimensions for most of the age classes still is deficient.

The outline drawings (Fig. 2) show males and females of average dimensions at 0 (calf of the year), 1, 2, 3, 4 to 5, 6 to 9, 10 to 15, and >15 years of age. Recognizing that the variation in size among members of each class is wide (about ± 20 to 50%), and that the overlap between classes is extensive (e.g., see Fay, 1982, fig. 81), we accepted the fact that some subjectivity would enter into the classification of "borderline" cases, and that some of the individuals placed in each class actually would belong in the preceding and some in the succeeding class. We believe those kinds of errors will tend to be uniformly present in all samples and will not affect the validity of comparisons among samples. Accuracy in aging is not a requirement in this sampling scheme; the requirement is for precision in classifying the animals into groups that are morphologically alike.

Table 1. Average dimensions of tusks[1] and snout[2] of Pacific walruses in each age class.

	Males				Females			
Age class (yrs)	Tusk length (cm)	Snout dimensions(cm)			Tusk length (cm)	Snout dimensions(cm)		
		N	Width M ± SD	Depth M ± SD		N	Width M ± SD	Depth M ± SD
0	0	2	17.0±1.41	7.8±1.06	0	1	16.0	11.0
1	2	2	20.0±2.83	11.5±0.71	2	0	-	-
2	7	0	-	-	5	0	-	-
3	11	3	25.2±1.23	13.5±1.80	8.5	1	24.0	11.0
4-5	16	2	24.5±0.71	14.5±2.12	12.5	4	22.5±0.58	12.4±2.75
6-9	24	4	31.2±3.20	17.0±1.41	20	5	25.3±2.59	14.7±1.92
10-15	36	4	31.8±1.50	17.8±1.50	33	8	26.6±3.07	14.9±2.40
>15	52	12	35.6±2.64	18.7±2.20	44	15	27.2±3.76	16.0±2.09

[1] Length of tusk along anterior surface, from edge of gingiva to distal tip. Rounded estimate of mean, based on Fay (1982, fig. 81) and data gathered during this project. This is the length visible in anterior view only; in side view, about 2 to 4 cm of the base of the tusk is hidden by the upper lip.

[2] Mean ± one standard deviation of N measurements of greatest width and depth of snout on non-distorted, dead specimens.

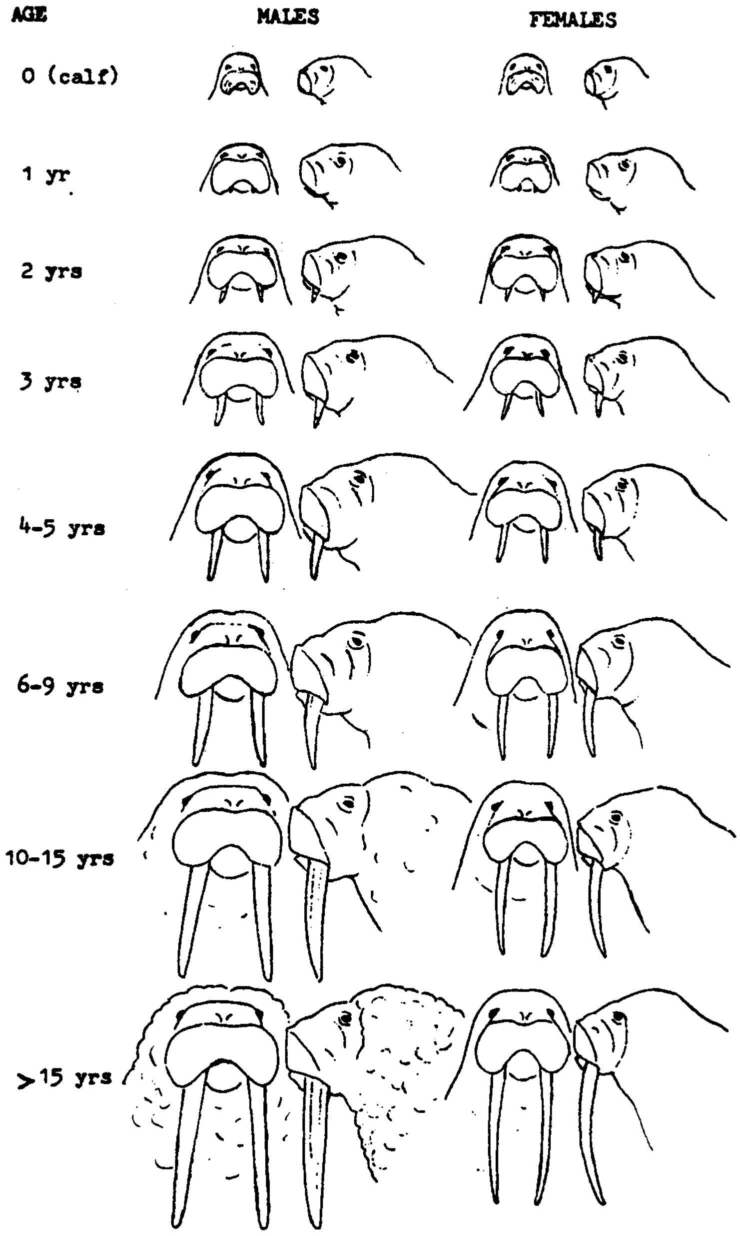

Figure 2. Facial outlines used for classification of walruses by age, during visual surveys of group composition. Age classification is based primarily on tusk size and shape, relative to depth and breadth of the snout.

For animals in the first five age classes, identification to sex was regarded as unimportant, since nearly all of those are sexually immature. Only the animals 6 years and older were identified to sex, based in part on facial and tusk characters and in part on shape and coloration of the body, texture of the skin, presence of urogenital apertures, and such indicators as attendance of suckling young. Adult females often were classified only as "6+ years", since they usually were too numerous to classify further in the short time spent with each group. About two-thirds of the 6-yr-old females are sexually mature; nearly all of the older females are mature (Fay, 1982). For the males, which were less numerous, hence more easily considered individually, we classified the animals 6 yrs and older as 6-9, 10-15, and >15 years. Males 6 to about 15 years old are subadults; nearly all of the males more than 15 years old are sexually and socially mature adults (Fay, 1982).

Feeding Habits

We obtained new information about the kinds of food eaten by walruses in their natural environment by examining the stomach contents of specimens collected at sea. Some of those specimens were from scientific samples taken during two Soviet-American research cruises; most of the rest were from the Eskimos' spring harvests in the eastern Bering Sea in 1980 and 1982.

For each specimen, the sex, date, and location, were recorded. Stomach contents were washed in sea water to remove the fine, particulate digesta and to separate the organic matter from the heavier inorganic sediments. Prey were identified by visual comparison of items in the stomachs with expertly identified whole specimens in the reference collections of the Institute of Marine Science, University of Alaska, Fairbanks. The identifiable prey were sorted into taxonomic groups to the lowest rank possible. Each group was weighed to the nearest gram and the number of individuals counted. Fragments not assignable to Genus or Species often were assignable to Class, Order, or Family. For those, the number of individuals could not be determined, but the weight was recorded. The weight of inorganic sediments was recorded separately.

The feeding habits from a temporal aspect, in relation to age, sex, and season of the year, were investigated on the basis of daily records of the food intake by two breeding pairs of walruses and their offspring that were reared in captivity at the Marineland aquarium in California (Gehnrich, 1984). Those records consisted of the weights of foods consumed per day by each walrus from 1974 to 1982, as recorded by their keepers. The recorded intakes in pounds per day were converted to kilocalories (kcal) per day, based on their nutrient composition as given by Gerasi (1975) and the gross energy values provided by Pike and Brown (1975). Although the amount of food eaten by captive animals may not be precisely the same as that eaten under natural conditions, the relative amounts should vary in a similar way with body size and with seasonal biological events, such as breeding, pregnancy, lactation, and the molt.

Effects of Disturbance

As opportunity permitted in the course of other field work in this and the related projects, we gathered data on the effects of man-made disturbance on walruses. This was entirely a passive effort; we did not attempt to experiment with or intentionally disturb the animals.

In many instances, we were able to record the flight-distance in relation to wind direction and source of disturbance. We also obtained some data on who (sex/age class) was last to leave the ice, and how often calves were abandoned by the adults when disturbed.

Thus, this study had many facets, most of which were strongly reliant on specialized logistic support and exceptionally favorable weather. Because those two conditions coincided only once in while, and because we had only parts of 3 years in which to achieve our 4- or 5-year objectives, we did not solve all of the problems by any means, but we did contribute significantly to the solution of some of them. The following are the results of our work.

RESULTS

Historical Review

The recorded history of walruses in the Bering-Chukchi region begins with their first appearance there in the fossil record in late Sangamon (Pelukian) time, more than 52,000 but probably not more than 101,000 years ago. Skeletal remains known or presumed to be of that age have been recorded from marine deposits in the eastern Chukchi Sea near Barrow, Point Lay, Noorvik, and Cape Espenberg, Alaska, as well as in the northern Bering Sea near Nome, on St. Lawrence Island, and in the Dease Inlet-Dall Lake area of southeastern Bering Sea (Hopkins, 1967; Repenning and Tedford, 1977; C. A. Repenning, J. J. Burns, and F. H. Fay, unpublished). The implication of those records is that the distribution of walruses in the region, presumably not long after their arrival from the North Atlantic Ocean, may have been about as great in latitude as it is now.

With the subsequent climatic cooling, lowering of sea level, and exposure of the Bering "land-bridge," during the last (Wisconsin-Würm) glacial advance (Hopkins, 1972), the range of walruses apparently expanded markedly to the south, along both sides of the North Pacific Ocean. A skull and skeleton found recently near Qualicum Beach, Vancouver Island were radiocarbon dated at 40,000 years B.P. (C. R. Harington, pers. commun.). Part of another skull (not dated) was dredged up from a submerged Pleistocene beach off central California, not far from a 19,000 year B.P. Steller sea cow (Harington, 1978; C. A. Repenning, pers. commun.). A fragment of a walrus tusk found on the Queen Charlotte Islands, British Columbia also may be of Wisconsin age (Harington, 1975).

Although walruses appear to have been widely distributed along the North American coast during the Wisconsin glaciation, they probably were not numerous there, even in the Bering Sea, for the narrow continental shelf would have offered them little area for feeding. They probably were more abundant on the Asian coast, where they had access to a much broader shelf in the Okhotsk Sea. Late Pleistocene finds from Sakhalin (Matsumoto, 1926) and from the adjacent Siberian mainland (Borisiak, 1930) attest to the former presence of walruses there at that time. In the Chukchi Sea, north of the land bridge, walruses probably were scarce or absent, for the continental shelf was dry land, and the adjacent Arctic Ocean was deep and at least as perpetually ice-bound as it is now (Herman _et al._, 1971; Herman, 1974).

For several thousand years in the end of the Pleistocene Epoch, as climatic warming and inundation of the Bering land bridge took place, walruses evidently re-occupied the Bering-Chukchi region and withdrew from most of their southern areas of expansion. They evidently continued to inhabit the Okhotsk Sea until rather recent time, however, as indicated by the presence of "blackened" (?semi-fossil) tusks at Kin'kil and Nagaev Bay on the coast of northwestern Kamchatka (Arsen'ev, 1927; Nikulin, 1941) and by remains associated with human habitation in several locations on southern Sakhalin (Voronov and Voronov, 1981). Blackened, semi-fossilized ivory and bones have been found also in several locations along the present Bering Sea coast of Alaska, for example on Cape Constantine (Bristol Bay), at St. Paul Island (Pribilofs), and on St. Lawrence and the Punuk islands, near Bering Strait (F. H. Fay, unpublished).

For the past two or three millennia, walruses probably were distributed about as widely in the Bering-Chukchi region as they are today, to judge from the occurrence of their ivory in Aleut and Eskimo archaeological sites. Although implements made from walrus ivory are common in Alaskan coastal sites from Bristol Bay to Barrow, they are scarce to absent in the Aleutian Islands and the Gulf of Alaska (De Laguna, 1934, 1956; Geist and Rainey, 1936; Collins, 1937; Oswalt, 1955; Heizer, 1956; Ford, 1959). On the Asian coast, walruses are said to have occurred in the Bering Sea as far south as eastern Kamchatka and the Commander Islands (Tikhomirov, 1964a; Chugunkov, 1970), and they apparently were present also about the Kuril Islands and throughout the Okhotsk Sea, as well (Voronov and Voronov, 1981). Far to the north, their limits in the pre-contact (by Russians) period have not been defined authoritatively in the literature but presumably were about the same as they are now. Their greatest concentration, apparently, was in the Bering Strait region, much as it is today (Rudenko, 1961; Arutiunov and Sergeev, 1968). They were abundant enough there to have had a major influence on the foundation and development of the marine-oriented Eskimo culture.

The Russian Expansion Period, 1648-1867

Quantities of walrus ivory were discovered at the mouth of the Anadyr River by Russian cossacks about 1648-49, when they first reached that area ostensibly from the north, via the Kolyma River and Bering Strait (Ray, 1975). The news of that discovery, however, did not reach the rest of the world until a century later, and in the meantime, Kamchatka was discovered and had been subjugated (Collins, 1937). By the time of Bering's second voyage in 1741, the walruses of the Okhotsk Sea no longer existed, but the Bering-Chukchi walrus population probably was in virtually primeval condition. Although it already had been cropped by aborigines for several thousand years, their catches probably were not large enough to have had any significant effect on the size or composition of the population. At that time, the 5,000 or so walrus-hunting natives of the region were centered principally in the northern Bering and southern Chukchi seas, as they are now. With their primitive weapons, they might have been able to take as many as 2 to 3 thousand walruses per year (but probably not more) to meet their material and nutritional needs. Hence, when the first boatloads of Russian hunters arrived in Alaska in the mid-18th century, they probably found walruses about as numerous and widespread as the carrying capacity of the environment would allow. Over the next 126 years, however, they considerably changed that status.

In the first 40 years of Russian expansion into the Bering Sea, the hunters ranged mainly along the Commander and Aleutian islands, from which they brought back ample cargos of skins from sea otters, fur seals, and foxes but very little walrus ivory (Table 2). Certainly, they were not unaware of the value of the ivory, for it had been an important commodity in their trade with the orient and middle-east for at least the previous 8 or 9 hundred years (Cammann, 1954). Apparently, the scarcity of ivory in the cargos of vessels returning from the Commander and Aleutian islands was due to the walruses being as scarce there in the 18th century as they are today.

By the 1760's, the hunters were pressing farther eastward for their game, as the stocks of furbearers became depleted in the islands (Berkh, 1974). When they reached into Bristol Bay and northward to the Pribilof Islands in the 1780's and 90's, their cargos of ivory increased dramatically. An extreme example was recorded in the late 1780's, when a team of 20

Russian and 20 Aleut hunters at the Pribilof Islands took more than 16,500 kg of tusks in two years (Tikhmenev, 1979). Since the Pribilofs were used as a haulout area almost entirely by male walruses (Tikhmenev, 1978), and one tusk from an adult male averages about 2.54 kg (S.D. = 0.565, N = 83 : U.S. Fish and Wildlife Service data by A. Thayer, unpublished), that catch probably was of about 3,250 animals. Those animals probably were taken principally from the Northeast Point on St. Paul Island, since that apparently was the largest hauling ground. The hunters were so effective that, by 1805, walruses were "all gone" from St. Paul and St. George islands, according to Agent Sarichev (True, 1899), but they still "covered" nearby Walrus Island, and the hunters were sent there to harvest them about that time (Tikhmenev, 1979).

Table 2. Amounts of walrus ivory acquired by the Russian hunting companies in the Bering Sea, 1743 to 1860.

	Walrus ivory (kg)	
Years	Total	Average/year
1743 - 62[1]	1,015	51
1763 - 82[1]	6,186	309
1783 - 98[1]	22,434	1,496
1798 - 1822[1]	32,570	1,303
1821 - 42[2]	106,456	4,839
1842 - 60[3]	47,972	2,525

[1] From Berkh (1974).

[2] From Tikhmenev (1978).

[3] From Golovin (1979).

The expansion of Russian influence in the Bering Sea took place in a disorderly fashion by individual fur-trading companies until 1797, but those companies were merged in that year into one company under government franchise (Tikhmenev, 1978). Thus, the Russian-American Company from its birth was well established in North America, and by 1820 it commanded 15 settlements that reached from the Pribilof Islands to central California. About that time, the Company was exporting nearly 5,000 kg of walrus ivory annually from Alaska, mainly to Turkey and Persia (Okun, 1951). That amount of ivory is equivalent to at least 1,000 male walruses or about twice as many females and young per year. Probably about half of those walruses were taken by the Russians; the other half were taken by the native inhabitants of the region. The catch of walruses by the Russian hunters was entirely for the ivory, as the Company had no markets for the thick, tough hides or for the meat or oil at that time. The natives' catch, conversely, was primarily for the meat, oil, and skins, so they usually had a surplus of ivory available for trade.

Acquisitions of walrus ivory by the Russian-American Company continued to rise for at least another 20 years, principally in connection with further expansion into the northern Bering Sea. Apparently, much of that increase in acquisitions was from trade with the Eskimos. In June 1830, for example, Captain Etholen sailed from Sitka to Norton Sound, where he found walruses present in "enormous number" around the shores of Sledge Island, near the present city of Nome. Presumably, his crew caught some of those, but he also found walrus ivory available in some quantities for trade at St. Lawrence Bay and in the five villages on St. Lawrence Island, whose primary industry was walrus hunting. He evidently stopped as well at St. Matthew and Hall islands, where he found walruses present (Tikhmenev, 1978) and may have taken some. Three years later, Captain Teben'kov acquired over 7,000 kg of walrus ivory in trade from the natives at Mechigmen Bay, Chukotka (Ibid.).

From 1842 to 1860, the Company's average annual export of walrus ivory was down nearly 50%, to about 2,500 kg per year. At least one-third of that was from barter with the natives, especially at the Company's station in Port Moller, Bristol Bay (Tikhmenev, 1978; Golovin, 1979), and ever greater reliance for ivory was being placed on the native catch in the northern Bering Sea. The decline in weight of ivory exported may have been caused in part by inclusion of more tusks from females and young, which are much smaller than those from adult males. The decreasing export also was caused in part by depletion of some of the most accessible herds, such as those on the Pribilof Islands.

Thus, from the time of Vitus Bering's historic voyage of discovery to southeastern Alaska, until the purchase of Alaska from imperial Russia by the United States, the record of the Pacific walrus population is mainly a record of human events. From it, we can surmise that the great herds of bull walruses, which summered in Bristol Bay and about the Pribilof Islands were nearly extirpated by the mid-19th century, and we can guess that the same kind of damage probably was done on the other side, in the Koryak-Kamchatka region. Apparently, the herds in the pack ice to the north were little affected. Although there may have been some indirect impact, caused by development of ivory trade with the Eskimos, the amount of that impact probably was insignificant, compared with that of the Yankee whalers, who were next on the scene.

The Yankee Whaler Period, 1848-1914

While the Russian-American Company was still expanding its sphere of influence in western North America, the Yankee whalers entered the Bering-Chukchi region. At first, they conducted their whale-catching only in the vicinity of the Aleutian Islands, but by 1848 they reached northward to Bering Strait (Bockstoce, 1980). Their primary objective there was the taking of bowhead whales (Balaena mysticetus). They also began almost at once to take a few walruses, as well. At first, the walruses may have been taken "more out of curiosity than...for economic gain." By the late 1860's, however, when the bowhead population had been severely reduced and a strong market for walrus products developed, the "deliberate walrus hunt" was underway (Bockstoce and Botkin, 1982, p. 183).

The walrus population of the region evidently was still very large when the whalers began their harvesting. Even after the heavy toll taken earlier by the Russians, some animals still could be found in Karaginskii Gulf and Bristol Bay, as well as on the Pribilof and St. Matthew islands (Dall, 1870; Scammon, 1874; Elliott, 1875; Townsend, 1887; Arsen'ev, 1927; Chugunkov, 1970; Pinigin and Prianishnikov, 1975). Farther north, in the ice, the animals were abundant, having been hunted only by the natives, whose catches were mainly for their own subsistence. We have not been able to determine the size of those catches, for they apparently were not recorded and have never been estimated. We suspect that, even with a bit of excess for trading, the total native catch was no more than 2-3,000 walruses per year.

The whalers took only insignificant numbers of walruses up to the mid-1860's. And because they killed the animals by means of harpoon and lance, the number that escaped mortally wounded and the number killed and lost due to sinking probably were negligible. By 1869, however, their catch had risen steeply (Fig. 3), and their hunting methods had changed markedly, for they began to kill the animals by means of firearms. With that conversion to firearms, the number of animals wounded and the number lost due to sinking rose markedly. According to Nye (1879 in Allen, 1880) and Arsen'ev (1927), only about one-third of the animals shot were retrieved. Although those may have been overly pessimistic views, there are few data with which to confirm or deny them. The only recorded statistics known to us are

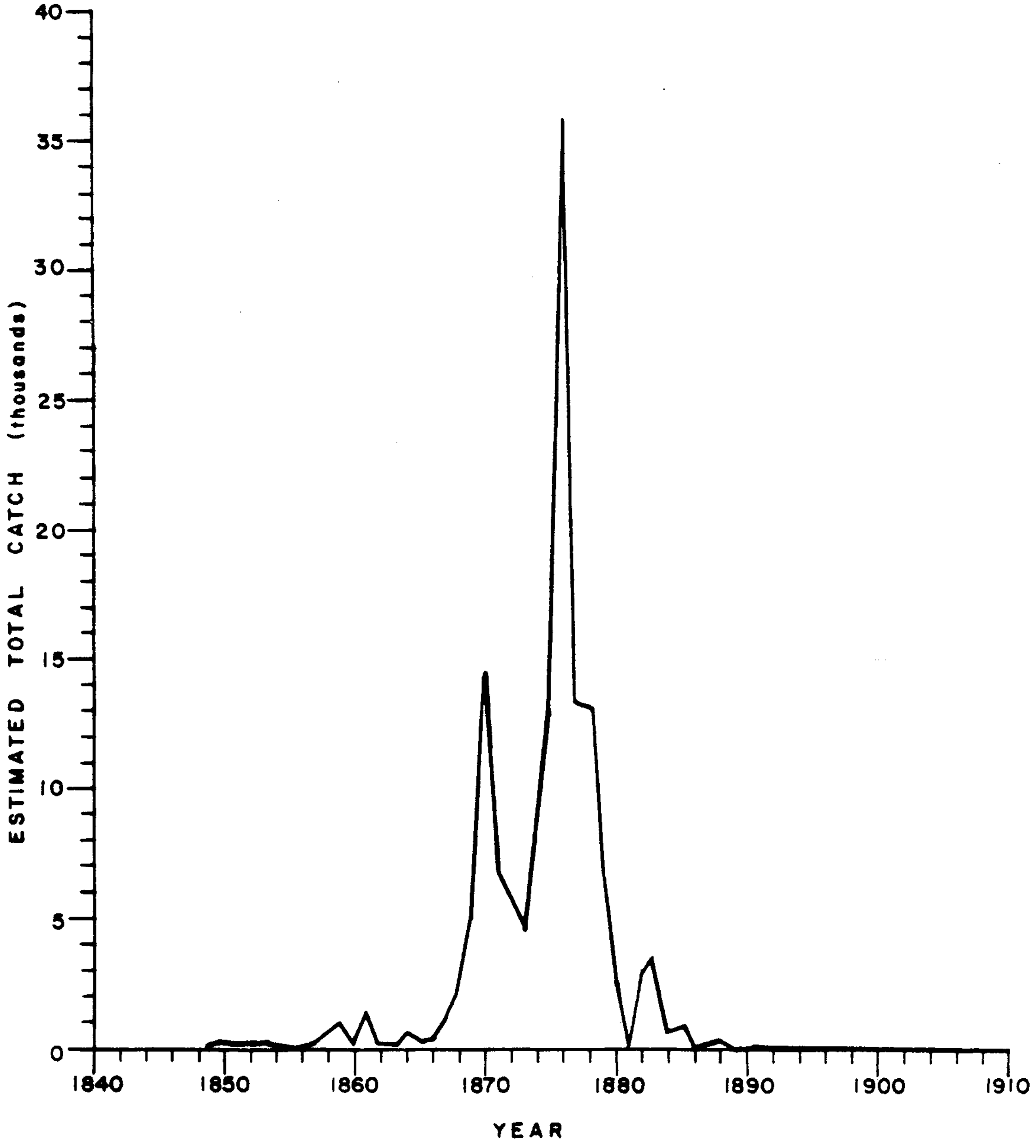

Figure 3. Estimated annual catch of Pacific walruses by the Yankee whalers in the Bering-Chukchi region, 1849-1910 (after Bockstoce and Botkin, 1982).

those extracted by Bockstoce from the whalers' logbooks (Bockstoce and Botkin, 1982). Expressed as number retrieved/number shot, those statistics were as follows: 59/82, 0/24, 118/130, and 18/40 or 50. Thus, the proportion retrieved ranged from 0 to 90% and, as a whole, suggested that the average proportion retrieved may have been about two-thirds of the number shot, as it has been in recent years (Buckley, 1958; Krylov, 1968).

The Yankee whalers directed their hunting mainly toward the walruses in the pack ice, north of Bering Strait. More than 90% of their catches were taken in the ice of the Chukchi Sea in late June, July, and August (Bockstoce and Botkin, 1982). The distribution of those catches and of their additional sightings of walruses corresponds well to present distribution of the animals in those months (Fig. 4). For that reason, we assume that the sex/age composition of the herds that they hunted also was comparable to the composition of herds found there at present. The walruses that summer in that region nowadays are mainly adult females with their young. Whereas the Russian-American Company's hunters had been taking mostly adult male walruses in the south, the Yankee whalers apparently were taking mostly females and young in the north. The latter was confirmed by Nye (1879 in Allen, 1880). Hence, the whalers' impact on the walrus population was much more depletive, for not only were they lowering the numbers, they were lowering the reproductive capacity of the population, as well. Additional mortality probably was caused by the whalers setting free the young calves, after their mothers were shot (Clark, 1887). Although a few calves may have been "adopted" by other females (e.g., see Burns, 1965; Eley, 1978; Fay, 1982), the rest of them probably died from starvation.

In the 12 years from 1869 to 1880, the catch of walruses by the Yankee whalers amounted to an estimated 130,000 walruses (Bockstoce and Botkin, 1982). More than half of those were taken within a 4-year period, from 1875 to 1878. The average annual catch by the whalers alone over the 12-year period was on the order of 11,000 walruses per year, and the losses from wounding, sinking, and abandoned calves probably were at least an additional 6-8,000 per year. Some additional number was taken by vessels of other nations, as well as by the native inhabitants of the region, who by this time also were using firearms (Ray, 1975; Fitzhugh and Kaplan, 1982). The overall result by 1880, according to Nelson and True (1887), was that the walrus population had been reduced to about half of its former size, and the native population that was dependent on it underwent a 33% reduction, due to starvation (Allen, 1895). In those villages where the dependence on walruses was greatest, because the economic base was narrow (i.e., on the Bering Sea islands), about half to two-thirds of the native residents died (Nelson and True, 1887; Muir, 1917).

The catching of walruses by the whalers continued at a reduced rate for about 35 years longer. By 1890 it was down to a few score per year, and from 1890 onward, it dwindled to insignificance. It ceased altogether

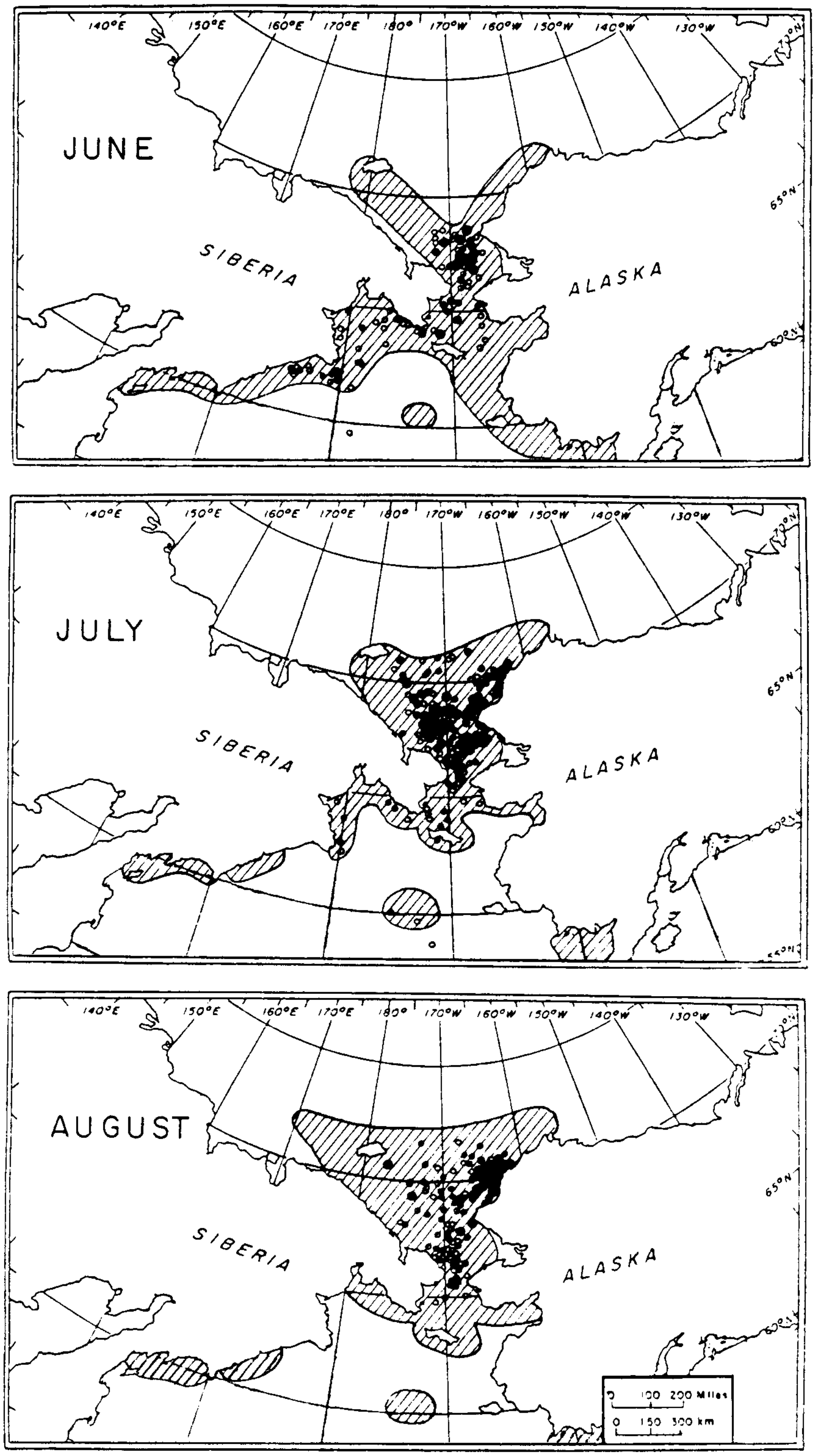

Figure 4. Distribution of sightings (open circles) and catches (darkened dots) of walruses by the Yankee whalers in June-August, during the first 20 years of their harvesting (J. R. Bockstoce and D. B. Botkin, pers. commun.). Present range of the Pacific walrus (cross-hatched, after Fay, 1982) in those months is shown for comparison.

at the beginning of World War I, when, according to Madsen and Douglas (1957) and Bockstoce and Botkin (1982), the world market for walrus products collapsed. The size of the take by natives at that time is not completely known. Krupnik's (1977) resumè for 1895 (based on "Patkanov, 1912") indicates that at least 1,300 animals were taken per year in Chukotka. We assume that several hundred more were taken in Alaska.

From Depletion to Partial Recovery, 1900-1935

In the declining years of the Yankee whaling fleet, a new group of users of the Pacific walrus population arose. These were the "arctic traders," who dealt primarily in barter with the natives of the region for ivory and furs, and who partook in walrus hunting as a profitable sideline. Americans were the primary participants in that enterprise, according to Arsen'ev (1927) and Nechiporenko (1927), but they were not the only ones involved. Vessels of Canadian and Norwegian registries, at least, also participated in the venture.

Walruses apparently had reoccupied the eastern coast of Kamchatka, where they had been left virtually untouched by the whalers. They hauled out regularly on Karaginskii and Verkhoturov islands (Fig. 5), where they were hunted by the Koryak natives, and not infrequently, they occurred as far south as Avacha Bay (Arsen'ev, 1927; Nikulin, 1941; Chugunkov, 1970; Pinigin and Prianishnikov, 1975). In the end of the 19th century, however, three American schooners came to Karaginskii and Verkhoturov islands annually, and they quickly reduced the number of walruses there to zero (Arsen'ev, 1927). A government official at Karaga reported to Niedieck (1909) that the last walrus on Karaginskii Island was shot there about 1899 or 1900, and that none had been seen since. The skull of another, obtained in Avacha Bay in June 1900 by the U.S. Fish Commission vessel ALBATROSS, is in the Museum of Comparative Zoology at Harvard University (MCZ-10108). Apparently, only two other individuals were sighted in the entire region over the next two decades: one in Morzhovoi Bay in 1909 and one in Shlyupochnoi Bay in 1920 (Arsen'ev, 1927; Nikulin, 1941). Similarly, on the Alaskan side walruses were reported to have been numerous along the north side of Unimak Island until 1898 or 99, when a group of non-native hunters arrived and killed or drove away all of them (Murie, 1959). Only single animals and groups of "very limited number" were sighted in the Bristol Bay region for more than three decades thereafter, and even those were heavily hunted (Osgood, 1904; Madsen and Douglas, 1957; Murie 1959).

Thus, the traders apparently were responsible for extirpating walruses from the Koryak-Kamchatka region, and they probably had a similar effect along the north side of the Alaska Peninsula and in Bristol Bay by the early 1900's. The U. S. government placed a prohibition on the taking of walruses in Alaskan waters by non-natives in 1909 (Madsen and Douglas,

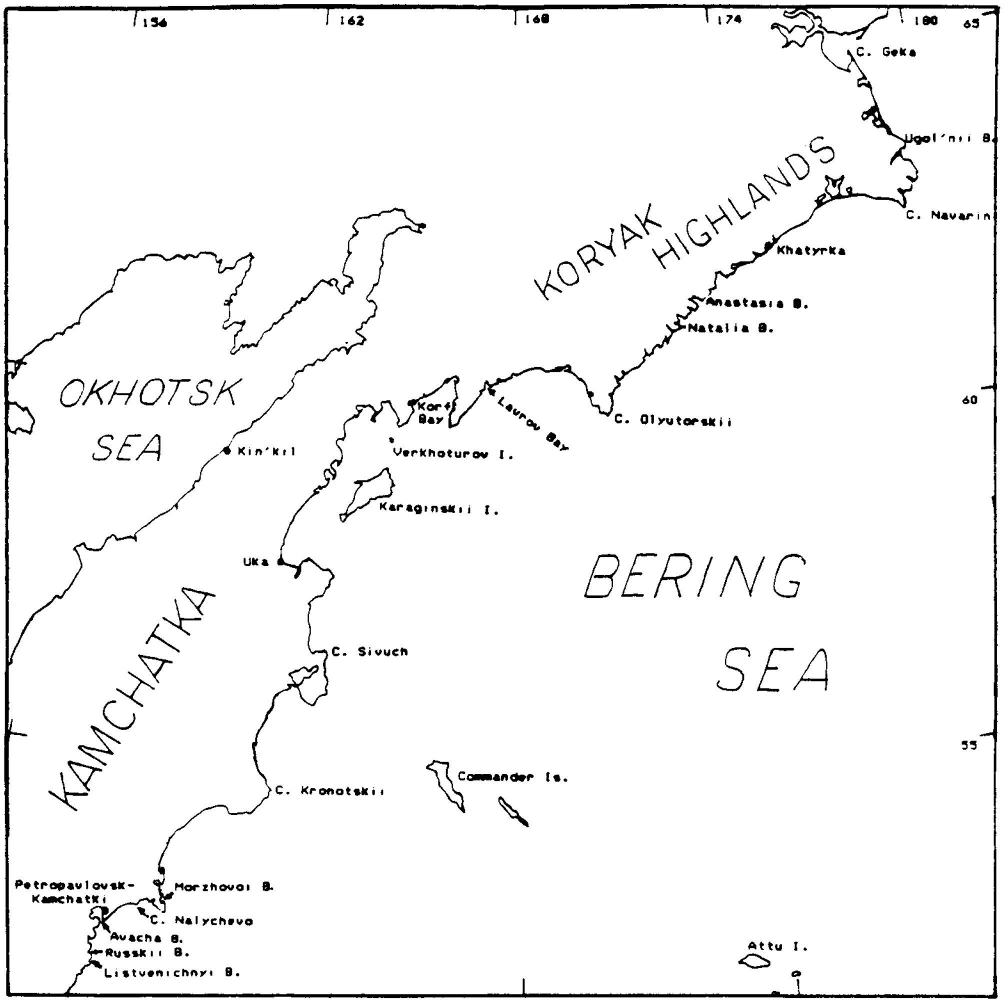

Figure 5. The Koryak-Kamchatka district of the Soviet Far-East, showing localities mentioned in the text.

1957), and on the taking of walruses for ivory alone by 1915 (Chandler, 1943). Having already depleted the more accessible herds on the Alaskan side anyway, the traders apparently were encouraged by those regulations to relocate all of their hunting to more northwestern waters. Their catches began to have a noticeably depleting effect in Chukotka by 1912, according to Nechiporenko (1927), and although they stopped for a time during World War I, they evidently resumed immediately after the war. Brooks (1954) stated that the hunting was "heavy" at that time, and Burns (1965) speaks of one vessel in 1917 taking more than 1,300 animals near Wrangel Island.

Nechiporenko (1927) reported that the hunting by "foreign 'predators'" declined along the Soviet coast after 1920. Nonetheless, Bernard (1925) indicated that it was still heavy on the Alaskan side, however, at least until 1923, when more than 1,000 carcasses washed ashore between Cape Lisburne and Barrow. During the 1920's, the Eskimos and coastal Chukchi of the Soviet Far East took between 1,300 and 3,000 walruses per year (Nechiporenko, 1927; Krupnik, 1980). The catches by Alaskan Eskimos in that period were not recorded, but a decade later they were estimated at 1,000 to 1,500 per year (Collins, 1940).

The combination of the continuing harvests by the natives and the additional take by the traders apparently was sufficient not only to prevent the recovery of the walrus population (after the whalers withdrew) but to reduce it even further. The elder Eskimos at Little Diomede Island whom Brooks (1954) queried in 1952-53, felt that the lowest ebb of the walrus population in the present century took place about 1920. On the Soviet coast, Nechiporenko (1927) reported that walruses were "very rare" south of Kresta Bay at that time. Arsen'ev (1927), citing "Suvarov," indicated that they occurred no farther south than Cape Geka, at the entrance to the Anadyr estuary.

A few groups of walruses began to reappear in the Kamchatka district in the late 1920's. In the winter of 1928-29, a group was seen near the village of Uka, southwest of Karaginskii Island, and in 1931, another group appeared farther north, in Korf Bay (Nikulin, 1941). Then, in 1935, about 500 were sighted in Natalia Bay, on the Koryak coast, and more than 1,000 were reported south of Cape Navarin. By 1939, individuals and small groups were reappearing at Verkhoturov and Karaginskii Islands, as well, where they had not been seen for 40 years (Nikulin, 1941; Kosygin and Sobolevskii, 1971; Pinigin and Prianishnikov, 1975). One wanderer even reached Honshu, Japan in 1937 (Scheffer, 1958).

To the north, herds were absent from former haulouts on parts of St. Lawrence and the Punuk islands in the 1920's, but they reappeared there in substantial numbers by the early to mid-1930's (Murie, 1936). A year or two of unusually high natural mortality of walruses on their autumn hauling grounds on the Punuk Islands also was reported at that time (L. Kulukhon <u>in</u>

Fay and Kelly, 1980). Similarly, on the Soviet side they had been absent in the 1920's from such major hauling grounds as Arakamchechen, Naukan, and Big Diomede (Fig. 6), but they reoccupied those haulouts in the 1930's (Arsen'ev, 1927; Ognev, 1935); Zenkovich, 1938; Belopol'skii, 1939). Of 38 hauling grounds recorded on the Soviet coast, the number in use rose from 17 in the 1920's to 19 in the 1930's, and the number in regular, annual use rose from 4 to 6 (Table 3). One of the former haulouts (Cape Geka), however, apparently was abandoned during the 1930's and has not been reoccupied since then. According to Soviet biologists queried by us, that abandonment was due to frequent disturbance by increased shipping and other traffic in the Anadyr estuary (G. A. Fędoseev, V. N. Gol'tsev, pers. commun.).

In the 1930's, F. A. Zeusler, captain of the U. S. Coast Guard ship that brought legal, medical, and dental aid to the Alaska coast each year, circulated 100 questionnaires to missionaries, teachers, and native residents of the villages from Mekoryuk to Barrow. He asked for their opinion about the current status of the walrus population. The response from the natives and missionaries, whose long term residence should have given the best perspective, was that the population was increasing. The response from the teachers, most of whom stayed in a village no more than 2 years and often found the walrus hunt repugnant, was that the population was decreasing. Thus, the real status of the population during this period is somewhat enigmatic. Our interpretation is that the traders' incursions virtually extirpated again the southern herds of summering males in the Bering Sea, and that their work in the pack ice continued to suppress but probably did not cause any major decrease in numbers there. We judge that because the population apparently began its recovery rather quickly, after the traders reduced their impact on it in the 1920's. But recovery was never completed, because another intensive harvesting program arose on the Soviet side very soon after the traders withdrew.

The Soviet Exploitation Period, 1931-1962

Up to the 1920's, the revolutionary government of the newly established Union of Soviet Socialist Republics paid little heed to its distant eastern border. The inhabitants of coastal Chukotka had more frequent and closer contact with American traders at that time than they did with their own officials. They even conducted their financial matters with American money and were reliant on goods brought to them from North America (Arsen'ev, 1927; Rozanov, 1931)). In an effort to bring those natives back into the Soviet sphere of influence and to dissolve their relationship with the Americans, the Soviet government sent its representatives into Chukotka in the 1920's to review the situation and make recommendations for improvement. Arsen'ev (1927), Nechiporenko (1927), and Rozanov (1931) were among those dispatched to Chukotka to review the means, amounts, and industrial

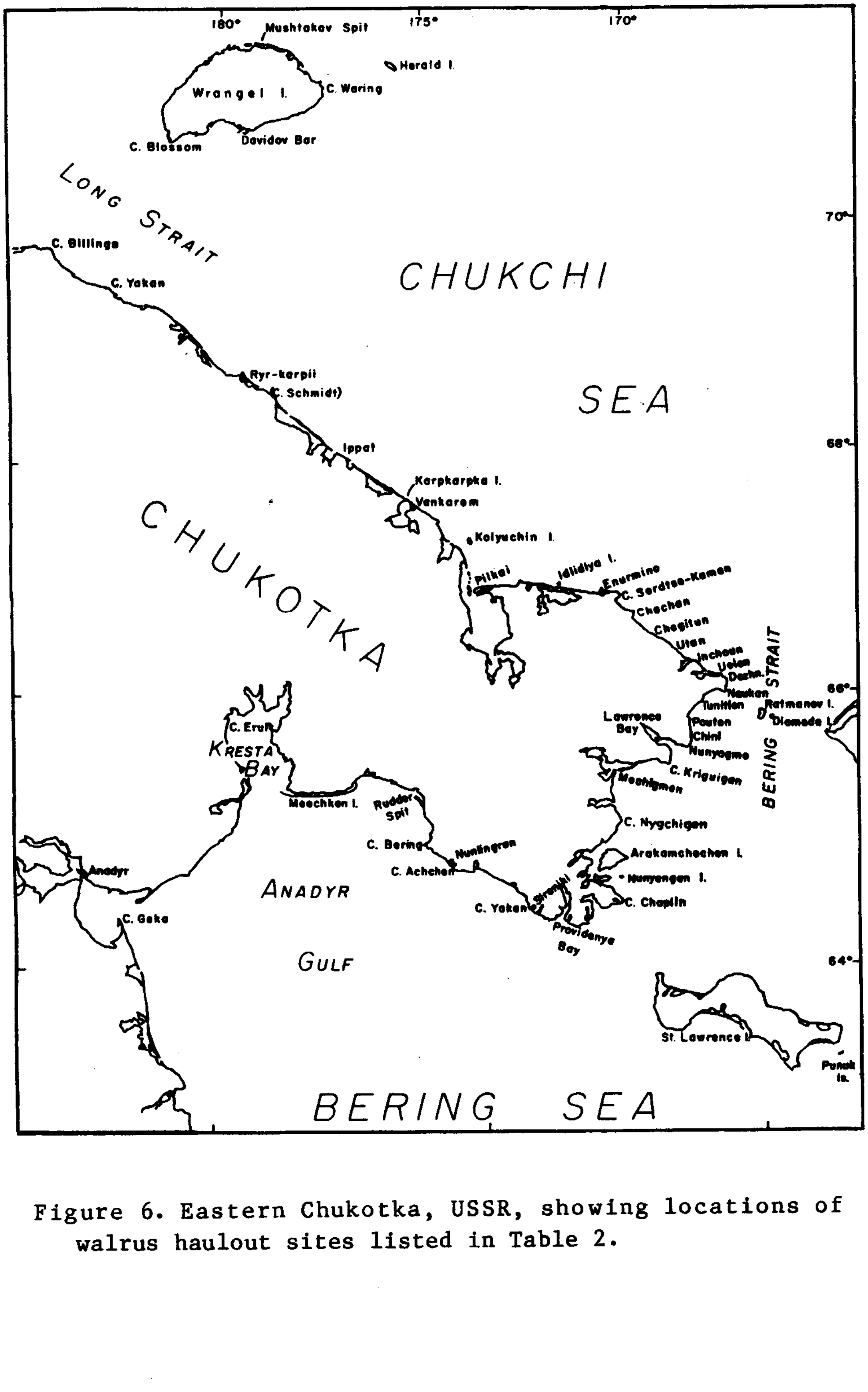

Figure 6. Eastern Chukotka, USSR, showing locations of walrus haulout sites listed in Table 2.

Table 3. Use by walruses of haulout areas on the coast of Chukotka per decade, 1920-1980, as reported in Soviet literature.[1]

Haulout[2]	1920's	1930's	1950's	1960's	1970's
Cape Geka	Regular	None	None	None	None
Meechken	Regular	Regular	None	Regular	Regular
Cape Erulen	None	Irreg.	None	None	None
Cape Maska	None	Irreg.	None	None	None
Rudder	Regular	Regular	Regular	Regular	Regular
Cape Bering	None	Regular	None	None	None
Cape Chaplin	None	None	None	None	None
Nunyangan	None	None	None	None	Irreg.
Arakamchechen	None	Regular	Irreg.	Irreg.	Regular
C. Nygchigen	Irreg.	None	None	None	None
Mechigmen	Irreg.	None	None	None	None
Lawrence Bay	None	Irreg.	None	None	None
Nunyagmo-Chini	None	Irreg.	None	None	Irreg.
Tunitlen	None	Irreg.	None	None	None
Pouten	None	None	None	Irreg.	None
Naukan-Dezhnev	None	Irreg.	None	Irreg.	Irreg.
Big Diomede	None	Irreg.	None	Irreg.	Regular
Uelen	Irreg.	Irreg.	None	Irreg.	None
Inchoun	Irreg.	Regular	Irreg.	Irreg.	Regular
Utan	Irreg.	None	None	None	None
Chegitun	Irreg.	Irreg.	None	None	None

Table 3. Continued

Haulout[2]	1920's	1930's	1950's	1960's	1970's
Chechan	None	Irreg.	None	None	Irreg.
Serdtse-Kamen	Irreg.	Regular	None	Irreg.	Regular
Enurmino	None	None	None	Irreg.	None
Idlydlya	None	Irreg.	None	Irreg.	Irreg.
Pil'kai	Irreg.	None	None	None	None
Kolyuchin	Regular	Irreg.	None	Irreg.	None
Vankarem	Irreg.	Irreg.	None	None	None
Karpkarpka	None	None	None	Irreg.	None
Ippat	Irreg.	None	None	None	None
Ryr-karpii	Irreg.	None	None	None	None
Blossom	None	None	None	Irreg.	Irreg.
Davidov	None	None	None	Irreg.	Irreg.
Mushtakov	None	None	None	Irreg.	Irreg.
C. Waring	None	None	None	Irreg.	None
Herald I.	None	None	None	Irreg.	Irreg.
Shelagskii	Irreg.	None	None	None	None
Prykadtagn	Irreg.	None	None	None	None

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[1] Data for 1920's from Arsen'ev (1927), Nechiporenko (1927), and Rozanov (1931); for 1930's from Ognev (1935), Zenkovich (1938), Belopol'skii (1939), and Nikulin (1941); for 1950's from Rass et al. (1955) and Geller (1957); for 1960's from Fedoseev (1966) and Gol'tsev (1968); and for 1970's from Gol'tsev (1975a), Fedoseev (1981, 1982), and Somov et al. (1982).

[2] "Regular" indicates annual use by one or more herds of 100 or more animals; "Irreg." indicates intermittent use by such herds; "None" means that the haulout was not used at all by such herds.

yields from the hunting of walruses, for the trade in walrus products was one of the strongest links with foreign sources. Finding the methods crude and the returns poor, they recommended that the productivity of the natives be increased by better mechanization of the hunting and rendering processes. They also recommended that the Soviet government offer higher prices and provide trade goods sufficient to replace those brought by the Americans. In response, the government began subsidizing their far-eastern natives, providing small vessels and new whaleboats to some communities and rendering plants to others (Rozanov, 1931; Krypton, 1956). At the same time, although the recommendations included prohibition of walrus hunting for "commercial gain" (Arsen'ev, 1927), the economics of the situation evidently required that the catch on the Soviet side be increased substantially by an additional take from government vessels, manned by non-native crews. The task of those crews was to harvest walruses mainly for ivory and hides, much as the American so-called "predators" had done before (Zenkovich, 1938). The American traders, meanwhile, also continued to take some walruses on the high seas (numbers unknown), and the Alaskan Eskimos continued to hunt for their own subsistence and to some extent for trade.

The walrus population, depressed for so long by the whalers' and traders' excessive catches, has been estimated to have recovered to more than 250,000 animals by 1931 (Kibal'chich and Borodin, 1982), based on a computer model using recent vital statistics and the record of catches since that time. A population of that size would have been sufficient to sustain a modest, well regulated fishery. But the Soviets evidently acted without sufficient time for reasoned judgement, for their catches of walruses rose markedly from a norm of 2-3,000 per year in the late 1920's to a high of at least 8,000 per year in the 1930's (Fig. 7). The general trend of the Soviet catch after 1938 was gradually downward until the early years of World War II; then it leveled off about 3-6,000 animals per year, during the 1940's and 1950's. That recorded catch apparently was the amount taken from the sealing vessels only, for the data presented by Krylov (1968), ostensibly for the total, do not jibe well with those compiled for the native catches by Krupnik (1980). That is, some additional amount apparently was taken by shore-based boats.

The average catch by Eskimos in Alaskan waters during the 1930's was estimated to have been between 1,000 and 1,500 animals per year (Collins, 1940; Brooks, 1954; Fay, 1955, 1958), but it evidently fluctuated widely. Missionaries B. LaFortune, T. Cunningham, and G. Carroll (unpubl. data), who resided on Little Diomede and King islands from 1929 to 1958, recorded wide variations in hunting success at those two localities; increase or decrease of the walrus population was not mentioned. Both Fay (1957, 1982) and Hughes (1960) reported some extremely low catches (30 to 70/village/year) at St. Lawrence Island in the 1940's and 50's, and A. Heinrich (in litt.) reported a low catch of only 20 at Little Diomede Island in

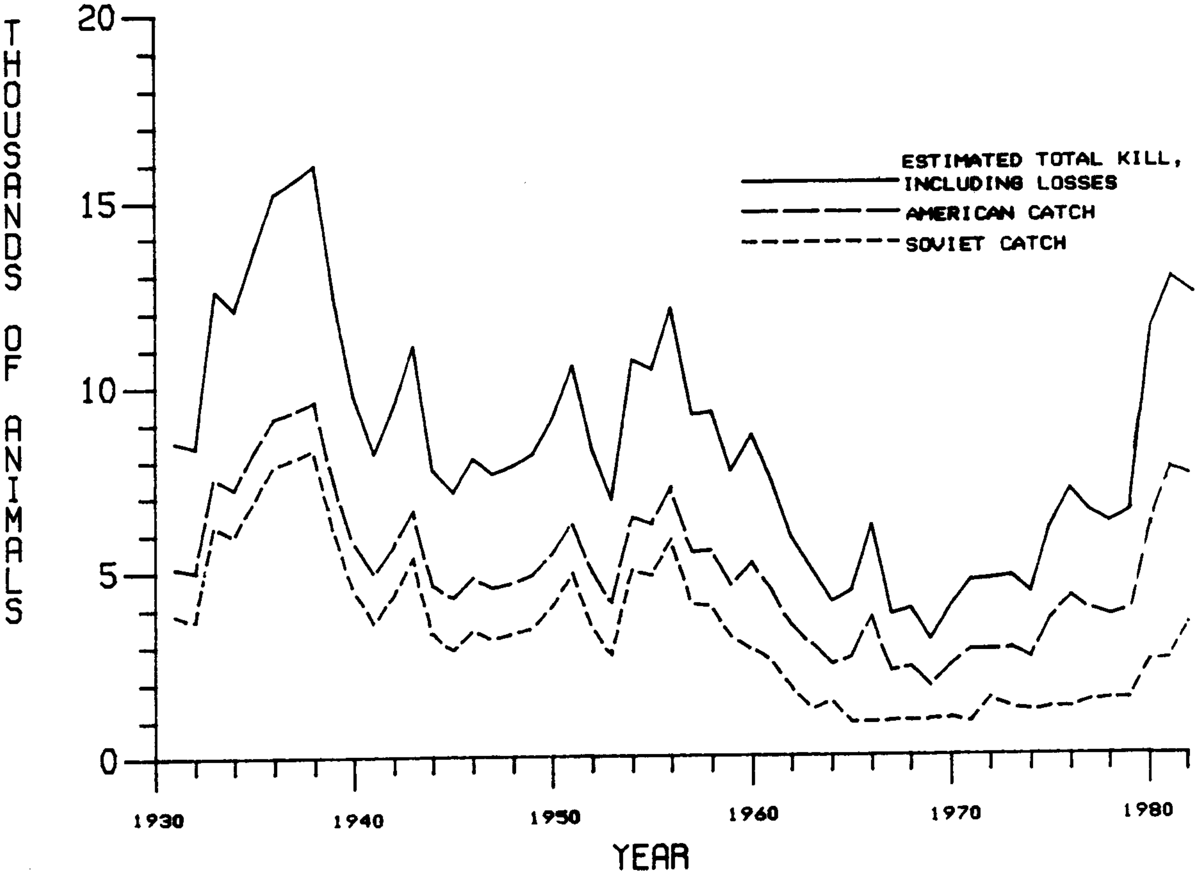

Figure 7. Reported annual catches of Pacific walruses, 1931-82. Curves based on reported data from Chukotka (lower, short dashes), plus the reported catches in Alaska (middle, longer dashes), to which has been added the best estimate of losses from sinking and wounding, to get the estimated total annual kill (upper, solid line).

1946, whereas catches of about 250 were not uncommon there about that time (Collins, 1939 in Brooks, 1954). The occurrence of those poor catches probably can be attributed in part to unfavorable ice conditions (Fay, 1982), but it also indicates extreme scarcity of walruses in areas where they usually had been most readily available. That is, the very large commercial catches by the Soviet Union apparently were having a telling effect. Commercial hunting of walruses by American traders was no longer a major factor in this decline, for the taking of walruses for any but subsistence purposes had been slowed by American federal regulation in the late 1930's and virtually stopped by the U. S. Walrus Act of 1941 (Ch. 368, 55 Stat. 632, 48 U.S.C. 248)

In both Chukotka and Alaska, the catches in this period were taken with high-powered rifles, but the rate of success in retrieval of the shot animals was not high. The catches amounted to about 60% of the numbers of animals shot; the remaining 40% were killed and lost due to sinking, or they escaped with mortal wounds (Zenkovich, 1938; Brooks, 1954; Buckley, 1958; Krylov, 1968). Thus, the overall kill in Chukotka and Alaska, including losses, probably went as high as 15-16,000 animals per year at the height of the Soviet harvests of the 1930's and probably did not dip below 7-8,000 per year in the rest of this 30-year period. The impact evidently was comparable to that of the Yankee whalers, 50-60 years earlier, although it was spread over a much longer period of time. During that period (1930's to 50's), Soviet reports of the walruses' use of traditional haul-out sites in Chukotka indicated a decline in the number of sites occupied from 19 in the 1930's to only 3 in the 1950's, and only one of those three was used on a regular, annual basis (Table 3). Large herds that had been hauling out on Big Diomede (Ratmanov) Island during the autumn migration were absent or very small and irregular in occurrence after 1939 (N. Whitaker, A. Heinrich, J. J. Burns, pers. comm.). South of Anadyr Gulf, walruses became absent once again, except for one wanderer in the Okhotsk Sea in 1940 and another in 1957 (Rass et al., 1955; Kosygin and Sobolevskii, 1971). V. A. Arsen'ev (1976) has suggested that those two animals might have been brought southward from the Chukchi Sea by Soviet sealers and released in the Okhotsk area.

On the American side, as well, a great reduction in the use of coastal hauling grounds was evident. The small herds seen intermittently at Cape Lisburne in the 1930's and early 40's (L. S. Vincent, K. M. Kimble, unpubl. data) apparently were absent during the 1940's to 60's, judging from the lack of reports of their occurrence there; they reappeared there in the 1970's (A. Springer, D. Roseneau, pers. comm.). In Bristol Bay, the use of Amak Island by walrus herds was discontinued in the 1930's (F. A. Zeusler, unpubl. data) and apparently not resumed until the 1960's (K. W. Kenyon, pers. comm.).

Concern for the welfare of the walrus population and of the native people who were dependent on it was expressed on the Soviet side by Geller (1957), Kleinenberg (1957), and Sleptsov (1961) and, simultaneously, on the American side by Fay (1957) and Kenyon (1960b). The awareness of the depleted state of the walruses had been derived independently on each side of the, then, "iron curtain", and the reactions that followed on each side also were unilateral, without any cross-communication. On the basis of recommendations from its scientists, the Soviet government in 1956 enacted a decree for "security of the animals of the Arctic" (Kleinenberg et al., 1964) and conducted a considerable national campaign thereafter to make the need for protection widely known and understood (Kosygin, 1975). Gradually, the composition of the Soviet harvests was shifted from mixed sexes to males alone, killing of animals in the water and on the coastal hauling grounds was prohibited, and the vessel- and shore-based catches of walruses in the Bering-Chukchi region were reduced (Tikhomirov, 1964a). Finally, the government-operated catching from vessels was terminated in 1962 (Gol'tsev, 1975a), and a small quota of 1000 to 1500 animals was distributed among the native kolkhozes (Tikhomirov, 1964a). In Alaska, the walrus hunting had been limited earlier (1941) to that by natives for their own subsistence, and the newly formed State of Alaska implemented further protective measures to reduce the catch of adult females and prohibit taking on the principal hauling ground in Bristol Bay. These measures, on both sides, were intended to give the walrus population unprecedented protection and help it to restore itself.

The Protective Period, 1952-1982

The Soviet state walrus hunting industry, ostensibly based on sound biological data and internationally accepted wildlife management principles, had failed abysmally as a controlled cropping scheme by the mid-1950's, having depleted the very resource on which it was dependent. By then, the managers realized that not enough was known about the biology and ecology of walruses to manage them effectively on a sustained yield basis. The results also should have made clear the fact that neither country was capable of managing this common resource unilaterally, without even consulting the other.

In retrospect, the protective reactions that followed appear to have been over-reactions, but the information needed for conservation with a better foundation simply was not available. The greatest immediate value of the responses on both sides was that they drew attention to and support for further biological research. Those programs of research were justified on the grounds of dependence of the coastal natives of Chukotka and Alaska on the walrus as a major natural resource.

The importance of walruses to rural Alaskans had been made clear by the work of Brooks (1953, 1954), Kenyon (1960b), and others and was a major point in the foundation of the research and management program of the new State of Alaska's Department of Fish and Game (ADF&G) in 1959. That program was developed at once and supplemented by occasional contributions from the research program of the U. S. Fish and Wildlife Service. Over the next two decades, it made significant advancements in knowledge about the walrus population.

Exchanges of information between American and Soviet biologists about walruses and hair seals also were begun in the late 1950's, at first through the North Pacific fur seal meetings, then through the Marine Mammal Project of the US-USSR Environmental Protection Agreement of 1972 (Miller and Zemskii, 1984). Since then, the information acquired by both sides, jointly and separately, concerning the Pacific walrus has provided one of the best documented records available of the natural and man-made dynamics of a pinniped population.

The following is a resumè of some of the principal findings from that work. In many instances, the data sets are not large, and the results derived from them, individually, are of little significance. Taken as a whole, however, they at least indicate the direction of change, if not the exact amount. Included is information on geographical distribution, size of the population, age composition, reproductive performance, feeding habits, physical condition, and natural mortality of the Pacific walrus population over the past 30 years.

Distribution.--Soviet records of the use by walruses of summering areas along the Koryak-Kamchatkan shores of southwestern Bering Sea indicate that the animals began to re-appear there in the 1960's, after a 25- to 30-year absence, and that they subsequently became comparatively common again in all parts of the region (Chugunkov, 1970; Kosygin and Sobolevskii, 1971; Gol'tsev, 1975a; Pinigin and Prianishnikov, 1975). Since 1969-70, herds of 500 to 1,500 have been seen repeatedly in summer along the Koryak coast in the vicinity of Anastasia and Natalia bays. In the same period, herds at first of 25 to 200 and now of up to 1000 (G. A. Fedoseev, pers. commun.) have appeared in summer at Verkhoturov and Karaginskii Islands, as well. Nearly all of those have been males, as before; the record of one female with a calf in Lavrov Bay in the summer of 1970 was an unusual occurrence (Kosygin and Sobolevskii, 1971). More recently, herds of males have been seen along the Koryak coast, as far south as Olyutorskii Bay in late winter and spring (Kibal'chich, 1981; Calkins et al., 1981), and a few females with young have been sighted as far south as Khatyrka (G. A. Fedoseev, pers. comm., 1980).

On the Alaskan side of the Bering Sea, south of the Yukon estuary, there are eight localities in which major hauling grounds are now or were formerly used on a regular, annual basis by large herds of walruses. Those are Amak Island, Port Moller, Cape Seniavin, Round Island, Big Twin Island, Cape Newenham, Pribilof Islands, and St. Matthew Islands. More than 15 other sites have been used one or more times by herds of 20 or more animals, but not on a regular basis (Frost et al., 1982). The summering aggregation of bulls that hauls out on the Walrus Islands in northern Bristol Bay has grown from about 3000 in the late 1950's to about 12,000 in recent years (Kenyon, 1958; Taggart and Zabel, 1980; Frost et al., 1982). Walruses, probably from that same group, reappeared on Amak Island in 1962, after about a 30-year absence, and they seem to have reappeared in Port Moller about the same time. They recently have established themselves on another hauling ground at Cape Seniavin, but the history of that one is unknown (L. F. Lowry, C. Smith, pers. comm.).

Walruses apparently re-occupied the St. Matthew Islands in the fall of 1980 (R. D. Jones, pers. commun.), and they evidently began to reside there in summer, as well, by the following year (Frost et al., 1982; D. Irons, pers. commun.). To the best of our knowledge, the only previous records of their presence there were those by Etholin in 1830 (Tikhmenev, 1978) and by Hanna (1920) nearly a century later. We and several other observers have searched for walruses in that area numerous times in the 1960's and 70's, usually without sighting any or, at most, only one or two individuals. (D. R. Klein, R. L. Rausch, A. L. Sowls, A. DeGange, S. W. Stoker, and F. H. Fay, unpubl. data). That is, the recent re-occupation of the St. Matthew Islands appears to have been en masse, rather than by gradual increase. The hauling grounds on the Pribilof Islands, however, still remain unoccupied by any more than occasional individuals (Fay, 1982; Frost et al., 1982; F. H. Fay, K. W. Kenyon, and R. S. Peterson, unpubl. data). The recent use of Capes Pierce and Newenham probably also is not new but a re-occupation, though we have found no definite record of use of those sites before.

In the northern Bering and Chukchi seas, the walruses' use of haulouts on Chukotka showed a marked increase from a low of 3 sites in the 1950's to a high of 18 in use in the 1960's and 15 in the 1970's (Table 3). In those three decades, the number of hauling grounds in regular, annual use increased from 1 to 2 to 6, respectively. Of the latter, the Meechken and Rudder sites always were occupied principally in summer; the Arakamchechen, Big Diomede, and Inchoun sites at first were occupied only during the autumn migration, then during the summer as well; the Serdtse-Kamen site always was used during only the autumn migration (Nikulin, 1947; Kleinenberg et al., 1964; Gol'tsev, 1968; Fedoseev, 1982). The Cape Chaplin haulout, which ostensibly was used often in the 19th century and earlier (Arsen'ev, 1927), has not yet been re-occupied in this century, for reasons unknown. Others, like those at Capes Geka in the Anadyr estuary, Erulen and Maska in Kresta Bay, Uelen at Bering Strait, and Vankarem and Ryr-karpi (Cape Schmidt) on the northern coast of Chukotka are now regarded as "extinct," inasmuch as walruses apparently are prevented or discouraged from hauling out there by continual human disturbances (construction, shipping, etc.) (Fedoseev, 1982 and pers. commun.). None of the hauling grounds west of Cape Serdse-Kamen and on Wrangell and Herald Islands can be used on a regular basis, because they often are inaccessible due to heavy ice (Krylov et al., 1964; Gol'tsev, 1968; Tomilin and Kibal'chich, 1975).

On the Alaskan side north of the Yukon estuary, the number of regularly used haulouts apparently never was as large as on Chukotka (Table 4). Walruses began hauling out regularly in large numbers on the northwestern cape of St. Lawrence Island, near Gambell, in the fall of 1962, having been absent from that area for some 25 years (V. K. Slwooko, pers. commun.). Since then, the numbers hauling out and the duration of their stay have increased steadily (at least to 1978: T. Antoghame, pers. comm.). They also hauled out in abundance on the northeastern end of that island in the fall of 1978, for the first time in at least 40 years (Murie, 1936; Fay and Kelly, 1980). At Kialegak Cape, on the southeastern part of the island, they reappeared in the fall of 1970, having been absent for several decades (V. K. Slwooko, pers. commun.), they hauled out there by the thousands in 1978 (Fay and Kelly, 1980).

On the Punuk Islands, just east of St. Lawrence Island, walruses have hauled out regularly during the fall migration for at least the past century, and the presence of a few there nearly every summer also was regarded as normal from about 1914 to 1945 (L. Kulukhon, pers. commun.). They were virtually absent there in summer for the next 25 years, with only one known exception (in 1956), but they have re-appeared there in summer on a regular basis since the 1970's (A. Akeya, T. Antoghame, F. H. Fay, and B. P. Kelly, unpubl. data).

Farther north, in Bering Strait, walruses re-occupied Big Diomede Island in the fall of 1965, after about 30 years of absence or scarcity (J. J. Burns, pers. comm.). The numbers and duration of their stay there have increased steadily since that time (Frost et al., 1982). Nowadays, they occur not only during the fall migration but all summer, as well. Since the mid-1970's, some also have used Little Diomede and King islands intermittently, despite frequent harassment (E. Muktoyuk, J. J. Burns, pers. commun.).

In the eastern Chukchi Sea, the two haulouts at Cape Thompson and Point Hope saw irregular use in the past, during the fall migration. To the best of our knowledge, they have not been re-occupied. The haulout at Cape Lisburne, however, was re-established at least by 1975 (D. Roseneau, A. Springer, pers. comm.), after about 30 years of disuse. Farther north and east, walruses had not been seen in the Beaufort Sea for many years, but they began to reappear there in small numbers in the 1960's (Burns, 1965), and they now occur there more frequently.

Table 4. Use by walruses of haulout areas on Alaskan shores of the northern Bering Sea and Chukchi Sea in the present century.[1]

Haulout	1920's	1930's	1940's	1950's	1960's	1970-80's
Egg I.	UNK	UNK	UNK	None	None	Irreg.
Besboro I.	UNK	UNK	UNK	None	Irreg.	Irreg.
Cape Darby	UNK	UNK	UNK	UNK	None	Irreg.
Sledge I.	Irreg.	Irreg.	None	None	None	Irreg.
Punuk Is.						
(summer)	Irreg.	Irreg.	Irreg?	Irreg.	None	Reglr.
(fall)	None	Irreg.	Irreg?	Reglr.	Reglr.	Reglr.
St. Lawrence I.						
Kialegak Pt.	None	None	None	None	None	Irreg.
N. E. Cape	None	None	None	None	None	Irreg.
Salghat	Irreg.	Irreg.	None	None	None	Irreg.
C. Chibukak	Irreg.	Irreg.	None	Irreg.	Reglr.	Reglr.
King I.	UNK	UNK	UNK	None	None	Irreg.
Little Diomede	UNK	Irreg.	None	None	Reglr.	Reglr.
C. Thompson	UNK	Irreg.	UNK	None	None	None
Pt. Hope	UNK	Irreg.	UNK	None	None	None
C. Lisburne	UNK	Irreg.	Irreg.	None	None	Irreg.

[1] From Hanna (1920, 1923), Murie (1936), Collins (1940), Brooks (1954), Frost et al. (1982, 1983), and unpublished notes from U. S. Fish and Wildlife Service and Alaska Department of Fish and Game files, as well as from A. Akeya, T. Antoghame, R. Baxter, J. J. Burns, A. DeGange, F. H. Fay, T. Gologergan, Jr., R. D. Guthrie, D. Irons, W. James, R. D. Jones, B. P. Kelly, K. W. Kenyon, D. L. Klein, L. Kulukhon, E. Muktoyuk, R. L. Rausch, D. Roseneau, V. K. Slwooko, T. Smith, A. Sowles, A. Springer, S. W. Stoker, R. Tremaine, and M. Ward.

Another indicator of change in the population is the frequency of occurrence of individual wanderers outside the usual limits of the range. In the 1950's, there were only three records of such wandering -- an animal sighted on Kodiak Island in 1954, one in Cook Inlet in 1955 (R. A. Ryder and L. Temple in Fay, 1982), and another in the Okhotsk Sea in 1957 (Kosygin and Sobolevskii, 1971). In the 1960's, four more were recorded: an individual was sighted in upper Cook Inlet in 1964 (Fay, 1982), and three were seen on the southeastern coast of Kamchatka in 1966 — one individual at Listvenichnyi Bay, one in Russkii Bay, and the third was found dead at Cape Nalychevo in that year (Chugunkov, 1970).

On the Commander Islands, where only a few beach-cast carcasses had appeared in the 1950's and 60's (Chugunkov, 1970), two living walruses were seen in the early 1970's (Pinigin and Prianishnikov, 1975). Farther east, at least one animal was reported to have reached Atka Island in the central Aleutians in 1976 (K. W. Kenyon, pers. comm.), and two others were killed there about 1979 (Fay, unpubl. data). These were the first occurrences at Atka in 30 to 40 years, according to local residents. Still farther to the east, a group of about 20 made its way out through Unimak Pass and up along the southern coast of the Alaska Peninsula in the spring of 1979 (C. Smith, K. Pitcher, D. Calkins, pers. comm.). That group was gradually reduced in number as it moved eastward, through the Shumagin Islands, Chignik Bay, Shelikof Strait, and Cook Inlet; the last known survivor reached Yakutat Bay by mid-summer. In the 1980's, so far, the only report known to us has been of one walrus found dead in the northern Kuril Islands in 1983 (Yu. A. Bukhtiyarov, pers. comm.), the first known to have made its way that far south in about 45 years.

Population Size.--Estimation of the size of the Pacific walrus population by direct censuses began in the 1950's. Previous estimates were educated guesses, not based on actual census data. The first census estimate was based on counts along the cruise track of the American icebreaker NORTHWIND, which travelled widely in the pack ice of the Bering and Chukchi seas in May and June 1954. Assuming that the cruise track was made up of a series of random transects and that the observed number of animals per unit area could be extrapolated to the total range of the walrus population in that month, Fay (1957) estimated that the Pacific walrus population was made up of about 40 to 50 thousand animals. Although the method of census was primitive and the assumptions were not necessarily correct, the result, by chance, was very similar to some later estimates.

An aerial survey conducted by P. G. Nikulin (in Fedoseev, 1962) on the Soviet side in the summer of 1958 yielded an estimate of about 40,000 animals there; the number on the American side at that time was unknown but believed to be very small. Another Soviet aerial census, this time using aerial photography of the herds on the coastal hauling grounds and visual estimates of those on the ice, was conducted on the Soviet side in the autumn of 1960 by Fedoseev (1962). From it he estimated that there were about 46,000 animals west of the Date Line at that time, and he guessed that there were perhaps 4,000 more on the Alaskan side. In that same year, however, Kenyon (1960a) and co-workers had conducted two aerial censuses over the Bering Sea pack ice, the first in late February to early March and the second in mid-April. The results from both of their surveys were very similar, with highest and lowest estimates ranging from 70 to 113 thousand animals and medians of about 85 to 95 thousand, respectively. These were nearly double the Soviet estimates, but the fact that they were different is not surprising, for they were based on surveys of nearly the entire population on its wintering range in the Bering Sea, whereas the Soviet survey had covered an unknown proportion of the population on the summering range in the western Chukchi Sea. In retrospect, we can see why the Soviets' results underestimated the whole population, because, as the latest censuses have shown, nearly half of the population probably was on the American side, out of range of the Soviets at the time.

Kenyon (unpublished data) conducted another census over the Bering Sea pack ice in March 1961 and, again, estimated the population between about 70 and 110 thousand (median, 85,000) animals. A third Soviet census in the autumn of 1964 by Gol'tsev (1968) yielded estimates of about 47 to 71 thousand (median, 59,000) animals for the portion of the population on the Soviet side. Gol'tsev did not make an estimate for Alaskan waters, apparently because he assumed that there was only an insignificant number of animals there. A fourth census by Kenyon and co-workers (unpublished data) in April 1968 again covered most of the population in the Bering Sea and yielded estimates ranging from 73 to 110 thousand animals.

The fourth Soviet census was conducted by Gol'tsev (1972) in the autumn of 1970, and from it he estimated about 101,000 animals in the whole population, apparently including a guess at the number in Alaskan waters. A fifth census by Kenyon (1972), conducted in April of 1972, yielded a similar median estimate of 123,000 for the whole population, with upper and lower limits of 85 to 162 thousand. This survey covered nearly the whole geographic range of the population in that month, hence was the best overall estimate to date.

Each of those censuses was done without benefit of communication between the Soviet and American biologists who conducted the surveys. Not until 1973 was that communication established, and it quickly led to discussion of past findings and plans for the future. The first cooperative census was conducted more or less concurrently on both sides of the International Date Line in September and October of 1975 (Gol'tsev, 1975a; Estes and Gilbert 1978), and it was followed by another in the same time period in 1980 (Fedoseev, 1981; Johnson et al., 1982). In each of those, the Americans used strip sampling methods, involving visual counts along north-south transects over the Chukchi pack ice, east of 174°W; the Soviets made visual estimates from transects over the pack ice in the western Chukchi Sea, west of 174°W, and used direct counts from aerial photos of large herds on the ice and of all herds on the coastal hauling grounds. The results in 1975 indicated that there were about 120,000 animals in Soviet waters and about 112,000 in Alaska (Table 5). In 1980, the median estimates were again about 130,000 for Soviet waters and about 115,000 for Alaska. The estimates for the total population in those years, as we interpret them, were about 232,000 and 245,000, respectively, but these are not significantly different, because of the wide confidence limits.

The population estimates derived from all of those surveys probably were very conservative, because they could not take into account the effects of such factors as activity rhythms and animals out of sight underwater, which could exert very large influences on both the collection and the interpretation of the data. We assume that such errors tend to be relatively constant, and that the trend in numbers estimated, at least, was real. That trend was clearly upward in both the Soviet and the American results (Fig. 8), even though the timing and methods were quite different on each side, during most of that time. Because the Soviet census method remained basically the same from 1960 to 1980, the increase in population size indicated by their estimates cannot be ascribed to increased sophistication of methods or equipment. In each of their surveys, about 60% of the estimate was based on actual counts from photographs of the large herds on the ice as well as on each of the coastal hauling grounds; the rest of their estimate was based on strip sampling over the ice. The confidence limits on the results from the strip sampling are unknown to us but presumed to be wide, because the samples were small. Because the American estimates were based entirely on strip sampling and the confidence limits on the results are known to be extremely wide, we regard the American median estimates as less reliable than those from the Soviet side. Furthermore, the American surveys were done in different areas, at different times, with different equipment, and the analyses of the data were done by different methods, among years. Those conditions probably contributed further to making the American results incomparable from year to year.

The Soviets' results indicate that the proportion of the population that summers on their side tripled from 1958 to 1975 but leveled off in the late 1970's. Essentially the same is indicated by the estimates of the total population, as we interpret them. Although the implied magnitude of that change is questionable, because of the wide confidence limits on the estimates, we feel that the direction is believable because increase has been indicated also by the other indices of the population's status. Using a numerical model, DeMaster (1984) has shown that doubling of population might have been possible in the 20 years between 1955 and 1975, if (1) the initial population was at least 96,000 animals, (2) the adult survival rate

Table 5. Estimated size of the Pacific walrus population, based on Soviet-American cooperative censuses in 1975 and 1980.[1]

Date and location				Estimate
1975	Soviet side	5-6 Oct	W. Chukchi ice	26,600
		18-21 Sep	Chukotka haulouts	94,139
		4 Oct	Koryak haulouts	220
	American side	8 Sep	E. Chukchi ice - est. I	100,600 ± 57,700
			- est. II	90,800 ± 63,600
			Bristol Bay[2]	6,500
1980	Soviet side	8 Oct	W. Chukchi ice	55,000
		9 Oct	Chukotka haulouts	69,400
		17 Oct	Koryak haulouts	4,000
		27 Sep	Kamchatka haulouts	1,500
	American side	15-20 Sep	E. Chukchi ice - est. I	101,200 ± 22,600
			- est. II	96,200 ± 19,200
		Jul-Sep	Bristol Bay[3]	15,000

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[1] Soviet estimates based on data from Gol'tsev (1975a) and Fedoseev (1981), excluding any possible duplicate counts of the same animals. American estimates for 1975 based on Estes and Gilbert (1978), but only for North-South strips, comparable with the 1980 estimates by Johnson _et al_. (1982). The American estimates for both years were derived by two methods: I - from average numbers of individuals per unit area and II - from average groups per unit area. For each estimate, the mean and standard error are given.

[2] From an estimate of "5-8,000" on Round Island on 29 June to 4 July 1977 (Arneson and McDonald _in_ Frost _et al_., 1982).

[3] From Taggart and Zabel (_in_ Johnson _et al_., 1982).

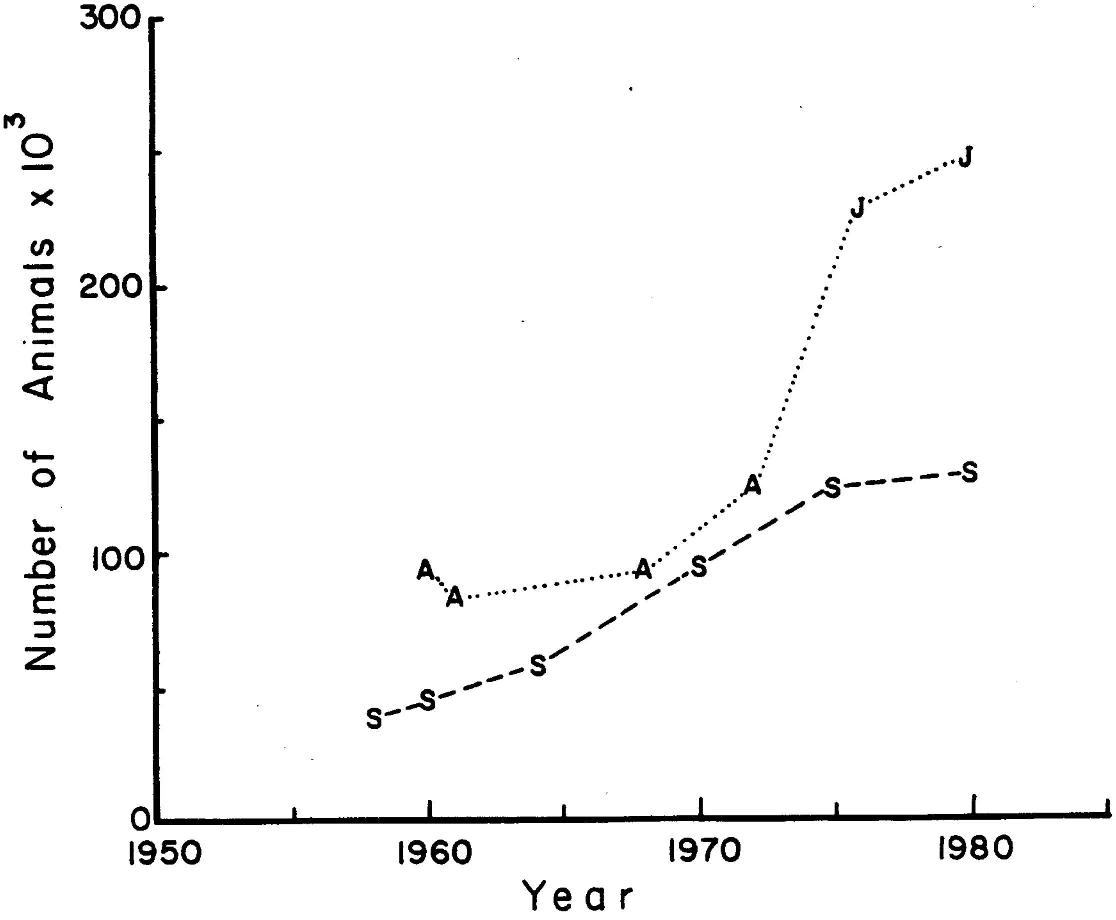

Figure 8. Estimates of the size of the Pacific walrus population, 1958-1980. Results from Soviet censuses of the number of animals west of the International Date Line in September-October (S) are compared with the results from American (A) and joint Soviet-American (J) mean estimates of the total population (data from Kenyon, 1960a, 1972, and unpublished; Fedoseev, 1962, 1981; Gol'tsev, 1968, 1972, 1975a; Estes and Gilbert, 1978; Johnson et al., 1982).

was at least 0.95, (3) the sex ratio of adults was 1 male to 3 or more females, and (4) the productivity was at its maximum. We think that all of those provisions were met, hence that the population at least doubled between 1955 and 1975, and that it probably did not increase significantly since then.

Age Composition of Native Catch.--Samples for analysis of the age/sex composition of the annual catch by Alaskan Eskimos were obtained intermittently over the past 30 years by Fay in 1952-59, by the Alaska Department of Fish and Game in 1960-79, and by the U.S. Fish and Wildlife Service and Eskimo Walrus Commission in 1980-84. Those samples were obtained principally in spring at the villages of Gambell and Savoonga on St. Lawrence Island and at Ignaluk on Little Diomede Island. They represent about two-thirds of the annual catch in Alaska in those years (Fay, 1958; Burns, 1965, 1973).

The samples consisted of one or two cheek-teeth from nearly every animal taken (other than calves), during the spring hunt. Each tooth was sectioned longitudinally, and the age of the animal was determined by counting the annual layers of cementum (Burns, 1965; Fay, 1982). All of the age determinations reported here were done by J. J. Burns (Alaska Department of Fish and Game) and F. H. Fay (University of Alaska), who cross-checked their determinations repeatedly and found them comparable.

The samples were not collected every year or in any pre-arranged schedule but were obtained mainly as opportunity and funds permitted. The data from them have been treated as age-frequency tables, with sexes separated. Because the natives' catch tends to be biased toward adult animals, the immature age classes are very poorly represented. Hence, the age-class frequencies tend to be normally distributed on the x-axis (Fig. 9). This allows them to be compared by means of statistics of central tendency. The results of those comparisons are as follows:

Males: The mean age of males taken in the spring harvests at all three villages tended to be relatively constant at 13 to 15 years during the 1950's and early 1960's (Fig. 10). After the early 1960's, however, the mean age of males rose steadily in each village's annual catch and was approaching 19 to 22 years in the most recent samples. This is a very significant increase. It was a gradual increase, and it took place without any change in the selective bias, according to the hunters that we have interviewed (A. Akeya, T. Antoghame, M. Iya, L. Kulukhon, C. Pungowiyi, pers. commun.). In all three villages, the hunters consistently selected for males with large tusks. In male walruses, tusk size increases with age, almost indefinitely (Fay, 1982).

The trend of increasing mean age of males in the catches since the early 1960's has been produced by the taking of more old animals and fewer

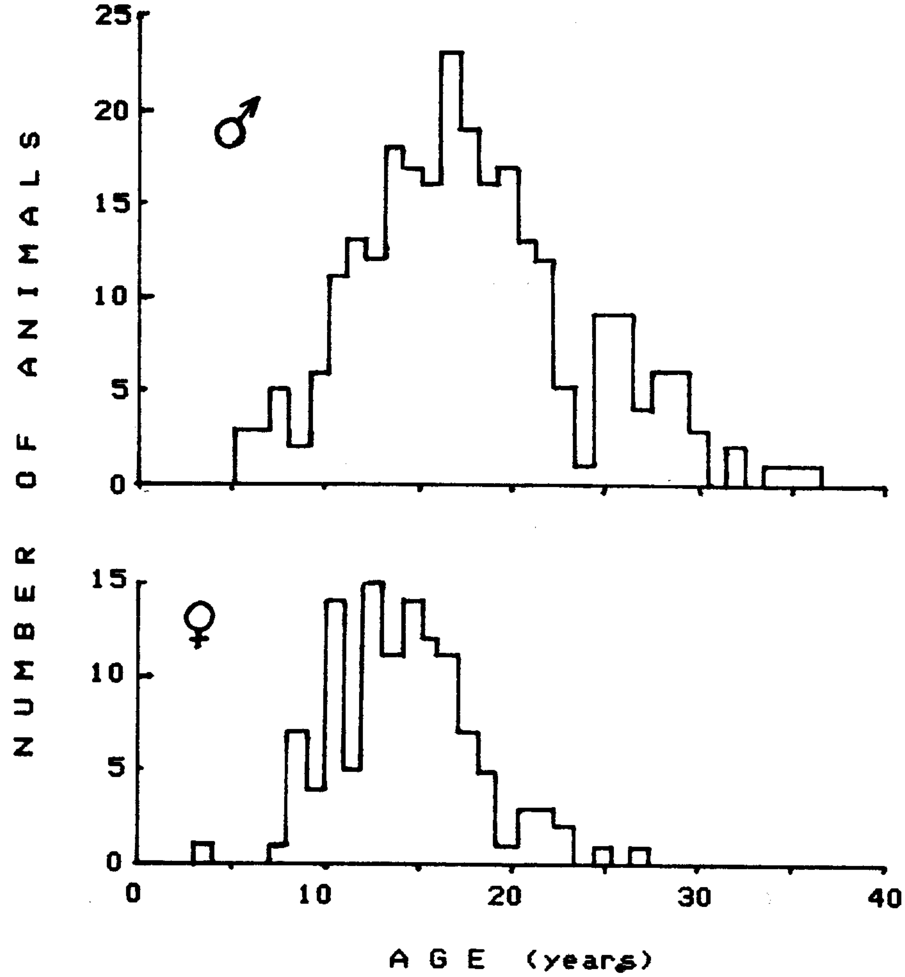

Figure 9. Age frequency histograms for male (upper) and female (lower) Pacific walruses taken at Little Diomede Island in the spring of 1972 (Alaska Department of Fish and Game, unpubl. data).

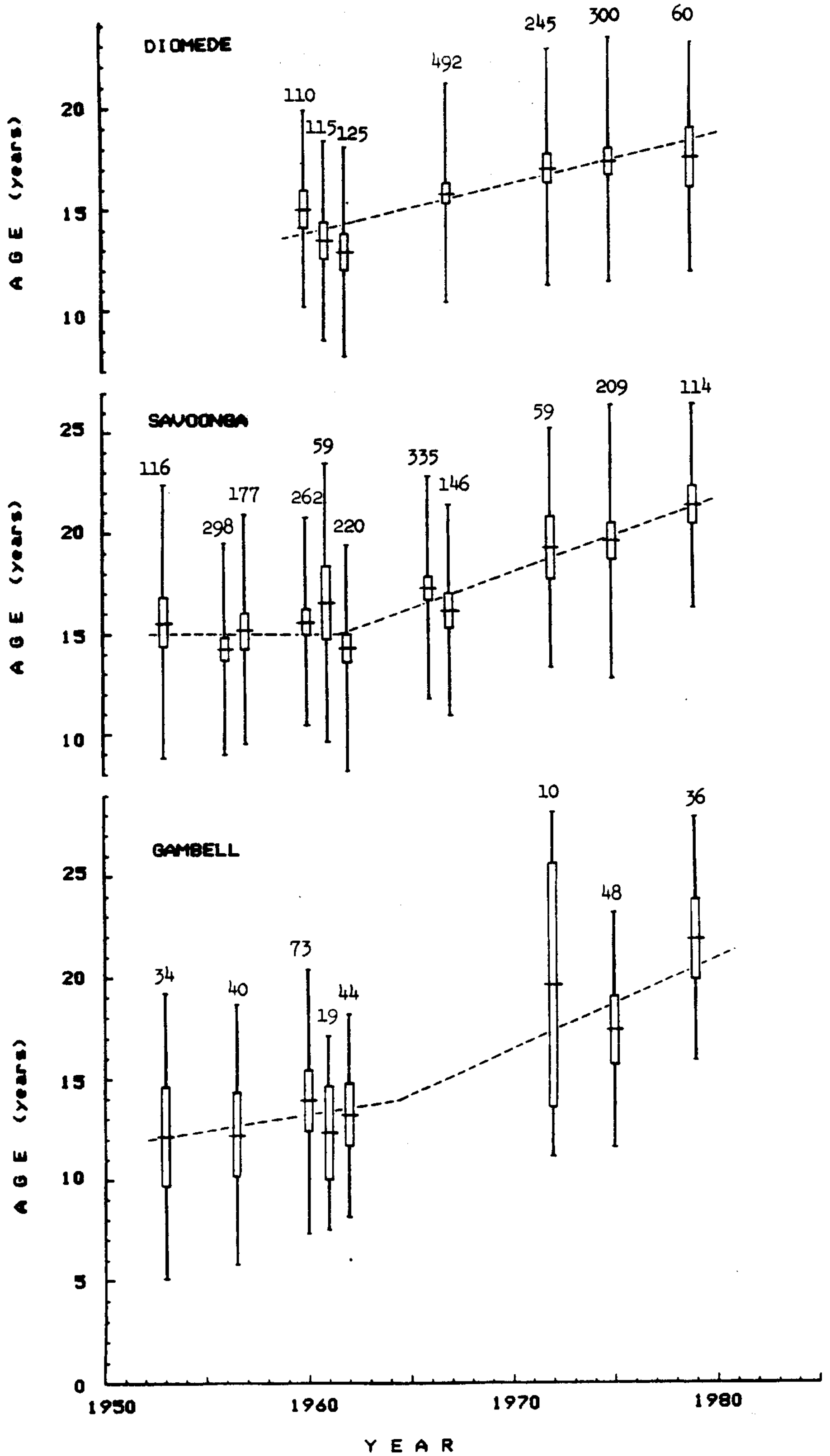

Figure 10. Change in mean age of the catches of male walruses, 1950-70's. Each bar represents one sample, of the size shown above it. Cross-bar is the mean; thin bars are ± 1 S.D.; open bar shows 95% confidence limits about the sample mean. Curves fitted by least squares.

young ones. The implication of this is that the old males have become more available and/or that the young males have become less available, over the past 20 years. Those conditions might be correlated with an increase in size of the walrus population, a shift in age composition to more old animals (brought on by either lowered recruitment or increased juvenile mortality), or a combination of those causes.

Females: The selective bias affecting the catch of females by the hunters at Little Diomede is essentially the same as it is for the males. The hunters take primarily the larger, older animals, though about as much for the quality of the meat and hides as for the tusks. The meat of adult females is desired for human consumption, and the hides of the largest females are required for building and maintaining their "skin-boats" - (umiaks). The tusks of adult females also are preferred for carving, because the ivory is of a finer, more uniform quality than in the males. The ivory of the females is of optimal size and quality at ages between 15 and 25 years; after about 25 years, it tends to check increasingly and to diminish in length due to fracture and abrasion (Fay, 1982). Hence, where there is such selective bias and the availability is unlimited, the mean age of females in the catch should approach and level off about 17 to 20 years. The mean age of the females in the catches at Little Diomede, like that of the males, was relatively stable during the population's recovery to rapid growth, in the late 1950's and early 1960's. Thereafter, it tended to rise steadily and was up to about 17 years by 1982 (Fig. 11).

At Gambell and Savoonga, the selective bias for females is different than it is for males and different than it is at Diomede. Here, the hunters search primarily for females with newborn calves, which are sought for their meat (dried for human consumption) and their skins (used for making rawhide ropes). Given the opportunity to choose from several females with calves, the hunters secondarily select for large body size and large tusks (Fay, 1958). As at Diomede, the meat of the adult females is preferred over that of the males for human consumption, the female hides are needed for the umiaks, and the ivory of females is preferred for carving.

In the 1950's and 60's, the mean age of females taken at both Gambell and Savoonga tended to be constantly about the 11-year level. This is a reflection of the fact that the age class of females with the highest probability of producing a calf was 11 years at that time (Fay, 1982). Then, in the 1970's and early 1980's, the mean age of females taken at both villages rose significantly. That increase might have been due in part to a change in age-relative fecundity and/or to an increase in average age of the females available. It apparently was not due to any change in the hunters' selection, for the hunters in both Gambell and Savoonga at that time were complaining about the scarcity of females with calves. That is, they still were seeking them preferentially but were having less success in

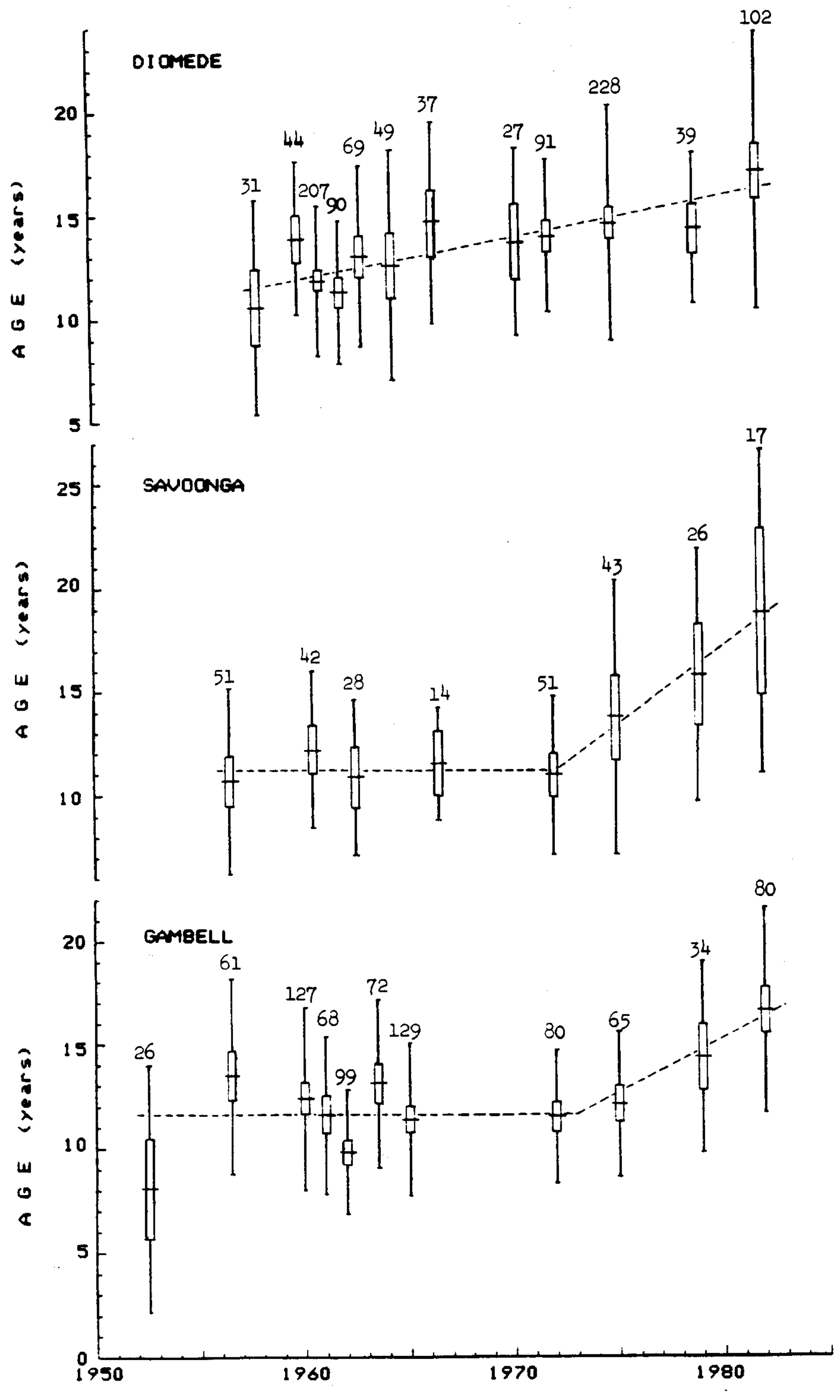

Figure 11. Change in mean age of the catches of female walruses, 1950-80's. Each bar represents one sample, of the size shown above it. Cross-bar is the mean; thin bars are ± 1 S.D.; open bar shows 95% confidence limits about the sample mean. Curves fitted by least squares.

finding them. Some of the hunters also remarked (to Fay) about an unusual abundance of females with stout, short, heavily abraded tusks. Such tusks are characteristic of very old animals, and fecundity decreases markedly in old age (Fay, 1982 and unpublished).

Another indication of increasing age of the females was the change in number of corpora counted in the ovaries (Fay and Stoker, 1982a,b). Because the corpora albicantia in the ovaries persist for many years, the number in each animal tends to increase with age (Mansfield, 1958; Burns, 1965; Krylov, 1966). The numbers of corpora per female in the catch samples at Diomede appeared to increase continually from the 1950's to the 1980's. At Gambell, conversely, the number per female did not appear to change significantly up to the 1970's, but it did increase by the 1980's (Fig. 12). By comparing the cumulative relative frequencies of those samples, using the Kolmogorov-Smirnov Two Sample Test, the increases were found to be highly significant ($P<0.001$). Those increases at both villages are directly attributable to increasing mean age of the animals in the catch.

Natural Mortality on the Punuk Islands.--During the southward migration each autumn, large numbers of walruses haul out on the Punuk Islands, apparently to rest briefly before continuing on their way to the wintering areas. During that pause, some of the animals die from natural causes (Fay and Kelly, 1980). The numbers of carcasses remaining in the following spring, after the autumn storms and winter ice have rearranged them, have varied from 0 to 466 per year over the past 35 years (Fig. 13). The trend in numbers per year, from the late 1940's to contemporary times was upward, possibly to a peak in 1978. That increase was highly significant, even when the unusually high mortality of 1978 was excluded (1948-65, $n = 8$ yrs, mean ± s.e. = 35.3 ± 7.6 carcasses/yr; 1968-81, $n = 6$ yrs, 87.8 ± 13.7/yr; $t = 3.36$, $P<0.01$). The mortality in the fall of 1982 apparently was very low, for only 18 carcasses remained in the spring (A. Akeya, pers. comm.).

We obtained a series of samples of the age composition of walruses that died over the course of several years on the Punuk Islands. Those samples consisted of one cheek tooth for age determination from each carcass. As in the foregoing, age was determined from counts of cementum layers in thin longitudinal sections of the teeth. Nearly all of the samples are very small, hence their variances are large. Nonetheless, they show an upward trend in both sexes, just as in the catch samples (Fig. 14).

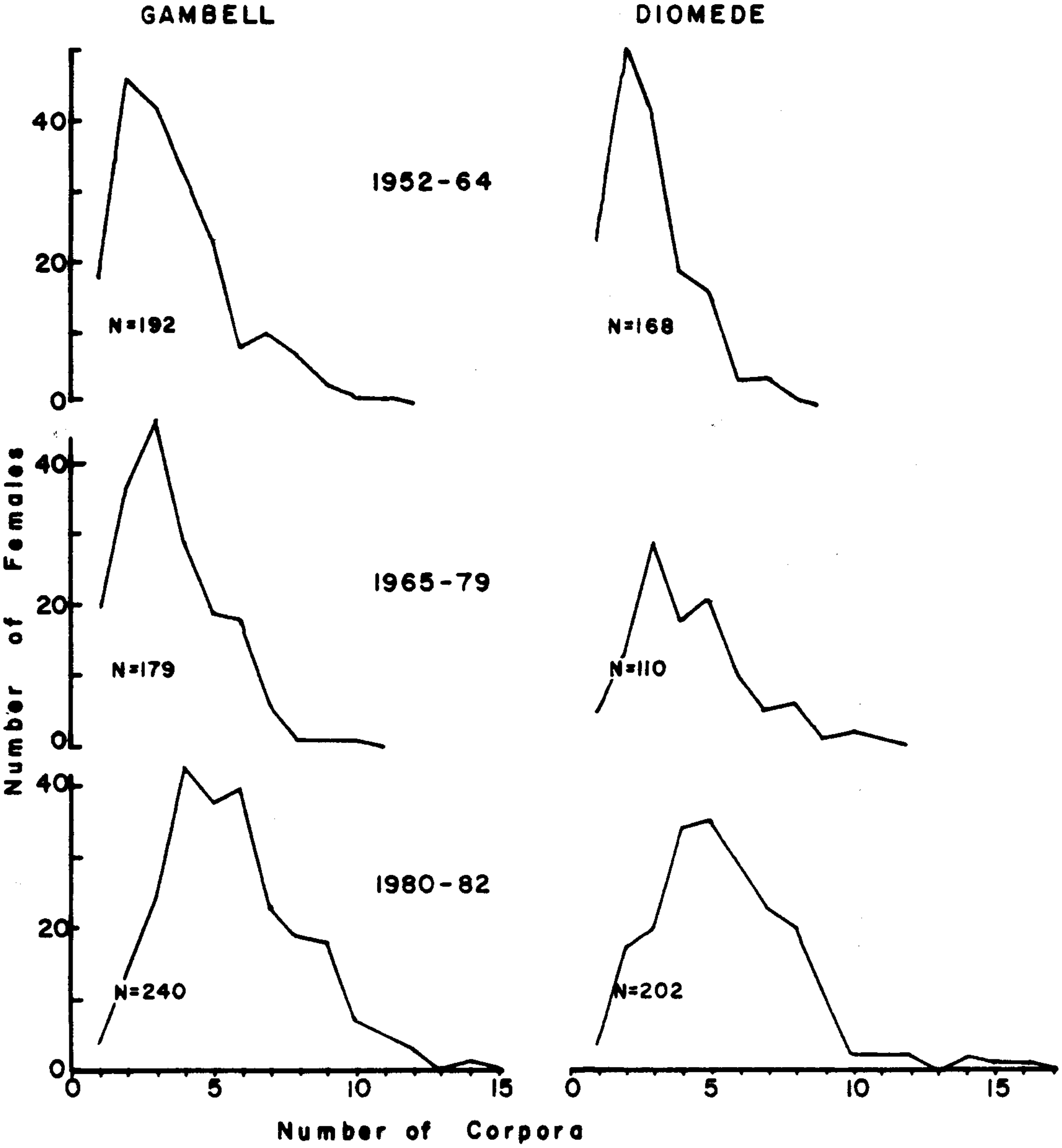

Figure 12. Comparative frequency of occurrence of numbers of corpora (lutea and albicantia, combined) in the ovaries of adult females from the spring catches at Gambell and Little Diomede, 1952-82. Sample sizes (N) are shown for each curve (J. J. Burns and F. H. Fay, unpubl. data).

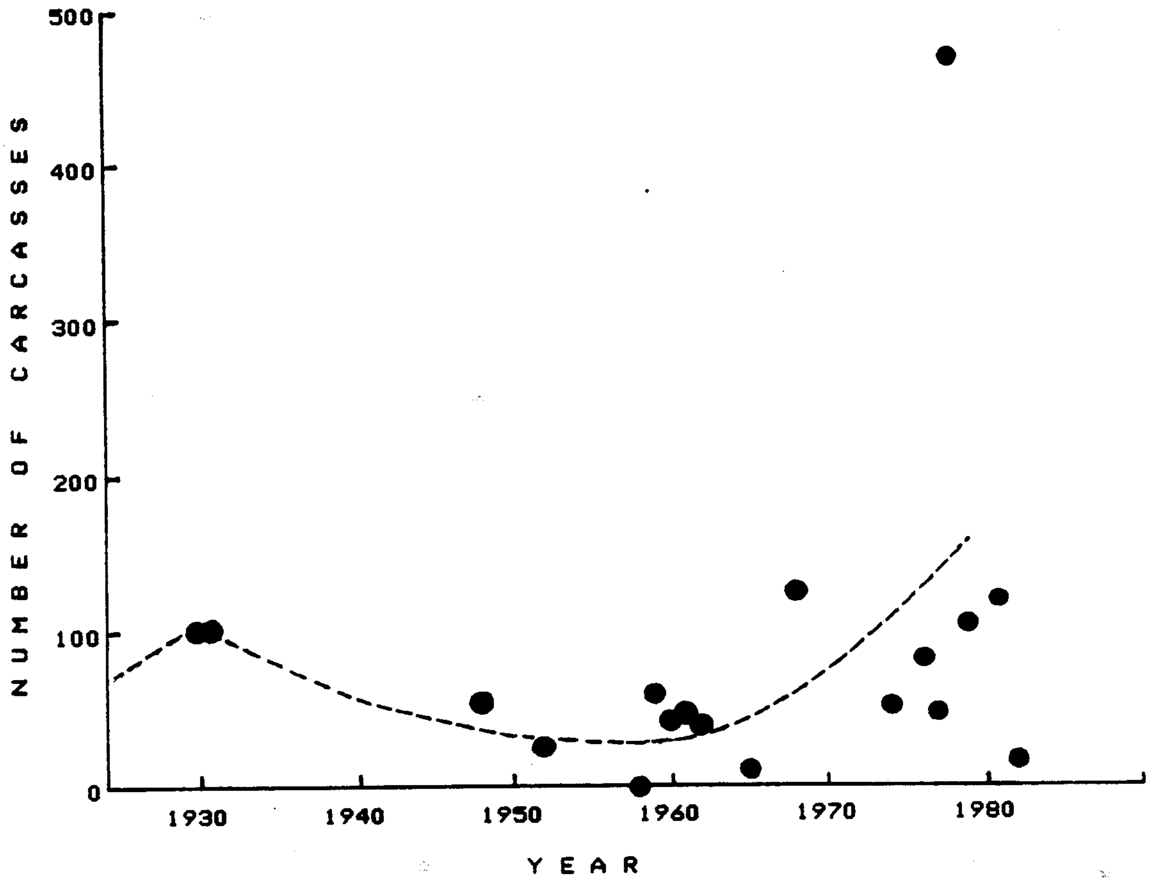

Figure 13. Natural mortality on the Punuk Islands during the autumn migration, 1930-82. Each dot represents the number of carcasses found there in the following spring. Dashed line is suggested trend (after Fay and Kelly, 1980 and unpubl. data).

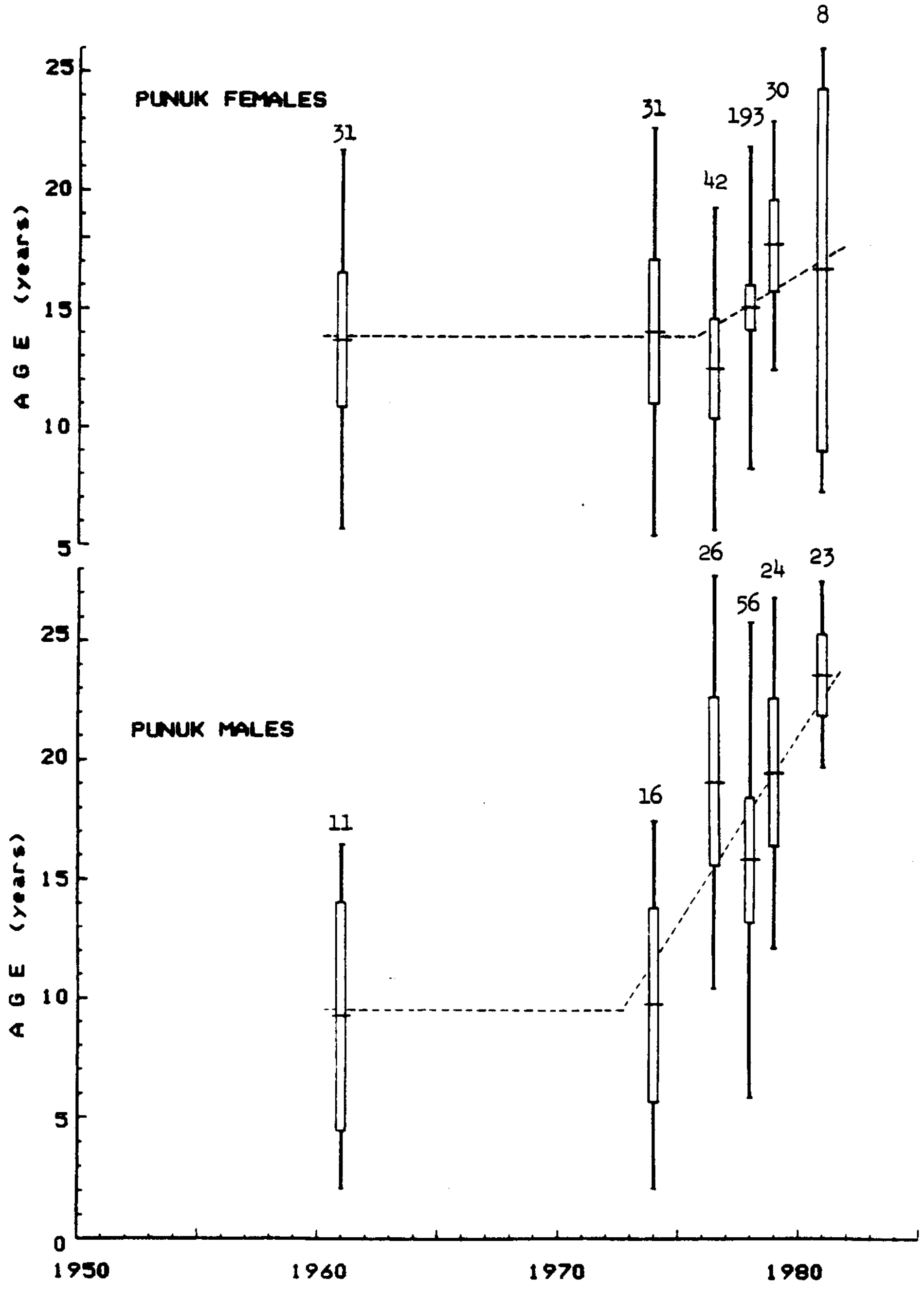

Figure 14. Change in mean age of walruses dying from natural causes on the Punuk Islands, 1961-81. Each bar represents one sample, of the size shown above it. Cross-bar is the mean; thin bars are ± 1 S.D.; open bar shows 95% confidence limits about the sample mean. Curves fitted by method of least squares.

Reproduction.--Walruses give birth in the spring, mainly between mid-April and mid-June, during the northward migration from the Bering to the Chukchi Sea (Fay, 1982). Hence, the females taken at that time, in the spring catch, are readily classified as:

(1) **immature**, if they are not and never have been in estrus (i.e., have no corpora or ripe follicles in their ovaries),

(2) **newly pregnant**, if they show a new corpus luteum of pregnancy, whether or not an embryo can be seen in the uterus,

(3) **parturient**, if they are pregnant with a full-term fetus or have recently given birth to a new calf,

(4) **barren**, if they are none of the above but have experienced at least one estrus.

Although the samples from the catch are non-random, as noted above, hence not necessarily representative of a cross-section of the female population, those from any given locality are comparable from year to year, because they are affected by the same selective biases each year. The largest sets of those samples have been obtained at Gambell and Little Diomede, beginning in 1952. From that time until the present, the most marked change indicated by them has been in the birth rate, as follows:

From the 1950's to the late 1970's, the frequency of occurrence of parturient females in the catches at both Gambell and Diomede varied somewhat but appeared to be comparatively stable, year after year. In seven small samples from Little Diomede in that period, the percentage of parturient animals per sample ranged from about 40 to 50%, which did not differ significantly from the expected values (Table 6). In 1980, however, the frequency was much lower than expected, and in 1982, it was somewhat higher than expected. At Gambell, in the 1950's to mid-60's, the observed frequency of occurrence tended to be higher than expected, because of the selection for cows with calves. That was followed by a period of little or no deviation from expected values in the late 1960's to late 70's, then by an extremely low frequency in 1980, and back to the higher than expected level again in 1982.

Because the age composition of the catches also changed significantly at both villages in that same 30-year period, we presumed that some of the deviations could have been attributable to age of the animals. To test for that, we compared the observed frequencies with expected values derived from mean ages of the catches and the age-relative fecundity as described by Fay (1982, tables 34, 35) and Fay and Stoker (1982b, table 4). The

Table 6. Chi-square goodness of fit test, comparing observed with expected frequencies of occurrence of parturient animals in samples of adult females from the spring catches of walruses at Little Diomede and Gambell, 1952-82. (Extracted from Appendix A)

DIOMEDE	Year of catch						
	1952-58	1962-64	1965	1966-68	1979	1980	1982
N	47	61	39	35	40	102	110
Obs. f	22	31	16	17	16	15	57
Exp. f	19.33	25.09	16.04	14.40	16.45	41.55	41.14
Chi-Sq.	0.37	1.39	0.00	0.47	0.01	16.96	6.12

GAMBELL	Year of catch							
	1952-61	1962-64	1965	1966-68	1975	1979	1980	1982
N	93	109	114	11	43	29	163	87
Obs. f	77	87	101	7	33	16	36	64
Exp. f	60.33	70.71	73.95	7.14	27.89	18.81	105.74	56.44
Chi-Sq.	4.61	3.75	9.89	0.00	0.94	0.42	45.99	1.01

results are shown in Table 7. For Diomede, the frequency of occurrence of parturient females in the catches did not differ greatly from the expected frequencies, during 1952 to 1979, but in 1982, the frequency was much higher than expected. At Gambell, where there is strong selective bias for parturient females, the observed frequencies in the 1950's to mid-60's were consistently much higher than those predicted from age composition of the catches. But from the late 1960's to late 70's, at least, there was a tendency away from that pattern, with observed frequencies approaching the expected.

Table 7. Goodness of fit comparison of observed with expected frequencies of occurrence of parturient animals in samples of adult females from the spring catches of walruses at Little Diomede and Gambell, 1952-58, using mean age of the catch and age-relative fecundity to generate expected values.[1]

DIOMEDE	Year of catch					
	1952-58	1962-64	1965	1966-68	1979	1982
N	47	61	39	35	40	100
Obs. f	22	31	16	17	16	57
Exp. f	22.86	26.40	15.58	10.36	13.36	23.79
Chi-Sq.	0.03	0.80	0.01	4.26	0.52	46.37

GAMBELL	Year of catch						
	1952-61	1962-64	1965	1966-68	1975	1979	1982
N	93	109	114	11	43	29	87
Obs. f	77	87	101	7	33	16	64
Exp. f	38.79	50.78	52.13	3.32	18.36	9.40	21.21
Chi-Sq.	37.64	25.84	45.82	4.08	11.68	4.63	86.30

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[1] After Fay and Stoker (1982b, table 4).

Although the observed values at each village fluctuated from year to year during the 1950's and 1960's, those fluctuations were asynchronous between the two villages. This indicated that the variation within each village's catches was not reflecting any population-wide changes but was attributable simply to variation in local hunting conditions and availability of animals, together with the normal variation among small samples. The coincidence of minor deviations, however, beginning in 1966-68, and of subsequent major deviations in 1980 and 82, suggested that the catches in both villages were being affected by changes in the population as a whole.

The ostensibly random samples taken by Soviet biologists in 1972-3 (Gol'tsev, 1975b) and during subsequent joint Soviet-American research cruises also suggested a trend of decrease in fecundity (Table 8). Some of that decrease may have been due to change in age; unfortunately, we do not yet have the age data from all of those samples, so cannot compare them with expected values. Certainly, the maximal decrease indicated in 1983 was not due to age alone, since that sample showed other, unique characters not related to age. In addition to having one of the lowest proportions of parturient females ever observed, it had the highest proportion of ovulations (72/120 = 60%) on record. Furthermore, nearly half of those ovula-

Table 8. Frequency of occurrence of parturient, pregnant, and barren females in non-selected samples of adult walruses taken during Soviet and joint Soviet-American research cruises, 1972-83.[1]

		1972-3	1976	1981	1983
Sample N		201	34	73	120
Parturient	n	91	14	27	25
	(%)	(45.3)	(41.2)	(37.0)	(20.8)
Pregnant	n	87	15	26	33
	(%)	(43.3)	(44.1)	(35.6)	(27.5)
Barren	n	23	5	20	62
	(%)	(11.4)	(14.7)	(27.4)	(51.7)

[1] From Gol'tsev (1975b), Fay (1982), and F. H. Fay and A. A. Kibal'chich, unpublished.

ting females had either rejected the blastocyst or failed to conceive (implant). That was the highest proportion of failures (44%) ever found in any sample. Of the females that had conceived successfully (N=40), 6 already in August had aborted their fetuses, and 1 other had a defective fetus that probably would have been aborted or born dead. That proportion of fetuses aborted also was extremely high (17.5%), similar to the proportion indicated in recent samples from the Alaskan Eskimos' catch (Fay and Stoker, 1982a,b). Thus, only 33 (27.5%) of the 120 animals in the sample were newly pregnant with an apparently healthy fetus, and that, too, is a lower proportion of pregnancies than in any previous Soviet samples.

The proportion of newly pregnant animals in those non-selective samples also showed decline from 1972 to 1983 (Table 8). The frequency of occurrence of pregnancies in the catch samples, however, has been more difficult to trace, mainly because of small samples and selective bias, particularly at Gambell. The proportion of newly pregnant animals in the samples from both Diomede and Gambell in the 1950's, 60's, and 70's were consistent with expected values (Table 9). But by the early 1980's,

Table 9. Frequency of occurrence of new pregnancies in the catch samples from Diomede and Gambell, in relation to expected values, 1952-82. (Extracted from Appendix A)

DIOMEDE	1952-58	1962-64	1965	1966-68	1979	1980	1982
Sample N	47	61	39	35	40	102	100
Obs. f	18	19	16	9	16	63	26
Exp. f	18.56	24.08	15.40	13.82	15.79	39.88	39.48
Chi-Sq.	0.02	1.07	0.02	1.68	0.00	13.41	4.60

GAMBELL	1952-61	1962-64	1965	1966-68	1975	1979	1980	1982
Sample N	93	109	114	11	43	29	163	87
Obs. f	10	16	8	3	8	6	68	9
Exp. f	18.34	21.50	22.48	2.17	8.48	5.72	32.15	17.16
Chi-Sq.	3.79	1.41	9.33	0.32	0.03	0.01	39.98	3.88

the frequencies at both villages deviated significantly upward in 1980 and downward in 1982.

The proportion of pregnancies that resulted in successful births decreased significantly in the interval between 1952-68 and 1980-82 (200/203:192/230; $X^2=28.47$, $p<0.001$). Most of that decrease apparently was the result of an order of magnitude increase in abortions and premature births, which rose from about 1.5% of the fetuses per year in the 1950's and 60's to about 16.5% in 1980 and 1982 (Fay and Stoker, 1982a,b).

As a whole, each of the data sets indicates a trend of decrease in productivity in recent years and increased irregularity, with intermittent years of very high and very low production. The overall trend of decrease in productivity, if gradual could have been entirely a function of age composition of the samples. As shown earlier, the older females reproduce less often and are less successful than the younger ones in carrying out a full pregnancy (Fay, 1982). The increased irregularity in the productivity of the samples, however, does not appear to be attributable to increased age; it seems to be due to synchronization of breeding, with a high proportion of females in estrus one year, a low proportion in the next, etc. We suggest that the synchrony may have been brought about by a very high rate or reproductive failures in one year, resulting in a very high proportion of the females coming into estrus the following year.

Recruitment.--Walruses reproduce very slowly, relative to other pinnipeds, and for that reason they are presumed to have very high survivorship and recruitment rates (Mansfield, 1958). Those rates are impossible to estimate from catch samples, because of the biases of selective hunting, but as Chapskii (1936) recognized they can be estimated from visual sampling of the sex/age composition of the population at large. Because the harvesting of walruses usually is not aimed at the cohorts of immature animals from 1 to about 5 years old, that part of the population is practically unaffected by man and is influenced only by natural mortality. The relative abundance of those young cohorts in the population, therefore, should be indicative of their natural survival rate and should reflect also the general magnitude of recruitment to breeding age, at least for the females, most of which mature at 6 to 7 years of age.

Using visual methods, we conducted compositional surveys of summering walruses in the Chukchi Sea, during five research cruises there. We also obtained a compositional sample by observation of the autumnal migrants on the Punuk Islands. In each of those samples, the young animals were classified visually as 0-, 1-, 2-, 3-, and 4 to 5-year-olds, without regard for sex. Females 6 years old and older were regarded as adults. The data gathered during shipboard surveys were of groups on the ice, and in each case we included only the counts from groups that were completely classified. The importance of including only the completely classified groups to avoid sampling bias is discussed elsewhere in this report. With incomplete classification, there is a tendency for bias in favor of overrepresenting the younger age classes. The only non-shipboard sample, which was from the Punuk Islands, was made up of ten different subsamples of animals on the periphery of very large herds that were lying on shore. Because those were not complete classifications of whole herds, and because there is a tendency for immature animals to be most numerous on the edges of the herd and for females with calves to be most numerous there, as well (Popov, 1960; Miller, 1975; Miller and Boness, 1983), the Punuk sample probably was biased toward higher than random proportions of females with young.

Before conducting the first survey in 1981, we assumed that we would find at least 25% of the females with calves of the year, at least 20% with 1-year-olds. That assumption was based on the knowledge that the pregnancy rate was at least 35% per year during the late 1970's and at least 30% per year early in the 1980's (Fay and Stoker, 1982a,b), and that the survivorship of the first and second year young had been estimated to be at least 80% (Chapskii, 1936). Thus, our findings in the first survey (July 1981) of only 5 to 6% of the females with calves of the year and only about 3% with 1-year-olds were completely unexpected (Table 10). Because they differed significantly from the expected findings, we sampled at every subsequent opportunity, to obtain further data and seek clarification of the situation. All of the results from the additional surveys were very similar to those from the first survey; even our most optimistically biased sample from the Punuk Islands suggested that, in recent years, either the prenatal mortality has been higher than Fay and Stoker's (1982a,b) data indicated, or the early postnatal survival of calves has been extremely low (or both).

The relative size of the successive cohorts in a given year and of the same cohorts in successive years indicates that the birth and/or survival rates of the calves had been declining at least since 1976, had reached their nadir in 1980, and have been rising slowly ever since then. The cohort with the poorest representation (1980) was produced in the same year in which the catch samples indicated the lowest birth rate on record.

Change in Diet.--Large samples of stomach contents were obtained from walruses taken in the vicinity of Gambell, Savoonga, and Little Diomede in 1975, 1979, 1980, and 1982. Each year in each locality, 60 to 90% by weight of the food items in the stomachs were bivalve mollusks; the rest were mainly polychaetes, sipunculids, echiurids, gastropods, crustaceans, and holothurians (Fay *et al*., 1977; Lowry and Frost, 1981; Lowry *et al*., 1982; Fay and Stoker, 1982a,b).

In general, the relative amounts of bivalves in the stomachs tended to decrease and the amounts of non-bivalves tended to increase in each successive sample. Fishes were found in the stomach contents for the first

Table 10. Relative abundance of the younger cohorts of walruses in visually classified samples from the Bering and Chukchi seas, 1981-83.

Date and location	No. of adult females	Number of young per cohort (and expressed as % of adult females)							
		1976	1977	1978	1979	1980	1981	1982	1983
July 1981, E. Chukchi	1208	167 —(13.8)—		77 (6.4)	56 (4.6)	39 (3.2)	66 (5.5)	- -	- -
Sept 1981, E. Chukchi	278	22 —(7.9)—		14 (5.0)	6 (2.2)	4 (1.4)	8 (2.9)	- -	- -
Nov 1981, Punuk Is.	374	69 —(18.4)—		44 (11.8)	36 (9.6)	16 (4.3)	53 (14.2)	- -	- -
July 1982, E&W Chukchi	456	-	39 —(8.6)—		15 (3.3)	8 (1.8)	32 (7.0)	108 (23.7)	- -
Aug 1982, E&W Chukchi	881	-	52 —(5.9)—		31 (3.5)	14 (1.6)	63 (7.2)	94 (10.7)	- -
Aug 1983, W. Chukchi	326	-	-	27 --(8.3)--		9 (2.8)	8 (2.4)	24 (7.4)	36 (11.0)

time in 1980, but only in trace amounts. By 1982, however, they were present in significant amounts (3.4% by weight) at Gambell, where they were present in 9 of 31 stomachs. Further evidence of their growing importance in the diet was shown also by the rising frequency of infection of the walruses by anasakid nematodes (Table 11), parasites that reside in the walrus' stomach and can be acquired only by eating fishes, the intermediate hosts. In addition to the fishes, such apparently unusual prey as anthozoans were present frequently and in large amounts in the 1980 and 1982 samples, whereas they had been found only once before. Also, jellyfish (Scyphozoa) appeared for the first time and in large amounts in the 1982 sample. At the same time, holothurians occurred more often and in larger quantities by weight than before.

Table 11. Comparative frequency of occurrence and numbers of anasakid nematodes parasitizing the stomach of Pacific walruses in spring harvest samples, 1964-1982.

		Anasakids in stomach			
			Number per walrus		
Year	No. of walruses	Frequency (%)	Range	Mean	Source
1964-66	95	1.0	5	-	Yurakhno and Treschev (1972)
1975	107	6.5	1-20	6.0	L. M. Shults, (unpublished data)
1980-81	114	14.0	1-61	14.3	Fay & Stoker, (1982b)
1982	76	14.5	1-37	15.8	Fay & Stoker, (1982b)

From 1975 to 1982, an apparent trend of decreasing average size of all types of prey in the stomachs also was reported by Fay and Stoker (1982b). Concurrently, the diets of males and females appeared to be convergent on the same types and sizes of prey, whereas they evidently had been quite divergent earlier (Fay et al., 1977). A peculiar increase in the frequency of occurrence of seal-eating walruses also took place in the late 1970's and early 80's (Lowry and Fay, 1984), but we are not yet sure how much of that can be attributed to use of "alternate" prey. That is, much of it might have been due to unusual environmental conditions that brought the walruses and seals together.

The full significance of the findings concerning feeding habits, as regards their relationship to population status, will not be known until the data have been re-analyzed in more appropriate ways. That task is underway (J. L. Sease, in prep.). In the meantime, we suggest only that they do indicate change, and that the change may have been associated with the rapid growth of the walrus population and its increased pressure on existing food supplies, as suggested also by Lowry et al. (1980).

Blubber Thickness.--The blubber or hypodermis of the skin of pinnipeds serves the combined functions of (1) storage depot for fats, (2) thermal insulating layer, and (3) smoothing of body contours for hydrodynamic efficiency. In the adult males, the fat tends to be thickest in the beginning of the breeding season. At that time, it may also serve a social function, since dominance is partly a correlate of body size (Miller, 1975). For the breeding bulls, it also serves as a nutrient supply while they fast during the rut. In addition, it may be useful to them as padding, dampening and distributing some of the shock of tusk strikes by their opponents. In females, the blubber tends to be thickest at the time of parturition, when its main function presumably is as a nutritive reserve for both mother and calf in the first weeks of lactation.

As in other wild mammals, the amount of fat on the body is an indicator of the general health of the individual and of the quality and quantity of the food supply. For that reason, we and others have routinely measured blubber thickness mid-ventrally over the sternum on many of the specimens that we have examined. We compared those measurements from walruses taken during the 1950's to early 1970's with those from animals taken more recently. The results (Table 12), when tested by a Kruskal-Wallis non-

Table 12. Comparative sternal blubber thickness of Pacific walruses, 1958-1983.

		1958-72 (Jan-Sept)	1980 (May-Jun)[1]	1981 (Feb-Mar)	1983 (Jul-Aug)
MALES	N	8	22	85	56
	Range	25-76	4-60	15-54	10-37
	Mean	49.6	27.4	32.6	24.4
	S.D.	14.08	11.73	7.70	5.76
FEMALES	N	18	122	87	321
	Range	30-102	12-75	24-68	13-59
	Mean	57.3	38.9	39.6	29.5
	S.D.	21.61	10.81	8.98	7.83

[1] Unpublished U. S. Fish and Wildlife Service data by T. E. Smith.

parametric ANOVA, indicated that the animals taken in recent years have been significantly ($P<0.02$) leaner than those taken earlier. Although some of the difference among samples can be attributed to seasonal change (Fay, 1982), even the recent winter specimens (which should have been the fattest) were much leaner than the earlier ones. The implication is that the walruses are not as well fed as they were before, possibly because food is scarcer, lower in nutrients, or requires more effort to obtain. We interpret the greater leanness as a correlate of increase in size of the population.

Distribution and Composition

Monthly Distribution

The following is a resumé of distributional information obtained by us in this and related projects and of some contributed by other observers. This information is new since Fay's (1982) compilation, which included all of the data available to him up to 1979. We use that compilation as a background for our description here, because it was done on a monthly basis. Consideration of the distribution per month is most useful for identification of major concentrations and migration routes.

January.--The details of distribution of the Pacific walrus population in this month still are unknown. The few sightings reported up to 1979 were mainly from interviews with Eskimos at Diomede, St. Lawrence, and Nunivak islands. The lack of data elsewhere is mainly due to lack of effort (Fig. 15, JAN). Most of the reports near the islands were of subadult and adult male walruses. The location of the females and young is not known for this month. Because the height of the mating season appears to be in January and February (Fay, 1982; Fay et al., 1984), we assume that the distribution in this month is similar to that in the following one.

The only new information that we have for this month is from an aerial survey of the Bristol Bay area, which was done for a complementary project (Fay and Lowry, 1981). The northern half of the Bay was ice-covered at the time, and the only walruses sighted in the entire area were three on the ice, just east of Hagemeister Island. Their sex and relative age were not determined.

February.--A substantially greater amount of data was available up to 1979 for the month of February, most of it from Kenyon's (1960a) first aerial survey and from three icebreaker cruises on which walrus sightings had been recorded (F. H. Fay, B. P. Kelly, R. A. Ryder, unpubl.). Each of those data sets suggested a regularity to the pattern of distribution, in which the animals were clumped in two areas: (1) from the St. Lawrence polynya southward and (2) in the area south of Nunivak Island and Kuskokwim

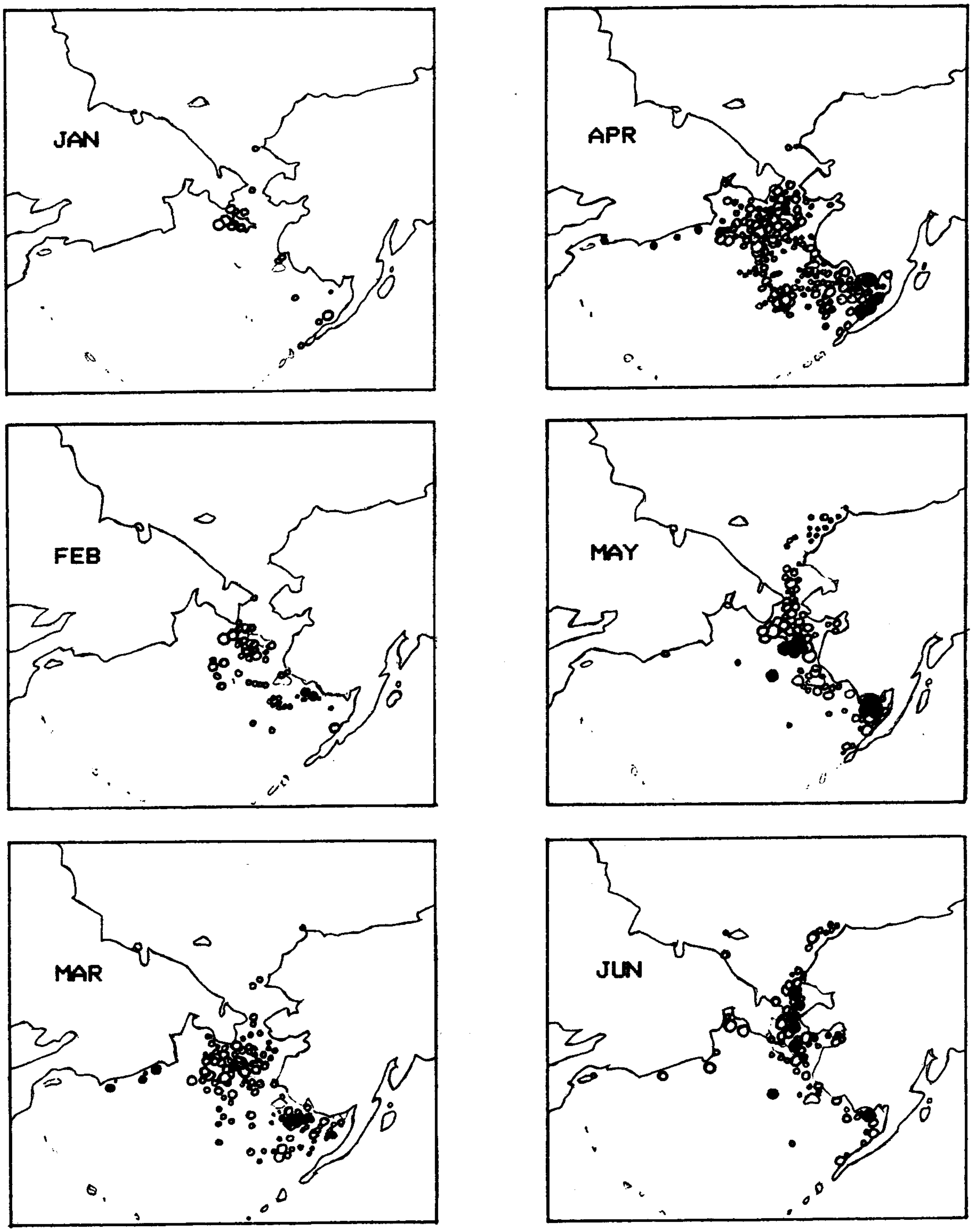

Figure 15. Distribution of the Pacific walrus population, January to June. Open circles are from Fay (1982); black dots are new data from various sources. Size of symbols is proportional to number of animals sighted.

Bay (Fig. 15, FEB). A clear preponderance of adult females and young had been seen in the first area; the animals in the second area at first were assumed to have been males from the Bristol Bay summering herds. Through aerial photography in 1972, however, they were found to include females and young, as well (Fay, 1982).

Fay and Lowry's (1981) aerial survey of Bristol Bay in this month again showed only one small group on the ice in the northwestern part of the Bay. A few days later in that same year, however, we found (via the ZRS ZVYAGINO) a clump of some thousands farther to the northwest, just off the Kuskokwim estuary. These were mostly herds of females and young, accompanied by a few adult males, and the sex ratio of adults was like that in the St. Lawrence wintering area (i.e., about 1 male/10 females). These were breeding herds; many of the males were engaged in courtship displays in the water, alongside the herds of females.

March.--The distribution was better known up to 1979 for the month of March than for the previous month. It appeared to be essentially the same or very similar to that in February, with the principal clumps of walruses in the St. Lawrence Island and Nunivak-Kuskokwim-Bristol Bay regions (Fig. 15, MAR). Our observations during an icebreaker survey of the St. Lawrence area in 1972 had confirmed that the animals there were mostly females and young, with a number of males still conducting courtship displays (Fay et al., 1984). In some years, the beginning of northward movement was evident from the increase in number of animals north of St. Lawrence Island, usually by the end of the month (Fay, 1982).

On the Soviet side, Kibal'chich (1981) and co-workers found numerous small groups (mostly 5 to 15) of males in the ice along the Koryak coast from just south of Cape Navarin to the vicinity of Natalia Bay. Fay and Lowry (1981) also found about 700 males in Bristol Bay in this month, which was a large increase over the number present in January and February. At the same time, however, some breeding herds still were in place, south of Kuskokwim Bay, and many males still were displaying there. Nearer the southern edge of the pack ice were small groups of subadult males.

April.--The documentation of distribution up to 1979 was better in this month than in the previous three combined (Fig. 15, APR), principally due to Kenyon's aerial surveys. Again, it indicated essentially the same two clusters, one to the south of St. Lawrence Island and the other in Bristol and Kuskokwim Bays, but the clusters appeared to be spreading and linking together, to a greater extent than before.

The northward migration clearly is underway by the middle of this month in all years. It is most evident in the north, for the animals wintering near St. Lawrence Island begin to move by the thousands through Anadyr Strait, between Gambell and Cape Chaplin. The herds of females and young from the Bristol-Kuskokwim wintering area also begin to move northward in the first half of this month, some passing through Etolin Strait and others around the western end of Nunivak Island.

Our additions to the distributional data in this month were only in Bristol Bay, where two aerial and one shipboard surveys in 1980-81 showed the numbers of males to be greater than in the previous month. A total of about 15,000 animals were congregated at Round Island, on Cape Seniavin, and in the nearshore waters along the northern coast of the Alaska Peninsula (Fay and Lowry, 1981). We presume that those males had moved there from the breeding aggregations south of Kuskokwim Bay.

May.--The distribution in the eastern Bering and eastern Chukchi seas was well documented in this month by Fay's (1982) compilation, but there was little information from Soviet waters. That continues to be the status, today. The apparent concentration of animals along the Alaskan coast (Fig. 15, MAY) probably does not fully portray the location of the whole population, for some must also be in the Anadyr area at that time; others are said to penetrate into the western Chukchi Sea as far as Cape Serdtse-Kamen (Krylov et al., 1964). Most of the animals passing through Bering Strait in this month are females and young from the St. Lawrence wintering area. Those from the Bristol-Kuskokwim wintering area are still moving up the eastern side of the Bering Sea, into the vicinity of eastern St. Lawrence Island and Norton Sound. Any of the males that have migrated north with either group seem to move only as far as Anadyr Gulf and the Chirikof Basin, where they congregate on the remaining ice, long after the females and young have passed by.

Fay and Lowry's (1981) aerial surveys of Bristol Bay in this month, in both 1980 and 1981, confirmed again the presence only of the summering cluster of adult and subadult males. The numbers appeared to be approximately the same as in April. To the west, another, smaller summering group of males has recently re-occupied the St. Matthew - Hall Island area (D. Irons, pers. comm.), apparently for the first time in more than 30 years.

June.--Practically all of the females and young and a few of the subadult and adult males have passed through Bering Strait by the end of this month. Those remaining behind in the Bering Sea are mainly adult males, who summer principally in Anadyr Gulf, Bristol Bay, western Chirikof Basin, and Bering Strait. Again, the concentration of sightings on the Alaskan side (Fig. 15, JUN) is due principally to shortage of data from Soviet waters. According to Krylov et al. (1964), about 8,000 males begin to use the Rudder Spit hauling ground in Anadyr Gulf by the end of this month, and many of the migrants into the Chukchi Sea have moved as far as Long Strait by this time.

In an aerial survey of Bristol Bay, Fay and Lowry (1981) found the males still abundant and clustered mainly in the northern part of the Bay, near the Walrus Islands. To the west, D. Irons (pers. comm.) observed about 400 males in the St. Matthew-Hall Island area, and we saw a few more in the vicinity of the Punuk Islands, just east of St. Lawrence Island.

July-September.--Both Soviet and American data have indicated that practically all of the females and young are in the Chukchi Sea by July, and that they remain there at least through September (Fig. 16, JUL, AUG, SEP). They appear to congregate there in two large areas, (1) from about 170°W to the vicinity of Point Barrow and (2) along the northern coast of Chukotka to Long Strait and Wrangell Island. Many of those along northern Chukotka, at least as far as Inchoun and Kolyuchin Bay, are males; farther to the west and north in the pack ice they are mostly females and young. The animals remaining in the Bering Sea at that time are virtually all males (Brooks, 1954; Fedoseev, 1962; Burns, 1965; Gol'tsev, 1968).

The results from aerial surveys in Bristol Bay in 1980 indicated that the number of males still there was about 15,000 during these three months (Fay and Lowry, 1981). At least 400 males also have been present on St. Matthew and Hall islands (D. Irons, R. D. Jones, pers. comm.), and we saw a few near the Punuk Islands, as well. At Arakamchechen and Nunyangan islands, off the Soviet coast, at least 4,000 males and four adult females were present in 1983 (Fay et al., 1983).

October.--Southward migration of the animals usually begins in this month (Krylov et al., 1964). The data available up to 1979 suggested that practically all of the animals that had summered in the eastern and western Chukchi Sea converged on the northern coast of Chukotka before moving southeastward toward Bering Strait (Fig. 16, OCT). That same pattern is inferred also by newer data from the Soviet side (Fedoseev, 1981).

Fay and Lowry's (1981) aerial survey for this month in Bristol Bay indicated a substantial decline in number of animals (males) there. Concurrently, the number at the Punuk Islands grew to nearly 1,000 (Fig. 17).

November.--The data on walrus distribution for November still are sparse (Fig. 16, NOV). Up to 1979, nearly all of the information for that month had been obtained by interview with Alaskan Eskimos, for there had been none from either aerial or shipboard surveys and none from the Soviet side. We have added to this the observations from an aerial survey of Bristol Bay (Fay and Lowry, 1981), and from our monitoring of the autumnal migration at the Punuk Islands. A high proportion of the 10,000 or more animals arriving on the Punuk haulout were adult females, which presumably swam there via Bering Strait from their summering areas in the Chukchi Sea. We know, however, that some of the adult males that arrived there had migrated northward, rather than southward, for at least three of them had

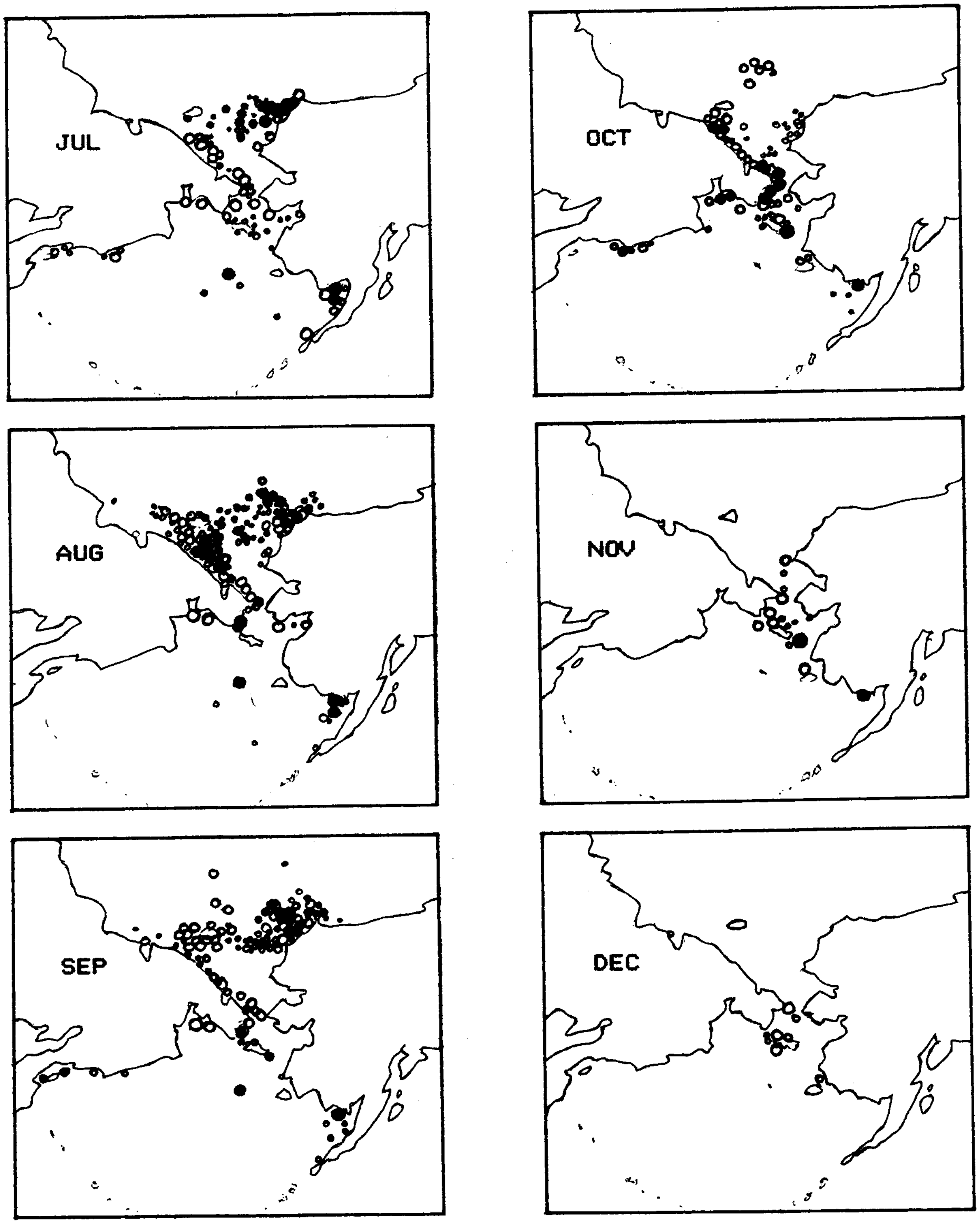

Figure 16. Distribution of the Pacific walrus population, July to December. Open circles are from Fay (1982); black dots are new data from various sources. Size of symbols is proportional to number of animals sighted.

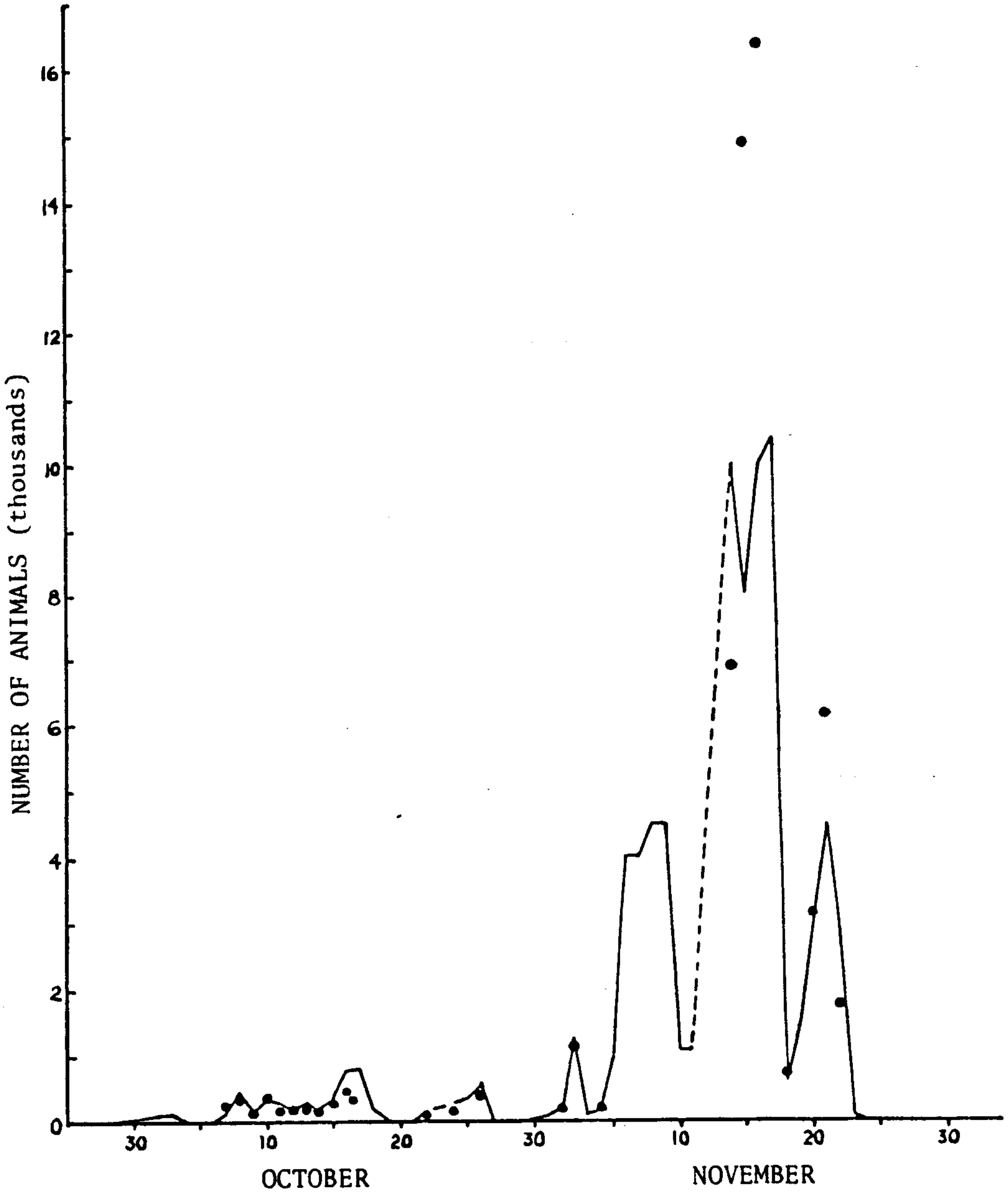

Figure 17. Numbers of walruses on the Punuk haulout each day, 28 September to 30 November 1981. Line connects numbers actually counted or extrapolated from sample counts. Dots are estimates based on area occupied, assuming 2 m^2 per walrus.

been radio-tagged at Round Island, Bristol Bay, a few months earlier (J. Taggart and C. Zabel, pers. commun.). The last of the animals left the Punuk Islands on November 23rd, and the haulout there became ice-bound the following day.

December.--The distribution in December is practically unknown (Fig. 16, DEC), and we were not able to contribute anything positive to improve on that situation.

Time of Mating

The time of mating of walruses is in mid-winter, rather than in the spring. This was discovered about 30 years ago, partly as a result of Fay's (1955) observation that the testes of the mature males were already showing seasonal retrogression by May, and of Mansfield's (1958) finding that some adult males were becoming fertile as early as November. By tracing the histological stages in the annual spermatogenetic cycle of the males from November to August, Fay (1982) observed that the adults reached their peak of fertility about the end of December, apparently were in rut during January and February, and generally were showing signs of retrogression as early as March. The adolescent males, conversely, appeared to reach their peak of testicular development about two months later than the adults. Thus, assuming that the breeding season must coincide with the rut, Fay concluded that the females probably were in estrus in January-February, rather than in May and June as presumed by most previous investigators.

The data from females were fewer and less complete, but they were supportive of the schedule implied by the males. The ovaries of some of the potentially estrous females (i.e., the adults that were not already pregnant with an advanced fetus) that were obtained by Fay (1982) in November, December, and the first days of January contained some slightly enlarged vesicular follicles, which were suggestive of the beginning of estrus, but none was clearly near ovulation. One of two potentially estrous females taken by E. Muktoyuk (Alaska Department of Fish and Game) in mid-February, however, already had ovulated approximately 2 weeks earlier; the other apparently was barren. Three more taken in late March and early April by Fay (1982) and co-workers had fully formed new corpora lutea of pregnancy from ovulations that had taken place at least one month earlier. That is, these few specimens indicated that ovulation was taking place mainly in late January to early February.

Although a few females taken in April, May, and June had some very large vesicular follicles, suggestive of estrus, they were a distinct minority. Practically all of the potentially estrous females taken at that time already had very large, fully developed corpora lutea of pregnancy, and in some cases their embryos already were beginning to implant. None showed any evidence of having ovulated any later than early March. The results from the females, therefore, also indicated that the breeding season of the Pacific walrus began in January and ended not later than early March. Even though a few females had come into estrus after that time, apparently none of them had been bred (Fay, 1982).

The concept of a breeding season in winter was novel and contradicted all previous reports, notably by Allen (1880), Belopol'skii (1939), Collins (1940), Nikulin (1941), Freiman (1941), Brooks (1954), Tikhomirov (1964a), Krylov *et al*. (1964), Krylov (1969), and Fedoseev (1976). Soviet biologists were skeptical of the new findings as late as 1976, and they remained skeptical, even after Gol'tsev (1978) reported that the series of specimens taken on the first Soviet-American walrus research cruise in March-April 1976 confirmed the existence of an earlier (than March-April) mating season.

For various reasons, mainly logistic, the investigation of the breeding season of the Pacific walrus still is incomplete, but the weight of confirming evidence is now much heavier and more widely accepted. The Soviet biologists finally confirmed to their own satisfaction that walruses breed in winter, not spring, and that they are polygynous, not monogamous. That took place during another Soviet-American cruise, in late February-early March 1981. Nearly all of the potentially estrous females that were taken (between 25 February and 10 March) had well-developed corpora lutea, and the advanced development of those corpora indicated that ovulation had taken place at least 2 weeks to a month earlier. A few other females still had large vesicular follicles in their ovaries, indicating that they were still in estrus; a few more were reproductively inactive (barren). During that same cruise, additional confirming evidence was obtained also from the males. Nearly all of the adolescent and adult males taken had spermatozoa in their epididymides, but the sperms in many of the older adults were nonmotile, indicating that they were no longer fertile. High motility of the sperms in the younger males, however, showed that they still were in an active state of rut, again confirming that the adolescent males come into rut later than the adults.

Location of the Breeding Areas

We suspect that the males, most of whom summer in the Bering Sea, meet up with the females, all of whom summer in the Chukchi Sea, in October-November. That meeting seems to take place primarily in the Bering Strait region, from St. Lawrence, Punuk, and Arakamchechen islands to the East Cape and Inchoun hauling grounds. Apparently, it takes place as a result of the males' coming northward from their summering areas and the females coming southward from theirs. The northward movement of males on the

Soviet side was reported earlier by Soviet biologists, who observed major shifts of male herds in late summer and autumn between the Rudder, Arakamchechen, and Inchoun areas (Nikulin, 1947; Krylov et al., 1964; Gol'tsev, 1968). On the Alaskan side, it was detected for the first time during this study, when males radio-tagged in Bristol Bay in summer were sighted at the Punuk hauling ground in November. About that same time, a large proportion of the Bristol Bay males apparently left that area, and they did not return until March and April (Fay and Lowry, 1981; Fay, 1982).

Their further progress into the wintering areas and in establishing organized breeding groups is unknown, but we presume that the animals are influenced greatly in both of those events by the development of the seasonal pack ice. Depending on the timing and extent of ice formation, the entire population may be in the Bering Sea and distributed in their wintering areas as early as the end of November, in some years; in other years, they may not settle into the wintering/breeding pattern until January. To describe that pattern precisely, however,is not possible at present. Without fuller information on the means and extremes of distribution of the animals during November, December, and January, we can only guess at their location in a very general way.

As noted above, practically all of the mating that results in pregnancy seems to take place during January and February and may extend into the first days of March. We know the general distribution in March with some precision and know that it can be related to ice conditions in a predictable way (Burns et al., 1980; Fay, 1982). Hence, we assume that the north-south extent of the distribution will tend to increase from January to March, because of the gradual increase in extent of the pack ice. Because the variation among years in extent of ice is even greater than that among months in this period (Brower et al., 1977; Burns et al., 1980, 1981), the estimation of location of the mating herds is more appropriately linked with extent of the ice than with time.

Our best estimates of the location of the breeding herds under minimal, median, and maximal extents of winter ice (Fig. 18) are based on distribution in relation to ice conditions, as reported by Wartzok and Ray (1980) and Braham et al. (1984), as observed and photographically documented during Kenyon's (1960a, 1972) aerial surveys, and as observed by us and by J. J. Burns, G. C. Ray, R. A. Ryder, and S. W. Stoker (pers. comm.) during seven different cruises via American icebreakers and Soviet sealers in the winter ice of the Bering Sea.

The estimate of breeding areas during the minimal extent of winter ice has no empirical basis, for there have been no surveys of breeding herds under that condition. We have guessed at the location, based on our belief that the animals choose areas that are well within the pack, on the leeward side of ice-forming zones. There, divergence of the ice continually per-

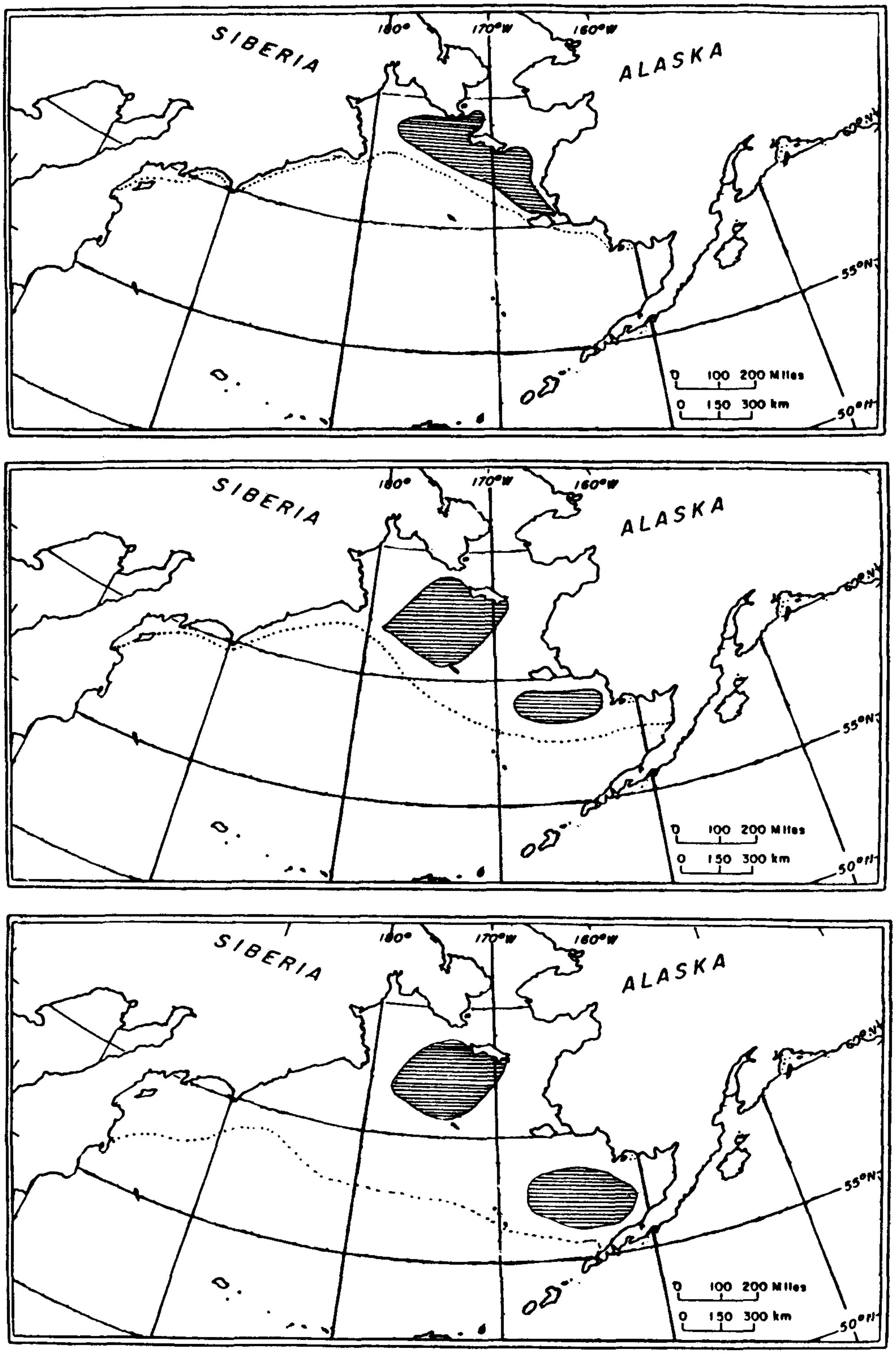

Figure 18. Estimated location of mating herds (cross-hatched), January-March, during minimal (top), median (center), and maximal extent of the pack ice. Dotted line is approximate location of ice edge.

mits leads and polynyas to form, and the floes are thick enough to be supportive and dry. Presence of food in some abundance may be another factor in selection of an area, but we feel that it is secondary to choice of the ice habitat.

Apparently, all of the adult females and most of the adult males are concentrated in those mating areas, during at least January to early March. There, the females and young tend to stay together in groups of about 10 to 50 individuals, and each of those groups is attended by one or more large, mature males. When the herd hauls out onto the ice to rest, the bulls station themselves in the water alongside the floe. There they perform their courtship displays (Fay et al., 1984). Each display lasts 2 to 3 min, and consists of an underwater, acoustical portion, in which a series of pulses ("clicks" or "knocks") and bell-like sounds are made (Ray and Watkins 1975), followed by a surface portion, in which the bull raises his head above the water and emits one or more single pulses, then a short, harsh whistle, before diving again. Each such male displays continuously, for as long as the females remain at rest. Presumably, the displays serve as advertisement to the females of the males's sexual readiness and as a warning to other males in the vicinity to stay away. We saw females leave the herd and join a displaying male in the water. After some preliminary play (nuzzling, mounting), they dove beneath the surface, where copulation probably took place (Fay et al., 1984).

When more than one bull was displaying before a herd of females, each bull maintained a distance of about 7 to 10 m from the other(s) and each performed his displays in a fixed location. Invasion of one male's display site by another male resulted in agonistic interaction, with each male visually threatening the other by posturing, showing its tusks. That was followed by violent fighting and, finally, withdrawal of the "loser". We frequently saw bulls with bleeding wounds, which suggested that the fights between bulls often result in physical injury to one or both of the combatants (Fay et al., 1984).

The observed ratios of adult males to potentially available mates in the breeding areas, from late February to early April, have ranged from about 1 male:5 females to 1:15 (average, about 1:10). Adolescent males were absent within the mating areas but were abundant outside the mating areas. Juvenile males up to 6 or 7 years old were numerous within the herds of females and young, but they were too immature to function as breeders or to interact with the adult males.

The adult males evidently begin to leave the breeding areas in March, for they start to re-appear then in large numbers in Bristol Bay (Fay and Lowry, 1981). By late April, practically all of the males that summer in Bristol Bay have returned there, presumably from the Bristol-Kuskokwim wintering/breeding area. The females, by that time, have begun their northward migration, and apparently many of the adolescent males, which by then are in rut, migrate with them.

Time and Place of Birth

For a long time, the birth of walruses has been known in a general way to take place in spring, principally in May, but that knowledge was based more on inference than on observation (Chapskii, 1936; Nikulin, 1941; Mansfield, 1958; Burns, 1965; Krylov, 1969). Drawing on all available data, Fay (1982) estimated that nearly all births take place between mid-April and mid-June, with a probable peak just before the middle of May. At that time, females of the Pacific walrus population are in migration from the Bering to the Chukchi Sea.

Most of the recorded instances of births and of newborn (<12 hr old) calves in the Bering-Chukchi region have been from the vicinity of St. Lawrence Island, probably because of more concentrated effort there. A much broader survey of possible calving areas is needed for further documentation of both the time and the place of birth. Our best estimate of the place of birth (Fig. 19), is based on the knowledge of distribution in that period. Because of varying ice conditions, the actual area occupied in any given year will be less extensive but will be within the area shown.

Within that area, the parturient females are not stationary but are in motion, slowly migrating from south to north. Their progress is made principally by swimming, and they haul out frequently on ice floes to rest. Apparently, birth of the young usually takes place on the ice, not in the water (Fay, 1982). Often, the females giving birth to calves haul out individually, in isolation from all other walruses. Others may give birth within herds. Apparently, within a day or two after the birth, the mother and calf generally join up with large "nursery herds" of other females and newborn young (Burns, 1965, 1970).

For the first few days or weeks after parturition, the female tends the calf very closely, defending it vigorously, carrying it on her back or under her arm in the water, pushing it into the water ahead of her when danger threatens, and calling it back or following when it strays. The new calf probably is tended by its mother most closely in the first few days or weeks after birth. By mid-summer, the calf seems to assume the primary responsibility for maintaining the maternal bond, by following its mother closely and calling loudly to her when unable to follow (Gehnrich, 1984).

Figure 19. Estimated maximal extent of calving areas (cross-hatched) of the Pacific walrus population in mid-April to mid-June.

Sex/Age Composition

Most of our efforts in this part of the study were directed at gaining understanding of the sex/age composition of walruses summering in the eastern Chukchi Sea. There, they congregate in the transportation corridor used by vessels travelling to and from the Canadian and American Beaufort Sea oil fields. There, also, they may eventually be affected by oil exploration and development activities in the Barrow Arch lease area.

Earlier, both Collins (1940) and Brooks (1954) had indicated that most of the walruses taken by Eskimos in the vicinity of Barrow in July and August were adult males, though females and young were said to linger to the south, near Point Franklin. Farther south near Wainwright, Burns (1965 and unpublished) found females and young abundant in July, and G. C. Ray (pers. comm.) found them common also in the ice northwest of there in July. The implication of those reports was that sexual segregation prevailed, with the males clumped near Barrow and the females farther south and west, but this needed clarification. From the herds of females and young, we hoped also to obtain information on survivorship of the young cohorts and of the recruitment to the breeding population, as explained earlier in this report.

During our first compositional survey, via the CGC POLAR STAR on 16 to 28 July 1981, we began by searching the pack ice from Barrow to 169°W, using both the ship and its helicopters to probe into the ice up to 75 km north of its edge. We found a few walruses deep within the pack, but most of the animals were less than 20 km from the southern edge (Fig. 20). Sexual segregation within that area was apparent (Table 13). Males occurred more often than expected in the groups nearest Barrow (east of 159°W) and very significantly less often than expected in the farthest west sector (west of 163°W) (X^2=22.629, 2 d.f., P<0.001). Throughout the whole area, nearly all of the groups that we met were made up only of adult females and their dependent young.

During that survey, we sighted a total of 516 groups of walruses, containing more than 5,000 animals. The majority of animals sighted in the water were in groups of only one or two individuals, whereas most of those on the ice were in larger groups (Table 14). We were able to classify to sex and age 2,179 of the animals in 324 groups. These included 216 groups from which every member was classified (i.e., "complete groups") and 108 for which only partial classification was possible ("incomplete groups").

We had greater success in classifying groups that were on the ice than in classifying those in the water. Our level of success in completely classifying groups on the ice was inversely related to group size; for in-water groups, the success was disproportionately high for group size 2,

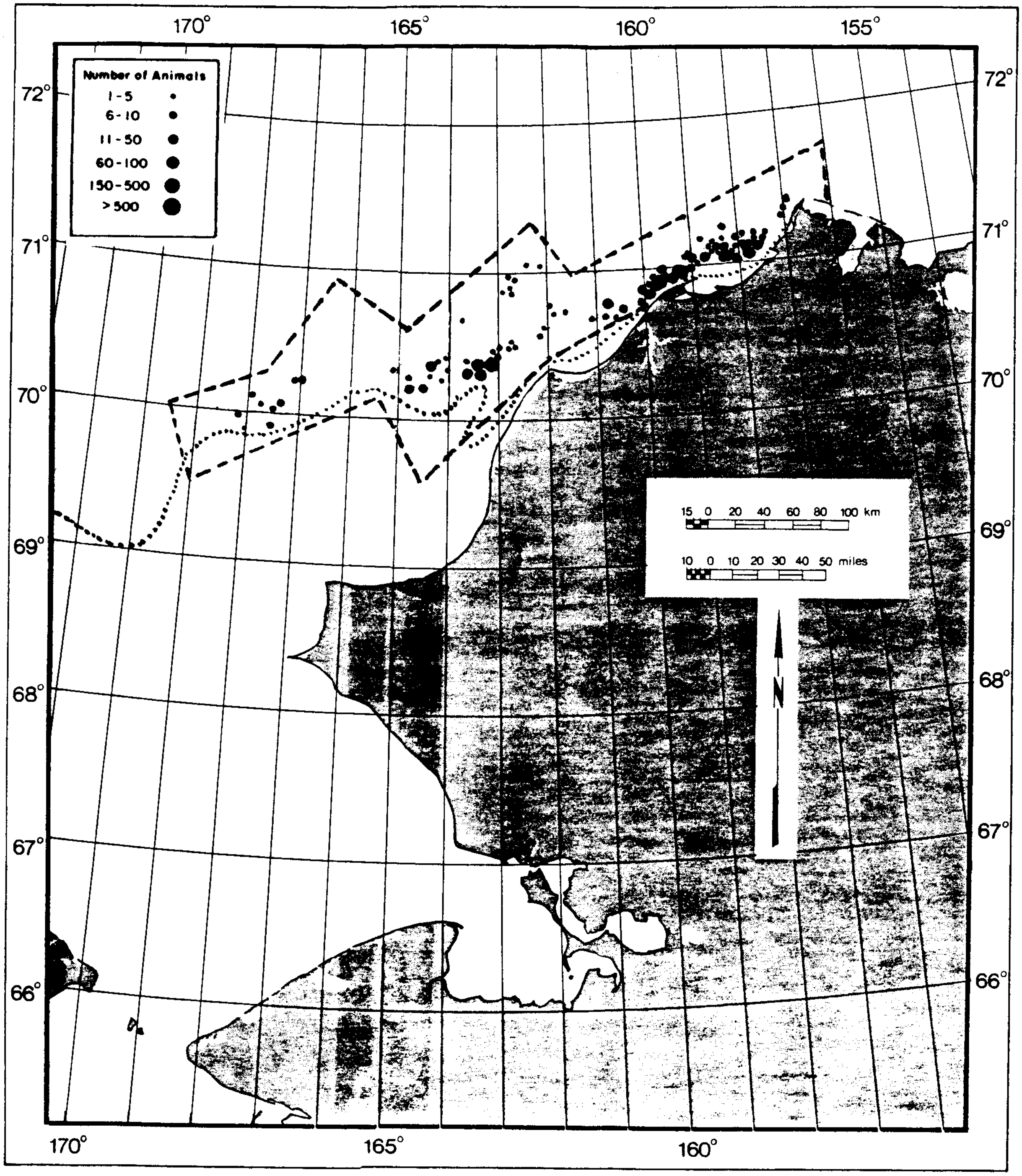

Figure 20. Chart of northeastern Chukchi Sea, showing location of walrus herds, 16-28 July 1981. Dashed line is the boundary of the surveyed area. Dotted line indicates the position of the ice edge.

Table 13. Comparative composition of walrus groups in five sectors of the pack ice of eastern Chukchi Sea in late July 1981.[1]

Longitude	Total no. of animals	Percentage per sex/age class			
		Females & young :		Subadult & adult males	
		No.	%	No.	%
156-159°W	1235	1136	91.98	99	8.02
159-161°W	177	162	91.53	15	8.47
163-166°W	313	311	99.36	2	0.64

[1] Limited to completely classified groups on ice. Sample sizes were too small in sectors 161-163°W (n=2) and 166-169°W (n=3) to be tested by the chi-square method, since expected values for males were <1.

Table 14. Percentage frequency of occurrence of group sizes of walruses on ice _versus_ in the water, eastern Chukchi Sea, 16-28 July 1981.

Location of group	No. of groups	Group size (no. animals/group)						
		1	2	3-4	5-9	10-20	21-50	51-200
On ice	285	10.2	14.4	16.5	22.8	17.5	12.3	6.3
In water	231	25.5	38.5	20.8	10.8	3.0	0.8	0.4

in which cow-calf pairs (which are the most easily identified) predominated (Fig. 21). Apparently as a result of that bias, the proportion of calves in both the completely and the incompletely classified in-water groups was five times that from the completely classified groups on ice (Table 15). Since we regard the completely classified groups on ice as our most reliable sample, we rejected the in-water sample as entirely biased and unreliable and turned to comparison of the on-ice samples.

Table 15. Percentages of walruses in each sex/age class per compositional sample, eastern Chukchi Sea, July 1981.

Type of sample	No. of animals	Sex/age class (yrs)						
		Both sexes					Females 6 and older	Males 6 and older
		0	1	2	3	4-5		
On-ice:								
Completely classified	1691	3.8	2.3	3.3	4.5	9.8	69.3	6.9
Incompletely classified	348	9.2	4.0	3.2	6.0	11.2	55.2	11.2
In-water:								
Completely classified	104	19.2	5.8	2.9	1.9	10.6	57.7	1.9
Incompletely classified	36	44.4	16.7	2.8	5.7	8.3	22.2	0.0

The composition of the incompletely classified groups on ice was similar to that shown by the completely classified groups, but it indicated a much lower proportion of adult females and higher proportions of males and young animals than did the completely classified sample. This was not due to disparate sample sizes but to the field method. In most instances, we routinely classified the youngest animals first, then the subadult and adult males, and lastly, the adult females. In doing so, we frequently were able to classify all or most of the young and the males but did not have time to confirm that all the rest were adult females, before the group dispersed. For that reason, we rejected the incomplete sample as unreliable and accepted only the completely classified groups on ice as being representative of the population in the area surveyed.

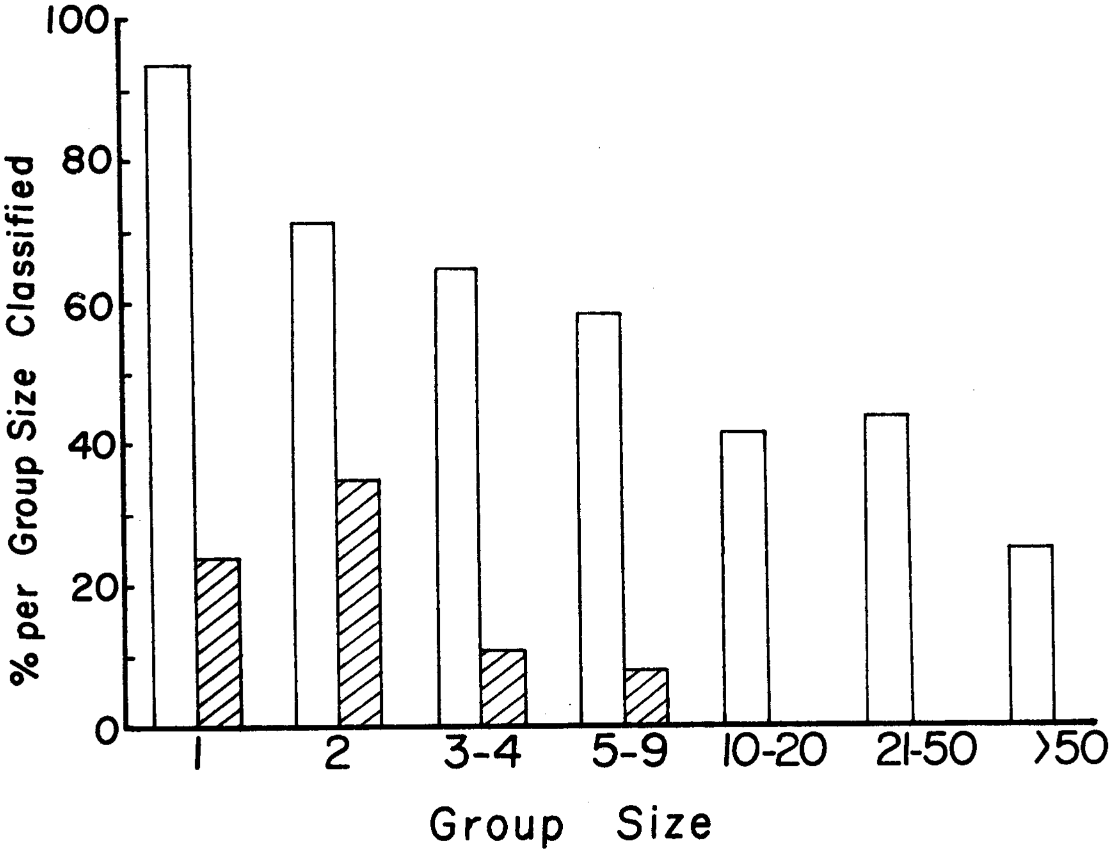

Figure 21. Proportions of animals per group size that were visually classified to sex/age. Bars show percentages completely classified: open = groups on ice; hachured = groups in water.

The composition of groups on ice that were completely classified tended to vary somewhat with group size (Table 16). Animals in the three youngest age classes did not occur singly, but they were about equally represented in groups of two or more individuals. Independent juveniles 3 to 5 years old tended to be most numerous in groups of 1 to 4 animals, usually not including any older or younger individuals. Subadult and adult males were found mainly in the smallest (1-2) and largest (>50) groups; adult females were most numerous in groups of 10 or more. Had our sampling of groups of different sizes been very unequal, those variations might have biased the results of our survey, but we think they did not in this case. Hence, our findings suggested that the early postnatal survivorship of the young had fallen to a very low level and that it had been that way for at least 6 years. Only about 5.5% of the adult females were accompanied by calves of the year, instead of the expected 30-35% (Fay, 1982), and the successively older cohorts were even smaller.

Table 16. Percentage representation of sex/age classes of walruses in completely classified groups on ice, in relation to group size, eastern Chukchi Sea, 16-28 July 1981.

Group size	No. of animals	Sex/age classes						
		0	1	2	3	4-5	M 6+	F 6+
1	27	0.0	0.0	0.0	7.4	40.7	14.8	37.0
2	58	1.7	5.2	1.7	8.6	19.0	12.6	51.7
3-4	105	3.8	1.0	4.8	11.4	13.3	5.7	60.0
5-9	254	3.1	4.3	5.5	6.3	10.6	9.4	60.6
10-15	149	3.4	2.7	2.7	2.0	11.4	6.7	71.1
16-30	456	3.3	2.0	3.9	4.4	9.2	0.9	76.3
31-50	136	7.4	2.2	2.9	2.9	9.6	3.7	71.3
>50	506	4.4	1.6	1.8	3.0	6.1	11.3	71.9

We considered that those results might have been incorrect, perhaps because our sample was not representative of the whole population. That is, we had no basis for assuming that animals summering in the eastern Chukchi Sea were typical of the entire population. The possibility of their being a unique group with lower productivity than the rest of the female population could not be discounted. We clearly needed to survey in other areas to determine whether the low survivorship was population-wide or peculiar to just the eastern Chukchi group.

We sampled again in the eastern Chukchi Sea in September 1981, via the N/S OCEANOGRAPHER, and during the southward migration in November 1981 from our field camp on the Punuk Islands. The results were similar to those from the first survey, except that the proportion of cows with calves (14.2%) at Punuk was higher than in either of the Chukchi surveys. At the time, we did not know whether that was attributable to its being more representative of the population or, perhaps, to its being biased by incomplete classification and other circumstances, such as segregation. The latter seemed especially probable, because the Punuk sample was made up of ten incomplete counts of animals in the periphery of large herds, where females with young calves tend to cluster (Popov, 1960; Miller and Boness, 1983).

The opportunity to sample both the eastern and the western Chukchi Sea came in the following summer, when we were invited to participate in a joint Soviet-American survey of marine mammals in the entire Chukchi ice edge. The vessel, K/S ENTUZIAST, was not an icebreaker but a whale catcher, so it was not able to go far into the ice. Nonetheless, with the winds from the south most of the time, the ice was compacted and the animals were abundant in the edge, where they were easily reached. Not only were we able to cover both the eastern and the western ice, we did so twice, two weeks apart, and each time with a different group of observers. Our results from the western part of the Chukchi Sea were very similar to those from the eastern part (Table 17), indicating that the herds in the eastern Chukchi probably are representative of the whole female population, hence that the low survivorship of young probably was a population-wide phenomenon. As in each of the previous samples, the 1980 cohort, then 2 years old, was by far the smallest.

Thus, by means of our compositional counts, we confirmed that male walruses are more common near Barrow than farther west, but we clearly identified the walruses inhabiting the Barrow Arch lease area as predominantly adult females and dependent young. Judging from the 1975 and 1980 census results in that area, as described earlier, the eastern Chukchi animals constitute about half of the total female population. We also have documented an extremely low survival rate of calves that has been taking place at least since the early 1970's. That poor survival appears to have led to very low recruitment into the breeding population, at least since the mid-1970's. That low recruitment probably has contributed to the predominance of elderly animals in the population.

Table 17. Percentage composition of walrus herds in the eastern and western Chukchi Sea, July-August 1982.

Area	N	Both sexes (yrs)					Males 6 and older	Females 6 and older
		0	1	2	3	4-5		
East of 170°W	1520	11.2	5.3	1.1	2.8	5.0	1.1	73.4
West of 170°W	315	8.5	4.7	1.6	1.3	4.7	9.5	69.1

Feeding Habits

The information available on seasonal and regional feeding habits of Pacific walruses up to 1978 was reviewed by Fay (1982). Most of that information was not very detailed, and nearly all of it was from the Bering Strait region in spring. Some additional spring data from that region were obtained in the meantime by Lowry and Frost (1981) and by Fay and Stoker (1982a,b); some winter and spring data were obtained in the southern Bering Sea by Kibal'chich (1981), by Fay and Lowry (1981), and by us. Lastly, we recently obtained some information on feeding habits in summer in the western and central Chukchi Sea (Fig. 22).

Winter, Southeastern Bering Sea

During the cruise of the ZRS ZVYAGINO in February-March 1981, we observed more than 5,000 walruses in the pack ice south of Nunivak Island and Kuskokwim Bay. Most of those were females and young, which seemed to be rather synchronous in their feeding, though they did not follow a circadian schedule. A tabulation of our sightings each day indicated that nearly all of the animals tended to be in the water feeding for 24 to 36 hours, then to spend 36 to 48 hours at rest on the ice (Table 18). The feeding forays usually took place about the time of passage of a storm front through the area; the periods of rest were mainly in the periods of fair weather between storms.

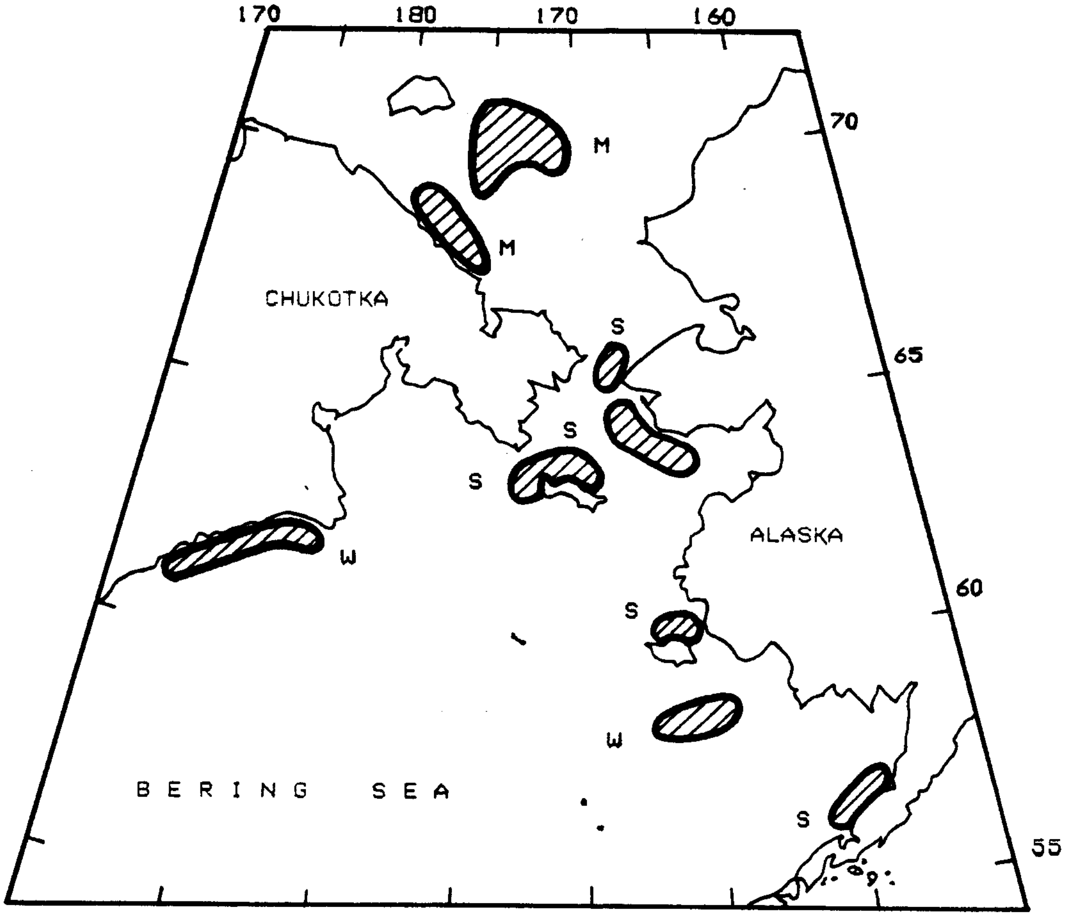

Figure 22. Locations from which walrus stomach contents were obtained by personnel of this and complementary projects: in winter (W), spring (S), and summer (M).

Table 18. Daily compilation of sightings of walruses within 1 km of the ship's track, in relation to activity. Animals on the ice were most sleeping; those in the water were mostly feeding. ZRS ZVYAGINO, southeastern Bering Sea, winter 1981.

Date	Walruses sighted		
	N	% on ice	% in water
25 February	272	98.5	1.5
26 February	169	83.4	16.6
27 February	599	2.0	98.0
28 February	15	100.0	0.0
1 March	129	94.6	5.4
2 March	369	98.6	1.4
3 March	400	25.5	74.5
4 March	139	76.3	23.7
6 March	63	52.4	47.6
7 March	13	53.8	46.2
8 March	231	100.0	0.0
9 March	44	93.2	6.8
10 March	155	36.1	63.9
11 March	63	95.2	4.8
12 March	36	19.4	80.6
13 March	484	51.4	48.6
14 March	2,144	98.4	1.6
15 March	94	73.4	26.6
Totals	5,419	73.7	26.3

From 180 specimens taken during that cruise, about 120 km offshore in waters 25 to 45 m deep (Fig. 22), we obtained 15 samples of stomach contents. All previous winter and spring samples in southeastern Bering Sea had been obtained much farther south, in deeper water (Tikhomirov, 1964b; Fay, 1982). About 95% by weight of the foods in the 15 stomachs consisted of four kinds of bivalve mollusks: the Alaska tellin (Tellina lutea), surf clam (Spisula polynyma), Greenland cockle (Serripes groenlandicus), and razor clam (Siliqua alta). The tellins predominated by far, in both numbers and weight (Table 19). Of lesser importance by weight but frequent in occurrence were echiurids (Echiurus echiurus), polychaetes (mainly Nephthys

Table 19. Contents of the stomachs of 15 walruses taken in outer Kuskokwim Bay, during February-March 1981.

Kind of prey	Frequency of occurrence	No. of individuals	Weight (gm)
Anemones	1	4	13
Polychaetes	9	150	254
Echiurids	11	114	813
Snails	12	53	87
Tellins	15	4,839	20,184
Surf clams	15	283	5,352
Cockles	12	162	2,221
Razor clams	13	229	985
Astarte borealis	2	3	<1
Crustaceans	9	30	52
Meat fragments	15	-	3,182
Shell fragments	15	-	59
Inorganic sediments	15	-	1,200
Totals		5,867	34,402

spp.), whelks (Neptunea spp., Buccinum spp.), and moon snails (Natica spp., Polinices spp.). The stomachs of two 9-month-old calves contained only milk.

Three of the 15 animals with food in the stomach were males; the rest were females. The males that contained food ranged in age from 1 to 16 years, and they made up 13.3% of the 24 animals in that age range; none of the 66 older males contained any food. Conversely, the 12 females that had food in the stomach were randomly distributed throughout the age range of the whole sample (N=90), of which they made up 12.5%. The implication of those findings is that the young males feed about as much as the females during the breeding season, but the adult males eat very infrequently or not at all. That implication was supported further by the shrunken condition of the digestive tracts of the adult males. The tracts in the largest males were smaller than those in the adult females and in any but the youngest (1 to 3 yrs old) of the immature animals. Those shrunken organs indicated that the adult males had been fasting for a long time, which was indicated also by their leanness. The blubber on the adult males was significantly thinner than on the adult females, even excluding those with a near-term fetus, which are fattest (Table 20).

Table 20. Comparative thickness of sternal blubber in adult male and adult female walruses taken in southeastern Bering Sea, February-March 1981.

		Blubber thickness (mm)		
Sex	N	Range	Mean	S.D.
Males	65	15-54	32.5	8.25
Females[1]	27	31-54	41.0	6.70

[1] Excluding the pregnant females with a nearly full-term fetus.

Many of the snails and bivalves in the stomachs were complete enough to indicate that the walruses had eaten all of the fleshy parts, not just the feet or siphons as Vibe (1950), Brooks (1954), Fay (1955), and Mansfield (1958) had supposed earlier. That is, they had eaten everything but the shells. Shells were absent, except for a few chips from the edges of the valves. Those chips made up only 0.2% of the weight of the ingesta, whereas the entire shells of the bivalves would have made up 50 to 75% of the total weight, had they been eaten. That scarcity of shells was not due to digestion, for the chips were in virtually undigested condition. Indeed, the shells are more resistant to digestion than are the meats. Frequently, we have found that the shells even of very tiny mollusks pass through the digestive tract with little change, whereas the meats of even the largest ones are fully digested.

Winter, Southwestern Bering Sea

Stomach contents from an unknown number of walruses were collected during the cruise of the ZRS ZAGORSKII in the pack ice of the Koryak-Kamchatka region in March-April 1980. Those animals were all males, the majority of them subadults. Their principal foods were Greenland cockles, soft-shelled clams (*Mya* spp.), and possibly razor clams (Kibal'chich, 1981). Although some small clams, such as *Hiatella arctica* and *Macoma* spp. have been reported as abundant in that area, they were not found in any of the stomachs.

Spring, Eastern Bering Sea

Bristol Bay.--During our aerial surveys of Bristol Bay in April 1980 and 81, as well as on the cruise of the R/V RESOLUTION there in April 1981, we observed several thousand males in the water, and most of them appeared to be feeding. Nearly all were adults in small groups of 1 to 7 individuals (mean, 3). We obtained stomach contents from four of those males, (Table 21).

Table 21. Contents of the stomachs of four male walruses taken in Bristol Bay, April 1981 (after Fay and Lowry, 1981).

Kind of prey	Frequency of occurrence	No. of individuals	Weight (gm)
Anemones	1	16	1,806
Polychaetes	3	5	4
Echiurids	1	1	6
Snails	3	55	146

Table 21. Continued

Kind of prey	Frequency of occurrence	No. of individuals	Weight (gm)
Tellins	3	2,209	2,921
Surf clams	4	1,013	12,635
Cockles	2	6	54
Razor clams	1	20	219
Mya truncata	2	15	368
Crustaceans	2	6	75
Holothurians	1	3	81
Meat fragments	4	-	2,177
Shell fragments	4	-	42
Inorganic sediments	4	-	593
Totals		3,349	23,401

The foods in their stomachs were very similar to those in the winter sample from Kuskokwim Bay, except that the proportions differed. Here, surf clams predominated by weight, and tellins and anthozoans made up most of the rest of the identifiable prey. Because these walruses had been feeding when they were taken, part of their stomach contents was not yet affected by digestion. Again the fleshy parts of the bivalves were found to be nearly complete, but the shells were absent. That is, the walruses had eaten practically all of the meats -- not just the feet and siphons, but the mantles, gills, viscera, and even the adductor muscles. Only the shells were missing, and their absence clearly was not due to digestion.

Nonetheless, digestion apparently had altered the condition of some of the foods, for the larger meaty parts were more numerous in each stomach than were the smaller ones from the same clams. Noting that, Fay and Lowry (1981) re-examined the Kuskokwim Bay sample and observed that the smaller tellins were best represented in the freshest samples, and the larger surf clams predominated in the more digested samples, indicating that digestion had affected the composition of the stomach contents.

Nunivak Island.--Stomach contents from five male walruses taken in the vicinity of Mekoryuk and Etolin Strait contained mainly tellins, soft-shelled clams, and some large anemones, possibly of the genus Metridium (Table 22). Next in order of abundance were razor clams. In much smaller

Table 22. Contents of the stomachs of five male walruses taken in the vicinity of Mekoryuk and Etolin Strait, Nunivak Island in May and June 1982 (after Fay and Stoker, 1982b).

Kind of prey	Frequency of occurrence	No. of individuals	Weight (gm)
Anemones	2	204	3,500
Polychaetes	2	25	31
Echiurids	1	2	25
Priapulids	1	1	2
Brachiopods	1	2	3
Snails	4	24	35
Tellins	2	2,671	4,744
Surf clams	1	3	50
Cockles	1	11	122
Razor clams	2	518	768
Mya spp.	3	176	2,904
Crustaceans	2	12	13
Holothurians	3	8	66
Meat fragments	5	-	1,187
Inorganic sediments	5	-	876
Totals		3,657	12,978

quantities were Greenland cockles, surf clams, holothurians (*Cucumaria* spp.), moon snails, polychaetes (especially *Nephthys* spp., *Phyllodoce* sp.), and echiurids.

St. Lawrence Island.—Stomach contents from 108 walruses taken in the vicinity of Gambell and Savoonga in May and June of 1980 and 1982 suggested again that walruses in the St. Lawrence Island region feed on a very wide variety of prey (Table 23).

Table 23. Contents of stomachs of 108 walruses taken in the vicinity of St. Lawrence Island, April-June 1980 and 1982 (after Fay and Stoker, 1982a,b).

Kind of prey	Frequency of occurrence	No. of individuals	Weight (gm)
Anemones	10	68	401
Nemerteans	1	1	1
Polychaetes	30	955	1,814
Sipunculids	16	73	257
Echiurids	38	1,209	4,202
Priapulids	59	212	1,419
Snails	98	1,624	4,146
Tellinids	35	2,696	838
Surf clams	14	551	3,496
Cockles	91	1,494	24,602
Mya spp.	96	10,102	63,130
Hiatella	8	4,288	2,356
Yoldia	10	104	48
Nucula	1	1	1

Table 23. Continued

Kind of prey	Frequency of occurrence	No. of individuals	Weight (gm)
<u>Thyasira</u>	1	1	1
<u>Liocyma</u>	3	7	10
Octopus	3	3	10
Amphipods	7	14	17
Shrimps	35	785	2,641
Crabs	45	230	703
Holothurians	30	61	992
Tunicates	9	22	43
Fishes	12	811	1,581
Meat fragments	89	-	8,298
Shell fragments	9	-	49
Inorganic sediments	79	-	17,871
Totals		25,312	138,927

In general, 68% by weight of this sample was made up of bivalve mollusks, especially of the genera Mya and Serripes. Most of the other prey were polychaetes, echiurids, snails, crustaceans, and fishes (sand lance, Ammodytes hexapterus). Inorganic sediments made up nearly 13% of the total weight.

Nome - King Island.--The stomachs of eight specimens taken in 1980 and 1982, from just south of Cape Nome to the vicinity of King Island, contained mainly Greenland cockles and soft-shelled clams (Table 24). Tellins, echiurids, and holothurians ranked next; other kinds of prey were present in trace amounts.

Table 24. Stomach contents of eight walruses taken from the vicinity of Nome to King Island, May 1980 and 82 (after Fay and Stoker, 1982a,b).

Kind of prey	Frequency of occurrence	No. of individuals	Weight (gm)
Polychaetes	2	7	7
Echiurids	2	40	320
Priapulids	2	5	13
Snails	4	21	43
Cockles	3	1,635	4,490
Mya	7	515	4,172
Tellinids	3	116	316
Hiatella	1	5	4
Yoldia	2	86	26
Shrimps	2	22	56
Crabs	2	2	6
Holothurians	3	78	850
Tunicates	1	7	12
Meat fragments	2	-	125
Inorganic sediments	3	-	1,940
Totals		2,539	12,380

Bering Strait.--The stomach contents of 50 walruses taken in Bering Strait, between Cape Prince of Wales and the Diomede Islands in May-June 1980 and 82, had the greatest variety of prey (Table 25). Again, clams of the genus Mya predominated by weight, making up 62.5% of the total; second in importance were cockles at 14.4%; third were holothurians at 6.5%. Peculiar to this sample were jellyfish (Scyphozoa), which were present in considerable quantities in four stomachs.

Table 25. Stomach contents of 50 walruses taken in Bering Strait, May-June 1980 and 82 (after Fay and Stoker, 1982a,b).

Kind of prey	Frequency of occurrence	No. of individuals	Weight (gm)
Anemones	6	18	122
Jellyfish	4	102	510
Polychaetes	17	156	755
Sipunculids	17	356	1,172
Echiurids	12	200	1,179
Priapulids	18	34	478
Snails	40	539	1,299
Tellinids	14	1,425	618
Surf clams	1	11	50
Cockles	27	789	12,498
Mya spp.	49	2,698	54,280
Hiatella	16	2,333	843
Yoldia	2	50	30
Thyasira	1	1	tr
Octopus	9	8	101
Amphipods	2	3	4
Shrimps	2	3	24

Table 25. Continued

Kind of prey	Frequency of occurrence	No. of individuals	Weight (gm)
Shrimps	2	3	24
Crabs	4	16	64
Holothurians	29	387	5,621
Tunicates	1	1	1
Meat fragments	44	-	2,628
Shell fragments	8	-	22
Inorganic sediments	44	-	4,525
Totals		9,130	86,814

Summer, Chukchi Sea

During the cruise of the ZRS ZYKOVO in July-August 1983, we obtained stomach contents from 40 walruses. Half of those walruses were taken in the west-central part of the Chukchi Sea, from just east of Herald Shoal to about 55 km east of Wrangell Island (Fig. 22). The other half were taken along the northern coast of Chukotka, from the vicinity of Vankarem to the eastern part of Long Strait.

The sample from the west-central Chukchi was made up principally of three food types: whole polychaetes (especially maldanids and terebellids), fleshy parts of moon snails (mostly of the genus Polinices), and strips and chunks of flesh from ringed seals (Phoca hispida) (Table 26). Sipunculids, priapulids, crustaceans, tunicates, and fleshy fragments from pennatularian polyps (sea pens), each made up greater proportions of the ingesta than did the bivalves, which were scarce and mostly of very small size. Most of the stomachs contained large amounts of inorganic solids (sediments), but unfortunately we were not able to measure those amounts. The terebellids and pennatularians had not been identified previously as walrus foods.

Table 26. Stomach contents of 20 walruses taken in west-central Chukchi Sea, July-August 1983.

Kind of prey	Frequency of occurrence	No. of individuals	Weight (gm)
Sea-pens	10	unknown	661
Polychaetes	13	2,191	3,293
Sipunculids	7	135	462
Echiurids	4	4	25
Priapulids	4	25	474
Snails	19	3,246	2,776
Tellinids	1	1	tr
Cockles	9	61	191
Mya spp.	1	1	17
Astarte borealis	8	105	18
Yoldia sp.	1	9	4
Nucula sp.	3	3	tr
Nuculana sp.	8	39	1
Octopus	9	8	172
Amphipods	1	2	1
Shrimps	6	50	83
Crabs	16	243	277
Tunicates	3	112	562

Table 26. continued

Kind of prey	Frequency of occurrence	No. of individuals	Weight (gm)
Seal	3	3	2,345
Shell fragments	8	-	19
Totals		6,238	11,308

The nearshore sample from northern Chukotka was made up about equally of polychaetes, priapulids, snails, bivalves, tunicates, and seal flesh (Table 27). As in the more northern sample, the polychaetes were mainly maldanids and terebellids, the snails predominately *Polinices*, and the seals were ringed seals. Crustaceans were abundant but tiny.

Although bivalves and snails were by far the most abundant prey, they were mostly of very small size. The mean weight of the bivalves was less than 0.2 g. Even so, the meats had been neatly separated from the shells, with the exception of some of the smallest clams of the genera *Nucula* and *Nuculana*, which had been swallowed whole.

Table 27. Stomach contents of 20 walruses taken along the northern coast of Chukotka, from Vankarem to Long Strait, July-August 1983.

Kind of prey	Frequency of occurrence	No. of individuals	Weight (gm)
Polychaetes	14	495	1,334
Sipunculids	3	18	53
Echiurids	11	12	35
Priapulids	14	387	1,247

Table 27. Continued

Kind of prey	Frequency of occurrence	No. of individuals	Weight (gm)
Snails	19	1,674	1,489
Tellinids	16	2,096	386
Cockles	12	249	245
Mya spp.	6	65	157
Hiatella arctica	2	2	2
Astarte borealis	13	3,335	337
Yoldia sp.	6	379	52
Nucula sp.	2	2	tr
Nuculana sp.	1	1	tr
Octopus	1	2	4
Cumaceans	3	51	5
Amphipods	12	86	36
Shrimps	7	31	82
Crabs	9	146	217
Holothurians	1	8	120
Tunicates	12	954	1,057
Seals	2	2	2,344
Meat fragments	7	-	42
Shell fragments	6	-	12
Totals		9,997	9,244

The high proportion of seal-eating walruses in these summer samples from the western Chukchi Sea is remarkable but perhaps not unusual. The only previous data from that area were collected by Krylov (1971) nearly 20 years ago, and in his sample of 35 stomachs, he found 3 that contained seal flesh. Although seal eating is regarded as unusual in the Bering Sea (Lowry and Fay, 1984), it may be a very common practice in summer in the western Chukchi Sea, where the benthic prey appear to be mostly very tiny. Seal eating generally has been regarded as a masculine habit in walruses, but only three of our five seal eaters were males; the other two were females. Chapskii (1936) also observed that both males and females were feeding on seals in the Kara Sea in summer.

Amount Eaten in Relation to Age, Sex, and Season

The quantity of food consumed by a single walrus per day or for a longer period of time cannot be measured in the natural environment at present. For that reason, we turned to the records of food intake by walruses reared in captivity, for they at least provide a tangible basis for estimating the intake by wild walruses (Fay, 1982). Many walruses have been reared successfully in captivity in the present century, some of them to more than 20 years of age. Two pairs at Marineland in California also have reproduced several times, for the first time in history. The daily feeding records for those pairs and their surviving offspring, from 1974 to 1982, were made available to one of us (PHG) by the management of that facility.

The kinds and quantities of foods eaten by each of the Marineland walruses was recorded after each feeding bout. The animals were fed varying proportions of whole, oily fishes and shucked (shell-free) clams. Converting those foods into gross caloric content, we estimated that the walruses consumed energy at mean annual rates ranging from about 25,120 kcal/day in a 2-year-old female to 70,310 kcal/day in an 18-year-old male. The annual mean of daily intakes increased with age at about the same rate in both sexes, up to 7 or 8 years. From that point, their consumption rates diverged, the females' tending to level off, and the males' rising again until about 15-16 years of age, before leveling off (Fig. 23). Females consumed more when pregnant or lactating than when non-pregnant or non-lactating. Even so, they usually ate less than the adult males.

The body weights of walruses reared in captivity do not differ from those of wild walruses (Fay, 1982), hence we assumed that the total body weight (TBW) of each of the Marineland animals was about the same as the mean TBW for wild walruses of the same age and sex. On that basis, we estimated their daily intakes of energy per unit of body weight. Those estimates ranged from about 240 to 470 $\mathrm{kcal/kg}^{3/4}$ TBW per day (Fig. 24).

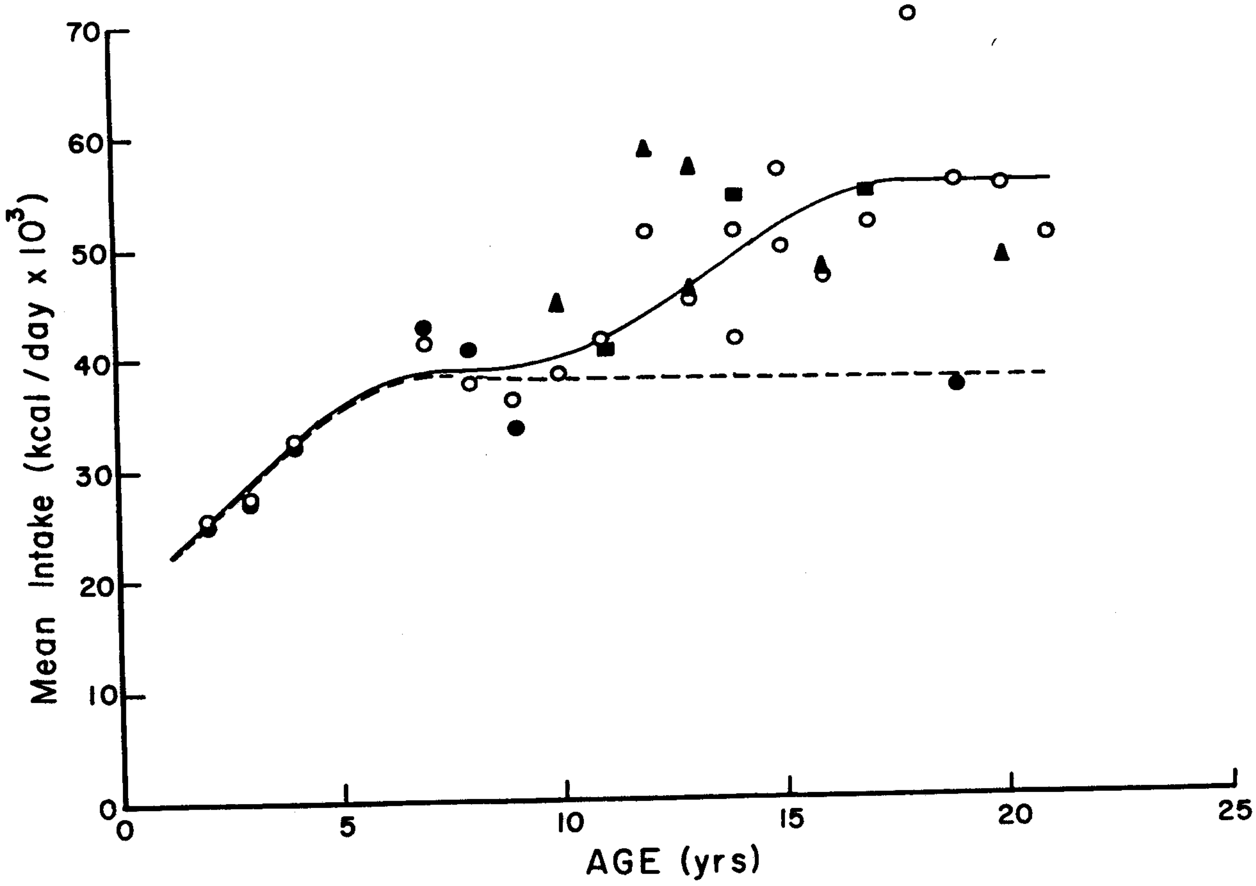

Figure 23. Mean daily energy intake of male (o) and female (● non-pregnant, ▲ pregnant, ■ lactating) walruses per calendar year at Marineland, in relation to age (after Gehnrich, 1984).

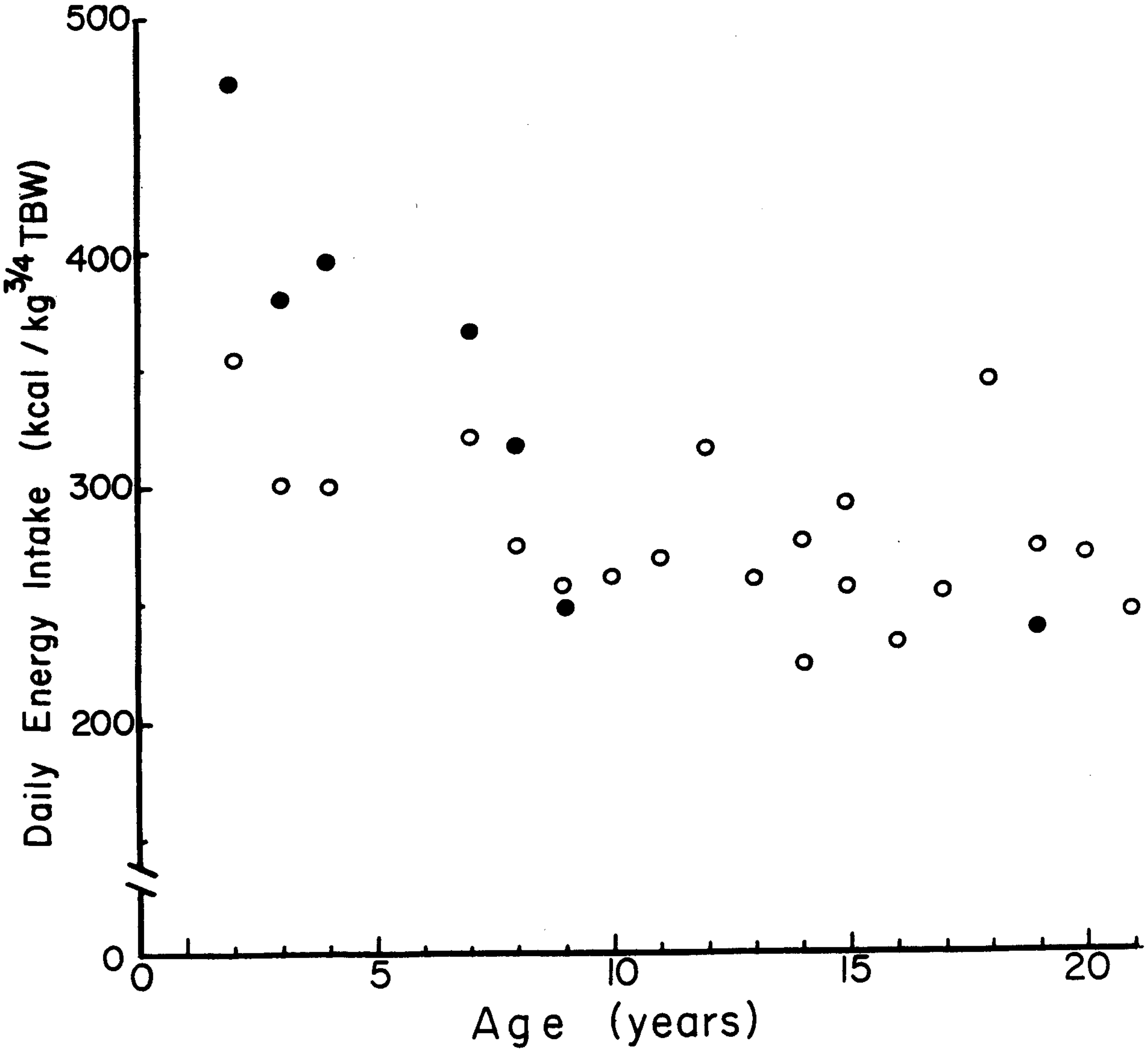

Figure 24. Mean daily gross energy intake per age, in relation to estimated unit body weight, for male (o) and female (•) walruses reared at Marineland (after Gehnrich, 1984).

The highest intakes per unit weight were in the youngest, growing individuals; the lowest were in the mature adults.

The young animals' daily intake of energy was comparatively uniform throughout each year, at least up to 4 years of age; it became more variable after that time (Fig. 25). The variation in later years apparently was correlated mainly with reproductive status. For example, the daily energy intake of the adult females usually dropped to zero for several days about the time of estrus, then rose again to the previous level. The males also fasted during those days of the females' estrus (Gehnrich, 1984). Following estrus and mating, the females' consumption of energy increased steadily through the spring, summer, and fall, usually reaching its maximum in mid-term gestation (November - December). The mean rate of intake during that mid-term maximum for the two females in five different pregnancies ranged from about 52,500 to 69,300 kcal/day. For the next 4 or 5 months, feeding rates decreased again somewhat erratically, then fell to zero for several days about the time of birth. It usually remained very low and very erratic for some days or weeks thereafter. Often there was a brief period of fasting also in August, about the time of the post-partum estrus (cf. Fay, 1982). After that, the trend was upward to a new level that persisted with little change through the rest of lactation.

The mean daily energy intake during each of those five pregnancies, from the time when the intake began to increase in April or May, until it fell off a year later at calving, ranged from 49,250 to 57,960 kcal/day (Table 28). Those intakes amounted to 40 to 50% increases over the means for the same animals when they were non-pregnant and not lactating (Gehnrich, 1984). The females also consumed about 50% more energy when lactating than they did when not pregnant or lactating. Their intakes during the first year of lactation ranged from about 50,480 to 55,500 kcal/day. Immediately after separation from the calf, their intakes fell to the normal non-pregnant, non-lactating level.

The males' energy intakes also became very unstable and variable in adulthood. Both of the males as adults tended to eat very little during a 3- to 5-month period in the winter (Fig. 26). On many days in that period, they ate nothing. That intermittent fasting took place from December or January to April or May, corresponding to the time of rut in the wild males. It took place slightly earlier in the old than in the young male. The younger male was nearly 7 years old when he started this fasting, but it was rather brief and unremarkable until his 10th winter. At that time, he first bred the female successfully.

In both males, the fasting has tended to increase in intensity and duration each year, as they have grown older. Although they have eaten less each year during the breeding season, they have counterbalanced that

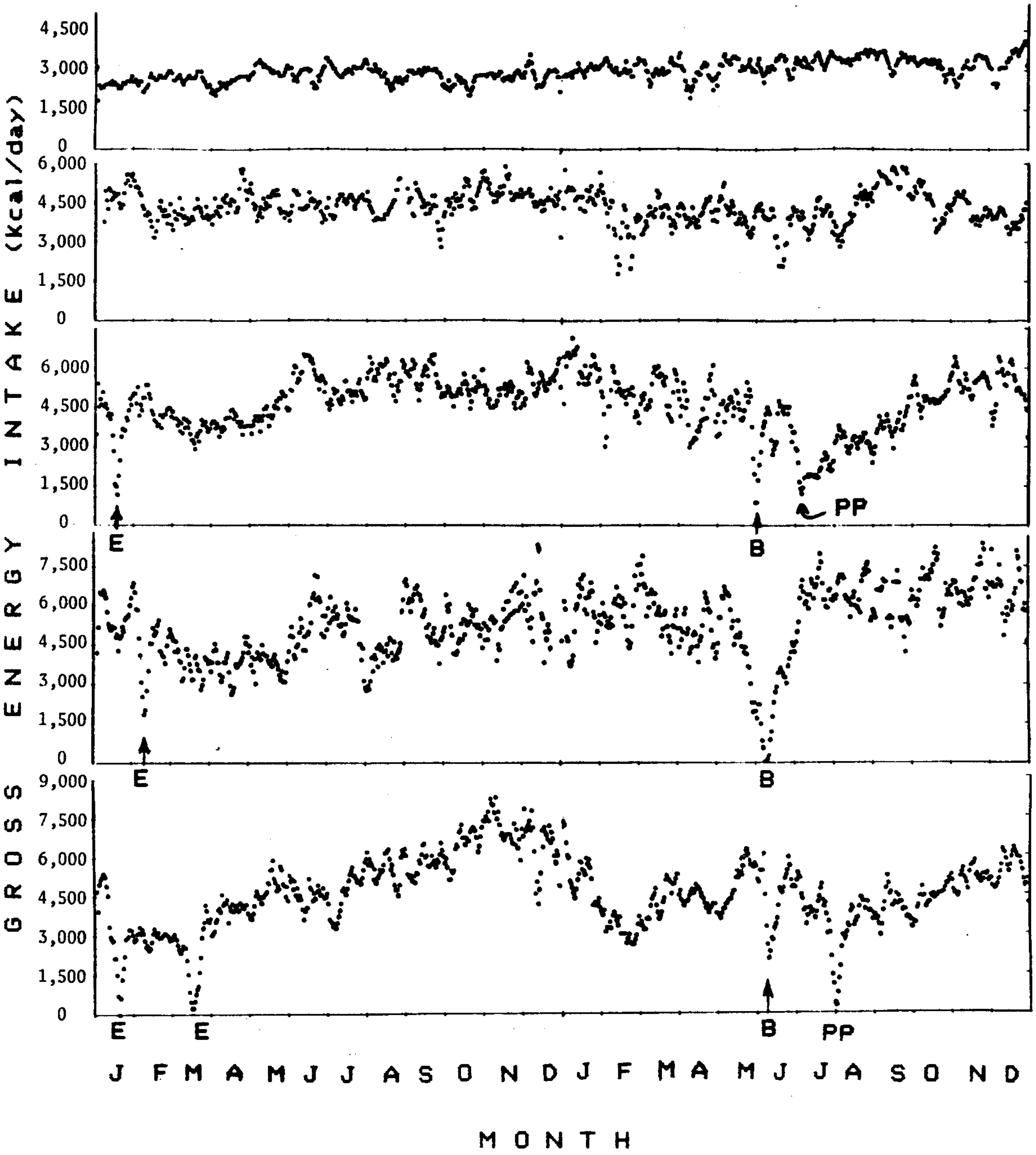

Figure 25. Five day running averages of gross energy intakes for female walruses of different ages at Marineland. Top two in fourth and seventh years; bottom three as adults, during three pregnancies. Deviations linked with estrus at mating (E), birth (B), and postpartum estrus (PP) are indicated.

Table 28. Mean daily energy intakes by pregnant and lactating female walruses at Marineland. Intakes by the same individuals when not pregnant or lactating are shown for comparison.

Age of female (years)	Mean energy intake (kcal/day)		
	Non-pregnant, non-lacteal	Pregnant	Lactating
Female A			
7	43,011	-	-
8	40,995	-	-
9	33,685	-	-
10	-	50,787	-
11	-	-	50,477
13	-	49,250	-
Female B			
13	-	57,963	-
14	-	-	54,764
16	-	50,873	-
17	-	-	55,498
19	36,834	-	-
20	-	52,385	-

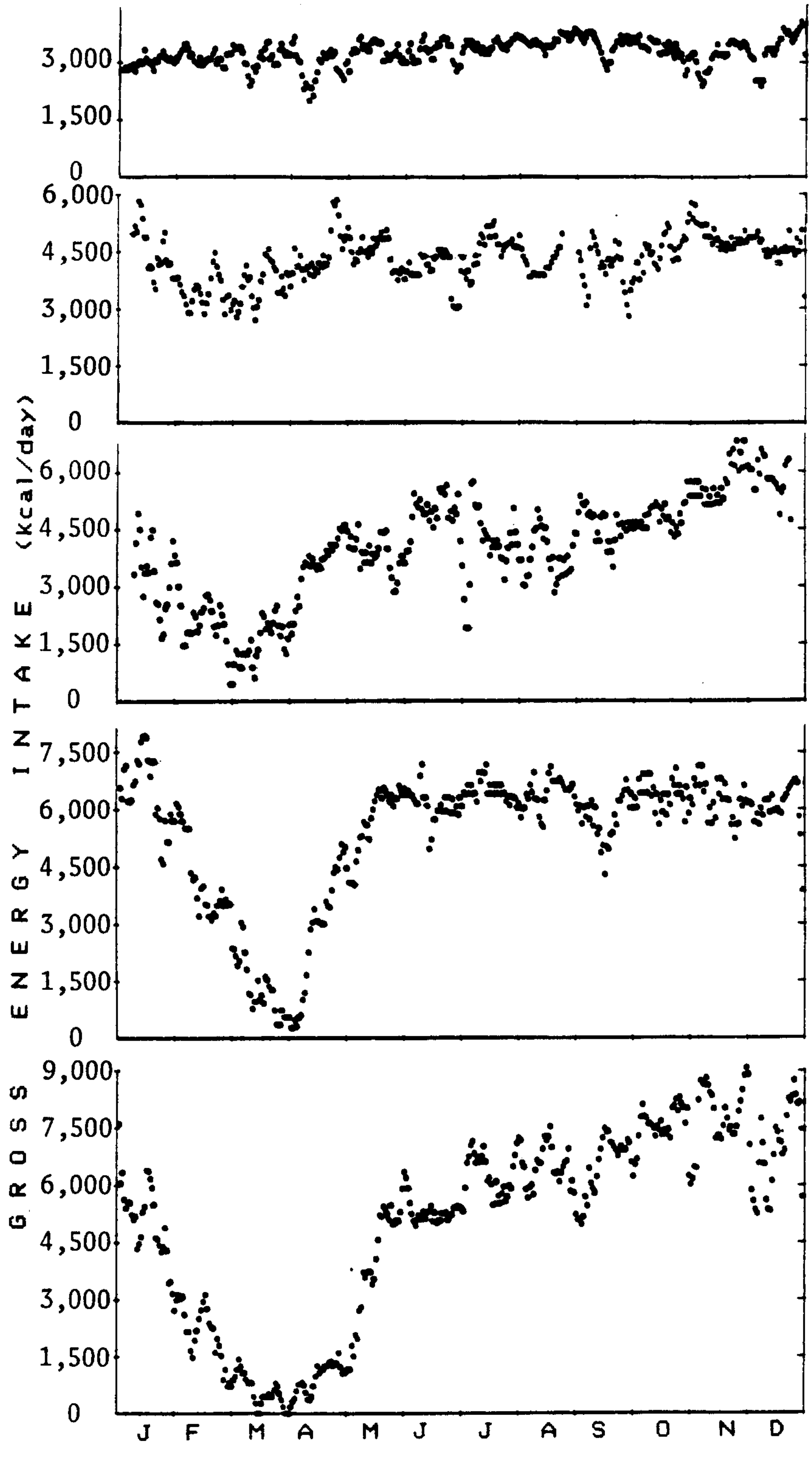

Figure 26. Five day running averages of gross energy intakes for male walruses of different ages at Marineland. Top to bottom: in fourth, seventh, tenth, twelfth, and fifteenth years (Marineland, Los Angeles, unpubl. data).

by steadily increasing their energy intake outside the breeding season (Gehnrich, 1984). Like the females, their maximal intake during the year has tended to be in November-December, which corresponds to the time of the autumnal migration of the wild walruses.

Responses to Man-made Disturbance

Man-made disturbances apparently are perceived by walruses principally through the senses of smell, sight, and hearing. That their sense of smell is keenest is suggested by their quick response to odors at great distances and in the absence of other stimuli (Loughrey, 1959). Their hearing also is keen. "One needs only to step onto the ice and take several steps, whereupon all of the resting animals are awakened, as if by command" (Bel'kovich and Yablokov, 1961:55). But it is common knowledge that vision is poor and that they do not respond in the same way all of the time.

On ice or on shore, males tend to be less shy than females and individuals less shy than groups. Weather appears to play a part in affecting the response. The animals appear to be more alert in windy or stormy conditions than in fair weather. The length of time that they have been out of the water also seems to play a part; that is, they seem to be more easily frightened when they first haul out than after they have been out for a few hours. In the water, where they usually are awake and alert, they tend to be more trusting, evidently feeling more secure there than on land or ice (Fay and Ray, 1968). Their responses to disturbance when in the water appear to be much more predictable than on ice or land. Visually, they appear to be influenced in their response not only by the distance of the disturbing object from them but by its shape, size, and motion.

Females with calves appear to be the most sensitive to disturbance (Popov, 1960; Salter, 1979; Miller, 1982), and animals lying on shore are more sensitive than those lying on the ice (Loughrey, 1959). Disturbance of animals on ice or on shore usually leads to temporary abandonment of the haulout; i.e., the animals withdraw to the comparative safety of the water. Chronic disturbance may lead to permanent abandonment of the haulout (True, 1899; Bissett 1968 in Salter, 1978; Gol'tsev, 1968, 1975a). In Chukotka, several former haulouts are no longer in use, apparently because of persistent disturbance by ships and aircraft. Stampedes from a haulout can result in trauma-induced abortions, injuries, and death (Tomilin and Kibal'chich, 1975; Fay and Kelly, 1980).

In this project, we did not experiment with any of those conditions but did make some effort to observe closely and record our observations, in the course of our other work. Our results were as follows:

On Ice, in Winter

During the cruise of the ZRS ZVYAGINO (Feb-Mar 1981), we observed that, when the ship was breaking ice and approaching the walruses upwind, they appeared to awaken when the ship was up to 2 km away. Evidently they were awakened by the sound alone, since they could not have smelled it upwind and could not have seen it when asleep. We also observed that the animals were less easily awakened when the ship was operating in open water than when it was breaking ice. That is, the walruses appeared to be reacting more to the sound of the ice than to the ship's engines. Other pinnipeds of the pack ice also appear to be alerted more by the sound of breaking ice than by the steady, low frequency sounds of diesel engines.

When first awakened by the approaching ship, the adult males usually just raised their head, looked at the ship briefly, then lay down again until the ship was within about 100 to 300 m. Then, they usually looked again before going into the water, without hesitation. Groups of females and young were more wary, usually watching the ship's approach to about 0.5 to 1 km, whereupon they entered the water and swam away. A similar difference between sexes was evident when the hunters approached the animals on foot over the ice. By approaching upwind and taking cover behind ice ridges, they frequently approached within 2 or 3 m of sleeping males, but they rarely came closer than 20-30 m of females and young.

On Ice, in Spring and Summer

From the CGC POLAR STAR in the open pack ice south of St. Lawrence Island in May 1980 and in the Chukchi Sea in July 1981, we observed that the herds of females and young could be approached upwind by the ship in open water at very slow speeds (3-4 kt or less) usually to within about 200 m. When approached faster (6-12 kt), the walruses left the ice at distances of 5-600 m ahead of the ship, indicating that the speed of the disturbing object was a factor in their response. Since we could hear the throb of the ship's engines up to 5 km away, we assumed that the animals could hear it at least as well. Hence, the inescapable conclusion was that the walruses were not frightened as much by the sound of the ship as they were by the nearness (sight) of it (or a combination of those).

On downwind approach in open water, however, the animals left the ice at distances of 1.5 to 2 km, apparently irrespective of the ship's speed (Table 29). Several times, we also observed that herds at those distances entered the water and swam away when the exhaust cloud from the ship's stack crossed their position. That is, the importance of odor as a stimulus was comfirmed as foremost. Where odor was the primary factor, the animals fled at distances about ten times those from upwind approaches, where only sight and sound could have played a role.

Table 29. Flight distances (meters) of walrus herds when disturbed by the ship, its helicopters, and two types of small boats, during the cruise of the CGC POLAR STAR in the open ice of the Chukchi Sea, July 1981.

	Direction of approach				
Vehicle	N	Upwind	N	Downwind	Remarks
Ship	5	100-650	4	1500-2000	Speed <3 kt
Ship	>5	500	-	-	Speed >5 kt
Survey boat	4	40-60	1	600	All slow speed
Zodiac	5	10-20	2	200-300	With engine
Zodiac	2	1-3	-	-	With paddles
Helicopter	3	400-600	7	1000-1800	Altitude 500 ft

We observed a similar differentiation among their responses to odors, sights, and sounds when we were working among the herds with small boats. With slow, upwind approach, the 30-ft Arctic Survey Boat could go within about 60 m of the herds, without causing any apparent disturbance. But with downwind approach, irrespective of speed or sound, the animals took flight at distances of 5-600 m or more. On several occasions, observers in a Zodiac were able to paddle upwind to within 1-3 m of drowsy animals without alerting them; however, with the outboard engine running, 25 m was the minimal distance upwind before the animals were aroused and began to flee. Downwind, even the Zodiac caused some herds to flee at 300 m or more, especially when the boat was moving at moderate to high speeds.

During the cruise of the K/S ENTUZIAST in the Chukchi Sea in July-August 1981, the herds again appeared to be aroused and to respond to the approach of the ship at significantly greater distances downwind than upwind (Table 30). The distance at which they responded when the ship approached them across the wind was virtually the same as upwind. That is, where the sense of smell could not possibly have contributed to the animals' assessment of the source of the disturbance, their flight distance tended to be about half to a third as great as it was when odor was a factor. That difference was not as great as was measured from the POLAR STAR, possibly because the ENTUZIAST was a much smaller, less smoky ship.

Those findings suggest that the intensity of the animals' response varies with the size of the vessel, as well as its direction and speed, and that the response is least to sight and sound and greatest to the combination of sight, sound, and odor. For audible cues, the quality of the sound seems to be important. Low-frequency, diesel engines appear to cause less disturbance than high-frequency outboard engines. The sound of aircraft engines and the sight of an aircraft moving rapidly overhead appear to be particularly disturbing.

Table 30. Flight distances (meters) of walruses when they were approached upwind, crosswind, and downwind by the K/S ENTUZIAST in the ice edge of the Chukchi Sea, July-August 1982.

Statistic	Direction of approach		
	Upwind	Crosswind	Downwind
N	39	49	21
Range	15-300	7-400	8-800
Mean	70.8	93.8	206.6
Std. error	12.06	12.21	49.29
95% conf. lim.	46.7-94.9	69.4-118.2	108.0-305.2

On Shore, in Spring, Summer, and Fall

At Cape Seniavin in Bristol Bay, we observed a herd of about 1,000 males at rest on the beach at 1000 hours on 8 April 1981. Within 8 hours, that number was reduced to zero by the passage of three fixed-wing aircraft and one helicopter, each at "sight-seeing" altitudes of 60 to 80 m. By 0800 hrs on 9 April, about 100 animals were back on the haulout, but about half of them left when another fixed-wing craft passed them at less than 100m. About 100 were present also at 1100 hrs on 10 April, but those were stampeded into the water about an hour later by another passing aircraft. By evening, only 30 animals had returned, and they did not stay long.

On the Punuk Islands in October-November 1981, we observed only one man-made disturbance of herds on the beach. That happened on 8 November at 0845 hours, when a twin-engine aircraft made three passes over the walruses at an altitude of about 60 m. At that time, there were about 4,500 animals on the beach. About 1,000 of them raised their head when the aircraft passed, but less than 100 of them went into the water. That same day, two other aircraft passed within hearing range but caused no apparent response among the walruses.

In Water, All Seasons

Walruses in the open water, unlike the animals on the ice, usually showed little concern about an approaching vessel, unless the ship was about to run over them. At that, they simply dove and swam off to the side. Often when a ship was stationary, walruses swam to within 20 m of it. Frequently, they dove under it and emerged on the other side, apparently more curious than concerned.

Walruses in ice-covered waters, however, often scrambled rapidly onto the ice, rather than diving under it, when a ship was breaking ice toward them. That kind of response appears to be common among pinnipeds inhabiting the pack ice, for we have seen it in meetings not only with walruses but with both ringed and bearded seals, as well. The reason for it is unknown, but we presume that it has survival value in the pack, when the ice is compacting, breaking, and ridging under pressure.

The Consequences of Disturbance

To estimate the consequences of man-made disturbances on walruses is difficult. Certainly they range from very minor to major, depending on the circumstances. The most obvious possibility of potentially major importance in our experience was the abandonment of dependent young, which probably starve to death. Of more than 300 groups on the ice that were frightened by the ships and put to flight, only three groups left a calf behind and did not return to retrieve it while we had them in view. Earlier, Fay (1982) had observed during the spring walrus hunt at St. Lawrence Island that six calves were abandoned when some 50 herds of females and young were driven off the ice by hunters. This is a much higher rate of abandonment per group, but it may not have been higher per individual, for the herds tend to be larger in spring than in other seasons.

If the shipping traffic is heavy enough through an area in which walrus herds are concentrated, the number of calves abandoned presumably will be a multiple of the number of ships passing. For example, in the shipping lane from Icy Cape to Barrow, where walruses can be abundant in

July to October (Fay, 1982), the effect could be significant. The number of abandoned calves in that area has been unusually high over the past three years, according to reports from the North Slope Borough and U. S. Fish and Wildlife Service. Possibly, this can be attributed to that kind of disturbance, with increased shipping to and from the Beaufort oil fields.

We do not know whether abandonment is likely to take place more often or with greater effect in one season of the year than another. Not enough is known yet about the possibility of seasonal changes in strength of the cow-calf bond. From studies of walruses in captivity at Marineland and from our more extensive but less rigorous observations of wild females with calves, we judge that the probability of the mother's abandoning a calf increases with time after birth. That is, the bond appears to be strongest in the beginning, when it is maintained primarily by the mother. With passage of time, the calf apparently assumes increasing responsibility for maintaining it by following closely and vocalizing when in need of assistance. Thus, we think that the probability of abandonment is less during the calving period than it is later in the year. This needs to be examined more thoroughly, however.

Another, related consequence of disturbance in the Chukchi ice is predation by polar bears (Ursus maritimus). We observed one incident of that type, when a calf was captured from a ship-disturbed herd by a bear. The bear apparently had been stalking the walruses and had lain in ambush behind an ice ridge on an adjacent floe. At the instant when the disturbed herd was entering the water, the bear leaped to their floe, took the calf in its mouth, and carried it away some distance before killing it with a bite to the head. Whether the bear could have caught the calf without the "aid" of the ship, of course, is not known. Apparently, the bears in their own hunting for young walruses routinely rush the herds and stampede them into the water, relying on some calves being left behind (Nikulin, 1941; Popov, 1958, 1960). We observed that a calf was the last to enter the water in 6 of 84 herds put off the ice by ships, and we assume that some bears would not fail to make use of that advantage. Some of the bears in the Chukchi Sea are notoriously unconcerned by ships and tend to occur in some numbers in the vicinity of the shipping lanes and the walruses on both the Soviet and American sides.

Finally, the question of interference of man-made disturbance with mating activities in the wintering areas remains unanswered. We assume that some inhibition of communication through garbling or "drowning out" of underwater vocalizations could take place, as it does in harp seals (Ronald and Dougan, 1982), if the noise level were high enough. Mansfield (1983) suggests that the noise alone may be sufficient to drive the animals out of areas where oil and LNG developmental activities are intense.

DISCUSSION AND CONCLUSIONS

Demographic History

Understanding of the population dynamics of large, wild mammals has advanced greatly in recent years (e.g., see Fowler and Smith, 1981), and the walrus can now be placed in that context. Like other *K*-selected species, walruses are long-lived, slow to mature, and have low fecundity, which must be coupled with very high survivorship. The social, reproductive, and demographic similarities of Pacific walruses to African elephants, for example, are striking (Table 31). Although the elephants have a much longer life-span than the walruses and consequently more prolonged development, the similarities between them otherwise are much greater than their thick skin and long tusks. Both require about 15 to 35% of their potential longevity to reach maturity; both have long intervals between single births, becoming longer with age; the calves of both are weaned at 2 or more years, and whereas the young females remain with the adults, the young males leave and form all-male groups about the time of puberty. The basic social groups of both walruses and elephants are matriarchal, consisting mainly of adult females and their young; small groups of males often are bimodal in age, with one old male and the rest much younger; single females usually are very old, but single males can be of any age; adult survival in elephants is fixed at an extremely high rate, and we surmise that the same is true also in walruses.

Populations of large mammals, when in equilibrium, can weather minor changes in their environment very well, because of their very high adult survival rates (Goodman, 1981). Their late maturity and very low recruitment rates, however, place them at a distinct disadvantage when major environmental changes take place suddenly, for they usually are unable to respond quickly enough to adapt to them. This is because their populations in equilibrium tend to be made up mainly of old animals which reproduce very infrequently. Such a population is very susceptible to over-harvesting, especially of adult females, for it is incapable of reproducing rapidly to compensate for the mortality (DeMaster, 1981; Goodman, 1981; Murphy and Jarrell, 1983).

We surmise that the primitive, pre-exploitation population of Pacific walruses also was in equilibrium with its environment, and that it must have been dominated by elderly, comparatively unproductive animals. We think that it was not greatly affected by the catches of the Russian merchant companies in the 126 years before the sale of Alaska to the United States, for they took only about 45,000 animals, or an average of about 360 animals per year. That could not have had much impact on the size of the primeval population, but at times it might have altered the sex ratio somewhat, because the catches were mainly of adult males. The succeeding

Table 31. Comparative social, reproductive, and demographic characteristics of Pacific walrus and African elephant populations.[1]

Character	Elephants	Walruses
1st breed	12-23 yrs	4-11 yrs
Calving interval	3-9 yrs	2-5 yrs
Gestation	22 mos	15 mos
Calves/birth	1	1
Weaning	2 or more yrs	2 or more yrs
Males leave at age	8-10 yrs	5-7 yrs
Basic social group	2-29 ♀♀&yg	2-5 ♀♀&yg
Adult survival	94-96 %	~95 %?
Longevity	60-70 yrs	30-40 yrs

[1] From Laws *et al.* (1975), Laws (1981a), Fay (1982 and unpubl. data).

catches by the Yankee whalers, conversely, must have had a catastrophic effect, for they were directed principally at the most sensitive part of the population (the adult females), and they amounted to removal of at least 130,000 in 12 years (average, 11,000/yr). By the time the whalers stopped their catching, the walrus population apparently had been brought to extreme depletion, for even the strategically situated walrus-hunting Eskimos of the Bering Strait region starved to death in large numbers.

The whalers' reduction of the population also changed its age composition by removing principally the older adults (for their large tusks) and leaving the younger animals. We think that, in doing so, they made it more resilient and more responsive than it was before, for in its reduced state, it was broadly based in the younger, most productive age classes. Hence, it probably was on the increase again by the mid-1880's, when the whalers had all but ceased their catching.

The population was subjected to further pressure, however, about a decade later, when the arctic traders began their work. And they continued their taking, well into the present century, again mainly of the older animals. During their 30+ years of commercial harvesting, the traders certainly depressed the population, but because of its youthfulness and resiliency, they may not have depleted it to as great a degree as the whalers had, for the walrus-hunting natives at the same time were still getting their subsistence harvests, without registering any major complaints of the population's being depleted, at least until the 1920's. The traders, by directing much of their taking at first on the adult males in the southern Bering Sea (whose ivory and hides were most marketable), actually may have contributed to the population's eventual recovery by helping to restore its proper sex ratio. And when they lowered their pressure on the walruses in the early 1920's, the population must have been still broadly based, with a high proportion of young, productive females. We surmise this because it evidently recovered very rapidly and probably was still in a steep climb when the Soviets began their intensive harvesting in 1931.

Although the harvests by the Soviets were nearly as large as those by the Yankee whalers', they did not bring the population down as rapidly, probably because of its youthful resilience. That is, the animals were better able to withstand the excessive catches, because their productivity was very high. Eventually, the population was depleted by those harvests, perhaps to the lowest level in history, but in that depleted state it evidently maintained its youthfulness and productivity, for it "exploded" when the Soviets lowered their pressure on it around 1960. That explosion took about 20-25 years, which probably was prolonged somewhat, because the animals still were being cropped at a low rate. The growth of the population during that time was aided in part also by a reversal of the sex ratio of the catches. On both sides of the Bering Sea, the earlier catches had been mainly of females, but by the early 1960's they were changed by regulation in both Alaska and Chukotka to about 75% males (Burns, 1965, 1973; Krylov, 1968). We and Lowry et al. (1980) think that the food supply also played a part in helping the rapid response. For a long time, the walrus population had been too small to place much pressure on its food resources and was not using them at all in some areas. That the walruses were much fatter in the 1950's and 60's than they are now speaks of a greater abundance and/or better quality of food in those years.

By the mid- to late 1960's, walruses were re-appearing in places where they had not been seen for 25 to 40 years. That re-expansion into their former range apparently continued well into the late 1970's and early 80's. It may still be underway. At the same time, the results of both the Soviet and American aerial surveys indicated a rapid increase in numbers. The rate of increase appeared to be more rapid than was possible, according to

Kosygin (1975), Estes and Gilbert (1978), and DeMaster (1984), but we think that the data were not interpreted correctly. Only the Soviet estimates of numbers on their side of the Bering and Chukchi seas appear to have been comparable from year to year, and they suggested about a 7% rate of increase in the 1950's and 60's (which is plausible: cf. Mansfield, 1966) and a decelerating rate thereafter. The estimates of the total population, which were generated from the American surveys up to 1972 and from the joint surveys in later years, suggested a much higher rate of increase, but we feel that all or most of that "higher rate" was due to changes in the American census methods, equipment, and analytical procedures.

The expansion of range and increase in size of the population were accompanied by a gradual shift upward in average age and downward in physical condition, from principally fat, young adults, to lean, old animals. The change in condition apparently was the result of gradually increasing pressure on the food supply; the increase in average age is attributable to declining recruitment. The two causes probably are linked, for reproduction of mammals is influenced by nutrition. Because female walruses become less and less productive as they grow older, this was a self-reinforcing process, resulting in ever lower productivity and recruitment. We believe that the population reached its maximal size in the late 1970's, being very large but made up mostly of rather old-aged animals. By 1980, the recruitment was extremely low and fecundity began to vary widely from year to year. We think that for most of the females to have become synchronized into a high production mode in some years and unusually low production in others would have been extremely improbable, unless there had been some extraneous, synchronizing factor. We suggest that the factor was disease and that the newly discovered calicivirus of walruses (Smith et al., 1983) was the agent. Neutralizing antibodies to that virus were detected at titres of 1:10 to 1:20 in 3/40 animals (7.5%) sampled in 1976 and at 1:10 to 1:80 in 17/173 (9.8%) in 1981 (Ibid.; Smith, Fay, and Skilling, unpublished). That increase probably was not significant but illustrates the fact that the virus was widespread in the population. The virus is closely related to the San Miguel sea lion virus (SMSV) and vesicular exanthema of swine virus (VESV), known or implicated as a cause of abortion and other pathologic conditions. We suppose that it could have lowered reproductive success enough in one year (1980?) to cause synchronous production by a high proportion of females in some subsequent years.

The very low recruitment that we have detected in our compositional surveys also is difficult to rationalize as a function of age alone of the mothers. It appears to have been significantly below the predicted level, at least since the mid-1970's. It seems to be a result of extremely poor survivorship of calves, and about two-thirds of the calf mortality seems to have been taking place in the first 2 months after birth. High infant mortality is not unusual in some other pinnipeds in the first few weeks after birth. Although it seems exceptional for walruses, the comparative basis for that judgement was gained during the rapid growth of the population in the 1950's and 60's, and it may have been representative only of that growth phase. That is, high infant mortality may be perfectly normal for a walrus population when it is at or near K.

The progress of the population into the future is difficult to predict, without some modelling. Since the late 1970's, the walruses have shown distinct signs of decreased fertility, highly variable fecundity, poor recruitment, declining physical condition, change in feeding habits, increase in average age, and increased natural mortality, all of which are characteristic of stabilization or decline (Eberhardt and Siniff, 1977). We think that the population already reached its peak in the late 1970's, and that it is on the way down again at this time. That its decline already has begun is suggested by the somewhat larger cohorts of young since the nadir in 1980, by the Eskimos' reports of increasing fatness, and by an apparently declining annual mortality on the Punuk Islands. We think that the population will continue to decline for some years, because the recruitment still is very low, the catches on both sides of the Bering Sea are still going up, and many of the adults are nearing the end of their natural life-span. The fecundity rate probably will continue to decrease for some years yet, for the majority of females are well past their prime and capable only of producing less, not more each year. But calf survival probably will rise markedly and soon result in substantial increases in recruitment. Meanwhile, the population will continue in a downward trend, until the new recruits are abundant enough to produce cohorts sufficiently large to counterbalance the high mortality.

Distribution and Movements

In our efforts to fill the gaps in the distributional information for the Pacific walrus population, we accomplished much less than we had hoped for in the autumn-winter period. That gap may remain forever, if a specific effort is not made to fill it.

We were able to confirm that the southeastern wintering-breeding area lies well inside the pack, in the ice-generating zone of that region, and that the sex ratio of adults in the breeding herds there is about 1 male:10 females, as it is in the north-central (St. Lawrence) breeding area (Fay et al., 1984). We assume that the breeding males in the southeastern wintering/breeding area are those that summer in Bristol Bay, for Fay and Lowry (1981) learned that they leave the Bay in autumn and do not return until after the breeding season has ended. We also learned that some of those males come at least as far north as the Punuk Islands in autumn, presumably to meet up with the southbound females, before the beginning of the breeding season. The Rudder and Arakamchechen males on the Soviet side apparently perform the same kind of reverse migration in autumn (Nikulin, 1947; Krylov et al., 1964; Gol'tsev, 1968), and we presume that they are mainly the breeding males of the north-central (St. Lawrence) wintering/breeding area.

The new distributional information obtained by us and by other OCSEAP and MMS investigators (Leatherwood et al., 1983; Brueggeman et al., 1984; etc) has not contributed further to understanding of the location and extent of calving areas in spring. The population is distributed somewhat differently each year at calving time, depending on ice conditions, and the distributional information currently available is not sufficient to define the full range of that variation. We feel that better definition can only be obtained through a major, dedicated effort.

Recent reports of calving in mid-winter (Lukin, 1978; Brueggeman et al., 1984) are not reliable, since they were based on aerial surveys in which the coincidence of young animals and bloody ice were assumed to have been indicative of recent birth. Young walruses in their first winter (6-10 months old) can easily be misidentified from the air as newborn calves, and bloody ice in the wintering areas is not produced by births but by bulls who have been wounded in battles for courtship sites.

In the Chukchi Sea in summer, we confirmed repeatedly that the main concentrations of herds in July and August tend to be near the Alaskan and Chukotkan coasts, rather than in the center of the Chukchi Sea. We found that nearly all of the animals in both the eastern and the western Chukchi pack ice were females with dependent young, but males were common near shore, off Barrow, as reported earlier by Collins (1940) and Brooks (1954), and near the coast of Chukotka.

Feeding

The walrus is a K-selected predator that feeds primarily on K-selected prey (bivalve mollusks), most of which (1) require about as many years as the walruses to reach maturity and (2) live nearly as long as the walruses (Peterson, 1978; Fay and Stoker, 1982b). It is axiomatic that K-selected species with K-selected prey must inhabit stable environments, and that they are more likely to be upset by major changes in their environment than are the more responsive, opportunistic r-selected species with r-selected prey or even K-selected species with r-selected prey (Laws, 1981b). Because of the long lag time required by both the walruses and their prey to recover from depletion, any significant change in one will have a great influence on the other. We think that the depletion of the walruses in the 1930's to 1950's allowed their prey populations, especially in the Bering Strait region, to increase greatly and attain a new equilibrium structure, made up mainly of large, old individuals. When the first large samples of walrus stomach contents were collected for quantitative analysis at St. Lawrence and Little Diomede islands in 1975, those animals had been feeding in a region that had been used only during the spring and fall migrations for the previous 30 years. Since then, however, the area has been heavily used throughout the summer, as well, by several thousand males (Lowry et al., 1980). We estimate that those males increased the impact on the food supply there by at least 50%, and that, with the growing population of migrants as well, the total impact has more than doubled. The reported changes in feeding habits of the spring migrants from 1975 to 1982 presumably took place as a result of that greatly increased pressure on the abundant but limited supplies (Fay and Stoker, 1982a,b).

In the western Chukchi Sea, however, no evidence of change was detected in a comparison of our recent findings with those of Krylov (1971) and Tomilin and Kibal'chich (1975), from samples collected 10 to 20 years earlier. In each case, the amount of food per stomach was very small and the prey mostly very tiny. Bivalves often were not the predominant prey. The fact that at least half of the females and young summer in the western Chukchi suggests that the apparently meager food supply there may not be of critical importance to them in that season. Moderate to low food intakes in summer have been suggested also by our studies of walruses in captivity, but we are not sure how far those findings can be extrapolated to wild walruses. Because wild walruses molt during the summer (Mansfield, 1958; Fay and Ray, 1968; Fay, 1982 and unpublished), however, they may tend to eat less at that time, as other pinnipeds do (McLaren, 1958; Mansfield, 1967).

From the records of daily food intake by captive walruses, we now know that they do not feed at a constant rate per unit of body weight at all ages, as claimed by Fedoseev (1976). Like other mammals, they reduce their proportional intake with age. The amounts consumed, relative to body weight, are about the same as those reported for domestic animals (Kleiber, 1961), being largest during early growth and smallest for maintenance in adults. During pregnancy, the females increased their intake by 40-50% over maintenance, and they also increased about 50%, during lactation. This suggests that the wild walruses, which often are both pregnant and lactating concurrently, may eat nearly twice as much food at that time as their non-pregnant, non-lactating peers (Gehnrich, 1984).

Response to Disturbance

The walrus' basic response to disturbance amounts to escape, which usually translates into diving into the water from the ice or shore, or if already in the water, diving under the surface and swimming away. This kind of reaction is easily documented and, for that reason, would lend itself well to experimentation. By opportunistic observation, we obtained enough data of that kind to confirm Loughrey's (1959) and Bel'kovich and Yablokov's (1961) conclusion that scent is the strongest stimulus resulting in disturbance, with or without acoustical and/or visual cues. We also obtained strong indications that response to visual disturbance depends on the size, speed, and direction of movement of the disturbing object. Sounds also seemed to vary in effect, depending more on quality than quantity.

The long-term consequences of disturbances are much more difficult to document. Soviet reports of permanent abandonment of haulouts due to chronic disturbance seem plausible enough, but they have not yet been supported by any data. We think that separation of mother and calf could be a very important result of disturbance by ships and aircraft, but we have no real basis for estimating its total effect. Although our data suggest that for every 100 walrus groups disturbed only about 1 calf will be abandoned, we think the real rate probably is higher, because our data were from herds that withdrew in a comparatively orderly, peaceful manner, rather than being stampeded. The more usual situation is that the ship or aircraft approaches them rapidly and noisily, with the result that the animals stampede into the water. Stampedes can result not only in abandonment but in fatal injury to the young (Tomilin and Kibal'chich, 1975; Fay and Kelly, 1980).

The ultimate effects of abandonment may be non-lethal and only slightly disruptive, if the separation is only temporary or if the calf is quickly adopted and fostered by another cow. Separation can be lethal (due to starvation) for the calf if it is not adopted or is not fostered by the adoptee. We suspect that most separations lead to death of the calf, but we have no data to support that notion. To determine the outcome of separation usually is not feasible.

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APPENDIX A.

Chi-square contingency table analysis of parturient, newly pregnant, and barren female walruses harvested at Little Diomede and Gambell from 1952 to 1982.

DIOMEDE	Year of catch						
	1952-58	1962-64	1965	1966-68	1979	1980	1982
N	47	61	39	35	40	102	100
Parturient							
Observed	22	31	16	17	16	15	57
Expected	19.33	25.09	16.04	14.40	16.45	41.55	41.14
Chi-sq.	0.368	1.391	0.000	0.471	0.013	16.962	6.119
New.Preg.							
Observed	18	19	16	9	16	63	26
Expected	18.56	24.08	15.40	13.82	15.79	39.88	39.48
Chi-sq.	0.017	1.073	0.024	1.680	0.003	13.411	4.603
Barren							
Observed	7	11	7	9	8	23	17
Expected	9.11	11.83	7.56	6.79	7.75	19.58	19.39
Chi-sq.	0.489	0.058	0.042	0.723	0.008	0.598	0.294

Overall chi-square = 48.343 with 12 d.f.; P <.001

GAMBELL	Year of catch							
	1952-61	1962-64	1965	1966-68	1975	1979	1980	1982
N	93	109	114	11	43	29	163	87
Partur.								
Obser.	77	87	101	7	33	16	36	64
Expec.	60.33	70.71	73.95	7.14	27.89	18.81	105.74	56.44
Chi-sq.	4.607	3.754	9.894	0.003	0.935	0.420	45.993	1.014
N. Preg.								
Obser.	10	16	8	3	8	6	68	9
Expec.	18.34	21.50	22.48	2.17	8.48	5.72	32.15	17.16
Chi-sq.	3.794	1.406	9.330	0.318	0.027	0.014	39.983	3.879
Barren								
Obser.	6	6	5	1	2	7	59	14
Expec.	14.33	16.80	17.57	1.70	6.63	4.47	25.12	13.41
Chi-sq.	4.842	6.939	8.989	0.285	3.229	1.434	45.715	0.026

Overall chi-square = 196.831 with 14 d.f.; P <.001

DISTRIBUTION OF MARINE MAMMALS
IN THE COASTAL ZONE OF THE EASTERN CHUKCHI SEA
DURING SUMMER AND AUTUMN

by

Kathryn J. Frost, Lloyd F. Lowry, and John J. Burns

Marine Mammals Biologists
Alaska Department of Fish and Game

Assisted by

Sue Hills, Kathleen Pearse, and Jesse Venable

Final Report
Outer Continental Shelf Environmental Assessment Program
Research Unit 613

March 1983

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I. Abstract

The objectives of this study were to compile all available sightings of marine mammals in the coastal zone of the eastern Chukchi Sea during summer and autumn and evaluate the importance of coastal areas to the various species. Specific attention was given to identification of terrestrial hauling out areas used by pinnipeds, as well as those bays, lagoons, and estuaries utilized by cetaceans. The study area included the mainland coast from Cape Prince of Wales to Point Barrow, Alaska.

Based on available sightings, it was possible to identify in general terms the areas of greatest importance to marine mammals, as well as to examine some aspects of seasonal distribution and abundance in specific areas. Although marine mammals inhabit the entire coastal zone of the eastern Chukchi Sea during summer and autumn, their distribution is far from uniform. Spotted seals haul out in large numbers at Cape Espenberg and near Utukok and Akoliakatat passes in Kasegaluk Lagoon. They are abundant but do not haul out in large numbers in Eschscholtz Bay, Hotham Inlet, the Noatak and Kukpuk River estuaries, throughout Kasegaluk Lagoon, and in the mouths of the Kuk and Kugrua rivers. The only regularly used haulout for walruses is at Cape Lisburne. Major concentration areas for belukhas occur in Kotzebue Sound, particularly Eschscholtz Bay, and near Kasegaluk Lagoon. Harbor porpoises are occasionally present along the entire mainland coast. Killer whales occur regularly in low numbers, often in pursuit of gray or belukha whales. We located only three sightings of minke whales in the coastal zone, in Kotzebue Sound and off Cape Lisburne. Gray whales occur all along the coast but are especially numerous between Icy Cape and Point Barrow.

Available data indicate substantial fluctuations in numbers of animals at particular locations but are not adequate to measure those fluctuations or explain their causes. We suggest that OCSEAP initiate studies on representative species and areas, particularly spotted seals at Cape Espenberg and Kasegaluk Lagoon and belukhas in Kotzebue Sound and Kasegaluk Lagoon, in order that the effects of (OCS) activities on marine mammals in the coastal zone can be rigorously evaluated.

II. Introduction

The marine mammal fauna of the Chukchi Sea is much less diverse than that of the Bering Sea. Of the 26 species found in the Bering Sea, 10 are known to regularly occur in Alaskan waters north of Bering Strait. During approximately 9 months of the year, the northern seas are covered by ice, and the marine mammals present then--ringed seals (Phoca hispida), bearded seals (Erignathus barbatus), and polar bears (Ursus maritimus)--are those that are strongly ice associated and adapted to living in the pack or landfast ice. During summer months these species remain ice associated and move northward and offshore to summer in the pack ice. During the ice-free months there is an influx of species from the south. Some, such as spotted seals (Phoca largha), belukha whales (Delphinapterus leucas), and walruses (Odobenus rosmarus divergens), are ice associated during winter but prefer the more open ice front or pack, and some, such as harbor porpoises (Phocoena phocoena) and gray whales (Eschrichtius robustus), are not ice-adapted species. Not all of the species present during ice-free months are found nearshore. Those species regularly or potentially utilizing the coastal zone during summer and autumn include the spotted seal, walrus, belukha whale, harbor porpoise, and gray whale.

Killer whales (Orcinus orca) and minke whales (Balaenoptera acutorostrata) may occasionally be present in the Chukchi Sea, including the coastal zone. Although they are not known to occur there in significant numbers, they were included in this report. Polar bears are not regular summer-autumn inhabitants of the coastal zone; however, they do come ashore in early winter to den and have their young. Bowhead whales (Balaena mysticetus) migrate through the Chukchi and western Beaufort seas twice annually. Although they may sometimes pass through the coastal zone, they do not linger there; they are generally found farther offshore.

Nearshore areas are attractive to marine mammals for a variety of reasons. While in the coastal zone, spotted seals, belukha whales, and harbor porpoises forage on the abundant food resources available in nearshore waters. Spotted seals and walruses haul out at specific coastal locations where they rest between feeding forays. Gray whales are probably not specifically attracted to the coastal zone but utilize it as a continuum of the shallow feeding areas of the Chukchi platform.

While major features of the distribution and biology of these species are generally known (e.g., Lowry, Frost, Calkins Swartzman and Hills, 1982), specific published information on their utilization of coastal waters of the Chukchi Sea is generally not available. Proposed OCS leases will offer for sale much of the area adjacent to important coastal marine habitats in the Chukchi Sea. Potential effects of OCS exploration, development, and production activities on marine mammals include not only chronic and catastrophic discharge of hydrocarbons into the environment, but also disturbance factors associated with both onshore and offshore activities. Information on the distribution of marine mammals in the coastal zone must be of adequate resolution to provide input for tract selections, selection of onshore facilities sites, designation of transportation corridors, and design of stipulations relating to the nature and timing of activities. In addition, such information is required in order to evaluate "normal" changes in the distribution and numbers of marine mammals in coastal areas, as well as to monitor the future impacts of OCS activities.

This project has included two major components. The first involved field work, designed to increase the data available on distribution and food habits of marine mammals along the western coast of Alaska. Included were shipboard and aerial surveys and collections of animals conducted during May to October 1981. Results of the field studies have been compiled and reported (Lowry, Frost and Burns, 1982). The second component consisted of a compilation of all available data on distribution and abundance of marine mammals in the coastal zone of western Alaska during summer and autumn. The compilation of distributional information has been prepared in two parts, a previous report covering the Bering Sea coast, which was prepared and submitted to OCSEAP in September 1982, and this report, which covers the Chukchi Sea.

III. Current State of Knowledge

A. Spotted Seals

Published information on the distribution of spotted seals is limited to general descriptive accounts of their overall distribution (Shaughnessy and Fay 1977, Bigg 1981) or of their distribution in the Bering Sea ice front in spring (Burns 1970; Fay 1974; Burns and Harbo 1977; Burns et al. 1980; Braham et al., in press a). In late winter and spring, the entire Bering-Chukchi population is concentrated in or near the ice front (Burns and Harbo 1977, Burns 1978), with major pupping and breeding concentrations in the Bristol Bay-Pribilof Islands region, Karaginski Bay, and the Gulf of Anadyr (Shaughnessy and Fay 1977; Braham, Burns and Fedoseev, in press). In late winter and spring, the entire Bering-Chukchi population is concentrated in or is common along the eastern Bering and Chukchi Sea coasts, where they haul out on land, particularly on isolated, sandy beaches and barrier islands. They are common in bays, at the mouths of major rivers, and in estuaries (Burns and Morrow 1975). A few animals move eastward into the Beaufort Sea (Burns 1978). In autumn and early winter, as shorefast ice begins to form, spotted seals move offshore and southward to the edge of the pack ice (Fay 1974).

The population of spotted seals in the Bering-Chukchi region has been estimated at 280,000-300,000, of which 80,000 occur in Karaginski Bay (Burns 1978).

B. Pacific Walrus

Pacific walruses inhabit the broad continental shelf of the Bering and Chukchi seas. They migrate seasonally from wintering areas in the Bering Sea to summering grounds on the coast of the Bering and Chukchi seas and the Chukchi Sea ice edge. Based on observations conducted from 1960 to 1976, there are two areas of concentration in late winter and early spring, one south and west of St. Lawrence Island and the other in Bristol Bay (Fay 1982). The actual location of these concentrations is somewhat dependent on the extent of ice in the Bering Sea, which the animals use as a resting platform when not engaged in other activities such as feeding and breeding. Mating occurs in February-March, and females give birth in April-May while moving north with the receding ice edge. Much of the population migrates northward through Bering Strait in April and May. Subadults and females with young follow the retreating ice edge northward and summer primarily in the northern Chukchi Sea (Estes and Gilbert 1978). Adult males form large herds on hauling grounds in Bristol Bay, Bering Strait, and along the Chukchi Peninsula.

Most aerial surveys of walruses have been conducted over the pack ice in Bering Sea in spring or over the Chukchi Sea ice edge and coastal rookeries along the Chukchi Peninsula in late summer-early autumn. Thus, there are numerous accounts of winter-spring distribution in the offshore Bering Sea (e.g., Kenyon 1960, Kenyon 1972, Burns and Harbo 1977, Krogman et al. 1979) and summer distribution in the Chukchi Sea (e.g., Fedoseev 1962, Gol'tsev 1972).

Fay (1957) summarized the historical and present status of walruses and reported that in the 1930's walrus herds were present on hauling grounds at Cape Thompson, Cape Lisburne, and Icy Cape. By the 1950's, however, there were no regular hauling grounds in Alaska except the Walrus Islands in Bristol Bay. Fay also noted that, after 1900, records of walruses east of Point Barrow were rare.

Dunbar (1949), Bee and Hall (1956), and Harington (1966) discussed the occurrence of walruses east of Point Barrow. All reported that walruses were occasionally seen along the northern Alaskan and Canadian coasts east to Hershel Island and rarely at Banks Island in the eastern Beaufort Sea. Bee and Hall (1956) listed 12 records of sightings between Point Barrow and the Alaska-Yukon border.

Fedoseev (1962) discussed the distribution and status of Pacific walruses based on aerial surveys flown in autumn 1960. He noted that walruses were most abundant in the vicinity of Wrangel Island and that they hauled out on land at five locations, including Wrangel and Herald islands and three locations on the Chukchi Peninsula. Fedoseev's surveys did not include the American sector of the Chukchi Sea, but he cited Fay in saying there were no extant haulouts along the Alaskan Chukchi coast.

Gol'tsev (1972) reported on an autumn 1970 aerial survey for walruses in the western Chukchi Sea. He found that there were four onshore hauling grounds: one in the Gulf of Anadyr, two in Bering Strait, and one along the Chukchi coast. His surveys did not extend to the American Chukchi coast.

In autumn 1975, Gol'tsev (1976) again conducted aerial surveys of walruses in the Soviet sector of the Chukchi and northern Bering seas. He reported nine coastal hauling grounds, two of which were in the Chukchi Sea, and noted that a substantial increase in the Pacific walrus population had occurred since his previous survey. As in 1970, the 1975 survey included only the Soviet sector of the Arctic.

Krogman et al. (1979) summarized the historical and recent distribution and abundance of walruses. They noted that walruses have always been abundant along the Alaskan Chukchi coast but that few are found east of Point Barrow. They estimated that from July through September about 40% of the population along the Chukchi Sea ice front is located between 161°W and 166°W.

The best synoptic overview of walrus distribution in Alaska is provided by Fay (1982), in which he maps and discusses distribution by month. He states that solitary animals may overwinter near Point Hope, but that most walruses migrate southward through Bering Strait in October-December. Most return northward in April-July to spend the summer in the pack ice of the Chukchi Sea. From July through September, many are concentrated in the ice off the coast from Icy Cape to Barrow. He reported no recently used haulouts along the Alaskan Chukchi coast.

C. Belukha Whale

Belukha whales are widely though not uniformly distributed throughout seasonally ice-covered waters of Alaska. They spend the winter in offshore waters associated with drifting ice. In spring, as soon as the ice begins to break up and move offshore, they move toward the coast, some making extensive northward migrations in excess of 2,000 km, while others move relatively short distances. Most belukhas appear to spend the summer in coastal waters, concentrating in shallow bays or estuaries of large rivers, although an unknown proportion may remain associated with offshore pack ice. In late summer to late autumn, they move generally south and away from the coast, ahead of or with the advancing pack ice (Kleinenberg et al. 1964, Fay 1974, Gurevich 1980, Seaman and Burns 1981). Major summer concentrations in the Chukchi Sea occur in Kotzebue Sound and along the coast from Cape Lisburne to Point Barrow, primarily in the Kasegaluk Lagoon region (Seaman and Burns 1981; Burns et al., in prep.).

General accounts of the distribution of belukhas in Alaskan waters have been presented by Nelson (1887), Gurevich (1980), Seaman and Burns (1981), and Burns et al. (in prep.). Nelson found belukhas to be common summer residents from Bristol Bay north to Point Barrow. He considered them to be migratory over most of their range, moving north in spring as the ice melted and receded, and south in autumn as the pack ice advanced. Seaman and Burns (1981), and Burns et al. (in prep.) summarized the distribution of belukhas by 2- month intervals and also concluded that most belukhas winter in the drifting ice of the Bering Sea, move northward and toward the coast in spring and summer, and leave the coastal zone in late summer to late autumn. Burns et al. (in prep.) present a detailed discussion of the distribution of belukhas in the Chukchi Sea.

Braham, Krogman and Carroll (1984) plotted more than 400 sightings of a total of almost 2,000 belukhas. Many sightings were made in conjunction with spring bowhead whale surveys from Point Hope to just east of Point Barrow. They described the spring migration of belukhas from the Bering Sea through the Chukchi Sea to the eastern Beaufort Sea, noting that those whales summering in the Canadian Beaufort pass through the Chukchi in mid- to late April and May, using the nearshore lead. In May 1976 numerous belukhas were seen between Icy Cape and Point Barrow, and offshore to the northeast of Point Barrow. On three survey flights in May 1977, about 250 belukhas were seen from Cape Krusenstern to Cape Thompson. In transitting the Beaufort Sea to Banks Island, belukhas use offshore lead systems, rather than remaining nearshore as they do in the Chukchi Sea. Sightings in August through October suggest that the westward autumn migration of belukhas past Point Barrow is predominantly offshore.

Harrison and Hall (1978) presented results from 80,000 km of aerial survey tracklines, 6,000 km of which were in the Beaufort Sea and 2,000 in the Chukchi Sea. They observed belukhas in July and August in the western Beaufort Sea; all sightings occurred approximately 100 km offshore in water depths of 1,800 m. In the Chukchi Sea, surveys were flown in June, August, and October, and no live belukhas were seen. Harrison and Hall concluded that few belukhas remain in offshore waters of the Chukchi Sea during summer.

Ljungblad (1981) and Ljungblad et al. (1982) reported the results of aerial surveys for endangered whales in the northern Bering, Chukchi, and Beaufort seas. In spring 1980 they made 284 sightings of 3,404 belukhas, 2,042 of which were from the Chukchi and Beaufort seas. Over 1,900 of those were seen in the Beaufort, and virtually all were in offshore waters. Belukhas were sighted on two of three flights in the Chukchi Sea and 14 of 28 flights in the Beaufort. In August through October, whales were seen on only one of 41 flights in the Beaufort and on none of four flights conducted in the southern Chukchi Sea in late October. In 1981, belukhas were sighted in the Chukchi Sea on four of six spring flights and five of 12 summer flights. Most survey tracklines were in offshore waters. Monthly coastal surveys were conducted from Nome to Deadhorse in April through July. Most belukhas were seen in April (213) and May (79), with very few sighted in June (14) and July (1). On mid-June surveys of the southern Chukchi, belukhas were seen in Eschscholtz Bay and along the coast from Sheshalik to Cape Krusenstern.

Johnson (1979) reported sightings of belukha whales in conjunction with aerial surveys for birds in the central Beaufort Sea. In September 1977 he observed 75-100 belukhas swimming westward near Pingok Island, and in September 1978 an estimated 35 belukhas were seen near Thetis Island. In two summers of field work in Simpson Lagoon, no whales were seen between the barrier islands and the coast.

Fraker et al. (1978) and Fraker (1979) discussed the spring migration of belukhas in the Beaufort Sea in light of ice conditions and aerial surveys flown in the eastern Beaufort. They, like Braham and Krogman (1977), concluded that belukhas migrate eastward in the offshore leads in the polar pack rather than in the nearshore leads along the mainland coast.

D. Harbor Porpoise

Harbor porpoises are the smallest cetaceans found in Alaskan waters. They are commonly found near the coasts, often in waters less than 20 m deep (Tomilin 1957, Leatherwood and Reeves 1978). Limited evidence from the North Atlantic indicates that they migrate inshore in spring and offshore in autumn (Prescott and Fiorelli 1980). They are apparently poorly suited to living in extremely cold water; their metabolic rate is high despite a blubber layer comprising 40% of total body weight, and their body surface to volume ratio is greater than for other cetaceans (Prescott and Fiorelli 1980).

There are few published records of harbor porpoises north of Bering Strait. Hall and Bee (1954) reported the taking of two harbor porpoises, an adult female and several days later a calf, off Point Barrow in August 1954. Van Bree et al. (1977) reported a sighting of two, one of which was killed and retrieved by an Inuit hunter, in July 1973 in the Mackenzie River delta. Burns and Morrow (1975), based on personal observations and conversations with Eskimo residents, indicated that harbor porpoises probably occur in low numbers in the Chukchi Sea every summer.

E. Killer Whale

There is very little published information on the distribution of killer whales in Alaska. Tomilin (1957) reported that they occur in the southern Chukchi Sea in August and September. Dahlheim (1981) summarized their worldwide distribution and reported that killer whales occur north into the Chukchi and Beaufort seas. Ivashin and Votrogov (1981a) noted that killer whales were relatively scarce in the Chukchi Sea but migrated near Mys Uelen, Mys Ikigur, and Mys Serdtse Kamin. In the southern Chukchi, they were found farther from the coast.

F. Minke Whale

Pacific minke whales are distributed widely in inshore waters, often within 160 km of the coast, as well as in the southern edge of seasonal pack ice (Omura and Sakiura 1956, Tomilin 1957). There is little specific information on their distribution in the coastal waters of western Alaska. Tomilin (1957) reported that Pacific minke whales occur from the Chukchi Sea and Bering Strait to the coasts of Korea and China, and to Mexico. Along the west coast of North America, he reported them to occur from Kotzebue Sound to California. Most sightings from northern waters were made in summer, particularly August and early September, and most animals were observed to be feeding. Tomilin believed that whales occurring in the Chukchi Sea migrated south in winter.

Ivashin and Votrogov (1981b) described sightings of minke whales along the Chukchi Peninsula north to Mys Serdtse Kamin. They found these whales to be present in the coastal zone from about June to October, usually within 24 km and often within 1-3 km of the shore. Their sightings suggested that minke whales in the Chukchi Sea are present in low numbers and that they occur mostly as solitary individuals.

G. Gray Whale

The eastern Pacific stock of gray whales winters in the warm coastal waters of Baja California and the southern Gulf of California. From late February to May, the whales begin a northward migration, following the coast closely and occasionally stopping to rest or feed (Pike 1962). They enter the Bering Sea through passes in the eastern Aleutian Islands, particularly Unimak Pass, in April and May and continue moving along the coast of Bristol Bay and southern Nunivak Island, then toward St. Lawrence Island, where they arrive in May or June (Pike 1962, Braham et al. 1977, Frost et al. 1982). Upon reaching the vicinity of St. Lawrence Island, the whales disperse to spend the summer feeding in the shallow waters (usually less than 50-60 m deep) of the northern and western Bering Sea, the Chukchi Sea, and, to a much lesser extent, the Beaufort Sea (Pike 1962, Rice and Wolman 1971). Gray whales begin their southward migration in September or October, passing through Unimak Pass between late October and early January, and arrive in Baja California mainly in December to January (Pike 1962, Rugh and Braham 1979, Rugh 1981).

The eastern Pacific gray whale population was once severely depleted by commercial whaling but has since recovered to near pre-exploitation levels (Scheffer 1976, Blokhin 1979, Rugh and Braham 1979). Ohsumi (1975) estimated an original population of about 15,000 and suggested that it declined to a low of 4,400 in 1875. By the early 1970's, the population had increased to an estimated 11,000 (Rice and Wolman 1971, Mitchell 1973) and by 1980 to between 16,500 (Reilly et al. 1980) and 18,500 (Herzing and Mate 1981).

The distribution and migration of gray whales has been described most completely by Pike (1962) and Rice and Wolman (1971). Pike noted that gray whales do not move into the Chukchi Sea until the ice leaves, but that they are abundant along the Chukchi coast from July through September. He reported northward-migrating gray whales off Cape Thompson in the first half of July and southward-migrating whales as early as August near Wainwright and Cape Prince of Wales. He found gray whales to be present near Point Barrow until mid-September but generally scarce in that region. Rice and Wolman (1971) summarized northward and southward migrations.

Maher (1960) reported on recent records of gray whales along the north coast of Alaska. He presented the details of 10 animals killed at Wainwright and Barrow and described observations of gray whales near Cape Sabine, Wainwright, and Barrow. Based on those observations and information from the Eskimos, Maher mapped the movements of gray whales along the Chukchi coast, concluding that these whales arrive off Wainwright and Barrow in late June or early July and depart for the south in August or September, depending on ice conditions.

Wilke and Fiscus (1961) reported several sightings of gray whales in the southern Chukchi, although not in the coastal zone. On 10 and 16 August 1959, groups of about 100 were seen feeding in the southeastern Chukchi Sea. Additional sightings of 2-20 whales were made from 19-29 August. A group of 20 was seen on 29 August traveling generally southward.

Marquette and Braham (1982) discussed the distribution and catch of gray whales by Alaskan Eskimos. They noted that, although gray whales are common in the Chukchi Sea, most are seen in offshore areas. The exception is near Cape Lisburne, where gray whales are seen nearshore east of the cape in August and September. Marquette and Braham also reported that gray whales are seen regularly in low numbers near Wainwright and Barrow in July through September and occasionally at considerable distances to the east of Barrow.

Ljungblad (1981) and Ljungblad et al. (1982) reported on aerial surveys of endangered whales in the Beaufort, Chukchi, and northern Bering seas. In spring 1980 and 1981, they saw no gray whales north of Bering Strait. In July 1980, gray whales were sighted close to the beach near Point Hope, Cape Lisburne, Point Franklin, and Barrow, and in late October a few were seen just north of Bering Strait. In June 1981, gray whales were sighted nearshore near Wainwright; in July they were seen from Kivalina to Cape Lisburne, near Icy Cape, and near Point Franklin; and in August off Wainwright.

IV. Study Area

The principal emphasis of this study has been to document marine mammal utilization of coastal areas of western Alaska. This report covers information obtained for the eastern Chukchi Sea, which includes the Alaska coast from Bering Strait to Point Barrow. The study area was divided into two major sub-areas which correspond to the U.S. Department of Interior Outer Continental Shelf planning areas (Fig. 1). For purposes of cataloging information and for presentation of results, each planning area was divided into geographical regions which are described in Table 1. Geographical coordinates of specific locations referred to in text are given in Appendix I.

Our intention in this report has been to include all sightings of relevance to marine mammal distribution in the coastal zone. While it is obvious that sightings of animals hauled out on land or in lagoons and estuaries are significant, the evaluation of sightings made at sea is less straightforward. We did not attempt to review and compile all of the available pelagic sighting data. In general, all sightings made within 5 km of the coast have been included. For gray whales, sightings made somewhat farther offshore are listed.

V. Methods

We have attempted to make a complete review of all available sightings of marine mammals in the coastal zone of the Chukchi Sea during summer and autumn. Our intention in restricting the study to the summer-autumn period was to eliminate the seasons when the coastal zone is covered by shorefast ice, which excludes most species of marine mammals. By so doing, we have eliminated from our study ringed seals and bearded seals, which, in Alaska, only very rarely utilize terrestrial haulouts. We have included in this report any sightings of the seven species discussed in section II which occurred during the open-water season.

As discussed in section IV, the study area has been limited to the coastal zone of the Chukchi Sea. Emphasis was given to identification of terrestrial hauling areas of pinnipeds, and lagoons, bays, and estuaries regularly utilized by cetaceans and pinnipeds. We have not reviewed all available pelagic sightings of cetaceans and generally have included only sightings made within 5 km of the shore. We have dealt primarily with sightings made since 1950 and have not attempted a complete review of earlier historical information, since what is available is usually presented in general terms and is of anecdotal value. Reports and sightings of beached, dead animals have not usually been included.

The idea of cataloging sightings and information on distribution of Chukchi Sea marine mammals is not new. In fact, a number of investigators have maintained files of sightings, and we have benefited greatly from their efforts. Although some relevant information is contained

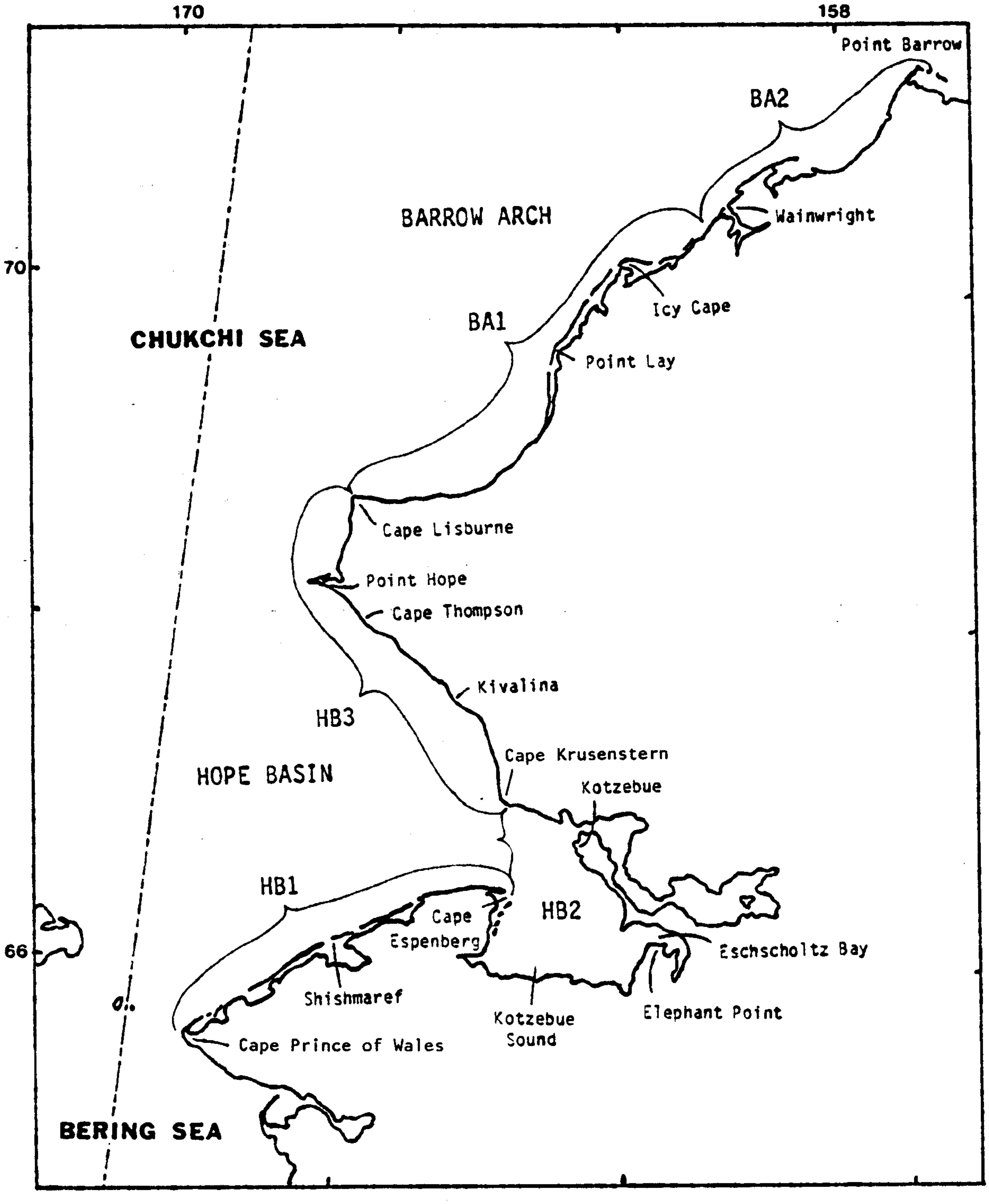

Figure 1. Map of the study area showing Outer Continental Shelf planning areas and subdivisions used in data compilation.

Table 1. Geographical subdivisions of the Chukchi Sea study area.

Hope Basin

HB 1 - north coast of Seward Peninsula from Cape Prince of Wales to and including Cape Espenberg

HB 2 - Kotzebue Sound from just south of Cape Espenberg to, but not including, Cape Krusenstern

HB 3 - coast from Cape Krusenstern to, but not including, Cape Lisburne

Barrow Arch

BA 1 - Cape Lisburne to just south of Wainwright

BA 2 - Wainwright to and including Point Barrow in published literature (e.g., see section III), much of the specific information on sightings is usually lost in the process of data reduction. We have therefore, to the maximum extent possible, derived sighting information from original sources, which are usually the files of individual investigators or agencies and notes and observations of field biologists. Sources which we have used, in addition to published literature (section X), are given in Table 2. The observations and files of personnel associated with the U.S. Fish and Wildlife Service wildlife refuge system and with the Alaska Department of Fish and Game have been particularly useful. Dr. F. H. Fay (University of Alaska, Institute of Marine Science) contributed much from the wealth of data he has collected during many years of observing Alaskan marine mammals.

Data were recorded on formatted sighting cards, which were cataloged by species and area. Geographical subunits of the study area are shown and described in section IV. Depending on the specificity of the data source, we recorded for each sighting the species, number of animals, date, time, location, and any other significant observations such as sex/age classes, apparent behavior, etc.

We have presented our results principally in a series of tables in which sightings are ordered by species, location, and time of year. The location given to each sighting is generally the nearest recognized geographical locale. For example, sightings of both seals hauled out at and whales swimming by Cape Lisburne are recorded as at Cape Lisburne. Place names and associated geographical coordinates are from Orth (1971) and are listed in Appendix I. Some place names not in Orth (1971) are included in tables, maps, and Appendix I; latitudes and longitudes of those places were determined from 1:250,000 USGS maps. Acronyms for sources given in data tables are explained in Appendix II. We have indicated the source from which we obtained the data, which may not in all cases be the original observer. Sightings for a particular species and area are arranged by time of year to elucidate seasonal patterns in abundance.

Although the data-compilation phase of this project terminated at the end of calendar year 1981, new information has been regularly received during the course of preparation of the report. We have incorporated as much of this new information as possible; however, we do not consider the data included for the summer of 1982 to be complete.

VI. Results

A. Hope Basin (Figure 2; Tables 3-5)

Spotted Seal

Spotted seals are present along the entire northern coast of the Seward Peninsula, but there are no major haulout sites in that region. At Cape Espenberg, however, over 1,000 seals have been seen hauled out

Table 2. Information sources consulted in addition to published literature.

ADF&G (Alaska Department of Fish and Game) Annual Project Segment Reports - Federal Aid in Wildlife Restoration Projects, 1960-1981.

ADF&G Files - Fairbanks, Nome

ADF&G Herring Surveys - southern Chukchi Sea to Kotzebue Sound, aerial surveys

ADF&G Marine Mammal Field Reports - cruises and aerial surveys

ADF&G Marine Mammal Harvest Data

Alaska Maritime NWR (National Wildlife Refuge) - letter to refuge manager requesting information from files

Burns, J. - ADF&G, field notes 1962-1982

Entuziast cruise report - joint US/USSR marine mammals cruise in August 1982

Fay, F. - Institute of Marine Science, Univ. Alaska, Fairbanks

Field, P. - ADF&G, field notes 1979 (Point Hope)

Frost, K. - ADF&G, field notes 1975-1982

Hills, S. - ADF&G, field notes

Kelly, B. - Institute of Marine Sciences, Univ. Alaska, Fairbanks; and ADF&G; field notes 1977-1982

Lowry, L. - ADF&G, field notes 1975-1982

Table 2., continued

Melchior, H. - ADF&G, personal communication

Nelson, R. - ADF&G, field notes, field reports

Quinlan, S. - ADF&G, seabird biologist; personal communication

Schamel, D. - Institute of Arctic Biology, Univ. Alaska, Fairbanks; personal communication

Seaman, G. - ADF&G, field notes, field reports 1975-1980

Selawik NWR - Annual Report 1981 and letter to refuge manager requesting data from files

Shanahan, C. - ADF&G, field notes 1967 (Wainwright)

Springer, A. - seabird biologist, personal communication

Strickland, D. - ADF&G, field notes 1978 (Wainwright)

USFWS (U.S. Fish and Wildlife Service) Aerial Surveys for waterfowl - NPRA (National Petroleum Reserve Alaska)
- Barrow to Wainwright to Utukok Pass; 28 May 1978; R. King
- Agiak - Cape Sabine - Point Lay - Icy Cape - Wainwright - Peard Bay - Barrow; 16 August 1978; R. King
- Barrow - Dillingham; 15-22 September 1977; R. King
- Barrow - Point Lay; 21 September 1978; R. King

USFWS SBCS (Seabird Colony Status) Reports - files of all sightings/censuses/visits to established seabird colonies along entire Alaskan coast, usually visited during breeding season; 1976-- A. Springer and D. Roseneau; 1977 - A. Degange and A. Sowls

USFWS Walrus Harvest Reports - 1980 and 1981

USFWS Walrus Survey - joint project with ADF&G and Soviet Union, 10-23 September 1980, Barrow to Bristol Bay.

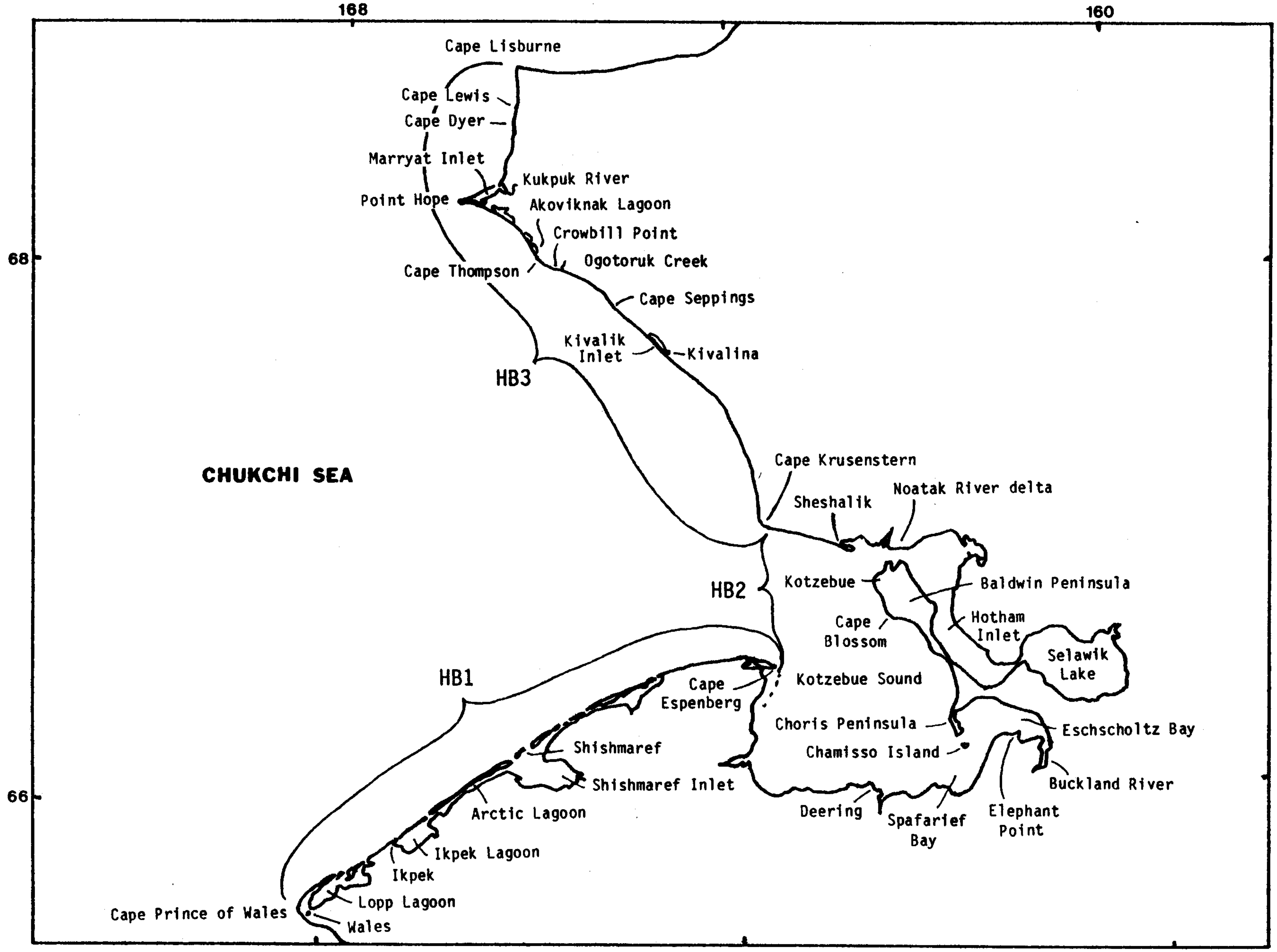

Figure 2. Map of the Hope Basin, regions HB 1, HB 2, and HB 3.

Table 3. Sightings of coastal marine mammals along the northern Seward Peninsula, Hope Basin, region HB 1.

Location	Date	Number	Comments	Source
SPOTTED SEAL				
Wales	Jun	very abundant		Bailey and Hendee 1926
Wales to Shishmaref	10 Jun 81	many	hauled out on broken-up ice floes	K. Frost
Wales	11 Jun 72	present	1st of year taken	J. Burns
	22 Jun 66	some	1st of spring taken	"
	summer-autumn	many	present in any of bays, lagoons, or estuaries, including Lopp, Ikpek, and Arctic lagoons and Shishmaref Inlet; haulout depends on intensity of human activity; present throughout summer, move into rivers and haul out more in autumn	"
Shishmaref	late Jun - early Jul 71	present	hunted	"
	Jul-Aug 72	present	"	"
Shishmaref Inlet	late summer-autumn	many	inside and outside the inlet; hunted	Shishmaref residents through G. Seaman
Shishmaref spit	late summer-autumn	present	sometimes haul out	"
Shismaref	10 Sep 65		26 killed	ADF&G, Nome files
	autumn	present	often hunted	F. Goodhope through J. Burns
	late Nov 72	present	hunted	J. Burns
Shishmaref-Cape Espenberg	summer-autumn	many	hauled out on low sand beach	Alaska Planning Group
Cape Espenberg	late Aug	1,000 +	year unknown; hauled out; photos to document	F. Fay
	21 Sep 81	400	at least 1 seal had been hauled out on the spit off the Cape--others were moving from the lagoon to the ocean through the pass	L. Lowry
	summer-autumn	> 1,000	hauled out at tip of the Cape	Alaska Planning Group
	summer-autumn	many	excellent hauling area; many seals use this area	J. Burns

Table 3., continued

Location	Date	Number	Comments	Source
BELUKHA WHALE				
Cape Prince of Wales, 3 mi NW of	Feb 77	3 +	trapped in ice	Wales hunters through G. Seaman
Wales	late Mar - early Apr	many	moving N; ice present; usually pass by at this time	residents through R. Tremaine
Cape Prince of Wales, 20-30 mi N	6 Apr 81	> 150	including cow/calf pairs	Ljungblad et al. 1982
	28 May 79	2 small pods	close to shore; 1 pod of 8+; hunted	R. Tremaine
Wales	5 Jun 81	2	seen moving N offshore by Fred Ozenna	USFWS walrus harvest rep. 1981
	8 Jun - 3 Dec	present		Lensink 1961
Wales to Shishmaref	Oct 75	few present	aerial survey	G. Ray
Ikpek to Cape Espenberg	breakup and throughout summer	common	once seen commonly in this area	Shishmaref residents through G. Seaman
Lopp and Arctic lagoons	late Jun, Jul early 1900's	present	seen by reindeer herders of Wales and Shishmaref; some years a few, others there were several hundred; would remain for several weeks if undisturbed	"
Shishmaref, 15-20 mi W and S of	5 Mar 76	30-35	apparently trapped on ice; hunted	Shishmaref hunters through G. Seaman
Shishmaref, 4 mi W near shore	4 Jun 79	20 +	1 gray, 1 part gray	C. Weyiouanna through R. Tremaine
Shishmaref Inlet	Jul	present	occasionally entered during periods of high water	Shishmaref residents through G. Seaman
Shishmaref, along coast	Jul-freeze-up	present	sometimes caught in nets set in drifting ice near village at freeze-up; not often sighted near Shishmaref in recent years	"
Shishmaref	early Oct	present	used to go in west channel; sometimes tangled in seal nets in early Oct	C. Weyiouanna
HARBOR PORPOISE				
Chukchi Sea	summer	present	probably present in low numbers every summer based on personal observations and Eskimo residents	Burns and Morrow 1975

Table 3., continued

Location	Date	Number	Comments	Source
KILLER WHALE				
Chukchi Sea	summer	present	probably present every summer in low numbers; occasionally in the coastal zone	coastal residents through J. Burns
Shishmaref Inlet	summer, 1970's	1	reliable source	Shishmaref residents through G. Seaman
Shishmaref	summers	present	residents see every summer	"
Ikpek to Cape Espenberg	29 Jul 80	1	dead on beach	D. Stewart through J. Burns
GRAY WHALE				
Wales	May-Jul 78, 79	present	many moving northward close to shore in May Jun, fewer in Jul	S. Hills
Cape Prince of Wales	10 Jun 81	1	swimming, leaving mud trail	K. Frost
	1 Jul 77	30-50	appeared to be feeding	"
Cape Prince of Wales to Icy Cape	Jul 58	"many"	feeding 8-15 mi from shore; seen from tugboat <u>Neptune</u>	Pike 1962
Cape Prince of Wales, N of	Aug 58	1	feeding in 5 fathoms of water; mud trail seen from tugboat <u>Neptune</u>	"
	24 Aug 59	20	moving S, scattered	Wilke and Fiscus 1961

Table 4. Sightings of coastal marine mammals in Kotzebue Sound, Hope Basin, region HB 2.

Location	Date	Number	Comments	Source
SPOTTED SEAL				
Chamisso Is.	late summer/ autumn	present	haulout	USFWS 1969
	12 Aug 77	20	hauled out on rocks between Chamisso and Puffin islands	USFWS/SBCS Rep., A. Degange/A. Sowls
	Sep to freeze-up	present	hunted regularly by local people; eating flatfishes	J. Burns
	20 Sep 81	4	hauled out on small rock off NE end of Chamisso Is.	L. Lowry
Eschscholtz Bay	late summer-autumn	many	present all over bay, particularly E end in mouth of Buckland River; occasionally haul out on tip of Elephant Pt.	Buckland residents through G. Seaman
Buckland R., mouth of, Igloo Pt. to first main upstream island	Sep - Oct	many	in the mouth of the river	"
Hotham Inlet	summer-autumn	very common	probably as abundant as in Eschscholtz Bay	Kotzebue residents through G. Seaman
Selawik Lake	summer-autumn	present		"
Noatak Delta islands	ice-free months	present	occasionally haul out	Foote and Williamson 1966
BELUKHA WHALE				
Deering	summer	uncommon	whales prefer northern and eastern Kotzebue Sound	Deering residents through G. Seaman
Eschscholtz Bay, NW end of bay	8 Jun 79	200 +	moving into bay, in channel	NANA pilot and N. Lee through G. Seaman
Chamisso Is., S of	11 Jun 78	20-25	in open water; 1st confirmed sighting of year	Kotzebue hunter through G. Seaman
Elephant Pt., 3 mi W of	12 Jun 78	50-150	nearshore, W of 1st point from Elephant Pt.	Deering hunters through G. Seaman
Eschscholtz Bay	12 Jun 79	100's (300+)	moving into bay through deep channel on high tide; 1st day of hunting	hunters through G. Seaman
Eschscholtz Bay, along NE shore	13 Jun 78	500-700 +	spread along deep channel; hunted	"
Eschscholtz Bay	14 Jun 78	many	most coming into bay; hunted	"

Table 4., continued

Location	Date	Number	Comments	Source
BELUKHA WHALE, cont.				
Eschscholtz Bay, by Gallahan on N side of bay	15-16 Jun 79	low 100's (200 +)		belukha hunters through G. Seaman
Eschscholtz Bay	15-18 Jun 80	many	hunted	K. Frost
	15-16 Jun 81	present	hunted	J. Burns
Eschscholtz Bay, W end	16 Jun 78	100-150 seen, more present	hunted	hunters through G. Seaman
Eschscholtz Bay	17, 18 Jun 78	present	hunted	G. Seaman
Spafarief Bay	18 Jun 79	30-40	hunted; ice not far offshore	Deering hunter through G. Seaman
Chamisso Is., N and W of	19 Jun 79	300-600		Munz Airlines pilot and NANA pilot through G. Seaman
Eschscholtz Bay, near mouth	19 Jun 78	50-100 +		belukha hunters through G. Seaman
Eschscholtz Bay	19 Jun 81	few		J. Burns
Eschscholtz Bay, central	20 Jun 78	50-75		hunters through G. Seaman
Eschscholtz Bay, NE corner	21 Jun 82	100 +	seen at night	A. Fields through J. Burns
Chamisso Is.	21 Jun 79	about 100	moving into bay	hunters through G. Seaman
Eschscholtz Bay	22 Jun 82	present	1st hunt of the year	J. Burns
	23 Jun 80	800 +		Elephant Pt. hunters through J. Burns
Chamisso Is., N of	Jul 60	900-1,200	moving N along Choris and Baldwin Peninsula	J. Burns
Buckland R., N of mouth of	4 Jul 78	several hundred	along shore	L. Thomas
Eschscholtz Bay, along NW shore	8 or 9 Jul 78	900-1,000	appeared to be milling; new calves present; seen from air	N. Lee
Kotzebue Sound and Hotham Inlet	spring-summer	present - "large numbers"	". . . feed in the shallow, warm waters near the river deltas."	Foote and Williamson 1966
Kotzebue Sound	31 May - 23 Oct	present		Lensink 1961
	summer	present	very abundant at times	Nelson 1887

Table 4., continued

Location	Date	Number	Comments	Source
BELUKHA WHALE, cont.				
Kotzebue Sound, near Baldwin Peninsula	Jun or Jul 77	present	calving	D. Krammer through G. Seaman
Kotzebue, S of near Cape Blossom	1 or 2 Jun 79	30 +		Kotzebue pilot through G. Seaman
Kotzebue, 10+ mi S of, near Riley wreck	6 Jun 79	80-100	appeared to be following channel; in open water; ice 5-6 mi to S	G. Barr
Choris Peninsula, N of	12 Jun 81	2		Kotzebue hunters through J. Burns
Choris Peninsula, off of	Jun 73	1,000 +	covered area 1/2 mi by 5 mi	J. Jacobson through J. Burns
Kotzebue area	13 Jun 80	lots		hunters through K. Frost
Kotzebue, 10+ mi S of, near Riley wreck	13 Jun 81	1,000 +		pilot through J. Burns
Kotzebue Sound, along Baldwin Peninsula	13 or 14 Jun 79	200-300 +	aerial observation; 5 mi N of channel between Chamisso Is. and peninsula	Kotzebue pilot with Sheldon's through G. Seaman
Kotzebue Sound, Baldwin Peninsula, W of	14 Jun 81	200-300 +		Kotzebue pilot with Sheldon's through J. Burns
Kotzebue Sound, SE	15 Jun 81	± 100		Ljungblad et al. 1982
Kotzebue, 10+ mi S of, near Riley wreck	16 Jun 81	± 50	aerial observation	J. Walker to J. Burns
Kotzebue Sound, Cape Blossom	16 Jun 81	± 60	aerial observation	K. Persons
Kotzebue Sound, Baldwin Peninsula, S coast	20 Jul 77	66	headed WNW	ADF&G herring survey
Kotzebue to Cape Krusenstern	16 Jun 81	± 40		Ljungblad et al. 1982
Kotzebue Sound, Hotham Inlet	late Jun and Jul	a few small groups	may be present but usually scared away by boat traffic	Kotzebue residents through G. Seaman
Sheshalik	summers until 1965	present	commercial salmon fishery developed in 1965, not as abundant now	Seaman and Burns 1981
Sheshalik to Cape Krusenstern	7 Jun 82, late that week	large numbers	moved into shore between Sheshalik and Cape Krusenstern, then moved SE toward Kotzebue Sound; locals say belukhas move clockwise into Kotzebue Sound	W. Goodwin through J. Burns

Table 4., continued

Location	Date	Number	Comments	Source
BELUKHA WHALE, cont.				
Sheshalik area	15-25 Jun 79	groups of 10's to 75-100		Sheshalik/Kotzebue people through G. Seaman
Sheshalik	21 Jun 82	present	as of this date, ± 20 whales had been netted	local hunters through J. Burns
HARBOR PORPOISE				
Kotzebue Sound, W of Cape Blossom	summer	present	source described porpoise fitting description of harbor porpoise	Y. Wilson through G. Seaman
Kotzebue Sound	summer	present	sometimes caught in salmon nets	Kotzebue residents through J. Burns
KILLER WHALE				
Eschscholtz Bay	late Jun 79	3 or 4	chasing either gray or minke whale	G. Seaman
	summer	present	occur regularly in summer; sometimes there when belukhas are there	Buckland residents through G. Seaman
Buckland R. mouth	summer, late 70's	1	good source	Buckland resident through G. Seaman
MINKE WHALE				
Kotzebue Sound	summer	present		Y. Wilson through G. Seaman
Eschscholtz Bay	autumn 78 or 79	2	beached in mouth of Buckland River; Seaman has one of skulls	G. Seaman
GRAY WHALE				
Kotzebue Sound, W of Baldwin Peninsula	summers	present		Kotzebue Sound residents through G. Seaman
off Kotzebue Sound	Jul 58	present	feeding	Pike 1962

Table 4., continued

Location	Date	Number	Comments	Source
GRAY WHALE, cont.				
Kotzebue Sound	10-20 Aug 59	200 +	feeding	Wilke and Fiscus 1961
Sheshalik	early Jul 80	1	18- or 19-ft gray whale killed by hunters	P. Merrit through J. Burns

Table 5. Sightings of coastal marine mammals from Cape Krusenstern to Cape Lisburne, Hope Basin, region HB 3.

Location	Date	Number	Comments	Source
SPOTTED SEAL				
Pt. Hope	summers	few	hunted; in estuaries in area	Johnson et al. 1966
Pt. Hope area	Jun-Jul 59	present	migrating by; hunted	Foote 1960
Kukpuk R. delta	Sep-Nov 59	numerous	congregate in river to feed on fish; hunted by local residents	"
Kukpuk R., Marryat Inlet	late summer-autumn	numerous	found up to 20 mi up the Kukpuk R. feeding on smelt, herring, salmon	North Slope Planning Document
Kukpuk R.	late Oct	many	concentrated near river outlet; no indication that they haul out	Johnson et al. 1966
Kivalik channel	Nov 59	present	about 10 taken with ringed seals; unusually large numbers of seals; many arctic cod in area	Saario and Kessel 1966
WALRUS				
Kivalina, 2.5 mi SE	31 Oct 59	1	sleeping on beach; killed	Saario and Kessel 1966
Cape Thompson	summer 1930's, 1940's	occasionally large numbers	not known to haul out there in recent years; photo of haulout from 40's	F. Fay
Pt. Hope	summer-autumn	present	infrequently haul out at tip of Pt. Hope spit and along sandy beaches of barrier islands at N end of Marryat Inlet	North Slope Planning Document
	7 Sep 59	1	on beach; killed	Foote 1960
Pt. Hope	winter	few	solitary animals occasionally overwinter near Pt. Hope	J. Burns
Cape Lewis	11 Aug 80	1	bull; hauled out	B. Kelly
	14 Aug 80	4	bulls; hauled out	"
BELUKHA WHALE				
Kivalina	Mar-Apr	present	move N in leads in ice	Saario and Kessel 1966
	25 May 79	12-13	in heavy ice	local pilot through G. Seaman

Table 5., continued

Location	Date	Number	Comments	Source
BELUKHA WHALE, cont.				
Kivalina area	May and Jun	numerous sightings	belukhas pass by in groups of variable size	Kivalina people through G. Seaman
Kivalina, near shore	21 Jun 79	many (200-300)	nearshore	"
Kivalina, off the shore of	24 Jun 79	200-300 +	near village; moving NW along coast	"
Kivalina, 14 mi S of	29 Jun 82	1	moving NW toward Pt. Hope	residents through J. Burns
Kivalina area	early Jul 60	present	moving NW along coast	Saario and Kessel 1966
Kivalina	1st 3 weeks of Sep	common	usually swimming toward Pt. Hope; rarely seen after that time	Kivalina residents through G. Seaman
Kotzebue Sound to Pt. Hope	mid-Aug 1881	abundant	close to shore; Eskimos said they were there every year	Nelson 1887
Cape Seppings	20 Jul 80	1	aerial survey for bowheads	Hobbs and Goebel 1982
Cape Thompson	mid-Jul 77	30-40	< 100 m from shore; swimming parallel to shore toward Pt. Hope	E. Murphy through J. Burns
Pt. Hope	late 1800's, early 1900's	present		Bee and Hall 1956
Pt. Hope, S of	Jan-Feb	rare	present following strong N winds which open up ice	Pt. Hope hunters through G. Seaman
Pt. Hope, lead SE of	21 Mar 76	200	moving N; earliest recent sighting; 2 "waves"	Pt. Hope people through G. Seaman
Pt. Hope	late Mar 78	> 100	passing through leads in ice	residents through G. Seaman
	early Apr 79	several hundred	passing by through lead in ice	J. Oktollik through P. Field
	week of 8 Apr 79	present	hunted; 2 taken	H. Melchior
	11 Apr-late Jul 60	present	1st of year on 11 Apr; continued to pass by through Jul	Foote 1960
	21-27 Apr 77	present	hunted	G. Seaman
	24 Apr 81	present		Ljungblad et al. 1982
	25 Apr - 9 May 78	present	1st of the year seen on 25 Apr; 10 taken; more taken 27 Apr; seen also on the 28th; still being seen 9 May	G. Seaman

Table 5., continued

Location	Date	Number	Comments	Source
BELUKHA WHALE, cont.				
Pt. Hope to Barrow	28 Apr-22 May 76	present	at least 2 "waves;" most sightings from Wainwright to Barrow	**Marquette 1977; Braham, Krogman and Carroll 1984.**
Pt. Hope	30 Apr - 16 May	present	seen	Fiscus and Marquette 1975
Pt. Hope, 15 mi SE	May 76	several groups of 8-15	swimming S along shore ice toward Kotzebue Sound	Pt. Hope residents through G. Seaman
Pt. Hope	2 May - 12 May	present	main concentrations	Fiscus and Marquette 1975
	1 May 79	10	moving N in lead in ice	P. Field
	2 May 79	15	"	"
	3 May 79	30	"	"
	4 May 79	30	"	"
	5 May 79	60	"	"
	6 May 79	1500 +	"	"
	7 May 79	some	"	"
	8 May 79	50	"	"
	9 May 78	present		"
	19 May 80	± 1000	1st verified major movement of year by Pt. Hope	D. Smullen
Pt. Hope, S shore	late Jun 79	75 + 100	moving N	D. Frankson
Pt. Hope	20 Jul 1887	present	females with calves plus 2 or 3 males near each female; swimming up and down the shore	Nelson 1887
	Sep-Oct	present	moving S along shore	Pt. Hope seal hunters through G. Seaman
HARBOR PORPOISE				
off Cape Thompson	18 Sep 81	2	boat observation; water depth 5 m	L. Lowry
off Cape Dyer	18 Sep 81	3	boat observation; water depth 25 m	"

Table 5., continued

Location	Date	Number	Comments	Source
KILLER WHALE				
Kivalina	summer	present	regularly seen; when present, they drive belukhas in close to shore, making them easy to hunt	Y. Wilson through G. Seaman
	summer - date unknown	1	male; chased pod of belukhas close to shore; captured and killed adult (white) whale; story related in Jun 1980	Kotzebue hunter through J. Burns
Pt. Hope area	summer	present	at least 2 known recent instances of killer whales killing gray whales; long history (20-30 yr ago and more) of killer whales beaching gray whales N of the point	village residents through G. Seaman
GRAY WHALE				
Kivalina to Cape Thompson	8 Jul 81	present	very near shore	Ljungblad et al. 1982
Kivalina, S of	25 Jul 81	present		"
Cape Thompson	summer	1	within 50 ft of beach	D. Craighead
	1st half of Jul each yr	present	moving northward; from residents through F. Fay	Pike 1962
Ogotoruk Cr. mouth, 0.8 km S of (Cape Thompson vicinity)	9 Aug 76	3	rolling, blowing, diving, heads out of water; then moved N up coast; within 100 m of shore	Springer and Roseneau 1977
Cape Thompson	10 Aug 76	5	2 moving rapidly N about 100-200 m offshore; 3 within 50 m of beach, rolling, sounding, extending heads out of water, "wallowing"	"
Crowbill Pt.	13 Aug 76	1 +		USFWS/SBCS Rep., A. Springer/ D. Roseneau
Cape Thompson, 5.6 km S of	20 Aug 76	1	"playing" at surf line within 100 m of beach	Springer and Roseneau 1977
Cape Thompson, 7.2 km N of (N end Akoviknak Lagoon)	20 Aug 76	1	traveling steadily northward within 50 m of shore	"

Table 5., continued

Location	Date	Number	Comments	Source
GRAY WHALE, cont.				
Pt. Hope, N of	20 Jul 80	2	within 2 km of beach; feeding and social behavior	Ljungblad 1981
Pt. Hope to Cape Lisburne	20 Jul 80	3	aerial survey for bowheads	Hobbs and Goebel 1982
Pt. Hope	8 Jul 81	present	feeding; 3 cow/calf pairs	Ljungblad et al. 1982
	summer	present		Durham 1979
	25 Jul 81	present		Ljungblad et al. 1982
Pt. Hope to Cape Lisburne	summer-autumn	present		Marquette and Braham 1982
Pt. Hope, W of, to Cape Lisburne	Aug 82	11	one 10 mi W Cape Lisburne; two 10-15 mi SSW Pt. Hope; eight about 20 mi W Kivalina	Fay and Kelly 1982

in late August, making this the largest known hauling area in Hope Basin. In late September 1981, at least 400 seals were present in that area, all of which were seen in the water.

Spotted seals are present throughout Kotzebue Sound, but there are no major haulouts comparable to that at Cape Espenberg. Seals haul out on the rocks near Chamisso Island in late summer and autumn. Many are present in late summer and autumn in Eschscholtz Bay, particularly at the mouth of the Buckland River. They occasionally haul out on the tip of Elephant Point. These seals are also present in Hotham Inlet, sometimes in Selawik Lake, and around the islands of the Noatak River delta, where they occasionally haul out. They do not, however, haul out there in large numbers on a regular basis due to intense human activity along the north coast of Kotzebue Sound.

Spotted seals are present but not particularly abundant in summer along the coast from Cape Krusenstern to Cape Thompson and Point Hope. However, in autumn they are quite numerous in the Kukpuk River estuary (near Point Hope) and up to 30 km upriver, where they congregate to feed on locally abundant fishes such as salmon (Oncorhynchus spp.) and smelt (Osmerus mordax). In November 1959, there was reported to be an unusually large number of seals in Kivalik channel and also many arctic cod (Boreogadus saida) in the area. There is no indication that seals haul out near Point Hope, probably due to human activity there.

Walrus

There are no major hauling areas for walruses in Hope Basin. In the 1930's and 1940's, large numbers occasionally hauled out at Cape Thompson; however, none have been known to haul out there in recent years. Single animals or small groups are occasionally seen on the beach from Cape Krusenstern to Cape Lewis. Walruses infrequently haul out on the tip of Point Hope spit and on the barrier islands at the north end of Marryat Inlet.

Belukha Whale

Belukhas are seen migrating along the coast of the Seward Peninsula through leads in the ice from late March until June but apparently no longer frequent that area during the summer. According to long-time residents of Shishmaref, these whales were once commonly seen from breakup through summer all along the coast. In some years up to several hundred might be present in Arctic or Lopp Lagoon, where they would remain for several weeks if undisturbed. They also occasionally entered Shishmaref Inlet. Near Shishmaref, belukhas were sometimes caught in nets set in drifting ice in early October. Residents report that belukhas have not often been sighted near Shishmaref in recent years.

Belukhas are very common in Kotzebue Sound during summer, generally first arriving in early June. The largest sightings have been made in and near Eschscholtz Bay. Over 1,000 whales were seen in June 1973; 900-1,000 on 8 or 9 July 1978; 500-700 on 13 June 1978; 800+ on 23 June 1980; and over 1,000 on 13 June 1981. Sightings of groups of several hundred whales are common. Belukhas are reported to move into Eschscholtz Bay on rising tides and leave on falling tides. They are commonly seen along the western shore of the Baldwin Peninsula and in northern Kotzebue Sound in the Sheshalik area, where sightings of groups of 75-100 whales are not uncommon.

Northward migrating belukhas are seen swimming through leads in the ice along the coast from Cape Krusenstern to Point Hope (primarily near Point Hope) during late March through June or early July. Near Kivalina in June 1979 200-300 whales were seen moving northwest along the coast. Belukhas are also reported to be common near Kivalina during the first 3 weeks of September but rare after then. At Point Hope most sightings are in April and May of whales on their way to the Mackenzie River estuary. Some sightings have been made in June and July. In September and October, belukhas are seen moving south along the shore near Point Hope.

Harbor Porpoise

Reports by residents of villages along the Chukchi coast suggest that harbor porpoises are probably present in low numbers every summer. Harbor porpoises are reported by residents of Kotzebue Sound to be present there in summer. They are occasionally caught in salmon nets.

Harbor porpoises probably occur all along the coast from Cape Krusenstern to Cape Lisburne. Two sightings were made on 18 September 1981: two individuals were seen in 5-m water depth off Cape Thompson, and three were seen in 25 m of water off Cape Dyer.

Killer Whale

Killer whales are present in the Chukchi Sea in low numbers every year. Residents of Shishmaref report seeing them every summer. During the mid-1970's, one killer whale entered and was seen inside Shishmaref Inlet. A dead one washed up on the beach between Ikpek and Cape Espenberg in July 1980.

In late June 1979, three or four killer whales were seen chasing a gray or minke whale in Eschscholtz Bay. In the late 1970's, a single animal was seen in the mouth of the Buckland River. Older residents report that killer whales occur quite reqularly outside the entrance to Eschscholtz Bay. They sometimes co-occur with belukhas, scaring them into the Bay and preventing them from coming back out.

At Kivalina, residents also report that killer whales are regularly seen, sometimes chasing belukhas in close to shore and killing them. At Point Hope there is a long history of killer whales killing or beaching gray whales north of the Point.

Minke Whale

We located only two sightings of minke whales in Hope Basin. In autumn 1978 or 1979, two of these whales beached themselves in the mouth of the Buckland River. A resident of the Kotzebue area reported that whales fitting the description of minke whales are sometimes present in summer in Kotzebue Sound.

Gray Whale

Gray whales have been seen moving north by Cape Prince of Wales in May through early July. They were seen feeding in that area in June through August.

Gray whales have been seen in Kotzebue Sound, sometimes in substantial numbers. In August 1959 over 200 were reported to be feeding there. They are more regularly seen and reported along the coast from Kivalina to Cape Lisburne, where sightings of small groups including cows with calves have been made in July and August. Animals were often sighted within 100-200 m of shore and were sometimes engaged in feeding or social behavior.

B. Barrow Arch (Figure 3; Tables 6-7)

Spotted Seal

Spotted seals are present in the water near Cape Lisburne in summer and autumn but do not haul out there due to unsuitable terrain. They are extremely abundant to the north in Kasegaluk Lagoon, where they are ubiquitous from the south end of the lagoon to the north end. They become common there in mid- to late July and remain so through September. On 18 September 1974, there were an estimated 2,500-3,000 seals in the lagoon. The two major haulout areas in the lagoon are on the sandbars just east of Utukok Pass and on the sandbars and spits on either side of Akoliakatat Pass. Sightings at Utukok Pass include 700-900 seals on 10 July 1978; 400-500 on 19 and 20 July 1979; 1,000 on 15 August 1981; and 300 on 17 September 1981. At Akoliakatat Pass, the largest sighting was of approximately 1,000 seals on 15 August 1981. Other haulout areas include Kukpowruk Pass, the entrance to Avak Inlet, and several spits 5-10 km up Avak Inlet. Spotted seals are often present but do not haul out in the lagoon and mouth of the Kokolik River near Point Lay, where they feed on salmon, smelt, and other fishes.

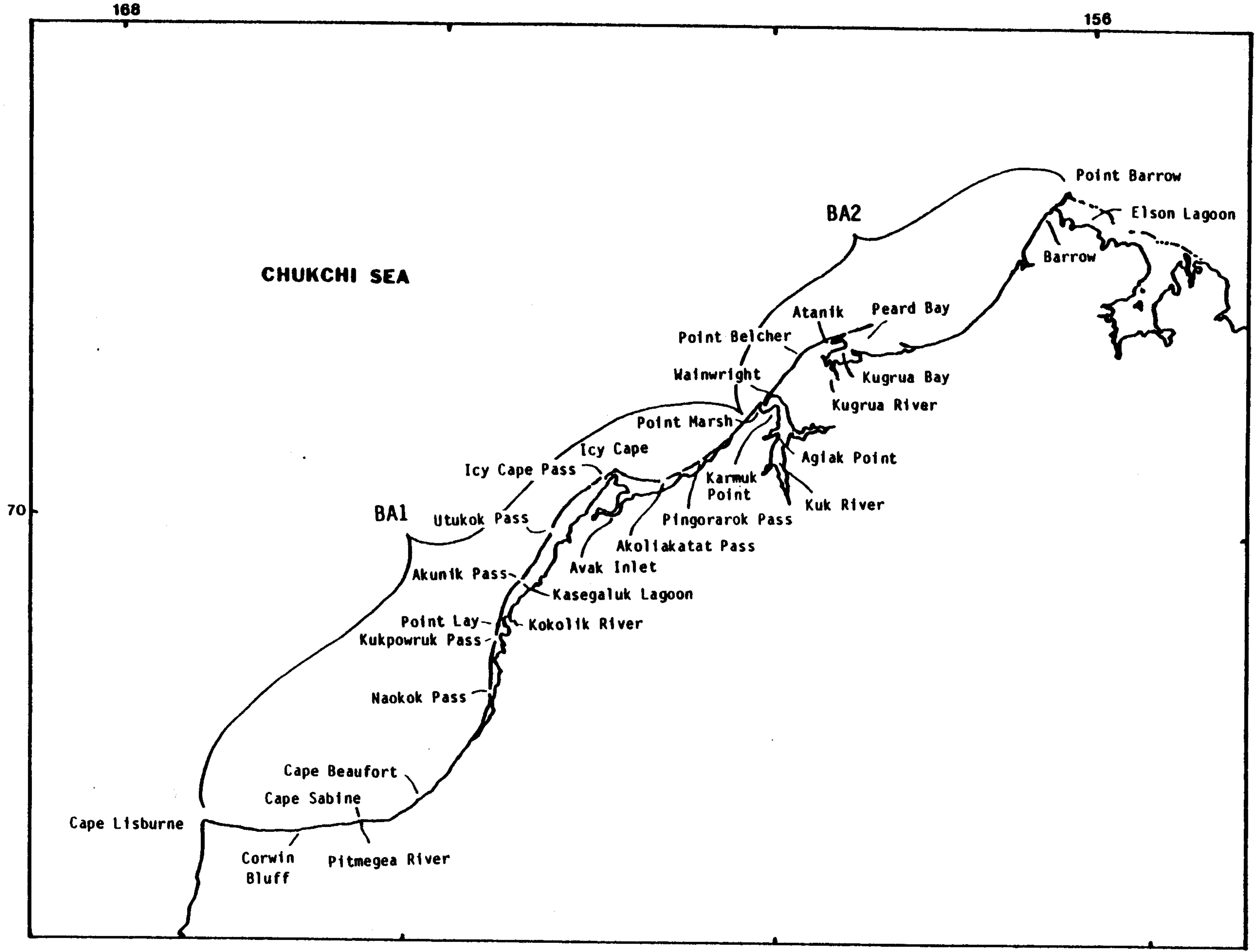

Figure 3. Map of the Barrow Arch, regions BA 1 and BA 2.

Table 6. Sightings of coastal marine mammals from Cape Lisburne to Wainwright, Barrow Arch, region BA 1.

Location	Date	Number	Comments	Source
SPOTTED SEAL				
Cape Lisburne	summer	present	in water, but this is not a good hauling area	J. Burns
	14 Aug 80	4-10	in water about 1/4 mi offshore of Ayugatak Lagoon	B. Kelly
Cape Lisburne area	19 Aug 80	numerous		"
Kasegaluk Lagoon	summer-autumn 70's	numerous	1st became common in mid- to late Jul; moving N at this time	G. Seaman
Kasegaluk Lagoon, near Pt. Lay	Jul 78, 79	small number	mostly moving N along outside of islands; some haul out occasionally on N side of Kukpowruk Pass	"
	8 Jul 78	± 50	in lagoon	D. Strickland
	18 Sep 74	2500-3000 est.	aerial survey; single group of 500-700; ubiquitous from N end to S end of of lagoon; haulouts were on insides of islands near entrances	J. Burns
Kukpowruk Pass	summer 78	small numbers	occasionally haul out	G. Seaman
Pt. Lay, Kokolik R.	summer-autumn	present	feed in river mouth on salmon, smelt, etc.	North Slope Planning Document
Utukok Pass, sandbar just E of the pass	10 Jul 78	700-900 est.	hauled out; "probably most predictable haulout area in Kasegaluk Lagoon area . . . hot spot all years there. . . ."	G. Seaman
	19 & 20 Jul 79	400-500 each day	"	"
Utukok Pass	15 Aug 81	1000	2 haulout sites--1 N side of pass, 1 on inside of island; many in water in pass and lagoon	R. Nelson
	17 Sep 81	300	some (about 60) had been hauled out at the N side of the pass--many moving into lagoon; 5 collected, stomachs empty	L. Lowry
Icy Cape lagoons	summers	present		Bailey and Hendee 1926

Table 6., continued

Location	Date	Number	Comments	Source
SPOTTED SEAL, cont.				
Icy Cape	summer 80	21 sightings, both individuals & loose groups of up to 10 animals	most often seen in the lagoon or near a pass between the lagoon and sea; none seen on land but Natives said they haul out at Akoliakatat Pass and along the spit at the mouth of Avak Inlet.	Lehnhausen and Quinlan 1981
Icy Cape Pass	15 Aug 81	many	in water	R. Nelson
Avak Inlet, W side	Jul 78 & 79	± 50 to 75	haulout area of secondary importance	G. Seaman
Avak Inlet, W side and middle inlet	Jul 78 & 79	< 50 average	"	"
Akoliakatat Pass, W side	10 Jul 78	100 +	primary haulout area	"
	19 Jul 79	40-50	"	"
Akoliakatat Pass, E of	15 Aug 81	1000	± 100 hauled out, rest in water	R. Nelson
Akoliakatat Pass	16 Sep 81	200	hauled out and in water; some had been hauled out on small spit about 2 mi E of the pass on the lagoon side of barrier island	L. Lowry
WALRUS				
Cape Lisburne	summer	present	historically hauled out E of the cape prior to construction of DEW-line station	North Slope Planning Document
	summer 79	300 +	most bulls, some cows and calves; hauled out; on 10-15 Aug they moved 27 mi E to Corwin Bluff	A. Springer
	Jul 38	"hundreds"		G. Collins through F. Fay
	22 Jul - 22 Aug 78	± 200	hauled out; probably there for the previous week also; approximately 75% bulls, rest cows with older calves	A. Springer
	Aug 42	present	"small herd most every summer"	G. Wilson through F. Fay

Table 6., continued

Location	Date	Number	Comments	Source
WALRUS, cont.				
Cape Lisburne, cont.	11 Aug 80	6	hauled out; 3 bulls, 2 immatures, 1 adult of unknown sex	B. Kelly
	18 Aug 80	2	1 bull, 1 immature	"
	24 Aug 80	4	bulls; hauled out; 4 others offshore	"
	26 Aug 80	7	in water	"
	28 Aug 80	30-40	hauled out; mostly bulls with a few immatures	"
Cape Lisburne, about 10 miles S	25 Aug - 3 Sep 76	4	old cow, immature and 1 cow, 1 bull; old cow was probably 1st seen at site that year	A. Springer
Cape Lisburne	approx. 10 Aug 77	± 25	hauled out; did not arrive before 10 Aug; remained until early Sep	"
	8 Sep 75	30	in water immediately offshore; aerial survey	J. Burns
Cape Lisburne, S of	21 Sep 78	100	aerial survey for waterfowl	R. King
Cape Lisburne	last week Oct 78	± 500	hauled out	R. Pegau, from Cape Lisburne personnel
Kukpowruk Pass, S of	Jun or Jul, late 70's	1	hauled out; another sighting several days later of 1 walrus in same area but on lagoon side of the island	G. Seaman
Icy Cape	spring and autumn	present	infrequently haul out on seaward beaches of barrier islands near Icy Cape during spring and autumn migrations	North Slope Planning Document
off Icy Cape	10 Jun 81	500-1000	some (100+) in water; most hauled out on ice	K. Frost
Icy Cape to Barrow	Jul - Sep	present	on ice, several thousand	Fay 1982
Icy Cape	23 Aug 80	present	small animal in water; small number seen going by on ice earlier in season but no date	Lehnhausen and Quinlan 1981

Table 6., continued

Location	Date	Number	Comments	Source
BELUKHA WHALE				
Cape Lisburne, N of	10 Jun 81	± 15	swimming NE about 1/4 mi off edge of ice	K. Frost
Cape Sabine, mouth of Pitmegea River	24 Jun 58	50 +		Childs 1969
Cape Sabine to Cape Beaufort	3 Jul 82	2000-2500 +	swimming N parallel to shore; extended 20 miles along coast; lead group with 500 + whales, calves present	R. Quimby through J. Burns
Cape Sabine to Naokok Pass	6 Jul 82	500-1,000	close to shore; milling, diving, stirring up mud; survey did not extend N of Naokok Pass	T. Smith, J. Rudd through J. Burns
near Cape Sabine	8 Jul 81	1		G. Seaman
Cape Beaufort to Icy Cape	early 1800's	present		Bee and Hall 1956
Cape Beaufort, N of	May & Jun	present	in open water	Braham, Krogman and Carroll 1984.
Cape Beaufort	3 Jul 79	500 +	quite close to shore	E. Tounai
Naokok Pass, 2 mi S	9 Jul 79	400-500 +	heading N; many, many "as far as observers could see"	A. Agnassagga
Naokok Pass	2 Jul 78	100 +	among 1st of year; moving N close to shore	Pt. Lay people through G. Seaman
Kukpowruk Pass, ocean side	22 Jun 79	100 +	1st of year; hunted; very early breakup	Pt. Lay hunters through G. Seaman
Kukpowruk Pass	30 Jun 79	400-500	assembled in pass	Cape Smythe Air Service pilot through G. Seaman
	2 Jul 79	"many"	nearshore and in lagoon	W. Neakok
	3 Jul 78	40-50		G. Seaman
	10 Jul 78	1,000 +	moving S; about half of those seen were in or just outside pass, rest to S; those in mouth were floating or milling; 703 actually counted from aerial photographs	"
	12 Jul 79	250-300 +		C. Agnassagga

Table 6., continued

Location	Date	Number	Comments	Source
BELUKHA WHALE, cont.				
Kasegaluk Lagoon	late Jun or Jul until late Jul or mid-Aug	many	usually appear 1st at southern end of lagoon; depart to the N, occasionally following coast by Wainwright	Pt. Lay residents through G. Seaman
Pt. Lay, old town site	24 Jun 79	many groups for 3/4 to 1 hr	moving S	G. Agnassagga
	28 or 29 Jun 79	many groups - probably 100's +	heading N	"
	4-7 Jul 78	groups of 50's - 100's	moving both N and S; inside and outside lagoon	Pt. Lay people through G. Seaman
Pt. Lay, near old village site	5 Jul 81	> 100	moving S; "chased" by killer whales; very shallow water	villagers through G. Seaman
Pt. Lay, old town site	8 Jul 78	50-75	inside lagoon; moving N	G. Seaman
	8 Jul 78	some	Eskimos witnessed birth of calf; Seaman saw cow with newborn calf	"
	8 Jul 78	20 +	1 pod	"
	9 Jul 78	100-150	moving S, ocean side	"
	10 Jul 79	350 +	steady flow of whales nearshore for ± 5 hr	"
	13 Jul 79	100 +	heading N nearshore, 0200-0300	"
	15 Jul 79	3-5	pursued by killer whale	"
Pt. Lay to Icy Cape	16 May 81	present	aerial survey	Ljungblad et al. 1982
Akunik Pass (Kokolik Pass)	8 Jul 81	60-70 +	moving N, within 200 yd of shore	G. Seaman
Akunik Pass	9 Jul 79	300-500+	moving S; headed out to open water	B. Neakok
near Akunik Pass	10 Jul 78	2	cow with newborn calf in lagoon	G. Seaman
Utukok R., shallows of	general	present	frequently use shallows of Utukok R.	W. Bodfish
Utukok Pass, 3-4 mi N of	3 Jul 79	25 +	many with calves; at least 2 were newborns	G. Seaman

Table 6., continued

Location	Date	Number	Comments	Source
BELUKHA WHALE, cont.				
Utukok Pass	8 Jul 79	500 +	N side; in area 2 or 3 days	B. Neakok
Icy Cape to Barrow	22 May 80	± 60	aerial survey	Ljungblad 1981
Icy Cape, SW of, near pass	4 Jul 79	200 +		Cape Smythe pilot through G. Seaman
S Icy Cape	6 Jul 81	5 +	nearshore	G. Seaman
Icy Cape, N of	6 Jul 81	10 +	"	"
Icy Cape Pass	8 Jul 81	400-600 +	more than half with calves; most in ice-free muddy water	"
Icy Cape	11 Jul 80	28 counted; 50 est.	moving N just off barrier islands to 1/2 km offshore; several gray animals with group	Lehnhausen and Quinlan 1981
S Icy Cape Pass	11 Jul 81	35-45 +	up to 300 yd offshore	G. Seaman
Icy Cape Pass, S of	11 Jul 81	5 or 6		"
Akoliakatat Pass	13 Jul 79	1600-1700	whales present from 13-18 Jul; ice nearshore S of Wainwright; 1104 actually counted from aerial photographs; 80% of whales within 2 mi of the pass, rest spread out to the NE	"
	15 Jul 79	2300-2400	1601 actually counted from aerial photographs; very concentrated in or just outside of pass; smaller numbers distributed up the coast for about 10 mi	"
	15 Jul 81	75-100	feeding?--swimming around a small area; adults, immatures, and cows with calves present; shallow water	K. Frost
Pingorarok Pass	19 Jul 79	1000 +	moving N; one large group > 1 mi long	W. Negovanna through G. Seaman
KILLER WHALE				
Pt. Lay, old town site	5 Jul 81	present	chasing belukhas	villagers through G. Seaman

Table 6., continued

Location	Date	Number	Comments	Source
KILLER WHALE, cont.				
Pt. Lay, old town site, cont.	15 Jul 79	1	chasing 3-5 belukhas; killed belukha calf < 100 yd offshore	G. Seaman
N Utukok Pass	11 Jul 81	1	about 50 yd offshore	"
MINKE WHALE				
Cape Lisburne area	19 Aug 80	1	< 1 mi offshore; off Ayugatak Lagoon	B. Kelly
GRAY WHALE				
Cape Lisburne	8 Jul 81	present		Ljungblad et al. 1982
Cape Lisburne, S of	20 Jul 80	2	feeding and social behavior; within 12 km of beach	Ljungblad 1981
Cape Lisburne, E of	summer-autumn	present		Marquette and Braham 1982
Cape Lisburne	11 Aug 80	1	adult; swimming W in the surf zone	B. Kelly
Cape Lisburne to Cerush Bluff	19 Aug 80	many	close to shore (< 1 mi off); included cow with calf	"
Cape Sabine	3-5 Aug 59	"a few"	moving SW	Maher 1960
Cape Sabine, off mouth of Pitmegea River	5 Aug 59	10-12	feeding; 3 calves with females, plus 4-6 other adults; gone the following day	"
Cape Beaufort, NW of	Jul 79	4 +	offshore	G. Seaman
Naokok Pass, 5-7 mi N of	10 Jul 78	3	moving N along outside of islands; 100-150 yd from shore	"
near Pt. Lay	8 Jul 81	3	swimming N about 3 mi offshore; seen from shore	"
	11 Jul 81	1	about 3 mi out	"
Utukok Pass, S of	11 Jul 81	10	3/4-1 mi offshore; some 2 mi off	"
Utukok Pass, N of	22 Jul 81	3	about 3/4 mi off beach	R. Nelson
Icy Cape, S of	8 Jul 81	1		G. Seaman

Table 6., continued

Location	Date	Number	Comments	Source
GRAY WHALE, cont.				
near Icy Cape Pass	8 Jul 81	2	2 octas of ice	G. Seaman
Icy Cape	17 Jul - 4 Aug 80	several separate sightings	moving N	Lehnhausen and Quinlan 1981
	25 Jul 81	present		Ljungblad et al. 1982
	4-15 Aug 80	several - one group?	feeding, resting offshore near Cape Island	Lehnhausen and Quinlan 1981
	21 Aug 80	1	heading S; last one seen that summer	"
Icy Cape to Barrow	summer	common	seen nearshore by Eskimos	Maher 1960

Table 7. Sightings of coastal marine mammals from Wainwright to Barrow, Barrow Arch, region BA 2.

Location	Date	Number	Comments	Source
SPOTTED SEAL				
Kuk River area	summer-autumn	present	present all summer; enter river and haul out more in autumn	J. Burns
	summers	present	occasionally used haulouts at Pt. Marsh, Karmuk Pt., and S of Agiak Pt.	G. Seaman
Wainwright	15-21 Jul 67	none		C. Shanahan
	28 Jul 75	1 shot, 2 others seen	1st of season; drifting pack ice	J. Burns
	1 Aug 65	present	hunted	"
	4 & 11 Aug 75	present	"	"
	4, 7, & 16 Aug 64	present	"	"
	late summer-autumn	present	small numbers most years; 1st ones arrive mid-Aug	"
Kugrua R. area	summer	present	haul out on land	Wainwright villagers through J. Burns in 1964
Peard Bay, including Kugrua R.	summer	present	haul out but not as many as in Kasegaluk Lagoon	J. Burns
WALRUS				
Wainwright area	Jul 67	very few	bad hunting year	J. Burns
Wainwright	31 Jul 66	30		ADF&G, Nome files
Wainwright to Barrow	8 Jul 78	5000-10,000	on ice	T. Brower through D. Strickland
near Barrow	12 Mar 78	2		H. Melchior
Barrow	1st week of Aug 66	1		ADF&G, Nome files
BELUKHA WHALE				
Wainwright and Barrow	spring	common	1st ones seen in March, most in Apr and May on northward migration	Nelson 1969; ADF&G files
Wainwright	spring 52	2		Bee and Hall 1956

Table 7., continued

Location	Date	Number	Comments	Source
BELUKHA WHALE, cont.				
Wainwright, cont.	27 Apr - 19 May 78	large numbers	moved N through leads in ice	R. Tremaine
	9 May (1920's ?)	present	moving N; 1st ones seen that year	Bailey and Hendee 1926
Wainwright, 18 mi off	1 May 79	± 70	1 pod	J. Burns
Wainwright to Barrow	late May 76	many		Braham et al. 1980
Wainwright Inlet, mouth of Kuk River	summers "long ago"	moderate numbers	sometimes congregated at mouth of inlet and moved into Kuk River	Wainwright residents through G. Seaman
Wainwright	Jul	present	after ice had gone out; hunted	Van Valin 1941
	Jul & Aug	present	usually moving NE along coast; most common in these 2 months	Nelson 1969
	15 Jul 78	± 100	headed NE	D. Strickland
	17-18 Jul 79	pod	traveling NE along coast; hunted on 2 days; took 4 on the 17th, 34 the 18th	R. Tremaine and G. Seaman
Wainwright village	17 Jul 79	100's (probably about 200)	moving N	Wainwright people through G. Seaman
Wainwright village	19 Jul 79	200 +	early morning; moving N	Wainwright hunters through G. Seaman
Wainwright village and near Kuk R.	19 Jul 79	500 +	observed moving N, 2200-2300; probably same group seen at Pingorarok Pass	"
Wainwright village	20 Jul 79	100's (400-500 +)	passed by the coast for hours; moving N	R. Tremaine
Wainwright, NW of	20 Jul 80	2		Ljungblad 1981
Wainwright	Aug 75	many	aerial survey	G. Ray
	Sep	rare		Wainwright residents through G. Seaman
	3 Sep 75	numerous		Fiscus et al. 1976
Wainwright to Barrow	11-13 Sep 75	small groups		"
Pt. Franklin, N of	20 Jul 80	1	aerial survey for bowheads	Hobbs and Goebel 1982
Pt. Franklin	20 Jul 80	2		Ljungblad 1981

Table 7., continued

Location	Date	Number	Comments	Source
BELUKHA WHALE, cont.				
off Barrow	28 May 78	15	aerial survey for birds	R. King
	20 Jul 80	1	feeding in 5/10 ice coverage, less than 1 km off beach	Ljungblad 1981
Barrow	summer 1881-83	large groups	passed by as soon as there was open water off the beach and again 7-10 days later	Murdoch 1885
	every summer	once common	once commonly seen near village every summer before so much noise from boats and the town	Barrow residents through G. Seaman
	28 Sep 1881	100 +	within 20 yd of beach; Sep sightings uncommon	Murdoch 1885
Barrow	unspecified	present		Bee and Hall 1956
HARBOR PORPOISE				
Pt. Franklin, NW part Kugrua Lagoon	1 Aug 37	2	young (about 1-1/3 m long); chasing fish in shallow water 3 m from shore	Bee and Hall 1956
	1940 (sic)	2	1 large, 1 small; same part of lagoon as those seen in 1937	"
Wainwright, 11 mi NE	1 Sep 33	1	dead on beach	"
Wainwright	every year	present	seen every year at Pt. Barrow and Wainwright as long as Eskimos can recall, only 5 or 6 each season; from Pete Sovalik and Adam Levitt	"
Atanik	1 Sep 33	1	dead on beach	"
Barrow	every year	present	seen every year at Pt. Barrow and Wainwright as long as Eskimos can recall, only 5 or 6 each season; from Pete Sovalik and Adam Levitt	"
	"in last few years" (1952)	present	seen on several occasions by Pete Sovalik	"

Table 7., continued

Location	Date	Number	Comments	Source
HARBOR PORPOISE, cont.				
Barrow, cont.	summer 52	1		Bee and Hall 1956
Barrow, NW Elson Lagoon	6 Aug 52	1	adult female caught in gillnet	"
	23 Aug 52	1	recently born calf	"
KILLER WHALE				
Wainwright	summer	present	regularly seen; have been seen pursuing gray whales	village residents through G. Seaman
	13 Jul 78	some	breaching	village residents through D. Strickland
Barrow	summer	present	occasionally sighted	village residents through G. Seaman
	summer 78 or 79	several	seen from Borough building	J. Adams through H. Melchior
GRAY WHALE				
Wainwright	summer 1924	present	1 or 2	Bailey and Hendee 1926
	summer 1934	present	2 taken	Maher 1960
Wainwright, S of and NE of	summer	present		Marquette and Braham 1982
near Wainwright	10 Jun 81	10	swimming NE; no mud trails; several "groups;" in lead in ice	K. Frost
Wainwright	10 Jun 81	3	swimming NE in lead in ice	"
Wainwright, N of to S end of Peard Bay	10 Jun 81	15	close to shore	Ljungblad et al. 1982
Wainwright	5 Jul 54	many	heading N right after ice went out; 1/2-1 mi off beach	Maher 1960
Wainwright, just N of Kuk River	6 Jul 81	1		G. Seaman
Wainwright, SW of	20 Jul 80	1	aerial survey for bowheads	Hobbs and Goebel 1982
Wainwright	25 Jul 75	30-40	some drifting pack ice	J. Burns
	9-10 Aug 53	50-100	moving S; seen from beach	Maher 1960

Table 7., continued

Location	Date	Number	Comments	Source
GRAY WHALE, cont.				
Wainwright, cont.	9-15 Aug 54	1	killed	Maher 1960
	24 Aug 81	6		Ljungblad et al. 1982
Wainwright to Peard Bay	10 Jun 81	13		K. Frost
	20 Jul 80	4	aerial survey for bowheads	Hobbs and Goebel 1982
Wainwright and Barrow	late Jun - early Jul	present	1st arrive	Maher 1960
Wainwright to Pt. Barrow	18 Jul - 13 Sep 54-59	9	taken by residents	Maher 1960
Wainwright, ± 15 mi NE of	22 Jul 81	3	breaching and feeding; cow with calf and another, about 1/2 mi off beach	R. Nelson
Pt. Belcher	6 Jul 81	3	about 3/4 mi offshore; less than 1 octa ice	G. Seaman
Pt. Franklin	25 Jul 81	present		Ljungblad et al. 1982
Pt. Franklin to about 20 mi SW of Barrow	Jul 81	many	*Polar Star* cruise; "hot spot" for many things--many seals, walruses, heavy phytoplankton and zooplankton blooms	F. Fay
	Jul-Aug 82	300	*Entuziast* cruise, between shore and ice edge; "hot spot"	Fay and Kelly 1982
Barrow	summer	common	appear "settled"	Maher 1960
Pt. Barrow	summer	present	frequently seen	Durham 1979
	general	uncommon	reported by Pete Sovalik	Bee and Hall 1956
Barrow, SW of	20 Jul 80	1	aerial survey for bowheads	Hobbs and Goebel 1982
Pt. Barrow	Jul-Aug 78	16	in a 40-day period	Marquette and Braham 1982
	18, 19 Jul 59	3	hunted; calf and lactating female, plus calf	Maher 1960
	Aug 78 or 79	6 +	moving W	H. Melchior
	Aug - mid-Sep 1950's	present	may begin moving southward in early Aug	Maher 1960
	Aug 54	1	playing in surf	"
	10 Aug 54	2	calf associated with an adult	"

Table 7., continued

Location	Date	Number	Comments	Source
GRAY WHALE, cont.				
Pt. Barrow, cont.	mid-Sep 58	present	2 killed	Maher 1960
	mid-Sep 59	some	3 killed, including lactating cow with calf and another calf	"
Barrow, 20-30 mi SW of (71°08'N, 158°00'W)	12 Sep 81	20-25	feeding; kittiwakes active in area	L. Lowry
Pt. Barrow	Sep 78	2	very close to beach	Durham 1979
	late autumn 78	20	migrating westward; information from T. Brower	"

Spotted seals are less abundant to the north of Kasegaluk Lagoon. However, they are present during summer and autumn in and around the Kuk River near Wainwright and the Kugrua River in southern Peard Bay. As along the rest of the Bering and Chukchi sea coasts, they enter the rivers and haul out more often in autumn. In the Kuk River, occasionally used haulouts include Point Marsh, Karmuk Point, and south of Agiak Point. Seals also haul out near the mouth of the Kugrua River.

Walrus

There are no major terrestrial walrus haulouts along the coast of the Barrow Arch planning area, although many walruses are seen from June through September hauled out on the drifting offshore pack ice. Cape Lisburne was historically used as a haulout prior to construction of the DEW-line station there, with a sighting of "hundreds" in July 1938. Since 1975 some walruses have hauled out near Cape Lisburne every year, usually in August or September. The largest reported sightings were during summer 1978, when about 200 animals were hauled out in July and August, 100 in late September, and 500 during the last week in October. In other years, sightings did not exceed 30-40 animals. Lone walruses have occasionally been seen hauled out on the barrier islands of Kasegaluk Lagoon.

Belukha Whale

Belukhas are very abundant in the Kasegaluk Lagoon region of the Barrow Arch planning area. They are first seen south of the lagoon at Cape Sabine and Cape Beaufort and in the southernmost passes (Naokok Pass and Kukpowruk Pass) in late June or early July. They usually appear from north of Point Lay to Icy Cape in the first or second week of July and from Icy Cape to Wainwright slightly later, usually during the third week of July. The whales are frequently seen concentrated in or near the passes into the lagoons and sometimes in the deeper channels of the lagoons themselves. Calving has been observed on several occasions. The largest single sightings in the Kasegaluk Lagoon area were on 3 July 1982, when 2,000-2,500 belukhas were seen swimming north along the coast between Cape Sabine and Cape Beaufort, and on 15 July 1979, when over 2,000 belukhas were concentrated in or near Akoliakatat Pass. That group was reported to be present from 13 July until 18 July, when they moved north. A group of over 1,000 was seen at Pingorarok Pass on 19 July 1979, and on 19 and 20 July over 1,000 were seen moving north by Wainwright. Sightings of 300 or more whales have been made at all major passes in Kasegaluk Lagoon, including Naokok, Kukpowruk, Akunik, Utukok, Ice Cape, Akoliakatat, and Pingorarok passes. In the 3 years (1978, 1979, 1981) when aerial surveys were conducted, major sightings occurred from late June through the third week in July. In some years the whales are present in this region until mid-August. Near Wainwright, belukhas may be present in July and August and are considered rare in September. In 1978-1980, most sightings were in the third week of July. Few belukhas are seen during summer nearshore between Wainwright and Barrow.

Harbor Porpoise

We located no sightings of harbor porpoises along the coast from Cape Lisburne to Wainwright. However, they are reported to be present in small numbers every year at Wainwright and Barrow. In the 1930's, two were found dead on the beaches near Wainwright, and several were seen at the south end of Peard Bay in·Kugrua Lagoon. In summer 1952, one was reported off Barrow, and in August of the same year a cow and calf were caught in the northwestern portion of Elson Lagoon.

Killer Whale

Killer whales are probably present during most summers along this section of the coast. They were seen chasing belukhas very close to shore near Point Lay in July 1979 and 1981. On 11 July 1981, a single killer whale was seen within 50 m of the beach north of Utukok Pass. They are sighted regularly at Wainwright, where they have been seen in pursuit of gray whales, and occasionally at Barrow.

Minke Whale

We are aware of a single minke whale sighting in the Barrow Arch planning area. One whale was seen close to shore near Cape Lisburne on 19 August 1980.

Gray Whale

Gray whales are regularly seen all along the coast from Cape Lisburne to Barrow during summer. Most sightings are in July and August, although a few whales are seen in June and September. They are often seen within 1-2 km of the beach, sometimes feeding. In July most whales for which directional swimming is reported are moving northward, whereas in August they are moving southward. The largest reported sightings were of 50-100 whales seen off Wainwright on 9-10 August 1953 and of over 200 seen near Point Franklin in July and August 1982.

VII. Discussion

A. Spotted Seal

In late winter and spring, spotted seals are distributed in and near the ice front of the Bering Sea, where they have their pups, breed, and molt from March through May or June. As the ice disintegrates and recedes north in spring, these seals move generally northward and toward the coast, where they spend the ice-free months feeding mainly in nearshore waters and hauling out on land. Some remain in the Bering Sea throughout the summer (see Frost et al. 1982), while others move farther north to the Chukchi Sea (Fig. 4). Spotted seals remain in the coastal zone until late autumn when the shorefast ice begins to form.

Spotted seals are present in coastal areas of Hope Basin from the time the ice breaks up in spring until freeze-up. They are found along the entire northern coast of the Seward Peninsula and may be present in any of the bays, lagoons, or estuaries, including Lopp, Ikpek, and Arctic lagoons and Shishmaref Inlet. They haul out, particularly in autumn, on the low sandy beaches characteristic of this section of the coast, in areas that are relatively free from human activity. The largest haulout in Hope Basin is at Cape Espenberg, where over 1,000 seals have been seen hauled out in August. Although they do not haul out in large numbers elsewhere, they are abundant, particularly in late summer and autumn, in Eschscholtz Bay, particularly at the mouth of the Buckland River; in Hotham Inlet and at the mouth of the Noatak River; and in the Kukpuk River estuary. They congregate in these areas to feed on locally abundant fishes such as salmon, herring (Clupea harengus), smelt, or saffron cod (Eleginus gracilis).

Spotted seals are present along virtually the entire northern Chukchi coast but are most abundant in three areas: Kasegaluk Lagoon, the mouth of the Kuk River near Wainwright, and the mouth of the Kugrua River in southern Peard Bay. Over 2,000 seals seasonally utilize Kasegaluk Lagoon, with major haulouts near Utukok Pass and Akoliakatat Pass. Fewer seals are present in the Kuk and Kugrua rivers, but there are no estimates of actual numbers. As in other areas of the Bering and Chukchi seas, spotted seals congregate near rivers and haul out more in late summer and autumn.

B. Walrus

As the ice breaks up in spring, walruses leave their wintering grounds in the Bering Sea and move north to the Chukchi Sea, where most spend the summer feeding on the shallow Chukchi platform. Subadults and females with young summer primarily in the pack ice in the northern Chukchi Sea (Estes and Gilbert 1978), while adult males form large herds on hauling grounds in Bristol Bay, Bering Strait, and along the Chukchi Peninsula.

A substantial proportion of the walrus population is concentrated in the ice off the Alaskan coast from Icy Cape to Barrow from June or July through September (Krogman et al. 1979, Fay 1982). However, there are no large, regularly used haulouts along the Alaskan Chukchi coast. In the 1930's, walrus herds were present on hauling grounds at Cape Thompson, Cape Lisburne, and Icy Cape, but by the 1950's those haulouts were no longer used (Fay 1957). Since 1975 some walruses have again begun to haul out near Cape Lisburne every year (Fig. 5). Sightings

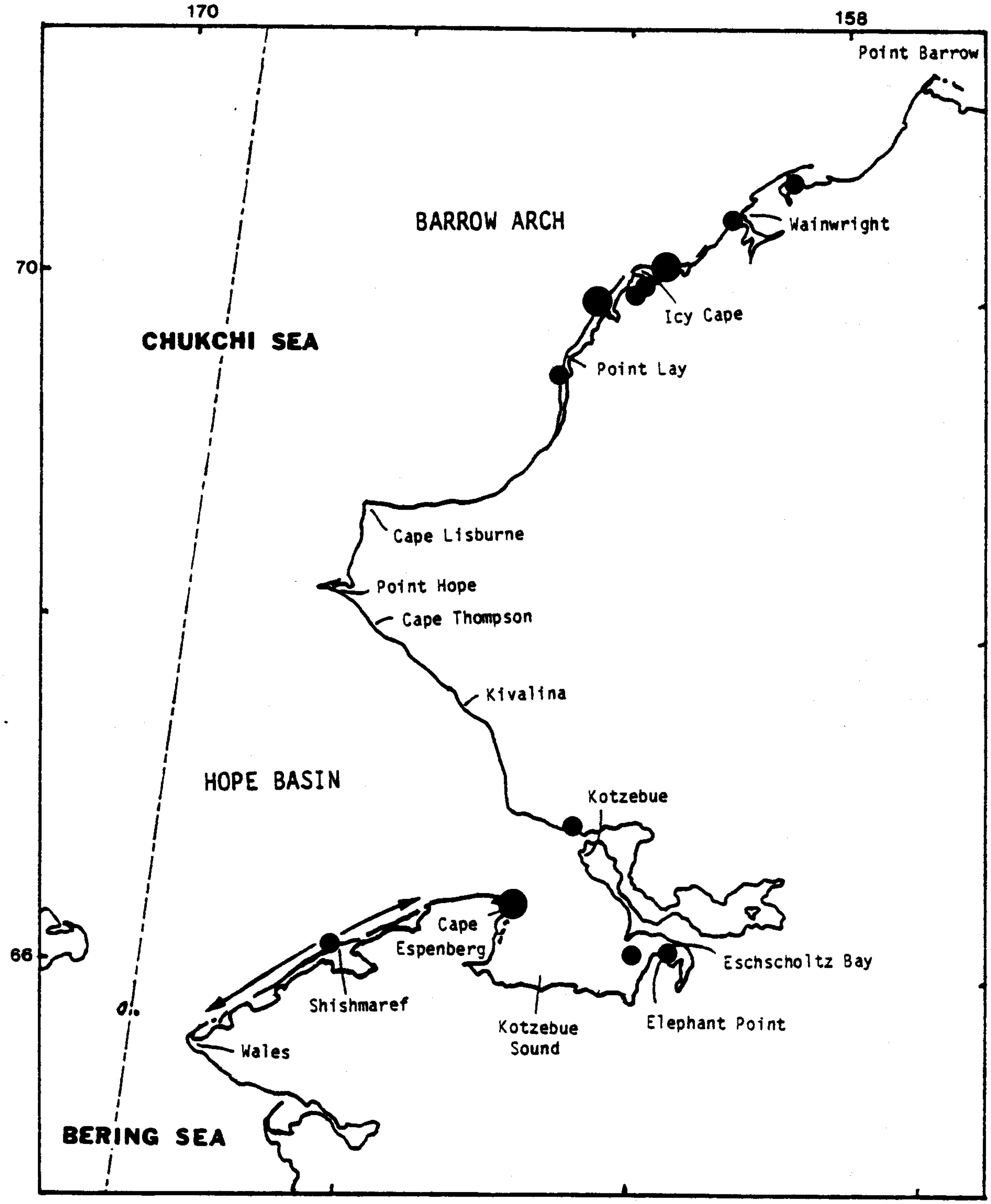

Figure 4. Map of the eastern Chukchi Sea showing major haulouts used by spotted seals. Large dots represent areas with maximum reported numbers of greater than 500 seals. Small dots represent haulouts of less than 500 seals.

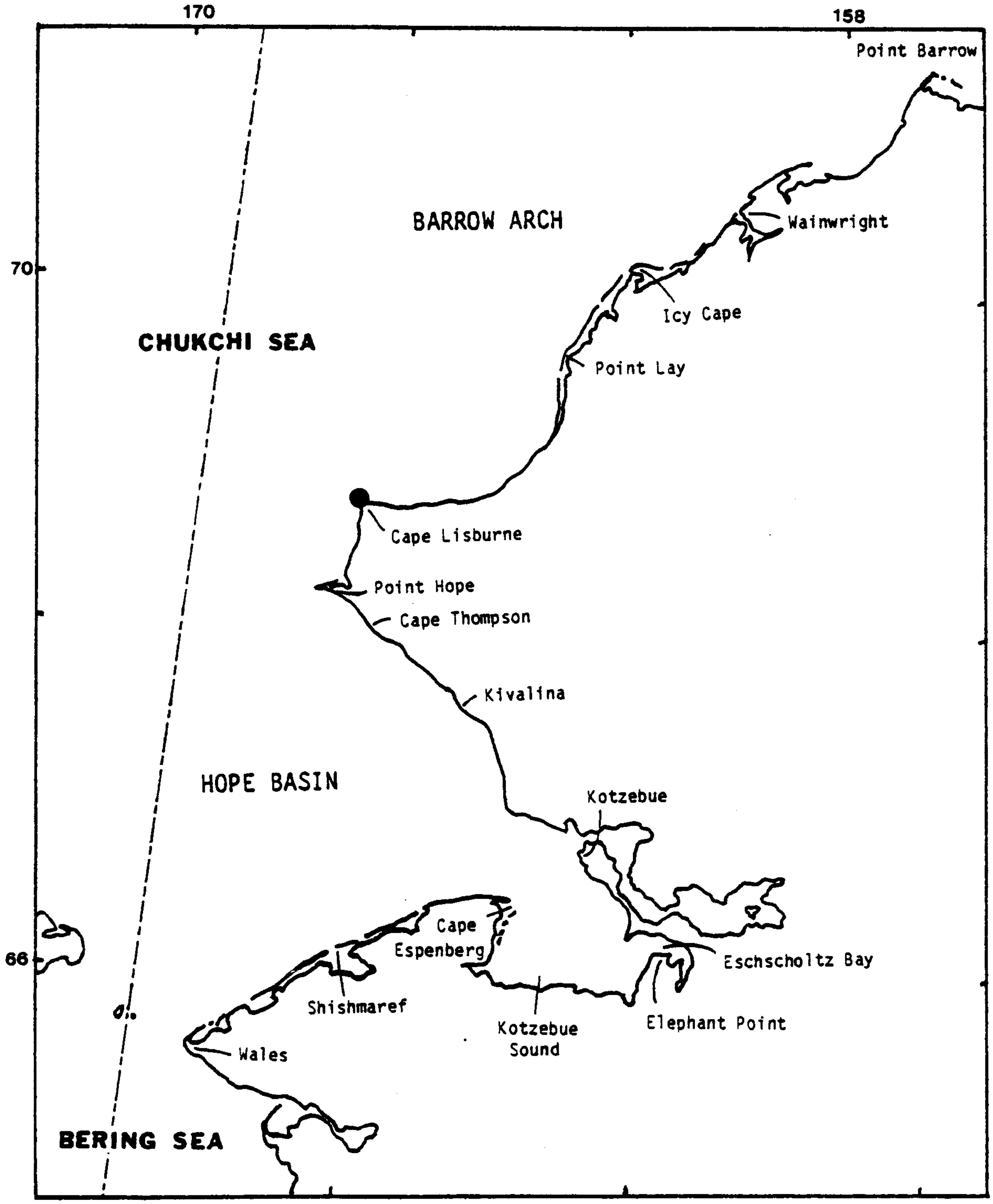

Figure 5. Map showing the only regularly used walrus haulout in the coastal zone of the eastern Chukchi Sea.

have ranged from 30-40 in some years to approximately 500 in late October 1978. Single animals or small groups have been seen hauled out on the beach from Cape Krusenstern to Cape Lewis and on the barrier islands of Kasegaluk Lagoon.

C. Belukha Whale

Belukhas spend the winter months offshore in the pack ice of the Bering Sea. In spring, as the ice begins to melt and recede northward, they move toward the coast. Some remain in the Bering Sea throughout the summer. Others travel north through Bering Strait to spend the summer in Kotzebue Sound, along the Chukchi coast north to Barrow, or in the eastern Beaufort Sea near the Mackenzie delta. Of an estimated population of 12-16,000, about 2,500-4,800, depending on the year, spend parts of the summer in coastal regions of the Chukchi Sea.

There are two main concentration areas for belukhas in the Chukchi Sea: Kotzebue Sound, particularly Eschscholtz Bay in Hope Basin; and in and adjacent to Kasegaluk Lagoon in the Barrow Arch (Fig. 6). Belukhas appear in northern Kotzebue Sound from Sheshalik to Cape Blossom in late May to mid-June, usually during or shortly after breakup. They appear slightly later in Eschscholtz Bay, usually in mid-June. There appears to be considerable movement of belukhas in Kotzebue Sound, with the whales seen near Sheshalik, Kotzebue, and Cape Blossom almost certainly part of the same group seen in Eschscholtz Bay. Some whales remain in the Sound until autumn; however, most sightings are in June and July.

The largest sightings of belukhas have been of over 1,000 whales in and near Eschscholtz Bay in June and July. Considering all observations, we estimate that the peak number of whales in Kotzebue Sound/ Eschscholtz Bay during summer ranges from 500 to 1,800, with considerable year-to-year variability which cannot at present be explained.

Belukhas feed in Kotzebue Sound, probably following local movements of fish and feeding on species which are particularly abundant at certain times (Seaman et al. 1982). In Eschscholtz Bay there are sizable runs of herring, smelt, char (Salvelinus alpinus), and salmon, in addition to large numbers of saffron cod (Barton 1979; Burns, Frost, and Seaman, pers. observations). Calving has been reported in coastal regions of the Sound in June and July. Most observations are from near Sheshalik and from the eastern end of Eschscholtz Bay, particularly the latter in recent years. Local residents indicate that belukhas are less common in nearshore areas near Sheshalik and Kotzebue than they once were but remain common offshore. This change has been attributed to increased boat traffic and perhaps other noises associated with modernization.

Historically, belukhas were also common along the northern Seward Peninsula from Ikpek to Cape Espenberg during breakup and throughout

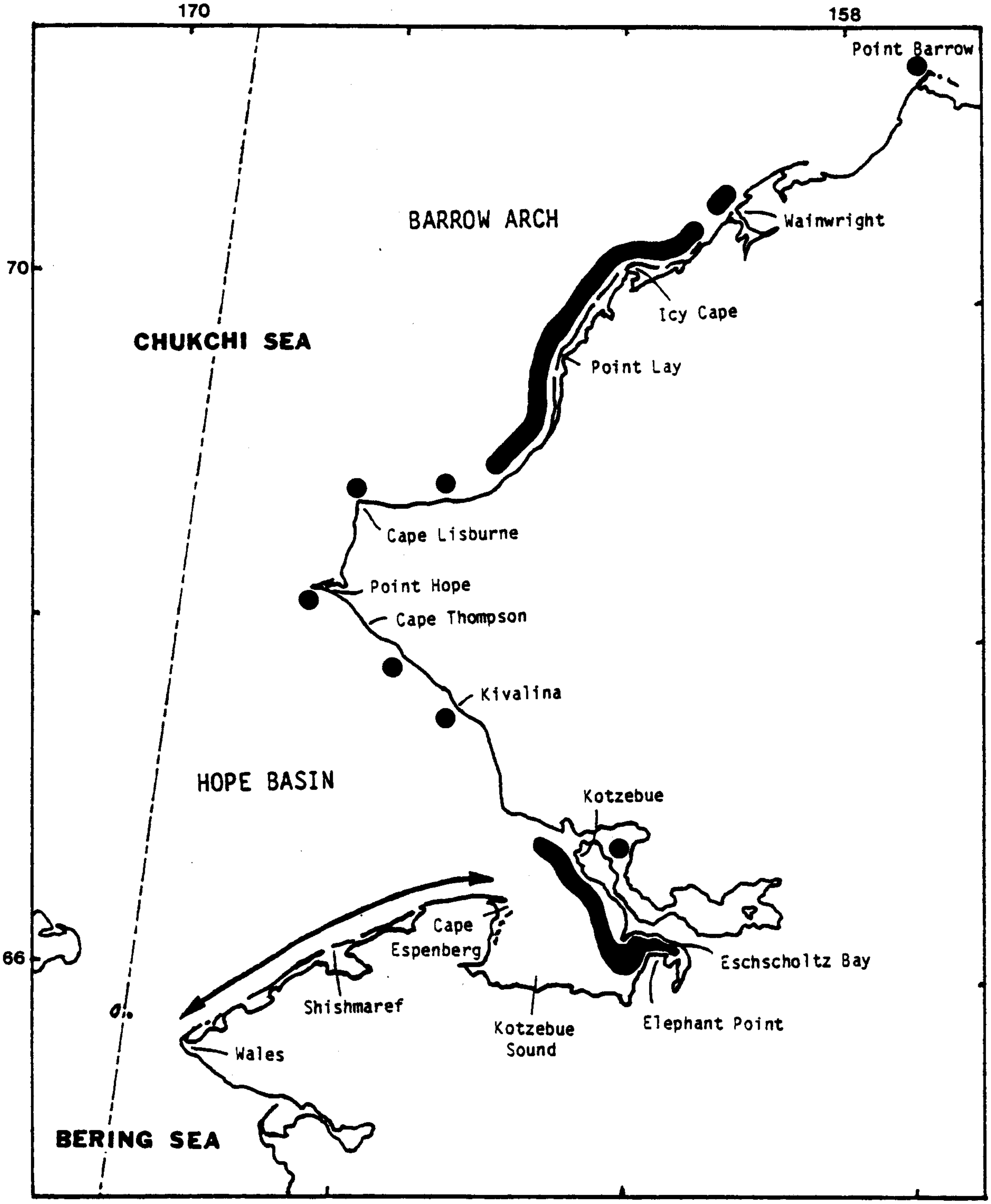

Figure 6. Map of the eastern Chukchi Sea showing sightings of belukha whales in the coastal zone. Dark bands represent concentration areas.

summer but in recent years have been sighted infrequently. As in the Kotzebue area, this change has been attributed to increased boat traffic.

Belukhas are present in the Kasegaluk Lagoon area from late June until late July or mid-August. They characteristically appear in the southern part of the region near Ledyard Bay in mid- to late June and move gradually northward following the retreat of seasonal ice. They may be found both outside the barrier islands and in deeper portions of Kasegaluk Lagoon, although nearshore waters outside the lagoon are used most extensively. They are usually concentrated in and outside of major passes, particularly Kukpowruk, Utukok, Icy Cape, and Akoliakatat, and to a lesser extent Akunik, and within 1/2-3/4 km from shore. The whales usually depart to the north, moving offshore or occasionally following the coast where they are seen at Wainwright and less commonly at Barrow. We estimate that 2,000-3,000 belukhas may occur near Kasegaluk Lagoon in most years, although in some years the abundance of whales in the area may be considerably less.

Belukha whales calve in and near Kasegaluk Lagoon. Although little is known about their food habits or the local fish fauna in this area, they probably feed on fishes such as salmon, char, or saffron cod.

Belukhas are now seen less frequently at Wainwright and Barrow during the ice-free period. Historically, they sometimes congregated at the mouth of Wainwright Inlet and the Kuk River, but they no longer do so.

D. Harbor Porpoise

Harbor porpoises probably occur occasionally during summer along the entire Chukchi coast, but because they are difficult to see and identify there are relatively few reported observations (Fig. 7). Most sightings were of one or two individuals. In several instances, females with small calves were seen. Sightings were usually made in August; the latest were on 18 September off Cape Thompson and Cape Dyer. In Kotzebue Sound and near Barrow, harbor porpoises are sometimes caught in gillnets.

E. Killer Whale

Sighting records suggest that killer whales are quite widely distributed in low numbers in the coastal zone of the Chukchi Sea (Fig. 8). Residents of Shishmaref report seeing them every summer. Hunters from Eschscholtz Bay, Kivalina, Point Hope, Point Lay, and Wainwright relate that killer whales regularly occur in those areas in summer. The whales are often seen chasing belukha or gray whales, sometimes stranding gray whales in shallow water or driving belukhas nearshore or into bays or lagoons where they can be easily hunted.

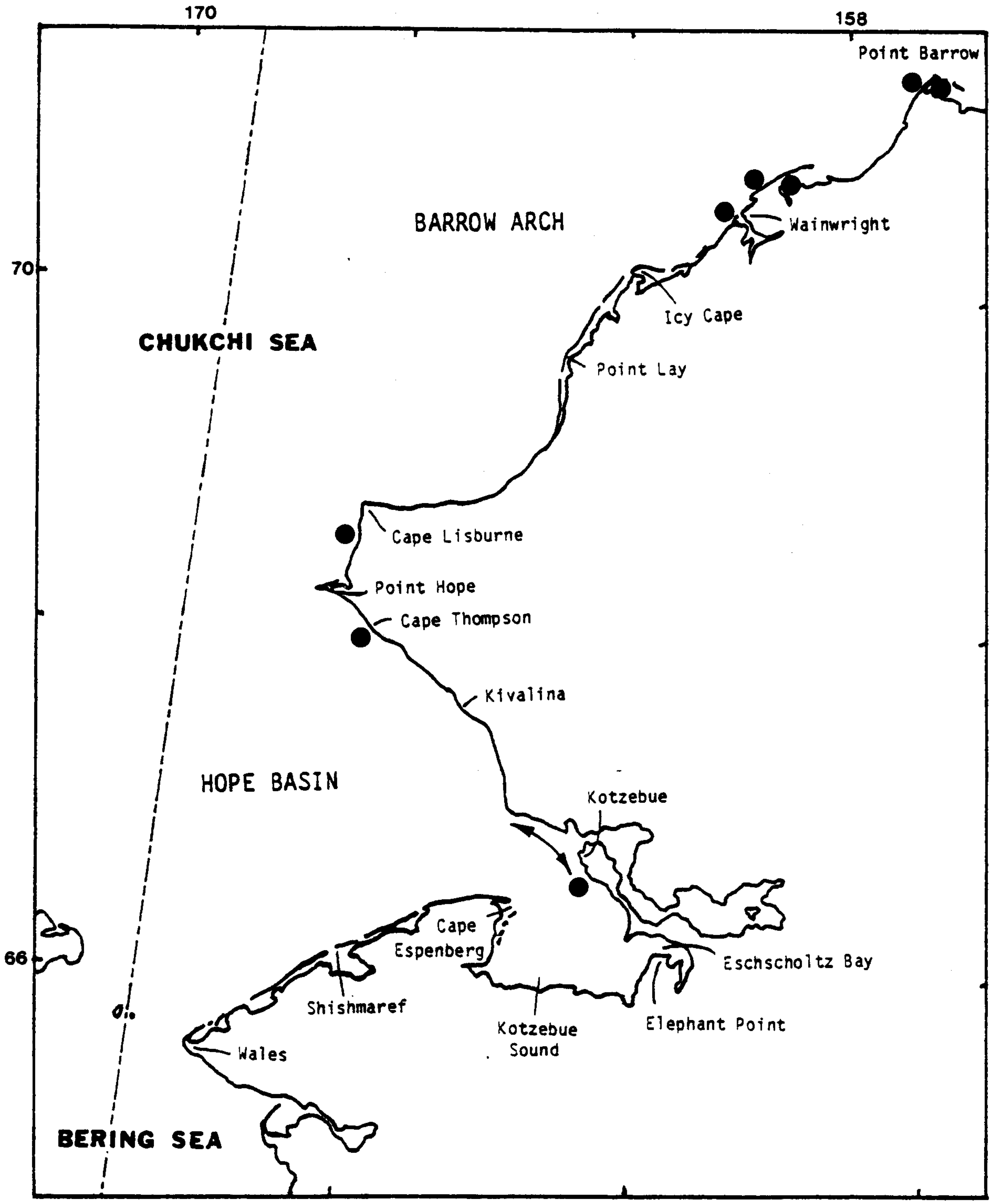

Figure 7. Map of the eastern Chukchi Sea showing sightings of harbor porpoises in the coastal zone.

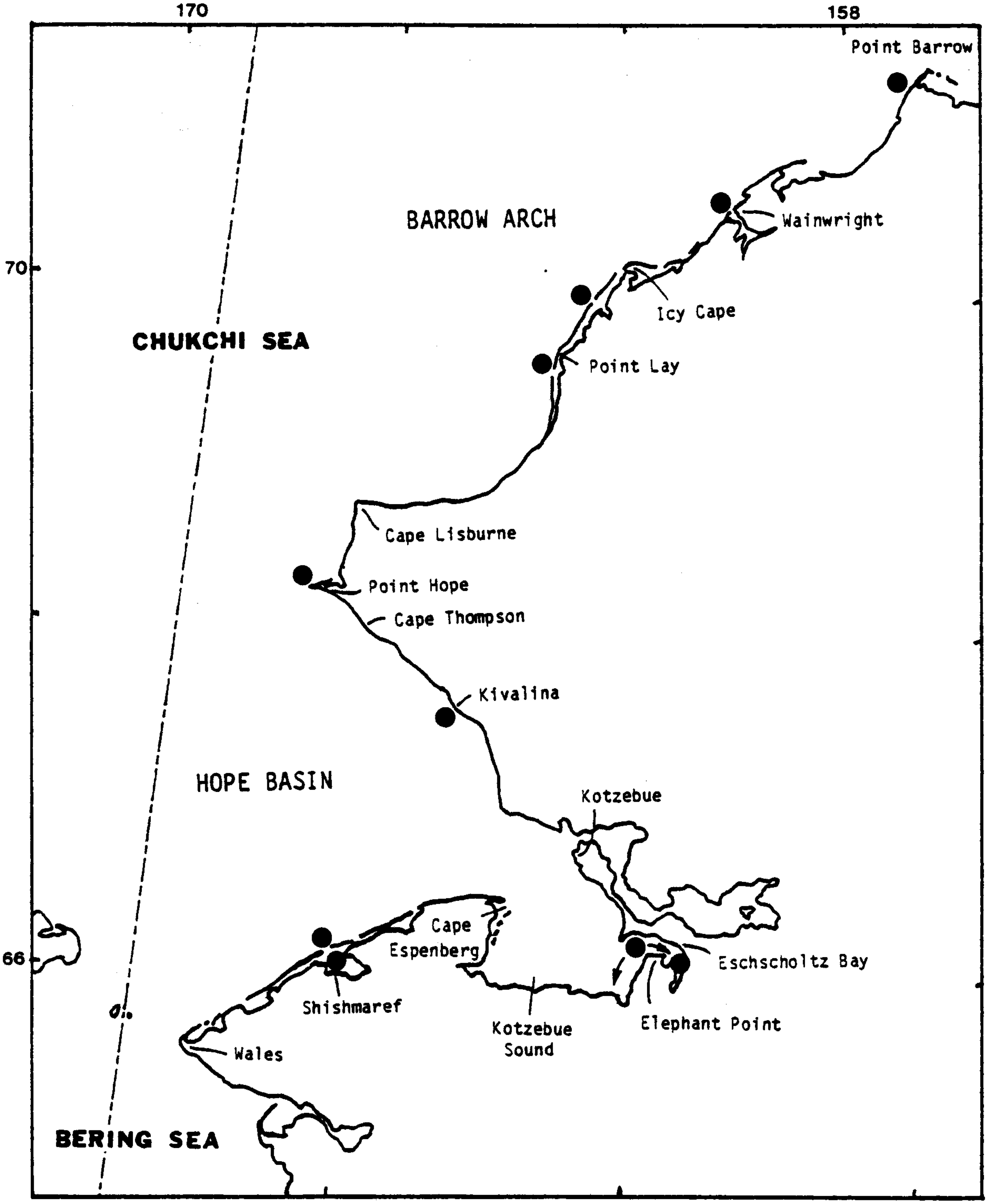

Figure 8. Map of the eastern Chukchi Sea showing sightings of killer whales in the coastal zone.

F. Minke Whale

We are aware of only three sightings of minke whales in the coastal zone of the Chukchi Sea. Two were from Kotzebue Sound in summer and autumn, and the third was from Cape Lisburne in August (Fig. 9). One of the Kotzebue Sound reports was of two whales that beached themselves at the mouth of the Buckland River.

G. Gray Whale

Gray whales migrate annually from the coastal waters of Baja California and the southern Gulf of California to the northern Bering and Chukchi seas. They follow the coast closely as they move north, entering the Bering Sea mostly through Unimak Pass in April through June, thence north toward the Chirikof Basin and Bering Strait. Most gray whales spend the summer feeding in the Chirikof Basin and Chukchi Sea. Those entering the Chukchi Sea move through Bering Strait in May through early July and are seen along the coast from Wales to Barrow (Fig. 10) in June through September, with most sightings in July and August. Sightings, many within 1-2 km of the beach, are usually of small groups, often including cows with calves. Feeding animals trailing visible mud plumes are often seen. Through July most traveling gray whales move northward, whereas after early August most are swimming southward. Few are seen in the Chukchi Sea after mid-September. There are no obvious concentration areas for gray whales in the coastal zone of the Chukchi Sea; however, they are apparently somewhat more common from Icy Cape to Barrow. The largest reported sightings anywhere along the Chukchi coast were near Wainwright and Point Franklin.

VIII.Conclusions

A. Adequacy of Sighting Data

The portion of the Alaska coastline included in this study is approximately 1,200 km in length. This is a large and relatively remote area over which to document all localities used by marine mammals. Nonetheless, the combined observations of persons who have worked onshore, at sea, and in the air provide considerable information on where and when marine mammals occur. The inherent interest of local residents in the natural resources which surround them has been encouraged and supplemented by the work supported by OCSEAP, as well as other federal agencies, and the State of Alaska.

This has been the first attempt to compile all existing data on coastal marine mammal distribution and abundance in the Chukchi Sea during the ice-free season in a comprehensive manner. We generally did not attempt to collect new data nor did we have the funds necessary to interview coastal residents in the manner which would be necessary to maximize the value of existing local knowledge. However, through

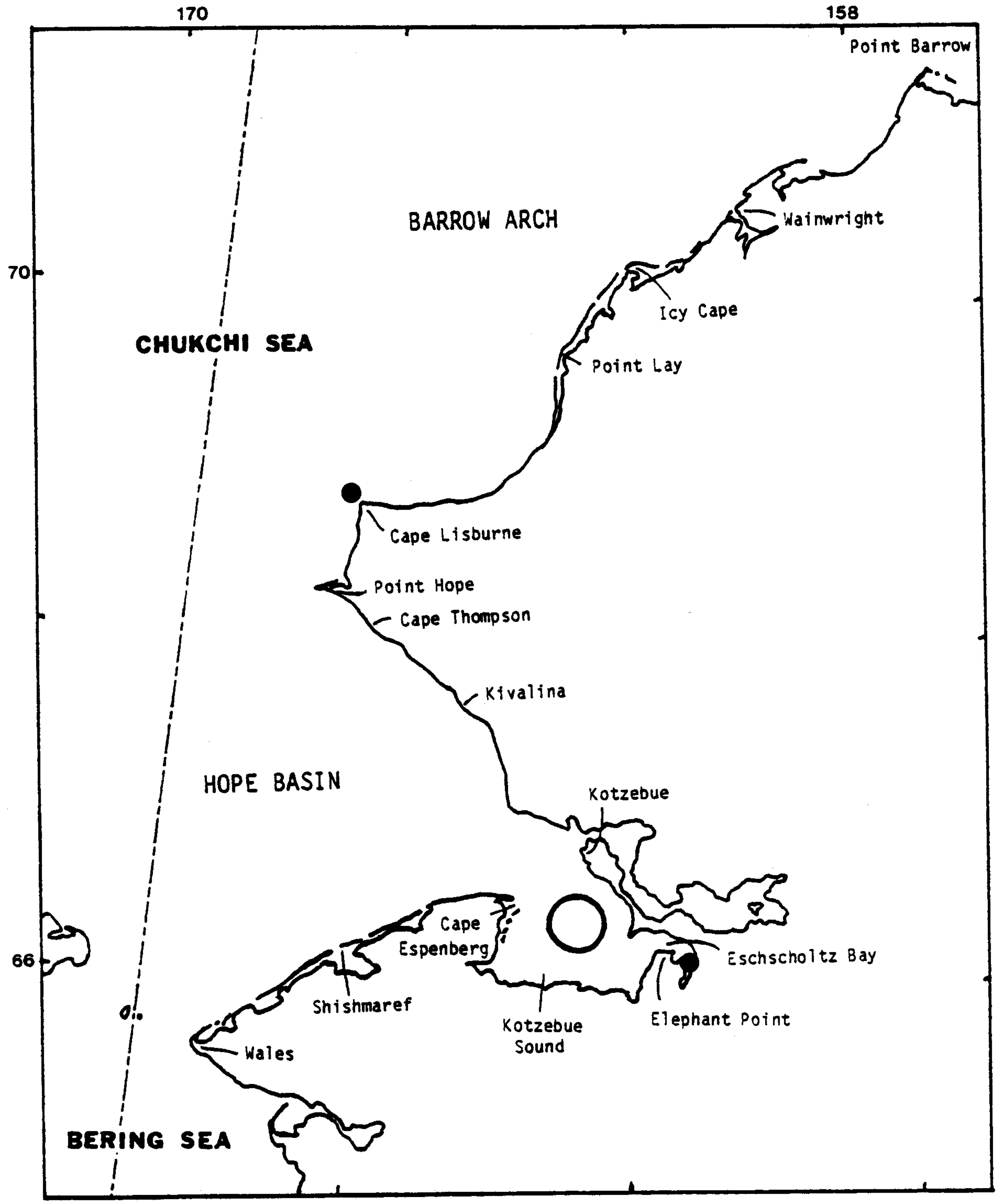

Figure 9. Map of the eastern Chukchi Sea showing sightings of minke whales in the coastal zone.

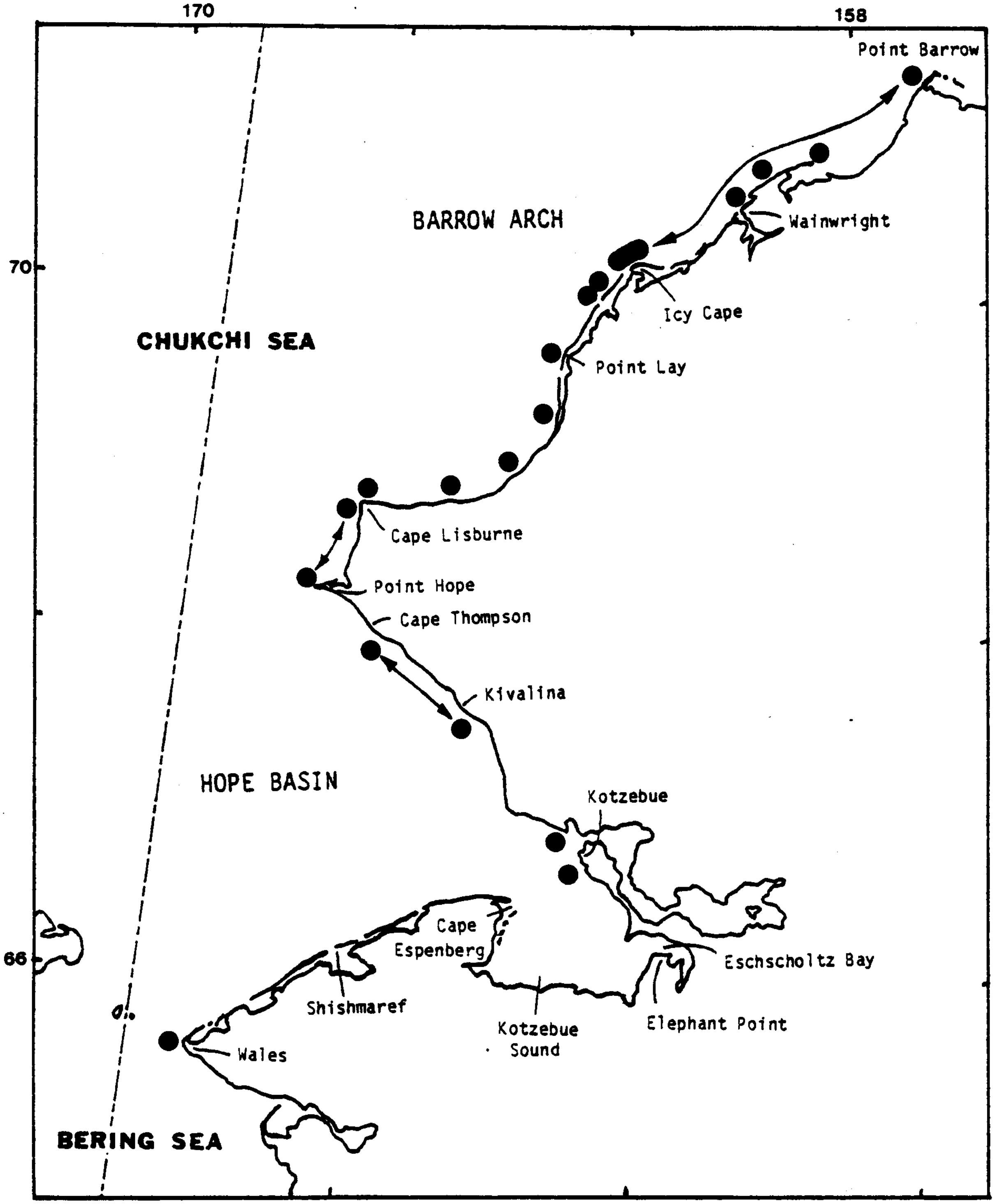

Figure 10. Map of the eastern Chukchi Sea showing sightings of gray whales in the coastal zone.

the research projects conducted by ADF&G over the past 23 years, several investigators have had the opportunity to spend time in most of the villages along the Chukchi coast and to discuss marine mammal distribution and abundance with residents. ADF&G employees visited Wales, Shishmaref, Wainwright, and Barrow in the course of pinniped and polar bear studies and Elephant Point, Kotzebue, Point Hope, and Point Lay while studying belukhas. Since much of the data available has been collected on an opportunistic basis, it was sometimes difficult to evaluate whether the composite picture derived from sightings accurately reflects the pattern of marine mammal distribution and abundance. This was particularly true when data were derived from informants who were present in or made observations of an area for only part of the ice-free season. In some cases, such as Eschscholtz Bay and Kasegaluk Lagoon, specific studies of belukha whales have been conducted, but information on other species in those areas, such as spotted seals, has not been collected in a systematic manner. Few studies have been done along the remainder of the Chukchi coast. Several site-specific studies of seabird colonies have been conducted over the past 10 years, and marine mammal observations made in the course of those studies have been included in this report. In 1976-77, ADF&G personnel conducted annual surveys of herring spawning concentrations along most of the coast from Bering Strait to northern Kotzebue Sound, and marine mammal observations were recorded on those flights.

We are confident that most major coastal areas utilized by marine mammals in summer and autumn have been identified in this report and that data are adequate to describe, in a general sense, the use of various regions of the coast by marine mammals. This information should be of considerable value for planning and, where necessary, perhaps regulating the development of OCS hydrocarbon reserves. However, without exception, available data on the numbers and activities of marine mammals at specific locations are not sufficient to estimate total numbers of animals or to measure or monitor the impacts of OCS activities or other factors on them.

B. Importance of Coastal Regions to Marine Mammals

Marine mammals inhabit virtually the entire coastal zone of the eastern Chukchi Sea during summer and autumn. However, their distribution is not uniform. In Hope Basin the greatest concentration of marine mammals occurs in Kotzebue Sound, which is inhabited by up to 2,000 + belukhas and an unknown but large number of spotted seals. Belukhas are most concentrated and predictably present offshore from Sheshalik, west of the Baldwin Peninsula, and particularly in Eschscholtz Bay. In Kotzebue Sound, spotted seals are most numerous in Eschscholtz Bay, Hotham Inlet, and at the mouth of the Noatak River. They are also present and haul out at locations along the coast from Wales to Cape Espenberg. Cape Espenberg and the string of islands extending south of it are the largest known spotted seal haulouts in Hope Basin. Harbor porpoises, killer whales, minke whales, and gray whales occur in Hope Basin. Gray whales are most frequently seen from Kivalina to Cape Lisburne. There are no regularly used walrus haulouts in Hope Basin.

In the Barrow Arch, the greatest concentration of marine mammals occurs in and near Kasegaluk Lagoon, which is used by 2,000-3,000 belukhas and at least 2,000-3,000 spotted seals. Belukhas are usually concentrated near the major passes, particularly Kukpowruk, Utukok, Icy Cape, and Akoliakatat. Spotted seals are abundant throughout Kasegaluk Lagoon and haul out in large numbers at Utukok and Akoliakatat passes. They are less numerous but still abundant near the mouth of the Kuk River near Wainwright and the Kugrua River in southern Peard Bay.

There are no major, regularly used haulouts for walruses in the northeastern Chukchi Sea, although some have hauled out at Cape Lisburne each summer since 1975.

Killer whales are seen off Point Lay and Wainwright in most years, and minke whales have been sighted at Cape Lisburne. Harbor porpoises have been seen near Wainwright, in Peard Bay, and near Barrow, and probably pass along all of the coast. Gray whales are present and feed along the entire northeastern Chukchi coast during summer and autumn. They are most common between Icy Cape and Barrow, particularly off Wainwright and Point Franklin.

C. Potential Effects of OCS Activities

The possible effects of OCS exploration and development in the Chukchi Sea are of two principal types: 1) those associated with hydrocarbons which are released into the environment, and 2) those related to disturbances which may affect the behavior and distribution of animals. Possible direct impacts of oil pollution have been discussed by Davis and Anderson (1976), Geraci and Smith (1976, 1977), Costa and Kooyman (1980), Geraci and St. Aubin (1980, 1982), and Cowles et al. (1981). Generally speaking, direct effects of oil are expected to be greatest on animals which rely on fur for insulation, which includes polar bears and the newborn young of ice-inhabiting seals. Effects of oil which may be ingested in the process of feeding or growing were discussed by Geraci and Smith (1976, 1977) and Cowles et al. (1981). Results available to date are inconclusive, although some physiological effects have been documented. Effects of oil on foods of marine mammals in the Chukchi Sea were discussed in detail in Lowry et al. (1981). In the remainder of this section we will discuss only the possible effects of disturbance on the abundance, distribution, and behavior of marine mammals in the coastal zone of the eastern Chukchi Sea.

There can be little question that air- and water-borne noise will in many cases be audible to marine mammals (e.g., see Myrberg 1978). The possible effects of such disturbances caused by noise or the physical presence of humans, vessels, or equipment are poorly known since very few studies have systematically addressed the question. Terhune et al. (1979) documented a decrease in vocalizations of harp seals (*Phoca groenlandicus*) in the presence of an operating vessel, which they attributed primarily to motor noise. It has been suggested that an increase in "water tourism" has caused a decrease in abundance of harbor seals (*Phoca vitulina*) in the Netherlands (Bonner 1978). Disturbance by humans has caused an elevated mortality in recently born Hawaiian monk seals (*Monachus schauinslandi*) (Rice 1964) and reduced productivity of Mediterranean monk seals (*Monachus monachus*) (Sergeant et al. 1978). Salter (1979) has documented a number of behavioral responses of walruses to over-flying aircraft, and we have noted that seals, sea lions (*Eumetopias jubatus*), and walruses almost invariably flee into the water when approached by humans or low-flying aircraft. Fay (pers. commun.) observed instances when walruses at Cape Seniavin were stampeded into the water by low-flying aircraft. When animals flee from the hauling areas, some mortality, especially of recently born young, will occur through injury or abandonment and subsequent starvation. The magnitude of this problem will vary by species, location, and time of year. In the case of walruses, regular human disturbance has prevented the long-term use of haulouts at Cape Newenham, Sledge Island, and to some extent King Island in the Bering Sea (ADF&G, unpubl.). Salter (1979) suggested that disturbances associated with the establishment of permanent bases in the Arctic may have caused changes in the summer distribution patterns of walruses, and, in fact, construction of the DEW-line station at Cape Lisburne did alter haulout patterns of walruses there (ADF&G, unpubl.).

Disturbance responses of cetaceans are more difficult to observe and quantify. Nishiwaki and Sasao (1977) are of the opinion that human activities, principally vessel traffic, have altered the migration routes of Baird's beaked whales (*Berardius bairdii*) and minke whales off the coast of Japan. In the case of minke whales, the greatest effect may have been on females with calves which avoided traditionally used coastal areas. Fraker (1977) discussed the effects of disturbance on belukha whales in the Mackenzie delta area. We have observed that outboard-powered boats affect belukha movements in rivers and bays. When a boat approached whales moving up the Snake River, they changed direction and moved downstream. When boats approached a large group of whales in shallow areas of western Nushagak Bay, they all turned and headed eastward toward deeper water. Changes in the summer distribution pattern of belukhas in Kotzebue Sound are closely correlated with changes in human activities and associated boat traffic (Burns et al., in prep.).

The actual results of responses to disturbances such as those discussed above are even less well known than the responses themselves. Mortality and injury of animals, particularly newborn or nursing young, will definitely occur in some circumstances, as has been documented for walruses and monk seals. More subtle effects on animal condition may also occur when disturbances interfere with normal activities such as nursing, resting, breeding, and molting. Perhaps most significant is the long-term displacement of animals that will be caused by continuous or regular and frequent disturbance. Since feeding is a major activity for marine mammals during summer and autumn, it is reasonable to assume that concentration areas of most marine mammals occur mainly in locations where they can obtain their food most efficiently. Pinnipeds require hauling areas on which to rest between feeding forays, and some species of cetaceans may likewise need protected areas in which to rest, care for young, and socialize. These coastal concentration areas occur at specific locations and are limited in number. Displacement from these areas will mean that those feeding grounds are abandoned or that animals will have to travel greater distances to reach them from the nearest resting area, either of which would be detrimental in energetic terms. One might speculate that such displacement would have the greatest effect on a species such as walrus, which feed on sessile organisms that occur abundantly only in limited areas. However, the principal prey of many other marine mammal species such as capelin (Mallotus villosus), herring, and salmon are equally concentrated at specific areas and times of year. Changes in distribution and abundance which prevent a species from exploiting its potential food resources in the most efficient manner will result in long-term changes in productivity, survival, and abundance.

IX. Needs for Further Study

This study covered the portion of the Alaska coastline from Bering Strait to Point Barrow and included several locations which are important marine mammal habitats during spring and autumn. A similar report dealing with the Bering Sea coast was submitted in September 1982. Many coastal areas of the Aleutian Islands and the Gulf of Alaska are also important habitat for marine mammals, particularly sea lions, sea otters, and harbor seals. A review of available data on distribution and abundance of marine mammals in the coastal zone would be very useful for planning OCS activities in those areas.

This report includes all sighting data available to us up to the end of 1981. Some significant observations made in summer 1982 are also included. Undoubtedly, we have missed some past observations which should have been included. In addition, with the present intensity of field research in western Alaska, much new information will be generated each year. We consider this report to be a working document which will be of greatest value if it can encourage researchers to record their sightings of marine mammals and make them available to others. A single sighting which seems of little value in itself may be of substantial significance when considered in combination with all the other data available. Consideration should be given to updating and revising this report on a regular basis, perhaps every 2 years.

Although we have been able to describe general features of the distribution and abundance of marine mammals in the coastal areas of the eastern Chukchi Sea using the existing data base, with few if any exceptions the available data are not adequate to predict or monitor the effects of OCS development or other human activities on marine mammals. There have been no systematic studies which have described the distribution, abundance, and activities of marine mammals at a particular location throughout the time they occur there and for a series of years. The available data show quite conclusively that the number of animals using particular areas has changed over time, and we predict that such fluctuations will continue to occur during OCS exploration and development. Without some additional research on the biology of marine mammals in the coastal zone, it will be difficult to detect and measure the fluctuations and impossible to identify the causes.

We suggest that OCSEAP initiate studies that will deal with representative species and habitats in areas that are likely to be impacted by OCS activities in the near future. Some potential species and areas are as follows:

Spotted seals - Kasegaluk Lagoon, Cape Espenberg

Walruses - Cape Lisburne

Belukha whales - Kotzebue Sound, Kasegaluk Lagoon

Of principal interest at each location is documentation of the seasonal cycle in numbers of animals using the area. Activity patterns should be examined as they relate to enumeration of animals as well as for documentation of "normal" activity. Present levels of disturbance and their effects, if any, should be monitored. Information should be gathered on the relationships among groups of animals at various locations; i.e., what is the rate of interchange among areas and what degree of fidelity do individuals have to particular locations. Research should include, as possible, observations of group composition, birth and survival rates, and present causes of mortality. Finally, the significance of the area to the animals should be determined; i.e., is it used principally for feeding, birthing, breeding, or some combination of purposes.

More specifically, the distribution and movements of belukha whales along the Chukchi coast should be studied through application of tagging techniques being developed in Bristol Bay and should be conducted in conjunction with aerial surveys during times of peak abundance. Large aggregations of belukhas occur in two known locations in the eastern Chukchi Sea: Kotzebue Sound and the Kasegaluk Lagoon area. It is unknown whether these aggregations are two separate groups of animals or the same group moving up the coast as the season progresses. Food habits of belukhas in the Kasegaluk Lagoon area are unknown, as are the availability of prey and the probable importance of this section of the coast as a feeding area.

Relatively little is known about the use of Chukchi coastal areas by spotted seals. In late summer, large aggregations are known to occur at Cape Espenberg and Kasegaluk Lagoon. The actual number of seals using those areas, the duration of their stay, and their activity patterns while there are unknown. However, these are clearly two of the largest documented spotted seal aggregations along the entire coastline of northwest Alaska.

If such studies are begun prior to OCS leasing and continued at intervals after exploration and development begin, it should be possible to make some definitive statements regarding the effects of OCS activities.

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APPENDIX I.

Geographical Coordinates of Locations Referred to in Text

Name	Region	Latitude	Longitude
Agiak Point	BA 2	70°29'05"N	159°54'15"W
Akoliakatat Pass	BA 1	70°18'N	161°18'W
Akoviknak Lagoon	HB 3	68°12'N	166°02'W
Akunik Pass (Kokolik Pass)	BA 1	69°53'45"N	162°49'30"W
Arctic Lagoon	HB 1	66°12'N	166°09'W
Atanik	BA 2	70°50'N	159°21'W
Avak Inlet	BA 1	70°15'N	161°38'W
Baldwin Peninsula	HB 2	66°45'N	162°20'W
Barrow	BA 2	71°17'30"N	156°47'15"W
Barrow, Point	BA 2	71°23'29"N	156°28'30"W
Beaufort, Cape	BA 1	69°02'N	163°50'W
Belcher, Point	BA 2	70°47'40"N	159°39'02"W
Blossom, Cape	HB 2	66°44'N	162°30'W
Buckland River	HB 2	66°14'N	161°01'W
Chamisso Island	HB 2	66°13'N	161°50'W
Choris Peninsula	HB 2	66°17'N	161°53'W
Corwin Bluff	BA 1	68°52'40"N	165°03'15"W
Crowbill Point	HB 3	68°06'05"N	165°48'07"W
Deering	HB 2	66°04'N	162°42'W
Dyer, Cape	HB 3	68°39'08"N	166°13'50"W

Name	Region	Latitude	Longitude
Elephant Point	HB 2	66°16'N	161°20'W
Elson Lagoon	BA 2	71°15'N	155°51'W
Eschscholtz Bay	HB 2	66°20'N	161°30'W
Espenberg, Cape	HB 1	66°33'N	163°36'W
Franklin, Point	BA 2	70°54'28"N	158°47'50"W
Hope, Point	HB 3	68°20'20"N	166°50'40"W
Hotham Inlet	HB 2	67°00'N	162°00'W
Icy Cape	BA 1	70°20'N	161°52'W
Icy Cape Pass	BA 1	70°18'N	161°57'W
Ikpek	HB 1	65°54'N	167°17'W
Ikpek Lagoon	HB 1	65°56'N	167°00'W
Karmuk Point	BA 2	70°35'10"N	159°53'45"W
Kasegaluk Lagoon	BA 1	70°28'N to	160°29'W to
		69°16'N	163°18'W
Kivalik Channel (Inlet)	HB 3	67°47'N	164°41'W
Kivalina	HB 3	67°43'40"N	164°32'30"W
Kokolik Pass (Akunik Pass)	BA 1	69°53'45"N	162°49'30"W
Kokolik River	BA 1	69°45'15"N	163°00'W
Kotzebue	HB 2	66°54'N	162°35'W
Kotzebue Sound	HB 2	66°45'N	163°00'W

Appendix I

Name	Region	Latitude	Longitude
Krusenstern, Cape	HB 2	67°08'N	163°44'45"W
Kugrua Bay	BA 2	70°47'N	159°08'W
Kugrua River	BA 2	70°46'30"N	159°17'W
Kuk River	BA 2	70°35'N	159°53'W
Kukpowruk Pass	BA 1	69°40'30"N	163°06'W
Kukpuk River	HB 3	68°25'N	166°22'W
Lay, Point	BA 1	69°45'45"N	163°03'05"W
Lewis, Cape	HB 3	68°42'50"N	166°12'01"W
Lisburne, Cape	BA 1	68°53'N	166°13'W
Lopp Lagoon	HB 1	65°45'N	167°45'W
Marryat Inlet	HB 3	68°22'N	166°33'W
Marsh, Point	BA 2	70°36'25"N	160°07'W
Naokok Pass	BA 1	69°27'30"N	163°08'30"W
Noatak River delta	HB 2	67°00'N	162°30'W
Ogotoruk Creek	HB 3	68°05'52"N	165°45'15"W
Peard Bay	BA 2	70°51'N	158°48'W
Pingorarok Pass	BA 1	70°22'N	160°49'W
Pitmegea River	BA 1	68°54'40"N	164°37'W
Prince of Wales, Cape	HB 1	65°36'N	168°05'W

Appendix I

Name	Region	Latitude	Longitude
Sabine, Cape	BA 1	68°55'N	164°36'15"W
Selawik Lake	HB 2	66°30'N	160°45'W
Seppings, Cape	HB 3	68°58'N	165°11'W
Sheshalik	HB 2	66°59'30"N	162°49'45"W
Shishmaref	HB 1	66°15'N	166°04'W
Shishmaref Inlet	HB 1	66°15'N	166°05'W
Spafarief Bay	HB 2	66°08'N	161°51'W
Thompson, Cape	HB 3	68°08'40"N	165°58'40"W
Utukok Pass	BA 1	70°05'N	162°31'W
Wainwright	BA 2	70°38'15"N	160°01'45"W
Wales	HB 1	65°37'N	168°05'W

APPENDIX II.

Source Names Index

Appendix II

Burns and Morrow 1975 - HB 1

Childs 1969 - BA 1

Collins, G. - BA 1
from files of F. H. Fay, Univ. Alaska, Fairbanks

Craighead, D. - HB 3
ADF&G, Kotzebue

Degange, A. - HB 2
seabird observer, Seabird Colony Status Program, USFWS, Anchorage

Durham 1979 - HB 3, BA 2

Fay, F. H. - HB 1, HB 3, BA 1, BA 2
walrus researcher, Inst. Marine Science, Univ. Alaska, Fairbanks

Fay 1982 - BA 1

Fay and Kelly 1982 - HB 3, BA 2

Field, P. - HB 3
ADF&G seasonal employee (marine mammals)

Fields, A. - HB 2
Kotzebue resident; pers. commun. to J. Burns, ADF&G, Fairbanks

Fiscus and Marquette 1975 - HB 3

Fiscus et al. 1976 - BA 2

Foote 1960 - HB 2, HB 3

Foote and Williamson 1966 - HB 2

Frankson, D. - HB 3
Point Hope resident

Frost, K. - HB 1, HB 2, BA 1, BA 2
marine mammal researcher, ADF&G, Fairbanks

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Goodhope, F. - HB 1
Shishmaref resident; pers. commun. to J. Burns, ADF&G, Fairbanks

Goodwin, W. - HB 2
employee of NANA Corp., Kotzebue; pers. commun. to J. Burns, ADF&G, Fairbanks

Hills, S. - HB 1
seabird observer, Univ. Washington; pers. commun. to K. Frost, ADF&G, Fairbanks

Hobbs and Goebel 1982 - HB 3, BA 2

Jacobson, J. - HB 2
Kotzebue resident; pers. commun. to J. Burns, ADF&G, Fairbanks

Johnson et al. 1966 - HB 3

Kelly, B. - HB 3, BA 1
marine mammal researcher, ADF&G and Inst. Marine Science, Univ. Alaska, Fairbanks

King, R. - BA 1, BA 2
aerial surveys for waterfowl, USFWS, Fairbanks

Krammer, D. - HB 2
Kotzebue resident; pers. commun. to G. Seaman, ADF&G, Anchorage

Lee, N. - HB 2
Buckland resident; pers. commun. to G. Seaman, ADF&G, Anchorage

Lehnhausen and Quinlan 1981 - BA 1

Lensink 1961 - HB 1, HB 2

Ljungblad 1981 - HB 3, BA 1, BA 2

Ljungblad et al. 1982 - HB 1, HB 2, HB 3, BA 1, BA 2

Lowry, L. - HB 1, HB 3, BA 1, BA 2
marine mammal researcher, ADF&G, Fairbanks

Maher 1960 - BA 1, BA 2

Marquette 1977 - HB 3

Marquette and Braham 1982 - HB 3, BA 1, BA 2

Melchior, H. - HB 3, BA 2
ADF&G, Area Biologist, Barrow

Merrit, P. - HB 2
ADF&G, FRED Division, Kotzebue

Murdoch 1885 - BA 2

Murphy, E. - HB 3
seabird researcher, Univ. Alaska, Fairbanks

Neakok, B. - BA 1
Point Lay resident; pers. commun. to G. Seaman, ADF&G, Anchorage

Neakok, W. - BA 1
Point Lay resident; pers. commun. to G. Seaman, ADF&G, Anchorage

Negovanna, W. - BA 1
Wainwright resident; pers. commun. to G. Seaman, ADF&G, Anchorage

Nelson 1887 - HB 2, HB 3

Nelson 1969 - BA 2

Nelson, R. - BA 1, BA 2
marine mammal researcher, ADF&G, Nome

North Slope Planning Document 1982 - HB 3, BA 1
unpublished report prepared by Maynard and Parch, Woodward-Clyde
Consultants. Alaska Coastal Management Program.

Oktollik, J. - HB 3
Point Hope resident; pers. commun. to P. Field, ADF&G, Fairbanks

Pegau, R. - BA 1
ADF&G, Nome

Persons, K. - HB 2
pers. commun. to J. Burns, ADF&G, Fairbanks

Appendix II

Pike 1962 - HB 1, HB 2, HB 3

Quimby, R. - BA 1
pers. commun. to J. Burns, ADF&G, Fairbanks

Ray, G. - HB 1, BA 2
marine mammal researcher, Univ. Virginia, Charlottesville

Robus, M. - HB 3
ADF&G, Fairbanks

Rudd, J. - BA 1
pilot, Kotzebue

Saario and Kessel 1966 - HB 3

Seaman and Burns 1981 - HB 2

Seaman, G. - HB 1, HB 2, HB 3, BA 1, BA 2
ADF&G, Anchorage

Shanahan, C. - BA 2
pers. commun. to J. Burns, ADF&G, Fairbanks

Smith, T. - BA 1
ADF&G, Nome

Smullen, D. - HB 3
bowhead whale program, National Marine Fisheries Service, Seattle

Sowls, A. - HB 2
seabird observer and coordinator, Seabird Colony Status Program, USFWS, Anchorage

Springer, A. - BA 1
seabird researcher, LGL Ltd., Fairbanks

Springer and Roseneau 1977 - HB 3

Stewart, D. - HB 1
NMFS, Anchorage; pers. commun. to J. Burns, ADF&G, Fairbanks

Strickland, D. - BA 1, BA 2
ADF&G seasonal employee (marine mammals), Fairbanks

Thomas, L. - HB 2
Buckland resident; pers. commun. to G. Seaman, ADF&G, Anchorage

Tounai, E. - BA 1
Point Lay resident; pers. commun. to G. Seaman, ADF&G, Anchorage

Tremaine, R. - HB 1, BA 2
ADF&G seasonal employee (marine mammals), Fairbanks

USFWS (U.S. Fish and Wildlife Service) walrus harvest report, 1981 - HB 1

USFWS 1969 - HB 2

USFWS/SBCS Reports - HB 2, HB 3
Seabird Colony Status Reports, USFWS, Anchorage

Van Valin 1941 - BA 2

Walker, J. - HB 2
pilot, Walker Air, Kotzebue; pers. commun. to J. Burns, ADF&G, Fairbanks

Weyiouanna, C. - HB 1
Shishmaref resident; pers. commun. to R. Tremaine, ADF&G, Fairbanks

Wilke and Fiscus 1961 - HB 1, HB 2

Wilson, G. - BA 1
pers. commun. to F. H. Fay, Univ. Alaska, Fairbanks

Wilson, Y. - HB 2, HB 3
pers. commun. to G. Seaman, ADF&G, Anchorage

EARLY SPRING DISTRIBUTION, DENSITY, AND ABUNDANCE OF THE PACIFIC WALRUS (Odobenus rosmarus) IN 1976

by

Bruce D. Krogman, Howard W. Braham,
Ronald M. Sonntag, and Richard G. Punsly

Final Report
Outer Continental Shelf Environmental Assessment Program
Research Unit 14

March 1986

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This report does not constitute a publication and is for information only.
All data herein are to be considered provisional.

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Figure 16. Map depicting the June 1976 survey area in the northern Bering and Southern Chukchi Seas after post-stratification of walrus densities.

INTRODUCTION

This report includes original research data covering the 1976 late winter-early spring distribution and abundance of the Pacific walrus (Odobenus rosmarus divergens) in the Bering Sea, and also summarizes the historical records on seasonal distribution and abundance throughout Alaska. Research on the Pacific walrus is part of a large scale effort by the U. S. Department of the Interior to collect baseline information on the status of marine resources occurring in proposed oil lease site areas in Alaska. Specifically, this report is the result of a contract with the Environmental Research Laboratory, National Oceanic and Atmospheric Administration, U. S. Department of Commerce, Boulder, Colorado, and Juneau, Alaska, as part of the Outer Continental Shelf Environmental Assessment Program (OCSEAP) funded by the Bureau of Land Management, and represents research carried out under the amended OCSEAP Research Unit 14, originally contracted to the U. S. Fish and Wildlife Service (USFWS), Anchorage, Alaska.

The objectives of this study were to assess walrus distribution on the pack ice during the maximum extent of ice coverage in the Bering Sea, and to make an evaluation of the numbers and location of walrus groups with respect to potential oil and gas leasing sites in Bristol Bay, Norton Sound, and Kotzebue Sound. To this end, this final report is divided into four sections: (1) HISTORICAL OVERVIEW--which summarizes our knowledge throughout Alaska since the 1600's; (2) MATERIALS AND METHODS--which discusses the experimental, analytical (i.e., mathematical), and computational (i.e., programming) procedures for collecting data and estimating abundance; (3) RESULTS AND DISCUSSION--narrative comparing a common data base simultaneously collected by marine mammal scientists from the Soviet Union, Alaska Department of Fish and Game (ADFG) and the National Marine Fisheries Service (NMFS); and (4) SUMMARY AND CONCLUSIONS--which addresses our present knowledge of the walrus in Alaska and provides conclusions on population status in general and with regard to proposed oil lease areas.

HISTORICAL OVERVIEW

Harvest

Commercial harvest of the Pacific walrus became intensive during the last four decades of the nineteenth century, resulting in a pronounced reduction in the population size (Fay 1957). By the end of the first decade of the twentieth century, the walrus fishery had all but ended, though the marine mammal industry of the Soviet Far East continued with a substantial harvest (Krylov 1968). Commercial harvest of walrus was prohibited for United States citizens by the Walrus Act of 1941. Subsistence harvest by Alaskan Eskimos was allowed, and a limited sport hunt in Alaska waters is currently in effect.

Pre-1957 Distribution and Abundance

An evolutionary history of odobenids presented by Repenning (1976) postulates that a form of the North Pacific walrus occurred in the southerly extremes of the North Pacific Ocean some 5 to 8 million years ago. This walrus-like marine mammal passed into the Atlantic Ocean through the Central American Seaway between Central and South America and, after evolving into the modern bottom-feeding walrus, returned to the Pacific by way of the Arctic Ocean, probably less than one million years ago.

Fay (1957) presents a history of the numeric status of the Pacific walrus from 1650 to 1956 and describes the changes in summer range attributable to commercial exploitation. Unfortunately, there are scant data documenting winter distribution. Fay's historical analysis, summarized below, was drawn from chronicles of early naturalists and explorers (cf. Cook 1822; Beechey 1831; Elliot 1882, 1886; Murdock 1885; Clark 1887; Healy 1887, 1889; Niedieck 1909; and Muir 1917) and from the more recent works of Freimann (1940), Nikulin (1940), Brooks (1954), Fay (1955), and others.

1. 1650-1850. Walrus occurred in areas adjacent to the Siberian coastline (Figure 1) from the mouth of the Kolyma River (69°57'N, 161°30'E) to the mouth of the Anadyr River (64°45'N, 178°00'E), and south to Karaginskiy Island (58°00'N, 164°00'E), and were abundant along the coast and islands of the Chukchi Sea. Relatively few walruses occurred east of Pt. Barrow to Banks Island. [For a somewhat more detailed record of occurrences along the north coast of Alaska see Bee and Hall (1956).] Walrus were common along the Bering Sea coasts and islands of Alaska to as far south as Unimak Pass and the Shumagin Islands, but were probably not common east of the Shumagins. Walrus were generally absent from the Aleutian Islands. The estimated population size was at least 200,000.

2. 1850-1900. During this period large harvests caused a range reduction most evident in the south. Walrus became rare south of the Alaska Peninsula and absent from Karaginskiy Island. Amak and Hall Islands, Port

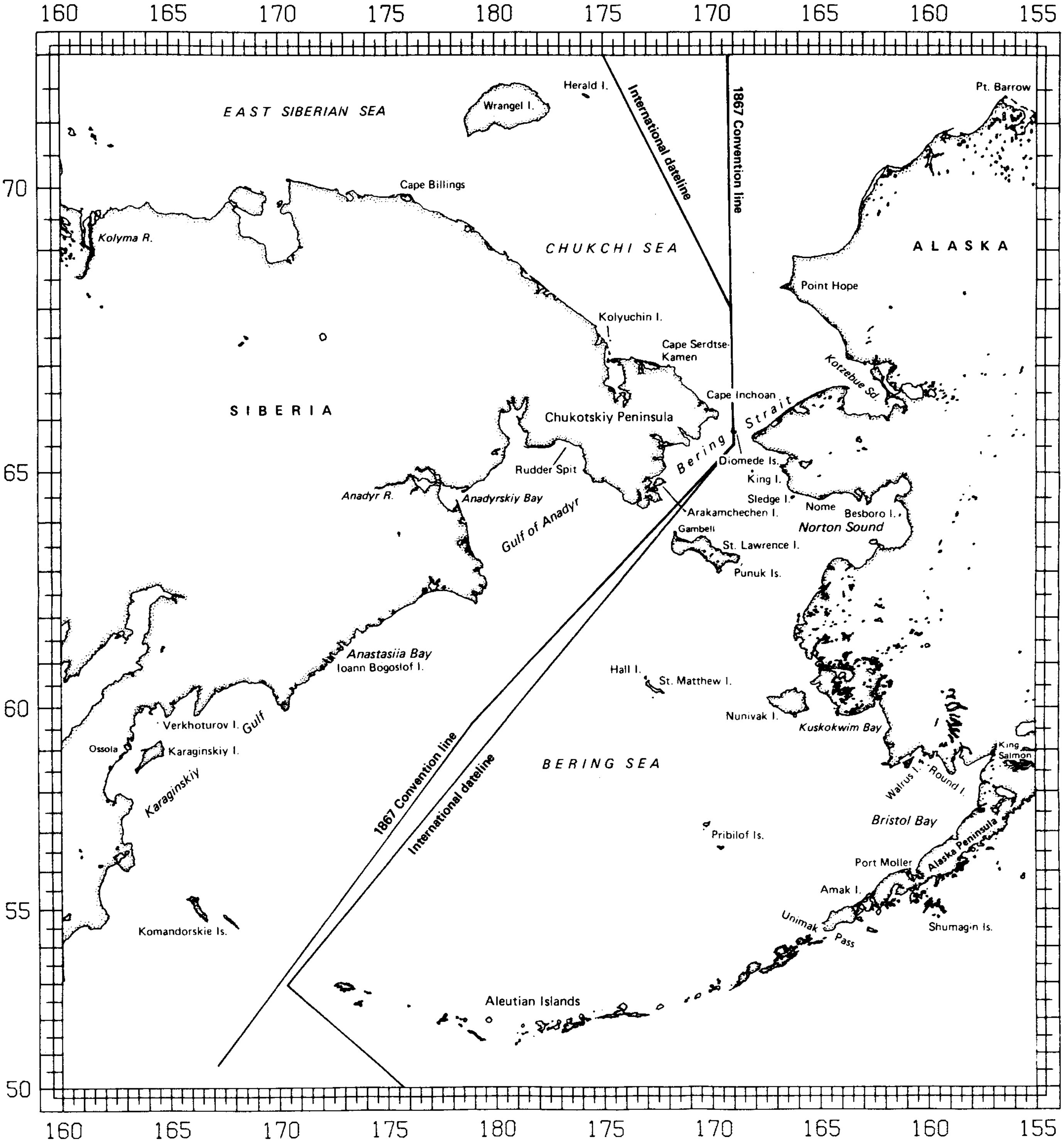

Figure 1. Area map.

Moller, and the Walrus Islands were still utilized by walrus but the large herds of the Pribilof Islands were diminished to 150 animals. In the northern part of their range walruses were still abundant, though reduced in total numbers, with the largest reduction occurring east of Pt. Barrow.

3. 1900-1930. The size of the Pacific walrus population finally fell below half of its pre-commercial size during this period; the continued decline was attributed to intensive commercial exploitation. Except for small groups occurring on the Walrus Islands, Hall Island, and the north coast of the Alaska Peninsula, walruses became all but absent south of 60°N.

4. 1930-1950. No significant change in population status was detected.

5. 1950-1956. The size of the walrus population continued a modest decline to a minimum estimate of 45,000. [Note: Kenyon (1960a) felt that estimate was low, based on his own work in 1960.] During this period the only hauling areas in the southern part of their range that were regularly used by walruses were the Walrus Islands.

1957-1975 Distribution and Abundance

Since Fay's (1957) foundation work, research on the biology and ecology of the walrus has continued through the works of Fay (1960, 1974a, 1974b, 1975); Kenyon (1960a, 1960b, 1960c, 1965); Fedoseev (1962, 1966); Krylov (1962, 1966, 1968); Burns and Croxton (1963); Tikhomirov (1964); Burns (1965a, 1965b, 1965c, 1966, 1967, 1970); Branson (1968); Gol'tsev (1968, 1972, 1976); Shustov (1967, 1972); Tomilin and Kibal'chich (1975); Estes (1976); Burns and Harbo (1977); Burns, Shapiro,and Fay (1977); and Estes and Gilbert (1978). From these works an account of the population status of walrus from 1957 to the present can be made.

6. 1957-1960. P. G. Nikulin (unpubl. manuscr., 1958, TINRO Archives, 20 Lenin St., Vladivostok, U.S.S.R.), cited in Fedoseev (1962), flew aerial surveys in 1958 in the eastern East Siberian and western Chukchi Seas, and concluded that the population size was approximately 40,000. A more complete assessment of the population for this period can be made from review of the works of Kenyon (1960a) and Fedoseev (1962).

Fedoseev (1962) flew aerial surveys in September and October 1960 and concluded that the southern boundary during the summer and autumn along the Soviet coast was in the Gulf of Anadyr at Rudder Spit (65°30'N, 176°00'W and Anadyrskiy Bay (64°30'N, 178°00'W). Up to 90% of the walruses were located in the following areas; 1) drift ice edge in eastern East Siberian and Chukchi Seas; 2) Wrangel Island; 3) Herald Island; and on Siberian coastal hauling areas of (4) Cape Serdtse-Kamen (67°05'N, 172°45'W); 5) Cape

Inchoan (66°15'N, 170°15'W); and 6) Rudder Spit. Fedoseev compared his work with Belopolsky (1939), Nikulin (1940), and Fay (1957) and concluded that in summer and autumn males haul out on the Chukotskiy Peninsula and the Walrus Islands,and females with young and sexually mature males often migrate to the northwestern Chukchi Sea and eastern East Siberian Sea. Fedoseev (1962) estimated the population at 50,000, with 85% of the population summering in the Soviet portion of the Arctic. While this estimate was comparable to the 45,000 estimate Fay (1957) made for the 1950-1956 period, Fedoseev expressed the opinion that the population was declining, as evidenced from a reduction in overall use of former haulout areas.

During the same year (1960) that Fedoseev flew aerial surveys to delineate summer and autumn distribution, Kenyon (1960a) flew surveys during late February and early March and again in April in the eastern and northern Bering Sea. His major finding was that the Pacific walrus population was concentrated in areas south and southwest of St. Lawrence Island. Other areas of concentration were on the pack ice south of Nunivak Island, in outer Kuskokwim Bay, and in northern Bristol Bay. Kenyon (1960a) estimated the North Pacific population at 78,000 - 113,000. This is probably nearer the true population size than the estimate of 50,000 made by Fedoseev since, on the basis of the more recent work of Estes (1976), it appears that Fay (1957) and Fedoseev (1962) underestimated the number of walruses occurring along the autumn ice front in the U.S. sector, i.e. east of the International Dateline.

7. 1961-1965. In March 1962, Tikhomirov (1964, p. 278) surveyed by ship the southeastern Bering Sea, and found 10,000 - 15,000 walruses on the ice edge near Nunivak Island; "soon afterwards" he observed the "same stock" 100 miles east of the Pribilof Islands on the ice edge.

Gol'tsev (1968) counted from 47,000 to 51,000 walruses on Soviet coastal rookeries in 1964, thus establishing that there were certainly more than 50,000 walruses if the U.S. sector were taken into account. Burns (1965b) derived a minimum population estimate of 90,000 from harvest statistics.

Burns (1965b),by assessing haulout area use in the Bering Sea, provides some evidence that the population was showing a slight increase during this period, e.g., walruses were becoming more abundant on the Walrus Islands during summer haulout. Sightings of walrus herds on areas previously abandoned included Amak Island, Besboro Island, and the Punuk Islands, and individuals were observed along portions of the northwest coast of Alaska.

8. 1966-1970. Kenyon (1972) estimated the population at 73,000 - 110,000 during 1968, based on aerial surveys in April in the Bering Sea. Burns (1967) thought the population was continuing to increase in size. His conclusion is supported by increased use of former hauling grounds on Arakamchechen Island in the Bering Strait (Gol'tsev 1976).

Walrus distribution was displaced 200-300 miles north during the winter and spring of 1967 as reported by Burns (1970). The winter of 1967 was unusually warm and stormy preventing the usual southern extension of the ice front in the southern Bering Sea. Burns (1970) observed a large concentration of walrus in the Bering Strait during April and May aerial surveys. Apart from yearly variation such as occurred in 1967, data collected by Soviet researchers from 1966 to 1970 indicated a continued southern range extension (Gol'tsev 1972). Groups of walrus were sighted in Karaginskiy Gulf, and a new hauling ground on Verkhoturova Islands (59°35'N, 165°20'E) was noted, in addition to individual sightings made near Komandorskie Islands and on the ice in the Okhotsk Sea (Gol'tsev 1972).

Gol'tsev (1972) surveyed the coast of the Chukotskiy Peninsula and western Chukchi Sea during 13 September to 19 October 1970 and estimated the Pacific walrus population at 101,000. This estimate is particularly reliable since 62% of the estimate is based upon photographs of animals.

9. <u>1971-1975</u>. Kenyon (1972) flew aerial surveys over the Bering Sea 7-16 April 1972. As during his previous surveys (1960, 1961, and 1968), he observed two general areas where a large number of walruses occurred: 1) south and north of the west end of St. Lawrence Island and 2) central Bristol Bay. Within these areas, particularly near St. Lawrence Island, Kenyon identified through comparison of surveys among different days that gross fluctuations in numbers of walruses can occur on a local scale because of drifting ice. Correcting 10% upward for animals missed, Kenyon estimated about 136,000 walruses for the Bering Sea with a range of 93,000 to 178,000.

The next major effort to estimate population abundance was made by Estes (1976) and Gol'tsev (1976). As planned, the studies were highly complementary in that Estes surveyed the autumn ice front east of the International Dateline and Gol'tsev surveyed to the west. Based on data collected on 8 September, Estes derived an estimate of the number of animals in his survey area of approximately 80,000 ± 40,000, with most walrus concentrated along the ice front between 162°W and 165°W near 70°30'N. This region is approximately the same area where large numbers of walrus were observed on 16 and 23 September 1974 (unpubl. data, cooperative ADFG, NMFS, and USFWS aerial survey, on file, NMFS, Marine Mammal Division, Seattle, Wash.). Gol'tsev (1976) conducted aerial surveys from 17 September to 16 October in the Soviet sector and derived a total estimate of 128,000 to 130,000 walrus. The area surveyed included the Soviet coast from Ossola (59°10'N, 163°05'E) to Kolyuchin Island (67°29'N, 174°37'W) in the Chukchi Sea, and west over portions of pack ice to Cape Billings.

Migration of walruses south through the Bering Strait takes place from October to December (Fay 1975), so the lag of Gol'tsev's survey behind Estes' probably did not account for a significant amount of double counting, i.e., walrus moving from Estes' to Gol'tsev's survey area. Combining the results of the two studies (cf., Gol'tsev 1976; Estes and Gilbert 1978) results in an estimate of 209,000±41,000. This value is comparable to Fay's (1957) estimate of the minimum pristine stock size.

Noteworthy is evidence discussed by Gol'tsev (1976, p.2) that the walrus population continued to advance southward along the Soviet coast "striving to occupy its former habitat". In 1971 a female walrus and pup were harvested on the Soviet coast (lat. 61°20'N, long. 173°15'E); and the Ioann Bogoslof Island hauling grounds were identified as being used again during the 1975 survey. A final note of interest was an observation of approximately 13,000 walruses northwest of St. Matthew Island 8 April 1975 (Dr. Carleton Ray, Department of Pathobiology, The Johns Hopkins University, Baltimore, Maryland, pers. commun.).

In summary, the walrus population by 1975 may have reached its pre-commercial level and thus near the carrying capacity of its habitat (Interagency Task Group 1978, p. 51).

10. 1976. The remainder of this report addresses the status of the Pacific walrus population as was determined from aerial surveys conducted over the Bering and southern Chukchi Seas during the late winter and spring of 1976. For a discussion of results acquired from aerial surveys flown in 1977, refer to Braham et al. (in prep.).

STUDY AREA AND DATA SOURCES

The study area includes the Bering Sea above 56°N and the Chukchi Sea to 68°20'N. Sea ice coverage in the Chukchi Sea begins to advance south in early October from its most northerly limit near 72°N and extends southward through the Bering Strait, which is usually covered from late November through late June (Shapiro and Burns 1975). Sea ice is present winter and spring over most of the intercontinental shelf of the northern and eastern Bering Sea, and occurs infrequently in the southwest Bering Sea (Fay 1974a). Normally, the most southerly limit occurs in March or April and typically extends no further south than the 200 m depth contour from 168°W to 178°W (Burns and Harbo 1977). Occasionally sea ice may extend beyond the 500 m isobath (Fay 1974a). Figure 2 depicts sea ice coverage over the study area for the months in 1976 when surveys were made. Note that coverage in April was extensive. Since the occurrence and migration of walrus is so closely linked with the advance and retreat of the Bering-Chukchi pack ice (Burns et al. 1977), it follows that April 1976 provided an unusually good window for viewing the near maximal extent to which walrus become distributed in the Bering Sea.

By prior agreement, and as part of the US-USSR Cooperative Agreement on the Environmental Protection of Marine Mammals, the Bering Sea was divided into three regions concurrently surveyed by:

NMFS. Dr. Howard W. Braham led an aerial survey team which surveyed the eastern Bering Sea pack ice north of the ice front. Figures 3, 4, and 5 depict flight paths during which survey information used in this report was recorded. These surveys were part of OCSEAP research units 14, 67, and 69.

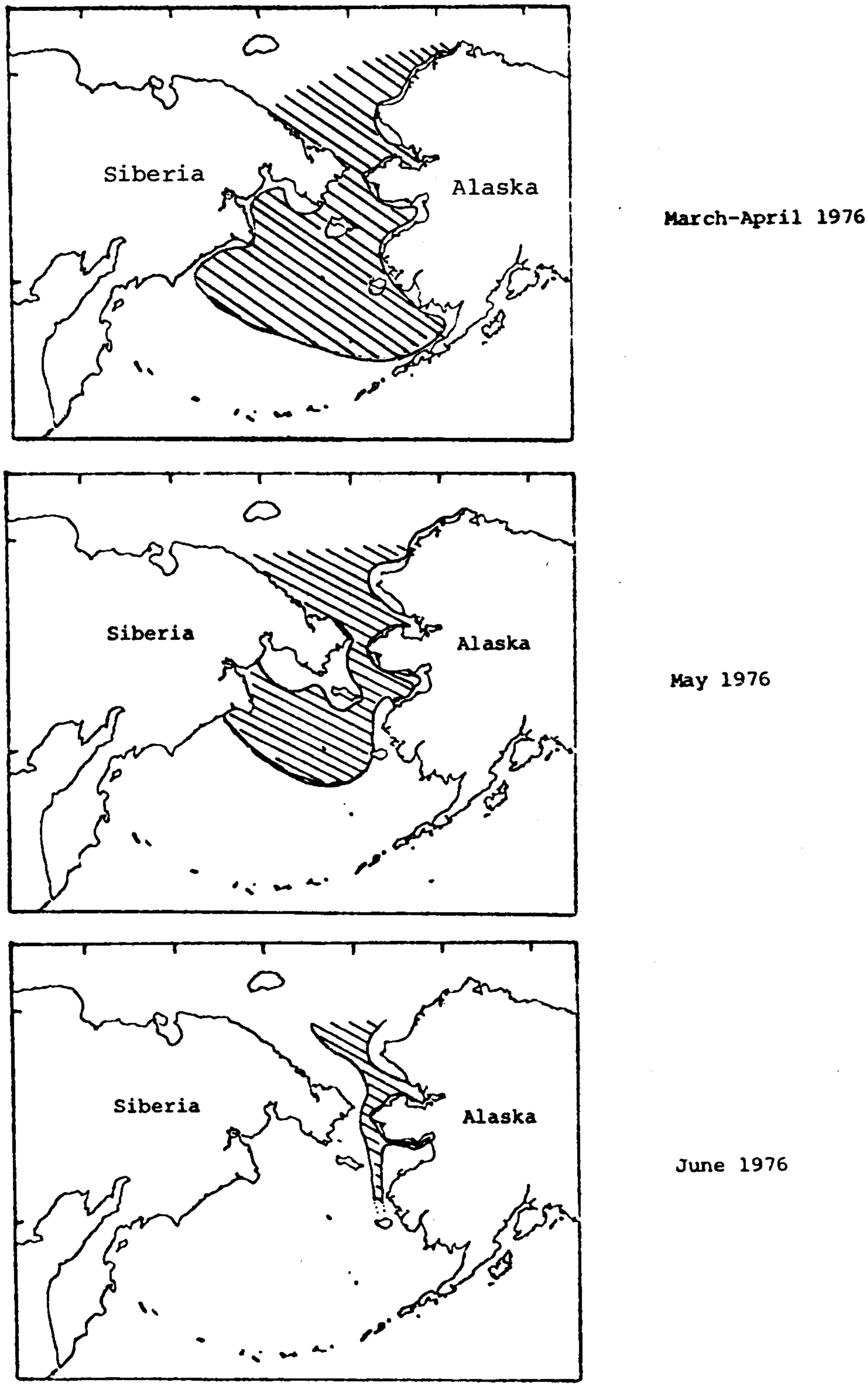

Figure 2. Pack ice conditions in the Bering and southern Chukchi Seas during NMFS aerial surveys conducted under OCSEAP research units 14, 67, and 69. Data compiled from daily field logs and NOAA satellite imagery.

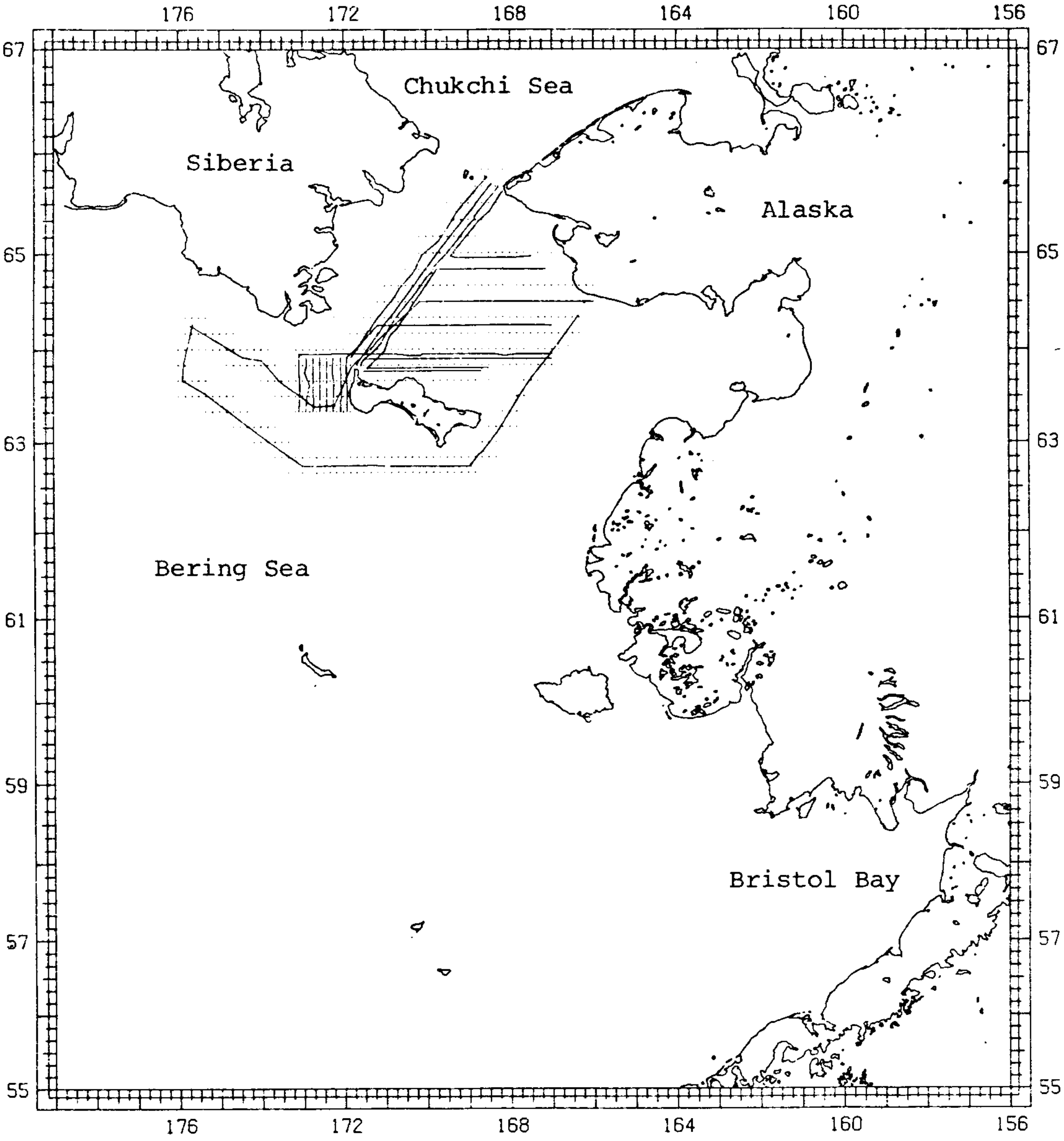

Figure 3. Computer plot of aerial survey strips flown by NMFS scientists (RUs 14, 67, and 69) on 15, 18, 19, and 21 March 1976 near St. Lawrence Island. Dots depict corners of 10 x 10 minute latitude/longitude cells that were overflown by the aircraft. Heavy pack ice covered most of the region north of St. Lawrence Island. Ice was thinner south and near the west end of the Island.

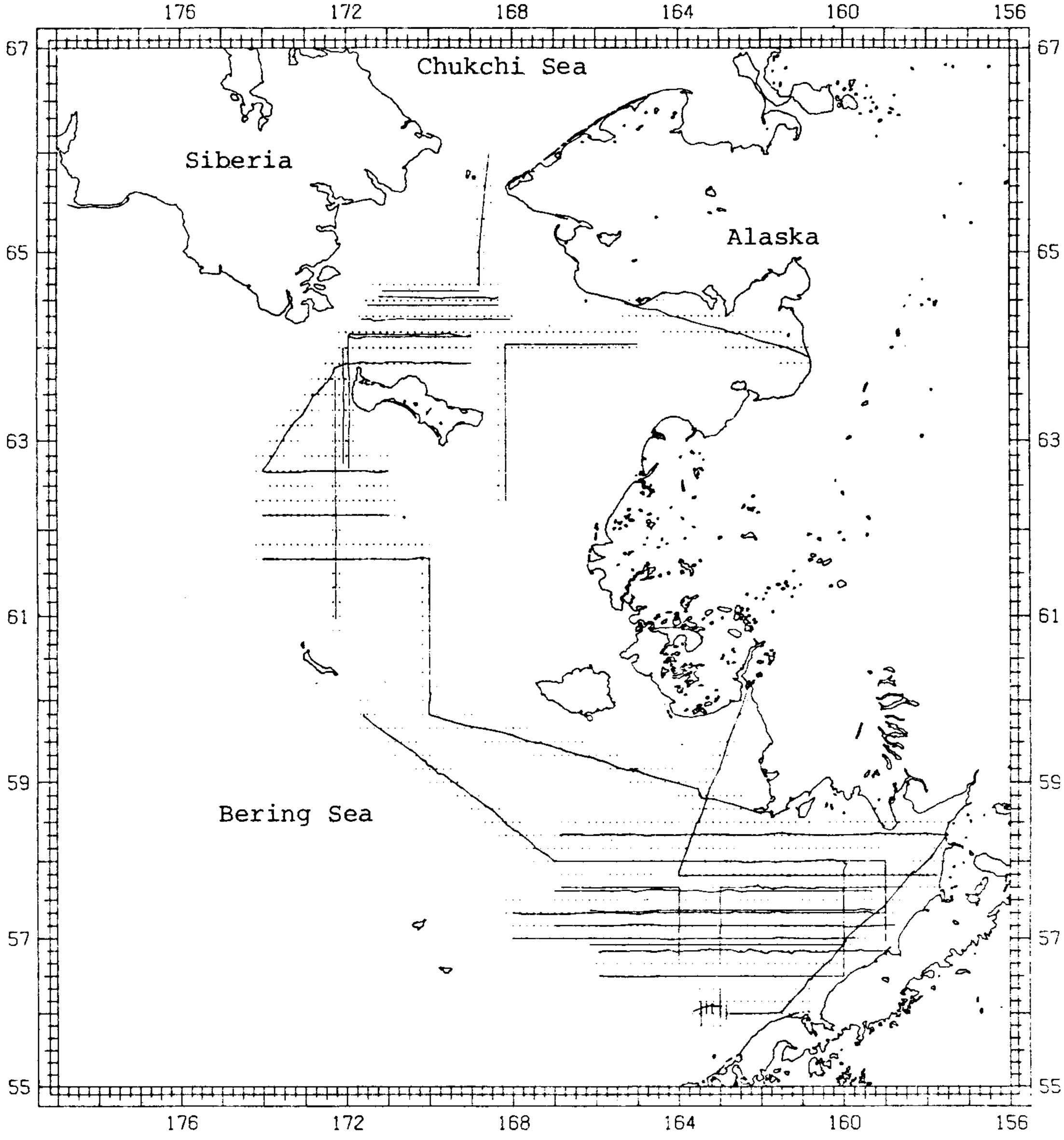

Figure 4. Computer plot of aerial survey strips flown by NMFS scientists (RUs 14, 67 and 69) on 6, 8, 9, 12, 13, 15, 17, 18, and 19 April 1976 in Bristol Bay. Strips near St. Lawrence Island were flown on 13, 15, 19, 20, 21, 22, and 23 April 1976. Dots depict corners of 10 x 10 minute latitude/longitude cells that were overflown by the aircraft. Refer to Table 1 and text for additional details.

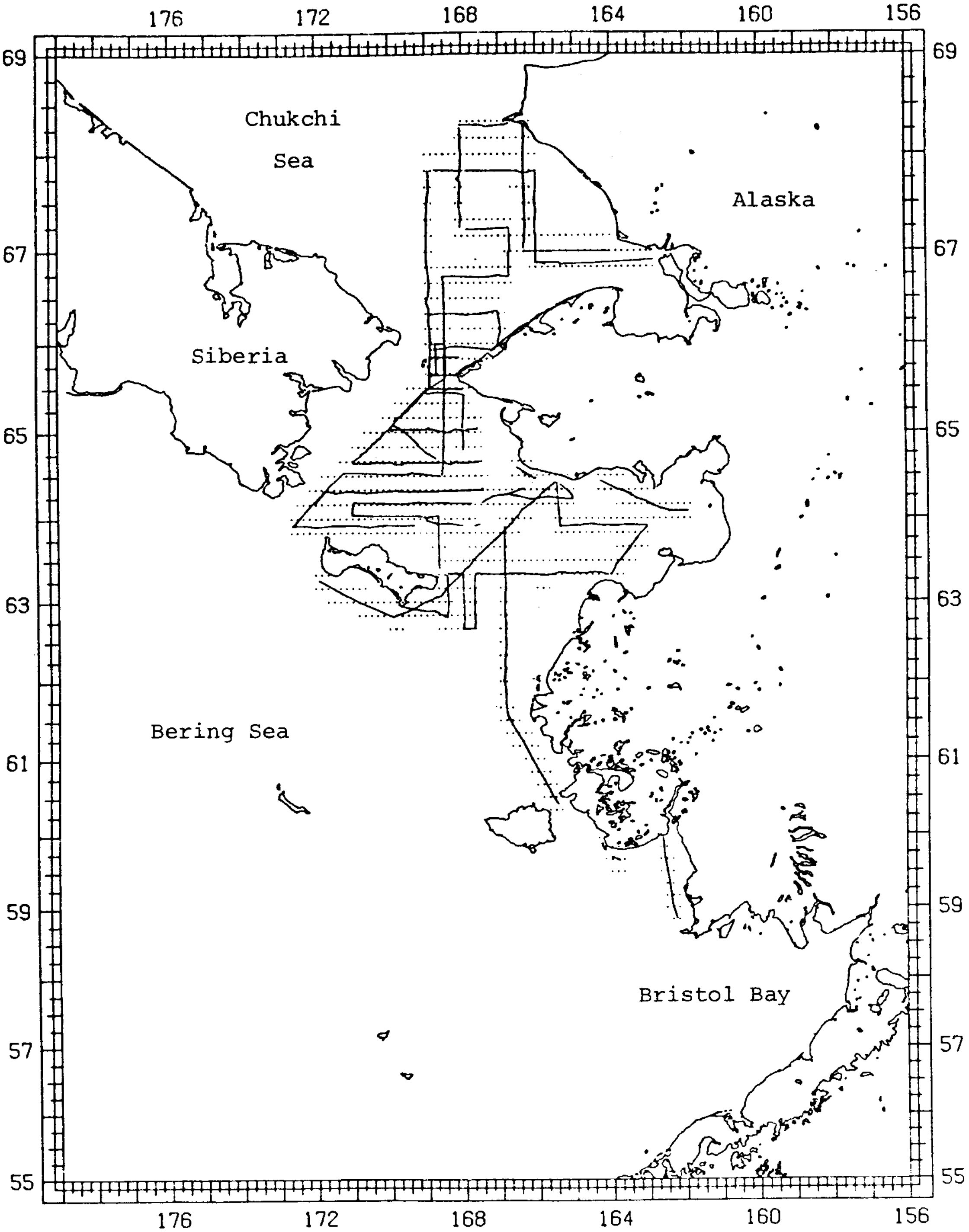

Figure 5. Computer plot of aerial survey strips flown by NMFS scientists (RUs 14, 67, and 69) 8-14 June 1976 in the northern Bering Sea and southern Chukchi Sea. Dots depict corners of 10 x 10 minute latitude/longitude cells that were overflown by the aircraft.

ADFG. John J. Burns, Alaska Department of Fish and Game, Anchorage, led an aerial survey team which flew along the ice front and west of the NMFS survey area (Figure 6). This survey was conducted as part of OCSEAP research unit 231.

U.S.S.R. Research. Dr. Genadi A. Fedoseev, Pacific Scientific Research Institute of Fisheries and Oceanography (TINRO), Magaden, led an aerial survey team which surveyed the ice front and pack ice in the western Bering Sea (Figures 7 and 8).

Raw data collected by each of these parties reside as digitized data in the Marine Mammal Division computer file library. Table 1 catalogs the NMFS raw data files used in this analysis.

MATERIALS AND METHODS

Field Procedures

The NMFS surveys were divided into three periods: 15-21 March, 6-23 April, and 8-14 June. Surveys in the northern Bering Sea were based in Nome, Alaska; surveys of the southern Bering Sea were based in King Salmon, Alaska. No surveys were conducted in May because of other research commitments.

Sample strips were chosen according to several criteria: 1) number of flight hours allocated under contract; 2) results of the previous day's survey; 3) prior knowledge of walrus high and low density areas; 4) proximity of the survey area to alternate airports; 5) objectives of other NMFS-OCSEAP research units (i.e., RUs 67, 69); 6) weather; and 7) avoidance of Soviet territory. In general, the total survey area was initially surveyed using randomly selected strips. Subsequent surveys were flown with strips chosen systematically to further delineate areas of high abundance. Once strips were scheduled, deviations did not occur except as necessitated by weather, logistics, or mechanical problems.

Strip censuses were flown in the turbo-jet powered amphibian Grumman Goose (N780) and the Lockheed P-2V (N48347). The P-2V was used only on 13 and 15 April. Both aircraft were chartered from the Office of Aircraft Services, U.S. Fish and Wildlife Service, Anchorage, Alaska. Air speed was generally 120-140 knots (kts) and survey altitudes varied between 300 and 1000 feet (ft) with most surveys flown at 500 ft. A crew of four was used for most surveys. Two observers, one recorder, and one person resting aft rotated hourly to reduce observer fatigue.

Information recorded included species identification; number of adults and/or calves; local time of sighting; geographic position to one square nautical mile (nmi) obtained from an onboard Global Navigation System (model GNS500)[1/]; perpendicular angular distance from aircraft to animal

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[1/] Reference to trade name does not imply endorsement by the National Marine Fisheries Service, NOAA.

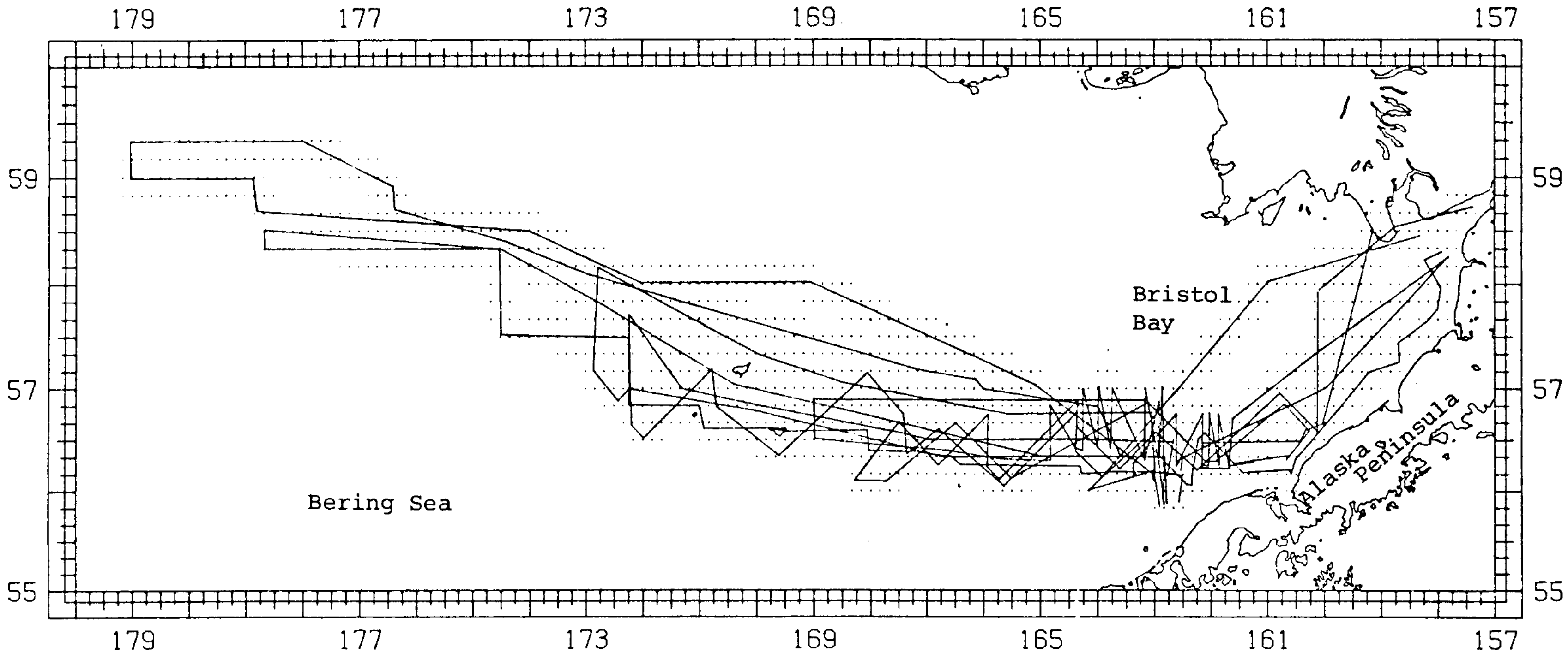

Figure 6. Computer plot of aerial survey strips flown by ADF&G scientists on 8,9,11,17,19,20, 21, and 23 April 1976 in the southern Bering Sea. Dots depict corners of 10 x 10 minute latitude/longitude cells that were overflown by the aircraft. Data were collected as part of OCSEAP RU 231 by Burns and Harbo (1977). According to their report, the southern limit of surveys marks the southern limit of the pack ice, and the northern limit of surveys approximately marks the inner margin of the ice front.

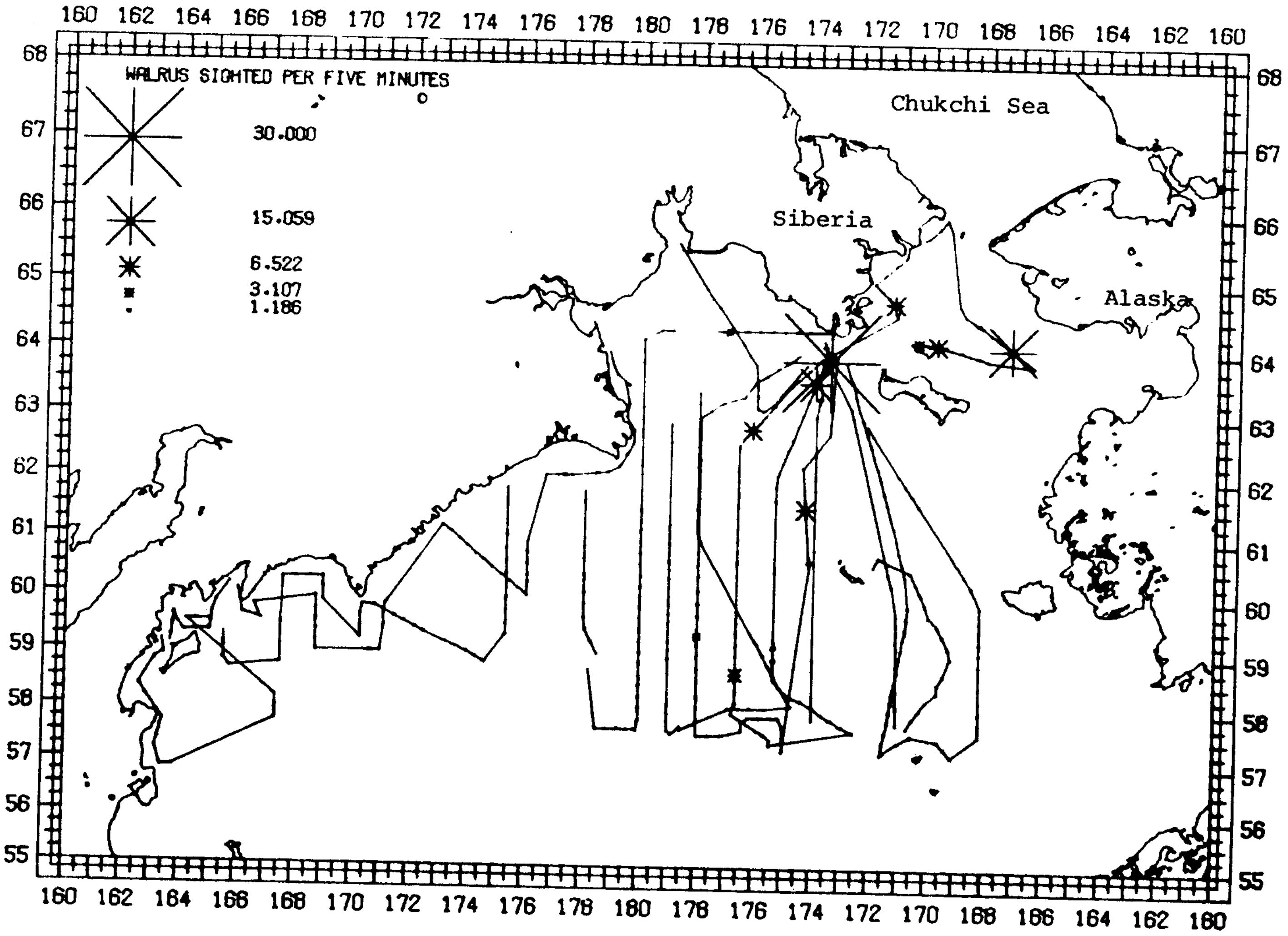

Figure 7. Computer plot of aerial survey strips flown by the Soviet scientist, G. A. Fedoseev during 12-15, 17, 18, 21-26 April 1976. Stars are centered on positions where walruses were observed, and represent the number of animals observed per five minutes of flight time. See inset legend for quantitative details.

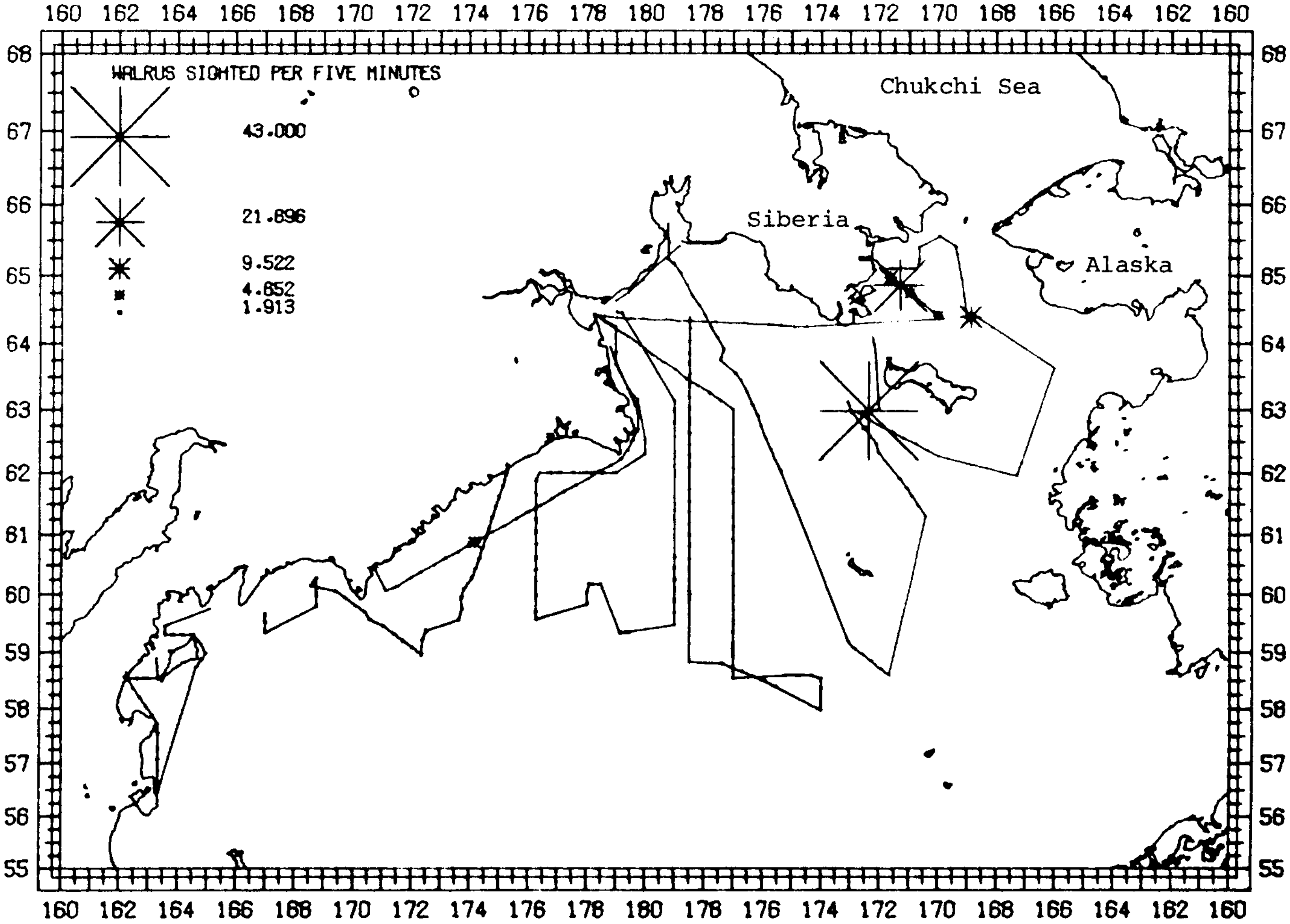

Figure 8. Computer plot of aerial survey strips flown by the Soviet scientist, G. A. Fedoseev, during 3-7, 9, 10 May 1976. Stars are centered on position where walruses were observed, and represent the number of animals observed per five minutes of flight time. See inset legend for quantitative details.

Table 1. Aerial surveys flown during 1976 as part of OCSEAP Research Unit 14. File identifiers are those used on both Environmental Data Service OCSEAP 027 format and Marine Mammal Division format. Data analysis was conducted on Marine Mammal Division formatted data.

File Identifier	Survey Date	Description (Survey Origin / Area Surveyed)
176075	15 March	Nome / St. Lawrence Is., Gulf of Anadyr
176078	18 March	Nome / St. Lawrence Is., Bering Strait
176079	19 March	Nome / N. & S.W. St. Lawrence Is.
176081	21 March	Nome / N. St. Lawrence Is.
176097	6 April	King Salmon / Bristol Bay, ice front
176099	8 April	King Salmon / Central Bristol Bay
176100	9 April	King Salmon / Bristol Bay
176103	12 April	King Salmon / Central Bristol Bay
176104	13 April	King Salmon / Bristol Bay, St. Lawrence Is.
176106	15 April	Nome / St. Lawrence Is., St. Matthew Is., Bristol Bay
176108	17 April	King Salmon / Central Bristol Bay
176109	18 April	King Salmon / Central Bristol Bay
176110	19 April	King Salmon / Bristol Bay, St Lawrence Is.
176111	20 April	Nome / St. Lawrence Is., Bering Strait
176112	21 April	Nome / St. Lawrence Is., Bering Strait
176113	22 April	Nome / St. Lawrence Is.
176114	23 April	Nome / Norton Sound
176160	8 June	Anchorage / Norton Sound
176161	9 June	Nome / St. Lawrence Is., Bering St.
176162	10 June	Nome / N. Bering Sea, S. Chukchi Sea
176163	11 June	Nome / N. Bering Sea, S. Chukchi Sea
176164	12 June	Kotzebue / Bering Strait, N. St. Lawrence Is.
176165	13 June	Nome / Norton Sound, St. Lawrence Is.
176166	14 June	Nome / Bering Strait, E. Bering Sea

taken with an optical reading clinometer (model PM-5/360 PC, made by Suunto Oy of Finland); animal activity; and environmental conditions including data on weather, visibility and ice.

Sighting distances were recorded as angles whenever possible; the angles were converted to distance in the laboratory. During periods when high concentrations of walrus were observed, sightings were called out by 1/4 statute mile (mi) sectors out to 3/4 mi on each side of the aircraft (i.e. section A = 0 - 1/4 mi; B = 1/4 - 1/2 mi; C = 1/2 - 3/4 mi; D = >3/4 mi). Sector boundaries were offset to each side of the aircraft during flights made in the Goose since observers could not see directly below the aircraft. Sector boundaries for all flights were delineated by the inclinometer. All animals observed within sectors A and B on both sides of the aircraft were used in this analysis. The strip width therefore equaled 1 mi or .868 nmi for the NMFS data. The strip width for the ADFG and Soviet data was 1 nmi.

These procedures are generally comparable to the methodology employed by Burns and Fedoseev during their aerial surveys. Burns and Harbo (1977) described in detail the methodology used by ADFG. Fedoseev's data were transmitted to Braham and Burns during meetings of the US-USSR Convention for the Environmental Protection of Marine Mammals. Details of Fedoseev's procedures are not available at this time.

Laboratory Analysis

No modifications were made to the Fedoseev data other than the usual processing to prepare the data for computer graphics. Data collected by the NMFS Marine Mammal Division and the Alaska Department of Fish and Game were treated to the following analyses.

Population abundance estimates by survey area were based on the number of walruses hauled out on ice plus those which were visible near the surface of open water. Estimates were based on post-stratification of density plots for regions of similar densities. Stratification of areas after sampling reduced the upward bias of estimates that would have resulted if the entire area had been treated as one unit.

Density regions were determined by first generating density plots from a modified density computer program which calculated the numbers of walrus sighted per minute of time for each block of 10 x 10 minutes (') of latitude-longitude from the aircraft survey. When a 10 x 10' block was overflown more than once, the densities were averaged, thus standardizing the survey effort. To quantify our stratification procedures, a stratification methodology was developed through repeated experimentation. Stratification of total areas was accomplished by the following steps:

Step 1. The density plot legend was examined and density blocks were categorized as low, medium, and high density groups (cf., Figure 9).

ǀ	1.700	low
ǁ	5.000	
ǀǀǀ	8.300	
ǀǀǀǀ	11.600	
1	14.167	medium
2	25.636	
3	42.444	
4	53.000	high

Step 2. The three density groups, starting with the high density group, were further delineated into strata. Each stratum was formed by combining adjacent blocks belonging to the same density group.

Step 3. If two strata of similar density were separated by only one dissimilar block, they were joined as one larger stratum unless that different block was contiguous with a stratum of its own density.

Step 4. Each stratum had to have been sampled by more than one strip (= n).

Step 5. Four or more adjacent low density blocks were grouped as a stratum. Empty blocks, isolated low density blocks, and adjacent low density blocks composed of three or fewer blocks were combined as a low density stratum.

Step 6. For computational reasons, no stratum was allowed to encircle another stratum.

Step 7. If a stratum covered an extensive geographical area but was narrowly constricted near its center, it was separated at the constriction to yield better resolution of density for areas "geographically separated".

The general strategy was to apply these steps sequentially until all steps were optimally satisfied.

Computer programs (Table 2) were used to calculate the area of each stratum, select the subset of data collected in each stratum, and make all necessary insertions of time and position so that total survey effort could be determined. Numerical estimates were similarly derived using computer programming.

Calculation of density and abundance estimates for each stratum was based upon Estes' and Gilbert's (1978) "Method I" :

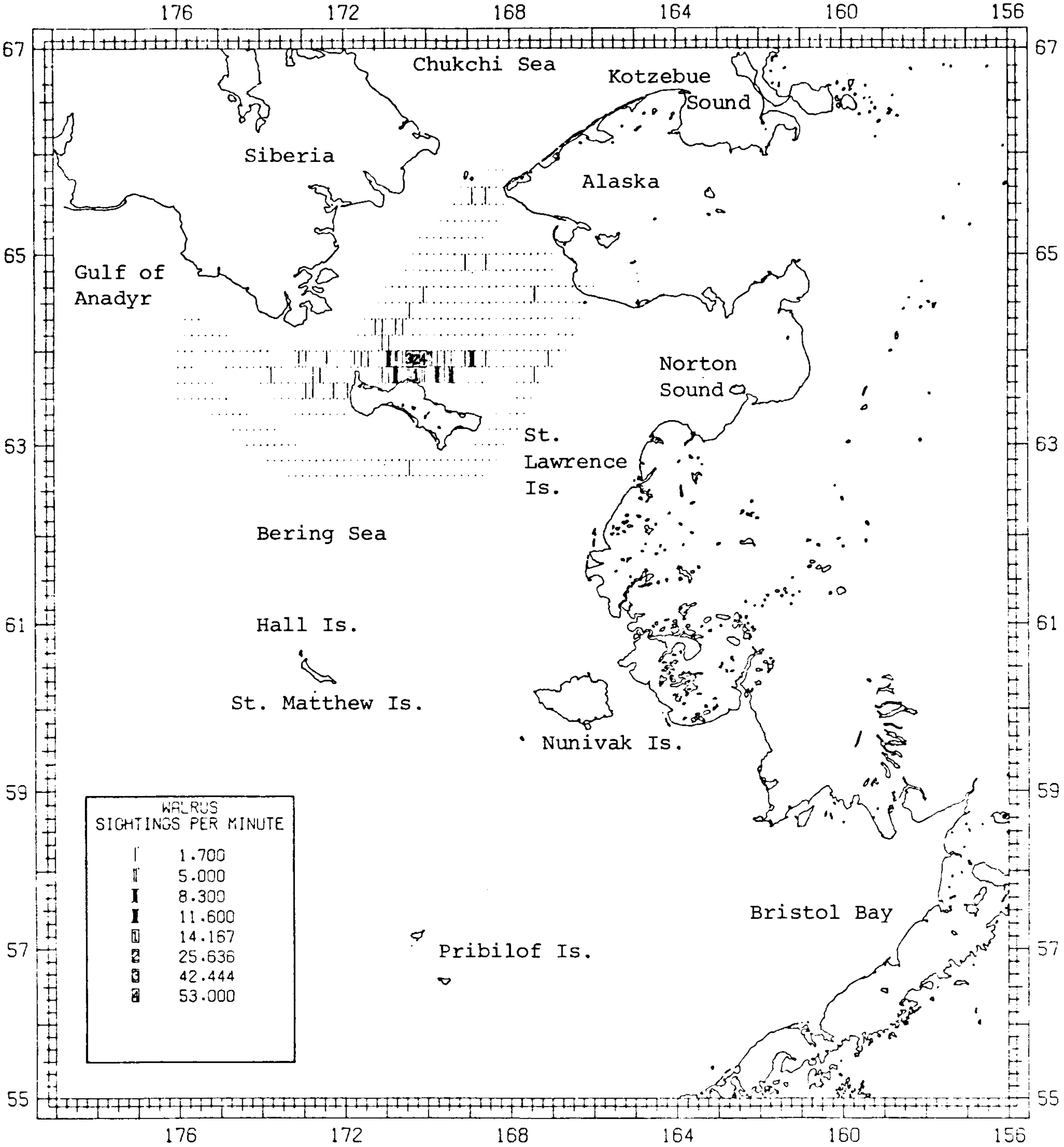

Figure 9. Map depicting walrus densities in the northern Bering Sea as sightings (= number) of animals observed per minute during the 15-21 March aerial surveys conducted by NMFS. Dots depict 10 x 10 minute latitude/longitude cells overflown by the aircraft. Empty cells equate to zero density. Densities listed in the legend are midpoints of density intervals. Cells with numbers represent density ranges falling within the upper 10% of all observed cell densities.

Table 2. Authors, computer program routines, and descriptions of routines used for major parts of data analysis in this report. Further information regarding these programs may be obtained by contacting the senior author of this report.

Program Routine	Author	Function
ABUN	B. D. Krogman	Calculates density, abundance, and related sample statistics
AMP	R. M. Sonntag	Comprehensive mapping routine used to make plots
INOUT	R. M. Sonntag	Determines whether a cartographic point is inside or outside any n-sided stratum
MAIN	A. Anschell	Calculates density as sightings per minute of time for each 10 x 10 minute latitude/longitude block overflown by aircraft
PAREA	R. M. Sonntag	Approximates area of stratum via straight line integration
POLY	R. G. Punsly	Finds intersections of flight tracts with sides of stratum and inserts time and position to preserve survey effort

(1) $\hat{R} = \Sigma y_i \; / \; \Sigma \chi_i$

where: $\hat{R}$ = density of walrus per square nautical mile

y_i = number of walrus in the ith strip

χ_i = area of the ith strip

Note that in this analysis strips containing data acquired during poor visibility (i.e. when some animals in survey strip were obscured by fog, snow, etc.) were separated as two strips with poor visibility data automatically deleted. The strips with good visibility data remained.

(2) $S^2_{\hat{R}} = \left[\Sigma (y_i^2 \; / \; \chi_i) - \hat{R} \Sigma y_i \right] \; / \; (n-1) \; (\Sigma \chi_i)$

where: $S^2_{\hat{R}}$ = variance of $\hat{R}$

n = number of strips

(3) $\hat{T}_y = \hat{R}A$

where: $\hat{T}_y$ = walrus abundance in stratum

A = total area of stratum

(4) $V(\hat{T}) = A(A - \Sigma \chi_i) S^2_{\hat{R}}$

where: $V(\hat{T})$ = variance of $\hat{T}_y$

Additional statistics presented in this report include:

(5) $\overline{G} = \Sigma y_i \; / \; \Sigma O_i$

where: $\overline{G}$ = average group size in stratum

O_i = number of observations (= groups) in the ith strip

(6) $S^2 = \Sigma (y_i - \overline{G})^2 \; / \; \Sigma O_i \; - I$

where: S^2 = group size variance

Abundance estimates with confidence intervals were made for each region we surveyed (e.g., north St. Lawrence Island and Bristol Bay). Each estimate of abundance by region is presented with a 95% confidence interval (CI), which is a measure of precision of the estimate. The confidence intervals are calculated as:

$$(7) \quad \hat{T} \pm t_{.05(2)V} \sqrt{V(\hat{T})}$$

The notation $t_{.05(2)V}$ refers to the critical value of t where alpha (α) = .05 ($1-\alpha = .95$) based upon a two tailed test with V degrees of freedom. Degrees of freedom are calculated as the total number of strips minus the number of strata.

RESULTS AND DISCUSSION

March 1976

From 15 to 21 March 1976 four aerial surveys were flown in the vicinity of St. Lawrence Island. Ice coverage in the Bering Sea for March to June is depicted in Figure 2. Winds were predominantly from the north 12-15 knots. Air temperature remained close to -12°C. Skies were usually clear.

The 15 March survey was flown north of St. Lawrence Island, west into the Gulf of Anadyr and then south and east of St. Lawrence Island (Figure 3). From this first survey, it was determined that 1) few walruses were in the immediate area south of St. Lawrence Island, as only one observation was made in that region (the ice south of St. Lawrence Island to at least 62°N appeared too thin to support walrus pods); and 2) walruses were distributed in larger numbers west and north than south of St. Lawrence Island. Further survey effort in the Gulf of Anadyr was not practical as the area was at the extreme end of the range of our aircraft.

The next three surveys (18, 19, and 21 March) were flown in the region north of St. Lawrence Island. The 18 March survey concentrated in the area from Gambell to the Bering Strait immediately parallel to the U.S.-U.S.S.R. 1867 Convention line. The pack ice became increasingly thicker north to the Bering Strait. To the west of the Convention line, north of 64°30'N, the ice appeared solid all the way to the Siberian coast. Few walruses were observed north of 65°00'N.

The 19 March survey concentrated on the near west side and just north of St. Lawrence Island. It was on this survey that a large aggregation of walruses was observed just north of the Island. The 21 March survey was flown to delineate this aggregation.

Densities of walrus were greatest just north of St. Lawrence Island and tapered off to the west and east (Figure 9).[2] The abrupt change in density north of the main herd is an artifact of the plot. No survey effort was made in the row of cells immediately north of the row of cells containing blocks numbered "2", "3", and "4". Nevertheless, the number of walruses declined rapidly north of these densities because in the next higher row of cells (63°40'N to 63°50'N) substantial survey effort resulted in near zero density estimates.

To reduce the variance of statistical estimates of population parameters, the total region of significant survey effort was bounded and stratified. Stratum numbers (Figure 10) are ranked according to observed densities of walrus with low stratum numbers depicting low densities.

Evident from Figure 10 is the extreme variation in stratum size. In general, strata with low densities tend to be large and strata with high densities tend to be small. Also, the smaller the strata the more variable the density and abundance become, because effects of animal movement become proportionally larger in magnitude as stratum size is reduced.

Stratum 1 (Figure 10), with an observed density equal to zero (Table 3), is bounded by strata of higher densities, and illustrates the extreme gregariousness of these animals. The low density of stratum 2 conforms to results from aerial surveys conducted by Kenyon (1972). Barring extraordinary ice and weather conditions, walrus density in stratum 2, particularly to the east and north, is consistently low year after year during March. The higher density in stratum 3 reflects the migration route used by walruses traveling between areas north of St. Lawrence Island and areas southwest of the Island.

The abundance estimate for this survey region around St. Lawrence Island based on post-stratified sampling is 11,185 ± 7,068 (95% CI). At the bottom of Table 3 is the estimated abundance for the total region left unstratified. This estimate, which is biased upward because of how survey strips were chosen (see methods), is presented for comparative purposes only.

The number of walrus occurring in the survey area represented a small fraction of the total population, the remainder of which was distributed southwest and south of St. Lawrence Island to the ice front and southeast of Nunivak Island into Bristol Bay. These areas were surveyed in April approximately three weeks after the March surveys. No movement of animals between areas occurred.

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[2] Caution should be exercised when reading the figure legend or when examining the density of any one cell in the survey area because when the aircraft flies through a small portion of the cell (i.e., flies over a corner of a 10x10' block) an inflation of the density estimate may result. Nevertheless, the density plots do offer an excellent overview of walrus distribution.

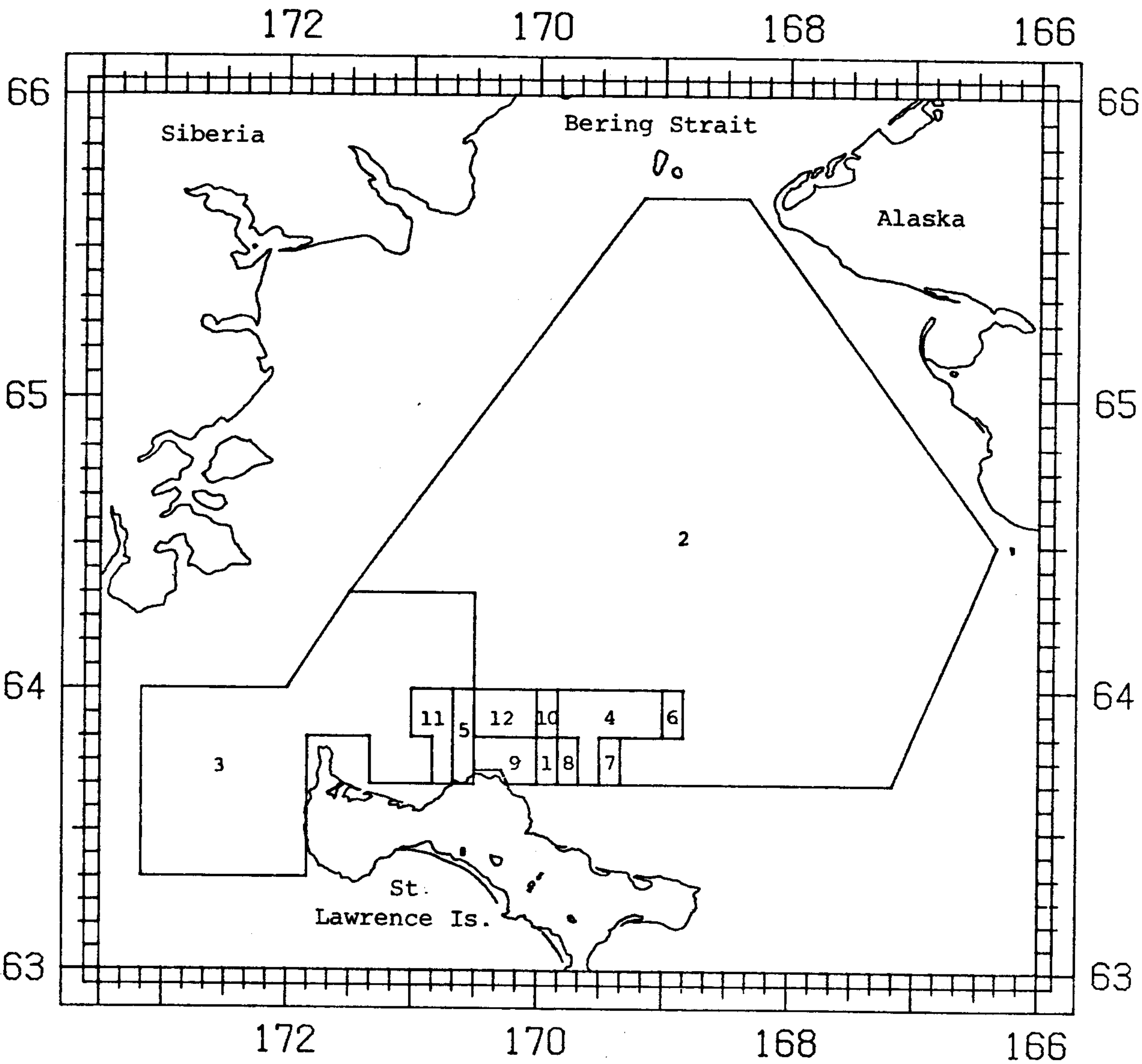

Figure 10. Map depicting the March 1976 survey in the northern Bering Sea after post-stratification of walrus densities. Statistics associated with each stratum are in Table 3. Strata with low numbers have low walrus densities, and strata with high numbers have higher densities.

Table 3. Statistics from aerial survey conducted 15-21 March 1976 near St. Lawrence Island, Alaska. Two treatments of data are presented. Post stratification of the total region resulted in an estimated total abundance of 11,185 walrus. Values for each stratum are summed where appropriate. Strata numbers refer to areas depicted in Figure 10. The second treatment of data, based upon the total region left unstratified (bottom line of table), resulted in an abundance estimate of 16,331 walrus.

Stratum	Stratum[1/] Area nm²	Percent of Area Sampled	Transects Flown (=n)	Walrus counted	Individuals Per nm²	Variance	Average Group Size	Variance	Groups Per nm²	Variance	Total	Variance (In millions)
1	44	17.37	2	0	0.0	0.0	-	-	0.0	0.0	0	0.0
2	9302	7.92	18	11	0.02	>0.00	1.11	0.01	0.01	>0.00	139	>0.00
3	2404	23.09	23	146	0.26	0.01	5.62	0.84	0.05	>0.00	632	0.05
4	264	17.39	4	39	0.85	0.21	6.50	5.12	0.13	0.01	224	0.01
5	88	17.44	4	53	3.46	2.47	7.57	2.52	0.47	0.04	304	0.02
6	44	17.39	2	51	6.68	44.57	25.50	600.25	0.26	0.07	293	0.07
7	44	17.37	2	55	7.17	44.26	18.33	250.78	0.39	0.02	317	0.07
8	44	17.37	2	58	7.56	2.43	14.50	24.42	0.52	>0.00	334	>0.00
9	113	20.31	2	185	8.04	15.68	15.42	30.90	0.52	0.01	911	0.16
10	44	17.38	2	65	8.52	72.43	32.50	56.25	0.26	0.07	374	0.12
11	132	17.39	4	211	9.20	7.88	14.07	7.61	0.65	0.04	1213	0.11
12	132	16.06	2	1035	48.93	812.40	38.33	166.65	1.28	0.06	6444	11.83
Sum of Strata	12655		67	1909							11185	12.44
Unstratified	12500	11.69	31	1909	1.31	0.24	16.75	11.40	0.08	>0.00	16331	32.53

[1/] Areas are approximated by straight line integration and thus minor discrepancies exist between summation of areas of individual strata and area calculated for total unstratified region.

April 1976

Northern Bering Sea. Seven aerial surveys were conducted in the northern Bering Sea from 13 to 23 April 1976. Most of the effort was again made north of St. Lawrence Island, but areas southwest, south and east received more effort than during the March survey. One survey (21 April) extended north all the way to Point Hope, but no walruses were observed north of the Bering Strait.

Pack ice was thick between 64°N and 65°N in the vicinity of St. Lawrence Island. South of 64°N pack ice was of medium thickness. Ice coverage at this time of year was still extensive: 70-100 percent, with 80 percent coverage being most common. Large expanses of ice with 100 percent coverage occurred northwest of St. Matthew Island.

On 13 and 15 April winds were variable from 4 to 25 knots from the north and northeast. Air temperature varied from -5 to 3°C. No flights took place 16-19 April. When the survey was resumed on 20 April, winds were from the north and varied between 6 and 25 knots. Thereafter, winds were from the north and variable, commonly between 5 and 10 knots. Air temperature from 20-23 April remained from -17°C to -13°C.

Few animals were observed in Norton Sound. The distribution of walrus near St. Lawrence Island was similar to that observed in March except that more animals were present over a wider region (Figure 11). Density cells west of St. Lawrence Island suggest that walruses were moving from outer Gulf of Anadyr and southwest of St. Lawrence Island northeasterly past Gambell toward the Bering Strait. At the very least, the substantial densities of walrus present along the west and north boundary of the survey area indicated that there were undoubtedly more walruses present to the west and north. Fedoseev's April flights substantiate this observation (Figure 7).

The estimated walrus abundance for the total northern Bering Sea region we surveyed was 25,320 ± 9,744 (95% CI) (Table 4, Figure 12).

Bristol Bay. Nine aerial surveys were flown over pack ice in Bristol Bay from 6 to 19 April 1976. The 6 April survey, in addition to surveying for ice seals under RU 67, was flown for the purpose of mapping the extreme southern extent of pack ice. The remainder of the survey sampled the central and northeastern parts of the southern Bering Sea. On two survey dates the P-2V was used, which made it possible to survey north from Bristol Bay to St. Lawrence Island (13 April) and then to survey back to Bristol Bay (15 April).

Throughout this survey period air temperatures ranged from -15°C to 5°C, but were more frequently in the -5°C to 5°C range. Winds were usually northeasterly 5-15 knots. The distribution of the pack ice during this period was extensive (Figure 2).

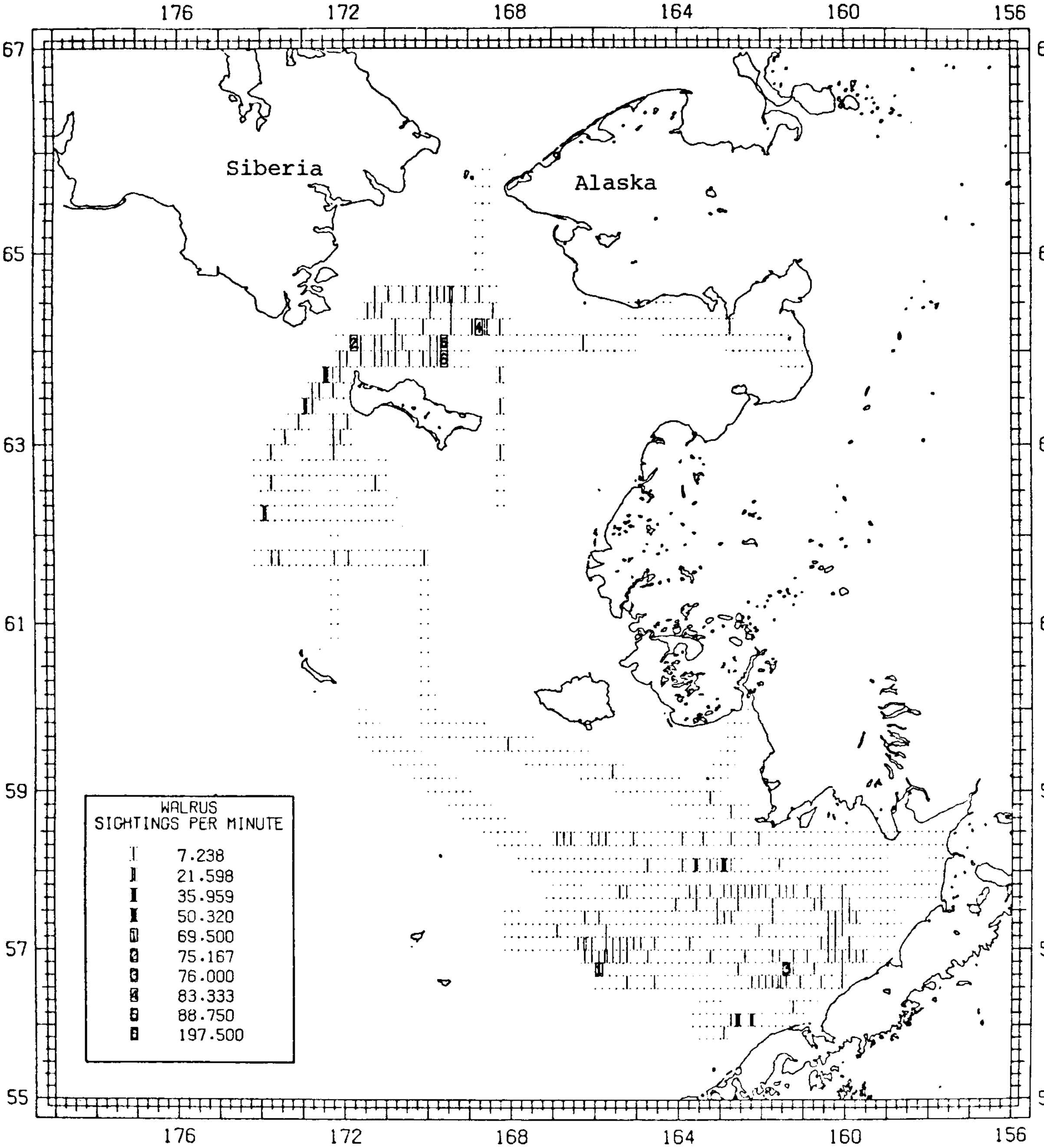

Figure 11. Map depicting walrus densities in the Bering Sea from the 6-23 April 1976 aerial surveys conducted by NMFS scientists. See Figure 4 for additional details.

Table 4. Statistics from aerial survey conducted 13-23 April 1976 near St. Lawrence Island, Alaska. Two treatments of data are presented. Post stratification of the total region resulted in an estimated total abundance of 25,320 walrus. Values for each stratum are summed where appropriate. Strata numbers refer to areas depicted in Figure 12. The second treatment of data, based upon the total region left unstratified (bottom line of table), resulted in an abundance estimate of 35,622 walrus.

Stratum	Stratum[1/] Area nm^2	Percent of Area Sampled	Transects Flown (=n)	Walrus counted	Individuals Per nm^2	Variance	Average Group Size	Variance	Groups Per nm^2	Variance	Total	Variance (In millions)
1	6683	5.00	12	32	0.10	>0.00	6.40	21.71	0.03	>0.00	641	0.12
2	394	14.57	6	12	0.21	0.01	3.00	1.83	0.07	>0.00	82	>0.00
3	315	19.28	3	66	1.09	0.59	4.13	3.03	0.26	0.03	342	0.05
4	3945	10.90	13	698	1.62	0.20	8.13	3.12	0.20	>0.00	6401	2.74
5	1343	5.44	3	267	3.66	0.82	20.54	124.92	0.18	>0.00	4908	1.40
6	133	14.63	2	254	13.09	195.59	18.14	88.27	0.72	0.45	1736	2.94
7	86	8.69	2	250	33.30	1102.89	125.00	625.00	0.27	0.07	2876	7.51
8	44	17.40	2	451	59.39	3522.23	56.37	1765.64	1.05	1.11	2592	5.54
9	87	13.06	3	750	65.69	425.86	83.33	600.00	0.79	0.07	5742	2.83
Sum of Strata	13030		46	2780							25320	23.13
Unstratified	12878	7.80	17	2780	2.77	0.60	17.94	12.05	0.15	>0.00	35622	91.96

[1/] Areas are approximated by straight line integration and thus minor discrepancies exist between summation of areas of individual strata and area calculated for total unstratified region.

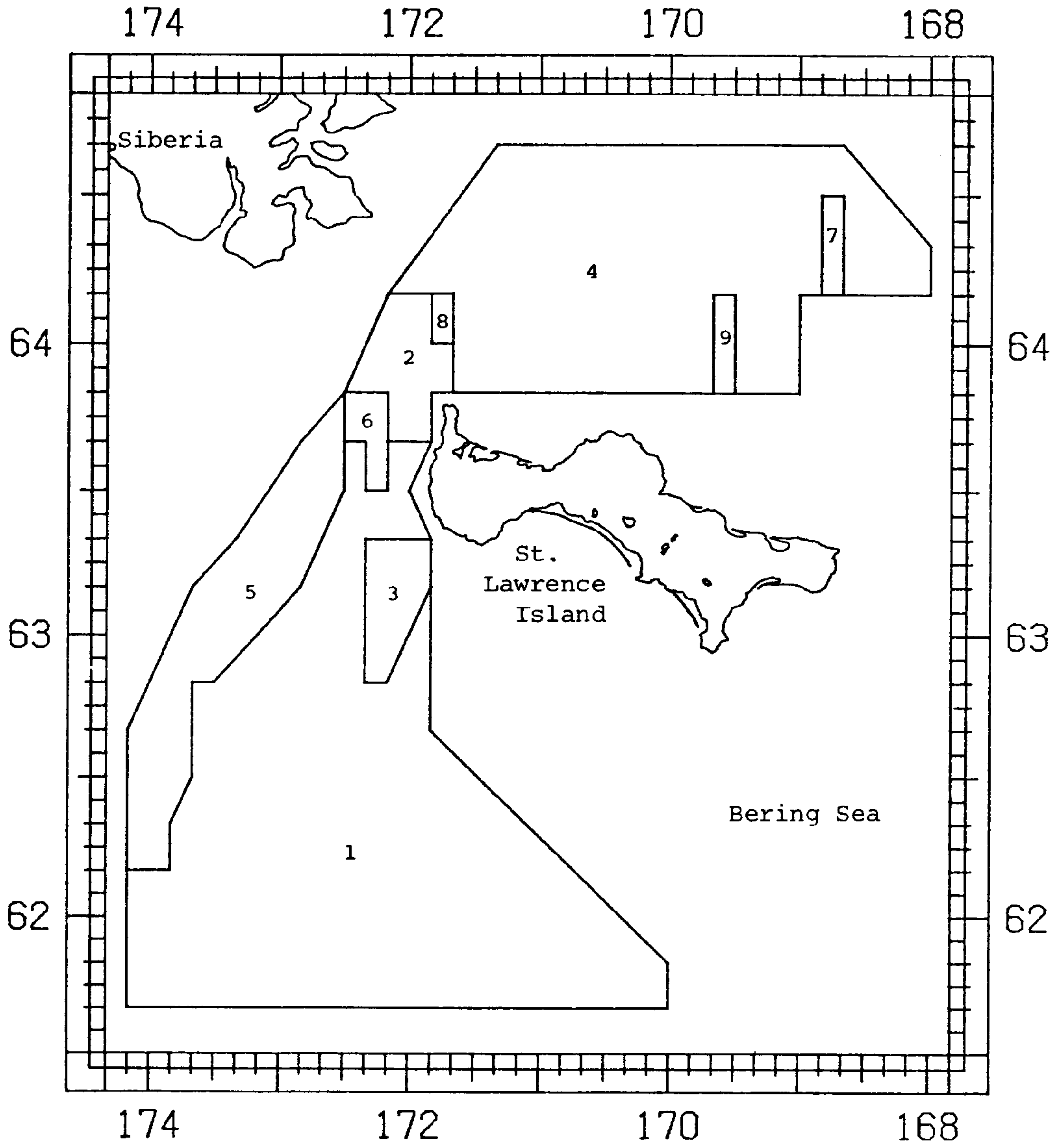

Figure 12. Map depicting the April 1976 survey area in the northern Bering Sea after post-stratification of walrus densities. Statistics associated with each stratum can be found in Table 4. Strata with low numbers have low walrus densities; strata with high numbers have high densities.

Walruses were all but absent in Bristol Bay east of 159°30'W (Figures 11 and 13), and were completely absent from Round Island. The greatest numbers of walruses occurred in mass in central Bristol Bay (depicted as strata 5, 8, 9, and 10 in Figure 14) and in an area to the west of 165°W (strata 6, 7, and 11 in Figure 14). Walruses were present in low densities west of 167°W (Figures 6 and 13). Walrus density was generally low along the ice front (Figure 13).

The estimated abundance for the total Bristol Bay region surveyed was 30,358 ± 13,933 (95% CI) (Table 5). In the region surveyed by ADFG to the west of our survey effort in outer Bristol Bay, an abundance estimate of 1,319 was calculated using their data and our estimating procedures (Figures 6 and 13).

May 1976

Flights made by Fedoseev show the presence of walrus in substantial numbers southwest and north of St. Lawrence Island (Figure 8). According to the data base transmitted to the Marine Mammal Division, a few animals were observed at approximately 60°50'N and 174°07'E. A quantitative estimate of abundance based upon Fedoseev's data was deferred until more information becomes available regarding his survey methodology.

June 1976

Seven aerial surveys (8-14 June) were flown over most of the northern Bering Sea including areas just south of St. Lawrence Island, east into Norton Sound, north through the Bering Strait and into Kotzebue Sound. Most surveys were flown north of St. Lawrence Island and through the Bering Strait. On 14 June a survey was flown south to north Bristol Bay.

Weather conditions were mild with temperatures varying from 6°C to 20°C and winds were from the northwest at 1-15 knots. The pack ice had receded considerably (Figure 2).

Walrus were observed migrating north in great numbers from Nunivak Island north through the Bering Strait (Figure 15). Animals were crowded tightly onto 10-20 m diameter floes; others were swimming in large dispersed herds as mostly pairs and singles. Most of the pairings were cows and calves. This was especially prevalent in the Bering Strait. Based on the one strip flown south of Nunivak Island, walruses were apparently absent or at least rare in the open water of Kuskokwim Bay. On Round Island in northern Bristol Bay, 8,190 walruses were photographed at 1730 on 14 June.

No walruses were observed immediately south of St. Lawrence Island, and few were observed in Norton Sound. Walruses were absent from the central portion of Kotzebue Sound, which was covered with heavy rafted pack and fast ice. A constriction of animals in the U.S. sector through the Bering

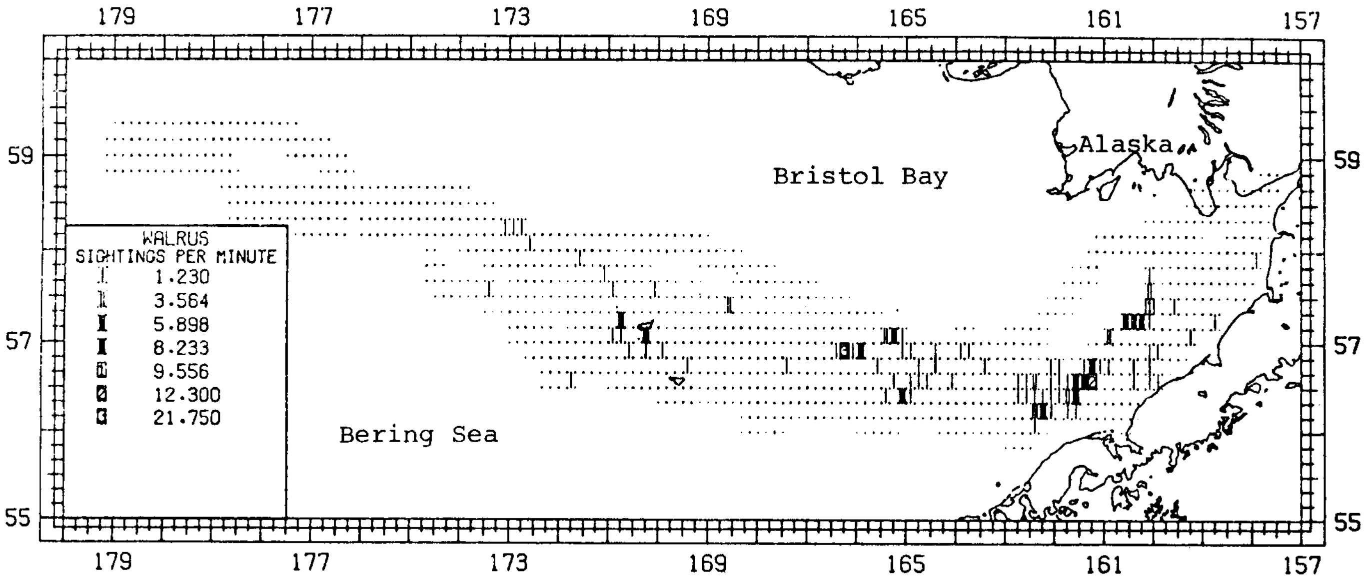

Figure 13. Map depicting walrus density in Bristol Bay from the 6-19 April 1976 aerial surveys conducted by Burns and Harbo (1977). See Figure 6 for additional details.

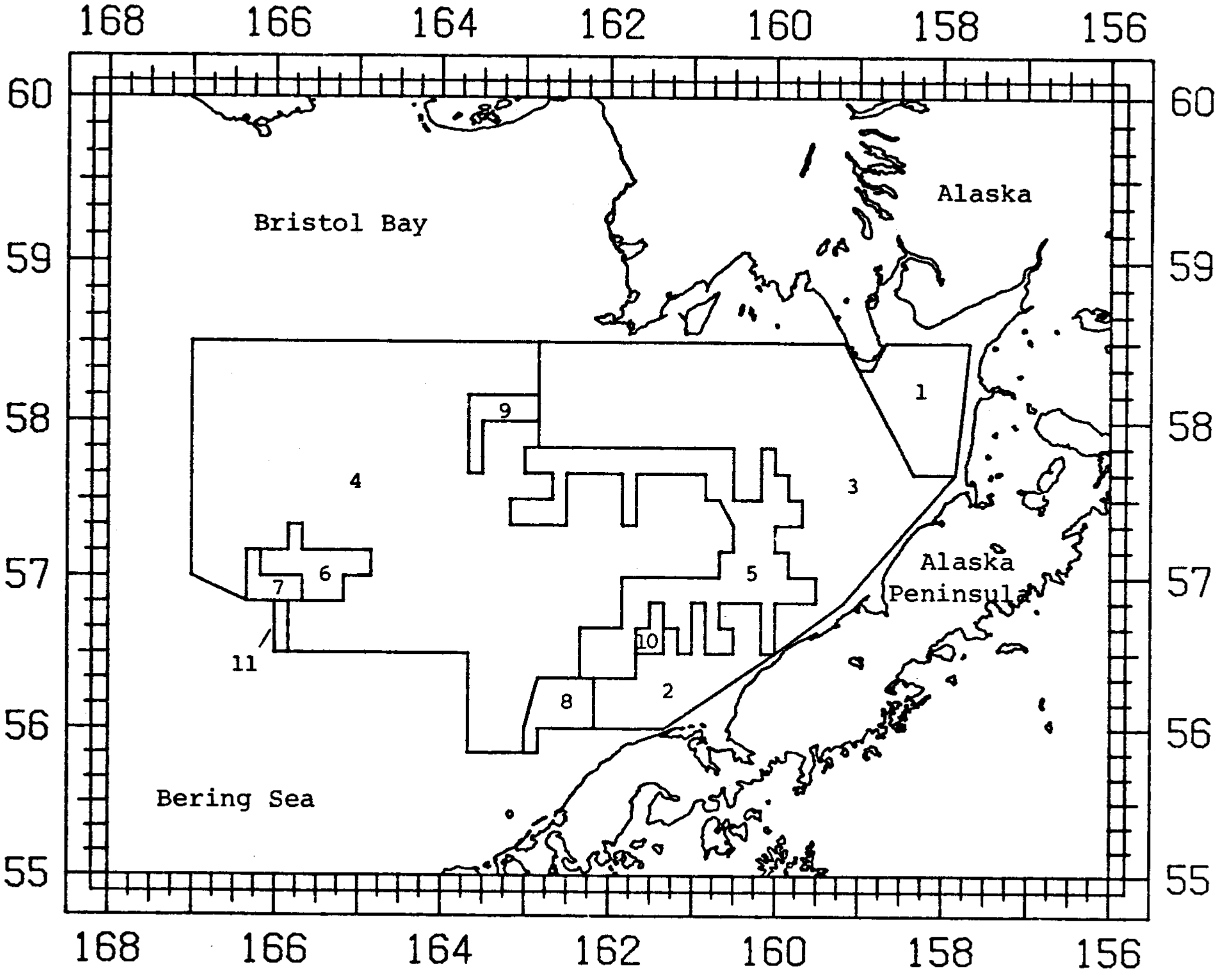

Figure 14. Map depicting the April 1976 survey area in Bristol Bay after post-stratification of walrus densities. Statistics associated with each stratum are based on surveys flown by NMFS scientists and can be found in Table 5. Strata with low numbers have low walrus densities, and strata with high numbers have higher densities.

Table 5. Statistics from aerial survey conducted 6-19 April 1976 in Bristol Bay. Two treatments of data are presented. Post stratification of the total region resulted in an estimated total abundance of 30,358 walrus. Values for each stratum are summed where appropriate. Strata numbers refer to areas depicted in Figure 14. The second treatment of data, based upon the total region left unstratified (bottom line of table), resulted in an abundance estimate of 29,014 walrus.

Stratum	Stratum[1/] Area nmi^2	Percent of Area Sampled	Transects Flown (=n)	Walrus counted	Individuals Per nmi^2	Variance	Average Group Size	Variance	Groups Per nmi^2	Variance	Total	Variance (In millions)
1	1472	5.32	3	0	0.00	0.00	-	-	0.00	0.00	0	-
2	1772	5.62	7	1	0.01	>0.00	1.00	-	> .00	-	18	>0.00
3	8037	6.27	15	13	0.03	>0.00	1.86	0.31	0.01	>0.00	207	0.00
4	18063	8.82	37	298	0.19	>0.00	5.05	1.83	0.04	>0.00	3378	1.54
5	3895	14.09	36	712	1.30	0.06	3.61	0.21	0.36	>0.00	5054	0.81
6	652	9.67	4	124	1.97	0.65	2.70	0.18	0.73	0.07	1282	0.25
7	272	6.97	2	81	4.28	13.20	4.05	1.38	1.06	2.15	1163	0.91
8	556	5.02	2	273	9.80	46.46	21.00	120.21	0.47	0.05	5441	13.64
9	370	6.22	2	302	13.12	37.72	20.13	73.20	0.65	0.05	4854	4.84
10	165	8.71	2	344	23.99	284.42	10.42	35.85	2.30	0.78	3947	7.03
11	110	5.78	2	290	45.72	1791.73	18.13	27.59	2.52	5.45	5014	20.30
Sum of Strata	35364		112	2438							30358	49.32
Unstratified	35230	8.40	32	2438	0.82	0.05	5.99	0.63	0.14	>0.00	29014	58.80

[1/] Areas are approximated by straight line integration and thus minor discrepancies exist between summation of areas of individual strata and area calculated for total unstratified region.

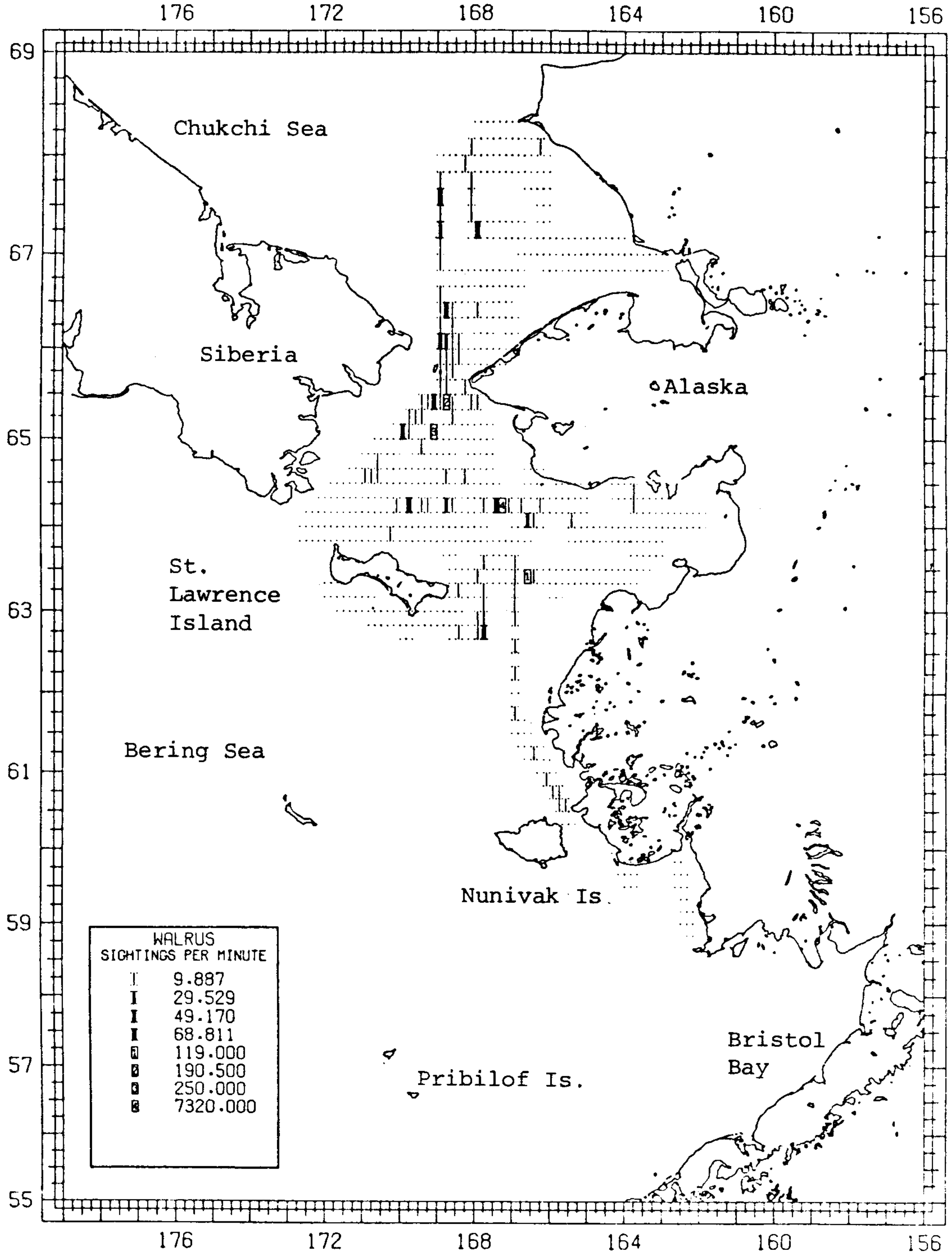

Figure 15. Density plot depicting walrus density in northern Bering Sea from the 8-14 June 1976 aerial surveys conducted by NMFS scientists. See Figure 5 for additional details.

Strait was apparent (Figure 16). Low density strata 1-4 occur to the west and east of the north-south corridor--the corridor consisting of the remaining higher density strata. Note that this corridor follows the pack ice configuration depicted in Figure 2.

An incredibly large aggregation of walrus was observed at 64°15'N and 167°11'W on 13 June at 1700 hours. Figure 15 depicts this location as the only density cell labeled with the number 4. The aggregation completely filled the first 1/4 mi width on one side of the aircraft and took several seconds to fly over, resulting in an estimate of approximately 15,000 animals. No counts were attempted beyond the first 1/4 mi width on either side of the aircraft because of the compactness of the "group". On the following day a total count of these animals was attempted by systematically covering the entire herd. A total count (by counting groups at 25, 50-100, and more than 100 per group) yielded 31,100 animals, an estimate for which no confidence interval can be ascribed.

An abundance estimate for the entire June northern Bering Sea survey area was calculated at 112,474 ± 34,719 (95% CI)(Table 6). Several more thousand walrus certainly were present south of this region (Figure 15) in addition to 8,190 counted on Round Island. Also several more thousand walruses may have occurred west and north of our survey area north of the Bering Strait. Six to eight thousand more were probably present in the Gulf of Anadyr, there to remain throughout the autumn-winter period (Gol'tsev 1976). These results of our June survey compare favorably with the derived estimate of 209,000 ± 41,000 based on our combination of results of Gol'tsev (1976) and Estes and Gilbert (1978).

Biases and Estimate Confidence

Results of this study have not been corrected for the biases we intuitively know to be present but which we have not yet quantitatively described, i.e., effects due to observer performance; aircraft size, sound and altitude; and weather. For example, our own laboratory studies suggest that observers accurately enumerate walruses in pod sizes consisting of 15 animals or fewer. For larger pods, observers estimated 61% ± 11% (95% CI) of the total. Kenyon (1960a) felt that estimates of the total for large groups were 75% to 90% of the true value, and later Kenyon (1972) applied a 10% upward correction to his estimates. Wartzok and Ray (1976), on the other hand, indicate that observers may tend to overestimate group sizes of walrus. These contradictory results illustrate the need for further research into aerial survey methodology, perhaps emphasizing photography and/or remote sensing techniques.

From a comparison of data collected from the three research parties contributing data for this report, it appears that aircraft type (e.g. Lockheed P-2V versus Grumman Goose) has a significant effect on either response of animals to aircraft or observer performance, and probably both. Burns and Harbo (1977, p. 9) state "The winter and spring of 1976 was a period of prolonged north winds, lower than normal temperatures (especially

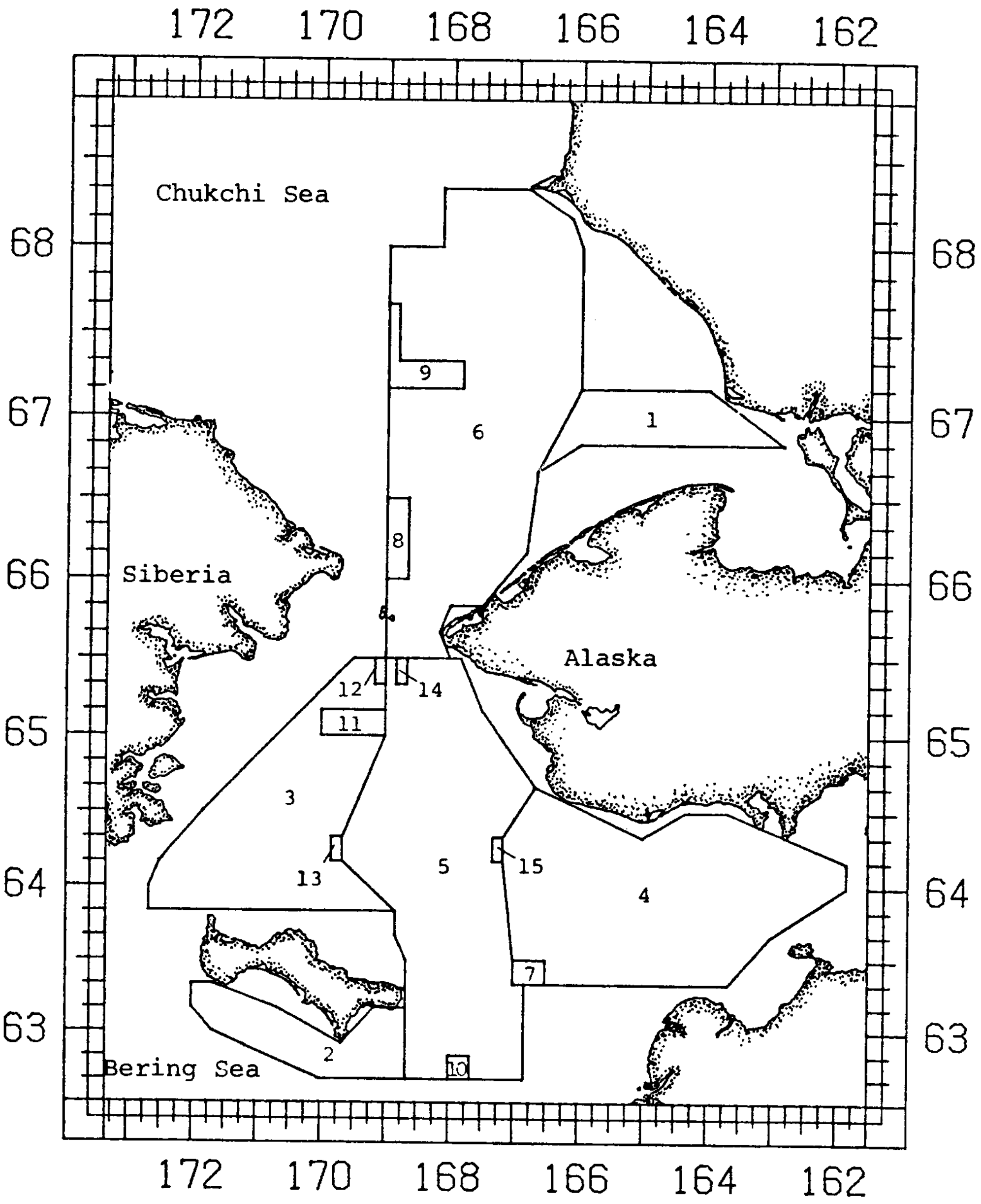

Figure 16. Map depicting the June 1976 survey area in the northern Bering and southern Chukchi Seas after post-stratification of walrus densities. Statistics associated with each stratum are in Table 6. Strata with low numbers have low walrus densities; those with high numbers have higher densities.

Table 6. Statistics from aerial survey conducted 8-14 June 1976, northern Bering and southern Chukchi Seas. Two treatments of data are presented. Post stratification of the total region resulted in an estimated total abundance of 112,474 walrus. Values for each stratum are summed where appropriate. Strata numbers refer to areas depicted in Figure 14. The second treatment of data, based upon the total region left unstratified (bottom line of table), resulted in an abundance estimate of 327,942 walrus. See text for further explanation.

Stratum	Stratum[1/] Area nmi^2	Percent of Area Sampled	Transects Flown (=n)	Walrus counted[2/]	Individuals Per nmi^2	Variance	Average Group Size	Variance	Groups Per nmi^2	Variance	Total	Variance (In millions)
1	1365	8.69	3	0	0.00	0.00	-	-	0.00	0.00	0	0.00
2	1953	5.46	3	0	0.00	0.00	-	-	0.00	0.00	0	0.00
3	5024	8.25	14	50	0.12	0.01	1.61	0.04	0.08	>0.00	606	0.12
4	7804	4.87	12	83	0.22	0.01	4.88	8.12	0.05	>0.00	1703	0.82
5	8304	6.98	28	784	1.35	1.02	10.32	6.57	0.13	>0.00	11228	64.89
6	8364	7.49	28	2503	3.99	2.88	12.45	37.22	0.32	0.01	33401	186.36
7	134	15.20	2	240	11.78	101.78	26.67	353.64	0.44	0.08	1579	1.54
8	240	20.99	4	723	14.33	61.87	14.18	19.72	1.01	0.12	3445	2.83
9	345	8.92	3	593	19.30	28.86	4.94	3.00	3.91	1.24	6652	3.12
10	91	19.02	2	430	24.72	613.42	107.50	1639.58	0.23	0.05	2261	4.15
11	252	17.47	5	1875	42.52	311.29	46.88	618.08	0.97	0.09	10732	16.36
12	42	39.24	4	917	56.26	2390.28	31.62	57.39	1.78	0.57	2337	2.51
13	43	17.40	2	530	70.22	4952.26	21.20	7.35	3.31	11.02	3046	7.70
14	42	17.38	2	762	105.55	11104.88	127.00	6500.20	0.83	0.69	4384	15.83
15[2/]	43	100.00	-	31100	723.26	-	161.98	37395.82	4.47	-	31100	-
Sum of Strata	34046		112	40590[3/]							112474	306.23
Unstratified	32668	7.36	64	24151	10.04	55.31	36.93	33.09	0.27	>0.00	327942	54679.08

[1/] Areas are approximated by straight line integration and thus minor discrepancies exist between summation of areas of individual strata and area calculated for total unstratified region.

[2/] Statistics in stratum 15 are based upon a total count as opposed to strip sampling.

[3/] Includes total count from stratum 15 as opposed to strip sample count which is used in unstratified estimate.

in April)..." which suggests severe wind chill factors during the period of survey. Gol'tsev (1968) associated a temperature drop from -3° to -12°C with a rapid departure of walrus from haulout areas into the water. Fay and Ray (1968) field observations suggested walrus avoid cold temperatures especially during high winds. Quite possibly during our study significant numbers of walrus were in the water on some days because of weather conditions. If this were the case, many walrus would go uncounted based upon our strip width (Estes and Gilbert 1978). Possible sources of bias relating to diving and feeding cycles deserve field study since they 1) can be identified with proper research designs, and 2) may contribute to errors in the population estimate which would disguise any real changes.

Addressing other sources of variability, stratification of survey areas resulted in a 62%, 75%, and 16% decrease in variance of the total abundance estimate for the March and April surveys when compared to the same estimates based upon unstratified sampling. A comparison of the June stratified versus unstratified estimates would not be completely fair because of the treatment of a stratum in Figure 16 as a total count, thus resulting in zero variance for that stratum. Confidence intervals for March and April surveys are ±63%, ±38%, and ±46% of the estimates of total abundance which are still uncomfortably imprecise. We feel, however, that more precision could be achieved through survey design modification which would sample areas proportional to density. The walrus population was extremely clumped in all survey regions from March through June. When one or more walrus was observed, more were likely to be immediately encountered. One survey technique to accommodate this distribution would be to fly systematic strips separated by 10 miles. When large numbers of walrus are encountered, the aggregation could be further delineated by adding strips 5 miles apart. Survey regions would then be post-stratified as in this study.

Aerial survey conducted from March through June is currently the best method for delineating walrus distribution in the Bering Sea. Surveys intended to monitor changes in total abundance should be flown only in the September-October period, even though weather conditions are generally poor, because 1) the population is most confined to the receded ice front and Siberian haulout areas and, 2) using photography, aerial survey technology is most effective in enumerating animals on haulout areas.

SUMMARY AND CONCLUSIONS

Following abatement of the intense commercial exploitation during the late nineteenth century, the range of the Pacific walrus population has expanded southerly to include much of its former range. Based on the combined 1975 aerial survey results from Estes and Gilbert (1978) and Gol'tsev (1976) the walrus population is estimated at 209,000 ± 41,000 which is believed to be at or near the carrying capacity of the environment.

Probably 40 percent of the walrus population is distributed along the ice front in the U.S. sector of the Chukchi Sea from July to September as far north as 72°N with the greatest number of animals occurring in the area from 161°W to 166°W. The remainder of the population is distributed east along the ice front and on haulout areas in the U.S.S.R. A small proportion of the population, mostly males, remains near haulout areas the northern Gulf of Anadyr and in northern Bristol Bay.

From October to December a southward migration of the Pacific walrus population occurs from the Chukchi Sea through the Bering Strait and into the Bering Sea. Walruses pass across the outer Kotzebue Basin as the ice front advances south. Much of the population reaches the St. Lawrence Island vicinity as early as late October and most of the population arrives by late December. During its southward movement through the Bering Strait large aggregations of walrus occur on haulout areas in the Soviet sector, and on King Island and Punuk Islands, but not along the Alaskan coast.

From December to March of 1976 a large proportion of the population was distributed in the St. Lawrence Island vicinity--mainly to the west, but more southwest and north than has occurred in the recent past. Instead of occurring in the area just southwest of St. Lawrence Island, walrus were observed north of St. Lawrence Island, and were distributed further south toward St. Matthew Island. Repeated sightings of walrus north of St. Lawrence Island during April substantiate that a large proportion of the population is beginning to deplete its food resource in the traditional wintering areas and is shifting to less preferred habitats (i.e., in terms of ice type) where the food resource is less depressed. Results of our survey are consistent with this hypothesis, though other factors, particularly weather patterns, could have accounted for walrus remaining north of St. Lawrence Island during 1976.

Few walrus occur in the inner Gulf of Anadyr, Norton Sound, or in the area north of Nunivak Island. In this southern part of the range, south of Nunivak Island, densities of walrus are lower along the ice front than in the pack ice and are lower in northeastern Bristol Bay and west of Bristol Bay.

During the April to July period most of the population moves northward from Bristol Bay and south of St. Lawrence Island through the Bering Strait into the Chukchi Sea. The highest proportion of calves during the year occurs during this period in the northern Bering Sea from outer Norton Sound to the Bering Strait.

In the July to September period, probably 40 percent of the walrus population is distributed along the ice front in the U.S. sector to as far north as 72°N, with the greatest number of animals occurring in the area from 161°W to 166°W. The remainder of the population is distributed east along the ice front and on haulout areas in the U.S.S.R. A small proportion remains near haulout areas in the northern Gulf of Anadyr and in northern Bristol Bay.

Associated with oil lease site development will be increased barge, tanker, and aircraft traffic. It is unlikely that the walrus population will decline as a direct result of disturbance from these activities, particularly if operation guidelines are developed to avoid harassment of animals. If major disturbance occurs, it will probably result from interference with the food resource (Fay et al. 1977), particularly in wintering areas where reproductive functions take place and where food resources are least available (Burns et al. 1977; Stoker, Fay, and Shults in prep.).

ACKNOWLEDGEMENTS

John Burns, Alaska Department of Fish and Game, and Dr. Genadi Fedoseev, Pacific Scientific Research Institute of Fisheries and Oceanography (TINRO), Magaden, U.S.S.R., are gratefully acknowledged for their cooperation, demonstrated by allowing us to analyze their raw data for use in this report. We also thank Dr. James Estes, U.S. Fish and Wildlife Service, and Dr. Francis Fay, Institute of Marine Science, University of Alaska, for their suggestions and discussion during the initial stages of the research. While in Nome we received invaluable assistance from Carl Grauvogel and Ed Muktoyuk, and in King Salmon from Jim Faro and Nick Steen, all with the Alaska Department of Fish and Game.

Aircraft logistics were provided by the Office of Aircraft Services, U.S. Fish and Wildlife Service, Anchorage, Alaska. We sincerely appreciate the interest and efforts of Tom Belleau, Lou Caulkett, Dotty Herd, Janice Frank, Herman Ruess, and John Sasso of that agency.

Robert Everitt participated in all phases of research, particularly the design and execution of aerial surveys, and is thanked for his significant contribution to this research. Other Marine Mammal Division personnel who were instrumental during field work and laboratory workup of data and manuscript preparation include: Teresa Bray, Clifford Fiscus, Leola Hietala, Patrick McGuire, Mary Nerini, Keith Parker, David Rugh, Nancy Severinghaus, and David Withrow.

Donald Day, Rod Swope, and George Lapiene, NOAA's OCSEAP Project Office, Juneau, Alaska, helped us immeasurably during the initial stages of our program development and during the period of report preparation.

Appreciation is extended to Dr. Douglas G. Chapman, University of Washington, Seattle, and to Dr. Michael F. Tillman, Marine Mammal Division, for statistical consultation.

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ASSESSMENT OF THE DISTRIBUTION AND ABUNDANCE OF SEA OTTERS ALONG THE KENAI PENINSULA, KAMISHAK BAY AND THE KODIAK ARCHIPELAGO

by

Karl B. Schneider
Alaska Department of Fish and Game

Final Report
Outer Continental Shelf Environmental Assessment Program
Research Unit 240

January 1977

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I. Abstract

Sea otters are the most vulnerable of all marine mammals to the effects of environmental oil spills. Many populations have not recovered from the period of excessive exploitation during the 18th and 19th centuries. Relatively small oil spills could not only kill large numbers of sea otters but could virtually eliminate small isolated populations or retard range expansion into unpopulated former sea otter habitat. Outer Continental Shelf development currently poses the most significant threat to the complete recovery of sea otters. As sea otters may be a "keystone" species, altered sea otter abundance could have a profound effect on the structure of nearshore communities.

The current distribution and relative abundance of sea otters along the Kenai Peninsula, Kamishak Bay and the Kodiak Archipelago were determined through aerial and boat surveys and miscellaneous observations. These data were compared to previously existing information to determine the history of population growth, present status, probable future trends and to identify critical areas.

The outer Kenai Peninsula coast was repopulated in the 1960's. Most of the available habitat south and east of Port Graham is presently occupied and range expansion into Kachemak Bay and lower Cook Inlet is occurring. Another population has occupied Kamishak Bay for many years and has recently expanded its range southwestward along the Alaska Peninsula. Both of these populations currently occupy, and are expanding into, habitat that lies within or adjacent to the proposed lower Cook Inlet OCS lease area. There is a potential for oil spills to kill large

numbers of sea otters and perhaps seriously retard repopulation of former sea otter habitat in lower Cook Inlet.

The Barren Islands were completely repopulated by sea otters in the 1950's. Although this population may have played a major role in repopulation of the Kenai Peninsula in the 1960's it does not appear to be contributing significantly to the repopulation process at this time. Most of the population occupies a small area and could be vulnerable to relatively small oil spills or other localized impacts.

A remnant population of sea otters survived north of Shuyak Island. This group has increased in numbers and is rapidly expanding its range around both sides of Afognak Island. This expansion is expected to continue until all of Kodiak Island is repopulated. Although this population is likely large enough to survive even major oil spills, repopulation of Kodiak could be seriously retarded by OCS related activities.

Another population of unknown size inhabits the extensive area of shallow water between the southwestern end of Kodiak Island and Chirikof Island. The potential for growth of this population appears high, however, much of its habitat lies within the proposed western Gulf of Alaska OCS lease area. More information on the status of this population is needed.

Several other populations outside of the study area appear threatened by proposed OCS development and should be studied in greater detail.

II. Introduction

Sea otters were reduced to very low numbers by commercial hunting between 1742 and 1911. A number of small nuclear populations did survive, however, and many have steadily grown and expanded their ranges. For the past 20 years the pattern of repopulation of former sea otter habitat has been monitored by the U. S. Fish and Wildlife Service and the Alaska Department of Fish and Game through a series of surveys (Lensink 1960, Kenyon 1969, Schneider unpublished data). In recent years survey techniques have been refined to permit more realistic estimates of abundance, although we are still unable to census sea otters with a high degree of confidence over large areas (Schneider 1971, Estes and Smith 1973).

Most of the repopulation studies focused on the Aleutian Islands where rapid range expansion was taking place. Through a combination of extensive aerial surveys and intensive boat and shore counts it was possible to assess the status and trends of sea otter populations, identify critical areas, predict patterns of range expansion and evaluate the impacts both natural and unnatural catastrophic events.

Sea otter populations in the Gulf of Alaska have generally been smaller and less attention has been devoted to them. The status of these populations has been monitored through a haphazard series of fragmentary surveys and reported sightings. Calkins et al. (1975) summarized most of the pertinent available data. Even though the basic distribution of sea otters was known and some rough estimates of abundance had been made

(A.D.F.& G. 1973) it was clear that the basis for assessment of changes in distribution and abundance was poor.

Concern for the potential effects of the Trans-Alaska oil pipeline terminal, the proposed Trans-Alaska gas pipeline terminal and associated tanker traffic on marine mammals in general and sea otters in particular caused scientists to turn their attention to the Prince William Sound area. The Alaska Department of Fish and Game conducted two helicopter surveys (Pitcher 1975) and cooperated with the U. S. Fish and Wildlife Service in a supportive boat survey. The U. S. Fish and Wildlife Service then initiated more intensive studies adjacent to tanker routes and terminal sites. Proposals for expanded human activities in the marine environment, particularly those associated with OCS development, have increased the need to update information on sea otter distribution and abundance in other areas.

Sea otters are probably the most vulnerable of all marine mammals to the direct effects of oil. Unlike most marine mammals they have no thick blubber layer. They rely on air trapped in their dense fur for conservation of body heat and buoyancy. When clean, this mat of fur is waterproof and the skin over most of the body remains dry. If the fur is soiled it loses its water repellency and insulative qualities. If this is not corrected quickly the animal will die of hypothermia. Although little information is available on the quantities and types of petroleum products necessary to kill a sea otter, it appears that relatively small amounts of both refined fuels and crude oil will cause death (Kenyon 1971

Schneider unpublished data). Kenyon (1969) cited cases where massive kills may have occurred near shipwrecks.

Long-term effects of chronic pollution on all high trophic-level species are possible if one or more of the links in the food chain are affected. Sea otters require very large quantities of food (20 to 25 percent of their own body weight per day) to support their high metabolic rate. The main factor limiting most sea otter populations appears to be food availability.

Sea otters in most areas appear to be relatively sedentary and feed on relatively sessile organisms. Therefore they may be exceptionally sensitive to changes in the food chain and any such effects would tend to be site specific..

All of the sea otter populations bordering the Gulf of Alaska are still recovering from the period of commercial exploitation, and are expanding their range into unpopulated or sparsely populated habitat. The range of some of these populations is extremely limited. Very localized effects of human activity could endanger some of these populations and seriously retard the process of repopulation of former sea otter habitat.

Sea otters exert a profound influence on nearshore plant and animal communities and have been described as a keystone species (Faro 1969, Estes and Palmisano 1974, and others). A knowledge of the history of sea otter occupancy of an area is necessary for studies of changes in those communities.

The objectives of this project were to map the present range of sea otters around the Kenai Peninsula, Kamishak Bay and the Kodiak Archipelago; to determine the relative abundance of sea otters throughout their present range; to determine recent patterns of change in distribution and abundance providing a basis for predicting future changes; and to identify areas critical to the survival and continued growth of sea otter populations. It is anticipated that this information will be useful for making decisions on the regulation of human activities in the marine environment so as to minimize adverse impacts on sea otters. The information should also be useful to ecologists studying changes in nearshore communities.

III. Current State of Knowledge

Calkins et al. (1975) provided the most up to date summary of available information on sea otter distribution and abundance in the study areas prior to the initiation of this project. The following discussion is adapted from that report.

Kenai Peninsula

Prior to 1967, only scattered observations of sea otters had been reported from Cape Puget to Port Graham on the Kenai Peninsula. Lensink (1960) reported a sighting of 15 animals near Elizabeth Island in 1953, and Kenyon (1969) felt that no significant population of otters occupied the area by the mid-1960's. In 1967 large numbers of otters began to be sighted regularly on the southern tip of the Kenai Peninsula in the area from Koyoktolik Bay to Chugach Bay. On a 1968 survey of this area 400 otters were seen. The apparent movement of large numbers of otters to the southern tip of the Kenai Peninsula, probably from the Barren Islands, and subsequent expansion up the southeast side of the Kenai Peninsula probably occurred in the years 1966 to 1968. At the same time, otters from Prince William Sound probably contributed to the repopulation of the area east of Gore Point.

Our most recent information from surveys conducted in 1970 confirmed there were concentrations of otters on the tip of the Kenai Peninsula with scattered groups along the coast to Cape Puget (Table 1). It is important to realize that data presented in Table 1 originated from a series of surveys conducted by different observers under varying conditions from various fixed-wing aircraft. The large variability between surveys renders them useless for comparative purposes. This information should only be used to indicate the presence of animals and can in no way be extrapolated to give total numbers. Reports from the public in the early 1970's indicated that up to 200 otters were regularly seen in Port Graham and that small numbers were straying into Kachemak Bay. Sightings from north of Kachemak Bay as far as Ninilchik were increasing.

Kamishak Bay

The Kamishak Bay area including Augustine Island, Shaw Island and Cape Douglas has been partially surveyed on numerous occasions. Lensink (1962) reported that approximately 50 otters were seen near Augustine Island in 1948 and that Spencer counted 40 at Augustine Island and one

Table 1. SEA OTTERS COUNTED ON AERIAL SURVEYS OF KENAI PENINSULA
June, 1970 - January, 1971

AREA	JUNE 5 & 9	JULY 15-20	AUG. 14	OCT. 12	NOV. 12	JAN. 12
C. Junken-C. Resurrection	5	30	42	27	10	30
Resurrection Bay	2	2	0	4	2	NS
Aialik Bay	1	20	5	8	0	21
Harris Bay	8	18	7	5	3	* 25
Nuka Bay	106	56	NS	31	28	27
Port Dick	0	11	NS	NS	3	23
Rocky Bay-Port Chatham	121	125	NS	NS	9	26
Koyuktolik Bay-Port Graham	0	0	NS	NS	0	NS
Total	243	262	54	75	55	152

* 38 Sea otters counted from shore and skiff 11/20/70.
NS = No sightings

at Shaw Island in 1957. Lensink counted 52 on Augustine in 1959, but he considered it a poor count. In 1965 Kenyon counted 18 around Augustine Island and 101 in the Shaw Island-Cape Douglas area. In 1969 Alaska Department of Fish and Game biologists tallied 62 and 130 animals in the Augustine Island area on different counts. In 1971 Alaska Department of Fish and Game biologists counted 150 otters between Augustine Island and Tignagvik Point. Also in 1971 Prasil (1971) counted 60 otters between Augustine and Shaw Islands. A 1970 survey by Schneider indicated that this population had expanded its range southwestward to the vicinity of Shakun Island. Prasil (1971) subsequently counted up to 443 sea otters around the Shakun Island and 92 at Douglas Reef on a series of aerial surveys made in 1970 and 1971.

Kodiak Archipelago

Sea otter habitat in the Barren Islands is separated from that in the rest of the Kodiak Archipelago by approximately 15 km of deep water. This probably limits movements between the island groups. Sea otter sightings in the Barren Islands date back to 1931, when two otters were seen near Sud Island. Otters have been observed regularly in the Barren Islands since then. The highest count prior to 1970 was 325 animals seen in 1957 (Lensink 1960). Kenyon (1969) reported seeing 272 otters in the Barren Islands during a 1959 survey and estimated a population of 363 animals.

In June 1970 Schneider flew as the only observer in a Grumman Goose during a survey of the Barren Islands. Offshore coverage was poor although conditions and visibility were good and a complete count of the Barren Islands was made with a total count of 307.

Portions of the Kodiak-Shuyak-Afognak area, including the Trinity Islands and Chirikof Island, contain good sea otter habitat. Kodiak was an important hunting area during the period of Russian exploitation, but the population was never completely extirpated.

Reports from the Kodiak area are fragmentary and incomplete; no complete surveys have been attempted. We knew that a relatively large population has existed for many years at the north end of the group and a population of unknown size occurred at the south end.

In 1948 Refuge Manager Beals reported three otters off Shuyak Island and in 1951 Chapados and Spencer saw 15 on Sea Otter Island and 67 at Latax Rocks (Lensink 1960). In 1957 Lensink saw 14 in the Trinity Islands and 281 around the Shuyak area. In 1964 E. Klinkhart counted 63 sea otters at Latax rocks, 13 at Seal Island and one at Marmot Island.

Sightings at areas other than the north and south ends included five sighted by James Faro at Uyak Bay and three near the south end of Chirikof sighted by the crew of the MV "Teal." Occasional individuals were reported from Marmot and Chiniak Bays.

The most recent survey information came from Schneider (1970, unpub. report) who saw 18 between Ban Island and Shuyak Strait, 6 in Pernosa Bay, 3 at Marmot Island, 121 in the area of Sea Otter Island, 33 on the west side of Shuyak Island and 26 in the area of Latax Rocks and Dark Island for a total of 207. On a separate flight six were seen midway between Tugidak and Chirikof Islands. Reports of small numbers and the incidence of beached, dead animals on Tugidak Island indicated that at least moderate number occur there.

Reports since 1970 suggested that range expansion was occurring along both sides of Afognak Island. B. Ballanger sighted 15 south of Marmot Strait and 10 at Outlet Cape in 1975 and reported an increase in sightings near the town of Kodiak. Lensink (1960) estimated the total sea otter population of the Kodiak Archipelago including the Barren Islands at 800-1,500, while Kenyon (1969) indicated that the Kodiak area had not been repopulated to a significant degree with a total estimate of 1,118 otters. Based on more recent information ADF&G (1973) estimated the population at 4,000 sea otters.

IV. Study Area

The study area included the shoreline, all offshore rocks and islets and floating glacial and sea ice pans and adjacent waters less than 80 m in depth in the following areas.

1. The Kenai Peninsula from Cape Puget to the mouth of the Kenai River including the Chugach Islands.

2. The west side of lower Cook Inlet from Tuxedni Bay to Cape Douglas including Augustine Island.

3. The entire Kodiak Archipelago including the Barren Islands, Shuyak Island, Afognak Island, Marmot Island, Kodiak Island, the Trinity Islands and Chirikof Island.

V. Methods of Data Collection

Between 1 October and 7 October 1975 a helicopter survey was made of the Kenai Peninsula and the northern part of the Kodiak Archipelago. A Bell 206B "Jet Ranger" II helicopter (N90217) was flown along the survey trackline at altitudes of 50 to 70 m and an average airspeed of 70 knots (130 km/hr). Both altitude and airspeed were varied according to counting conditions. A forward observer sat in the left front seat and counted animals directly in front and to the left of the helicopter, an offshore observer sat in the right rear seat and counted on the right side, and a recorder sat in the left rear seat and recorded all observations and photographed concentrations of marine mammals. Both the pilot and recorder assisted the observers by pointing out animals. Personnel were Vernon Lofstedt - pilot, Karl Schneider - forward observer, Donald Calkins - recorder, Warren Ballard - right observer on the Kenai P Peninsula, and Kenneth Pitcher - right observer on Afognak Island. This survey required a total of 38.4 hours of flying time including 25.1 hours of actual survey time.

Sea otters were counted visually. Large pods of sea otters were photographed and the number of individuals was determined from projected 35mm slides.

Between 3 February and 11 February 1976 counts of sea otters were made from skiffs along portions of the Kodiak Archipelago. Three observers jointly counted numbers of pups and numbers of adults as the skiff paralleled the shoreline and circled offshore rocks. Binoculars were used to aid counts offshore and to identify pups.

Sightings and partial counts of sea otters were made on the following aerial surveys of sea lions conducted under RU #243.

12 March - 14 March 1976 - covering portions of the Kenai Peninsula and Kodiak Archipelago.

20 May 1976 - covering portions of the Barren Islands.

8 June - 10 June 1976 - covering portions of the Kenai Peninsula, Barren Islands and the Kodiak Archipelago.

The trackline on these surveys normally covered only small portions of sea otter habitat. The observer placement in the aircraft was such that few sea otters could be seen from the left side of the aircraft. Therefore, the number of sea otters counted was generally low.

The trackline was modified to cover selected areas of sea otter habitat more thoroughly when survey conditions were suitable. Emphasis was placed on the fringes of expanding populations and areas that had not been surveyed previously.

The scientific party included:

Karl Schneider - Alaska Department Fish and Game -
Principal Investigator and observer 12 - 14 March,
20 May, 8 - 10 June 1976.

Donald Calkins - Alaska Department Fish and Game -
Principal Investigator RU #243 and observer 12 - 14 March,
20 May, 8 - 10 June 1976.

Charles Irvine - Alaska Department Fish and Game -
Observer - recorder 12 - 14 March 1976.

Roger Aulabaugh - Alaska Department Fish and Game -
Observer - recorder 8 - 10 June 1976.

A Grumman Super Widgeon flown by Ken Bunch was used on all of these surveys.

On 1 April, 1976 a systematic survey of Kamishak Bay and portions of Kachemak Bay was made from a Grumman Turbo Goose.

Tracklines were flown over open water in shallow areas believed to support sea otters. The aircraft was flown along east and west tracklines spaced 2 minutes of longitude apart. Navigation was aided by The Global Navigation System (GNS 500). One observer counted sea otters out of each side of the aircraft. A limited track width was not used as the objective of the survey was to determine distribution and relative abundance rather than to estimate numbers. The effective track width for individual animals was probably no more than 400 m, however.

Survey conditions which influence the sightability of sea otters were classified on all of the above surveys according to the following system.

<u>Code</u>

1 <u>Excellent</u> - surface of water calm, usually a high overcast sky with no sun glare. Sea otters appear dark against a uniformly light gray background of the water's surface. Individuals easily distinguished at a distance.

2 <u>Very good</u> - may be light ripple on water's surface or slightly uneven lighting but still relatively easy to distinguish individuals at a distance.

3 <u>Good</u> - may be light chop, some sun glare or shadows. Individuals at a distance may be difficult to distinguish but individuals nearby and small groups at a distance are readily identified.

4 <u>Fair</u> - usually choppy waves and strong sun glare or dark shadows in part of the survey track. Individuals in kelp beds, in the lee of rocks, or near the observer and most pods readily identified but most individuals and some pods in areas of poor lighting or at a distance difficult to distinguish.

5 Poor - individuals difficult to distinguish unless very close and some pods at a distance may be missed, however, conditions still good enough to give a very rough impression of the distribution of animals.

6 Unacceptable - heavy chop with many whitecaps, lighting poor or large waves breaking on rocks. No surveys should be conducted under these conditions but occasionally a sighting of significance may be made in the course of other activities.

Conditions may vary within a single count area. Therefore, the classification may represent the average conditions encountered.

Tracklines of all the above surveys are presented in the RESULTS section of this report.

Significant sightings made by other biologists from both federal and state agencies were collected. Those made by personnel working on RU #3/4, 229 and 243 were particularly useful.

Pertinent information on past distribution and abundance was extracted from the literature and Alaska Department of Fish and Game files.

VI. Results

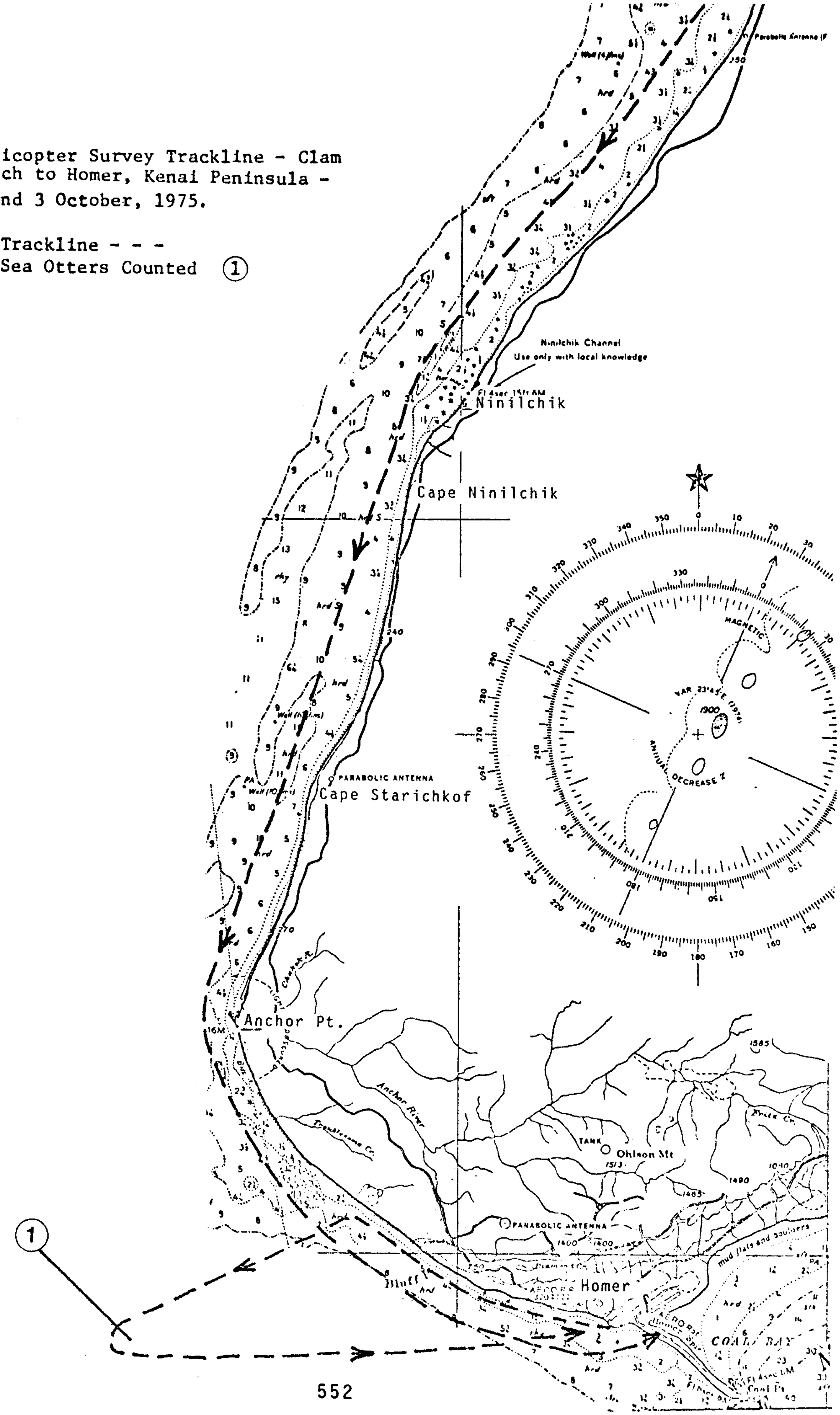
Results of the October helicopter survey are presented in Table 2 and Figs. 1-6, the February boat survey in Table 3 and Figs. 7-8, the March

Table 2. Results of helicopter sea otter survey of portions of the Kenai Peninsula and the Kodiak Archipelago, 1-7 October 1975.

Area	Date	Sea Otters Counted	Survey Conditions	Completeness of Coverage
Kenai Peninsula				
Kenai-Clam Gulch	10/1/75	0	Fair	Incomplete
Clam Gulch-Ninilchik	"	0	"	"
Ninilchik-Anchor Pt.	"	0	"	"
Anchor Pt-Coal Pt.	"	0	"	"
Coal Bay	"	0	Very Good	Complete
Bear Cove	"	5	Good	"
Halibut Cove	"	1	"	"
Tutka-Sadie	"	1	"	"
Seldovia	"	4	"	"
Port Graham	"	16	Fair	"
Port Chatham	"	54	Poor	"
Chugach Bay	10/2/75	66	"	"
Rocky Bay	"	90	Fair	"
Port Dick	"	15	"	"
Nuka Passage	"	32	"	"
West Nuka	"	20	Poor	Incomplete
McCarty Arm	Not Surveyed			
East Arm Nuka	10/3-4/75	26	Poor	Incomplete
Pye Reef-Two Arm	10/4/75	1	"	Complete
Harris Bay	"	92	Very Good	"
Aialik Bay	"	36	"	"
Resurrection Bay	10/4-5/75	29	Fair	Incomplete
Day Harbor	10/5/75	13	"	Complete
Whidbey-Johnstone	"	15	"	"
Puget Bay	"	25	Good	"
Kodiak Archipelago				
Ouzinki	10/6/75	0	Poor	Incomplete
Afognak Bay	"	6	Fair	"
Kazakof Bay	"	0	Poor	"
Duck Bay	"	1	"	"
Izhut Bay (West)	"	1	"	"
Izhut Bay (East)	"	0	"	"
King Cove	10/7/75	16	Fair	"
Marmot I.	"	529	"	Complete
Tonki Cape	"	134	Good	"
Tonki Bay	"	32	"	"
Seal Bay (East)	"	164	"	"
Seal Bay (West)	"	342	"	"
Perenosa Bay (South)	"	290	Excellent	"
Perenosa Bay (North)	"	58	"	"
Shuyak (East)	"	10	Good	"
Sea Otter I.	"	156	Fair	Incomplete
Point Banks	"	9	Very Good	Complete
Shuyak (North)	"	14	"	Incomplete
Latax Rocks	"	59	"	Complete
Shuyak (West)	"	12	"	Incomplete
Shuyak Strait	"	2	"	"
Bluefox Bay	"	81	"	"
Foul Bay	"	61	"	"

Fig. 1 Helicopter Survey Trackline - Clam Gulch to Homer, Kenai Peninsula - 1 and 3 October, 1975.

Trackline - - -
Sea Otters Counted ①



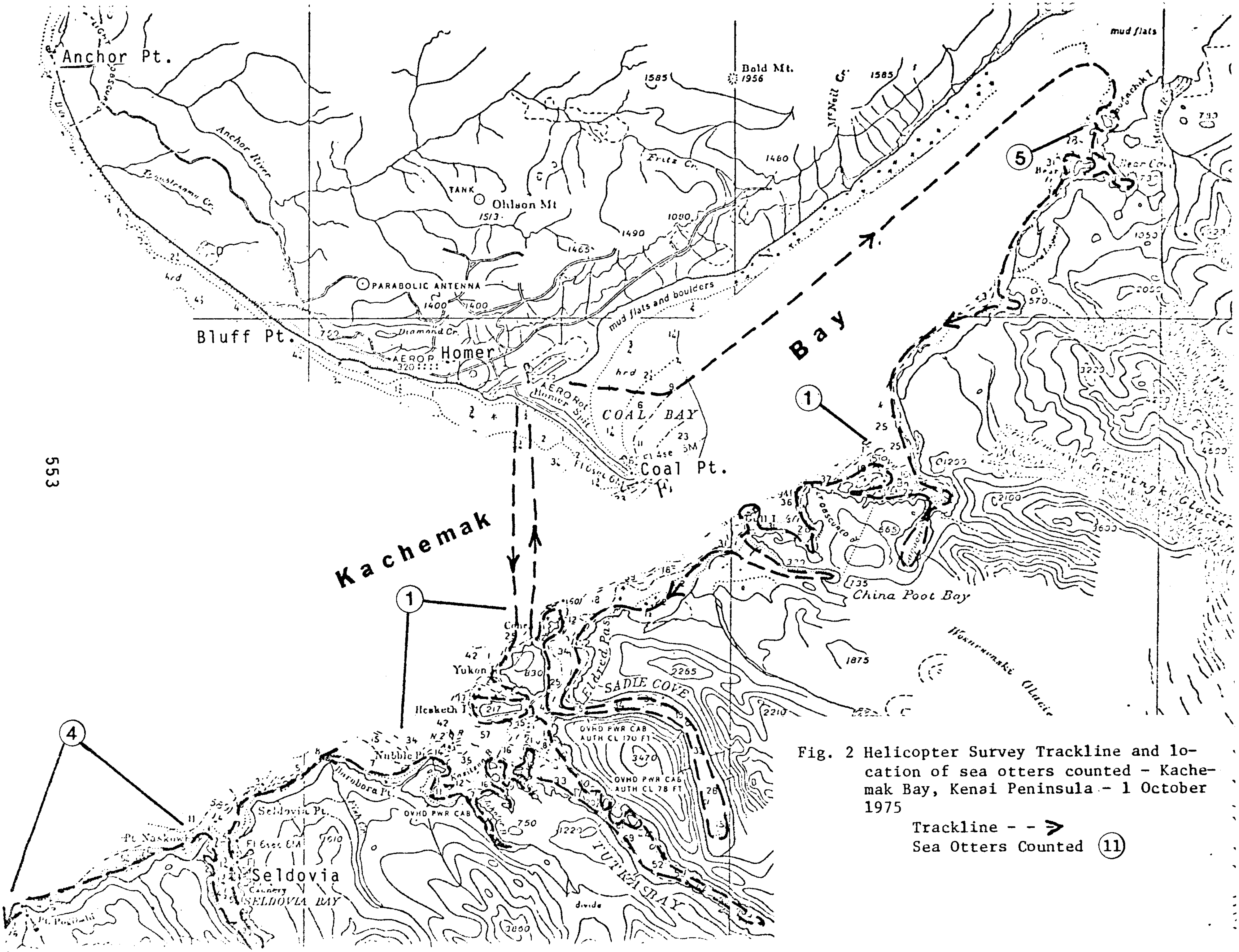


Fig. 2 Helicopter Survey Trackline and location of sea otters counted - Kachemak Bay, Kenai Peninsula - 1 October 1975

Trackline - - ➤

Sea Otters Counted ⑪

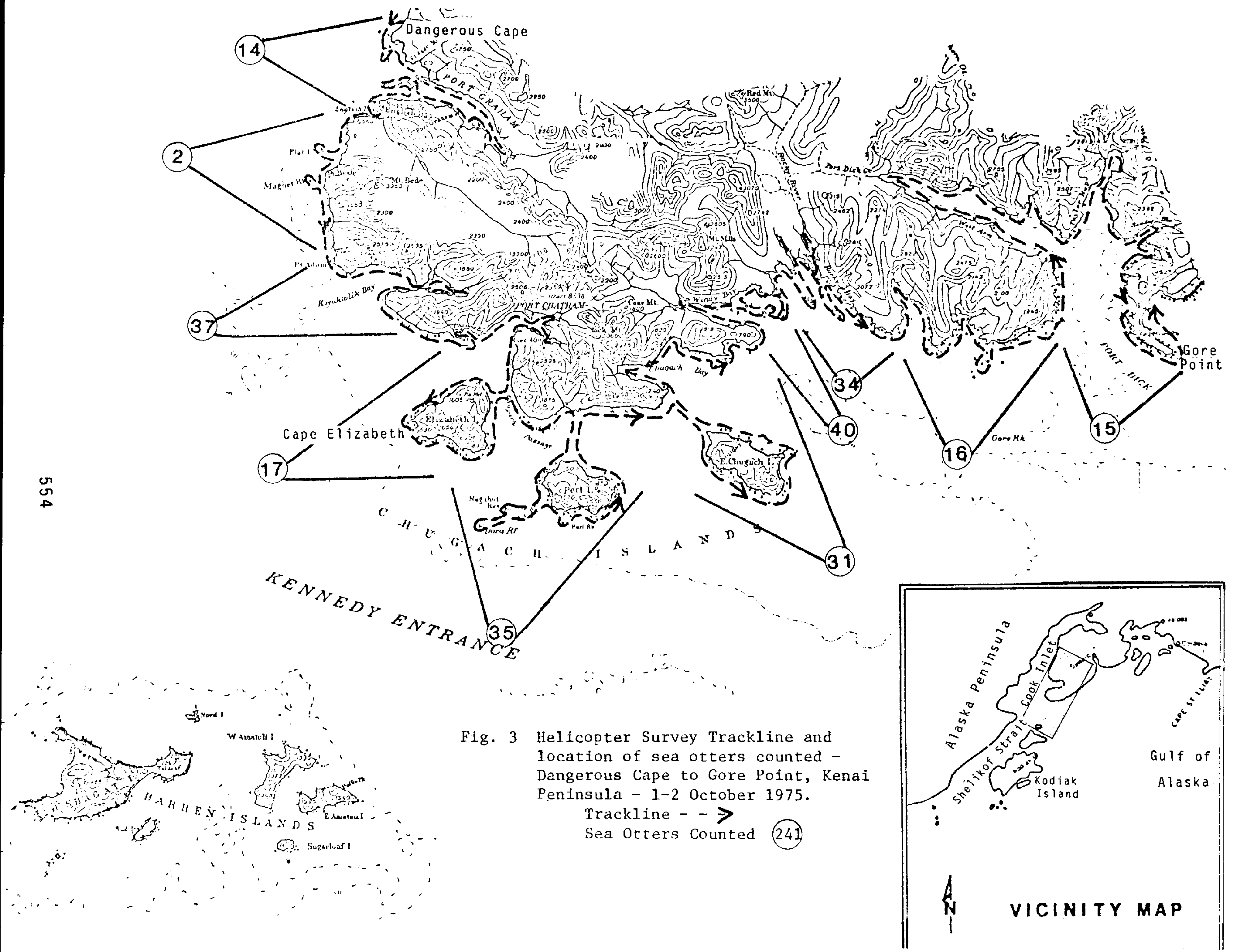


Fig. 3 Helicopter Survey Trackline and location of sea otters counted - Dangerous Cape to Gore Point, Kenai Peninsula - 1-2 October 1975.

Trackline - - >

Sea Otters Counted (241)

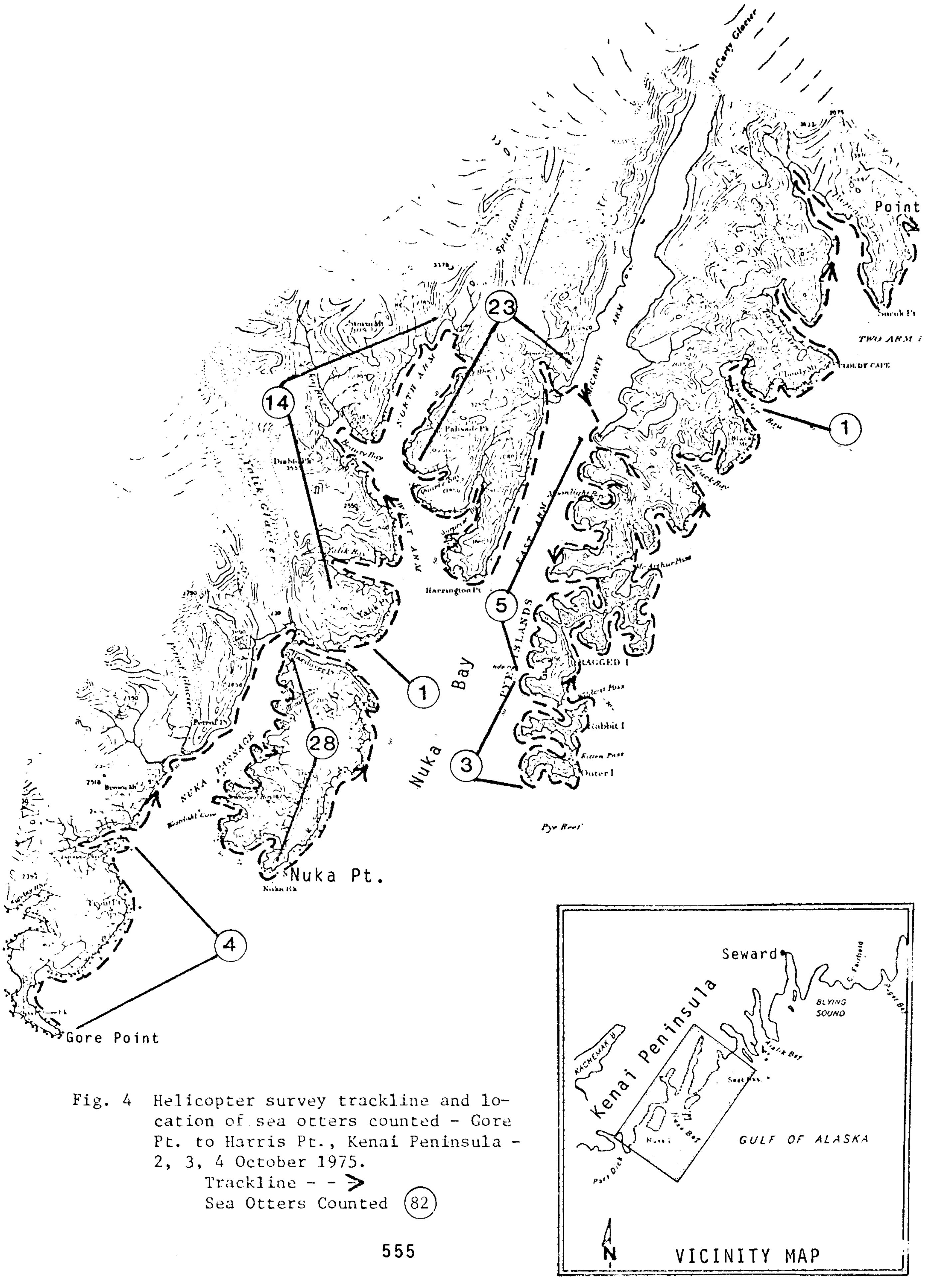


Fig. 4 Helicopter survey trackline and location of sea otters counted - Gore Pt. to Harris Pt., Kenai Peninsula - 2, 3, 4 October 1975.

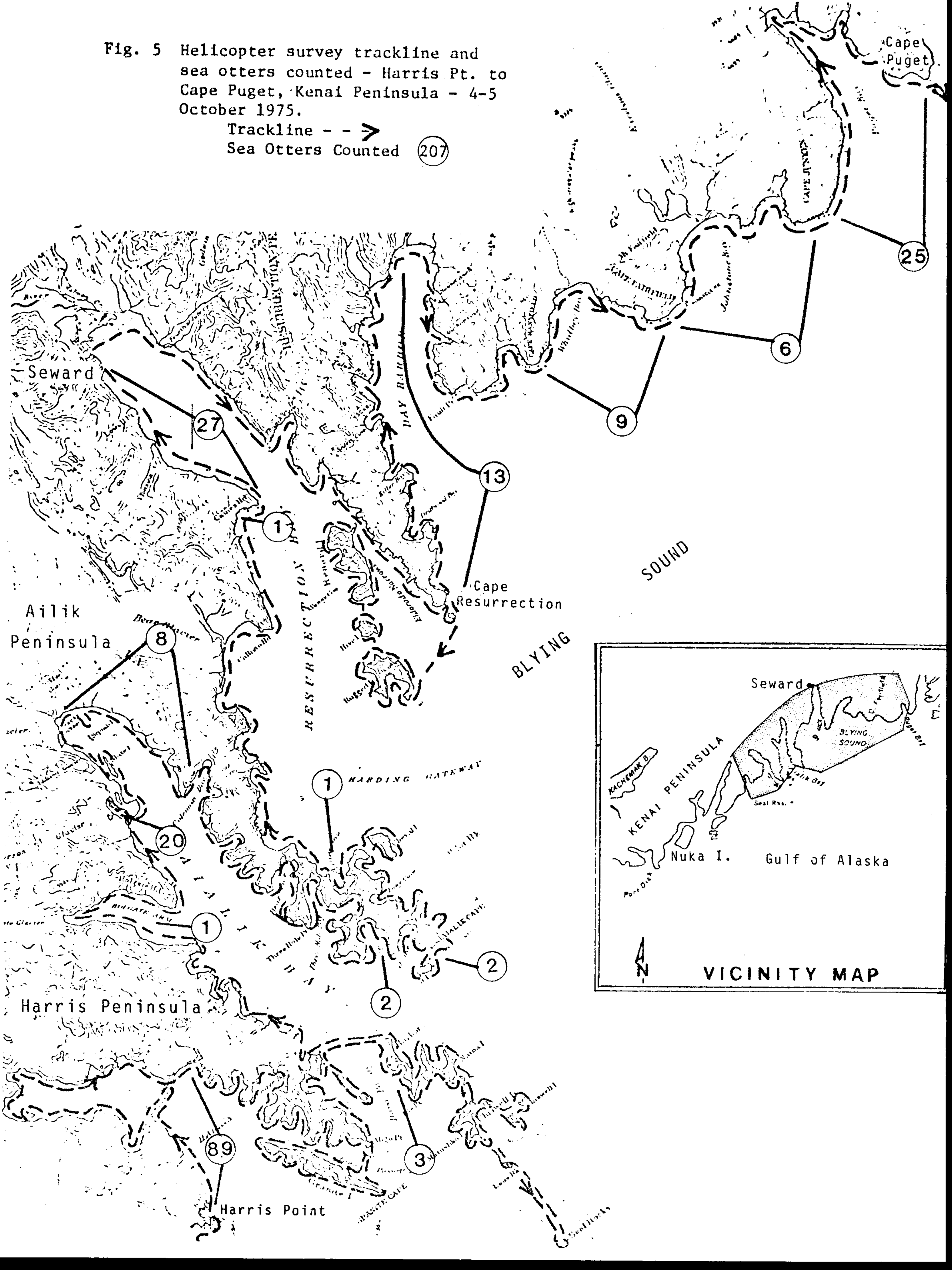
Trackline - - >

Sea Otters Counted (82)

Fig. 5 Helicopter survey trackline and sea otters counted - Harris Pt. to Cape Puget, Kenai Peninsula - 4-5 October 1975.

Trackline - - >

Sea Otters Counted ⑳⑦



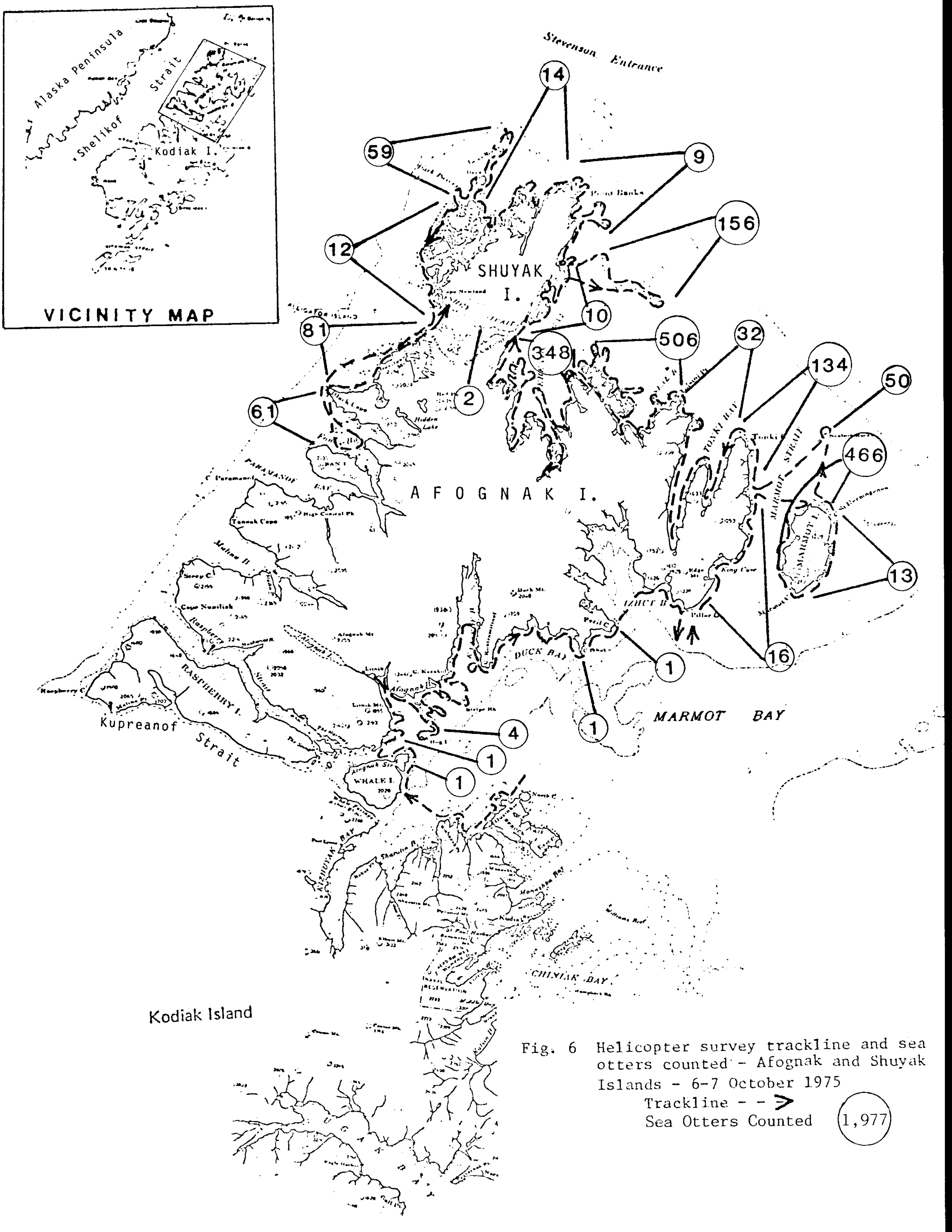


Fig. 6 Helicopter survey trackline and sea otters counted - Afognak and Shuyak Islands - 6-7 October 1975

Trackline - - >

Sea Otters Counted (1,977)

Table 3. Results of boat sea otter survey of portions of the Kodiak Archipelago, 3-11 February 1976.

Area	Date	Sea Otters Counted	Survey Conditions	Completeness of Coverage
Kupreanof Strait	2/3/76	1	Poor	Incomplete
Paramanof Bay	2/4/76	15	Fair	"
Foul Bay	"	60	Poor	"
Bluefox Bay	"	32	Fair	"
Shuyak Strait	"	14	"	"
Shuyak (West)	2/5/76	272	Poor	"
Uganik Passage	2/10/76	37	Excellent	"
Cape Ugat	"	1	Fair	"
Uyak Bay (East)	2/11/76	1	"	"
Uyak Bay (South)	"	0	Very Good	"
Kodiak	2/9/76	0	Fair	"

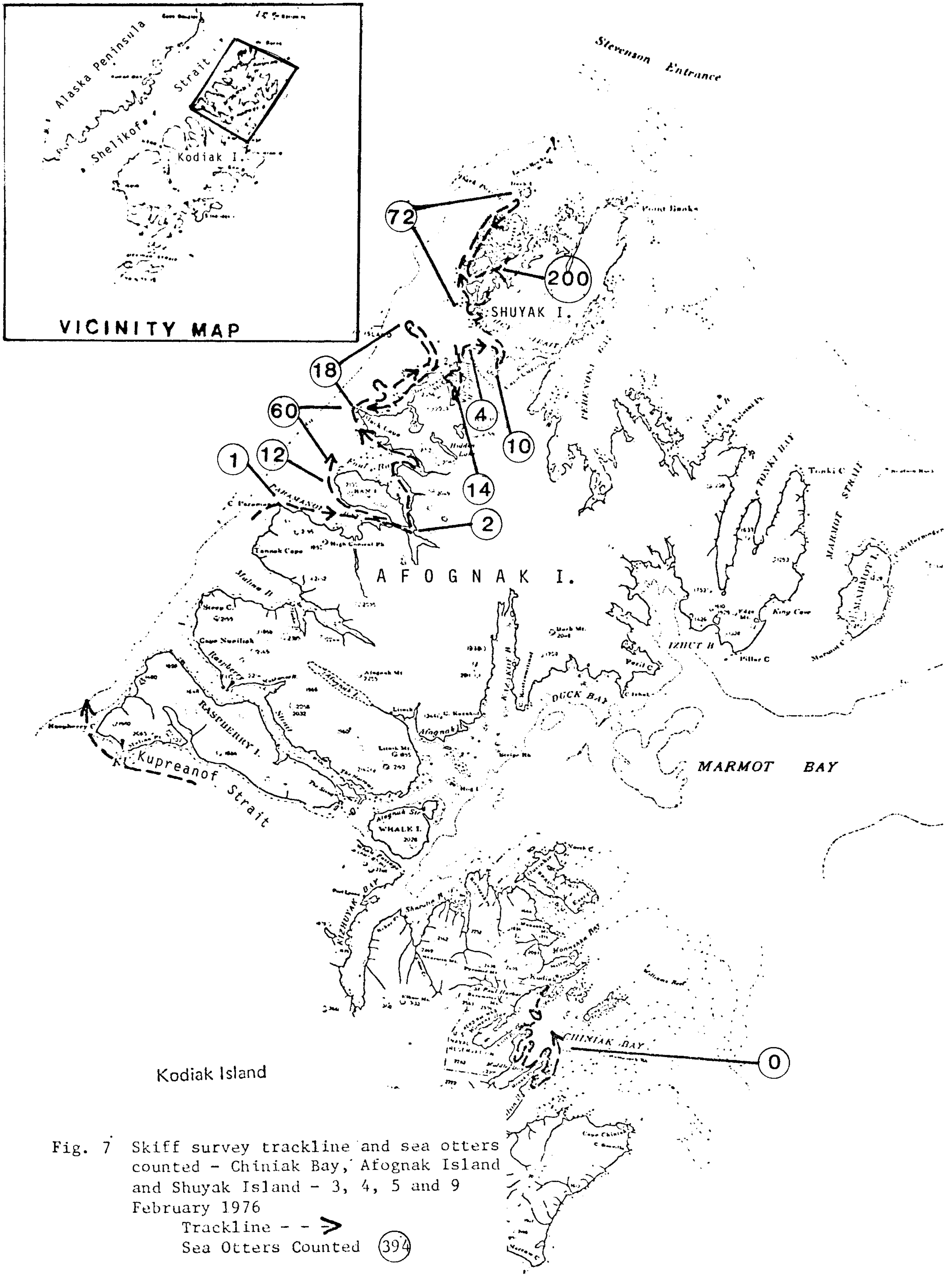


Fig. 7 Skiff survey trackline and sea otters counted - Chiniak Bay, Afognak Island and Shuyak Island - 3, 4, 5 and 9 February 1976

Trackline - - >

Sea Otters Counted (394)

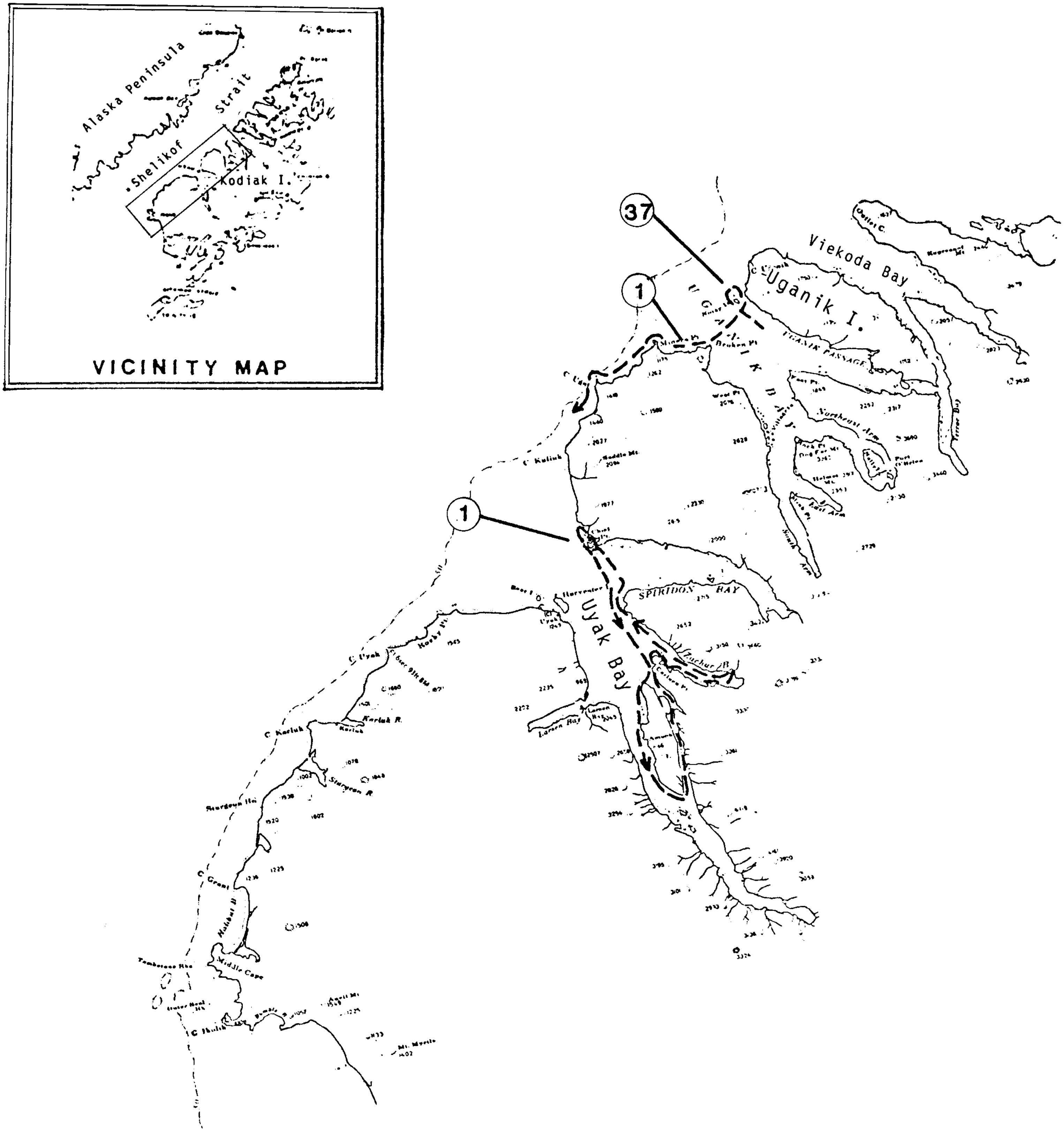


Fig. 8 Skiff survey trackline and sea otters counted - Uganik Island to Uyak Bay, Kodiak Island - 10-11 February 1976
Trackline - - >
Sea Otters Counted ㊴

fixed-wing survey in Table 4 and Figs. 9-13, the April aerial strip survey in Table 5 and Figs. 14-15, the May fixed-wing survey in Table 6 and Fig. 16 and the June fixed-wing survey in Table 7 and Figs. 17-21. Survey tracklines are shown in Figs. 1-21. Counts presented in Tables 2-4 and 6-7 are grouped into standardized count areas to facilitate comparison.

Sea otter observations made by personnel conducting three aerial surveys of birds under RU #3/4 are presented in Figs. 22-28. All three surveys include the area within 400 m of shore along the entire shoreline from Gore Point to the East Foreland. Sea otters offshore were not counted and at times otters inside the survey strip were ignored if many birds were present.

Sightings made in various parts of the Kodiak Archipelago from helicopters and boats by personnel working on RU #229 and 243 in October and November 1976 are presented in Figs. 29-32. These observations often were made under poor conditions and reflect only the presence or absence of sea otters close to shore.

Recent significant sightings from other sources are presented in Table 8.

VII. Discussion

The effectiveness of surveys of the type used in this project can be highly variable. The results should be interpreted carefully with consideration of the survey conditions and the completeness of coverage.

Table 4. Sea Otter sightings made during aerial survey of sea lions around the Kodiak Archipelago, 13-14 March 1976.

Area	Date	Sea Otters Counted	Survey Conditions	Completeness of Coverage
Kodiak Archipelago				
Izhut Bay (East)	3/13/76	0	Fair	Incomplete
Duck Bay	"	6	"	"
Cape Chiniak	"	0	"	"
Kodiak	"	0	"	"
Sequel Pt.	"	1	Good	"
Ugak I.	"	0	Poor	"
Ugak Bay	"	0	"	"
Dangerous Cape	"	0	"	"
Sitkalidak I. (South)	"	0	"	"
Twoheaded I.	"	0	"	"
Aiaktalik I.	"	0	"	"
Sitkinak I. (South)	"	1	Fair	"
Tugidak I. (South)	"	21	Good	"
Tugidak-Chirikof	"	1	"	"
Chirikof	"	10	Very Good	"
Tugidak I. (North)	"	1	Fair	"
Alitak Bay	"	0	"	"
Ayakulik	"	0	"	"
Halibut Bay	3/14/76	1	Good	Complete
Karluk	"	0	"	"
Rocky Point	"	0	"	"
Uyak Bay (West)	"	5	Very Good	Incomplete
Cape Ugat	"	0	Fair	Complete
Uganik Passage	"	12	Poor	Incomplete
Viekoda Bay	"	1	Very Good	Incomplete
Kupreanof Strait	"	20	Good	"
Raspberry Strait	"	20	"	"
Malina Bay	"	31	Fair	"

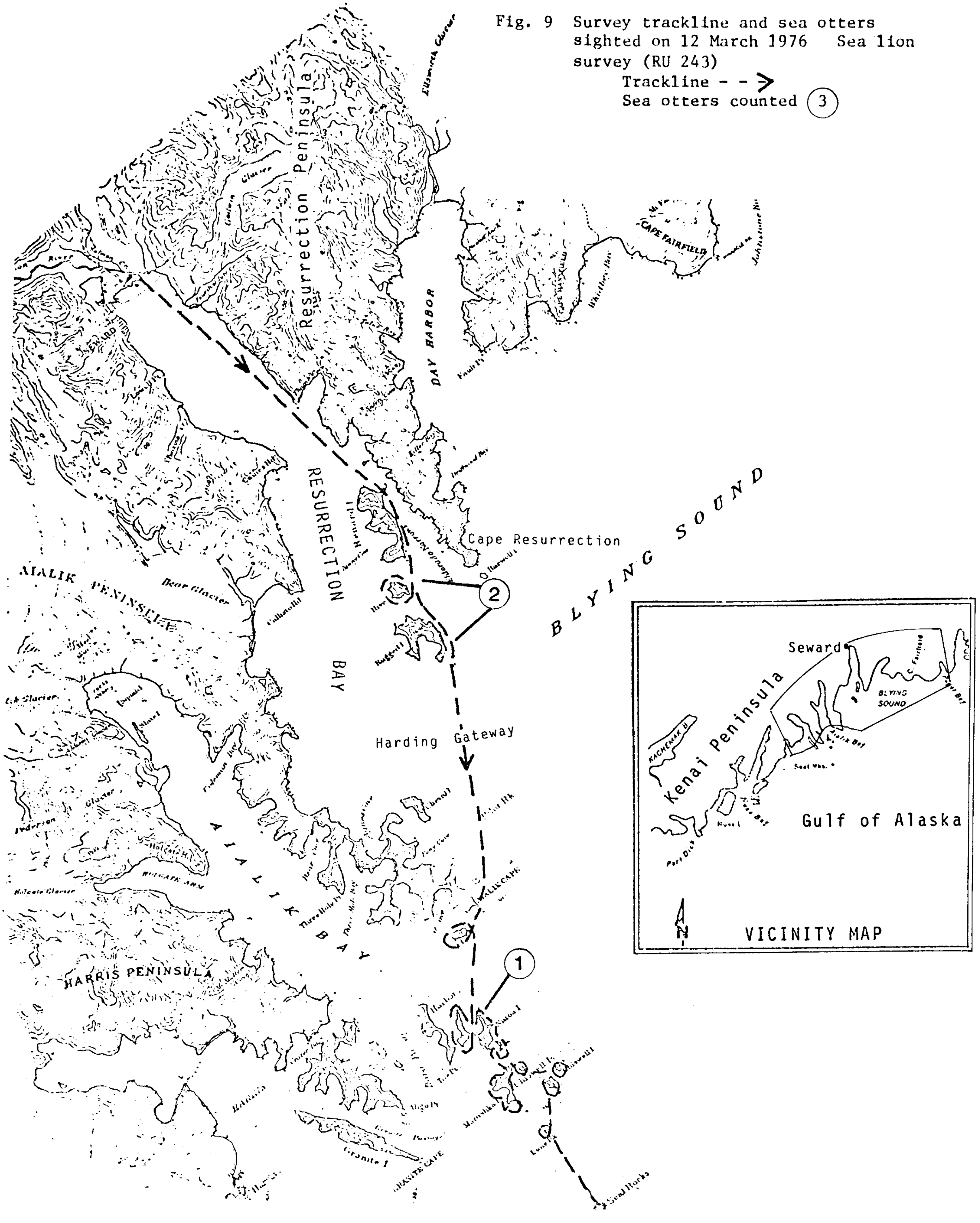


Fig. 9 Survey trackline and sea otters sighted on 12 March 1976 Sea lion survey (RU 243)

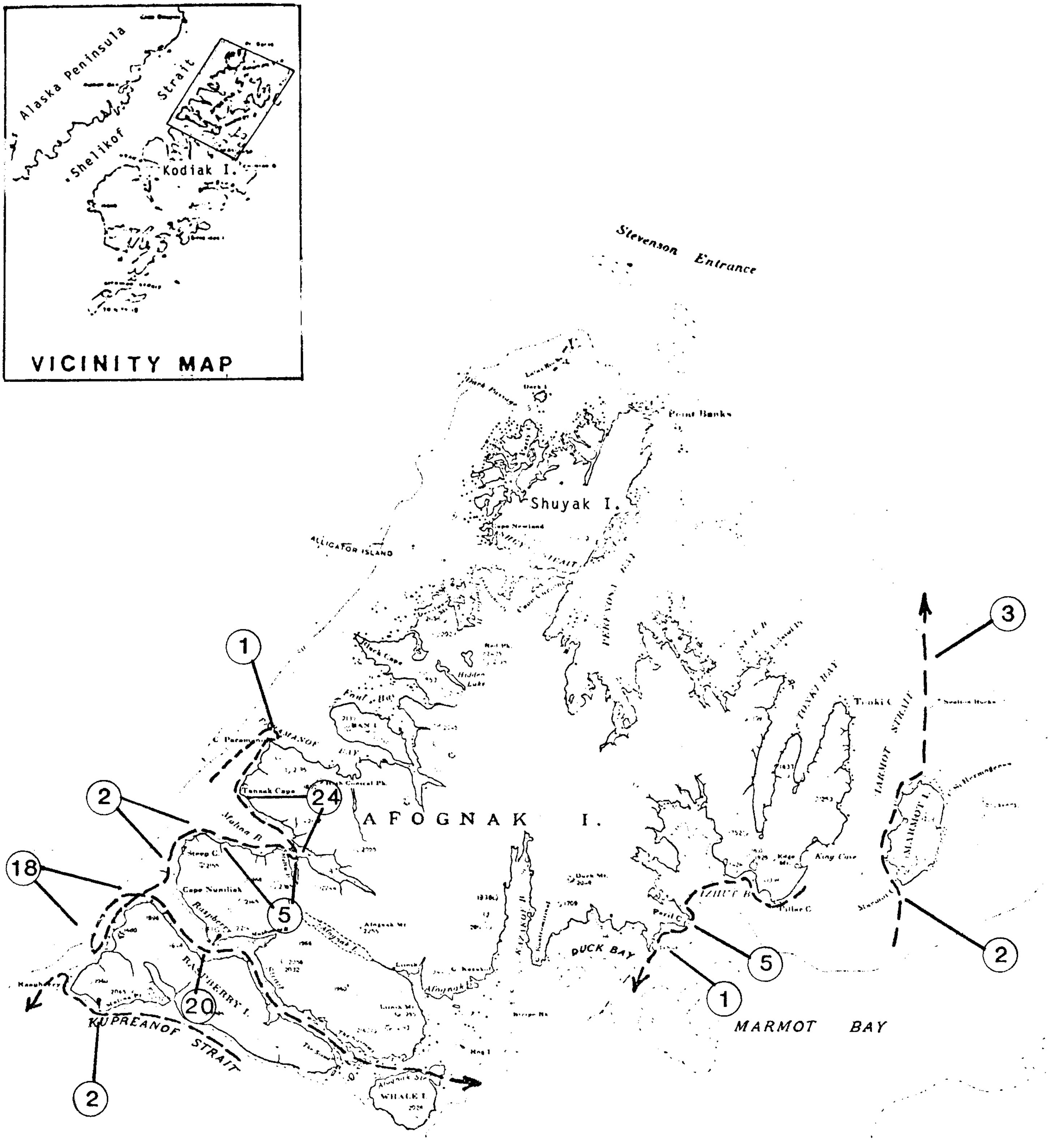


Fig. 10 Survey trackline and sea otters sighted on 13-14 March 1976 Sea lion survey (RU 243)
Trackline - - >
Sea otters counted ㊸

Fig. 11 Survey trackline and sea otters counted on 13-14 March 1976 Sea lion survey (RU 243)

Trackline - - >

Sea otters counted ①

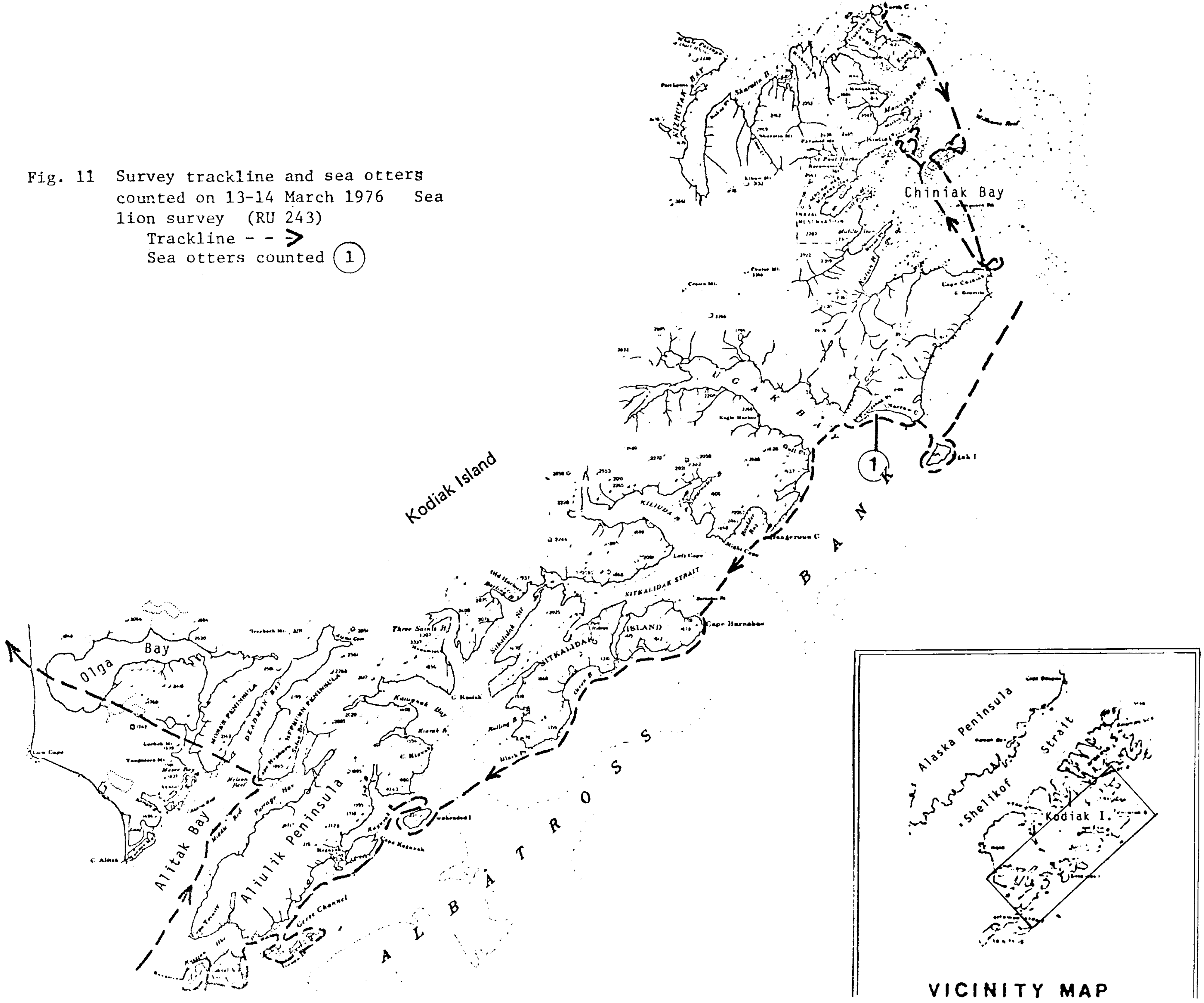
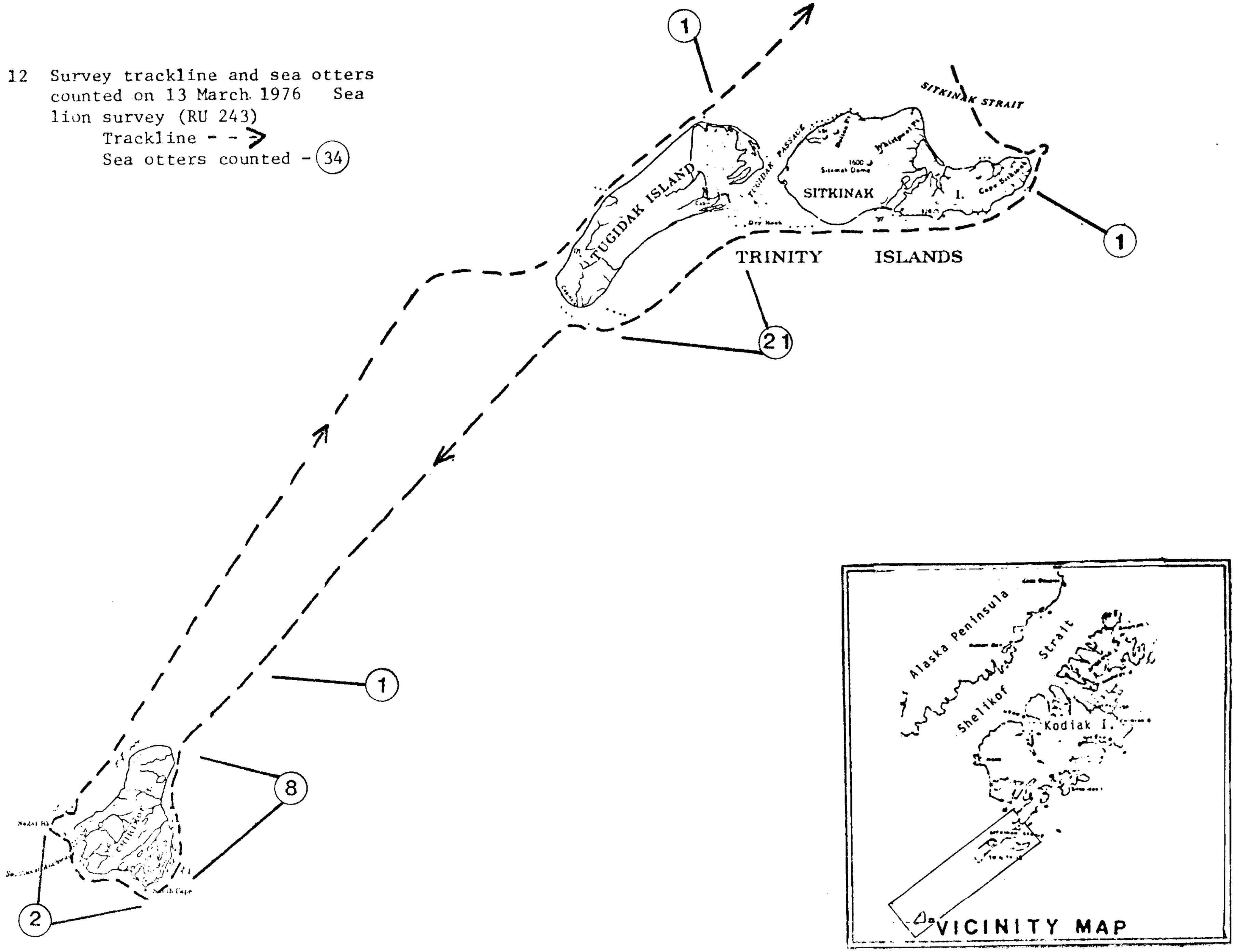


Fig. 12 Survey trackline and sea otters counted on 13 March 1976 Sea lion survey (RU 243)

Trackline - - >

Sea otters counted - (34)



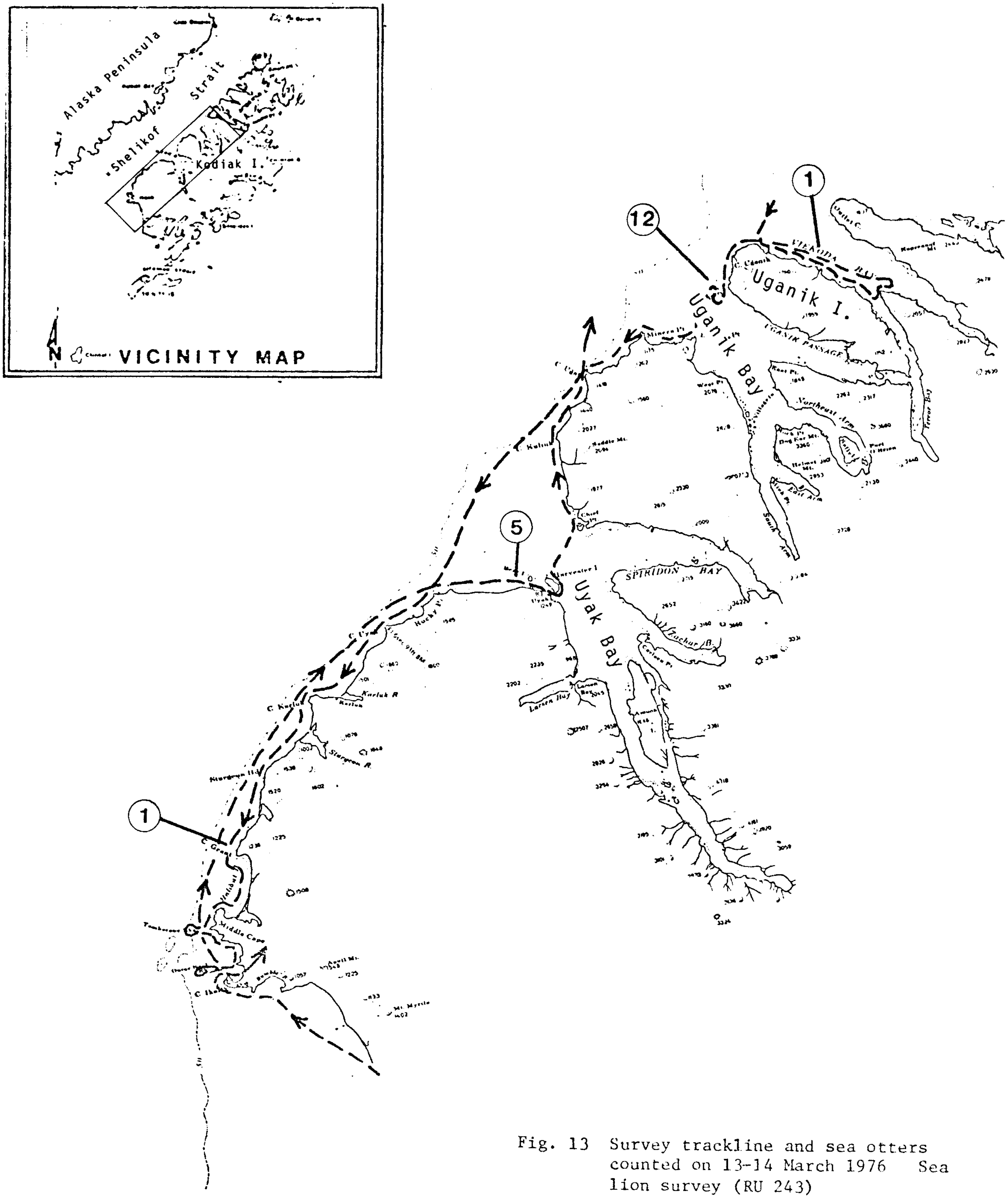


Fig. 13 Survey trackline and sea otters counted on 13-14 March 1976 Sea lion survey (RU 243)

Trackline - - >

Sea otters counted ⑲

Table 5. Sea otter sightings made on unlimited-width strip transect survey in Kamishak Bay and Kachemak Bay, 1 April 1976.

Kamishak Bay

Tracklines - Even minutes of latitude extending from the shore of Kamishak Bay to;

153° 00' W Long between 59° 36' N Lat and 59° 20' N Lat
153° 10' " " " 59° 18' " " 59° 08' " "
153° 15' " " " 59° 06' " " " 59° 04' " "

and shoreline from Shaw I. to C. Douglas

Sighting Latitude	Sighting Longitude	Number of Sea Otters Sighted	Survey Conditions
59°32' N	153°22' W	1	Very Good
59 32	153 26	1	"
59 26	153 40	1	"
59 26	153 39	4	"
59 26	153 37	2	"
59 26	153 29	1	"
59 26	153 28	34	"
59 22	153 57	1	"
59 22	154 00	4	"
59 21	153 56	1	"
59 21	153 54	2	"
59 21	153 52	1	"
59 21	153 50	1	"
59 22	153 45	1	"
59 23	153 22	1	"
59 19	153 29	1	"
59 19	153 28	1	"
59 20	153 34	2	"
59 20	154 00	1	"
59 18	154 02	1	"
59 16	154 03	1	"
59 16	154 04	1	Good
59 12	153 57	1	"
59 12	154 04	1	"
59 12	154 07	2	"
58 54	153 18	1	"
58 52	153 18	3	"
58 50	153 19	1	"

Table 5 (Cont.) Sea otter sightings made on unlimited-width strip transect survey in Kamishak Bay and Kachemak Bay, 1 April 1976.

Kachemak Bay

Tracklines - Even minutes of latitude extending from the shore of The Kenai Peninsula to 152° 10' W Long between 59° 34' N. Lat and 59° 48' N Lat.

Sighting Latitude	Sighting Longitude	Number of Sea Otters Sighted	Survey Conditions
59°34' N	151°30' W	1	Very Good
59 34	151 33	1	"
59 34	152 03	4	"
59 34	152 05	1	"
59 36	151 59	1	"
59 36	151 45	1	"
59 36	151 34	1	"
59 38	151 51	1	"
59 38	151 54	1	"
59 38	151 56	1	"
59 38	151 57	1	"
59 38	152 02	1	"
59 38	152 06	1	"
59 40	152 04	1	"
59 40	151 57	1	"
59 40	151 55	2	"
59 40	151 52	5	"
59 40	151 48	2	"
59 40	151 47	2	"
59 42	151 50	4	"
59 42	151 45	1	"
59 42	151 58	3	"
59 42	151 59	2	"
59 42	152 01	1	"
59 44	152 06	2	"
59 44	152 03	1	"
59 46	152 06	3	"
59 48	152 06	1	"
59 48	151 59	1	"
59 48	151 58	1	"

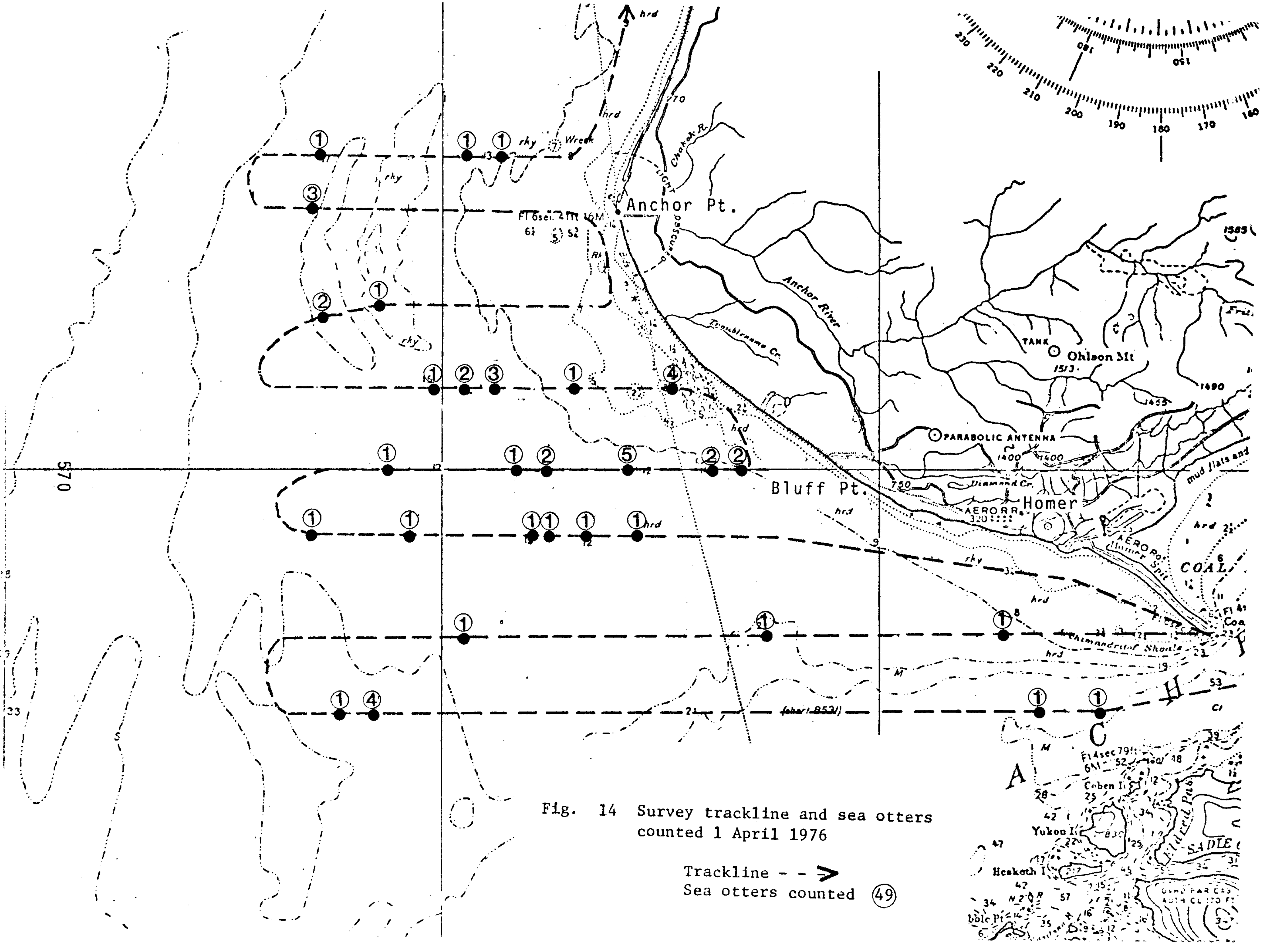


Fig. 14 Survey trackline and sea otters counted 1 April 1976

Trackline - - >
Sea otters counted ㊾

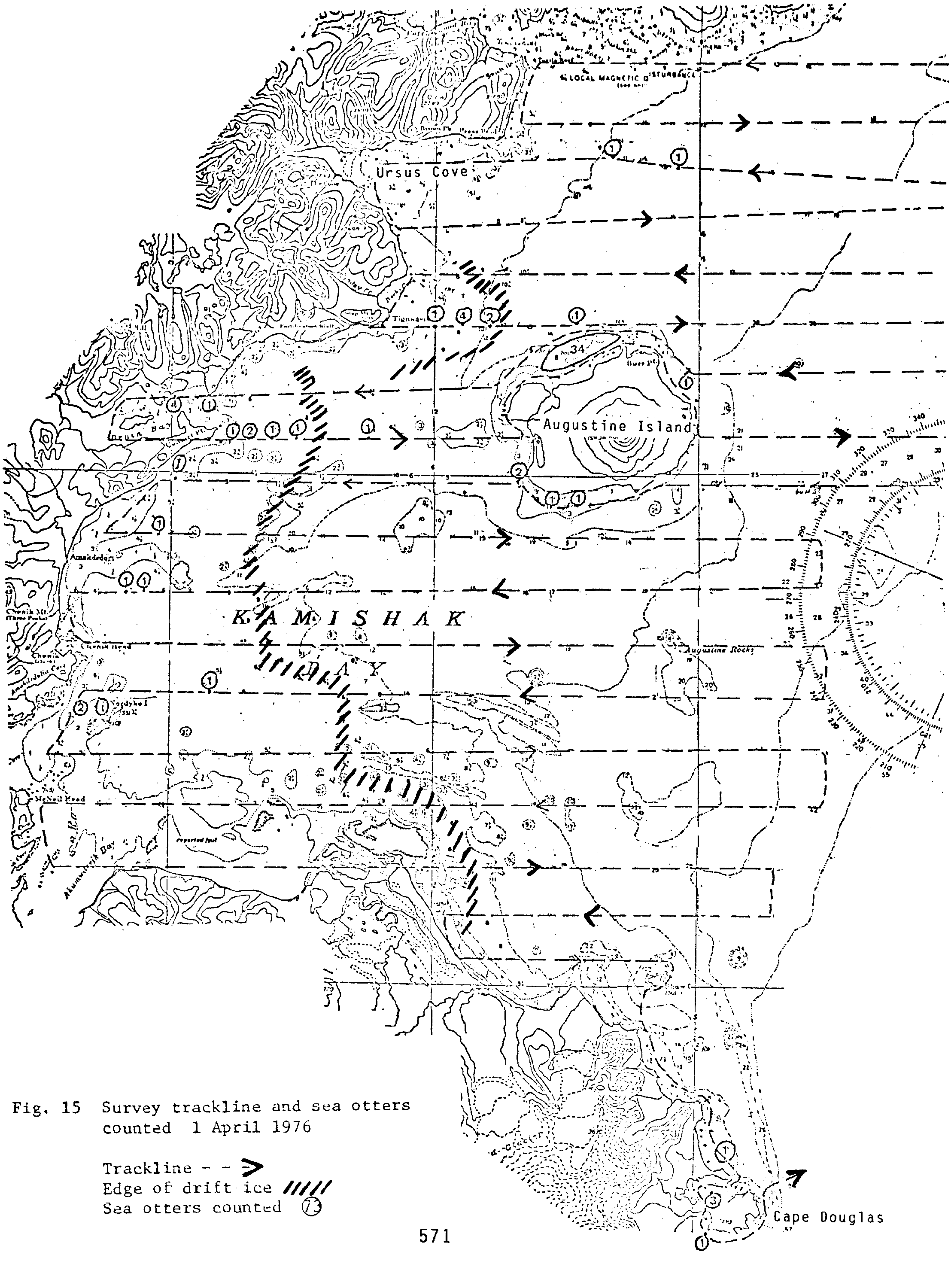


Fig. 15 Survey trackline and sea otters counted 1 April 1976

Trackline - - >

Edge of drift ice /////

Sea otters counted ⑦

Table 6. Sea otter sightings made during aerial survey of sea lions around the Barren Islands, 20 May 1976.

Area	Date	Sea Otters Counted	Survey Conditions	Completeness of Coverage
West Amatuli I.	5/20/76	8	Poor	Incomplete
N. side Ushagat I.	"	10	"	"
S. side Ushagat I.	"	40	"	"
Sud I.	"	33	"	"
Carl I.	"	60	"	"

Table 7. Sea otter sightings made during aerial survey of sea lions around the Kodiak Archipelago including the Barren Islands, 10 June 1976.

Area	Date	Sea Otters Counted	Survey Conditions	Completeness of Coverage
Kodiak Island				
Low Cape	6/10/76	2	Fair	Incomplete
Kodiak	"	1	Excellent	"
Barren Islands				
Sugarloaf Island	"	1	Fair	Complete
E Amatuli I.	"	0	"	"
W. Amatuli I.	"	2	"	"
Nord I.	"	0	"	"
N. side Ushagat I.	"	8	"	"
S. side Ushagat I.	"	35	"	"
Sud I.	"	15	"	"
Carl I.	"	50	"	Incomplete

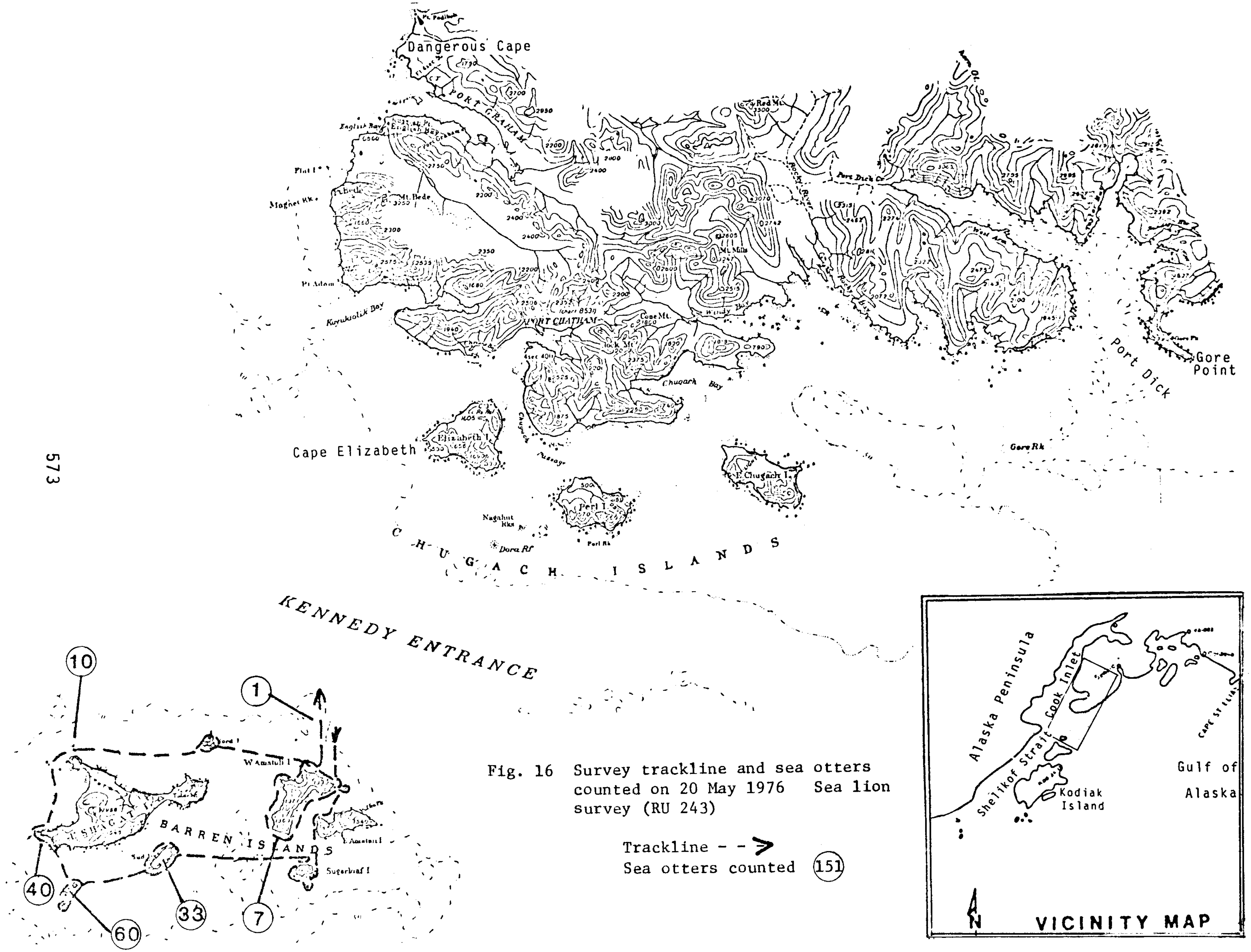
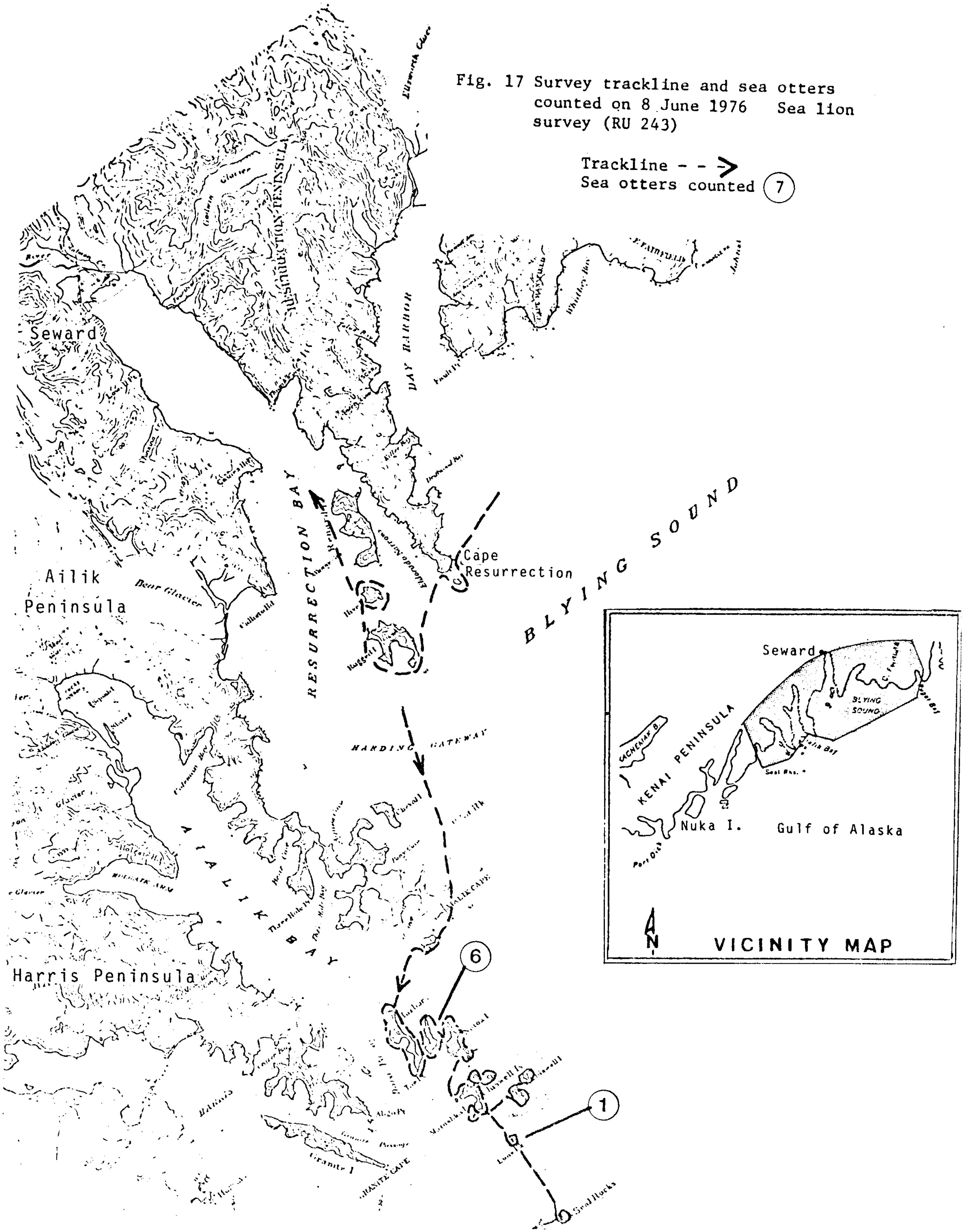


Fig. 16 Survey trackline and sea otters counted on 20 May 1976 Sea lion survey (RU 243)

Trackline - - >

Sea otters counted ⑮①

Fig. 17 Survey trackline and sea otters counted on 8 June 1976 Sea lion survey (RU 243)



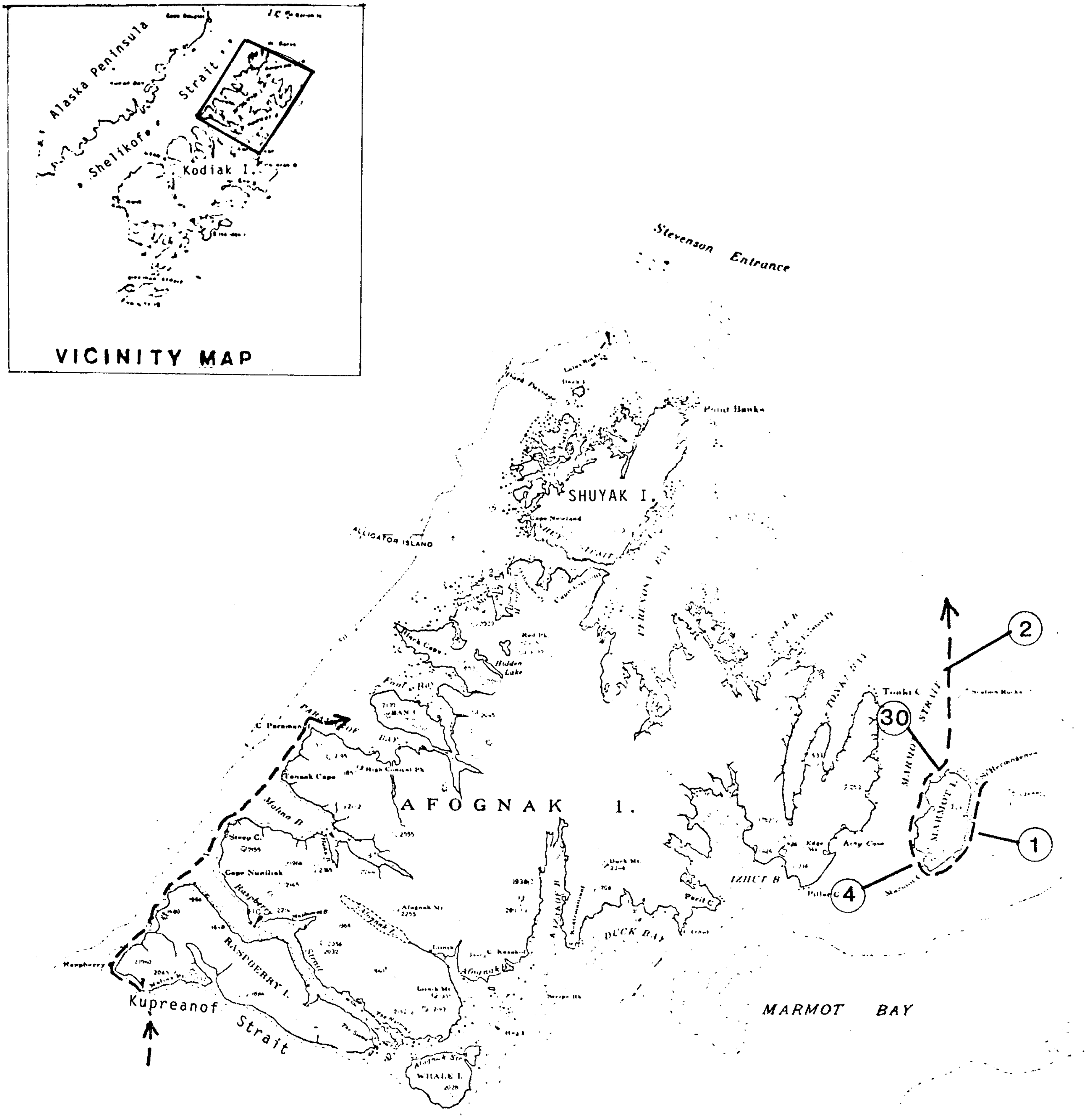


Fig. 18 Survey trackline and sea otters counted on 8 and 10 June 1976 sea lion survey (RU 243)

Trackline - - >
Sea otters counted (37)

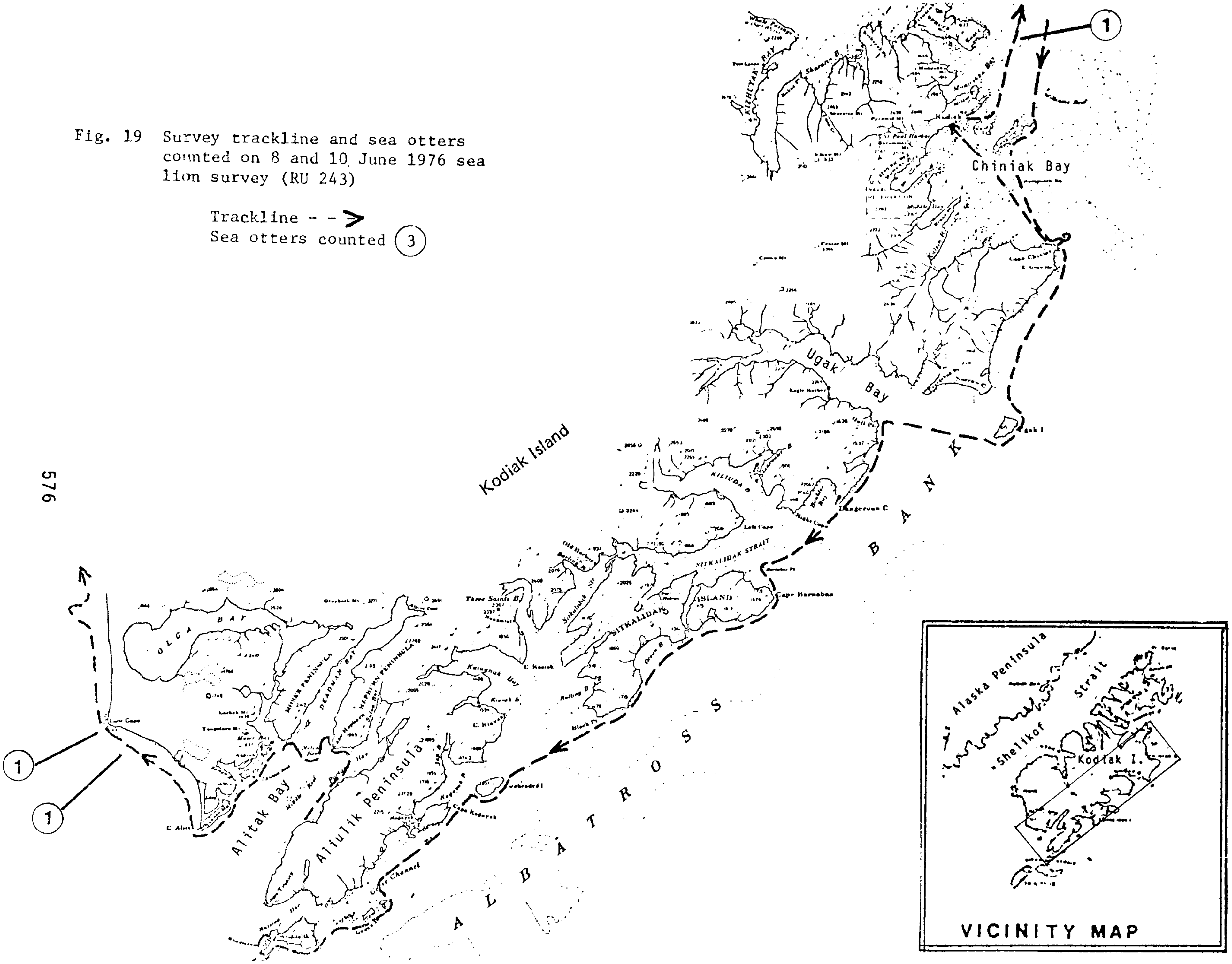


Fig. 19 Survey trackline and sea otters counted on 8 and 10 June 1976 sea lion survey (RU 243)

Trackline - - >
Sea otters counted ③

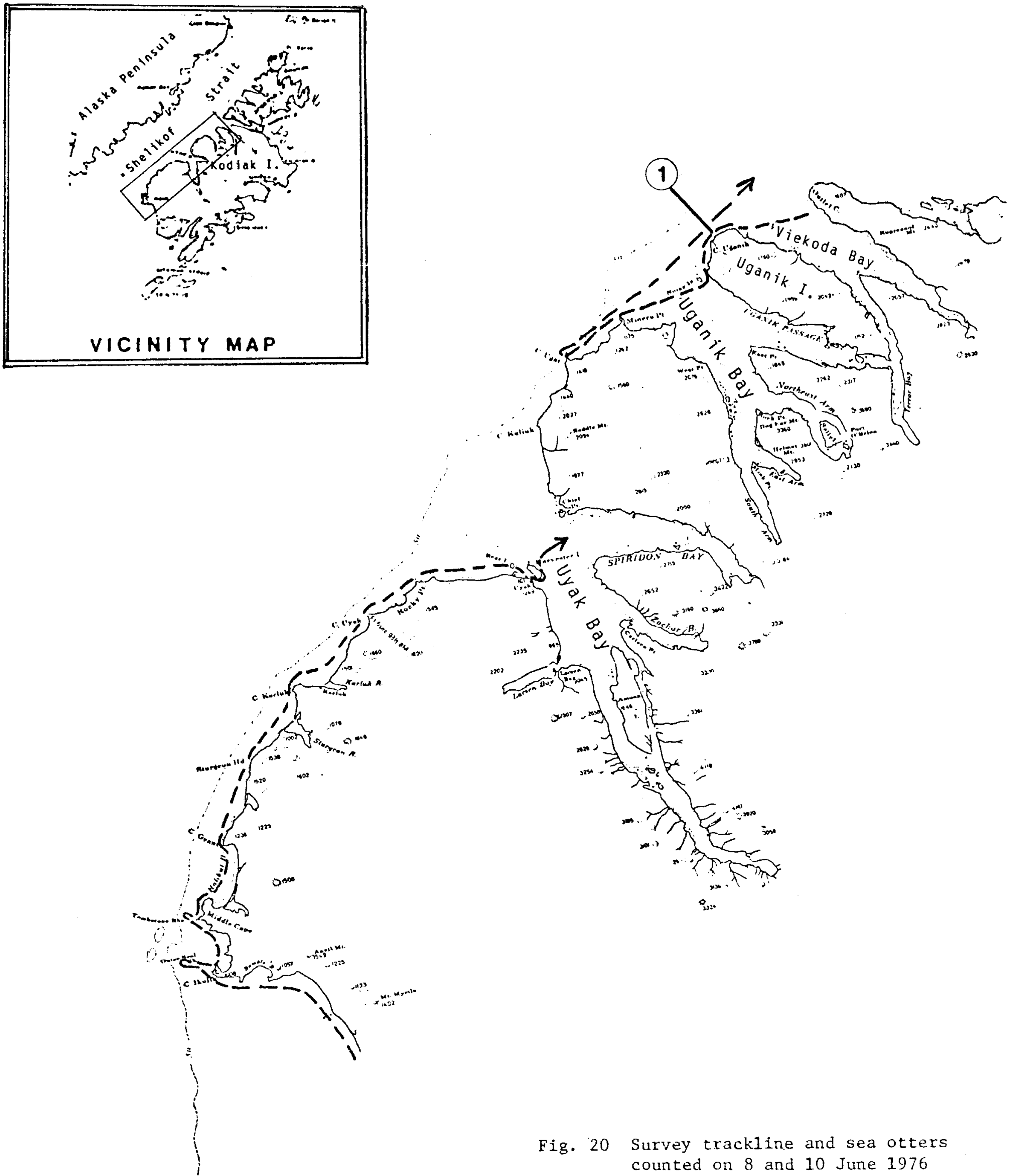


Fig. 20 Survey trackline and sea otters counted on 8 and 10 June 1976 sea lion survey (RU 243)

Trackline - - >
Sea otters counted ①

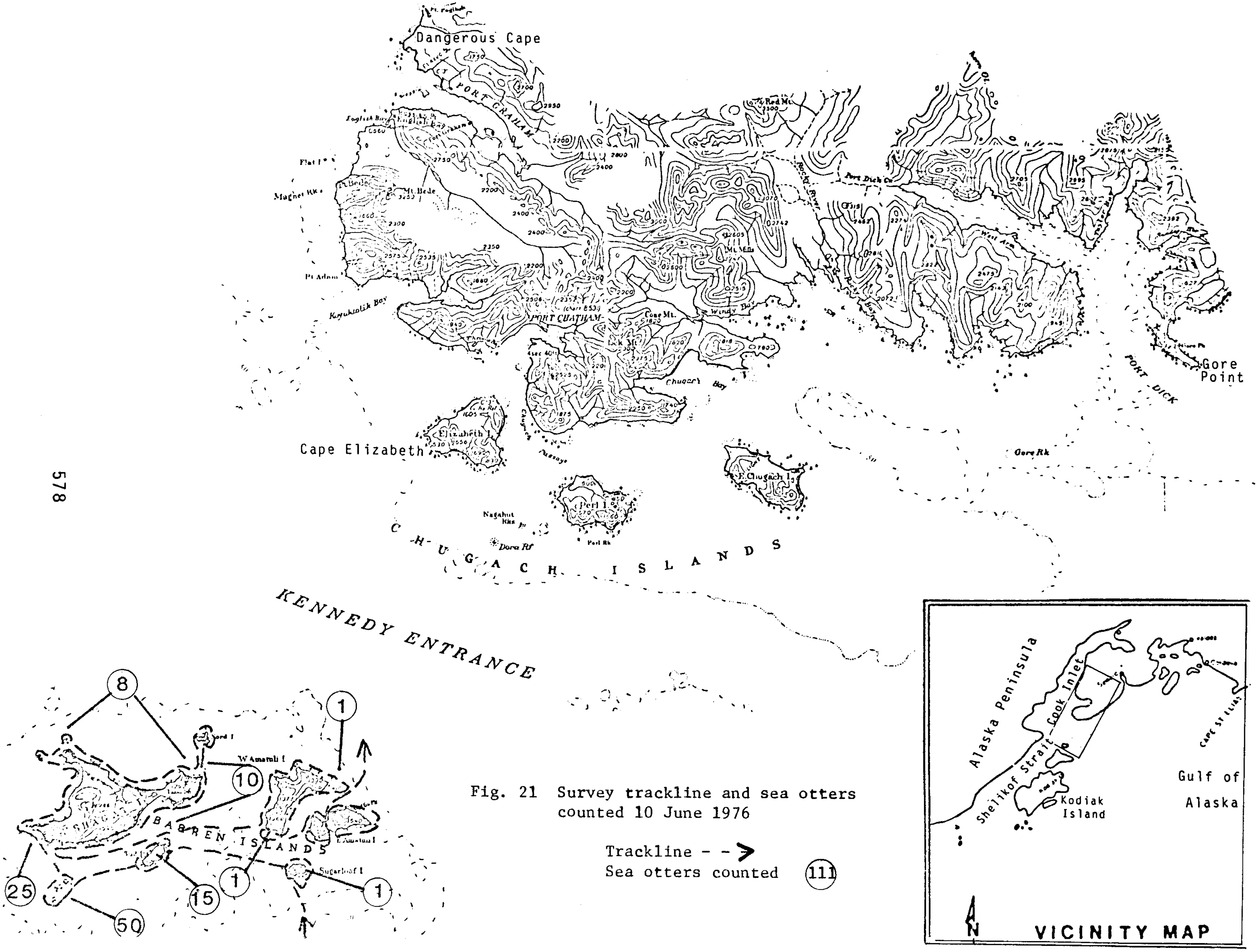


Fig. 21 Survey trackline and sea otters counted 10 June 1976

Trackline - - >
Sea otters counted ⑪

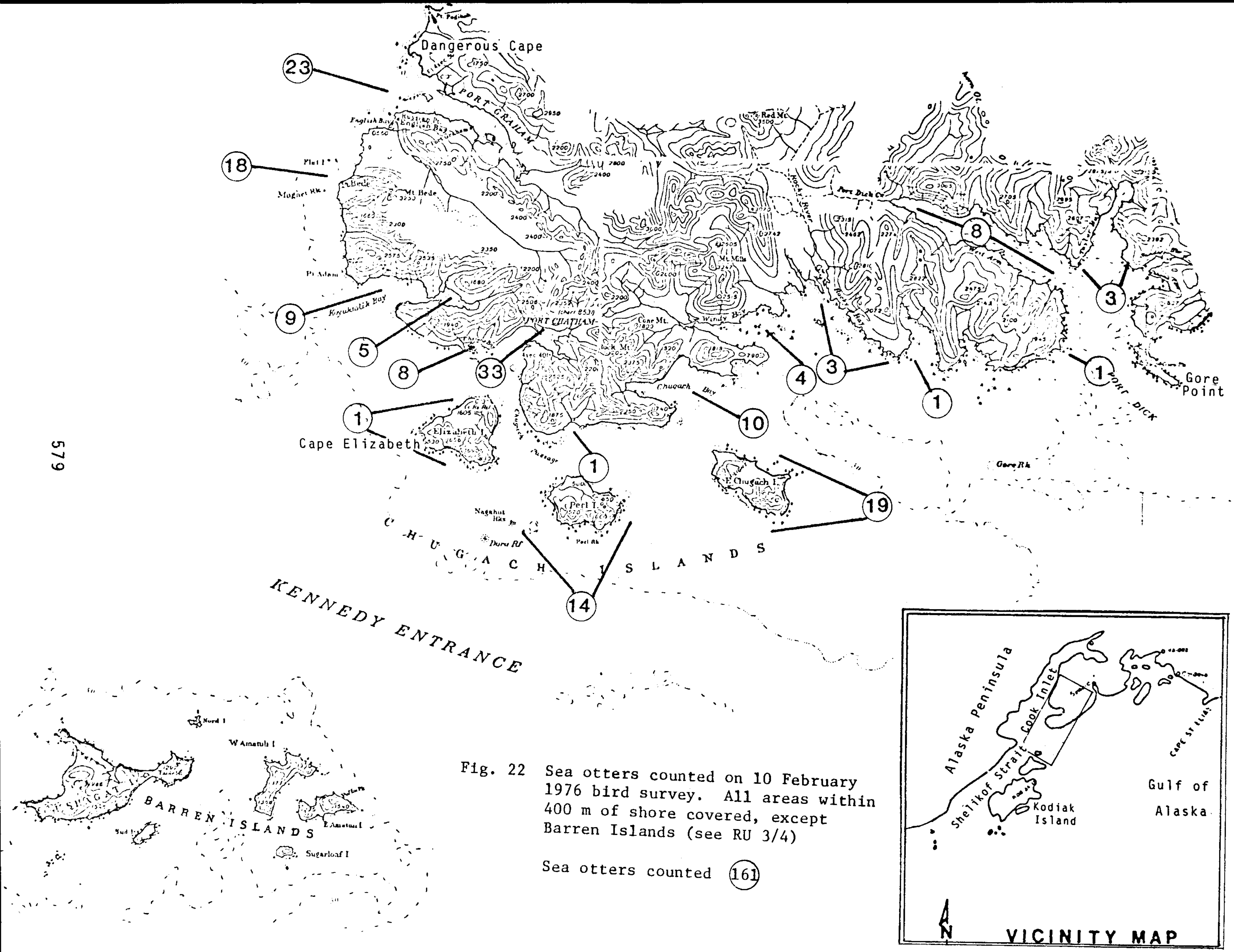


Fig. 22 Sea otters counted on 10 February 1976 bird survey. All areas within 400 m of shore covered, except Barren Islands (see RU 3/4)

Sea otters counted (161)

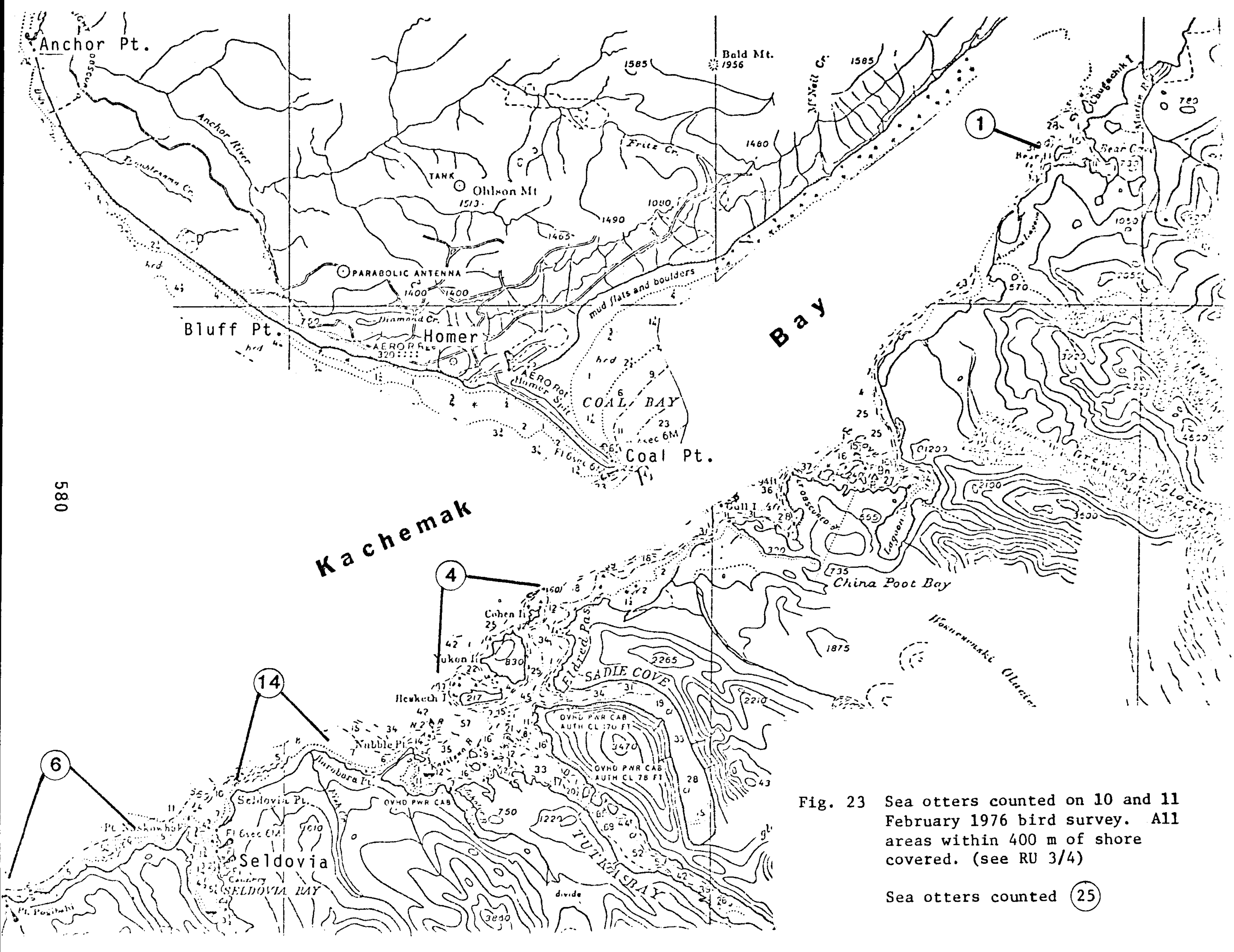


Fig. 23 Sea otters counted on 10 and 11 February 1976 bird survey. All areas within 400 m of shore covered. (see RU 3/4)

Sea otters counted ㉕

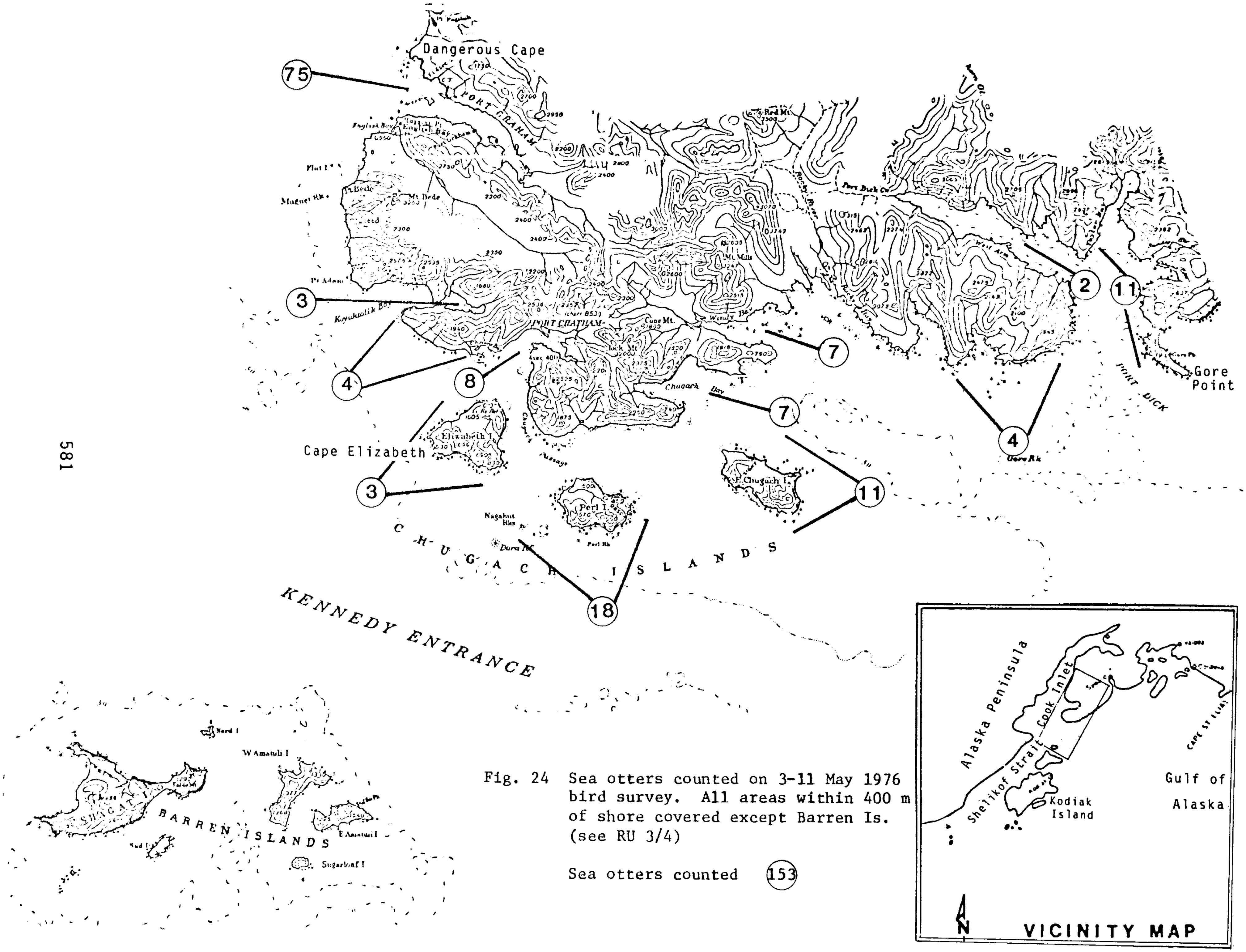


Fig. 24 Sea otters counted on 3-11 May 1976 bird survey. All areas within 400 m of shore covered except Barren Is. (see RU 3/4)

Sea otters counted ⑮③

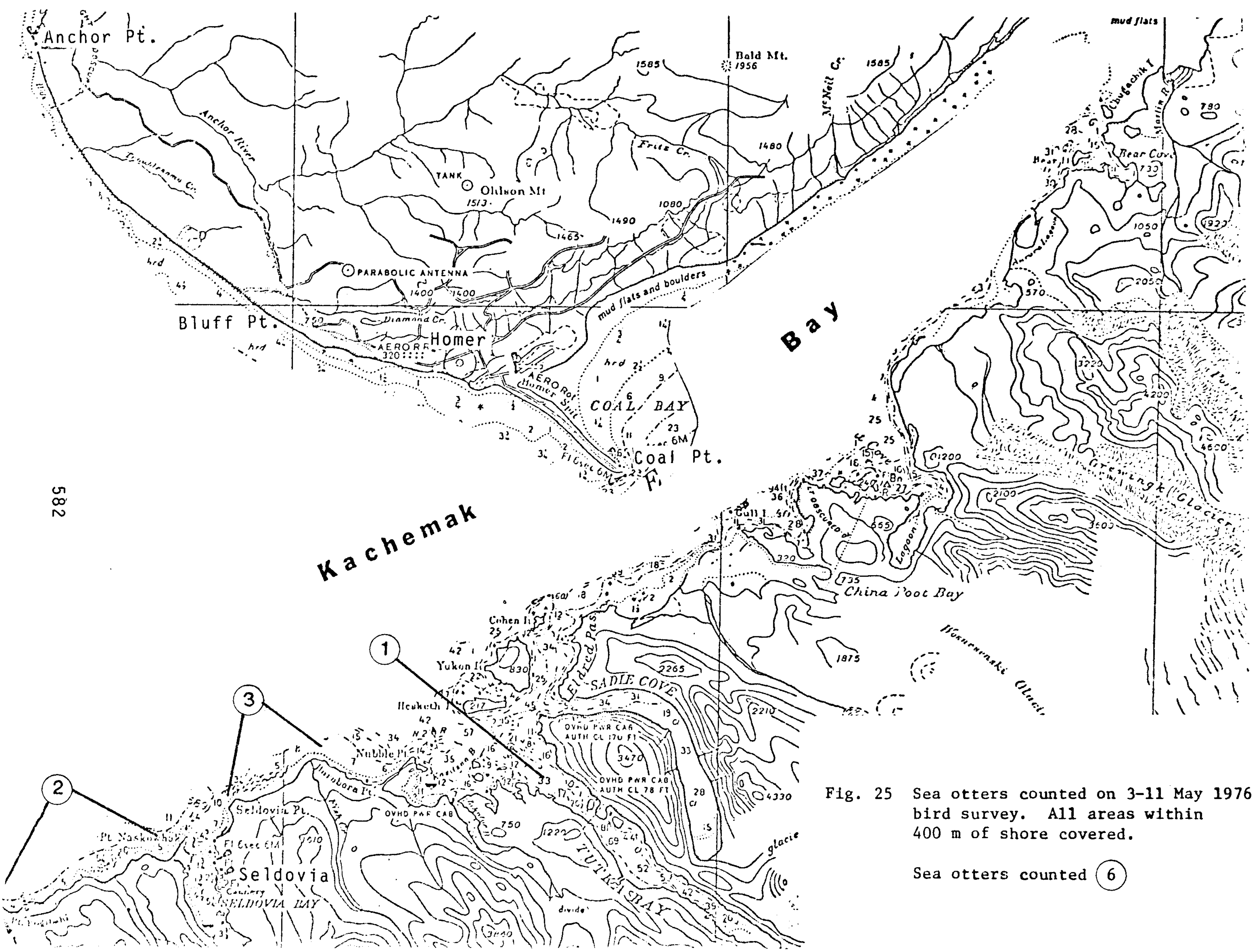


Fig. 25 Sea otters counted on 3-11 May 1976 bird survey. All areas within 400 m of shore covered.

Sea otters counted ⑥

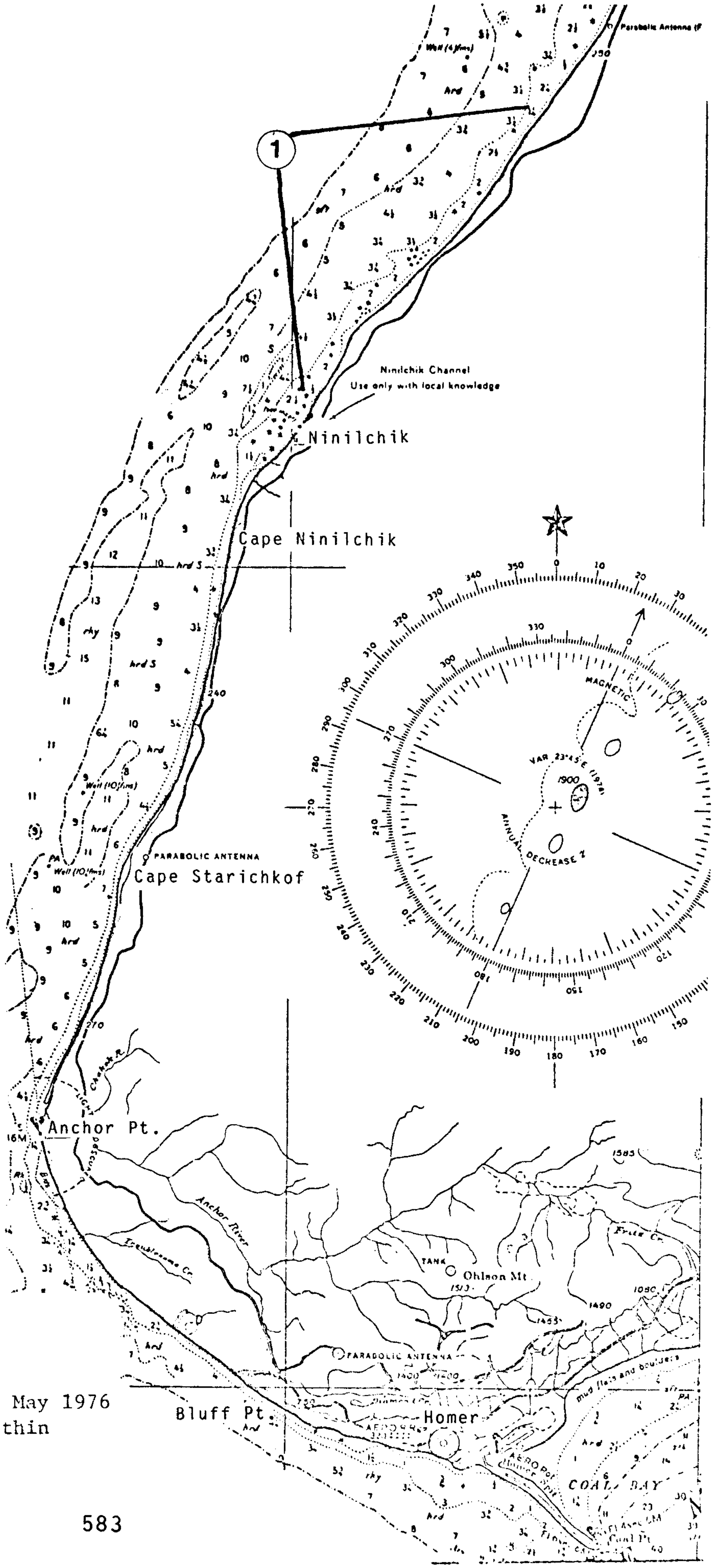


Fig. 26 Sea otters counted on 3-11 May 1976 bird survey. All areas within 400 m of shore covered.

Sea otters counted ①

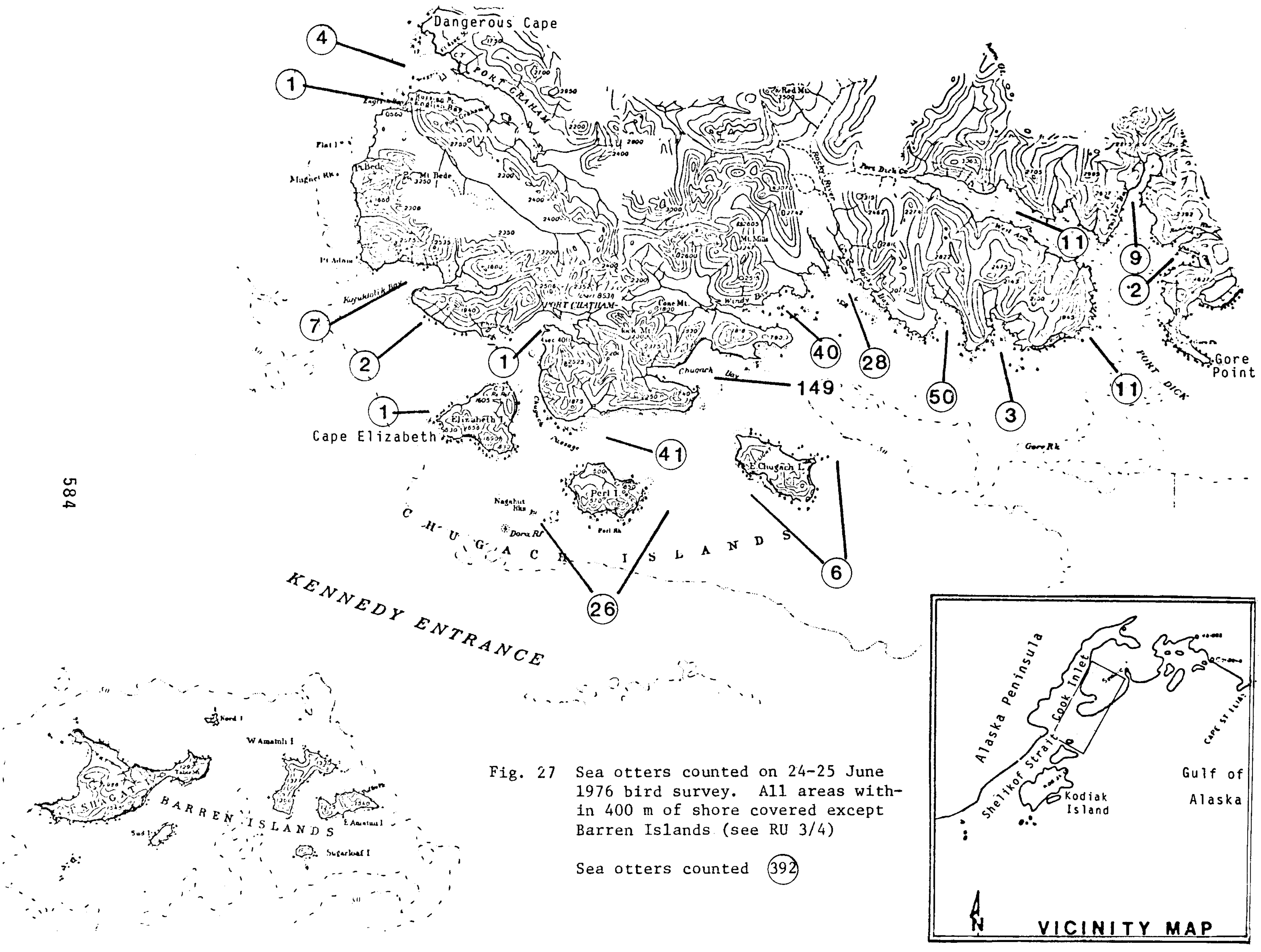


Fig. 27 Sea otters counted on 24-25 June 1976 bird survey. All areas within 400 m of shore covered except Barren Islands (see RU 3/4)

Sea otters counted (392)

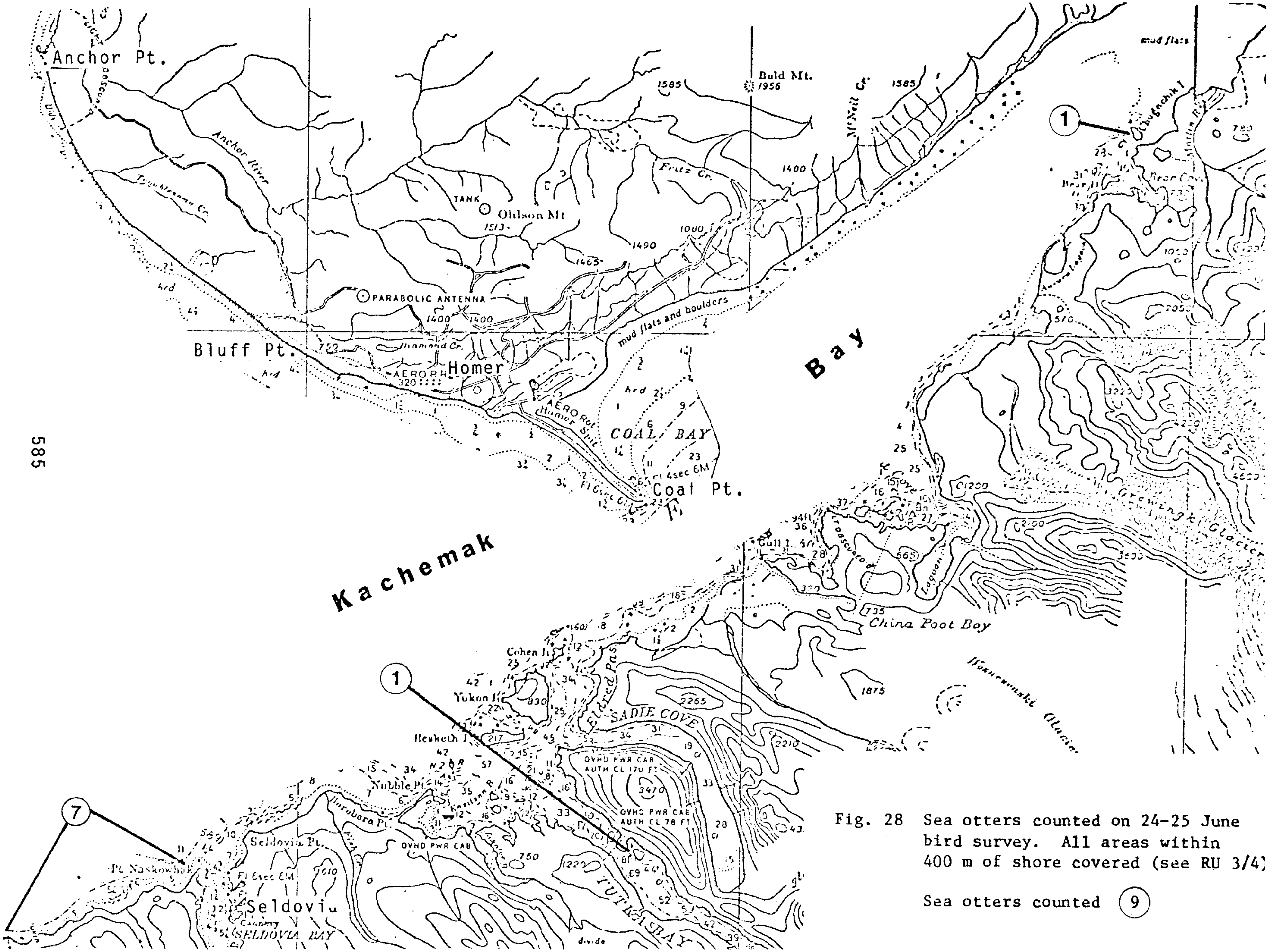


Fig. 28 Sea otters counted on 24-25 June bird survey. All areas within 400 m of shore covered (see RU 3/4)

Sea otters counted ⑨

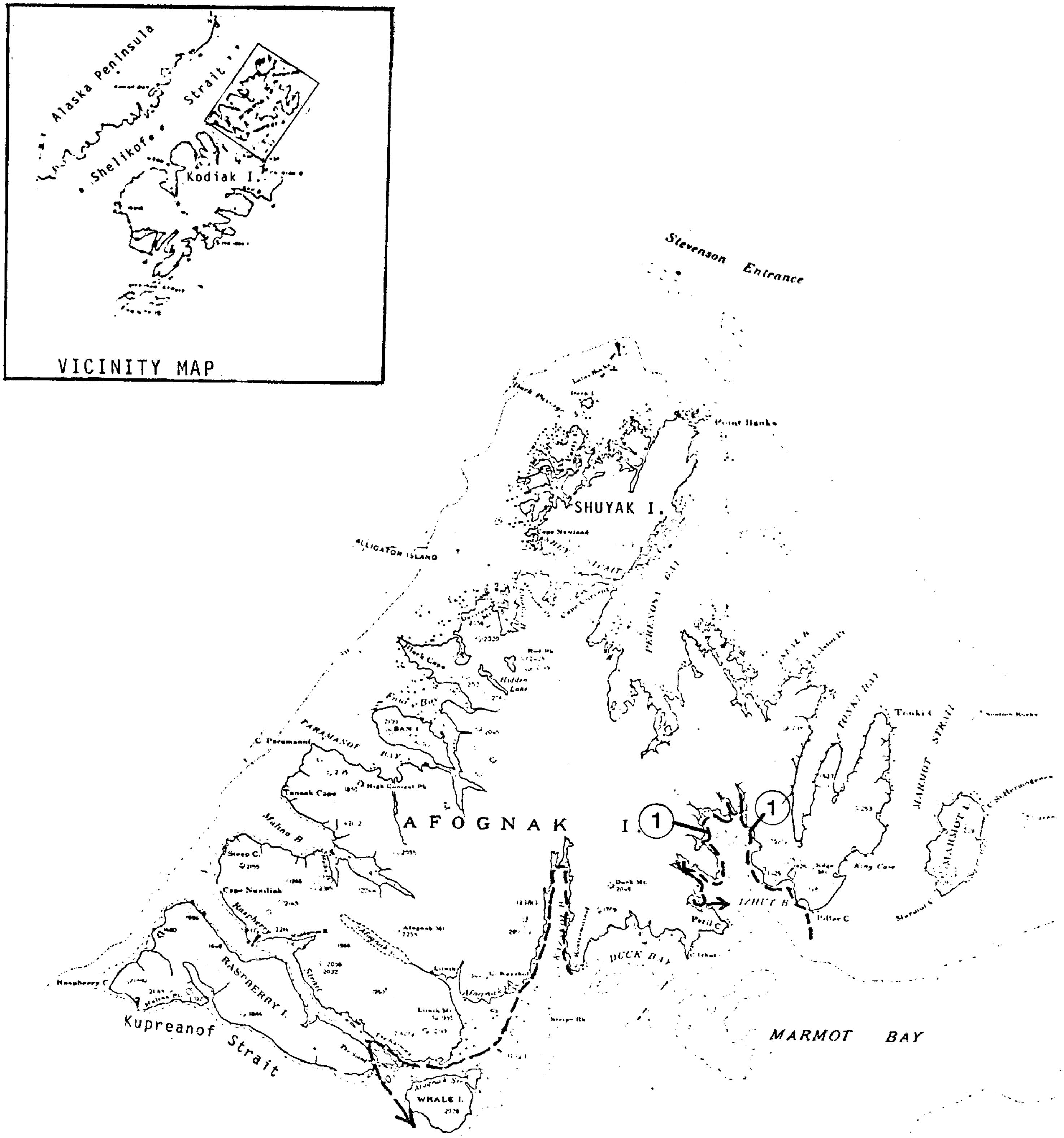
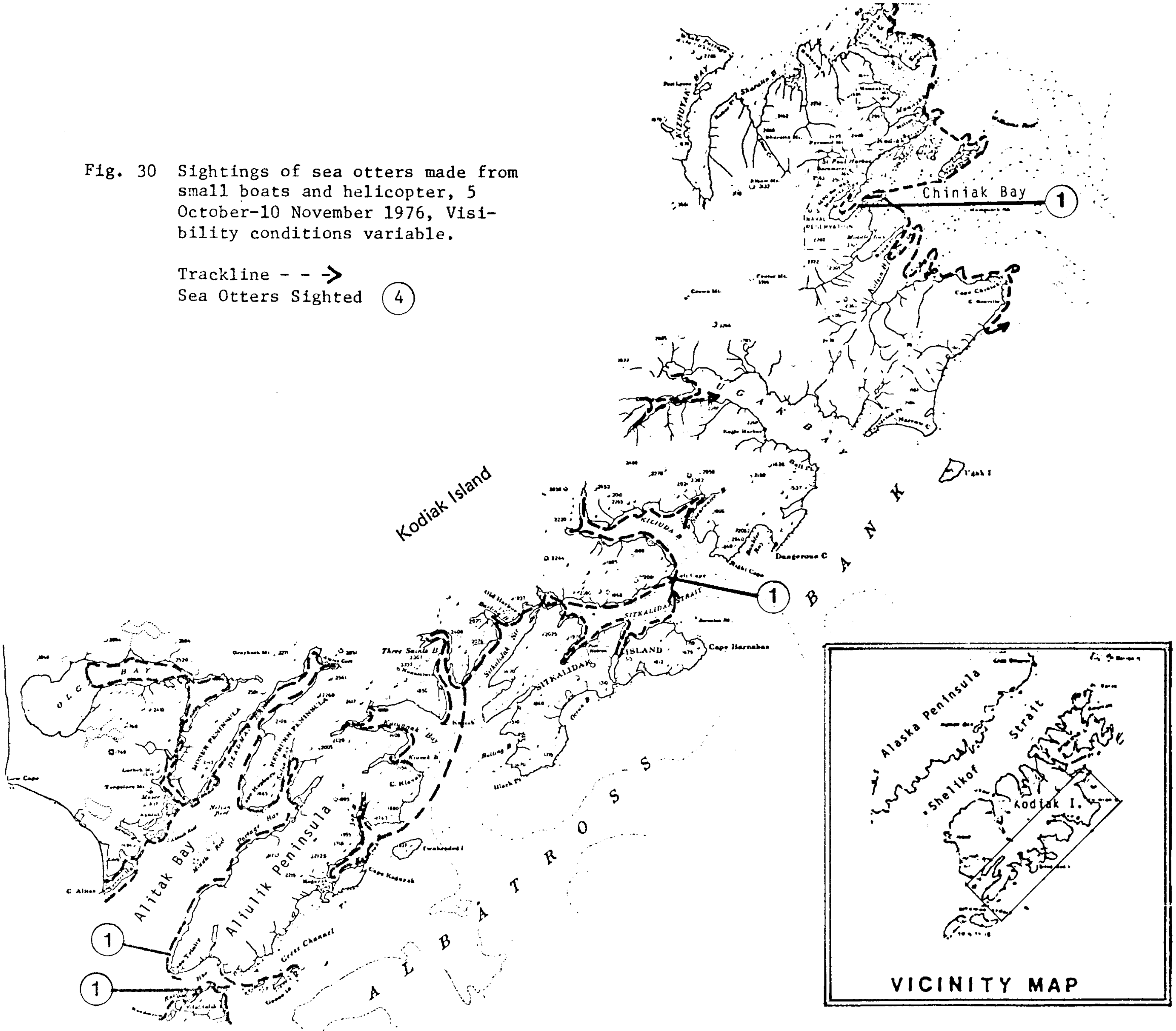


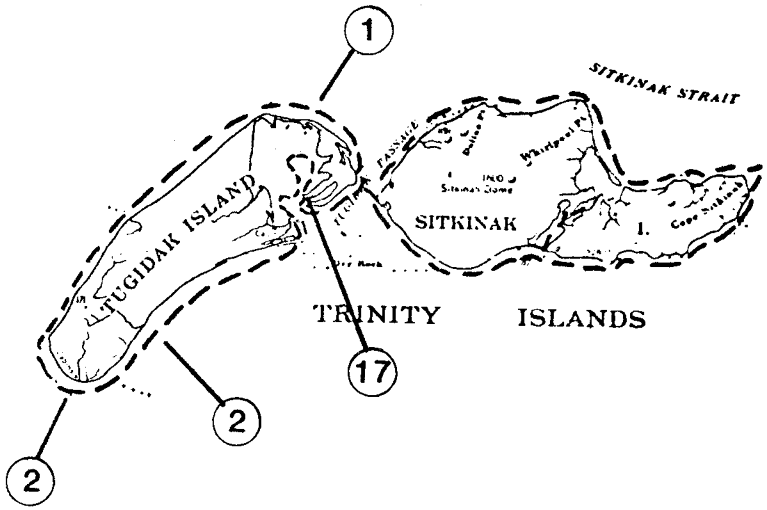
Fig. 29 Sightings of sea otters made from small boats October 1976. Visibility conditions variable.

Trackline - - ->
Sea Otters Sighted ②

Fig. 30 Sightings of sea otters made from small boats and helicopter, 5 October-10 November 1976, Visibility conditions variable.

Trackline - - ->
Sea Otters Sighted ④





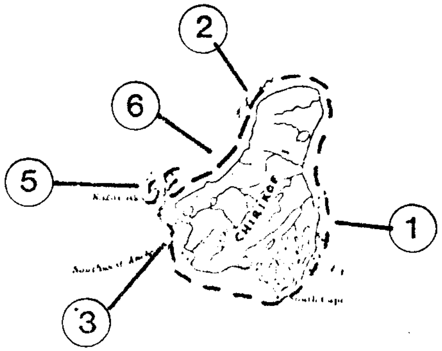
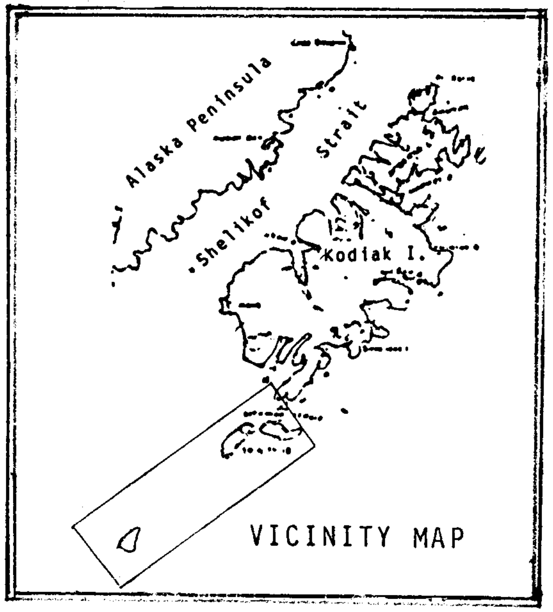


Fig. 31 Sightings of sea otters made from helicopter, 8-9 October 1976. Visibility conditions poor.

Sea Otters Sighted (39)



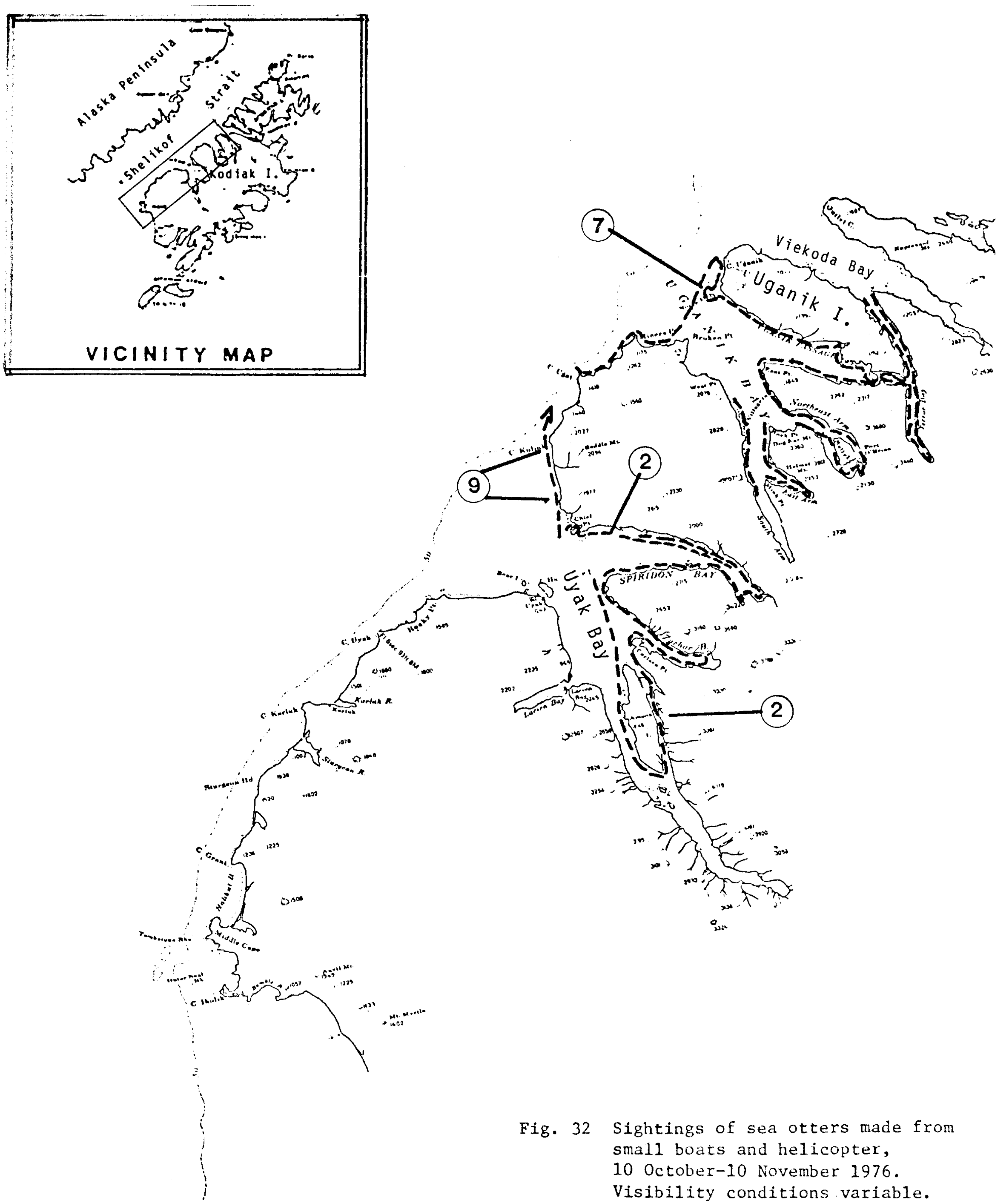


Fig. 32 Sightings of sea otters made from small boats and helicopter, 10 October-10 November 1976. Visibility conditions variable.

Trackline - - ➤

Sea Otters Sighted ⑳

Table 8. Recent significant sightings of sea otters.

Location	Date	Number of Sea Otters	Observer
Kachemak Bay			
Bear Cove	Spring 1973	1	M. McBride
Peterson Bay	Spring 1973	1	M. McBride
Glacier Spit	1 June 1975	1	Bill McDermitt
Sadie Cove	4 May 1975	2	Merle Wolford
Tutka Bay	April-May 1975 (daily)	1	T. Kronin
Homer Spit	Spring-Summer 1976 (died Aug. 1976)	1	Numerous
26.7 Naut. Mi. Transect Homer Spit west along 59°35'54" N Lat.	30 March 1976	30	D. Erickson
Yukon Island	17 March 1976	2	Ballard & Erickson
Bluff Point	13 March 1976	27	Ballard
Outer Kenai Coast			
Quartz Bay (Nuka Bay)	2 May 1975	50	S. Linderman
Chugach Passage	1 April 1975	"Hundreds"	T. Edwards
Port Graham	13 June 1975	40-50	K. Kyle
Harris Bay	31 August 1976	100	P. Arneson
East Arm Nuka Bay	31 August 1976	5	P. Arneson
West Arm Nuka Bay	31 August 1976	45	P. Arneson
Kamishak Bay & Cook Inlet			
Augustine Island	5 March 1976	50 hauled out	Ballard-Erickson
59°26'N 152°52'W	10 May 1976	1	Erickson
59°28'N 152°00'W	10 May 1976	1	Erickson
59°29'N 152°22'W	30 Sept 1976	2	Erickson & Kurhajec
Kalgin Island	9 June 1975	2	USFWS-Briggs
Kodiak			
Malina Pt. Raspberry I.	Spring 1975	20	"A Pilot"(B. Ballenger)
South of Marmot Strait	July 1975	25	B. Ballenger
Raspberry Strait	1975	1	B. Ballenger
Spruce Cape	"frequently" 1975	1-2	G. Hadju
Outlet Cape	22 April 1975	10	B. Ballenger
Gull Point	28 February 1976	2	P. Arneson
Foul Bay	22 March 1976	48	P. Arneson
Kupreanof Strait	22 March 1976	1	P. Arneson
Deadman Bay	5 March 1976	2	P. Arneson
Tugidak I.(Northwest side)	30 June 1976	1 dead	B. and P. Johnson
Tugidak	8 July 1976	1 dead	B. and P. Johnson
Tugidak	10 July 1976	1 dead	B. and P. Johnson
Tugidak	23 July 1976	1 dead	B. and P. Johnson
Tugidak	25 July 1976	1	B. and P. Johnson
Tugidak	29 July 1976	2 (1 pup)	B. and P. Johnson
Tugidak	1 August 1976	1 dead	B. and P. Johnson

Table 8 (Cont'd.) Recent significant sightings of sea otters.

Location	Date	Number of Sea Otters	Observer
Tugidak	9 August 1976	3 (1 pup)	B. and P. Johnson
Tugidak	27 August 1976	1 dead	B. and P. Johnson
Tugidak	31 August 1976	1	B. and P. Johnson
Tugidak	13 September 1976	1	B. and P. Johnson
Marmot Bay			
58°08'N, 152°01' W	22 May 1976	2	USFWS-Bartonek
58°09'N, 152°00' W	16 July 1975	1	USFWS-Cline
58°07'N, 152°00' W	16 July 1975	2	USFWS-Cline

The probability of sighting a sea otter is influenced by the speed and altitude of the platform, distance from the trackline, lighting conditions, sea state, activity of the animal, group size and presence of birds, other marine mammals, kelp etc. Experience indicates that many otters are missed even under ideal conditions and ideal conditions rarely occur along Alaska's coast. Some success has been achieved in attempts to census sea otters through intensive use of combinations of air and ground counts over small areas and at considerable cost. These indicate that there may be 1.5 to 4 times as many sea otters as are seen from a helicopter and perhaps 4 to 10 times as many as seen from a fixed wing aircraft, but it has never been possible to measure all variables. Therefore, the counts presented in this report should not be considered total counts. They indicate distribution and relative abundance and permit only rough estimates of population size.

KENAI PENINSULA

A summary of significant counts of sea otters around the Kenai Peninsula is presented in Table 9. All counts are arranged by standardized count areas to facilitate comparison. Locations are the approximate midpoints of each count area. These counts were conducted by different individuals using different survey platforms under varying conditions of visibility. All possible sea otter habitat was rarely covered. Changes in numbers seen in each count area are often due to differences in surveys rather than actual changes in numbers of sea otters present. When considered with reports from residents of the area and biologists frequently visiting the area certain patterns are evident, however.

Table 9. Summary of significant counts of sea otters around the Kenai Peninsula.

Area	Location Latitude	Location Longitude	1951-[*] 1953	1967-[*] 1968	1970-[**] 1971	Oct 1975 Helicopter Survey	Feb 1976 Bird Survey	Apr 1976 Strip Census	May 1976 Bird Survey	June 1976 Bird Survey	Jun-[***] July 1976 Boat Survey	Aug 1976 Mapping Flight
Puget Bay	59° 58' N	148° 31' W	No significant population	Few sightings	NS	25						
Whidbey-Johnstone	59° 55'	148° 50'			22	15						
Day Harbor	59° 58'	149° 10'			8	13						
Resurrection Bay	59° 58'	149° 23'			2	29					9	
Aialik Bay	59° 45'	149° 42'			20	36					36	
Harris Bay	59° 43'	149° 53'			38	92					72	100
Pye Reef-Two Arm	59° 30'	150° 14'			1	1					16	
East Arm-Nuka	59° 27'	150° 25'			85	26					35	5
McCarty Arm	59° 38'	150° 18'			8	NS						
West Nuka	59° 28'	150° 34'			41	20					127	45
Nuka Passage	59° 20'	150° 48'			10	32					56	2
Port Dick	59° 14'	151° 03'	1		23	15	12		13	33	134	
Rocky Bay	59° 12'	151° 20'			4	90	8		11	121		
Chugach Bay	59° 10'	151° 35'		400+	76	66	44		36	222	260	
Port Chatham	59° 12'	151° 50'	15		50	54	56		18	11		
Port Graham	59° 22'	151° 55'	No significant population		0	16	41		75	5		
Seldovia	59° 27'	151° 44'		Few sightings	Few sightings	4	20		5	7		
Tutka-Sadie	59° 30'	151° 30'				1	4		1	1		
Halibut Cove	59° 36'	151° 15'				1	0		0	0		
Bear Cove	59° 43'	151° 06'				5	1		0	1		
Coal Bay	59° 42'	151° 14'				0	0		0	0		
Coal Pt-Anchor Pt	59° 40'	151° 45'				0	0	400 est.	0	0		
Anchor Pt-Ninilchik	59° 55'	151° 47'				0	0	0	0	0		
Ninilchik-Clam Gulch	60° 09'	151° 30'				0	0	0	1	0		
Clam Gulch-Kenai	60° 22'	151° 20'				0	0	0	0	0		

* From Lensink (1962)

** Composite of highest counts from several surveys

*** Bailey (1976)

NS = None seen

History

Sea otters probably were eliminated from the Kenai Peninsula by the early 1900's. It appears that remnant populations may have survived in southwestern Prince William Sound, the northern Kodiak Archipelago and Kamishak Bay. Small numbers were occasionally reported between the Chugach Islands and Cape Puget in the 1950's and early 1960's but Kenyon (1969) concluded that no significant population occurred in the area. Reports increased steadily through the mid-1960's and in 1967 several hundred and perhaps over 1,000 abruptly appeared in the vicinity of Port Graham and Chugach Bay. This concentration diminished over the next few years, perhaps as the result of dispersal to the east.

By 1970 sea otters were distributed in small numbers along the entire peninsula from Cape Puget to Port Graham. Rare sightings occurred in Kachemak Bay. It appeared that repopulation was the result of range expansion by the Prince William Sound population and large scale immigration from another area, perhaps the Barren Islands. Between 1970 and early 1975 no major changes were reported although sightings in Kachemak Bay increased and sea otters became a common sight near Seward.

Present Status

Survey conditions around the Kenai Peninsula during October 1975 helicopter survey were less than ideal. The percentage of sea otters recorded was probably in the lower range for helicopter surveys. There may be three or more times as many as counted. Results of the June 1976 bird survey, Bailey's (1976) boat counts and other sightings (Tables 8 and 9) tend to support this view. The survey did delineate the distribution of the population and provide good information on the relative abundance of sea otters occupying various parts of the area. These were the primary objectives of the survey. Bailey's (1976) boat counts (Table 9) probably provide the best information on distribution and abundance within the area he covered. The technique he employed would tend to give more uniform results in areas where extensive offshore shallow areas do not exist. His counts should still be considered minimal especially in the area west of Gore Point.

The October helicopter survey and recent sightings indicate that the distribution of sea otters along the outer Kenai coast is essentially the same as in 1970. Some range expansion into Kachemak Bay has occurred. The distribution and relative densities of sea otters between Port Graham and Cape Puget generally seem to conform to the distribution of suitable habitat. This indicates that no major range expansion is occurring in that area and it is unlikely that significant changes will occur in the future, although densities may increase. Sea otters appear established in the area from Port Graham to Seldovia but their densities are low. Scattered otters occur along the entire south side of Kachemak Bay but no groups of breeding animals have become established there.

There have been occasional sightings of sea otters near Homer and as far north as Deep Creek since the late 1960's. These appeared to be stray animals and were usually old males. In 1975 there was an increase in sightings of sea otters in offshore areas west of the area between Homer and Anchor Point indicating recent range expansion. The 1 April 1976 strip transect survey confirmed that a substantial number of sea otters were dispersed over a large area. A reliable population estimate is not possible from these data, however, it would appear that over 400 sea otters occupy the area surveyed and their numbers are increasing. No pups have been reported in this area suggesting that this group is composed of sexually inactive animals probably mostly "surplus" males. Such animals are usually the first colonizers of vacant habitat. Their numbers increase through immigration from adjacent areas of high density rather than through reproduction in the recently populated area. It may take several years for a significant level of reproduction to develop in this area.

The survey did not cover all of the presently occupied habitat as sea otters were seen near the ends of the tracklines and on both the first and last tracklines. General observations indicate that there are few north of Anchor Point, however. The first recent observation of a sea otter north of Ninilchik was made in May 1976 (Fig. 26). An unusual characteristic of this population is its offshore distribution which is similar to that found north of Unimak Island and the Alaska Peninsula (see RU 241).

Future

Kenyon (1969) described a common pattern of range expansion for sea otters. Concentrations often build up at the fringes of a population then abruptly disperse into adjacent habitat only when competition for food arises. This abrupt movement is often preceded by an increase in the occurrence of stray transient animals. This pattern appears to be occurring in the lower Cook Inlet-Kachemak Bay area today. High densities built up in the area between Rocky Bay and Port Graham in the late 1960's and early 1970's. Stray animals in Kachemak Bay increased then an abrupt shift to the area northwest of Homer occurred. At the same time there appears to have been a decrease near Port Graham where frequent unconfirmed reports of over 200 were received in the early 1970's. Some immigration from Kamishak Bay might also have occurred. This pattern of range expansion should continue for several years. We can expect continued movement of animals from the outer Kenai Peninsula into Kachemak Bay and northward up Cook Inlet.

Kachemak Bay, particularly the south side, should eventually support relatively high sea otter densities. Opportunities for the general public to view sea otters in Alaska are extremely limited. Kachemak Bay will probably eventually be the most accessible sea otter viewing area in Alaska. Therefore, the importance of the bay and the sea otter population that will repopulate it is increased.

The potential for range expansion north of Kachemak Bay is less certain. Sea otters are capable of feeding in waters 80 m deep and in rare cases more than 100 m deep although most normally remain in water 60 m deep or less. Therefore, potential sea otter habitat extends across Cook Inlet and this population may become contiguous with that in Kamishak Bay. Food availability and perhaps the occurrence of sea ice will probably determine the eventual northern limit of this population. At this time it is difficult to predict what the northern limit will be. A recent sighting near Kalgin Island (Table 8) suggests that at least stray individuals may eventually occur throughout lower Cook Inlet.

Critical Areas

The potential for adverse impacts of OCS development on sea otters inhabiting the waters around the Kenai Peninsula appears high. Presently occupied or potential sea otter habitat lies in and adjacent to proposed lease areas and sites for onshore activities. Oil spills, in particular, could greatly reduce sea otter numbers and retard the process of repopulation of former habitat. Impacts in some areas would have greater detrimental effects than those in other areas.

Densities of sea otters between Gore point and Cape Puget are low. The area consists of deep, steep-sided fiords. Waters of suitable depths for sea otter foraging are limited to a narrow band along the shores and a few scattered submerged glacial moraines and shallow lagoons. The observed distribution of sea otters generally coincided with the distribution of shallow water. Most concentrations were inside the major bays. Very few sea otters were seen near exposed capes. Areas with a direct southeast exposure to the Gulf of Alaska are generally precipitous and wave scoured and offer little habitat for sea otters.

The combination of topography of the area and distribution of sea otters would probably limit the impact of offshore oil spills in this area. Sea otters east of Gore Point are probably contributing less to repopulation of new areas than those west of Gore Point. If a short-term impact such as an oil spill reduced sea otter numbers east of Gore Point, recovery could be rapid provided the relatively dense populations in Prince William Sound and west of Gore Point remained unaffected. Perhaps the greatest loss in human terms would be a loss of opportunity to view sea otters should a reduction occur in Resurrection Bay.

The situation west of Gore Point is quite different. Concentrations of sea otters near the fringes of expanding populations appear to be important to the repopulation process. Animals toward the center of the population probably contribute less to repopulation than those near the fringes. From this standpoint the area from Port Graham to Rocky Bay may be critical. A reduction in sea otter densities in that area could seriously retard repopulation of Kachemak Bay and Lower Cook Inlet. Kachemak Bay and all waters of lower Cook Inlet less than 60 m deep, at least as far north as Ninilchik, should also be considered critical because of their potential as sea otter habitat.

KAMISHAK BAY

History

The history of sea otters in Kamishak Bay is vague. Most surveys of the area have included only the shoreline of Augustine Island and perhaps Shaw Island and Cape Douglas. Occasional sightings of large numbers offshore and dramatic fluctuations in shoreline counts suggested that considerable movement occurred and that much of the occupied habitat lay outside of the area surveyed. The 1 April 1976 survey was the first attempt to locate sea otters in all potential habitat in Kamishak Bay. Table 10 presents the most significant counts made in Kamishak Bay and adjacent areas. These counts were made under variable conditions and should be compared with caution.

It appears that a small remnant population of sea otters remained in Kamishak Bay in the early 1900's. This population, centered around Augustine Island, probably grew throughout the 1940's and 1950's although no growth is evident in the counts. By 1965 some range expansion to the south had occurred. Counts made between 1969 and 1971 indicated that there may have been an increase in numbers around Augustine Island and the waters immediatedly to the north and west and that there had been a substantial movement around Cape Douglas to the vicinity of Shakun Rocks. The relatively high numbers seen by Prasil (1971) southwest of Cape Douglas suggest that the population within Kamishak Bay proper had reached a much higher level in the early 1960's than indicated by the counts.

Most likely, densities in the bay increased steadily through the 1960's then stabilized or declined slightly as animals emigrated to the southwest and possibly to the east across Cook Inlet. There is also a possibility that periodic oil spills influenced numbers although no direct evidence of oil related mortality is available from that area.

Present Status

The available information indicates that the range of the population extends from northern Kamishak Bay to Cape Nukshak. Otters may occur

Table 10. Summary of significant counts of sea otters in Kamishak Bay and adjacent waters.

	1948[1]	1957[1]	1959[1]	1965[2]	1969	1970	1970-71[3]	1971	Apr 1976[4]	Jun 1976
North of Chinitna Pt	Reports						60			
Augustine I. shoreline	50	40	52	18	132			24	40	
Chinitna Pt-Douglas R. (including offshore areas)	Reports							100-150	28	
Douglas R-C. Douglas		1		71.		0			5	
C. Douglas-Kiukpalik I.		0	0	30		0	92			
Kiukpalik I.-C. Chiniak		0	0	0		71	443			
C. Chiniak-C. Nukshak		0	0	0		0	0			
C. Nukshak-C. Kubugakli		0	0	1		0	0			0
C. Kubugakli-C. Unalishagvak		0	0	0		7				35

1 Lensink (1962)
2 Kenyon (1969)
3 Highest counts from Prasil (1971)
4 Partial coverage, see fig. 15

throughout the shallow waters of Kamishak Bay and often range far from shore. The distribution observed on 1 April 1976 (Fig. 15) seemed to be influenced by the distribution of sea ice. Many sea otters were associated with patches of drift ice and 17 were hauled out on ice. The sea otters appear to be relatively mobile in this area and major shifts may occur periodically. Concentrations usually occur around Augustine Island, particularly the north side; in the waters west of Augustine Island; around Shaw Island and Cape Douglas; at Douglas Reef; and at Shakun Rocks. Observed numbers in each of these areas have fluctuated widely, however.

Sea otters inhabiting the Alaska Peninsula coast between Cape Douglas and Cape Chiniak should be considered part of the Kamishak population. Those sighted near Puale Bay in 1970 and 1976 are probably at the extreme fringe of the large population that is centered near Kujulik and Amber Bays. Therefore, the Kamishak population and the Kujulik population are expanding their ranges toward each other and should eventually become contiguous. A superficial survey of the area between Cape Nukshak and Puale Bay in June 1976 indicated that little expansion of range has occurred since 1970 but the pattern of range expansion is clear.

Although a reliable population estimate cannot be derived from data collected on 1 April 1976, crude estimates indicate that there might be between 500 and 1,000 sea otters in Kamishak Bay. The number southwest of Cape Douglas probably equals or exceeds that number.

Future

The population should continue to expand its range to the southwest. Eventually some range expansion to the north should occur. The range of this population could become continuous with that of the Kenai Peninsula. Recent sightings in the middle of lower Cook Inlet (Table 8) indicate that some interchange already occurs. At this time it is not possible to predict how far up Cook Inlet either population will expand.

Critical Areas

At the present time the area around Augustine Island and northern Kamishak Bay should be considered most critical to the process of repopulation of former sea otter range. The concentration inhabiting the Shakun Rocks area is also expected to contribute significantly to the repopulation of vacant habitat and is highly vulnerable. However, the presence of the large and rapidly expanding Kujulik Bay population to the southwest makes survival and growth of the Shakun Rocks group less critical.

KODIAK ARCHIPELAGO

Three separate population centers of sea otters exist in the Kodiak Archipelago. These are: (1) the Barren Islands, (2) Shuyak-Afognak and (3) Trinity Islands-Chirikof Island. Each will be discussed separately.

1. Barren Islands

History

Significant counts of sea otters made in the Barren Islands are presented in Table 11. These counts were made under different conditions and may not be directly comparable.

No real change in numbers is apparent after 1957. All of the lower counts including those made in 1976 were made under poor conditions or were incomplete. The difference between the 1951 and 1957 counts is not easy to explain. Either a substantial nucleus population was present in 1951 but was missed on the survey, or a group emigrated from the Shuyak Island area. In either case the island group was fully repopulated by 1957. Lensink (1962) speculated that regular movements occurred between Shuyak and the Barren Islands. The fluctuations in counts which lead him to suggest this were more likely caused by scattering of animals offshore but some major movements may have occurred.

The group of several hundred sea otters that appeared on the Kenai Peninsula in 1967 may have come from the Barren Islands. If this is the case there may have been substantial fluctuations in the number of sea otters occupying the Barren Islands that are not evident in the counts.

Present Status

At the present time this population can be considered at or near the carrying capacity of the habitat. Densities are highest in the shallow

Table 11. Summary of significant counts of sea otters around the Barren Islands.

Area	Latitude	Longitude	1951*	1957*	1957*	1959*	1964	1966	1970	1974**	1975**	May 1976	June 1976
Sugarloaf I.	58° 53' N	152° 02' W							0		6		1
E. Amatuli I.	58° 55'	151° 59'							0		5		0
W. Amatuli I.	58° 56'	152° 03'							2		21	8	2
Nord I.	58° 58'	152° 09'							0		12		0
N. side Ushagat	58° 57'	152° 15'							75	150	21	10	8
S. side Ushagat	58° 54'	152° 15'						150+	1		20	40	35
Sud I.	58° 54'	152° 13'							29	120	71	33	15
Carl I.	58° 53'	152° 19'							200		70	60	50
Total			0	325	234	272	81		307		226	151	111

* Lensink 1962

** Bailey 1975

waters south of Ushagat Island including those around Carl Island and Sud Island. Low densities are usually found throughout the remainder of the island group. This distribution has been evident in most counts and probably reflects the quality of the habitat.

Future

Little change is expected in the status of sea otters in the Barren Islands. Numbers may fluctuate but the distribution should remain similar to that observed in recent years. Occasionally sea otters might immigrate to the Kenai Peninsula or Shuyak Island but such movements will be difficult to detect. The Barren Island population is no longer playing an important role in the process of repopulation of vacant sea otter habitat.

Critical Areas

Complete elimination of the Barren Island population would have relatively little impact on other areas. Therefore, consideration of critical areas can only be based on survival of the population as a separate entity. Perhaps two-thirds of the population regularly inhabits the relatively small area around the south side of Ushagat Island, Carl Island and Sud Island. Most reproductive activity probably occurs there. Therefore, this area is critical to the survival of the Barren Island population.

Because that area is small, the population is highly vulnerable and could be severely reduced by a minor oil spill. Repopulation of the

Barren Island group would eventually occur through immigration from the Kenai Peninsula or Shuyak Island, but this could take many years.

2. Shuyak-Afognak

History

Significant counts of sea otters around the area between Shuyak Island and Chirikof Island are summarized in Table 12.

A remnant population survived in the vicinity of Latax Rocks and Sea Otter Island. By the 1950's this population was well established and appeared to be growing rapidly, expanding its range to Afognak Island in the vicinity of Seal Bay.

Little change was evident in the 1960's. The range of the population remained the same although stray individuals were seen around Kodiak Island. No increase in numbers was evident. There may be several reasons for this apparent lack of growth. First, sea otter populations often increase in numbers without expanding their range for several years. Traditional survey techniques are not always sensitive enough to detect increases in densities. Counts made during the 1960's were incomplete and often not directed specifically at sea otters. Second, immigration to the Barren Islands and eventually to the Kenai Peninsula may have occurred. This would explain the lack of a major reduction of the Barren Island population when several hundred sea otters appeared on the Kenai Peninsula in the mid-1960's. Third, oil, probably from tanker

Table 12. Summary of significant counts of sea otters around the Kodiak Archipelago

			1951*	1957*	1957*	1958*	1959*	1964	1966	Sightings 1964-1971	1970	Sightings 1975	Heli-copter 1975	Boat 1976	Air March 1976	Misc 1976
Cape Chiniak	57° 38'N	152° 15'W								1					0	
Kodiak	57° 45'	152° 20'								2		Few		0	0	1,1
Spruce I.	57° 55'	152° 23'														
Ouzinki	57° 57'	152° 30'											0			
Sharatin Bay	57° 53'	152° 41'														
Kizhuyak Bay	57° 49'	152° 52'														
Whale Passage	57° 56'	152° 50'										1				
Afognak Bay	58° 02'	152° 43'											6			
Kazakof Bay	58° 08'	152° 35'											0			
Duck Bay	58° 07'	152° 27'											1		6	
Izhut Bay (West)	58° 11'	152° 17'										Few	1			1
Izhut Bay (East)	58° 11'	152° 12'											0		0	1
King Cove	58° 12'	152° 00'											16			
Marmot I.	58° 13'	151° 50'						1			3	25	529			
Tonki Cape	58° 21'	151° 59'								3			134			
Tonki Bay	58° 18	152° 08'											32			
Seal Bay (East)	58° 22'	152° 10'											164			
Seal Bay (West)	58° 23'	152° 16'				581	365	13		Many			342			
Perenosa Bay (South)	58° 22'	152° 25'									2		290			
Perenosa Bay (North)	58° 27'	152° 28'									4		58			
Shuyak (East)	58° 31'	152° 23'		5	12								10			
Sea Otter I.	58° 31'	152° 12'	15		75				150+		121		156			
Point Banks	58° 38'	152° 19'			75				100+				9			
Shuyak (North)	58° 36'	152° 28'	67	89	119								14			
Latax Rocks	58° 40'	152° 31'						63			26		59			
Shuyak (West)	58° 34'	152° 39'									33		12	272		
Shuyak Strait	58° 29'	152° 35'									0		2	14		
Bluefox Bay	58° 27'	152° 44'									18		81	32		
Foul Bay	58° 21'	152° 50'											61	60		48
Paramanof Bay	58° 18'	152° 56'												15		
Malina Bay	58° 13'	153° 05'													31	3
Raspberry Strait	58° 06'	153° 06'													20	
Kupreanof Strait	57° 59'	153° 10'										10, 20		1	20	1
Viekoda Bay	57° 54'	153° 14'													1	
Uganik Passage	57° 51'	153° 24'												37	12	7
Uganik Bay	57° 48'	153° 30'														
Cape Ugat	57° 52'	153° 51'												1	0	9
Uyak Bay (East)	57° 39'	153° 50'								5				1		2
Uyak Bay (South)	57° 25'	153° 50'												0		2
Uyak Bay (West)	57° 36'	153° 58'													5	

Table 12 (Cont.) Summary of significant counts of sea otters around the Kodiak Archipelago

			1951*	1957*	1957*	1958*	1959*	1964	1966	Sightings 1964-1971	1970	Sightings 1975	Heli-copter 1975	Boat 1976	Air March 1976	Misc 1976
Rocky Point	57° 40'N	154° 12'W														
Karluk	57° 35'	154° 30'													0	
Halibut Bay	57° 25'	154° 43'													0	
Ayakulik	57° 10'	154° 35'													1	
Low Cape	56° 55'	154° 20'													0	
Alitak Bay	56° 53'	154° 05'														2
Deadman Bay	57° 04'	153° 57'													0	1
Olga Bay	57° 08'	154° 15'														2
Tugidak I. (North)	56° 35'	154° 35'	0	0												
Tugidak I. (South)	56° 25'	154° 35'	0	0						Beach Deads					1	1
Sitkinak I. (South)	56° 30'	154° 10'	0	0	15					Annually					21	21
Sitkinak I. (North)	56° 38'	154° 05'	0	0						Present					1	
Tugidak-Chirikof	56° 00'	155° 30'														
Chirikof I.	55° 50'	155° 40'	0							6					1	
Aiaktalik I.	56° 43'	154° 00'								4					10	17
Twoheaded I.	56° 53'	153° 37'													0	1
Three Saints Bay	57° 06'	153° 28'								1					0	
Sitkalidak I. (West)	57° 04'	153° 25'														
Sitkalidak I. (South)	57° 05'	153° 05'														
Sitkalidak I. (North)	57° 12'	153° 05'													0	
Kiliuda Bay	57° 19'	153° 00'														1
Dangerous Cape	57° 19'	152° 38'														
Ugak Bay	57° 27'	152° 40'													0	2
Ugak Island	57° 23'	152° 15'													1	
Sequel Point	57° 31'	152° 15'													0	
															0	

* Lensink (1962)

ballast, has periodically killed many sea birds in this area. Some mortality of sea otters might have occurred.

The 1970 survey and increased sightings around Afognak Island and northern Kodiak Island indicated that range expansion along the northern and western sides of Afognak Island had finally started. The 1975 and 1976 surveys indicate that the rate of range expansion has accelerated and that the size of the population has, in fact, increased substantially.

The population has gone through the classic pattern of growth described by Kenyon (1969). It remained concentrated in a small area, built to high densities, then abruptly expanded its range into adjacent vacant habitat. Whether expansion to the south was retarded by immigration to the north or by mortality from oil spills is uncertain. The population has overcome whatever limiting influences that might have existed and has entered a period of rapid range expansion.

Present Status

Survey conditions were generally good around the north side of Afognak and Shuyak Islands during the October 1975 helicopter survey. Many sea otters were resting in pods increasing their sightability. The percentage of sea otters seen was probably much higher than that seen around the Kenai Peninsula at the same time. We were forced to terminate the helicopter survey before we could clearly delineate the southwestern fringe of the population. The February 1976 skiff survey and March 1976 aerial survey corrected this one flaw and provided some information on shifts in distribution and sex segregation. Although Kodiak Island was not systematically surveyed most of its shoreline was visited during 1976. The data collected provide an excellent picture of the present distribution of the population (Figs. 6, 7, 8, 10 and 13).

The primary range of the population currently extends from Shuyak Island south to Raspberry Island on the west side of the archipelago and to Marmot Island on the east side. The area between Ban Island and Marmot Island supports sea otter densities comparable to those anywhere in the world. High proportions of females with pups were observed throughout this area. Most of the groups south of Malina Bay and Marmot Strait are probably composed of reproductively inactive animals. Scattered individuals and occasional small groups occur along the entire coast of Kodiak Island. Those between Uganik Bay and Low Cape on the northwest side and between Cape Chiniak and Two Headed Island on the southeast side probably do not represent established groups.

This distribution is typical of rapidly expanding populations, a central area of high density with well defined boundaries or "fronts" of expansion, occasional groups of nonbreeding animals ahead of the "fronts" in areas of good habitat and occasional stray animals far ahead of the "fronts." The "front" on the western side of the archipelago is less well defined than that on the eastern side, probably because areas of high quality habitat on the west side of Kodiak Island are widely separated encouraging greater dispersal.

Future

Range expansion southward along both sides of the archipelago should continue at a rapid rate over the next few years. This will be most noticeable in Marmot and Chiniak Bays which appear to contain large areas of suitable sea otter habitat. The timing of this expansion is difficult to predict but it seems reasonable to expect moderate to high densities to build up in those areas in the next 5 to 10 years. Abrupt movements of several hundred animals from Marmot Strait to such areas as Hog Island, Williams Reef and Cape Chiniak could occur at any time.

Eventually the population should become continuous with the Trinity Island population. Potential sea otter habitat on the northwest side of Kodiak Island north of Cape Ikolik appears limited and should require less time to become fully repopulated than the remainder of the island. We can expect a relatively sparse distribution of sea otters with a few small concentrations in areas such as the Noisy Islands, Chief Point and Harvester Island. The area south of Cape Ikolik is discussed under the Trinity Island population.

The southeast side of Kodiak Island has a number of large shallow areas that will probably support large numbers of sea otters. The number of stray individuals and small groups in the area should increase over the next few years. Eventually large numbers of sea otters should move into the area, primarily from the north but also from the Trinity Islands. It may take many years for sea otters to reach carrying capacity throughout the entire area.

Critical Areas

Virtually all reproduction in the Shuyak-Afognak population presently occurs around Shuyak Island and the northern half of Afognak Island. Rapid repopulation of Kodiak Island depends on maintenance of a high rate of reproduction in this area. Even when Kodiak Island is fully repopulated the area should remain one of the most important pieces of sea otter habitat in southcentral Alaska.

Marmot and Chiniak Bays will also be critical to the process of repopulation of the extensive areas of potential habitat along the east side of Kodiak Island for many years.

Many areas southwest of Cape Chiniak will become critical in the future. Quality of the habitat in that area should be maintained even though short-term impacts would have little effect until Chiniak Bay becomes densely populated.

3. Trinity Islands-Chirikof Island

History

An extensive area of almost 10,000 km^2 of water shallow enough to support sea otters lies between Kodiak Island and Chirikof Island. Small numbers were present in the Trinity Island area in the 1950's although no significant population could be found (Lensink 1962). This group probably represented a remnant population but could have formed from animals straying from

Shuyak Island. During the 1960's sightings around the Trinity Islands and Chirikof Island increased (Table 12). Beached, dead animals were found on Tugidak Island each year by seal biologists but live otters were rarely seen from shore. In 1971 a survey of the area between Tugidak Island and Chirikof Island was attempted but poor conditions and fog interfered. Six sea otters were seen midway between Tugidak and Chirikof Islands. This suggested that the range of the population was extensive and that the population was larger than suspected.

Present Status

No funds were available to survey this area under this research unit and the area remains to be properly surveyed. The observations made during activities funded under RU 243 (Figs. 11, 12, 19, 30 and 31) provide some information on distribution of the population.

There appears to be a concentration of sea otters south of Tugidak and Sitkinak Islands. Potential sea otter habitat extends over 20 km from shore in this area. A much larger area of potential sea otter habitat exists north of the Trinity Islands. Although only occasional sightings have been made in this area, the incidence of beached, dead animals on the northwest shore of Tugidak Island (Table 8) indicates that significant numbers occur there. These animals probably tend to remain well offshore and are missed on nearshore surveys.

Another concentration occurs near Chirikof Island. Again there is a large area of potential habitat offshore and there may be many more sea otters than indicated by the limited observations presented in this report. The potential sea otter habitat around Chirikof is continuous with that around the Trinity Islands. Sea otters have been seen between the islands indicating some use of this area. Densities appear lower there than they are closer to the islands, however.

Alitak Bay was reasonably well surveyed during 1976. Occasional stray sea otters occur there but no established groups were found. Similarly, densities around the Aliulik Peninsula are low even though habitat there appears excellent. This suggests that densities around the Trinity Islands and Chirikof Island are below carrying capacity and there has been little incentive for major range expansion.

The number of sightings in the area and along the south shore of Kodiak has increased steadily, however, indicating steady population growth.

Future

This population can be expected to grow for many years. Eventually the entire area within the 80 m depth contour may support moderate to high densities. The population should expand its range into Alitak Bay and northward along both sides of Kodiak Island until its range becomes continuous with that of the northern Kodiak population. Some interchange of stray animals may have already occurred.

Critical Areas

Until more information is available, all waters less than 80 m deep southwest of Kodiak should be considered critical to this population.

VIII. Conclusions

The outer Kenai Peninsula was repopulated by sea otters emigrating from Prince William Sound and perhaps the Barren Islands. The present population is contiguous with that in Prince William Sound. All of the habitat south and east of Port Graham is presently occupied. The population is currently expanding its range into Kachemak Bay and lower Cook Inlet. The potential for significant impacts of oil and gas development on sea otters appears greatest in the area between Rocky Bay and Ninilchik.

A separate population inhabits Kamishak Bay. This population has grown and expanded its range southwestward along the Alaska Peninsula. Potential sea otter habitat in Kamishak Bay is contiguous with habitat on the Kenai Peninsula. The two populations may become continuous and it is possible that some exchange is occurring at present. Both populations should expand northward until some factor such as food availability or seasonal sea ice limits further expansion.

The Barren Islands population appears to be near carrying capacity. Little change is expected in the future.

The Shuyak-Afognak population of sea otters is rapidly expanding its range on both sides of the Kodiak Archipelago. Densities around Kodiak Island remain low but should increase dramatically as sea otters emigrate from Afognak Island. The population appears large enough to survive a major oil spill; however, such an event could seriously retard repopulation of Kodiak Island.

A separate population occupies the shallow waters between Kodiak and Chirikof Islands. This population appears to be well established and growing, however, data on distribution and abundance are inadequate.

The present distribution of sea otters in the study area and patterns of range expansion are shown in Figs. 33 and 34.

Several areas appear to be critical to the survival of healthy sea otter populations or to the process of repopulation of former sea otter habitat. These areas are shown in Figs. 35 and 36.

As sea otters expand their range into new areas significant changes in nearshore communities can be expected. Many areas currently supporting high densities of sea otters are probably rapidly changing. The history of sea otter occupancy of an area should be considered by individuals attempting to understand those communities.

IX. Needs for Further Study

Coverage of most of the study area was adequate to meet the objectives of the study. The main deficiency was in the area around the south end

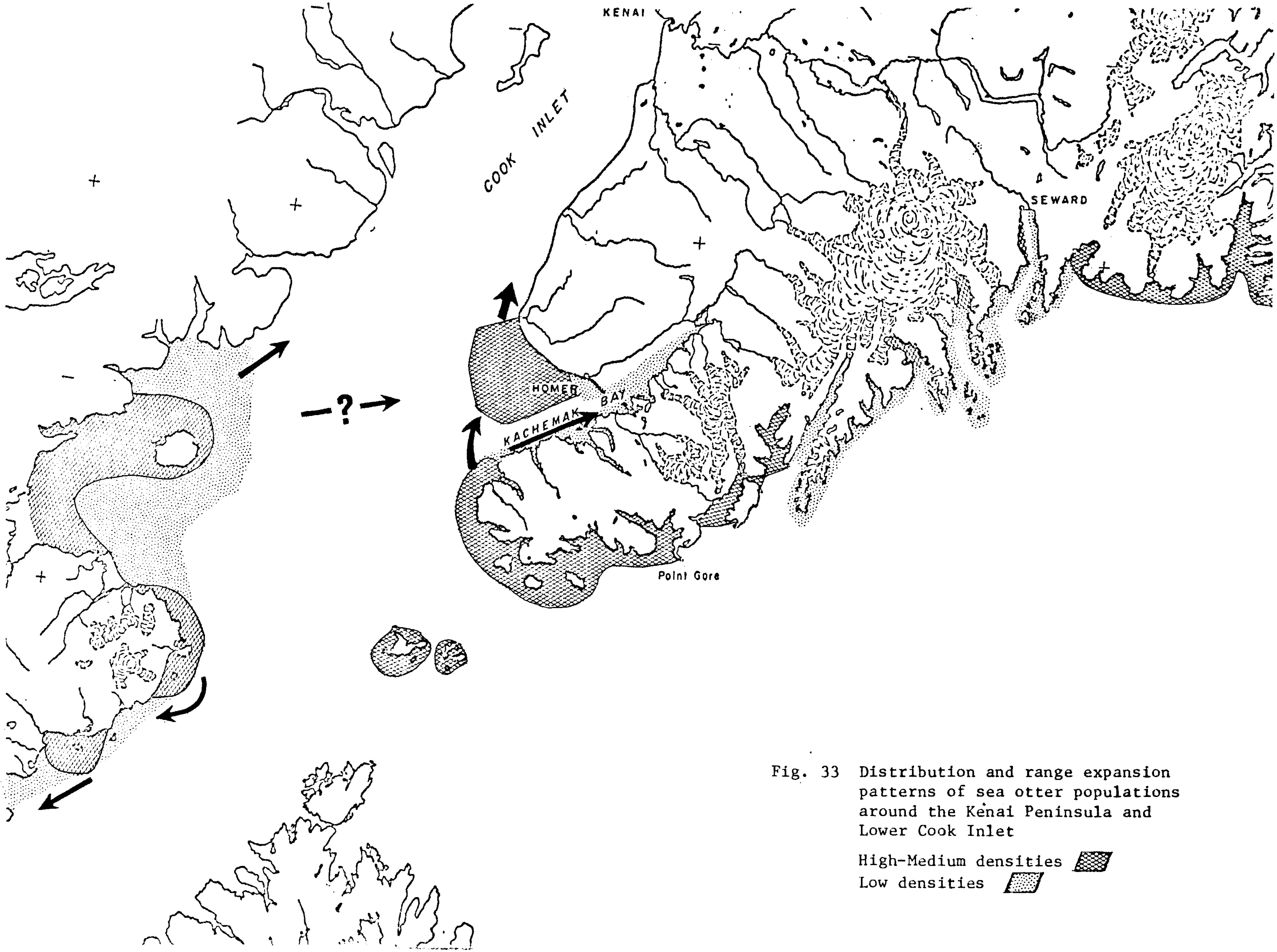


Fig. 33 Distribution and range expansion patterns of sea otter populations around the Kenai Peninsula and Lower Cook Inlet

High-Medium densities ▨

Low densities ░

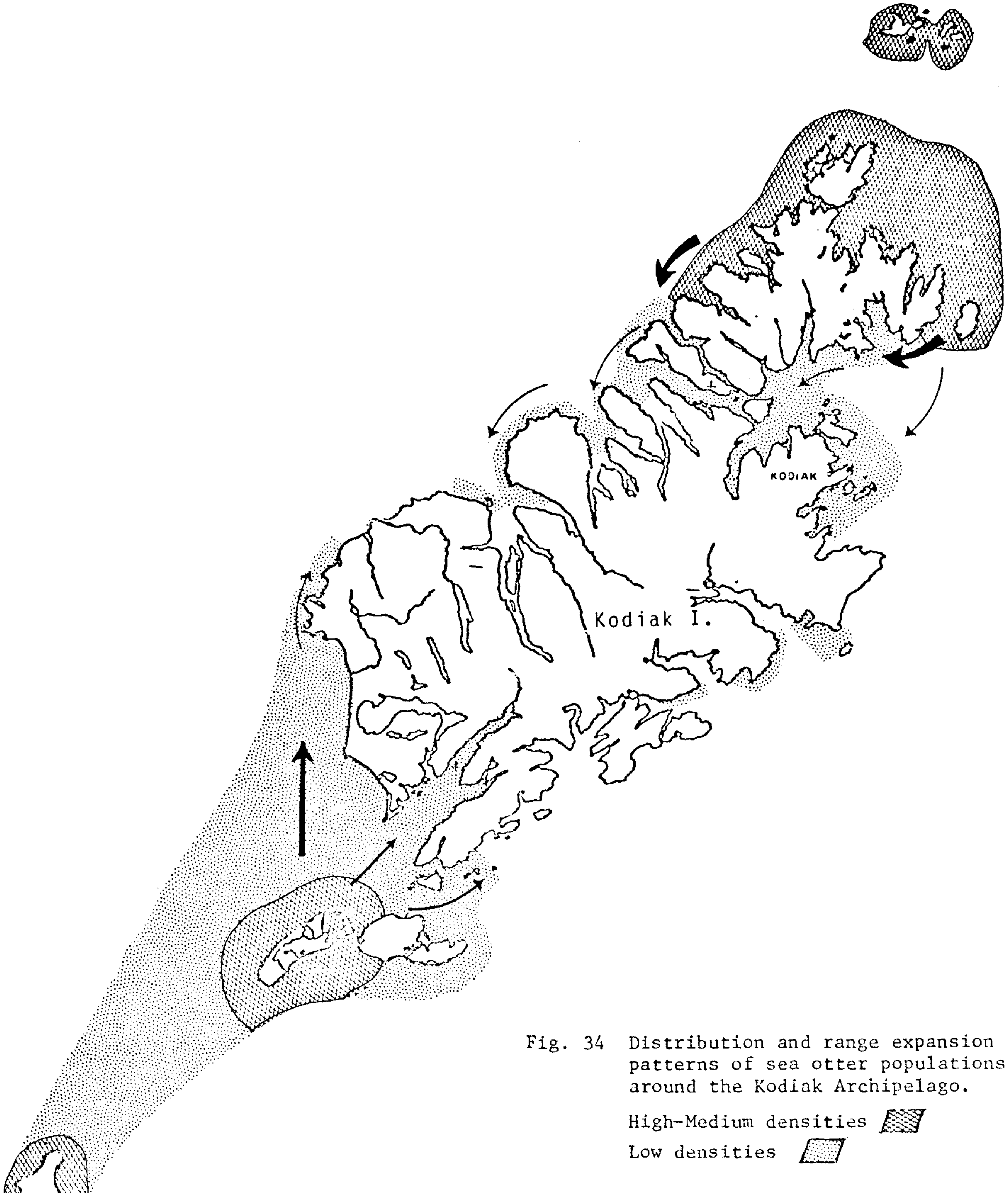


Fig. 34 Distribution and range expansion patterns of sea otter populations around the Kodiak Archipelago.

High-Medium densities ▨

Low densities ░

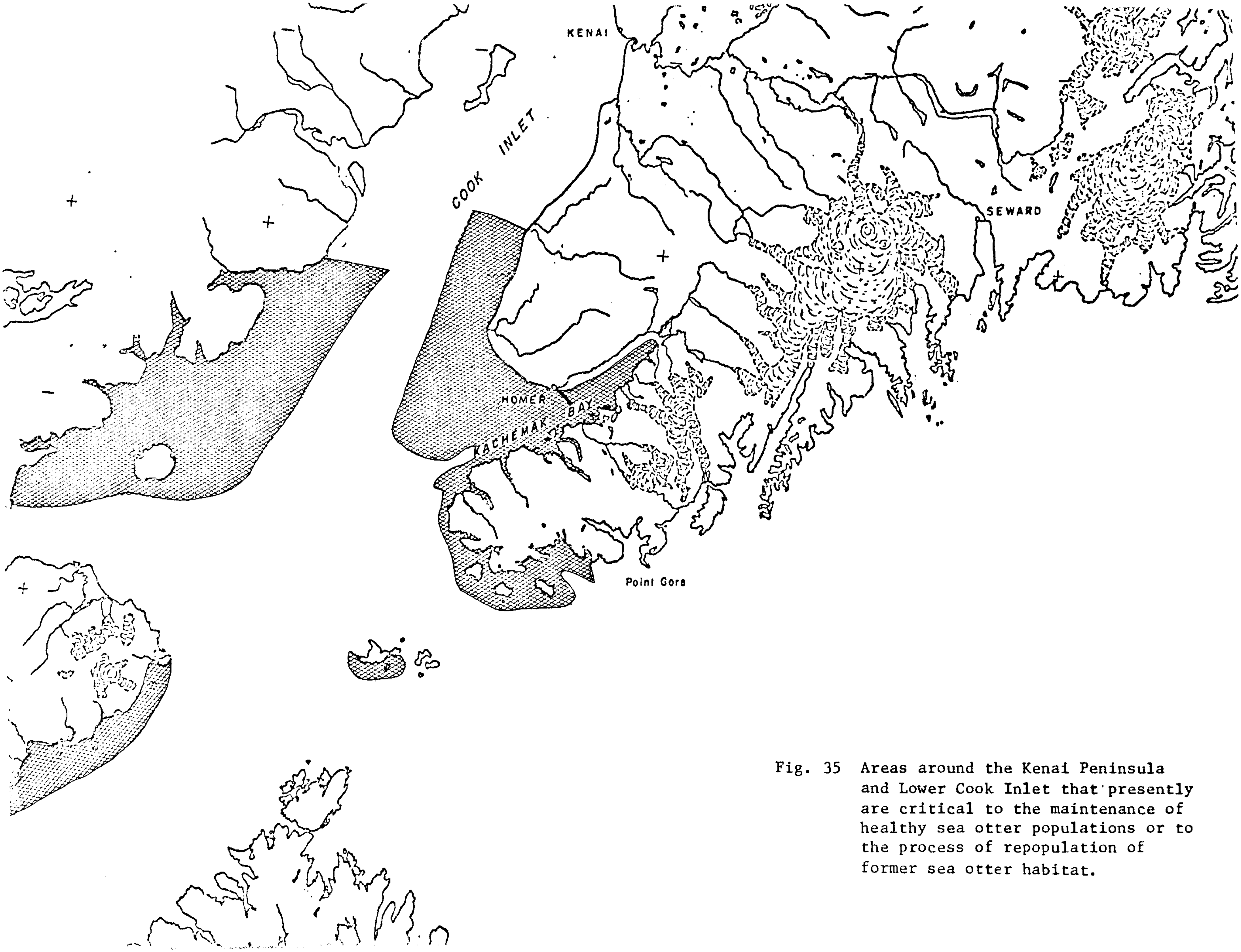


Fig. 35 Areas around the Kenai Peninsula and Lower Cook Inlet that presently are critical to the maintenance of healthy sea otter populations or to the process of repopulation of former sea otter habitat.

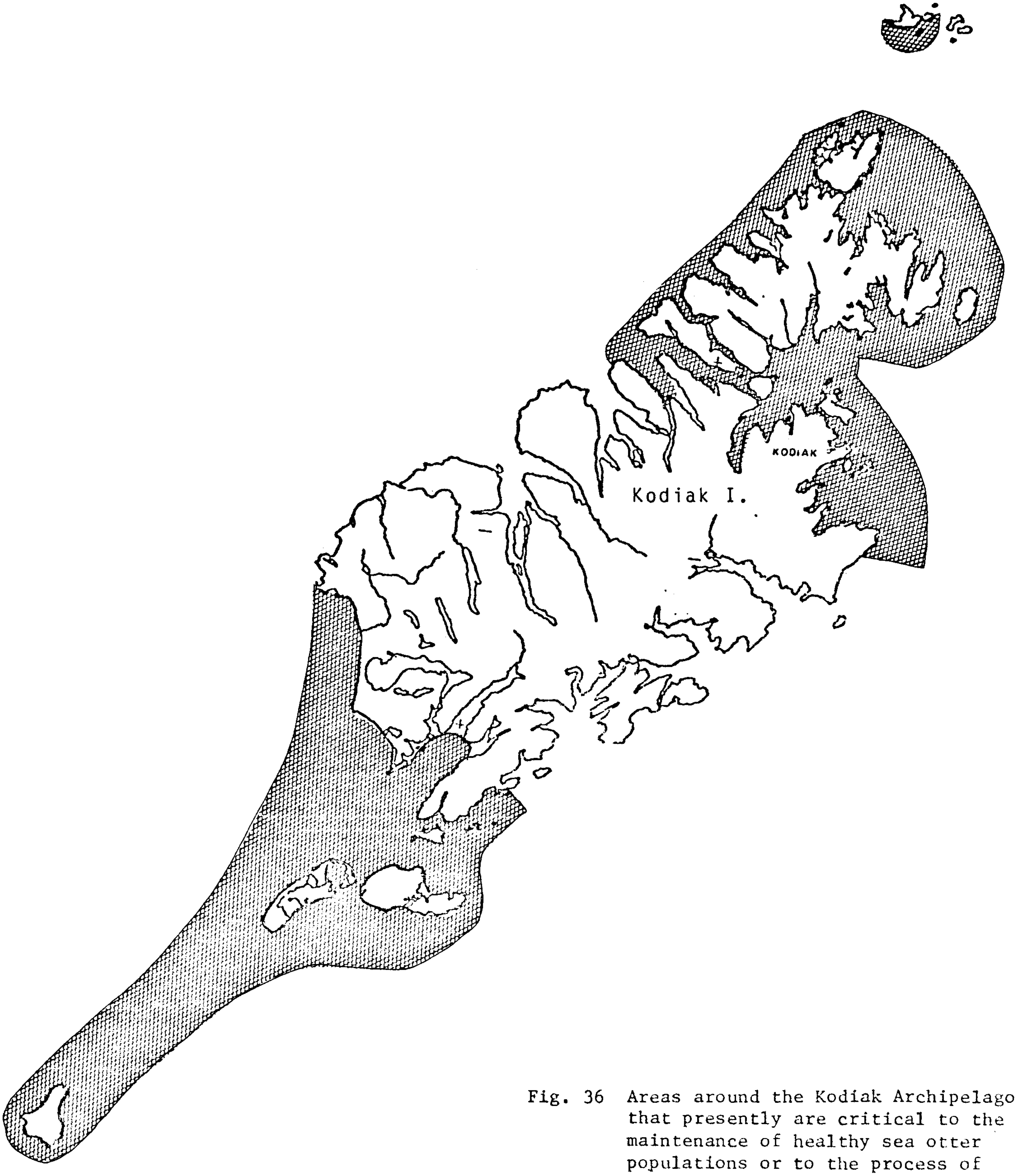


Fig. 36 Areas around the Kodiak Archipelago that presently are critical to the maintenance of healthy sea otter populations or to the process of repopulation of former sea otter habitat.

of Kodiak Island, the Trinity Islands and Chirikof Island. Shoreline surveys were not adequate in extensive shallow areas where sea otters may be scattered over hundreds of square miles. Over 9,000 km^2 of potential sea otter habitat exists southwest of Kodiak Island. Much of this lies within the proposed western Gulf of Alaska lease area. The limited observations available indicate that sea otters already inhabit much of this area. This area should be able to support several thousand sea otters. A systematic survey of the entire area should be conducted to determine the present status of the population and to delineate areas of concentrations.

Changes in sea otter distribution and abundance throughout the remainder of the study area should be monitored. This could be done in conjunction with other activities at no additional operational cost for a few years. It might be necessary to survey selected areas where range expansion is rapid in 3 to 4 years.

There are several areas of concern outside of the study area. These include:

1. Northeast Gulf of Alaska coast - The outer coast of the northeast Gulf of Alaska has generally been considered to be devoid of sea otters. Earlier surveys indicate substantial numbers south of Hinchinbrook Island and small numbers around Kayak Island (Pitcher 1975). In 1966, 10 were transplanted to Yakutat Bay. Recent observations indicate that increasing numbers of sea otters are occurring around the Copper River Delta and that small groups now occur at Icy Bay and along the outer

coast between Yakutat and Cape Fairweather. This suggests that natural repopulation of this extensive area has begun. Little of this area has been surveyed for sea otters. If the status of these groups is as tenuous as believed, it would take little to stop the repopulation of the gulf coast. The status of sea otters should be determined before extensive offshore drilling, or onshore site construction occurs. The role of the Hinchinbrook Island population should be assessed before areas west of Kayak Island are leased.

2. Southern Alaska Peninsula - Several sea otter populations occur along the south side of the Alaska Peninsula including the Semidi Islands, Shumagin Islands, Sanak Island and the Sandman Reefs. Some of these populations could be impacted by OCS development although they are more removed from proposed lease areas. Most of these populations have not been surveyed since 1970. The status of each could be determined by reviewing existing data and making additional observations during work on other research units.

3. Fox and Krenitzin Islands - The Fox and Krenitzin Islands contain large areas of vacant, former sea otter habitat. There are currently four distinct populations of sea otters and a few other small groups and scattered individuals in the area. Some of these populations have verged on extinction for many years but have recently started to grow rapidly. All are concentrated within a few km^2 and all are adjacent to the proposed Aleutian Shelf lease area. A very small oil spill could eliminate any one of these populations. Reasonably good information exists on these populations, the most recent gathered under RU #67 in

1975. This information should be summarized and additional information could be gathered during the course of other activities at little additional cost.

4. Pribilof Islands - Sea otters were once common in the Pribilof Islands but were completely exterminated. Several transplants have been made in attempts to reestablish the population. Recent surveys by National Marine Fisheries Service biologists indicate very small numbers surviving there. However, all surveys have been made during summer while fur seals were present complicating identification of sea otters. A survey, probably by boat, should be conducted while fur seals are absent. Also the possibility of larger numbers existing in shallow offshore areas should be investigated.

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DISTRIBUTION AND ABUNDANCE OF SEA OTTERS IN SOUTHWESTERN BRISTOL BAY

by

Karl B. Schneider
Alaska Department of Fish and Game

Final Report
Outer Continental Shelf Environmental Assessment Program
Research Unit 241

October 1976

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I. Abstract

Extrapolations from survey results indicate a total population of over north of Unimak Island and the Alaska Peninsula. The main range of the population extended from Cape Mordvinof to Cape Lieskof including Bechevin Bay, Izembek Lagoon and Moffet Lagoon. Portions of the population range over 40 km from shore. Small numbers are believed to be scattered to the west and northeast particularly near Port Moller. This range was greatly reduced from that observed in 1970 as a result of mortality caused by extreme sea ice conditions in 1971, 1972 and 1974. No range expansion has been observed since 1972; however, repopulation of former habitat between Cape Lieskof and Port Heiden should occur in the absence of severe sea ice conditions.

Survey results were expanded to indicate a total population of over 17,000 sea otters. The present population appears below the 1970 level and within the carrying capacity of the present range. Distribution within the range was influenced by water depth and perhaps weather. Observed densities averaged 3.1 sea otters/km^2 in waters 0 to 20 m deep, 5.8/km^2 in water 20-40 m deep, 0.5/km^2 in water 40-60 m deep and 0.03/km^2 in water over 60 m deep. Previous surveys indicate that at times higher densities occupy waters between 40 and 80 m deep. Few animals stray beyond the 80 m depth contour. Between Cape Mordvinof and Cape Lieskof, from shore seaward to the 60 m contour (including Bechevin Bay), should be considered an area critical to the survival of this population of sea otters.

II. Introduction

A large, and in many respects unique, population of sea otters occupies the shallow waters of southwestern Bristol Bay north of the Alaska Peninsula and Unimak Island. Most sea otter populations reside close to shore, concentrating in areas with offshore rocks and kelp beds. In contrast, otters in this population range widely in offshore waters. While at times they concentrate within a few kilometers of the adjacent sandy beaches, they frequently scatter to the vicinity of the 80 m depth contour, 50 km or more from shore.

Sea otters are probably the most vulnerable of all marine mammals to the direct effects of oil. Unlike most marine mammals they have no thick blubber layer. They rely on air trapped in their dense fur for conservation of body heat and buoyancy. When clean, this mat of fur is waterproof and the skin over most of the body remains dry. If the fur is soiled it loses its water repellency and its insulative quality. If this is not corrected quickly the animal will die of hypothermia. While little information is available on the quantities and types of petroleum products necessary to kill a sea otter it appears that relatively small amounts of both refined fuels and crude oil will cause death (Kenyon 1971, Schneider unpublished data). Kenyon (1969) cited cases where massive kills may have occurred near shipwrecks.

Long-term secondary effects of chronic pollution on all high trophic level species are possible if one or more of the links in the food chain are affected. Sea otters require large quantities of food (20 to 25 percent of their own body weight per day) to support a high metabolic rate. The main factor limiting most sea otter populations appears to be food availability. Sea otters in most areas appear to feed on relatively sessile organisms. Therefore, they may be exceptionally sensitive to changes in the food chain and any effects would tend to be site specific.

The southwestern Bristol Bay sea otter population appears to be vulnerable to oil spills. It is bounded by the proposed Bristol Bay OCS lease area and by Unimak Pass, a potential hazard area for tankers. The population periodically concentrates, making it possible for a small spill to directly kill large numbers of otters. This population appears to be a likely source of otters that will repopulate the Fox and Krenitzin Islands. These island groups contain some of the largest areas of unpopulated sea otter habitat remaining in Alaska and, at present, support only a few tenuously established groups of sea otters. A severe reduction of the Unimak-Alaska Peninsula population could delay repopulation of these islands for many years.

The range and distribution of the Bristol Bay population have fluctuated in recent years, partly as a result of periodic formation of sea ice (Schneider and Faro 1975). There appear to have been some fluctuations in numbers but no reliable estimates have been made.

The objectives of this project were to:

1. Determine the current range of the population.

2. Determine the distribution of sea otters within that range.

3. Identify areas of potentially critical habitat.

4. Estimate the size of the population.

Of particular interest were the offshore limits of distribution, distribution in relationship to water depth, characteristics of the northeastern fringe of the range of the main population, which can be expected to change in the future, and the precise locations of high densities of sea otters that might indicate areas of abundant food organisms.

III. Current State of Knowledge

A number of fixed-wing aerial surveys of the study area have been flown since 1957 by U. S. Fish and Wildlife Service and Alaska Department of Fish and Game personnel. The most significant counts are summarized in Table 1. None of these surveys systematically covered the entire area and the numbers of sea otters counted varied greatly. A general pattern of changes in distribution is evident however.

A remnant population probably survived the period of commercial exploitation prior to 1911. This population was concentrated north of Unimak Island

Table 1. Sightings of sea otters along the north side of the Alaska Peninsula and Unimak Island.

	1957	1958	1962	1965	1969	1970	March 1971	Oct. 1971	March 1972	May 1972	Oct. 1972 to June 1973	June 1975	Aug. 1975
Cape Chichagof to Cape Greig										0	4	0	0
Cape Greig to Reindeer Creek				0				4		0		0	0
Reindeer Creek to Cape Kutuzof				0			5	40		0	3	0	0
Cape Kutuzof to Cape Lieskof				39			74	60	18	1		2	0
Cape Lieskof to Moffet Point				20			38	24	1	2		24	0
Moffet Point to Otter Point	786		811	2765	330	2157	20	273	400-600	79		198	2585
Otter Point to Cape Mordvinof				58	152							1	19
Cape Mordvinof to Cape Sarichef				10	0							0	1
Cape Sarichef to Scotch Cap		75										0	0
Total	786	75	811	2892	482	2157	137	401	-	82	7	223	2605

1957-1965 from USFWS reports by Kenyon and Lensink.
1975 Surveys conducted under RU 67 Outer Continental Shelf Environmental Assessment Program.
None of these surveys covered the entire area. The primary purpose of this table is to demonstrate changes in distribution and relative abundance in some area..

and Izembek Lagoon. During the early 1960's it expanded its range to the vicinity of Port Moller although the largest numbers remained north of Izembek Lagoon (Kenyon 1969). By 1970 sea otters were common as far northeastward as Port Heiden and occasional individuals were seen near Ugashik and Egegik Bays. In 1971, 1972 and 1974 sea ice, which normally forms only to the vicinity of Port Heiden, advanced to Unimak Island. Many sea otters were killed and others were forced southwestward (Schneider and Faro 1975). The cumulative effects of the 3 years of ice formation appeared to severely restrict the range of this population to the area west of Cape Lieskof. Occasional sea otters have been sighted to the northeast of that point particularly near Port Moller; however, no established groups have been located and no evidence of expansion of the main population into formerly occupied habitat northeast of Cape Lieskof has been found since 1972 (Fig. 1).

The effects of the sea ice on numbers of sea otters were less evident. During 1971 and 1972 mortality of several hundred sea otters was observed and it is probable that even more deaths were unobserved. In the 1960's considerable range expansion occurred when densities were high, and a decade later, no comparable range extension was observed. This suggests that sea otter densities west of Cape Lieskof underwent reduction and are now lower than in the 1960's,

Because potential range of the population covers over 10,000 km^2 of open water, traditional survey methods have not been adequate to estimate the size of the population. Kenyon (1969) estimated that the population was greater than 3,800 in 1965, but more recent information indicates that his

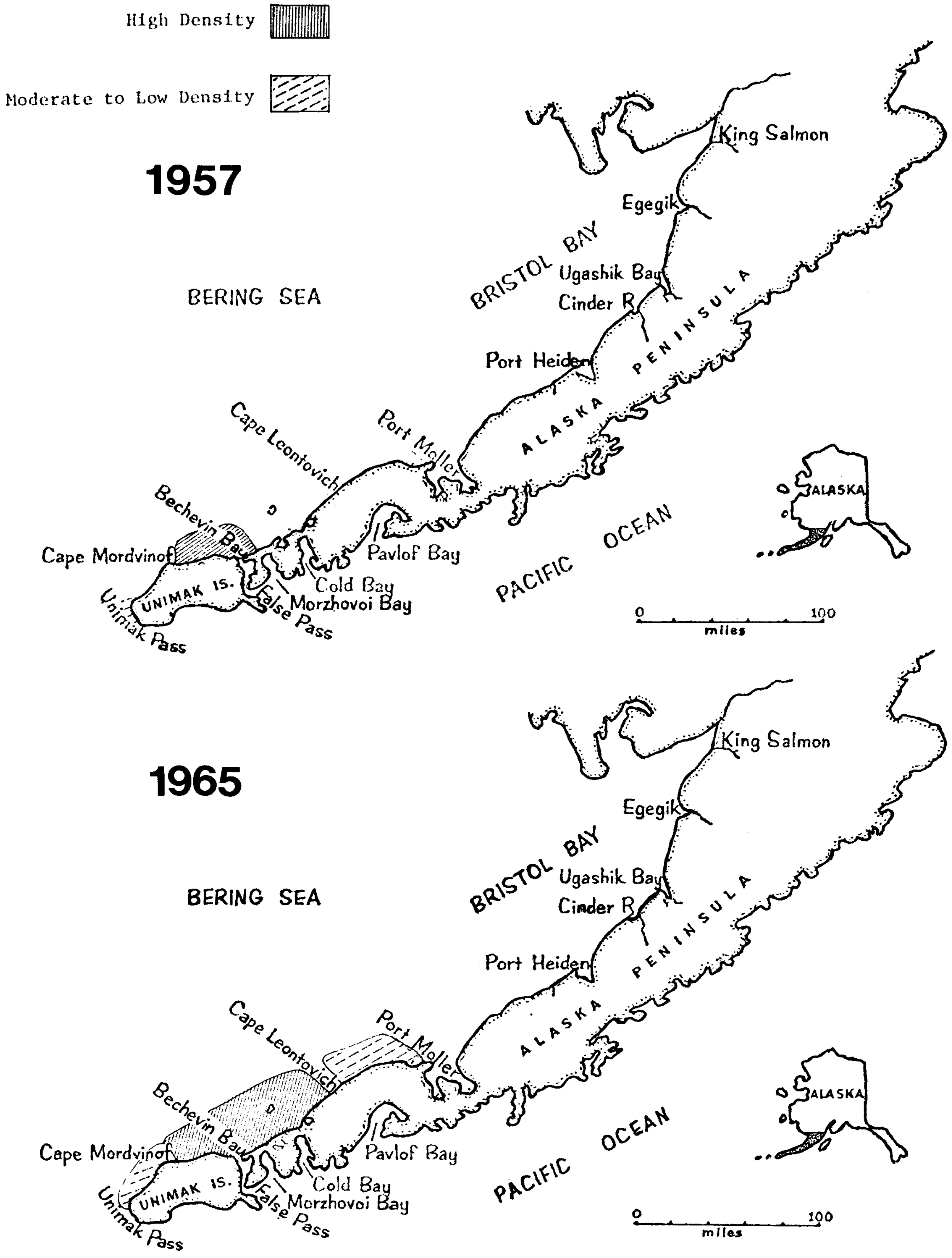


Figure 1a. Changes in distribution of sea otters north of the Alaska Peninsula and Unimak Island 1957-1965.

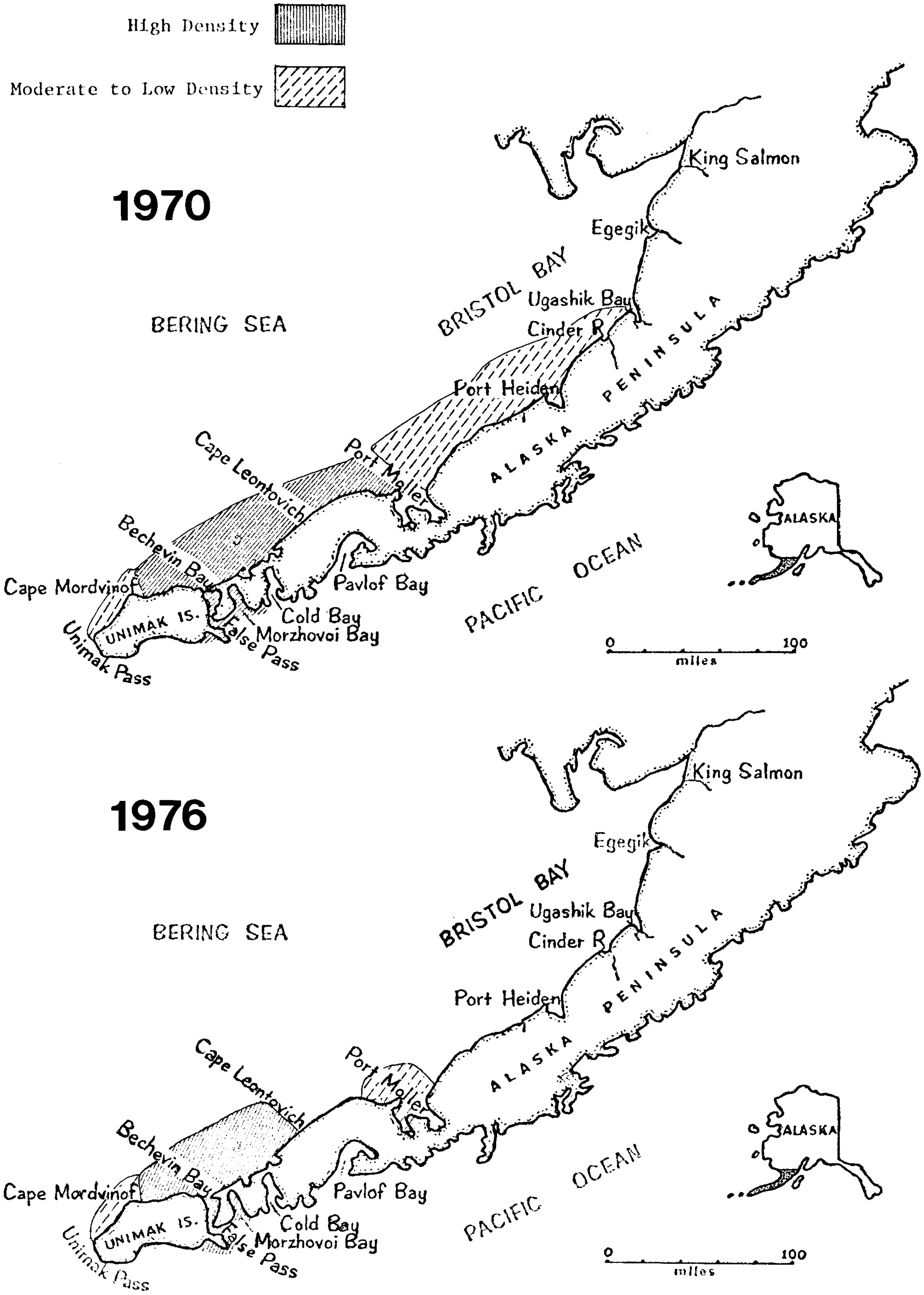


Figure 1b. Changes in distribution of sea otters north of the Alaska Peninsula and Unimak Island 1970-1976.

survey did not cover the entire range of the population and that considerable population growth occurred after that time. In 1970 a total of 2,157 sea otters was counted in photographs of several pods clustered southeast of Amak Island. One of these pods was the largest ever recorded, containing over 1,000 sea otters. No pups were visible in the photographs, indicating that all segments of the population were not represented. Crude estimates made from aerial surveys conducted prior to 1970 indicated that this population contained on the order of 8,000 to 10,000 sea otters (Alaska Department of Fish and Game 1973). These estimates would not stand up to statistical scrutiny however.

IV. Study Area

At one time or another parts of this population have been observed in the waters north of Unimak Island and the Alaska Peninsula from Scotch Cap to Egegik Bay (Fig. 1). They have occupied Bechevin Bay, Izembek Lagoon and Port Moller frequently and probably at least small numbers have used all of the bays and lagoons in the area. Surveys indicate that large numbers may occasionally move offshore to the vicinity of the 80 m depth contour north of Unimak Island and Izembek Lagoon. Some otters have been sighted 50 km from shore and one moribund animal was found over 100 km from shore (T. Newby, pers. comm.). The potential study area delineated by these observations is over 10,000 km^2.

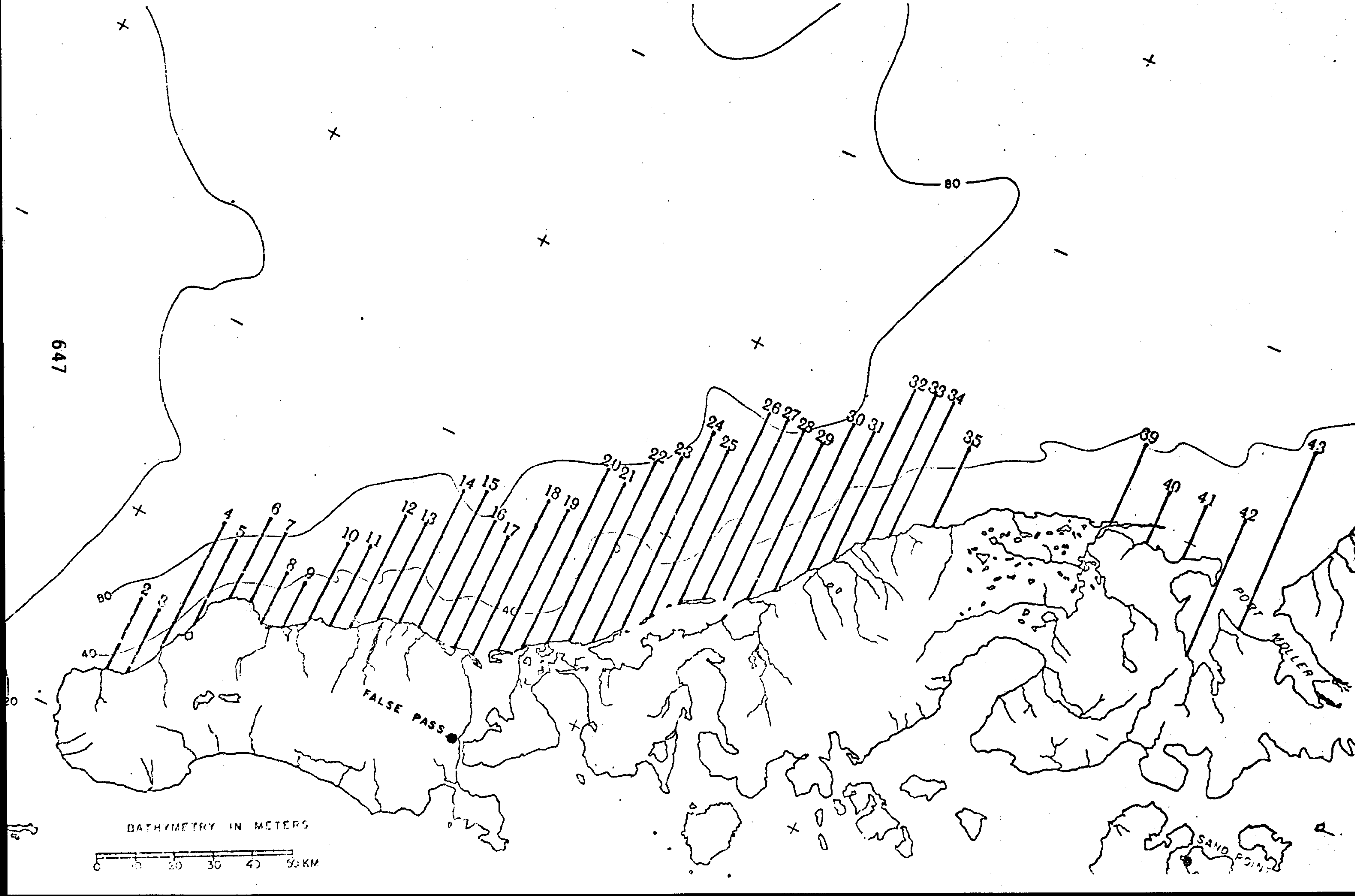
Although information was gathered throughout the entire area during the contract period, most of the effort was directed at the area from Cape Sarichef to Port Moller.

V. Methods

Information on the distribution of the population was gathered on aerial surveys conducted under RU 67 in June and August 1975 and RU 243 in June 1976. These surveys were made from a Grumman Super Widgeon flown in an irregular pattern over concentrations of marine mammals. All sea otters sighted were counted visually or photographed with motor-driven 35 mm cameras.

On 30 and 31 July 1976 a systematic aerial survey of the main population's range was made. The survey platform was the U. S. Department of Interior, Office of Aircraft Services turbo Goose N780. The aircraft was flown along predetermined tracklines which generally extended along north-south lines extending from shore to the vicinity of the 80 m depth contour. Navigation was aided by the Global Navigation System (GNS 500). Corrected flightlines are shown in Fig. 2. The aircraft was maintained at a constant altitude of 200 feet (61 m) and a constant airspeed of 120 knots (222 km/hr). Two observers counted all sea otters seen within 0.1 nautical mile (185 m) strips on either side of the aircraft. Strip width was determined with the aid of an inclinometer specifically designed for the survey. Allowance was made for a strip directly under the aircraft that was not visible to the observers. All observations were transmitted over a portable intercom system to a third individual who recorded them on standardized data sheets. For each group of sea otters the time of the observation, group size, their activity state, and side of the aircraft were recorded.

Figure 2. Strip Transects flown on 30-31 July 1976 sea otter survey.



Two other observers sat in the rear of the aircraft and recorded all sea otters seen regardless of distance from the aircraft. Particular attention was paid to the occurrence of large pods outside of the limited strip transects. While these observers counted "unlimited" width strips, their range was limited by a variety of conditions and no duplication occurred on consective transects. One of the observers recorded observations for both rear observers.

Both recorders synchronized stop watches at the start of each transect and recorded the times of observations to the nearest second. The recorder for the limited strip survey also periodically recorded latitude and longitude indicated by the GNS 500. This procedure permitted fairly precise determination of the location of each observation and facilitated comparison of observations between the limited and unlimited strip surveys.

An irregular flight pattern was used in Bechevin Bay as past surveys indicated that sea otters tended to concentrate in specific parts of the bay making a strip census inappropriate. A direct count was made of this area.

Visibility conditions were classified for each transect according to the following system:

Code

1 *Excellent* - surface of water calm, usually a high overcast sky with no sun glare. Sea otters appear dark against a uniformly light gray background of the water's surface. Individuals easily distinguished at a distance.

2 *Very good* - May be light ripple on water's surface or slightly uneven lighting but still relatively easy to distinguish individuals at a distance.

3 *Good* - may be light chop, some sun glare or shadows. Individuals at a distance may be difficult to distinguish but individuals nearby and small groups at a distance are readily identified.

4 *Fair* - usually choppy waves and strong sun glare or dark shadows in part of the survey track. Individuals in kelp beds, in the lee of rocks, or near the observer and most pods readily identified but most individuals and some pods in areas of poor lighting or at a distance difficult to distinguish.

5 *Poor* - individuals difficult to distinguish unless very close and some pods at a distance may be missed, however, conditions still good enough to give a very rough impression of the distribution of animals.

6 Unacceptable - heavy chop with many whitecaps, lighting poor or large waves breaking on rocks. No surveys should be conducted under these conditions but occasionally a sighting of significance may be made in the course of other activities.

This system differs somewhat from that used by Estes and Smith (1973), but is similar to that used by Kenyon (1969).

Personnel participating in the 30-31 July survey were Herman Reuss - pilot, John Sasso - co-pilot, Karl Schneider and Kenneth Pitcher - limited strip observers, Roger Aulabaugh - recorder, Donald Calkins and James Faro - unlimited strip observers. Paul Arneson conducted a survey of birds under RU 3/4 from the rear of the aircraft. Distances were expressed in nautical miles because this unit's relationship to latitude and the speed of the aircraft facilitated the plotting of observations.

VI. Results

Results of the survey are presented in Tables 2 and 3. Each transect was broken into 2 nautical mile (3.7 km) long segments. Segment A extended from shore to 2 nm (3.7 km) from shore, segment B from 2 nm (3.7 km) to 4 nm (7.4 km) from shore, etc. Each segment in the limited width strip survey would represent two parallel rectangles 2 nm (3.7 km) long and 0.1 nm (0.185 km) wide separated by approximately 50 m. The total area surveyed in each limited width segment was 0.4 nm^2 (1.37 km^2). Each segment also represents approximately 1.0 minute of survey time. The data have been grouped into these segments for convenience.

Table 2. Results of sea otter transect survey north of the Alaska Peninsula and Unimak Island - 30 and 31 July 1976.

Transect Number	Trackline Deg. Min. Longitude	Start Date/Time ADT Day	Hour Min.	Visibility Code	Sea Otters Counted Left Track (0.1nm) Resting	Active	Right Track (0.1nm) Resting	Active	Total 0.2nm Track	Unlim. Track	Density 0.2nm Track (Otters/nm²)	Ratio * Unlimited/ 0.2nm Track
2 A	164° 50' W	31	1221	6	0	0	0	0	0	0	0	
B					0	0	0	0	0	0	0	
C					0	0	0	0	0	0	0	
D					0	0	0	0	0	0	0	
E					0	0	0	0	0	0	0	
F					0	0	0	0	0	0	0	
3 A	164° 45' W	31	1214	2	0	0	0	0	0	0	0	
B					0	0	0	0	0	0	0	
C					0	0	0	0	0	0	0	
D					0	0	0	0	0	0	0	
4 A	164° 40' W	31	1202	2	0	0	0	0	0	0	0	
B					0	0	0	0	0	0	0	
C					0	0	0	0	0	0	0	
D					0	0	0	0	0	0	0	
E					0	0	0	0	0	0	0	
F					0	0	0	0	0	0	0	
G					0	0	0	0	0	0	0	
H					0	0	0	0	0	0	0	
I					0	0	0	0	0	0	0	
J					0	0	0	0	0	0	0	
5 A	164° 35' W	31	1153	2	0	0	0	0	0	0	0	
B					0	0	0	0	0	0	0	
C					0	0	0	0	0	0	0	
D					0	0	0	0	0	1	0	+
E					0	0	0	0	0	0	0	
F					0	0	0	0	0	0	0	
G					0	0	0	0	0	0	0	
6 A	164° 30' W	31	1143	2	0	0	0	0	0	0	0	
B					0	0	0	0	0	0	0	
C					0	0	0	0	0	0	0	
D					0	0	0	0	0	0	0	
E					0	0	0	0	0	0	0	
F					0	0	0	0	0	0	0	
7 A	164° 25' W	31	1136	3	0	0	0	0	0	0	0	
B					0	0	0	0	0	0	0	
C					0	0	0	0	0	0	0	
D					0	0	0	0	0	0	0	
E					0	0	0	0	0	0	0	

Table 2. (cont'd)

Transect Number	Trackline Deg. Min. Longitude	Start Date/Time ADT		Visibility Code	Sea Otters Counted						Density 0.2nm Track (Otters/nm^2)	Ratio * Unlimited/ 0.2nm Track
					Left Track (0.1nm)		Right Track (0.1nm)		Total			
		Day	Hour Min.		Resting	Active	Resting	Active	0.2nm Track	Unlim. Track		
8 A	164° 20' W	31	1128	6	0	0	0	0	0	0	0	
B					0	0	0	0	0	0	0	
C					0	0	0	0	0	0	0	
D					0	0	0	0	0	0	0	
E					0	0	0	0	0	0	0	
9 A	164° 15' W	31	1122	6	0	0	0	0	0	0	0	
B					0	0	0	0	0	0	0	
C					0	0	0	0	0	0	0	
10 A	164° 10' W	31	1112	1	2	0	0	2	4	11	10.0	2.8
B					13	0	2	6	21	27	52.5	1.3
C					0	0	6	0	6	26	15.0	4.3
D					0	1	0	0	1	13	7.5	13.0
E					0	0	0	0	0	0	0	
F					0	0	0	0	0	3	0	+
G					0	0	0	0	0	0	0	
11 A	164° 05' W	31	1103	1	0	0	0	0	0	0	0	
B					7	0	0	0	7	46	17.5	6.6
C					0	0	15	2	17	50	42.5	2.9
D					0	0	0	0	0	0	0	
E					0	0	0	0	0	0	0	
F					0	0	0	0	0	0	0	
12 A	164° 00' W	31	1053	2	1	0	0	0	1	4	2.5	4
B					21	0	0	7	28	44	70.0	1.6
C					1	1	0	1	3	3	7.5	1.0
D					0	0	0	0	0	0	0	
E					0	0	0	0	0	0	0	
F					0	0	0	0	0	2	0	+
G					0	0	0	0	0	0	0	
H					0	0	0	0	0	0	0	
13 A	163° 55' W	31	1044	1	2	2	11	0	15	19	37.5	1.3
B					0	0	0	5	5	4	12.5	0.8
C					0	0	0	0	0	0	0	
D					0	0	0	0	0	1	0	+
E					0	0	0	0	0	1	0	+
F					0	0	0	0	0	0	0	
G					0	0	0	0	0	0	0	

Table 2. (cont'd)

Transect Number		Trackline Deg. Min. Longitude	Start Date/Time ADT Day	Hour Min.	Visibility Code	Sea Otters Counted						Density 0.2nm Track (Otters/nm^2)	Ratio * Unlimited/ 0.2nm Track
						Left Track (0.1nm)		Right Track (0.1nm)		Total			
						Resting	Active	Resting	Active	0.2nm Track	Unlim. Track		
14	A	163° 50' W	31	1032	1	4	0	0	0	4	8	10.0	2.0
	B					9	0	0	26	35	171	87.5	4.9
	C					0	0	0	0	0	3	0	+
	D					0	0	0	1	1	0	2.5	0
	E					0	0	0	0	0	0	0	
	F					0	0	0	1	1	0	2.5	0
	G					0	0	0	0	0	0	0	
	H					0	0	0	0	0	0	0	
	I					0	0	0	0	0	0	0	
	J					0	0	0	0	0	0	0	
15	A	163° 45' W	31	1020	1	1	1	0	2	4	8	10.0	2.0
	B					0	0	0	0	0	0	0	
	C					0	0	0	0	0	4	0	+
	D					0	0	0	0	0	0	0	
	E					0	0	0	0	0	0	0	
	F					0	0	0	0	0	0	0	
	G					0	0	0	1	1	1	2.5	1.0
	H					0	0	0	0	0	0	0	
	I					0	0	0	0	0	0	0	
	J					0	0	0	0	0	1	0	+
16	A	163° 40' W	30	1720	1	3	0	0	0	3	29	7.5	9.6
	B					97	0	5	42	144	246	360.0	1.7
	C					0	0	4	0	4	17	10.0	4.25
	D					3	0	1	0	4	5	10.0	1.25
	E					0	0	1	0	1	2	2.5	2.0
	F					0	0	0	0	0	2	0	+
	G					0	0	0	0	0	0	0	
	H					0	0	0	0	0	0	0	
	I					0	0	0	0	0	0	0	
17	A	163° 35' W	30	1711	2	2	1	0	0	3	6	7.5	2.0
	B					0	0	0	1	1	1	2.5	1.0
	C					0	0	0	0	0	0	0	
	D					0	0	0	0	0	2	0	+
	E					0	0	0	0	0	1	0	+
	F					0	0	0	0	0	0	0	
	G					0	0	0	0	0	0	0	
18	A	163° 30' W	30	1658	2	0	0	2	1	3	2	7.5	0.7
	B					0	0	2	0	2	1	5.0	0.5
	C					0	0	0	0	0	2	0	+

Table 2. (cont'd)

Transect Number	Trackline Deg. Min. Longitude	Start Date/Time ADT Day Hour Min.	Visibility Code	Sea Otters Counted						Density 0.2nm Track (Otters/nm^2)	Ratio * Unlimited/ 0.2nm Track
				Left Track(0.1nm)		Right Track(0.1nm)		Total			
				Resting	Active	Resting	Active	0.2nm Track	Unlim. Track		
18 D				0	0	0	0	0	0	0	
E				1	2	1	2	6	2	15	0.3
F				0	0	0	0	0	0	0	
G				0	0	0	0	0	0	0	
H				0	0	0	2	2	2	5.0	1.0
I				0	0	0	0	0	0	0	
J				0	0	0	0	0	0	0	
K				1	0	0	0	1	1	2.5	1.0
L				0	0	0	0	0	0	0	
19 A	163° 25' W	30 1644	2	0	0	0	0	0	0	0	
B				0	0	0	0	0	44	0	+
C				0	0	0	7	7	2	17.5	0.3
D				0	0	1	1	2	3	5.0	1.5
E				0	2	0	0	2	1	5.0	0.5
F				0	0	0	0	0	0	0	
G				0	1	1	0	2	0	5.0	0
H				0	0	0	0	0	0	0	
I				2	0	0	0	2	1	5.0	0.5
J				0	0	0	0	0	0	0	
K				0	0	0	0	0	0	0	
20 A	163° 20'W	30 1320	1	13	2	0	0	15	25	37.5	1.7
B				0	0	0	0	0	2	0	+
C				0	0	0	0	0	0	0	
D				0	0	1	0	1	3	2.5	3.0
E				0	0	0	0	0	0	0	
F				0	0	0	1	1	1	2.5	1.0
G				0	1	0	0	1	0	2.5	0
H				0	0	1	1	2	4	5.0	2.0
I				0	0	0	0	0	0	0	
J				0	0	0	0	0	1	0	+
K				1	0	0	0	1	0	2.5	0
L				0	0	0	0	0	0	0	
M				0	0	0	0	0	0	0	
21 A	163° 15'W	30 1307	1	0	0	1	1	2	1	5.0	0.5
B				0	0	0	0	0	1	0	+
C				0	0	0	0	0	3	0	+
D				0	0	0	0	0	0	0	
E				0	0	0	0	0	0	0	
F				0	0	0	0	0	0	0	

Table 2. (cont'd)

Transect Number	Trackline Deg. Min. Longitude	Start Date/Time ADT Day Hour Min.	Visibility Code	Sea Otters Counted						Density 0.2nm Track (Otters/nm^2)	Ratio * Unlimited/ 0.2nm Track
				Left Track (0.1nm)		Right Track (0.1nm)		Total			
				Resting	Active	Resting	Active	0.2nm Track	Unlim. Track		
21 G				0	0	0	0	0	1	0	+
H				0	0	0	0	0	0	0	
I				0	0	0	0	0	2	0	+
J				0	0	0	0	0	0	0	
K				0	0	0	0	0	0	0	
22 A	163° 10' W	30 1250	1	0	1	0	1	2	0	5.0	0
B				100	0	0	0	100	50	250.0	0.5
C				0	0	1	0	1	5	2.5	5.0
D				1	0	0	0	1	2	2.5	2.0
E				0	0	0	0	0	0	0	
F				0	0	0	0	0	0	0	
G				0	0	0	0	0	0	0	
H				0	0	0	0	0	0	0	
I				0	0	0	0	0	0	0	
J				0	0	0	0	0	0	0	
K				1	0	0	0	1	1	2.5	1.0
L				0	0	0	0	0	0	0	
M				0	0	0	0	0	0	0	
N				0	0	0	0	0	0	0	
23 A	163° 05' W	30 1235	2	0	0	9	0	9	129	22.5	14.3
B				1	1	0	0	2	33	5.0	16.5
C				0	0	1	0	1	20	2.5	20.0
D				2	0	0	0	2	122	5.0	61.0
E				0	0	0	1	1	0	2.5	0
F				0	0	0	1	1	0	2.5	0
G				2	0	0	0	2	1	5.0	0.5
H				0	0	0	0	0	0	0	
I				0	0	0	0	0	0	0	
J				0	0	0	0	0	0	0	
K				0	0	1	0	1	0	2.5	0
L				0	0	0	0	0	0	0	
M				0	0	0	0	0	2	0	
N				0	0	0	0	0	0	0	
O				0	0	0	0	0	2	0	+
24 A	163° 00' W	30 1218	2	0	0	0	0	0	0	0	
B				1	3	1	0	5	3	12.5	0.6
C				0	0	0	0	0	1	0	+
D				0	0	0	0	0	0	0	

Table 2. (cont'd)

Transect Number	Trackline Deg. Min. Longitude	Start Date/Time ADT		Visibility Code	Sea Otters Counted						Density 0.2nm Track (Otters/nm^2)	Ratio * Unlimited/ 0.2nm Track
		Day	Hour Min.		Left Track(0.1nm)		Right Track(0.1nm)		Total			
					Resting	Active	Resting	Active	0.2nm Track	Unlim. Track		
24 E					0	0	0	0	0	2	0	+
F					0	0	0	0	0	0	0	
G					0	0	0	0	0	0	0	
H					0	0	0	0	0	0	0	
I					0	0	1	0	1	0	2.5	0
J					0	0	0	0	0	0	0	
K					1	0	0	0	1	1	2.5	1.0
L					0	0	0	0	0	0	0	
M					0	0	0	0	0	0	0	
N					0	0	0	0	0	0	0	
O					0	0	0	0	0	0	0	
P					0	0	0	0	0	2	0	+
25 A	162° 55'W	30	1203	1	0	0	0	0	0	0	0	
B					0	0	0	0	0	1	0	+
C					0	0	1	0	1	0	2.5	0
D					2	0	0	0	2	0	5.0	0
E					0	0	0	0	0	3	0	+
F					0	0	0	0	0	0	0	
G					0	0	0	0	0	0	0	
H					0	0	0	0	0	0	0	
I					0	0	0	0	0	0	0	
J					0	0	0	0	0	0	0	
K					0	0	0	0	0	0	0	
L					0	0	0	0	0	0	0	
26 A	162° 50'W	30	1146	1	0	0	0	0	0	0	0	
B					0	2	0	0	2	0	5.0	0
C					0	0	0	1	1	2	2.5	2.0
D					2	0	0	0	2	3	5.0	1.5
E					0	0	0	0	0	0	0	
F					0	0	1	0	1	0	2.5	0
G					0	0	0	0	0	1	0	+
H					0	0	0	0	0	0	0	
I					0	0	0	0	0	0	0	
J					0	0	0	0	0	0	0	
K					0	0	0	0	0	0	0	
L					0	0	0	0	0	0	0	
M					0	0	0	0	0	0	0	
N					0	0	0	0	0	0	0	
O					0	0	0	0	0	0	0	

Table 2. (cont'd)

Transect Number	Trackline Deg. Min. Longitude	Start Date/Time ADT Day	Start Date/Time ADT Hour Min.	Visibility Code	Sea Otters Counted: Left Track (0.1nm) Resting	Left Track (0.1nm) Active	Right Track (0.1nm) Resting	Right Track (0.1nm) Active	Total 0.2nm Track	Total Unlim. Track	Density 0.2nm Track (Otters/nm^2)	Ratio * Unlimited/ 0.2nm Track
27 A	162° 45'W	30	1130	1	1	0	0	0	1	1	2.5	1.0
B					0	2	0	2	4	39	10.0	9.8
C					10	4	22	0	36	52	90.0	1.4
D					0	0	0	0	0	0	0	
E					1	0	0	0	1	2	2.5	2.0
F					0	0	0	1	1	1	7.5	1.0
G					0	0	0	0	0	0	0	
H					0	0	1	0	1	2	2.5	2.0
I					0	0	0	0	0	0	0	
J					0	0	0	0	0	0	0	
K					0	0	0	0	0	0	0	
L					0	0	0	0	0	0	0	
M					0	0	0	0	0	0	0	
28 A	162° 40'W	30	1115	1	0	0	0	0	0	1	0	+
B					0	0	0	1	1	38	2.5	38
C					2	1	3	15	21	29	52.5	1.4
D					8	3	2	4	17	19	42.5	1.1
E					3	2	1	8	14	40	35.0	2.9
F					0	0	0	0	0	0	0	
G					0	0	0	0	0	0	0	
H					1	1	0	0	2	0	5.0	0
I					0	0	0	0	0	0	0	
J					0	0	0	0	0	0	0	
K					0	0	0	0	0	0	0	
L					0	0	0	0	0	4	0	+
M					0	0	0	0	0	0	0	
29 A	162° 35'W	30	1100	1	0	0	0	0	0	0	0	
B					0	0	2	1	3	0	7.5	0
C					0	0	25	0	25	23	62.5	0.9
D					1	3	1	0	5	87	12.5	17.4
E					4	4	0	0	8	3	20.0	0.4
F					6	3	1	1	11	7	27.5	0.6
G					1	0	0	0	1	68	2.5	68.0
H					0	0	4	0	4	29	10.0	7.3
I					0	0	0	0	0	4	0	+
J					0	0	0	0	0	0	0	
K					0	0	0	0	0	0	0	

Table 2. (cont'd)

Transect Number	Trackline Deg. Min. Longitude	Start Date/Time ADT Day Hour Min.	Visibility Code	Sea Otters Counted						Density 0.2nm Track (Otters/nm^2)	Ratio * Unlimited/ 0.2nm Track
				Left Track (0.1nm)		Right Track (0.1nm)		Total			
				Resting	Active	Resting	Active	0.2nm Track	Unlim. Track		
30 A	162° 30' W	30 1454	1	1	0	0	0	1	0	2.5	0
B				2	0	0	0	2	9	5.0	4.5
C				2	0	0	0	2	3	5.0	1.5
D				0	0	0	0	0	0	0	
E				0	0	50	0	50	60	125	1.2
F				0	6	0	0	6	42	15	7.0
G				0	0	0	0	0	2	0	+
H				0	0	0	2	2	3	5.0	1.5
I				0	0	0	3	3	8	7.5	2.7
J				0	0	0	0	0	0	0	
K				0	0	0	0	0	3	0	+
L				0	0	0	0	0	0	0	
M				0	0	0	0	0	0	0	
31 A	162° 25' W	30 1509	1	1	0	0	14	15	2	37.5	0.13
B				0	2	3	0	5	3	12.5	0.6
C				35	1	0	0	36	29	90.0	0.8
D				0	0	0	0	0	15	0	+
E				0	0	0	1	1	1	2.5	1.0
F				3	0	0	0	3	1	7.5	0.3
G				0	0	0	0	0	0	0	
H				0	0	0	0	0	0	0	
I				0	0	0	0	0	0	0	
J				0	0	0	0	0	0	0	
K				0	0	0	0	0	0	0	
32 A	162° 20' W	30 1518	1	0	0	2	0	2	2	5.0	1.0
B				0	1	0	0	1	0	2.5	0
C				0	0	0	0	0	0	0	
D				0	0	0	1	1	0	2.5	0
E				0	0	0	0	0	0	0	
F				0	0	0	0	0	0	0	
G				0	0	0	0	0	1	0	+
H				0	0	0	0	0	0	0	
I				0	0	0	0	0	0	0	
J				0	0	0	0	0	0	0	
K				0	0	0	0	0	0	0	
L				0	0	0	0	0	0	0	
M				0	0	0	0	0	0	0	
33 A	162° 15' W	30 1537	1	0	1	0	0	1	1	2.5	1.0
B				0	0	0	2	2	10	5.0	5.0

Table 2. (cont'd)

Transect Number	Trackline Deg. Min. Longitude	Start Date/Time ADT Day Hour Min.	Visibility Code	Sea Otters Counted: Left Track (0.1nm) Resting	Left Track (0.1nm) Active	Right Track (0.1nm) Resting	Right Track (0.1nm) Active	Total 0.2nm Track	Total Unlim. Track	Density 0.2nm Track (Otters/nm^2)	Ratio* Unlimited/ 0.2nm Track
33 C				4	2	2	0	8	4	20.0	0.5
D				6	2	0	0	8	0	20.0	0
E				0	0	0	0	0	0	0	
F				0	0	0	0	0	0	0	
G				0	0	0	0	0	0	0	
H				0	0	0	0	0	0	0	
I				0	0	0	0	0	0	0	
J				0	0	0	0	0	0	0	
K				0	0	0	0	0	0	0	
L				0	0	0	0	0	0	0	
34 A	162° 10' W	30 1555	1	0	0	0	0	0	0	0	
B				0	0	0	0	0	0	0	
C				0	0	0	0	0	0	0	
D				0	0	0	0	0	0	0	
E				0	0	0	0	0	0	0	
F				0	0	0	0	0	0	0	
G				0	0	0	0	0	0	0	
H				0	0	0	0	0	0	0	
I				0	0	0	0	0	0	0	
J				0	0	0	0	0	0	0	
K				0	0	0	0	0	0	0	
35 A	162° 00' W	30 1612	3	0	0	0	0	0	0	0	
B				0	0	0	0	0	0	0	
C				0	0	0	0	0	0	0	
D				0	0	0	0	0	0	0	
E				0	0	0	0	0	0	0	
F				0	0	0	0	0	0	0	
39 A	161° 20' W	31 1421	2	0	0	0	0	0	0	0	
B				0	0	0	0	0	0	0	
C				0	0	0	0	0	0	0	
D				0	0	0	0	0	0	0	
E				0	0	0	0	0	0	0	
F				0	0	0	0	0	0	0	
40 A	161° 10' W	31 1430	1	0	0	0	0	0	0	0	
B				0	0	0	0	0	0	0	
C				0	0	0	0	0	0	0	
D				0	0	0	0	0	0	0	

Table 2. (cont'd)

Transect Number	Trackline Deg. Min. Longitude	Start Date/Time ADT Day	Hour Min.	Visibility Code	Sea Otters Counted Left Track (0.1nm) Resting	Active	Right Track (0.1nm) Resting	Active	Total 0.2nm Track	Unlim. Track	Density 0.2nm Track (Otters/nm^2)	Ratio * Unlimited/ 0.2nm Track
41 A	161° 00' W	31	1433	1	0	0	0	0	0	0	0	
B					0	0	0	0	0	0	0	
C					0	0	0	0	0	0	0	
D					0	0	0	0	0	0	0	
42 A	160° 50' W	31	1445	1	0	0	0	0	0	0	0	
B					0	0	0	0	0	0	0	
C					0	0	0	0	0	0	0	
D					0	0	0	0	0	0	0	
E					0	0	0	0	0	0	0	
F					0	0	0	0	0	0	0	
G					0	0	0	0	0	0	0	
H					0	0	0	0	0	0	0	
I					0	0	0	0	0	0	0	
J					0	0	0	0	0	0	0	
43 A	160° 40' W	31	1502	1	0	0	0	0	0	0	0	
B					0	0	0	0	0	0	0	
C					0	0	0	0	0	0	0	
D					0	0	0	0	0	0	0	
E					0	0	0	0	0	0	0	
F					0	0	0	0	0	0	0	
G					0	0	0	0	0	0	0	
H					0	0	0	0	0	0	0	
I					0	0	0	0	0	0	0	
J					0	0	0	0	0	0	0	
K					0	0	0	0	0	0	0	
L					0	0	0	0	0	0	0	
M					0	0	0	0	0	0	0	
Bechevin Bay		30	1732	5						186		

* + = Infinity

Table 3. Sizes of sea otter groups sighted on 30-31 July 1976 transect survey.

Transect	Track width	Frequency of Occurrence of Group Size					Sizes of Larger Pods
		1	2	3	4	5	
5 D	0.2 nm						
	Unlimited	1					
10 A	0.2 nm	2	1				
	Unlimited	3	2		1		
B	0.2 nm	2		3			10
	Unlimited	3	2	1			7, 10
C	0.2 nm	1	1	1			
	Unlimited		3			1	6, 9
D	0.2 nm	1					
	Unlimited	2					11
F	0.2 nm						
	Unlimited			1			
11 B	0.2 nm	2	1	1			
	Unlimited	2			1		20, 20
C	0.2 nm	2					15
	Unlimited		2		1		14, 20, 8
12 A	0.2 nm	1					
	Unlimited	1		1			
B	0.2 nm	2	1				6, 7, 11
	Unlimited			2		1	6, 27
C	0.2 nm	3					
	Unlimited	3					
F	0.2 nm						
	Unlimited		1				
13 A	0.2 nm	5	5				
	Unlimited	4	2	2		1	
B	0.2 nm	3	1				
	Unlimited	1		1			
D	0.2 nm						
	Unlimited	1					
E	0.2 nm						
	Unlimited	1					
14 A	0.2 nm	2	1				
	Unlimited	3					
B	0.2 nm	2	1			1	7, 11, 13
	Unlimited				1		80, 20, 30, 20, 17
C	0.2 nm						
	Unlimited	1	1				
D	0.2 nm	1					
	Unlimited						
F	0.2 nm	1					
	Unlimited						

Table 3. (cont.) Sizes of sea otter groups sighted on 30-31 July 1976 transect survey.

Transect	Track width	Frequency of Occurrence of Group Size					Sizes of Larger Pods
		1	2	3	4	5	
15 A	0.2 nm	2	1				
	Unlimited	2	3				
C	0.2 nm						
	Unlimited	2	1				
G	0.2 nm	1					
	Unlimited	1					
J	0.2 nm						
	Unlimited	1					
16 A	0.2 nm	1	1				
	Unlimited	1	1	1			23
B	0.2 nm	7	6				35, 60, 30
	Unlimited		5				100, 40, 8, 9, 50, 17, 12
C	0.2 nm	1		1			
	Unlimited				1		6, 7
D	0.2 nm	4					
	Unlimited	1	2				
E	0.2 nm	1					
	Unlimited	2					
F	0.2 nm						
	Unlimited	2					
17 A	0.2 nm	1	1				
	Unlimited	4	1				
B	0.2 nm	1					
	Unlimited	1					
D	0.2 nm						
	Unlimited	2					
E	0.2 nm						
	Unlimited	1					
18 A	0.2 nm	1	1				
	Unlimited		1				
B	0.2 nm		1				
	Unlimited	1					
C	0.2 nm						
	Unlimited		1				
E	0.2 nm	4	1				
	Unlimited	2					
H	0.2 nm		1				
	Unlimited		1				
K	0.2 nm	1					
	Unlimited	1					

Table 3. (cont.) Sizes of sea otter groups sighted on 30-31 July 1976 transect survey.

Transect	Track width	Frequency of Occurrence of Group Size					Sizes of Larger Pods
		1	2	3	4	5	
19 B	0.2 nm						
	Unlimited						9, 35
C	0.2 nm		1				5
	Unlimited	2					
D	0.2 nm	2					
	Unlimited	1	1				
E	0.2 nm	2					
	Unlimited	1					
G	0.2 nm	2					
	Unlimited						
I	0.2 nm		1				
	Unlimited	1					
20 A	0.2 nm	2			1		9
	Unlimited	1		1			6, 7, 8
B	0.2 nm						
	Unlimited	2					
D	0.2 nm	1					
	Unlimited			1			
F	0.2 nm	1					
	Unlimited	1					
G	0.2 nm	1					
	Unlimited						
H	0.2 nm	2					
	Unlimited	2	1				
J	0.2 nm						
	Unlimited	1					
K	0.2 nm	1					
	Unlimited						
21 A	0.2 nm	2					
	Unlimited	1					
B	0.2 nm						
	Unlimited	1					
C	0.2 nm						
	Unlimited	1	1				
G	0.2 nm						
	Unlimited	1					
I	0.2 nm						
	Unlimited		1				
22 A	0.2 nm	2					
	Unlimited						
B	0.2 nm						100
	Unlimited						50
C	0.2 nm	1					
	Unlimited					1	
D	0.2 nm	1					
	Unlimited	2					
K	0.2 nm	1					
	Unlimited	1					

Table 3. (cont.) Sizes of sea otter groups sighted on 30-31 July 1976 transect survey.

Transect	Track width	Frequency of Occurrence of Group Size					Sizes of Larger Pods
		1	2	3	4	5	
23 A	0.2 nm	1					8
	Unlimited						50, 50, 15, 14
B	0.2 nm	2					
	Unlimited	1	1				30
C	0.2 nm	1					
	Unlimited	1					9, 10
D	0.2 nm		1				
	Unlimited	2					20, 100
E	0.2 nm	1					
	Unlimited						
F	0.2 nm	1					
	Unlimited						
G	0.2 nm		1				
	Unlimited	1					
K	0.2 nm	1					
	Unlimited						
M	0.2 nm						
	Unlimited		1				
O	0.2 nm						
	Unlimited		1				
24 B	0.2 nm	2		1			
	Unlimited	1	1				
C	0.2 nm						
	Unlimited	1					
E	0.2 nm						
	Unlimited	2					
I	0.2 nm	1					
	Unlimited						
K	0.2 nm	1					
	Unlimited	1					
P	0.2 nm						
	Unlimited		1				
25 B	0.2 nm						
	Unlimited	1					
C	0.2 nm	1					
	Unlimited						
D	0.2 nm		1				
	Unlimited						
E	0.2 nm						
	Unlimited	1	1				
26 B	0.2 nm	2					
	Unlimited						
C	0.2 nm	1					
	Unlimited	2					
D	0.2 nm		1				
	Unlimited	1	1				
F	0.2 nm	1					
	Unlimited						
G	0.2 nm						
	Unlimited	1					

Table 3. (cont.) Sizes of sea otter groups sighted on 30-31 July 1976 transect survey.

Transect	Track width	Frequency of Occurrence of Group Size					Sizes of Larger Pods
		1	2	3	4	5	
27 A	0.2 nm	1					
	Unlimited	1					
B	0.2 nm	2	1				
	Unlimited	3					16, 20
C	0.2 nm	6	1	1			8, 17
	Unlimited	2		2	1		7, 7, 10, 16
E	0.2 nm	1					
	Unlimited	2					
F	0.2 nm	1					
	Unlimited	1					
H	0.2 nm	1					
	Unlimited		1				
28 A	0.2 nm						
	Unlimited	1					
B	0.2 nm	1					
	Unlimited						30, 8
C	0.2 nm	4	1				15
	Unlimited	1		1			9, 16
D	0.2 nm	5	2	1		1	
	Unlimited	6	1	1	2		
E	0.2 nm	3	1	1			6
	Unlimited	2	1		2		16, 12
H	0.2 nm	2					
	Unlimited						
L	0.2 nm						
	Unlimited		2				
29 B	0.2 nm	1	1				
	Unlimited						
C	0.2 nm						25
	Unlimited	2	1				19
D	0.2 nm	5					
	Unlimited	1					25, 50, 11
E	0.2 nm				2		
	Unlimited	3					
F	0.2 nm	4	1			1	
	Unlimited	1					6
G	0.2 nm	1					
	Unlimited	1		2		1	6, 50
H	0.2 nm	1		1			
	Unlimited		1	1			10, 14
I	0.2 nm						
	Unlimited	1		1			

Table 3. (cont.) Sizes of sea otter groups sighted on 30-31 July 1976 transect survey.

Transect	Track width	Frequency of Occurrence of Group Size					Sizes of Larger Pods
		1	2	3	4	5	
30 A	0.2 nm	1					
	Unlimited						
B	0.2 nm		1				
	Unlimited	3	1		1		
C	0.2 nm		1				
	Unlimited	1	1				
E	0.2 nm						50
	Unlimited				2		12, 40
F	0.2 nm						6
	Unlimited						11, 10, 21
G	0.2 nm						
	Unlimited		1				
H	0.2 nm		1				
	Unlimited			1			
I	0.2 nm	3					
	Unlimited	2	1		1		
K	0.2 nm						
	Unlimited			1			
31 A	0.2 nm	1	1				12
	Unlimited		1				
B	0.2 nm	3	1				
	Unlimited	1	1				
C	0.2 nm	3				1	28
	Unlimited	1			1		24
D	0.2 nm						
	Unlimited						15
E	0.2 nm	1					
	Unlimited	1					
F	0.2 nm			1			
	Unlimited	1					
32 A	0.2 nm	2					
	Unlimited		1				
B	0.2 nm	1					
	Unlimited						
D	0.2 nm	1					
	Unlimited						
G	0.2 nm						
	Unlimited	1					
33 A	0.2 nm	1					
	Unlimited	1					
B	0.2 nm		1				
	Unlimited	1	1	1	1		
C	0.2 nm	1	2	1			
	Unlimited				1		
D	0.2 nm		1				6

In some cases a partial segment beyond those indicated was surveyed. No sea otters were seen in these partial segments and they have been omitted from the tables to prevent confusion. Flightlines and distribution of sea otters counted in Bechevin Bay are shown in Fig. 3.

VII. Discussion

Although the 30-31 July survey was considered highly successful there are a number of limitations that should be considered before interpreting the data. The time available for preparation of this report did not allow detailed analysis of all aspects of the survey. Therefore, this discussion will cover factors influencing the survey and the most important conclusions drawn from it. A more detailed analysis might be necessary for comparison with any subsequent surveys.

Strip transects were chosen over line transects because measurement of radial angles, radial distances or right angle distances for each sighting would have been impossible given the speed of the aircraft, number of observations and short distances of observation.

A systematic arrangement of transects was chosen over a random distribution because major objectives of the survey involved determining the distribution of sea otters throughout the entire area. Use of a systematic survey greatly complicates estimation of variance in the population estimate as neither the transects nor the sea otters were randomly distributed. This problem could have been overcome by repetitive surveys but, given

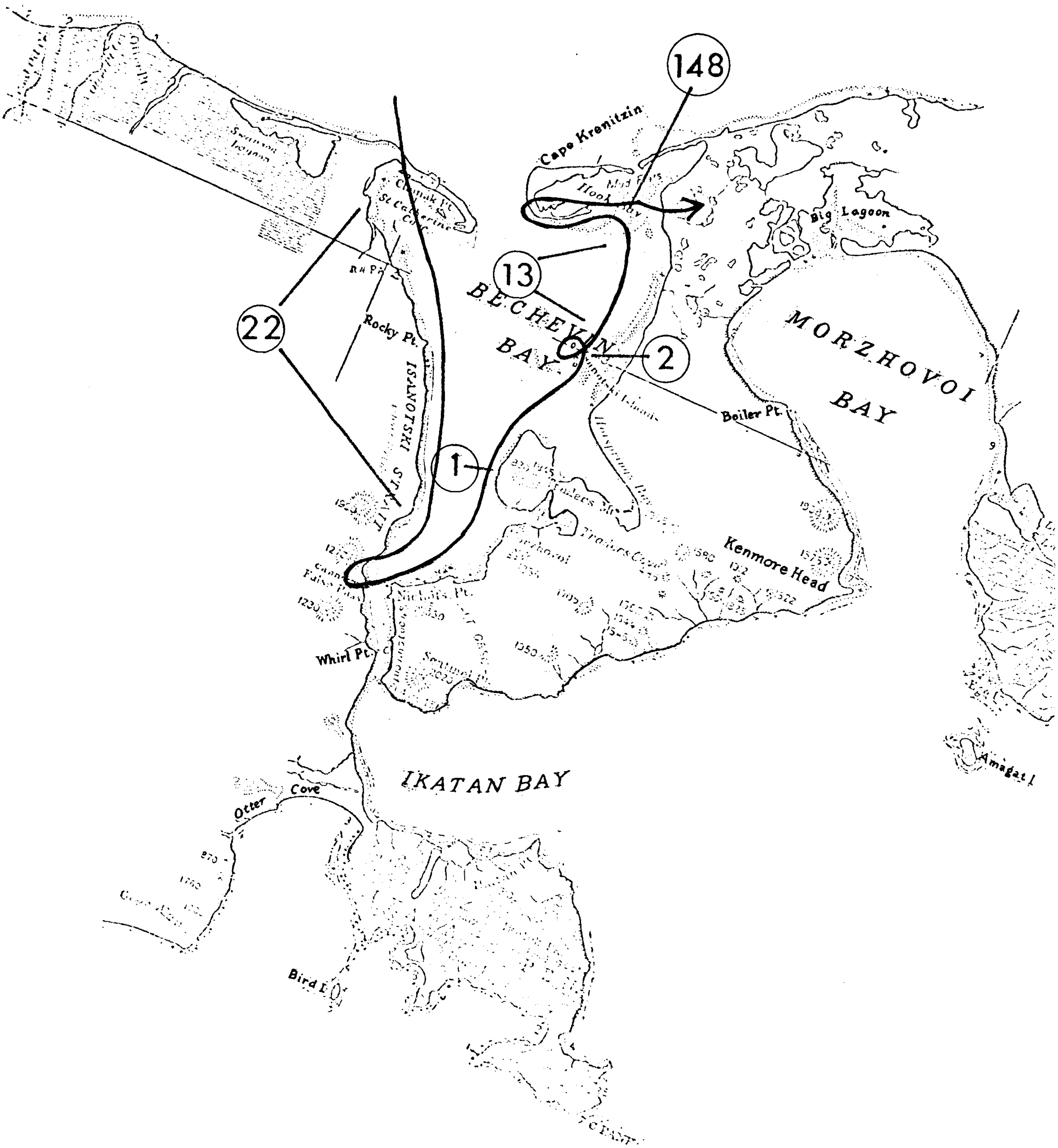


Figure 3. Survey Trackline and locations of sea otters counted in Bechevin Bay on 30 July 1976.

limited funding, several less intensive and perhaps less accurate surveys might have introduced more variability while providing the means to estimate that variability. Systematic sampling can produce estimates that compare favorably with stratified random samples provided no periodicity occurs in the population (Cochran 1963). No known periodicity that would cause bias in the present survey exists.

Effect of Pods

A major problem anticipated in this survey was the distribution of the sea otters in relation to one another. During past surveys distribution has varied from widely scattered individuals to the occurrence of large pods of up to 1,000 with a few scattered individuals nearby. The occurrence of large pods could strongly influence estimates of densities depending on whether a pod fell within a count area or not. This was a major reason for conducting an unlimited width strip survey at the same time as the limited width strip survey. It provided information useful in evaluating the influence of large pods. It also increased the possibility of detecting low densities of sea otters.

The occurrence of pods does not appear to have been a serious problem in this survey. No pods of over 100 individuals were seen. Most pods were of moderate size and a number of pods usually occurred within an area so some fell within the limited width strips (Table 3).

A total of 1,901 sea otters was counted in the unlimited transects while 811 were counted in the 0.2 nm transects for a ratio of 2.3. The ratio of the number of pods containing over 10 individuals was 50:15 or 3.2. This might indicate that too few pods were seen in the 0.2 nm transect; however, the effective width of the unlimited width counts would be greater for pods than for individuals since sightability increases with group size. This is evident when the numbers of single animals sighted are compared. Fewer single animals were seen in the unlimited width transects than in the 0.2 nm transects (126:149, ratio 0.85) and a higher percentage of all animals seen were in pods over 10 (71 percent vs. 53 percent). Therefore the effective width of the unlimited width transects was greater for pods than for individuals and the higher ratio of pods sighted between the two surveys would be expected.

The ratio of the number of sea otters in pods was similar to the ratio of the number of pods (3.1 vs 3.2) indicating that pod size had little influence for pods over 10.

This does not rule out the possibility that the occurrence of pods biased the counts. Some bias probably did occur, at least within small areas. Large pods may have occurred between transects out of view of all of the observers. The unlimited width transect observers probably sampled less than half the area even for large pods. Therefore, while no bias resulting from the occurrence of pods could be readily identified, some could have occurred.

Effect of Diving Animals

A major assumption made with most strip transect surveys is that all animals in the strip are counted. This assumption is seldom justified and it certainly isn't in the case of diving mammals. There have been several attempts to estimate the percentage of time a sea otter spends under water. Estes and Smith (1973) estimated that at Amchitka Island 30 percent of the population was underwater at any given instant even during periods of minimum feeding activity. The proportion decreases with time, however. If we assume that the observers on the present survey could view a 0.2 nm long strip at any instant, any given point would remain in his field of view for only 6 seconds. The decrease in number of sea otters on the surface would be insignificant during that time. In reality the time the observer could devote to effectively watching one spot is considerably less than 6 seconds.

Estimates by Estes and Smith (1973) were based on observations made in quite different habitat and generally shallower depths (less than 30 m). No suitable data are available for the area north of Unimak Island and the Alaska Peninsula. Water depths are generally greater requiring considerably more time to dive to the bottom. At extreme depths the sea otter would be forced to rest longer between dives however. Food items might be more abundant in that area requiring less time to locate them.

Many sea otters reacted to the aircraft by diving. Observers frequently saw sea otters dive just as they came into view and occasionally saw splashes that could not be positively identified. Observers counting in unlimited width strips sat in the rear of the aircraft and had poorer forward vision than those counting in the limited strips. Many sea otters were underwater by the time their location came into view.

While no reliable adjustment can be made for the effect of diving animals on the present survey, Estes and Smith (1973) estimated that 30 percent underwater would probably be conservative.

Sightability of Animals on the Surface

Experience has shown that not all sea otters on the surface of the water are seen during aerial surveys. Many factors influence the sightability of an individual sea otter. These include:

1. Visibility conditions - Many factors influence the visibility of sea otters in the water. These factors often influence each other providing a wide array of conditions. Often conditions change rapidly. Among the more common factors are sea state and lighting conditions. Any type of wave will reduce visibility. Sharp, choppy waves are worse than large swells so wind velocity and direction at the time of the survey are major factors. Lighting conditions often magnify the effect of sea state. Sun glare on the water's surface, reflection on the windshield of an aircraft, low light intensity because of clouds or time of day and the wave lengths of light reflected from the water's surface strongly influence visibility. Since the angle of incidence of light is important,

visibility on one side of the observer may be significantly different from that on the other side.

The visibility code assigned to each transect was an attempt to classify all of these factors (Table 2). Conditions encountered on this survey were the best ever encountered in this area during a survey. This greatly reduced the effects of visibility conditions on the counts. Only on transects 8 and 9 and in Bechevin Bay did visibility conditions seriously interfere with the survey. A 13 August 1975 survey indicated that substantial numbers of sea otters existed in the area of both transects 8 and 9 although few were found west of there. Some correction should be made for these two transects. Allowing half the number seen on transect 10 for transect 9 (16) and half of that (8) for transect 8 would seem to be a conservative approach.

Visibility conditions probably also reduced the Bechevin Bay count considerably. On 13 August 1975 a total of 444 sea otters was counted in the bay under slightly better conditions. Since sea otters may move in and out of the bay no reliable correction factor can be suggested.

2. Presence of confusing objects - The presence of other species of marine mammals, birds, certain types of kelp, drift or any object that appears similar to the target species will distract the observer and reduce his ability to identify the target species.

There was little kelp or drift in the area. Visibility conditions made identification of other marine mammals and birds relatively easy. The only serious interference was from several million shearwaters in dense flocks. Flocks on the water resembled pods of sea otters at a distance. This tended to distract the unlimited width strip observers and reduced their ability to identify pods at a distance. As the aircraft approached flocks of shearwaters they would take off and fly back and forth over the count area. This created a "screen" effect making it extremely difficult to identify sea otters under them. Fortunately the area of highest shearwater concentrations appeared to lie offshore from the area of highest sea otter density. Some sea otters were probably missed as a result of the presence of birds, however.

3. Behavior - The way animals react to the survey platform, their activity and posture in the water, and their distribution in relation to each other and in relation to geographical features have a strong influence on sightability. Distribution of individuals has an effect that often overrides the effects of all other factors. When most animals are resting on the surface of the water in large groups, counts are almost always high. When they are widely scattered, counts will be low unless other conditions are ideal.

   Generally, sea otters are most visible when they are resting on their backs and in groups and least visible when alone and upright in the water. Some movements will enhance sightability, particularly swimming on their backs. Many factors influence behavior including time of day, presence of the aircraft, present weather conditions and even weather conditions of the past few days.

Group size and whether the animals were resting or active were recorded for each sighting in the hope that some comparison of these factors between areas could be made. It would appear that the two limited width strip observers used slightly different definitions of resting and active. The left observer classed as active only those animals that were moving in such a way as to hinder identification. Only 13 percent fell into this catagory. The right observer used a somewhat broader definition and classified 48 percent as active. The difference probably represents animals beginning to react to the aircraft but not diving or upright in the water.

Even when all of the above factors are ideal some animals will be missed. The human eye can not sweep an area giving equal attention to all areas. It tends to focus on points and rapidly move from point to point. The less time available to search a given area and the more distant the area the less efficient the observer. The aircraft used on this survey was relatively fast, giving the observer only a few seconds to locate, identify and count sea otters. There was no way to increase the time of observation without changing the survey platform. This would have been at the expense of coverage or safety.

A relatively narrow strip width was selected to at least partially overcome the problems of aircraft speed and other factors that reduce sightability. It is certain that some sea otters were missed throughout the survey. The bird observer in the rear of the aircraft counted birds in a 100 m strip and noticed some sea otters missed by the left observer. These were not included in the counts.

Observer ability can strongly influence counts. All observers were experienced and all except one of the unlimited width strip observers had participated in intensive sea otter counts in the past year. The left observer counted 55 percent of the sea otters recorded in the 0.2 nm wide strips; however, he saw only 51 percent of the singles and pairs. This suggests that both observers had similar ability and the difference was due to the size of a few larger groups.

All of the factors discussed above tend to reduce the percentage of sea otters on the surface that are seen. Unfortunately without some form of ground truth it is impossible to quantify these factors. It was not logistically or economically feasible to attempt to gather ground truth information on this survey.

Comparisons of aerial counts with shore counts or boat counts have been attempted in other areas. All indicate that a significant percentage of sea otters are missed in aerial counts. However, these comparisons have never included strip counts over open water. Therefore, there is no reliable way to estimate the percentage of sea otters on the surface that are missed. One must simply recognize that the counts and any estimates derived from the counts are low.

Sea Otters Outside of the Survey Area

The available information indicates that most of the population was in the area surveyed but that small numbers may have been outside the area. Only one sighting of sea otters south of Cape Sarichef has been recorded (Table 1). Seventy-five sea otters sighted there in 1958 may have been a transient group as none have been reported from there since and none were seen on two surveys in 1975. The 1975 surveys indicated that few sea otters were west of Cape Mordvinof, perhaps even fewer than in 1965 when Kenyon (1969) counted 10. Results of the present survey seemed to confirm this (Table 2).

We encountered fog and were unable to complete transects 36-38. No sea otters were sighted on transects 34 or 35 and none were seen in the Port Moller area. A total of six survey tracklines paralleling the shore at various distances from shore have been flown in this area since June 1975. The last of these was made under excellent conditions the morning of the first day of this survey. On all of these surveys only two sightings of sea otters, both near the western side of the entrance to Port Moller and Herendeen Bay, have been made. Reports from biologists in the area indicate that very few sea otters remain northeast of Cape Lieskof. Therefore, it appears that scattered individuals and perhaps a few very small groups were northeast of Cape Lieskof. We were not able to survey intensively enough to estimate their numbers. They probably compose only a fraction of a percent of the population.

Sea otters have frequently been seen in water over 60 m deep, especially in the area surveyed, but only occasional individuals have been seen in water over 80 m deep. There are several records of sea otters caught in crab pots nearly 100 m deep and resting animals have been seen in water over 200 m deep, however, those regularly feeding in water over 80 m deep would appear to be unique and are usually adult males. Therefore, the 80 m depth contour was selected as the outer boundary of the survey area. Problems with the GNS 500 navigation aid caused us to underestimate or overestimate our distance from shore. Therefore, not all areas within the 80 m contour were surveyed (Fig. 2). Sea otters were seen in the northern-most segment of three transects (15, 23, 24). Estimated depths near these sightings ranged from 70 to 80 m. Transects 10, 11, 12, 13, 16, 17, 18 and 19 were probably cut too short although the number of sea otters that would have been seen had they been extended would have been small. Transects 8 and 9 were cut short purposely because of visibility conditions. There is also a possibility that a small number of otters were beyond the 80 m depth contour.

Izembek and Moffet Lagoons were not specifically surveyed. However, during refueling trips, the aircraft was flown over most parts of the lagoons likely to contain sea otters. No sea otters were seen there. We might have missed scattered individuals, however.

A line opposite the False Pass cannery was arbitrarily selected as the southern boundary of the population. Substantial numbers of sea otters exist along the south shore of Unimak Island and the Alaska Peninsula between Cape Lazaref and Cold Bay. There is a strong possibility that many of the animals repopulating this area in the late 1960's immigrated from the Bering Sea through Isanotski Strait. Small numbers are seen in the strait today and movement through the strait has been observed during periods of extremely heavy sea ice formation (Schneider and Faro 1975). Some interbreeding between sea otters in the Bering Sea and those from the Sandman Reefs and Sanak Island probably occurs. Therefore the population being discussed here is not entirely discrete. Isanotski Straits appears to be the point at which interchange is most restricted but the Bering Sea population could periodically gain or lose animals through this interchange.

In summary, small numbers of sea otters were probably farther offshore than the transects extended, northeast of the survey area or in Izembek and Moffet Lagoons. There is no evidence that inclusion of these animals would significantly increase the population estimate, however.

Population Estimate

Time limited the extent of data analysis. As indicated above, there were many factors influencing the survey that could not be quantified. Therefore, only a simple extrapolation to a population estimate will be presented, with no estimate of variance. It is anticipated that with additional time a more refined estimate could be produced.

An area of approximately 7175 km^2 was sampled. Of that area 506.3 km^2 fell within the limited width strip transects. A total of 811 sea otters was counted in the strips. If we expand this to the entire area we get:

	11,495
Add Bechevin Bay count	186
Unadjusted estimate	11,681

If we compensate for the poor visibility conditions along transects 8 and 9 by assuming that a total of 24 sea otters would have been seen if visibility conditions and the transect lengths were the same as transect 10, we would have an adjusted estimate of:

11,681 + 340 = 12,021

This would be an estimate of the number of sea otters that would have been counted if the entire area had been surveyed.

An unknown proportion of the population would have been under water at the time of the survey. While recognizing that this may not apply to particular area, if we use Estes and Smith's (1973) estimate of 30 percent we get:

12,021 on surface + 5,152 diving = 17,173

This estimate assumes that:

1. All sea otters on the surface in the strip transects were counted.

2. All sea otters on the surface in Bechevin Bay were counted.

3. All sea otters were within the area sampled.

4. No sampling error occurred.

5. 30 percent of the sea otters were not on the surface.

From the previous discussion of factors influencing the survey it is evident that assumptions 1-3 are incorrect and would tend to yield an underestimate of numbers. Assumption 4 could yield an overestimate or an underestimate although no gross errors were immediately obvious. Assumption 5 could yield an overestimate or an underestimate, however, it fails to consider diving in reaction to the aircraft which would tend to produce an underestimate. Therefore, the overall estimate would tend to be conservative unless sampling error was great.

The above estimate indicates a density of 2.3 sea otters/km^2. If we exclude those areas west of Cape Mordvinof and east of Cape Leontovich the overall density would be 3.0 sea otters/km^2. This is a modest density for a sea otter population when compared to those observed in other areas (Kenyon 1969, Estes and Smith 1973); however, most other estimates have assumed that sea otter habitat did not extend beyond the 60 m depth contour. The observed density within the 60 m depth contour in the primary range of the population (between transects 10 and 33) was 2.7 sea otters/km^2 or with the 30 percent correction for diving animals 3.9/km^2, still a moderate density.

There is reason to believe that both the total population and the densities of sea otters in the area surveyed were lower than in the 1960's. During the 1960's the range of the population expanded rapidly. By 1970 substantial numbers had reached Port Heiden and there was evidence of expansion to the south side of the Alaska Peninsula and Unimak Island. Such expansion usually indicates that sea otter densities have become too high in relation to food availability. Sea ice conditions in the early 1970's reduced the range of the population (Schneider and Faro 1975). Since 1972 no repopulation of former habitat to the northeast has been observed. Fragmentary surveys indicate little change in the range of sea otters on the south side of Unimak Island and fewer sea otters inhabit the area west of Cape Mordvinof. Residents of Cold Bay have observed a reduction in the number of sea otters using Izembek Lagoon (Robert Jones, USFWS, pers. comm.). These factors indicate that competition for food and hence the need to expand range have been reduced. This is probably the result of lower densities.

If this is the case, the population can be expected to increase in numbers unless some factor increases mortality or limits the food supply.

Range

The main range of the population presently extends from the vicinity of Cape Mordvinof to Cape Lieskof and includes Bechevin Bay. Izembek and Moffet Lagoons are used to a lesser extent. Small numbers may occur west of Cape Mordvinof; however, less offshore habitat exists in that area. Small numbers appear to persist near Port Moller and it is possible that scattered individuals may stray as far to the northeast as Egegik. Those animals presently northeast of Cape Lieskof are probably not contributing substantially to the growth of the population.

The population should again expand its range as its numbers increase as long as severe sea ice conditions similar to those in 1971 and 1972 do not occur. Range expansion to the northeast will probably be rapid once it begins. It is not possible to predict how long it will take for the population to reoccupy all of its 1970 range. If sea ice conditions remain moderate it should take less than 10 years, however.

When assessing the possible impacts of both offshore and onshore activities on sea otters, the potential range of the population should be considered. This extends to the Port Heiden area. Sea otters have occurred farther to the northeast in the past and may in the future. However, average sea ice conditions would eliminate most of those animals. Densities of sea otters between Port Heiden and Port Moller will probably fluctuate dramatically as sea ice conditions vary. In rare, extreme cases the range may be restricted to its present distribution.

Distribution

Sea otters were not distributed uniformly within the present range of the population. Small areas of extremely high densities were evident. The range was stratified into high, medium and low density areas on the basis of the unlimited width strip count (Table 4, Fig. 4). No attempt was made to delineate small areas of concentration although it appears

Table 4. Approximate water depth, sea otter density stratum and number of sea otters counted in 0.2 nm strip for each transect segment surveyed between Urilia Bay and Cape Lieskof. Densitites were recorded as high (H), medium (M) or low (L).

Transect Number	Depth (m)	Density	Number of Sea Otters Counted
10 A	20-40	H	4
B	"	H	21
C	"	H	6
D	40-60	H	1
E	"	M	0
F	"	M	0
G	60+	L	0
11 A	0-20	M	0
B	20-40	H	7
C	"	H	17
D	"	H	0
E	40-60	M	0
F	"	M	0
12 A	0-20	M	1
B	"	H	28
C	20-40	H	3
D	40-60	M	0
E	"	M	0
F	"	M	0
G	"	L	0
H	"	L	0
13 A	0-20	H	15
B	20-40	H	5
C	"	H	0
D	"	M	0
E	40-60	M	0
F	"	M	0
G	"	L	0
14 A	0-20	H	4
B	20-40	H	35
C	"	H	0
D	"	H	1
E	40-60	M	0
F	"	M	1
G	"	L	0
H	60+	L	0
I	"	L	0
J	"	L	0
15 A	20-40	H	4
B	"	H	0
C	40-60	H	0
D	"	H	0
E	"	M	0
F	"	M	0
G	60+	L	1
H	"	L	0
I	"	L	0
J	"	L	0
16 A	0-20	H	3
B	20-40	H	144
C	"	H	4
D	40-60	H	4
E	"	M	1
F	"	M	0
G	"	M	0
H	"	L	0
I	60+	L	0
17 A	0-20	H	3
B	20-40	H	1
C	"	H	0
D	"	M	0
E	40-60	M	0
F	"	M	0
G	"	M	0
18 A	0-20	H	3
B	20-40	H	2
C	"	H	0
D	"	M	0
E	40-60	M	6
F	"	M	0
G	"	M	0
H	"	M	2
I	"	M	0
J	"	L	0
K	60+	L	1
L	"	L	0
19 A	0-20	H	0
B	20-40	H	0
C	"	H	7
D	40-60	M	2
E	"	M	2
F	"	M	0
G	"	M	2
H	"	M	0
I	"	M	2
J	"	M	0
K	60+	L	0
20 A	0-20	H	15
B	20-40	H	0
C	"	M	0
D	"	M	1
E	40-60	M	0
F	"	M	1
G	"	M	1
H	"	M	2
I	"	M	0

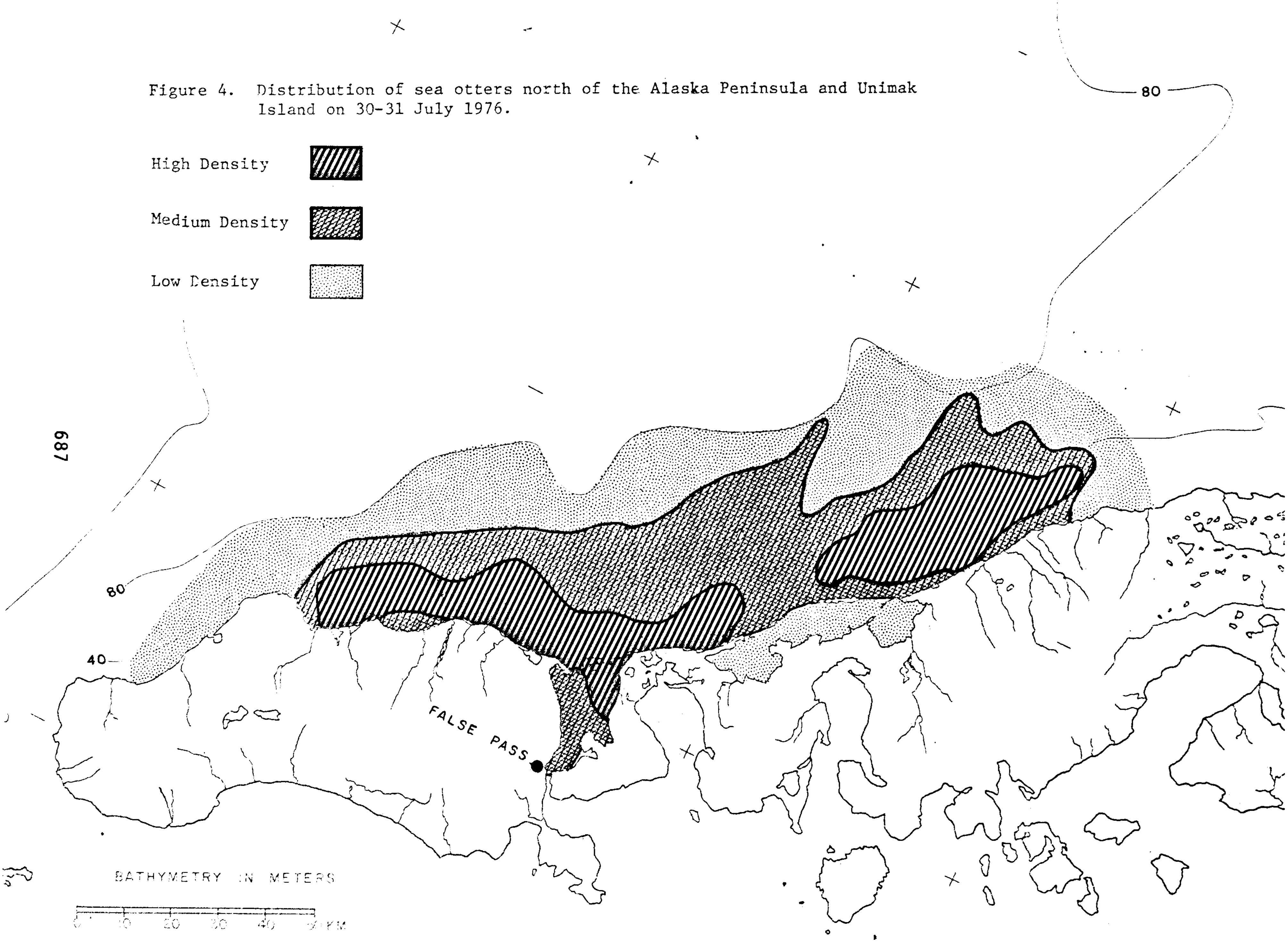
Table 4. (cont.) Approximate water depth, sea otter density stratum and number of sea otters counted in 0.2 nm strip for each transect segment surveyed between Urilia Bay and Cape Lieskof.

Transect Number	Depth (m)	Density	Number of Sea Otters Counted	Transect Number	Depth (m)	Density	Number of Sea Otters Counted
20 J	40-60	M	0	24 E	40-60	M	0
K	"	L	1	F	"	M	0
L	60+	L	0	G	"	M	0
M	"	L	0	H	"	M	0
21 A	0-20	H	2	I	"	L	1
B	20-40	H	0	J	"	L	0
C	"	M	0	K	"	L	1
D	"	M	0	L	"	L	0
E	40-60	M	0	M	60+	L	0
F	"	M	0	N	"	L	0
G	"	M	0	O	"	L	0
H	"	M	0	P	"	L	0
I	"	M	0	25 A	0-20	M	0
J	"	M	0	B	"	M	0
K	60+	L	0	C	20-40	M	1
22 A	0-20	H	2	D	"	M	2
B	20-40	H	100	E	40-60	M	0
C	"	H	1	F	"	M	0
D	"	H	1	G	"	M	0
E	"	M	0	H	"	M	0
F	"	M	0	I	"	L	0
G	"	M	0	J	"	L	0
H	"	M	0	K	"	L	0
I	40-60	M	0	L	60+	L	0
J	"	M	0	26 A	0-20	M	0
K	"	M	1	B	"	H	2
L	60+	M	0	C	20-40	H	1
M	"	L	0	D	"	H	2
N	"	L	0	E	"	M	0
23 A	0-20	H	9	F	"	M	1
B	20-40	H	2	G	40-60	M	0
C	"	H	1	H	"	L	0
D	"	H	2	I	"	L	0
E	"	M	1	J	"	L	0
F	"	M	1	K	60+	L	0
G	40-60	M	2	L	"	L	0
H	"	M	0	M	"	L	0
I	"	M	0	N	"	L	0
J	"	M	0	O	"	L	0
K	"	M	1	27 A	0-20	M	1
L	60+	M	0	B	20-40	H	4
M	"	M	0	C	"	H	36
N	"	M	0	D	"	H	0
O	"	M	0	E	"	H	1
24 A	0-20	M	0	F	"	H	1
B	20-40	M	5	G	40-60	M	0
C	"	M	0	H	"	M	1
D	"	M	0	I	"	M	0

Table 4. (cont.) Approximate water depth, sea otter density stratum and number of sea otters counted in 0.2 nm strip for each transect segment surveyed between Urilia Bay and Cape Lieskof.

Transect Number	Depth (m)	Density	Number of Sea Otters Counted
27 J	40-60	L	0
K	"	L	0
L	60+	L	0
M	"	L	0
28 A	0-20	M	0
B	20-40	H	1
C	"	H	21
D	"	H	17
E	"	H	14
F	40-60	H	0
G	"	M	0
H	"	M	2
I	"	M	0
J	"	M	0
K	"	M	0
L	60+	M	0
M	"	M	0
29 A	0-20	M	0
B	20-40	H	3
C	"	H	25
D	"	H	5
E	40-60	H	8
F	"	H	11
G	"	H	1
H	"	H	4
I	"	H	0
J	"	M	0
K	60+	M	0
30 A	0-20	M	1
B	20-40	H	2
C	"	H	2
D	"	H	0
E	"	H	50
F	40-60	H	6
G	"	H	0
H	"	H	2
I	"	M	3
J	"	M	0
K	60+	M	0
L	"	L	0
M	"	L	0
31 A	0-20	H	15
B	"	H	5
C	20-40	H	36
D	"	H	0
E	"	H	1
F	"	H	3
31 G	40-60	M	0
H	"	M	0
I	"	M	0
J	60+	L	0
K	"	L	0
32 A	0-20	M	2
B	"	M	1
C	20-40	H	0
D	"	H	1
E	"	H	0
F	40-60	M	0
G	"	M	0
H	"	L	0
I	60+	L	0
J	"	L	0
K	"	L	0
L	"	L	0
M	"	L	0
33 A	0-20	M	1
B	20-40	H	2
C	"	H	8
D	"	H	8
E	40-60	M	0
F	"	L	0
G	"	L	0
H	60+	L	0
I	"	L	0
J	"	L	0
K	"	L	0
L	"	L	0

Figure 4. Distribution of sea otters north of the Alaska Peninsula and Unimak Island on 30-31 July 1976.



that such areas exist. Observed densities within the 0.2 nm strips averaged 6.5 sea otters/km^2 in high, 0.3/km^2 in medium and 0.06/km^2 in low density areas.

This distribution is only representative of the situation on 30 and 31 July 1976. Somewhat different distributions have been observed on previous surveys. This population is more mobile than those occupying typical, rocky, sea otter habitat. Differences have generally been in the degree of dispersal offshore. At times large numbers have been concentrated near shore while at other times low densities were found near shore and high densities occurred 15 to 30 km from shore. The 30-31 July 1976 distribution appears intermediate between those extremes and may be more typical. There appeared to be at least two separate areas of high density roughly separated by a line between Amak Island and Cold Bay. This separation has been observed on past surveys and may reflect varying quality of habitat.

Configuration of shoreline, offshore islands and rocks appears to strongly influence the distribution of sea otters in most populations. Many animals seek sheltered areas to rest. There is relatively little relationship between these features and distribution in this area except in Bechevin Bay. Occasionally small pods have been seen near Amak Island but that is usually not a high density area.

Water depth seems to influence distribution more than the shoreline. Each segment of transects 10-33 was classified by depth. Throughout much of the area the outer edge of "high" density areas closely conformed to the 40 m depth contour and the edge of the "medium" density conformed to the 60 m depth contour. Sea otters northeast of Amak Island were distributed slightly farther offshore with medium densities extending to the 80 m contour in one area and high densities extending to areas 50 m deep.

Densities observed in the 0.2 nm strips averaged 3.1 sea otters/km^2 in water 0 to 20 m deep, 5.8/km^2 in water 20 to 40 m deep, 0.5/km^2 in water 40 to 60 m deep and 0.03/km^2 in water over 60 m deep. True densities would have been higher because diving animals weren't counted. The observed densities in water over 60 m deep may be low. Only 0.25 percent of the sea otters counted in the limited width strips were beyond the 60 m depth contour while 0.84 percent counted in the unlimited width strips were beyond the 60 m countour. In either case only a small percentage of the population was in water deeper than 60 m. During a survey of the area west of Amak Island made on April 1969 most of the sea otters seen were in water deeper than 40 m and many were beyond the 60 m depth contour. Sea otters observed in deep areas have usually been widely scattered. Large pods usually occur in water less than 40 m deep.

Weather seems to play a role in determining offshore distribution. Concentrations near shore frequently follow severe storms while animals tend to be farther offshore and widely dispersed after several days of calm weather. The 30-31 July 1976 survey followed a period of moderately rough weather with winds reaching 35 knots.

to the 40 m depth contour and the edge of the "medium" density conformed to the 60 m depth contour. Sea otters northeast of Amak Island were distributed slightly farther offshore with medium densities extending to the 80 m contour in one area and high densities extending to areas 50 m deep.

Densities observed in the 0.2 nm strips averaged 3.1 sea otters/km^2 in water 0 to 20 m deep, 5.8/km^2 in water 20 to 40 m deep, 0.5/km^2 in water 40 to 60 m deep and 0.03/km^2 in water over 60 m deep. True densities would have been higher because diving animals weren't counted. The observed densities in water over 60 m deep may be low. Only 0.25 percent of the sea otters counted in the limited width strips were beyond the 60 m depth contour while 0.84 percent counted in the unlimited width strips were beyond the 60 m countour. In either case only a small percentage of the population was in water deeper than 60 m. During a survey of the area west of Amak Island made on April 1969 most of the sea otters seen were in water deeper than 40 m and many were beyond the 60 m depth contour. Sea otters observed in deep areas have usually been widely scattered. Large pods usually occur in water less than 40 m deep.

Weather seems to play a role in determining offshore distribution. Concentrations near shore frequently follow severe storms while animals tend to be farther offshore and widely dispersed after several days of calm weather. The 30-31 July 1976 survey followed a period of moderately rough weather with winds reaching 35 knots.

water persisted in this area to permit survival of many healthy adult animals. No such area exists to the northeast except for limited areas near Port Moller.

The area from Cape Lieskof to Port Moller is critical for range expansion although not to the survival of the population.

VIII. Conclusions

A remnant sea otter population survived in the shallow waters north of Unimak Island and the Izembek area of the Alaska Peninsula. This population grew and expanded its range through the 1950's and 1960's. By 1970 substantial numbers had reached Port Heiden and scattered individuals occurred at Egegik. Expansion to the Pacific Ocean through Isanotski Strait had started. Most animals remained between Cape Mordvinof and Cape Lieskof, however. Extreme sea ice conditions in 1971, 1972 and 1974 restricted the range of the population to the area between Cape Mordvinof and Cape Lieskof with only small numbers to the southwest and in the vicinity of Port Moller. The size of the population was probably reduced substantially and little expansion of range has occurred in recent years. The present population probably exceeds 17,000 animals.

All waters less than 80 m deep are potential sea otter habitat, however, most of the population remains in waters less than 60 m deep. These waters extend far from shore throughout the area.

The population could grow and expand its range as far northeastward as Port Heiden in the absence of severe sea ice conditions.

All waters less than 60 m deep between Cape Lieskof and Cape Mordvinof, including Bechevin Bay, should be considered critical to the survival of this population.

IX. Needs for further study

Studies of activity patterns and movements of sea otters in the study area would greatly enhance our ability to evaluate the census. The cost of such studies probably exceeds their value to the OCSEAP program, however. Little is known about the food habits of this population and the relationship between concentrations of sea otters and the distribution of potential food species has not been examined.

The distribution of this population should be monitored to determine future patterns of range expansion. The northeastern fringe of the population should be of particular concern.

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