Outer Continental Shelf Environmental Assessment Program

Final Reports of Principal Investigators

Volume 42 June 1986

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National Oceanic and Atmospheric Administration
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OUTER CONTINENTAL SHELF

ENVIRONMENTAL ASSESSMENT PROGRAM

FINAL REPORTS OF PRINCIPAL INVESTIGATORS

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Minerals Management Service
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ENDANGERED WHALE SURVEYS
OF THE NAVARIN BASIN, ALASKA

by

John J. Brueggeman, Richard A. Grotefendt,

and Albert W. Erickson

Envirosphere Company

Final Report
Outer Continental Shelf Environmental Assessment Program
Research Unit 625

1984

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ABSTRACT

Density, distribution, and habitat use of endangered species of whales in the Navarin Basin planning unit of the Bering Sea were determined during four seasonal surveys between 1982-83. Vessel and aerial surveys were conducted along systematic tracklines randomly distributed over the outer continental shelf, slope, and rise. Right, gray, fin, and bowhead whales were encountered during approximately 5,500 nautical miles (nm) of aerial and 2,500 nm of vessel surveys completed in the 54,078 nm^2 Navarin Basin. Right whales were observed only during the summer and gray whales only during the fall. Fin whales were present during all four seasons. Gray, fin, and right whales were distributed in the outer continental shelf waters in significantly higher numbers than in the slope or rise waters. Observed densities were 10.7, 6.2, and 1.1 animals per 1,000 nm^2 for gray, fin, and right whales, respectively. Bowhead whales wintered in the marginal ice front, which closely corresponded to the southern limit of the outer continental shelf. They were particularly prevalent in the fringe areas of ice adjacent to the St. Matthew Island polynya. Observed density of this species in the marginal ice front was 10.4 animals per 1,000 nm^2. One group of six fin whales was observed in the southern edge of the ice front. No calves were observed with the four endangered whale species. The results confirm that the Navarin Basin is a feeding area for gray, fin, and possibly right whales during the ice-free period and a wintering area for bowhead and fin whales during the seasonal ice period. The open water of the St. Matthew Island polynya may function as a refuge to bowheads from heavy sea ice, while the shallow shelf waters provide access to food organisms commensurate with the diving characteristics of the other species. Densities of endangered whales in the Basin appear to be variable to other areas within their range. Other whales recorded in the Basin were beluga, minke, and killer whales, and Dall's porpoises.

INTRODUCTION

Little information is available on whale utilization of the northcentral Bering Sea, particularly in the Navarin Basin. Most information derives from catch (Aldrich 1889, Cook 1926, Townsend 1935, and Tomilin 1957) and scouting (Berzin and Rovnin 1966, Nishiwaki 1974, and Wada 1981) expeditions by commercial whaling vessels. Since the cessation of commercial whaling in the Bering Sea during the 1960s, new information has been largely limited to the National Marine Fisheries Service's Platforms of Opportunity Program (Consiglieri and Bouchet 1981). This program relies on vessels of opportunity collecting marine mammal data primarily on species composition and distribution in the Bering Sea and elsewhere. The only recent dedicated study of whales was conducted by Brueggeman (1982), who examined bowhead whale abundance, distribution, and habitat use in the northcentral Bering Sea, including the Navarin Basin, during early spring. Few additional studies have been conducted in this remote area because of the high costs and difficult logistics required to study it.

Based on the historic and recent literature, at least five of the world's ten species of baleen whales seasonally inhabit the Navarin Basin. Three of these species--fin (Balaenoptera physalus), gray (Eschrichtius robustus), and right (Balaena glacialis) whales--migrate from lower latitudes to feed in the Basin during the ice-free period (Tomilin 1957, Berzin and Rovnin 1966, Rice and Wolman 1971, Rice 1974, Votrogov and Ivashin 1980, Marquette and Braham 1982). Conversely, bowhead whales (Balaena mysticetus) migrate from northern latitudes to winter in the Basin during the seasonal ice period (Braham et al. 1980, Brueggeman 1982). The minke whale (Balaenoptera acutorostrata) also occurs in the Basin and is probably present yearlong in varying numbers (Tomilin 1957, Sleptsov 1961, Ivashin and Votrogov 1981). All of these whales, except the minke whale, are classified as endangered species throughout their range (U.S. Dept. Comm. 1979). Other whales occurring in the Basin are the beluga (Delphinapterus leucas), killer whale

(Orcinus orca), Dall's porpoise (Phocoenoides dalli), and possibly some beaked whales. Sperm (Physeter macrocephalus), sei (Balaenoptera borealis) and humpback (Megaptera novaeangliae) whales, while found in the Bering Sea, primarily occur south of the Navarin Basin (Berzin and Rovnin 1966, Wada 1981).

Stock sizes of these species in the Bering Sea are poorly known. General estimates are available, however, for the North Pacific Ocean including the Bering Sea (Table 1). Of the baleen whales, the fin whale stock is the largest; it is estimated at 21,000 to 29,000 animals (Gambell 1976). Gray whales of the eastern Pacific stock number 13,600 to 19,400 animals (Reilly et al. 1980), while Pacific right whales number only 100-200 animals (Gambell 1976). The proportion of these stocks using the Bering Sea is uncertain. Estimated number of bowhead and beluga whales which winter in the Bering Sea are more certain. Best estimates indicate that approximately 3,390 to 4,325 bowheads (IWC 1983) and 15,000 to 18,000 beluga (Lowry et al. 1982) whales winter in the Bering Sea (Braham et al. 1977). The largest cetacean stock in the Bering Sea is the Dall's porpoise, which is estimated at 97,000 to 147,000 animals (Bouchet 1982). Estimates are not available for killer or beaked whales. The proportion of whales from these various populations using the Navarin Basin planning unit has not been determined.

The Navarin Basin is scheduled for petroleum exploration and development in 1984. The Endangered Species Act of 1973 and the Outer Continental Shelf Lands Act of 1978 mandate that studies be conducted to determine whether these proposed habitat alterations will have any adverse effects on populations of endangered species of marine mammals. In 1982, the National Oceanic and Atmospheric Administration awarded Envirosphere Company a contract to develop baseline data on endangered and other marine mammals in the Navarin Basin for assessing potential petroleum development impacts on these species. The objectives of the contract were:

TABLE 1

ESTIMATED STOCK SIZES OF CETACEAN SPECIES
FOUND IN THE NORTHCENTRAL BERING SEA

Species	Stock location[a]	Estimated size	Source
Fin whale	N. Pacific Ocean	21,000 to 29,000[b]	Gambell (1976)
Gray whale	N. Pacific Ocean	16,500 ± 2,900[c]	Reilly et al. (1980)
Bowhead whale	W. Arctic Ocean	3,857 ± 468	International Whaling Commission (1983)
Right whale	N. Pacific Ocean	150 ± 50	Gambell (1976)
Beluga	W. Arctic Ocean	15,000 to 18,000	Lowry et al. (1982)
Dall's porpoise	Bering Sea	122,000 ± 25,000	Bouchet (1982)

[a] N. Pacific and W. Arctic ocean estimates include the Bering Sea.

[b] Fin whale estimate includes Asiatic and N. American stocks.

[c] Gray whale estimate is composed only of E. Pacific Ocean stock.

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. Assess habitat use by endangered species of whales during the ice-free season. Identify and enumerate the endangered species of whales in the Basin 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.

Objectives 1 and 2 are fully addressed in this report. Objective 3 is treated for cetaceans (whales, dolphins, and porpoises). A second report (Brueggeman and Grotefendt 1984) addresses pinnipeds (seals, sea lions, and walruses) in the Navarin Basin that fulfills Objective 3.

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STUDY AREA

The Navarin Basin planning unit (hereafter referred to as 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 bound 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 3,000 m outside the shelf. The shelf comprises approximately half of the total area in the Basin, while the continental slope and rise comprise 36 percent and 14 percent, respectively. There are no islands.

The climate of the Basin features harsh environmental conditions that promote the seasonal development of sea ice (Figure 2). The environmental conditions typically consist of cold temperatures, high wind speeds, poor visibility, and extreme ranges in day length (Brower et al. 1977). Average annual air temperature and wind speed are 0°C and 14 kt yearlong, and visibility less than 2 nm persists approximately 14 percent of the time during the year. Temperatures are coldest during the early spring when wind velocities are lowest. Wind velocities exceeding 20 kt are most frequent in the fall when visibility is poorest; the best visibility conditions occur in the winter but daylength is less than 6 hours.

Sea ice persists in the Navarin Basin from December through June (Potocsky 1975). Ice coverage of the Basin is greatest from February through April. It seldom extends south of the outer continental shelf and is typically less than 1 m thick. Breakup of the sea ice begins in mid-April, and the Basin is generally ice-free by late June. The combination of sea ice, harsh environmental conditions, and remoteness demonstrate the difficulties of surveying marine mammals in the Navarin Basin.

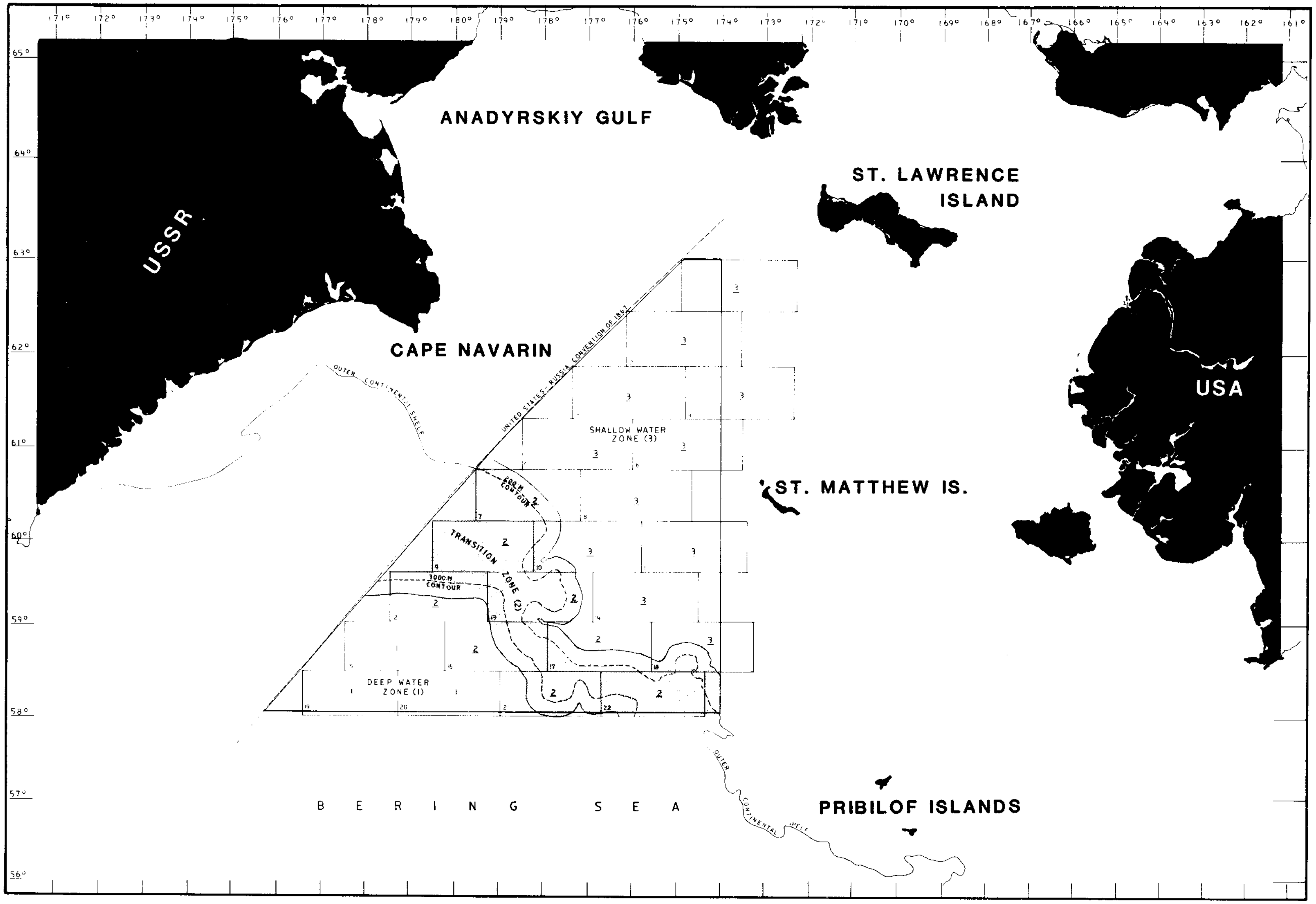

FIGURE 1 STUDY AREA AND SAMPLING DESIGN IN THE NAVARIN BASIN FOR SPRING THROUGH FALL SURVEY PERIOD, 1982.

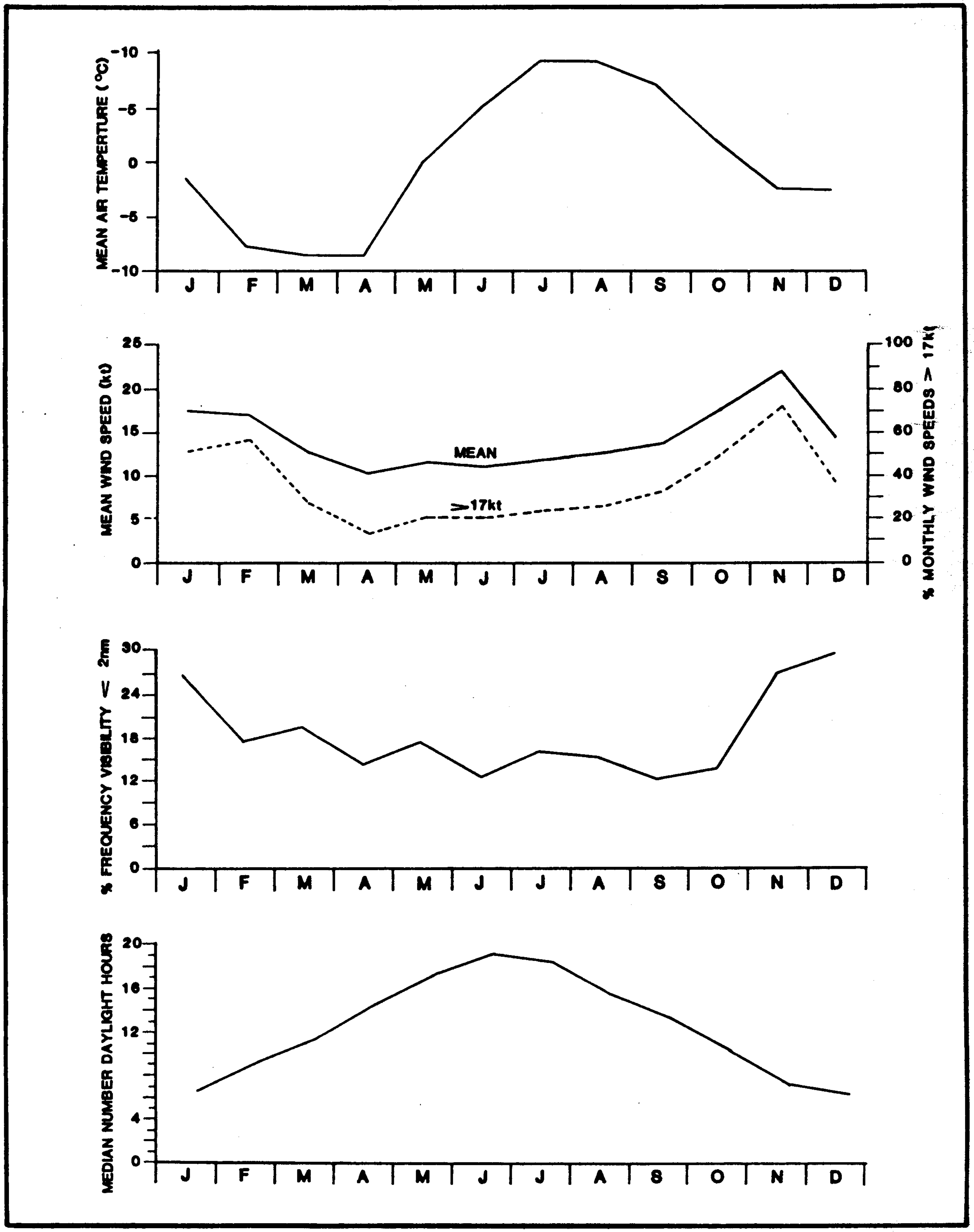

FIGURE 2 HISTORIC ENVIRONMENTAL CONDITIONS OF THE NORTH CENTRAL BERING SEA (BROWER ET AL. 1977).

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 is prevalent in the Basin. Because of the distinct differences between survey conditions and animal distributions during the ice-free and seasonal ice periods, two sampling approaches were necessary to accomplish the surveys.

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 3,000 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 3). This configuration provided thorough coverage of a sampling unit and prevented double surveying of adjacent lines or units.

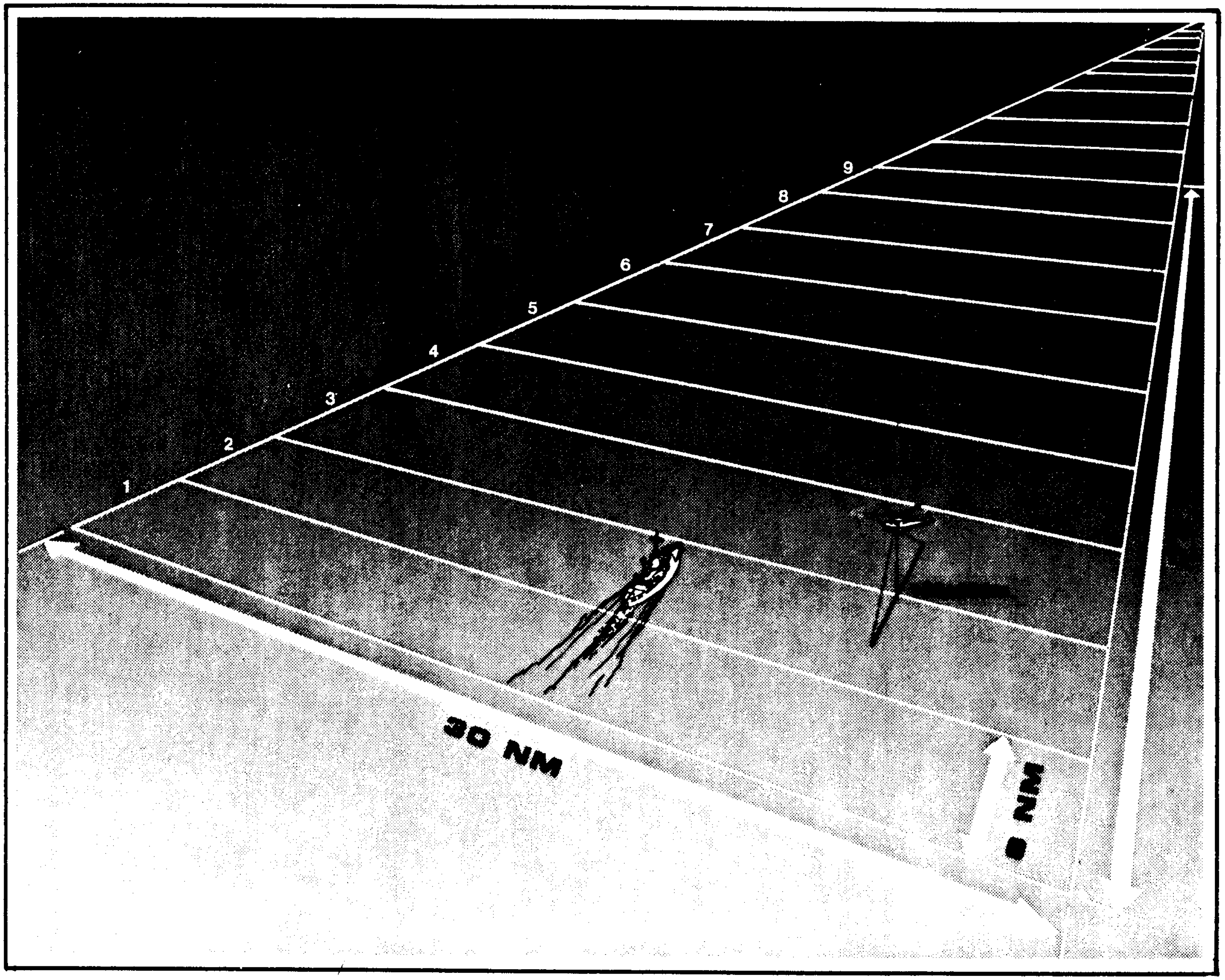

Figure 3 TRACKLINE ORIENTATION OF AERIAL AND VESSEL SURVEYS DURING SPRING THROUGH FALL PERIOD.

Aerial and vessel surveys were conducted along the transect lines of randomly selected sampling units (Figure 3). 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.

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 included number, species, vertical angle when an animal was perpendicular to the trackline, direction of travel, reaction to the aircraft, group size, time, and position. Environmental conditions including visibility (Appendix Table A-1), Beaufort Sea State Scale (Appendix Table A-2), sea surface 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 sea surface temperatures were obtained from a Barnes PRT-5. 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 less than 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 18.2 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. Sea surface temperature, however, was obtained from bucket grab samples, and radial angles, instead of vertical angles, were taken with a sighting board or 10 minute surveyor's transit; 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 3). 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, providing safeguards to the helicopter crew, and permitting efficient refueling of the helicopter during the aerial surveys.

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. 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 zone was intermediate to 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 zone 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. 1980, Brueggeman 1982).

Six sampling units were equidistantly distributed across the marginal ice front between longitudes 171°12'W and 179°36'W (Figure 4). 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 from the interface of the marginal ice front with the open water into the pack ice; 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 parallel to each other or singly along the transect lines at speeds of 65-75 kt and at altitudes of 150-230 m. Observer and data collection procedures were the same as followed 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 evaluated every 3 nm along the transect line by the observer occupying the co-pilot's seat in each helicopter; ice characteristics were evaluated by the same two observers for every survey to maintain data consistency (Appendix Table A-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 range of the helicopter to 8 nm from the ship. To maximize the use of a single helicopter, the ship travelled a predetermined course, while the

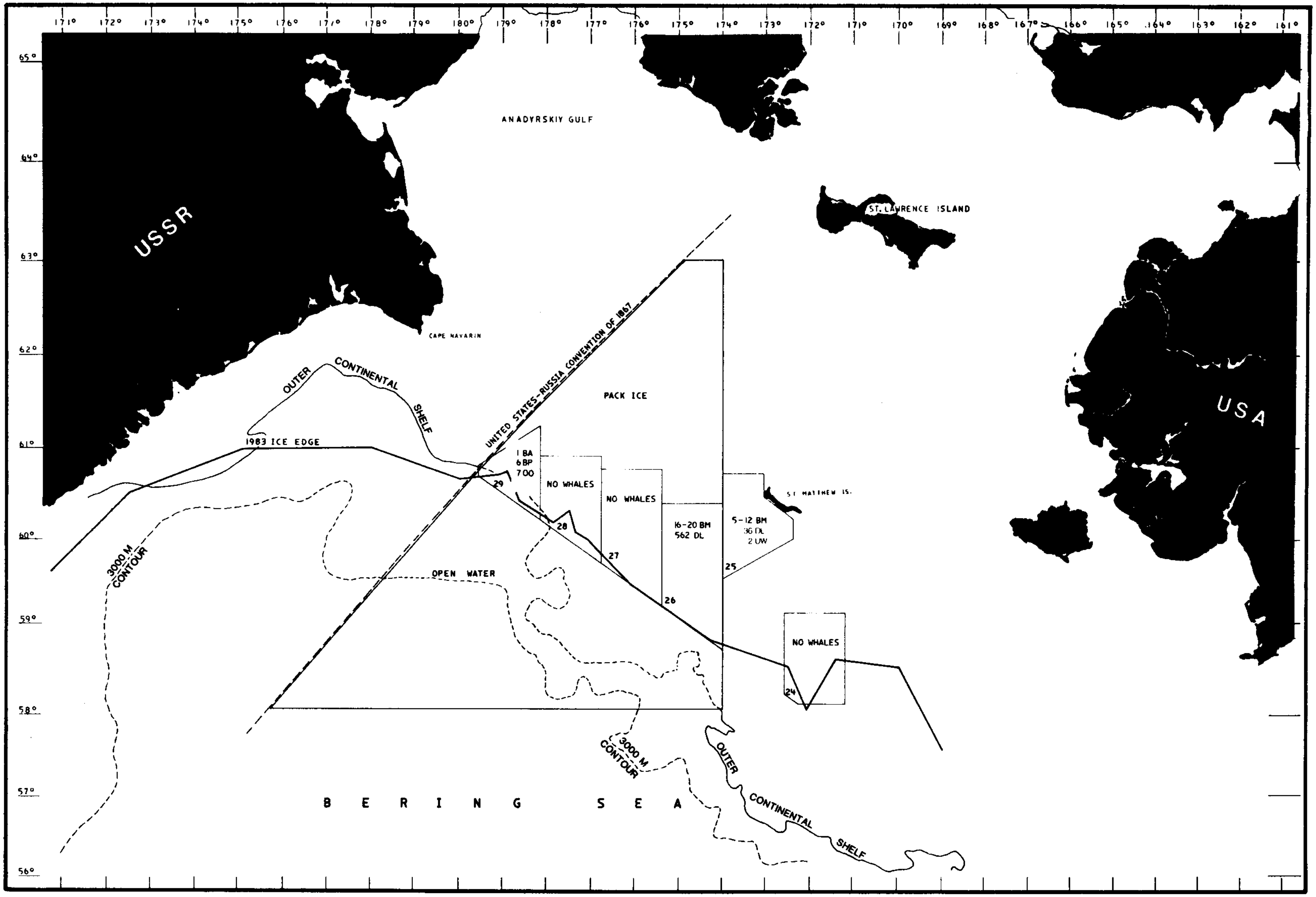

FIGURE 4 SAMPLING DESIGN AND DISTRIBUTION OF WHALES IN THE SIX SAMPLING UNITS SURVEYED IN THE VICINITY OF THE NAVARIN BASIN DURING WINTER, 19 FEBRUARY - 18 MARCH, 1983 (SEE FIGURES 7 AND 8 AND TABLE 5 IN APPENDIX A FOR LOCATIONS OF SURVEY TRACKLINES AND ANIMALS).

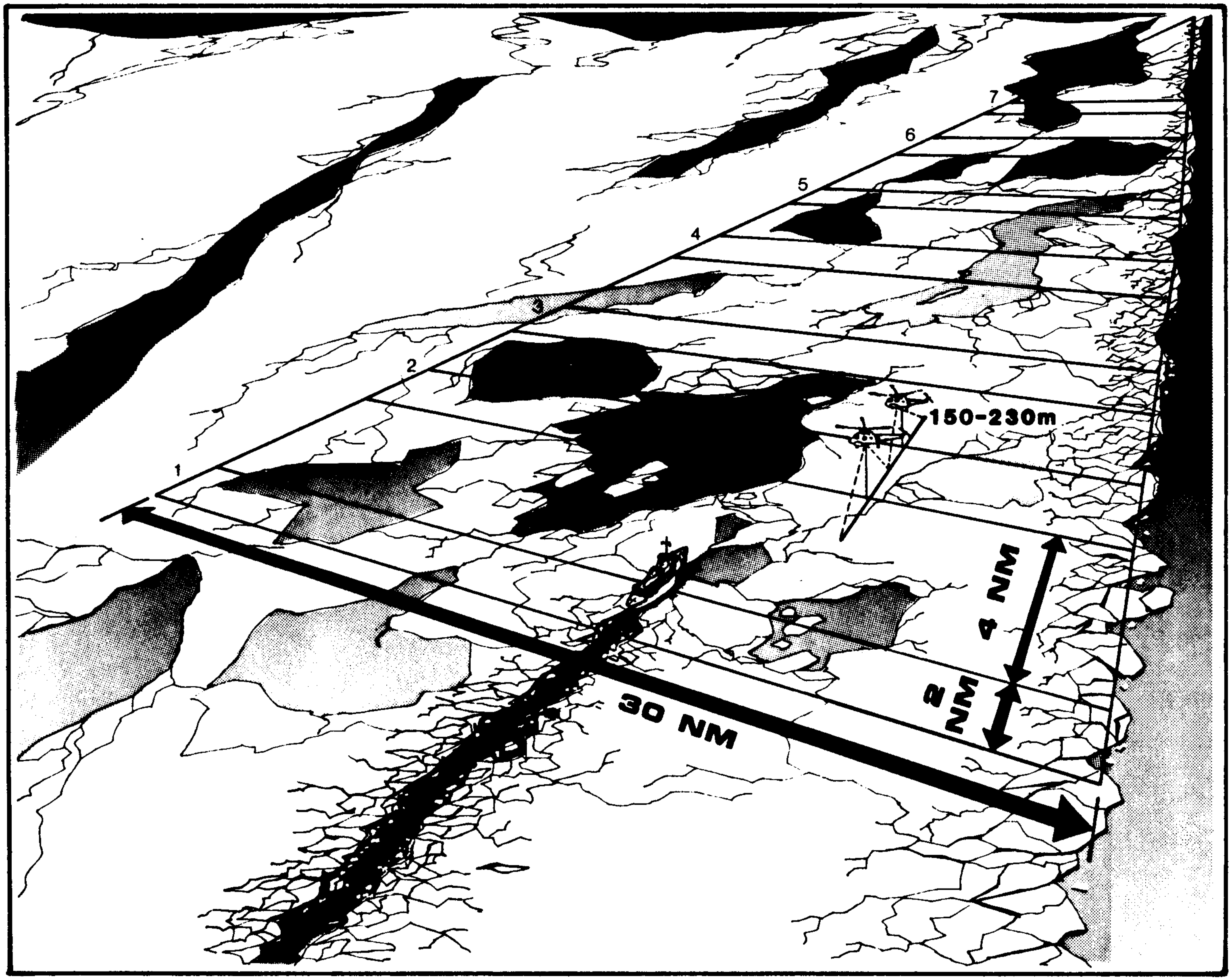

FIGURE 5 TRACKLINE ORIENTATION OF AERIAL AND VESSEL SURVEYS DURING WINTER.

helicopter flew a 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 wind speeds exceeded 25 kt, ceiling height was below 91 m, visibility range was less than 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, 33.5 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 due to one helicopter being 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, the method provides the best relative index of whale abundance for this study. This method was preferable to the line-transect method (Burnham et al. 1980) because of sample size problems. Small sample sizes caused poor or unreliable fits of the data to the standard population estimation models (Fourier series, negative exponential, normal, half normal, power series, and exponential) and large variances. This problem persisted throughout numerous manipulations of the data, including different forms of pooling. Burnham et al. (1980) recommended a minimum sample size of 40 observations for the line-transect method, which exceeds our sample sizes. Line-transect procedures and estimates calculated during our analysis are provided in Appendix B for the purpose of comparing results derived from different estimation procedures.

Whale abundance was estimated from systematic aerial and vessel surveys. Estimates were made from whale observations occurring in a strip width of 1.0 nm (0.5 nm per side of the trackline) for the spring through fall surveys and 0.5 nm (0.25 nm per side of the trackline) for the winter surveys. Statistical analysis (Table 2) showed that data collected during fair and good to excellent conditions could be pooled for aerial surveys but not for vessel surveys; thus only observations collected under good to excellent conditions were used for vessel surveys. The number of whale 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.

Frequency histograms of perpendicular distances were constructed to determine strip widths for individual species or groups of larger sized species (fin, gray, and minke); pooling of species and also seasons was necessary to increase sample size (Figures 6, 7). Histograms were constructed by pooling perpendicular distances of whales from the trackline into 0.25 nm intervals. The set of intervals from the transect line with the majority of observations defined the strip width. The strip width for the vessel surveys was assumed to be the same as for the aerial surveys, since the number of whale observations was insufficient to compile frequency histograms and we felt confident most whales within that distance were observed. Dall's porpoise abundance was estimated entirely from vessel surveys using a 0.50 nm strip width because these animals were not readily detectable from the helicopter at the altitudes flown (Figure 6).

TABLE 2

TEST OF UNIFORMITY OF WHALE OBSERVATIONS RECORDED UNDER VARIOUS VISIBILITY CONDITIONS DURING THE SPRING THROUGH FALL AERIAL AND VESSEL SURVEYS

	Aerial surveys[b]			Vessel surveys[c]			
Visibility[a] condition	Distance surveyed (nm)	Observed number	Expected number[d]	Distance surveyed (nm)	Observed number	Expected number	X^2 value
Fair	805	4	3	1153	7	13	2.86
Good-excellent	6898	25	26	1657	25	19	.99
Total	7703	29	29	2810	32	32	4.85[e]

a/ Unacceptable and poor conditions were excluded from analysis because of small numbers of whale observations. Good to excellent conditions were pooled to increase sample sizes.

b/ Large whales (fin, gray, and minke pooled) were included in the analysis, while too few sightings were recorded for killer whales to analyze. All whales were assumed to be equally visible during fair to excellent conditions.

c/ Only Dall's propoises were included in this analysis, since the number of other whales were insufficient for analysis. All other whales were assumed to be equally visible under good to excellent conditions.

d/ Expected values were not statistically testable since more than 20 percent of those values were less than 5.

e/ Statistically significant at the 0.05 level.

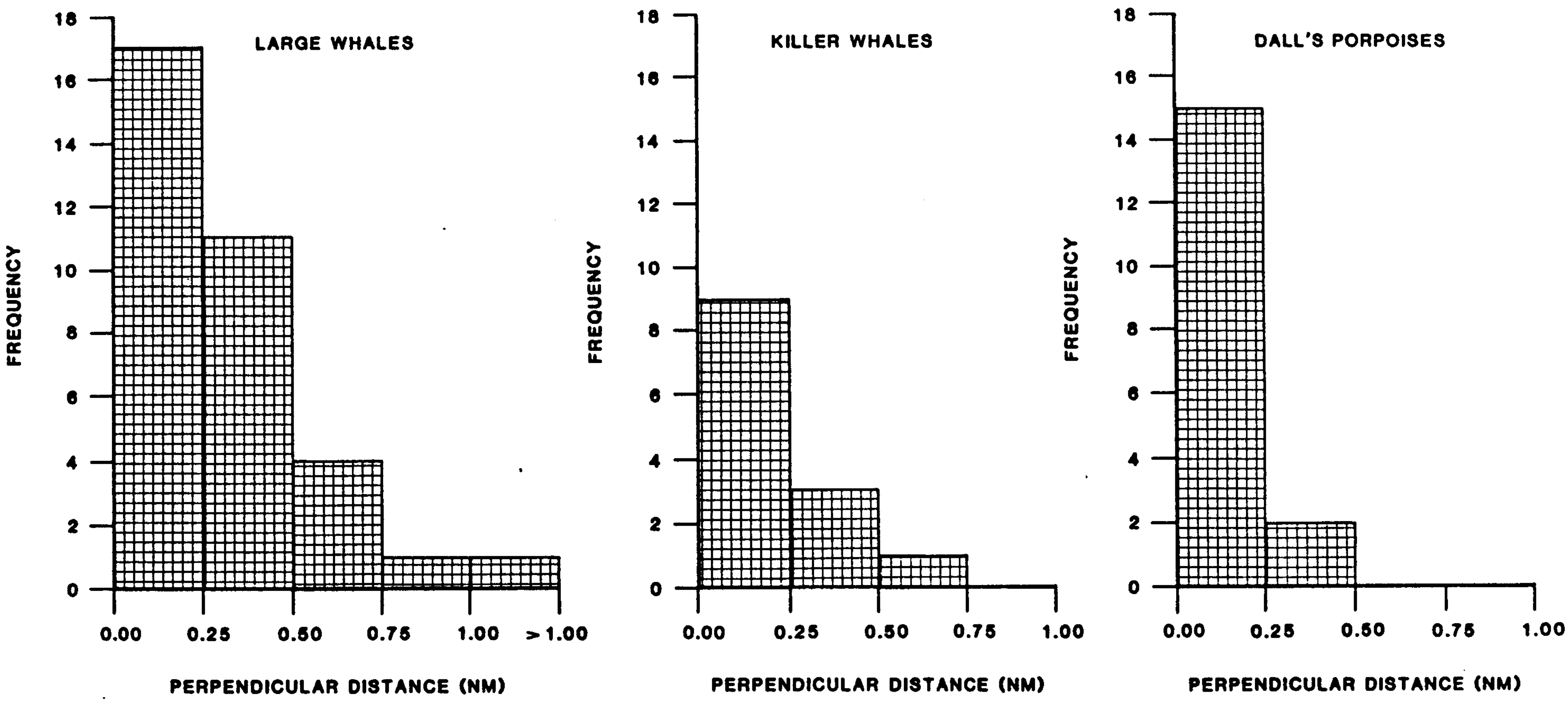

Figure 6 FREQUENCY DISTRIBUTION OF PERPENDICULAR DISTANCES OF LARGE (fin, gray, minke,) AND KILLER WHALES SIGHTED DURING AERIAL SURVEYS AND DALL'S PORPOISES SIGHTED DURING VESSEL SURVEYS.

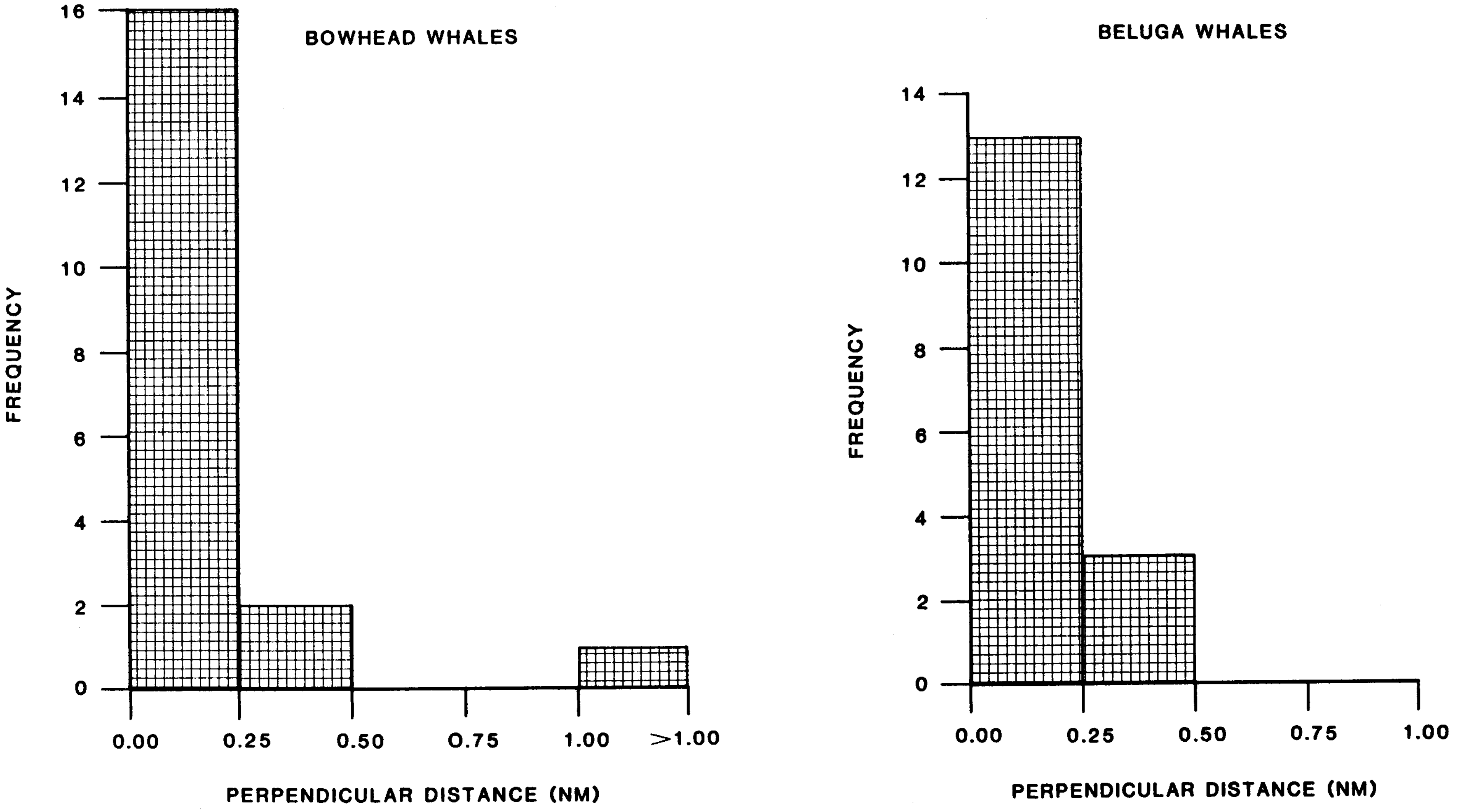

Figure 7 FREQUENCY DISTRIBUTION OF PERPENDICULAR DISTANCES OF BOWHEAD AND BELUGA WHALES SIGHTED DURING AERIAL SURVEYS.

Estimates of the density and abundance of whales and associated variances were calculated from methods developed by Estes and Gilbert (1978) for strip-transect analysis. Density and abundance were calculated by summing the sampling unit estimates for each zone and then summing the zone 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 whales per nm^2 for a zone
y_i = the number of whales in the i^{th} transect strip, and
x_i = the area of the i^{th} transect strip

Estimated variance of D_i is:

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

where n = the number of transects surveyed.

Estimated abundance for a zone is:

$$T_i = D_i \ A_i$$

where: T_i = abundance of whales in a zone, and
A_i = total area of that zone

Estimated abundance for all zones is

$$T = \Sigma \ T_i$$

Estimated variance of T is:

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

The 95 percent confidence interval for T is:

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

Other statistical procedures used in the analysis were Chi-square goodness of fit for testing habitat utilization by whales and ANOVA for comparing group sizes of whales and testing habitat characteristics. All tests were performed at the 0.05 level of significance.

RESULTS

A total of 147 to 158 observations of 968 to 979 whales, representing eight species, were recorded in the Navarin Basin during four seasonal surveys between 11 May 1982 and 18 March 1983 (Table 3). Four endangered species of whales--fin, gray, bowhead, and right--were recorded during the aerial and vessel surveys. These species comprised over 31 percent of the total observations and 12 percent of the individuals. Fin whales were most abundant, followed by gray, bowhead, and right whales. Other species encountered in the Basin were minke, beluga, killer whales and Dall's porpoises. These species represented over 62 percent of the whale observations and 86 percent of the individual animals. Belugas were most abundant followed by Dall's porpoises, killer whales, and minke whales. Fin, minke, and killer whales were observed in the Basin every season, while Dalls' porpoises were recorded during the three ice-free seasons and beluga and bowhead whales during the winter. Right whales were observed only during the summer and gray whales only during the fall. There were also 3 observations of 5 unidentified baleen whales. Over 83 percent of all whales recorded were observed from helicopters, which travelled 68 percent of the 8,136 nm surveyed in the 54,078 nm^2 Navarin Basin. No calves were encountered in the Basin.

SPRING SURVEY PERIOD

Four species and 129 individual whales were observed during 2,482 nm of aerial and vessel surveys in the Basin (Table 4). The Dall's porpoise was the most commonly encountered species, followed by the killer, fin, and minke whales. Fin and killer whales were chiefly recorded during aerial surveys, while minke whales and Dall's porpoises were observed primarily from the vessel. Aerial surveys accounted for approximately 74 percent of the 2,135 nm of systematic trackline censused; an additional 347 nm of opportunistic vessel surveys were covered in the Basin.

TABLE 3

NUMBER OF OBSERVATIONS AND INDIVIDUALS OF WHALES 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

Species	Spring				Summer				Fall				Winter				Total			
		No. Individuals				No. Individuals				No. Individuals				No. Individuals				No. Individuals		
	No. obs.	Ves-sel	Aer-ial	Total	No. obs.	Ves-sel	Aer-ial	Total	No. obs.	Ves-sel	Aer-ial	Total	No. obs.	Ves-sel	Aer-ial	Total	No. obs.	Ves-sel	Aer-ial	Total
Fin whale	11	-a/	26	26	3	-	6	6	5	-	13	13	1	6	-	6	20	6	45	51
Right whale	-	-	-	-	1	2	-	2	-	-	-	-	-	-	-	-	1	2	-	2
Gray whale	-	-	-	-	-	-	-	-	18	-	44	44	-	-	-	-	18	-	44	44
Bowhead whale	-	-	-	-	-	-	-	-	-	-	-	-	7-18	1	20-31	21-32	7-18	1	20-31	21-32
Minke whale	3	3	-	3	1	1	-	1	3	-	3	3	1	1	-	1	8	5	3	8
Killer whale	10	1	34	35	2	2	3	5	3	-	17	17	1	7	-	7	16	10	54	64
Beluga whale	-	-	-	-	-	-	-	-	-	-	-	-	29	-	598	598	29	-	598	598
Dall's porpoise	17	61	4	65	18	37	17	54	10	34	22	56	-	-	-	-	45	132	43	175
Unidentified whale	-	-	-	-	-	-	-	-	2	3	-	3	1	-	2	2	3	3	2	5
TOTAL	41	65	64	129	25	42	26	68	41	37	99	136	40-51	15	620-631	635-646	147-158	159	809-820	968-979

a/ Dash (-) signifies no animals were observed.

TABLE 4

NUMBER OF WHALES OBSERVED DURING THE SPRING AERIAL AND VESSEL SURVEYS OF THE NAVARIN BASIN, 11 MAY - 10 JUNE 1982

Zone	Sampling unit	Trackline distance surveyed[a] Aerial (%)	Vessel (%)	Total(nm)		Fin whale No. obs	No. indiv	Minke whale No. obs	No. indiv	Killer whale No. obs	No. indiv	Dall's porpoise No. obs	No. indiv	Total No. obs	No. indiv
Shallow water	5	53	47	210	[23][b]	-	-[c]	-	-	-	-	-	-	-	-
	8	30	70	298	[21]	-	-	2	2	-	-	3	8	5	10
	10	100	0	270	[71]	11	26	-	-		-	1	2	12	28
	11	100	0	270	[33]	-	-	-	-	10	35	1	2	11	37
Subtotal		71	29	1048	[148]	11	26	2	2	10	35	5	12	28	75
Transition	7	100	0	270	[63]	-	-	-	-	-	-	1	2	1	2
	21	100	0	270	[64]	-	-	-	-	-	-	-	-	-	-
	22	6	94	277	[0]	-	-	-	-	-	-	5	14	5	14
Subtotal		68	32	817	[127]	-	-	-	-	-	-	6	16	6	16
Deep water	20	100	0	270	[73]	-	-	1	1	-	-	6	37	7	38
Subtotal		100	0	270	[73]	-	-	1	1	-	-	6	37	7	38
TOTAL		74	26	2135	[347]	11	26	3	3	10	35	17	65	41	129

a/ Total trackline length available in each sampling unit was 270 nm.

b/ Brackets [ ] include nautical miles surveyed by the vessel during aerial surveys; incidental marine mammal sightings were recorded for determining species distribution in the Basin.

c/ Dash (-) signifies no animals were observed.

Eight sampling units were surveyed in the Basin (Table 4). Four of these eight were in the shallow water zone, three in the transition zone, and one in the deep water zone. Correspondingly, approximately 49 percent of the survey effort was in the former zone, 13 percent in the latter zone, and 38 percent in the transition zone. Aerial surveys predominated the survey effort in each zone, although units 8 and 22 were primarily censused by vessel because of weather conditions. Virtually the entire 270 nm of trackline available in each of the eight sampling units was censused. Surveys in the northern third of the Basin (units 1 through 4) were precluded by sea ice which was too extensive for the vessel to penetrate.

Sea state and visibility conditions during the surveys were usually sufficient to accurately census whales during 13 of the 30 day spring field season (Table 5). Visibility was good to excellent during 80 percent of the survey time that included less than 50 percent glare. Wind speed averaged 11 kt and sea state was below Beaufort 4, 65 percent of the survey time. Survey conditions were marginal only in sampling unit 22 of the transition zone where Beaufort 5 sea state and fair visibility predominated. Additional surveys were precluded by bad weather, piggyback scientific operations, transit time to and from the Basin, and ancillary ship activities that accounted for 17 of the 30 field days (Appendix Table A-4).

Whales were observed in all three zones of the Navarin Basin (Figure 8). Animal counts were highest in the shallow water zone of the outer continental shelf and lowest in the transition zone. Species diversity was also greatest on the shelf. Fin and killer whales were observed only in the shelf waters, while Dall's porpoises occurred in all three zones, particularly the deep water zone. Fin whales were in sampling unit 10 at a water depth of 130 m, killer whales in unit 11 at a depth of 100 m, and Dall's porpoises in 6 of the 8 units at depths ranging from 126 m to over 3,700 m. Minke whales were observed in both the shallow and deep water zones in depths similar to those for Dall's porpoises. No whales were observed in units 5 and 21.

TABLE 5
VISIBILITY AND SEA STATE CONDITIONS DURING SPRING AERIAL AND VESSEL SURVEYS OF MARINE MAMMALS IN THE NAVARIN BASIN, 11 MAY - 10 JUNE 1982

Zone	Sampling unit	Beaufort wind scale (%)						Visibility conditions (%)[a/]						Total distance surveyed (nm)
		0	1	2	3	4	5	UN	PO	FA	GO	VG	EX	
Shallow water	5	-	-	-	73	27	-	-[b/]	4	31	44	21	-	210
	8	-	9	2	87	2	-	2	-	14	23	58	3	298[c/]
	10	-	-	-	56	44	-	-	-	-	72	28	-	270
	11	-	42	47	11	-	-	-	-	-	-	58	42	270
Subtotal		-	13	13	57	17	-	T[d/]	T	10	34	43	12	1048
Transition	7	-	-	11	89	-	-	-	1	6	58	35	-	270
	21	-	-	-	-	100	-	-	-	15	79	6	-	270
	22	-	-	-	-	41	59	-	-	93	7	-	-	277
Subtotal		-	-	4	29	47	20	-	T	38	48	14	-	817
Deep water	20	-	-	56	40	4	-	-	-	6	19	75	-	270
Subtotal	20	-	-	56	40	4	-	-	-	6	19	75	-	270
TOTAL		-	6	15	44	27	8	T	T	20	38	36	6	2135

a/ UN = unacceptable, PO = poor, FA = fair, GO = good, VG = very good, and EX = excellent as defined by NODC.
b/ Dash (-) signifies that a visibility condition did not occur.
c/ Trackline distance exceeded 270 nm because vessel course varied about the line.
d/ T signifies percentage less than 0.5.

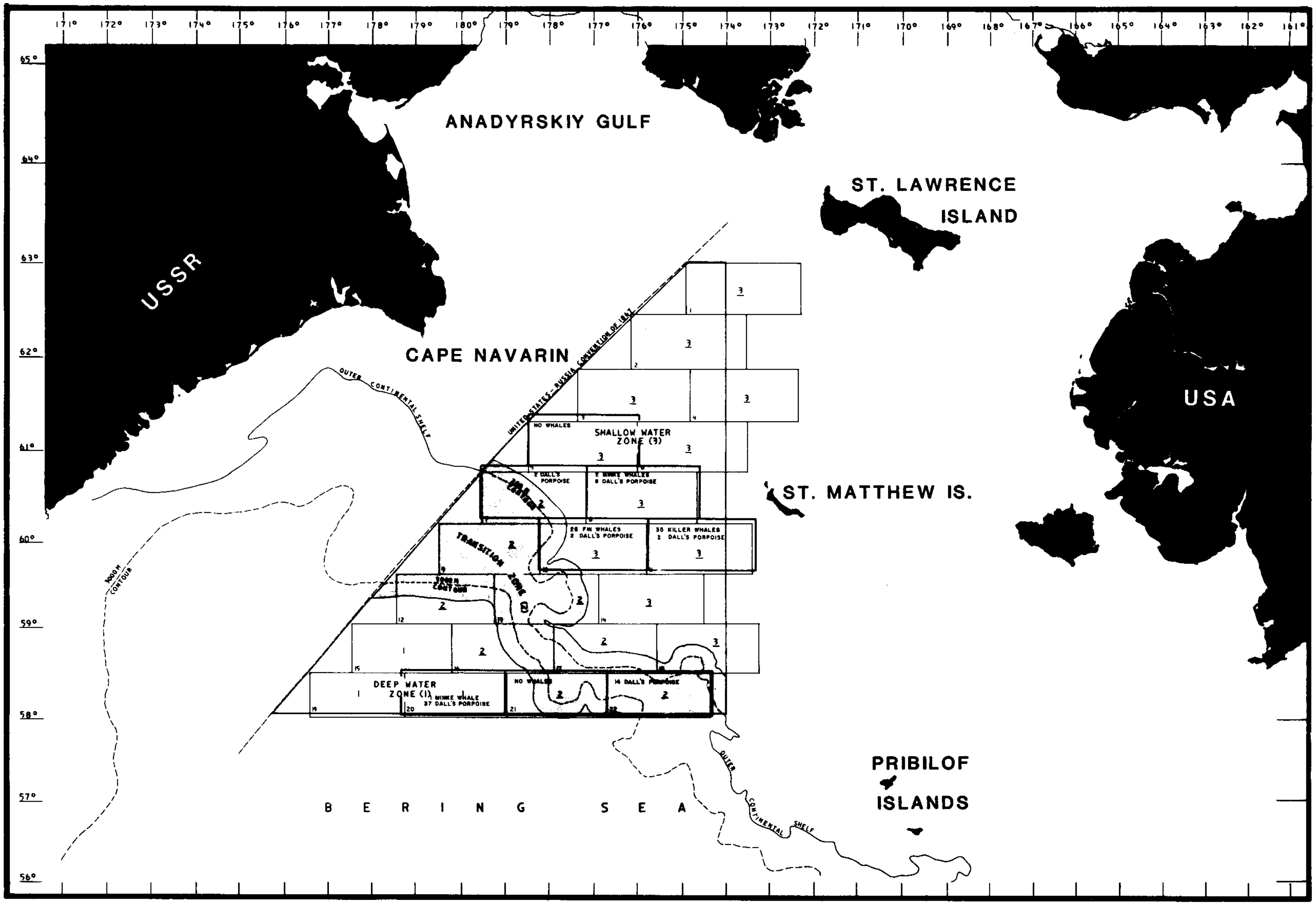

FIGURE 8 DISTRIBUTION OF WHALES IN THE EIGHT SAMPLING UNITS SURVEYED IN THE NAVARIN BASIN DURING SPRING, 11 MAY - 10 JUNE, 1982 (SEE FIGURES 1 AND 2 AND TABLE 5 IN APPENDIX A FOR SPECIFIC LOCATIONS OF SURVEY TRACKLINES AND ANIMALS).

Movements of whales in the Basin were variable during spring (Figure 9). Fin and minke whales were observed moving in a northerly to westerly direction in groups averaging 2.1 (n=11) and 1 (n=1) animals, respectively. Fin whales appeared to be feeding while travelling, since large concentrations of birds and water discoloration were associated with the whales (Harrison 1979). Killer whales also seemed to be primarily travelling in northerly to westerly directions, but along the fringe (Burns et al. 1980) of the pack ice in groups averaging 3.5 (n=10) animals where pinnipeds were prevalent. There was no consistent direction of movement for Dall's porpoises, which had an average group size of 3.8 (n=21) animals. Since the Dall's porpoises and minke whales were primarly encountered during vessel surveys, their movement patterns may have been influenced by the vessel. The other species did not appear to be disturbed by the survey platforms.

An estimated 670 fin, minke, and killer whales or 16 animals per 1,000 nm^2 were in the Basin during spring (Table 6). This estimate was based on observations of 49 animals along 1,769 nm of systematic trackline, representing approximately 4 percent coverage of the Basin. Killer whales were most abundant and minke whales least abundant. Fin whales, the only endangered species encountered, had an estimated abundance of 259 animals or 6 animals per 1,000 nm^2. All whales occurring within the boundaries of the survey strip were solely in the shallow water zone, although coverage in the transition and deep water zones was 2.8 percent and 3.7 percent, respectively, compared to 6.3 percent in the shallow water zone. Dall's porpoise abundance was not estimated because too little area was surveyed under acceptable viewing conditions to provide a meaningful value. The confidence limits around the abundance estimates for the other species were wide because of the small sample sizes. Moreover, these estimates do not account for animals below the surface or otherwise missed during a survey. Consequently, the actual abundance was probably higher, particularly since replicate counts of several whale pods exceeded twice the number of animals initially recorded.

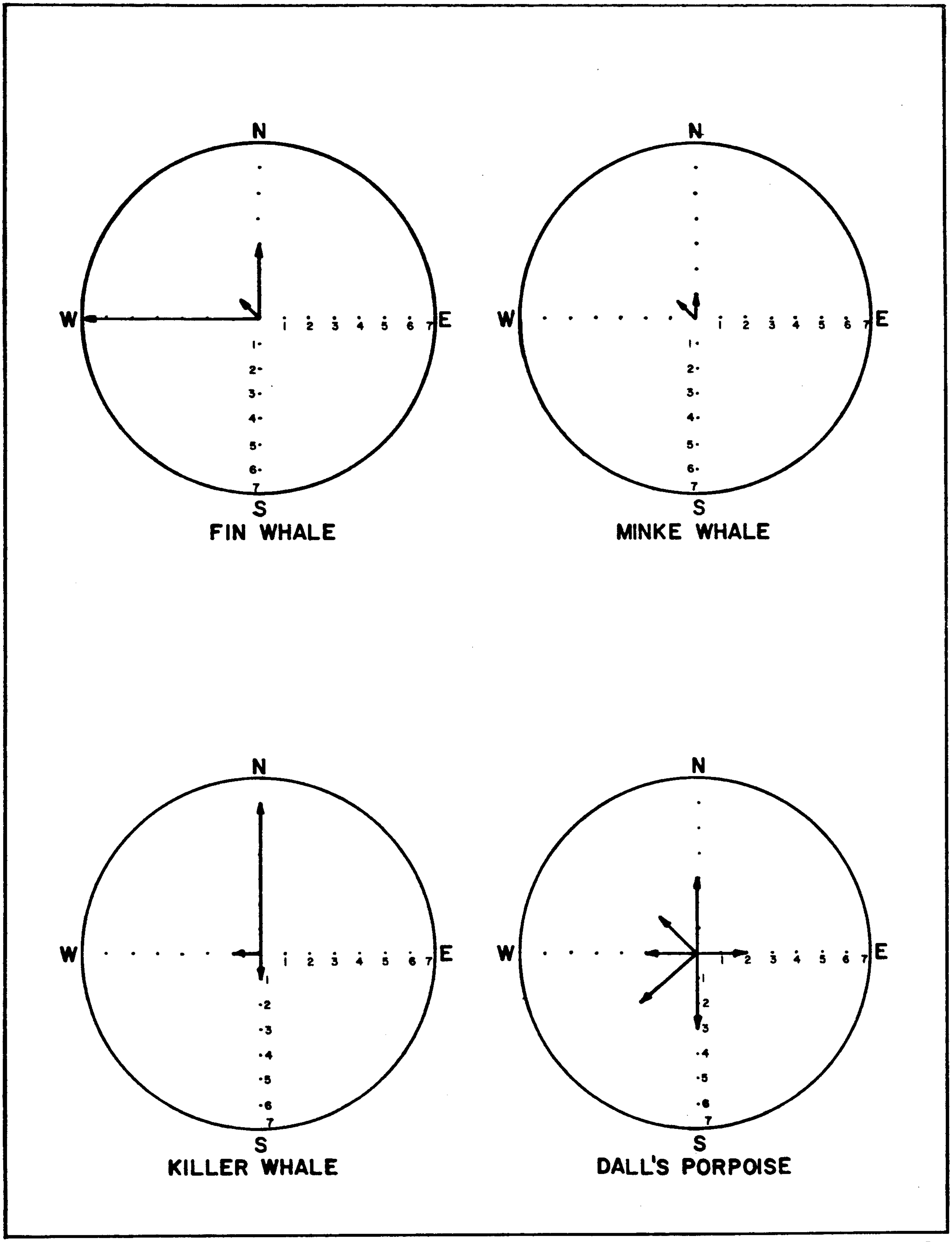

Figure 9 FREQUENCY OF WHALES OBSERVED POINTED IN A GIVEN DIRECTION OF TRAVEL IN THE NAVARIN BASIN DURING SPRING, MAY - JUNE 1982.

TABLE 6

ESTIMATED ABUNDANCE OF WHALES IN THE NAVARIN BASIN DURING SPRING

Zone	Sampling unit	Total area (nm^2)	% area coverage Aerial	Vessel	Total	Fin whale Obs.[a] No.	Est. No.	Minke whale Obs. No.	Est. No.	Killer whale Obs. No.	Est. No.	Total Obs. No.	Est. No.
Shallow	5	2458	4.5	1.3	5.8	-[b]	-	-	-	-	-	-	-
water	8	2452	3.7	6.5	10.2	-	-	1	10	-	-	1	10
	10	2461	11.0	0	11.0	19	173	-	-	-	-	19	173
	11	2461	11.0	0	11.0	-	-	-	-	29	264	29	264
Subtotal		9832	7.5	2.0	9.5	19	173	1	10	29	264	49	447
All units		14,740	5.0	1.3	6.3		259		15		396		670
Transition	7	2452	11.0	0	11.0	-	-	-	-	-	-		-
	21	2461	11.0	0	11.0	-	-	-	-	-	-		-
	22	2461	0.7	0.4	1.1	-	-	-	-	-	-		-
Subtotal		7374	7.6	0.1	7.7	-	-	-	-	-	-	-	-
All units		19,651	2.8	T	2.8		-		-		-		-
Deep water	20	2461	11.0	0	11.0	-	-	-	-	-		-	-
Subtotal		2461	11.0	0	11.0	-	-	-	-	-		-	-
All units		7379	3.7	0	3.7		-		-		-		-
TOTAL		41,770	3.8	0.5	4.3	19	259 ± 559[c]	1	15 ± 40	29	396 ± 713	49	670

a/ Number of whales recorded in survey strip.
b/ Dash (-) signifies no animals.
c/ Ninety-five percent confidence limits.

SUMMER SURVEY PERIOD

Sixty-eight whales comprising five species were recorded during 1,590 nm of aerial and vessel surveys in the Basin (Table 7). Dall's porpoises represented almost 80 percent of the total observations, while six or fewer fin, killer, right, and minke whales were recorded. The majority of the fin and killer whales were observed during aerial surveys, whereas most animals of the other three species were counted from the vessel. Aerial surveys accounted for 71 percent of the 1,385 nm of systematic trackline examined; the remaining 402 nm of systematic and 205 nm of opportunistic trackline were censused by vessel.

Eight sampling units were surveyed in the Basin during summer (Table 7). Five units were censused in the shallow water zone, two in the transition zone, and one in the deep water zone. Survey effort in these zones was 66 percent in the former zone, 14 percent in the latter zone, and 20 percent in the transition zone of the total 1,386 nm censused. Helicopter surveys predominated in each zone except for the transition zone, which was primarily censused by vessel. The vessel was predominantly used in sampling units 22 and 11 where weather conditions limited use of the helicopter. There was no sea ice in the Basin during the summer period to cause access problems similar to those reported in the spring.

Sea state and visibility conditions were largely acceptable for censusing whales during 10 of the 31 day summer field season (Table 8). Visibility was good to excellent approximately 75 percent of the survey time and sea state was below Beaufort 5, 91 percent of the time; under these environmental conditions glare was less than 50 percent and wind speed averaged 14 kt. Survey conditions were marginal for over half the distance surveyed in sampling units 11, 20, and 22. Additional surveys were not conducted during the remaining 21 of the 31 day summer field period because of bad weather, piggyback scientific operations, transiting to and from the study area, and ancillary ship activities (Appendix Table A-4).

TABLE 7
NUMBER OF WHALES OBSERVED DURING THE SUMMER AERIAL AND VESSEL SURVEYS
OF THE NAVARIN BASIN, 20 JULY - 19 AUGUST 1982

Zone	Sampling unit	Trackline distance surveyed[a/] Aerial (%)	Vessel (%)	Total (nm)		Fin whale No. obs	Fin whale No. indiv	Right whale No. obs	Right whale No. indiv	Minke whale No. obs	Minke whale No. indiv	Killer whale No. obs	Killer whale No. indiv	Dall's porpoise No. obs	Dall's porpoise No. indiv	Total No. obs	Total No. indiv
Shallow water	1	94	6	255	[50][b/]	-[c/]	-	-	-	-	-	-	-	-	-	-	-
	5	100	0	270	[63]	3	6	-	-	1	1	1	3	12	38	17	48
	6	64	36	210	[24]	-	-	1	2	-	-	-	-	-	-	1	2
	8	100	0	75	[18]	-	-	-	-	-	-	-	-	-	-	-	-
	11	18	82	101	[6]	-	-	-	-	-	-	1	2	2	5	3	7
Subtotal		81	19	911	[161]	3	6	1	2	1	1	2	5	14	43	21	57
Transition	9	81	19	129	[18]	-	-	-	-	-	-	-	-	2	5	2	5
	22	0	100	150	[0]	-	-	-	-	-	-	-	-	2	6	2	6
Subtotal		38	62	279	[18]	-	-	-	-	-	-	-	-	4	11	4	11
Deep water	20	69	31	195	[26]	-	-	-	-	-	-	-	-	-	-	-	-
Subtotal		69	31	195	[26]	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL		71	29	1385	[205]	3	6	1	2	1	1	2	5	18	54	25	68

a/ Total trackline length available in each sampling unit was 270 nm.

b/ Brackets [ ] include nautical miles surveyed by the vessel during aerial surveys; incidental marine mammal sightings were recorded for determining species distribution in the Basin.

c/ Dash (-) signifies no animals were observed.

TABLE 8

VISIBILITY AND SEA STATE CONDITIONS DURING SUMMER AERIAL AND VESSEL SURVEYS OF MARINE MAMMALS IN THE NAVARIN BASIN, 20 JULY - 19 AUGUST 1982

Zone	Sampling unit	Beaufort wind scale (%)							Visibility conditions (%)[a]						Total distance surveyed (nm)
		0	1	2	3	4	5	6	UN	PO	FA	GO	VG	EX	
Shallow water	1	-	-	-	73	27	-	-	-[b]	-	4	72	24	-	255
	5	-	-	56	44	-	-	-	6	-	-	-	94	-	270
	6	-	-	-	64	21	15	-	-	1	7	43	34	15	210
	8	-	-	-	100	-	-	-	-	-	-	-	100	-	75
	11	-	-	15	39	46	-	-	6	8	54	27	5	-	101
Subtotal		-	-	18	61	17	4	-	2	1	9	33	51	4	911
Transition	9	-	-	-	54	23	23	-	3	15	12	70	-	-	129
	22	-	-	-	40	40	20	-	-	25	49	26	-	-	150
Subtotal		-	-	-	46	32	22	-	1	21	32	46	-	-	279
Deep water	20	-	-	-	-	80	20	-	-	1	51	48	-	-	195
Subtotal		-	-	-	-	80	20	-	-	1	51	48	-	-	195
TOTAL		-	-	12	50	29	9		2	5	19	38	34	2	1385

[a] UN = unacceptable, PO = poor, FA = fair, GO = good, VG = very good, and EX = excellent as defined in Appendix Table 1.

[b] Dash (-) signifies that a visibility condition did not occur.

Whales were observed in 2 of the 3 zones during the summer (Figure 10). The majority of whales were recorded in the shallow waters of the outer continental shelf where the species diversity was also highest. Fin, right, minke, and killer whales were exclusively encountered in the shelf waters. Right whales were observed in unit 6 at a water depth of 104 m, while fin, minke, and killer whales all occurred in sampling unit 5 at depths ranging from 110 to 120 m; killer whales also were in unit 11. Dall's porpoises were more widespread than the other species since they occurred in 4 units distributed in the shallow water and transition zones where depths ranged from 110 m to over 1,000 m. No whales were observed in sampling units 1, 8, or the deep water zone.

Summer movement patterns of whales in the Basin were unclear (Figure 11). Directions of movement of fin whales and Dall's porpoises were quite variable, possibly suggesting these species were feeding in the Basin. Fins travelled in average group sizes of 2.0 (n=4) and Dall's porpoises in groups of 2.8 (n=13) animals. Too few observations were recorded for the other species to suggest any definite movement patterns; one group of 2 right whales and 2 groups of 5 killer whales were recorded. The movements of the animals did not appear to be influenced by the survey platforms, except for Dall's porpoises and minke whales, which may have been attracted to the vessel.

During the summer period, 183 whales at a density of 3 animals per 1,000 nm^2 were estimated in the Basin (Table 9). This estimate was based on observations of 8 whales along 1,085 nm of strip transect representing 2 percent coverage of the Basin. Densities were highest for fin whales and lowest for killer whales; right whales were intermediate in abundance. Abundance estimates for these species were 84 fin whales or 2 animals per 1,000 nm^2, compared to 57 right whales and 42 killer whales at densities of 1.1 and 0.8 animals per 1,000 nm^2, respectively. All animals recorded in the designated strip boundaries were in the shallow water zone where survey coverage was 2.9 percent; coverage in the deep water zone was 1.8 percent and 0.7 percent

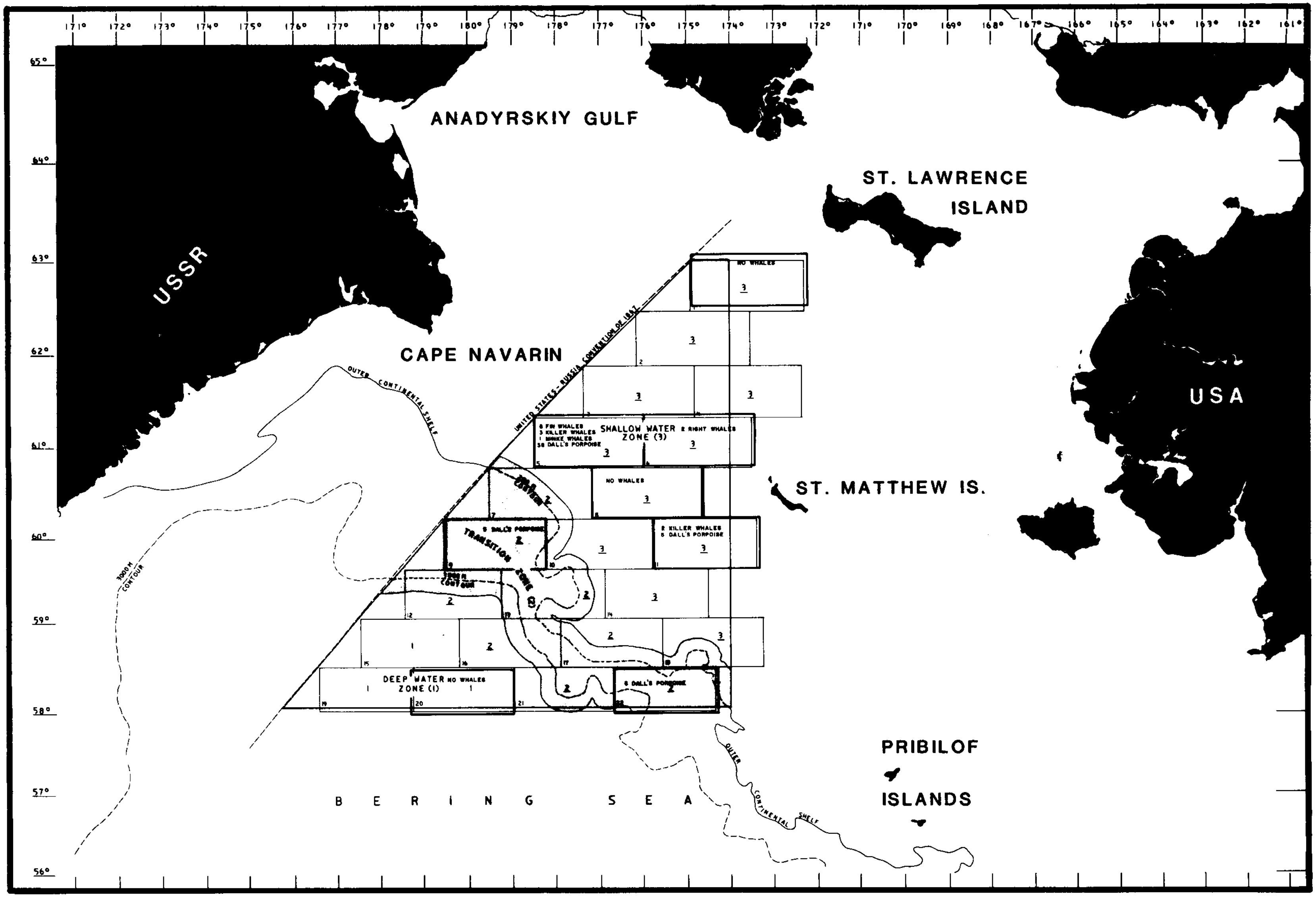

FIGURE 10 DISTRIBUTION OF WHALES IN THE EIGHT SAMPLING UNITS SURVEYED IN THE NAVARIN BASIN DURING SUMMER, JULY 20 - AUGUST 19, 1982 (SEE FIGURES 3 AND 4 AND TABLE 5 APPENDIX A FOR LOCATIONS OF SURVEY TRACKLINES AND ANIMALS).

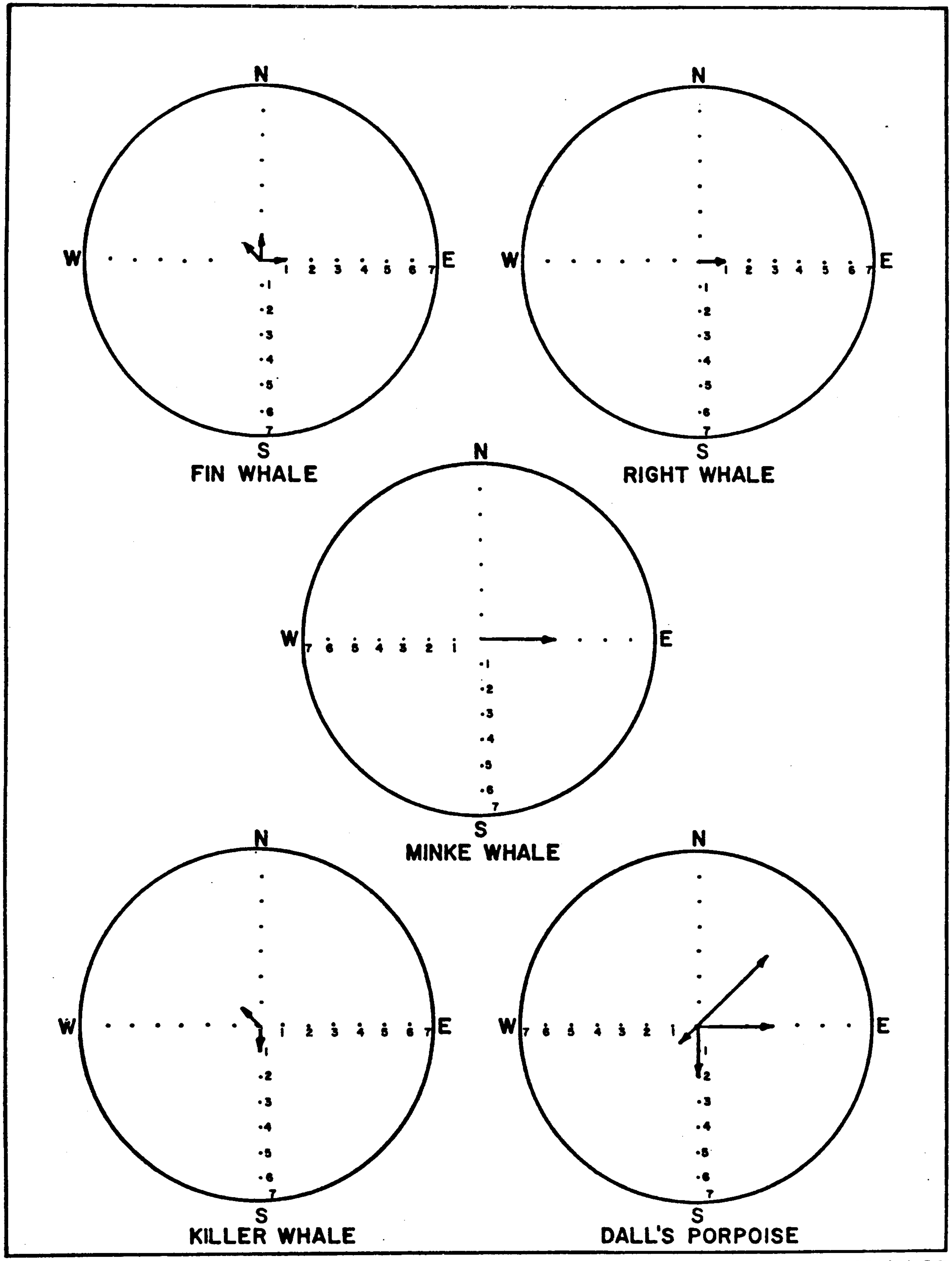

Figure 11 FREQUENCY OF WHALES OBSERVED POINTED IN A GIVEN DIRECTION OF TRAVEL IN THE NAVARIN BASIN DURING SUMMER, JULY - AUGUST 1982.

TABLE 9

ESTIMATED ABUNDANCE OF WHALES IN THE NAVARIN BASIN DURING SUMMER, 20 JULY - 19 AUGUST 1982

Zone	Sampling unit	Total area (nm^2)	% area coverage Aerial	% area coverage Vessel	% area coverage Total	Fin whale Obs. no.[a]	Fin whale Est. no.	Right whale Obs. no.	Right whale Est. no.	Killer whale Obs. no.	Killer whale Est. no.	Total Obs. no.	Total Est. no.
Shallow water	1	2463	9.8	0.2	10.0	-[b]	-	-	-	-	-	-	-
	5	2458	10.4	0	10.4	4	38	-	-	2	19	6	57
	6	2458	5.4	2.4	7.8	-	-	2	26	-	-	2	26
	8	2452	3.1	0	3.1	-	-	-	-	-	-	-	-
	11	2461	0.5	1.1	1.6	-	-	-	-	-	-	-	-
Subtotal		12,292	5.8	0.7	6.5	4	38	2	26	2	19	8	83
All units		27,048	2.6	0.3	2.9		84		57		42		183
Transition	9	2461	4.3	0	4.3	-	-	-	-	-	-	-	-
	22	2461	0	1.6	1.6	-	-	-	-	-	-	-	-
Subtotal		4922	2.1	0.8	2.9	-	-	-	-	-	-	-	-
All units		19,651	0.5	0.2	0.7		-		-		-		-
Deep water	20	2461	5.5	0	5.5	-	-	-	-	-	-	-	-
Subtotal		2461	5.5	0	5.5	-	-	-	-	-	-	-	-
All units		7379	1.8	0	1.8		-		-		-		-
TOTAL		54,078	1.8	0.2	2.0	4	84 ± 184[c]	2	57 ± 118	2	42 ± 118	8	183

a/ Number of whales recorded in survey strip.
b/ Dash (-) signifies no animals.
c/ Ninety-five percent confidence interval.

in the transition zone. Abundance was not estimated for Dall's porpoise because of insufficient amount of trackline surveyed and no minke whales were encountered in the survey strip. The confidence limits of these estimates were wide because of small sample sizes. The estimates do not reflect the number of whales below the surface or otherwise missed during the surveys.

FALL SURVEY PERIOD

During the fall survey period, 136 whales comprising five species were recorded during 1,575 nm of aerial and vessel surveys (Table 10). As with the previous two survey periods, the Dall's porpoise was most abundant, followed by gray, killer, fin, and minke whales; three unidentified baleen whales were also recorded. All of these species, except for the unidentified baleen whales and the majority of the Dall's porpoises, were observed from the aircraft. Approximately 99 percent of the 1,346 nm of systematic trackline surveyed was by helicopter and the remainder by vessel; vessel surveys were also conducted along 229 nm of opportunistic trackline in the Basin.

Five sampling units were surveyed in the Basin (Table 10). Four units were in the shallow water zone and one in the transition zone; no surveys were done in the deep water zone because of persistent high seas. Survey effort in these zones relative to total trackline covered was 80 percent in the shallow water zone and 20 percent in the transition zone. Aerial surveys represented the primary survey platform in each zone, with virtually the entire 270 nm of trackline in each sampling unit censused.

Sea state and visibility conditions were generally conducive to obtaining accurate censuses of whales during 7 of the 20 day fall field period (Table 11). Visibility conditions were good or better during 81 percent of the survey time, which included glare less than 50 percent. Wind speeds averaged 13 kt and sea states below Beaufort 3 occurred 86 percent of the survey time. None of the units surveyed were

TABLE 10
NUMBER OF WHALES OBSERVED DURING THE FALL AERIAL AND VESSEL SURVEYS
OF THE NAVARIN BASIN, 29 OCTOBER - 12 NOVEMBER 1982

Zone	Sampling unit	Trackline distance surveyed[a/] Aerial (%)	Vessel (%)	Total(nm)		Fin whale No. obs	Fin whale No. indiv	Gray whale No. obs	Gray whale No. indiv	Minke whale No. obs	Minke whale No. indiv	Killer whale No. obs	Killer whale No. indiv	Unid. whale No. obs	Unid. whale No. indiv	Dall's porpoise No. obs	Dall's porpoise No. indiv	Total No. obs	Total No. indiv
Shallow water	1	100	0	269	[52][b/]	5	13	18	44	1	1	1	6	2	3	-[c/]	-	27	67
	5	94	6	270	[54]	-	-	-	-	-	-	-	-	-	-	5	20	5	20
	6	100	0	267	[61]	-	-	-	-	1	1	-	-	-	-	-	-	1	1
	11	100	0	270	[61]	-	-	-	-	1	1	-	-	-	-	3	19	4	20
Subtotal		99	1	1076	[229]	5	13	18	44	3	3	1	6	2	3	8	39	37	108
Transition	22	100	0	270	[0]	-	-	-	-	-	-	2	11	-	-	2	17	4	28
Subtotal		100	0	270	[0]	-	-	-	-	-	-	2	11	-	-	2	17	4	28
Deep water		Zone not surveyed																	
TOTAL		99	1	1346	[229]	5	13	18	44	3	3	3	17	2	3	10	56	41	136

a/ Total trackline length available in each sampling unit was 270 nm.

b/ Brackets [ ] include nautical miles surveyed by the vessel during aerial surveys; incidental marine mammal sightings were recorded for determining species distribution in the Basin.

c/ Dash (-) signifies no animals were observed.

TABLE 11
VISIBILITY AND SEA STATE CONDITIONS DURING FALL AERIAL AND VESSEL SURVEYS OF MARINE MAMMALS IN THE NAVARIN BASIN, 29 OCTOBER - 12 NOVEMBER 1982

Zone	Sampling unit	Beaufort wind scale (%)							Visibility conditions (%)[a]						Total distance surveyed (nm)
		0	1	2	3	4	5	6	UN	PO	FA	GO	VG	EX	
Shallow water	1	-[b]	-	80	20	-	-	-	-	-	28	9	63	-	269
	5	-	-	50	28	22	-	-	-	-	7	17	76	-	270
	6	-	-	-	52	48	-	-	-	-	34	21	45	-	267
	11	-	-	67	33	-	-	-	-	1	11	38	50	-	270
Subtotal		-	-	50	33	17	-	-		T[c]	20	22	58	-	1076
Transition	22	-	-	-	100	-	-	-	-	-	13	11	76	-	270
Subtotal		-	-	-	100	-	-	-	-	-	13	11	76	-	270
Deep water		Zone was not surveyed													
TOTAL		-	-	39	47	14	-	-	-	T	19	19	62	-	1346

[a] UN = unacceptable, PO = poor, FA = fair, GO = good, VG = very good, and EX = excellent as defined in Appendix Table B-1.

[b] Dash (-) signifies Beaufort or visibility conditions did not occur.

[c] T signifies percentage less than 0.5.

predominated by marginal viewing conditions. Poor weather, however, prevailed during 13 of the 20 day field season (Appendix Table A-4). Furthermore, the scheduled length of the field period was reduced because of persistent storms.

Whales were seen in both zones surveyed in the Basin during fall (Figure 12). All of the species occurred in the shallow water zone, while only Dall's porpoises and killer whales were in the transition zone. Fin and gray whales occurred in 1 unit at depths averaging 65 m, whereas killer whales were in 2 units and minke and Dall's porpoises in 3 units. Killer whales occurred in water depths ranging between 78 and 2043 m, compared with 78 to 95 m for minke whales and 97 to 930 m for Dall's porpoises. All five of these species, except Dall's porpoises, were encountered in sampling unit 1. Whales were recorded in every sampling unit surveyed.

Movement patterns of whales in the Basin during fall were indefinite because of the small sample sizes (Figure 13). Direction of movement observed for fin, gray, and killer whales, was primarily southward. Grays and fins were encountered in the same geographic vicinity feeding in groups averaging 2.4 (n=18) and 2.6 (n=5) animals, respectively. Killer whales travelled in groups averaging 5.7 (n=3) animals. Dall's porpoises showed no specific directionality in their movements while minkes travelled northerly and westerly. Dall's porpoise group sizes were 5.7 (n=6) and minkes occurred in singles. Movement patterns did not appear to be influenced by the survey platform, except for minkes and Dall's porpoises which may have been attracted to the vessel.

An estimated 1,548 large whales at a density of 33 animals per 1,000 nm^2 were in the Basin during fall (Table 12). This estimate was derived from observations of 41 animals along 1,342 nm of systematic transect line comprising 2.9 percent coverage of the Basin. Killer whales had the highest estimated abundance at 798 animals and minke

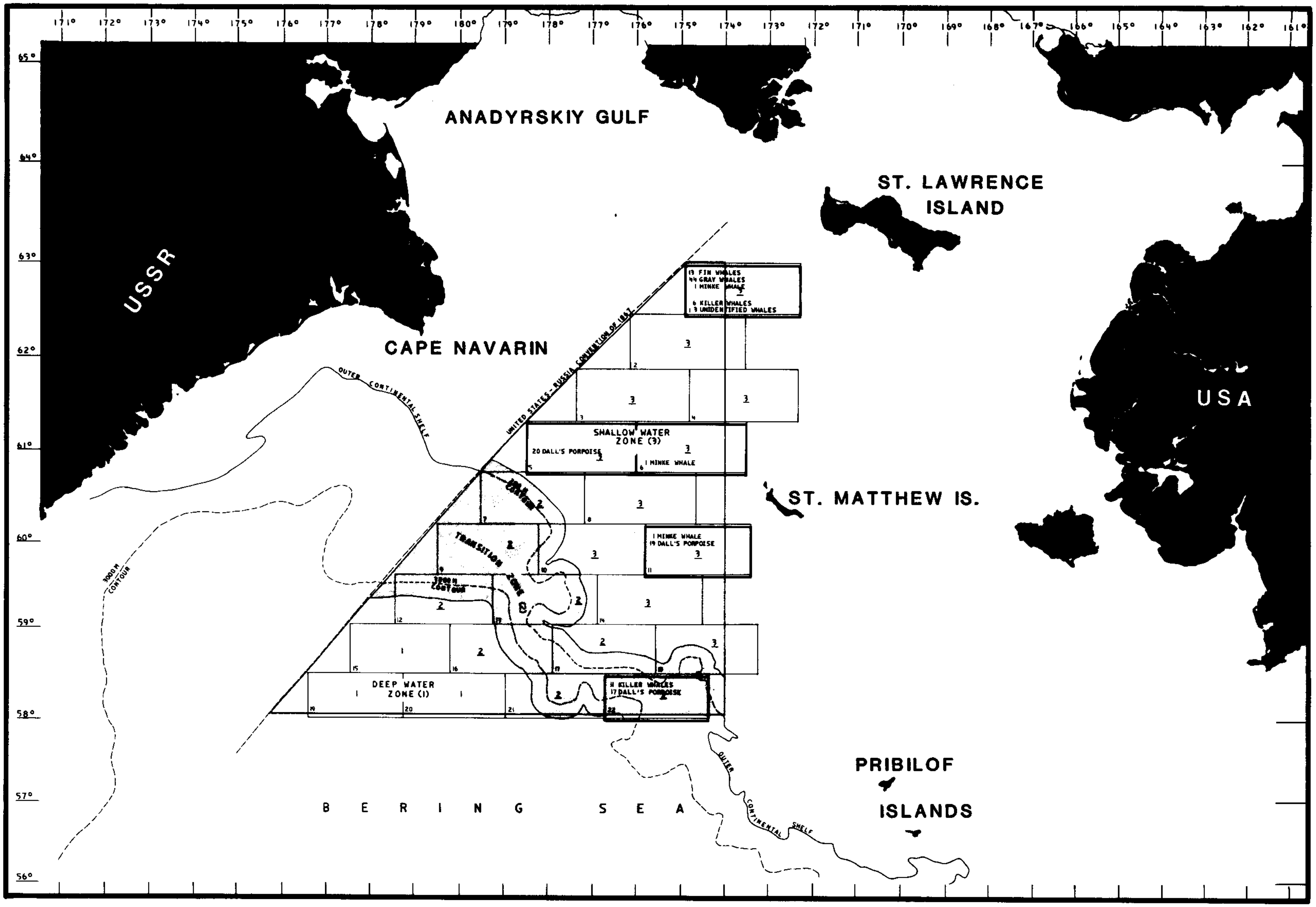

FIGURE 12 DISTRIBUTION OF WHALES IN THE FIVE SAMPLING UNITS SURVEYED IN THE NAVARIN BASIN DURING FALL, 29 OCTOBER - 12 NOVEMBER 1982 (SEE FIGURES 5 AND 6 AND TABLE 5 IN APPENDIX A FOR LOCATIONS OF SURVEY TRACKLINES AND ANIMALS).

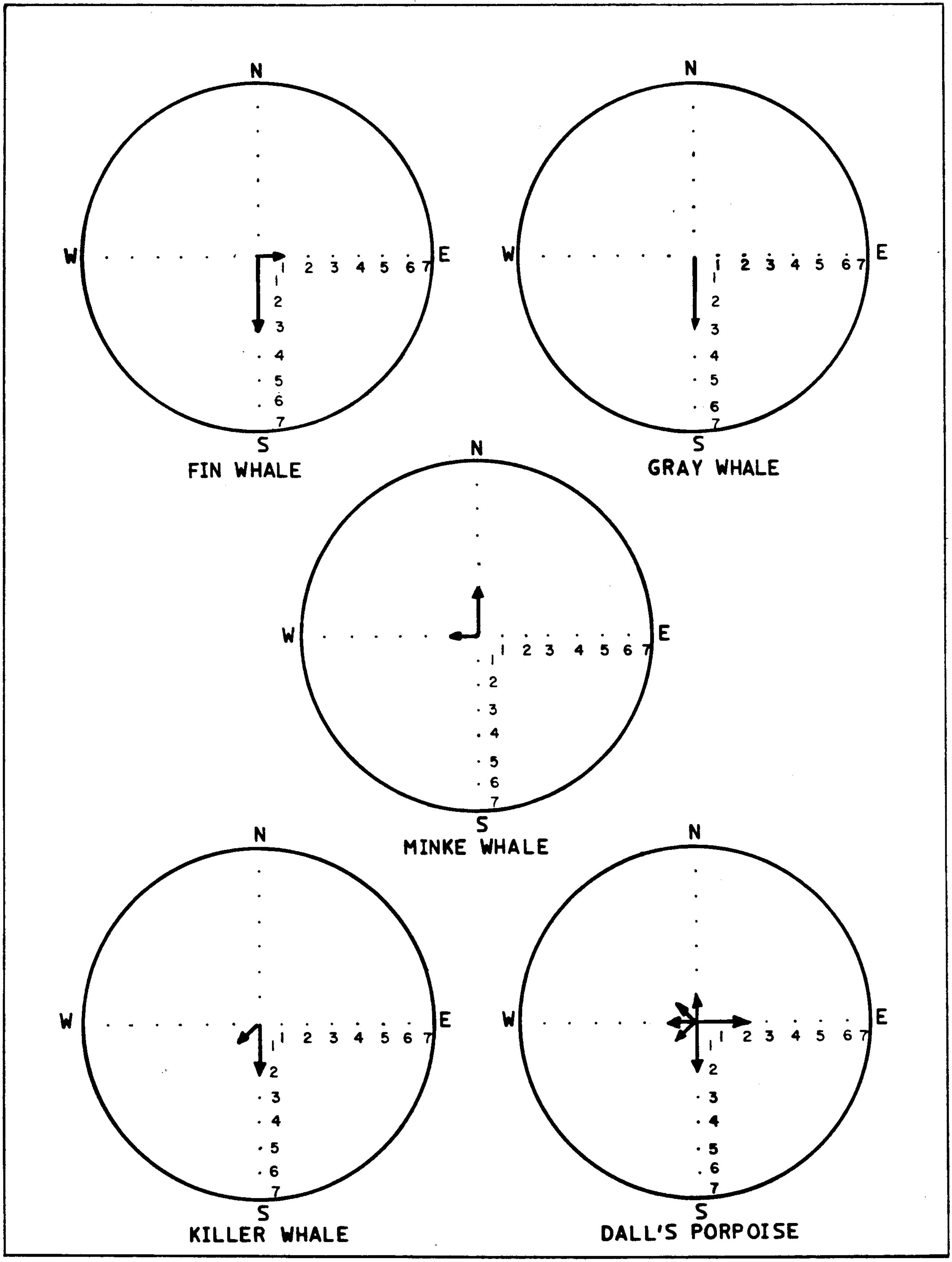

Figure 13 **FREQUENCY OF WHALES OBSERVED POINTED IN A GIVEN DIRECTION OF TRAVEL IN THE NAVARIN BASIN DURING FALL, OCTOBER - NOVEMBER 1982.**

TABLE 12

ESTIMATED ABUNDANCE OF WHALES IN THE NAVARIN BASIN DURING FALL, 29 OCTOBER - 12 NOVEMBER 1982

Zone	Sampling unit	Total area (nm^2)	% area coverage			Fin whale		Gray whale		Minke whale		Killer whale		Total	
			Aerial	Vessel	Total	Obs.[a] no.	Est. no.	Obs. no.	Est. no.	Obs. no.	Est. no.	Obs. no.	Est. no.	Obs. no.	Est. no.
Shallow water	1	2463	11.0	0	11.0	9	82	20	182	-	-	-	-	29	264
	5	2458	10.4	0.5	10.9	-[b]	-	-	-	-	-	-	-	-	-
	6	2458	10.9	0	10.9	-	-	-	-	1	9	-	-	1	9
	11	2461	11.0	0	11.0	-	-	-	-	-	-	-	-	-	-
Subtotal		9840	10.8	0.1	10.9	9	82	20	182	1	9	-	-	30	273
All units		27,048	3.9	T[c]	4.0		225		500		25		-		750
Transition	22	2461	11.0	0	11.0	-	-	-	-	-	-	11	100	11	100
Subtotal		2461	11.0	0	11.0	-	-	-	-	-	-	11	100	11	100
All units		19,651	1.4	0	1.4		-		-		-		798		798
Deep water		Not surveyed													
TOTAL		46,699	2.9	T	2.9	9	225 ± 520[d]	20	500 ± 966	1	25 ± 48	11	798 ± 1558	41	1,548

a/ Number of whales recorded in survey strip.

b/ Dash (-) signifies no animals.

c/ T signifies percentage less than 0.5.

d/ Ninety-five percent confidence intervals.

whales the lowest estimated abundance at 25 animals. Fin and gray whale estimated abundances were intermediate at 225 and 500 whales, respectively. Dall's porpoises, while recorded in the Basin, were not enumerated because none were seen in the 0.5 nm survey strip. As noted for the other survey periods, confidence limits of the estimates were wide because of small sample sizes, and the estimates do not account for animals submerged or otherwise missed during the census.

WINTER SURVEY PERIOD

A total of 635 to 646 whales comprising 5 species were observed during 2,410 nm of aerial and vessel surveys in the marginal ice front of the Navarin Basin (Table 13). Over 90 percent of the whales recorded were beluga whales. In addition, there were 21 to 32 bowhead whales and 7 or fewer killer, fin, and minke whales. The latter three species were observed from the vessel and the majority of bowheads and belugas were recorded from the aircraft. Helicopter surveys accounted for over 68 percent of the trackline traversed in the 16,382 nm^2 defining the marginal ice front.

Six sampling units were surveyed which included four units in the Basin and two units immediately east of the Basin (Figure 4). The latter two units were surveyed to comply with an initial sampling strategy to census the entire marginal ice front between the Pribilof Islands and Cape Olyutorskiy (USSR). This strategy was modified to terminate surveys at the US-USSR Convention Line when the USSR denied the USCG permission to enter their territorial waters. Aerial survey effort predominated in every unit except units 24 and 29, which were primarily censused from vessel because of weather (Table 13). Surveys were not conducted in the open water because of persisent high seas nor in the heavy pack ice because of mechanical difficulties with the icebreaker.

Environmental conditions were adequate to survey marine mammals during 25 of the 30 day field season (Table 14). Visibility conditions were good to excellent 90 percent of the survey time. Marginal visibility prominated only in sampling unit 29. High winds, however, restricted

TABLE 13

NUMBER OF WHALES OBSERVED DURING THE WINTER AERIAL AND VESSEL SURVEYS
OF THE NAVARIN BASIN, 19 FEBRUARY - 18 MARCH 1983

Sampling unit	Trackline distance surveyed			Fin whale		Bowhead whale[a/]		Minke whale		Beluga whale		Killer whale		Unid. whale		Total	
	Aerial (%)	Vessel (%)	Total(nm)	No. obs	No. indiv	No. obs	No. indiv	No. obs	No. indiv	No. obs	No. indiv	No. obs	No. indiv	No. obs	No. indiv	No. obs	No. indiv
24	-	100	147	-[b]	-	-	-	-	-	-	-	-	-	-	-	-	-
25	82	18	462	-	-	3-10	5-12	-	-	4	36	-	-	1	2	8-15	43-50
26	71	29	613	-	-	4-8	16-20	-	-	25	562	-	-	-	-	30-34	578-582
27	83	17	482	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28	80	20	466	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29	23	77	240	1	6	-	-	1	1	-	-	1	7	-	-	3	14
TOTAL	68	32	2,410	1	6	7-18	21-32	1	1	29	598	1	7	1	2	40-51	635-646

a/ The range varies from a minimum number to a maximum number which includes possible duplicates.
b/ Dash (-) signifies no animals.

TABLE 14

VISIBILITY CONDITIONS AND WIND SPEED DURING WINTER AERIAL AND VESSEL SURVEYS OF MARINE MAMMALS IN THE NAVARIN BASIN, 19 FEBRUARY - 18 MARCH 1983

Sampling unit	Visibility conditions (%)[a]						Wind speed (%)			Total distance surveyed (nm)
	UN	PO	FA	GO	VG	EX	0-15 kt	16-25 kt	>25 kt	
24	-[b]	4	11	36	38	11	-	8	92	147
25	-	1	6	16	50	27	37	58	5	462
26	-	1	3	44	36	16	41	38	21	613
27	-	3	5	70	18	4	60	33	8	482
28	-	2	2	19	17	60	6	84	10	466
29	2	19	26	53	-	-	-	39	61	240
TOTAL	T	3	7	40	28	22	31	48	22	2410

a/ UN = unacceptable, PO = poor, FA = fair, GO = good, VG = very good, and EX = excellent as defined in Appendix Table A-1.

b/ Dash (-) signifies that a visibility condition did not occur.

aerial surveys to 7 days. Wind speeds were particularly high during surveys of units 24 and 29, which were primarily censused from vessel. Vessel surveys were implemented whenever wind speeds exceeded 25 kt because of USCG flight restrictions. Even under conditions of high winds, whales were still sightable from the vessel since sea ice generally moderated the influence of wind on the water. The remaining five days of the survey period were for transiting to and from the study area (Appendix Table A-4).

Whales were observed in 3 of the 6 sampling units surveyed (Figure 4). Fin, minke, and killer whales exclusively occurred in sampling unit 29. The fin and minke whales were together in a single group in the ice fringe, near open water. The killer whales were also in a single group, but in the ice front where spotted seals were relatively abundant. Sampling units 25 and 26 contained populations of bowhead and beluga whales. Although these species were more widespread than the others, they were largely concentrated along the western fringe of the St. Matthew Island polynya; however, no whales were seen in the polynya proper. Neither were any whales observed in sampling units 24, 27, or 28. The two unidentified whales were probably bowheads, judging from their large size and close proximity to the other bowheads encountered.

Movement patterns of whales were variable during winter (Figure 14). Bowhead whales showed no specific direction of movement. The animals were observed in group sizes averaging 1.78 (n = 18, sd = 2.60), although 1 group of 12 animals was recorded. Beluga whales were similarly non-specific in their observed movement patterns. They did, however, display a penchant toward moving northward, with one group of over 400 animals recorded travelling that direction. Average group size for belugas was 20.62 animals (n = 29, sd = 75.50). Data on direction of movement for the fin, minke, and killer whales were quite inconclusive, since only one observation was made for each of these species.

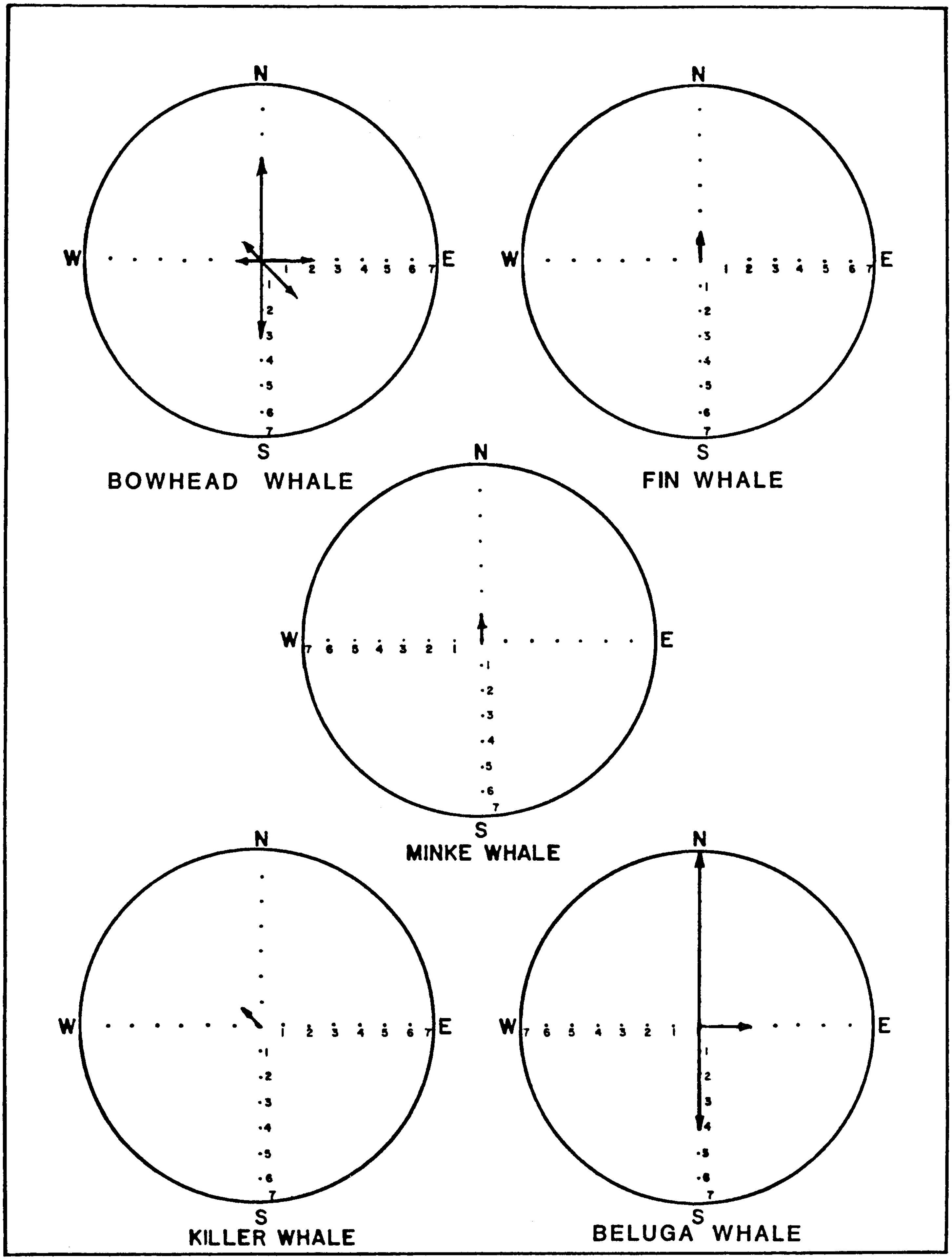

Figure 14 FREQUENCY OF WHALES OBSERVED POINTED IN A GIVEN DIRECTION OF TRAVEL IN THE NAVARIN BASIN DURING WINTER, FEBRUARY - MARCH 1983.

Ice coverage during the winter survey period was more extensive than average (Figure 15). The ice edge location was south of the 1954-70, 16 year mean (Potocsky 1975). The position of the ice edge resulted in approximately half of the Basin being covered in pack ice. The configuration of the pack ice was typical, since it tended to follow the edge of the outer continental shelf.

Ice coverage in the marginal ice front during the winter surveys averaged 76 percent (Table 15). Ice coverage in the sampling units increased from 68 percent in the western unit (29) to approximately 80 percent in the eastern units (24, 25). One way ANOVA (following arcsine transformation) indicated that the difference among units was significant ($F = 14.78$, 5,837 df, $p < .001$). Ice in the western units was more broken, having large proportions of area in the lower ice concentration and size categories but relatively thick ice. Ice in the eastern units was relatively thin but more compacted, having large amounts of area in the highest ice concentration and size categories. This was particularly apparent in sampling units 25 and 26 where almost 75 percent of the ice was new or young. These two units also contained all of the bowhead and beluga whales recorded during the survey period. Although the other whale species were encountered in sampling unit 29 where ice was thickest, the whales were near or in open water.

Bowhead and beluga whales were primarily observed in areas of thin but extensive ice coverage (Figure 16). Almost 90 percent of the bowhead and beluga whale observations were in areas of 80-100 percent ice concentration, predominated by new and young ice (Table 16). Few whales were observed in the lower ice concentrations, particularly the 0-20 percent category, and there were no whales encountered in areas of thin to medium first year ice. Floe size did not appear to influence bowhead or beluga habitat use patterns. Too few bowhead or beluga whales were observed to statistically substantiate these observations.

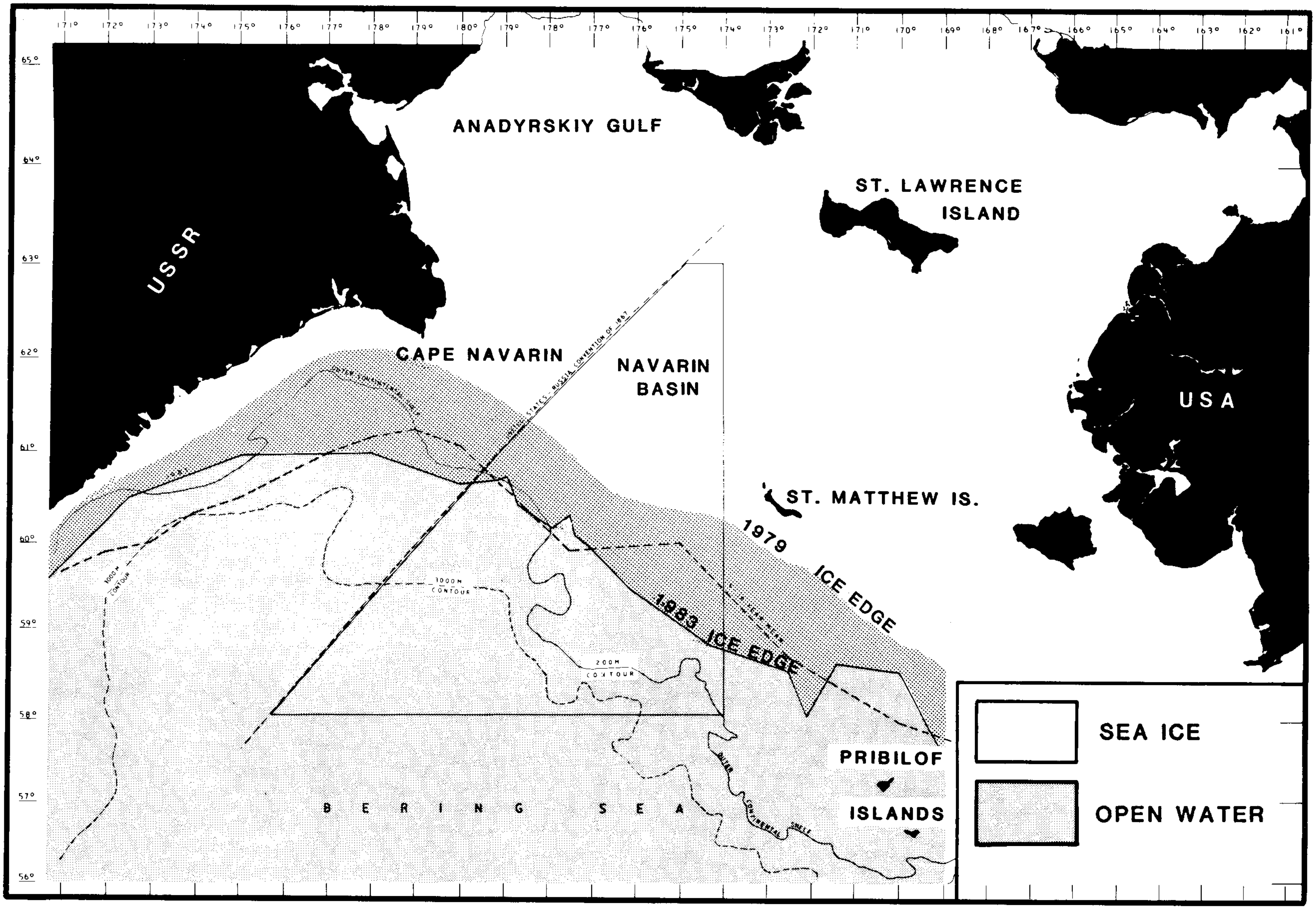

Figure 11 APPROXIMATE LOCATION OF ICE EDGE DURING 1979 AND 1983 STUDY PERIODS COMPARED TO A 5-16 YEAR MEAN (Potocsky 1975) IN THE BERING SEA.

TABLE 15

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				Percent area coverage of each ice thickness category			Total area surveyed (nm^2)
		0-20	21-40	41-60	61-80	81-100	Grease-brash	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 A-3.

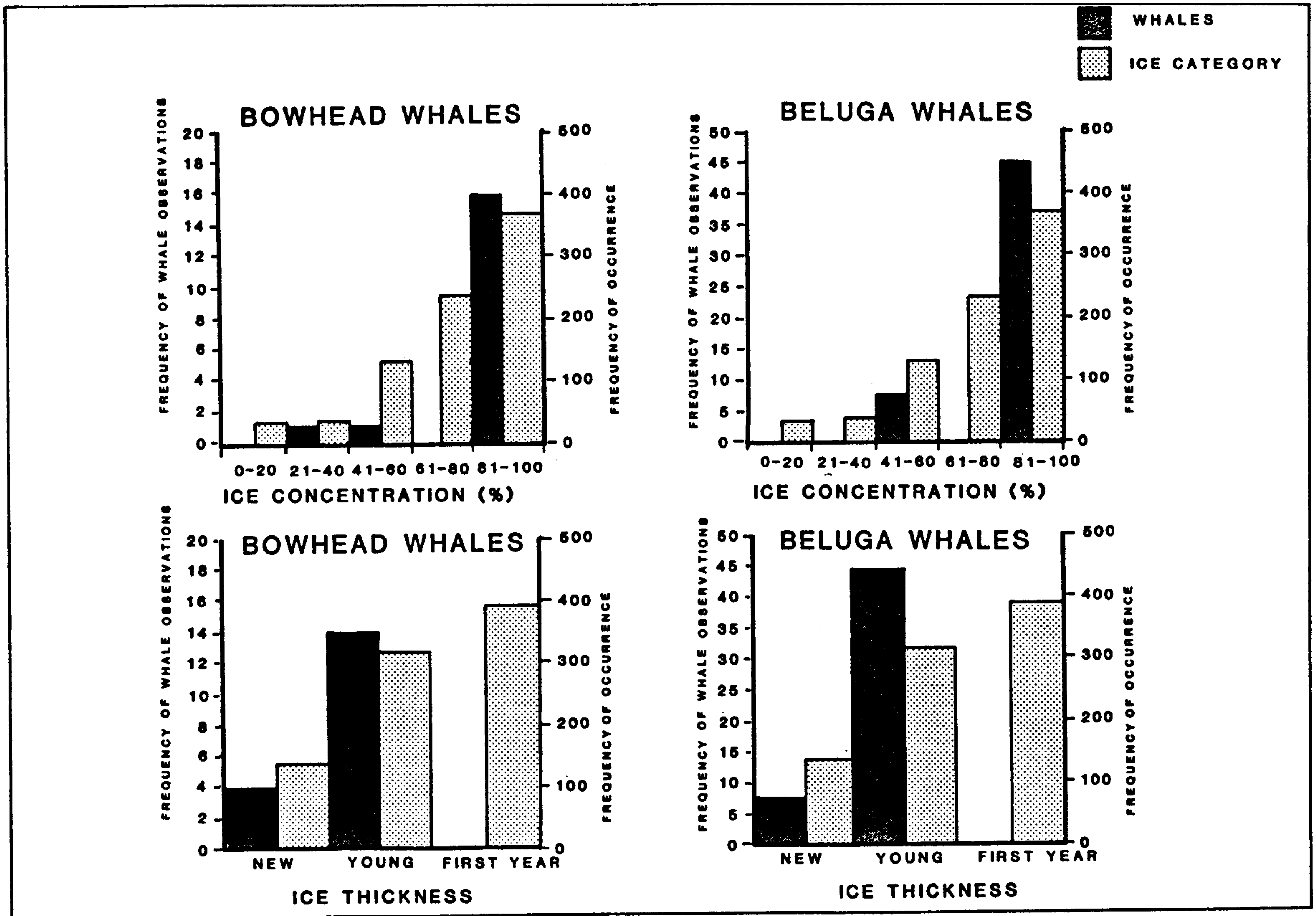

Figure 16 FREQUENCY OF WHALE OBSERVATIONS RELATIVE TO FREQUENCY OF ICE CONCENTRATION AND THICKNESS.

TABLE 16

NUMBER OF BOWHEAD AND BELUGA WHALES OBSERVED IN DIFFERENT ICE CONCENTRATION AND THICKNESS CATEGORIES

Ice concentration		Bowhead whales		Beluga whales	
Category	Freq.[a]	Number observed	Number of groups	Number observed	Number of groups
0-20%	36	0	0	0	0
21-40%	41	1	1	0	0
41-60%	139	1	1	7	2
61-80%	236	0	0	0	0
81-100%	351	16	7	45	12
TOTAL	803	18	9	52	14

Ice thickness		Bowhead whales		Beluga whales	
Category	Freq.[a]	Number observed	Number of groups	Number observed	Number of groups
New (< 10 cm)	95	4	4	2	6
Young (10-30cm)	312	5	5	12	20
First year (> 30 cm)	396	0	0	0	26
TOTAL	803	18	9	14	52

[a] Frequency of occurrence of each ice condition in a 3 nm survey unit along a transect line. Each trackline was partitioned in to approximately 10, 3 nm units.

An estimated 792 whales or 48 animals per 1,000 nm^2 wintered in the marginal ice front (Table 17). Fifty-eight whales were observed in the 6.7 percent area covered to calculate this estimate. Beluga whale abundance was estimated at 462 animals compared to 171 bowhead, 136 fin, and 23 minke whales; no killer whales were observed within the strip during acceptable viewing conditions. The confidence intervals around these estimates were expectedly wide because of small sample sizes and clumped distributions.

TABLE 17

ESTIMATED ABUNDANCE OF WHALES IN THE NAVARIN BASIN DURING WINTER, 19 FEBRUARY - 18 MARCH 1983

Sampling unit	Total area (nm^2)	% area coverage			Fin whale		Bowhead whale		Minke whale		Beluga whale		Total	
		Aerial	Vessel	Total	Obs.[a/] no.	Est. no.	Obs. no.	Est. no.	Obs. no.	Est. no.	Obs. no.	Est. no.	Obs. no.	Est. no.
24	2924	-	2.1	2.1	-[b/]	-	-	-	-	-	-	-	-	-
25	2381	8.0	1.1	9.1	-	-	3	33	-	-	-	-	3	33
26	3731	5.7	2.3	8.0	-	-	11	138	-	-	37	462	48	600
27	3429	5.8	0.8	6.6	-	-	-	-	-	-	-	-	-	-
28	2443	7.6	1.5	9.1	-	-	-	-	-	-	-	-	-	-
29	1474	1.9	2.5	4.4	6	136	-	-	1	23	-	-	7	159
TOTAL	16,382	5.0	1.7	6.7	6	136 $\pm$259[c/]	14	171 $\pm$113	1	23 $\pm$43	37	462 $\pm$578	58	792

a/ Number of whales recorded in survey strip.
b/ Dash (-) signifies no animals.
c/ Ninety-five percent confidence intervals.

DISCUSSION

The environmental conditions and whale species recorded during the four seasonal surveys define two ecological periods. The open water period encompasses the time frame of the spring, summer, and fall seasons. This period is characterized primarily by a virtual absence of sea ice in the Basin, except during early spring. The Basin at this time serves as a feeding ground for whales that winter in lower latitudes. Conversely, sea ice largely covers the Basin during the winter season. During this seasonal ice period bowhead and beluga whales, in association with numerous pinniped species, migrate from the northern latitudes to winter in the Basin. Since the seasonal ice period and ice-free period differ so dramatically in their environmental conditions and species composition, the results of the seasonal surveys in the Basin will be discussed according to these two periods.

ICE-FREE PERIOD

Seasonal abundance and species composition varied during the ice-free period. A total of six species of whales were observed in the Basin. Fin, minke, and killer whales, and Dall's porpoises were consistently observed each season. Right whales were encountered only during the summer season and gray whales only during the fall season. Species diversity was greatest in the summer and fall and lowest in the spring when survey effort was highest.

The density of large whales in the Basin was highest during fall and lowest during summer. An observed density of 33 whales per 1,000 nm^2 was estimated for fall compared to 16 whales per 1,000 nm^2 in spring and 3 whales per 1,000 nm^2 in summer. Species with the highest density for a given season was the killer whale, followed by the gray, fin, minke, and right whales. Densities for species encountered each season were greatest in the spring and fall and lowest in the summer. Although Dall's porpoises were the most commonly recorded species each season, seasonal densities were not calculated because most observations were outside the census strip. A pooled estimate of

Dall's porpoise density for all seasons was 48 animals per 1,000 nm^2 or 2,623 animals ($\pm$ 2,499)for 17 animals based on over 350 nm of vessel trackline surveyed during acceptable viewing conditions. These density estimates do not account for animals below the surface of the water or otherwise missed during the survey.

Whales were most abundant and diverse in the shallow water zone of the outer continental shelf each season (Figure 17). Fin, gray, and right whales were exclusively observed in this zone. Although right and gray whales were encountered in only one sampling unit, fin whales were observed in three different units, suggesting they were more widespread in their distribution than the other endangered species. Also observed in this zone were killer whales and minke whales. In addition, killer whales occurred in the transition zone, and minke whales in the deep water zone. Dall's porpoises were the only species found in all three zones. Moreover, Dall's porpoises were observed in more sampling units during each season than any other cetacean species. The distribution of all whales in these three zones differed significantly (X^2 = 27.8, 2df, p 0.001) from uniformity.

Seasonal movement patterns of whales in the Basin suggested directional trends for some species although the sample sizes were small. Trends were possible to examine only for fin, minke, and killer whales and Dall's porpoises; right and gray whales were observed in the Basin only one season. Fin whale movement patterns were in a northwesterly direction in the spring, varied in the summer, and southeasterly in the fall. Movements of minke whales were northwesterly in the spring and fall, and easterly in the summer. Killer whales were encountered moving primarily in a northerly direction in the spring, southerly in fall, but in no specific direction in summer. Dall's porpoises displayed no consistent movement orientation during any season. While the movement patterns of the Dall's porpoise and minke whale may have been influenced by the vessel, since they were primarily recorded during vessel surveys, the other species showed no obvious negative reaction to the aircraft.

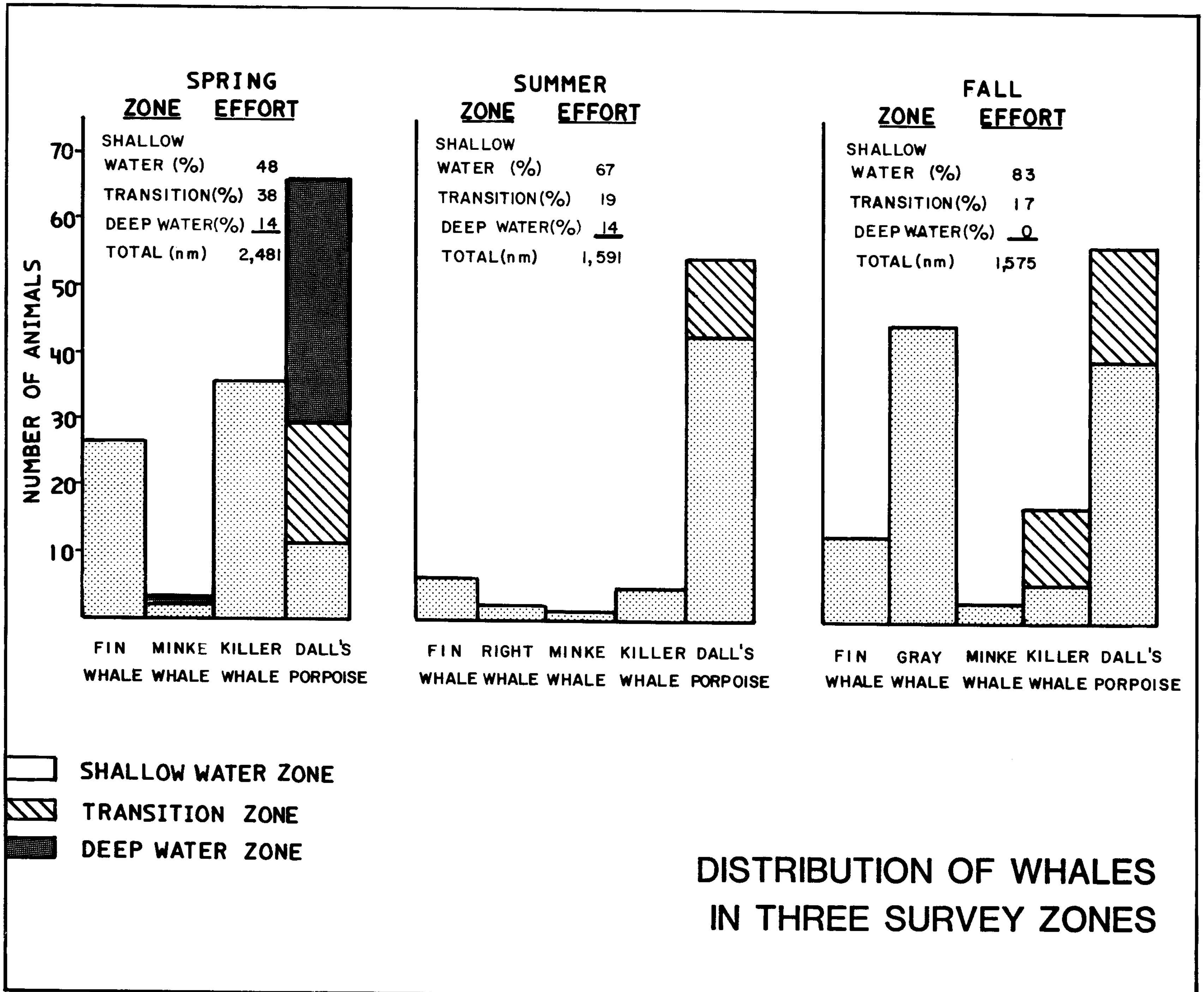

Figure 17 DISTRIBUTION OF WHALES AND PORPOISES IN THE THREE SURVEY ZONES OF THE NAVARIN BASIN DURING THE ICE-FREE PERIOD.

Most whales recorded in the Basin traveled in relatively large aggregations with animals clustered in small group sizes. This was particularly the case for fin and gray whales. In the spring, all 26 fin whales were within a 7 nm wide area, in the summer all 6 fins were in a 3 nm wide area, but in the fall they were more widespread. The average group size of 2.3 animals, however, did not differ significantly among seasons. The same situation was observed for gray and to a lesser degree killer whales which had average group sizes of 2.4 and 4.1 animals, respectively. All 44 gray whales were observed within approximately a 10 nm wide area and 25 of 35 killer whales within a 1 nm wide area; killer whales were widespread during the other seasons. Minke whales were very solitary, traveling as single animals each season. Less solitary, but widespread were Dall's porpoises, which were in group sizes averaging 3.9 animals. There was one observation of two right whales.

The combined results of the three seasonal surveys suggest that the Navarin Basin is a feeding area for species migrating through or summering in the Basin. Fin, right, minke, and killer whales and Dall's porpoises probably were resident in the Basin during the ice free period, while gray whales and some fin whales migrated through areas of the Basin to or from their feeding grounds. Fin whale occurrence and movements observed in the Basin agree with and expand upon reported findings that these whales migrate through the Basin in the spring to feed in the Gulf of Anadyr and in the fall to their wintering grounds in the Pacific Ocean, while some summer west of St. Matthew Island and off Cape Navarin (Berzin and Rovnin 1966, Nasu 1966, Nishiwaki 1974, Votorgov and Ivashin 1980, and Wada 1981). We observed fin whales moving toward the Gulf of Anadyr in the spring and away from the Basin in the fall, feeding in large aggregations. Conversely, fin whales observed during summer showed no directionality in their movements to suggest movement out of the Basin. Movements of minke and killer whales were less clear, but their irregular seasonal directionality and presence each season coincided with reports that these species probably reside in the Basin throughout the ice-free period (Lowry et al. 1982). Also resident were Dall's porpoises, as indicated by a consistent lack of directionality in movements and absence of large aggregations each season as documented in the literature by other researchers (Lowry et al. 1982, Bouchet 1982). The single season observations of right and gray whales suggested the former species may summer in historically used areas of the Basin (Scammon 1874, Townsend 1935, Wada 1981, Berzin and Doroshenko 1981), while gray whales seen in the fall moving through the northern third of the Basin in large aggregations and feeding, coincided with the timing of their fall migration from more northern summering grounds (Kuz'min and Berzin 1975, Braham In press, Rugh In press). Gray whales may have also summered in the Basin but were not encountered during the surveys because of the small proportion of the total area covered.

The distribution of whales in the Basin coincided with their reported feeding habits. Fin, right, and gray whales feed largely in shallow waters (Nemoto 1970). The former two species feed primarily on pelagic crustaceans including euphausiids and copepods (Tomilin 1957, Omura 1958, Klumov 1963, Nemoto 1959, Omura et al. 1969, Lowry et al. 1982), while gray whales feed on benthic invertebrates including gammarid amphipods (Pike 1962, Rice and Wolman 1971, Marquette and Braham 1982, Nerini and Oliver 1983). In years when euphausiids and copepods are not abundant in the Bering and Chukchi seas, fishes are of major importance in the diet of fin whales (Nemoto 1959, Klumov 1963). Correspondingly, we encountered these species of whales only on the shelf where waters are relatively shallow compared to the rest of the Basin and which typically support prey populations these species feed upon. The more generalized feeding habits of minke and killer whales and Dall's porpoises coincided with their wider distribution in the Basin. These species feed on squid, fishes, and euphausiids (only minke) which are distributed over the continental shelf, slope, and rise waters where these species occurred in the Basin (Nemoto 1959, Klumov 1963, Mizue et al. 1966, Nemoto 1970, Crawford 1981, Kajimura et al. 1980). Dall's porpoises were most widespread in the Basin and concurrently feed on the widest range of prey items (Crawford 1981). Some of the species may have been more widespread in the Basin than observed under the realized survey effort.

Estimated densities of whales observed in the Navarin Basin were compared to those reported by other researchers (Table 18). Caution must be taken in interpreting density comparisons for the following reasons: (1) all estimates are extremely variable with low degree of reliability, (2) estimation procedures vary, and (3) density estimates will differ greatly for stocks in feeding areas versus those obtained for the whole range of the species. For instance, North Atlantic Ocean estimates were derived from line-transect procedures, while those for the North Pacific Ocean and Gulf of Alaska were calculated from strip transect procedures; a combination of both procedures was used in estimates for the Bering Sea. The comparisons do, however, provide a relative index of abundance useful in describing the significance of the Navarin Basin to whales. Estimated densities of fin and minke whales in the Navarin Basin were below those reported in the North Atlantic Ocean (Scott et al. 1979), but were above those for right whales. Gulf of Alaska (Rice and Wolman 1982) estimates for fin whale densities were similar to the Basin, while those in the North Pacific Ocean (Nishiwaki 1974) were much lower; estimates for right and minke whales were not available for these two areas. Both estimated densities for gray whales and Dall's porpoises were below those reported for the Bering Sea (Bouchet 1982, Ljungblad et al. 1983). No comparable estimates were available for killer whales. Thus, estimated densities of whales in the Navarin Basin during the ice-free period were lower than elsewhere, except for fin and right whales, which were generally similar or higher. None of these estimates account for submerged animals.

TABLE 18

ESTIMATED DENSITIES OF WHALES AND PORPOISES REPORTED BY VARIOUS RESEARCHERS

Location	Source	Estimated density of whales and porpoises (no. per 100 nm^2)							
		Fin	Gray	Right	Bowhead	Minke	Killer	Beluga	Dall's
Bering Sea	Present study	0.62	1.07	0.11	1.04	0.05	1.71	2.82	4.85
N. Atlantic Ocean[a/]	Scott et al. (1979)	1.36	-[b/]	0.04	-	0.20	-	-	-
N. Pacific Ocean	Nishiwaki (1974)	0.04	-	-	-	-	-	-	-
Gulf of Alaska	Rice and Wolman (1982)	0.67	-	-	-	-	-	-	-
Bering Sea	Bouchet (1982)	-	-	-	-	-	-	-	21.62
Bering Sea	Ljungblad et al. (1983)[c/]	-	4.68	-	-	-	-	-	-
Bering Sea (marginal ice front)	Brueggeman (1982)	-	-	-	1.79	-	-	-	-
Bering Sea	Lowry et al. (1982)[d/]	-	-	-	-	-	-	2.46	-

a/ Study area was outer continental shelf of western Atlantic Ocean.

b/ Dash signifies no estimates available.

c/ Estimate was derived by dividing number of gray whales by total area surveyed as presented in Ljungblad et al. (1983).

d/ Estimate was derived by dividing estimated average population size of 16,500 animals by area of Bering Sea; the actual density is probably higher.

SEASONAL ICE PERIOD

Five species of whales wintered in the marginal ice front of the Navarin Basin. Bowhead and beluga whales occurred inside the front, while fin, minke, and killer whales utilized the fringe of the front. The latter three species are characteristically not found deep in the front, whereas an estimated population of 3,390 to 4,325 bowhead (IWC 1983) and 15,000 to 18,000 beluga (Lowry et al. 1982) whales winter in the sea ice of the Bering Sea (Brueggeman 1982). Consequently, to discuss abundance, distribution, and habitat use of ice covered areas by whales other than bowheads and belugas is inappropriate. Therefore, the discussion will center on these two species.

The distribution of bowheads and belugas in the marginal ice front appeared to be primarily influenced by ice conditions associated with the St. Matthew Island polynya. Suitable ice conditions for whales to occupy occurred throughout the front. In areas where ice concentrations were high, the ice was generally thin. Correspondingly, areas having thick ice usually had low concentrations. In fact, bowheads and belugas were encountered in the areas having the more extensive coverage, although the ice was thin enough for whales to freely move around. Therefore, it appears that ice in addition to other environmental factor(s) determine what is attractive habitat for these animals.

Another important factor appears to be St. Matthew Island, which was near the location of the whales. St. Matthew Island provides the physical setting for the creation of a persistent polynya (Stirling and Cleator 1981). The winds, which persist from the northeast during winter-spring, blow the ice southwesterly off the Island, resulting in a polynya. The polynya consists of a substantial area of open water in combination with new ice surrounded by heavier, more concentrated ice. Since the polynya is a persistent source of relatively open water, marine mammals may use it as a refuge from heavier ice.

The distribution of bowhead and beluga whales corresponded closely to the western fringe of the polynya. Although no animals were encountered in the polynya, which was thoroughly surveyed, they could still escape to it if ice conditions became unsuitable (compacted). The other borders of the polynya did not contain whales because these areas were heavily rafted with ice; the rafting was heavy enough to make penetration difficult for the icebreaker. The absence of use of the polynya proper is unclear, but a combination of high winds and open water could develop fairly high seas, possibly stressful to the animals. The influence of rough seas would be less important in the summer, when food is readily available and fat reserves are higher.

Brueggeman (1982) in surveys of the marginal ice front and interior pack ice in 1979, found concentrations of bowheads west of St. Matthew Island as well as west of St. Lawrence Island. The whales were also closely aligned with the polynyas associated with these two islands as well as the leeward side of the USSR coast. Over 77 percent of 109 whales were near the two islands in 1979. The whales appeared to winter near the two islands, then migrate north in spring to the Chukchi Sea. Densities in 1979 were similar to those observed during 1983 for bowheads. Beluga densities were also comparable to those estimated in the Bering Sea (Lowry et al. 1982).

SUMMARY

Four endangered species of whales - fin, right, gray, and bowhead - utilized the Navarin Basin during the ice-free and seasonal ice periods. Fin and right whales summered in the Basin. Gray whales and some fin whales moved through the Basin to either summering or wintering grounds elsewhere. All three species inhabited the shelf waters where they fed in water depths consistent with their foraging characteristics. Although no endangered whales were encountered beyond the shelf, some animals may have migrated through the deeper waters but were missed during the surveys. Densities of these species in the Basin were variable. Other species summering in the Basin were minke whales, killer whales, and Dall's porpoises.

Two endangered species of whales also wintered in the Navarin Basin during the seasonal ice period. Bowhead whales occurred in the marginal ice front while fin whales utilized the fringe ice of the front. The St. Matthew Island polynya appeared to be a refuge for bowhead whales from heavy ice conditions. These whales aligned themselves near the edge of the polynya. Surveys were not conducted in the open water or heavy pack ice of the Basin so the use of these areas by bowheads and fins was not known. Densities of bowheads in the Basin were similar to those reported in the literature for the Bering Sea ice front while comparable estimates for fin whales were not available since most winter south of the Aleutians. Other species of whales wintering in the Basin were minke, killer, and beluga whales.

In summary, fin whales utilized the Navarin Basin yearlong, while bowheads wintered and right whales summered there. Gray whales moved through the northern third of the Basin during fall. Of the species not classified as endangered, killer and minke whales also occurred in the Basin each season of the year, while belugas were present during the seasonal ice period, and Dall's porpoises were present during the ice-free period. No other whales were observed in the Navarin Basin.

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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.

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 SEA STATE SCALE
USED DURING AERIAL AND VESSEL SURVEYS

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 foam 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; while foam from breaking waves blown in streaks in direction of wind; spin drift	14	28-33
8	Moderately high waves of greater lengths; edges of crests break into span drifts; foam blown in well marked streaks	18	34-40

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.
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.

a/ Ice description 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

SUMMARY OF EVENTS DURING THE FOUR FIELD SEASONS, 1982-1983

SPRING FIELD SEASON

Date	Event
May 11	Left Kodiak Island for Navarin Basin
12	In transit to Navarin Basin
13	In transit to Navarin Basin
14	In transit to Navarin Basin
15	Arrived at St. Matthew Island to drop off U.S. Fish & Wildlife Service (USFWS) personnel but cancelled operation due to sea ice
16	Conducted vessel survey
17	Conducted vessel survey
18	Conducted aerial/vessel survey
19	Conducted aerial survey
20	Conducted aerial survey
21	Conducted aerial survey
22	Dropped off USFWS personnel at St. Matthew Island
23	Conducted aerial/vessel survey
24	Conducted vessel survey
25	Conducted vessel survey and left for Pribilof Islands to pick up Global Navigation System to replace one broken in helicopter
26	Left St. Paul for Navarin Basin
27	Arrived at Navarin Basin late in evening
28	Conducted aerial survey
29	Conducted aerial survey
30	Bad weather
June 1	Bad weather
2	Bad weather
3	Bad weather
4	Conducted vessel survey
5	Conducted aerial/vessel survey
6	Left Navarin Basin for Kodiak Island
7	In transit to Kodiak Island
8	In transit to Kodiak Island
9	In transit to Kodiak Island
10	Arrived at Kodiak Island

APPENDIX TABLE 4 (Continued)

SUMMER FIELD SEASON

July 20	Left Kodiak Island for Navarin Basin
21	In transit to Navarin Basin
22	In transit to Navarin Basin
23	In transit to Navarin Basin
24	In transit to Navarin Basin
25	Transferred USFWS personnel to St. Matthew Island and conducted aerial survey
26	Conducted vessel survey
27	Conducted aerial/vessel survey
28	Conducted aerial survey
29	Conducted aerial/vessel survey
30	Bad weather, collected bathymetry
31	Conducted vessel survey
August 1	Left Navarin Basin for Nome to repair ship
2	Spent day in Nome
3	Left Nome for Navarin Basin
4	Conducted vessel survey
5	Conducted aerial survey and left Navarin Basin for Pribilof Islands to medical evacuate fishermen
6	Left Pribilof Islands for Navarin Basin
7	Conducted vessel survey
8	Conducted vessel survey
9	Bad weather, left Navarin Basin for Pribilof Islands to evacuate crewman for funeral
10	Left Pribilof Islands for Navarin Basin
11	Picked up USFWS personnel at St. Matthew Island
12	Picked up USFWS personnel at St. Matthew Island
13	Bad weather, collected bathymetry
14	Conducted aerial/vessel survey
15	Left Navarin Basin for Kodiak Island
16	In transit to Kodiak Island
17	In transit to Kodiak Island
18	In transit to Kodiak Island
19	Arrived at Kodiak Island

APPENDIX TABLE 4 (Continued)

FALL FIELD SEASON

October 26	Left Kodiak Island for Navarin Basin
27	In transit to Navarin Basin
28	In transit to Navarin Basin
29	Conducted aerial survey
30	Bad weather
31	Bad weather
November 1	Bad weather
2	Conducted aerial/vessel survey
3	Bad weather
4	Conducted aerial survey
5	Conducted aerial survey
6	Conducted aerial survey
7	Bad weather
8	Conducted aerial survey
9	Bad weather
10	Conducted aerial survey
11	Bad weather
12	Bad weather
13	Left Navarin Basin for Dutch Harbor at Captain Sandquest's decision because of bad weather
14	Arrived at Dutch Harbor

WINTER FIELD SEASON

February 18	Left Dutch Harbor for Navarin Basin
19	Arrived at ice edge in evening
20	Conducted vessel survey
21	Conducted vessel survey
22	Conducted vessel survey
23	Conducted vessel survey
24	Conducted vessel survey
25	Conducted vessel survey
26	Conducted vessel survey
27	Conducted vessel survey
28	Conducted vessel survey
March 1	Conducted vessel survey
2	Conducted vessel survey
3	Conducted aerial/vessel surveys
4	Conducted aerial survey
5	Conducted aerial survey
6	Conducted vessel survey
7	Conducted vessel survey
8	Conducted vessel survey
9	Conducted vessel survey
10	Conducted vessel survey

APPENDIX TABLE 4 (Continued)

March 11	Conducted vessel survey
12	Conducted aerial survey
13	Conducted aerial survey
14	Conducted aerial survey
15	Conducted aerial survey
16	Conducted vessel survey
17	Bad weather
18	Left Navarin Basin for Dutch Harbor
19	Arrived at Dutch Harbor

APPENDIX TABLE 5
RECORD OF MARINE MAMMALS 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	OO	4	60° 10'N, 175° 41'W
5/21/82	PD	2	60° 06'N, 175° 38'W
5/21/82	OO	2	60° 07'N, 174° 34'W
5/21/82	OO	8	60° 07'N, 174° 34'W
5/21/82	OO	10	60° 07'N, 174° 34'W
5/21/82	OO	3	60° 07'N, 174° 34'W
5/21/82	OO	1	59° 55'N, 174° 29'W
5/21/82	OO	1	59° 55'N, 174° 29'W
5/21/82	OO	1	59° 45'N, 174° 18'W
5/21/82	OO	4	60° 01'N, 174° 18'W
5/28/82	PD	2	60° 18'N, 178° 36'W
5/29/82	BP	2	59° 47'N, 176° 59'W
5/29/82	BP	3	59° 46'N, 176° 59'W
5/29/82	BP	1	59° 46'N, 176° 59'W
5/29/82	BP	4	59° 46'N, 176° 59'W
5/29/82	BP	5	59° 46'N, 176° 59'W
5/29/82	BP	1	59° 46'N, 176° 59'W
5/29/82	BP	3	59° 46'N, 176° 59'W
5/29/82	BP	1	59° 41'N, 176° 59'W
5/29/82	BP	3	59° 41'N, 176° 59'W
5/29/82	BP	1	59° 41'N, 176° 59'W
5/29/82	BP	2	59° 40'N, 176° 43'W
5/17/82	PD	4	57° 49'N, 175° 9'W
5/17/82	PD	3	58° 10'N, 175° 9'W
5/17/82	PD	1	58° 14'N, 175° 25'W
5/18/82	PD	2	58° 08'N, 175° 55'W
5/18/82	PD	4	58° 07'N, 175° 55'W
5/19/82	PD	4	58° 13'N, 179° 32'W
5/20/82	PD	13	58° 13'N, 179° 00'E
5/20/82	BA	1	58° 13'N, 179° 29'E
5/20/82	PD	4	58° 13'N, 179° 42'E
5/20/82	PD	2	58° 13'N, 179° 46'E
5/20/82	PD	12	58° 13'N, 179° 47'E
5/20/82	PD	2	58° 13'N, 179° 49'E

[a] OO = killer whale, PD = Dall's porpoise, BP = fin whale, and BA = minke whale.

APPENDIX TABLE 5 (Continued)

SPRING SURVEY

Date	Species[a]	Number	Location
5/21/82	OO	1	59° 54'N, 174° 37'W
5/24/82	BA	1	60° 40'N, 176° 24'W
5/24/82	PD	1	60° 20'N, 176° 41'W
5/24/82	PD	5	60° 21'N, 176° 41'W
5/24/82	PD	2	60° 33'N, 176° 41'W
5/27/82	BA	1	60° 45'N, 174° 50'W
5/29/82	PD	2	59° 55'N, 176° 24'W

APPENDIX TABLE 5 (Continued)

SUMMER SURVEY

Date	Species[a]	Number	Location
7/28/82	BP	1	61° 03'N, 176° 41'W
7/28/82	BP	2	61° 05'N, 176° 41'W
7/28/82	BP	3	61° 06'N, 176° 41'W
7/28/82	BP	1	61° 03'N, 176° 57'W
7/28/82	PD	3	61° 19'N, 177° 17'W
7/28/82	PD	4	61° 20'N, 177° 26'W
7/28/82	OO	3	61° 03'N, 177° 47'W
7/28/82	PD	5	61° 03'N, 177° 47'W
7/28/82	PD	3	61° 11'N, 178° 21'W
7/29/82	PD	2	59° 59'N, 178° 51'W
7/26/82	BG	2	60° 48'N, 175° 18'W
7/28/82	PD	4	61° 03'N, 176° 11'W
7/28/82	PD	5	61° 03'N, 176° 12'W
7/28/82	PD	4	61° 03'N, 176° 18'W
7/28/82	BA	1	61° 03'N, 176° 36'W
7/28/82	PD	1	61° 03'N, 176° 43'W
7/28/82	PD	2	61° 03'N, 177° 04'W
7/28/82	PD	1	61° 03'N, 177° 09'W
7/28/82	PD	3	61° 03'N, 177° 12'W
7/28/82	PD	3	61° 03'N, 177° 18'W
7/29/82	PD	3	59° 55'N, 178° 49'W
7/31/82	PD	3	60° 03'N, 175° 22'W
7/31/82	PD	2	60° 04'N, 175° 22'W
8/04/82	OO	2	59° 40'N, 173° 30'W
8/08/82	PD	2	58° 17'N, 174° 54'W
8/08/82	PD	4	57° 50'N, 175° 25'W

a/ BG = Pacific right whale.

APPENDIX TABLE 5 (Continued)

FALL SURVEY

Date	Species[a]	Number	Location
10/29/82	PD	2	58° 30'N, 174° 44'W
10/29/82	OO	6	58° 08'N, 175° 10'W
10/29/82	OO	5	58° 08'N, 175° 10'W
10/29/82	PD	15	58° 21'N, 175° 10'W
11/2/82	PD	5	61° 03'N, 178° 21'W
11/4/82	BA	1	63° 00'N, 173° 35'W
11/4/82	BA	1	62° 57'N, 173° 35'W
11/4/82	OO	6	62° 46'N, 173° 31'W
11/4/82	BP	2	62° 30'N, 173° 35'W
11/4/82	BP	2	62° 28'N, 173° 30'W
11/4/82	ER	2	62° 53'N, 173° 18'W
11/4/82	ER	5	62° 51'N, 173° 18'W
11/4/82	ER	7	62° 51'N, 173° 18'W
11/4/82	ER	1	62° 52'N, 173° 18'W
11/4/82	ER	1	62° 54'N, 173° 18'W
11/4/82	ER	1	52° 54'N, 173° 18'W
11/4/82	ER	2	62° 56'N, 173° 18'W
11/4/82	ER	1	62° 56'N, 173° 18'W
11/4/82	ER	5	62° 56'N, 173° 18'W
11/4/82	ER	1	62° 57'N, 173° 18'W
11/4/82	ER	1	62° 58'N, 173° 18'W
11/4/82	ER	1	62° 58'N, 173° 18'W
11/4/82	ER	5	63° 00'N, 173° 18'W
11/4/82	ER	2	63° 00'N, 173° 18'W
11/4/82	ER	1	63° 01'N, 173° 12'W
11/4/82	ER	2	63° 01'N, 173° 07'W
11/4/82	ER	5	63° 01'N, 173° 12'W
11/4/82	ER	1	63° 01'N, 173° 05'W
11/4/82	BP	2	62° 34'N, 173° 00'W
11/4/82	BP	4	62° 33'N, 173° 00'W
11/4/82	BP	3	62° 31'N, 173° 00'W
11/5/82	PD	1	61° 15'N, 176° 32'W
11/6/82	BA	1	61° 13'N, 175° 17'W
11/10/82	BA	1	60° 10'N, 174° 30'W
11/10/82	PD	4	59° 39'N, 175° 21'W
11/4/82	UW	2	62° 45'N, 174° 21'W
11/4/82	UW	1	62° 45'N, 173° 19'W
11/5/82	PD	3	61° 03'N, 176° 25'W
11/5/82	PD	5	61° 03'N, 177° 08'W
11/5/82	PD	6	61° 03'N, 177° 33'W
11/10/82	PD	12	59° 55'N, 173° 48'W
11/10/82	PD	3	59° 55'N, 175° 06'W

[a] ER = gray whale.

APPENDIX TABLE 5 (Continued)

WINTER SURVEY

Date	Species[a/]	Number[b/]	Location
3/3/83	BA	1	60° 41'N, 179° 37'W
2/28/83	BP	6	60° 41'N, 179° 37'W
2/28/83	OO	6	60° 55'N, 178° 17'W
2/28/83	OO	1	60° 55'N, 178° 17'W
3/12/83	BM	3	60° 17'N, 173° 52'W
3/12/83	BM	1	60° 09'N, 174° 20'W
3/12/83	BM	1	60° 09'N, 174° 20'W
3/12/83	BM	12	59° 54'N, 174° 20'W
3/12/83	BM	2	60° 00'N, 174° 28'W
3/13/83	BM	1	60° 04'N, 174° 16'W
3/13/83	BM	1	60° 04'N, 174° 16'W
3/13/83	BM	1	60° 12'N, 174° 04'W
3/13/83	BM	1	60° 14'N, 174° 01'W
3/13/83	BM	1	60° 12'N, 173° 56'W
3/13/83	BM	1	60° 17'N, 173° 57'W
3/13/83	BM	1	60° 19'N, 173° 56'W
3/13/83	BM	1	60° 10'N, 173° 52'W
3/13/83	BM	1	60° 09'N, 173° 53'W
3/13/83	BM	1	60° 09'N, 173° 53'W
3/13/83	BM	1	60° 17'N, 173° 57'W
3/14/83	BM	1	60° 35'N, 173° 48'W
3/15/83	BM	1	59° 47'N, 173° 24'W
3/12/83	DL	11	59° 58'N, 174° 11'W
3/12/83	DL	4	59° 57'N, 174° 13'W
3/12/83	DL	5	59° 58'N, 174° 16'W
3/12/83	DL	2	59° 58'N, 174° 16'W
3/12/83	DL	25	60° 04'N, 174° 20'W
3/12/83	DL	2	60° 04'N, 174° 20'W
3/12/83	DL	2	60° 04'N, 174° 20'W
3/12/83	DL	6	59° 54'N, 174° 20'W
3/12/83	DL	2	59° 54'N, 174° 20'W
3/12/83	DL	8	59° 56'N, 174° 20'W

a/ BM = Bowhead, DL = Beluga
b/ Duplicate counts of bowhead and beluga whales may have occurred during the 12 and 13 March surveys.

APPENDIX TABLE 5 (Continued)

WINTER SURVEY

Date	Species[a/]	Number[b/]	Location
3/12/83	DL	4	59° 55'N, 174° 28'W
3/12/83	DL	1	59° 55'N, 174° 28'W
3/12/83	DL	2	60° 00'N, 174° 28'W
3/12/83	DL	12	59° 57'N, 174° 28'W
3/12/83	DL	6	59° 55'N, 174° 32'W
3/12/83	DL	7	59° 55'N, 174° 32'W
3/12/83	DL	6	59° 54'N, 174° 32'W
3/12/83	DL	6	59° 56'N, 174° 33'W
3/12/83	DL	2	59° 56'N, 174° 33'W
3/12/83	DL	3	59° 56'N, 174° 33'W
3/12/83	DL	1	59° 57'N, 174° 33'W
3/12/83	DL	3	59° 58'N, 174° 32'W
3/12/83	DL	3	59° 58'N, 174° 32'W
3/12/83	DL	6	59° 55'N, 174° 32'W
3/13/83	DL	433	60° 19'N, 174° 22'W
3/14/83	DL	13	60° 44'N, 173° 50'W
3/14/83	DL	3	60° 44'N, 173° 50'W
3/14/83	DL	18	60° 44'N, 173° 50'W
3/14/83	DL	2	60° 44'N, 173° 50'W

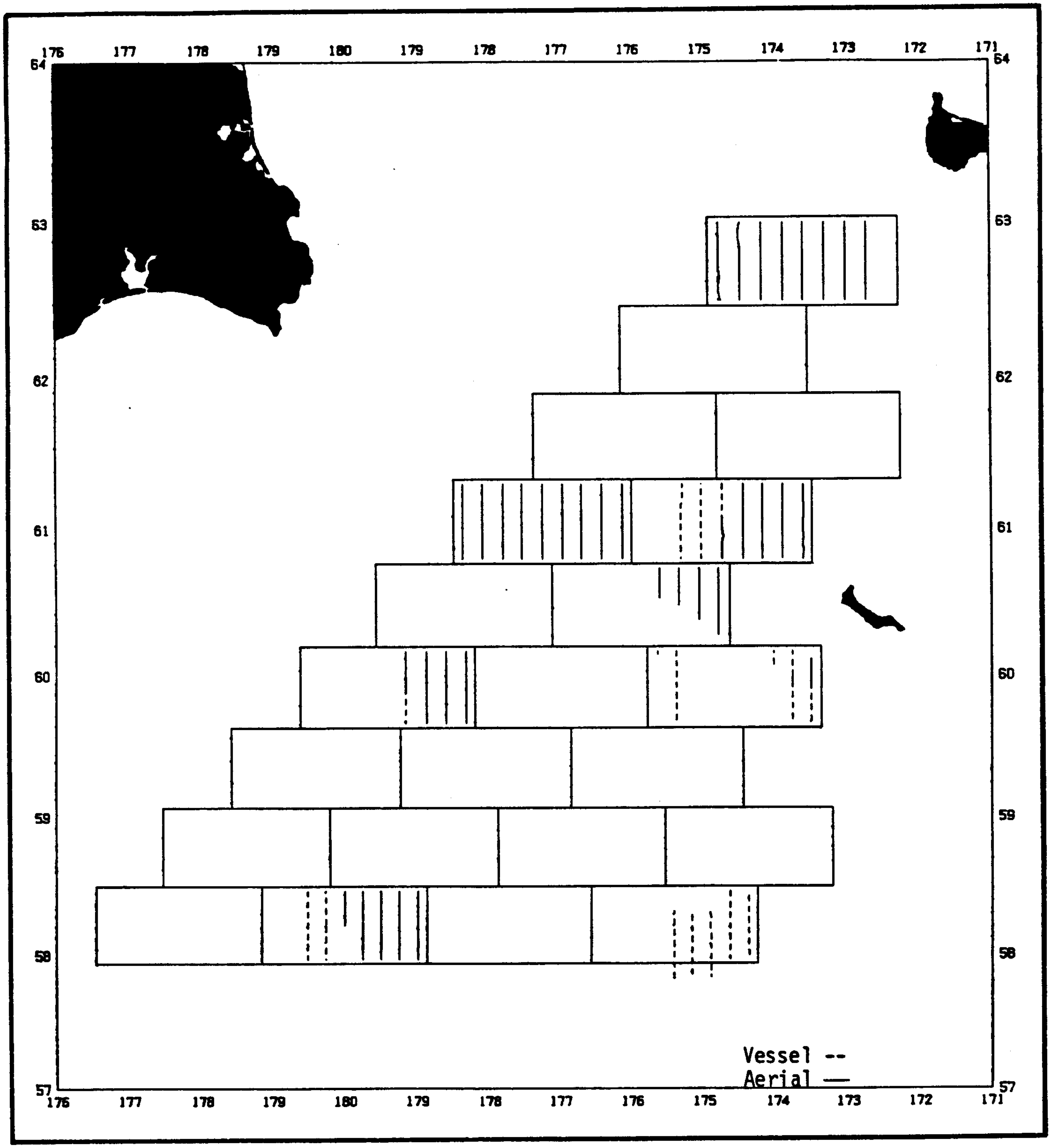


FIGURE 1 LOCATION OF AERIAL AND VESSEL TRACKLINES SURVEYED IN THE NAVARIN BASIN DURING SPRING, MAY - JUNE 1982.

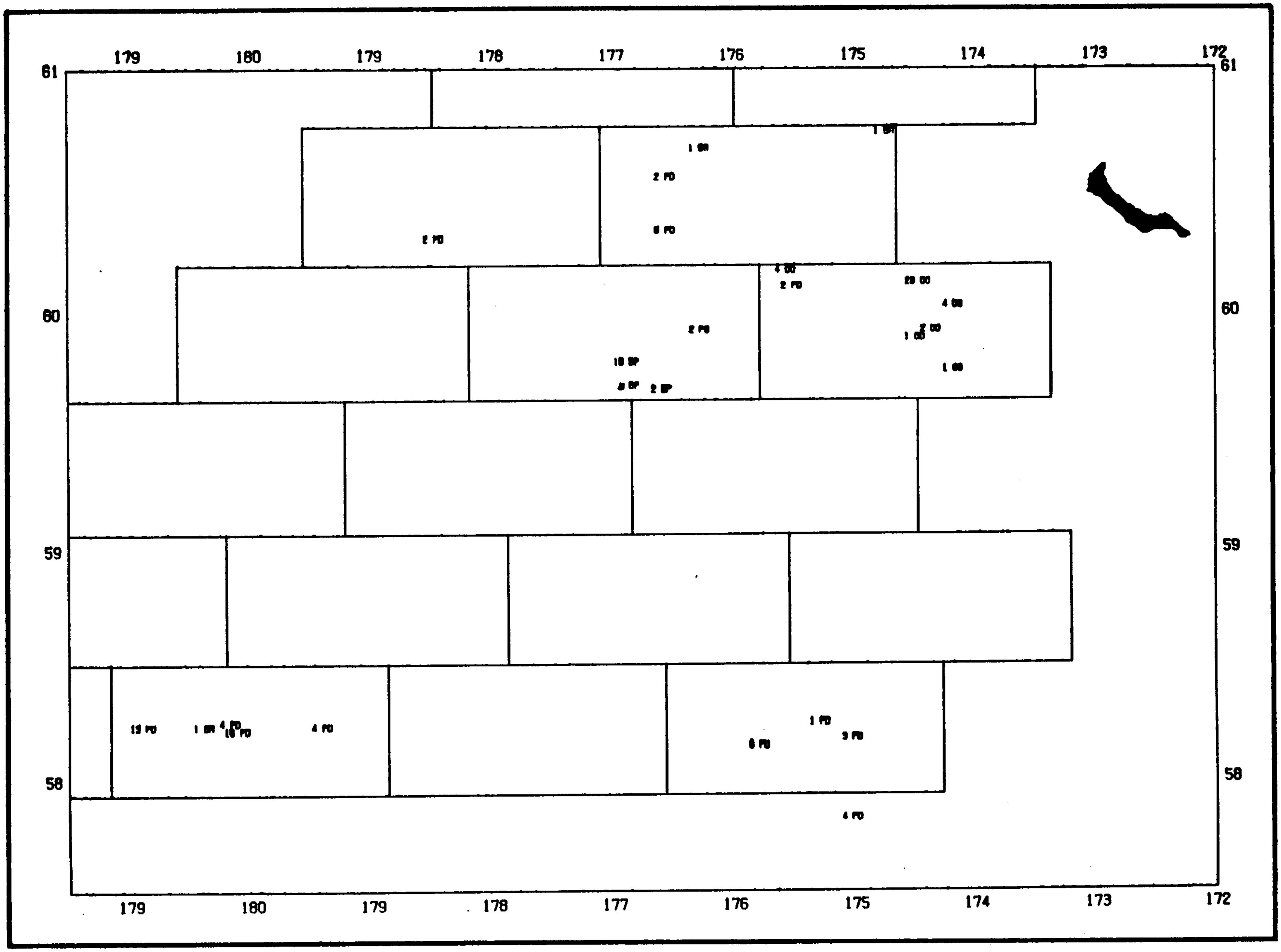


FIGURE 2 LOCATION OF WHALES OBSERVED IN THE NAVARIN BASIN DURING THE SPRING SURVEYS, MAY – JUNE 1982.

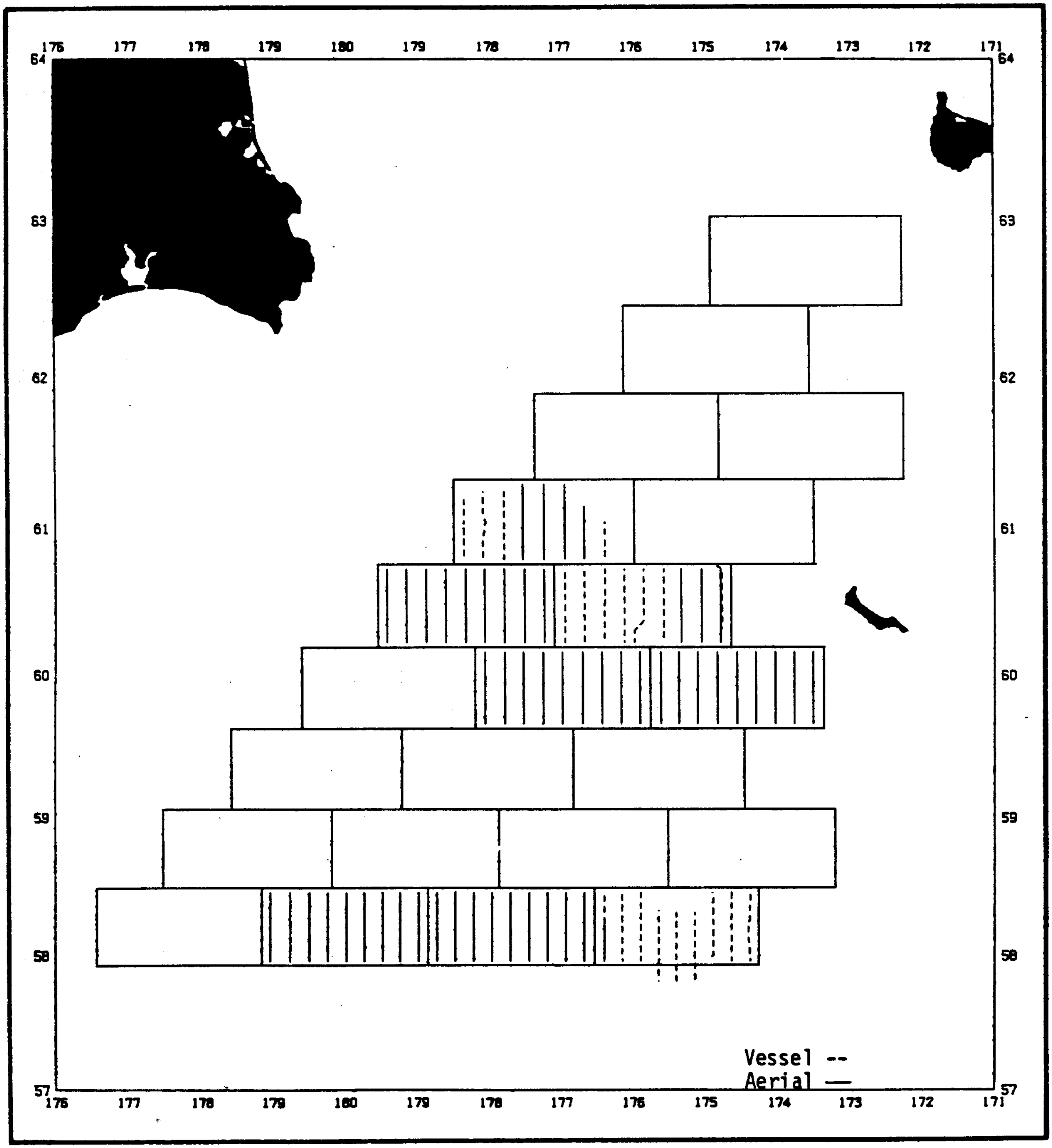
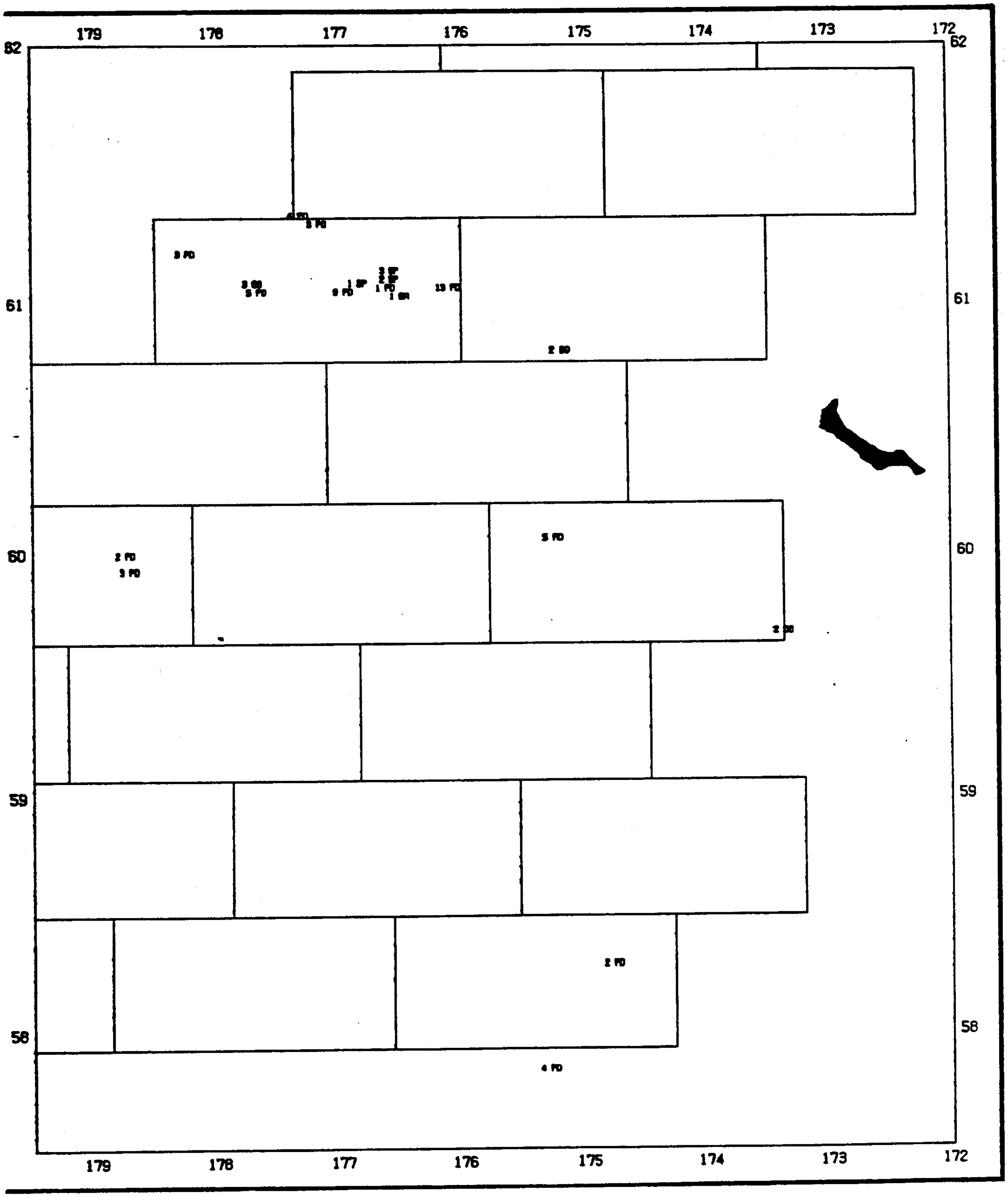


FIGURE 3 **LOCATION OF AERIAL AND VESSEL TRACKLINES SURVEYED IN THE NAVARIN BASIN DURING SUMMER, JULY - AUGUST 1982.**



IGURE 4 LOCATION OF WHALES OBSERVED IN THE NAVARIN BASIN DURING THE SUMMER SURVEYS, JULY - AUGUST 1982.

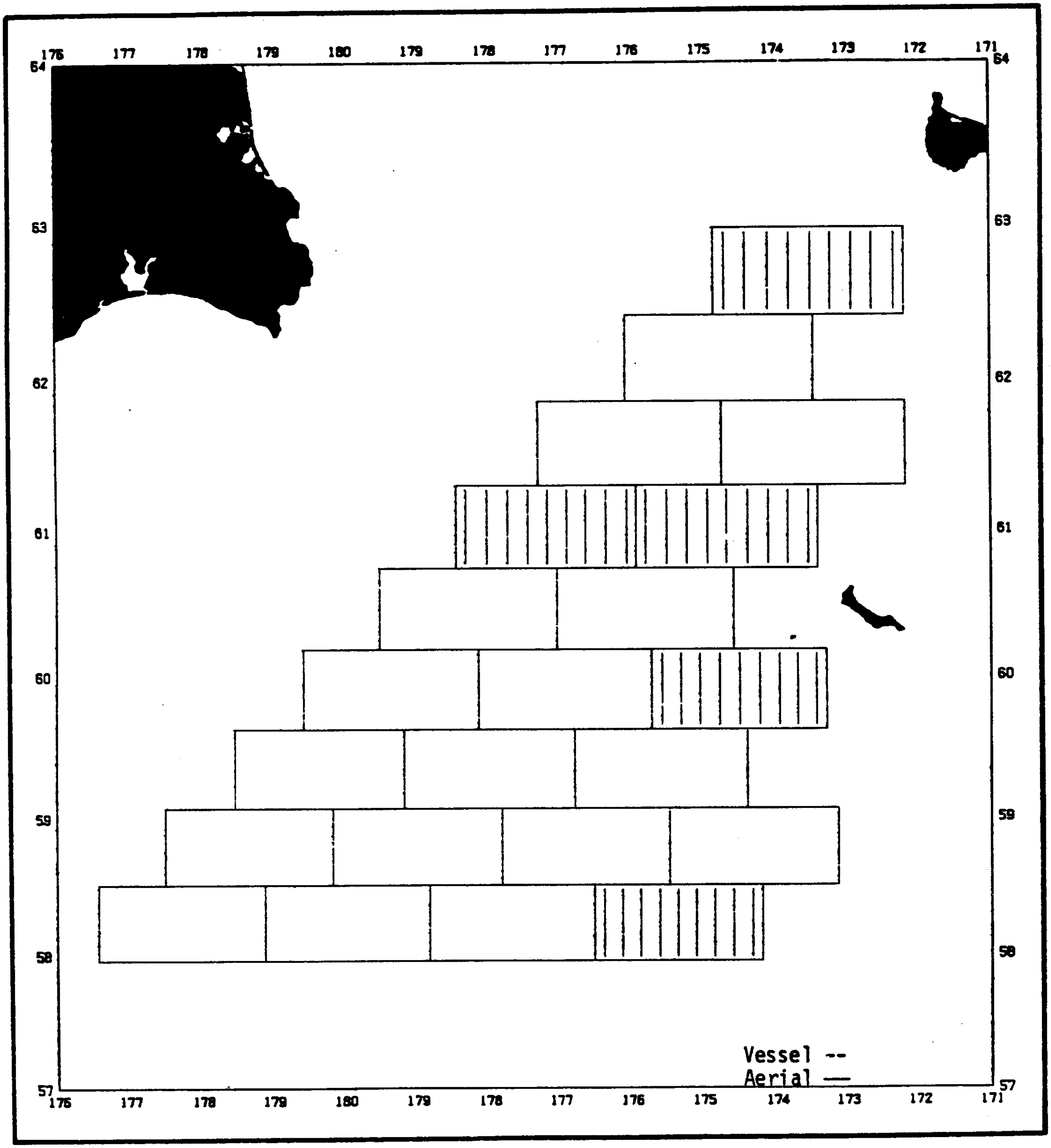


FIGURE 5 **LOCATION OF AERIAL AND VESSEL TRACKLINES SURVEYED IN THE NAVARIN BASIN DURING FALL,OCTOBER-NOVEMBER 1982.**

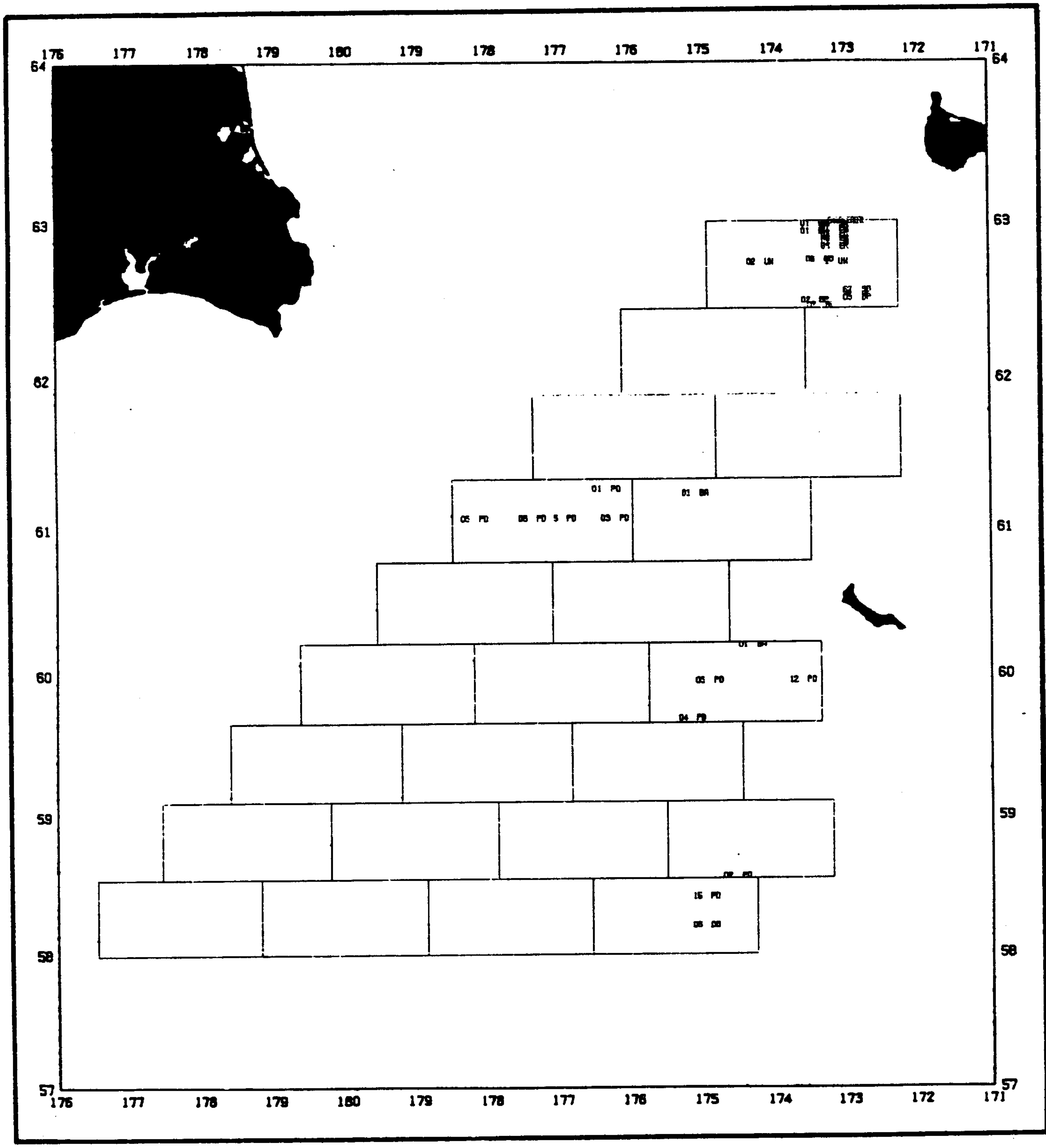


FIGURE 6 LOCATION OF WHALES OBSERVED IN THE NAVARIN BASIN DURING THE FALL SURVEY, OCTOBER-NOVEMBER 1982.

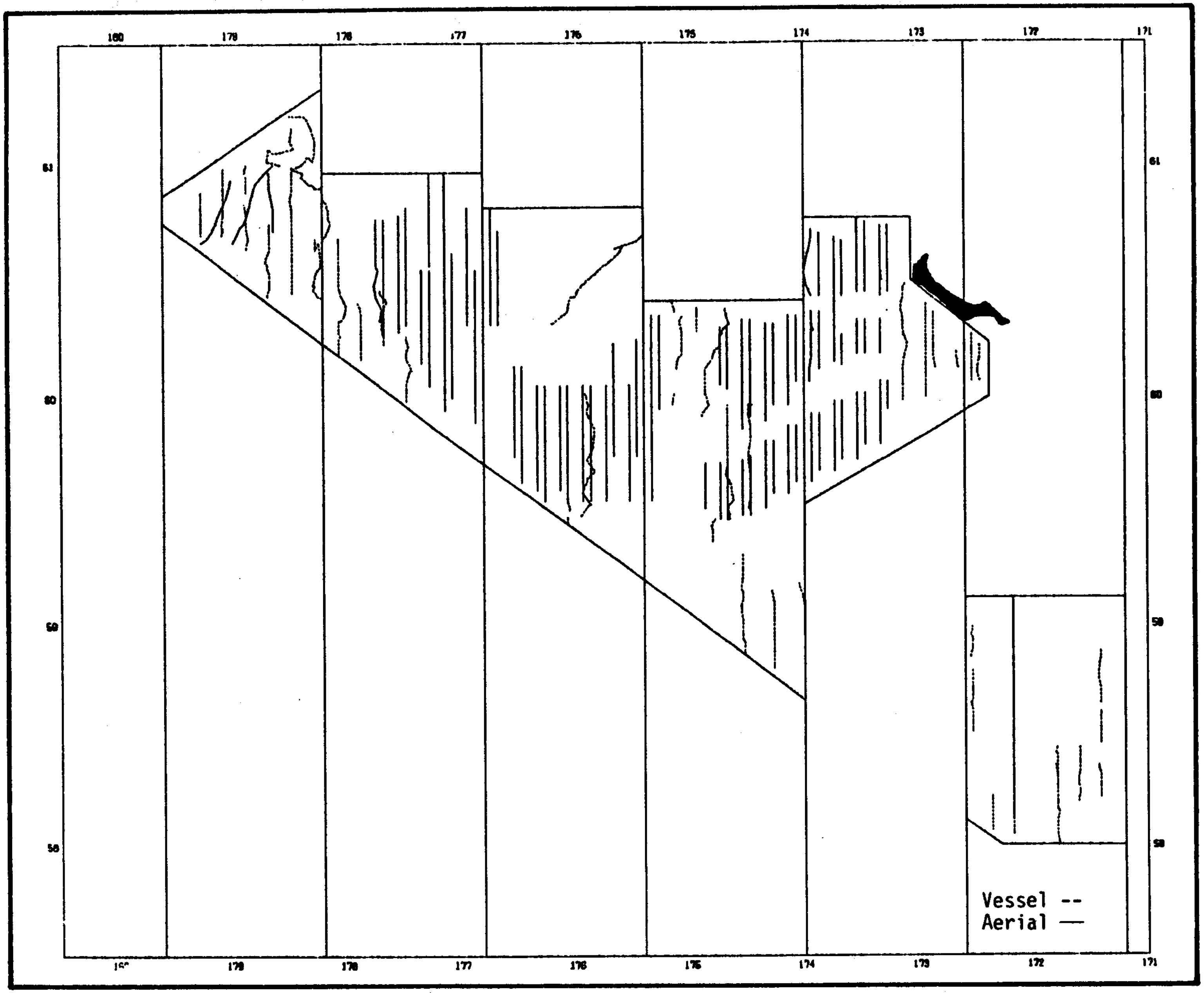


FIGURE 7 **LOCATION OF AERIAL AND VESSEL TRACKLINES SURVEYED IN THE NAVARIN BASIN DURING WINTER, FEBRUARY - MARCH 1983.**

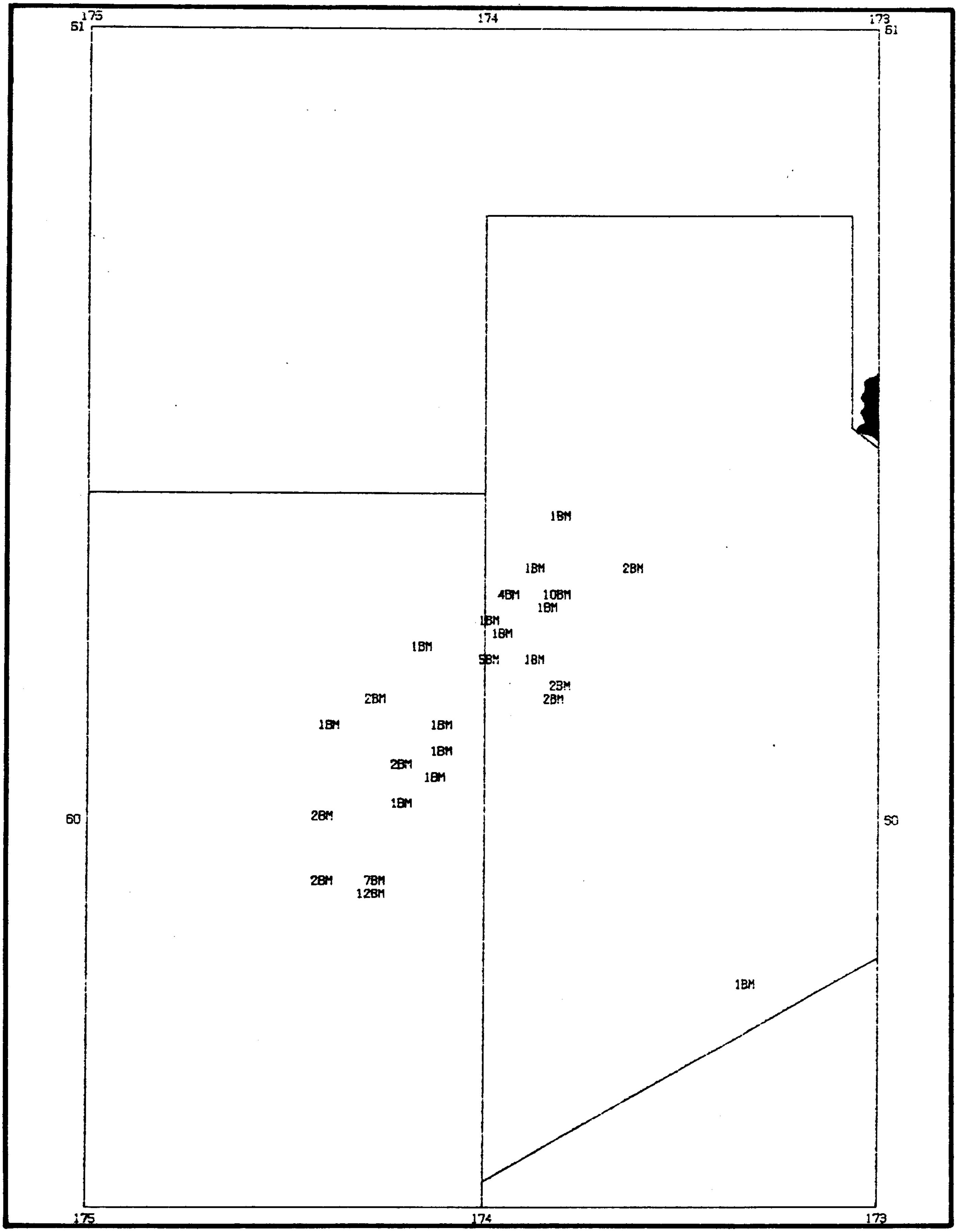


FIGURE 8 **LOCATION OF WHALES OBSERVED IN THE NAVARIN BASIN DURING THE WINTER SURVEY, FEBRUARY – MARCH 1983 (includes duplicate sightings).**

APPENDIX B

APPENDIX B

Line-transect theory was used to estimate densities and abundances of whales in the Navarin Basin as an alternative to the strip transect approach (Appendix Table B-1). Line-transect was not the primary method employed because the underlying assumptions of the theory may not have been met. The assumptions are:

1. Groups directly on the line will never be missed (i.e., they are seen with probability 1).

2. Groups are fixed at the initial sighting position; they do not move before being detected and none are counted twice.

3. Distances and angles are measured exactly; thus, neither measurement errors or rounding errors occur.

4. Sightings of groups are independent events.

Sample sizes achieved during the surveys were insufficient to test these assumptions. Sightability curves, developed from histograms of perpendicular sighting distances, indicated assumption 1 may have been violated (Figure B-1). Visibility of the line under the aircraft may have been obstructed since the sightability curves were not constantly decreasing functions. Small sample sizes may have contributed to the form of the curve; a larger sample size may have fit the data to a curve conforming to assumption 1. Failure to count all animals on the line (or in the strip for the strip transect method) underestimates the number of animals censused. Assumptions 2 and 3 are difficult to assess relative to the survey data; however, angles to animals were carefully measured by observers and flight patterns were designed to reduce duplicate counts of animals; whales certainly moved before they were seen. Because of difficulties in meeting the assumptions of line transect theory, and failure to obtain a minumum sample size of 40 observations (Burnham et al. 1980), the population estimates derived from this procedure should be viewed with caution, but are provided to show that alternative estimation approaches were applied to the data.

Line-transect sampling procedures were used to estimate numbers of fin, gray, and minke whales in each survey zone of the Basin (Table B-1). Pooled sighting data for gray, fin, and minke whales recorded during aerial surveys were used to estimate the essential parameter f(o), which is the sighting probability density function evaluated at a perpendicular distance of zero. Since the sightabilities of these whales are generally similar, the data were pooled to increase the sample size for estimating f(o). Sighting data for the other species of whales in the Basin or that data associated with the vessel surveys were not used in this analysis because of extremely small sample sizes of whale observations. The estimation of f(o) is described by Burnham et al. (1980).

For each species, the density of groups (D_{gi}) was calculated by sampling unit, then summed for each zone, i, as follows:

$$D_{gi} = \frac{n_i \, f(o)}{2L_i} \tag{1}$$

where: n_i = the number of groups observed during systematic surveys of transect lines in zone i.

f(o) = the pooled species sighting probability density at a perpendicular distance of zero.

L_i = the total transect line length in zone i.

The variance of group density was calculated as:

$$Var(D_{gi}) = (D_{gi})^2 \quad \frac{Var\ (n_i)}{(n_i)^2} + \frac{Var\ f(o)}{f(o)^2} \tag{2}$$

$$\text{with} \quad Var\ (n_i) = L \sum_{i=1}^{k} \frac{l_i \left[\frac{n_i}{l_i} - \frac{n}{L} \right]^2}{R - 1} \tag{3}$$

where l_i = the length of individual transect line
R = the total number of transect lines

The density of individuals (D_{ii}) is calculated as:

$$D_{ii} = D_{gi}\overline{g} \tag{4}$$

where $\overline{g}$ = the mean group size for a particular species

The number of animals in each survey zone was estimated as:

$$N_i = D_{ii}\ A_i \tag{5}$$

where: A_i = area of a survey zone

The number of animals of each species was calculated as:

$$N = \sum_{i=1}^{k} N_i \tag{6}$$

where: k is the number of survey zones.

Its variance was estimated as:

$$Var(N) = (D_{gi})^2\ Var(\overline{g}) + (\overline{g})^2\ Var(D_{gi}) \tag{7}$$

where: $Var(\overline{g}) = \frac{Var(g)}{n}$

The variance of n_i ($Var(n_i)$) was estimated empirically using equation 1.24 (p. 54) of Burnham et al. (1980). The variance of f(o) is a theoretical variance calculated according to the particular sighting model. Equations (1), (2), and (3) are taken from Burnham et al. (1980), while equations (4) to (7) were developed by D.G. Chapman for special situations of the present aerial survey.

Approximately ninety-five percent confidence intervals for the estimates of N were estimated as follows:

$$N \pm Z_{0.05}\sqrt{Var\ (N)}$$

Use of the Z statistic assumes the estimates are normally distributed; however, in view of the small sample sizes this is only approximately correct.

Program TRANSECT (Laake et al. 1979) was used to calculate f(o) for pooled data of fin, gray, and minke whales. For all cases, ungrouped sighting data were used for each species but all species were pooled and the Fourier series estimator of f(o) was used. The data were applied to numerous standard parametric estimators (normal, half normal, exponential, negative exponential, power series, etc.), but the Fourier series provided the best representation of all data sets. Moreover, this estimator is a non-parametric procedure that is model robust and pooling robust and its estimation efficiency for the small sample sizes is quite good (Burnham et al. 1980).

The line-transect estimates presented in Table B-1 are generally higher than the strip transect estimates. Although this is a typical characteristic of the line-transect procedure, differences between the two types of estimates were not significantly different, i.e., the estimates fell within the confidence intervals.

APPENDIX TABLE B-1

ESTIMATED ABUNDANCE OF ENDANGERED WHALES IN THE NAVARIN BASIN FROM LINE-TRANSECT SAMPLING PROCEDURE

Species[a/]	Season	Study area (nm^2) (A)	Transect length (nm) (L)	Number of groups (n_i)	Density (groups/nm^2) (Dg_i)	Mean[b/] group size (g)	Standard deviation of group size	Density (individuals/nm^2) (Dii)	Abundance (N)	Variance (Var(N))	95 percent confidence interval for line transect	95 percent[c/] confidence interval for strip transect
Fin whale	Spring	41,770	1,568	10	0.0049	2.37	1.16	0.0115	481	237,175	481±955	259±826
Fin whale	Summer	54,078	954	3	0.0012	2.37	1.16	0.0028	154	12,695	154±221	84±267
Fin whale	Fall	46,699	1,330	3	0.0017	2.37	1.16	0.0040	186	34,439	186±364	225±597
Gray whale	Fall	46,699	1,330	10	0.0056	2.44	1.98	0.0134	627	393,522	627±1299	500±1326
Minke Whale	Fall	46,699	1,330	2	0.0011	1	1	0.0011	51	1,279	51±70	25±66

a/ Bowhead whale abundance was not estimated because the data poorly fit standard parametric (negative exponential, exponential, half-normal, etc.) and non-parametric (Fourier series) estimation models.

b/ Mean group size of fin whales did not differ significantly (F=3.31, 2, 31df, P 0.10) among seasons so the data were pooled to obtain a single group size figure.

c/ Abundance estimates from strip transect sampling procedure are included for comparison to those derived from line-transect sampling procedures.

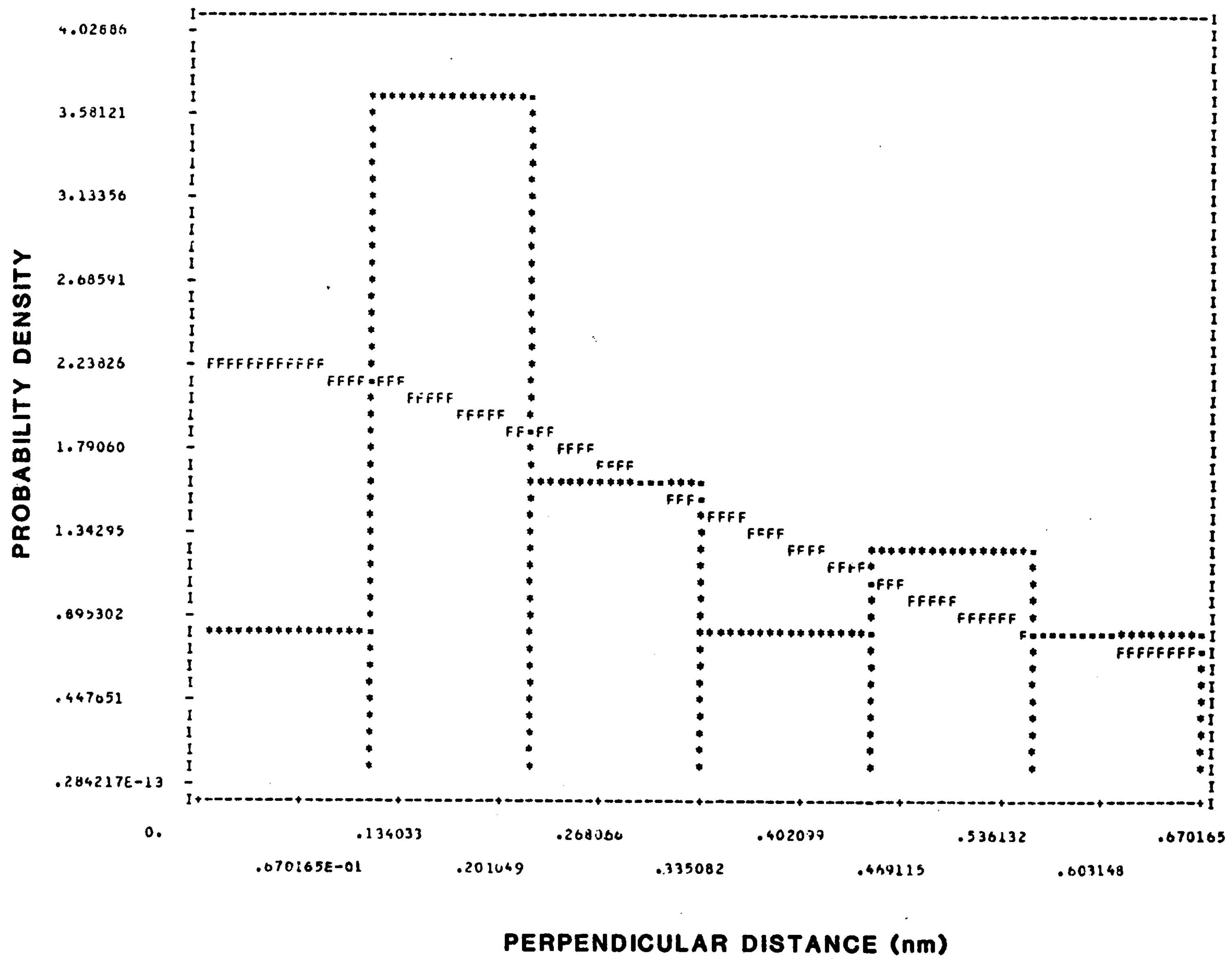


FIGURE 1 THE FOURIER SERIES ESTIMATOR OF THE PROBABILITY DENSITY FUNCTION OF PERPENDICULAR DISTANCE FIT TO THE HISTOGRAM OF THE DATA FOR ALL LARGE WHALE (FIN,GRAY,MINKE) SIGHTINGS.

APPENDIX C

APPENDIX C

INSTRUCTION MANUAL FOR HP-21C PROGRAM TO GUIDE HELICOPTOR ON SURVEY TRACKLINES FROM VESSEL

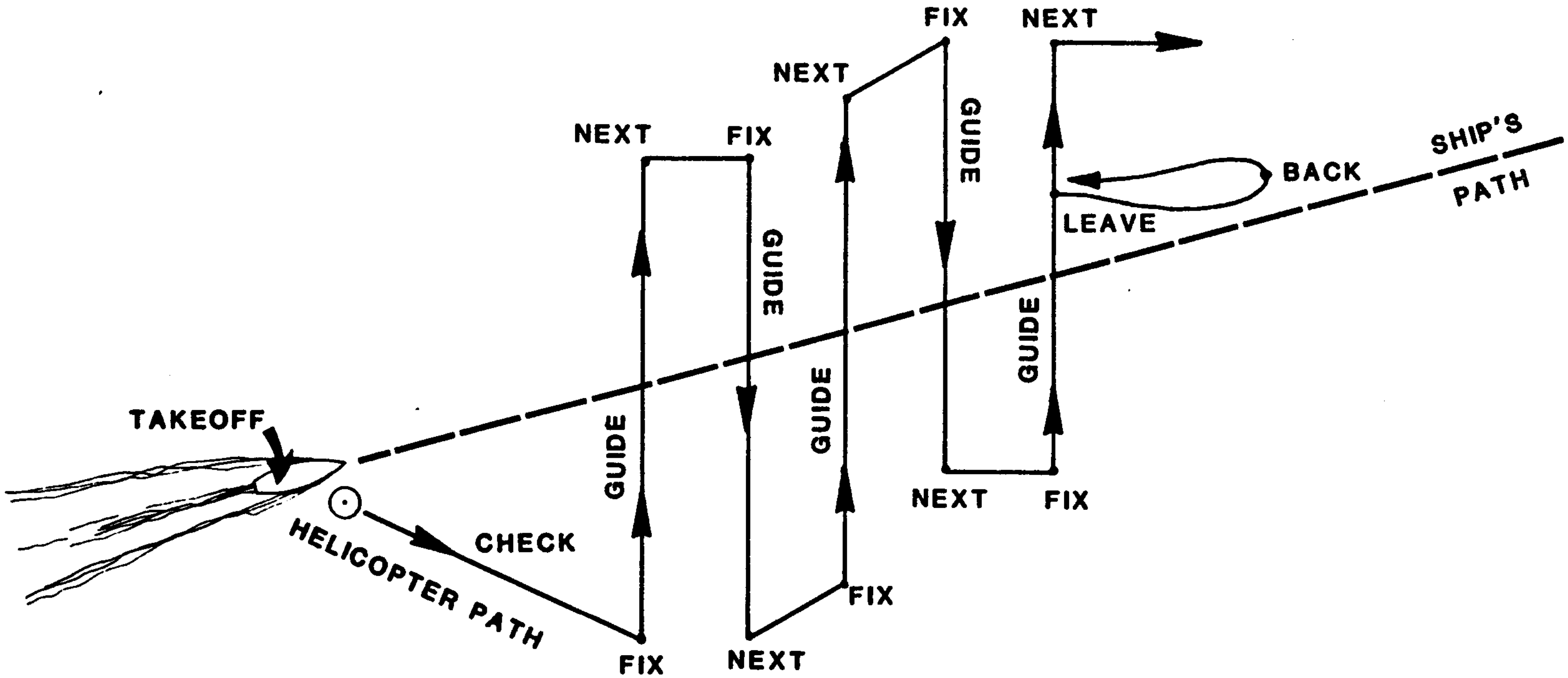
TABLE OF CONTENTS

I. INTRODUCTION

A series of programs was developed specifically for helicopter navigation during the 1983 winter aerial survey of endangered cetaceans in the Navarin Basin. Helicopter navigation systems (Loran C and radar) have broken down at critical times in past surveys, necessitating a reliable, independent navigation system. Since the tracklines are systematically placed within randomly chosen units, the helicopter must be guided along specific tracklines. Failure of the normal guidance systems, resulting in erratic survey tracklines, invalidates data collected. Thus, programs were developed to ensure a successful research effort.

The development and logic of the programs coincided with the sequence of conducting an aerial survey (Figure C-1). Independent of Loran C or radar guidance systems, the helicopter possesses instrumentation to determine the bearing and distance back to the ship and the ship knows its own location. Based on that information, plus time, ship speed and course, and helicopter speed, a tracking system was developed. The normal sequence of events during a survey is as follows: the helicopter takes off from the ship, proceeds to the start of the first survey trackline, travels north or south surveying mammals to end of trackline, and then flies east or west to the next survey trackline. The helicopter returns to the ship to end the survey and/or to refuel. During a flight, normal operations can be interrupted to resurvey a trackline or to investigate a sighting.

The observers in the helicopter may adjust the starting and ending locations of tracklines to survey within the proper habitat (i.e., marginal ice front).



After TAKEOFF from the vessel, the helicopter proceeds to the start of the trackline with its progress CHECKed along the way. Once there, its location is FIXed and it is GUIDEd along the trackline to the end. Then the helicopter is directed to the NEXT trackline's starting point where its location is again FIXed. This pattern is altered only when the helicopter LEAVEs the trackline for a random search afterwhich it is guided BACK to that point of departure.

FIGURE 1 **STAGES OF INITIATION OF DIFFERENT PROGRAMS USED IN NAVIGATING HELICOPTER ALONG TRACKLINES DURING WHALE SURVEY.**

The programs were developed to run on a Hewlett Packard (HP) 21C programmable calculator with a quad memory module, time module, navigation module, and printer. A general understanding of how to operate the calculator, its modules, and accessories is necessary to fully understand this manual.

There are 319 registers available on the HP-41C with the quad memory module. There are 7 bytes per register. Size 070 is entered to reserve registers 0 through 70 for data storage and module subroutines. The first 19 registers are reserved for module subroutines, although actual module subroutines occupy only registers 0 through 10. After the program is stored, there are 23 of the total 379 registers left.

Programs produce the results on paper with time written as "NEW TIME" or "OLD TIME", so that log sheets can be filled in after completion of surveys. Also, the ship's location is output so that its path and the helicopter's path can be mapped during the surveys. All programs can be stored on magnetic cards to be reloaded if program memory fails.

The following procedures are necessary to operate the program:

1. At the start of a trackline and while on a trackline, the operator gives the helicopter a bearing to head for 3 minutes to be on trackline.

2. If helicopter is less than 3 minutes from the end of a trackline, the operator provides bearing and time to the end point.

3. If helicopter leaves the trackline for random or replicate search, the helicopter pilot gives bearing and distance from ship to calculator operator and says "leaving line".

4. On south and north replicate searches, operator initiates program "LEAVE", at which time helicopter turns 180° and searches the area. When done, helicopter radios its distance and bearing to ship and ship guides helicopter back to point of departure from trackline. If the helicopter wants to make several more passes along a section of trackline, it goes to the original point of departure and informs the operator that it is leaving the trackline for another replicate. If the helicopter wants the turning point locations documented, helicopter will say "FIX" to operator and observers will write the time in their logsheets and get the location when back on ship.

5. Only one helicopter is guided; a second must tag along.

6. Course of helicopter is stored before "GUIDE" or "NEXT" program are executed.

7. Beginning latitude (BL2) and longitude (BLO2), and ending latitude (EL2) and longitude (ELO2) of each line are always entered.

8. East longitude is entered as a negative number by operator.

II. DESCRIPTION AND OPERATION OF PROGRAMS

A. DESCRIPTION OF PROGRAMS

"GUIDE"	Guides helicopter along trackline. Will give a heading to follow for 3 minutes. If less than 3 minutes to end of trackline, will notify helicopter. If greater than 3 minutes, will head helicopter straight back to trackline (east or west) and provide number of minutes to trackline.
"NEXT"	Given heading observers want to follow, provides number of minutes to start of next trackline and whether to head north or south when there.
"SHIP"	Gives location of ship at time indicated by words "NEWTIME".
"STD"	Converts speed of ship to distance.
"POS"	Calculates position of ship.
"HELI"	Gives position of helicopter at time indicated by words "NEWTIME" without storing it back in registers.
"HELIP"	Gives position of helicopter projected to where it will be when program execution stops.
"HELIR"	Gives position of helicopter at time indicated by words "NEWTIME" and stores it back in registers.
"PROJECT"	Used by program "HELIP" to take into account running time. Projects helicopter position to where it will be when program finishes.

"FIX"	Fixes location of an animal, trackline starting point, a turning point, or other notable marks. Outputs data on paper for later entry into logsheets.
"TAKEOFF"	Guides helicopter from ship to start of first trackline.
"OUTPUT"	Displays program results.
"NS"	Determines whether to head north or south on a trackline.
"CHECK"	Adjusts course from helicopter "TAKEOFF" to ensure starting point of trackline is reached.
"LEAVE"	Identifies location where helicopter leaves systematic trackline for replicate or random search.
"BACK"	Guides helicopter back to location recorded by "LEAVE".

B. INTERACTION OF PROGRAMS

Program	Uses	Seconds to Run (should be tested on ship)
GUIDE	HELIP GC[a/] GCPOS[a/] NS	88
NEXT	HELIR GC[a/] GCPOS[a/]	77
SHIP	STD POS	23
STD	None	
POS	GCPOS[a/]	
HELI	SHIP GCPOS[a/]	
HELIP	SHIP GCPOS[a/] PROJECT	
HELIR	SHIP GCPOS[a/]	

[a/] Denotes a subroutine of the HP navigation module for the HP-21C calculator.

Program	Uses	Seconds to Run (should be tested on ship)
PROJECT	GCPOS[a/]	
FIX	HELI	31
TAKEOFF	SHIP GC[a/] OUTPUT	42
OUTPUT	None	
NS	None	
CHECK	HELIP OUTPUT GC[a/] NS	66
LEAVE	HELI	60
BACK	HELI GC[a/]	55

C. VARIABLE LIST WITH STORAGE REGISTERS AND NOTES[a/]

Description	Variable	Register	Notes
Ship latitude (lat) source	SL1	17	d.d.
Ship longitude (long) source	SL01	18	d.d.
Ship course	SC	19	d.d
Ship speed	SS	20	knots
Calculated time helicopter (heli) to destination lat & long	TC	23	decimal minutes
Newtime (time when program executes)	NT	24	decimal hours
Oldtime (when SL1, SL01, first entered)	OT	25	decimal hours
Time difference of ship	TDS	26	
Time difference of heli	TDH	27	
Time of heli to end of trackline	TEL	28	minutes decimal
Distance of ship oldtime to newtime	DS	29	
Distance perpendicular trackline to heli	DP	30	used in GUIDE, NEXT
Distance heli must travel on hypotenuse	DH	31	
Distance from where DP intersects line to point where DH intersects line	DI	32	used in GUIDE, NEXT
Distance of heli to ship	DHS	33	
Distance of heli back to trackline after random or replicate	DB	34	
Distance of heli to beginning of trackline	DHB	35	

a/ n.m. = nautical miles; d.d. = decimal degrees; d.h. = decimal hours; d.m.s. = degrees minutes seconds; d.m. = decimal minutes; h.m.s. = hours minutes seconds. If input is needed in decimal the Hewlett Packard function HR must be executed after the h.m.s. or d.m.s. are entered.

Description	Variable	Register	Notes
Heli source lat	HL1	38	d.d.
Heli source long	HLO1	39	d.d.
Heli course	HC	40	stored as real d.d. true, output as d.m.s. magnetic.
Heli speed	HS	41	knots
Heli lat at newtime	HL2	42	d.d.
Heli long at newtime	HLO2	43	d.d
Heli true bearing to ship	TB	44	stored as d.d., input & output as d.m.s.
Beginning lat of present line	BL1	47	d.d.
Beginning long of present line	BLO1	48	d.d.
Ending lat of present line	EL1	49	d.d.
Ending long of present line	ELO1	50	d.d.
Beginning lat of next line	BL2	51	d.d.
Beginning long of next line	BLO2	52	d.d.
Ending lat of next line	EL2	53	d.d.
Ending long of next line	ELO2	54	d.d.
Heading east or west on deadheads	EW	57	east=+1;west=-1
Heli heading north or south	NS	58	positive=north negative=south
Temporary storage	TEMP	59	
Distance	D	X 01	in GC outputs D,HI; in GCPOS outputs L2, LO2

Heading	HI	Y	in GC outputs
		06	D,HI; in GCPOS outputs L2, LO2
Source lat	L1	07	d.d.
Source long	LO1	08	d.d.
Destination lat	L2	09	d.d
Destination long	LO2	10	d.d
Seconds to run "GUIDE"	SECG	60	
Seconds to run "NEXT"	SECN	61	
Seconds to run "CHECK"	SECC	63	
Special "LEAVE" lat	SPL	64	d.d, additional heli lat and
Special "LEAVE" long	SPLO	65	long storage locations
Declination	DECL	66	store this as d.d. (add declination when converting magnetic to true, and subtract declination when converting true to magnetic)
Left open for input of seconds to "HELIP"	SECH	67	
Heading to new line	HNL	68	assume given d.m.s. stored as d.d.
Trigonometric angle of HNL	THNL	69	d.d.

D. OPERATION OF PROGRAMS

1. Program TAKEOFF

Description: Guides helicopter from ship to start of first trackline.

Example:

Actual Program Output	Explanation
XEQ - TAKEOFF -	Input:
NEWTIME=	Initialize or update registers.
16.4019	17-SL1 51-BL2
OLDTIME=	18-SL01 52-BL02
15.5741	19-SC 53-EL2
DIFFERENCE=	20-SS 54-EL02
0.4238	25-OT 57-EW
SPEED=	41-HS 60-SECG
10.0000	47-BL1 61-SECN
DISTANCE=	48-BL01 63-SECC
7.1059	49-EL1 66-DECL
NEW SHIP LAT=	50-EL01
60.1759	
NEW SHIP LONG=	Response to program prompts.
144.3923	None.
NEWTIME=	
16.4019	
HEAD D:M:S=	
68.4140	
FOR N MINUTES=	
25.8717	
SHIP: RUN CHECK PROG IN HALF THIS TIME=	
12.9359 MINUTES	

Output: When all registers are filled and TAKEOFF is executed, the program shows the time the program was executed, the heading the helicopter should follow, the number of minutes the helicopter should follow the heading, and when the operator should check if the helicopter is going to reach the trackline starting location on time. Any changes in ship's course and speed should be changed by the operator as they occur throughout the flight.

Comments: The registers listed above should be filled prior to the helicopter taking off. The pilot should have provided the calculator operator the HS. The observers should have provided the calculator operator the survey lines and positions. The ship information must be obtained from the ship.

2. Program CHECK

Description: Adjusts course from TAKEOFF to make sure helicopter reaches starting point of trackline.

Example:

Actual Program Output		Explanation
XEQ - CHECK -		Input:
NEWTIME=		Initialize or update registers.
18.0919		All are full from TAKEOFF. Must change 47-BL1, 49-EL1, 51-BL2, and 53-EL2 if observers change starting latitude due to changing ice conditions.
OLDTIME=		
18.0558		
DIFFERENCE=		
0.0328		
SPEED=		
10.0000		Response to program prompts:
DISTANCE=		H BEAR? Input bearing (d.m.s.) and H DIST? distance (n.m.) from the helicopter to the ship. (Not the bearing from the ship to the helicopter.) Hit R/S after each entry.
0.5563		
NEW SHIP LAT=		
60.1756		
NEW SHIP LONG=		
145.0919		
NEWTIME=		
18.0919		Output: The program provides the heading (d.m.s) the helicopter should follow and for how long. Also whether the helicopter should head north or south. When helicopter hits start of trackline, helicopter should prompt operator to run FIX program. Operator should keep track of time.
H BEAR?		
254.0000	RUN	
H DIST?		
18.0000	RUN	
SECONDS=		
45.0000		
PROJECTED DIST=		
1.0625		
NEW HELI LAT=		
60.2145		
NEW HELI LONG=		
144.3419		
NEWTIME=		
18.0919		
HEAD D:M:S=		
73.1712		
FOR N MINUTES=		
23.3264		
THEN HEAD		
180.0000		

3. Program FIX

Description: Fixes position of the starting point of a trackline, an animal, a turning point, or other notable mark. Outputs data on paper for later entry into logsheets.

Example:

Actual Program Output	Explanation
XEQ - FIX -	Input:
NEWTIME= 18.2246	Initialize or update registers. None, already filled automatically.
OLDTIME= 18.0919	
DIFFERENCE= 0.1528	Response to program prompts: H BEAR? Input bearing (d.m.s.) and H DIST? distance (n.m.) from the helicopter to the ship. Hit R/S after each entry.
SPEED= 10.0000	
DISTANCE= 2.5766	Output: Outputs latitude and longitude location and newtime on paper for later entry into logsheets. Operator should be ready to prompt helicopter 3 minutes from newtime.
NEW SHIP LAT= 60.1756	
NEW SHIP LONG= 145.1431	
NEWTIME= 18.2446	
H BEAR? 270.0000 RUN	
H DIST? 37.0000 RUN	
NEW HELI LAT= 60.1735	
NEW HELI LONG= 143.5951	
NEWTIME= 18.2446	

4. Program GUIDE

Description: Guides helicopter along trackline. Will give a heading to follow for 3 minutes. Will notify helicopter when less than 3 minutes to end of trackline. If greater than 3 minutes will provide bearing to head helicopter straight back to trackline (east or west) and provide number of minutes to trackline.

Examples:

Actual Program Output When:

Greater than 3 minutes from line

```
   XEQ - GUIDE -
NEWTIME=
        19.3921
OLDTIME=
        19.3752
DIFFERENCE=
         0.0129
SPEED=
        10.0000
DISTANCE=
         0.2473
NEW SHIP LAT=
        60.0860
NEW SHIP LONG=
       143.5948
NEWTIME=
        19.3921
H BEAR?
  260.0000    RUN
H DIST?
   10.0000    RUN
SECONDS=
        90.0000
PROJECTED DIST=
         2.1250
NEW HELI LAT=
        60.1146
NEW HELI LONG=
       143.4341
NEWTIME=
        19.3921
HELI GT 3 MINS
AWAY FROM LINE.
***************
FOLLOW-----
HEADING=
       270.0705
FOR N MINUTES=
         5.7238
NAUTICAL MILES=
         8.1087
```

Normal travel along line

```
   XEQ - GUIDE -
NEWTIME=
        19.3752
OLDTIME=
        19.3625
DIFFERENCE=
         0.0127
SPEED=
        10.0000
DISTANCE=
         0.2428
NEW SHIP LAT=
        60.0860
NEW SHIP LONG=
       143.5918
NEWTIME=
        19.3752
H BEAR?
  225.0000    RUN
H DIST?
    5.0000    RUN
SECONDS=
        90.0000
PROJECTED DIST=
         2.1250
NEW HELI LAT=
        60.1438
NEW HELI LONG=
       143.5236
NEWTIME=
        19.3752
HEADING=
       300.1712
FOR N MINUTES=
         2.9986
NAUTICAL MILES=
         4.2481
```

Close to end of line

```
   XEQ - GUIDE -
NEWTIME=
        19.3625
OLDTIME=
        19.3424
DIFFERENCE=
         0.0201
SPEED=
        10.0000
DISTANCE=
         0.3348
NEW SHIP LAT=
        60.0860
NEW SHIP LONG=
       143.5848
NEWTIME=
        19.3625
H BEAR?
  180.0000    RUN
H DIST?
   16.0000    RUN
SECONDS=
        90.0000
PROJECTED DIST=
         2.1250
NEW HELI LAT=
        60.2706
NEW HELI LONG=
       143.5927
NEWTIME=
        19.3625
CLOSE TO END
HEADING=
       354.3631
FOR N MINUTES=
         2.0591
NAUTICAL MILES=
         2.9170
```

4. Program GUIDE - continued

Explanation
Input: Initialize or update registers. None, already filled automatically. Response to program prompts: H BEAR? Input bearing (d.m.s.) and H DIST? distance (n.m.) from the helicopter to the ship. Hit R/S after each entry. Output: Program provides heading to follow, number of minutes to follow heading, and number of nautical miles to trackline.

5. Program <u>NEXT</u>

Description: Given heading observers want to follow, provides number of minutes to start of next line and whether to head north or south when there.

Example:

Actual Program Output

```
         XEQ - NEXT -
NEWTIME=
                15.0427
OLDTIME=
                14.4314
DIFFERENCE=
                 0.2113
SPEED=
                10.0000
DISTANCE=
                 3.5349
NEW SHIP LAT=
                60.1760
NEW SHIP LONG=
               144.0708
NEWTIME=
                15.0427
H BEAR?
     180.0000     RUN
H DIST?
      13.0000     RUN
NEW HELI LAT=
                60.3060
NEW HELI LONG=
               144.0708
NEWTIME=
                15.0427
HEADING TO NEW LINE?
      90.0000     RUN
MINUTES TO NEW LINE=
                11.9011
THEN HEAD
               180.0000
SHIP,VIEW LEG
AND ENTER NEXT

                 RCL 47
      60.5166       ***
                 RCL 48
     143.5000       ***
                 RCL 49
      60.0166       ***
                 RCL 50
     143.5000       ***
```

Explanation

Input:

Initialize or update registers.

Under all conditions 51-BL2, 52-BL02, 53-EL2, and 54-EL02 must have been entered. The rest are already filled.

Response to program prompts:

H BEAR? Input bearing (d.m.s.) and H DIST? distance (n.m.) from the helicopter to the ship. Hit R/S after each entry.

HEADING TO NEW LINE? Input heading (d.m.s.) observers want pilot to follow to next line relative to ice conditions.

Output: Provides number of minutes to reach new line and whether to head north or south when there. Then prompts operator to view leg and store information for next trackline.

Comments: After this run is completed, new values must be input for registers 51-54 by storing (STO) information from registers 47-50 into registers 51-54, respectively.

When leaving a deadhead between tracklines for a random search, LEAVE and BACK programs must be executed after program NEXT. Once back to deadhead trackline NEXT must be executed again.

6. Program LEAVE

Description: Identifies position left from systematic trackline for replicate or random search.

Example:

Actual Program Output	Explanation
XEQ - LEAVE -	Input:
NEWTIME=	Initialize or update registers.
21.0550	None, all are already filled.
OLDTIME=	
21.0223	Response to program prompts:
DIFFERENCE=	H BEAR? Input bearing (d.m.s.) and
0.0327	H DIST? distance (n.m.) from the
SPEED=	helicopter to the ship. Hit R/S
10.0000	after each entry.
DISTANCE=	
0.5740	Output: The program outputs the helicopter
NEW SHIP LAT=	location and time.
60.1746	
NEW SHIP LONG=	Comments: The operator must wait for
146.0842	helicopter to supply bearing and distance
NEWTIME=	to head back to initial point of departure
21.0550	from systematic trackline.
H BEAR?	
245.0000 RUN	
H DIST?	
60.0000 RUN	
NEW HELI LAT=	
60.4221	
NEW HELI LONG=	
144.1733	
NEWTIME=	
21.0550	

7. Program BACK

Description: Guides helicopter to location recorded by LEAVE.

Example:

Actual Program Output

```
         XEQ - BACK -
NEWTIME=
                21.0652
OLDTIME=
                21.0550
DIFFERENCE=
                 0.0102
SPEED=
                10.0000
DISTANCE=
                 0.1726
NEW SHIP LAT=
                60.1746
NEW SHIP LONG=
               146.0902
NEWTIME=
                21.0652
H BEAR?
     247.0000       RUN
H DIST?
      61.5000       RUN
NEW HELI LAT=
                60.4058
NEW HELI LONG=
               144.1325
NEWTIME=
                21.0652
HEAD D:M:S=
               304.3159
FOR N MINUTES=
                 1.7326
```

Explanation

Input:
Initialize or update registers.
None, all are already filled.

Response to program prompts:
H BEAR? Input bearing (d.m.s.) and
H DIST? distance (n.m.) from the helicopter to the ship. Hit R/S after each entry.

Output: Gives helicopter's present location and the heading and number of minutes back to its LEAVE location.

Comments: Operator must remind pilot to circle and wait until directions are given on how to return to LEAVE location. Operator should also note time helicopter will arrive back on line (LEAVE location) and be ready to prompt pilot and execute GUIDE or NEXT programs.

8. Program SHIP

Description: Execute SHIP and the program outputs ship's new latitude and longitude.

```
PRP "FIX"

01♦LBL "FIX"
02 XEQ "HELI"
03 END

01♦LBL "NS"
02 RCL 47
03 RCL 49
04 -
05 STO 58
06 X<0?
07 GTO 01
08 GTO 02

09♦LBL 01
10 360
11 GTO 03

12♦LBL 02
13 180

14♦LBL 03
15 END

01♦LBL "OUTPUT"
02 X<>Y
03 STO 40
04 X<>Y
05 RCL 41
06 1/X
07 *
08 60
09 *
10 STO 23
11 RCL 40
12 RCL 66
13 -
14 CLA
15 "HEAD D:M:S="
16 AVIEW
17 HMS
18 VIEW X
19 RCL 23
20 CLA
21 "FOR N MINUTES="
22 AVIEW
23 VIEW X
24 END

01♦LBL "PROJECT"
02 RCL 41
03 *
04 60
05 /
06 60
07 /
08 STO 01
09 RCL 40
10 STO 06
11 RCL 09
12 STO 07
13 RCL 10
14 STO 08
15 XROM "*GCPOS"
16 END

01♦LBL "STD"
02 TIME
03 HR
04 STO 24
05 RCL 25
06 RCL 24
07 RCL 25
08 -
09 STO 26
10 RCL 26
11 RCL 20
12 *
13 STO 01
14 END

PRP "SHIP"

01♦LBL "SHIP"
02 RCL 17
03 STO 07
04 RCL 18
05 STO 08
06 RCL 19
07 STO 06
08 XEQ "STD"
09 XEQ "POS"
10 END

01♦LBL "CHECK"
02 RCL 63
03 STO 67
04 XEQ "HELIP"
05 RCL 42
06 STO 07
07 RCL 43
08 STO 08
09 RCL 47
10 STO 09
11 RCL 48
12 STO 10
13 XROM "*GC"
14 XEQ "OUTPUT"
15 XEQ "NS"
16 STO 40
17 RCL 66
18 -
19 HMS
20 CLA
21 "THEN HEAD"
22 AVIEW
23 VIEW X
24 END

PRP "LEAVE"

01♦LBL "LEAVE"
02 XEQ "HELI"
03 RCL 09
04 STO 64
05 RCL 10
06 STO 65
07 END

01♦LBL "BACK"
02 XEQ "HELI"
03 RCL 09
04 STO 07
05 RCL 10
06 STO 08
07 RCL 64
08 STO 09
09 RCL 65
10 STO 10
11 XROM "*GC"
12 XEQ "OUTPUT"
13 END

01♦LBL "TAKEOFF"
02 XEQ "SHIP"
03 RCL 17
04 STO 07
05 RCL 18
06 STO 08
07 RCL 47
08 STO 09
09 RCL 48
10 STO 10
11 XROM "*GC"
12 XEQ "OUTPUT"
13 CLA
14 "SHIP: RUN CHECK"
15 "⊦ PROG IN"
16 AVIEW
17 CLA
18 "HALF THIS TIME="
19 AVIEW
20 2
21 /
22 VIEW X
23 CLA
24 "                "
25 "⊦ MINUTES"
26 AVIEW
27 END

01♦LBL "POS"
02 XROM "*GCPOS"
03 CLA
04 "NEW SHIP LAT="
05 AVIEW
06 RCL 09
07 HMS
08 VIEW X
09 CLA
10 "NEW SHIP LONG="
11 AVIEW
12 RCL 10
13 HMS
14 VIEW X
15 CLA
16 "NEWTIME="
17 RCL 24
18 HMS
19 AVIEW
20 VIEW X
21 RCL 09
22 STO 17
23 RCL 10
24 STO 18
25 RCL 24
26 STO 25
27 END
```

```
PRP "HELI"

01♦LBL "HELI"
02 XEQ "SHIP"
03 "H BEAR?"
04 PROMPT
05 RCL 66
06 HMS
07 HMS+
08 HR
09 STO 44
10 180
11 -
12 STO 06
13 "H DIST?"
14 PROMPT
15 STO 33
16 STO 01
17 RCL 17
18 STO 07
19 RCL 18
20 STO 08
21 XROM "*GCPOS"
22 CLA
23 "NEW HELI LAT="
24 AVIEW
25 RCL 09
26 HMS
27 VIEW X
28 CLA
29 "NEW HELI LONG="
30 AVIEW
31 RCL 10
32 HMS
33 VIEW X
34 CLA
35 "NEWTIME="
36 RCL 24
37 HMS
38 AVIEW
39 VIEW X
40 END
```

```
PRP "HELIP"

01♦LBL "HELIP"
02 XEQ "SHIP"
03 "H BEAR?"
04 PROMPT
05 RCL 66
06 HMS
07 HMS+
08 HR
09 STO 44
10 180
11 -
12 STO 06
13 "H DIST?"
14 PROMPT
15 STO 33
16 STO 01
17 RCL 17
18 STO 07
19 RCL 18
20 STO 08
21 XROM "*GCPOS"
22 RCL 67
23 XEQ "PROJECT"
24 CLA
25 "NEW HELI LAT="
26 AVIEW
27 RCL 09
28 HMS
29 VIEW X
30 CLA
31 "NEW HELI LONG="
32 AVIEW
33 RCL 10
34 HMS
35 VIEW X
36 CLA
37 "NEWTIME="
38 RCL 24
39 HMS
40 AVIEW
41 VIEW X
42 RCL 09
43 STO 42
44 STO 38
45 RCL 10
46 STO 43
47 STO 39
48 END
```

```
PRP "HELIR"

01♦LBL "HELIR"
02 XEQ "SHIP"
03 "H BEAR?"
04 PROMPT
05 RCL 66
06 HMS
07 HMS+
08 HR
09 STO 44
10 180
11 -
12 STO 06
13 "H DIST?"
14 PROMPT
15 STO 33
16 STO 01
17 RCL 17
18 STO 07
19 RCL 18
20 STO 08
21 XROM "*GCPOS"
22 CLA
23 "NEW HELI LAT="
24 AVIEW
25 RCL 09
26 HMS
27 VIEW X
28 CLA
29 "NEW HELI LONG="
30 AVIEW
31 RCL 10
32 HMS
33 VIEW X
34 CLA
35 "NEWTIME="
36 RCL 24
37 HMS
38 AVIEW
39 VIEW X
40 RCL 09
41 STO 42
42 STO 38
43 RCL 10
44 STO 43
45 STO 39
46 END
```

III PROGRAM LISTING
(con't)

```
PRP "NEXT"

01♦LBL "NEXT"
02 XEQ "HELIR"
03 "HEADING TO "
04 "⊦NEW LINE?"
05 PROMPT
06 RCL 66
07 +
08 HR
09 ENTER↑
10 90
11 -
12 ENTER↑
13 -1
14 *
15 STO 69
16 RCL 42
17 STO 07
18 STO 09
19 RCL 43
20 STO 08
21 RCL 52
22 STO 10
23 XROM "*GC"
24 STO 30
25 RCL 57
26 *
27 STO 30
28 RCL 69
29 TAN
30 *
31 STO 32
32 X>0?
33 GTO 04
34 180
35 GTO 05

36♦LBL 04
37 360

38♦LBL 05
39 STO 06
40 RCL 32
41 ABS
42 STO 01
43 RCL 42
44 STO 07
45 RCL 52
46 STO 08
47 XROM "*GCPOS"
48 RCL 42
49 STO 07
50 RCL 43
51 STO 08
52 RCL 09
53 STO 47
54 RCL 10
55 STO 48
56 STO 50
57 XROM "*GC"
58 RCL 41
59 1/X
60 *
61 60
62 *
63 60
64 *
65 RCL 61
66 -
67 60
68 /
69 CLA
70 "MINUTES TO NEW "
71 "⊦LINE="
72 AVIEW
73 VIEW X
74 CLA
75 "THEN HEAD"
76 AVIEW
77 RCL 51
78 RCL 53
79 -
80 STO 58
81 X<0?
82 GTO 01
83 GTO 02

84♦LBL 01
85 360
86 GTO 03

87♦LBL 02
88 180

89♦LBL 03
90 STO 40
91 RCL 66
92 -
93 HMS
94 VIEW X
95 RCL 58
96 X<0?
97 GTO 10
98 -.5
99 GTO 11

100♦LBL 10
101 .5

102♦LBL 11
103 RCL 47
104 +
105 STO 49
106 CLA
107 "SHIP,VIEW LEG"
108 AVIEW
109 CLA
110 "AND ENTER NEXT "
111 AVIEW
112 END
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AERIAL SURVEYS OF MARINE MAMMALS IN THE SOUTHEASTERN BERING SEA

by

Stephen Leatherwood, Ann E. Bowles,
and Randall R. Reeves

Hubbs-Sea World Research Institute

Final Report
Outer Continental Shelf Environmental Assessment Program
Research Unit 622

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INTRODUCTION

In February 1982, the National Oceanic and Atmospheric Administration (NOAA), Office of Marine Pollution Assessment (OMPA), Outer Continental Shelf Environmental Assessment Program (OCSEAP), issued a contract to this Institute to conduct a series of eight semi-seasonal aerial surveys for marine mammals in the eastern Bering Sea (south of latitude 62°N and east of longitude 174°W) and Shelikof Strait, Alaska (Figure 1). The government's stated objectives in initiating the study were to identify habitats particularly important to "endangered" whales and to describe the nature and timing of use of those habitats by the whales. Given extensive ongoing and planned activities related to exploration for, removal of, and transport of oil and gas in major areas of Alaska, including those named in the present contract, and a prevalent national concern about effects of offshore resource development on marine communities, such information is needed as a basis for informed management decisions.

The contract defined the study areas; specified the survey platforms to be used; defined the number of surveys, their temporal distribution within the contract year, and the proportional coverage desired; and limited the amount of survey effort available for each of the eight surveys. In addition, it specifically required that we: determine seasonal distribution of endangered whales in and near the areas proposed for outer continental shelf oil and gas leasing; determine the seasonal abundance of endangered whales within these areas; correlate distribution and abundance of endangered whales with environmental conditions; and, for marine mammals other than endangered whales observed during the surveys document sightings and from those sightings characterize distribution and abundance within the study area.

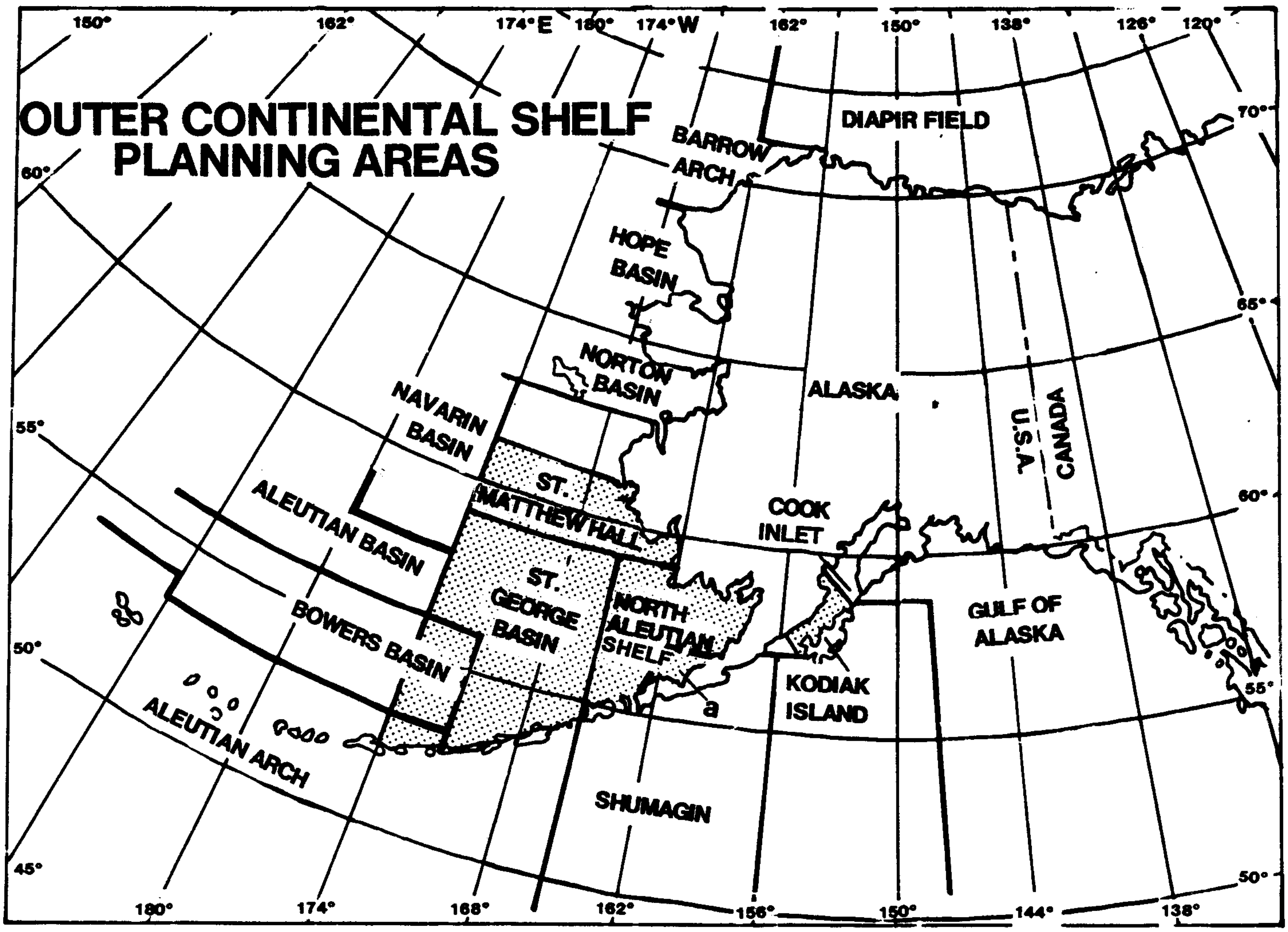

Figure 1. Alaska, showing outer continental shelf (OCS) oil lease planning areas - bold lines - and the areas covered by the present investigations - shaded - (modified from the Bureau of Land Management, undated, by permission of OMPA, Juneau).

This report summarizes field research activities under the contract from February 1982 through March 1983. It 1) provides details on the design and conduct of surveys and on the distribution of sightings by species, both spatially and temporally; 2) presents estimates of relative and, where appropriate, absolute abundance; 3) describes apparent habitat preferences by species, when they can be inferred; and 4) notes observed behavior. Results are presented in the context of previously available data for each species known or suspected to occur in the study areas (Table 1), with greatest emphasis on those cetaceans regarded by United States and international management agencies as in need of special protection (e.g. Anonymous 1972, Dept. of Int. 1982, Table 1). Whenever possible, findings are referenced to the five oil lease areas which fall completely or partially within our study areas (Figure 1) and to the 7 study blocks assigned for these investigations (Figures 2 and 3).

MATERIALS AND METHODS

Information was obtained from aerial surveys, literature review, interviews with colleagues and residents of the study areas, and reconnaissance of some areas by boat, land vehicle, or foot.

Description of Study Areas

The design and conduct of aerial surveys were dictated largely by the size of the study areas, the desire for broad coverage, and the logistical support (aircraft and ground support) available. Two areas were slated for coverage: Bristol Bay and the southeast Bering Sea south of 62°N and east of 174°W (Figure 2) and Shelikof Strait, between Kodiak Island and the adjacent Alaskan Peninsula (Figure 3).

Table 1. Marine mammals known or thought to occur in the Eastern Bering Sea (east of longitude 174°W and south of latitude 62°N) and in or near Shelikof Strait, Alaska and their present status and designations for management under US and international conservation schemes. Species receiving special attention in this report are indicated by an asterisk (*).

Name of Species		Known from		STATUS OR DESIGNATION			
Common	Scientific	Eastern Bering Sea	Shelikof Strait	Anonymous (1972)[a]	Dept. of the Interior (1982)[a]	N.M.F.S. U.S. Dept. of Commerce (1981)[a]	International Whaling Commission (1983)[b]
Bowhead* whale	*Balaena mysticetus*	Yes	No	ENDANGERED	ENDANGERED (since 2 June 1970)	ENDANGERED (1)[c]	PROTECTED (0)[d]
Right * whale	*Eubalaena glacialis*	Yes	Yes	ENDANGERED	ENDANGERED (since 2 June 1970)	ENDANGERED (1)[c]	PROTECTED (0)
Gray * whale	*Eschrichtius robustus*	Yes	Yes	ENDANGERED	ENDANGERED (since 2 June 1970)	ENDANGERED (1)[c]	Sustained management (Annual Quote = 179)[e]
Blue * whale	*Balaenoptera musculus*	Yes	Yes	ENDANGERED	ENDANGERED (since 2 June 1970)	ENDANGERED (1)[c]	PROTECTED (0)
Fin * whale	*B. physalus*	Yes	Yes	ENDANGERED	ENDANGERED (since 2 June 1970)	ENDANGERED (1)[c]	PROTECTED (0)
Sei * whale	*B. borealis*	Yes	Yes		ENDANGERED (since 2 June 1970)	ENDANGERED (1)[c]	PROTECTED (0)
Minke * whale	*B. acutorostrata*	Yes	Yes	Unlisted	Unlisted	- (1)[c]	Initial Management (0)[h]
Humpback * whale	*Megaptera novaeangliae*	Yes	Yes	ENDANGERED	ENDANGERED (since 2 June 1970)	ENDANGERED (1)[c]	PROTECTED (0)
Sperm * whale	*Physeter macrocephalus*	Yes	Yes	ENDANGERED	ENDANGERED (since 2 June 1970)	ENDANGERED (1)[c]	Unclassified (0)[i]
Narwhal	*Monodon monoceros*	Yes	No	Unlisted	Unlisted	- (2)[g]	Not covered by IWC schedule
White whale	*Delphinapterus leucas*	Yes	Yes	"	" "	- (2)[g]	Not covered by IWC schedule
Baird's beaked whale	*Berardius bairdii*	Yes	Yes	"	" "	- (1)[c]	Unclassified, No recommendation on "stock listing"[j]
Cuvier's beaked whale	*Ziphius cavirostris*	Yes	Yes	"	" "	- (2)[g]	Not covered [j]
Stejneger's beaked whale	*Mesoplodon stejnegeri*	Yes	Yes	"	" "	- (2)[g]	Not covered [j]
Killer whale	*Orcinus orca*	Yes	Yes	"	" "	- (2)[g]	Not covered by IWC schedule[j]
Risso's dolphin	*Grampus griseus*	Unlikely	Unlikely	"	" "	- (2)[g]	" "
Pilot whale	*Globicephala sp.*	Yes	Probable	"	" "	- (2)[g]	" "
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*	No	Possible	"	" "	- (2)[g]	Not covered [j]
Northern right-whale dolphin	*Lissodelphis borealis*	No	Possible	"	" "	- (2)[g]	" "

Table 1 (cont.)

Name of Species		Known from		STATUS OR DESIGNATION			
Common	Scientific	Eastern Bering Sea	Shelikof Strait	Anonymous (1972)[a]	Dept. of the Interior (1982)[a]	N.M.F.S. U.S. Dept. of Commerce (1981)[a]	International Whaling Commission (1983)[b]
Dall's porpoise	Phocoenoides dalli	Yes	Yes	Unlisted	Unlisted	- (2)(g	Not covered
Harbor porpoise	Phocoena phocoena	Yes	Yes	"	" "	- (2)(g	" "
Steller sea lion	Eumetopias jubatus	Yes	Yes	"	" "	- (2)(g	N/A
Northern fur seal	Callorhinus ursinus	Yes	Yes	"	" "	- -	"
Walrus	Odobenus rosmarus	Yes	No	"	" "	Unlisted -	"
Harbor seal	Phoca vitulina	Yes	Yes	"	" "	- -	"
Larga seal	Phoca largha	Yes	No(k	"	" "	- -	"
Ringed seal	Phoca hispida	Yes	No(k	"	" "	- -	"
Ribbon seal	Phoca fasciata	Yes	No(k	"	" "	- -	"
Bearded seal	Erignathus barbatus	Yes	No(k	"	" "	- -	"
Northern elephant seal	Mirounga angustirostris	Possible	Possible	"	" "	- (2)(g	"
Sea otter	Enhydra lutris	Yes	Yes	"	" "	- -	"
Polar bear	Ursus maritimus	Yes(m	No	"	" "	- -	"

a) Designations are for the species world-wide, unless otherwise noted; (b) designations are for the entire North Pacific or subset, as indicated in text. Numbers in parentheses are 1982 quotas (IWC, 1983:8); (c) 1- classified under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITIES) under Appendix I; (d) In 1979 the Scientific Committee strongly recommended protected status and a "0" catch limit; however, the Commission established a three-year block quota of 85 strikes for the years 1980-83; (e) western stock at low remnant levels or extinct - degree of mixing of putative remnants of that stock with eastern stock in study area probably low; (f) Japanese sightings data reportedly indicate increase for N. Pacific in general (IWC 1982:22); (g) 2 = classified under CITIES Appendix II; (h) refers to "Remainder Stock," those east of the Akhotsk Sea-West Pacific stock and presumably not involved in authorized takes from that stock of <1,678 from 1980 to 1984 inclusive and <401 in 1983 (IWC 1983:8); (i) left figure is for western N. Pacific stock, for which no advice on classification was offered to IWC by the Scientific Committee and 1982 quota was set by IWC at 0 (IWC 1983:9) - right figure is for eastern N. Pacific stock. Degree of mixing of males from the two stocks in present study areas is unknown; (j) there is no agreement about the IWC's competence and authority to "manage" small cetaceans; however, the Scientific Committee Subcommittee on Small Cetaceans recommended, and the Commission adopted, quotas of "less than the previous annual averages" = "40" and "0" for Baird's beaked whales and killer whales, respectively; (k) breeding ranges are restricted to waters north of the Aleutian Islands. Occurrence in northern Gulf of Alaska would be exceptional; (l) reported from the northern Gulf of Alaska and Dutch Harbor, Alaska in summer. Growing populations in the temperate North Pacific and long-term trends in warming of sea waters in the northern North Pacific could well result in increased sightings of males and juveniles in the study areas; (m) "Normal" range is north of E. Bering Sea study area but can be expected south of latitude 62 N, particularly in heavy-ice years; (n) a single verified stranding from St. Matthew Island (Hanna, 1920).

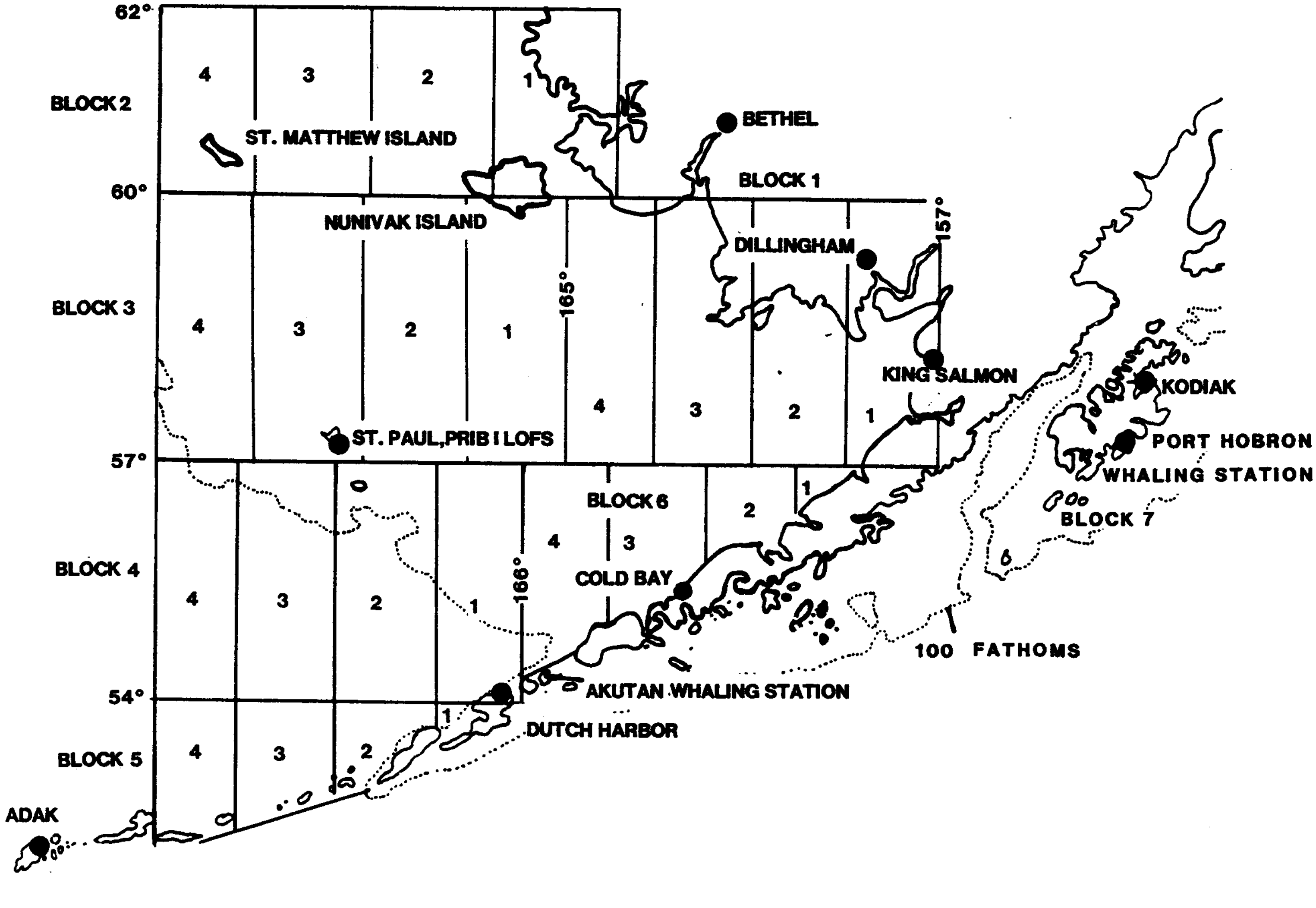

Figure 2. The eastern Bering Sea/Bristol Bay study area, showing the logistically determined strata (blocks 1-6 and their associated zones), principal depth contours, and major airfields from which flight operations were conducted.

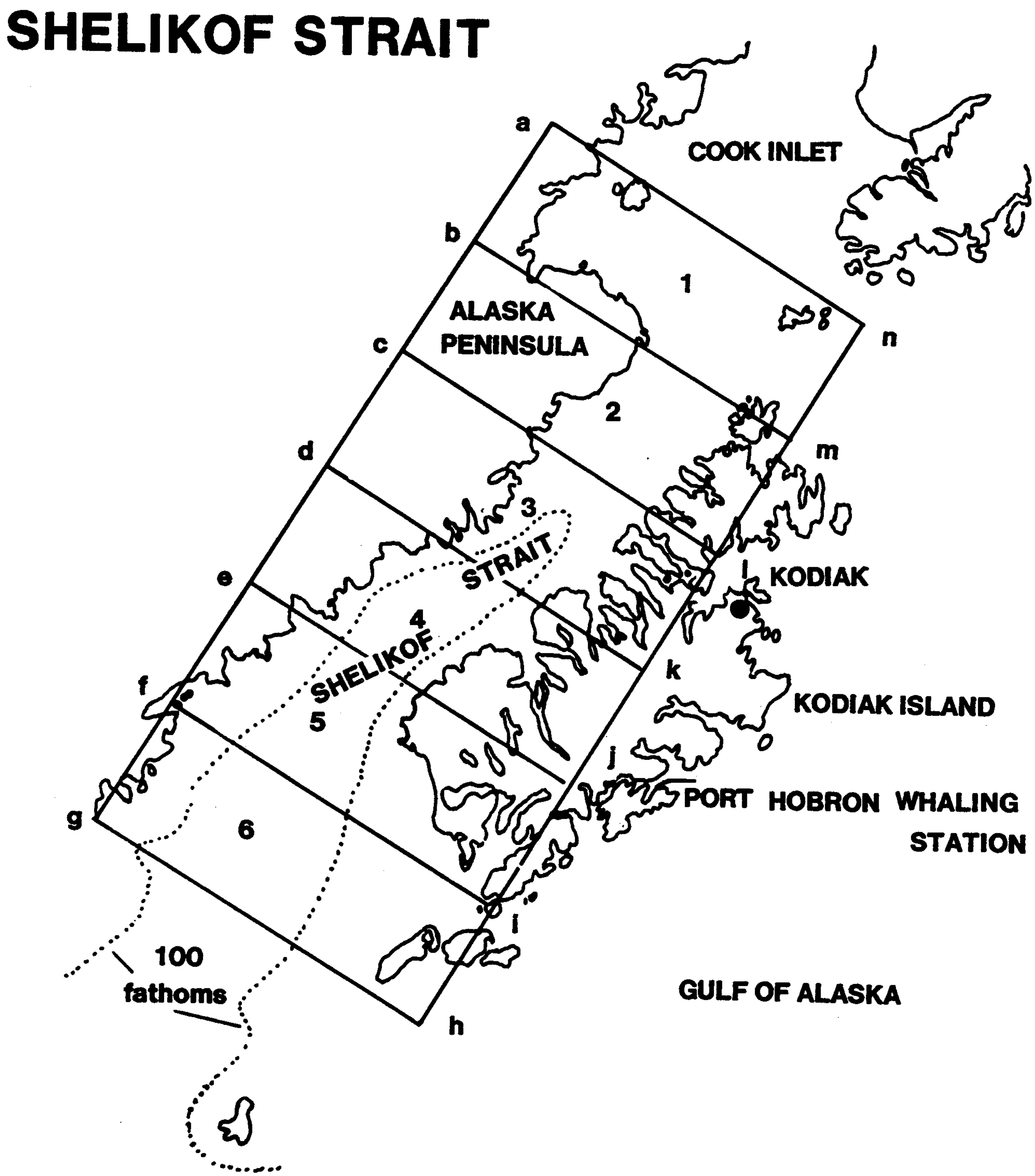

Figure 3. The Shelikof Strait study area (block 7) showing the 6 zones, principal depth contours, and place names referred to in the text.

The Bering Sea/Bristol Bay study area (Figure 2) includes approximately 184,470nm^2 (632,732 km^2)[1] of ocean surface (Table 2) and contains all or part of five proposed lease sale areas (the Aleutian Arch, Bowers Basin, St. George Basin, the St. Matthew-Hall Region, and the North Aleutian Basin). The area is largely continental shelf waters, except in its southwest portions. There, in an area comprising about 15% of the total, the continental shelf drops off steeply to depths of 1000 fathoms (1829 meters) or more (Figure 2). The study area is encroached seasonally by the Bering Sea ice front, which in severe years may extend to the Pribilof Islands and much of central and northern Bristol Bay (e.g. Potocsky, 1975)

The Shelikof Strait study area, includes approximately 8,916nm^2 (30,582 km^2) of ocean surface (Table 2) and contains the southwest end of the Cook Inlet lease sale area. The Kodiak lease sale area abuts the Shelikof Strait study area on its southwest corner (Figure 1). The strait, which is some 20 to 30nm (37 to 56 kilometers) wide, consists primarily of continental shelf waters less than 100 fms deep, into which a large triangular trough, 100 fms (183 meters) or deeper, intrudes from the southwest (Figure 3). Submarine slopes along the sides of this trough are often steep. The orientation of the strait relative to the prevalent weather patterns in the North Pacific creates extremely poor weather conditions, high winds, storm swells, and severe wind-chop much of the year. The shoreline along the strait, particularly that on the northwest sides of Kodiak and Afognak islands, is marked by numerous convoluted deepwater bays and straits fringed by precipitous mountains; so, aerial coverage of many habitats possibly important to marine mammals is difficult. Shelikof Strait itself is readily accessible from a well-equipped commercial airfield at the town of Kodiak on Kodiak Island (Figure 3).

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[1] Basic units are indicated in English system, as nautical charts are are graded in nm rather than in km. Conversions are provided for major entries but citations from published works are presented in the units reported.

Table 2. Areas and dimensions of blocks and zones, length of transect, desired apportionment of effort, number of random transects available in each zone, and area actually surveyed.

Block No.	Total Area	Approximate Proportion Ocean	Length of North-South Transects	Number of lines required for equivalent coverage/zone	Number of Zones Indicated	Width of Zone (°longitude)	Width of each zone (nm)		Random numbers available for transects at 1/8 nm intervals	Actual area surveyed
							Southern End	Northern End		
1 (BB)	44,384nm	0.64	180nm	3.89	4	2°0'	65.6nm	60.3nm	1-525	676 nm^2
2 (SEB)	31,507nm	0.86	120nm	4.17	4	2°30'	75.3nm	70.7nm	1-603	524 nm^2
3 (SEB)	47,177nm	1.00	180nm	3.89	4	2°0'	65.6nm	60.3nm	1-568	870 nm^2
4 (SEB)	44,950nm	1.00	180nm	3.89	4	2°0'	70.8nm	65.6nm	1-590	663 nm^2
5 (SEB)	33,614nm	0.5	120nm	4.17	4	2°0'	74.0nm	70.8nm	1-594	293 nm^2
6 (BB)	40,268nm	0.5	180nm	3.89	4	2°0'	70.8nm	65.6nm	1-567	450 nm^2
7 (SS)	8,916	N/A	Variable	N/A	6	N/A*	35.0 nm*		1-280	403 nm^2

*Boundary faces southeast, not parallel to latitude or longitude lines.
BB = Bristol Bay, SEB = Southeast Bering Sea, SS = Shelikof Strait.

The Bering Sea study area, however, is remote and serviceable by aircraft from only a handful of widely scattered and in many cases marginally equipped airfields (Figure 2). The weather is almost always unpredictable and often unsuitable for safe, low-altitude, overwater flying. Marine weather reporting is limited and generally coastal; so, translation of observed local and reported remote field weather conditions into useful predictions of weather conditions in the overwater areas scheduled for survey was problematical. In combination, the above factors made it prudent and advisable for us to program extra flight reserve into each survey flight to compensate for unpredicted closures of the primary air field.

Aerial Surveys

Intended Survey Coverage

The contract called for up to 10% coverage of the entire area in each of eight semi-seasonal surveys. To achieve that level of coverage, we were provided a total of 100 flight hours per survey, including on-transect, circling, and transit time, or 28 days total field time, whichever expired first. Aircraft available for the surveys were limited to 6 or 8 hours total range and 4 to 6 hours effective survey range. A glance at Figures 2 and 3 is sufficient to demonstrate that some areas, notably the westernmost zones in blocks 2, 3, and 4, are accessible from aircraft with such range only under ideal wind and weather conditions. Therefore, surveys were redesigned within those logistical and safety requirements.

Survey Design

The enormous size of the Bering Sea/Bristol Bay study area and the logistical constraints described above required that surveys there be conducted in discrete strata. These logistically defined strata are called blocks (6 total). Subdivisions of blocks are called zones (4 per block). Sizes of the blocks and zones were determined such that the amount of searching effort assigned within each was proportional to its area (Table 2). Transects (one per zone per survey) were selected randomly, as described below. Choosing random lines with lengths proportional to block and zone size insured that: 1) if there were enough on-transect sightings from a given survey, estimates of population density could be generalized for each block and zone even if the proportion of area searched was very small; and 2) if there were not enough sightings within a given zone or block, areas could be combined for a density estimate.

The much smaller Shelikof Strait study area, block 7, is far removed from the Bering Sea study area, and there was no intention to combine data from the two areas for analysis. Therefore, Shelikof Strait was considered a separate single block and was subdivided into 6 zones, each 35nm (65 km) wide, northeast to southwest (Figure 3).

Transect Placement and Selection

The primary targets in the present surveys were endangered whales. In previous aerial surveys of these large whales, the majority of animals has been seen within about 0.25nm (0.46 km) or less of the track-line (e.g. Hall, 1981; Hay, 1982; Scott and Gilbert, 1982). Therefore, to ensure that each portion of the study area(s) had equal probability of coverage, we placed and selected transects as follows: The southern boundary of each zone (in Shelikof Strait the southeast-facing boundary) was scored at one-eighth nautical mile (0.23 km) intervals. The intervals were numbered 1 to N beginning on the eastern corner. For each of the eight surveys one random number was selected for each zone. Because zones in blocks 1-6 were of variable width (due to the rapid convergence of longitude lines at these northern latitudes), different sets of available numbers were required for different blocks (see Table 2). Transects selected in blocks 1-6 were flown heading north or south along appropriate longitude lines (see Figure 4 for transects selected for Bering Sea for Survey 1). Those in block 7 were flown heading northeast or southwest, parallel to the zone boundaries. Given the orientations of major depth contours in both areas, resulting transects were roughly perpendicular to important depth strata.

Conduct of Surveys

We intended to conduct all 8 surveys from a single aircraft with unobstructed downward visibility. Data collected from such a platform might have been analyzed routinely using accepted statistical procedures (Burnham, et al., 1980). However, it was necessary to use three different aircraft, each with different window configurations and none with unobstructed downward visibility (Figure 5; Table 3) (all three aircraft were equipped with a Global Navigation System (GNS) flight computer to indicate position). Procedures for analyzing data from such aircraft are currently the subject of debate, and the validity of results obtained from them is in doubt (see contributions to Chapman, 1982 and discussion below). To achieve the highest level of consistency possible, the on-board crew was deployed as follows: Two observers were stationed on opposite sides of the aircraft, at whatever position afforded the best views of the survey strip.

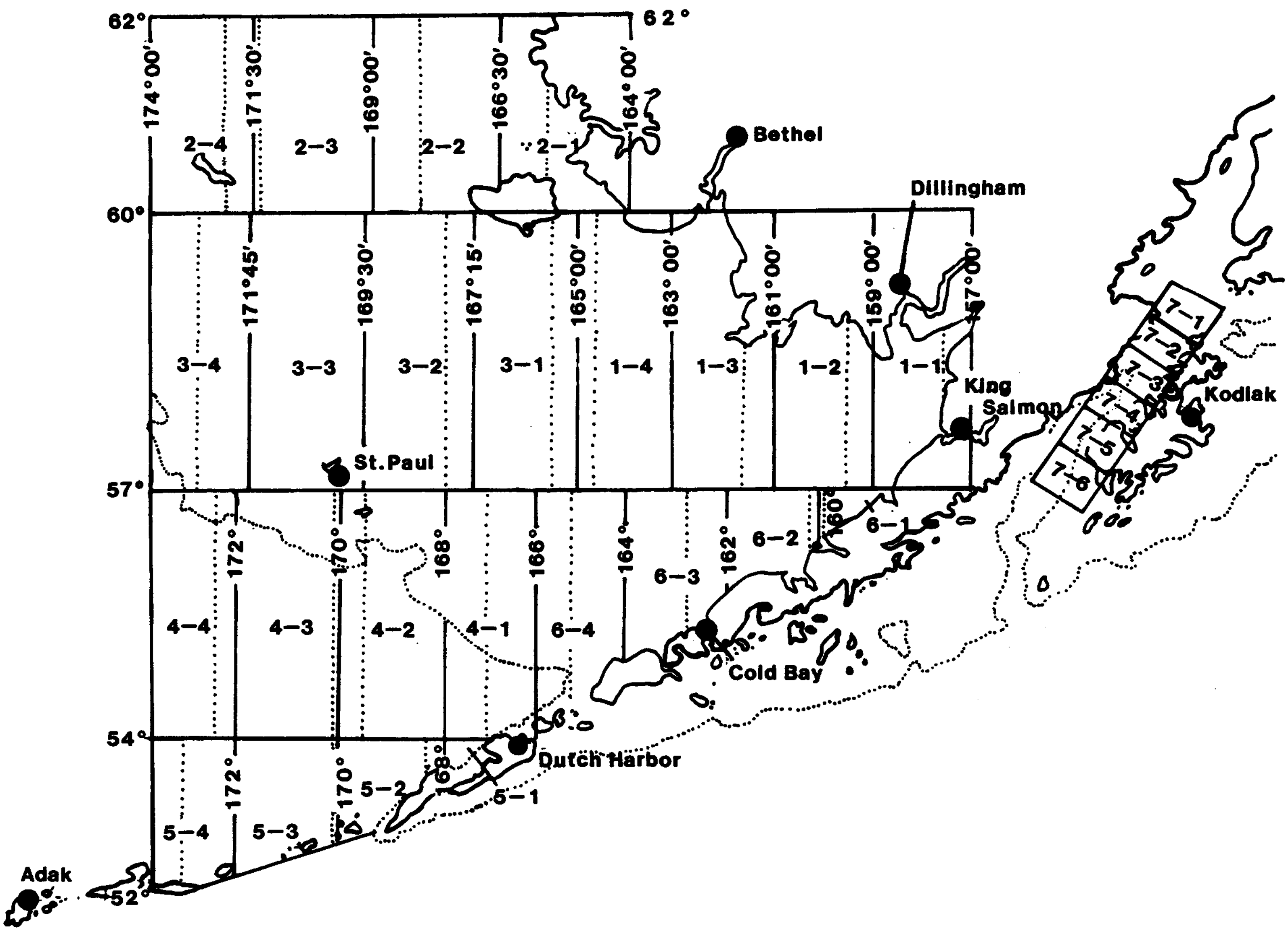

Figure 4. The eastern Bering Sea/Bristol Bay study area, showing placement of the random transects drawn for survey 1 (for transects actually flown on survey 1 see Figure 8). A new set of transects was drawn for each area for each of the eight survey periods.

Figure 5a. The "stretched" turbine Grumman Goose used on survey 1.

Figure 5b. The "standard" turbine Grumman Goose used on survey 2.

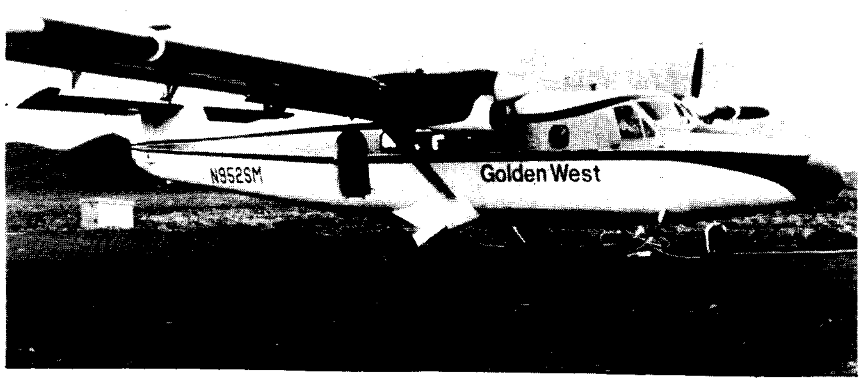

Figure 5c. The DeHavailland Twin Otter used on surveys 3-8. All three aircraft have different window configurations (see Table 3.).

Table 3. Characteristics of the 3 aircraft made available for the 8 aerial surveys (see Figure 5).

Survey No.	Dates Start	Dates End	Aircraft No.	Aircraft Type	Aircraft Speed	Observer positions/ Sightability Location	Observer positions/ Sightability Window Type	Min. Angle
1	3/13	4/1	N-780	Grumman Goose Stretch /turbine	150	Left front	Oblong bubble	70°
						Right front	" "	70°
						left rear(*)	Flat Plate Glass	60°
						right rear	" "	60°
2	5/10	6/3	N-642	Grumman Goose Standard Turbine	140-50	Left front(*)	" "	60-70°
						Right front	" "	60-70°
						Left rear	Large plexiglass bubble	70-90°
						Right rear	" "	70-90°
3	7/3	7/22	9525M	Dehavilland Twin Otter	140	Left front	Small plexiglass bubble	70-90°
						right front	" "	
						Left rear(*)	Flat plexiglass	60°
						right rear	" "	60°
4	8/5	8/24	"	"	135-152	Left front (8/5-8/8)	Small plexiglass bubble	70-90°
						Left front (≥8/9)	Large plexiglass bubble	90-100°
						Right front (8/5-1/15)	Small plexiglass bubble	70-90°
						Right front (≥8/15)	Large plexiglass bubble	90-100°
						Left rear (*) (8/5-8/15)	Flat plexiglass	60°
						Left rear (≥ 8/16)	Small plexiglass bubble	70-90°
						Right rear	Flat plexiglass	60°
5	9/11	9/29	"	"	120-140	Left front	Large plexiglass bubble	90-100°
						Right front	" "	"
						Left rear(*)	Small plexiglass bubble	70-90°
						Right rear	Flat plexiglass	60°
6	10/25	11/13	"	"	140	"	" "	"
7	1/4	2/1	"	"	140	"	" "	"
8	2/9	3/4	"	"	120-130	"	" "	"

* Recorder

The data recorder and an alternate observer occupied the remaining seats on opposite sides of the aircraft.

Data were collected from aircraft while on and off survey effort. On-effort segments consisted of transects (the randomly selected lines which were to be the basis for density estimation), connecting legs (essentially straight lines connecting transects with one another or with shore) and transits (winding coastal legs or miscellaneous routes among bases of operation, survey areas, and transect lines). Off-effort segments, when no effort data were collected, include circlings (the times between leaving and resuming transect - see below) and reconnaissance or secondary transit flights. These latter periods resulted in "incidental" sightings not used in the fundamental quantitative analysis.

Transects, transits, and connecting legs on which data were collected were flown at an altitude of 750 ft (229m), lower if necessitated by low cloud ceilings. Data were collected as long as the survey strip remained visible and the sea state remained below Beaufort 6. Aircraft cruise speed generally varied between 110 and 150 knots, differing among survey aircraft as a function of their respective capabilities. Slightly lower and higher speeds were sometimes flown in strong head- and tail-winds, respectively. Altitude and speed were occasionally reduced for prolonged observations of behavior and for photography.

Data Recording

On each transect and connecting leg and on many transit legs, the recorder noted starting time, position, and environmental/survey conditions. Each time any of these conditions changed, the recorder noted time, location, and the new conditions. Similar updates were logged for changes in aircraft altitude. These geographic positions and other periodic updates were used to calculate the distance searched (L = Line Length)*.[2]

Whenever marine mammals were sighted "on-effort" the following data were recorded: time, latitude and longitude, species(*), number of individuals(*), observer making sighting, sighting cue, initial behavior, response to aircraft, swim direction, number of calves or pups, and environmental conditions at the sighting location. The angle (γ) formed between the horizon and an imaginary line to the sighting when the aircraft was perpendicular to (abeam of) the animals (Figure 6), was measured with a clinometer. The clinometer angle was used to estimate the perpendicular distance (x)* of the sighting from the line of travel of the aircraft. This was done with the following formula:

$$x = H \tan (90-\gamma) \qquad \text{Equation (1)}$$

where H is the altitude of the aircraft in feet.

Whenever the aircraft left the transect, for example to circle animals, we also recorded: time and position at which the transect was broken, general notes of observations (species, relative sizes of individuals, behavior, etc.) made during circling, and time and position at which the transect was resumed.

All the above data were recorded on a standard form (Figure 7) designed to incorporate all the required information and to facilitate use in the field and transfer of data to computer storage for analysis. Meanings of data codes for Figure 7 are shown in Appendix I.

Following each day of survey the completed transects and all sightings were plotted on the navigation chart(s) which offered the most detailed information on water depth, from the following list:

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[2] This and other measurements essential for density estimation are indicated by an (*).

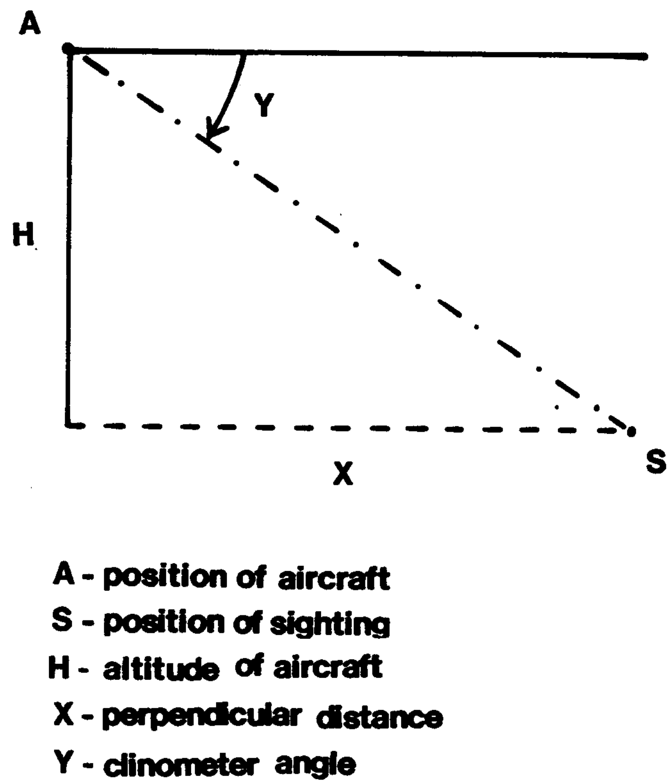


Figure 6. Relationships between clinometer angle, Y, and perpendicular distance from the transect line, x.

DATE ________ CHART PLOTTED ________ FLT # ________ PAGE ____ of ____

POSITION DATA				SIGHTING DATA											ENVIRONMENTAL DATA									NOTES
Time	Latitude	Longitude	[illegible]	Sighting #	Sp.	Total #	[illegible]	O.M.S.	Cue	I.B.	R T A	Swim Direction	# Calves/ Pups	Actual Depth (fm)	Water Temp.	B	W.E.A.	Vis L R	Ice type	% cover	Altitude	Depth Class	CHKDS.	

BLOCK ____ CONNECTING LEG ____ PILOT ________ OBSERVERS and POSITIONS ________ ________

ZONE ____ CO-PILOT ________ ________ ________

Figure 7. The field data form used during aerial surveys (for explanation of entries and codes see Appendix I).

Numbers of NOAA Charts used

1606	16011	16012	16013	16300	16322	16333
16343	16363	16380	16381	16382	16460	16471
16480	16500	16520	16540	16568	16570	16580
16590	16594	16597	16598	16601	16603	16604
16605	16606	16640	INT513	INT514		

Whenever a flight line crossed a major depth gradient (see Appendix I), the latitude, longitude, and code for the new depth class were inserted on the field data form (all such entries were later independently checked and verified at the laboratory). When transects crossed chart boundaries, the transect plot was split between or among maps to achieve the highest possible resolution of effort and sightings by depth.

If an accurate estimate of depth could be made for the position of the sighting, that depth was entered on the data form as "actual depth." During analysis actual depths were used to characterize distribution of animals by depth, as bottom topography in some areas often proved too complex to characterize accurately with simple depth-class entries.

It was also our intention to characterize distribution of effort and sightings by sea surface temperature. A Barnes PRT-5 radiometer was installed between surveys 1 and 2 and used during survey 2 to obtain temperatures at the location of each data entry. However, the entry procedure was difficult, and examination of data from this survey indicated that the device was not functioning properly. The manufacturer reported that the sensor had been damaged prior to survey 2 - presumably while being installed on aircraft N-642, as it had worked properly on the bench immediately prior to installation. It was examined, repaired, and reinstalled without any guarantee by the manufacturer. It failed to function on surveys 3 and 4. The manufacturer reported that sometime during that period the sensor had been submerged in fresh water, presumably during a water landing (no water landings were made by our crew during operations under the present contract). After consultation with the sponsor the unit was not returned to service.

Data Entry and Verification

Before the end of each survey the field team carefully checked the data for errors and inconsistencies, prepared a summary report, and returned the report and a clean copy of checked field data forms to the laboratory. At the laboratory, data were keypunched directly from the the field forms. Columns were added for block, zone, date of data collection, type of survey line (i.e. whether coastal transit, connecting leg, or random transect), and survey number (1 through 8). Data from random transects, all within the two primary study areas, were analyzed separately from all other data. Incidental sightings (i.e. those for which there were no associated data on survey effort) were not included in the data base; they are simply mentioned and described in the species accounts. The computer data base was transferred to the Inter-American Tropical Tuna Commission (IATTC) for analysis by P. Hammond and J. Laake, of IATTC, and Bowles and Leatherwood, of HSWRI.

During analysis, data were cross-checked for the following inconsistencies or anomalies: inconsistencies between reported flight times and line lengths; surprising or improbable changes in environmental conditions; values well out of range of others; sightings reported at unreasonable or unlikely locations; and, for the behavioral data, illogical or inconsistent behaviors. Corrected data were filed at IATTC and HSWRI to replace earlier uncorrected files.

Following analysis, tapes of the corrected data were transferred to Analytical Software, Inc. (ASI), Seattle, Washington, for conversion into OCSEAP format 127 for submission with the final report, as required by the contract.

Data Analysis

Data were examined as follows: 1) effort was tabulated overall, by survey, by depth, by ice cover, and by Beaufort condition; 2) sightings, by species, were tabulated overall, by survey, and by effort class; 3) indices of abundance were calculated, by species, for each survey and for pairs of surveys; 4) maps were prepared to summarize effort and sightings overall and by survey, and to summarize sightings, by species, in various temporal groupings; 5) sightings by species were tested for depth, ice, and Beaufort relationships; and 6) estimates of density and abundance were calculated for species, areas, and surveys for which there were sufficient sightings. In all analyses, the Bering Sea (blocks 1-6) and Shelikof Strait (area 7) were treated separately.

For each species we calculated indices of abundance by survey and by season, using

$$I = {}^{N}/_{L} \qquad \text{Equation (2)}$$

where N is the total number of individuals seen "on-effort" and L is the total number of miles flown "on-effort". For these simple calculations we grouped surveys by season as follows: spring (surveys 1, mid to late March, and 2, May to early June); summer (surveys 3, July, and 4, August); fall (surveys 5, September, and 6, late October through mid-November); and winter (surveys 7, January, and 8, mid-February to early March).

Maps were prepared on a PDP 11/34 minicomputer using the AMP Mapping Package produced by ASI. Estimates of abundance were calculated on the basis of line transect sampling.[3] The following discussion, abstracted from Burnham et al. (1980), briefly reviews the techniques, the assumptions, and the manner in which line transect theory has been applied to the present data.

Line transect sampling is a technique in which animals are directly observed and counted in a sample of the area which the target population inhabits. Such direct sampling techniques: 1) assume that a population of animals inhabits an area A* and that the goal of sampling is to estimate the number of individuals in that population (N*); 2) depend on selection from the total area (A*) of a sample area A (e.g., a set of rectangular strips, quadrants, or circular plots); and 3) assume that the actual number of animals (N) in the sample area is observed and counted.

Since the goal is to estimate the number (N*) or the density (D*), which equals N*/A*, it is necessary to relate the sample to the population. If our assumption is correct, i.e. that the sample density, D = N/A, is representative of the population, then the expected value of D is D*,

$$E(D) = D^* \qquad \text{Equation (3)}$$

Under these circumstances the number of animals in the population is estimated by

$$N^* = DA^* \qquad \text{Equation (4)}$$

---

[3] Abundance estimates were calculated by the IATTC, La Jolla, California, under subcontract to HSWRI and in consultation with the principal investigator, Leatherwood, and Bowles. Relevant materials in this report were abstracted from: IATTC (P. Hammond and J. Laake). 1983. Report on estimates of density of marine mammals sighted during aerial surveys of the south eastern Bering Sea and Shelikof Strait. Final Report to HSWRI, San Diego, Calif. 13 September 1983 from the Inter-American Tropical Tuna Commission, La Jolla, California, 92093, 13 September 1983, 33 pp + 14 figures on unnumbered pages.

This relationship is valid if the following assumptions hold: Assumption 1 - The total area (A^*) is sampled randomly, or the population of animals (N^*) is distributed randomly over the area; Assumption 2 - The animals do not move, or the sampling of the area occurs instantaneously with regard to any movement; and Assumption 3 - The number of animals (N) in the sample area (A) can be counted or estimated without bias.

Assumptions 1 and 2 jointly assure that the probability an animal is in the sample area, A, is equal to A/A^*. In this sense, the sample area is representative. Assumption 3 means that it is necessary to determine density for the sample area accurately. For strip transects it is assumed that all animals within the sample area are counted. This is usually an unrealistic assumption unless the strip is very narrow; so, in most applications of strip transects, the number of animals observed (n) is very likely an underestimate of the number in the sample area (N).

This realization is fundamental to line transect sampling, in which it is recognized that, for a variety of reasons, animals will be missed in the sample area. If animals are counted only once, then the number of animals (n) counted is the product of the number of animals (N) in the area and the probability (P) of seeing an individual animal. If P is known or can be estimated, then it is not necessary to assure that all animals are seen in the sample area, because a reliable estimate of N can be constructed as

$$N = n/P \qquad \text{Equation (5)}$$

and the estimate of the sample density as

$$D = N/A = n/AP \qquad \text{Equation (6)}$$

The estimation of P is the central concept of line transect sampling. In other direct sampling techniques, such as strip or quadrant sampling, P is assumed to be unity. The following describes the concepts and the necessary assumptions for estimation of P.

As with strip transect sampling, line transect sampling is performed by one or more observers who travel along a line, of length L, and search for animals out to a perpendicular distance, W, on either side of the line (so that A = 2LW). It is not necessary to define W because it effectively can be treated as infinite in the analysis. However, unlike the case in strip transects, in line transects the perpendicular distance (x) from the line to each observed animal is recorded (regardless of which side of the line it is on). P can be expressed as

$$P = \int_0^W g(x) \frac{1}{W} dx \qquad \text{Equation (7)}$$

where W is the width of the sample area and g (x)dx is the probability of seeing an animal or group of animals in the interval (x, x + dx). The probability density function (pdf) of the perpendicular distance f(x) is

$$f(x)dx = \frac{g(x)\frac{1}{W}}{\int_0^W g(x)\frac{1}{W}\, dx} = \frac{g(x)}{PW} \qquad \text{Equation (8)}$$

The above relationships provide a conceptual basis for estimating P by fitting a suitable function for f(x) to the observed perpendicular distances. Then, as Burnham and Anderson (1976) showed, if all animals close to the line are seen (Assumption 4), i.e. if

$$g(0) = 1, \qquad \text{Equation (9)}$$

then

$$f(0) = \frac{1}{WP} \qquad \text{Equation (10)}$$

and $$D = \frac{n}{2LWP} = \frac{nf(0)}{2L}$$ Equation (11)

This shows that P and D can be estimated from f(0), which is the value at the origin (x = 0) of the pdf of perpendicular distances.

An unbiased estimate of density is only possible if an unbiased estimate of f(0) can be made. This requires that either f(x) be completely known or that it can be estimated adequately from the data, at least near x = 0. Rarely would f(x) be completely known. At best, the parameters of a known function have to be estimated from the data. Therefore, it is necessary that all measurements of distance be without error (Assumption 5), so that the recorded distances reflect accurately the distribution f(x). This assumption can be relaxed if the distances can be recorded correctly into discrete intervals. An analysis can then be performed on the grouped data, rather than on the individual measurements.

An estimate of the sampling variance for density, as given by Burnham et al. (1980), is

$$Var(D) = D^2 \ (CV^2(n) + CV^2 \ (f(0)))$$ Equation (12)

where $$CV^2(n) = Var(n)/n^2$$ Equation (13)

and $$CV^2(f(0)) = Var(f(0))/(f(0))^2$$ Equation (14)

This will provide a valid estimate of the variance if sightings are independent events (Assumption 6).

A situation which obviously violates Assumption 6 is when animals are clustered in schools or groups. This problem has been examined by several authors (e.g., Hayes, 1977; Burnham et al., 1980; Quinn, 1980).

In such situations, the clusters are treated as objects which are sighted independently. The number of sightings (n) is the number of sighted clusters (e.g. schools or herds) and the perpendicular distance is recorded to the cluster center. These perpendicular distances are used to estimate f(0) and to construct an estimate of the density of clusters (D_c). An average cluster size ($\overline{C}$) is calculated and the density of animals is simply,

$$D = D_c\overline{C} \qquad \text{Equation (15)}$$

$$= \frac{n\ \bar{f}(0)C}{2L} \qquad \text{Equation (16)}$$

The estimate of D is unbiased if the above assumptions are met for D_c and if $\overline{C}$ is an unbiased estimate of the true average cluster size. For the latter to be true the following assumptions are required:

Assumption 7 - Cluster size must be measured without error; and

Assumption 8 - The size of the cluster must not affect its probability of being detected. An estimate of the sampling variance for D can be constructed by

$$\text{Var (D)} = D^2\ (CV^2(D)_c) + CV^2(\overline{C})). \qquad \text{Equation (17)}$$

The application of line transect sampling to a particular situation involves simply collecting and analyzing the data in a manner which is consistent with the above stated assumptions. The validity of the density estimates produced is directly related to how well the assumptions are satisfied. The present surveys, as described in the previous sections and in the Results and Discussion sections below, were designed and executed to collect the data for line transect sampling. Particular methods used for analysis are described further under Results and Discussion because they were, to a large degree, a consequence of some preliminary results.

In addition to calculating indices of abundance and estimates of density, we attempted, when data allowed, to correlate the observed distributions of marine mammals with environmental conditions. To do so, we grouped sightings by block, season and environmental type (Beaufort number, ice cover, and depth class), by block and environmental type, and by environmental type alone, depending on the number of sightings available.

Data so grouped were examined using a simple statistical test, the log-likelihood ratio-test ("G" Sokal and Rohlf, 1969: 549-601) for goodness of fit. The G-test is preferable over the Chi-square (X^2) test because in the former, tests performed over a subset of the data are additive, whereas in the latter they are only approximately additive. The G values are distributed as the X^2 values and are interpreted using the same table. A more rigorous multivariate regression analysis was rejected due to the sparseness and considerable biases of our sightings.

Because of the small sample sizes, data from various seasons, blocks, environmental variables and effort-classes had to be pooled. We are aware that combining sightings from on- and off-track in this manner reduces the usefulness of the test because the latter sightings were not collected randomly. However, we observed no significant difference in distribution of the sightings from on-track and those off-track and suspect the data are comparable. Total numbers of sightings were scaled by effort prior to statistical analysis.

We were only able to perform such analysis, with varying levels of success, for 6 species of cetaceans (gray, fin, minke and killer whales and Dall's and harbor porpoises) and 3 species of pinnipeds (walruses, Steller's sea lions and harbor seals). For even the most frequently encountered of these species, many cells in the above combinations were empty. For various reasons discussed throughout this report we regard all tests performed as exploratory and, at best, only suggestive of associations of the animals with the environmental conditions indicated. The tests are not "proof" of habitat preference.

The sampling scheme was not originally stratified by environmental factors. As a consequence, the effort is heavily skewed in favor of some depth classes, ice covers, or Beaufort levels. Moreover, depth class, ice cover, and Beaufort are not independent of one another. Since each of these factors affects the sightability of animals directly or in combination with correlated factors, and since we cannot examine their effects separately, any conclusions about the distribution of animals with respect to a given environmental type may be nothing more than an artifact of the effects on sightability of correlated factors, compounded by small sample sizes and heavily skewed effort.

Literature and Other Sources of Information

In addition to the data obtained during the aerial surveys, we reviewed available literature pertaining to the areas under study, concentrating on target species and recent publications. We also perused the files of willing colleagues, and in all villages that were visited, we interviewed scientists, fishermen, native leaders, and other people with local knowledge. Among the most important recent compilations of information on marine mammals of the study areas are Lowry, et al. (1982a,b) supplemented by Hills and Pearse (1982). We depended heavily on these three documents.

We solicited and received from colleagues reports of sightings of marine mammals in 1982-83 made during cruises as follows: R/V Miller Freeman, Kodiak to St. Lawrence Island return, July 1982 (Bernd Wursig, pers. comm., 17 November 1982); NOAA Ship Surveyor, Dutch Harbor to Navarin Basin return, July-August 1982 (John J. Brueggeman, pers. comm., 12 January 1983); and Dutch Harbor to St. Lawrence Island return, September 1982 (Randall S. Wells, pers. comm., 9 November 1982). Sightings of fin, minke, humpback and killer whales and harbor porpoises made on those cruises were plotted on figures summarizing sightings made during the present surveys or were included in text reviews. However, neither gray whale nor Dall's porpoise sightings, which were numerous, were plotted because patterns they indicated were already apparent from our survey data.

RESULTS AND DISCUSSION

The amount and quality of data collected during the eight aerial surveys limited both the types and the quality of analyses that could be performed. Therefore, before presenting systematic accounts of our findings by species, we discuss the survey effort, describe the specific methods used for density estimation and the preliminary results which dictated the use of those methods, present the summary results, and discuss limitations to the density estimates.

Survey Effort

Effort is expressed as number of linear nautical miles (nm) of flight during which data were systematically recorded. Planned and actual apportionment of effort by block and zone can be seen in Table 2. During the eight survey periods we flew a total of 28,743nm (53.232 km) "on effort".

Of that total, 1,596nm (2,956 km) were flown outside and 27,147nm (50,276 km) inside the study areas. Of this latter class, 24,164nm (44.752 km) were in the Bering Sea [17,376nm (32,108 km) on-transect and 6,788nm (12,571 km) off-transect] and 2,983nm (5,525 km) were in Shelikof Strait [2,015nm (3,732 km) on-transect and 968nm (1,793 km) off-transect]. The geographical and temporal distribution of effort is shown in Figures 8-11.

Before starting the analysis, we examined the effort by various combinations of area, survey(season), and environmental condition. We found no substantial differences in the distribution of effort on-transect and that off-transect with respect to the most important environmental variables (e.g. for wind force conditions encountered on-and off-transect see Figure 12). Therefore, for descriptive analysis we combined all effort in all areas.

The indices of abundance were calculated using all effort within the study areas. The subsamples of effort used for density estimates were the 17.376 nm (32,108 km) and 2,015 nm (3,732 km) of survey on transect, and their associated sightings in Bering Sea and Shelikof Strait, respectively.

The distribution of effort by Beaufort number and block is shown in Figure 13. Note that, in this figure and in following figures and tables the "other areas" are coastal transits and connecting legs. Effort by Beaufort number and season within each block is shown in Figure 14. The data represented in Figure 13 are summarized in Table 4. Overall, higher proportions of surveys were conducted in conditions of Beaufort 2 (17%), 3 (27%), and 4 (21%) than in remaining conditions (Beaufort 0,10%; 1,8%; 5,12%; 6,4%; and 7,<1%). In the Bering Sea, wind and sea surface conditions were generally most favorable to survey in the two easternmost blocks (1 and 6), and slightly less hospitable in the northernmost block (2). Sea state was consistently significantly higher in block 3 and reached a

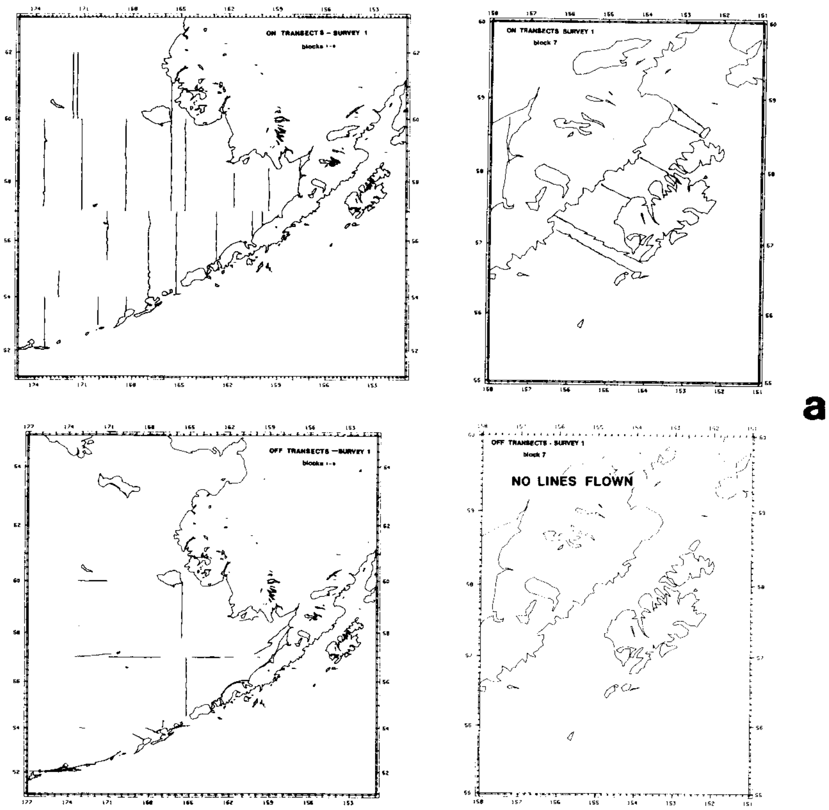


Figure 8a. Survey effort during Survey 1 (mid- to late-March) in Blocks 1-6 (left) and Block 7 (right). The panels show effort on random transect flights (top) and on all other flights (bottom).

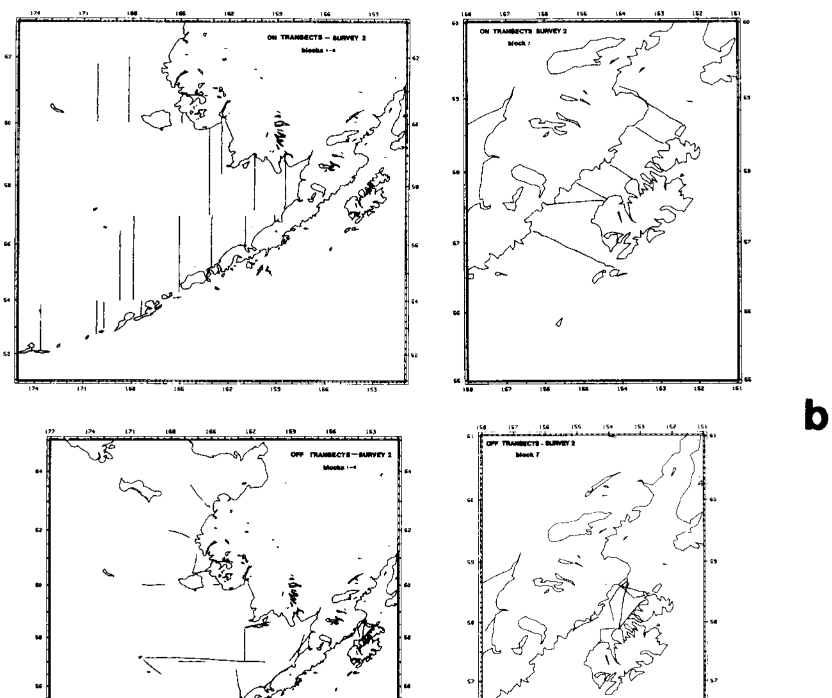
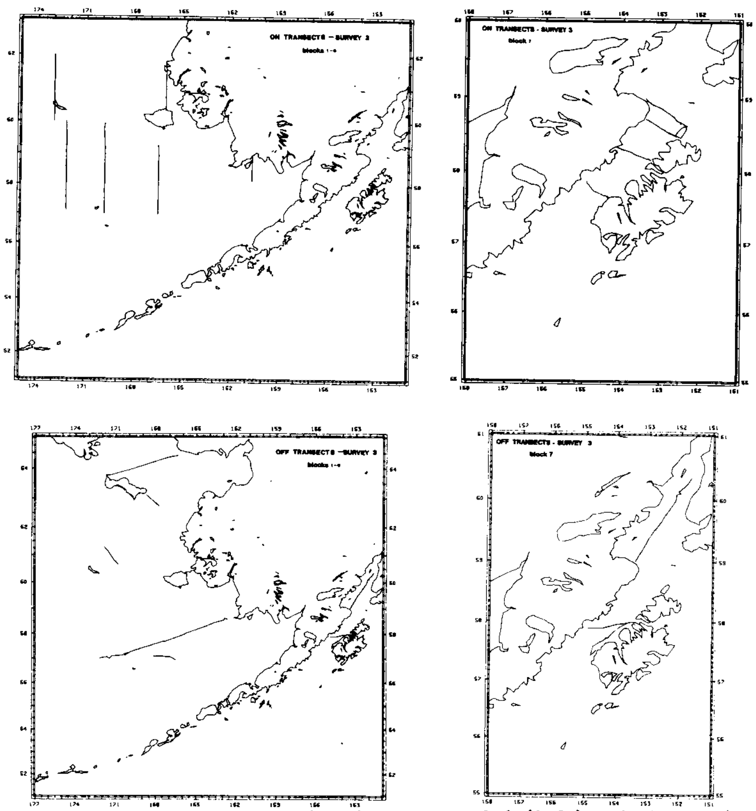
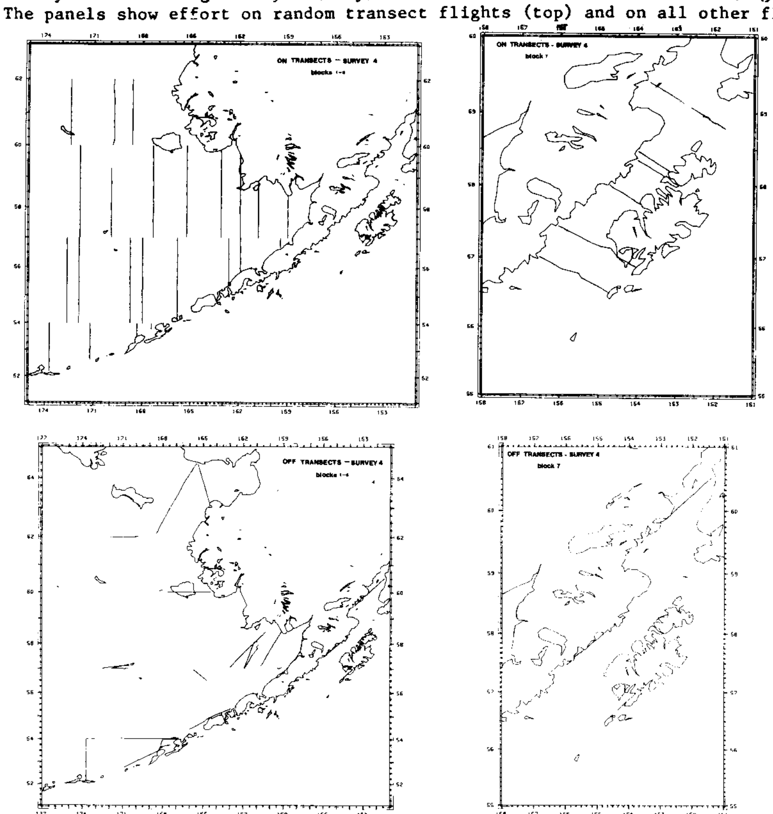


Figure 8b. Survey effort during Survey 2 (May to early June) in Blocks 1- 6 (left) and Block 7 (right). The panels show effort on random transect flights (top) and on all other flights (bottom).



a

Figure 9a. Survey effort during Survey 3 (July) in Blocks 1-6 (left) and Block 7 (right). The panels show effort on random transect flights (top) and on all other flights (bottom).



b

Figure 9b. Survey effort during Survey 4 (August) in Blocks 1-6 (left) and Block 7 (right). The panels show effort on random transect flights (top) and on all other flights (bottom).

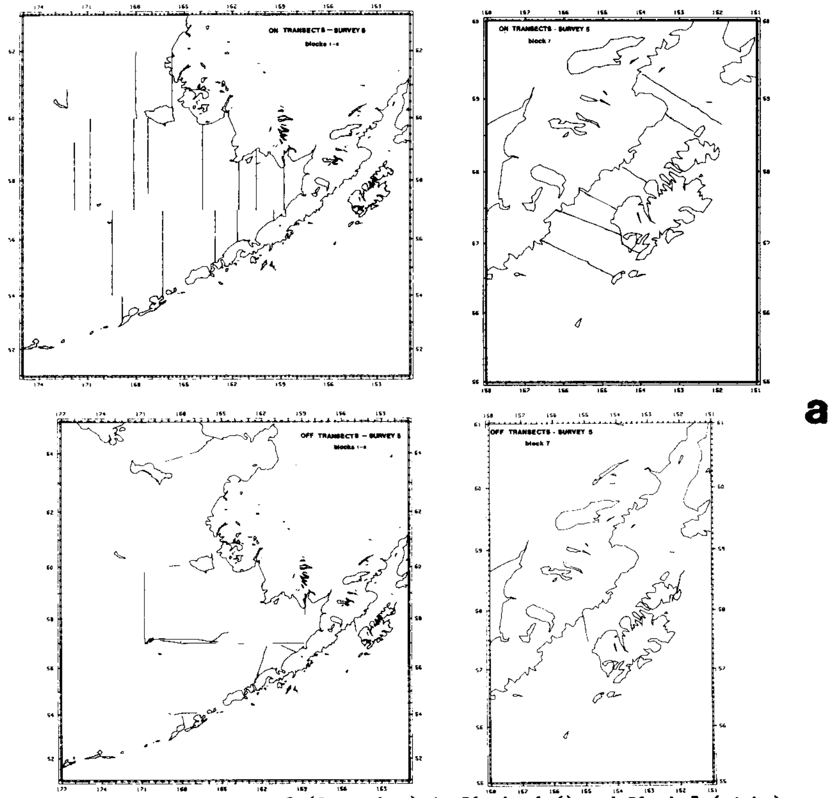


Figure 10a. Survey effort during Survey 5 (September) in Blocks 1-6) and Block 7 (right). The panels show effort on random transect flights (top) and on all other flights (bottom).

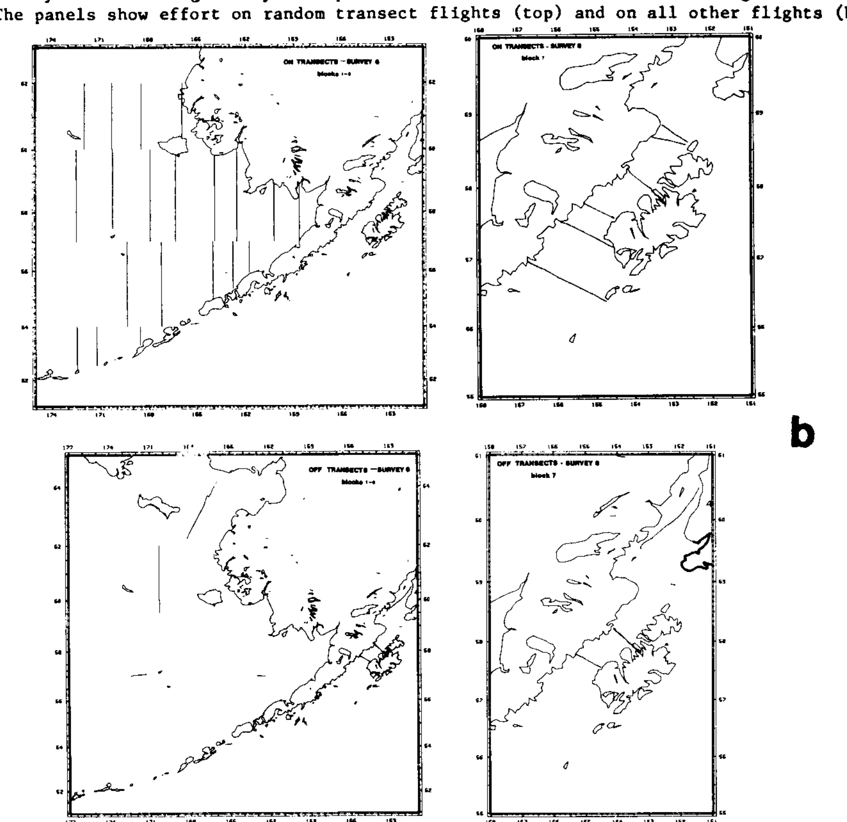
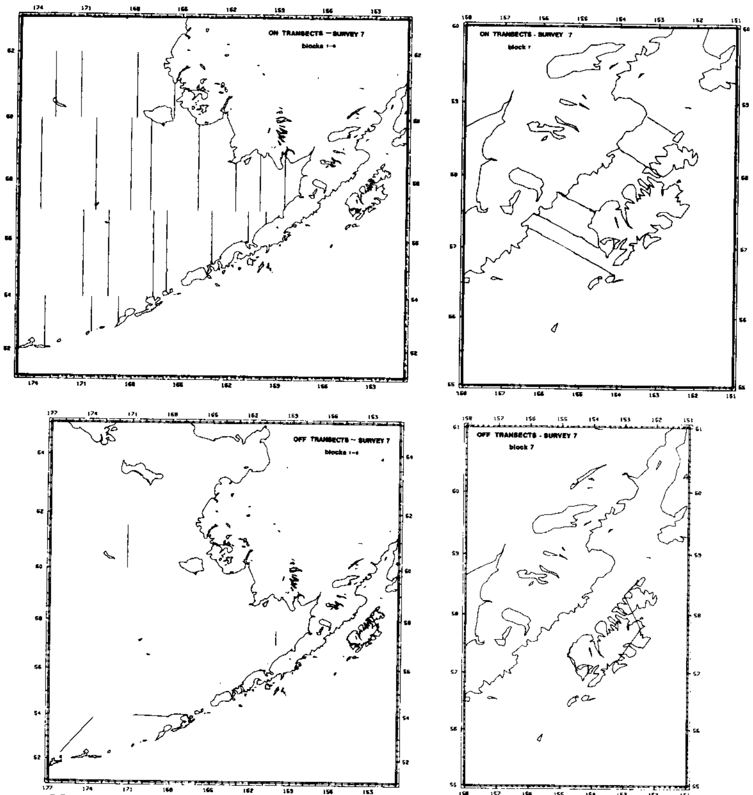
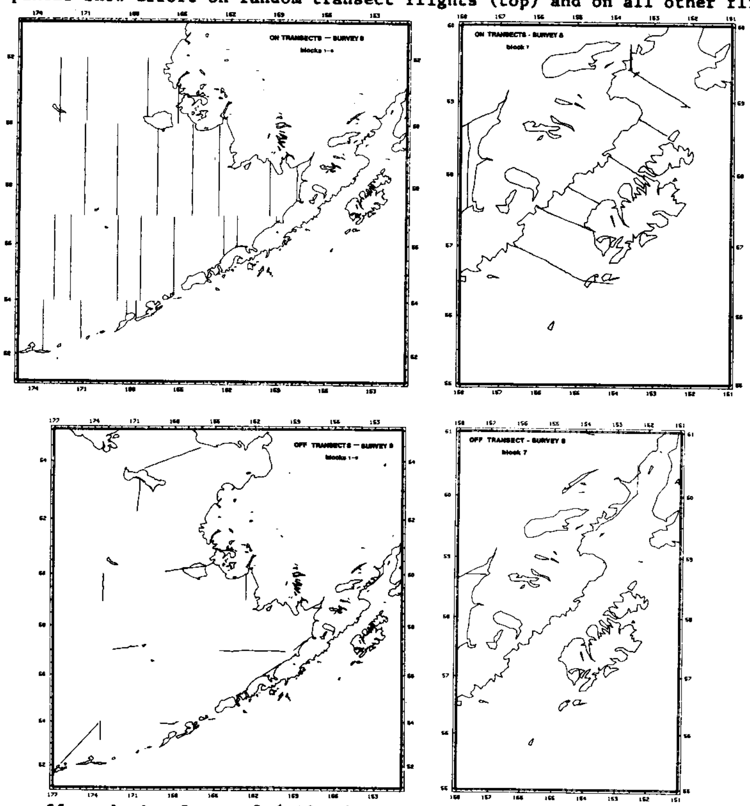


Figure 10b. Survey effort during Survey 6 (late October through mid-November) in Blocks 1-6 (left) and Block 7 (right). The panels show effort on random transect flights (top) and on all other flights (bottom).



a

Figure 11a. Survey effort during Survey 7 (January) in Blocks 1-6 (left) and Block 7 (right). The panels show effort on random transect flights (top) and on all other flights (bottom).



b

Figure 11b. Survey effort during Survey 8 (mid-February to early March) in Blocks 1-6 (left) and Block 7 (right). The panels show effort on random transect flights (top) and on all other flights (bottom).

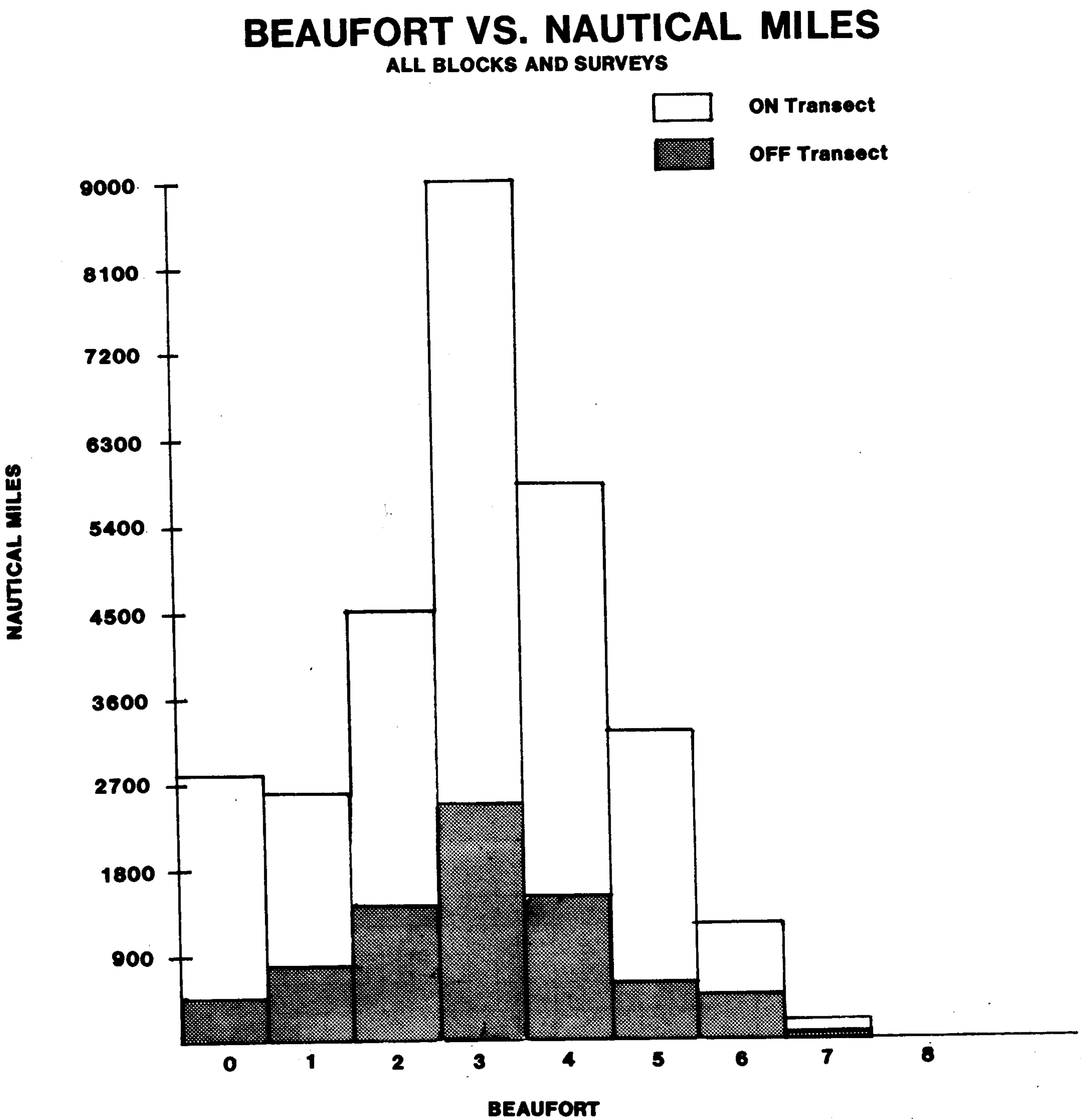


Figure 12. The distribution of survey effort by Beaufort numbers (all effort within the study areas).

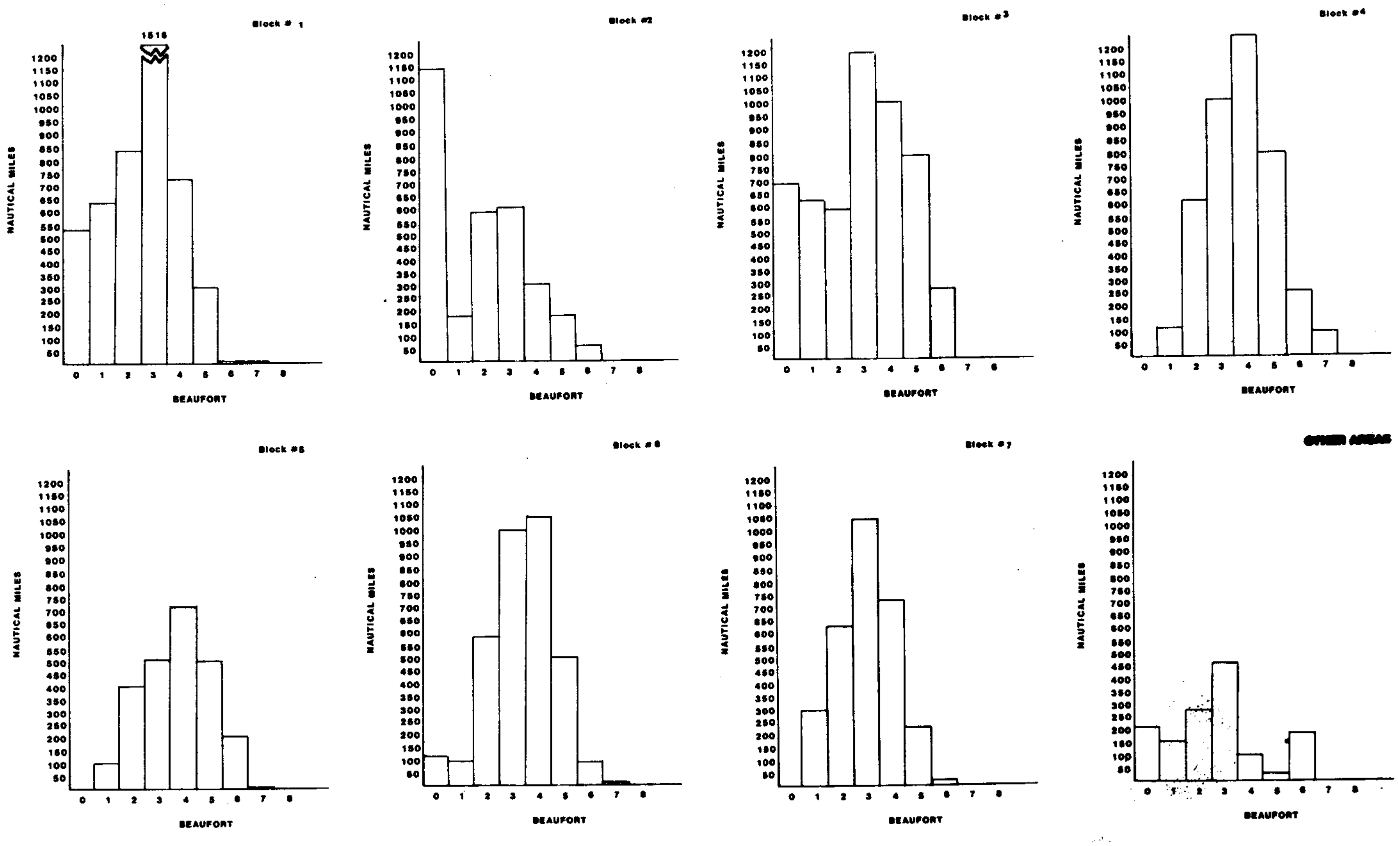


Figure 13. The distribution of survey effort by Beaufort number by block (all effort, all areas).

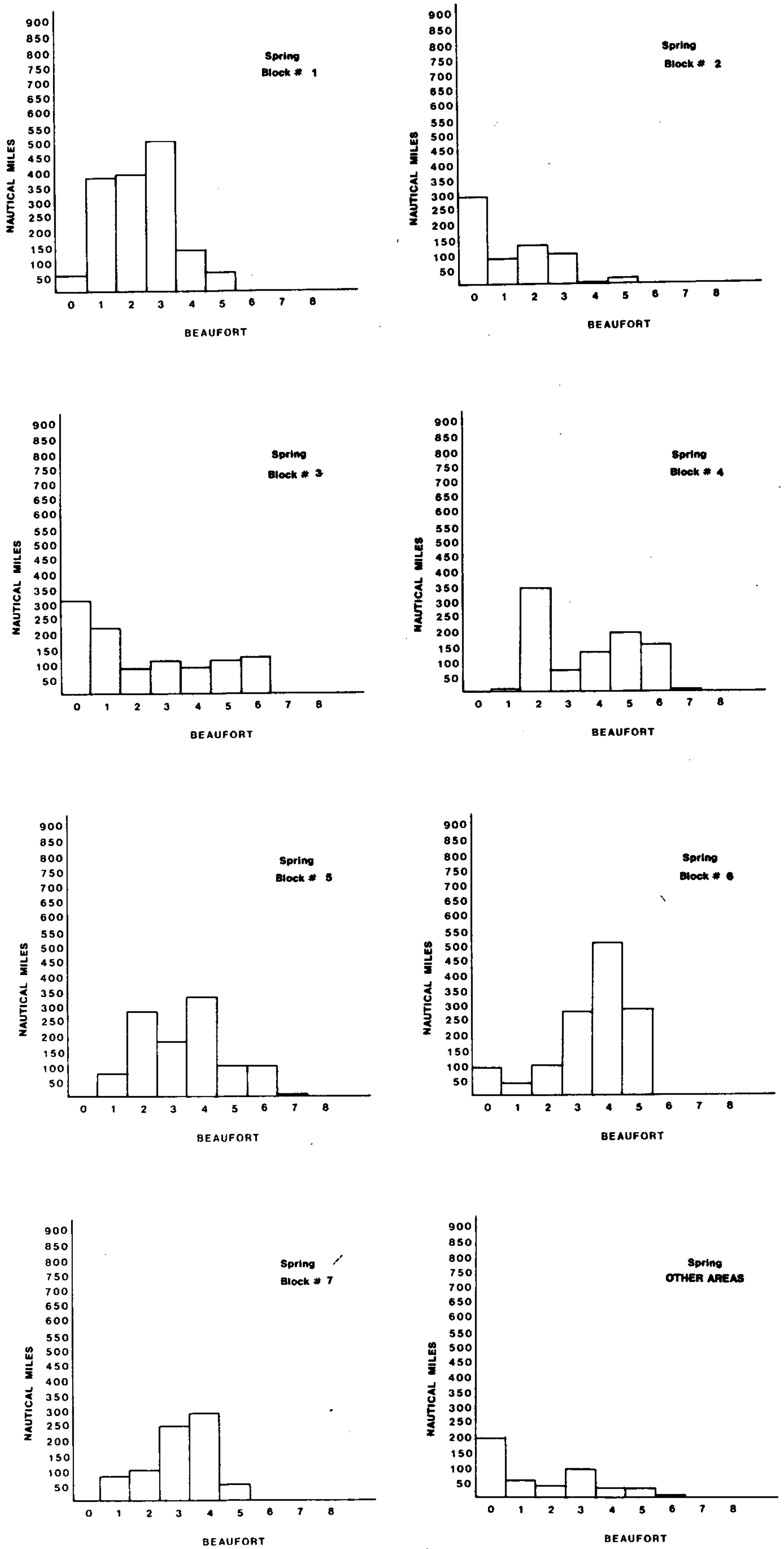


Figure 14 a. The distribution of survey effort by Beaufort number and block for spring.

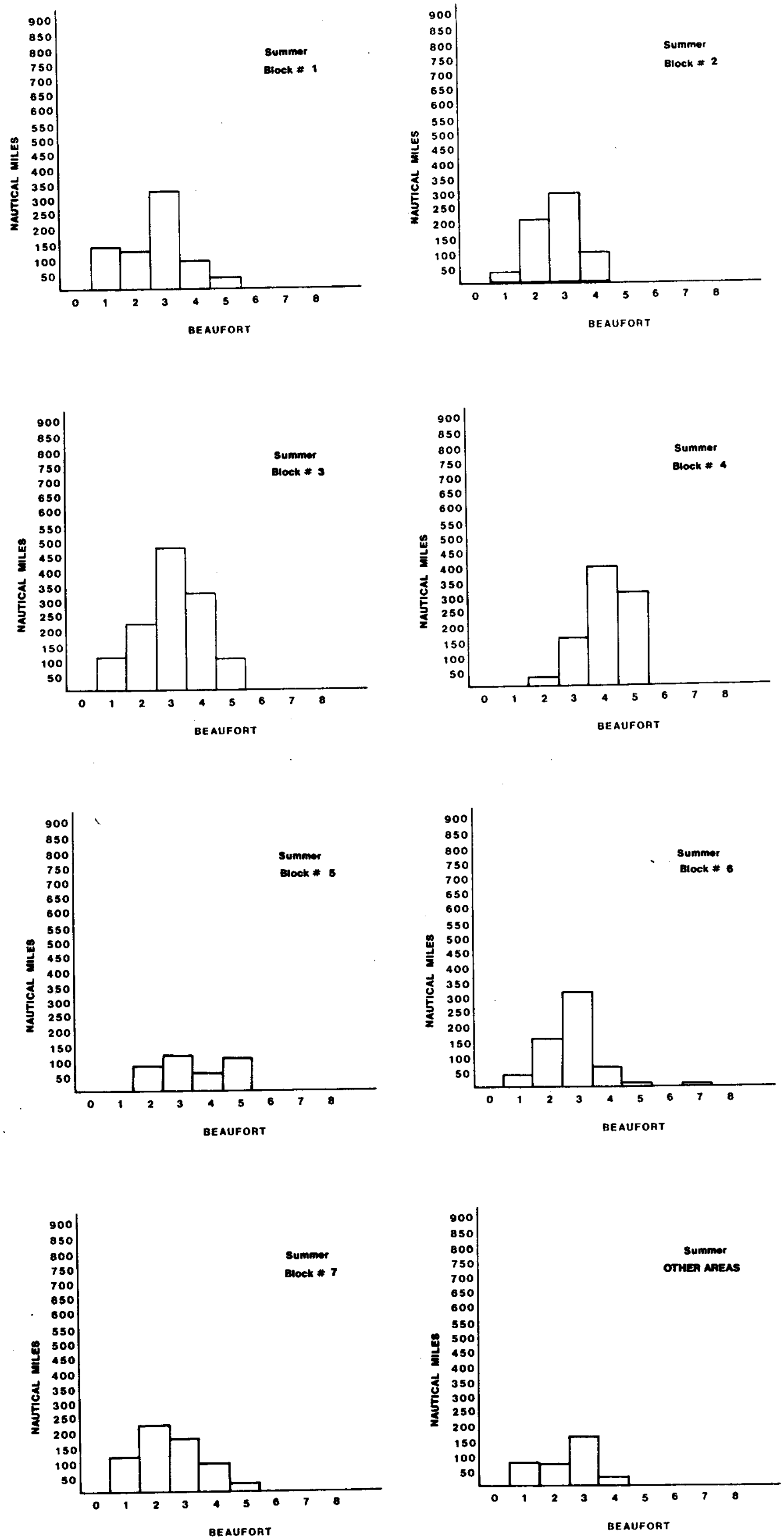


Figure 14 b. The distribution of survey effort by Beaufort number and block for summer.

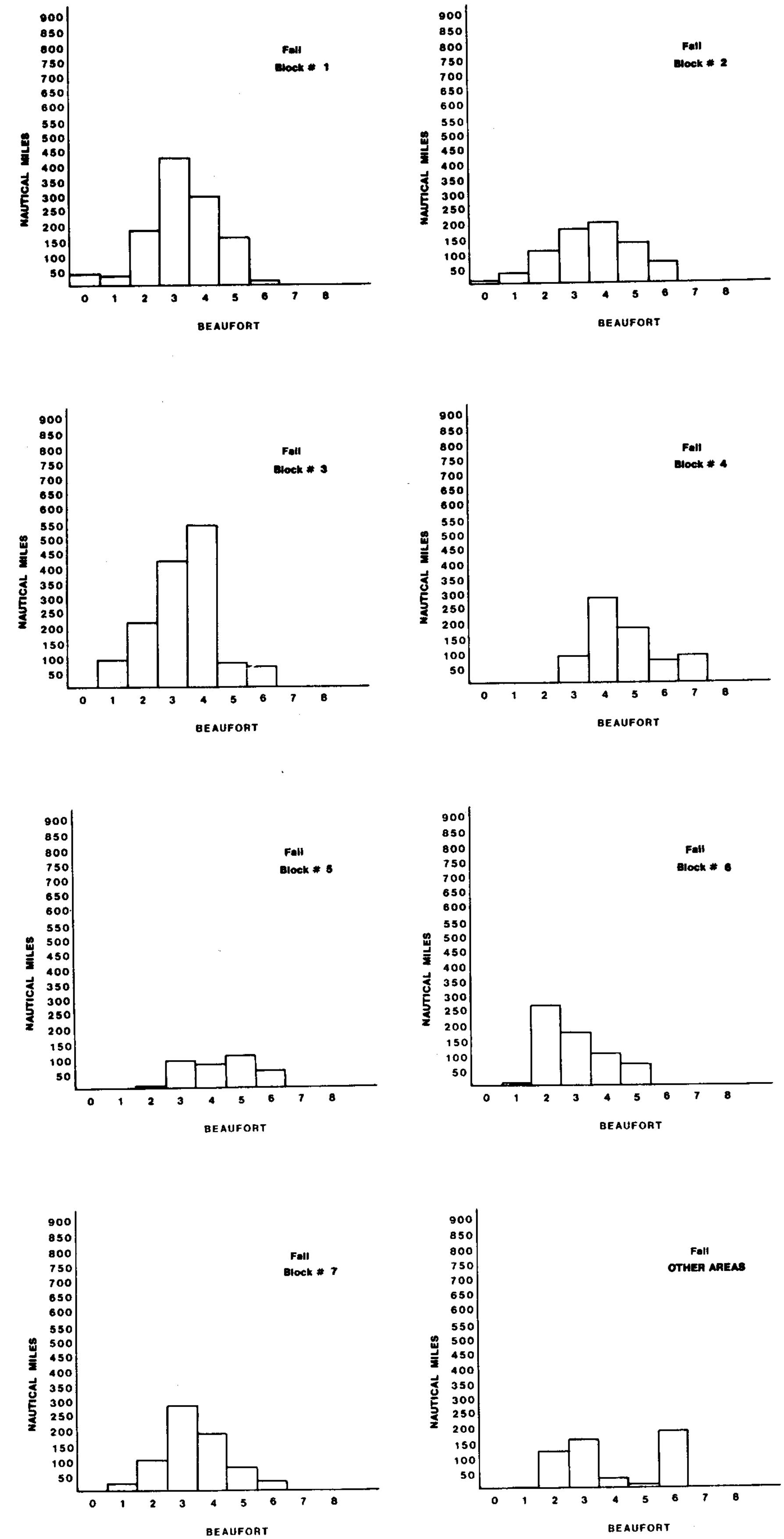


Figure 14 c. The distribution of survey effort by Beaufort number and block for fall.

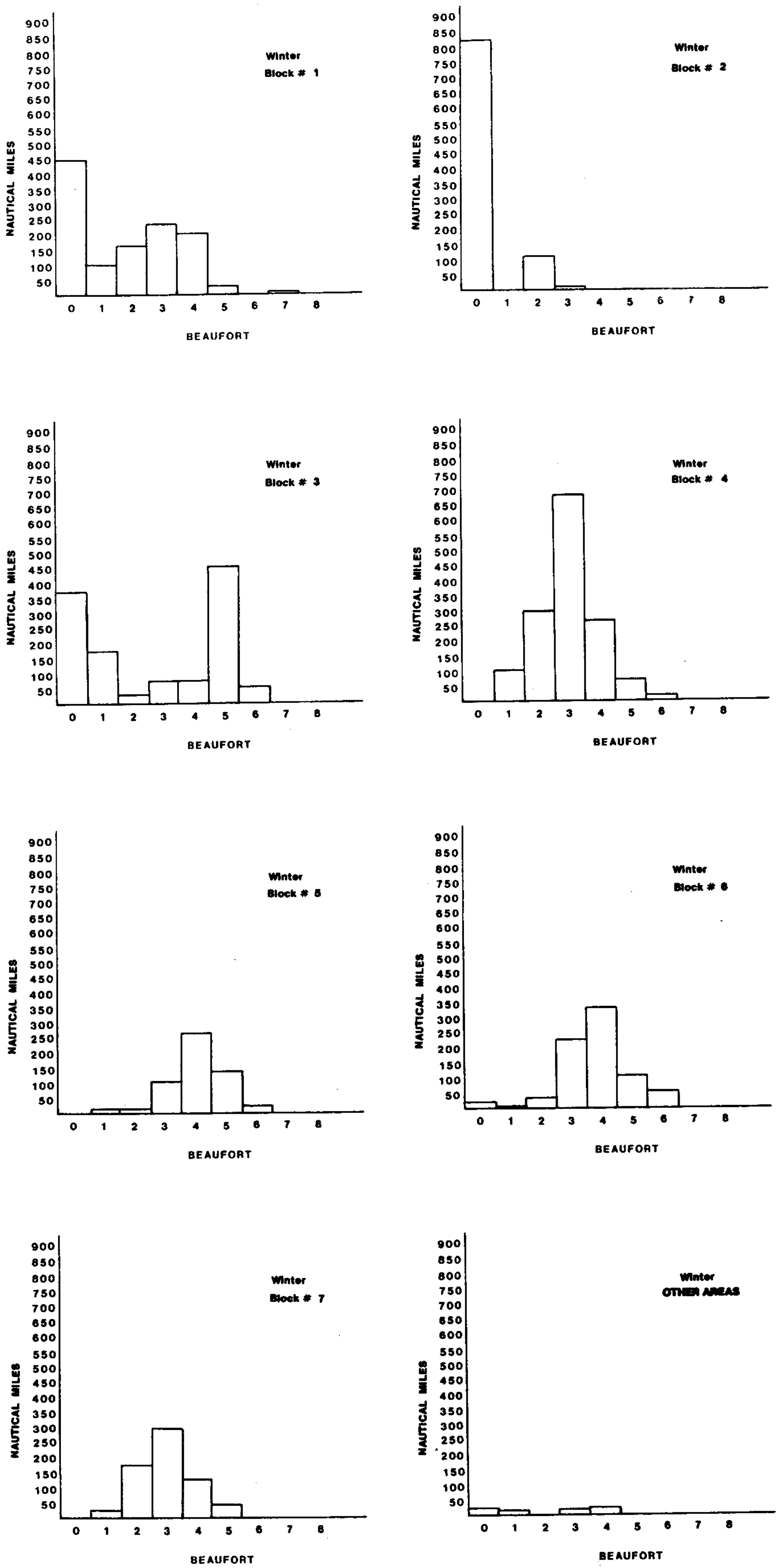


Figure 14 d. The distribution of survey effort by Beaufort number and block for winter.

Table 4. Summary of overall effort by block and Beaufort number.

Beaufort Effort Summary

Beaufort	0	1	2	3	4	5	6	7	Total	Proportion of total effort
all	2718	2260	4508	7278	5786	3296	1156	145	27147	1.00
trk	2233	1410	3107	4811	4338	2693	682	117	19391	.71
ot	485	850	1401	2467	1448	603	474	28	7756	.29
Overall block										
1	546	648	846	1516	736	301	12	14	4619	.17
2	1150	179	592	617	306	169	66	0	3079	.11
3	688	637	586	1098	1010	779	279	0	5077	.19
4	0	127	625	1019	1099	780	252	109	4011	.15
5	0	92	391	510	726	496	205	14	2434	.09
6	123	105	572	1011	1044	496	97	8	3456	.13
7	0	303	632	1046	731	228	43	0	2983	.11
9	211	169	264	461	134	47	202	0	1488	.05
SE Bering	2718	1957	3876	6232	5055	3068	1113	145	24164	.89
On -track block										
1	467	475	638	946	621	224	7	0	3348	.12
2	1056	167	547	464	300	56	30	0	2620	.10
3	688	353	532	980	821	761	216	0	4351	.16
4	0	96	473	854	806	725	252	109	3315	.12
5	0	57	97	315	521	380	84	8	1462	.05
6	22	51	374	604	753	359	87	0	2250	.08
7	0	211	446	648	516	188	6	0	2015	.07
SE Bering	2233	1199	2661	4163	3822	2505	676	117	17376	.64
Off-track block 1	79	173	208	570	115	77	5	14	1241	.05
2	94	12	45	153	6	113	36	0	459	.02
3	0	284	54	118	189	18	63	0	726	.03
4	0	31	152	165	293	55	0	0	696	.04
5	0	35	294	195	205	116	121	6	972	.04
6	101	54	198	407	291	137	10	8	1206	.04
7	0	92	186	398	215	40	37	0	968	.04
9	211	169	264	461	134	47	202	0	1488	.05
SE Bering	485	758	1215	2069	1233	563	437	28	6788	.25

peak in blocks 4 and 5 (Figure 13). These overall trends are probably related somewhat to ice cover (Figure 15; Table 5), as winds are often abated or their effects on the sea surface subdued by the presence of extensive ice cover. Blocks 4 and 5 are principally ice-free. The remaining four zones, however, are at least partially ice-covered in winter and spring. Consistent with the above observations, conditions within blocks 1-3 and 6 were better for survey in winter and spring than they were in summer and fall, while in blocks 4 and 5 conditions remained approximately the same throughout the year or worsened slightly during winter.

In Shelikof Strait, wind and sea surface conditions were roughly comparable overall to those for all Bering Sea blocks combined. However, there were no seasonal effects observed in the strait. The area is ice-free, year-round.

The distribution of survey effort by depth class is summarized in Figure 16 and shown by depth class by block in Figure 17 and Table 6. Overall, we spent 78% of our effort over water less than 100 fathoms (183m) deep and 69% over water shallower than 60 fathoms (110m) deep. The only areas where there was substantial effort over water deeper than 100 fathoms (183m) were Shelikof Strait and blocks 4 and 5, the latter two areas including significant amounts of water more than 500 fathoms (915m) deep.

Sightings of Marine Mammals

During the eight survey periods we made a total of 1,864 sightings of marine mammals, including 178 outside the study areas (6 in Cook Inlet, the remainder in the Bering Sea) and 37 for which no data were recorded on group (or herd) size. Because they complicated data analysis and represented

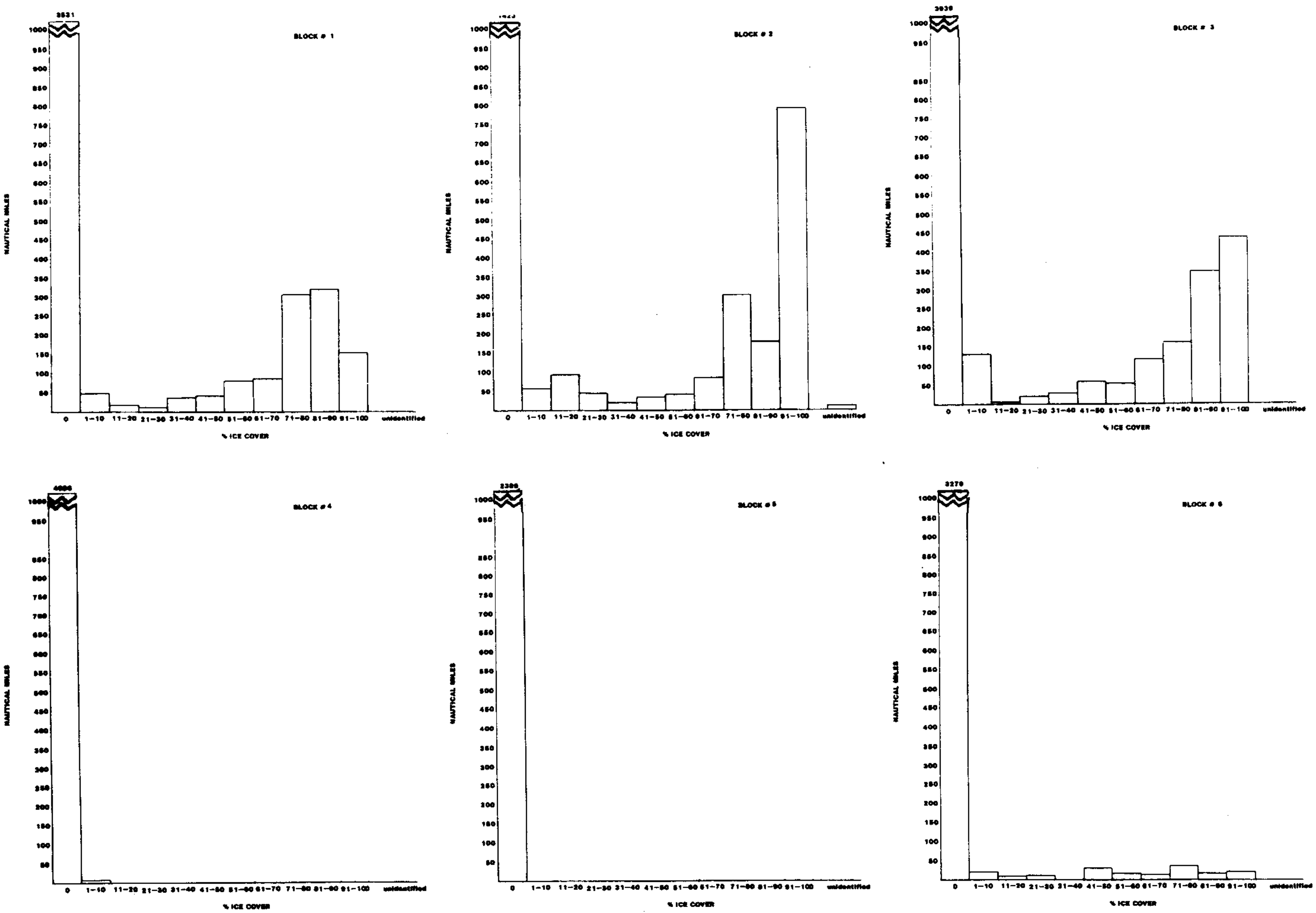


Figure 15. The distribution of survey effort by ice cover and block.

Table 5. Summary of overall effort by block and percent ice cover.

Ice cover	0	1-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	999	Total	Proprotion of total effort
All	23135	297	133	99	78	157	201	295	819	883	1390	10	27497	1.00
trk	15856	217	76	78	75	128	147	230	665	745	1191	0	19408	.71
ot	7279	80	57	21	3	29	54	65	154	138	199	10	8089	.29
Overall														
block 1	3531	50	21	15	32	37	81	84	311	321	157	0	4640	.17
2	1423	60	95	45	20	32	42	81	303	179	781	9	3070	.11
3	3939	134	8	20	26	61	55	118	163	349	429	0	5302	.19
4	4006	8	0	0	0	0	0	0	0	0	0	0	4014	.15
5	2389	0	0	0	0	0	0	0	0	0	0	0	2389	.09
6	3279	21	7	9	0	27	16	12	29	17	23	0	3440	.12
7	2996	0	2	0	0	0	0	0	0	0	0	0	2998	.11
9	1572	24	0	10	0	0	7	0	13	17	0	1	5084	.06
SE Bering	20139	297	131	99	78	157	201	295	819	883	1390	10	24499	.89
On-track														
block 1	2425	46	21	15	32	37	65	66	264	287	141	0	3399	.12
2	1181	32	45	45	17	32	38	62	303	162	705	0	2622	.10
3	3252	131	8	18	26	47	37	102	98	294	342	0	4355	.16
4	3309	8	0	0	0	0	0	0	0	0	0	0	3317	.12
5	1464	0	0	0	0	0	0	0	0	0	0	0	1464	.05
6	2226	0	0	0	0	12	7	0	0	2	3	0	2250	.08
7	1999	0	2	0	0	0	0	0	0	0	0	0	2001	.07
SE Bering	13857	217	74	78	75	128	147	230	665	745	1191	0	17407	.63
Off-track														
block 1	1106	4	0	0	0	0	16	18	47	34	16	0	1241	.04
2	242	28	50	0	3	0	4	19	0	17	76	9	448	.02
3	687	3	0	2	0	14	18	16	65	55	87	0	947	.03
4	697	0	0	0	0	0	0	0	0	0	0	0	697	.02
5	925	0	0	0	0	0	0	0	0	0	0	0	925	.03
6	1053	21	7	9	0	15	9	12	29	15	20	0	1190	.04
7	997	0	0	0	0	0	0	0	0	0	0	0	997	.04
9	1572	24	0	10	0	0	7	0	13	17	0	1	1644	.06
SE Bering	6282	80	57	21	3	29	54	65	154	138	199	10	7092	.26

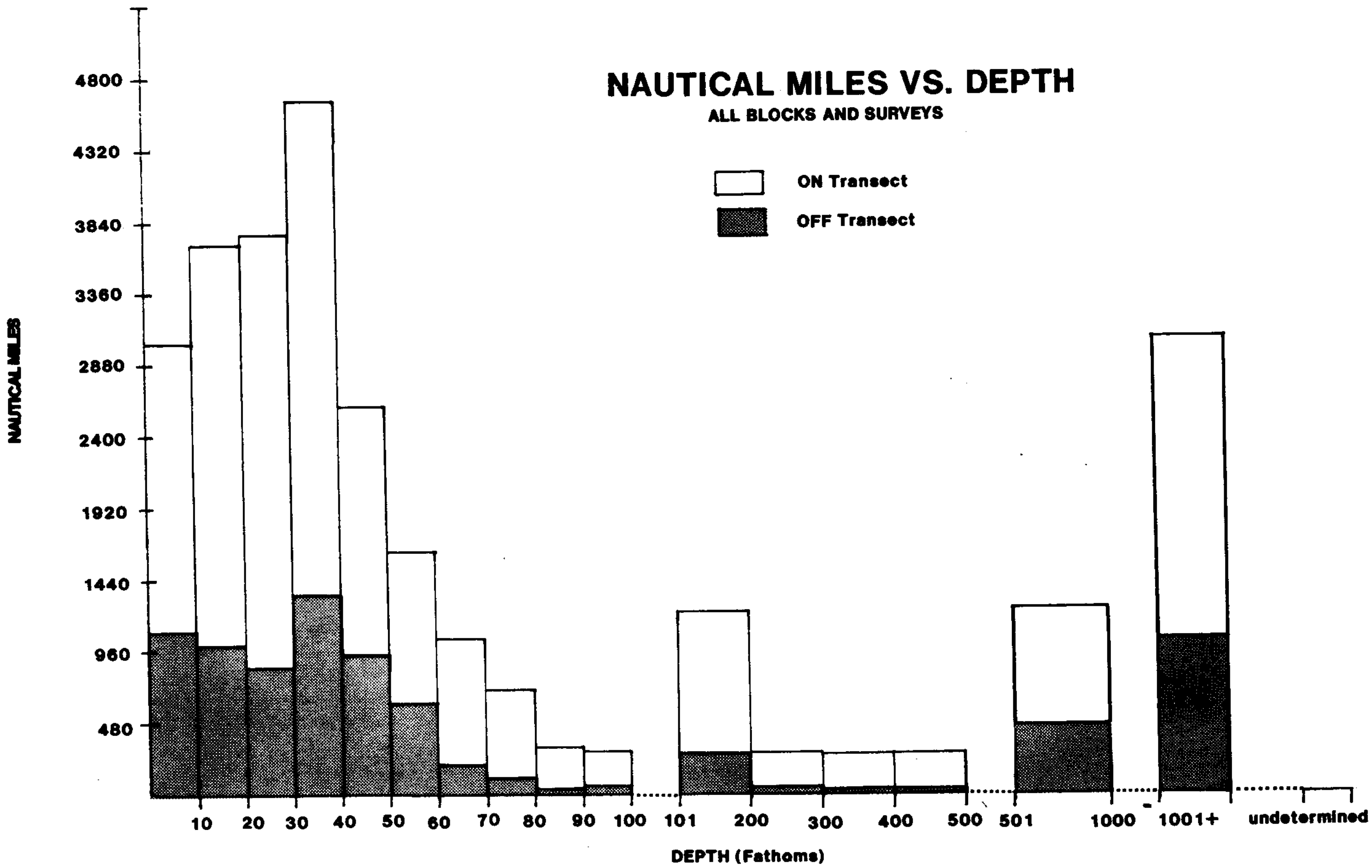


Figure 16. The distribution of survey effort by depth class, overall.

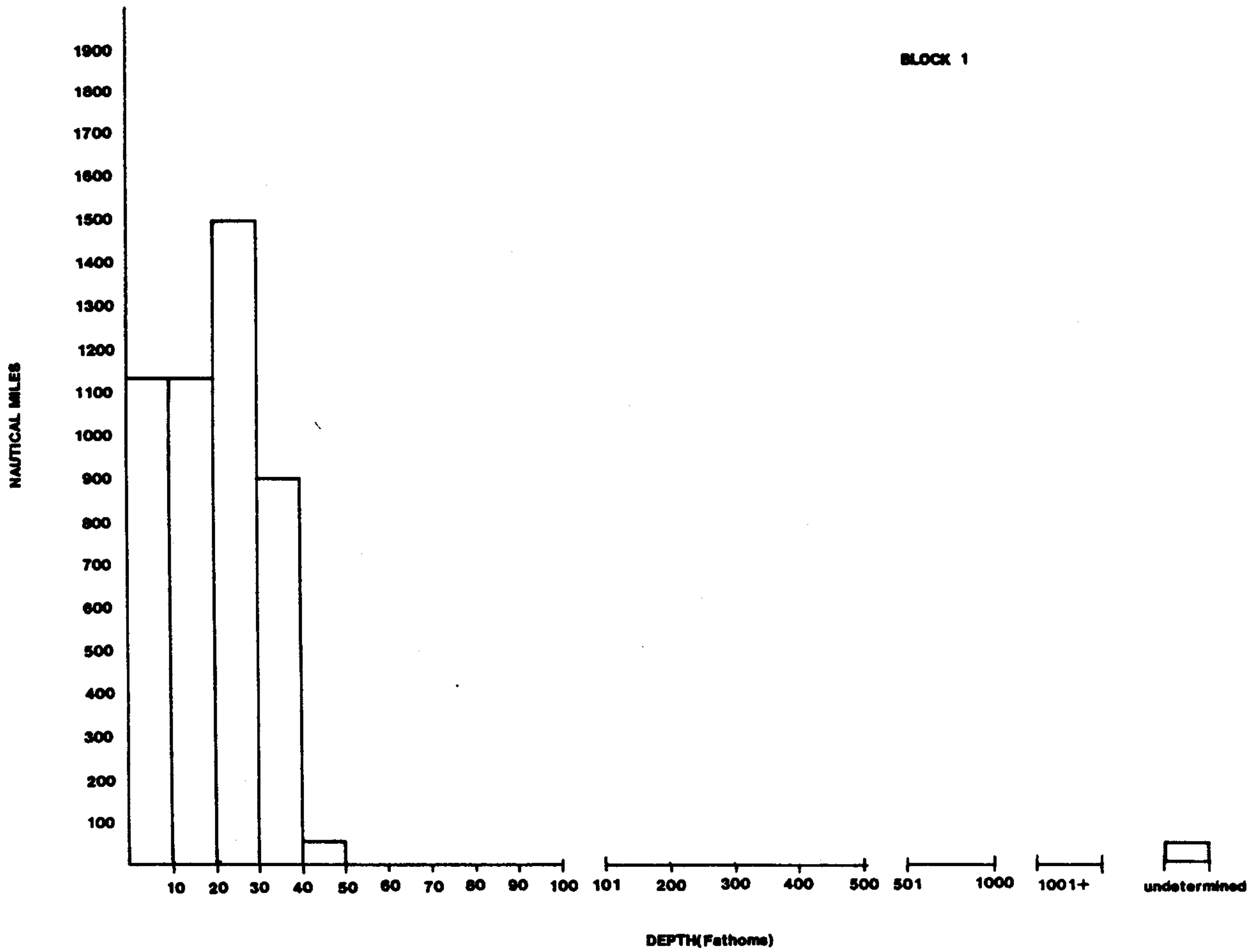


Figure 17a. The distribution of survey effort by depth class (Block 1).

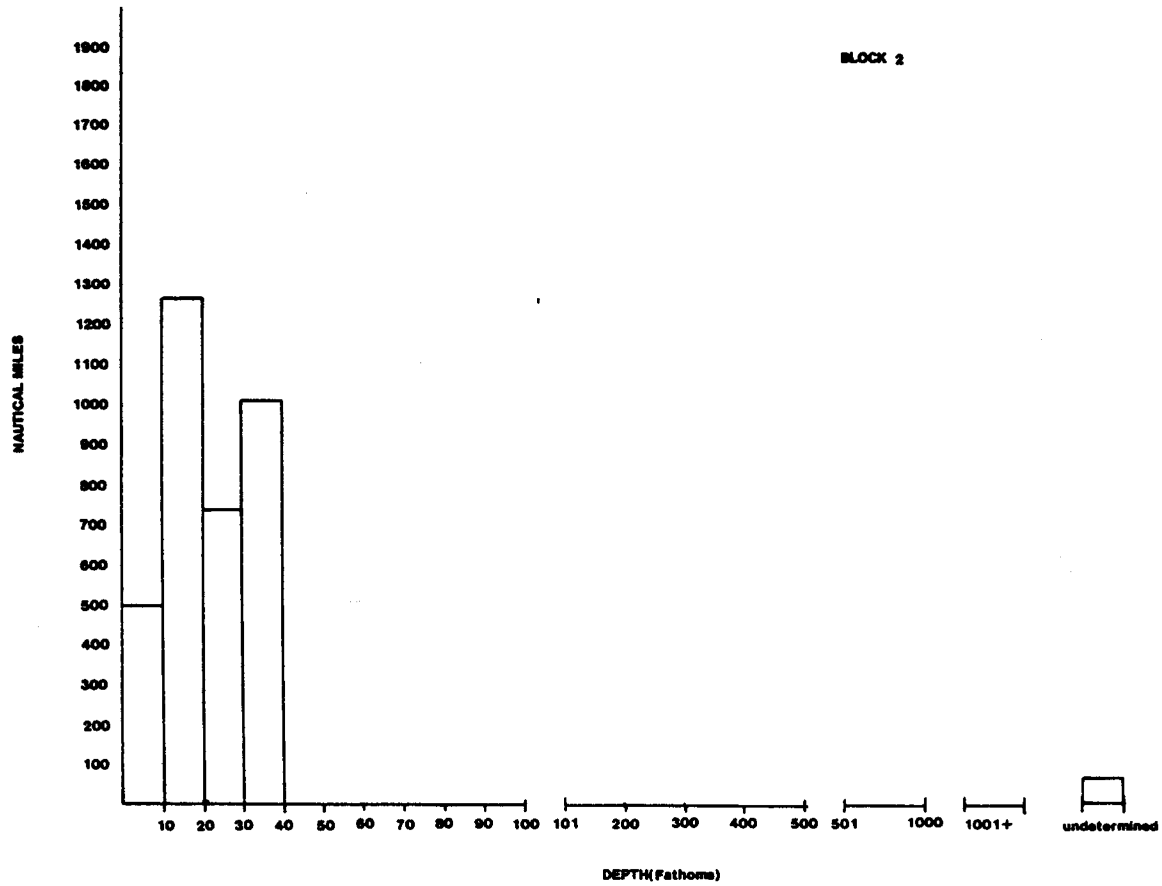


Figure 17b. The distribution of survey effort by depth class (Block 2).

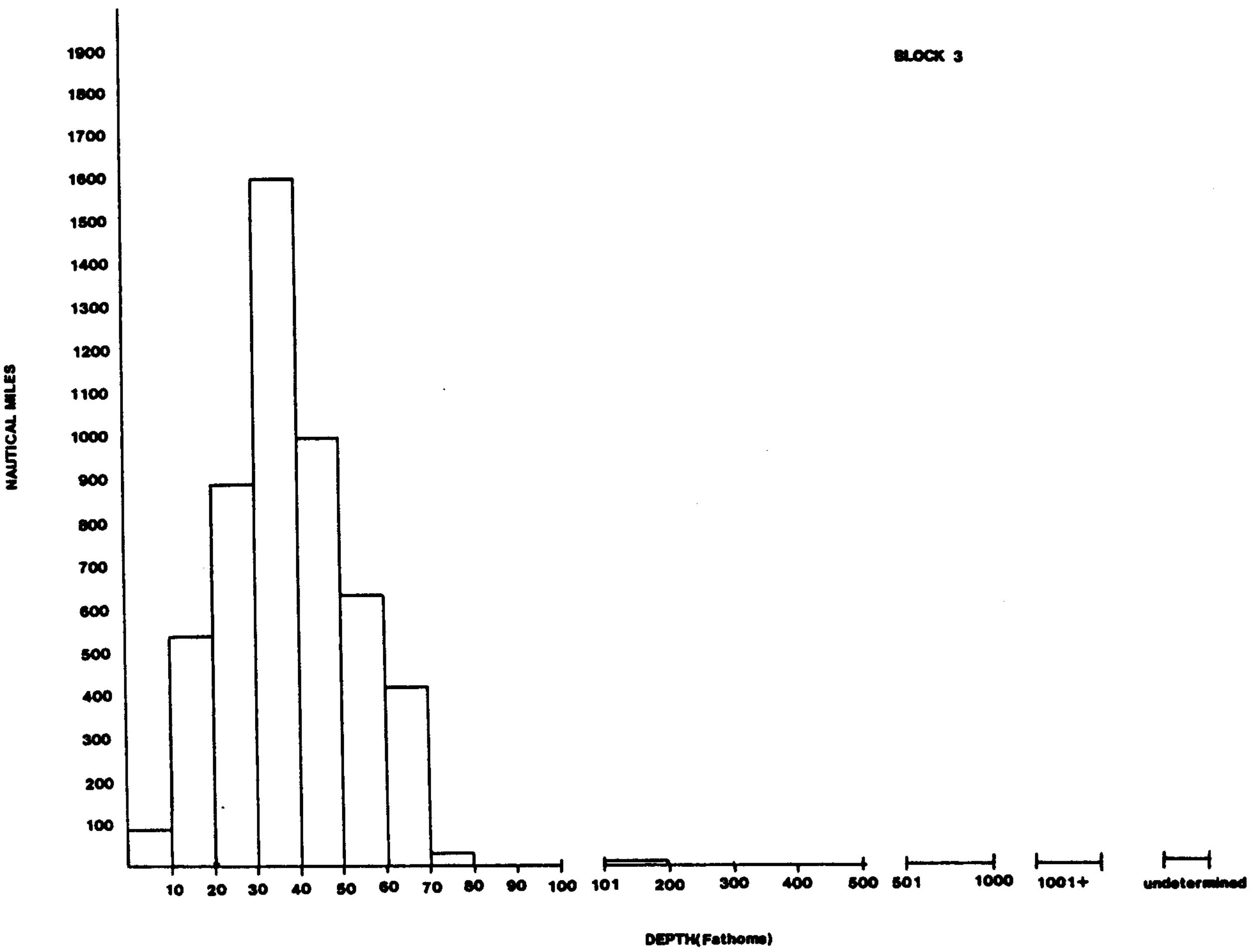


Figure 17c. The distribution of survey effort by depth class (Block 3).

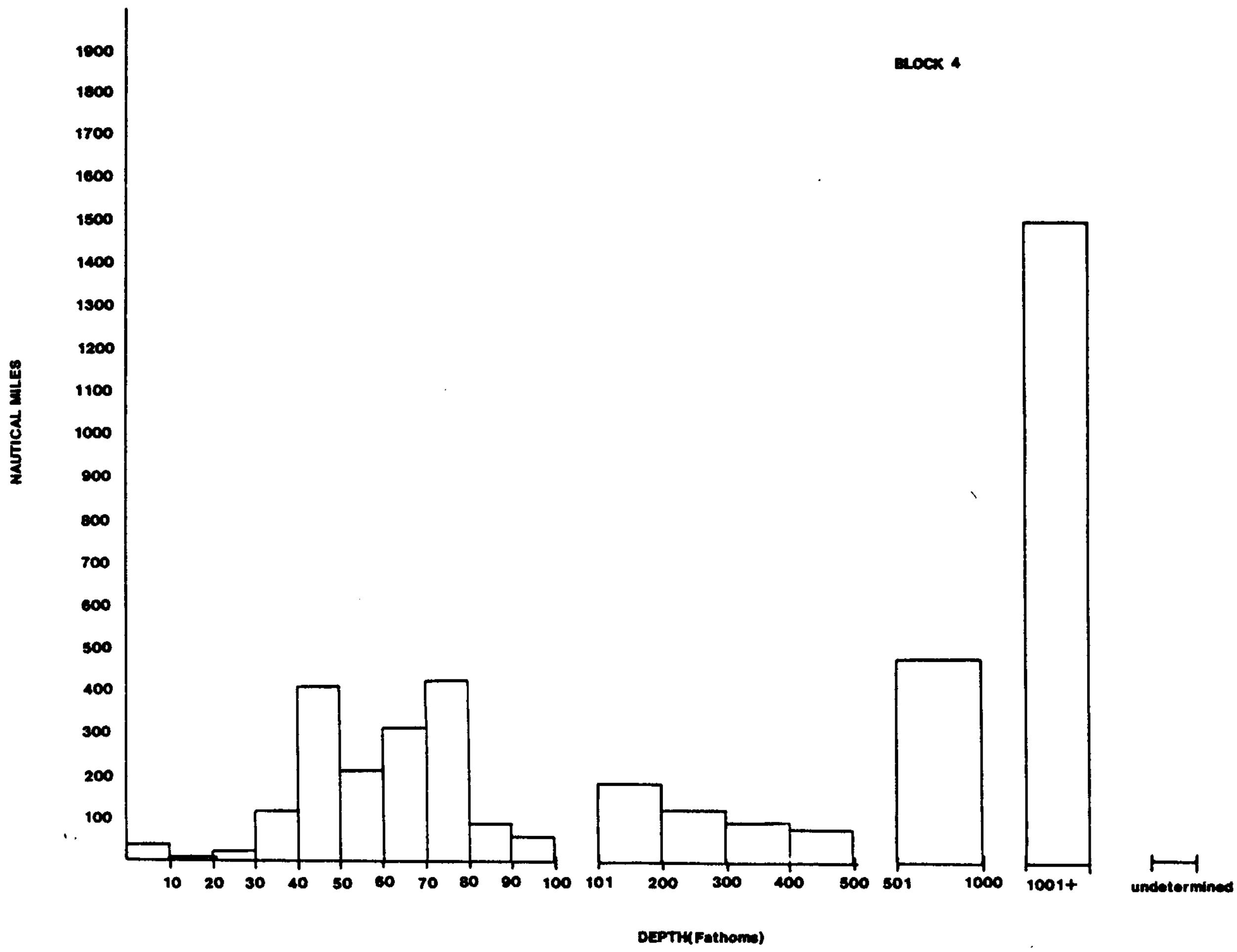


Figure 17d. The distribution of survey effort by depth class (Block 4).

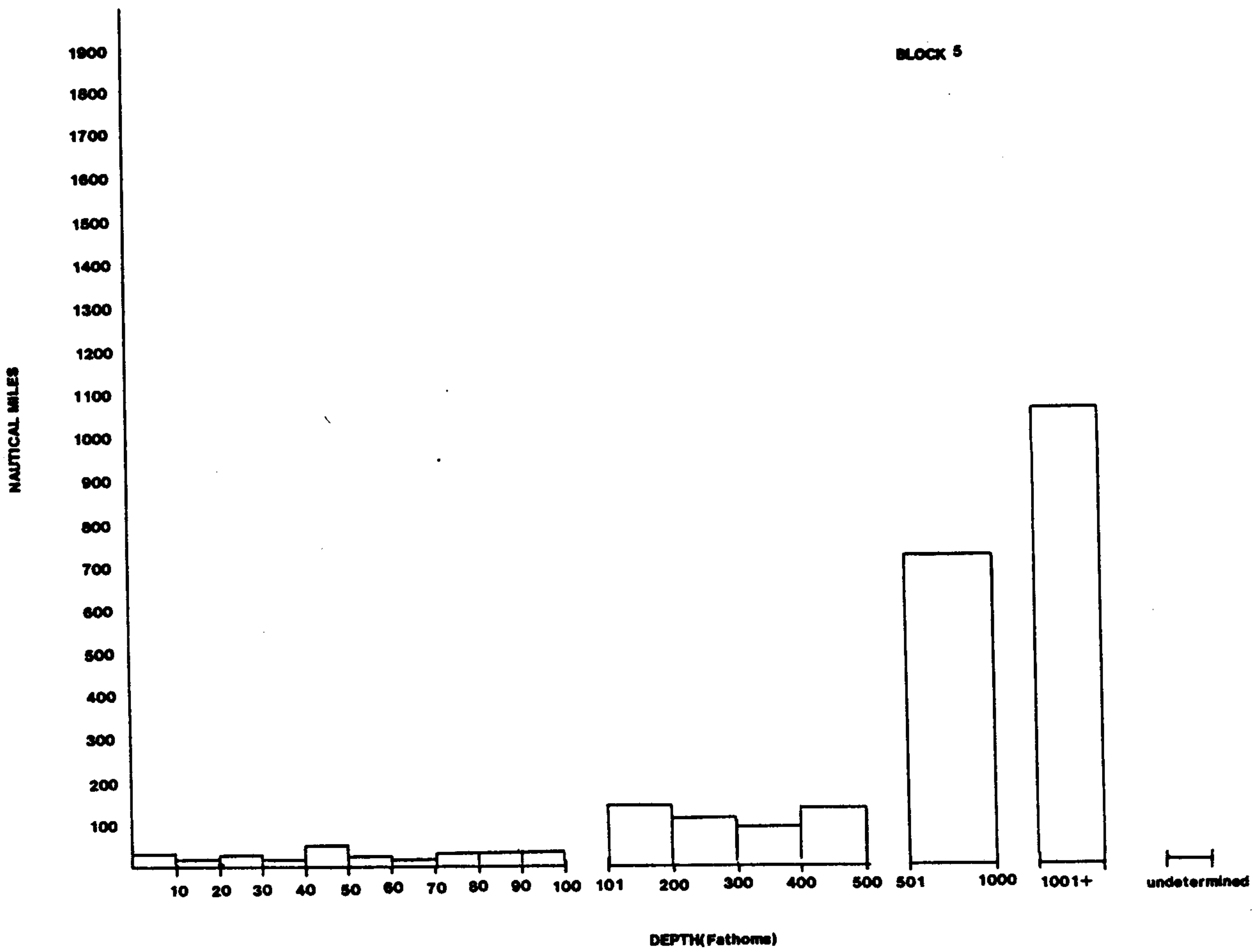


Figure 17e. The distribution of survey effort by depth class (Block 5).

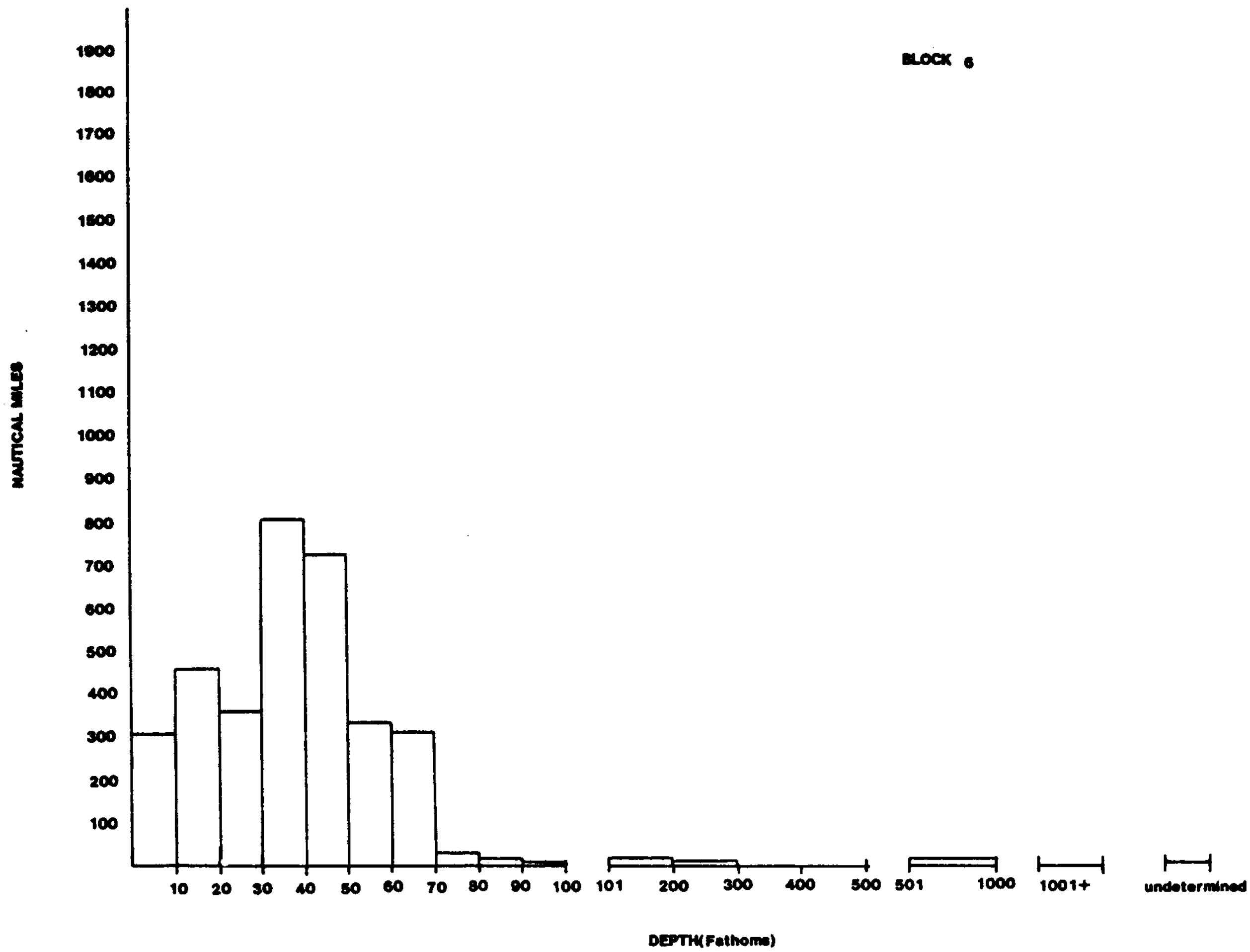


Figure 17f. The distribution of survey effort by depth class (Block 6).

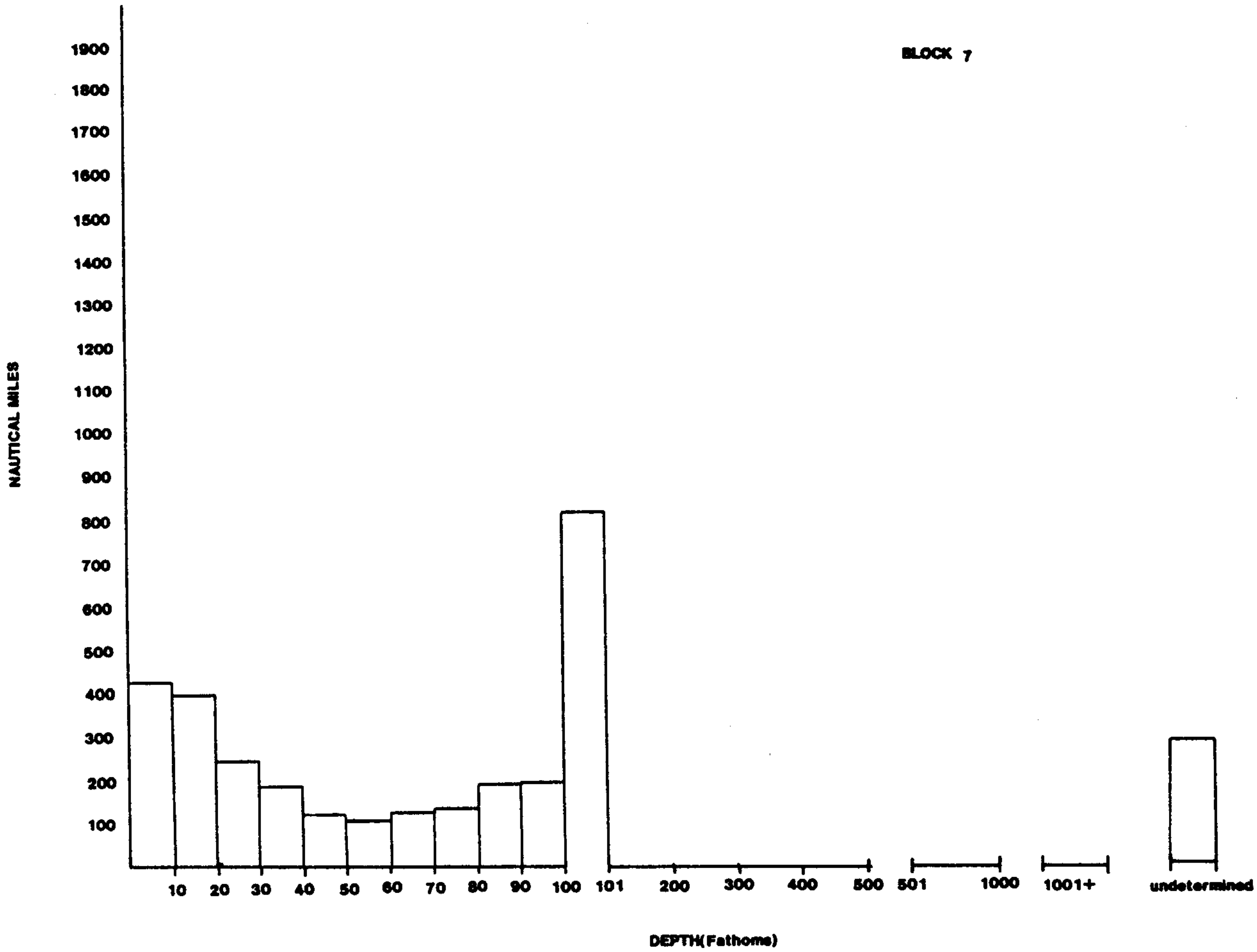


Figure 17g. The distribution of survey effort by depth class (Block 7).

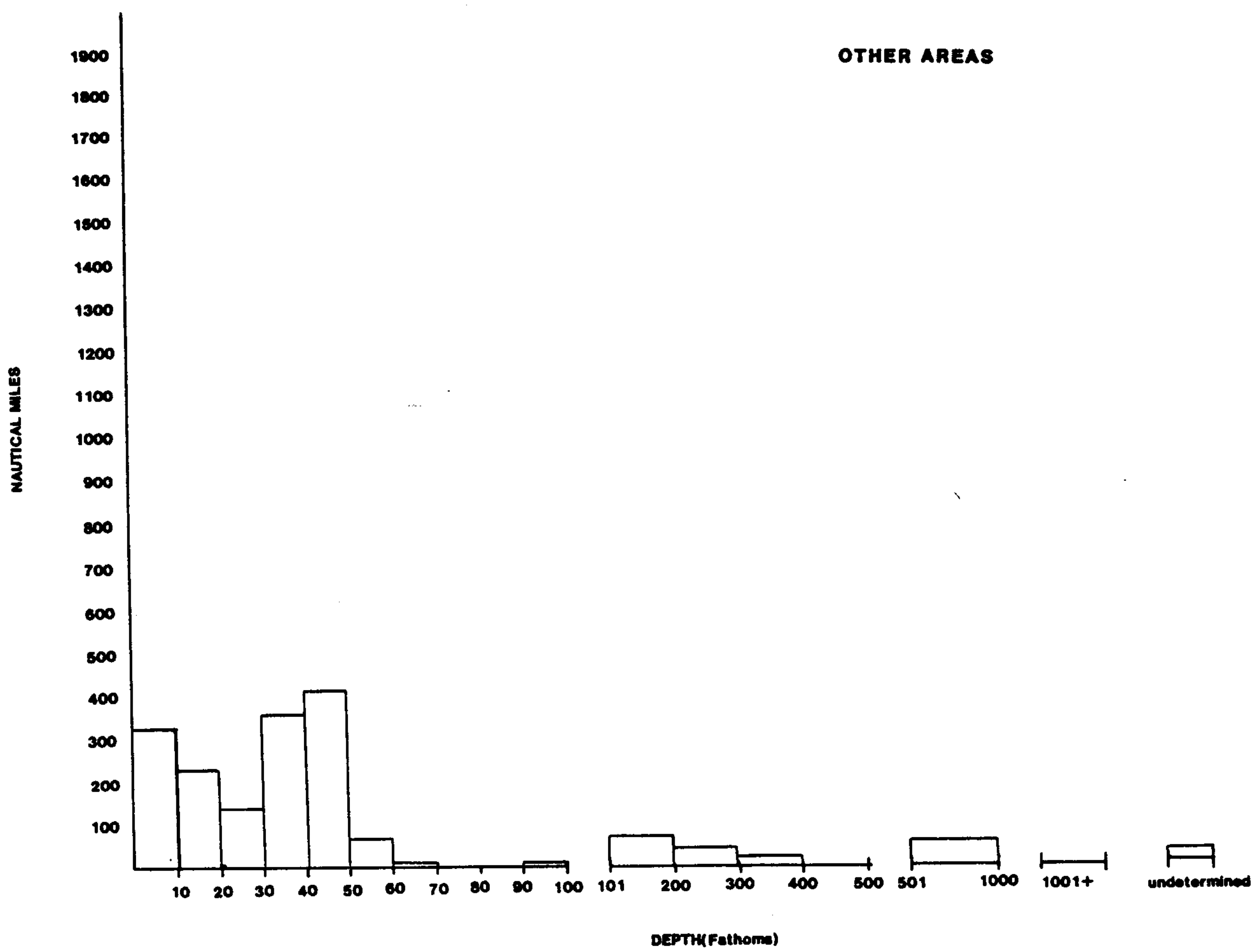


Figure 17h. The distribution of survey effort by depth class (Other areas).

Table 6. Summary of overall effort by block and depth class.

Depth	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	99	Total	Proportion of total effort
All	2910	3646	3705	4621	2589	1627	1153	651	313	293	1210	275	199	207	1208	3023	27630	1.00
On-trk	1113	979	820	1321	905	557	243	76	31	58	244	66	55	62	468	922	7990	.29
Off-trk	1797	2667	2885	3300	1684	1070	910	575	282	235	966	209	144	145	740	2031	19640	.71
Overall block																		
1	1156	1075	1493	847	57	0	0	0	0	0	0	0	0	0	0	0	4628	.17
2	557	928	591	972	0	0	0	0	0	0	0	0	0	0	0	0	3048	.11
3	94	655	880	1561	952	573	387	25	7	8	13	2	2	2	0	0	5161	.19
4	42	11	26	130	418	237	300	422	79	53	169	118	94	75	617	1879	4670	.17
5	78	21	26	19	44	40	14	26	27	29	130	96	71	117	527	774	2039	.07
6	291	449	320	821	724	361	302	40	25	23	37	26	12	6	16	1	3454	.12
7	401	397	235	158	108	84	111	118	171	170	802	0	0	0	0	339	3094	.11
9	291	110	134	113	286	332	39	20	4	10	59	33	20	7	48	30	1526	.05
SE Bering	2509	3249	3470	4463	2481	1543	1042	533	142	123	408	275	199	207	1208	3023	24536	.89
On-track block																		
1	915	890	1220	364	0	0	0	0	0	0	0	0	0	0	0	0	3389	.12
2	416	856	563	902	0	0	0	0	0	0	0	0	0	0	0	0	2737	.10
3	79	484	797	1345	757	507	305	22	4	5	8	1	2	2	0	0	4318	.16
4	10	3	8	60	212	165	264	420	76	47	152	111	83	62	364	1314	3354	.12
5	21	19	10	12	25	21	9	10	25	24	92	72	59	81	376	647	1503	.05
6	102	175	155	526	610	313	239	31	24	22	26	25	0	0	0	1	2249	.08
7	254	245	132	91	80	64	90	92	153	137	688	0	0	0	0	69	2090	.08
SE Bering	1543	2427	2753	3209	1604	1006	820	483	129	98	278	209	144	145	740	1962	17550	.64
Off-track block																		
1	241	185	273	483	57	0	0	0	0	0	0	0	0	0	0	0	1239	.04
2	141	72	28	70	0	0	0	0	0	0	0	0	0	0	0	0	311	.01
3	15	171	83	216	195	66	82	3	3	3	5	1	0	0	0	0	843	.03
4	32	8	18	70	206	72	33	2	3	6	17	7	11	13	253	565	1316	.05
5	57	2	16	7	19	19	5	16	2	5	38	24	12	36	151	127	536	.02
6	189	274	165	295	114	48	63	9	1	1	11	1	12	6	16	0	1205	.04
7	147	157	103	67	28	20	21	26	18	33	114	0	0	0	0	270	1004	.04
9	291	110	134	113	286	332	39	20	4	10	59	33	20	7	48	30	1536	.06
SE Bering	966	822	717	1254	877	537	222	50	13	25	130	66	55	62	468	722	6986	.25

only a small part of the data base, these last two types of sightings were discarded from data sets analyzed, though they were mapped on distribution plots. Included among the 37 sightings with no estimate of group size are 22 sightings of sea otters concentrated in a small segment of block 6, zone 2, on 24 September 1982.

Of the above sightings, 1649 were made on-effort within the study areas, 1,344 in the Bering Sea and 305 in Shelikof Strait (Tables 7, 8, 9). The subsample appropriate for density analysis, i.e. those sightings made while on the random transects, consisted of 1,106 sightings, 895 in the Bering Sea and 211 in Shelikof Strait (Appendix II).

In the Bering Sea, cetaceans were encountered with the following, decreasing frequency; gray whale, 105 sightings (323 individuals); Dall's porpoise, 66(166); harbor porpoise, 35(52); killer whale, 31(165); beluga whale, 25(109); minke whale, 28(35); fin whale, 6(12); humpback whale, 3(6); bowhead 1(7); and sei whale, 1(1) (Figure 18, Table 7). The remaining sightings of cetaceans 24(37), could not be positively identified to species. In the same area, other species were encountered as follows: walrus, 434(4,816);[3] sea otter, 180(1,256); harbor seal, 68(535); Steller's sea lion, 66(3,268); bearded seal, 48(60); northern fur seal, 13(33); ringed seal, 10(10); ribbon seal, 6(8); and largha seal, 4(4). The remaining pinnipeds seen 189(326), were not identified to species (see Figure 18, Table 8).

In Shelikof Strait, marine mammals were encountered as follows; sea otter, 94(1739); Steller's sea lion, 78(3,936)[4]; Dall's porpoise, 45(164); harbor porpoise, 27(48); fin whale, 16(44); harbor seal, 14(308); minke whale, 6(6); humpback whale, 5(9); killer whale, 4(67); beluga

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4 These figures for pinnipeds do not include some counts on rookeries. Once such concentrations were detected on routine surveys we returned to them, as possible, on subsequent surveys.

Table 7. Summary of sightings of cetaceans in blocks 1-6.

A = all
T = transects
0 = x legs & transits
NC = no count of animals
#sightings (# animals)

Survey	spp code 02	03	05	06	07	08	10	12	14	18	20	26	27	28	29	32
T1	1(2)	1(1)	1(1)	0	2(2)	0	1(7)	0	1(1)	2(45)	3(28)	0	0	2(4)	1(2)	
01	0	0	0	0	0	5(9)	0	0	0	1(2)	2(12)	1(2)	0	4(10)	0	0
all	1(2)	1(1)	1(1)	0	2(2)	5(9)	0	0	1(1)	3(47)	5(40)	1(2)	0	6(14)	1(2)	
T2	1(2)	0	1(1)	0	0	41(90)	0	0	0	1(2)	3(24)	0	1(1)	2(6)	5(10)	0
02	0	0	7(11)	0	1(1)	47(208)	0	0	3(4)	3(10)	6(29)	0	1(1)	5(26)	3(7)	0
all	1(2)	0	8(12)	0	1(1)	88(298)	0	0	3(4)	4(12)	9(53)	0	2(2)	7(32)	8(17)	0
T3	1(2)	0	1(1)	0	0	2(3)	0	0	0	0	0	0	0	3(4)	0	1(1)
03	0	0	3(3)	0	1(1)	2(3)	0	0	0	0	0	0	0	2(3)	0	0
all	1(2)	0	4(4)	0	1(1)	4(6)	0	0	0	0	0	0	0	5(7)	0	1(1)
T4	2(4)	0	4(5)	2(4)	0	0	0	0	2(3)	1(1)	2(4)	0	0	10(16)	13(15)	0
04	0	0	4(6)	0	0	0	0	1(1)	1(1)	0	5(23)	1(4)	0	6(6)	5(6)	0
all	2(4)	0	8(11)	2(4)	0	0	0	1(1)	3(4)	1(1)	7(27)	1(4)	0	16(22)	18(21)	0
T5	0	0	3(3)	0	1(1)	0	0	0	0	0	1(3)	0	0	3(5)	2(2)	0
05	1(2)	0	0	1(2)	0	7(9)	0	0	0	1(65)	4(27)	0	0	2(4)	3(5)	0
all	0	0	3(3)	1(2)	1(1)	7(9)	0	0	0	1(65)	5(30)	1(3)	0	5(9)	5(7)	0
T6	0	0	2(2)	0	1(1)	1(1)	0	0	0	1(1)	2(5)	1(3)	2(2)	5(7)	6(8)	0
06	0	0	0	0	0	0	0	0	0	0	1(6)	0	0	0	0	1(2)
all	0	0	2(2)	0	1(1)	1(1)	0	0	0	1(1)	3(11)	0	2(2)	5(7)	6(8)	1(2)
T7	0	0	2(2)	0	0	0	0	0	0	18(57)	2(4)	1(4)	0	14(54)	1(1)	1(2)
07	0	0	0	0	0	0	0	0	0	0	0	0	0	2(10)	0	0
all	0	0	2(2)	0	0	0	0	0	0	18(57)	2(4)	1(4)	0	16(64)	1(1)	1(2)
T8	0	0	0	0	0	0	0	0	0	2(10)	0	0	0	6(11)	0	0
08	0	0	0	0	0	0	0	0	0	7(27)	0	0	0	0	0	0
all	0	0	0	0	0	0	0	0	0	9(37)	0	0	0	6(11)	0	0
Tot T	5(10)	1(1)	14(15)	2(4)	4(4)	44(94)	1(7)	0	2(3)	22(104)	13(68)	1(4)	3(3)	45(107)	28(38)	2(3)
0	1(2)	0	14(20)	1(2)	1(1)	61(229)	0	1(1)	5(6)	3(5)	18(97)	3(9)	1(1)	21(59)	7(14)	1(2)
A	6(12)	1(1)	28(35)	3(6)	5(5)	105(323)	1(7)	1(1)	7(9)	25(109)	31(165)	4(13)	4(4)	66(166)	35(52)	3(5)

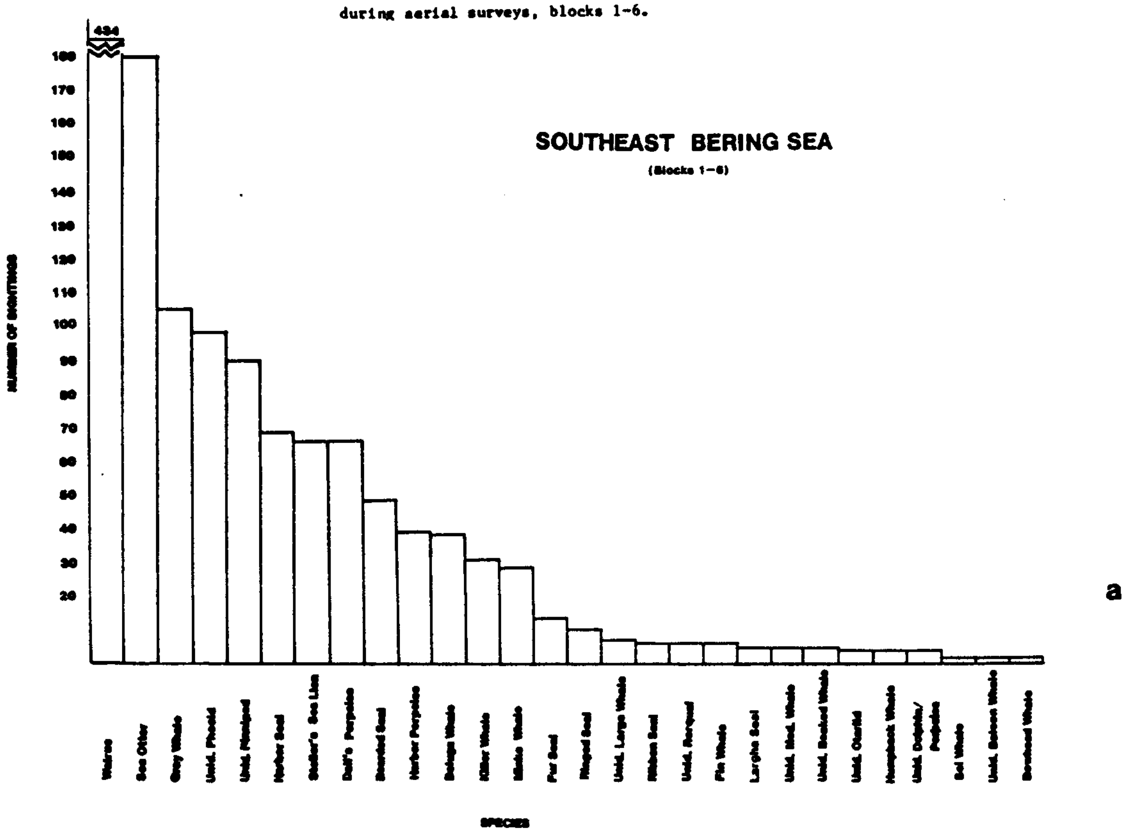
Table 8. Summary of sightings of pinnipeds and otters in blocks 1-6.
A = all
T =transects
O = x legs & transits
NC = no count of animals
#sightings(#animals)

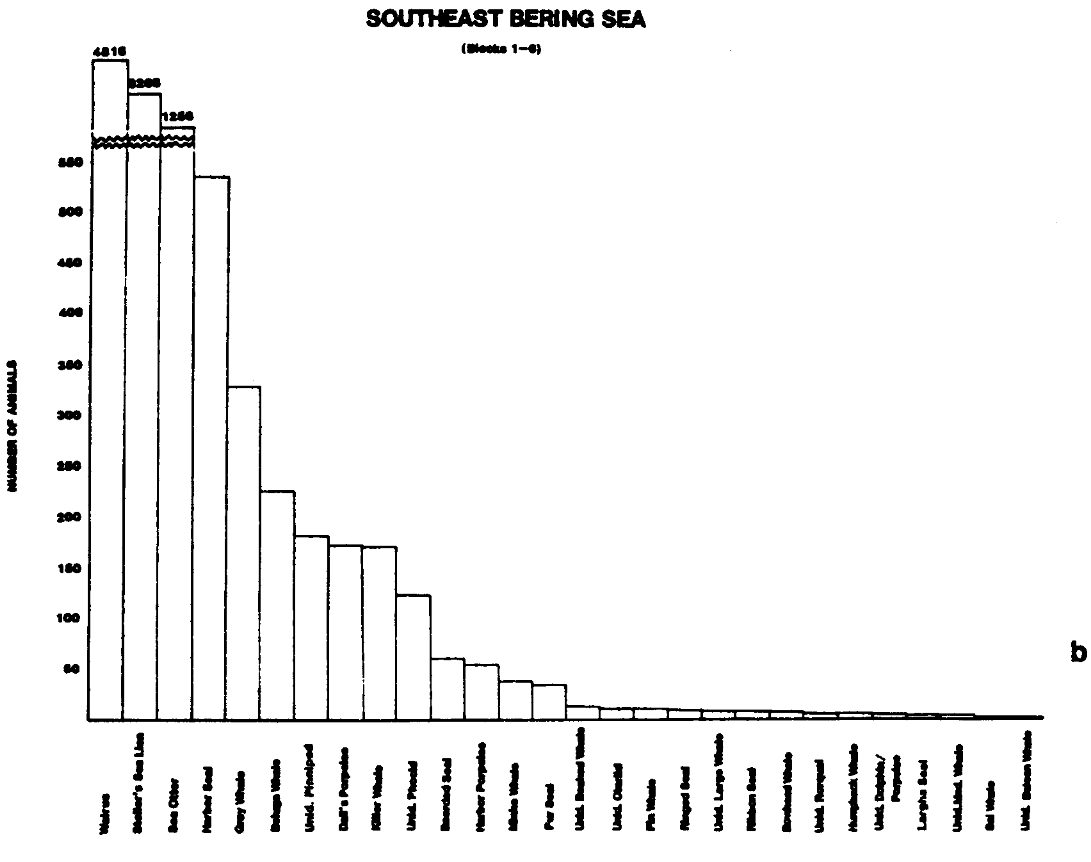
Survey	sp code 80	81	82	83	84	85	86	87	88	89	90	91
T1	3(3)	0	92(280)	2(2)	0	0	22(27)	0	24(51)	3(15)	6(86)	3(12)
O1	10(62)	7(59)	36(2290)	2(76)	0	0	0	0	5(8)	0	5(620)	0
all	13(65)	7(59)	28(2570)	4(78)	0	0	22(27)	0	29(59)	3(15)	11(706)	3(12)
T2	8(18)	21(35)	33(183)	22(143)	0	3(3)	10(17)	0	10(10)	0	2(92)	0
TO	44(309)	15(19)	36(504)	12(57)	3(3)	5(5)	7(7)	0	5(10)	0	24(104)	0
all	52(327)	36(54)	69(687)	34(200)	3(3)	8(8)	17(24)	0	15(20)	0	20(196)	0
T3	0	1(1)	0	0	0	0	0	0	0	3(4)	0	0
O3	1(1)	1(1)	1(1)	0	0	0	0	0	0	0	0	0
all	1(1)	2(2)	1(1)	0	0	0	0	0	0	3(4)	0	0
T4	20(40)	0	0	5(5)	0	0	0	0	18(19)	2(2)	0	0
O4	12(175)	2(7)	15(28)	5(18)	0	0	0	0	3(3)	0	6(1597)	0
all	32(215)	2(7)	15(28)	10(23)	0	0	0	0	22(23)	2(2)	6(1597)	0
T5	26(471)	9(11)	15(35)	10(195)	0	0	0	0	12(13)	0	6(77)	0
O5	6(10)	6(12)	1(1)	3(25)	0	1(1)	0	0	1(1)	5(12)	9(471)	0
all	32(481)	15(23)	16(36)	13(220)	0	1(1)	0	0	13(14)	5(12)	15(548)	0
T6	13(45)	4(4)	57(186)	6(11)	0	0	0	0	10(12)	0	1(1)	0
O6	0	1(1)	0	0	0	0	0	0	0	0	0	0
all	13(45)	5(5)	57(186)	6(11)	0	0	0	0	10(12)	0	1(1)	0
T7	33(117)	13(15)	48(369)	0	0	0	3(3)	0	1(1)	0	7(35)	0
O7	0	0	0	1(3)	0	0	0	0	0	0	3(171)	0
all	33(117)	13(15)	48(369)	1(3)	0	0	3(3)	0	1(1)	0	10(206)	0
T8	2(3)	9(12)	87(787)	0	1(1)	0	5(5)	6(8)	7(7)	0	3(14)	0
O8	1(1)	1(1)	13(152)	0	0	0	1(1)	0	0	0	0	0
all	3(4)	10(13)	100(939)	0	1(1)	0	6(6)	6(8)	7(7)	0	3(14)	0
Tot T	106(698)	57(78)	332(2105)	45(356)	1(1)	3(3)	40(52)	6(8)	82(113)	8(21)	25(305)	3(12)
O	74(558)	33(100)	102(2976)	23(179)	3(3)	7(7)	8(8)	0	15(23)	5(12)	41(2963)	0
A	180(1256)	90(178)	434(4816)	68(535)	4(4)	10(10)	48(60)	6(8)	97(136)	13(33)	66(3268)	3(12)

Table 9. Summary of sightings of marine mammals in block 7.
A = all
T = transects
0 = x legs & transits
NC = no count of animals
#sightings(#animals)

	02	05	06	14	18	20	28	29	32	80	81	83	89	90	91
T1	0	0	0	0	0	0	1(4)	1(2)	2(7)	7(149)	0	1(14)	1(1)	4(5)	3(3)
01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
all	0	0	0	1(1)	0	0	1(4)	1(2)	2(7)	7(149)	0	1(14)	1(1)	4(5)	3(3)
T2	2(2)	2(2)	0	0	0	0	10(38)	4(7)	0	9(38)	0	0	0	10(559)	0
02	1(1)	1(1)	0	1(1)	0	1(6)	10(54)	6(9)	3(4)	19(409)	0	0	0	11(165)	0
all	3(3)	3(3)	0	1(1)	0	1(6)	20(92)	10(16)	3(4)	0	0	0	0	20(720)	0
T3	2(6)	0	1(2)	1(1)	0	0	3(5)	2(3)	0	6(294)	0	0	0	2(1503)	0
03	7(24)	0	0	0	0	0	0	0	0	2(330)	0	0	0	0	0
all	9(30)	0	0	1(1)	0	0	3(5)	2(3)	0	8(624)	0	0	0	2(1503)	0
T4	2(6)	0	0	0	1(1)	3(61)	3(10)	1(1)	0	3(8)	0	1(1)	0	5(959)	0
04	1(2)	0	0	0	0	0	0	0	0	1(1)	0		0	4(170)	0
all	3(8)	0	0	0	1(1)	3(61)	3(10)	1(1)	0	4(9)	0	101)	0	9(1129)	0
T5	1(3)	1(1)	0	0	0	0	4(14)	6(17)	0	12(121)	0	7(254)	0	9(47)	0
05	0	0	4(7)	0	0	0	1(1)	4(5)	0	3(25)	0	0	0	2(16)	0
all	1(3)	1(1)	4(7)	0	0	0	5(15)	10(22)	0	15(146)	0	7(254)	0	11(63)	0
T6	0	2(2)	0	0	0	0	1(2)	0	0	6(262)	0	4(38)	0	12(307)	0
06	0	0	0	0	0	0	0	0	0	1(5)	1(1)	0	0	4(11)	0
all	0	2(2)	0	0	0	0	1(2)	0	0	7(263)	1(1)	4(38)	0	16(318)	0
T7	0	0	0	0	0	0	5(20)	1(2)	2(3)	11(61)	0	0	0	8(114)	0
07	0	0	0	0	0	0	0	0	0	0	0	0	0	6(80)	0
all	0	0	0	0	0	0	5(20)	1(2)	2(3)	11(61)	0	0	0	14(194)	0
T8	0	0	0	0	0	0	7(16)	2(2)	0	14(36)	0	1(1)	0	2(4)	0
08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
all	0	0	0	0	0	0	7(16)	2(2)	0	14(36)	0	1(1)	0	2(4)	0
Tot	7(17)	5(5)	1(2)	2(2)	1(1)	3(61)	34(109)	17(34)	4(10)	68(969)	0	14(308)	1(1)	51(3494)	3(3)
0	9(27)	1(1)	4(7)	1(1)	0	1(6)	11(55)	10(14)	3(4)	26(770)	1(1)	0	0	27(442)	0
all	16(44)	6(6)	5(9)	3(3)	1(1)	4(67)	45(164)	27(48)	7(14)	94(1739)	1(1)	14(308)	1(1)	78(3936)	3(3)

Figure 18a,b. Relative frequency of encounter with various species/species groups during aerial surveys, blocks 1-6.



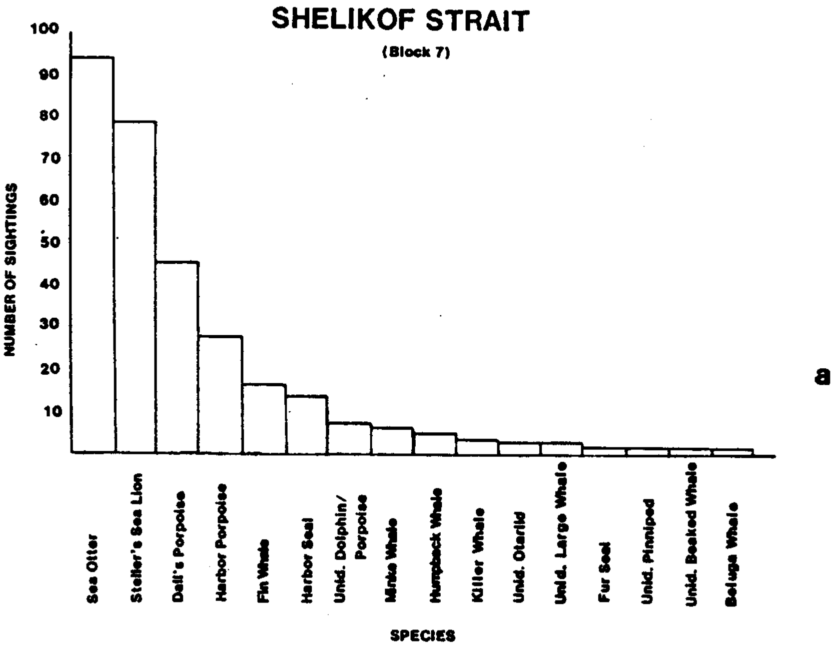


whale, 1(1); and northern fur seal, 1(1). The remaining sightings were not identified to species - cetaceans, 10(17), and pinnipeds, 4(4) (see Figure 19, Table 9).

As with effort, we examined sightings by species, survey (season), block, and environmental type, focusing on endangered whales and other species for which there were adequate numbers of sightings to support some analysis. Effort and sightings used in descriptive analysis and in calculating indices of density are summarized in Tables 4 through 9. Those used in estimating density are summarized by survey in Appendix II. In the appendix effort is stratified by Beaufort number, as this is the variable most likely to affect the probability of detecting animals in open water (Leatherwood and Show, 1980; R. Holt, N.M.F.S., pers. comm.).

Data Analysis

As can be seen in Table 2, which gives the lengths of lines and the proportions of areas searched, we achieved moderate success in obtaining a balanced random sample. (For the sample to have been completely random among strata in blocks 1-6, proportions of area and line-lengths should have been identical). The only major exception was in block 4, zones 3 and 4, which were surveyed in only 3 of 8 surveys (see Figures 8-11), due to poor weather conditions. In fact, sea states in blocks 4 and 5 were significantly worse than elsewhere. Therefore, these 2 blocks, containing a substantial area seaward of the continental shelf [as defined by the 1000 fathom contour (1,838m)] , were treated in the analysis separately from blocks 1-3 and 6, which comprise exclusively (blocks 1 and 2) or almost exclusively (3, ca. 97%, and 6, ca. 80%) continental shelf or continental slope waters. In all data analysis, block 7 is treated independently of blocks 1-6.



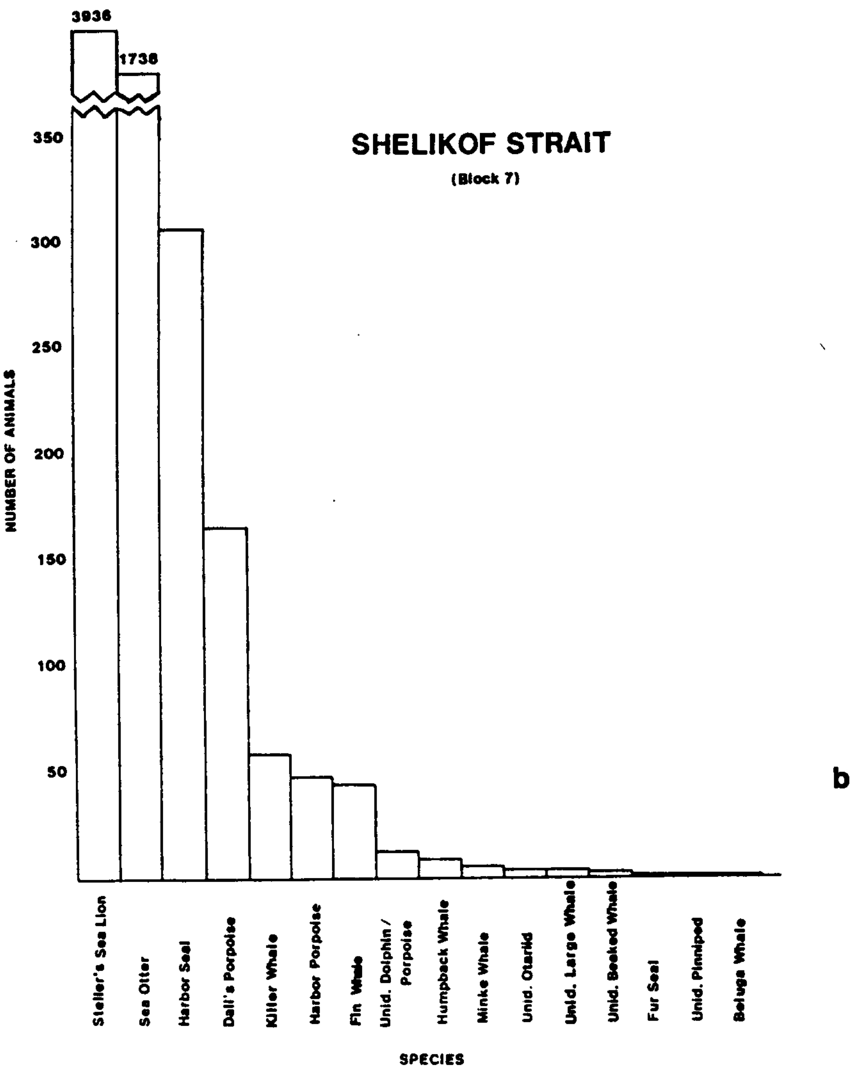


Figure 19a,b. Relative frequency of encounter with various species/species groups during aerial surveys, block 7.

Although analysis followed generally the procedures outlined by Burnham et al. (1980), certain modifications were required because of three major deficiencies in the data. First, most clinometer angles (90%) were rounded to 5 degree increments. To reduce the effects of this bias we considered the angles to be grouped in classes $\pm 2.5°$ around each multiple of 5°. Resulting angle groups correspond to varying lengths of perpendicular distance. For example, the 5° interval between 77.5° and 72.5°, near the track line, corresponds to a strip 0.012nm (0.02 km) wide, whereas the comparable span between 17.50° and 12.50°, far from the track line, corresponds to a strip 0.166nm (0.3 km) wide. For the probability of detection to be the same in these two intervals we would have needed roughly 14 times (0.166/0.012) more sightings in the far interval than in the close interval. This problem is apparent in Figure 20, in which the probability density functions are scaled to reflect the widening intervals.

Also illustrated in Figure 20 are two further problems, namely that very little was seen in the intervals indicated by angles from 90° to 72.5° [within ca. 0.039nm (0.07km) of the track line] and that the probability density varies widely in contiguous intervals. The first problem results from obstructed downward visibility in all three aircraft made available for the surveys - i.e. observers were simply not able to see along or near the track line. The second problem is probably a function of secondary rounding of angles into 10° increments. Most sightings were noted in 5° intervals; of those recorded in multiples of 5°, 59% were also recorded in multiples of 10°.

Based on all the above observations, we chose to consider in analysis in general only those sightings made at recorded angles less than 72.5°. This angle corresponds to the point under the aircraft used where the

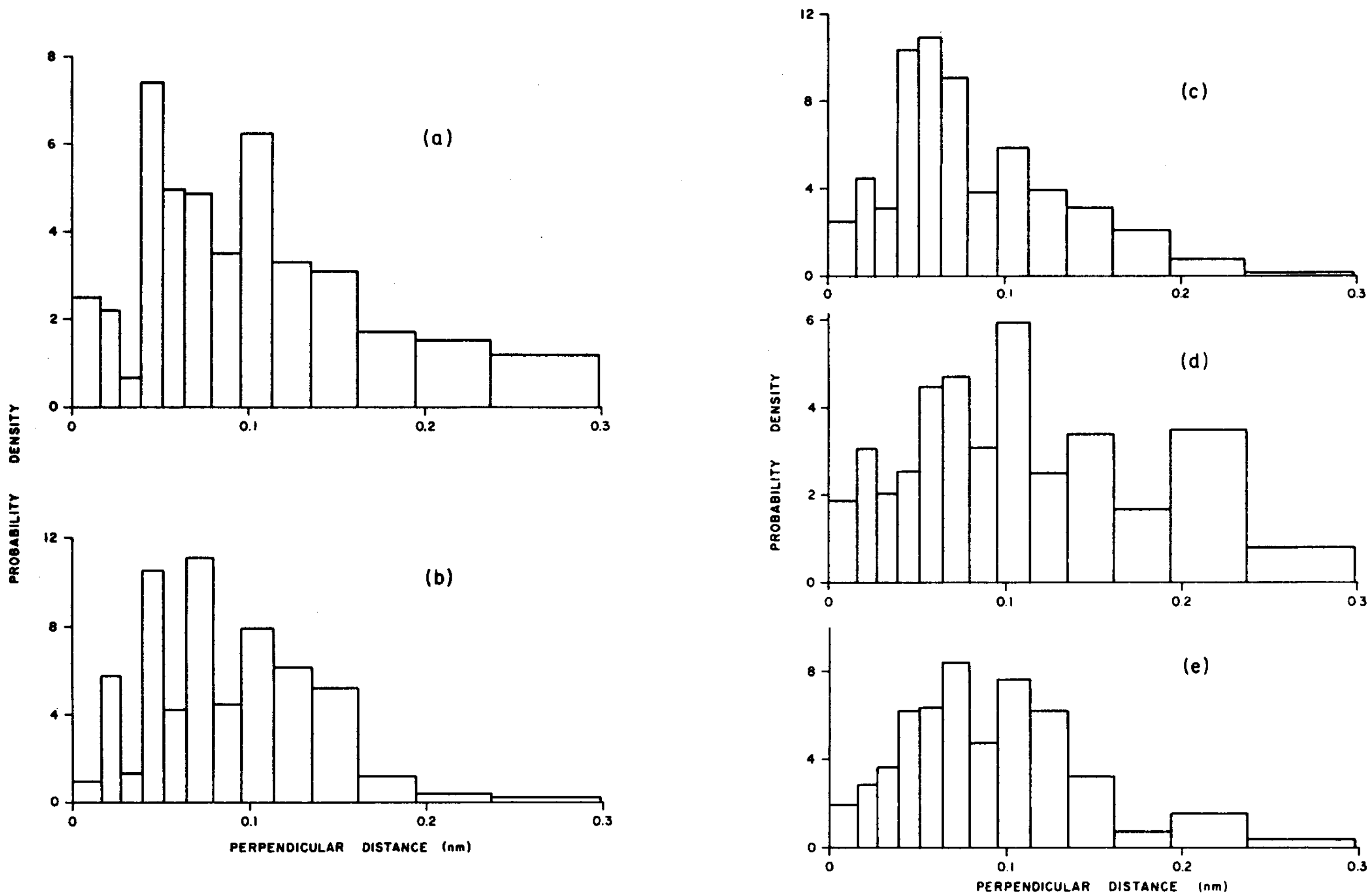


Figure 20. Perpendicular distance distributions plotted as probability density for (a) whales, (b) dolphins and porpoises, (c) sea otters, (d) walruses and, (e) seals and sea lions, showing the drop in sightings close to the transect line resulting from the inability to see under the aircraft.

detection probability of sightings drops precipitously. Following in-depth examination by species, we chose to further limit data on the walrus and bearded seal, accepting only sightings with recorded angles less than 67.5° (greater than ca. 0.051nm (0.09 km) from the transect-center-line). Thus, the assumption that $g(0) = 1$ is replaced in the present analysis by the assumptions that $g(0) = 1$ at $x = 0.039$ (for 72.5°) and at $x = 0.051$ (for 67.5°). The validity of these assumptions and their effects on results are discussed below.

Because of the tendency of observers to round in 10° increments we grouped the angles for analysis into increments of 10°. Thus, for species in which samples were truncated at 72.5°, the angle intervals were 72.5 - 62.5°, 62.5 - 52.5°, 52.5 - 42.5°, 42.5 - 32.5°, 32.5 - 22.5°, 22.5 - 12.5° and 12.5 - 2.5° and for those truncated at 67.5° the angle intervals were 67.5 - 57.5°, 57.5 - 47.5°, 47.5 - 37.5°, 37.5 - 27.5°, 27.5 - 17.5°, 17.5 - 7.5°, 7.5 - 2.5°.

We encountered two further problems in the data collected, namely that there were some sightings for which perpendicular distance was not noted and some sightings for which the species was not identified. To counter the first problem we used all sightings with known perpendicular distance to estimate $f(o)$ and then used all sightings to estimate density. This procedure assumes that sightings with unknown perpendicular distance are distributed the same as those with known (estimated) perpendicular distance. The proportion of such sightings for a given species was usually 5-10% (maximum 16%); so, that assumption is probably reasonable. The second problem could not be dealt with satisfactorily because we had no basis for prorating to species those sightings logged as unidentified categories with sufficient sample sizes.

In estimating f(0) from the estimates of perpendicular distance we investigated two models, a Fourier series - the sum of a series of cosines - and a generalized exponential of the form $f(x) = \exp(\quad -x^p)$. Both models can fit a variety of shapes of distribution and have been widely used in line transect applications. The specific model chosen to represent each distribution varied by species, based upon which performed better.

The variance of n was calculated by treating each segment of line-length searched within a zone as a replicate and accounting for varying line-lengths so that

$$\mathrm{var}(n) = \frac{L}{R-1} \sum_{i=1}^{R} \ell_i \left[\frac{n_i}{\ell_i} - \frac{n}{L}\right]^2 \qquad \text{Equation (18)}$$

where R is the number of replicates.

Density estimates

We were able to estimate density for only 9 species or species groups gray whales, Dall's porpoises, harbor porpoises, sea otters, Steller's sea lions, harbor seals, bearded seals, unidentified phocids, and walruses. They are presented as density of "schools" (= herds, pods, aggregations, etc.) expressed as schools per 1000nm^2 (3,430 km^2) and density of animals (expressed as animals per 1000nm^2), with standard deviations for each (Table 10). The distributions of perpendicular sighting distances supporting these estimates (shown as histograms of probability density) and the distributions of school sizes (shown as histograms of frequency) are

Table 10. Estimates of the density of "herds", mean herd size and the density of animals. Densities are expressed as numbers of herds or animals per 1000nm^2 (3430 km^2).

Species	Survey	Block	n	D_h	sd(D_h)	$\bar{h}$	sd($\bar{h}$)	D_a	sd(D_a)
Gray whale	2	1,2,6	33	120.2	100.5	1.970	0.211	236.8	199.6
Dall's porpoise	All	1,2,3,6	15	4.945	1.043	1.600	0.163	7.912	1.951
		4,5	27	34.08	14.79	2.852	0.760	97.20	49.50
		7	28	57.72	28.74	3.143	0.436	181.4	93.76
Harbor porpoises	All	1,2,3,6	27	9.518	2.593	1.370	0.121	13.04	3.734
		7	17	37.48	12.52	2.000	0.402	74.96	29.22
Sea otter	All	1,2,3,6	69	50.87	36.30	7.403	1.696	376.6	268.7
		7	55	174.5	34.86	11.83	3.826	2,064	784.6
Steller's sea-lion	All	7	39	104.5	23.79	27.45	10.53	2,869	1,280
Harbor seal	All	1,2,3,6	33	9.061	4.902	2.546	0.579	23.07	13.54
Bearded seal	All	1,2,3,6	38	13.80	5.596	1.316	0.142	18.16	7.620
Unidentified phocid	All	1,2,3,6	69	18.18	3.569	1.464	0.157	26.62	5.955
Walrus	6	1,2,3,6	51	83.47	85.37	3.255	0.630	271.7	282.8
	7	1,2,3,6	38	69.64	36.86	7.211	2.865	502.2	332.4
	8	1,2,3,6	68	82.60	41.88	10.03	2.598	828.5	471.7
	1	1,2,3,6	94	136.8	74.27	6.351	2.907	868.8	616.9
	2	1,2,3,6	25	72.84	91.66	3.280	1.008	238.9	309.5
	All	1,2,3,6	285	73.61	23.54	6.400	1.216	471.1	175.1

D_h = density expressed as numbers of herds

D_a = density expressed as numbers of animals shown under the species in the systematic accounts below. It is important to bear in mind that the sightings data have been truncated at a perpendicular distance of 0.051nm for the walrus and bearded seal but at 0.039nm for all other species. Also, for Dall's porpoise and the harbor porpoise, f(0) was estimated from all data collected in blocks 1, 2, 3, 6 and 7, but estimates of density were made separately for blocks 1, 2, 3, and 6 combined and block 7 independently. Periods and areas covered by the various estimates differed by species or species group (Table 10).

For all species or species groups other than the 9 indicated above there were simply insufficient data to estimate f(0); so, density could not be estimated. The absence of a density estimate should not be taken to mean that a species was not present in the study areas at the time of the surveys or that the areas are not important to the present or the recovering population(s) of such species (see systematic accounts, below). The small sample sizes, which severely restricted data analysis, resulted from the small amount of survey effort relative to the huge study area, the obstructed visibility under the aircraft (the most serious deficiency in the data), and the poor sighting conditions over much of the area.

Limitations to Density Estimates

Even for those species and species groups for which sample sizes proved large enough to support estimates of density, the resulting figures are fraught with problems. Such estimates of density can only be considered reliable if the assumptions of line transect sampling are met. In the present analysis important assumptions are certainly or probably violated.

First, and most important, the requirement that $g(0) = 1$ is not met. This is always true for aircraft with obstructed downward visibility, in which the transect center-line and some associated strips cannot be adequately surveyed, resulting in too few sightings at small perpendicular distances (Figure 20). Truncating the data at a certain perpendicular distance from the transect center-line, evaluating the function at this point, and assuming the underlying distribution to be flat up to $x = 0$, as tentatively investigated by Leatherwood et al., (1982d), definitely produces negatively biased estimates. Aerial surveys using suitable aircraft (i.e. with a nose bubble and high wings) have shown that the distribution of perpendicular distances is not flat close to $x = 0$ but, rather, can be very steep, with the frequency of sightings dropping rapidly as perpendicular distance increases. This effect presumably results from the fact that observers in the nose bubble have more time to detect animals on and close to the transect line than do observers who are seated in the rear of the aircraft and are searching predominantly away from the transect line. The effect was clear in all data obtained on the present surveys, even with the addition for surveys 3-8 of side bubble windows from which observers could theoretically see the transect line. It is impossible to estimate the degree of bias caused by the lack of visibility on the transect center-line, but a recent analysis (Rennie S. Holt, pers. comm.) has shown that the probability density in the first 0.05nm (0.09 km) interval, essentially under the aircraft, may be as much as twice as great as that in the next interval. The result is that when downward visibility is obstructed, density may be underestimated by up to one-half of the number actually present.

In the case of animals occurring in low density and detectable from aircraft only at close range, the negative bias is much greater.

Second, marine mammals spend a large proportion of their time submerged and therefore undetectable by a surface or airborne observer (Leatherwood et al., 1982b). This problem of detectability is compounded in surveys of animals that travel singly or in small groups. A wholly acceptable correction would require an estimate of proportion of "groups" missed which is based on realistic information on relative speeds of aircraft and animals, distribution of dive times by species, area, and season, and length of time a given point in the transect strip is visible to the observer. In the absence of realistic estimates of all the above factors, we regard corrections to survey data as haphazard manipulations of the numbers.

Third, in typical sightings from aircraft, particularly when circling time is limited (as for sightings of species groups of secondary importance, sightings made under circumstances compromising to safety, and observations made during periods of rough weather or sea surface when probability of recontact is low), marine mammals may be difficult to identify to species. For example, in an aerial census in 1979 of dolphins in the eastern tropical Pacific, 47% of the herds seen could not be positively assigned to a species. Data from the present surveys included many such sightings. The best way to treat such data would be to prorate them according to identified species based on observed densities. However, this approach would require sufficient samples to estimate density for all species identified; with our small sample sizes we were unable to meet this requirement. The alternative - prorating strictly on the basis of the number of sightings - unreasonably assumes equal sightability among species. When sightings of unidentified animals are not taken into account, density estimates are biased farther downward.

Fourth, weather affected the balance of the survey samples. To achieve wholly acceptable estimates, there must be sufficient survey time under acceptable condititons to obtain sample sizes large enough for for density estimation. This may require stratification of the study area into areas where similar sighting conditions are expected and apportioning searching effort in each of them based upon the expected severity of the conditions. The major point here is that poor weather conditions reduce the sightability of animals from aircraft, possibly on, but certainly away from the transect center-line. R. Holt (pers. comm.) has shown that sighting distributions of dolphin schools in the eastern tropical Pacific change markedly with sea state, becoming more "spiked" close to the transect line in poor weather. When combined with the problems resulting from obstructed downward visibility, the effects on density estimates of such poor weather could be severe, particularly for species which occur in small groups or in pelagic regions. During the present surveys, sighting conditions in blocks 4 and 5 were worse than those in other blocks; so, it was unreasonable to combine them with blocks 1, 2, 3, and 6. Consequently, estimates of density in blocks 4 and 5 could be made only for a few species with large sample sizes, i.e. Dall's porpoise, harbor porpoise, sea otter, and Steller's sea lion.

The following sections discuss background information and results from the present surveys, by species. Given the limitations discussed above, we have been conservative in interpreting our often scant results.

Systematic Accounts

Cetaceans

Bowhead Whale (*Balaena mysticetus*)

During the present surveys there was only one observation of bowhead whales. On 31 March 1982 seven large bowheads were seen in close proximity to one another just southeast of St. Matthew Island, at 60°05.6'N, 171°36.8'W (Figure 21). The whales were in water 36 fathoms (66m) deep, traveling slowly northward. They were at least 6 nm (11 km) into the pancake ice and about 23 nm (42.6 km) south of the point where such ice conditions gave way to extensive broken floes. From monthly summaries of ice conditions based on satellite imagery examined in Anchorage, the whales appeared to be at least 26 nm (48 km) north of open water and 23 nm (43 km) south of heavy pack-ice. There were no obvious signs of a response to the aircraft despite the fact that we circled overhead at an altitude of 750 ft. (229m) for 18 minutes in an attempt to observe and photograph the whales. When considered in the context of the species' historical distribution and the results of other recent survey programs in the area, this observation supports the view that waters near St. Matthew Island are important to the species. Bowheads were once widely distributed in arctic waters. Following several centuries of intensive whaling by Europeans and Americans in arctic waters of the North Atlantic and mainly by Americans in the Okhotsk, Bering, Chukchi, and Beaufort seas, populations in all areas were significantly depleted. At present, bowheads are considered for management purposes to exist in four or five geographic "stocks", called the Okhotsk Sea stock, the Bering Sea stock, the Hudson Bay stock, the Davis Strait stock, and the Spitsbergen stock (Allen, Chmn., 1978).

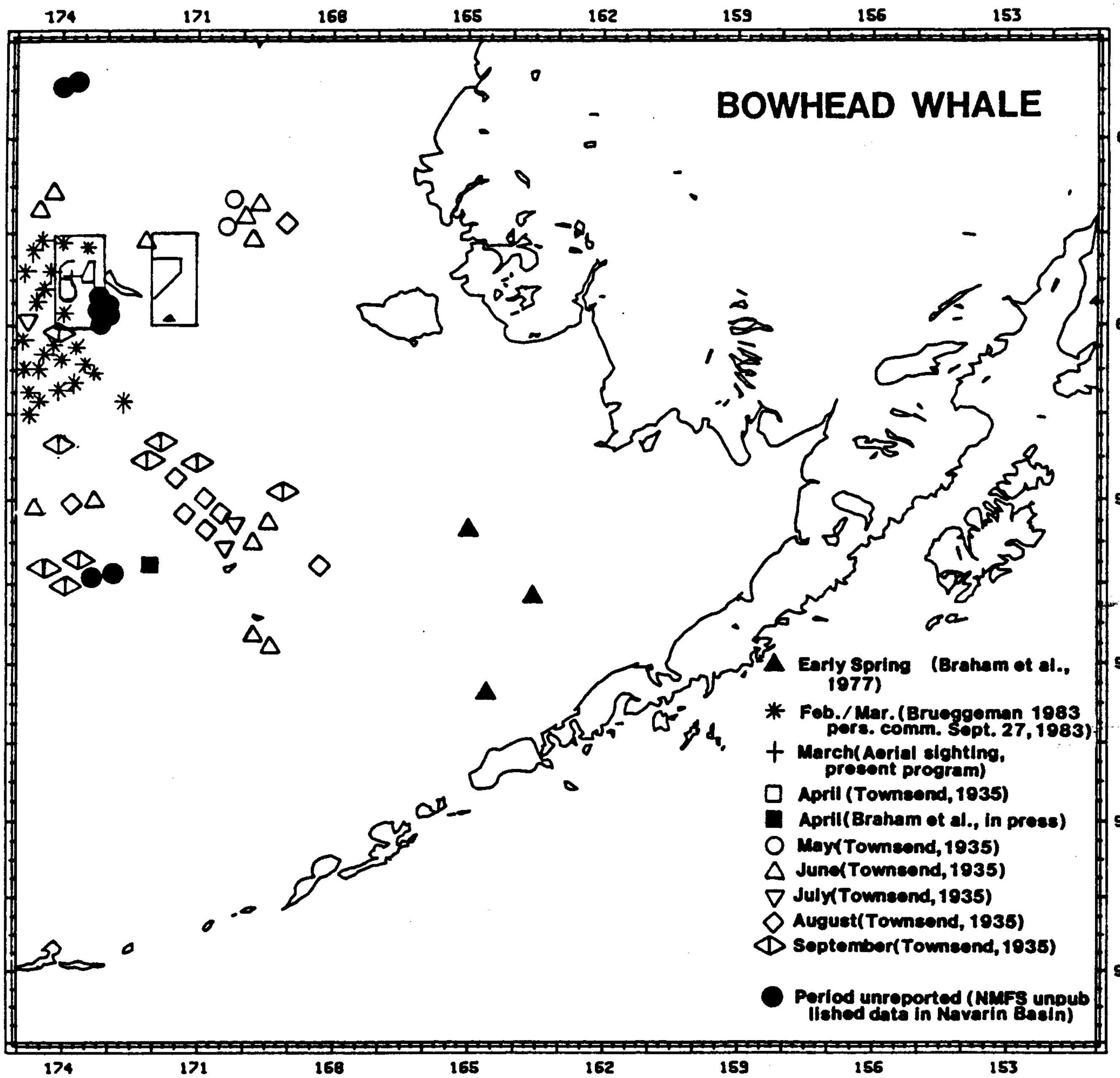


Figure 21. Approximate locations of takes (by nineteenth century yankee whalers) and sightings (on recent research surveys, 1978-present) of bowhead whales in the survey area. The number in the one-degree block east of St. Matthew Island indicates the total number of bowhead whales observed there during the present surveys; that in the blocks west of the island indicates the number seen on aerial surveys from an ice breaker in April 1979 (Brueggeman, 1982). Sources of other data are indicated in the legend.

The stock of primary interest to this study is the Bering Sea stock, commonly and somewhat imprecisely referred to in some U.S. and Canadian publications as the Western Arctic stock (i.e. the Western Arctic of North America). The Bering Sea stock moves seasonally among the Bering, Chukchi, Beaufort, and (to a limited degree) East Siberian seas.

Alaskan and Siberian aboriginal whalers have hunted the Bering Sea stock for more than a millenium (Marquette and Bockstoce, 1980). The size of the stock just prior to 1848, when its exploitation by Yankee pelagic whalers began, has been estimated as 14,000 to 20,000 individuals; it is thought more likely to have been near the upper end of that range (Bannister, Chmn., in press). American commercial whalers killed an estimated minimum of 18,658 animals between 1848 and 1915 (Bockstoce and Botkin, 1983). Whaling by Eskimos for subsistence has continued since 1915, and this activity is at the center of an international controversy concerning the stock's chances of survival and recovery (Mitchell and Reeves, 1980; Donovan, 1982; Gambell, 1983). In recent years this controversy has broadened to include concern about the effects of oil and gas resource development on the whale population and its ecosystem.

The Bering Sea stock was estimated to contain 3,817 individuals[5] in 1983 (Zeh, et al., 1983; Bannister, Chmn., in press). There have been definite removals of 8 to 17 whales per year from 1978 to 1983, and additional strikes of 6 to 18 whales per year during this time,

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5 In this report, reference is frequently made to estimates of current population size for whales of interest to the International Whaling Commission. It should be noted that in the case of whales which have not been exploited commercially since ca. 1946, population estimates are based mainly on censuses. Such estimates generally can be assumed to refer to the entire population, including all age-classes, at any given time. However, in the case of large whales which have been recently or continue to be commercially exploited (including the minke whale), many estimates refer to the recruited segment of the population only. In other words, calves and juveniles below the minimum size limit set for "harvesting" in the IWC's schedule are not included in the estimates.

resulting in some unknown amount of additional mortality. It is not clear whether the population has increased or decreased since 1915.

Townsend (1935) plotted positions, by month, of 5,114 bowhead kills in the Sea of Okhotsk and the Bering, Chukchi, and Beaufort seas, from latitudes 53°N to 73°N and longitudes 120°W to 135°E. These included 35 whales taken within our Bering Sea study area, at least one of them during each month from April through September (Figure 21). The southernmost of these records are from about latitude 56°30', just south of St. George Island, Pribilofs, in June. Other kills, spanning the months from spring through fall (April-September), were concentrated north and west of the Pribilofs and between latitudes 60°N and 62°N, near St. Matthew Island.

We recognize that Townsend's charts are not completely trustworthy. In particular, entries in whaling logbooks and journals, such as those used by Townsend as his primary sources of data, are not always clear in distinguishing bowheads from right whales (Reeves and Mitchell, in press; Bockstoce and Botkin, 1983:110). Since right whales are known to have occurred formerly in some portions of the southeast Bering Sea, we feel it is necessary to examine Townsend's original sources directly and critically before making any firm judgments about the significance of the data shown on his charts.

There is no information available on distribution of bowheads in the study area for the first seven decades of this century. There have, however, been some recent sightings (Figure 21). In addition to the single observation made by us in March, we are aware of five reports of sightings of bowheads in the southeast Bering Sea. Braham et al., (1977) - also cited in the caption to Figure 4.2 in Braham et al., (1982) as Braham and Rugh, in preparation (no citation listed) - plotted locations of 3 sightings in "early spring" between about latitude 55°30'N and 57°40'N near longitude 164°W. Braham et al. (1982) also reported a sighting made "just west of St. Paul Island in April 1976". This record was attributed to "Braham et al. (in press)" (no citation listed). Details of these records, including identity of observers and probable reliability of identifications, were not presented. However, L. Lowry (pers. comm., 15 March 1984) suggested that one of these sightings was probably made on 19 April 1976 from the NOAA ship R/V Surveyor at 57°08.4'N, 172°52.1'W. A single bowhead, approximately 11m long, was seen in 6 octa ice by Lowry and others.

In the Navarin Basin Synthesis report [see Science Applications Inc. (SAI), 1981, Figure 9.1] there are nine symbols indicating sightings of bowheads at unstated seasons. These records are attributed to "NMFS, unpublished data."

Brueggeman (1982) (also published previously as Braham et al., 1980) reported encountering 64 bowheads in a 55 x 59 km study block just west of St. Matthew Island during aerial surveys there in early April 1979. Those sightings were used to support his estimate of 119 whales for the block. Surveys in March and April in 15 other widespread study blocks, seven of them along the pack-ice edge in the mid-Bering Sea and nine south and west of St. Lawrence Island, produced sightings and estimates of only 45 and 57 whales respectively. Therefore, 60% of all bowheads seen and 68% of those estimated to have been in the study blocks during Brueggeman's surveys were near St. Matthew Island. Thirty nine percent of the whales sighted (and 31 percent of the whales estimated) were near St. Lawrence Island. Only one of the bowhead sightings was along the pack-ice edge in the central Bering Sea.

On ship-based aerial surveys of Navarin Basin in February and March 1983, observers saw bowhead whales only near St. Matthew Island, where an estimated total of 25 individuals (no duplicates) was reported for one study block (Brueggeman, 1983; pers. comm., September 26, 1983).

The winter distribution of the remnant Bering Sea stock of bowhead whales and the relative importance to them of the southeast Bering Sea remains problematic. It has often been stated that bowheads winter principally in the pack ice south and west of St. Lawrence Island and that they also range southward to St. Matthew Island and perhaps westward along the ice edge from the Pribilof Islands to the coast of the U.S.S.R. (Braham, et al., 1980; Braham et al., 1982; Morris, 1981). The "known" winter range has been extrapolated from rather scant evidence to include a major portion of the central Bering Sea north of latitude 57°N but not to extend farther southeast than about St. Matthew Island (Morris, 1981: Fig. 5.5). Such conclusions are apparently based on past whaling records (Townsend, 1935; Scammon, 1874; Cook 1926) and on observations by Alaskan Eskimos (Braham et al., 1980). Available data on present distribution, however (presented in Brueggeman, 1982; 1983; and supplemented by our own observations), can as easily be construed to indicate that in winter (February and March) the whales are more abundant near St. Matthew Island than elsewhere and that the concentrations observed near St. Lawrence Island during the whaling season of March through May (Marquette 1977, 1979; Marquette and Bockstoce, 1980) reflect a movement of the population to the polynyas near Southwest Cape anticipating the northward migration. There are no data on the mid-winter distribution of the species in other areas east of the USA/USSR convention line, and the data for that period closest to mid-winter (Feb.-March) support the hypothesis that substantial numbers of bowheads winter near St. Matthew Island. At the very least it appears, as postulated by Brueggeman (1982), that the open water areas around St. Matthew Island serve as a staging ground where whales from the southern ice front congregate to await the opening of a lead to open waters near St. Lawrence Island.

We note with interest the remarks by Hanna (1920) that the bones of this species, including some whole and some partial skeletons along the drift line and some bones half-buried in the tundra far back of the high tide mark, were abundant on all beaches of St. Matthew Island. If these identifications were correct these records provide evidence of the species' historic presence in the area.

Concerning present penetration of bowheads farther into our study area than St. Matthew Island, we have only the sightings discussed above and shown in Figure 21. To the extent that bowheads depend on the ice front and negotiable pack-ice regions for suitable habitat (Eschricht and Reinhardt, 1866), their distance of penetration into the southeast Bering Sea in any given year and their use of any specific area will be related to the maximum extent of ice advance (Potocsky, 1975). It is not yet clear whether bowhead whales feed during winter (Lowry et al. 1982b), nor is it clear what role ice plays in their behavior and natural history (for example, as sanctuary from bad weather and killer whales). Therefore, until more is known about the species, there is little basis for speculating about the importance of our present study area to bowheads or about the effects that destruction or modification by industry of the ice and substrate might have on their survival.

Right Whale (<u>Eubalaena glacialis</u>)

There were no observations of right whales during the present surveys. Though disappointing, this lack of sightings was not surprising. Of all mysticetes, the North Pacific right whale is among the most immediately threatened with extinction. The entire population has been estimated to contain a minimum of a "few" to 80 individuals (Rice, 1974; Wada, 1978) to a maximum of 100-200 individuals (Wada, 1973). There have been no signs of recovery in the population since it became protected in 1935. Because the species was formerly hunted in or near both our study areas, we offer here a review of the most important recent data.

Klumov (1962) divided the North Pacific population into three stocks which he felt did not intermix: American, Asiatic-Pacific Ocean, and Asiatic-Okhotsk Sea. Whales of interest to the present investigations presumably belong(ed) to the American and possibly the Asiatic-Pacific stocks. The Subcommittee on Protected Species and Aboriginal Whaling of the IWC Scientific Committee concluded that, in view of the continuing paucity of sightings, even in areas extensively surveyed, "... apart from the remnant of the Okhotsk Sea stock ... the continued existence of viable stocks of right whales in the rest of the North pacific is in doubt" (Best, Convenor, 1982:106).

Stranded whales, presumably including right whales, were used by various aboriginal groups along the west coast of North america from Oregon and Washington to mainland Alaska and the Aleutians (O'Leary, in press). In addition, aboriginal whalers hunted right whales along the Pacific northwest coast (R. Dougherty, cited in Scarff, 1983; Drucker, 1951; O'Leary, in press) and the Aleutian Islands (Mitchell, 1979).

Yankee whalers began taking right whales on the "Kodiak" or "Northwest Coast" ground in the Gulf of Alaska (50°-58°N, 140°-152°W) in the 1930s (see Scarff, 1983, for a review). They continued whaling throughout the nineteenth and into the twentieth century, taking at least 2,118 right whales in the North Pacific between 1839 and 1906, about 40 percent of them on the Kodiak ground (Townsend, 1935). Since Townsend sampled manuscripts covering only a fraction of the voyages made to the North Pacific, we assume the total kill was much higher than the above figure.

By the end of the nineteenth century, right whales were considered rare in the North Pacific, at least south of Alaska (Townsend, 1886; Collins, 1892). During the twentieth century they have constituted only a small part of the whale catch in the eastern North Pacific. Scarff (1983, Tables 4, 5) summarized captures from 1910 to 1982 as: 1 from California, 5 from British Columbia, and 21 from Alaska (including 3 taken prior to 1923).

From original records of the whaling companies and from Alaska Fishery and Fur Seal Industries (Bower 1917), we have accounted for 21 right whales taken at Akutan and Port Hobron, Alaska, alone between 1916 and 1935,(Table 11). Locations of 17 of those kills are shown in Figure 22, and some of the specimens taken are illustrated in Figures 23 and 24. Tønnessen and Johnsen (1982) reported 2 additional kills in 1917 and 1 in 1916, making the total removals of right whales from Alaska between 1916 and 1935 at least 25. There may have been a few more pre-1935 twentieth-century kills in Alaska than are accounted for above. Birkeland (1926, p.26) reported that two right whales were killed at Akutan "during my time". We assume by this he meant from June 1914 to October 1915, which was the period of his stay at the Akutan station. His book includes

Table 11. Right whales caught by vessels operating from shore stations in Alaska 1916-1935.
A = Akutan, PH = Port Hobron.

Date	Station	Location of Kill	Vessel	Sex	Length (ft)	Fetus Sex	Fetus Length	Remarks	Source of Data
– – 1916	A	Not reported.	–	–	–	–	–	–	2
14 July 1917	A	Not reported.		–	–	–	–	–	3
– – 1923	A	Not reported.	Tanginak	–	–	–	–	–	4
– – 1923	A	Not reported.	Kodiak	–	–	–	–	–	4
30 June 1924	A	30 nm S of Biorka Island.	Tanginak	F	57	–	–	"Good" condition.[3]	6
28 June 1925	A	10 nm SSE of Cape Prominence.	Paterson	F	55	–	5.5 ft	"Fair" condition.[3]	6
2 July 1926	A	25 nm SE of Rootok Island.	Aberdeen	F	41	–	–	"Fair" condition.[3]	6
18 September 1926	PH	18 nm S of Barnabas Island.	Aberdeen	F	62	M	18 ft	–	6
6 July 1927	A	Unimak Pass.	Westport	M	36	–	–	Logged as a "calf".	6
4 June 1928	PH	45 nm ESE of Cape Barnabas.	Moran	M	36	–	–	–	6
6 June 1928	PH	18 nm SE of Cape Barnabas.	Aberdeen	F	33	–	–	–	6
8 June 1928	PH	20 nm SE of Cape Barnabas.	Aberdeen	M	43	–	–	–	6
8 June 1928	PH	25 nm SE of Cape Barnabas.	Tanginak	F	46	–	–	–	6
3 July 1928	PH	25 nm E of Marmot Island.	Moran	F	50	–	–	–	6
5 July 1928	PH	20 nm ESE of Cape Barnabas.	Moran	M	50	–	–	–	6

4 June 1929	A	7 nm N of Tanginak.	<u>Unimak</u>	F	59	-	-	"Poor" condition.[3]	6
14 June 1932	PH	30 nm SE of Cape Barnabas.	<u>Aberdeen</u>	M	52	-	-	-	6
2 August 1932	PH	18 nm NE of Sitkinak Island.	<u>Westport</u>	M	44	-	-	-	6
1 August 1933	PH	45 nm SE of Cape Barnabas.	<u>Aberdeen</u>	F	45	-	-	-	6
3 June 1935	A	30 nm E of Rootok Island.	<u>Paterson</u>	F	47	-	-	-	6,7
20 August 1935	PH	60 nm SSE of Barnabas Island.	<u>Aberdeen</u>	F	39	-	-	-	6

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[1] 1. Production and Catch Summaries (Rose Harbour and Naden Harbour); 2. <u>Alaska Fishery and Fur-Seal Industries in 1916</u>; 3. Production and Catch Summaries (Akutan); 4. William S. Lagen Collection, Oversize unit No. 19096 5. Pike and MacAskie, 1969; 6. Station Tallies (Akutan and Port Hobron); 7. Catcher-Boat Logs.

[2] Source does not specify at which station whale was landed.

[3] Condition was subjectively assessed at boat- or dockside based on expected oil production.

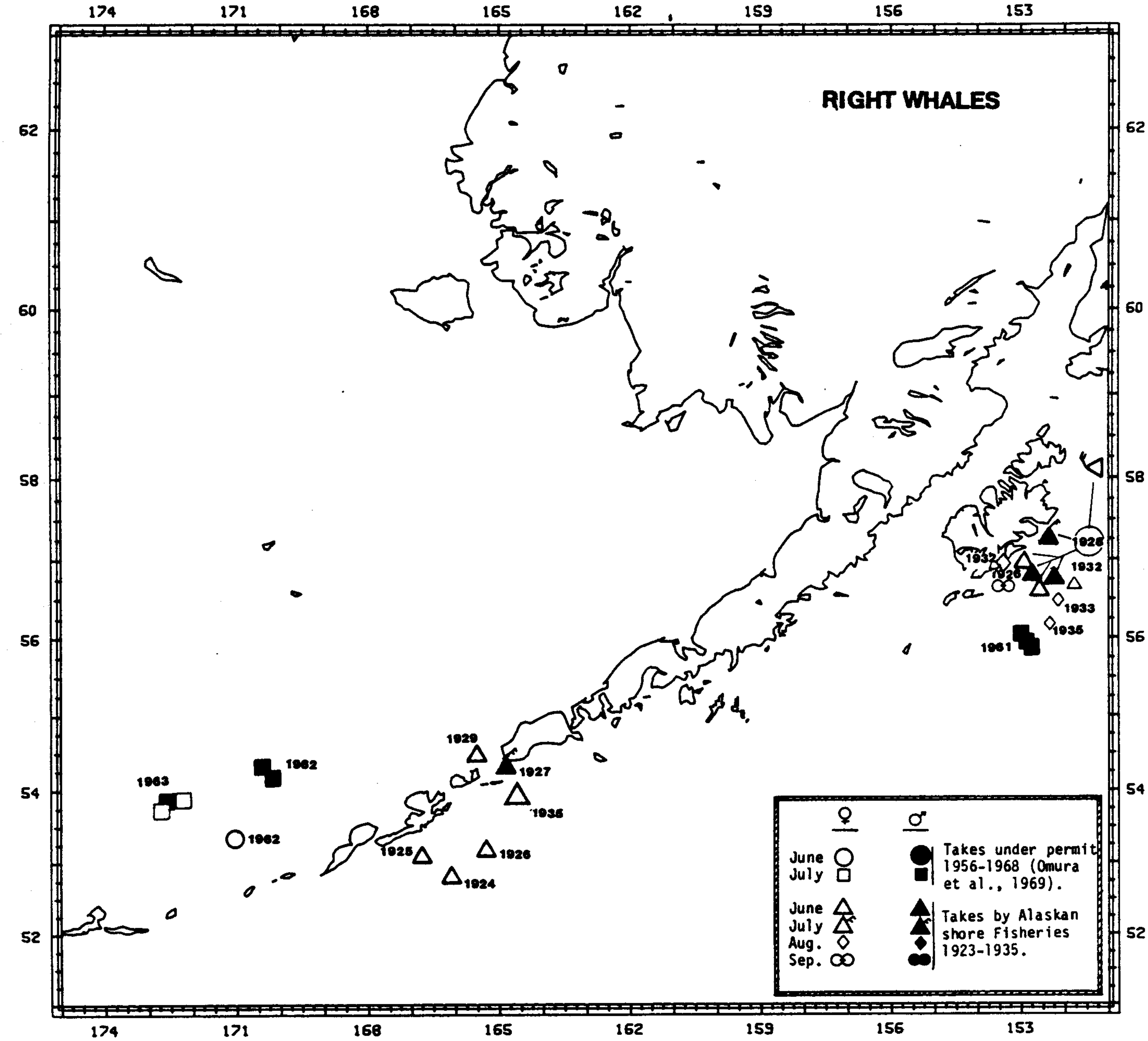


Figure 22. Location of right whale kills by whalers from Akutan (1923-1935) and Port Hobron (1926-1935) and by Japanese pelagic whalers (1956-1963) (Omura et al., 1969). For details see Reeves, Leatherwood, and Karl, in preparation.

Univ. Wash. Suzzalo Library Historical Photography Collection:
WHALES & WHALING-Flensing #47 "Wright [sic] Whale, Akutan"

Figure 23. Right whale on ramp at Akutan Whaling Station.

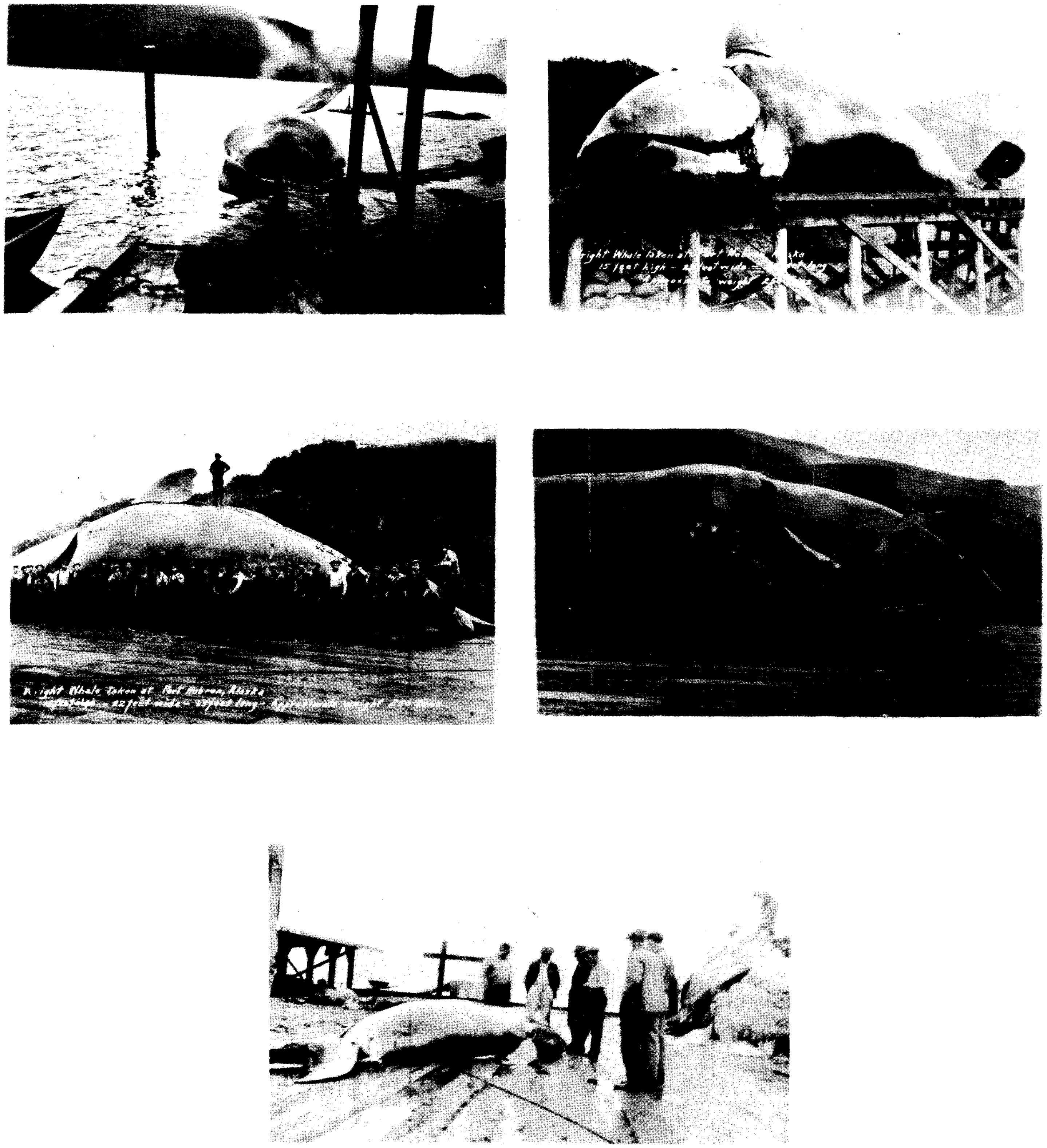


Figure 24. Right whales on ramp at Akutan Whaling Station.

two photographs of right whales on the flensing platform at Akutan (p.83,99), but there are no data on when they were taken. In the Pacific Fisherman's 1917 yearbook it was said in reference to the Alaskan shore stations, "a few sperm whales are taken each season while an occasional right whale is secured". Nichols (1926, p. 609) referred to takes at Akutan of "a few" right whales and included a photograph of a specimen on the ramp at Akutan.

There were 10 additional right whales taken from the eastern North Pacific and southern Bering Sea after 1935, one "accidentally" killed in 1951 off British Columbia by Canadian-based shore whalers (Pike and MacAskie, 1969; also see Table 11) and 9 killed in or near our study area by Japanese whalers under special scientific permits between 1956 and 1968 (Omura, 1958; Omura et al., 1969) (Fig. 22).

The only other pertinent modern data on right whales in the eastern North Pacific are sightings and tagging records. Scarff (1983, Table 4) reviewed sightings and strandings south of latitude 50°N between 1855 and 1982. There are few records for this century: 1 killed in 1924 near the Farallon Islands, 1 stranded in 1916 on Santa Cruz Island, and 33 sightings representing a total of 69 individuals. There are also relatively few modern records of right whales in the eastern North Pacific north of latitude 50°N, in spite of extensive scouting effort by whaling fleets and some coverage by research programs. Omura et al. (1969) summarized sightings from Japanese whale catchers (1941-1968) and from Soviet vessels (1951-57), the latter excerpted from Klumov (1962). Their figures 13.3-13.6 show the following patterns in the roughly 275 records from the eastern North Pacific: April - no sightings; May - a few sightings along the Aleutian islands and 3 east of Kodiak Island;

June - about 50 sightings in the southeastern Bering Sea (between 52°N and 58°N and 162°W and 174°W), about 50 sightings within approximately 60nm (111 km) of the Aleutians and the southern shore of the Alaskan Peninsula west of longitude 158°W, the majority in or near the former whaling grounds of the Akutan station, and another 40 from the Gulf of Alaska, mostly south and/or east of Kodiak Island; July - some 75 sightings in a roughly triangular area of the Bering Sea bordered on the west by 175°W and in the south by the Aleutians from 175°W to about False Pass, and another 50 in a band within approximately 100nm (185.2 km) of the Aleutians, the Alaska Peninsula and southern Kodiak Island; and August about 10 sightings each in two areas of the southeast Bering Sea (one 5-150 nm southwest of St. Matthew Island, the other between the Pribilofs and the Aleutians), two sightings northeast of St. Lawrence Island, and two in the southwest Chuckchi Sea. Wada (1975) and various subcommittee reports to the IWC (1976-1982) update those records through 1973 and 1981, respectively, with no change in patterns noted above.

Berzin and Rovnin (1966: Figure 6) showed distribution, relative density, and postulated spring migration routes of right whales in the Bering Sea and Northeast Pacific. Though they indicated sightings to have been widely scattered throughout the areas described above, they illustrated and stated that there was a concentration in the western Gulf of Alaska between longitudes 145°W and 151°W and that sightings in the Bering Sea were limited to the "southeast corner", an area they described by a line connecting Atka, St. Matthew, and Nunivak islands. Specific dates and locations of sightings were not reported; nor were details of effort necessary for a quantitative assessment of the published records.

Pike and McAskie (1969) mentioned three offshore sightings of solitary right whales in July and August, two from a weathership at 50°N, 145°W, and one at 54°N, 155°W. More relevant to our study areas are two right whales seen 26 August 1982 at 60°48'N, 175° 17.5'W (Brueggeman, 1983).

Five right whales were tagged in the eastern North Pacific by the Japanese from 1963 to 1965 (Ohsumi and Masaki, 1975), and 17 (IWC) to 20 (Ivashin and Rovnin, 1967) by the Soviet Union from 1954 to 1965.

There is only one confirmed recent (1975+) record near the present study areas - the sighting by Brueggeman (1983). A second, unverified sighting report has come to our attention. On 30 August 1982 Frank Wood, aboard the NOAA Ship Discoverer, sighted what he identified as a right whale at 64°50.1'N, 168°25.4'W. The animal, seen at a distance of 50m, was described as black to dark gray, with a V-shaped blow, no dorsal fin, and a smooth back (M. E. Dahlheim, pers. comm., January 1983).

It is clear that large numbers of right whales formerly used major portions of the northern Gulf of Alaska and southeastern Bering Sea, including portions of our study areas. The absence of sightings during our surveys should not be taken as proof that the species no longer inhabits these previously important grounds. To improve the right whale's chances of survival in the Northeast Pacific, it is important to conduct site-specific studies of areas planned for industrial development in order to determine whether such areas are still visited by these animals.

Gray Whale (*Eschrichtius robustus*)

Of all the cetaceans occurring in or near our study areas, the gray whale is among the most thoroughly studied (Rice and Wolman, 1971; Rice, 1978a). It is a coastal species with highly regular patterns of migration and behavior, bringing it close along some heavily populated segments of the

North American coast. Public and scientific interest has been high, and the whales are readily accessible for observation and study. Gray whales have twice been hunted to low population levels in the Northeast Pacific, first by nineteenth-century Yankee whalers operating from ships and shore stations, in the calving lagoons and along the migration route (Scammon, 1874; Henderson, 1972; Henderson, in press), and later by modern whaling fleets (Reilly, 1981; Reeves, in press). They now appear to have recovered to a level at or near their pre-exploitation stock size (Reilly et al., 1980; Reilly, in press). Gray whales are currently hunted from modern Soviet catcher vessels on the northern feeding grounds, and a few whales are taken by Eskimos in Alaska (Wolman and Rice, 1979; Marquette and Braham, 1982; Ivashin and Mineev, 1981). An annual quota of 178-179 has been set by the IWC since 1978. Because of its presence, at least seasonally, in or near areas involved in oil and gas development, the gray whale is a species often targeted for study (Kent et al., 1983; Tyack et al., 1983; Clark et al., 1983).

Details of the gray whale's migration, and important aspects of its ecology, based largely on observations of the population during periods of whaling or periods of recovery from heavy exploitation, have been reviewed by many authors (e.g. Scammon, 1874; Andrews, 1914; Hubbs, 1959; Gilmore, 1961; Pike, 1962; Rice and Wolman, 1971; contributors to Jones et al., eds., in press). Study has continued in the breeding/calving lagoons (e.g. Swartz and Jones, 1980, 1983; Rice et al., 1981; Bryant and Lafferty, 1980, 1983; Withrow, 1980; Norris et al., 1977; Norris et al., 1983), along the migration route (e.g. Rugh, in press; Darling, in press; Reilly et al., 1980), and on the summering grounds (Bogoslovskaya et al., 1982; Nerini, in press; Johnson et al., 1983). Results of recent investigations have been reviewed by Lowry et al. (1982a,b) and by various contributors to Jones et al., (eds., in press). Data pertinent to the present study areas are summarily reviewed below.

The vast majority of the estimated 17,000 eastern Pacific gray whales (Rugh, in press; Reilly, in press) migrate annually from breeding/calving lagoons off Baja California and mainland Mexico to feeding grounds from the central Bering Sea, north and east into the Chukchi and Beaufort seas. The migrating whales pass through or near both study areas covered by the present investigations. Not all whales migrate the full route northward in summer. Some linger to rest and feed (Pike, 1962), for example, off the Farallon Islands (Dohl et al., 1983), Washington State (Rice and Wolman, 1971), British Columbia (Hatler and Darling, 1974; Hudnall, 1983), Cape St. Elias (Hall et al., 1977; Braham, in press) and the south shore of Bristol Bay, especially Nelson lagoon (Gill and Hall, 1983). Some apparently also summer off Kodiak Island and in the eastern Bering Sea and Bristol Bay (see discussions below).

Previously the most incomplete parts of the story, the gray whale's migrations and behavior in southern Alaska and within the Shelikof Strait and Bering Sea study areas can now be reasonably well described. The northward migration occurs in two pulses, the first consisting of non-parturient adults and immature animals, the second principally of females and their calves of the year (Rugh, in press). All northbound whales apparently remain close (within ca. 400m - Hall et al., 1977 - to 2 km - Braham, in press) to the outer coast of the mainland and/or barrier islands as far as the Kenai Peninsula. From there they strike across open water, most moving past the Barren Islands toward the northern tip of Afognak Island, a smaller proportion heading across the mouth of Cook Inlet.

For whales in the first pulse of the migration, about 25% of those observed have been moving along the northwest-facing shores of Afognak and Kodiak islands; the remaining 75%, along the seaward shores of these islands at least as far as the Trinity Islands. The pattern is similar in the second phase. Four of 12 animals observed were on the northwest shore while 8 of 12 moved along the ocean shore. Two female-calf pairs apparently crossed the mouth of Cook Inlet directly and moved close along the shore of the Alaska Peninsula (Braham, in press: Figures 4a,b). We do not know how representative these small samples are of the population as a whole. Somewhere between the Trinity Islands and Chirikof Island, whales migrating outside Afognak and Kodiak islands move across the southwest end of Shelikof Strait to the shore of the Alaska Peninsula. Routes taken by whales migrating inside the islands are not known. Two whales seen off Trinity Islands during survey 1 were headed north toward the Peninsula. One sighting reported by Braham (in press) at 156°30'W was near shore along the south side of the Alaska Peninsula, as were a half dozen sightings made by Alaska Department of Fish and Game (ADF & G) personnel between 157°W and 160°W in 1980 and 1981 and reported by Moore and Ljungblad (in press: Figure 2). Westward movements along the remainder of the Peninsula are unreported.

The northbound migrants pass through Unimak Pass near the eastern shore between March and June (Hall et al., 1977; Rugh and Braham, 1979; Braham, in press; Rugh, in press) and continue along a principally coastbound route around the perimeter of Bristol Bay to Nunivak Island. Details of northward movements through Bristol Bay and the eastern Bering Sea can be described in some detail from data obtained in the present investigations and from activities of the Alaska Department of Fish and

Game (Lowry et al., 1982a,b; Moore and Ljungblad, in press; Baxter and Leatherwood, 1983, MS; Braham, in press). These accounts differ in very few details and can best be understood by reference to Figure 25 and to Braham (in press: Figure 5).

During the present surveys, we made a total of 126 sightings of gray whales, accounting for 373 individuals (Figures 25a-d and 26). An incidental sighting of one group was made in block 7 (2 animals seen during survey 1). Within the Bering Sea study area (blocks 1-6), however, we found 105 groups (323 individuals), 44 on-transect and 61 off-transect (Tables 7 and 9). From the 33 appropriate on-transect sightings made during these surveys, all in the Bering Sea and Bristol Bay and all during survey 2, we estimated population density for blocks 1, 2, and 6 combined as 120.2 $\pm$ 100.5 (19.7 to 220.7) herds and 236.8 $\pm$ 199.6 (37.2 to 436.4) whales per 1,000 nm^2 (3430 km^2) (Table 10). Such wide confidence intervals suggest that these estimates have little meaning and should be regarded as very crude. The distribution of sighting distances, the fitted model (a generalized exponential) used to produce the estimate of herd density, and the distribution of herd sizes used to estimate animal density are shown in Figure 27.

During the survey year, there were observations of gray whales in blocks 1-6 during surveys 1(9 whales), 2(298 whales), 3(6 whales), 5 (9 whales), and 6(1 whale). The timing and levels of effort of spring and summer surveys appear to have been adequate to characterize the northbound migration, which occurs during March through July (Hall et al., 1977; Rugh and Braham, 1979; Figure 28).

Most gray whales seen in the Bering Sea study area were near shore (within 1 km). Many were in very shallow water: <10 fms (18 m) (ca 45%)

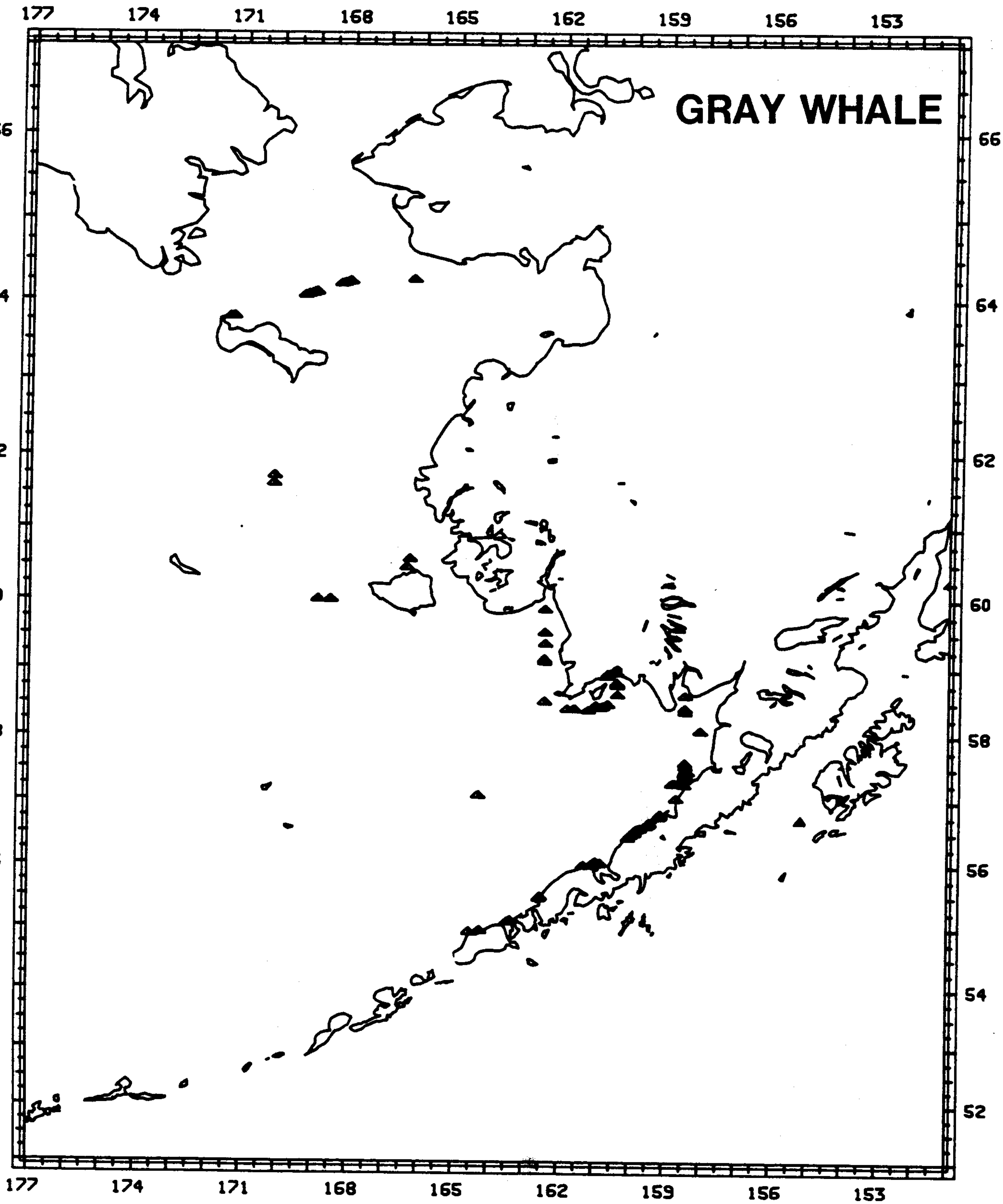


Figure 25a. Locations of aerial sightings of gray whales (all).

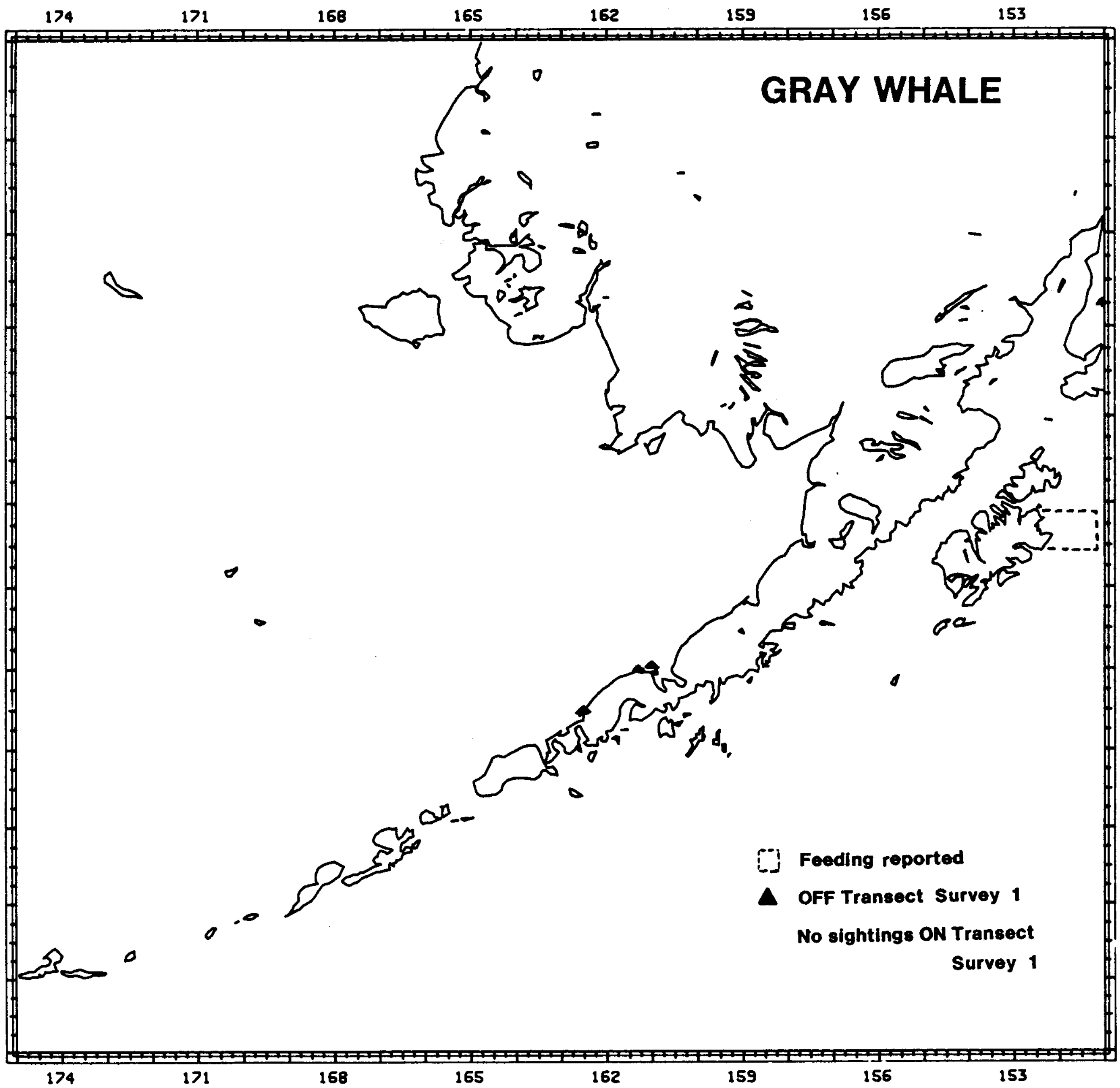


Figure 25b. Locations of aerial sightings of gray whales during survey 1 (13 March - 1 April 1982). Dotted circles indicate areas where feeding was observed (see Table 11), dotted squares where feeding has been reported previously (Braham, in press).

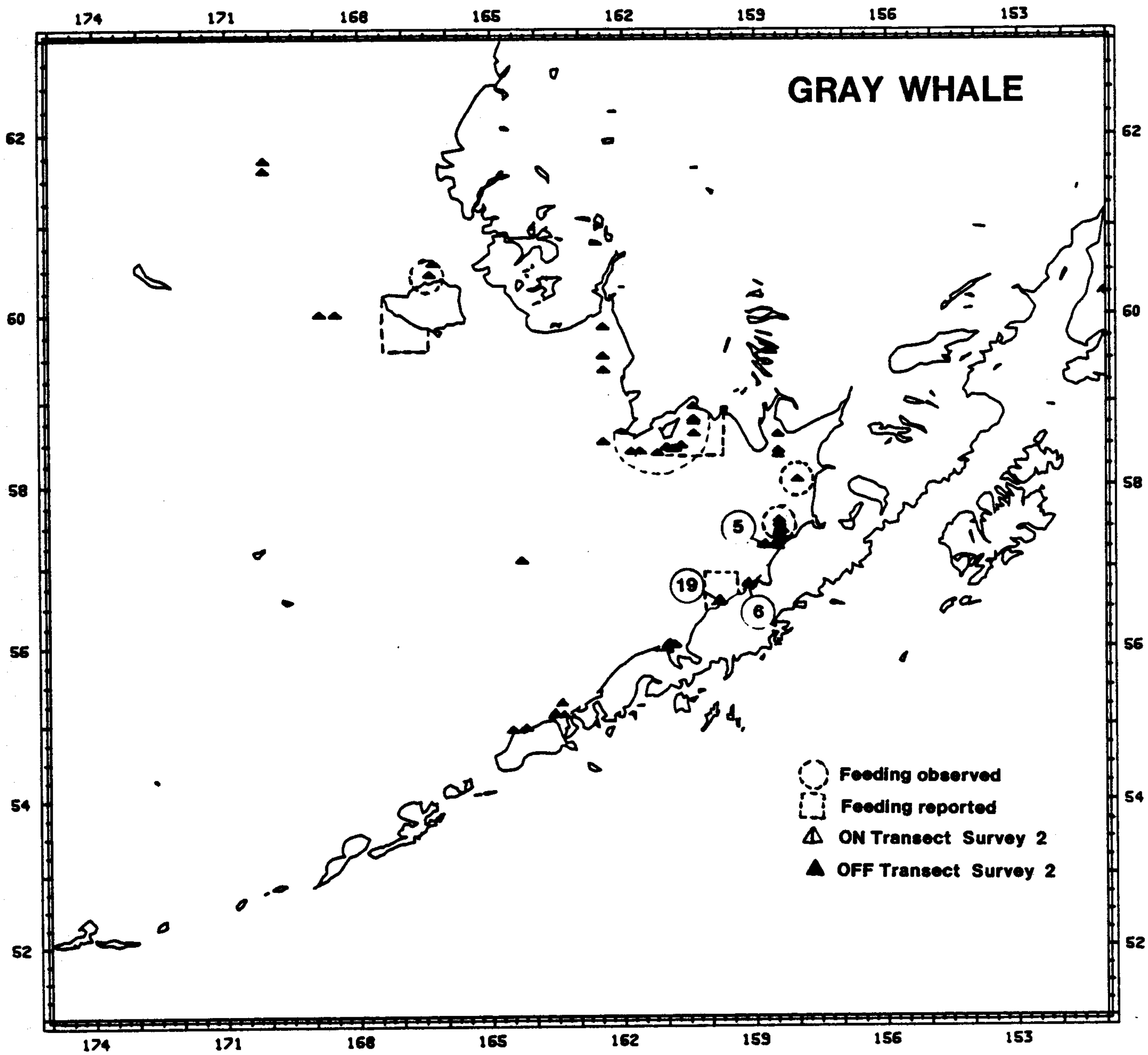


Figure 25c. Locations of aerial sightings of gray whales during survey 2 (10 May - 3 June 1982). Dotted circles indicate areas where feeding was observed (see Table 11), dotted squares where feeding has been reported previously (Braham, in press).

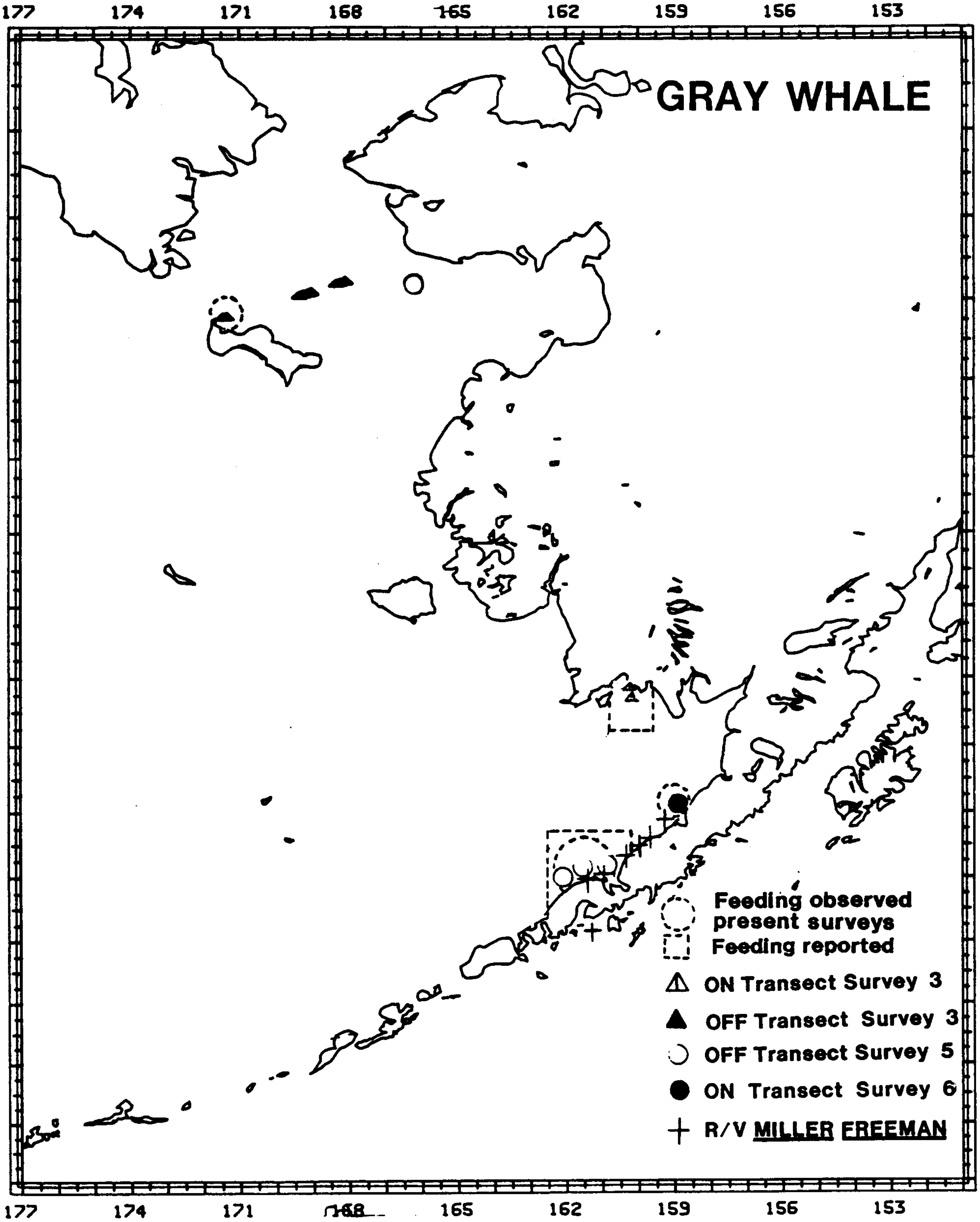


Figure 25d. Locations of aerial sightings of gray whales during surveys 3 (3-28 July 1982), 5 (11-22 Sept 1982), and 6 (26 Oct-13 Nov). Dotted circles indicate areas where feeding was observed (see Table 11), dotted squares where feeding has been reported previously (Braham, in press).

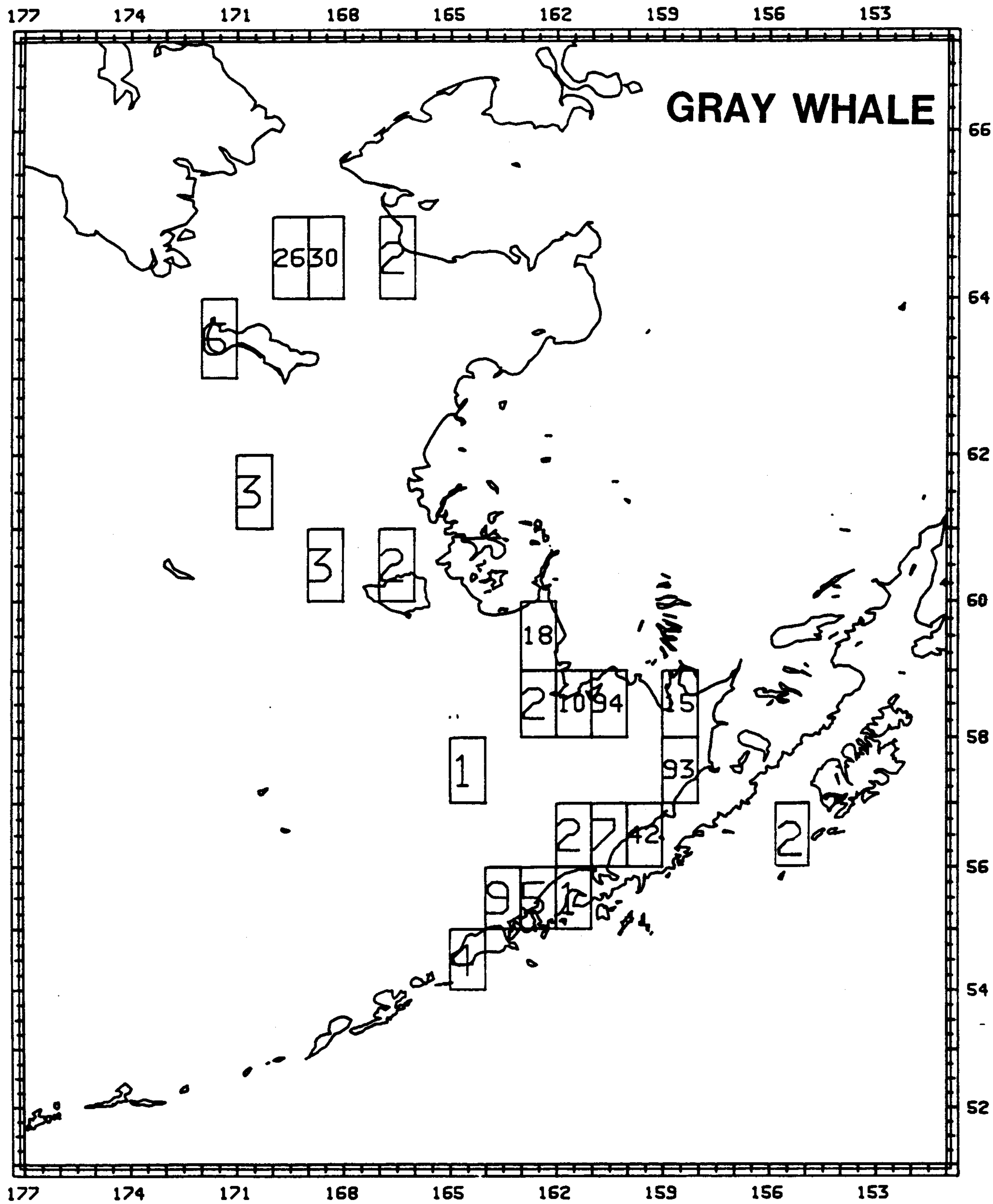


Figure 26. Total number of gray whales seen by 1° block.

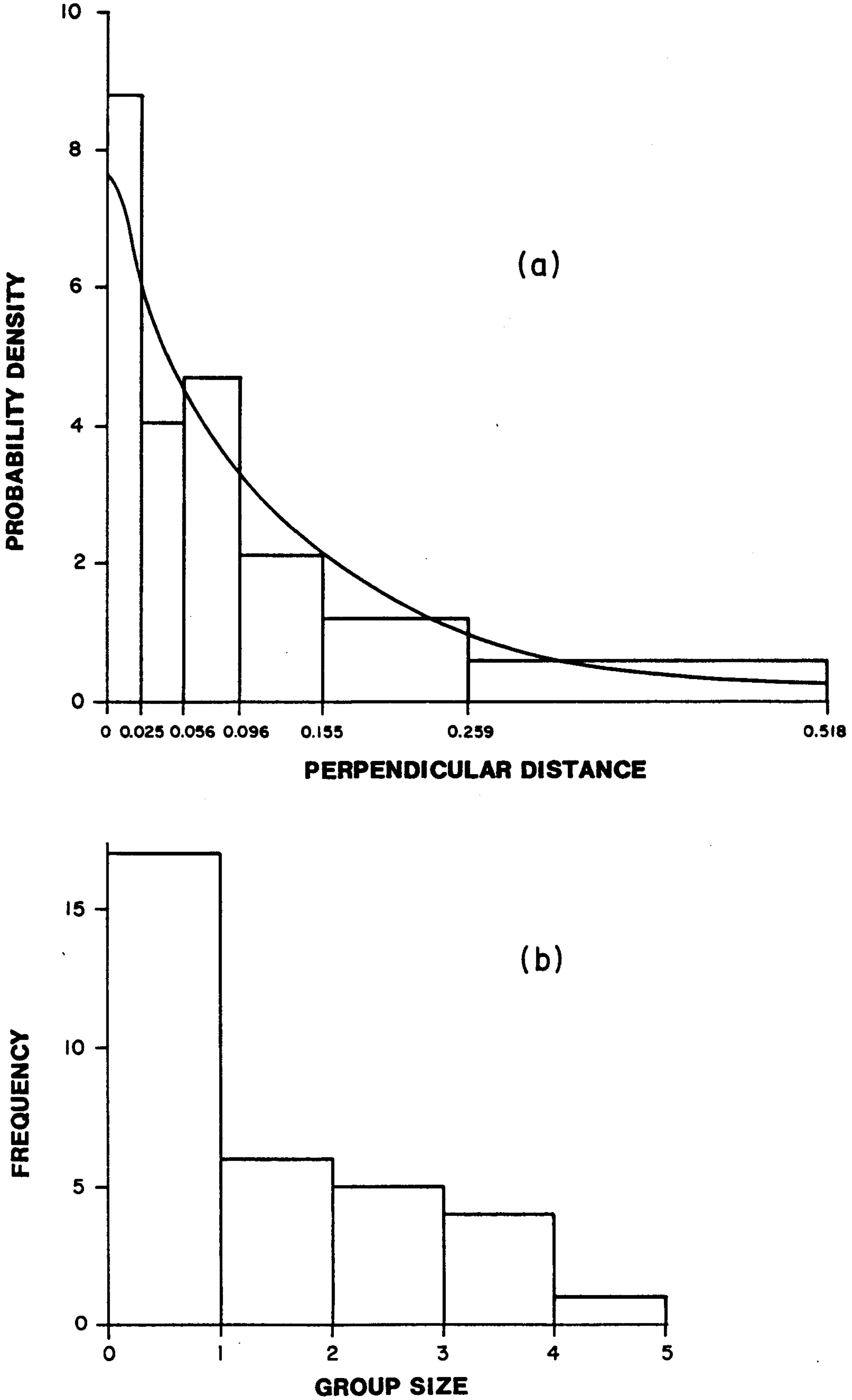


Figure 27. Perpendicular distances truncated under the aircraft at 0.039 nm and the fitted generalized exponential model (a) and group size distribution (b) for gray whales in blocks 1 and 6, survey 2.

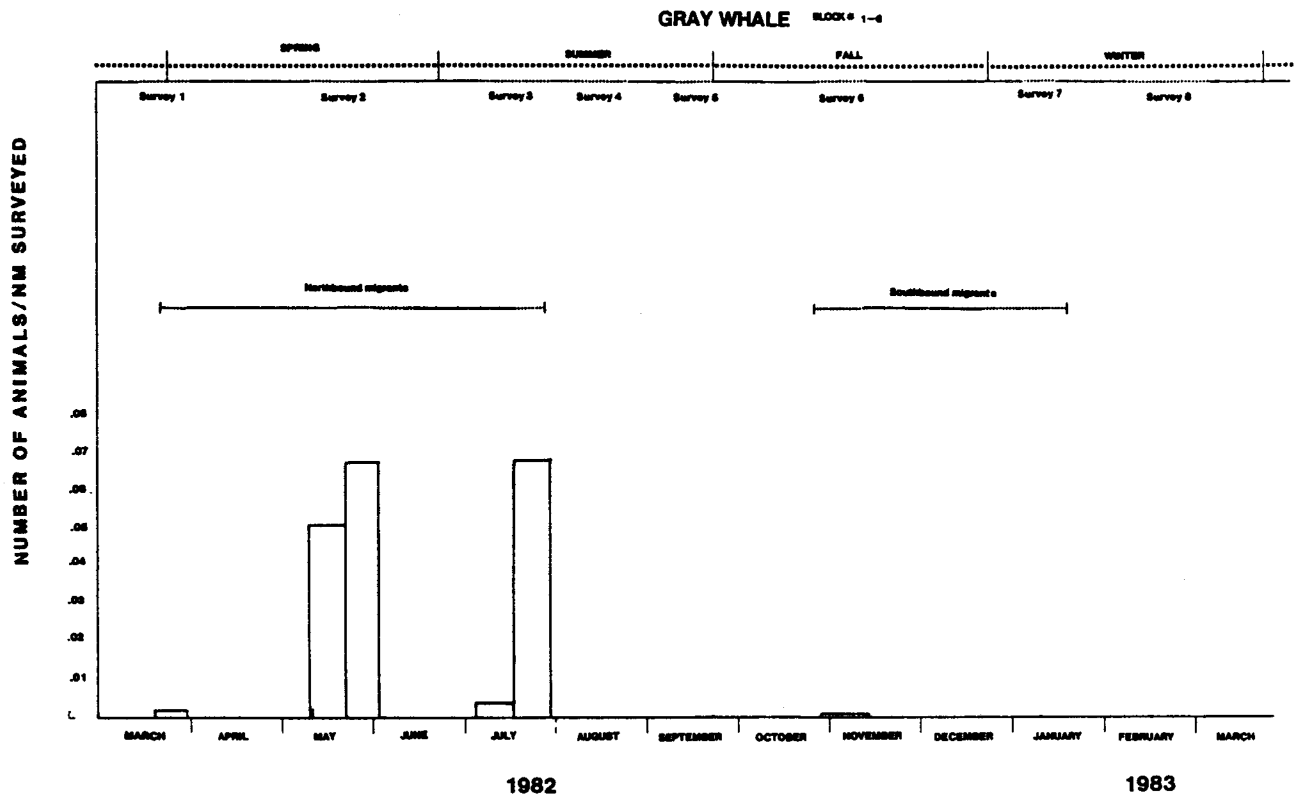


Figure 28. Indices of abundance of gray whales by survey in the Bering Sea/ Bristol Bay study area, from aerial observations. The bars across the top indicate expected periods of migration through the study area, with the solid lines peak periods and the dotted lines the tails of those distributions (from Hall et al., 1977; Rugh and Braham, 1979; Rugh, in press; Braham, in press).

or 10-20 fathoms (ca. 42%) (Figure 29). Almost all whales remained near shore along the north side of the Alaska Peninsula as far as Egigek, then streamed northward across Bristol Bay toward Nushagak and Cape Constantine (cf. Gill and Hall, 1983). Whales seen offshore in Bristol Bay during March and May surveys were associated with the southern edge of the pack-ice. It appeared to us in 1983 that while most animals continued to use a coastal route around the perimeter of Bristol Bay, as openings in the ice permitted, some turned west and followed the pack-ice edge. Such behavior might well account for offshore sightings reported elsewhere (Braham, in press; Braham and Rugh, in prep.) and for the arrival of a small number of gray whales in waters near the Pribilofs by early summer (Gilmore, 1960; Braham, in press; Braham and Rugh, in prep.). We observed six groups of whales among ice floes, in 2 to 30% ice coverage. Sixteen other groups seen in open water in May more than 1 km from shore were .25 to 6 nm ($\bar{x}$=2.1 nm) from the pack-ice edge and areas of 80% ice coverage.

Between 1975 and 1982 ADF&G personnel conducted extensive coastal surveys to inventory herring stocks from the Nushagak Peninsula to Cape Mohican on Nunivak Island and Cape Romanzov. During that program there were 240 hours of survey logged in 1978-1982. Though gray whales were a secondary target, sightings were noted (Baxter and Leatherwood, 1983, MS). From the ADF and G reports supplemented by our own surveys, it appears that a few of the migrating whales enter the mouth of Nushagak Bay. Most, however, round Cape Constantine and continue to follow the contour of the coast between Kulukak Bay and Summit Island. None are known to enter heavily surveyed Kulukak Bay or shallow Togiak Bay. After they pass Summit Island some whales cross the mouth of Togiak Bay

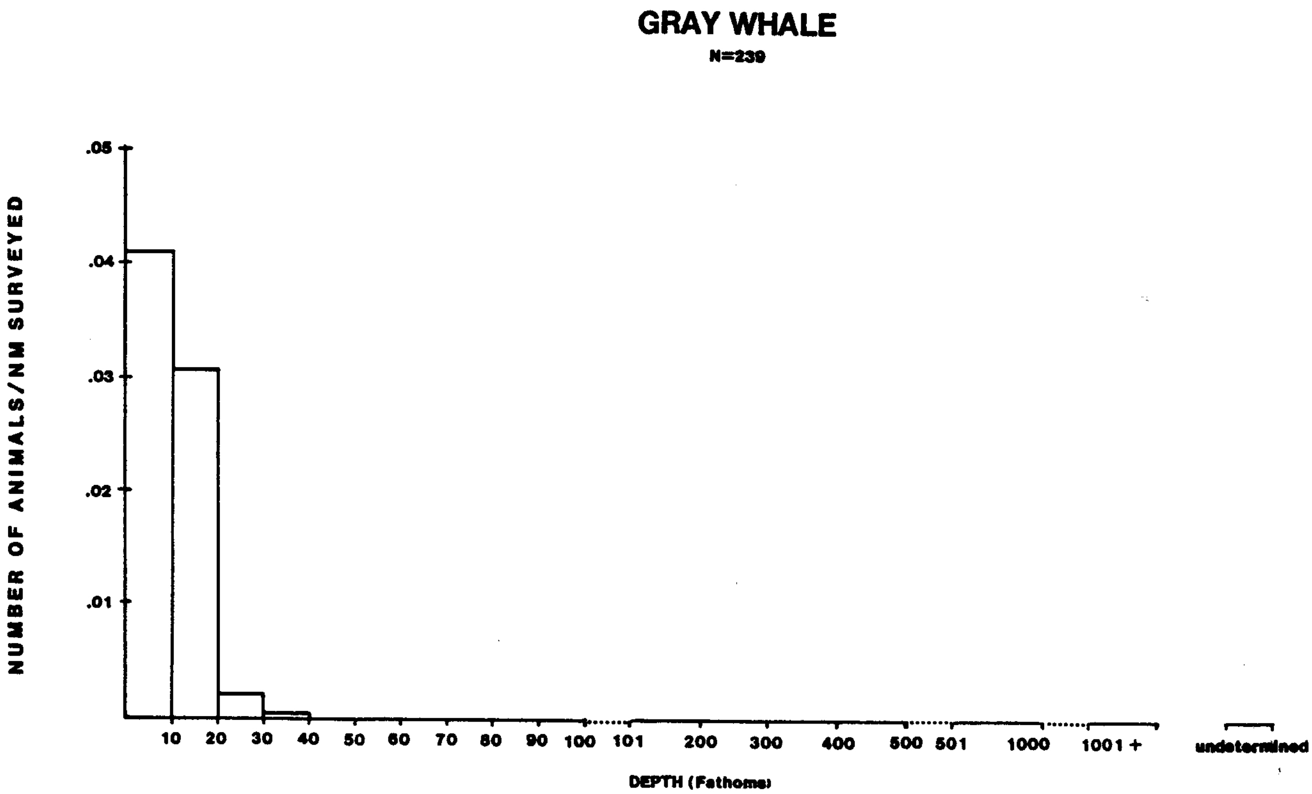


Figure 29. Indices of abundance of gray whales by depth class.

toward Tongue Island while others strike southwest toward Hagemeister Island; so, in the area of Cape Pierce and west of Summit Island the migration corridor is wider than elsewhere in northern Bristol Bay. The whales tend to converge towards Cape Pierce and Cape Newenham. Braham (in press) stated that from Cape Newenham the whales apparently move directly across Kuskokwim Bay (ca. 150 km distant) to Cape Mendenhal at the S.E. tip of Nunivak Island. However, we did see whales in the mouth of the Kuskokwim Delta as well (Figure 25a-d). Whichever route they take, the whales arrive at the southeast tip of Nunivak Island and travel principally along the southwest shore. We saw none in Etolin Strait and know of no reliable records from these waters (Baxter and Leatherwood, 1983). Beyond Nunivak Island the whales fan out across the Bering Sea to St. Lawrence Island, where they remain until about mid-October (Rice and Wolman, 1971).

The southbound migration has not been as clearly described. Based on shore censuses of gray whales migrating through Unimak Pass in fall 1977-79, Rugh (in press) concluded that the exodus from the Bering Sea occurs from late October through early January, with peak numbers passing during the last two weeks in November and the first two weeks in December. Logistic complications affecting our late fall and early winter surveys required us to fly before (survey 6, 26 October through 13 November 1982) and after (survey 7, 3 to 16 January, 1983) the reported peaks of gray whale abundance, rather than during them as originally planned (see Figure 28). As a result, we had only one sighting of gray whales on-effort during this period - a single whale feeding in the surf zone at 57°02.3'N, 158°41.1'W on 26 October 1982 (Figure 25d). Therefore, we can add little to the present understanding of routes of migration through the Bering Sea study area based on other recent summaries. During a coastal transit 24 September 1982 on which data were not being systematically recorded, we did see gray whales along the shore at 7 locations (55°41.1'N, 161°39.0'W; 55°58'N, 161°23'W; 56°01'N, 161°07.4'W; 56°.41'W, 160°26.8'W; 56°10.5'N, 160°25'W; 56°13.7'N, 160°23'W; 56°50.9'N, 158°56.9'W).

Rugh (in press) reviewed coastal sightings along the Bering Sea side of the Alaska Peninsula southwest of Port Moller, mostly from his own aerial surveys, and concluded that "southward migrating gray whales crossing the Bering Sea converged toward Unimak Island where the median of 10,223 shore-based sightings occurred 0.5 km off the west Unimak shore; no sightings occurred beyond 3.7 km." Relevant to the Bering Sea study area, Braham (in press: Figure 5) reviewed late summer (July/August) and early fall (September/October) sightings from various sources. Like Gilmore (1960), Rice and Wolman (1971), Braham et al. (1977), and Braham and Rugh (in prep), he showed a handful of records from open water near the Pribilof Islands in spring and summer (his Figures 5a and b). He added that there had been "occasional sightings east of St. Matthew Island to central Bristol Bay in October and November" (sightings actually made in October 1976 independently by two commercial airline pilots, not whale biologists) and based on those sightings suggested the southbound migration in the southwest Bering Sea "may be farther offshore than the northbound migration". At present, however, there are insufficient data to test this important hypothesis. Fall or winter programs in this area (Lowry et al., 1982a; present surveys) have resulted in only one sighting, near Port Moller, in late October. Therefore, the absence of sightings along shore in areas other than Unimak Island may as easily be attributed to a lack of timely effort as to a more seaward migration of whales.

Patterns of movement of "southward" migrating gray whales past the Shelikof Strait study area are equally uncertain. Braham (in press: Figure 4b) plotted about 20 sightings near Kodiak Island in October through January, one in the strait, ten off the southwest tip, and the remainder off the seaward shore. We observed no gray whales in or near Shelikof Strait during our October through January aerial surveys. Given the apparently concentrated nature of gray whale southbound movements, replicate surveys in early to mid-December, rather than the 2 one-day surveys with limited coverage we performed (1 each in late October and early January), would have provided the highest probability of detecting whales in that area. Therefore, we must continue to regard as unresolved the question of the importance of Shelikof Strait to southward migrating gray whales.

Feeding by gray whales has been observed in or near both study areas at various seasons (Figure 25b,c,d). Braham (in press) showed "apparent" feeding by gray whales just north of Cape Chiniak, Kodiak Island, in March through May (his Figure 4a), off the north side of the Alaska Peninsula, off Hagemeister Island, and off Nunivak Island in April-May (his Figure 5a). Gill and Hall (1983) observed gray whales feeding in various estuaries along the north side of the Alaskan Peninsula in summer. We observed gray whales trailing mud plumes, and thus presumably feeding, during surveys 2, 3, 5 and 6, on a total of 16 occasions (Table 12; Figure 25b,c,d). It is possible that gray whales remain all summer in portions of our study areas, as they do in some areas of the Northeast Pacific outside the Bering Sea.

Table 12. Summary of aerial sightings of "feeding" gray whales.

Survey No.	Date	Location (lat/long)	Block	# Individuals	(fms) Depth	Remarks
2	15 May '82	58°04.3'N, 158°01.3'W	1	12	14	-
2	15 May '82	57°28.6'N, 158°25.3'W	1	6	13	-
2	15 May '82	57°26.4'N, 158°26.2'W	1	3	12	-
2	15 May '82	57°32.0'N, 158°26.2'W	1	3	16	-
2	15 May '82	57°26.2'N, 158°26.3'W	1	4	14	-
2	15 May '82	58°28.7'N, 160°39.8'W	1	22	6	-
2	15 May '82	58°27.1'N, 160°58.3'W	1	15	6	-
2	15 May '82	58°27.1'N, 160°58.1'W	1	27	6	-
2	15 May '82	58°24.4'N, 161°36.3'W	1	2	17	-
2	15 May '82	58°24.4'N, 161°48.2'W	1	1	21	-
2	15 May '82	60°27.1'N, 166°22.4'W	2	1	9	Feeding among broken floes
3	12 July '82	63°47.2'N, 171°25.9'W	NA	1	10	-
5	24 Sept.'82	55°41.1'N, 161°39.0'W	6	2	?	-
5	24 Sept.'82	55°58.0'N, 161°23.0'W	6	1	?	-
5	24 Sept.'82	56°01.0'N, 161°07.4'W	6	1	?	-
6	26 Oct. '82	57°02.3'N, 158°41.1'W	1	1	4	-

Most of the world's gray whales enter Unimak Pass and remain very close to shore as they move along the Alaska Peninsula. Unimak Pass received a high impact rating for modeled oil spills (see Isakson et al., 1975, as cited by Rugh, in press). If some gray whales stay in the study areas all summer, as we suspect they do, and if the feeding that occurs here during spring through fall makes a significant contribution to these whales' energy demands, then the impact of any major spill or other industrial disturbance could be substantial. Also, the second pulse of the northward migration includes a high proportion of the annual calf production, at a time when, at 2 to 6 months of age, the calves may be especially vulnerable to environmental perturbations. Therefore, any proposed development of the study areas should carefully consider the needs of this whale population.

Blue Whale (Balaenoptera musculus)

In the years between 1910 and 1973 ca. 360,000 blue whales were killed worldwide (Tomilin, 1967; International Whaling Statistics, IWS). Though the vast majority of them (ca. 330,000) were taken in the Antarctic, there were significant catches in other areas as well: ca. 12,600 off Africa, 9,000 in the North Atlantic, and 8,200 in the North Pacific. With the exception of a few hundred taken off California and British Columbia, most from the North Pacific were taken from grounds between Japan and Kamchatka, and along the south side of the Aleutians on or between the "A" and "C" grounds of Omura (1955: Appendix 4).

Vessels based at the Akutan whaling station evidently encountered blue whales mainly to the south of the Aleutian chain, especially near Davidson Bank (Birkeland, 1926). At least 1,000 were landed at Akutan between 1914 and 1939 (Leatherwood, unpubl. data). A sighting of several whales, tentatively identified as blue whales, was made near Unalaska Island on 14 July 1937 (Murie, 1959:335). In addition, some 200 were taken within the ca. 100 nm (185 km) hunting radius of the Port Hobron station, mainly south of Kodiak Island, between 1926 and 1937 (Leatherwood, unpubl. data). The species has been fully protected from commercial whaling in the North Pacific and throughout the world since 1966.

Japanese researchers have generally maintained that blue whales are absent or at least scarce in the Bering Sea (Nemoto, 1959; Nishiwaki, 1966; Nasu, 1974), notwithstanding Omura's (1955: Appendix 2) map showing a blue whale ground centered at 55°N, 167-8°W. Evidently, his basis for mapping this ground was the sighting there of "a few" blue whales by a Japanese whaling vessel in 1954 (Omura, 1955:198-9). Soviet investigators have reported sightings along the Soviet Arctic coast as far north as Bering Strait and the southern Chukchi Sea (Berzin and Rovnin, 1966). Tomilin (1967) presented as evidence of their occurrence off Chukotka the familiarity of natives with blue whales, words in the local dialect referring specifically to blue whales, and sightings by Sleptsov in the Chukchi Sea. Leatherwood et al., (1982:18) described accounts by Eskimos on St. Lawrence Island of recent sightings of blue whales near that island following decades of absence.

While reviewing catch records for blue whales in the North Pacific, we noted that, according to the International Whaling Statistics, blue whales were taken in 1955 and subsequent years in the "Bering Sea" by "pelagic whaling". This geographic designation (see IWS No. 37:10) is misleading, as the so-called Bering Sea grounds included areas north and south of the Aleutians. Nishiwaki's (1966) Fig. 2 and Table 2 clarify the question of where the blue whales were taken in 1955 and subsequent years.

Blue whales were not among the species seen during 1982-83 surveys of Navarin Basin (Brueggeman, 1983) or included in the sightings reported to us by colleagues working in the northern Bering Sea and southern Chukchi Sea (e.g. Frost, Lowry, Burns, Wells, Wursig, Dahlheim, Nelson and Ljungblad). The only part of our Bering Sea study area where blue whales have been reported in the past is in the southeast corner of block 4 and the northeast corner of block 5, judging by Omura's (1955) Appendix 2 and Berzin and Rovnin's (1966) Figure 4. In both cases, the authors indicated very low densities from apparently scant data.

Rice (1974) identified three major summer concentration areas for blue whales in the northern North Pacific (which agree closely with those described by Berzin and Rovnin, 1966) - one in the eastern Gulf of Alaska from 130°W to 140°W, one south of the eastern Aleutians between 160°W and 180°, and one between the far western Aleutians and Kamchatka from 170°W to 160°E. He postulated that the whales found in the Gulf of Alaska and eastern Aleutians are summer migrants from Baja California waters. Blue whales have been hunted off Korea, Japan, and Taiwan, but apparently they have never been very abundant there (Nishiwaki, 1966; Tomilin, 1967).

Stock relationships of blue whales have not been well studied, although it is of considerable interest that a female blue whale tagged 22 May 1958 in the eastern Sea of Okhotsk at 50°13'N, 153°06'E was killed 5 June 1962 in the Gulf of Alaska east of Kodiak Island at 57°42'N, 147°16'W (Ivashin and Rovnin, 1967). This demonstrates a connection across the northern rim of the North Pacific. Blue whales also move from off Vancouver Island to the Kodiak region. There are wintering grounds in the Gulf of California (Patten and Soltz, 1980), along the coast of Baja California (Rice, 1974), and in the eastern tropical Pacific (Rice, 1978b; Wade and Friedrichsen, 1979), and from southwest Honshu to Taiwan in the western Pacific (Rice, 1978b). Rice (1978b) referred to the whales wintering on the western side as a separate stock from those wintering off North America and in the eastern tropical Pacific, but Tomilin (1967) considered it unlikely that the "populations" on either side of the North Pacific are completely separate. There are summer and winter records for much of the Pacific coast of the U.S. (Leatherwood et al., 1982c; Rice, 1974, 1978b) and for Korean and Japanese waters (Tomilin, 1967), and a few blue whales have been sighted in the mid-Pacific between 20° and 35°N latitude (Rice, 1978b). An aspect of blue whale ecology that unquestionably influences, perhaps even dictates, the species' distribution is its almost singular dependence upon euphausiids for food (Nemoto, 1959, 1970).

Blue whales apparently have always been much less abundant in the Northern Hemisphere than in the Antarctic (Tomilin, 1967). Estimates of "initial" population size for blue whales in the North Pacific range from 4,900 (Omura and Ohsumi, 1974) to about 6,000 (eastern North Pacific only - Rice, 1974). It was estimated that the summer population in the three main pelagic whaling areas dropped from about 2,430 in ca. 1946 to about 1,420 by 1964 due to intensive exploitation (Doi, Nemoto and Ohsumi, 1967, as cited by Rice, 1974; see Anon., 1967). The estimated population in the entire North Pacific in ca. 1972 was 1,400-1,900 (Chapman, Chmn, 1973:32). The current world population is estimated to be about 12,000 (Rice, 1978b).

There are no recent data to suggest that blue whales visit any part of our study areas <u>per se</u> in appreciable numbers. During 1965-1978, Japanese scouting boats reported blue whale sightings in very low density (ca. 5 whales per 10,000 nm (18,520 km) of scouting distance) in what would be our block 5 and generally along the south side of the eastern Aleutians

(Wada, 1980: Figure 4f). Relatively high densities (ca. 30 whales per 10,000 nm (18,520 km) were reported for an area west of Shelikof Strait.

We made no sightings during our surveys and assume, based on historical whaling records and results of recent sightings programs, that the southeast Bering Sea and Shelikof Strait are of little importance to blue whales. However, it is important to note that waters closely adjacent to both study areas may contain significant populations of this endangered species.

Fin Whale (Balaenoptera physalus)

Fin whales were formerly abundant in the southeast Bering Sea and along the south side of the Aleutian Islands. This abundance is proven by the large numbers of these whales killed within about 100 nm (185 km) of Akutan Island by shore-whalers operating from Akutan, 1911-1937 (over 3,000 fin whales killed) (Birkeland, 1926; Tønnessen and Johnsen, 1982; Table 45; International Whaling Statistics; Leatherwood, unpubl. data), by Japanese whalers operating with pelagic fleet expeditions around the Aleutians and along the continental shelf northwestward from Akutan towards the Pribilofs, 1952-1961 (over 3,000) (Nemoto 1963: Figure 1), and by Soviet whalers operating with pelagic fleet expeditions to the eastern Bering Sea in years after 1957 (number of whales unspecified) (Berzin and Rovnin, 1966).

The Japanese data in particular suggest an affinity of fin whales for the shelf edge north of the Aleutians, where there were heavy catches from 1954 to 1962 in the waters between ca. 53°N and 56°N and 165°W and 171°W (Nemoto, 1963: Figure 1; Nishiwaki, 1966: Table 3; Nasu, 1966). This productive whaling ground for fin whales (also mapped as area IV by Nasu, 1966, as area B by Omura, 1955, and as area C by Fujino, 1960) is centered in our study block 4 (Figure 2). Another major ground for

Japanese whaling for fin whales was southwest of St. Matthew Island (Nasu, 1966: Figure 22), on the western margins of our study blocks 2 and 3.

Soviet researchers also identified an important fin whale summering ground between Seguam Island and the Pribilofs in our blocks 4 and 5 (Berzin and Rovnin, 1966). In addition, they referred to concentrations of fin whales north and east of the Pribilofs and at 61°N between St. Matthew and Nunivak Islands (Berzin and Rovnin, 1966). In their Figure 3, Berzin and Rovnin (1966) indicated the highest fin whale densities (more than 50 whales per some unspecified unit area) off the south coast of Kodiak Island, near the site of the former whaling station at Port Hobron (on Sitkalidak Island) and along the north and south sides of the eastern Aleutians, with slightly lower densities in adjoining areas. They claimed that few fin whales enter Bristol Bay.

We know that there were substantial catches of fin whales in the North Pacific by Soviet whalers after 1957. In that year they began to work in Aleutian waters and elsewhere on the east side of the Bering Sea and in the Gulf of Alaska, continuing in subsequent years to expand their whaling activities eastward and southward. However, we have not found tables or charts showing positions of those kills. Rather, we have had to rely upon narrative descriptions of whale distribution by Soviet authors which we take to represent syntheses of their sightings and catch data.

Observations by Japanese scouting boats indicate that fin whales continue to exist at high levels of abundance on the former whaling grounds - ca. 100-200 whales sighted per 10,000 nm (18,520 km) scouting distance between 1965 and 1978 (Wada, 1980: Figure 4d). Also, sightings made from 1957 to mid-1980 and reported by SAI (1983: Figure 19.1), G.

Hunt (pers. comm.), and Braham and Rugh (in prep.) indicate that relatively large numbers of fin whales still occur in the Unimak Pass area and along the 100 m contour north of there, i.e., in our study blocks 4 and 6, especially during summer. A concentration of fin whales is also mapped just north of St. Paul Island by SAI (1981: Figure 9.1; also G. Hunt, pers. comm.).

Stock identity of fin whales in the North Pacific is not well understood, in spite of extensive tagging (e.g. see Ohsumi and Masaki, 1975) and large commercial catches. Serological and mark-recapture studies have been used to identify subpopulations and to evaluate movement patterns, respectively. "American" and "Asian" stocks have long been recognized (Tomilin, 1967), and it has been assumed that, in general, each follows its respective continental coast during migration which extends north at least to Bering Strait, where the two stocks intermingle (Kellogg, 1929). For management purposes, the 180° longitude line has been used as the boundary between the two stocks (Omura and Ohsumi, 1974). At least three subpopulations were identified in the northern North Pacific by Japanese workers; southeast of Kamchatka, north of the eastern Aleutians, and south of the eastern Aleutians (Omura, 1955; Fujino, 1956, 1960). In addition, an isolated stock inhabits the East China Sea (Fujino, 1960; Omura and Ohsumi, 1974), and the fin whales in the Gulf of California are suspected of being isolated and non-migratory (Leatherwood et al., 1982c). Fujino (1960) suggested that the whales off California and British Columbia may constitute another (sixth?) stock; there is tagging evidence of seasonal movement by individual fin whales from southern California to British Columbia and the Gulf of Alaska (Rice, 1974).

There is considerable east-west movement by fin whales, as documented by tag-recapture data (Kawakami and Ichihara, 1958; Ivashin and Rovnin, 1967; Nasu, 1974; Ohsumi and Masaki, 1975). Perhaps the most dramatic evidence of this is the whale tagged on 22 May 1958 in the southeast Sea of Okhotsk and captured 6 June 1964 far inside the Gulf of Alaska, northeast of Kodiak Island (Ivashin and Rovnin, 1967). Fin whales are thought to move along the boundary between Bering Sea coastal water and the oceanic water, perhaps taking advantage of an eastward-flowing current along the north side of the Aleutians to do so (Nasu, 1974). Our study areas appear to be visited by fin whales from both the "American" and the "Asian" stocks. The belief that the "American" stock migrates annually between Baja California and the Bering and Chukchi seas, as recounted by Lowry et al. (1982b), among others, is based on supposition rather than on direct documentary evidence, although one marked fin whale moved from Baja California in January to the Queen Charlotte Islands (Gulf of Alaska) in June (Nasu, 1974). Some fin whales reportedly winter near the Commander Islands (Barabash-Nikiforov, 1938) and others may winter at the ice edge near St. Matthew Island (Brueggeman, 1983).

The initial population of fin whales in the entire North Pacific has been estimated as 42,000-45,000, compared to an estimated size in 1970 of 13,000-17,600 (Omura and Ohsumi, 1974). The eastern or "American" component was estimated as 25,000-27,000 ("initial") and 8,520-10,970 in 1973 (Ohsumi and Wada, 1974:121), the western or "Asian" component as 17,000-18,000 and 5,100-7,710. Chapman (1976) accepted estimates of about 10,000 for the "American" stock and about 7,000 for the "Asian" stock in 1975. These estimates are all based on population modeling and Japanese sightings data rather than on direct censuses. Fin whales have had full protection from commercial whaling in the North Pacific since 1977. The size of the present population(s) is not known.

There were 20 sightings of fin whales (52 individuals) made on-effort and two incidental sightings (4 animals) during our surveys (Figure 30). In addition to these, we have plotted sightings from two vessel cruises - the R/V Miller Freeman in July 1982 (B. Wursig, in letter, 17 November 1982) and the NOAA ship Surveyor (R. Wells, in letter, 9 November 1982) - to supplement our aerial sightings made in the same year (Figure 31). The most striking features of the geographic distribution shown in these plots are the almost complete absence of sightings in blocks 4, 5 and 6 and the relatively large concentrations of sightings in Shelikof Strait (block 7) and between St. Paul and St. Matthew islands, in block 3. It is interesting to compare our records to plots of Japanese and Soviet catches and sightings. The Japanese killed several thousand fin whales between 1952 and 1961 within areas we have designated blocks 4, 5 and on the western edge of our block 6 (Nemoto, 1963, Figure 1). Soviet investigators reported the hightes concentrations in the same area (Berzin and Rovnin, 1966: Figure 3). Japanese sightings since 1965 have shown a continuing presence of fin whales here, with a suggestion that somewhat higher densities may be found to the north, in essentially the same area where we and the R/V Miller Freeman (Figure 31) found them in 1982-3 (Wada, 1980: Figure 4d). Our single sighting of two fin whales in southeastern Bristol Bay is noteworthy in light of Berzin and Rovnin's (1966) statement that the species is rare in the Bay.

As indicated in Figures 8 through 11, above, our survey coverage in blocks 4, 5 and 6 while not as complete as we might have wished, was substantial. The absence of sightings probably is, at least to some

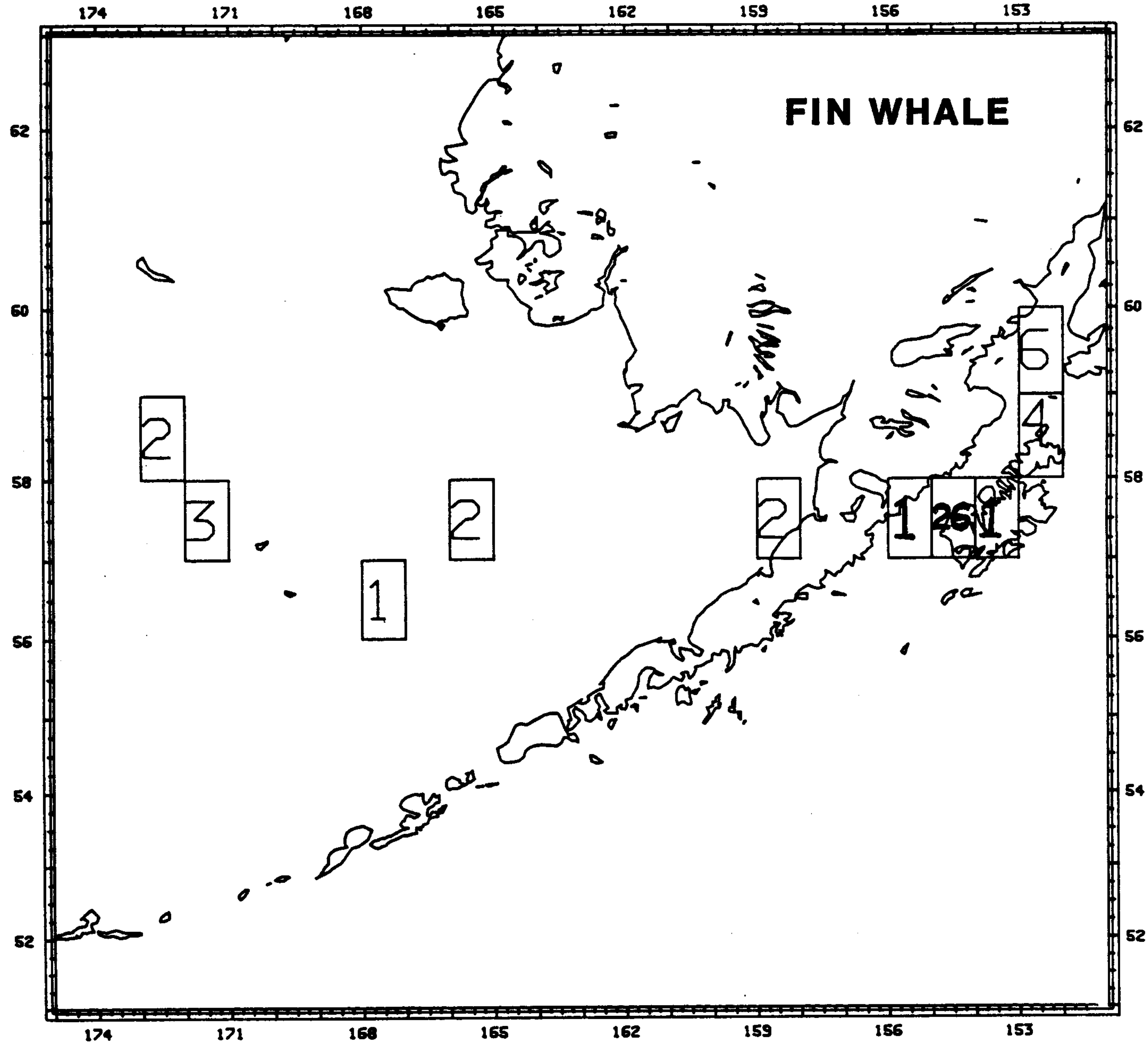


Figure 30. Total number of fin whales seen by 1° degree block.

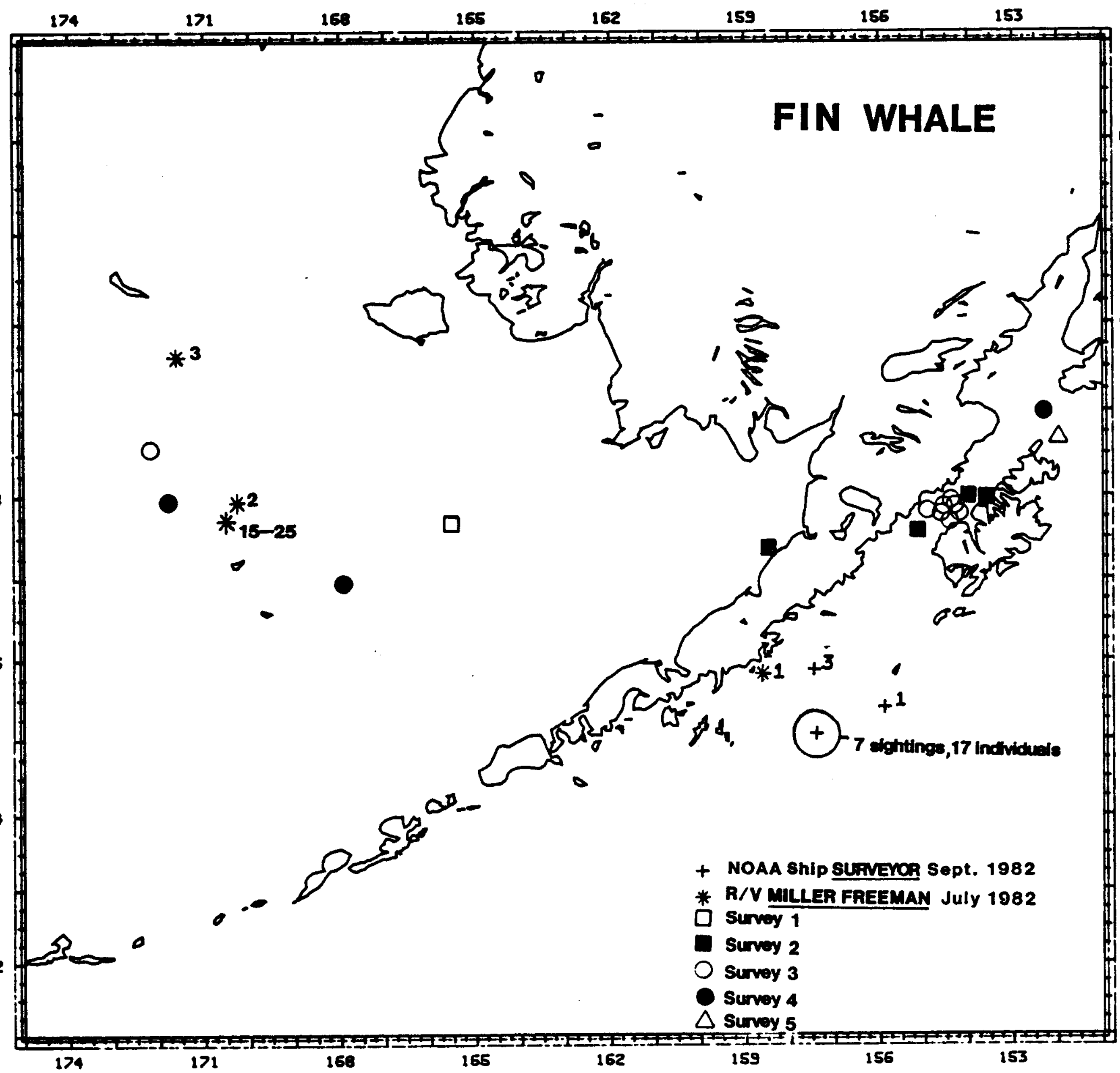


Figure 31. Locations by survey of fin whales seen during aerial surveys and sightings from other research activities in the area.

extent, and artifact of inadequae coverage or of the fact, noted in the section entitled "Survey Effort" above, that sea state was generally worse in blocks 4 and 5 than in other blocks. It could also reflect a locally reduced density of fin whales caused by intensive exploitation, first from the Akutan shore whaling station and later from Japanese and Soviet floating factories. At any rate, our failure to find more fin whales in the St. George Basin and Bowers Basin OCS planning areas should not be taken to mean that these areas are of minor importance to the species. They clearly were of major importance historically. We interpret the comparatively large number of fin whales sighted by the R/V Miller Freeman during a single transect through the St. George Basin and St. Matthew-Hall areas (our block 3) as further evidence that low-coverage replicate overflights are an inferior means of assessing whale abundance in such large and storm-tossed tracks as these.

None of the Japanese or Soviet sources we examined suggests a high density of fin whales in Shelikof Strait, *per se*. Thus, our records there are of considerable interest. Many sources indicate high densities for areas immediately outside Kodiak Island (Nasu, 1966: area VI; Berzin and Rovinin, 1966: Figure 3; Wada, 1980: Figure 4d; Fiscus et al., 1976). Shore whalers based at Port Hobron, Sitkalidak Island, killed over 300 within 100 nm (185.2 km) of the station from 1926 to 1942 (*International Whaling Statistics*; Leatherwood, unpublished data).

Our survey data show strong seasonality in the occurrence of fin whales in both the southeast Bering Sea (Figure 32) and Shelikof Strait (Figure 33). There were no sightings before significant 1 April or after 11 September in either area. This suggests a migration into and out of the study

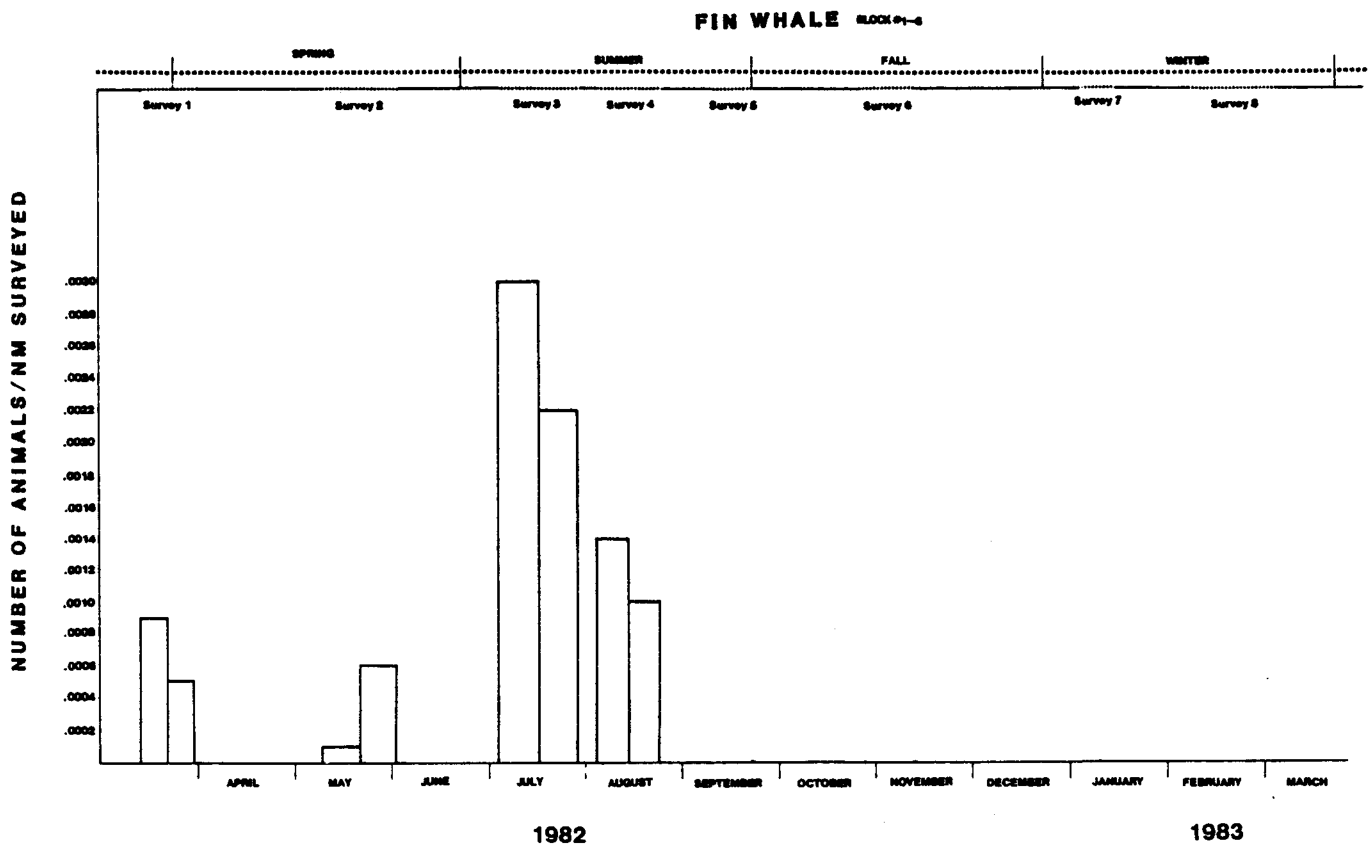


Figure 32. Indices of abundance of fin whales by survey in blocks 1-6.

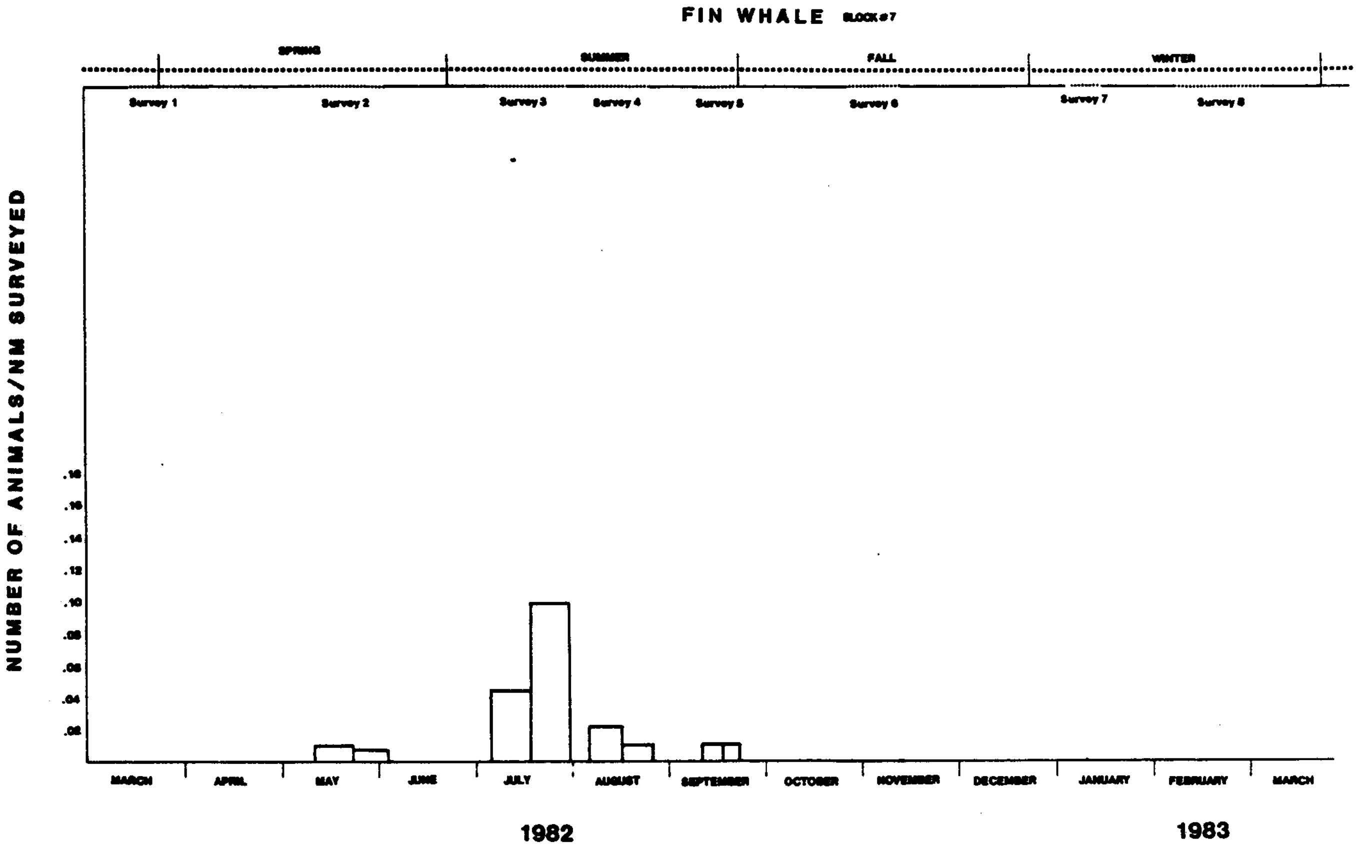


Figure 33. Indices of abundance of fin whales by survey in block 7.

areas, with a peak of abundance in summer, findings which agree with those of other investigators (e.g. Nasu, 1974).

All of our sightings were in water less than 60 fathoms (110 m) deep (Figure 34), which is consistent with the view that fin whales regularly inhabit continental shelf waters.

We made no observations of what could be interpreted as feeding behavior, although fin whales are known to feed intensively in our study areas during summer (see Lowry et al., 1982b, for a review).

A small calf (less than half the length of an accompanying adult) was seen deep inside a convoluted bay (in 6 fathoms, 11m, of water) at 57°48.9'N, 153°21.1'W, on 5 August 1982. It is generally stated that fin whales give birth mainly during winter at low latitudes (Tomilin, 1967; Ohsumi, Nishiwaki and Hibiya, 1958). Our preliminary check of fetal lengths of specimens taken at Akutan (and those mentioned by Murie, 1959:334) suggests an increasing trend in fetal size from 1 to 3 feet in June to 4 to 9 feet in August, and thus a peak of conceptions and births at a season other than summer. Judging by its small size relative to the adult nearby, the calf we observed near Kodiak Island may have been born as recently as the previous spring or even earlier in the same summer.

Sei Whale (Balaenoptera borealis)

Sei whales are widely distributed in the Atlantic, Pacific and Indian oceans. They appear, in general, to prefer subtropical to cold temperate pelagic regions and to avoid polar and shallow coastal waters (Tomilin, 1967). There are three putative stocks in the North Pacific, distributed in adjacent areas divided by longitudes 175°W and 155°W (Masaki, 1977).

Like other balaenopterids, sei whales apparently migrate to lower latitudes in winter and higher latitudes in summer. Thus, they would be

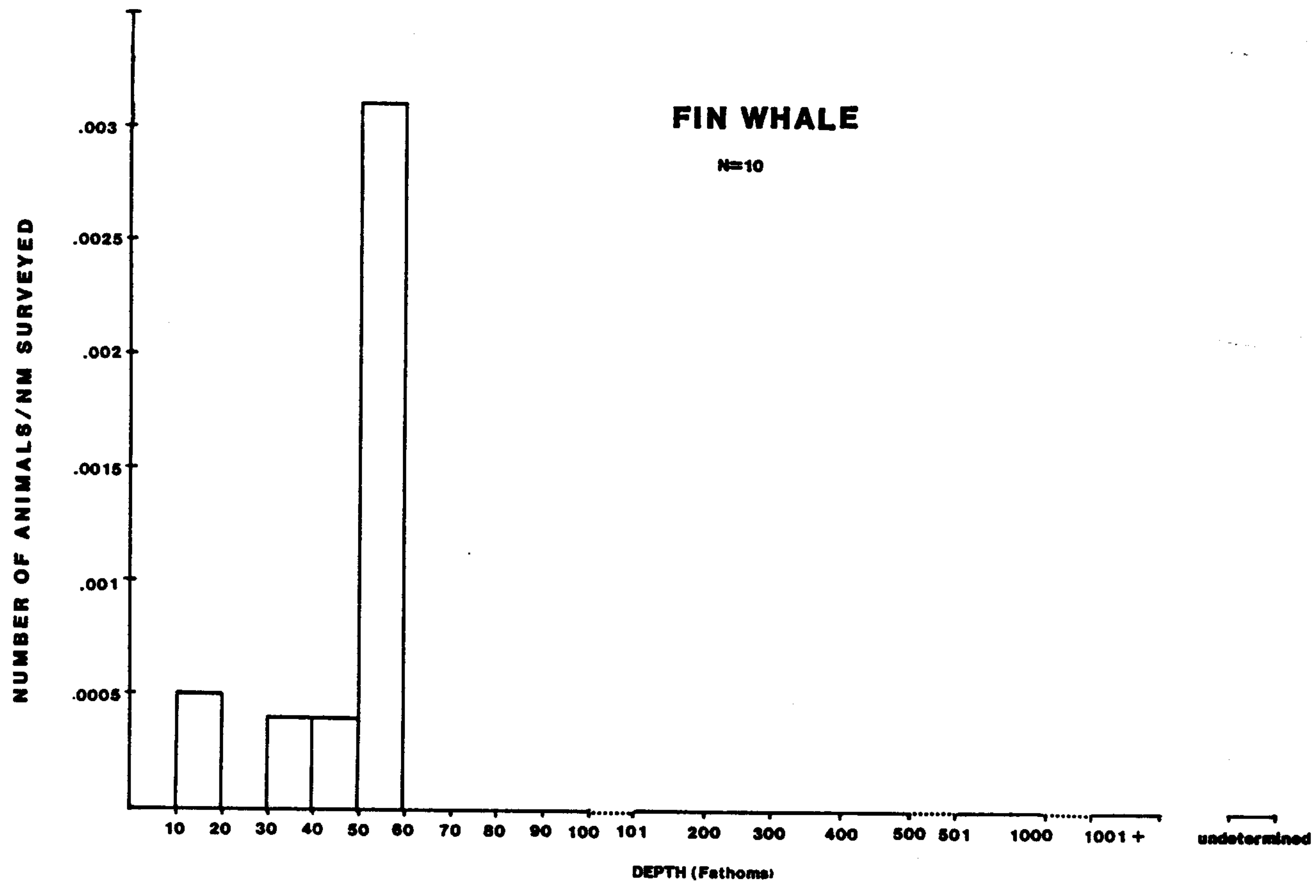


Figure 34. Indices of abundance of fin whales by depth class.

expected to be well south of our study areas during winter months. In summer, sei whales reportedly are common in the Gulf of Alaska and along the Aleutian Islands (Murie, 1959: 334-5; Nishiwaki, 1966; Masaki, 1977; Nemoto and Kawamura, 1977; Wada, 1980). They also have been reported occasionally in the northern Bering Sea (Masaki, 1977; see below) and even as far north as the southern Chukchi Sea (Tomilin, 1967:197-9).

The pre-exploitation size of the aggregate population of sei whales in the North Pacific has been estimated as between 42,000 (Tillman, 1977) and 82,000 (Omura and Ohsumi, 1974). Estimates of current population size, derived almost exclusively from Japanese catch and sighting data, range from 8,600 (Tillman, 1977) to the range 20,600 to 23,700 (Ohsumi and Fukuda, 1975). Wada (1981) suggested that though the population had decreased through 1976, it may have been increasing since then.

Regardless of which estimates are considered, it is clear that the sei whale population has been dramatically reduced since the early 1960's when intensive whaling began for this species. Sei whales were taken rarely by shore whalers at Akutan and Port Hobron in the first 40 years of the twentieth century (Leatherwood, unpublished data). Between 1945 and 1962, at least 10,893 sei whales were taken in the North Pacific, but only 23 were killed in the Bering Sea (Nishiwaki, 1966). From 1963 through 1974, at least another 43,719 were taken in the North Pacific (including the Bering Sea) (Tillman, 1977). It is unclear what proportion of the latter number was taken in the Bering Sea. Information presented by Masaki (1977: Figure 3) suggests that between 1952 and 1972 a very small number of whales were taken by Japan in the Bering Sea. Most of those were killed within a few degrees of latitude of the Aleutian chain, the northernmost at about 58°N, 173°W, at the western edge of our Bering Sea study area.

Some were also taken along the south sides of Kodiak Island, the Alaska Peninsula, and the Aleutian Chain.

There were no reported Japanese catches of sei whales in Shelikof Strait, but some 26-50 were killed just south of Tigidak and Sitkinak islands (Masaki, 1977).

Plots of Japanese sighting data from 1965 to 1972 show small numbers of sei whales in the Bering Sea in May, larger numbers in June, peak numbers in July and August, and none in the eastern half of the Bering Sea by September (Masaki, 1977: Figure 5). Unfortunately, there is reason to question the validity of these data. In Masaki's figure, large concentrations of sei whales are suggested for an area west of St. Lawrence Island during August and for an area near Cape Navarin in July. However, a more recent review of what we take to be the same data, combined with the corresponding data through 1978, indicates that no sei whales were sighted north of latitude 60°N in the Bering Sea (Wada, 1980: Figure 4e and Appendix Table 3). Further, Nasu (1974) claimed that sei whales were killed by Japanese in the Bering Sea "only rarely", and that the "main heards" do not penetrate the Bering Sea. The presentations by Masaki (1977) and Wada (1980) are consistent with respect to sei whale densities in Shelikof Strait and along the Aleutians; both indicate relatively high densities in these areas from May through August. Without examining the original data, we cannot reconcile the disparities between Masaki's and Wada's charts for the northern Bering Sea. However, we would consider their reports, together with other published documentation cited above, as an adequate basis for expecting to find relatively large numbers of sei whales in portions of our study areas during late spring and summer.

During this study there was only one sighting logged as a sei whale. It was of a single animal, estimated to be approximately 40 feet (12 m) long, seen with two fin whales on 1 April 1982 at 57°42.6'N, 165°31.6'W (Figure 35). Water depth at this position is 30 to 40 fathoms (55 to 73 m). The whale and its companions were swimming slowly and did not appear to respond to the aircraft. The water depth, the presence of the fin whales, and the near proximity of the whales to the ice edge caused us to query the species identification during review. However, there is no basis for changing the judgement made in the field.

The only other new evidence of sei whales in either study area is as follows: A single stranded whale, long dead, was found on a beach at Cape Constantine in northeast Bristol Bay, 30 May 1975 (R. Baxter, Bethel, Alaska, pers. comm., 20 May 1982). From characteristics of a sample of baleen examined by Leatherwood (color, length to width ratio, bristle density and texture), the whale was identified as a sei whale. Sightings of sei whales in Unimak Pass (ca. 57°N, 166°W), from NMFS programs, are plotted in the North Aleutian Basin report (SAI, 1983: Figure 19.1).

Sei whales feed on a variety of marine organisms (Gambell, 1977; Nemoto and Kawamura, 1977). In a sample of approximately 12,000 sei whale stomachs collected in the North Pacific, copepods were found most often (83%) followed by euphausiids (13%), fishes(3%), and squid (1%). Since so few sei whales have been taken in the Bering Sea, there is little information on prey for this region.

Japanese sighting and catch data suggest that Shelikof Strait and environs is an area of relatively high abundance for sei whales, and that the species is also seen with some regularity along the southern side of the Aleutians. However, there is no reason to consider the southeast Bering

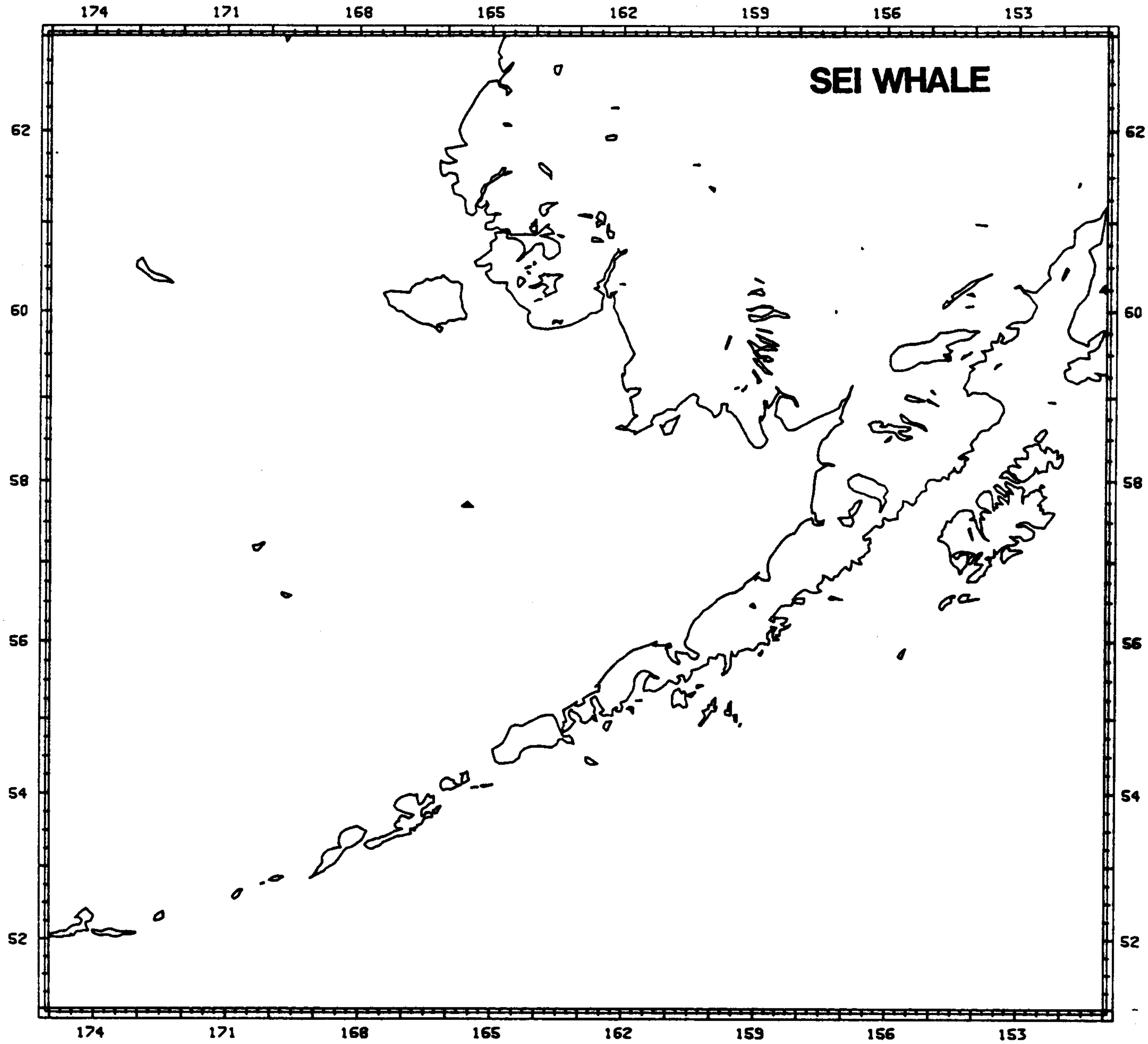


Figure 35. The sighting of a sei whale during these surveys.

Sea as an important part of the species' range. Those whales that visit our study areas probably do so primarily in mid-summer to feed.

Minke Whale (Balaenoptera acutorostrata)

The minke whale has a worldwide distribution. Because of its small size, however, it was not a major target of commercial whalers in most areas until the reduction in populations of larger, more valuable species required a shift in whaling effort. According to Scammon (1874), the natives of Cape Flattery, Washington, hunted minke whales in early times. Since World War II, modern commercial whaling from shore stations has become firmly established in the Republic of Korea (Brownell, 1981) and Japan (Omura and Sakiura, 1956; Ohsumi, 1975), and in both countries minke whales are an important part of the catch. Soviet coastal whaling accounted for 94 minke whales off the Kurile Islands in 1951-6 , and a total of 21 were taken by Soviet pelagic whalers in the North Pacific from 1933 to 1979 (Ivashin and Votrogov, 1981).

Modern shore whaling stations in western North America did not exploit the minke whale on a significant scale (Pike and MacAskie, 1969; Rice, 1974; Leatherwood, unpublished data). As a consequence, little was known until recently about its distribution and abundance on this side of the Pacific. As Scattergood (1949) stated:

> The paucity of published records results in a false picture of the relative abundance of this whale in the Northeastern Pacific.

Minke whales are in fact common during spring and summer months in the Bering Sea, coastal Gulf of Alaska, Puget Sound, and other inshore waters of the Pacific Northwest (see Stewart and Leatherwood, in press, and contained references). They are present during winter from the Gulf of California, the coast of Baja California and the Revillagigedos Islands, southwest of the tip of Baja California north to central California, including the Channel Islands (Rice, 1974; Leatherwood, 1982a). In summer they can be found virtually anywhere from Baja California to the Chukchi Sea, where Scammon (1874) described them to be "as much at home as their superiors in size, the bowheads and the California grays." Minke whales are present but not considered common along the Chukotka coast in spring and summer (Ivashin and Votrogov, 1981).

It is assumed that minke whales in the eastern North Pacific migrate north to summer feeding grounds and south to winter breeding grounds, but there is no tagging or other direct evidence of such movement. Because of the difficulty of detecting minke whales, especially in rough seas, it cannot be routinely assumed that an absence of records, particularly during winter months, denotes an absence of whales. For example, it has been suggested that although few observations have been reported for southern California waters, minke whales may be common there year-round (Norris and Prescott, 1961; Dohl, Norris, Guess, Bryant and Honig, 1980). A substantial population in Puget Sound may be resident (Scammon, 1874; Rice, 1974; Angell and Balcomb, 1982).

Stock identity in the North Pacific has been studied as specimens have become available through the whaling industry. To date, the International Whaling Commission has recognized three stocks: (1) Sea of Japan-Yellow Sea-East China Sea stock; (2) Okhotsk Sea-West Pacific stock; and (3) Remainder stock, which includes all animals east of 180° longitude and north of the equator (Ohsumi, 1983; Tillman, Convenor, 1983: Figure 1). It is not known whether individuals from these 3 putative stocks mingle in or near our study areas. Biochemical comparisons of samples from different areas in the North Pacific are expected eventually to refine the understanding of minke whale stock boundaries there (Tillman, Convenor, 1983; Wada, 1983). Also, efforts to identify individuals with photodocumentation may hold promise for facilitating research on stock identity, home range, and behavior (Doresy et al., 1983).

Scattergood (1949) learned from employees at the Akutan and Port Hobron whaling stations that minke whales were abundant in both areas. Published statistics on the catch at these two stations do not list any minke whales as having been taken (International Whaling Statistics; Tønnessen and Johnsen, 1982: Table 45), but a photo published by Morgan (1978) proves that they were caught at least occasionally. Also, our preliminary examination of logbooks kept on the catcher boats operating out of Akutan and Port Hobron (Leatherwood, unpublished data) has revealed a few catches. It is possible that some of the whales listed in the "Other" column of the catch statistics were minke whales.

Recent sightings programs in the Gulf of Alaska and Bering Sea have shown that minke whales are present in shallow shelf waters as well as in deep areas far from shore (Fiscus et al., 1976; Lowry et al., 1982a,b; SAI, 1981: Figure 9:1; SAI, 1983: Figure 19.1; Braham and Rugh, in prep.). The center of our Bering Sea study area, essentially the eastern portions of blocks 3 and 4 and the northwest corner of block 6, is the only part of the Bering Sea and Gulf of Alaska in which Japanese scouting vessels have reported indices of abundance greater than ca. 50 minke whales per 10,000 nm (18520 km) searched (Wada, 1980: Figure 4c). Here the index is ca. 100 animals per 10,000 nm. It has been suggested that minke whales occupy St. George Basin year-round, "with greatest concentrations in summer near the eastern Aleutian Islands" (Braham et al., 1982:59). Seasonal plots of sightings (Braham and Rugh, in prep.) indicate, however, that winter densities are lower and that the animals are generally found farther from shore during winter.

During our aerial surveys we had 34 sightings of minke whales, accounting for a total of 41 individuals, 28(36) in the Bering Sea and 6(6) in Shelikof Strait (Figure 36); an additional 5 sightings (5 animals) were made outside the study area in the northern Bering Sea. During the same period there were also sightings from the R/V Miller Freeman along the Pacific side of the Alaska Peninsula just east of Unimak Pass (2 sightings) and in the Bering Sea just north of the Pribilofs (2 sightings) (B. Wursig, in letter, 17 November 1982) and from the NOAA ship Discoverer along the 169°30'W longitude line between 62° and 63°N (4 sightings) and just outside the bay at Kodiak Township on Kodiak Island (2 sightings) (R. Wells, in letter 9 November 1982). There was not a sufficient number of sightings during our aerial surveys in either study area to calculate density.

There were observations over a wide area, but a notable concentration was in Bristol Bay. The distribution of sightings by season is shown in Figure 37 (a-d). Bristol Bay sightings coincided with the period of an active herring fishery (May-July), particularly within about 10 nm (18.52 km) of shore from Cape Constantine and Cape Newenham. The clumping of sightings near the fishing fleet may be due to the fact that minke whales can be detected more easily when they are actively feeding near the surface. Also, the convergence of individual minke whales to an area of high food availability presumably improves the chances some will be seen. Direct evidence concerning the diet of minke whales in the southeast Bering Sea is sparse, but Frost and Lowry (1981a) indicated that euphausiids and pelagic and semidemersal fishes, including herring, are taken.

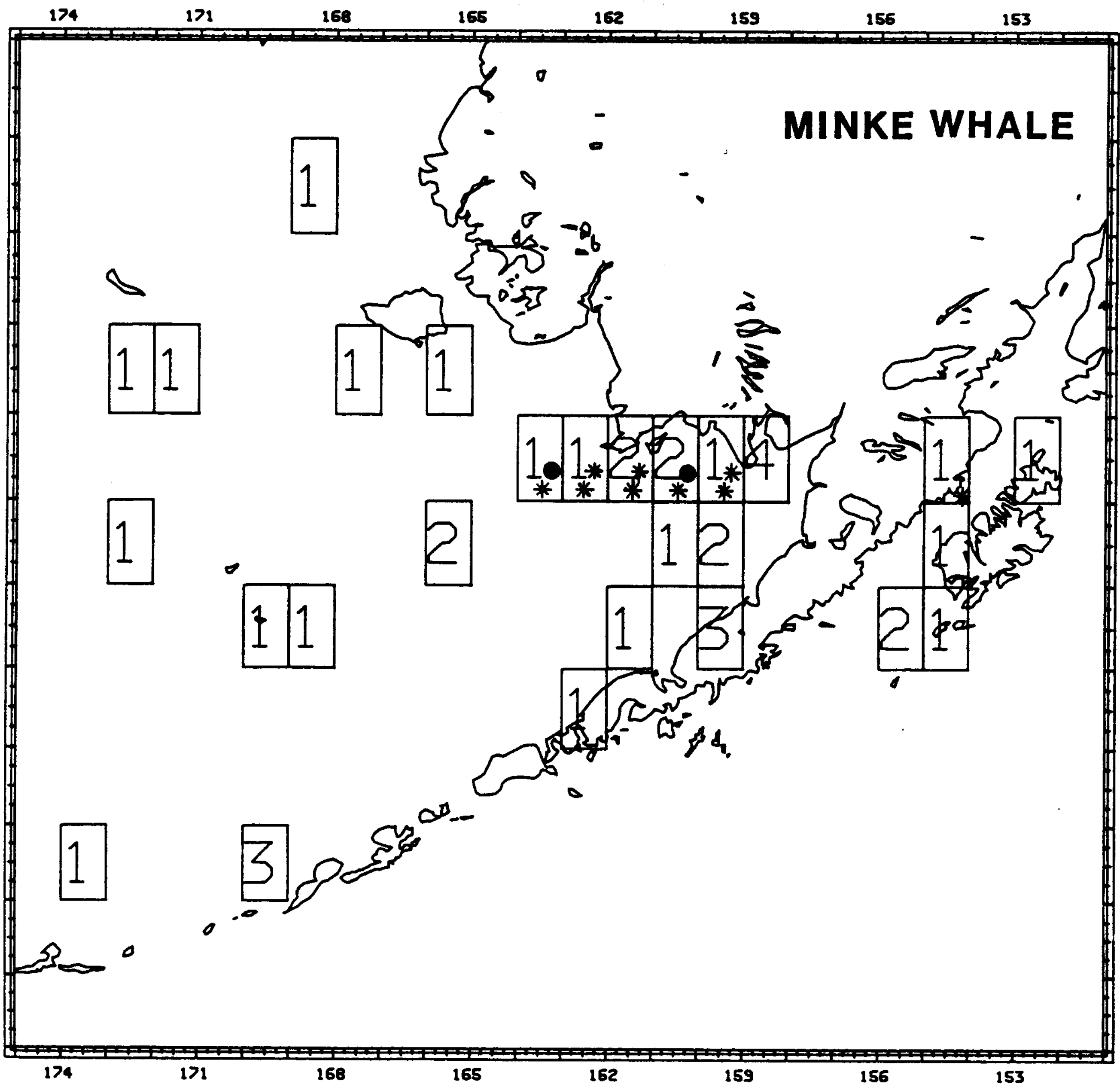
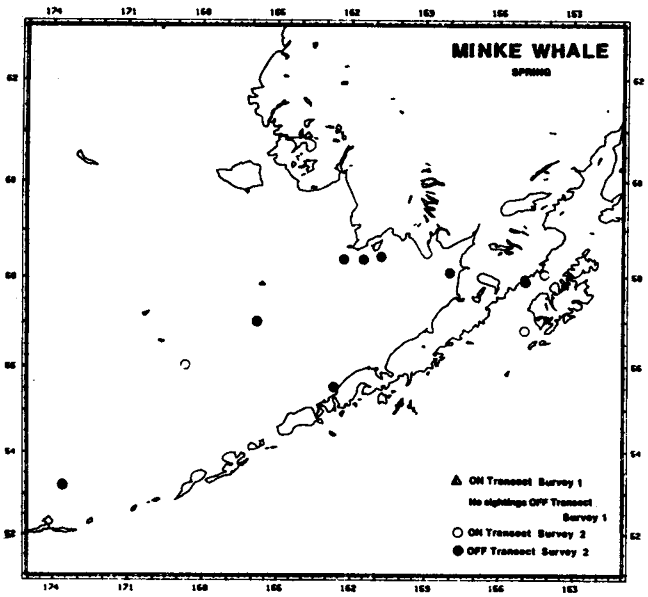
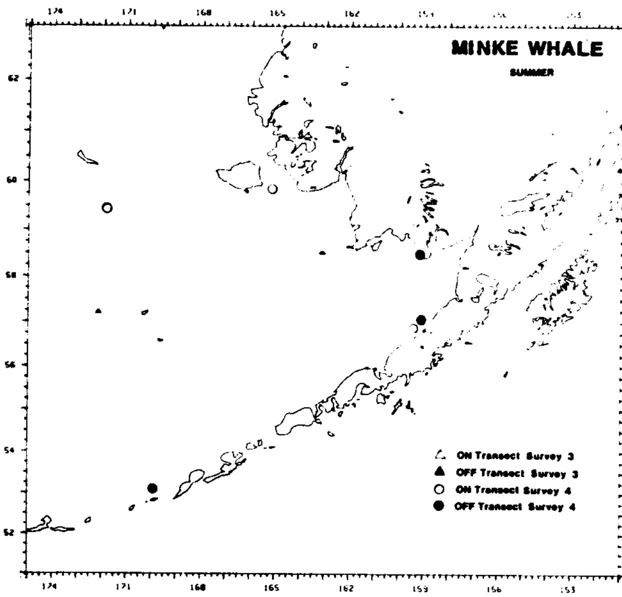


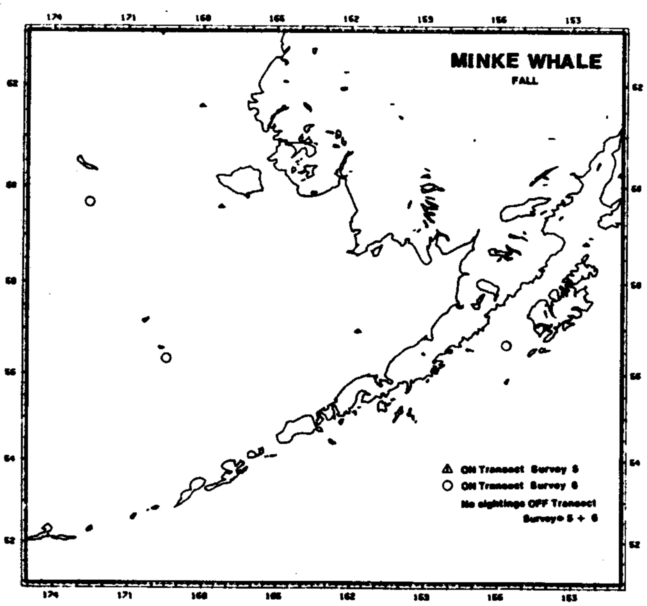
Figure 36. Total number of minke whales seen by 1° block. In blocks containing symbols the whales were reported as feeding, either from direct observation of their chasing fish (*) or by inference from their close proximity to the herring fishing fleet (•).



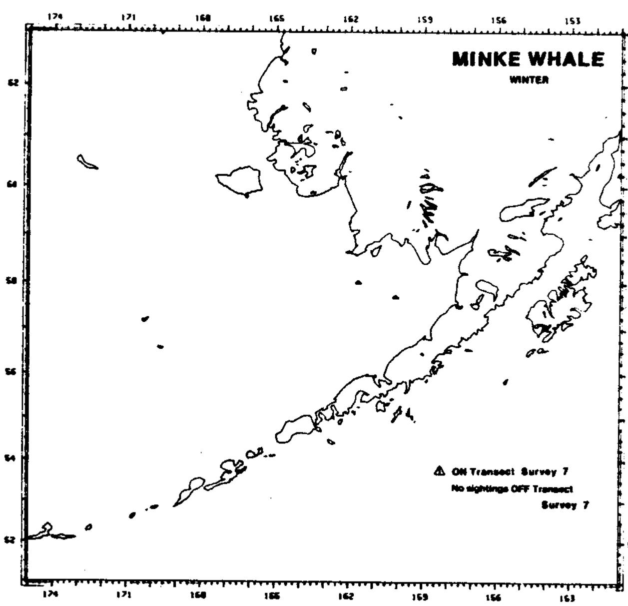
a. Spring



B. Summer



c. Fall



d. Winter

Figure 37. Distribution of sightings of minke whales during spring (a), summer (b), fall (c), and winter (d).

In four of our sightings, each of a lone individual, minke whales were observed swimming rapidly back and forth through visible schools of unidentified fish, and thus were presumed to be feeding. These sightings were on 15 May 1982 off Cape Pierce (58°22.9'N, 162°19.7'W) and Cape Newenham (58°22.4'N, 161°28.7'W), on 3 June 1982 in Shelikof Strait (58°02.9'N, 154°09.2'W), and on 20 August 1982 just northwest of Cape Constantine (58°29.0'N, 161°28.7'W). Because of the dates and locations of the sightings, and the known concentrations of herring in northern Bristol Bay, we suspect herring were the prey being chased by the whales. In two additional sightings, also in the vicinity of Cape Newenham and Hagemeister Island in May and June, the whales were in close proximity to working herring boats and were probably feeding (Figure 36).

Minke whales were observed in the Bering Sea during all surveys except survey 8, but the frequency of sightings increased rapidly in May to a peak in June, then declined rapidly through August to levels maintained the remainder of the monitoring year (Figure 38). We believe feeding activity is a large part of the explanation for the spring and summer peaks in sightings. The observed trend strongly suggests there are some minke whales in the Bering Sea year-round, as has been previously alleged (Dahlheim and Braham, 1981, cited in SAI, 1983 but not included in their reference list). In the Bering Sea, minke whales were seen near the pack-ice edge twice: in 10% floes in January (at 58°01'N, 165°33.7'W, block 1) and in 25% floes in April (at 57°50'N, 165°33.7'W, block 1). Sightings in block 7 were make only during surveys 2, 5 and 6; the earliest was in mid-May, the latest in late October (Figure 39).

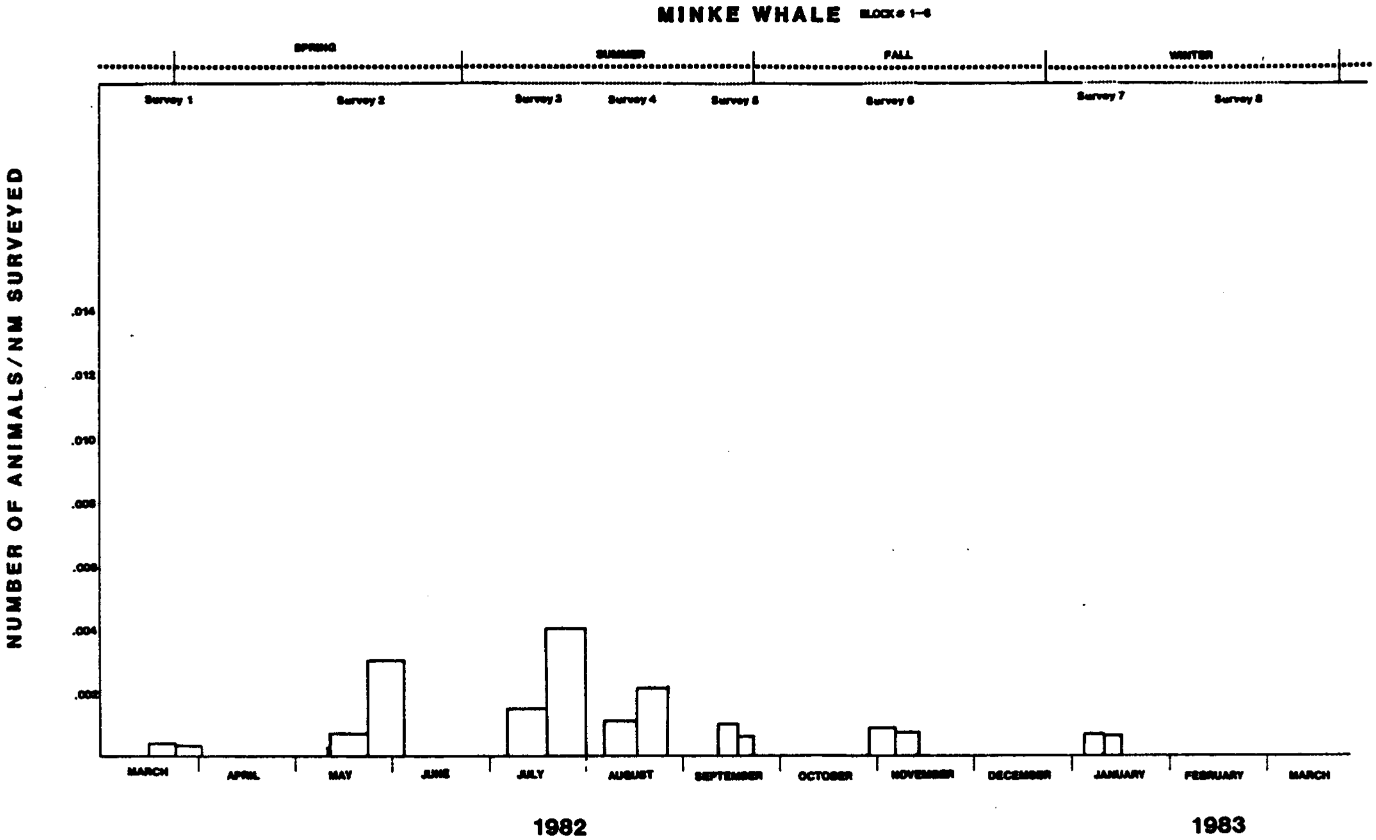


Figure 38. Indices of abundance of minke whales by survey in blocks 1-6.

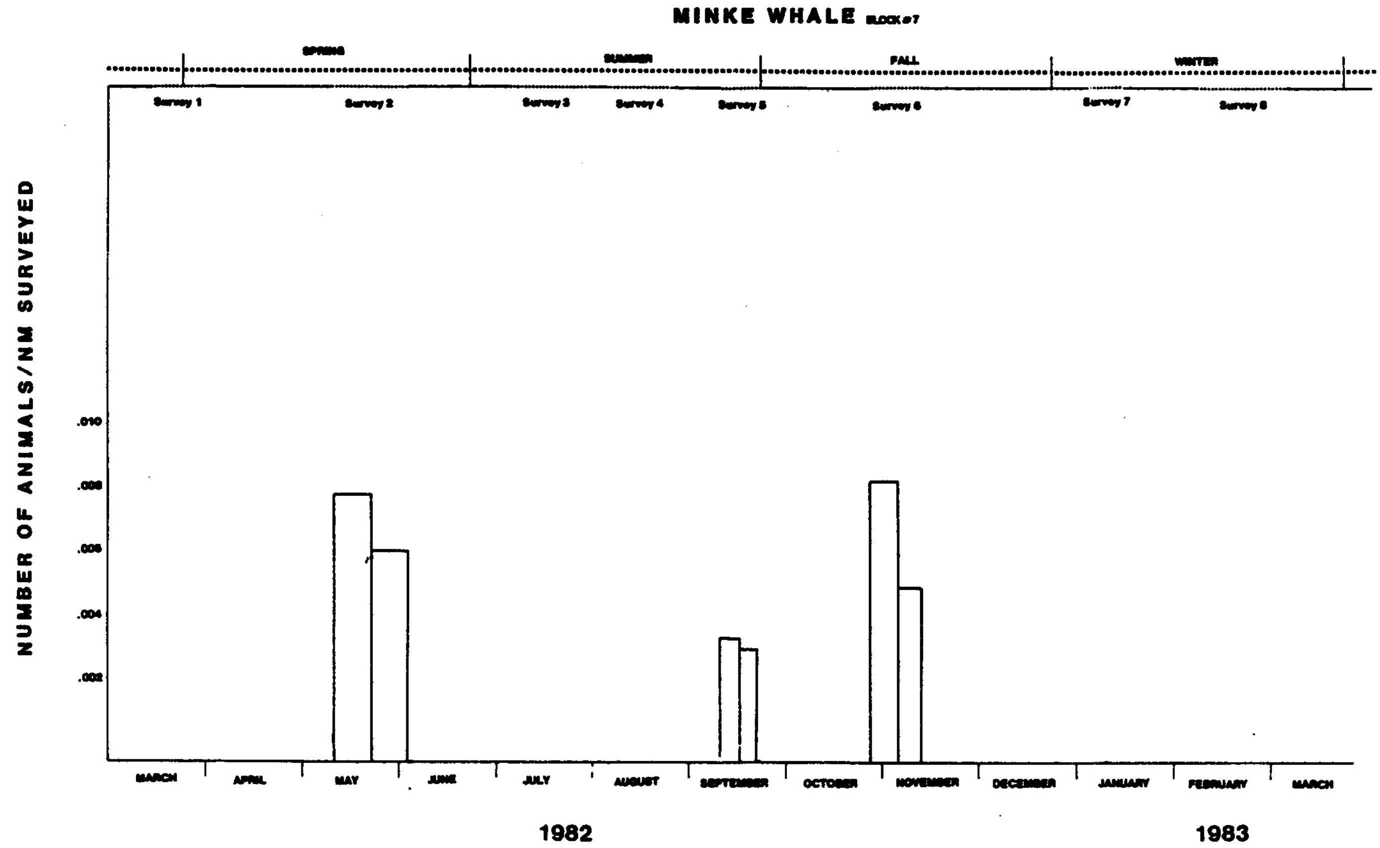


Figure 39. Indices of abundance of minke whales by survey in block 7.

Minke whales were seen in water from a few to more than 1,000 (1,830 m) fathoms deep (Figure 40). The relatively large number of observations in water less than 70 fathoms (128 m) were mainly in shallow Bristol Bay, in waters north and east of the Pribilofs (where there was significant searching effort in shallow water - see Figures 8-11), and along the narrow shelf edge in Shelikof Strait.

Only two calves were seen: a very small individual (less than half the length of the accompanying adult) on 15 May 1982 in 7 fms (12.8 m) at 58°27.0'N, 160°45.9'W (block 1) and a larger individual (ca. half the length of the accompanying adult) seen in 5 fms (9 m) on 12 August 1982 at 56°55.4'N, 159°25.6'W. North Pacific minke whales are thought to breed throughout the year, with calving peaks in December and June (Mitchell, 1975b). It is of interest that Dorsey et al. (1983), in spite of intensive summer searching effort in inshore waters of Washington State, have seen no calves. In the Antarctic, females congregate at higher latitudes than males (Ohsumi and Masaki, 1975). Off Newfoundland pregnant females and juveniles of both sexes penetrate deeper into embayments than other animals, and younger animals tend to remain in embayments much longer than mature animals (Mitchell and Kozicki, 1975). No such evidence of age or sex segregation is available for the Bering Sea or Shelikof Strait.

Humpback Whale (*Megaptera novaeangliae*)

The humpback whale has a coastal distribution on both sides of the North Pacific and also occurs regularly and in relatively large numbers around offshore islands, such as the Revillagigedos off Mexico, the Hawaiian islands in the mid-Pacific, and the Ryukyus off southern Japan (Tomilin, 1967; Rice, 1978c). Humpbacks were hunted by primitive methods off Japan (Omura et al., 1953) and along the Pacific northwest coast of

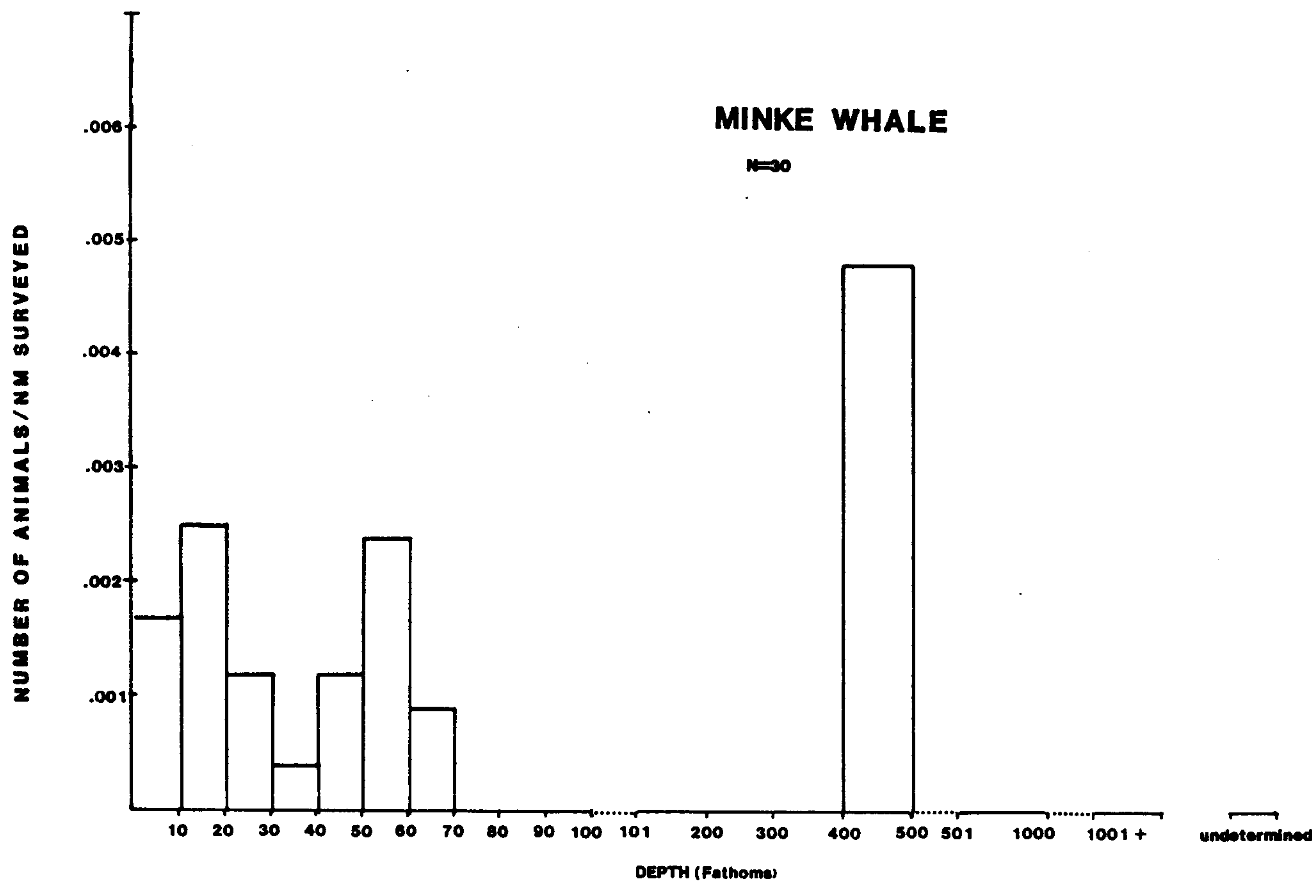


Figure 40. Indices of abundance of minke whales by depth class.

North America (Mitchell, 1979; O'Leary, in press) since very early times. Yankee pelagic whalers took them during the nineteenth century, mainly when more valuble species like the right whale and sperm whale were unavailable (Scammon, 1874; Henderson, 1972).

Large stocks of humpbacks nevertheless remained in the North Pacific when modern whaling methods were introduced there. A total of 23,215 were taken throughout the North Pacific by whalers from several nations between 1910 and 1965 (Rice, 1978c: Table 1). After the 1965 season, the species was given full protection from commercial whaling in the North Pacific. A substantial proportion of the reported catch through 1965 was made in or near our study areas. At least 1,793 humpbacks were landed at Akutan from 1914 to 1939; 1,452 at Port Hobron from 1926 to 1937 (Leatherwood, unpubl. data). By the early 1960's, the only area in the North Pacific where large numbers of humpbacks could still be found was around the eastern Aleutians and south of the Alaska Peninsula from 150°W to 170°W (Rice, 1974). The catches by Russian and Japanese factory ships during 1962-1965, totaling 4,006 humpbacks (Rice, 1978c: Table 1), presumably were made primarily in these areas.

There has been general agreement that humpbacks are divided into at least two stocks in the North Pacific - a western ("Asian") and an eastern ("American") stock (Kellogg, 1929; Tomilin, 1967). Three "stocks" have been tentatively identified on the basis of known wintering areas, thus: 1) a Mexican stock off the mainland and Baja California coasts of Mexico and around the offshore Revillagigedos; 2) a Hawaiian stock; and 3) an Asian stock around the Mariana, Bonin, and Ryukyu islands and Taiwan (Rice, 1978c). In addition, Rice (1978c) referred to "unconfirmed reports" suggesting the possibility of a small resident population in the Gulf of California.

Several tag returns have demonstrated trans-oceanic movement by humpbacks (Kawakami and Ichihara, 1958). One whale marked south of Unalaska Island (eastern Aleutians) on 23 July 1956 was captured west of Okinawa Island (south of Japan) on 7 January 1958. Two others marked on 4 and 5 September 1956 north of Unalaska were killed east of Okinawa on 28 January 1958 and west of Okinawa on 26 February 1958, respectively. Additional tag recoveries demonstrating similar movements were made in subsequent years (Nishiwaki, 1966; Rice, 1978c). Interestingly, no tags have been returned from humpbacks marked off California and Mexico (Rice 1974). Nevertheless, Rice (1974) considered it "probable" that some humpbacks wintering in these areas move far enough north during their summer feeding migration to mix with humpbacks from the western Pacific, a view shared by many other authors (e.g. Berzin and Rovnin, 1966).

With the recent development of photodocumentation and individual whale identification techniques, it has become possible to test the validity of long-held assumptions about humpback whale movements and stock relationships (e.g. Katona et al., 1979,1980; Katona and Whitehead, 1981; Mayo, 1983). Application of these techniques to humpbacks in the North Pacific has begun to reveal important new insights, and it promises to revise the simplistic conventional view that there are two stocks, and the untested hypothesis that there is little or no mixing between whales using different wintering grounds. Already, humpbacks that winter in Hawaii have been shown to travel to feeding grounds off southeast Alaska, south central Alaska, and British Columbia; and individual whales have been shown to winter in Hawaii and Mexico in different years (Darling, 1983; Darling and McSweeney, 1983; Darling and Jurasz, 1983). Thus, it has been suggested that there may be a single North Pacific stock rather than two or more separate stocks (Darling, 1983). We expect further work of this kind to improve our understanding of humpback stock relationships even further.

Berzin and Rovnin (1966) considered "the center of the summer habitat" of humpbacks in the North Pacific to be between 145°W and 170°W, south of the Aleutians, and "to the north of Unimak Strait." They also referred to concentrations south of Nunivak Island, close to Cape Newenham, and between the Pribilofs and Cape Newenham. Humpbacks were sighted by Japanese scouting vessels in portions of our study areas during 1965-1978 (Wada, 1980: Figure 4g). The highest indices of abundance (30 whales per 10,000 nm (18,520 km) searched) were in the square surrounding Kodiak Island (including Shelikof Strait) and in our block 3, between Nunivak Island and the Pribilofs. Much higher densities (to 75 whales per 10,000 nm) were reported for areas south of the Aleutians, from Unimak Pass and eastward. "Single wandering individuals occur more or less often" near the Commander Islands (Barabash-Nikiforov, 1938).

Recent observations indicate that humpbacks continue to be widely distributed during summer on the continental shelf of the southeastern Bering Sea, in particular south of Nunivak Island (Nemoto, 1978; Braham et al., 1982: Figure 4.2), north and northwest of the Pribilofs (SAI, 1981: Figure 9.1), just east of the Pribilofs (G. Hunt, pers. comm.), and in the Unimak Pass area (Braham et al., 1982: Figure 4.2; SAI, 1983: Figure 19.1). Several sightings have been reported in outer Bristol Bay as well (SAI, 1983: Figure 19.1), although Nemoto (1978) stated that few observations of humpbacks were made in "uppermost Bristol Bay according to the fisheries people."

The sightings plotted in the Unimak Pass area (SAI, 1983: Figure 19.1) amply demonstrate that humpbacks are commonly seen there, mainly along the narrow shelf to the west of the pass. Judging by Braham and Rugh's (in prep.) seasonal plots, humpback distribution expands during summer and fall into many parts of the southeastern Bering Sea as well as along both the north and south sides of the Aleutians. This increase in sightings presumably reflects the arrival of migrants from the southern breeding and calving grounds.

Rice (1978c) offered the hypothesis that there were about 15,000 humpback whales present in the North Pacific before 1905. He felt that trends in catch after that time would have been consistent with such an initial population level. There is no doubt, judging from marked declines in catch on various grounds, that the humpback population in the North Pacific has been severly depleted by whaling (Rice, 1974, 1978c). Although Doi et al.,(1967, as cited by Rice, 1974; see Anon., 1967) estimated a population of 2,100 in ca. 1966, Rice (1974) concluded that the eastern North Pacific stock numbered only "a few hundred" in 1971. Japanese investigators estimated in 1972 that there were 1,200-1,600 humpbacks in the North Pacific (Ohsumi and Wada in Chapman, Chmn., 1973:32), but Rice (1978c) used Japanese sightings data collected from 1965 to 1974 to make a rough estimate of 850 whales for the total North Pacific population between 120°W and 140°E. He considered most of these to be from winter grounds off Mexico and Hawaii, noting humpbacks were "scarce" on the Asian winter grounds.

As in the case of stock identity, individual whale identification by use of photodocumentation techniques can improve estimates of abundance. Between 1977 and 1982, 1,056 humpbacks were individually identified on the Hawaiian wintering grounds alone (Darling and McSweeney, 1983), and Darling (1983) guessed that "there are well over 2,000 in the northeast Pacific."

There were 8 sightings, involving 15 animals, made during our surveys (Figures 41, 42). There were far too few humpback sightings, separated by too great a distance, to allow us to make any density estimates for this species. It is, perhaps, noteworthy that our two sightings in the Bering Sea study area were in the general vicinity of sightings make by others during vessel transits through the area in the same year (Figure 41), and their positions are consistent with the published information on humpback distribution summarized above. Although we hesitate to generalize on the basis of such a modest sample, our data suggest that nearshore waters off the northeast corner of Kodiak Island may be important to summering humpbacks. It was in this area that the only humpback calf was observed, on 20 July 1982 in the company of one adult in shallow water (13 fms, 24 m) at 58°39.6'N, 152°29.8'W. All the humpbacks we observed were in shallow shelf waters less than 84 fms (154 m) deep.

Our data show a strong seasonality to the presence of humpbacks in the study areas, which is to be expected of these migratory animals. Most of our sightings (5) were in the second week of September; the others, from late July to mid-August. In only one of our sightings was it evident that the humpbacks were feeding - two animals seen in water 50 fms (91 m) deep at 54°19.1'N, 165°47.6'W on 8 August 1982.

Sperm Whale (*Physeter macrocephalus*)

The sperm whale's worldwide distribution, abundance, and population dynamics have been discussed by many authors (see, for instance, Tomilin, 1967; Berzin, 1972; Best, 1979; contributors to IWC, 1980, and other IWC

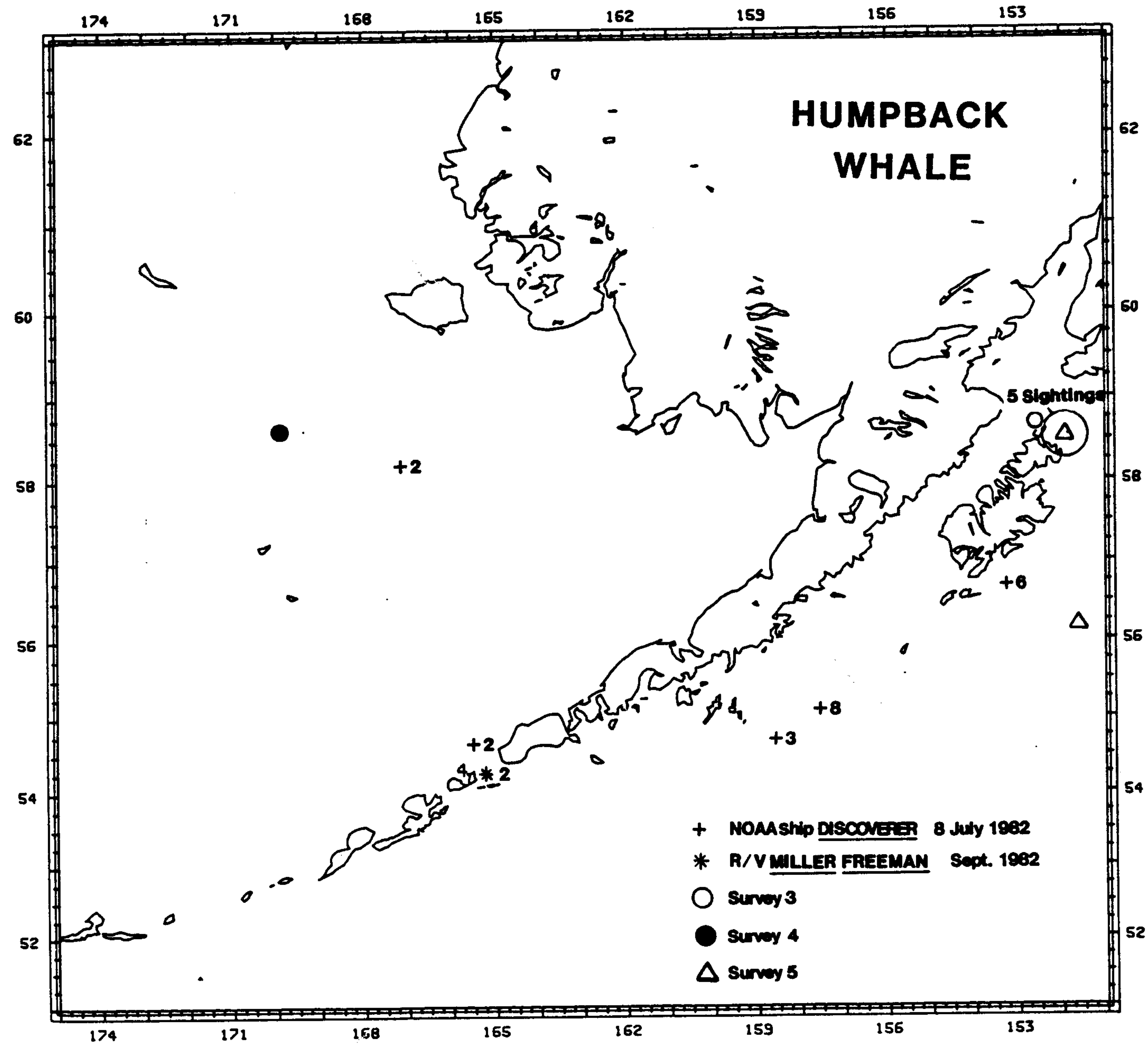


Figure 41. Sightings of humpbacks from the present aerial surveys and from other research activities, 1982-83, as indicated.

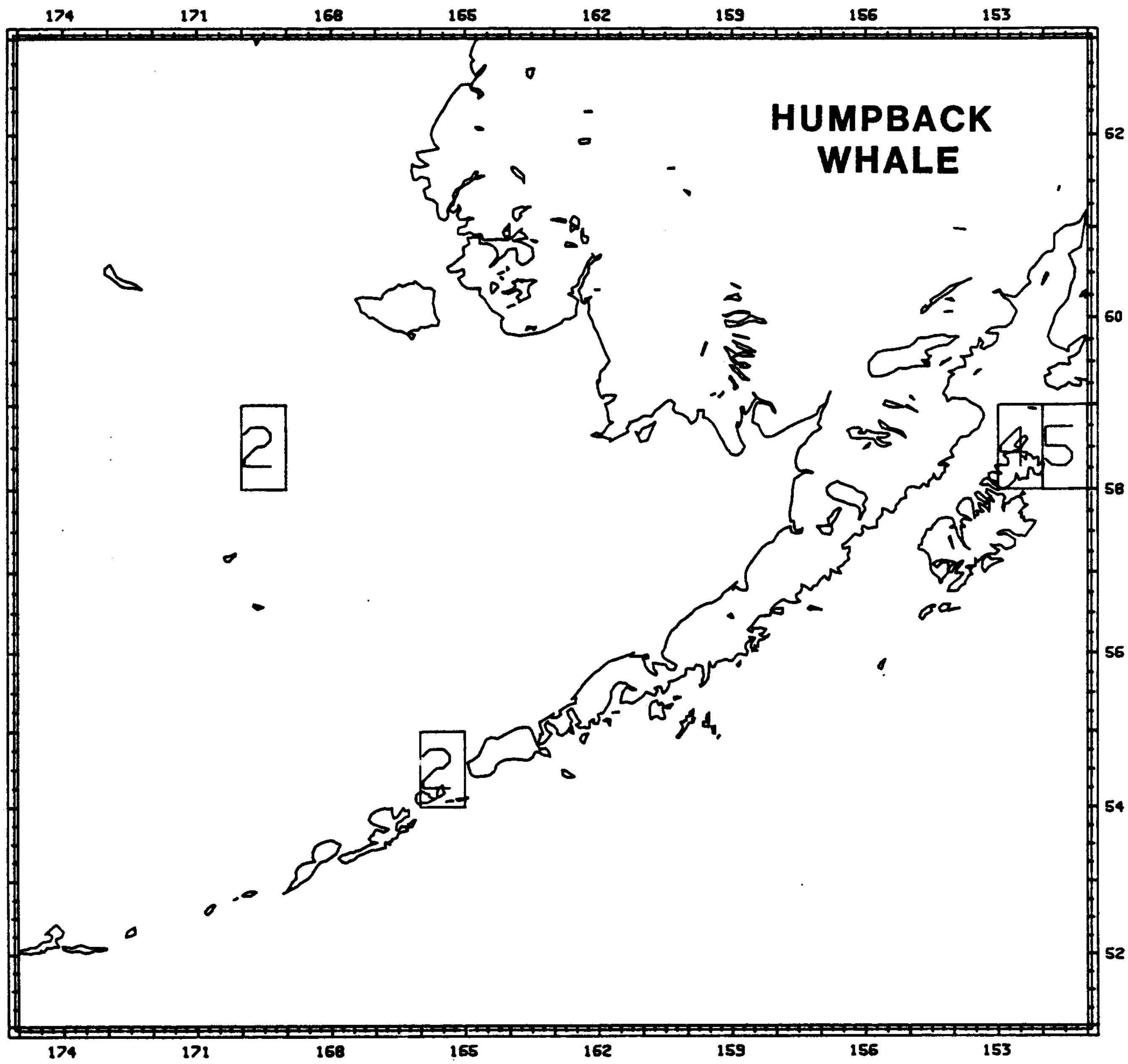


Figure 42. Number of humpback whales seen during aerial surveys, by 1° block.

reports). Rice (1978d) estimated the current world population as 800,000 adults, or 1.5 million whales including calves and juveniles. He believed nearly half of these to be in the North Pacific.

Large numbers of sperm whales were caught in the North Pacific by nineteenth century whalers, but most of this activity took place well south of our study areas, in fact south of 40°N latitude (Townsend, 1935; Bannister and Mitchell, 1980: Figure 7). Modern shore whalers killed relatively modest numbers in the eastern North Pacific: less than 1,000 in Alaska from 1912 to 1939 (Ohsumi, 1980); more than 5,000 in British Columbia from 1905 to 1967 (Pike and MacAskie, 1969: Appendix I), and over 1,000 in California from 1919 to 1971 (Rice, 1974; Ohsumi, 1980). But since World War II tens of thousands of sperm whales have been killed in the North Pacific by Japanese and Soviet whalers, from land stations and pelagic floating factories (Berzin and Rovnin, 1966; Tomilin, 1967; Nishiwaki, 1966; Tillman, 1977). The total North Pacific sperm whale catch between 1910 and 1976 has been estimated at nearly 269,000 (Ohsumi, 1980). The peak kill in a single year was over 16,000 taken in 1968. Although pelagic whaling for sperm whales has stopped, the species is still hunted from shore stations in Japan.

The question of sperm whale stock identity in the Norht Pacific is still open. At least three stocks - Asian, Central, and American - have been proposed by some authorities (e.g. Masaki, 1970; Tillman, 1977; Bannister and Mitchell, 1980). Others (e.g. Ohsumi and Maski, 1977) have argued for only two - Western (Asian) and Eastern (American). In 1978, the IWC adopted for management or reference purposes a boundary between Eastern and Western "stocks" of sperm whales in the North Pacific (Bollen, Chmn., 1979). This boundary consists of a line corresponding with the 180°

longitude line south to 50°N, the 50°N latitude line east to 160°W, the 160°w longitude line south to 40°N, the 40°N latitude line east to 150°W, and the 150°W longitude line south to the equator.

Female sperm whales do not move to latitudes as high as those reached by adult males. Females have been taken with some regularity in the western Bering Sea (Smith, 1980), but very few have been taken by Japanese pelagic whalers in the Bering Sea east of 18° (Ohsumi, 1966; Ohsumi and Masaki 1977: Figure 2); Hanna (1923, 1924, as cited in Tomilin, 1967:354) mentioned a record of a female marked in the eastern Bering Sea south of the Pribilofs (in our block 4) was killed east of British Columbia; by contrast, several males marked in the eastern Bering Sea were caught off Japan and Kamchatka or south of 40°N and west of 180° longitude (Ohsumi and Masaki, 1977: Figures 4, 5). Both sexes appear to move long distances, both latitudinally and longitudinally. Wintering grounds of sperm whales summering in waters in or near our study areas are not clearly known.

Omura (1955) proposed, and Berzin and Rovnin (1966) agreed, that the usual limit of sperm whale penetration into the Bering Sea is a line Pribilof Islands, with the greatest concentration to the north of Atka Island." Sperm whales are said to arrive near the Aleutians in March (some may overwinter), and large numbers to appear in the eastern Bering Sea by April (Berzin and Rovnin, 1966). In September, many of the sperm whales that summered there begin to migrate south.

Sperm whales show a clear preference for deep waters at the shelf edge, on the continental slope, or over deep offshore canyons. The distribution in the eastern Bering Sea mapped by Nishiwaki (1966: Figure 7), based on Japanese whaling data, and by Berzin and Rovnin (1966: Figure 1), based on their own observations supplemented by Soviet whaling data, shows a remarkably close correlation with the shelf edge. Thus, sperm whales are most likely to be encountered in our blocks 4 and 5, on and seaward of the continental slope. The narrow shelf along the south side of the eastern Aleutians, Alaska Peninsula, and Kodiak Island ensures that sperm whales appear regularly close to the southern borders of both of our study areas. Sperm whales were taken by both Akutan and Port Hobron whalers (Birkeland, 1926; Leatherwood, unpublished data).

Japanese sightings data from 1965 to 1978 show a complete absence of sperm whales in outer Bristol Bay and Shelikof Strait, but reasonably high densities (ca. 200 whales per 10,000 nm (18,520 km) surveyed) along the Alaska Peninsula and the eastern Aleutians (Wada, 1980: Figure 4b). A similar density is shown for the outer continental shelf waters between St. Matthew Island and the Pribilofs (our block 3 and the northern part of block 4). Higher densities (ca. 300 whales per 10,000 nm (18,520 km)) were estimated for the central Aleutians, including the deep (>100 fms (183 m)) waters in the western half of our blocks 4 and 5. Recent sightings by American researchers indicate that sperm whales occur, mainly during summer and fall, in or near Unimak Pass and on the continental slope west of the pass (SAI, 1983: Figure 19.4; Braham and Rugh, in prep.).

We sighted no sperm whales during our aerial surveys. The areas in which bulls, the animals most likely to have been seen, were expected were the least surveyed regions and were flown, in general, under the worst survey conditions encountered. Therefore, our failure to detect the solitary, long-diving bulls is not surprising. Nevertheless, there are sufficient historical catch and recent observational data to demonstrate that adult male sperm whales visit the deep areas south and west of the Pribilofs in substantial numbers during summer. There is no reason to believe any part of our study area is of direct importance to the female and young components of the sperm whale population. However, it is reasonable to conclude that the region is important as a foraging ground for adult males which prey mainly upon large squids, octopuses, and deepwater fishes (Caldwell et al., 1966). Bulls from the heavily exploited Western "stock" are probably at least as much involved in the use of this area as are bulls from the Eastern "stock" (see Ohsumi and Masaki, 1977).

Narwhal (Monodon monoceros)

The narwhal is primarily an inhabitant of deep Arctic waters, and its centers of distribution are generally far from our study areas (Reeves and Tracey, 1980). We are aware of only two confirmed records of the species in the Bering Sea (see Reeves, 1978, for a review of other Alaskan records). A 14-ft narwhal with a 7-ft tusk stranded alive at the mouth of the Caribou River in Nelson Lagoon on the Alaska Peninsula in April 1957 (Geist, Buckley and Manville, 1960). More recently, two narwhals with conspicuous tusks were observed on 26 April 1982 during an aerial survey of Bering Strait and the northern Bering Sea sponsored by the U.S. Minerals Management Service (Ljungblad, Moore and Van Schoik, 1983: pp. 35-37, Figure 7; also see Anon., 1983). The whales were in 8/10 floe ice about 8 km WNW of King Island in the Bering Sea. The authors speculated the whales had "apparently wintered in the Bering Sea and were migrating north with the bowhead and beluga whales."

No narwhal sightings were made during our surveys; nor did we learn of any additional records from in or near our study areas. Based on all available information, narwhals are not a normal component of the southeastern Bering Sea and Shelikof Strait marine mammal faunas.

White Whale or Beluga[6] (Delphinapterus leucas)

Belugas occur in many presumably discrete stocks in the Arctic and Subarctic (Kleinenberg, Yablokov, Bel'kovich and Tarasevich, 1969; Gurevich, 1980). During summer most herds congregate in river mouths, although in the Chukchi Sea some animals remain closely associated with the offshore pack-ice edge (Seaman and Burns, 1981). Belugas have been hunted, sometimes intensively, over their wide, almost circumpolar range.

Alaskan distribution has been reviewed recently by several authors (Harrison and Hall, 1978; Seaman and Burns, 1981; Lowry et al., 1982b). The total population using state waters was estimated as 10,000-16,000 by the Interagency Task Group (1978), cited in Lowry et al. (1982b), studying the return of management of the species from the federal government to the state. Later, Lowry et al. (1982b) stated that a combination of estimates from various areas suggests a total of "at least" 15,000-18,000 belugas in the "Bering-Chukchi-Beaufort stock".

Most authorities agree that the Cook Inlet stock is isolated from all others (Sergeant and Brodie, 1969; Fay, 1978; Lowry et al., 1982b). Although this small stock is considered non-migratory, its known distribution extends at least to Kodiak Island and the adjacent Alaska Peninsula in the west and Yakutat Bay in the east (Harrison and Hall, 1978). There was some sport hunting near Kenai during the mid-1960's (Interagency Task Group, 1978), but the stock is not exploited at present (Seaman and Burns, 1981; contra Murray and Fay, 1979 MS., as cited in Perrin, Chmn., 1980: Table 1, who indicated recent annual kills of more than 10 animals) and is considered "stable" (Interagency Task Group, 1978). Sergeant and Brodie (1975) gave 150-300 animals as an estimate for this population,

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6 In Alaska and the Soviet Union researchers call the species "belukha".

without citing their source. Other authors (Interagency Task Group, 1978; Lowry et al., 1982b) have claimed that there are 300-500 whales in the Cook Inlet region. Data from recent aerial surveys have been extrapolated to an estimate of 200-500 in the late 1970's (Murray and Fay, 1979 MS., as cited in Perrin, Chmn., 1980: Table 1).

Harrison and Hall (1978) saw belugas in Shelikof Strait in March and July (1975-1977). We made only one beluga sighting in or near Shelikof Strait during our aerial surveys (Figures 43, 44). On 6 August 1982 one beluga was seen close to the shore of the Alaska Peninsula near the southwest entrance of the strait (56°59.5'N, 156°27.6'W). Belugas were also observed repeatedly in the Cook Inlet complex during our transit flights into and out of Anchorage, particularly near the estuary of the Kenai River. One of these sightings, made during a training segment on-effort, is shown in Figure 44. We are unable to evaluate the estimates by others of the size of the Gulf of Alaska stock, both because of those authors' failure to publish the basis for their figures and because of the incidental nature of our own observations.

The distribution and abundance of belugas in Bristol Bay are better known. During the 1950's and 1960's, rudimentary studies were done in Bristol Bay by ADF&G scientists and others, prompted mainly by concern about beluga depredations on commercially valuable salmon stocks (Brooks, 1954 et seq; Lensink, 1961; Klinkhart, 1966; Fish and Vania, 1971). More recently, studies of beluga distribution, behavior, abundance, and movements have been initiated in the river complexes associated with upper Nushagak Bay (Stewart et al., 1983) and in Kvichak and Nushagak Bays (Frost et al., 1983).

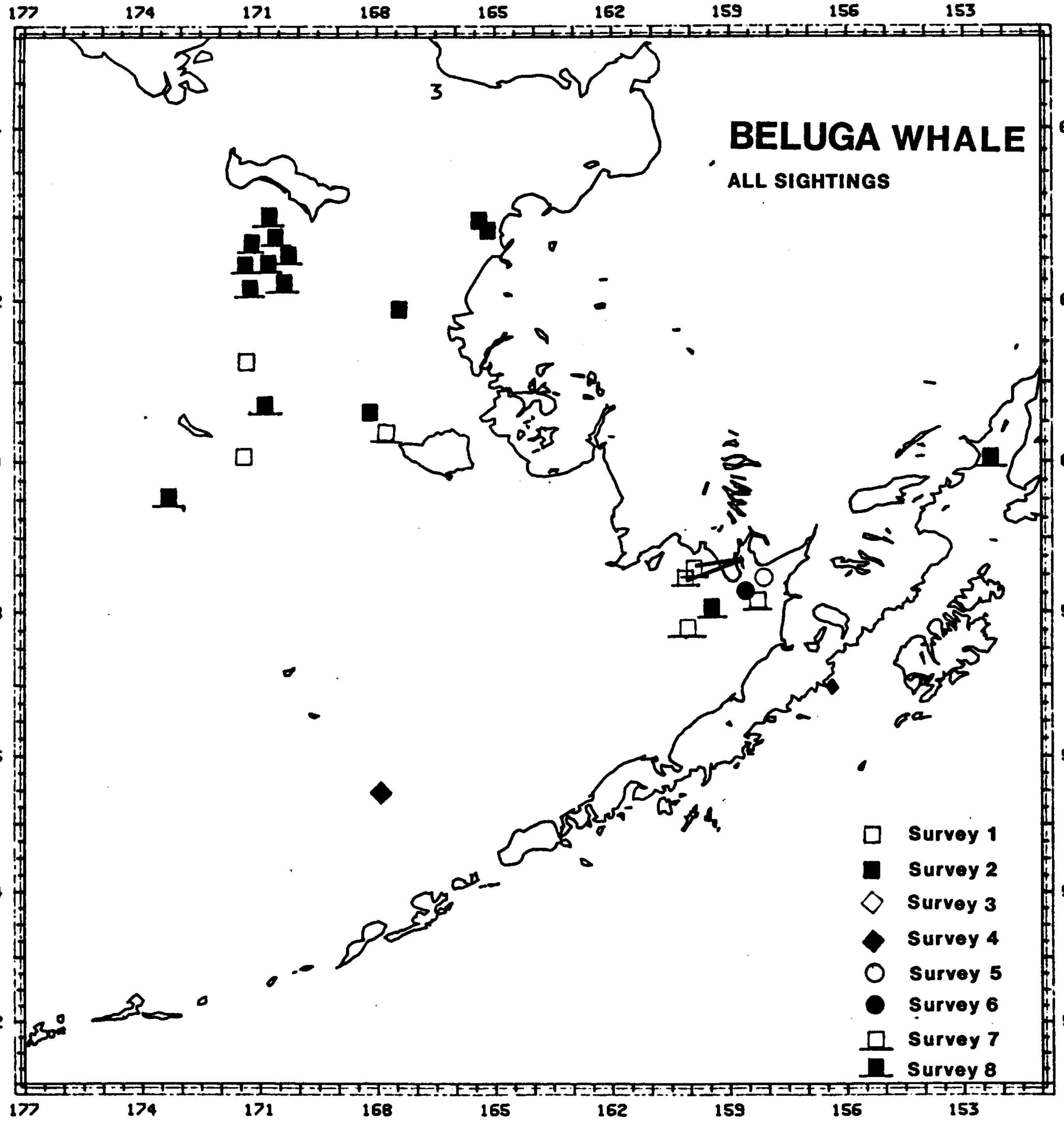


Figure 43. Sightings of white whales by survey.

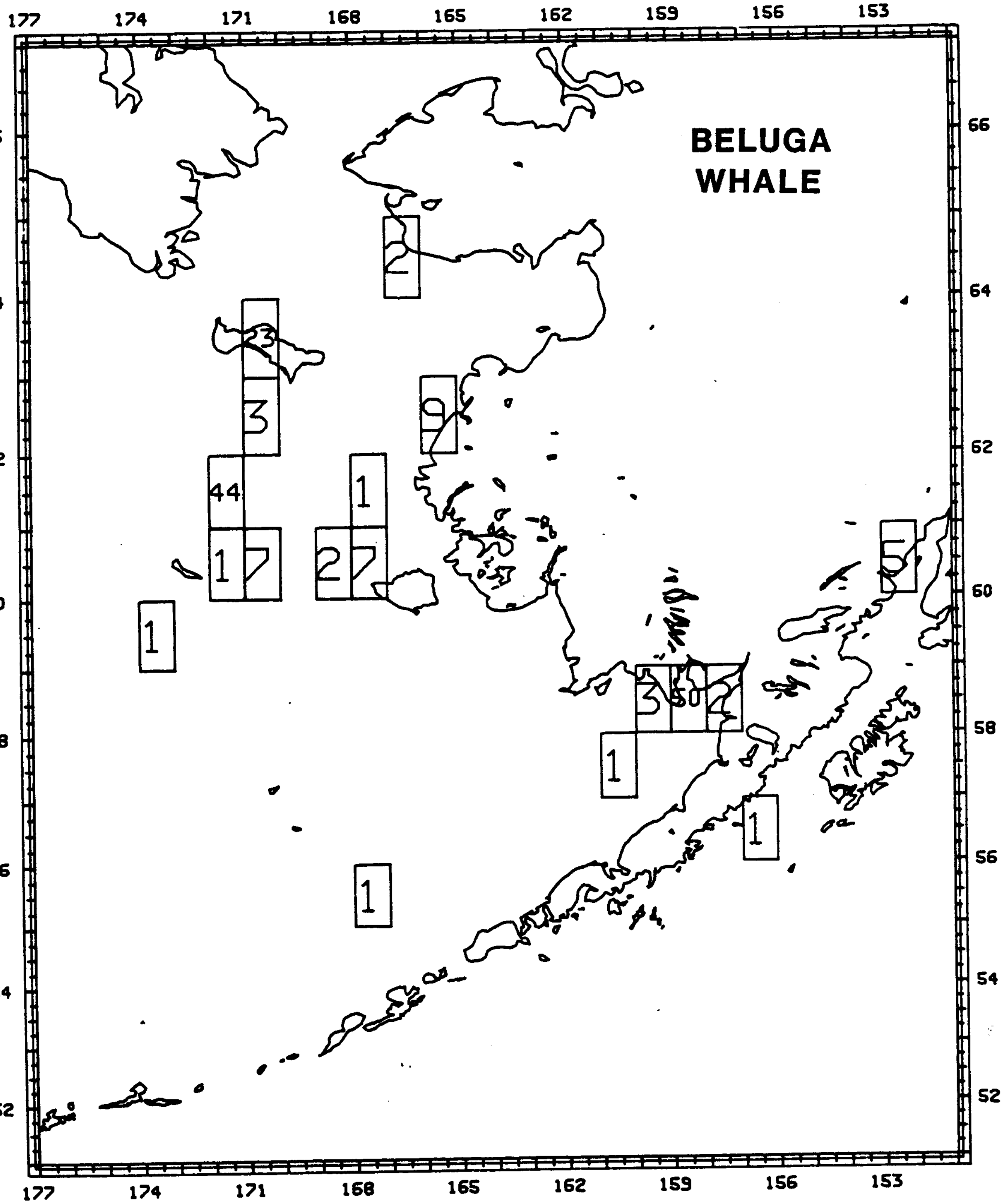


Figure 44. Total number of white whales by 1° block.

The discreteness of the beluga stock in Bristol Bay is less certain than that of the Cook Inlet stock. "The degree of interchange between this population and that of the northern Bering Sea, if any, is not known" (Interagency Task Group, 1978). Beluga distribution in summer is "continuous from Bristol Bay to the western Beaufort Sea," and "essentially" the entire population [of belugas in Alaska] resides in the drifting pack [of the Bering Sea] during winter" (Seaman and Burns, 1981).

The size of the Bristol Bay stock has been estimated as 1,000-1,500 animals (Sergeant and Brodie, 1975; Interagency Task Group, 1978), although the number present at any one time evidently can vary considerably (Brooks as cited in Lowry et al., 1982b:103). The maximum number observed in Nushagak Bay in 1982 was 400-600; in 1983, 135 were seen in Nushagak Bay and 400 in Kvichak Bay (Frost et al., 1983). Based on surveys conducted in July 1983, the number of belugas in the two bays was estimated to be 1,100, including neonates (Frost et al., 1983). The distribution and abundance of belugas in Bristol Bay today are "comparable" to what they were in the mid-1950's (Frost et al., 1983). Intensive hunting but lower harvests continued in Bristol Bay until recently, when local residents began to devote more of their attention to commercial fishing. Seaman and Burns (1981: Table 1) indicated a total catch of only 10 belugas in Bristol Bay during the period 1977-1979.

The belugas in Bristol Bay spend much of the year there (Fay, 1978; Frost et al., 1983). According to Seaman and Burns (1981), they "enter the bays and rivers of Bristol Bay as early as ice conditions permit, which may be in late March or early April," and they remain in these areas until late summer. The animals' movements are closely related to the presence of "sequentially abundant and highly available forage fishes" such as salmon, herring, smelt, and arctic and saffron cods (Lowry et al., 1982b). Aerial surveys in the southern Bering Sea during February, March, April, June, August and October resulted in summer sightings in Bristol Bay and offshore in the vicinity of the Pribilofs (Harrison and Hall, 1978). "Sightings in Bristol Bay during the winter months were more numerous and are clustered in the northern portion of the bay" (Harrison and Hall, 1978). These animals seen in March and April may have been headed to Kvichak and Nushagak bays. Harrison and Hall (1978) reported an absence of sightings in Moller Bay, but Frost et al. (1982b) showed two sightings in and near Port Moller. Frost et al. (1982b) nevertheless reported generally few sightings along the Alaska Peninsula and learned that local observers consider belugas "very uncommon along this (the southwest) part of the Alaska Peninsula."

During ice-free seasons belugas are scarce or absent in the St. George Basin (Braham et al., 1982) and throughout much of our Bering Sea study area (see distribution map in Fay, 1978). During our aerial surveys, we made only one sighting in the St. George Basin (corresponding to our blocks 4, 5 and 6), that of a single animal seen at 55°28.4'N, 167°56.9'W in 80 fathoms (146 m) of water on 8 August 1982 (Figures 43, 44). Other St. George Basin sightings (season unspecified) were reported at ca. 56°30'N, 166°40'W (SAI, 1983: Figure 19.4) and at ca. 58°30'N, 173°W (SAI, 1981: Figure 9.2).

Like Harrison and Hall (1978), we had relatively few summer sightings (Figure 45), probably because of the fact that the whales were concentrated in rivers or river mouths at this time and thus were unlikely to be seen on our transects. Frost et al. (1983) found that radio-tagged whales in Kvichak Bay made twice-daily upriver movements of as much as 30 miles

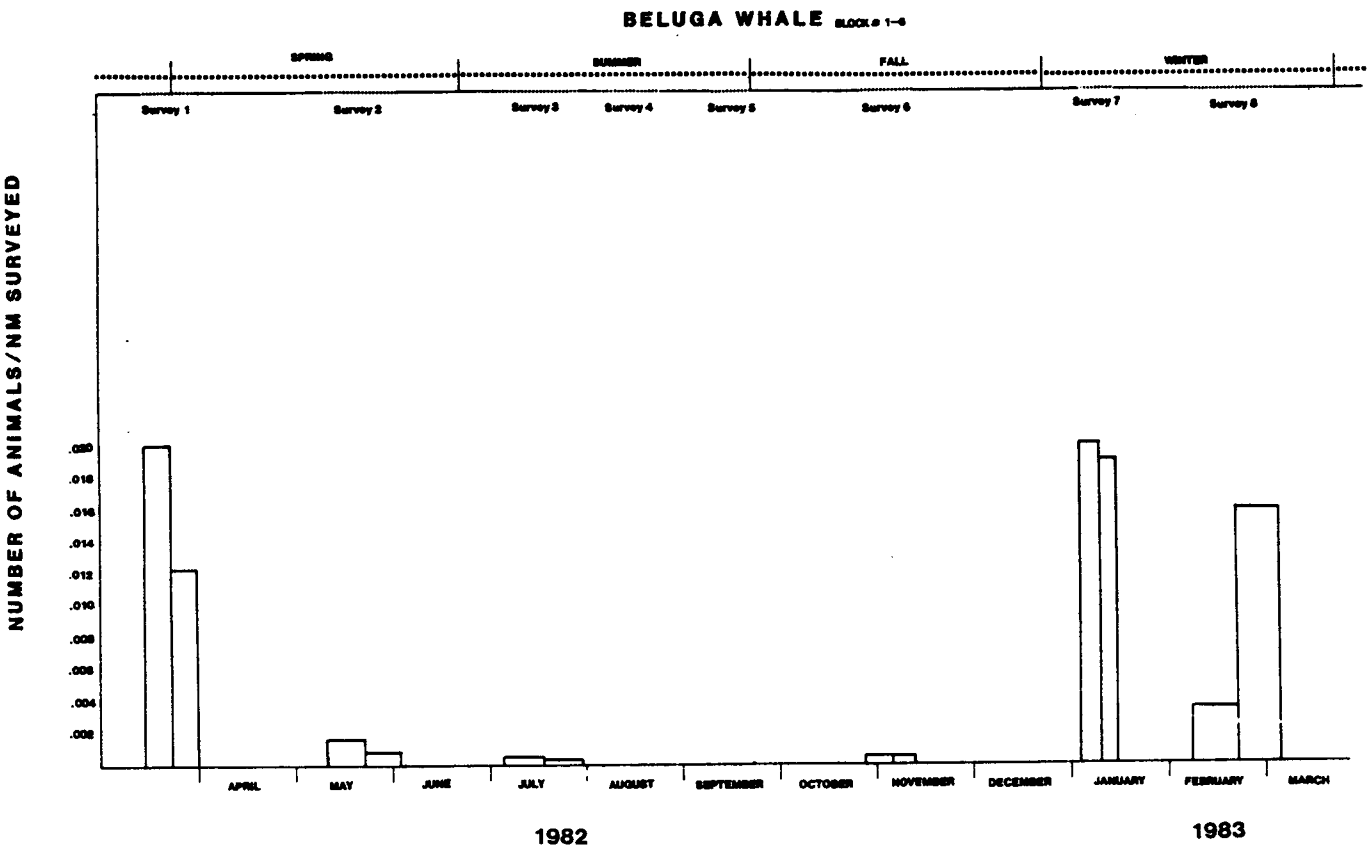


Figure 45. Indices of abundance of white whales by survey blocks 1-6.

(56 km). Two tagged whales followed for a two-week period between mid-May and mid-July did not leave Kvichak Bay. Our sightings overall were clustered in upper Bristol Bay and in study block 2, between St. Matthew and Nunivak islands (Figures 43, 44). The 7(26 belugas) sightings outside our Bering Sea study area, north of 62°N, were mostly in April in the pack-ice south of St. Lawrence Island and in the approaches to Norton Sound. The depth preferences suggested by our data (Figure 46) are not surprising. The majority of sightings were in water less than 30 fathoms (55 m) deep, and all sightings for which the position was known with sufficient precision to estimate the depth were on the continental shelf (80 fms (146 m) or less). In the aggregate, our data also indicate the well-known association of belugas with ice; there is a strong peak in sighting frequency in areas of 80% ice coverage (Figure 47).

We saw and recognized white whale calves on only one occasion. Two of 7 individuals seen at 60°22.9'N, 167°48.6'W (just west of Nunivak Island) on 15 January 1983 were calves. Ice coverage at the site was 95%, and the water was 15 fathoms (27 m) deep. There was also only one sighting in which we were confident that the animals were feeding. It involved two animals just west of Egegik Point, in the turbid coastal waters of eastern Bristol Bay (58°19.0'N, 157°34.9'W; 17 March 1982). Waves could be seen in front of the whales and in front of the small schools of fish which they were chasing at high speed.

Our data are not adequate for making a realistic estimate of beluga density in any portion of the study areas. In general, our findings concerning the use of Shelikof Strait and the southeast Bering Sea by white whales agree with the observations of others who have worked there (Harrison and Hall, 1978; Seaman and Burns, 1981; Lowry et al., 1982b;

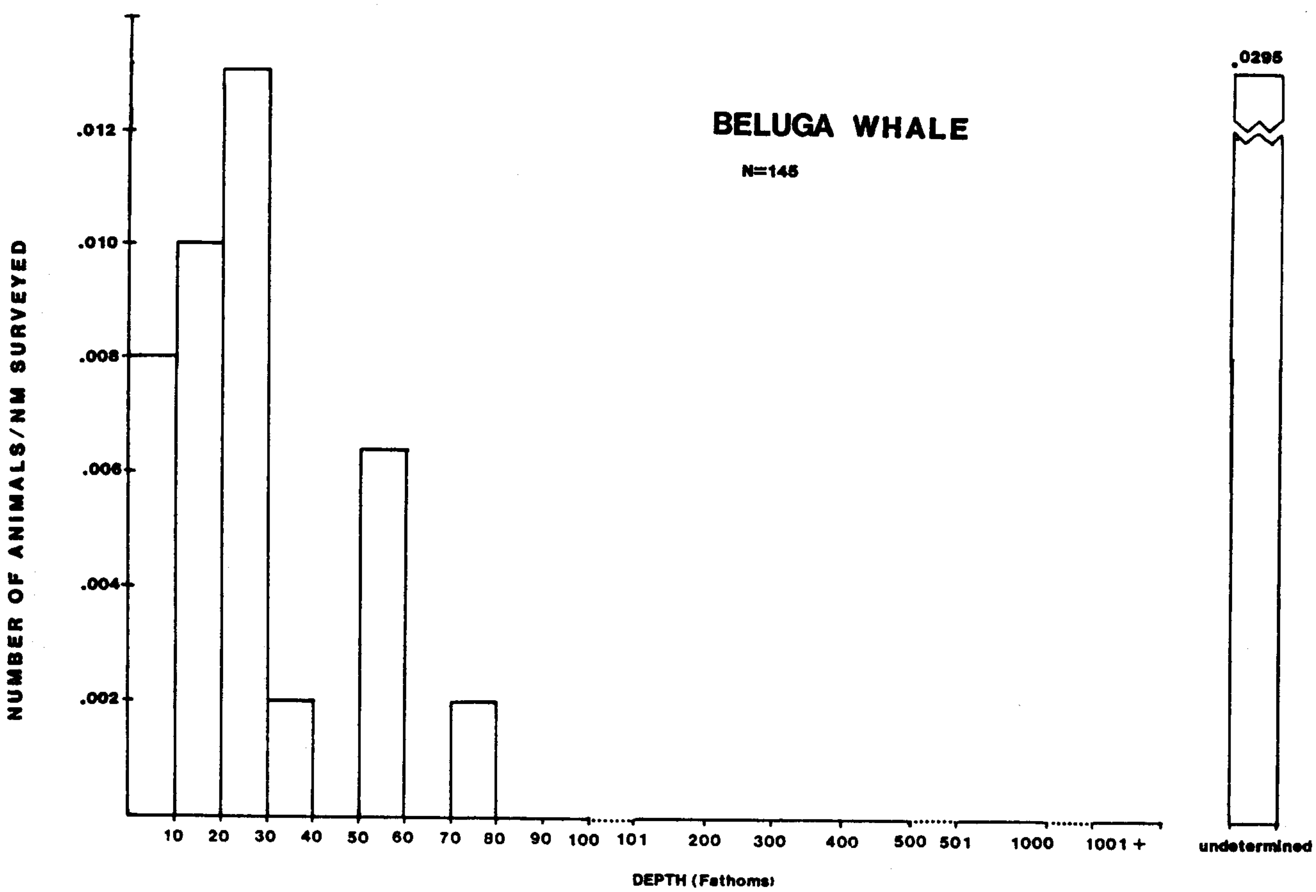


Figure 46. Indices of abundance of white whales by depth class.

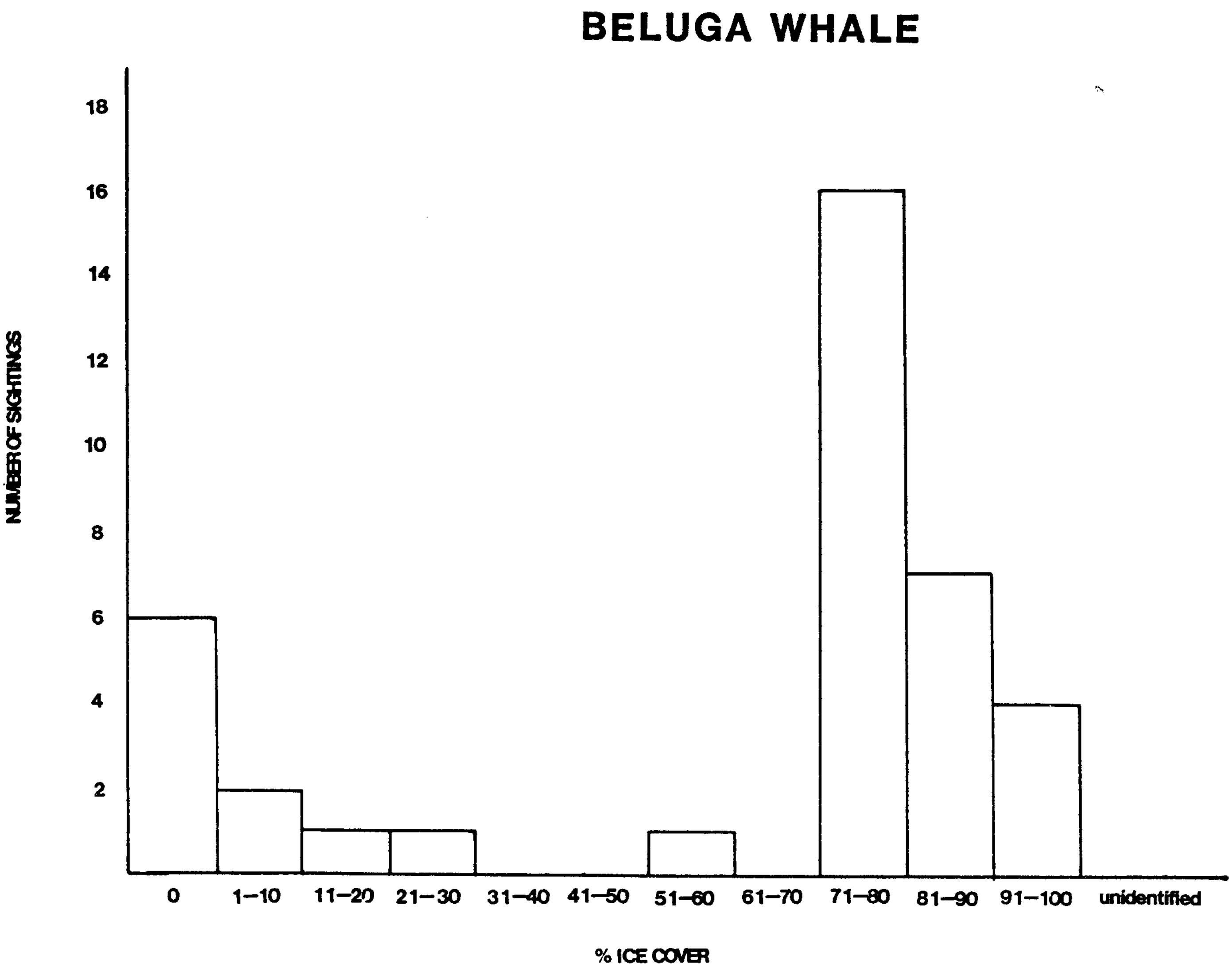


Figure 47. Distribution of white whales by percent ice cover.

Frost et al. 1983; Stewart et al., 1983). Shelikof Strait is relatively unimportant as beluga habitat. However, those belugas that do occasionally visit the strait probably belong to a stock centered in Cook Inlet which is small and almost certainly disjunct from more populous western stocks. Modification or contamination of any part of this stock's range must be viewed with concern. Bristol Bay supports a substantial year-round population of belugas. The animals appear to depend on productive estuarine waters in the upper bay as assembly sites during open-water months, and they move offshore with ice formation in the fall. It is possible that, during winter, animals from stocks which migrate northward in summer (Seaman and Burns, 1981) are present in portions of our Bering Sea study area where open water is available (e.g. the animals seen in April between St. Lawrence and St. Matthew islands-Figure 41).

Family Ziphiidae, The Beaked Whales

Only three species of ziphiids have been reported from the northern Gulf of Alaska and adjacent waters of the Bering Sea: Baird's beaked and Stejneger's beaked whale, Mesoplodon stejnegeri (Leatherwood et al., 1982c; Mead, Walker and Houck, 1982). These small to medium-sized whales, like other beaked whales, are often difficult to detect and positively identify even when a specimen is in hand (Moore, 1966; see Figure 48), let alone in encounters at sea. They occur in small groups, can dive for protracted periods, produce a low inconspicuous blow, and are often wary of vessels. They also tend to inhabit pelagic waters which, particularly in the areas covered by the present investigations, are often rough and inhospitable for visual censuses of cetaceans. Thus, the fact that there are relatively few confirmed identifications of these whales in our study areas and that they are known there principally from stranding

Figure 48. An unidentified beaked whale stranded at Amchitka Island, Alaska in 1978. Beaked whales are often difficult to identify even when a specimen is available (photo by F. B. Lee, courtesy F. Zeillemaker).

records do not necessarily demonstrate low levels of absolute or relative local abundance.

We note with interest the comment by Marakov (1967) that of 17 species of whales reported in the area of the Commander Islands, "the killer whale, the beaked whale and Baird's beaked whale are the most important species." He added "...the beaked whales [species unspecified] are often met in in-shore waters and their total numbers makes up 30 specimens. The beaked whales hold one by one; this peculiarity differs them from Baird's beaked whales." According to Marakov, between 1952 and 1962, 16 ziphiid specimens were observed along the Commander islands in the space of 3,000m.

During our surveys we observed live beaked whales on five occasions. Although glimpses of the animals were usually brief, and we were able to obtain photographs in only one instance, we have tentatively identified animals in these encounters to species based on the following characteristic features (Leatherwood et al., 1982c):

Baird's beaked whales are large (to 13m long) and have a bulbous forehead, a long dolphin-like beak, and a relatively low, sub-triangular dorsal fin. They are slate gray to brown with numerous scratches on the dorsal and lateral surfaces. From the air, the beak often appears lighter than the rest of the body and is often tipped with white, presumably the teeth.

Cuvier's beaked whales are smaller (to about 7 m long). They lack the bulbous melon and long beak of Baird's beaked whales, having instead a smoothly tapered head and a short, poorly defined beak. Their dorsal fin is prominent and falcate. Cuvier's beaked whales are tan to brown, with a light-colored head. Adult males in particular are often very lightly pigmented and have a white head; their back and sides often have scratches and light blotches.

Stejneger's beaked whales are not known to exceed 5.3 m in total body length. They have a roughly cone-shaped head and beak, and, apparently, lack the light coloration of the head characteristic of Cuvier's beaked whales. In dorsal view, the teeth of adult males, located near the middle of the lower jaws, may flash white.

During the aerial surveys, beaked whales not attributable to Baird's or Cuvier's beaked whale, each of which can be identified if seen clearly, were assumed to be Stejneger's beaked whales.

In addition to the 5 sightings mentioned above, we investigated 2 strandings of beaked whales - one of a Baird's beaked whale and one of a presumed Stejneger's beaked whale - and compiled all available records of beaked whales in and near the study areas. Findings are discussed below by species.

Baird's beaked whale (<u>Berardius bairdii</u>)

This species is endemic to the North Pacific, where it inhabits higher latitude temperate and lower latitude polar waters. It is generally seen in the deep ocean or deep canyons near the continental shelf (Davidson, 1929; Slipp and Wilke, 1953). There are records from as far south as 28°N off Baja California (Leatherwood et al., 1982c), between 25°N and 30°N off southern Japan, and above 30°N across the central North Pacific (Nishimura and Nishiwaki, 1964; Nishiwaki, 1967; Ohsumi, 1982; Kasuya and Ohsumi, 1983). These southern extremes may represent wintering limits (Tomilin, 1967) although southernmost eastern Pacific sightings are sporadic throughout the year (Leatherwood, unpublished data). North of the latitudes mentioned, the species is widely distributed around the North Pacific and Gulf of Alaska and is found throughout the Okhotsk Sea (Sleptsov, 1961a, 1961b). The population(s) reportedly migrates into the Bering Sea in spring, where the animals remain until September. During this season they probably reach their northernmost limits. True (1910) described specimens collected from St. George Island, Pribilofs in June and August, and Hanna (1920) reported on a specimen stranded in July on St. Matthew Island. Tomilin (1967) and Sleptsov (1961a, 1961b) stated that the species occurred in the western Bering Sea as far north as Olyutorskiy Bay, rarely to Cape Navarin. There are, in fact, few published records of the species' occurrence alive in the Bering Sea, except for near the Aleutian (Ohsumi, 1982; Kasuya and Ohsumi, 1983) and Commander islands (Barabash-Nikiforov, 1938). Sleptsov (1961a, 1961b) speculated that Baird's beaked whales possibly enter the Chukchi Sea, though he presented no evidence to support his speculation and we are aware of no confirmed records of this species from that far north. Given Baird's beaked whale's apparent preference for pelagic waters, such penetrations into shallow waters by healthy animals are not likely to occur routinely.

The twelve known specimens of this species found in Alaskan waters are summarized in Table 13, and locations of those within or near the study area are shown in Figure 49. Included on that figure is the location of the only confirmed sighting of Baird's beaked whales made during the present surveys. During a coastal survey on 10 August 1982, 4 whales were seen in block 5 zone 1, off Umnak Island, at 58°27.1'N, 168°56'W. The animals were positively identified from photographs as Baird's beaked whales. The whales, all of which were approximately the same length, were in a tight cluster swimming slowly westward. The whales were in

Table 13. Specimen records of Berardius bairdi from Alaska.

Number	Date	Location	Sex	Length	Specimen Number	Specimen	Source of Data	Remarks
1*	16 Jun 1903	St. George Island, Pribilofs	F	?	USNM 49726	USNM	True, 1910	Collected by J. Judge, complete skeletons
2*	16 Jun 1903	" " "	M	?	USNM 49726	"	" "	Specimen probably not preserved
3*	21 Aug 1909	" " "	F	?	-	-	" "	Reported by Maj. Ezra W. Clarke.
4*	Jul 1916	St. Matthew Is.	?	?	?	?	Hanna, 1920	Periotic bone only was preserved
5*	1948	Unalaska Island	?	?	USNM 276366	USNM	Scheffer, 1949	Skull only recovered
6	1956	Dry Bay	?	?		-	USNM File # STR02449	Reported by Peter Tack
7*	15 Aug 1977	Dutch Harbor	F	?		-	USNM File # SEAN2329	
8*	24 Apr 1978	Sitkadilik Island	M	?		-	USNM File # STR02369	Reported by G. Sanger
9*	15 Nov 1978	Cataract Cove, Unimak Island	?	?	NMML 9	NMML	D. Rugh, pers. comm.	
10	14 Jul 1979	Niziki Island, Semichi Islands	?	?	-	-	USFWS Adak	
11	25 Jul 1979	Buldir Island, Aleutians	M	?	-	-	USNM File #STR02387	
12	7 Sep 1979	Bering Sea 55°02'N, 167°46'W	?	?	NMML 10	NMML	Joe Munson, pers. comm.	Skull recovered in trawl net
13	? Jul 1983	Egegik Lagoon, Bristol Bay	?	?	-	-	Leatherwood, pers. observations	Identified from drawings, descriptions by ADF and G personnel, King Salmon and Dillingham. Specimen not seen

* = Occurrence within or near study area, plotted on Fig. 47.
USNM = U.S. National Museum, Smithsonian Institute, Washington, D.C.
NMML = National Marine Mammal Laboratory, Seattle, WA.
USFWS = U.S. Fish and Wildlife Service

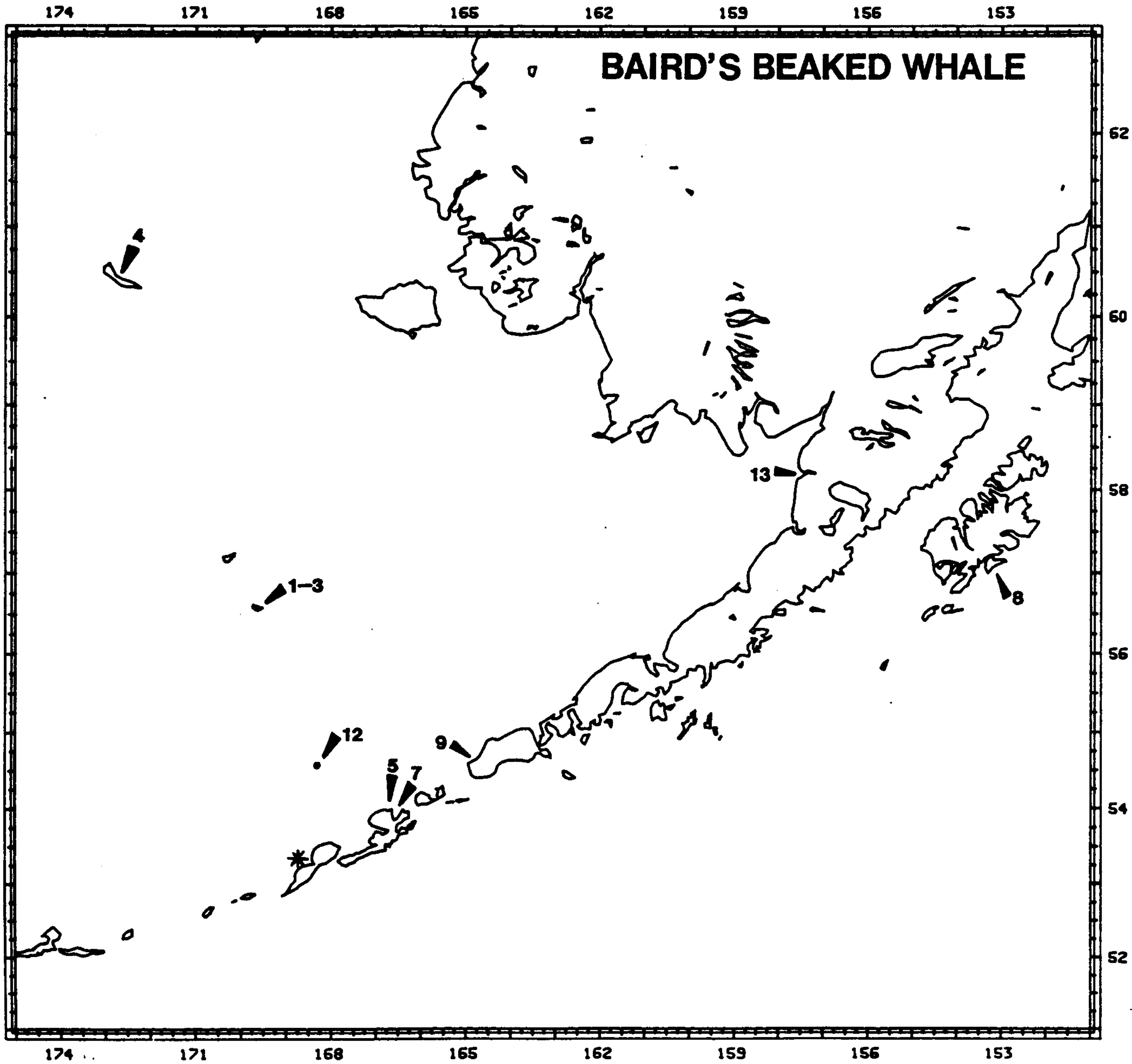


Figure 49. Locations of known specimen records of **Berardius bairdii** in and near the study areas. The numbers correspond to those in Table 12, in which all known Alaskan specimen records are summarized. (Entries 10 and 11 from Table 12 are not shown as they are west of the study area.) The (*) indicates the single sighting of the species during the present surveys.

water 360 fathoms (658.8 m) deep, but were along the steep shelf where depths drop to over 1000 fathoms (1830 m) within about 2nm (3.7 km).

Cuvier's Beaked Whale (Ziphius cavirostris)

Cuvier's beaked whale, the most nearly cosmopolitan of the beaked whales, is widely but sparsely distributed throughout the tropical and temperate oceans of the world (Norman and Fraser, 1949; Rice, 1977). It is considered the most widely distributed and frequently sighted beaked whale in Alaskan waters (Rice, 1978e), although knowledge of its distribution is based primarily on stranding records (Mitchell, 1968). Its known occurrences in the Bering Sea are largely limited to waters near the Aleutian Islands. The only specimen from north of that area (USNM 504912) was found stranded on St. Matthew Island in July 1916 (Table 14). There were no sightings during our surveys. We know of only one sighting reported from any other recent surveys. In the North Aleutian basin report (SAI, 1983, Figure 19.4) there is a symbol at approx. 56°N, 165°W indicating a sighting of a "Goosebeak whale". The sighting whale, Berardius bairdii, Cuvier's beaked whale, Ziphius cavirostris, is attributed to Braham (pers. comm.) but is presented with no explanation or supporting evidence. In the accompanying text it is noted "Sightings of... goosebeak whales were rare." C. Fiscus (cited in Lowry et al., 1982b) regarded Cuvier's beaked whales as rare in the Bering Sea and more common in the North Pacific Ocean south of the Aleutians.

All known Alaskan strandings of Cuvier's beaked whales are listed in Table 14. Those from in or near the present study areas are shown in Figure 50. Two specimens reported by Kenyon (1961) from Amchitka Island had been killed by gunshot wounds. There are no published accounts

Table 14. Specimen records of Ziphius cavirostris from Alaska.

Number	Date	Location	Sex	Length	Specimen Number	Specimen Location	Source	Remarks
1	? Sep 1904	Kiska Harbor,	?	?	-	-	True, 1910	Identified by photos (on file USNM 142579)
2*	12 Jul 1916	St. Matthew Island	?	?	USNM 504912	-	" "	
3	9 Jul 1917	Yakutat	?	?	USNM 219333	-	" "	
4	? ? 194?	"Alaska"	?	?	USNM 507319	-	" "	
5*	6 June 1947	Samalga Island	M	?	USNM 276022	?	Scheffer, 1949	Parts of skull
6	12 Jun 1956	Middleton Island	M	?	USNM 304959	-	USNM File	
7	26 Mar 1959	Amchitka Island	F	657.9	USNM 288019	-	Kenyon, 1961	Weight = 2717 Kg.
8	23 Apr 1959	Amchitka Island	M	543.5	USNM 288020	-	" "	
9	20 Feb 1962	Amchitka Island	?	?	?	?	Mitchell, 1968	Two teeth only, Rice, unpub.
10*	7 Jun 1968	Akun Island	?	?	-	-	Fiscus, et. al., 1969	
11	7 Feb 1975	Cape Yakataga	M	?	USNM 504294	-	USNM File	
12	29 Jun 1975	Nizki Island, near islands	?	?	-	-	USNM File# STR02422	
13	16 Jun 1976	Agatha Island	?	?	-	-	USNM File # STR02439	Reported by Pete Mickelson
14	? Jul 1976	Wooded Island, Prince William Sound	?	?	-	-	Hall et al. 1977	Specimen not recovered. Reported by C. S. Harrison.

15*	23 Apr 1977	Shumagin Islands	?	?	-	-	USNM File #STRO2084A	Specimen apparently not recorded
16*	18 May 1977	Atka Island	?	-	-	-	USNM File #SEAN 2274	
17*	5 Jul 1977	Cold Bay, Alaska Peninsula	?	116"	USNM 504732	USNM	USNM File	Collected by J. Sarvis
18	? Jul 1978	Cape Yakataga, Gulf of Alaska	?	-	-	-	USNM File # SEAN 4402	
19	14 Jul 1979	Niziki Island, Near islands	?	-	USNM 504939	-	USNM file	
20	24 Aug 1979	Amchitka Island	?	-	USNM 504940	-	" "	
21*	2 Jul 1980	Cape Kremitzin, Alaska Peninsula	?	22'	USNM	Izembek Refuge and USNM	J. Sarvis, pers comm.	Two teeth recovered and given to Izembek Refuge, skull to USNM
22	30 Jul 1981	Adak Island	?	?	-	-	USFWS Adak, Files. F. Zeilemaker, pers. comm.	Two individuals
23	31 Jul 1981	Adak Island	?	?	-	-	" "	Two individuals
24	8 Aug 1981	Adak Island	?	-	-	-	" "	
25	21 Aug 1981	Adak Island	?	-	-	-	" "	

* = Occurrence within or near study area, plotted on Fig. 50.

USNM = U.S. National Museum, Smithsonian Institute, Washington, D.C.

Table 14 (continued). Specimen records of _Ziphius cavirostris_ from Alaska.

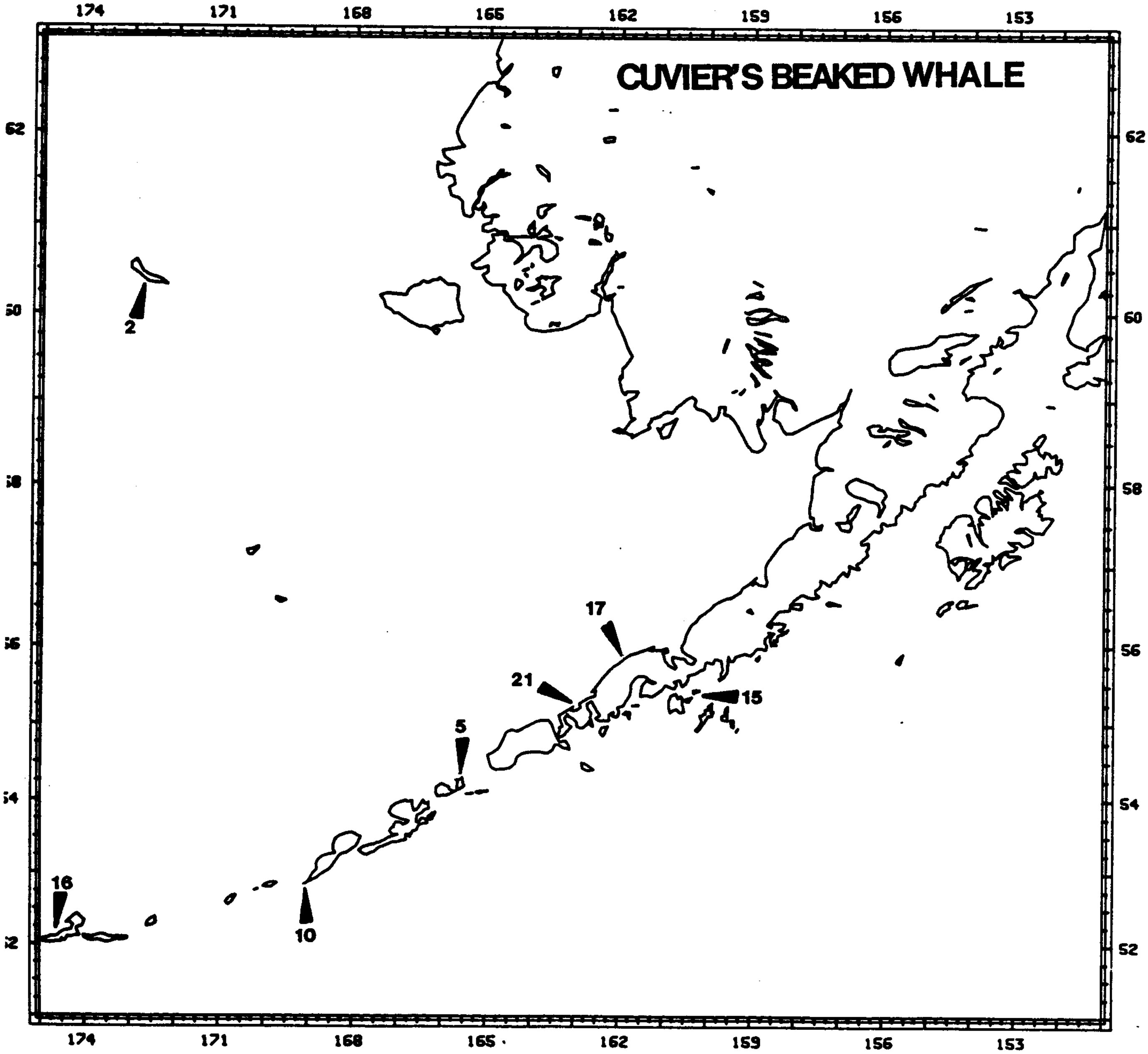


Figure 50. Locations of specimen records of Ziphius cavirostrus in and near the study area. The numbers correspond to those in Table 14, in which all known Alaskan records are summarized.

of aboriginal hunting, incidental capture, or fishery interactions involving this species in Alaska.

Stejneger's Beaked Whale (Mesoplodon stejnegeri)

Stejneger's beaked whale (also called the Bering Sea beaked whale by some authors) is the only representative of the genus Mesoplodon that has been positively identified from Alaskan waters. Like other mesoplodonts, it is difficult to detect and identify at sea. Skull examination is often necessary for positive identification of specimens, although adult males may be identifiable to species based on the position and other characteristics of the erupted teeth. Living Stejneger's beaked whales have rarely been sighted, identified and reported alive, and they are known almost exclusively from strandings (Loughlin, Fiscus, Johnson and Rugh, 1982b; Lowry et al., 1982b; Leatherwood et al., 1982c). We can account for at least 25 strandings of 31 individuals in Alaska from 1927 through 1981 (Table 15, Figure 51). Of those, 9 strandings involving 14 animals have been discovered at Adak Island (F. Zeillemaker, pers. comm., 1982). All reported strandings have been discovered between April and November.

Laughlin et al. (1982) report seeing 7 groups containing a maximum total of 52 animals near the Andreanof Islands, in the central Aleutians, in the summer of 1979. Like specimen recoveries, sightings have occurred in other than winter months, though this can be as easily attributed to patterns of effort as to seasonal patterns of distribution.

During the present surveys, we made five sightings of beaked whales. One was a Baird's beaked whale; none were Cuvier's beaked whales. Therefore, the 4 groups not attributable to either of the readily identifiable species

Table 15. Specimen records of *Mesoplodon stejnegeri* from Alaska.

Number	Date	Location	Sex	Length (cm)	Specimen Number	Specimen Location	Source of Data	Remarks
1	15 Aug.1927	Egg Is., Prince William Sound	M	?	USNM 252497	USNM	Orr, 1953; Moore 1963	Mandible of imm. males.
2	? ? 1938	Ilak Island	?	?	-	-	USNM file # STRO 2433	Presumably this species, photos on file, USNM.
3	12 Nov.1947	Amchitka Island	?	?	?	?	Scheffer, 1949	Tooth only saved by E. C. Hanson
4*	7 Sep.1951	St. Paul Island, Pribilofs	?	442	USNM 286826	USNM	Jellison, 1953	Skull without mandibles and some other bones preserved, photos of carcass in Jellison, 1953.
5*	Before 1957	Nushagak Penins.	M	?	UA4778	?	Moore, 1963	Skull without mandible
6*	11 May 1960	Kasilof River Kenai, Peninsula	F	?	AMNH 185311	?	Moore, 1963	Skeleton.
7	20 May 1968	W. of Cape Edgecumbe	M	360-470	NMML 1	NMML	T. Loughlin, pers. comm.	Correct location of floating carcass Fiscus, et al., 1969 57°04'N, 136°32'W (T. Laughlin, pers. comm).
8	No date	"Aleutian waters"	M	?	?	?	USNM File #STRO 1287	Tooth only
9	? Jul. 1972	Adak Island	?	?	-	-	USNM File #STRO 2474	Reported by E. D. Ash
10	17 Jul.1975	Adak Island	M,M F	455,460 490,	USNM 504329-30-31	-	USNM File	Three individuals
11	14 Apr.1976	Adak Island	F?	?	USNM 504345-6	-	USNM File	Two individuals
12	15 Apr.1976	Adak Island	F	?	-	-	USNM File Sean 1086	Probably same two as above

13	6 May 1977	Adak Island	?	?	-	-	USFWS Adak, F. Zeillemaker. pers. comm.	
14*	19 Jun.1977	Moffett Point AK Peninsula	M	499	USNM 504731	USNM	USNM File	Reported by F. Fay. Entire skeleton in USNM
15*	13 Sep.1977	Sand Point, Shunagin Island	F	525	?	?	USNM File # SEAN 2384	Reported by A. Wolman
16*	13 Nov.1977	Homer Spit, Kenai Pensinsula	M	525	?	Pratt Museum Homer	Rearden, ed., 1981	Photos also in Mead, et al., 1982, Fig. 1, P.3., and Reardon, ed., 1981.
17*	23 Nov.1978	Newman Island, AK, Peninsula	M	530	USNM 504865	USNM	USNM File	Reported by J. Sarvis, skull and stomach in USNM
18	3 May 1979	Adak Island	?	?	USNM 504905	USNM	USNM File	Collector unknown
19	29 Jun.1979	Tanaga Island	M,M	468 505	NML BDM 618,619	NMML	Loughlin, et al. 1982	Two individuals
20	1 Jul. 1979	Amchitka Island	?	?	USNM 504882	USNM	USNM File	Reported by T. J. Early
21	28 Jul.1980	Adak Island	M,M	389 ??	USNM 550013	USNM	USNM File	Three individuals
22*	30 Oct.1980	Kenai Rur, Kenai Peninsula	F	500 est	?	Pratt Museum, Homer	Rearden, ed., 1981	
23	16 Jul.1981	Adak Island	?	?	-	-	FWS Adak, pers. comm.	
24	18 Jul.1981	Adak Island	F?	?			" "	S33 USNM File # SEAN 6497
25	4 Aug.1981	Adak Island	?	?	-	-	" "	

* = Occurrence within or near study area, plotted on Fig. 51.
USNM = U.S. National Museum, Smithsonian.
NMML = National Marine Mammal Laboratory, Seattle, WA.
SEAN = Scientific Event Alert Network
USFWS = United States Fish and Wildlife Service

Table 15 (continued). Specimen records of *Mesoplodon stejnegeri* from Alaska.

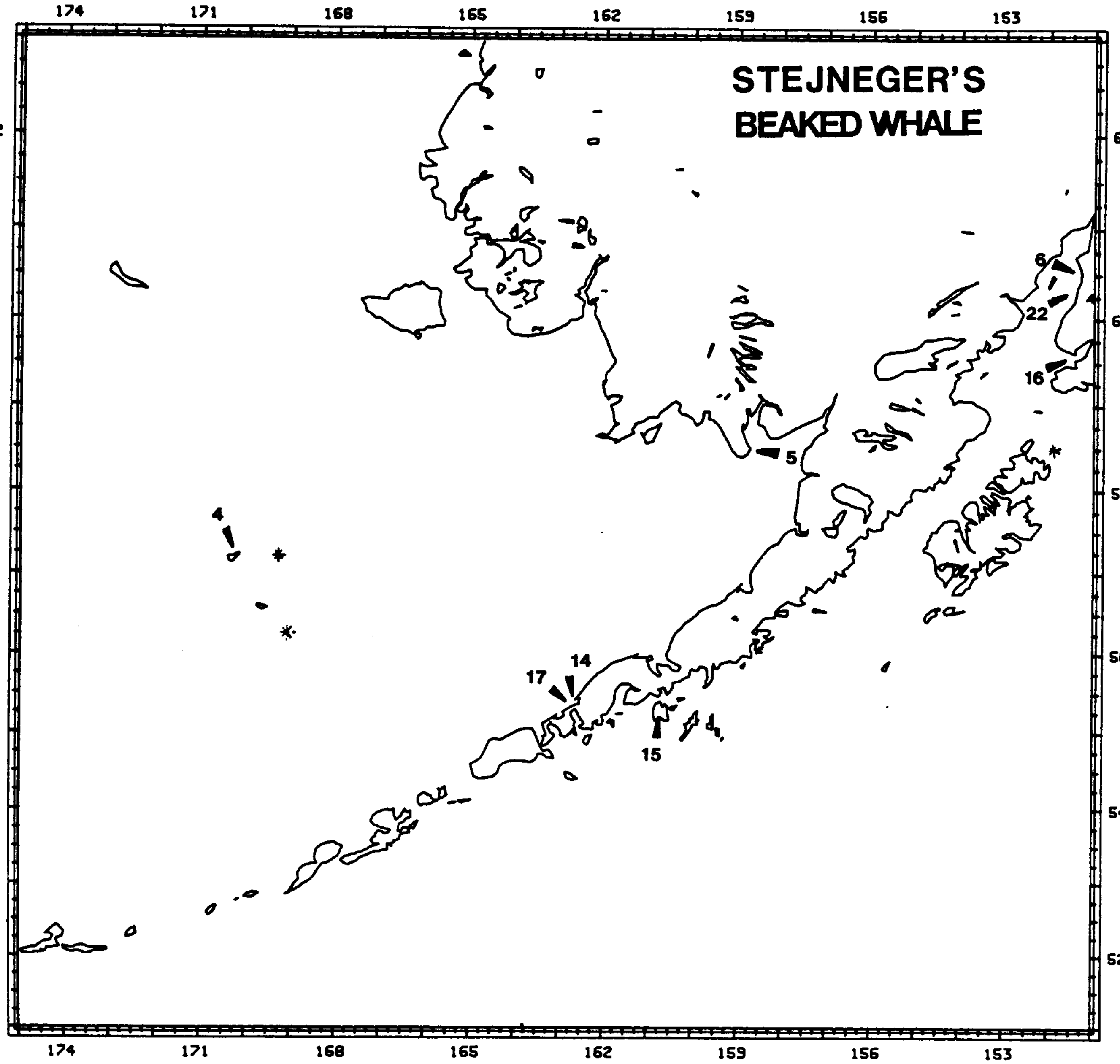


Figure 51. Locations of specimen records of Mesoplodon stejnegeri in and near the study area. The numbers correspond to those in Table 15, in which all known Alaskan records are summarized. The symbols (*) indicate locations of sightings of mesoplodonts made during the present surveys thought because of location to be this species.

were probably mesoplodonts which, because of their locations, we regard as Stejneger's beaked whales:

1) 30 March 1982 - During a connecting leg in block 4, zone 2, 2 whales were seen, apparently feeding, in the wake of a Japanese trawler at 56°59.5'N, 169°04'W, between St. Paul and St. George islands, Pribilofs. The animals were traveling slowly west remaining in the boil behind the vessel. Water depth at the location was about 100 fathoms (183 m).

2) 5 August 1982 - While returning to Kodiak from surveys in block 7, we encountered two unidentified medium-sized cetaceans in a protected bay at ca. 57°48.9°N, 153°21.1'W. After discussions, observers onboard agreed the animals were most probably beaked whales. The animals were in close proximity to an adult fin whale and its associated calf, but while the fin whales were moving into the bay the beaked whales were swimming northwestward, out of the bay. Water depth at the sighting location was about 60 fathoms (109.8 m).

3) 10 September 1982 - During a transit, 3 whales were seen near 2 fin whales and 2 humpback whales along a tidal rip east of Marmot Island, at 58°27.1'N, 151°52.0'W. Leatherwood identified them as beaked whales. One of the whales surfaced at a steep angle, briefly exposing the beak and part of the head. After 2-3 blows by each whale the group sounded. Water depth at the location was about 100 fathoms (182 m).

4) 16 January 1983 - On a transect in block 4, zone 2, we sighted 3 whales traveling on a heading of 280° in 1100 fathoms of water at 55°59.9'N, 169°29.0'W.

From the frequency of reported strandings and sightings during this and other investigations, Stejneger's beaked whales appear to be far from rare, at least seasonally, in and near both study areas. Their presence in protected inshore and shallow areas was surprising, as mesoplodonts are generally regarded as pelagic creatures. The only other point of interest raised by the data assembled here is that in one instance the whales were apparently feeding in association with a trawler. Such an association raises the possibility that the Stejneger's beaked whales may become entangled in gear, as do some other species so associated, and die incidental to fishing operations.

Killer Whale (Orcinus orca)

Killer whales have been observed in all areas and oceans. The prevalent understanding of their distribution, often recounted, is that while they may be encountered virtually anywhere in marine waters worldwide, they are most abundant in colder waters of both hemispheres, with centers of greatest abundance within about 800 km of continents (Mitchell, ed., 1975b). In some areas they appear to be migratory, while in others they are apparently present year-round. The patterns of distribution and movement worldwide have been reviewed recently (Leatherwood and Dahlheim, 1978; Dahlheim, 1981; Perrin, ed. 1982:617-619). But for most regions, such as southern Alaska, the Bering Sea and arctic Alaska, there are few published details on distribution, abundance, seasonal movement patterns, and habitat use.

Killer whales are known to occur in inland marine waters of southeast Alaska, Prince William Sound, and Cook Inlet (Braham and Dahlheim, 1982; Hall, 1981; Leatherwood et al., in press) and in northern waters of the Gulf of Alaska (Scammon, 1874; Ohsumi, Masaki and Wada; 1976), particularly over the continental slope and shelf (Fiscus et al., 1976; Braham and Dahlheim, 1982). There are notable concentrations in Prince William Sound and around Kodiak Island - in both the Cook Inlet and Kodiak Island proposed lease areas (Braham and Dahlheim, 1982: Figure 1; Hall, 1981; present investigations - see below). Gulf of Alaska populations are concentrated in summer in response to salmon migrations. At that season, populations in southeast Alaska, Prince William Sound, and Shelikof Strait have each been estimated to contain well over 100 animals (Hall, 1981; Matkin and Leatherwood, in press; Leatherwood et al., in press). A few from this last population were killed by shore whalers from Port Hobron, Alaska, between 1926 and 1942 (Leatherwood, unpubl. data). Killer whales occur both north and south of the Aleutians, particularly the eastern islands (Kawamura, 1975; Murie, 1959; Braham et al., 1977). Marakov (1967) noted they were the most numerous cetaceans in the Commander Islands, occurring there from March to October simultaneous with approaches of cod and lingcod to the coasts.

North of the Aleutian Islands, killer whales are found widely distributed in the Bering Sea (Tomilin, 1967; Leatherwood and Dahlheim, 1978; Braham and Dahlheim, 1982), north to Diomede Islands (Ivashin and Votrogov, 1982; Nikulin, 1946) into the western Chukchi Sea (Sleptsov, 1961a) and the eastern Chukchi Sea at least as far as Point Barrow and presumably to the ice edge (Scammon, 1874; Bailey and Hendee, 1926; Cook, 1926; Bee and Hall 1956). Leatherwood saw killer whales in 80% floes in the eastern Chukchi Sea in spring and fall 1978, Lowry and Frost (pers. comm., 1983) provided us photos from the western Bering Sea in 1979 of a pod along the pack ice-edge, and on the present surveys we encountered 10 killer whales in 40% coverage of broken ice floes 1 April 1982 at 57°54.8'N; 165°34.7'W, in block 1. L. Lowry (pers. comm., 1 March 1984) provided the following killer whale records: 1 male in 7/16 ice at 57°09.4'N, 172°08.1'W on 17 April 1976; a female and small calf in 3/30 ice at 55°33'N, 166°41'W on 21 March 1976; two animals in 4/22 ice at 60°30.5'N, 174°21.9'W on 24 May 1977; a group consisting of at least 3 large males and 6-8 medium-sized animals at 60°25.9'N, 168°56.3'W on 29 May 1977; and 12 animals including one large male and about 3 calves, at 58°27.9'N, 169°29.1'W on 26 March 1977. At least in summer, killer whales may continue eastward into the Beaufort Sea (Richardson, ed., 1981). On the Soviet side of the Bering Sea killer whales were taken by whalers between 1934 and 1942 but "formed only about 0.5% of the takes by the Aleut" (Vadivasov, 1947, as cited in Tomilin, 1967). A few were taken within ca. 100 nm (185.2 km) of Unimak Pass between 1911 and 1938 by shore whalers operating from Akutan (Morgan 1978: p 36. Figure upper right; Leatherwood, unpublished data). Birkeland (1926: p 22-24) noted that killer whales were found "in large numbers" among the Aleutians, but whalers "have for the most part ignored it."

Specifically within our Bering Sea study area, published data indicate wide distribution but relatively low densities shoreward of the 200 m contour, but higher densities in Unimak Pass, around Unalaska Island and along the 200 m contour northwestward to 60°N (blocks 5, 4 and 3). Greatest concentrations were plotted along the shelf southeast of the Pribilofs in block 4 (Braham and Dahlheim 1982: Figure 1). Except for Unimak Pass there are few records in our areas 1, 2 and 6. These same patterns are shown in the Navarin Basin report (SAI; 1981: Figure 9.2), St. George Basin Synthesis Report (Braham et al., 1982; Braham and Rugh, in preparation; unnumbered figure), and North Aleutian Basin Lease Report (SAI, 1983: Figure 19.4). Similarities presumably result because the basic data for all these accounts was NMFS/POP sightings. Data in Lowry et al. (1982a) and Braham and Dahlheim (1982) indicate intrusions of killer whales in to the eastern Bering Sea and Bristol Bay are most common in summer, presumably associated with migration of salmon and belugas. If true, these above described patterns support the conclusion of Braham et al. (1982) that some killer whales are present in the Bering Sea at all times of the year and that all the proposed lease sale areas within the present study area are important to the species.

During the 8 aerial surveys, we encountered 36 groups (236 individuals) of killer whales, 31(165) in or just adjacent to blocks 1-6, 4(67) in Shelikof Strait, and 1(4) on the southern tip of Kodiak Island (Figures 52 and 53; Tables 7 and 9). Two additional sightings (6 whales) were made west of 174°W on a transit along the Aleutians on 13 May 1982. The distribution of those sightings by season is shown in Figure 54 a-d. In blocks 1-6 killer whales were encountered on all surveys except in February; numbers appeared to peak in spring and decline slightly thereafter (Figure 55). In block 7 there were sightings from aircraft only during the summer (July) survey (Figure 56), though we saw animals from shore at other seasons and learned from interviews with fishermen that the whales were present around the island year-round (see Leatherwood et al., in press). The low sighting frequency in block 7 likely relates to the low coverage in the Strait (1 day per survey, across the depth gradient) and the seasonal concentrations of killer whales in convoluted embayments not surveyed because the steep cliffs along their shore made flying unsafe.

Most whales seen (28 of 35 for which behavior was recorded) were traveling. The only certain feeding was by a large group (65) seen feeding on salmon in the shallows of Viekoda Bay, Kodiak Island, in summer 1982. In other instances groups were milling and probably feeding; they were fluking and diving out of sight, but no prey were seen.

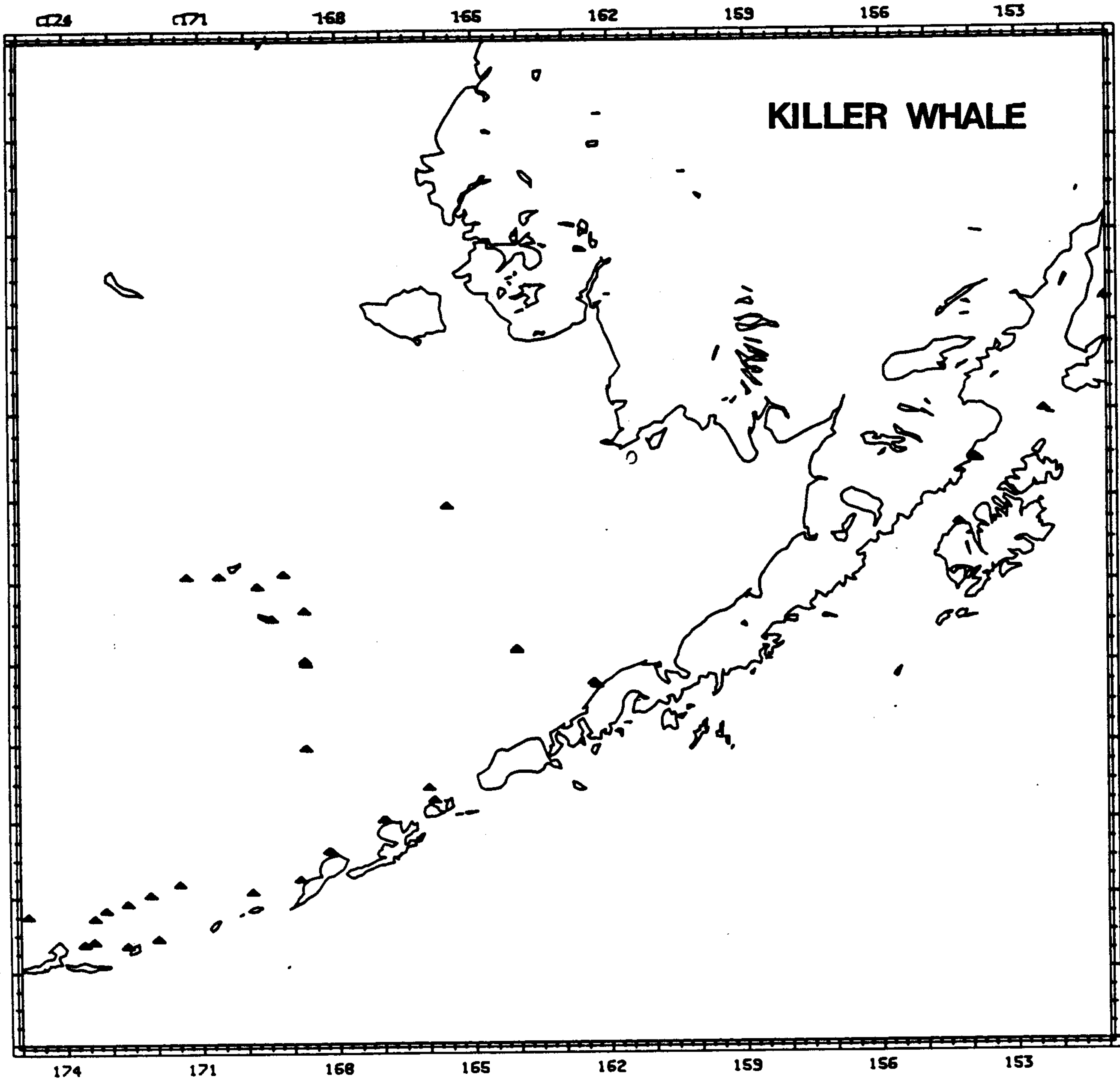


Figure 52. Distribution of all sightings of killer whales.

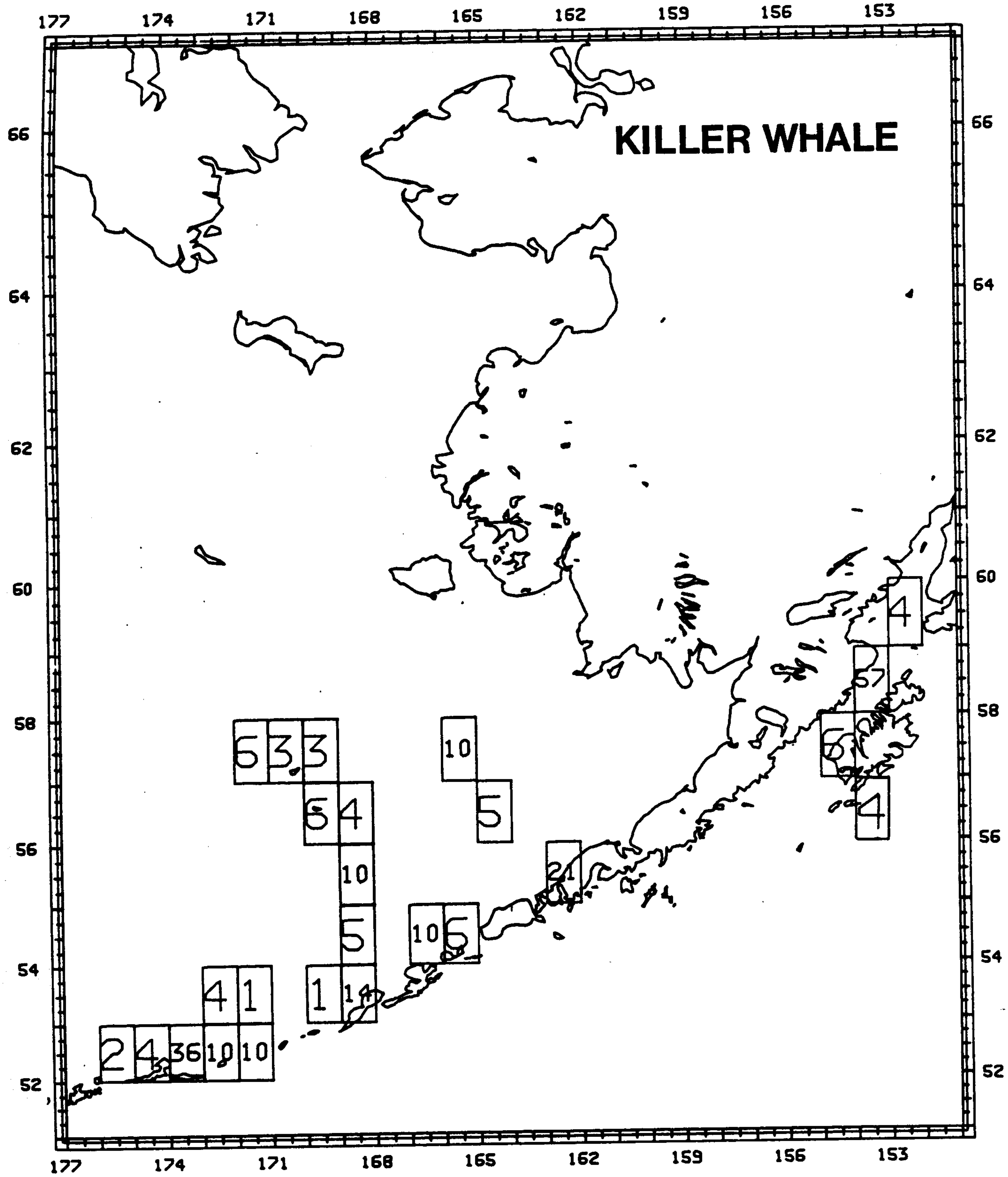


Figure 53. Total number of killer whales seen by 1° block.

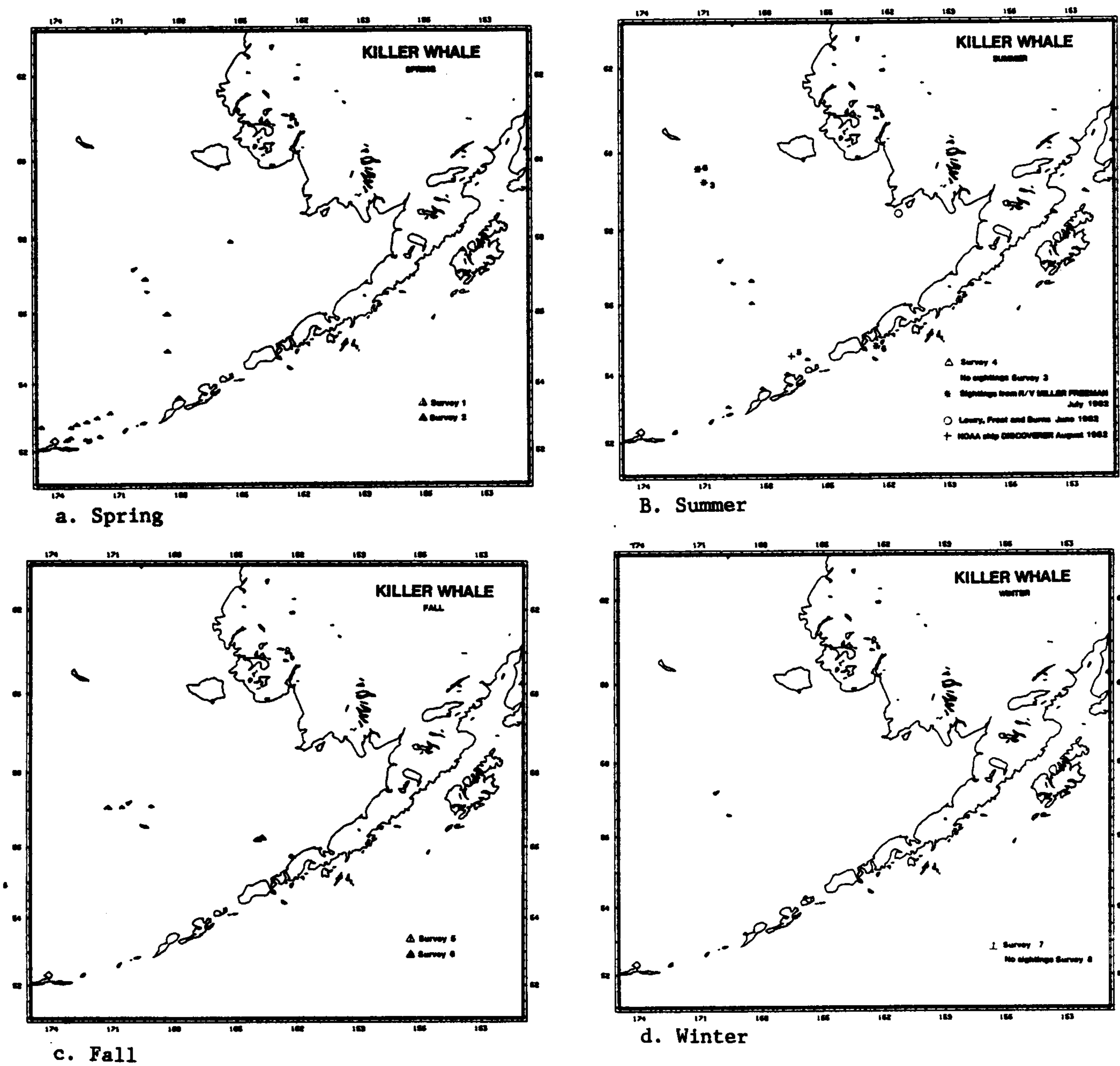


Figure 54. Distribution of sightings of killer whales in spring (a), summer (b), fall (c) and winter (d).

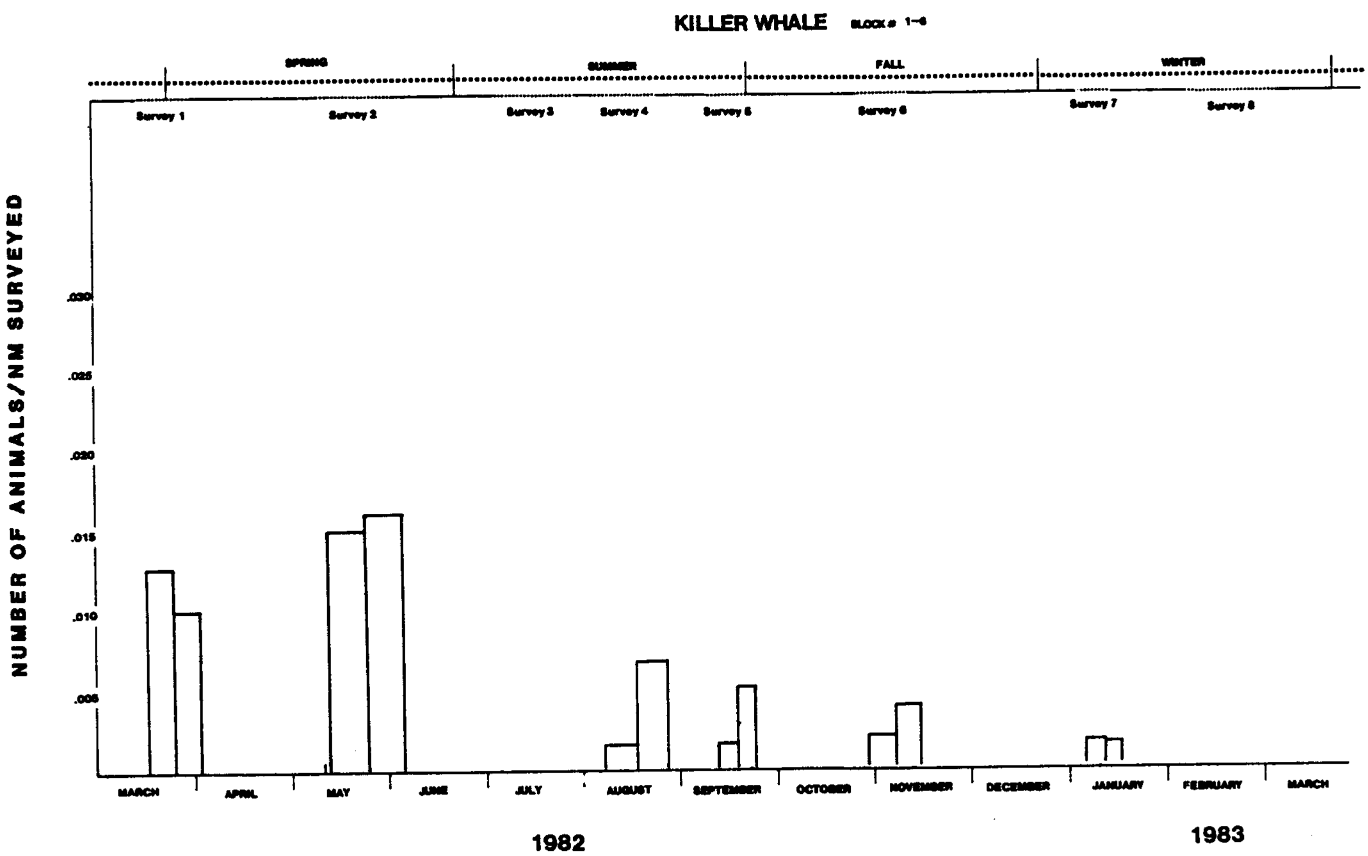


Figure 55. Indices of abundance of killer whales by survey in blocks 1-6.

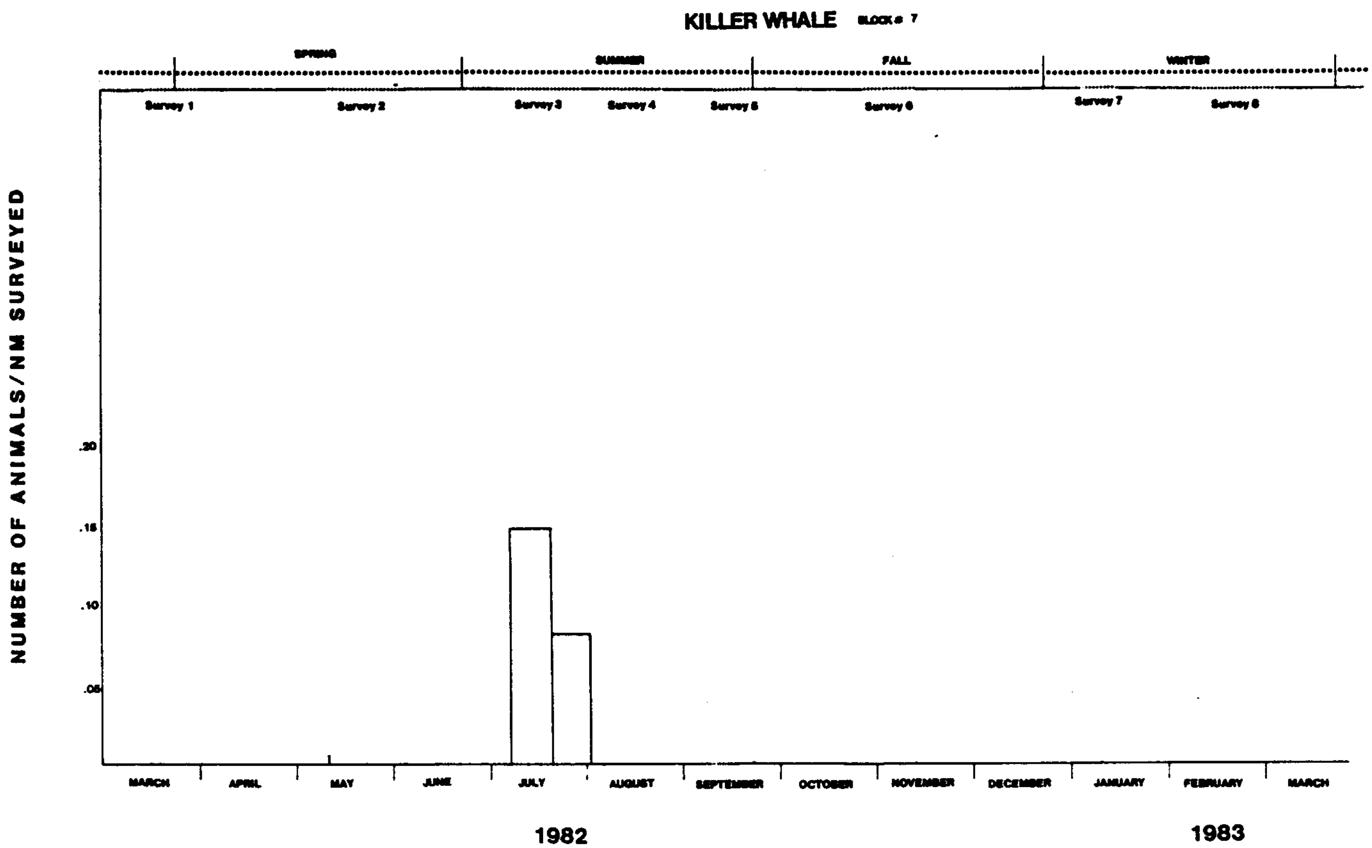


Figure 56. Indices of abundance of killer whales by survey in block 7.

The whales were generally distributed along the continental slope (Figure 57), but many were found on the shelf and in shallow bays in summer in Shelikof Strait. The distribution relative to depth appears to be different from that shown by Braham and Dahlheim (1982) who reported the majority of the animals as occurring along or shoreward of the 200 m (100 fathom) contour. They suspected such distribution was related to effort, the majority of the reported sightings having derived from Pelagic Fur Seal Investigations which concentrated along the shelf edge. The present figures, corrected for effort, suggest killer whales in studied areas of Alaska use continental shelf, continental slope, and pelagic waters equally.

Killer whale calves-of-the-year, so defined because of behavior and size relative to closely accompanying adults, were seen during surveys 1, 2 and 5, as follows (see Figure 52):

Date	Survey	Location	Block	No. individuals	No. calves	Water depth (fm)
23 Mar 1982	1	52°24.5'N,173°23.5'W	5	17	3	Not noted
19 Mar 1982	1	52°26.3'N,171°58.2'W	N/A	10	1	200
14 May 1982	2	52°54.3'N,172°38.4'W	5	8	2	1155
26 Sept 1982	5	55°44.9'N.162°20.7'W	N/A	6	1	17
26 Sept 1982	5	55°42.5'N,162°17.2'W	NA	15	1	12

Risso's dolphin (*Grampus griseus*)

We did not expect to encounter this tropical to temperate "dolphin" species in either of our study areas. In a review of all Northeast Pacific distribution records available through 1978, Leatherwood et al. (1980) could only document its occurrence as far north and west as 50°N, 145°W. They rejected as unsubstantiated reports by Collins et al.

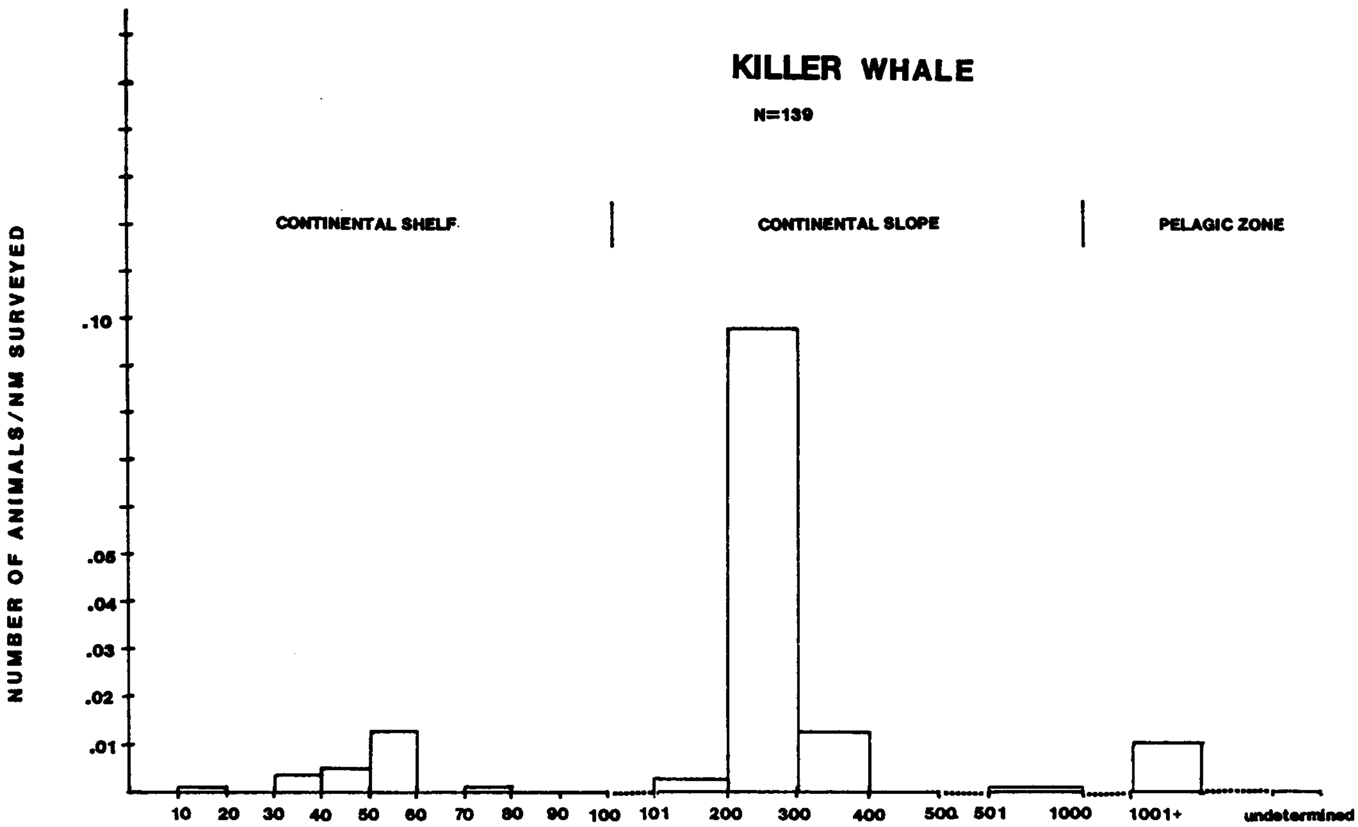


Figure 57. Index of abundance of killer whales by depth class.

(1945), resulting from no original field research or direct observations, that listed Risso's dolphins as occurring around the Aleutian Islands and in the Bering Sea. Tomilin (1967) regarded similar reports by Sleptsov (1952) as unsubstantiated.

Braham (1982) added five records unknown to authors of the former review, two of which are north of 50°N: 2 individuals at 12 March 1976 at 55°44.9'N, 145°56'W and 14 individuals on 27 March 1978 at 54°11'N, 133°01'W (the latter published by Reimchen, 1980). Neither sighting alters significantly the conclusions of Leatherwood et al. (1980) that Risso's dolphins are, at present, known only from mid-temperate waters southward. Therefore, we are puzzled somewhat in the North Aleutian Lease Report (SAI 1983: Figure 19.4) by a symbol at 56°N, 168°W representing a supposed sighting (attributed to Braham, pers. comm.) of a "whitehead grampus" and accompanied by the text note that "sightings of grampus...were rare." As the genus and species for "whitehead grampus" are not reported, we can only assume the symbol and account refer to _Grampus griseus_. The symbol is not coded to month, and no other details of the record are presented. Thus, we cannot assess its validity.

Pilot Whale, _Globicephala_ sp.

We are aware of two or more specimen records of pilot whales from waters off western mainland Alaska. There is a specimen (No. 00218768) in the U.S. National Museum collected on St. George Island, Pribilofs, by G. D. Hanna in November 1917. In the American Museum of Natural History (AMNH) files there are specimens and records of pilot whales collected by personnel from Frick Laboratory at unspecified dates in 1955, 1956 and 1958 at Elephant Point, Eschscholtz Bay, Chukchi Sea, as follows: AM181367, left ramus, no teeth, 1955; AM181369, field number A-714-2299, right ramus, no teeth, 1955; AM181370, field number A-714-2300, right partial ramus, no teeth, 1956; and AM181368, field number A-714-2298, right ramus, no teeth, 1958. We have not examined any of the above; so, we cannot verify identity or, in the case of AMNH records, ascertain duplicate entries.

There are, to our knowledge, no published records of live pilot whales north of the Aleutians. Murie (1959) found no evidence of their presence in the Aleutians. Pilot whales are not included in summaries of species seen in western Alaskan waters during over 20 years of Platforms of Opportunity Program records (Braham and Rugh, in prep.). Science Applications, Inc. has included plots of three sightings of "shortfin pilot whale(s)" in their summary of toothed whales occurring in the North Aleutian Basin (SAI, 1983: Figure 19.4). They are shown as symbols at approx. 57°30'N, 161°20'W, 57°30'N, 161°00'W, and 57°15'N, 159°20'W, all between the 10 and 50m contours. The paper presents no discussion; so, we are unable to evaluate these records. There is one additional sighting (at 54°-48'N, 167°-32'W) logged in the PROBES records as "probable pilot whales." As these 4 records would represent a range extension for the species, we urge that they be published in their entirety so they can be properly assessed. Until then, we regard them as spurious.

There were no sightings of pilot whales during the present investigations. Their occurrence in Shelikof Strait would be somewhat less surprising than in the Bering Sea, as pilot whales are reported to be "present, but not at all common, in the Gulf of Alaska...their movements north of about latitude 40°N are presumably related to incursions of warm water, the extent and timing of which may vary from year to year" (Leatherwood et al., 1982a). Fiscus et al. (1976) did not include pilot whales among the species they encountered or expected to see in the Gulf of Alaska.

Pacific white-sided dolphin (Lagenorhynchus obliquidens)

The patterns of distribution, movements, and abundance of Pacific white-sided dolphins in the Northeast Pacific, inferred from all records - published and unpublished - available through 1979, were reviewed by Leatherwood et al. (1983b). In both reports it was concluded that east of 180°W these gregarious dolphins occur from about 20°N to 61°N (the latter based on a stranding near Valdez, Alaska - Scheffer, 1950), in pelagic waters, over the continental slope and shelf, and in some inland marine waters of Washington, British Columbia, and southeast Alaska. They appear to be continuously distributed across the temperate North Pacific.

In waters near the present study areas their presence has been verified across the Gulf of Alaska and the North Pacific at least as far as Amchitka Island, in the Aleutians (Scheffer and Shipp, 1948; Cowan and Guiguet, 1956; Tomilin, 1967; Consiglieri and Braham, 1982). Apparently, they venture into more northern portions of this range only in warmer water seasons-spring through fall (Leatherwood and Walker, 1982; Consiglieri and Braham, 1982; Leatherwood et al., 1983b). During those seasons they might reasonably be expected to occur, at least occasionally, in or near the Shelikof Strait study area. However, we did not see any during aerial surveys there, nor were we able to confirm any records through interviews with knowledgeable local residents. They are known from around the shores of the Gulf of Alaska to southeastern Kenai Peninsula and waters about 60 nm (111 km) east of Afognak Island, July through October (Leatherwood and Walker, 1982) and 120 nm (222 km) east of Afognak in November (Fiscus et al., 1976). They do not regularly penetrate Prince William Sound (Hall, 1981).

Pacific white-sided dolphins have not been reported reliably as occurring in the Bering Sea even during the warmer water season (Tomilin, 1967; Nishiwaki, 1967; Consiglieri and Braham, 1982; Leatherwood and Walker, 1982; Leatherwood et al., 1983b). We did not see them on the present aerial surveys nor did we obtain any information suggesting they were seen in our Bering Sea study area. There are 9 sightings of "Pacific white-sided dolphin" plotted in the North Aleutian Basin lease area synthesis report (SAI, 1983 in press: Figure 19.4). The sightings, which reportedly occurred from 1957 to mid-1980, were attributed to Braham, pers. comm. We are unable to account for such records as they were not a part of summaries of data from the National Marine Mammal Laboratory, Platforms of Opportunity Program, summarized through 1979 provided to us (L. Jones, March 1980, pers. comm.) and considered in preparation of Leatherwood and Walker (1982) and Leatherwood et al. (1983b), nor were they included in other summaries of the NMFS data bases published or in preparation (Consiglieri and Braham, 1982; Rugh and Braham, in prep. - as cited in Braham et al., 1983) and provided to Leatherwood for review for preparation of this report. There are no details given in the SAI summary, and the substantial range extention represented by these sightings cannot be accepted until the documentary evidence is presented.

Northern Right Whale Dolphin (*Lissodelphis borealis*)

The northern right whale dolphin is sympatric with the Pacific white-sided dolphin, probably occurring continuously across the temperate North Pacific but avoiding colder northern waters. It has not been reported in or near the Shelikof Strait study area (Leatherwood and

Walker, 1979) or in the Bering Sea (Nishiwaki, 1967; Tomilin, 1967), and it was not sighted in either area during the present surveys.

Dall's Porpoise (Phocoenoides dalli)

This North Pacific endemic is the most frequently encountered and probably most abundant small cetacean in the northern North Pacific Ocean. It is distributed widely in cool temperate to subpolar waters from the latitudes of central Baja California on the east and southern Japan on the west north to the central Bering Sea, including the Gulf of Alaska, inland marine waters of Washington, British Columbia and Alaska, the eastern Sea of Japan and the Sea of Okhotsk (Leatherwood et al., 1982a; Nishiwaki, 1967). There are reports of its occurrence through Bering Strait into the southern Chukchi Sea (Braham et al., 1983). Bouchet et al. (1983), using data from various sources, principally fishing and research efforts associated with Japanese high-seas gill net fisheries for salmon, estimated the current population as from 790,000 to 1.73 million animals, depending on the statistical approach applied to the data. A conservative minimum estimate which accounts for biases in the data was 580,000 (NMML, 1981).

Formerly, two species of Phocoenoides were recognized, based primarily on color pattern differences: Dall's porpoise, P. dalli (True) and True's porpoise, P. truei (Andrews). The differences between them were subsequently deemed inadequate to warrant separate specific status (Houck, 1976) and the two coloration types, which have slightly overlapping geographical ranges, are now considered subspecies (see Morejohn, 1978). Little is known about the rare all-black and all-pale color variants which occur (Nishiwaki, 1967; Morejohn, 1978; Hall, 1981).

Kasuya (1978) suggested 3 stocks in the western North Pacific Ocean: 1) off the Pacific coast of Japan, consisting mostly of the True's type but including some Dall's type; 2) offshore in the North Pacific and Bering Sea, consisting exclusively of Dall's type - this stock may overlap with the above stock; and 3) the Okhotsk Sea and the Sea of Japan, composed only of the Dall's type.

The only direct commercial harvest of Dall's porpoise is a traditional coastal harpoon fishery in Japan, with annual landings of about 6,000 animals, predominantly of the True's type (Mitchell, 1975a; Kasuya, 1978).

Dall's porpoises are incidentally killed in the Japanese high-seas and land-based driftnet salmon fishery, which has operated in the North Pacific and Bering Sea since 1952 (Ohsumi, 1975b; Fredin, Major, Bakkala and Tanonaka, 1977). Accurate data on mortality are unavailable, and estimates vary widely within and among years. At the highest levels of fishing effort to date (369 catcher boats), 2,230 to 20,000 porpoise reportedly have been entangled and drowned annually (NMML, 1981). Currently, 173 boats comprise the mothership fleet. The U.S. has issued permits allowing for the take of 5,000 porpoise annually within U.S. territorial waters. Cooperative U.S.-Japanese research begun in 1981 is expected to provide more accurate data on mortality in the mothership fishery (Perrin, ed., 1983). Data on the incidental take in the land-based fishery, and the recently expanded Japanese high-seas driftnet fishery for squid (Court, 1980; 1981), are not yet available. Such data would undoubtedly increase estimates of mortality.

There are few existing records of Dall's porpoises being caught in domestic (U.S.) fisheries (NMML, 1981), though increased uses by U.S. fishermen of various forms of gill nets along the Pacific coast of North America have increased takes of at least coastal species (M. Webber and I. Scipaniak, pers. comm., 1983).

Dall's porpoises feed primarily on small fishes (various species) and cephalopods. Information on stomach contents, morphology, reproductive biology, and behavior was summarized by Morejohn (1978), the NMML (1981) and Lowry et al. (1982b). A vast quantity of biological samples is currently stored at the National Marine Mammal Laboratory in Seattle. When analyzed, this material should dramatically increase knowledge of the biology of this species. Because results of that program are forthcoming, we treat results of the present surveys in only a cursory way.

Overall, we logged 111 sightings, accounting for 330 animals (see Tables 7 and 9 and Figures 58 and 59). Of these, 79 sightings (216 individuals) were seen on-transect, 34 sightings (109 animals) off-transect.

In blocks 1-6, there were 66 sightings involving 166 individuals (Table 7), 45(107) on-transect and 21(59) off-transect. In block 7, there were 45 sightings (164 animals) (Table 9). There were 34(109) on-transect, and 11(55) off-transect. During transits to or from the study areas we logged 3 additional sightings for a total of 18 animals.

The distribution of encounters by seasons is shown in Figure 60. Within the eastern Bering Sea Dall's porpoises appear most restricted in range in spring and most widely distributed in summer, but they are present to near 59°N and well over the shelf in Bristol Bay in fall and winter, as well. They are present at all seasons in block 7. From the data, no clear trends in relative abundance by survey are apparent, though there are sizable peaks in early winter in blocks 1-6 and in spring in block 7 (Figures 61 and 62, respectively).

Sightings with appropriate data were used to calculate density estimates for blocks 1, 2, 3 and 6 combined, 4 and 5 combined and 7 alone (Table 10). The distribution of sighting distances, the fitted generalized

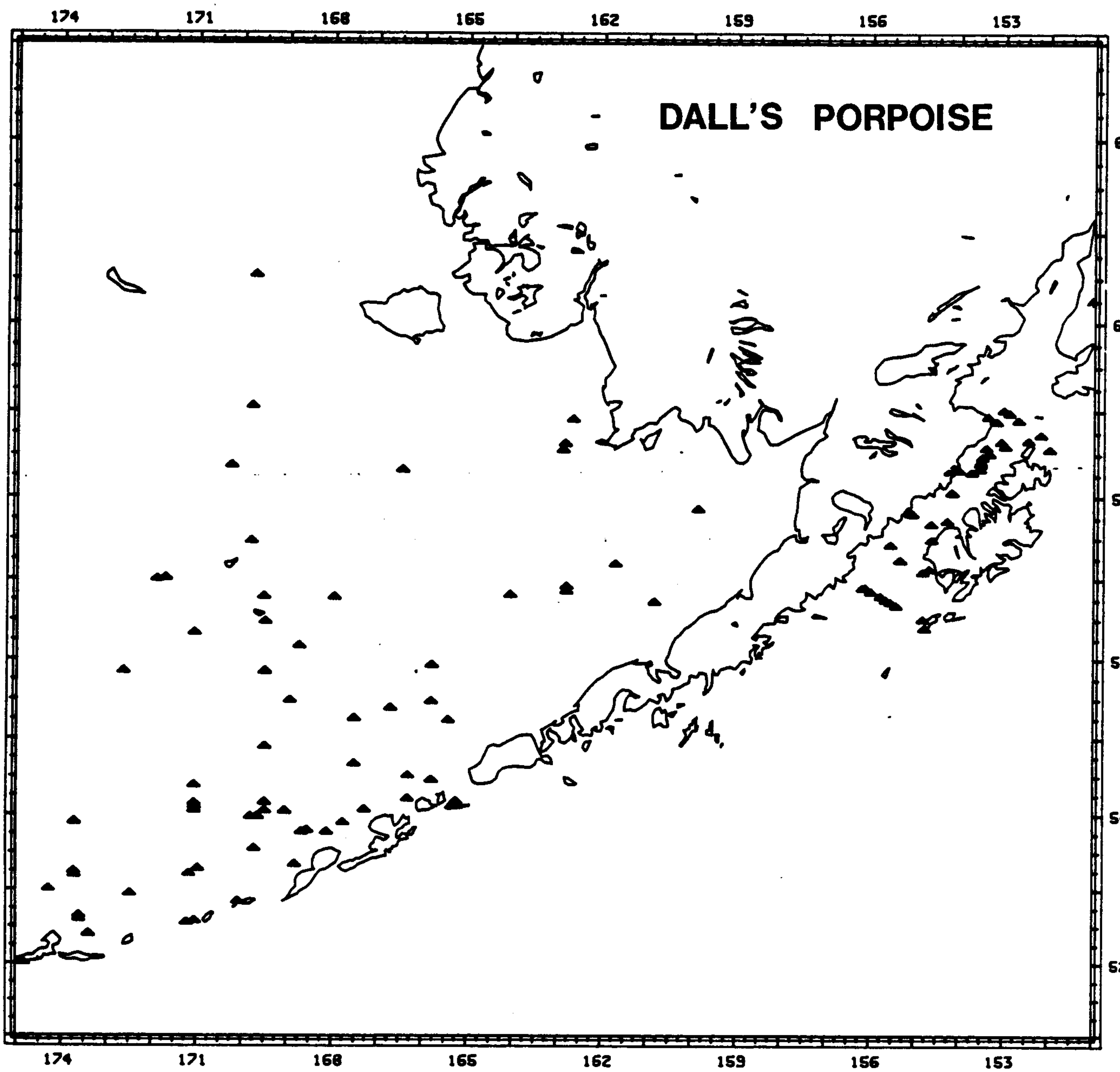


Figure 58. Distribution of all sightings of Dall's porpoises.

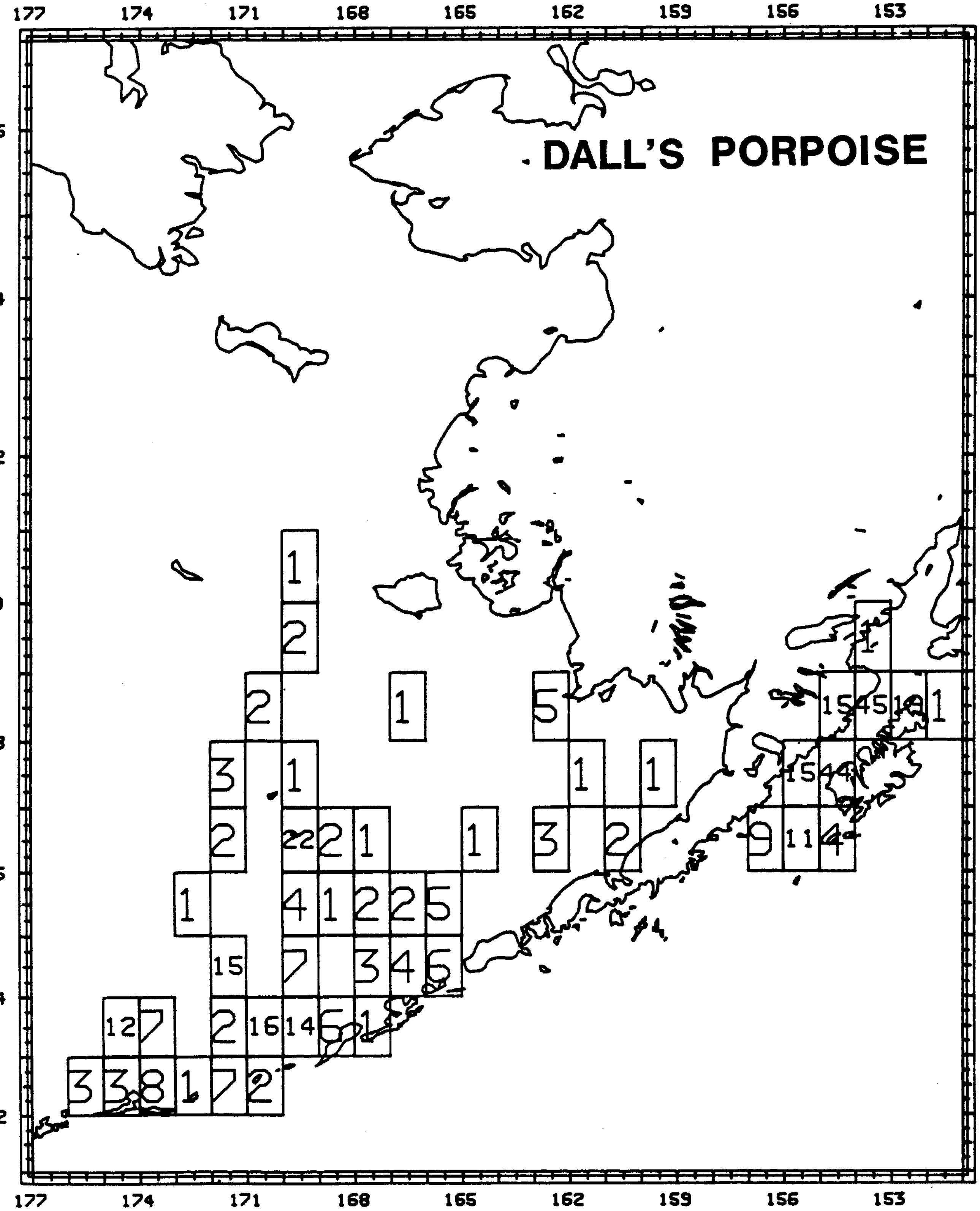
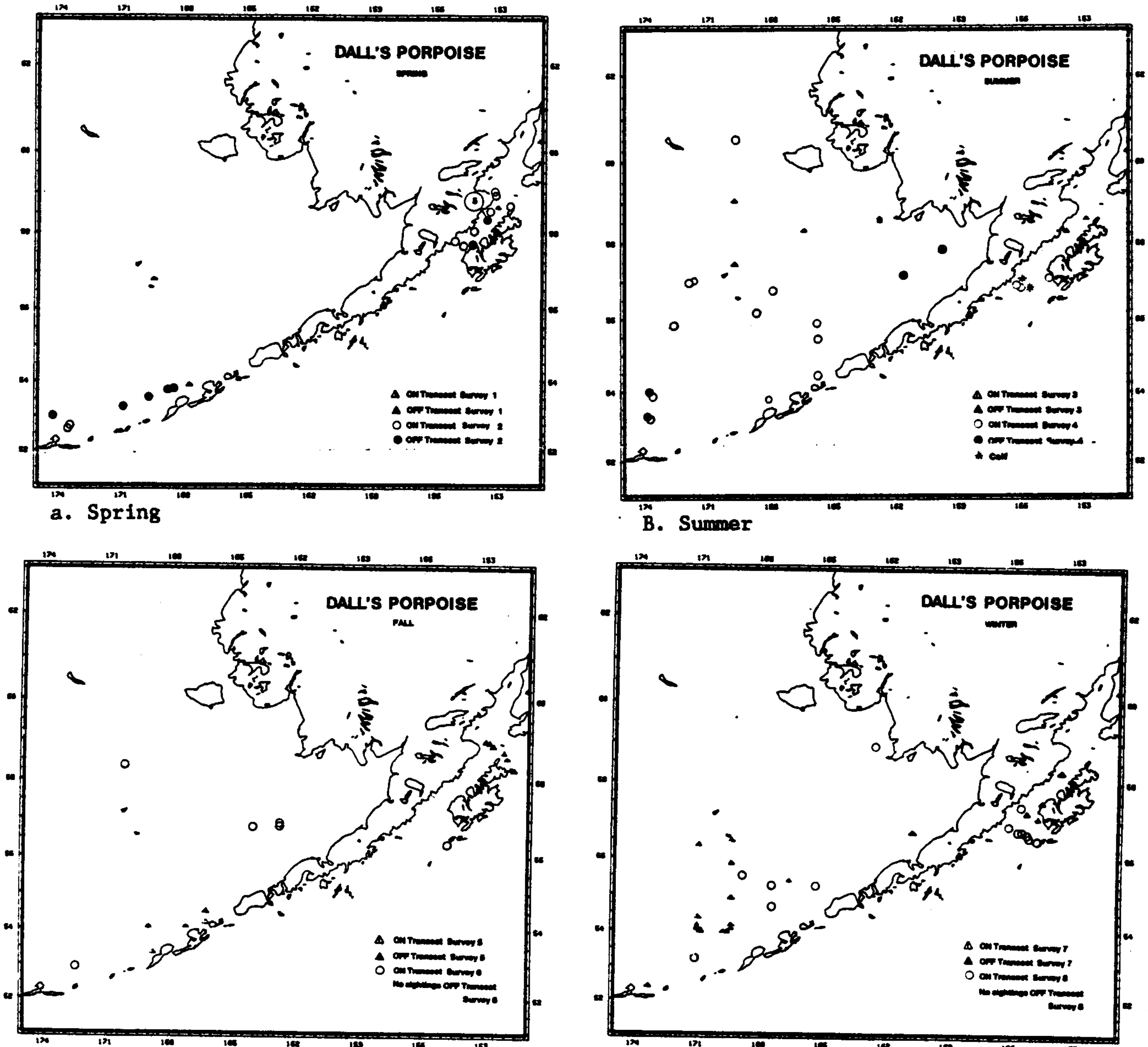


Figure 59. Total number of Dall's porpoise seen by 1° block.



a. Spring

B. Summer

c. Fall

d. Winter

Figure 60. Distribution of sightings of Dall's porpoise in spring (a), summer (b), fall (c), and winter (d).

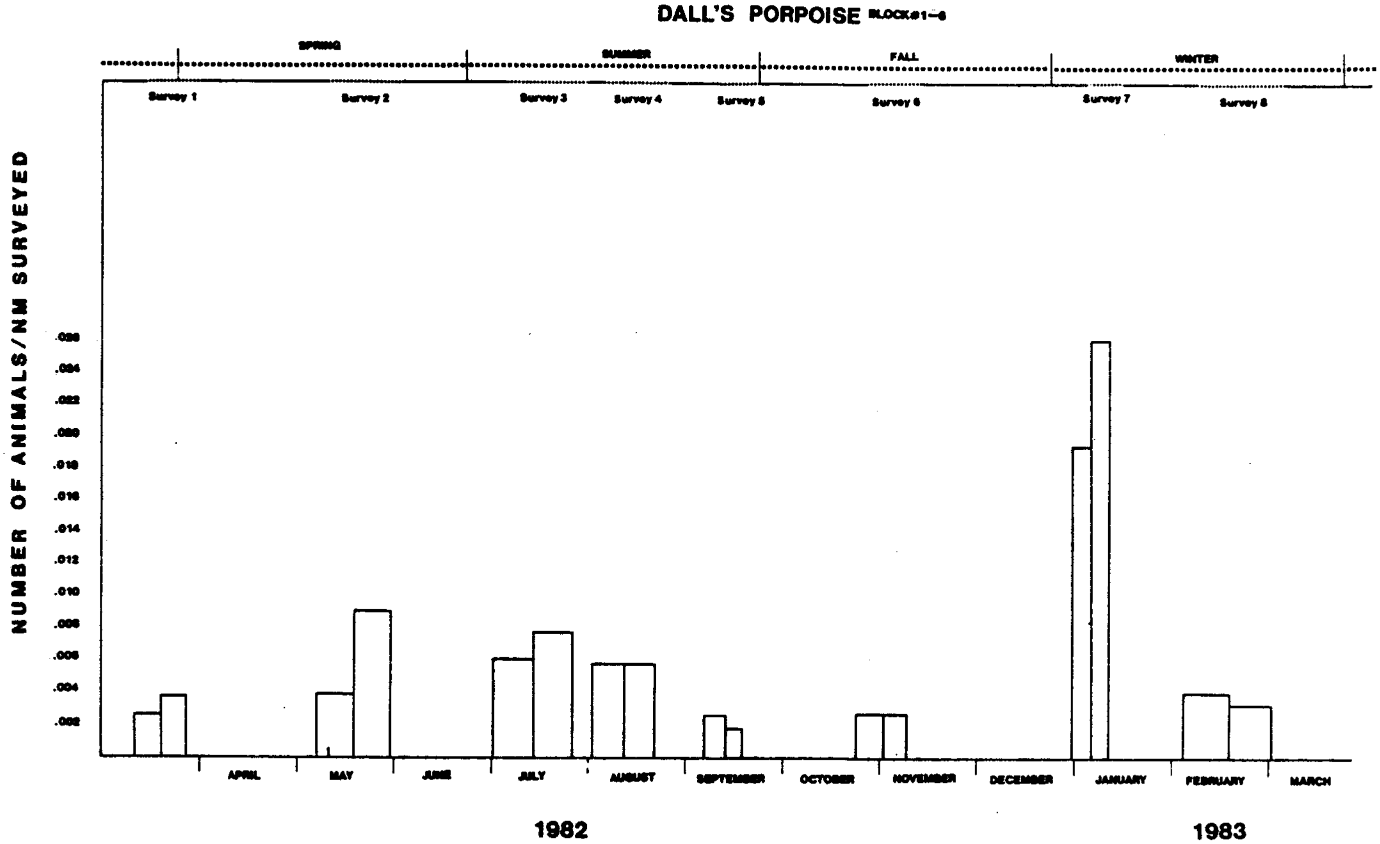


Figure 61. Indices of abundance of Dall's porpoise by survey in blocks 1-6.

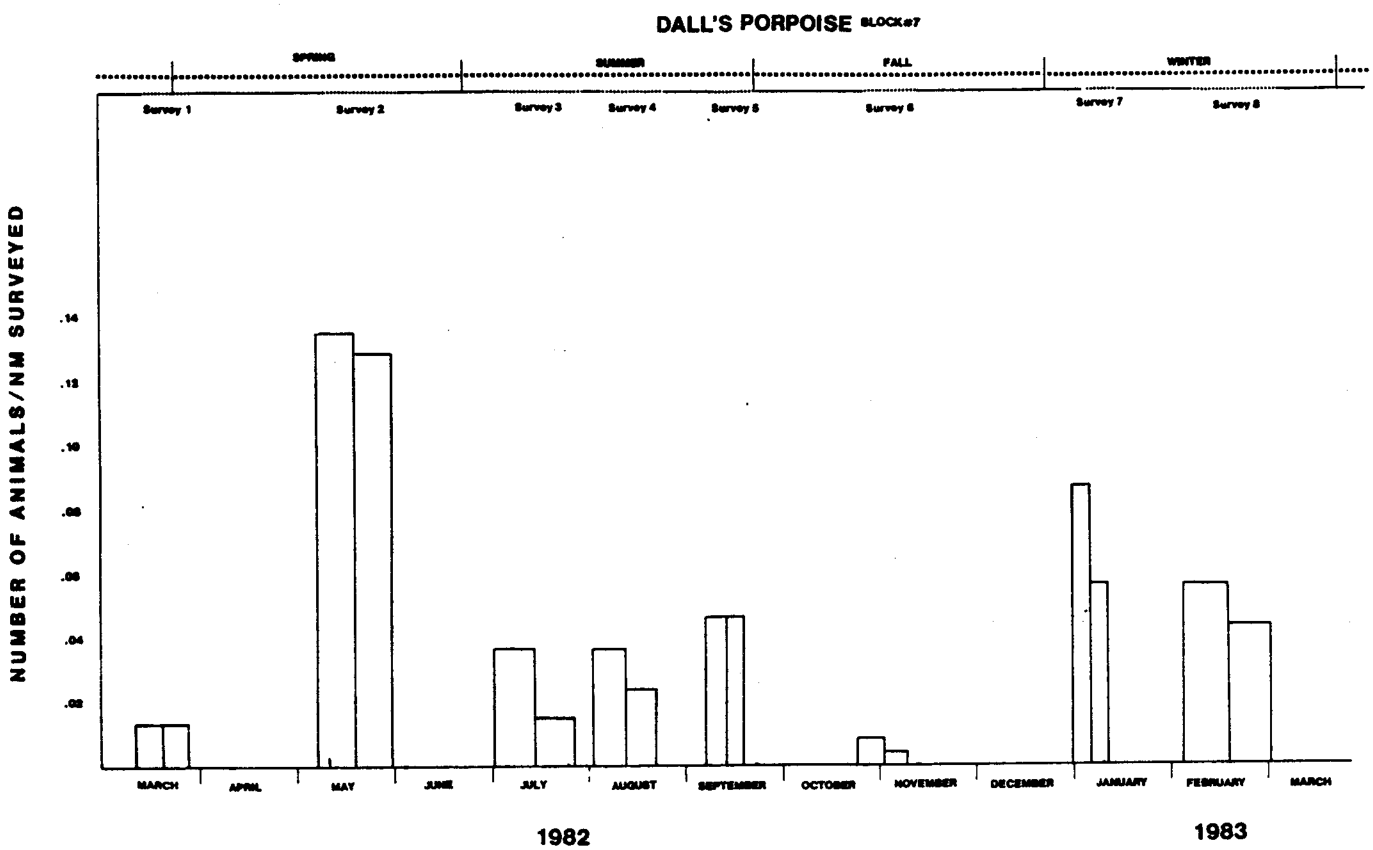


Figure 62. Indices of abundance of Dall's porpoise by survey in block 7.

exponential model, and the distribution of herd sizes used to support those estimates are shown in Figure 63. For the shallower regions in the northern and eastern portions of the Bering Sea study area Dall's porpoises were estimated to occur in densities of 7.912 ± 1.951 individuals/1000nm^2 (3,430 km^2); for more pelagic blocks (4 and 5) the estimates were 97.2 ± 49.5 individuals /1000nm^2 (3,430 km^2); highest densities were those in Shelikof Strait, where there were an estimated 181.4 ± 93.76 individuals/1000nm^2.

Data on distribution by depth are shown in Figure 64. These data tend to support the conclusions of Braham et al. (1983) who suggest (based on 23 years of opportunistic sightings data) that Dall's porpoises are most abundant in deep pelagic water and in areas along the continental shelf break. Our data are particularly conclusive in this regard, given the high densities derived from a relatively small amount of effort in areas characterized by consistently poor conditions for observation.

Harbor Porpoise (*Phocoena phocoena*)

The harbor porpoise is the only representative of its genus which occurs in or near the present study areas. Gaskin (1983) proposed that the harbor porpoises inhabiting the Bering Sea and adjacent Arctic waters be considered provisionally as three subpopulations: 1) those around the Bering Sea coast of Alaska, including the islands of the western shelf, the north coast of Alaska, and the coast of Yukon and Northwest Territories, Canada; 2) those along the Kamchatka coast adjacent to the Bering Sea and the continental shelf area north to Wrangel Island and the summer ice limit; and 3) those along the Aleutian chain to Atka Island. He also proposed that those from the Gulf of Alaska and eastern North Pacific be treated as three stocks, the northernmost of which, and the one of most interest

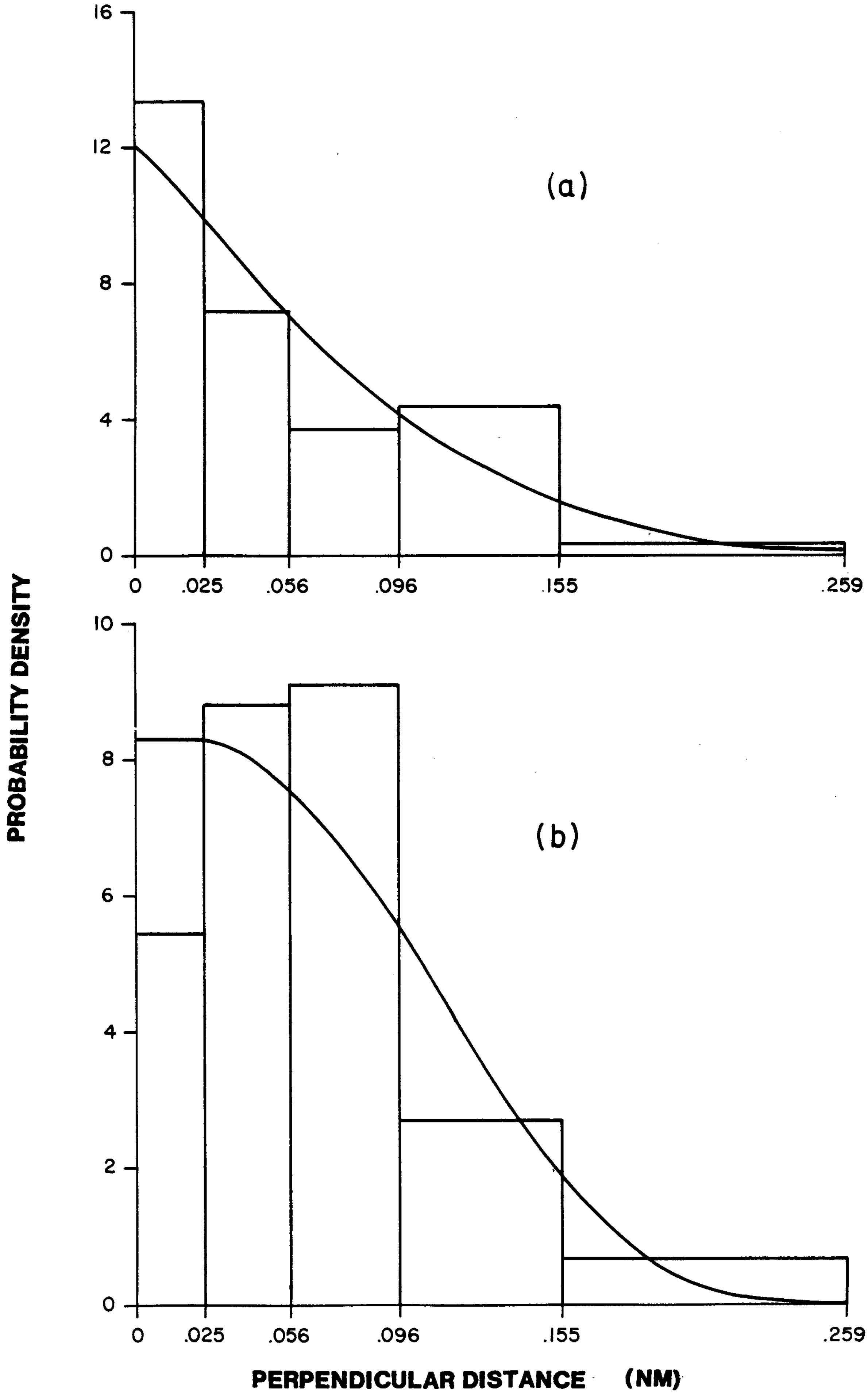


Figure 63. Perpendicular distances truncated under the aircraft at 0.039 nm and the fitted generalized exponential model (a) for blocks 4 and 5 and (b) for blocks 1, 2, 3, 6 and 7

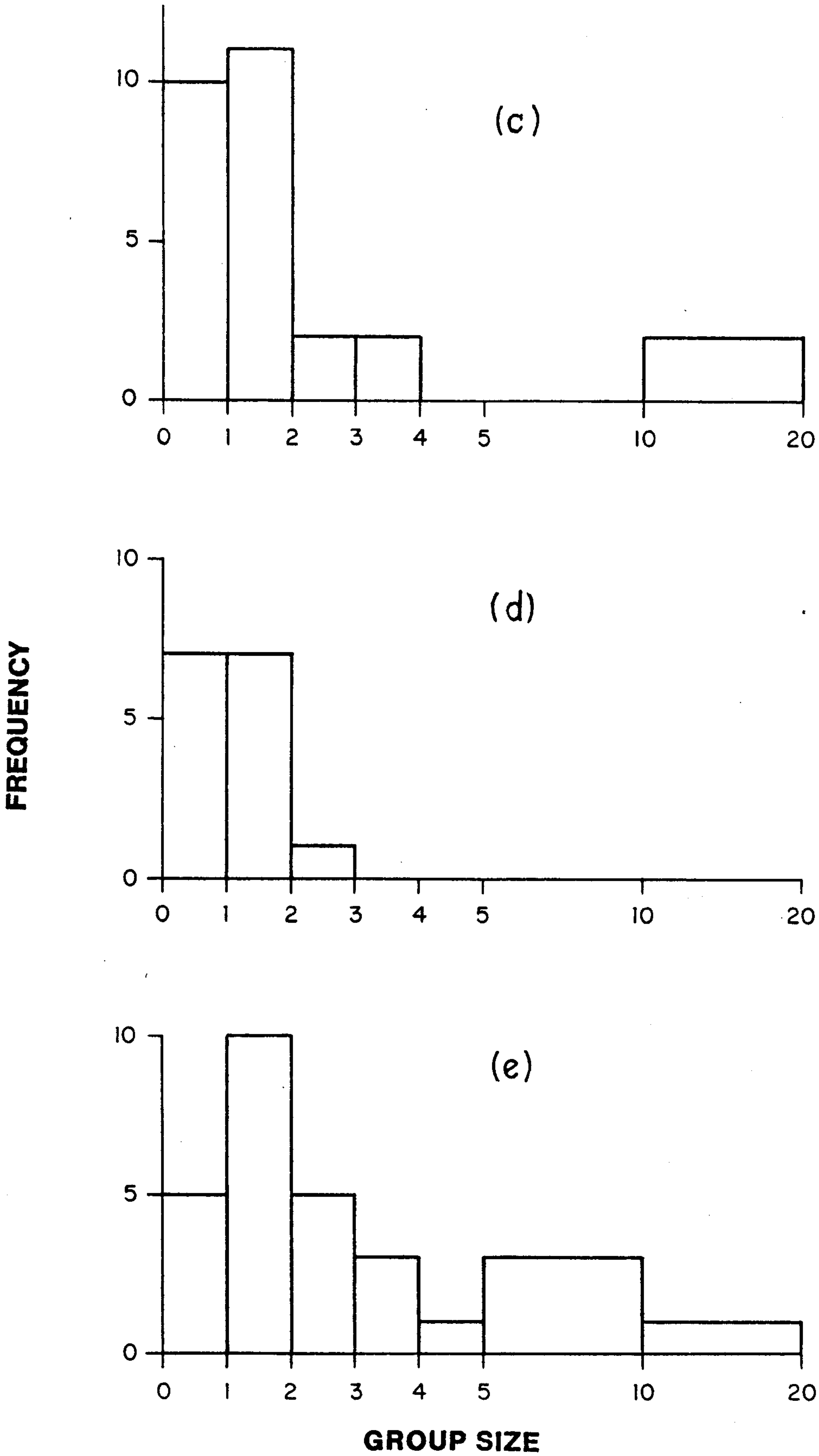


Figure 63 (continued). The distribution of group sizes of Dall's porpoises in blocks 4 and 5 (c), blocks 1,2,3, and 6 (d), and 7 (e) to support density estimates (see Table 10).

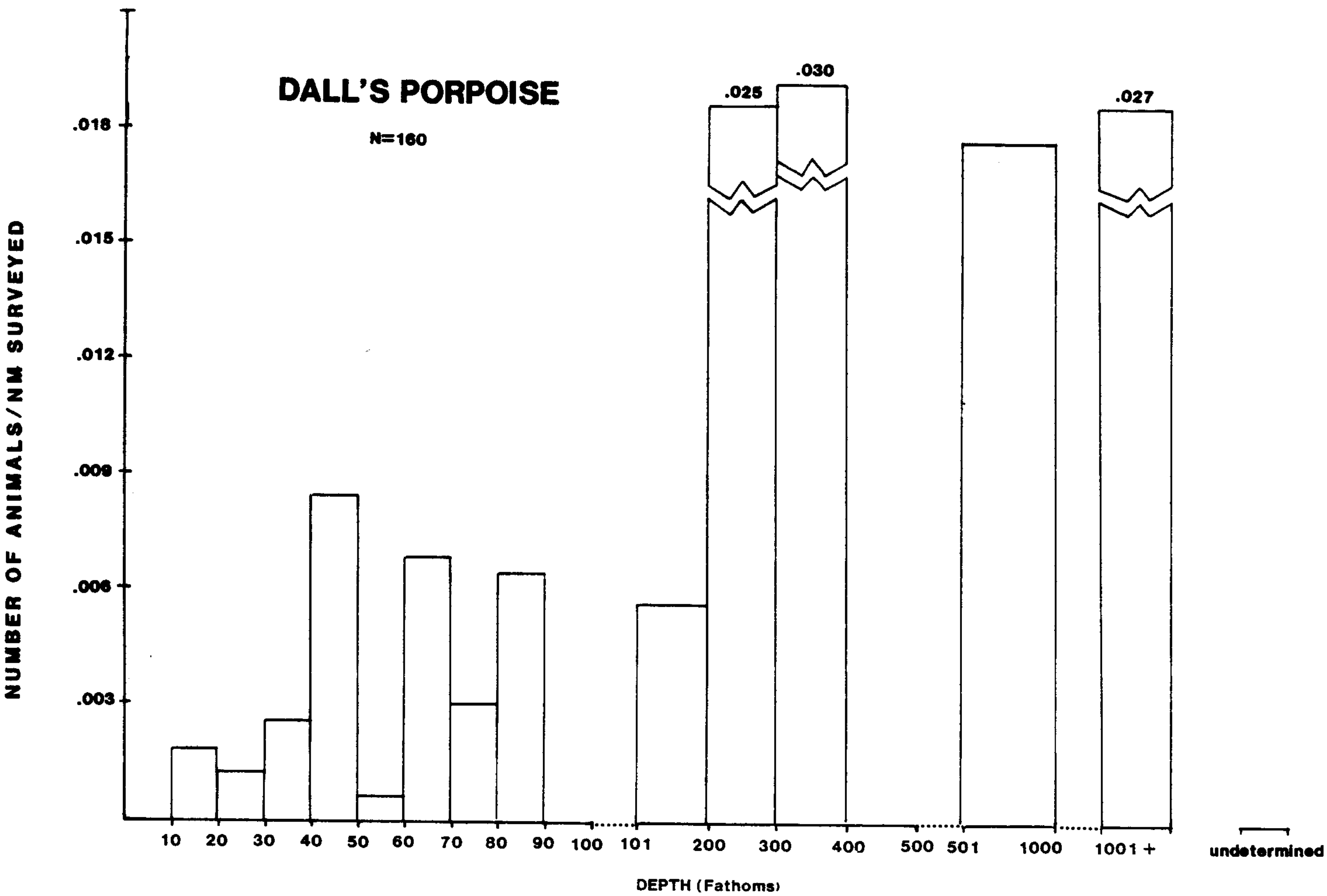


Figure 64. Indices of abundance of Dall's porpoises by depth class.

to us here, is that occurring in the Gulf of Alaska, Kodiak Island to Prince of Wales Island. Such putative stock boundaries are based on strictly geographical considerations. There is no biological evidence for different stocks in this region.

Harbor porpoises occur in both our study areas. They have been reported from as far north and east as the MacKenzie River Delta - 68°48'N, 136°35'E - in the southeastern Beaufort Sea (Van Bree et al., 1977), and as far north and west as Wrangel Island - 71°N, 180°W (Gaskin, 1983). During the brief ice-free season they probably occur with regularity in the coastal Chukchi Sea, at least as far north as Pt. Barrow (Lowry et al., 1982b; Bee and Hall, 1956). In and near the Bering Sea study area they have been reported to occur regularly along the mainland coast, including the north side of the Alaska Peninsula, Bristol Bay, the Yukon-Kuskokwim Deltas and Norton Sound (Lowry et al., 1982a).

Beyond these generalizations, there is little credible detail published on distribution and seasonality in the area. Leatherwood et al., (1983, abstract and attached tables) listed available stranding, collections and sighting records of the species in Alaska. Braham et al. (1983) plotted, without differentiation by month, all sightings from the NOAA Platforms of Opportunity Program (POP), 1958-1981. These sightings suggest a concentration in the vicinity of Unimak Pass and a sparse distribution elsewhere over the shallower waters of the southern Bering Sea continental shelf. There is some confusion in data from the POP program, however, as distribution plots prepared from the same data base and presented by Braham and Rugh (in prep.), indicate a pronounced incursion of the species into coastal Bristol Bay in summer. Further, in the North Aleutian Basin synthesis report (Braham et al., 1983) there is no indication of the presence of this species in the basin, at all. Whatever the shortcommings of the published data, they do suggest that harbor porpoises are at least seasonally widely distributed in the eastern Bering Sea and Bristol Bay. Similarly, harbor porpoises are a common feature of the coastal zone in and near the Shelikof Strait study area (Fiscus et al., 1976; Braham et al., 1983; Leatherwood et al., 1983a), though there is, for this as other areas, little published basis for defining distribution, seasonal abundance and habitat use.

During the present study, we recorded a total (all flights, all areas) of 62 sightings of harbor porpoises, accounting for 100 individuals (Tables 7, 8 and 9, Figure 65). Four sightings (4 individuals) were made outside the study area on 24 August 1982 north of 62°N. Of these, 45 sightings (72 individuals) were made on random transects - 28(38) in the Bering Sea and 17(34) in Shelikof Strait - and were therefore appropriate for density estimation (Table 10; Appendix II). The distribution of sighting distances for that subsample and the appropriate model fit (a negative exponential) are shown in Figure 66. It should be noted that harbor porpoises are small and inconspicuous, especially to an aerial observer, and that aerial estimates are, therefore, usually low. For example, in these surveys as elsewhere (e.g. Hall, 1981; Kraus, Gilbert and Prescott, in press) most animals have been detected within 1/8nm (0.23 km) of the aircraft. Herds we saw contained 1-10 individuals (s = 1.370, sd(S) = Ø.121 in blocks 1, 2, 3 and 6 and s = 2.0, Sd (s) = 0.402 in block 7) (Table 10). With these data we were able to conservatively estimate density for all surveys combined, in blocks 1, 2, 3 and 6 as a unit (13.04 animals/1000nm^2 $\pm$ 3.735) and in block 7 (74.96 animals/1000nm^2 (3,430 km^2) $\pm$ 29.22) (Table 10).

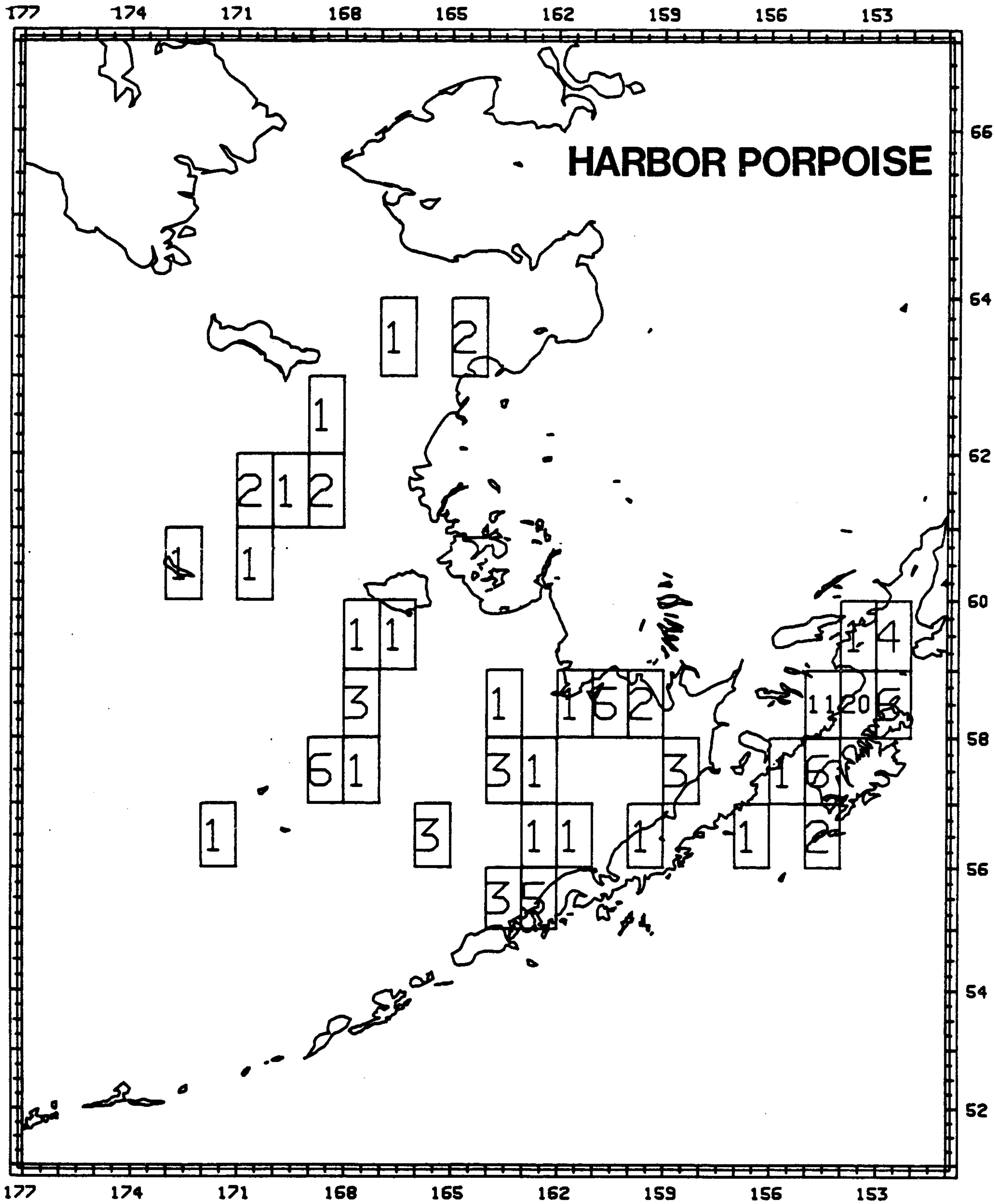


Figure 65. Total numbers of harbor porpoises seen, by 1° blocks.

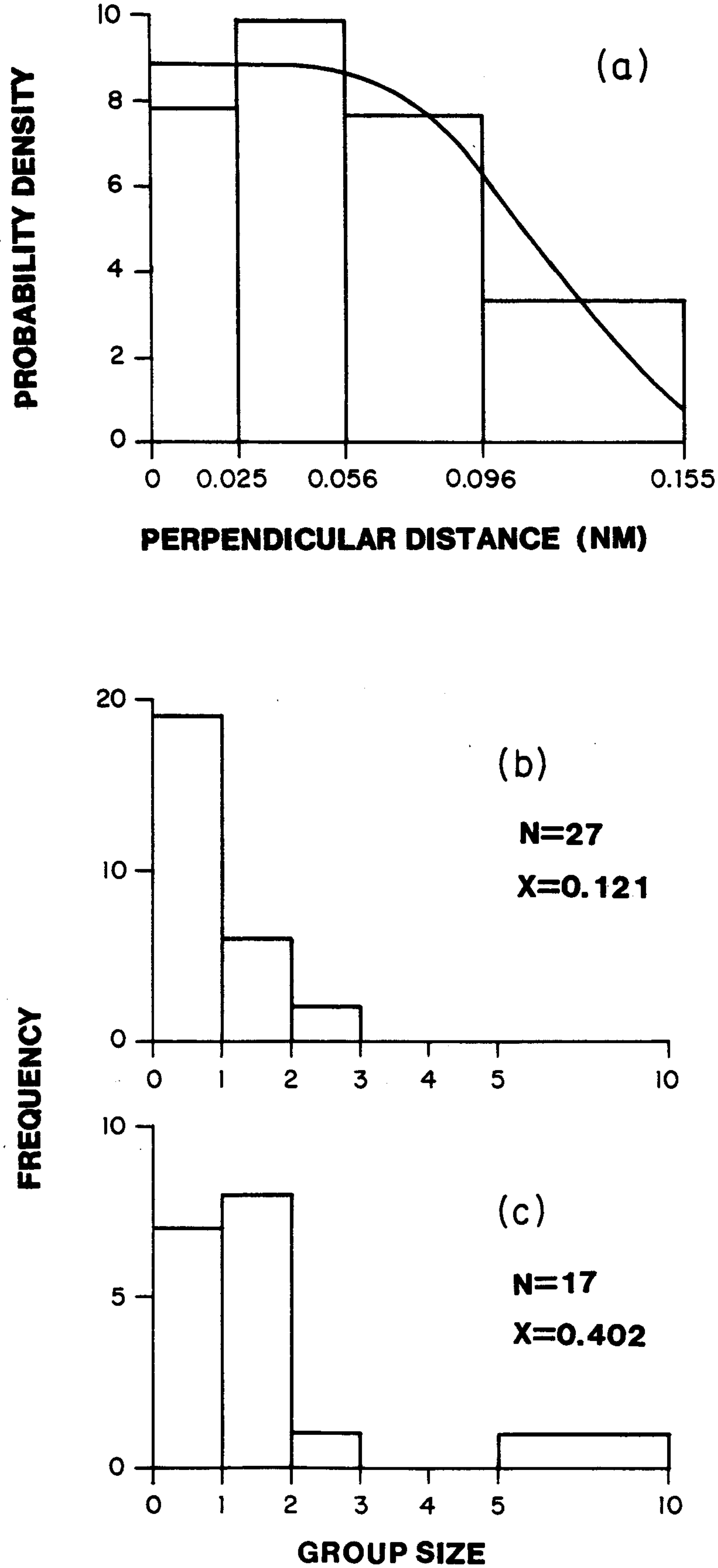


Figure 66. Data used to estimate density of harbor porpoise populations from aerial survey data: (a) perpendicular sighting distances, truncated under the aircraft at 0.039 nm, and the fitted negative exponential model for all sightings in blocks 1, 2, 3, 6 and 7; (b) distribution of herd sizes in Blocks 1, 2, 3 and 6; and (c) distribition of herd sizes in block 7.

The distribution of sightings by season is shown in Figure 67. The calculated indices of abundance (number of animals encountered per linear nautical mile) by month are shown in Figures 68 and 69 for Bering Sea (blocks 1-6) and Shelikof Strait (block 7), respectively. From both those presentations there are some apparent trends. Harbor porpoises are apparently almost entirely absent from the Bering Sea in winter, increase in numbers there through spring and summer, and decline again from fall to winter lows. There were no sightings of harbor porpoises in or near sea ice at any season. With the spring increase, presumably related to the retreat of the sea ice, the porpoises also disperse to utilize large portions of the eastern Bering Sea continental shelf. This dispersal may well be related to increased presence and broadening distribution of cod and herring, apparently the species' primary food in the region (Lowry et al., 1982b). At periods of lowest observed density in the Bering Sea these porpoises are apparently restricted to nearshore southerly waters.

The pattern in Shelikof Strait differs slightly. There harbor porpoises were more abundant during spring and summer surveys. There were no discernible shifts in distribution patterns among seasons. The apparent confinement to nearshore waters in Shelikof Strait, in contrast to the broader distribution in the Bering Sea, may be related to differences in bottom topography of the two areas. Most of the eastern Bering Sea is shallow (less than 60 fathoms (109.8 m) overall), while in Shelikof Strait the relatively narrow and shallow coastal shelf gives way in a short distance to steep cliffs and deeper water.

Harbor porpoises are generally found in shallow nearshore waters. Areas where they extend farther offshore, such as in the Black Sea

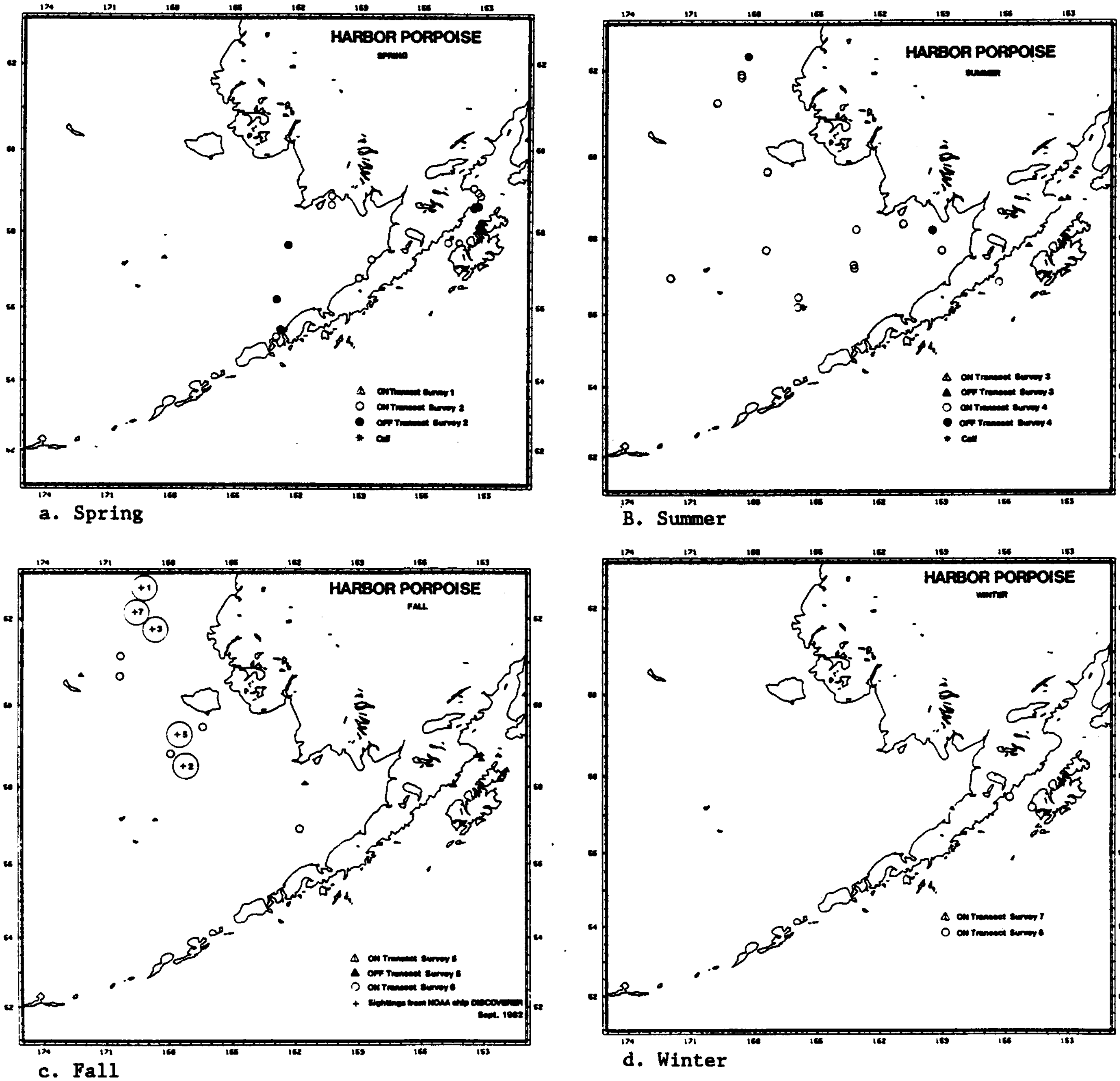


Figure 67. Distribution of sightings of harbor porpoise during spring (a), summer (b), fall (c), and winter (d).

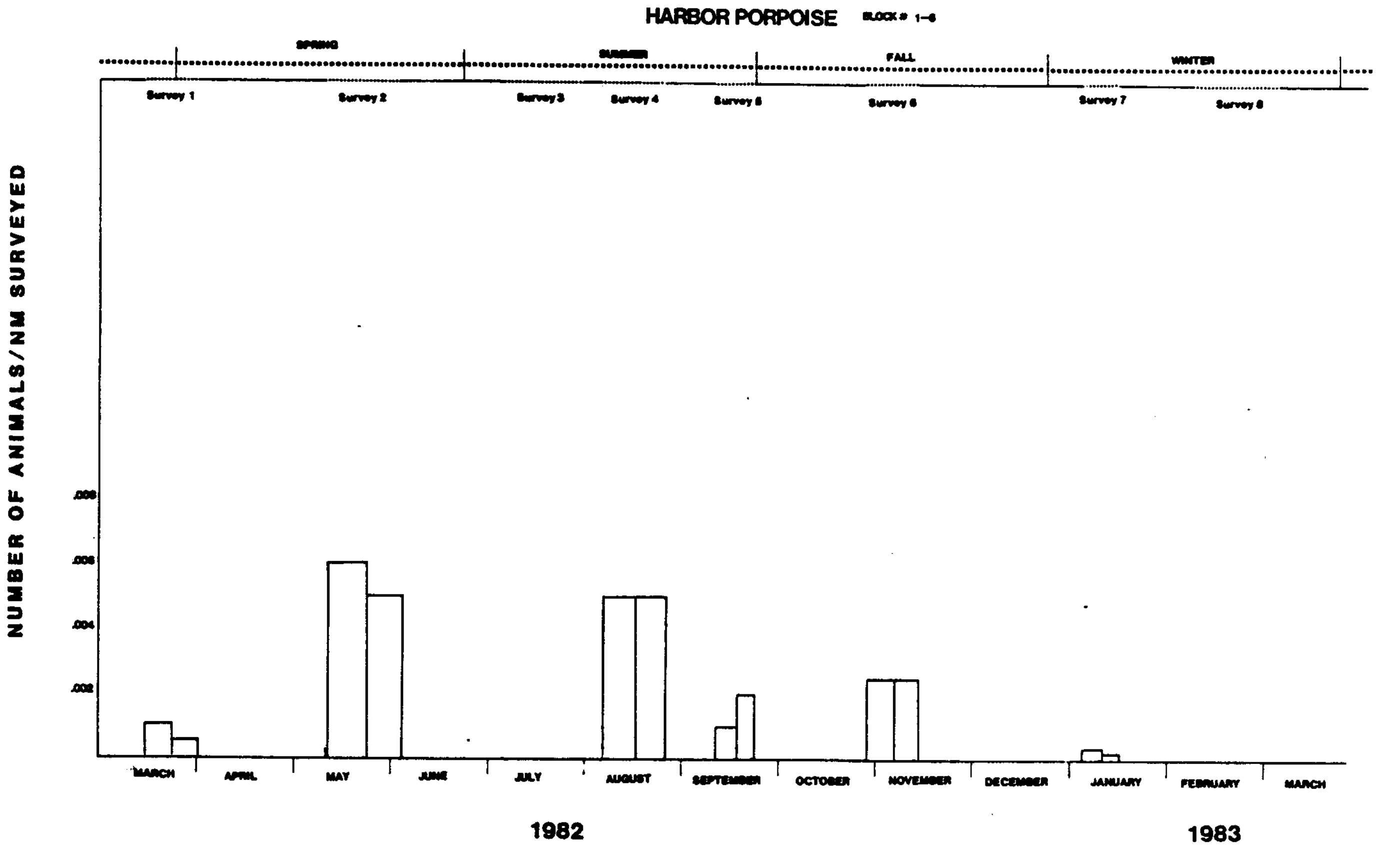


Figure 68. Indices of abundance of harbor porpoise by survey in blocks 1-6.

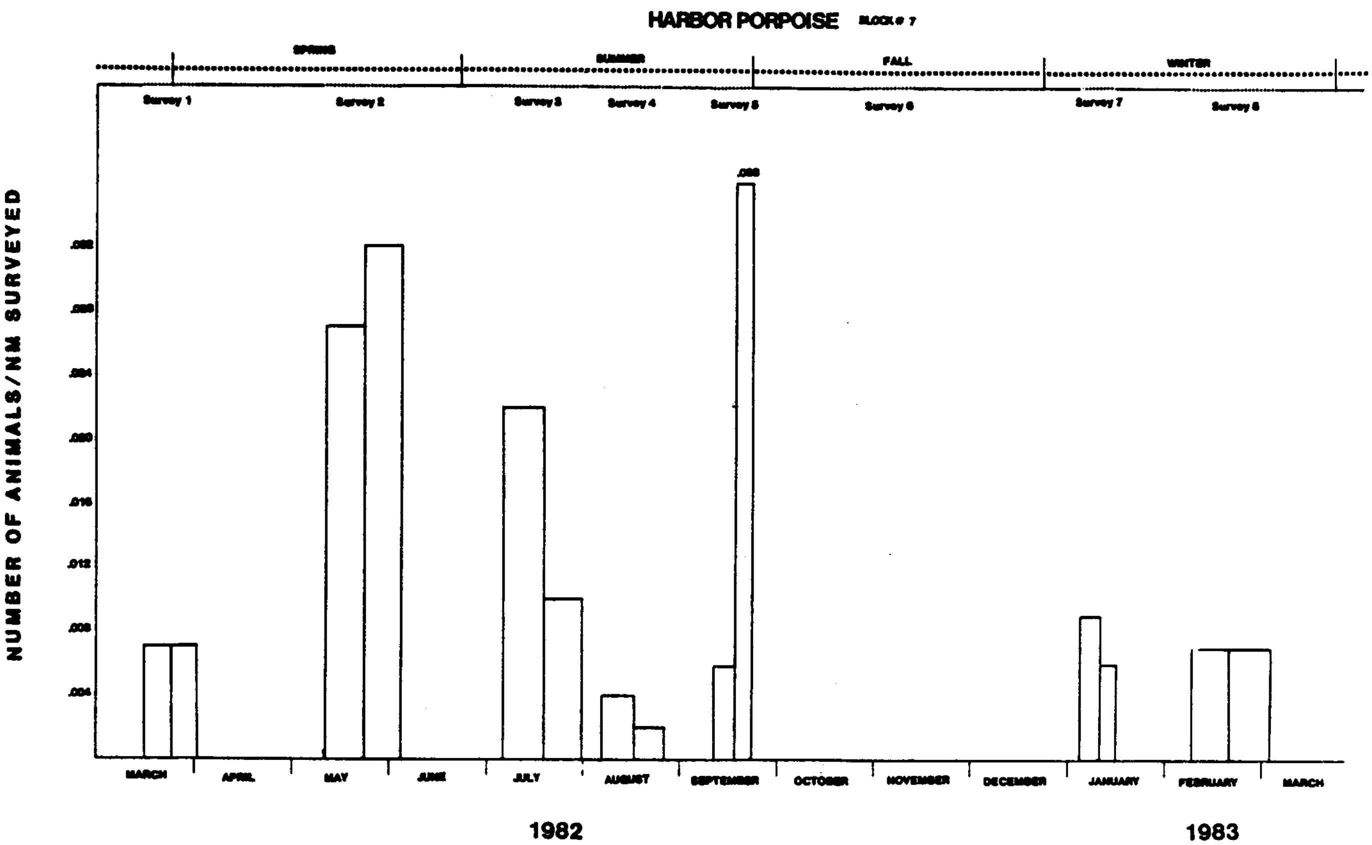


Figure 69. Indices of abundance of harbor porpoise by survey in block 7.

(Perrin, ed., 1983), southeast Canada (Gaskin, 1983) and the Bering Sea (present study), are characterized by broad, shallow shelves. Animals in the present investigations were seen mostly inside the 100-fathom (183 m) contour (97.5%) and largely inside the 70 fathom (128 m) contour (79%) (Figure 70).

There are few data available on the reproductive biology of harbor porpoises in Pacific/Alaskan waters. Studies conducted in British Columbia (Flaherty and Stark, 1982) and Southeast Alaska (Taylor and Dawson, 1983) suggested calving periods from April through September and resulted in peak numbers of cow/calf sightings in August. We saw only 3 calves classified as newborn, all during summer (Figure 67):

- One seen on transect during survey 2 in block 7, zone 4 (at 57°44.4'N, 154°50.3'W) on 3 June 1982 (Figure 65a). The calf was with a single adult in 130 fathoms (238 m) of water. The adult was "milling" and presumed to be feeding, as there was a tight swirling ball of unidentified bait in the proximity. Neither adult nor calf appeared to take alarm at the overflight of the aircraft.

- One seen from transect on survey 3 in block 7, zone 1 (at 58°57.7'N, 153°21.2'W) on 20 July 1982 (Figure 67b). Adult and calf were milling in 25 fathoms (46 m) of water and dived away promptly, probably in response to the plane.

- One seen from transect on survey 4 in block 6, zone 4 (at 56°27.5'N, 165°47.0'W) on 8 August 1982 (Figure 67b). The calf and accompanying adult, both milling when first seen, "bolted" in response to the shadow of the plane passing overhead.

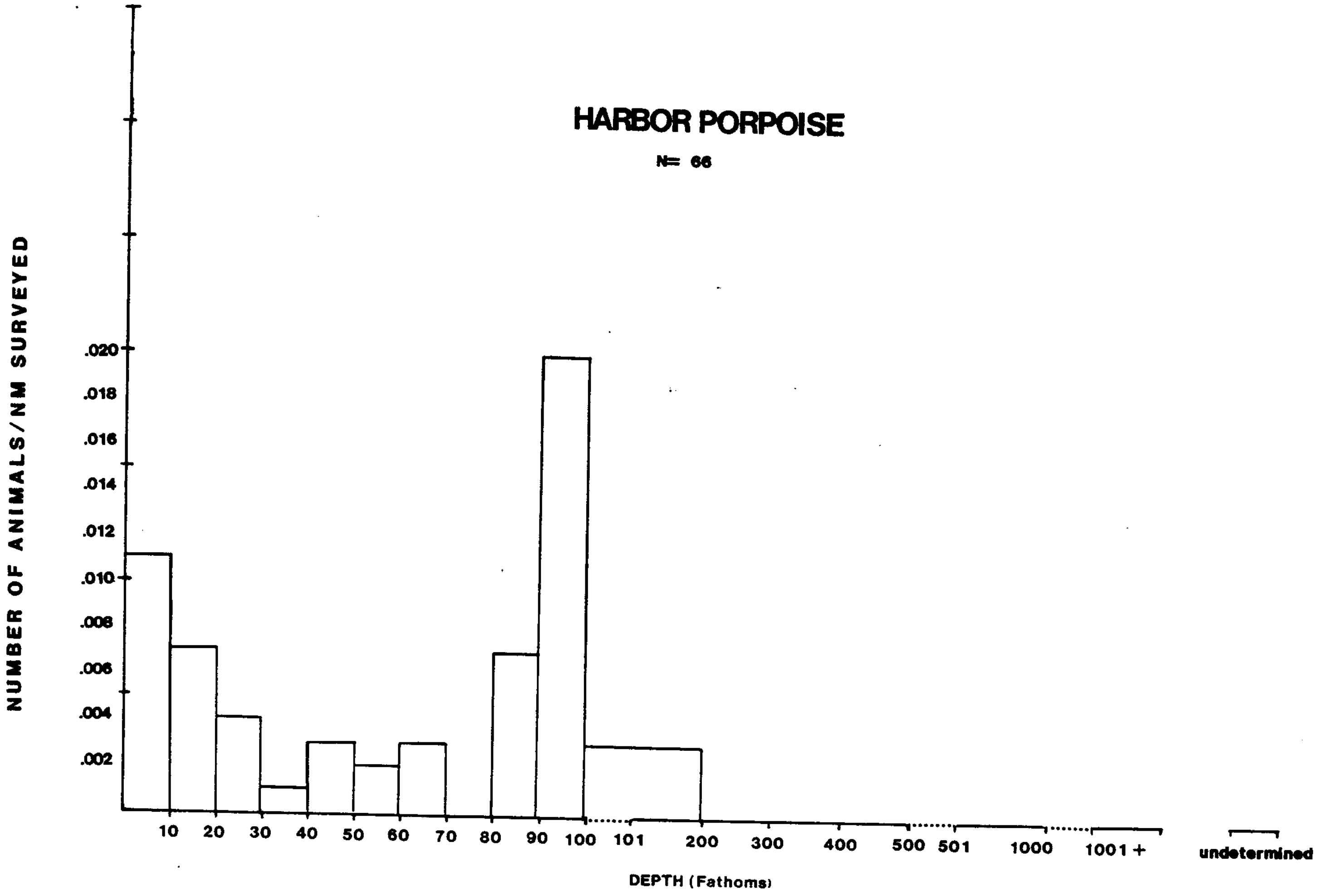


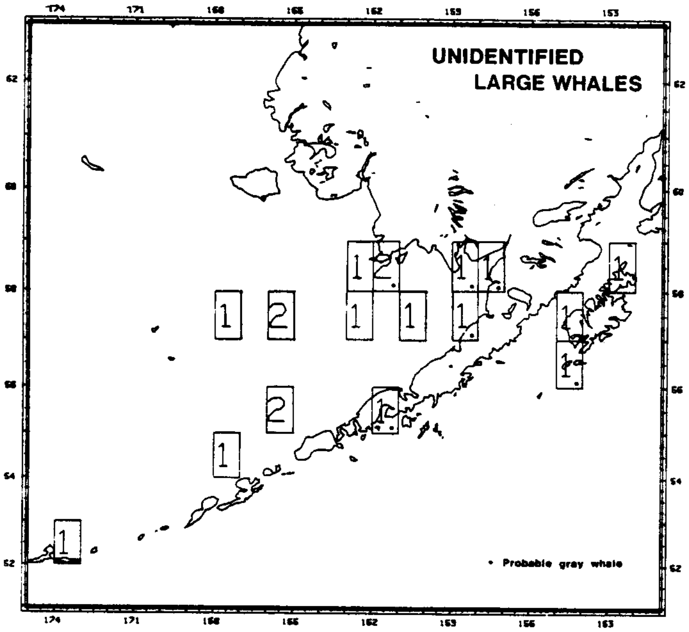
Figure 70. Indices of abundance of harbor porpoises by depth class.

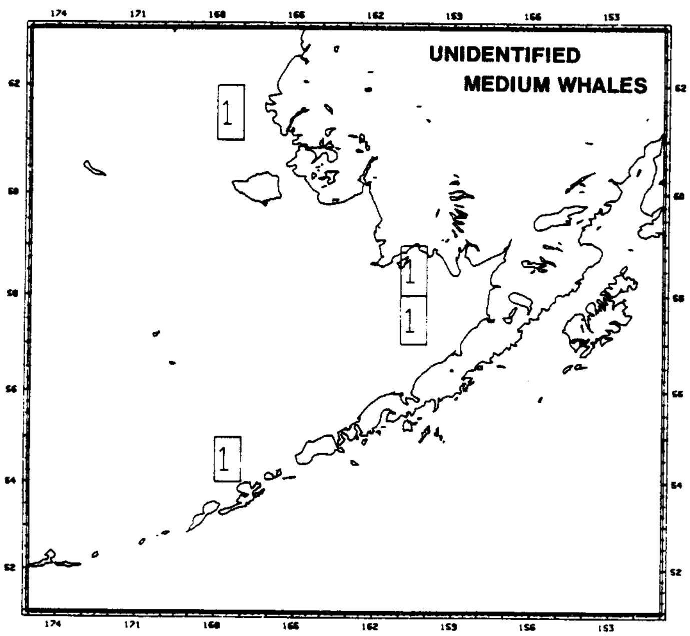
Harbor porpoises are small and difficult to detect. It is of interest, for example, that all 3 sightings of calves were in relatively clear water, when winds were calm (Beaufort 1-4), and involved animals milling and producing surface signs indicating their presence. Newborn harbor porpoise are larger relative to adult size than calves of most other cetacean species. Their large size at birth and rapid growth rate during early months of life compound the difficulty of detecting calves from aerial surveys.

There are no reported direct fisheries for harbor porpoises in Alaskan waters, but there are occasional takes by natives for "subsistence". Some are killed annually in monofilament gill nets for salmon on the high seas (Jones, 1983) and around the Copper River delta (Matkin and Fay, 1980). The frequency of previously unreported mortality, the intensive levels of coastal net fisheries in Alaska for salmon, herring and cod, and the close association of harbor porpoises with such fishing areas, if not directly with the fisheries, indicates mortality is much higher than reports indicated. As such fishing principally occurs during the same season when harbor porpoises calve, and when they are most widely dispersed, the population is likely then at its most sensitive and vulnerable.

Unidentified Cetaceans

During the present surveys there were a total of 28 sightings of unidentified cetaceans (45 individuals), as follows: unidentified large whale-13 sightings (15 individuals); medium-sized whales, possibly including minke whales-4 sightings (4 individuals) and an incidental sighting on 14 May 1982 for which there was no estimate of number recorded; and dolphins or porpoises-10 sightings (19 individuals) (Figure 71 top, middle, and bottom, respectively). All information available on





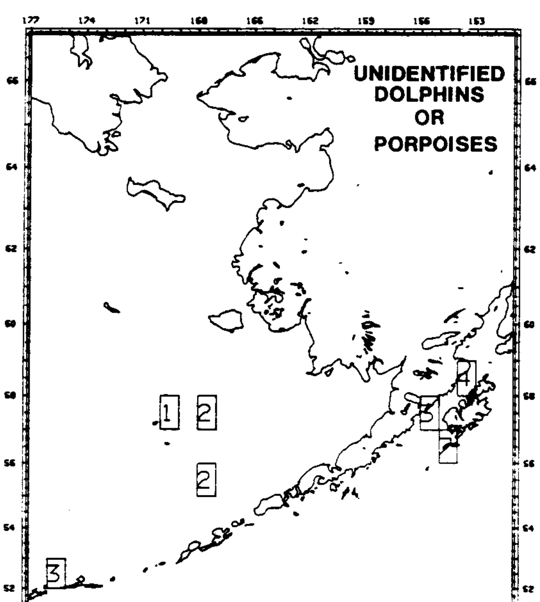


Figure 71. Total number of animals recorded as unidentified cetaceans, by 1° block; large whales (top), all of which are believed to have been baleen whales and some of which (*) were most probably gray whales medium sized whales (middle), and dolphins or porpoises (bottom).

these observations is summarized in Table 16. The sightings of unidentified large whales were widely distributed in the southern and eastern Bering Sea, near Adak, and around Kodiak Island. Most were detected by a distant blow but submerged prior to overflight and/or could not be relocated during circling. In 5 sightings, marked with an asterisk on Figure 71 (top), the animals were tentatively identified as gray whales. It was not possible with the other sightings logged as unidentified large whales to make even a guess as to the species involved. We are confident, however, that none was a sperm whale. All were logged as probable baleen whales. No unidentified cetaceans were assigned to species by pro-ration, for reasons discussed under data analysis, above; so, none of these sightings are reflected in density estimates.

Other Marine Mammals

In addition to the endangered whales (our target species) and other cetaceans, we obtained some information on pinnipeds, sea otters, and polar bears in and near the study areas. These data are summarized below with comments on the most important findings. In general, however, treatments of other-than endangered whales are cursory. Surveys were not designed or conducted to focus on pinnipeds, otters, or polar bears. Because of limitations on the amount of survey and circling time available we were often unable to linger in areas of sightings to ensure accurate identifications or counts. For some species, such as ringed, largha, and harbor seals and particularly sea otters, surveys were flown at too high an altitude to ensure that high proportions of the animals present were detected or counted. For other species, no attempt was made to census land- or ice-based populations as there simply was not sufficient time to do a respectable job. Further, some of those populations are subjects of

Table 16. Information available on animals logged as unidentified cetaceans.

Group	Date	Latitude	Longitude	Number	Initial Behavior	Swim Direction	Depth	Probable Species
	820401	57476	165337	1	2	270	9999	7
	820401	57384	165328	1	99	999	9999	7
	820511	57160	158486	1	99	999	18	7
	821101	58247	162332	1	1	270	15	7
	820703	57409	167244	1	1	90	37	7
	820918	57220	160296	1	1	300	34	7
	820812	58063	157359	1	1	160	1	12
Large	820514	52356	173572	1	1	150	820	14
whales	820313	56534	154411	1	3	180	21	14
(codes	820510	57433	154163	1	99	999	96	14
7, 12	820602	57428	162274	1	99	999	24	14
and 14)	820317	55579	161317	1	1	999	9999	14
	820602	58271	161509	2	99	999	25	14
	820720	58453	152406	1	1	300	106	14
	820808	55263	165475	2	1	280	63	14
	820806	58073	158589	1	1	90	12	14
	820808	54007	167144	1	1	90	9999	14
	820514	53346	169348	11	99	999	1097	27
Medium-	821030	54510	167150	1	2	90	186	27
sized	821026	58246	160151	1	1	90	5	27
whales	820602	57149	160232	1	2	90	33	27
(code 27)	820523	61572	167518	1	1	999	13	27
Dolphins/	820313	56370	154185	1	2	999	4	32
porpoises	820313	56431	154421	6	2	999	11	32
(code 32)	821030	55068	167149	2	2	220	86	32
	820510	58335	153269	1	1	20	72	32
	820510	58301	153289	1	1	999	79	32
	820510	58276	153305	2	1	999	79	32
	830104	57105	155090	1	1	10	127	32
	830104	57225	155499	2	1	100	65	32
	820706	57494	169479	1	1	90	38	32
	820926	57106	167337	2	5	555	41	32

other major long-term investigations (such as the research programs on northern fur seals on the Pribilof Islands and on walruses in Bristol Bay). The partial data we did obtain are best integrated with more complete and focused data, to be interpreted by specialists concerned with those species.

Pinnipeds

Steller's sea lion (Eumetopias jubatus)

Total numbers of Steller's sea lions seen by 1-degree block are shown in Figure 72. Steller's sea lions were seen along the ice edge southwest of St. Matthew Island (in spring) and near and on the Pribilofs (in fall and winter). With these few northerly exceptions, however, sightings of the species were concentrated on or near the Aleutians, the Alaska Peninsula and Kodiak Island at all seasons (Figure 73). Most individuals were seen on or adjacent to rookery or haul-out concentrations. In block 7 there were enough sightings in water (39 for all surveys combined) to fit a Fourier series model to the sightings data (Figure 74) and combine with associated group size distributions (Figure 75) to produce a density estimate of 2,869 $\pm$ 1,280 animals per 1000nm^2 (3430 km^2) for all surveys combined (Table 10). However, given the manner in which the data were collected, the narrow time window involved, and the unknown proportion of the population on land at the time of the surveys, such estimates should be regarded as little more than exercises. Overall, northern fur seals were the second most frequently encountered and abundant animals (behind walruses) in the Bering Sea study area (66 sightings of a total of 3268 animals-Table 8) and the most abundant in Shelikof Strait (78 sightings of a total of 3936 animals-Table 9). Five sightings (21 sea lions) were made west of 174°W along the Aleutians. In both study

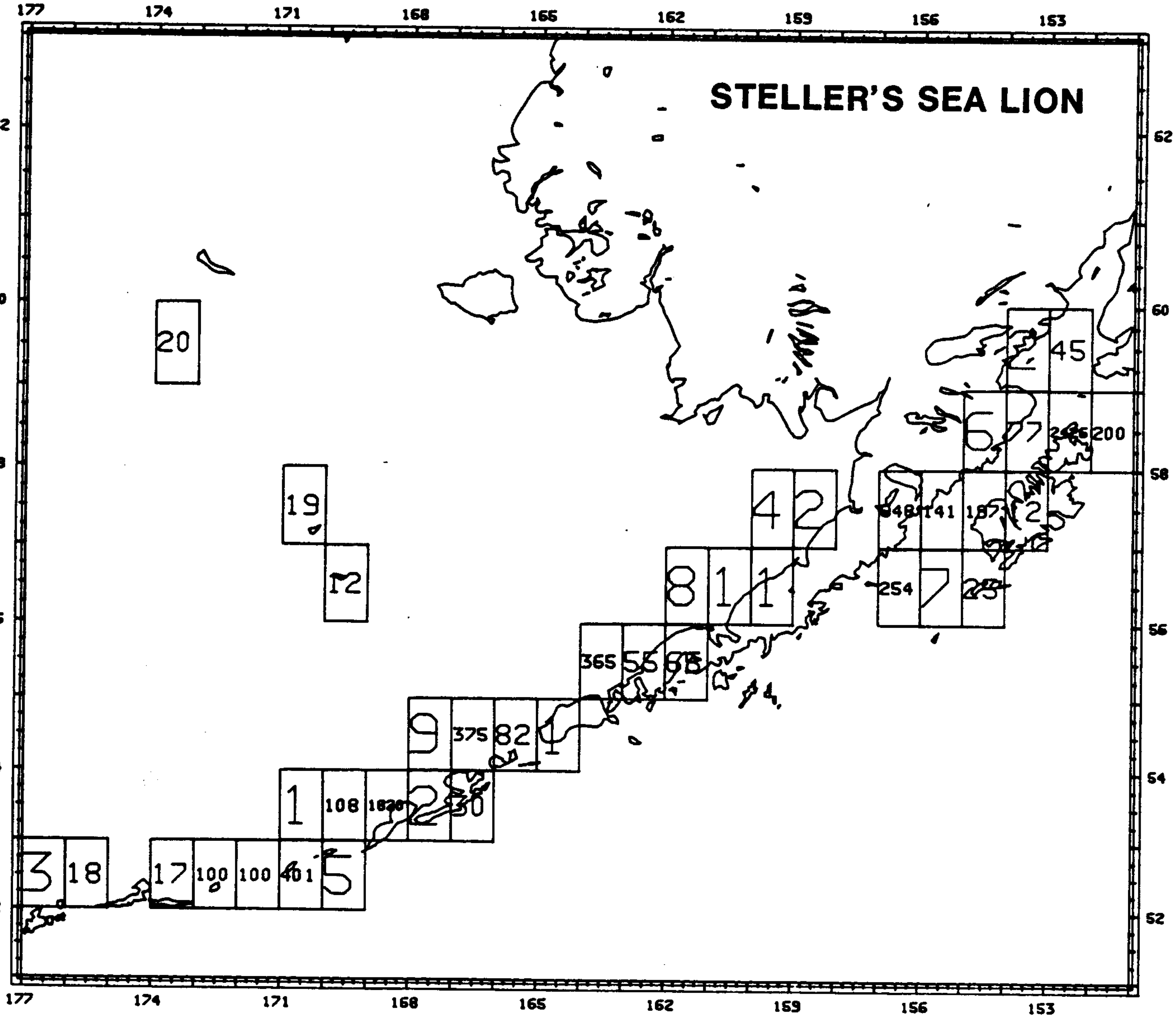
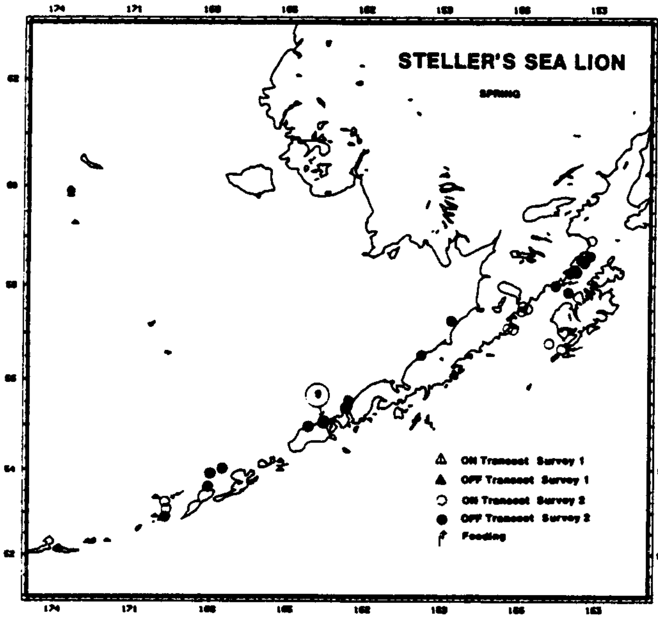
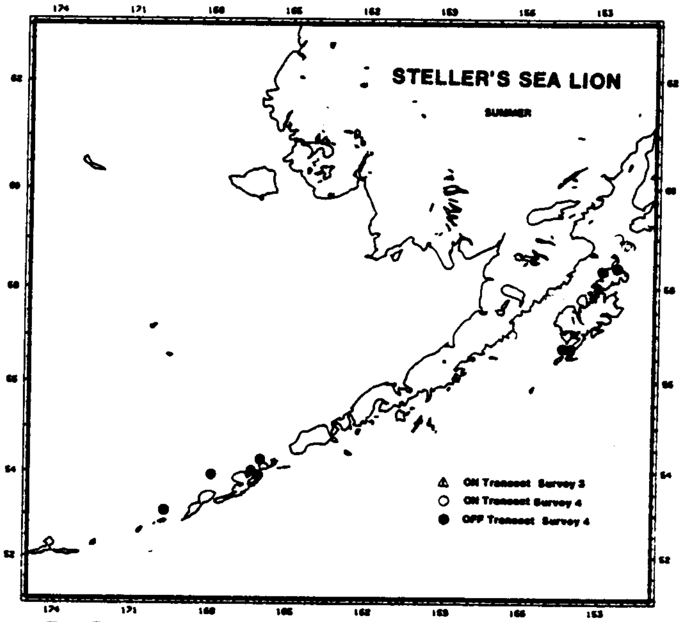


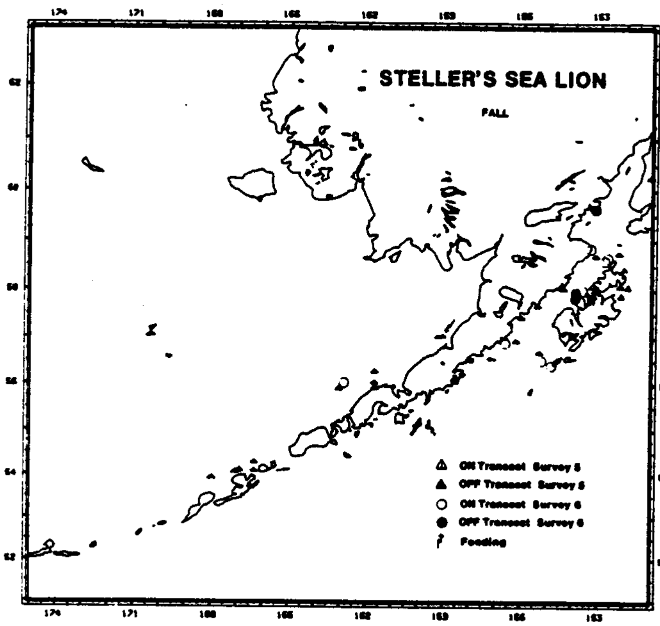
Figure 72. Number of Steller's sea lions seen by 1° block.



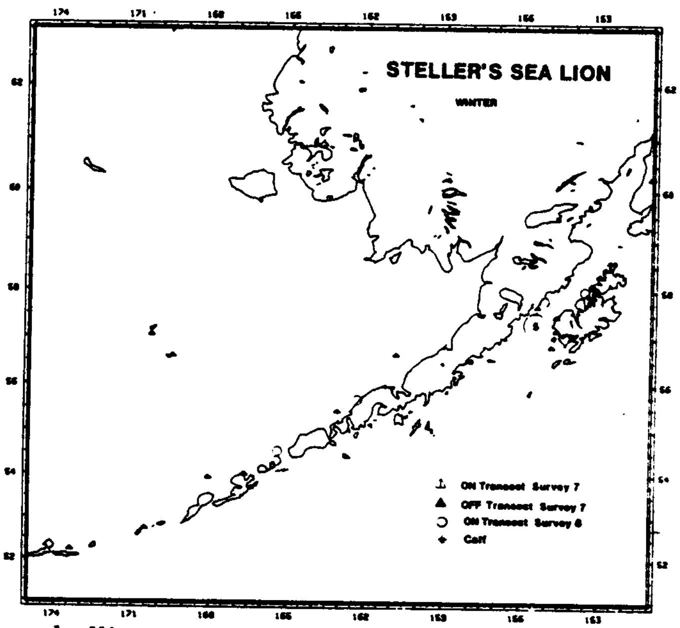
a. Spring



B. Summer



c. Fall



d. Winter

Figure 73. Location of sightings of Steller's sea lions by survey and season.

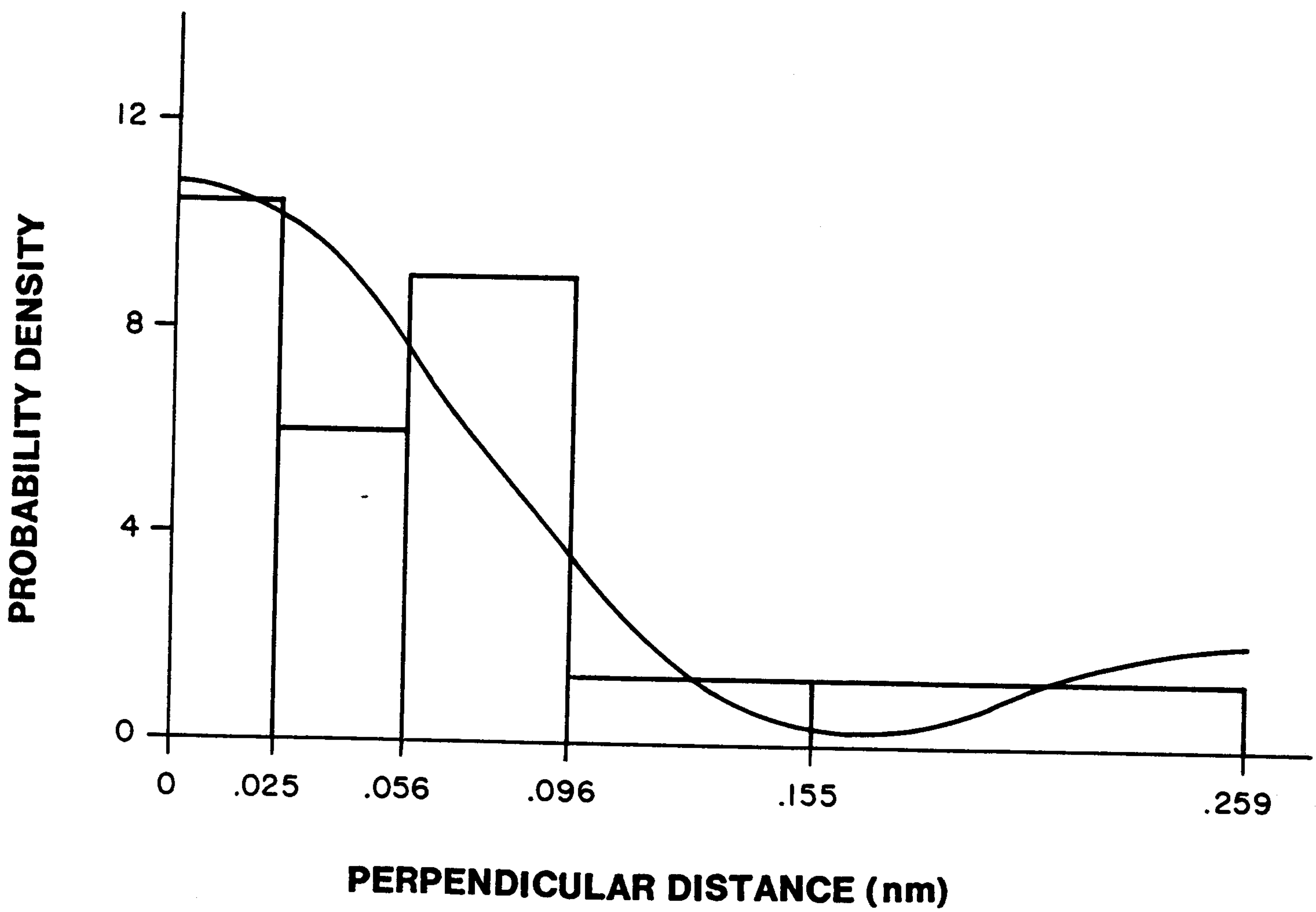


Figure 74. Perpendicular distances truncated under the aircraft at 0.039nm and the fitted Fourier Series model for Steller's sea lion in block 7, all surveys.

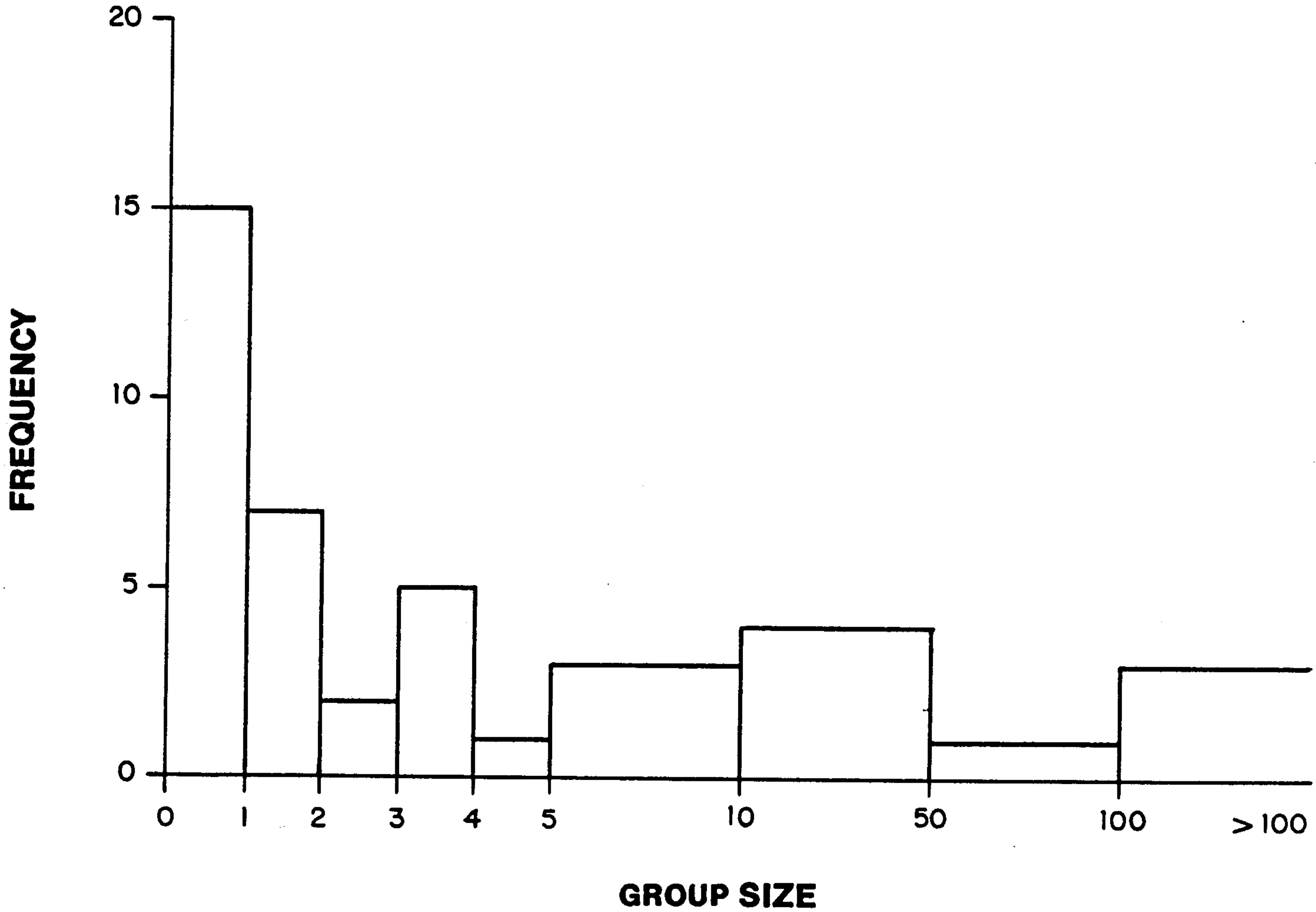


Figure 75. Distribution of sizes of groups of Steller's sea lions in water, block 7, all surveys.

areas they were more frequently encountered in summer than at other seasons (Figures 76 and 77). Neither the frequency of encounters nor the number of animals seen was surprising, given the known breeding and summering range of the species (see, for example, Schusterman, 1981:124). Judging by the numbers we saw and by data previously presented by others (see Lowry et al., 1982b), the Steller's sea lion is an important component of the marine fauna in at least the coastal portions of both study areas. Further, apart from those animals associated with rookery or haul-out areas there appear, to be components of the Steller's sea lion populations distributed on and seaward of the continental slope (Figure 78).

Northern Fur Seal (Callorhinus ursinus)

Fur seals are common summer residents of the Bering Sea, where they haul-out each year from May to August (males) or October (females and pups) on the Commander (estimated 265,000) and Pribilof (estimated 1,219,000) islands to pup and breed. The breeding population disperses from the islands to join the remainder of the population on feeding grounds in the southern Bering Sea and the northern North Pacific from November through May or June (Gentry, 1981; Lowry et al., 1982b). We expected to see numerous fur seals near the breeding islands in spring through fall and at least some adult males in the southern Bering Sea in winter. Fur seals were in fact so numerous near the Pribilofs and on the well-studied rookeries that we saw little reason to attempt haphazard counts while approaching or leaving our base of operations on St. Paul Island. Such incidental sightings would have had little significance, given the extent of previous and ongoing investigations.

There were 14 sightings (34 individuals) of fur seals away from the breeding islands, one in Shelikof Strait and the remainder in the southern

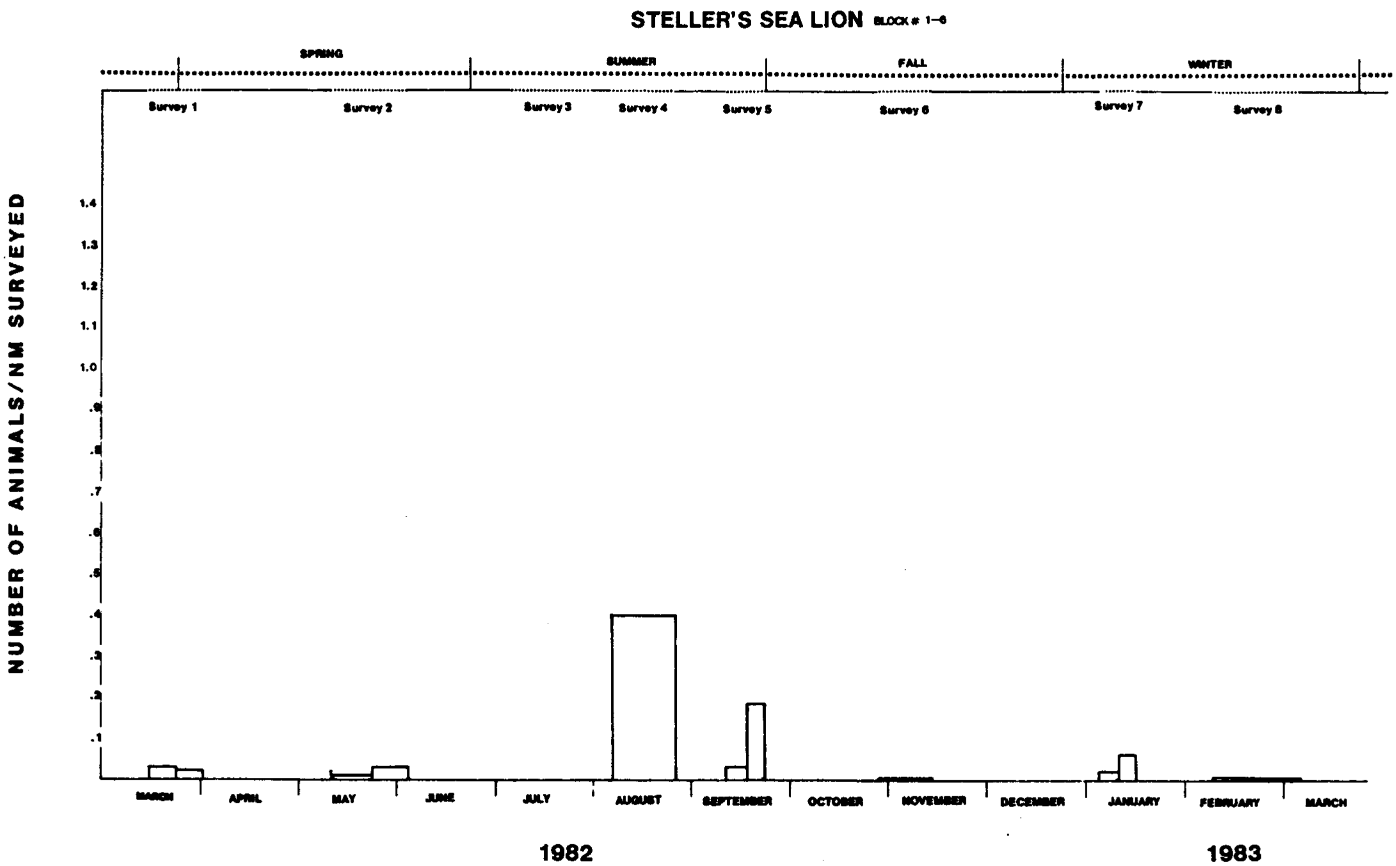


Figure 76. Indices of abundance of Steller's sea lions by survey, blocks 1-6.

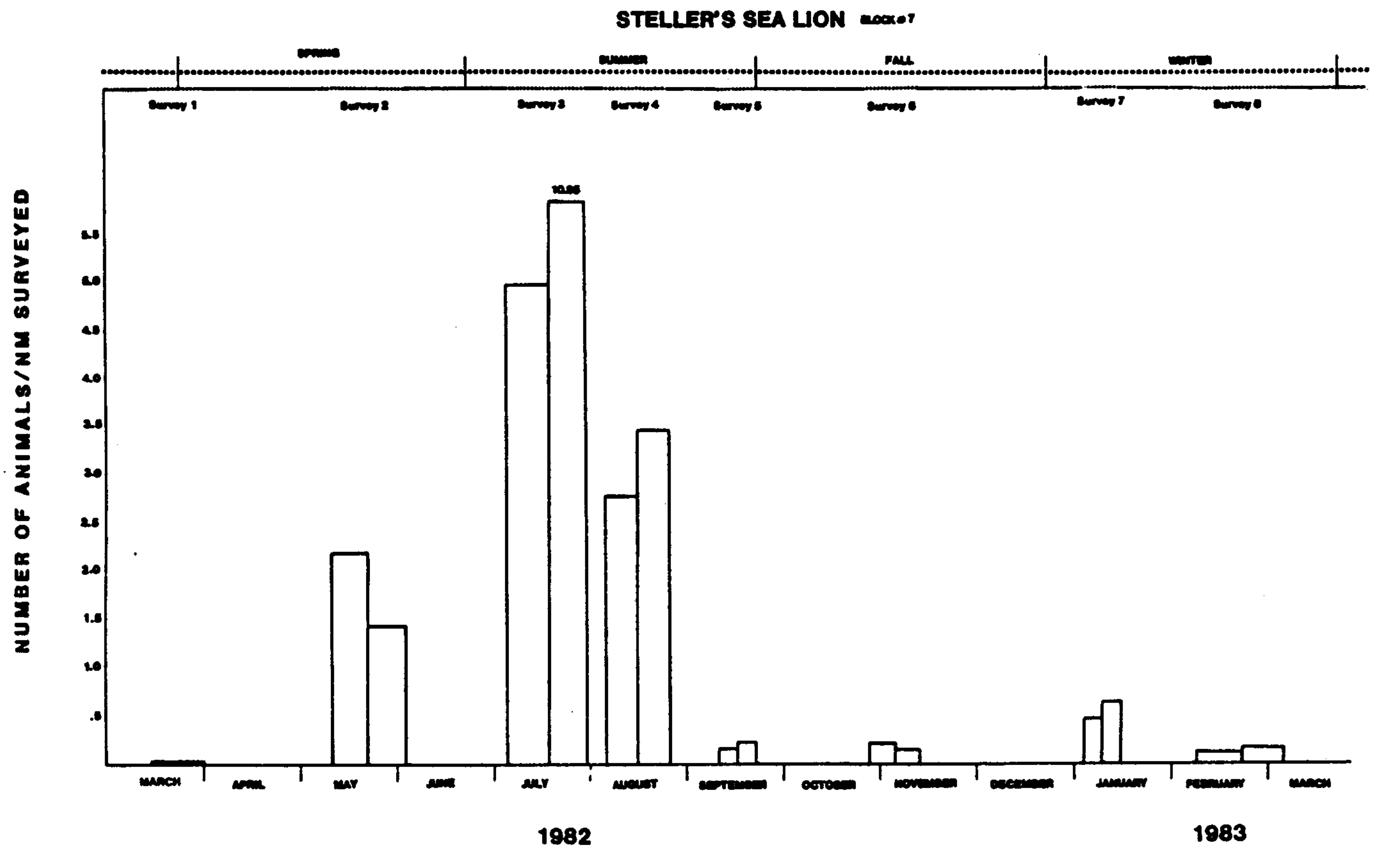


Figure 77. Indices of abundance of Steller's sea lions by survey, block 7.

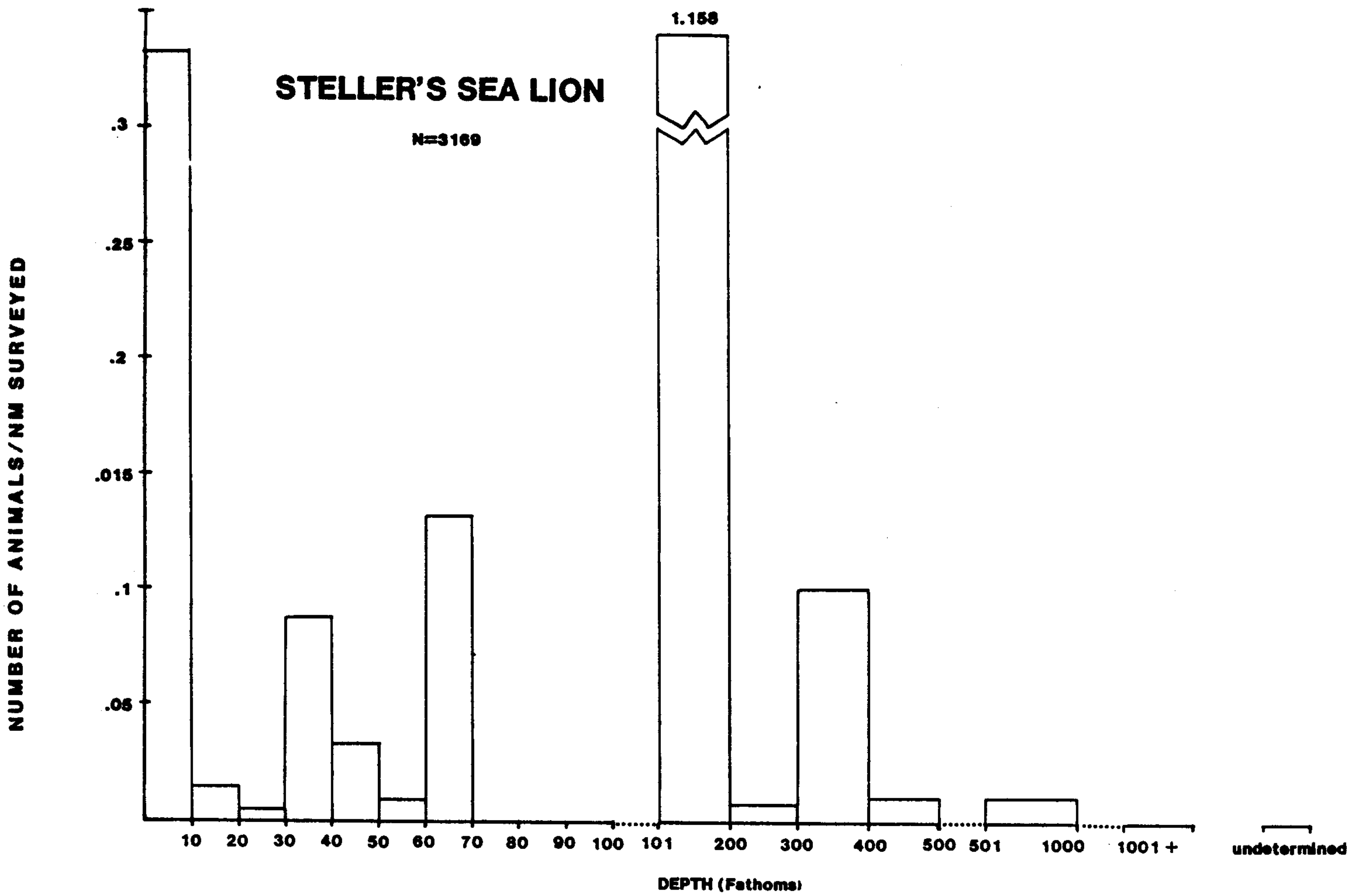


Figure 78. Indices of abundance of Steller's sea lions by depth class.

the Bering Sea (Figures 79 and 80). As they tend to occur in pelagic zones (see Gentry, 1981: Figure 1, p. 144) (such as our blocks 4 and 5), where sighting conditions were often poor, the usually solitary (Gentry, 1981:147), dark-colored males probably were often undetected or were logged as unidentified pinnipeds.

Walrus (Odobenus rosmarus)

Because we have more extensive and complete data on the walrus than on any other species, we treat it here in somewhat more detail than we did the other species of secondary importance to our study.

The walrus has a circumpolar distribution. Within that broad range, however, there are six isolated populatons: Hudson Bay-Davis Strait; eastern Greenland; Svalbard and Franz Josef Land; Kara Sea-Novaya Zemlya; Laptev Sea; and Bering and Chukchi seas (Fay, 1982). The walruses occurring in the last of these regions are considered a distinct subspecies, O. rosmarus divergens.

Walruses rear their pups near shore or on pack-ice during the spring (Stirling et al., 1983), and they feed mainly in water shallower than 100m (Fay, 1982). Thus Pacific walruses migrate from wintering areas in the Bering Sea to shoreline summering areas in the Bering and Chukchi seas or ice-edge habitats in the Chukchi Sea. Some animals remain in the southeast Bering Sea and Bristol year-round (Fay, 1982; Lowry et al., 1982b). According to Fay (1982) there are two areas of concentration during winter and early spring one southwest of St. Lawrence Island and another in Bristol Bay. The exact locations depend on ice conditions. In these seasons, females congregate and mate with mature males. In April and May, subadults and females with their young move north through the Bering Strait (Lowry et al., 1982b) in association

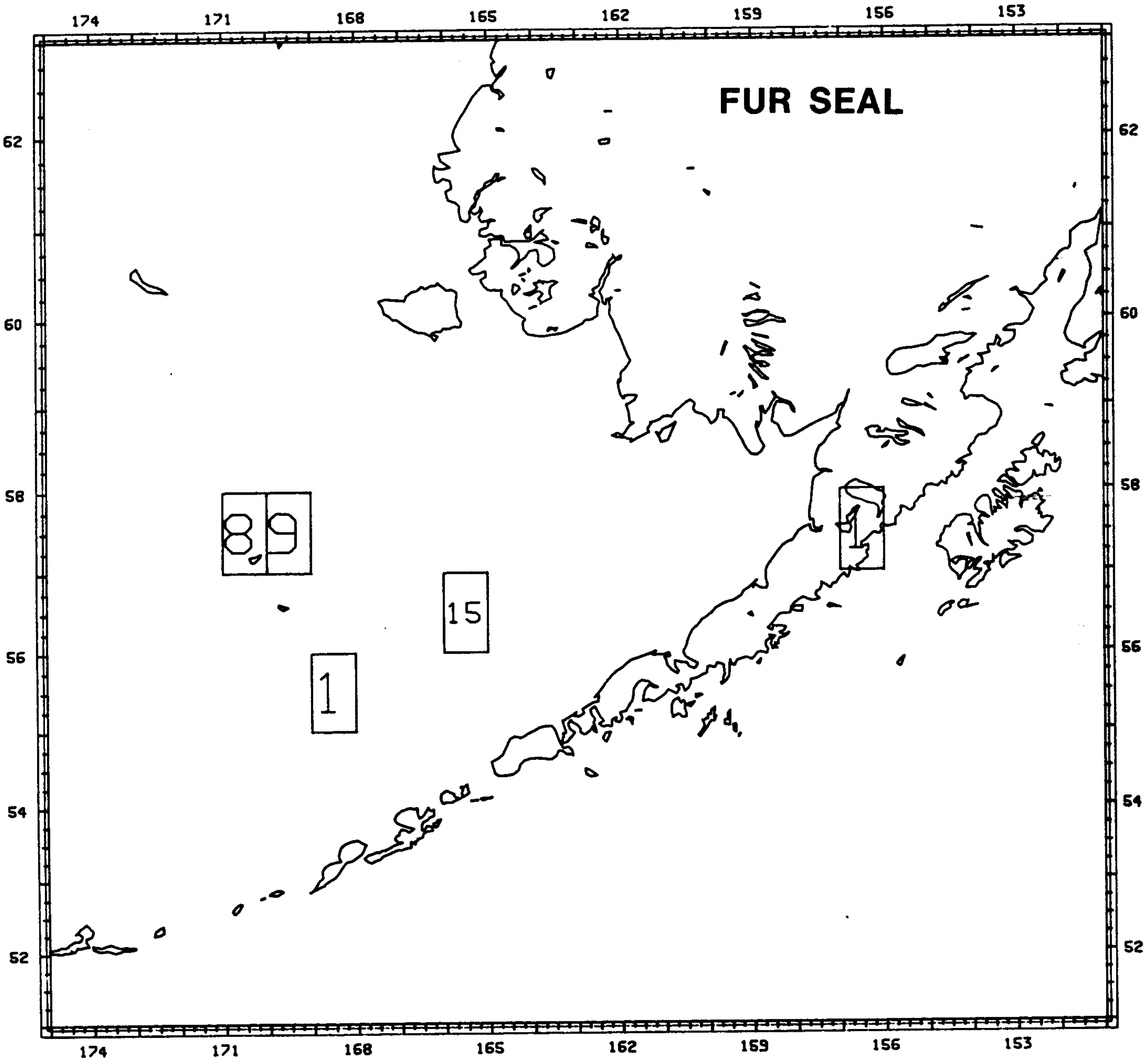


Figure 79. Total number of northern fur seals seen by 1° block.

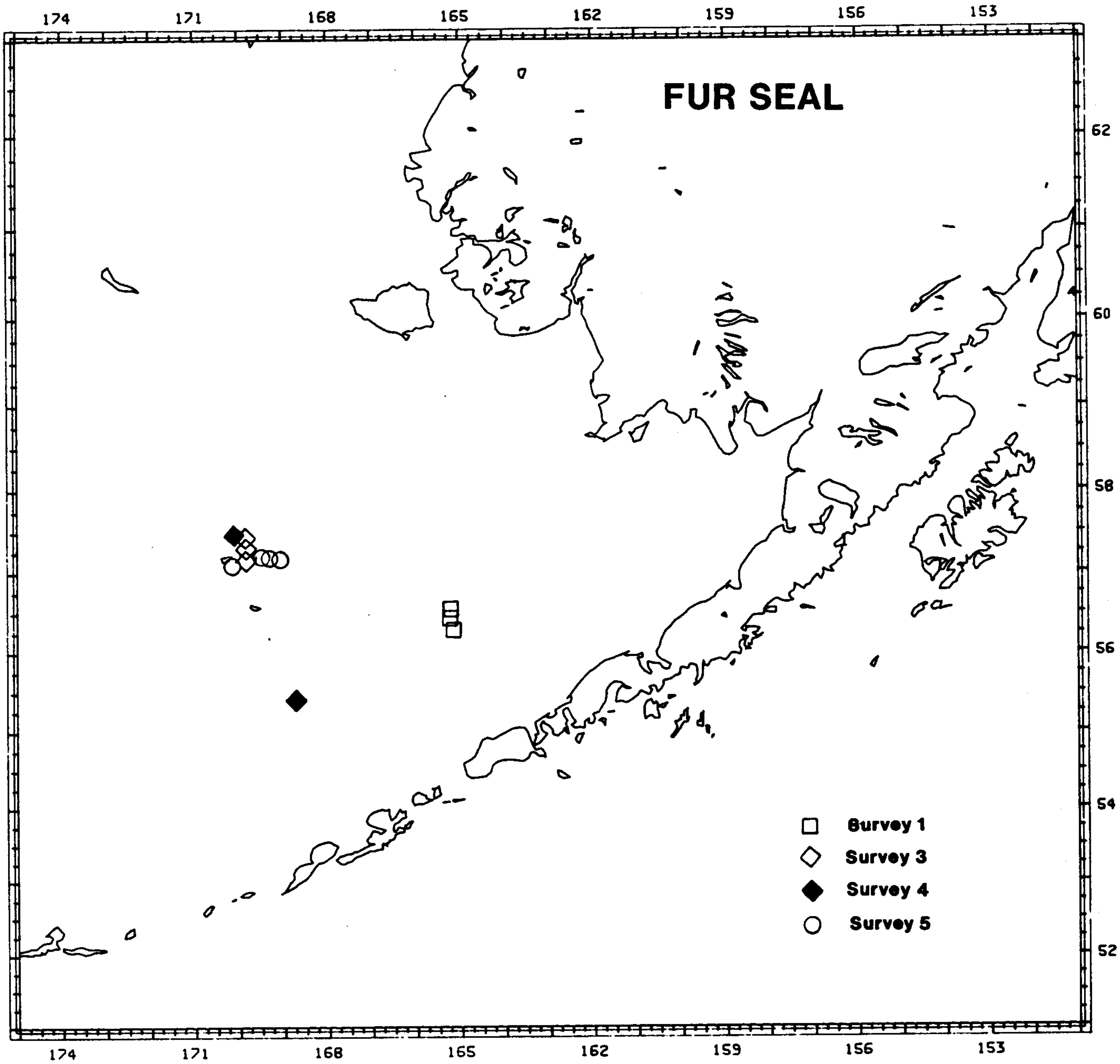


Figure 80. Locations of sightings of fur seals away from the Pribilof breeding grounds.

with the retreating ice edge. Adult males segregate on hauling grounds in Bristol Bay, Bering Strait, and along the southern Chukchi Peninsula (Lowry et al., 1982b) while females give birth and raise pups. Southward migration in the fall begins as early as October for animals in the Chukchi Sea. Fay and Lowry (1981) reported animals remaining on Round Island into November.

The walrus's diet is composed of over 60 genera of marine organisms, but about 80% of stomach contents contain bottom-dwelling bivalve molluscs (Lowry et al., 1982b). Thus walruses feed in productive shallow waters where nutrient turnover is high.

During our aerial surveys of the Bering Sea walruses were the most frequently encountered and abundant marine mammals, accounting for 434 sightings (4,816 animals) (Table 8). No walruses were seen in Shelikof Strait or anywhere else outside the Bering Sea. The total number of animals seen by 1 degree block is shown in Figure 81. Seasonal distribution is shown in Figure 82. In all seasons, more walruses were detected in block 1, which contains optimum wintering and summering habitats, than in other blocks. The relatively lower number in blocks 2, 3 and 6 reflects constriction of the species' range in fall through spring and extensions from block 1 north and west in spring and east and south in fall. The absence of walruses in blocks 4 and 5 probably reflects a combination of the absence of seasonal pack-ice, unproductive feeding areas, and generally deep water.

In the eastern Bering Sea, walruses use water less than 50 fathoms (92 m) deep. The majority of sightings occurred on water 21 to 30 fathoms (38-55 m) deep (Figure 83). Most animals which were associated with ice occurred in 10% to 68% coverage of floe-ice (Figure 84). However, only 36.4%

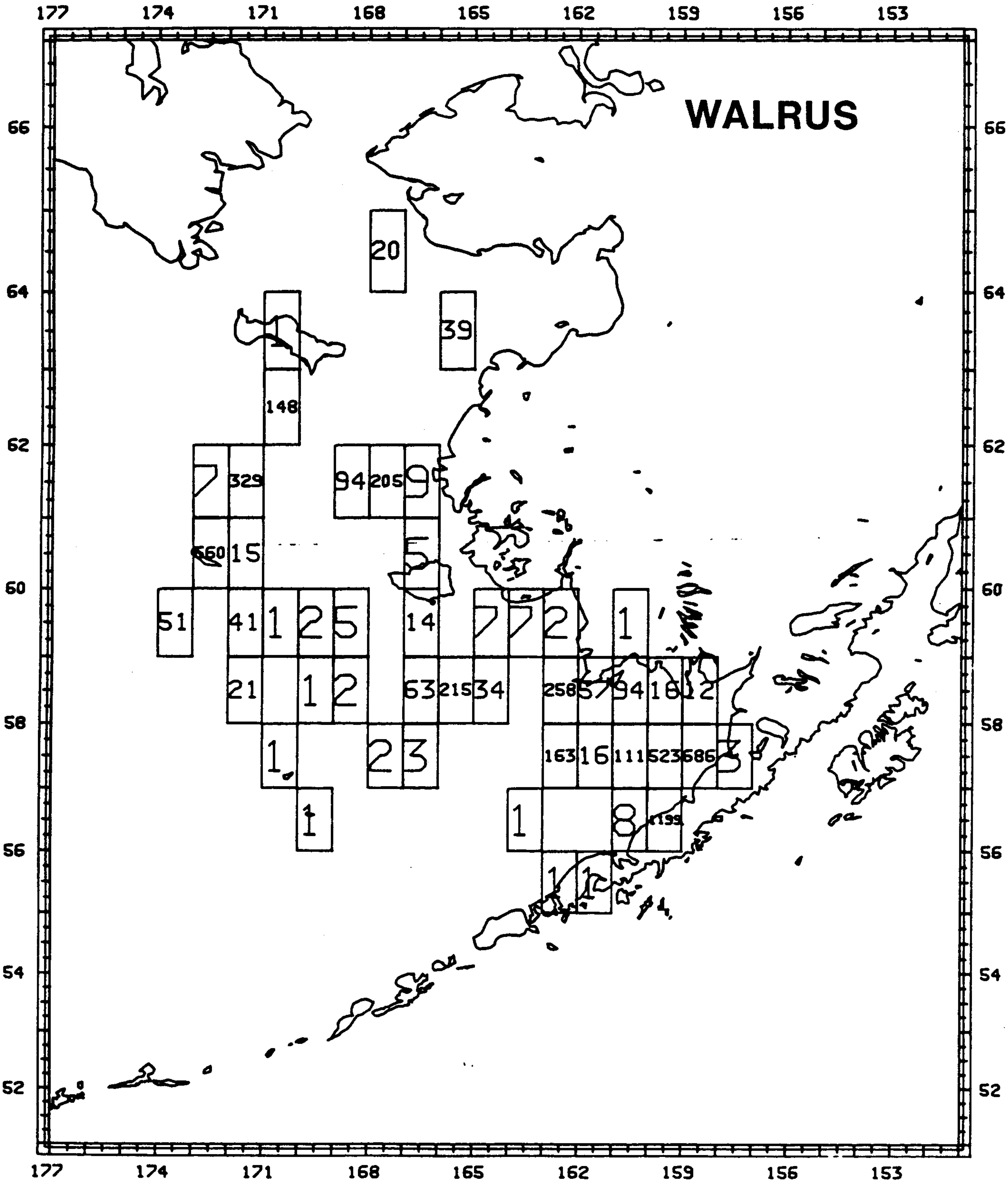


Figure 81. Total number of walruses seen by 1° block. The figure in the block between 58° and 59°N and 159° and 160°W does not include off transect counts on or near Round Island in summer.

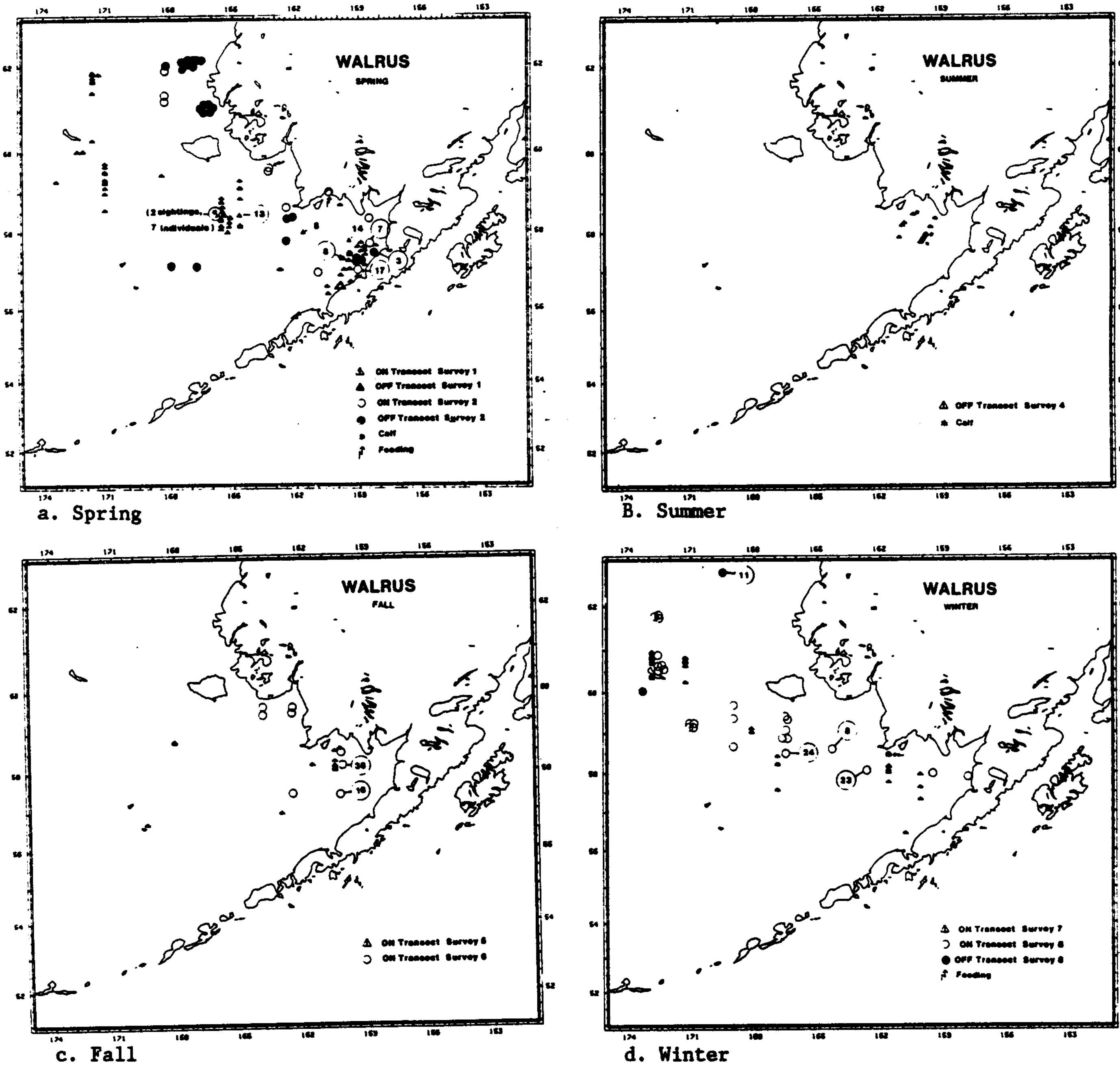


Figure 82. Distribution of sightings of walruses in spring (a), summer (b), fall (c), and winter (d).

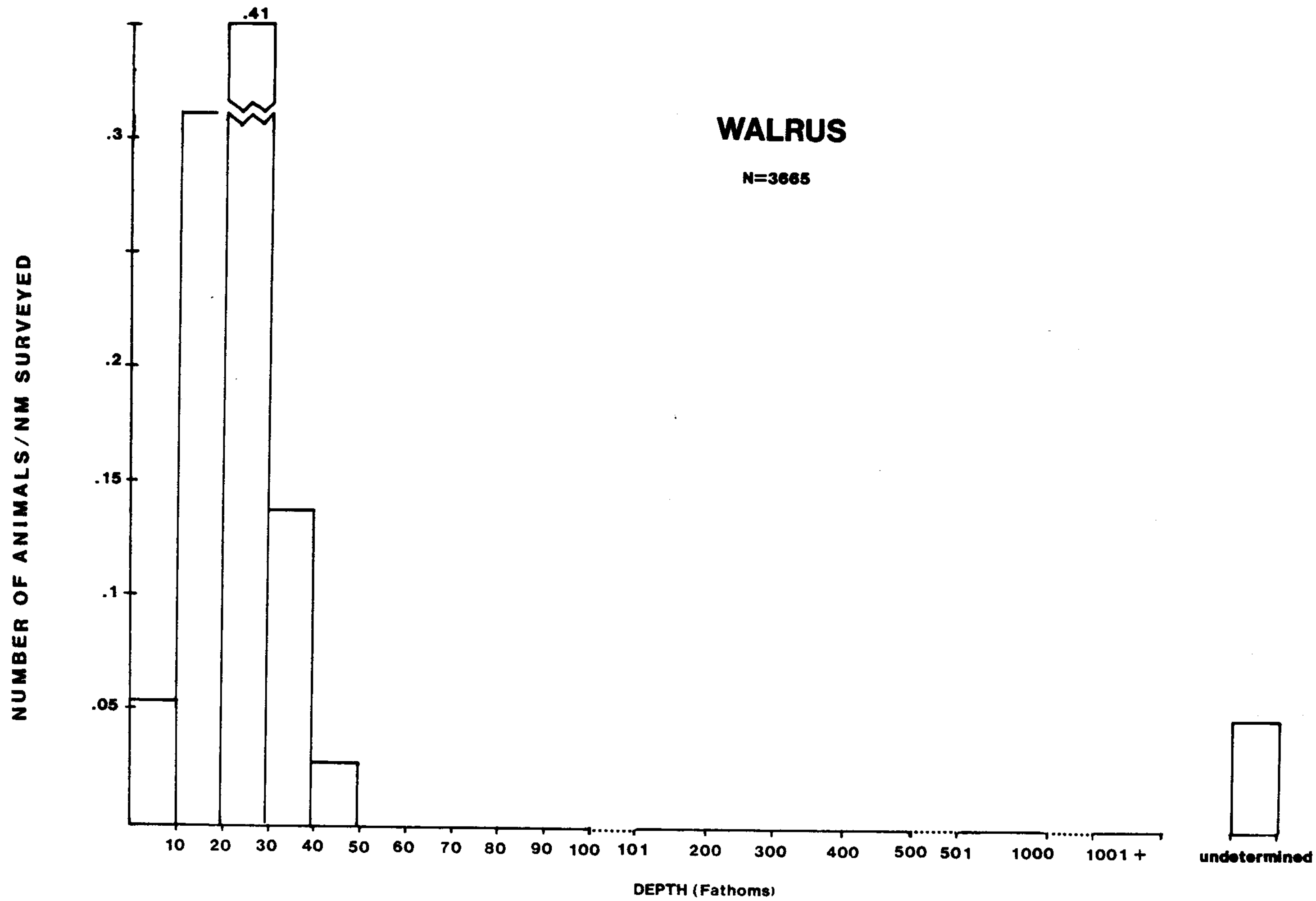


Figure 83. Indices of abundance of walruses by depth class.

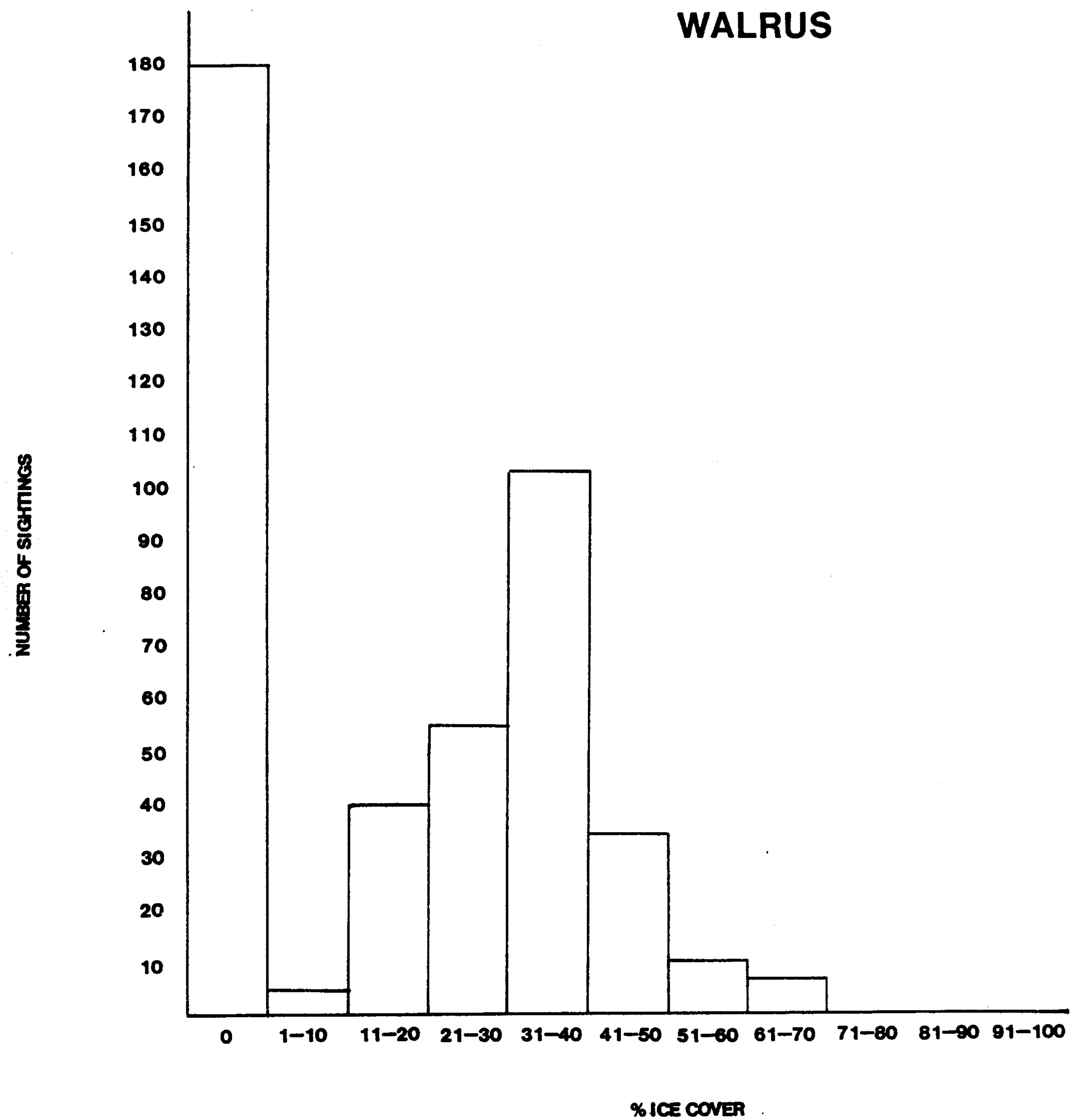


Figure 84. Indices of abundance of walruses by ice cover.

(2603) of all walruses seen were hauled-out. The remainder were detected in the water, though often adjacent to large haul-out concentrations.

Sightings data from random transects were adequate for blocks 1, 2, 3 and 6 combined to support separate estimates of density for each of 5 surveys (1, 2, 6, 7 and 8) and for all surveys combined (Table 10). The distribution of sighting distances, the fitted generalized exponential model, and the group size distributions used in these estimates are shown in Figures 85 and 86. Estimates for individual surveys ranged from 238.9 ± 309.5 (survey 2) to 868 ± 616.9 (survey 1) animals per 1000nm^2 (3,430 km^2). The estimate for all surveys combined is 471.1 ± 175.1 individuals per 1000nm^2. If that estimate is extrapolated to the combined area of blocks 1, 2, 3 and 6, (179,560nm^2)(615,891 km^2), there would appear to be 84,590 ± 31,429 walruses in Bristol Bay and the eastern Bering Sea. Given that our studies and the resulting estimate do not account for the entire Pacific walrus population, this estimate appears high. Other recent estimates, also considered high (cit. L. Lowry, pers. commn. 15 March 1984) are 270,000 to 290,000 for 1980 (from surveys by Johnsen and Burnes) well over 100,000 (Fay, 1982), and 66,548 (Fay and Lowry, 1981). Despite harvests by the USA and USSR, populations have increased markedly since the 1950's. However, there are no separate estimates for the eastern Bering Sea.

Harbor Seal (*Phoca vitulina*)

Harbor seals are common in littoral waters throughout the portions of Alaska we studied, including Shelikof Strait, southern Bristol Bay and the Aleutian Islands, and may be found hauled out on mainland beaches, islets and islands free from large terrestrial predators (Bigg, 1981:6-7). Everitt and Braham (1980) identified large concentrations at four locations

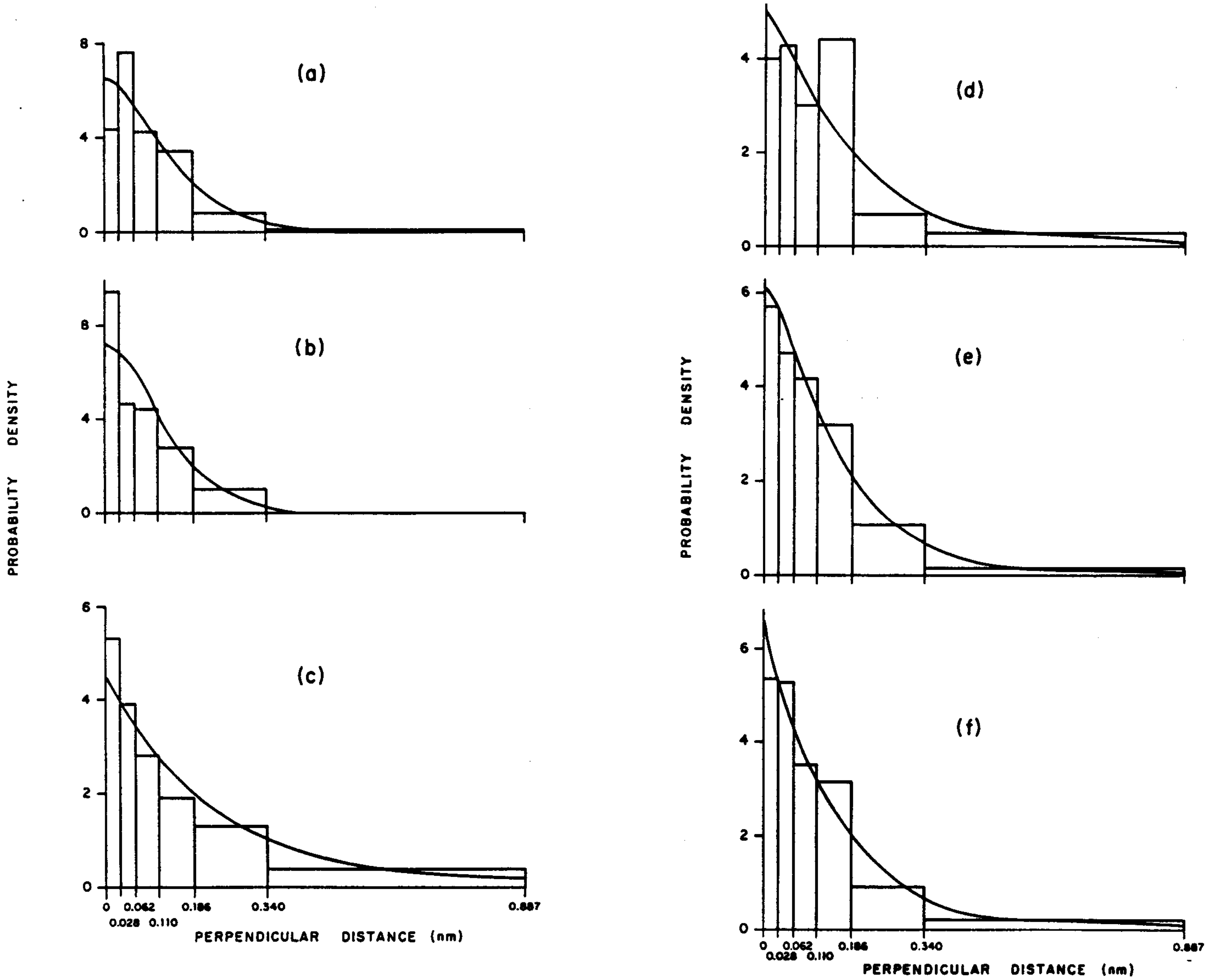


Figure 85. Perpendicular distances truncated under the aircraft at 0.051nm and the fitted generalized exponential models for walrus in blocks 1, 2, 3 and 6 in survey 6 (a), survey 7 (b), survey 8 (c), survey 1 (d), survey 2 (e) and all surveys combined (f).

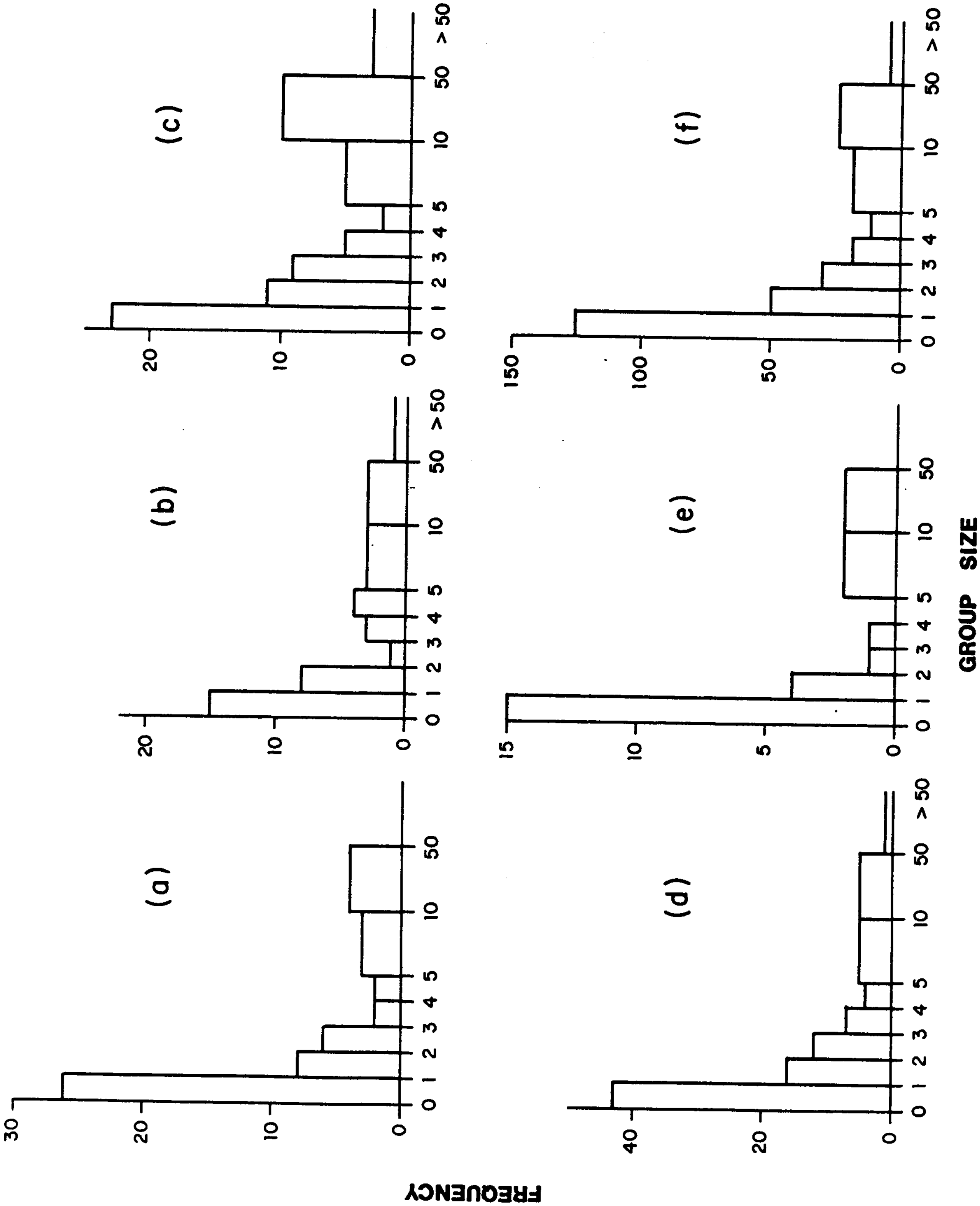


Figure 86. Group size distributions for walrus in blocks 1, 2, 3 and 6 in survey 6 (a), survey 7 (b), survey 8 (c), survey 1 (d), survey 2 (e) and all surveys combined (f).

along the north side of the Alaska Peninsula: Cinder River, Port Heiden, Port Moller and Izembeck Lagoon. Frost et al. (1982) summarized information for that area and also identified numerous small haulouts in northern Bristol Bay. They noted harbor seals on Otter Island in the Pribilofs as well. The population in Bristol Bay and the immediately adjacent Bering Sea, along the peninsula, is thought to number 30,000 (NOAA, 1979 as cited in Lowry et al., 1982b). That in the Aleutians is thought to number 20,000-25,000 (Fiscus, 1981 as cited in Lowry et al., 1982b:177). There is no separate estimate available for Shelikof Strait, though harbor seal habitat, distribution and numbers in the Gulf of Alaska are described in detail by Calkins et al. (1975).

During the present aerial surveys we saw harbor seals during transects and transits as follows: 68 groups (535 individuals) in the Bering Sea (Table 8) and 14 groups (308 individuals) in Shelikof Strait (Table 9). We saw an additional 5 groups of harbor seals (7 animals) outside the study area. Numbers observed by one degree square are shown in Figure 87, the distribution by season in Figure 88. In blocks 1-6 harbor seals were most widely distributed and abundant in spring and fall (Figure 89) and were concentrated near shore in eastern Bristol Bay in summer. In Shelikof Strait large numbers were detected in spring and fall (Figure 90). Harbor seal pups were seen only during survey 2. There were few winter sightings anywhere. Harbor seals were generally seen near haulout areas and in shallow water, though some animals were encountered in water 50 to 60 fathoms (91 to 110 m) (Figure 91).

Using appropriate sightings in the Bering Sea from all surveys combined (33) (Figure 92) and fitting a Fourier series model to the sighting distance

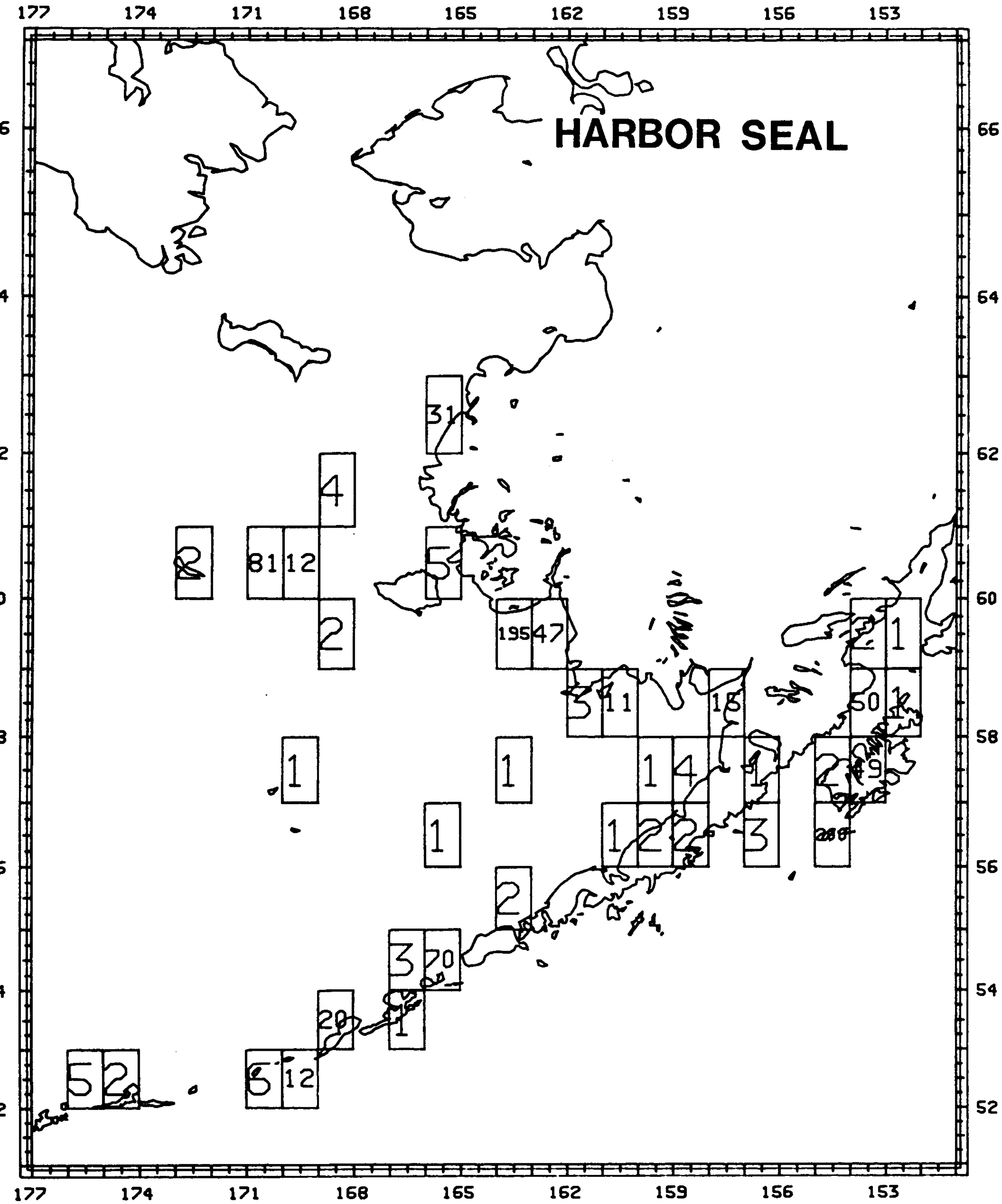


Figure 87. Total number of harbor seals seen by 1° block.

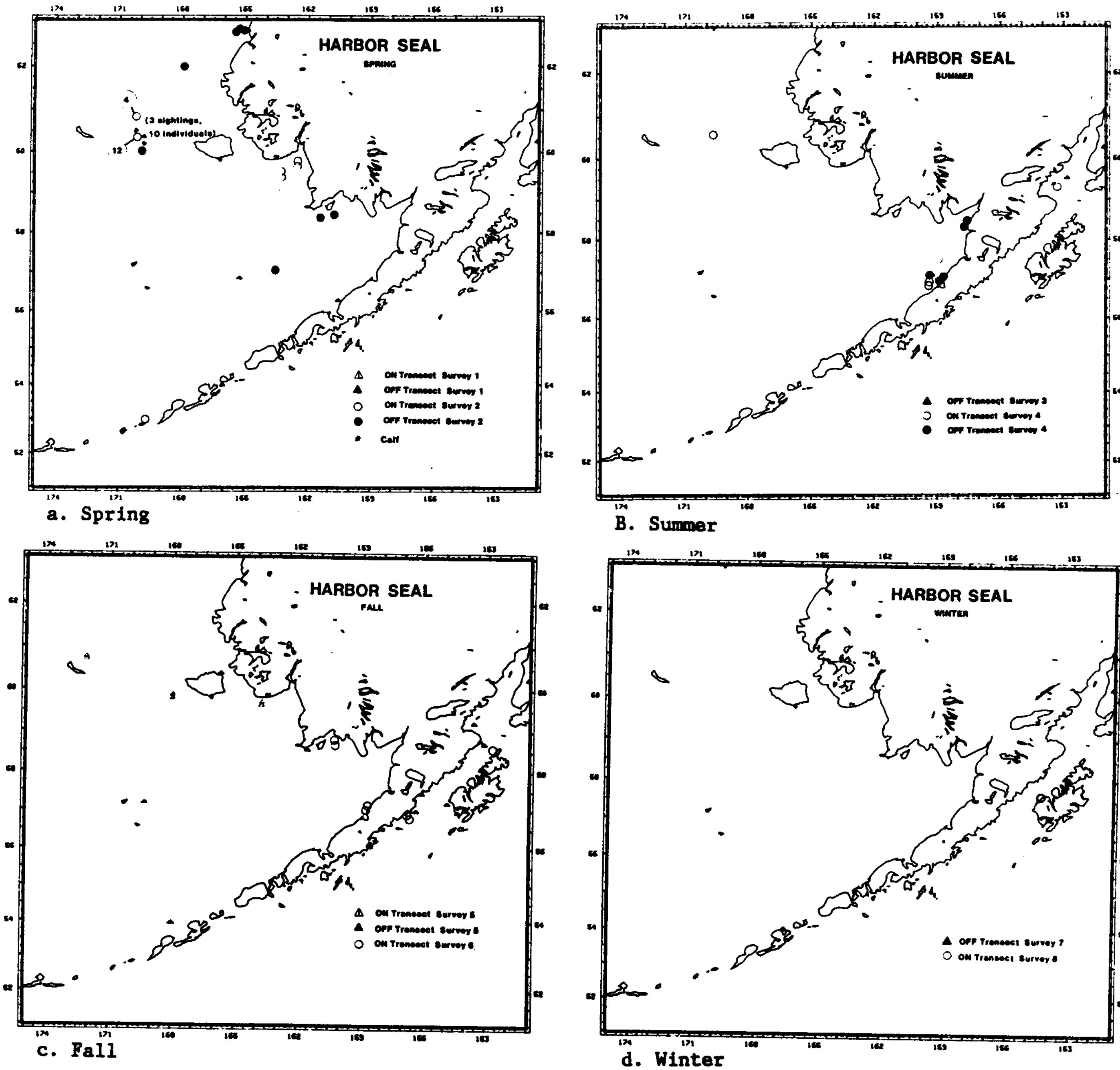


Figure 88. Distribution of sightings of harbor seals during spring (a), summer (b), fall (c), and winter (d).

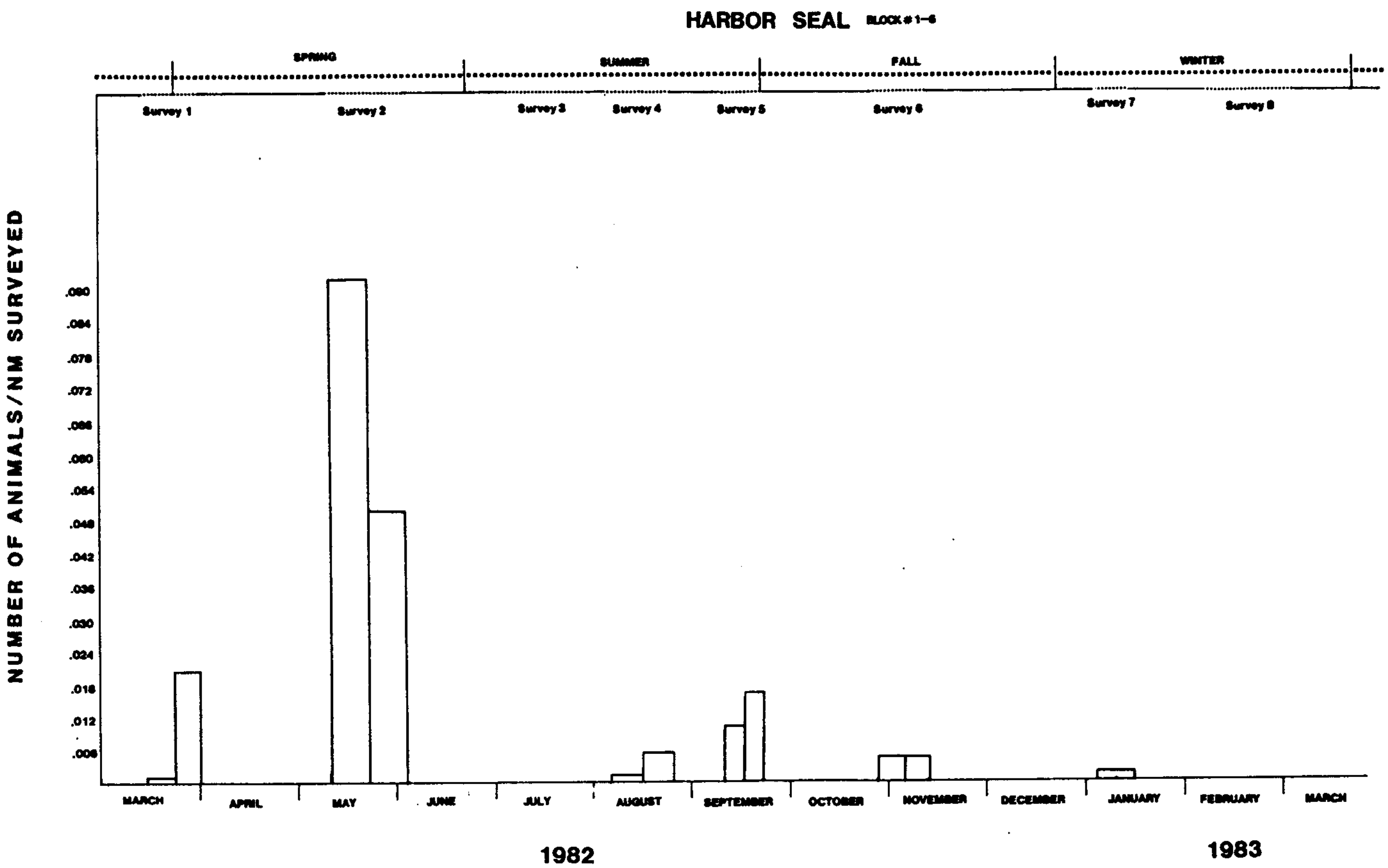


Figure 89. Indices of abundance of harbor seals by survey in blocks 1-6.

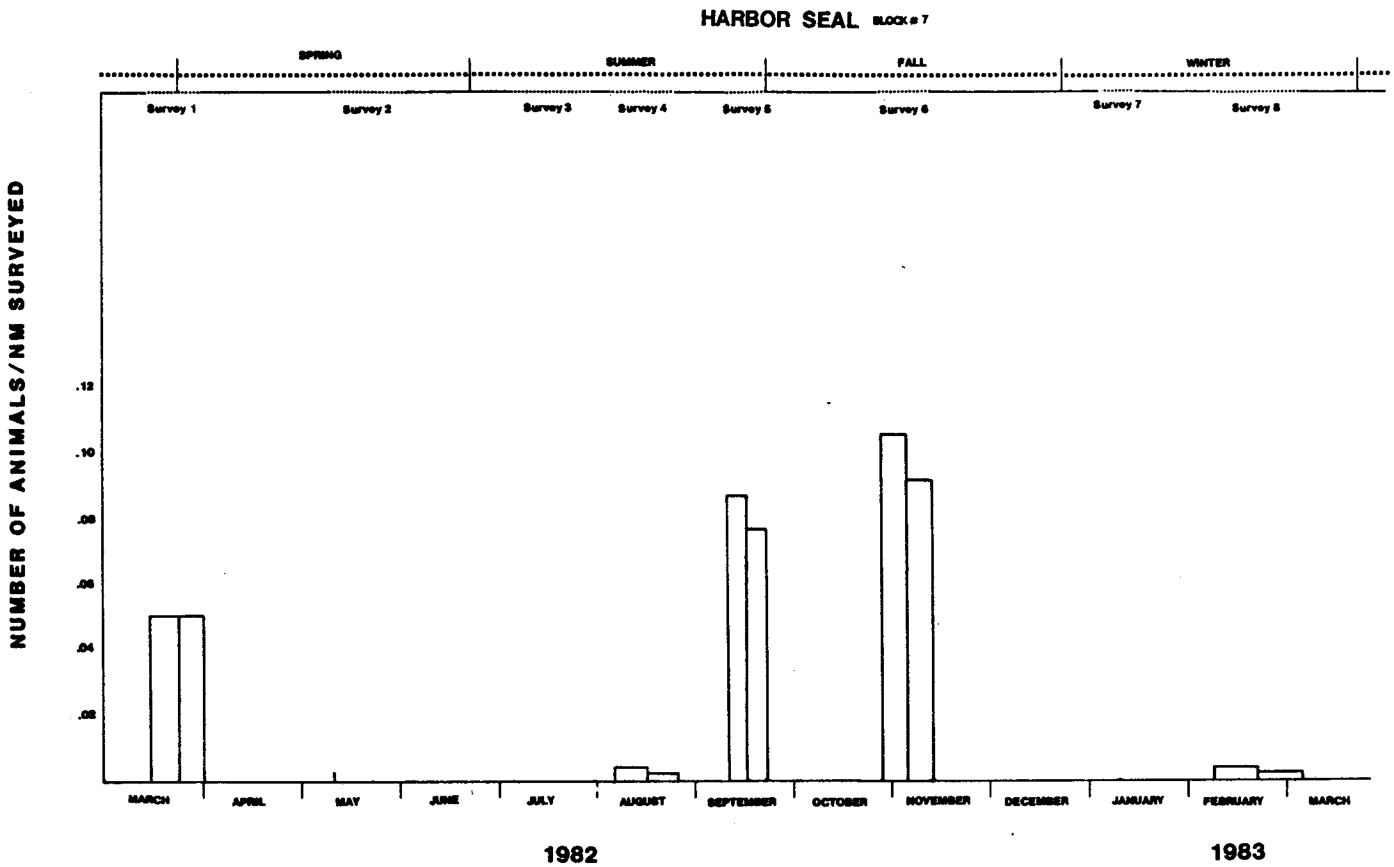


Figure 90. Indices of abundance of harbor seals by survey in block 7.

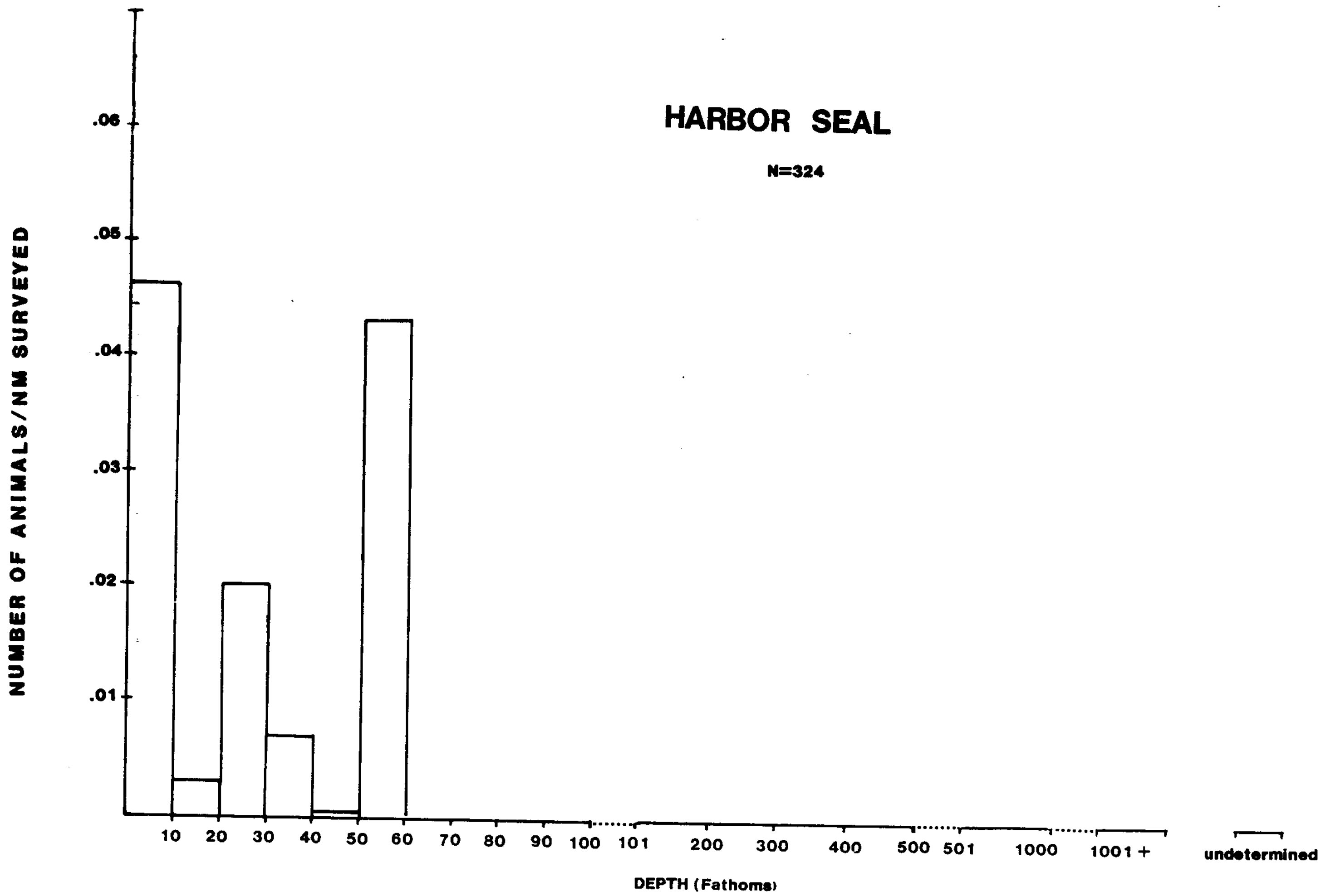


Figure 91. Indices of abundance of harbor seals by depth class.

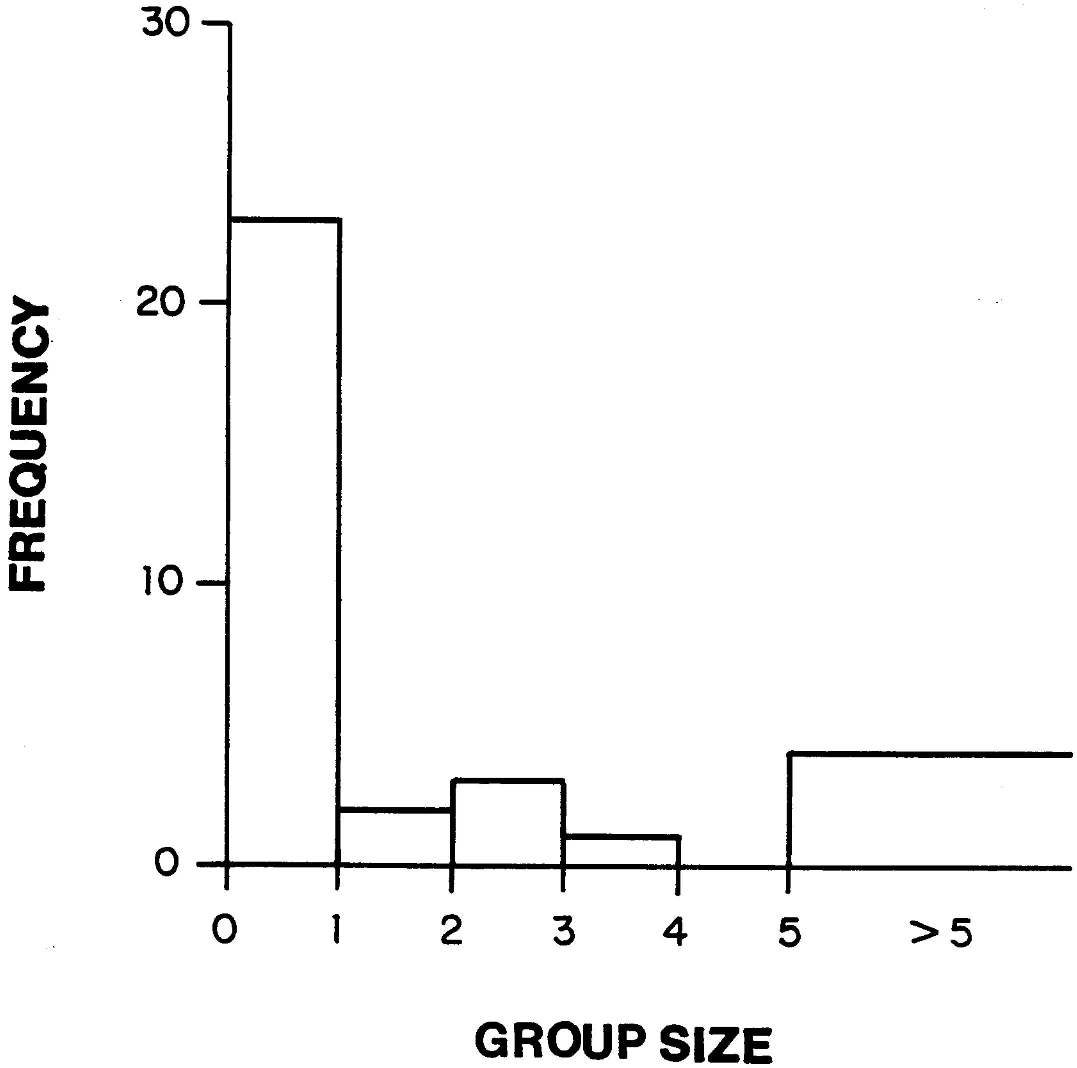


Figure 92. Distributions of group size for harbor seals.

distribution (Figure 93), it was possible to estimate harbor seal density for blocks 1, 2, 3 and 6 as 23.07 $\pm$ 13.54 individuals/1000nm^2.

Largha Seal (*Phoca largha*)

Largha seals are the pagophilic counterparts of the harbor seal. Like the harbor seal, they are primarily littoral during summer. But in fall and winter they migrate to the ice fringe and into recurrent leads within the ice pack (Fay, 1974). They remain in such areas through spring, giving birth and nursing their young on floes in the ice front and fringe (Bigg, 1981).

We saw 64 seals we identified as largha seals (Figure 94): solitary animals seen during survey 2 in block 6 (1) and block 1 (2) and survey 8 in block 3 (1), and two sightings (totaling 60 individuals) north of our study area in survey 2. All animals were associated with ice of 20 to 99% coverage, either on the ice or immediately adjacent to it (Figure 95).

Ringed Seals (*Phoca hispida*)

Ringed seals are widely distributed in seasonally and permanently ice-covered waters of the Northern Hemisphere. Portions of the population follow the annual advance and retreat of the ice (Frost and Lowry, 1981b). Popov (1976) estimated Bering Sea ringed seals to number 70,000 to 80,000. The total population of ringed seals in Alaskan waters has been estimated as at least 1-1.5 million (Lowry et al., 1982b). The average densities in haul-out areas in fast ice in the Beaufort and Chukchi seas ranged from 0.4/nm^2 to 6.2/nm^2 (Lowry et al., 1982b). Despite such numbers and densities, these small (to 135cm and 49 kg) and usually solitary seals (Frost and Lowry, 1981b) are difficult to detect from aircraft, particularly at the altitudes at which we were operating. Nevertheless,

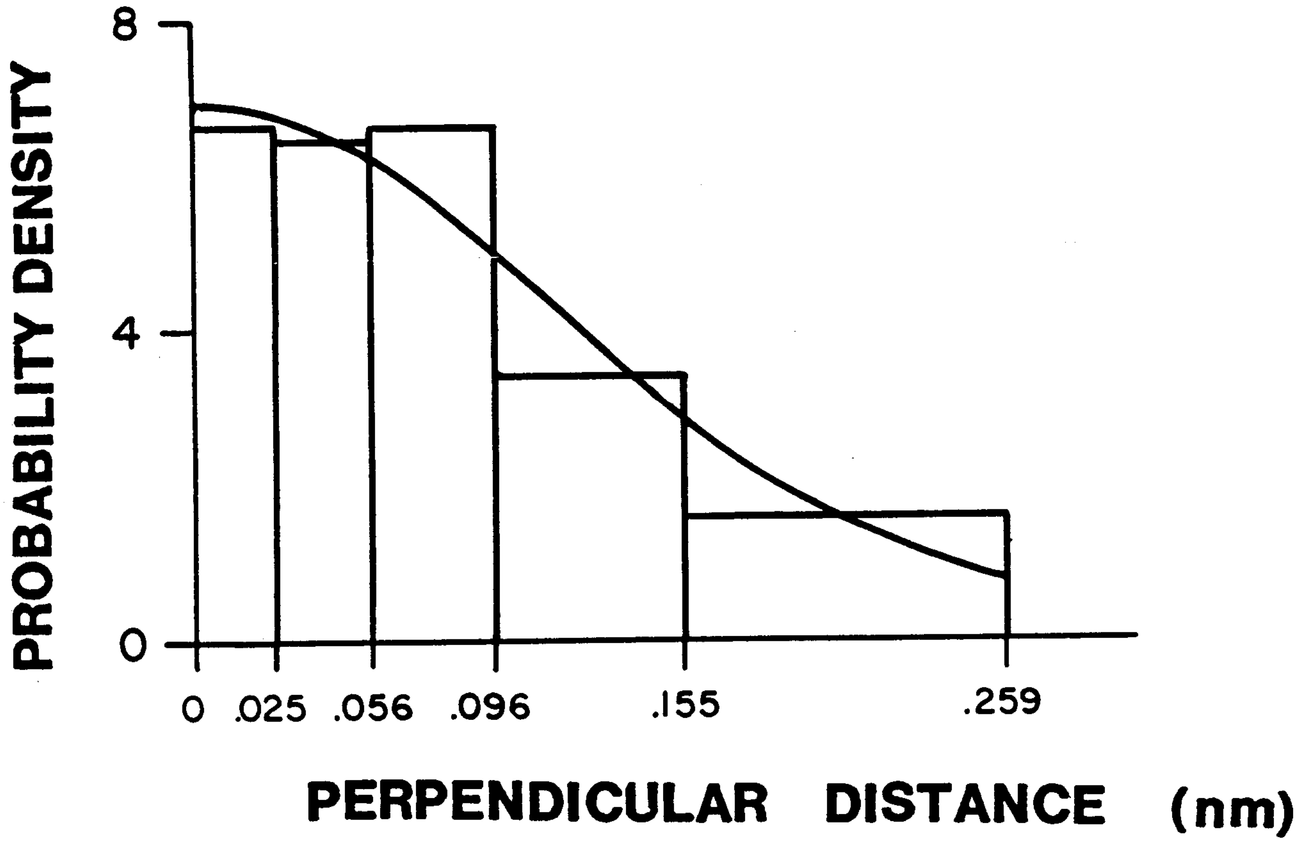


Figure 93. Perpendicular distances truncated under the aircraft at 0.439nm for the harbor seal and the fitted Fourier Series.

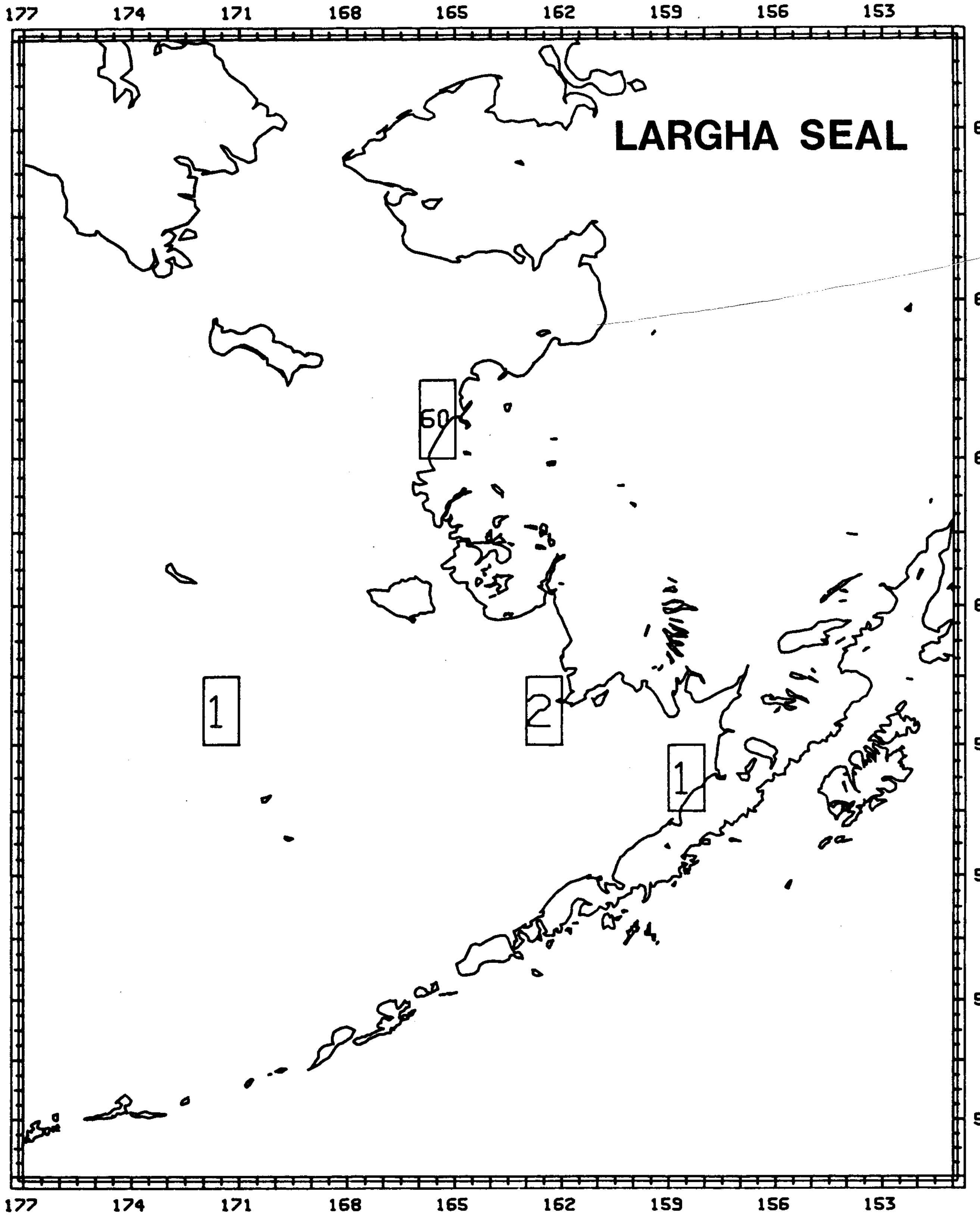


Figure 94. Total number of largha seals seen by 1° block.

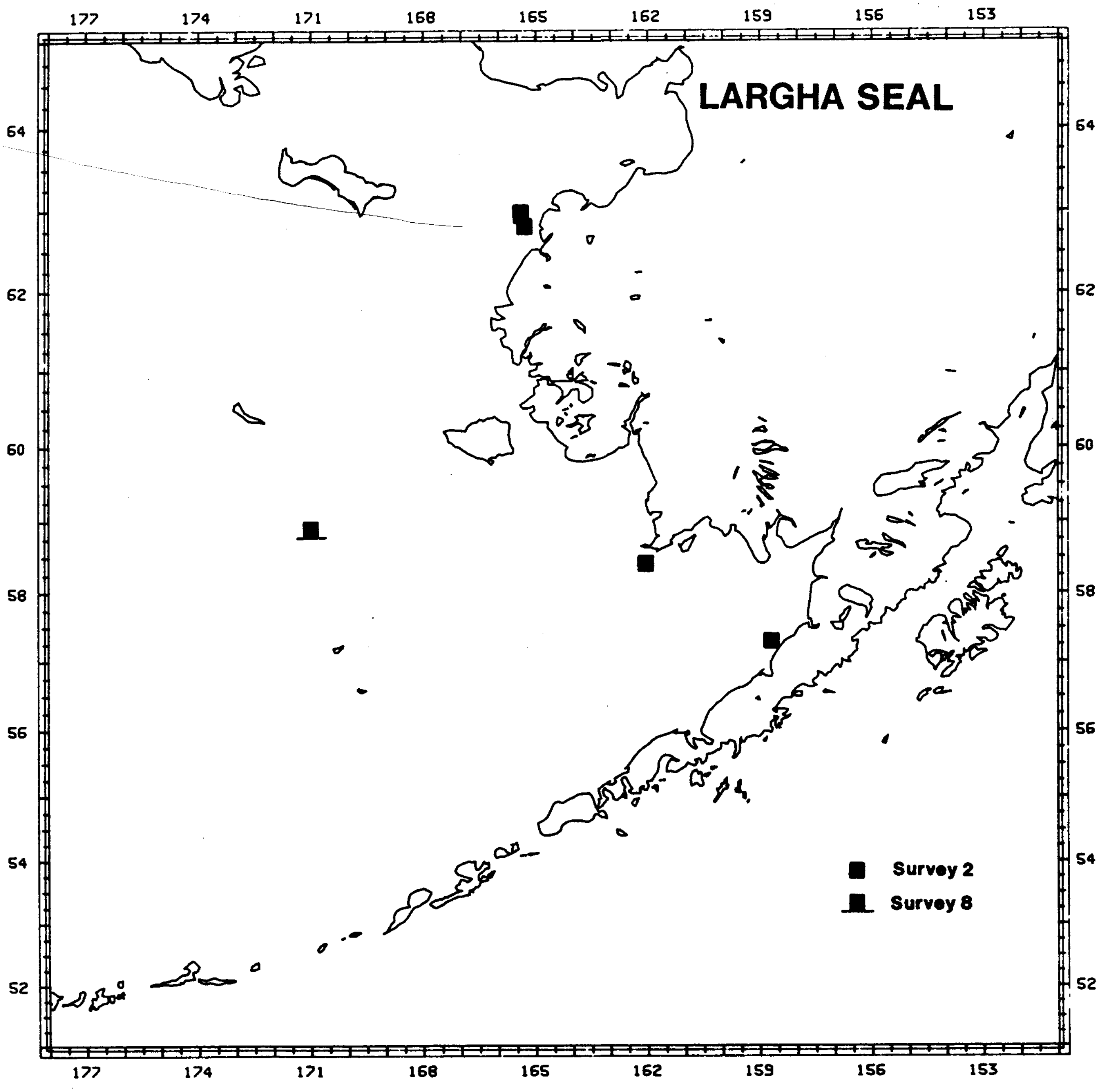


Figure 95. Locations of sightings of largha seals.

we were able to positively identify seals as ringed seals 18 times (Figure 96), 10 in the study area and the remainder north of the study area, at locations indicated in Figure 97. All sightings except one in open water during survey 5, were associated with 30-90% ice cover.

Ribbon Seal (Phoca fasciata)

In winter and early spring, ribbon seals concentrate along the ice edge in the Chukchi, Bering and Okhotsk seas to whelp, nurse their young, mate, and molt (Frost and Lowry, 1980; Burns, 1981a; Lowry et al., 1982b). Within and near our Bering Sea study area they may be found at such times in low densities in Bristol Bay and in higher densities north and west of the Pribilof Islands, west of St. Matthew Island, and southwest of St. Lawrence Island. In late spring the seals disperse with break-up and meeting of the pack-ice. They are presumed to be solitary and pelagic in summer and autumn but their distribution then is, in fact, all but unknown (Wilke, 1954; Naito and Kono, 1979; Burns, 1970, Burns, 1981a).

Burns (1981a) summarized the few published summer sightings from the central Bering Sea. The few other, more southerly records, are from Unalaska Island (Allen, 1880), Cordova, Alaska (Burns, 1981a), 51°09.5'N, 172°37.5'E, in the central North Pacific (Stewart and Everett, 1983), and Morro Bay, California (Roest, 1964). Therefore, we did not expect to see ribbon seals on other than winter or spring surveys (when ice was present) in the Bering Sea or at all in or near the Shelikof Strait study area.

There were 6 confirmed sightings of ribbon seals, totaling eight animals (Table 17). All were made on 3 March 1983 during survey 8, at the ice edge between the Pribilofs and St. Matthew Island (Figure 98). In addition, however, there were three sightings logged in the field as unidentified phocids, but with the notation, added later, that they were

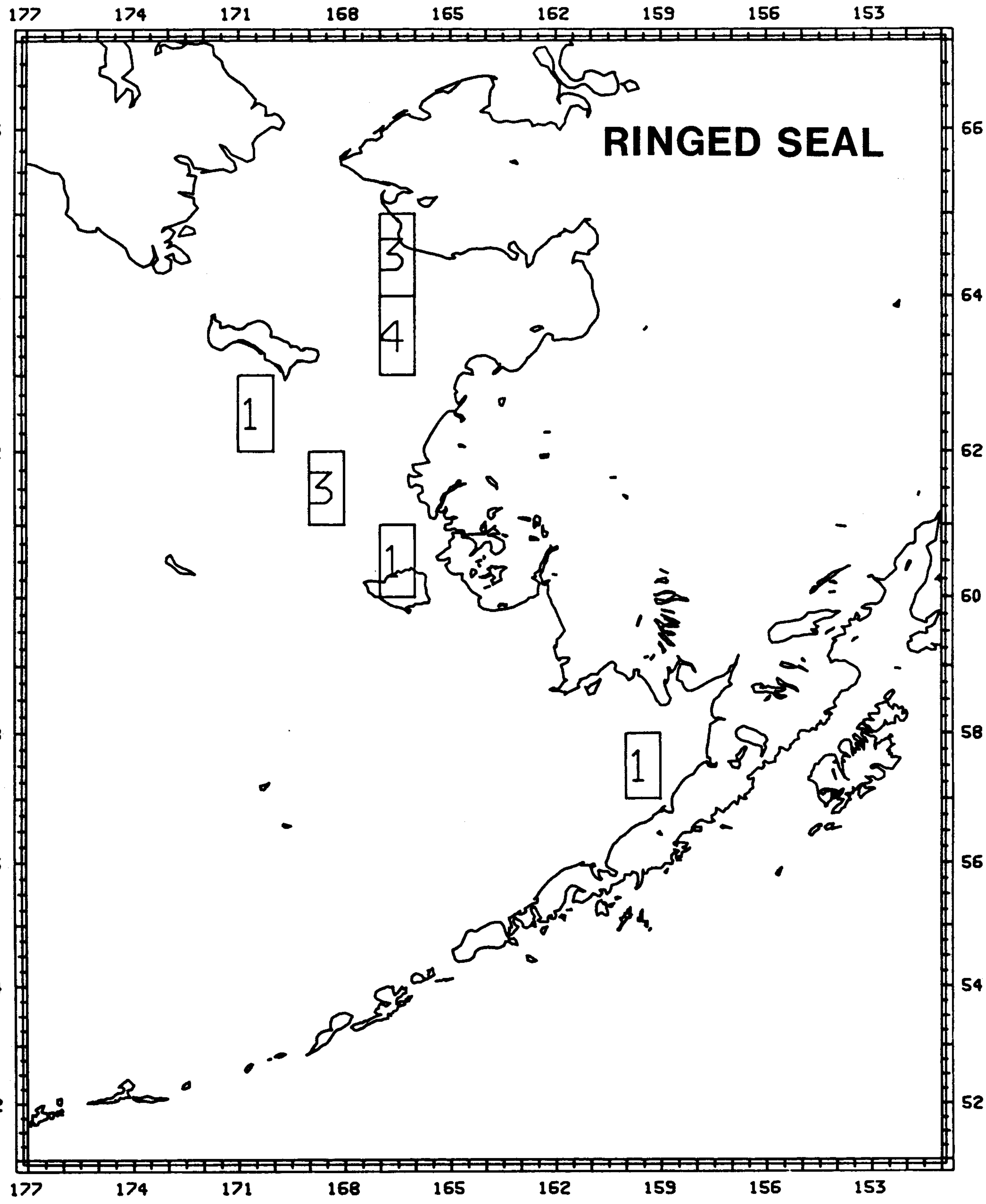


Figure 96. Total number of ringed seals seen by 1° block.

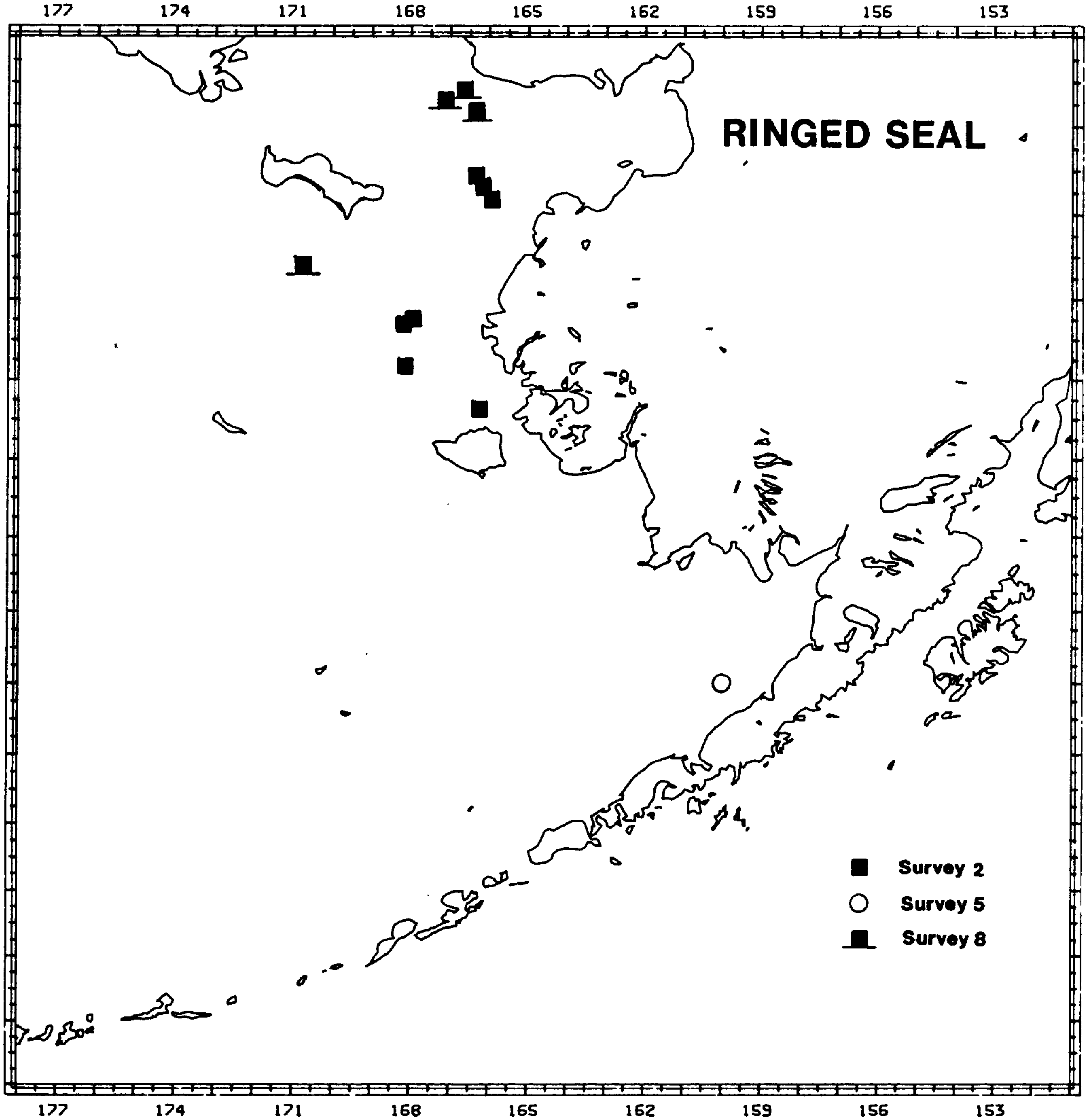


Figure 97. Locations of sightings of ringed seals by survey.

Table 17. Confirmed sightings of ribbon seals made during the aerial surveys.

Date	Time	Location	Number Individuals	Remarks
3 Mar 1983	1120	59°38.6'N, 170°59.8'W	2	On ice in area of 85% broken floes.
3 Mar 1983	1122	59°35.8'N, 171°00.3'W	1	On ice in area of 85% broken floes.
3 Mar 1983	1123	59°33.5'N, 171°10.0'W	1	On ice in area of 95% broken floes, bolted from aircraft shadow.
3 Mar 1983	1125	59°29.9'N, 170°69.4'W	2	On ice in area of 95% broken floes, bolted from aircraft shadow.
3 Mar 1983	1449	58°21.7'N, 169°00.1'W	1	On ice in area of 95% broken floes, bolted from aircraft shadow.
3 Mar 1983	1450	58°24.5'N, 169°00.0'W	1	On ice in area of 95% broken floes.

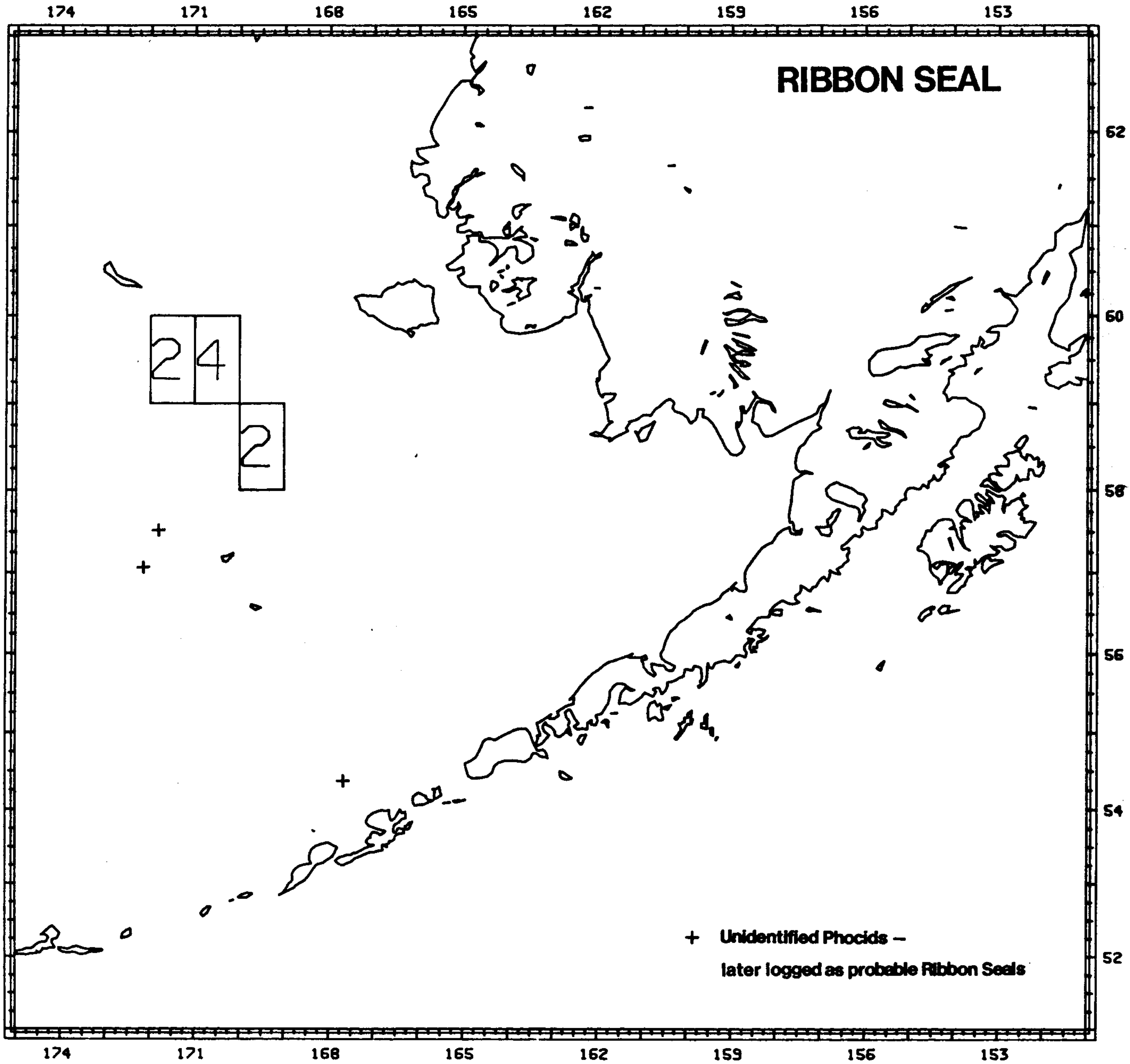


Figure 98. Locations of sightings of ribbon seals and number seen by 1° block.

probably male ribbon seals. One of those sightings occurred in July near Bogoslov Island, the other two in August north and west of the Pribilof Islands. Unfortunately, no other data are available for these last 3 records.

Bearded Seal (_Erignathus barbatus_)

The bearded seal is a circumpolar boreoarctic species occurring as two subspecies: _E. barbatus barbatus_ from the Laptev Sea westward to the Hudson bay region and _E. barbatus nauticus_ in the remaining region from the Canadian Arctic westward to the Laptev Sea (King 1964; Burns, 1981). The Bering Sea population(s) of the latter subspecies is estimated to contain 300,000 individuals (Burns, 1981b). Bearded seals are widely distributed in seasonal pack ice (Lowry et al., 1982b). We did not expect to see them within the Bering Sea study area except in spring and winter when ice was present. This was the case.

We saw 48 groups of bearded seals (60 individuals) (Figure 99), all during spring (surveys 1 and 2) and winter (surveys 7 and 8) (Figure 100). They were encountered most frequently during spring (Figure 101), the pupping season, which was to be expected as the seals are more visible in pairs or groups. Pups were seen only on survey 1. Animals were seen on or immediately adjacent to ice in areas of 90 to 99% coverage, primarily in water from 10 to 40 fathoms deep (Figure 102). With the exception of animals sighted at the ice edge in proximity to conspecifics, bearded seals were not positively identified in the water.

The distribution of sighting distances was fitted to a Fourier Series model (Figure 103) and treated with counts of group size (Figure 104)

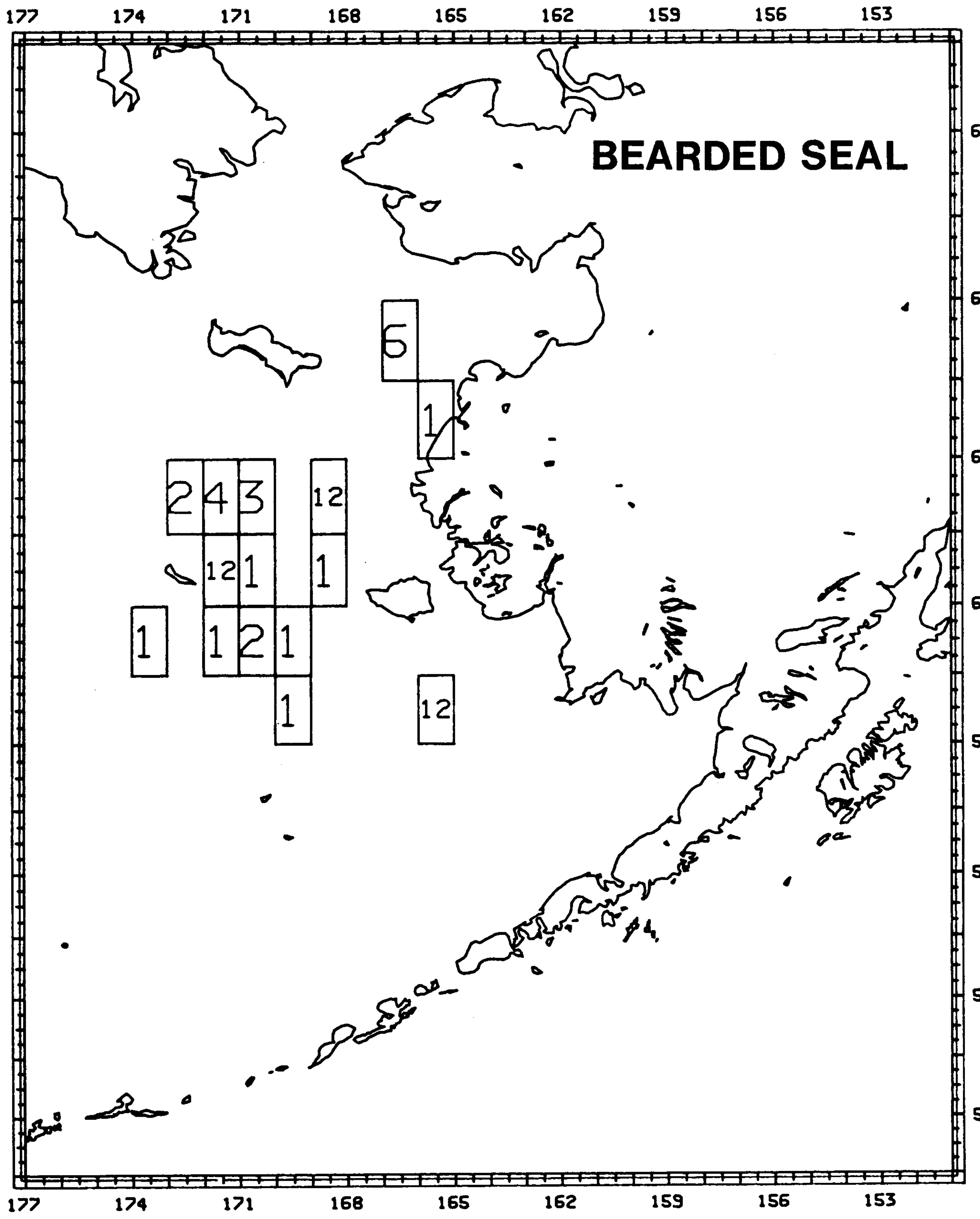
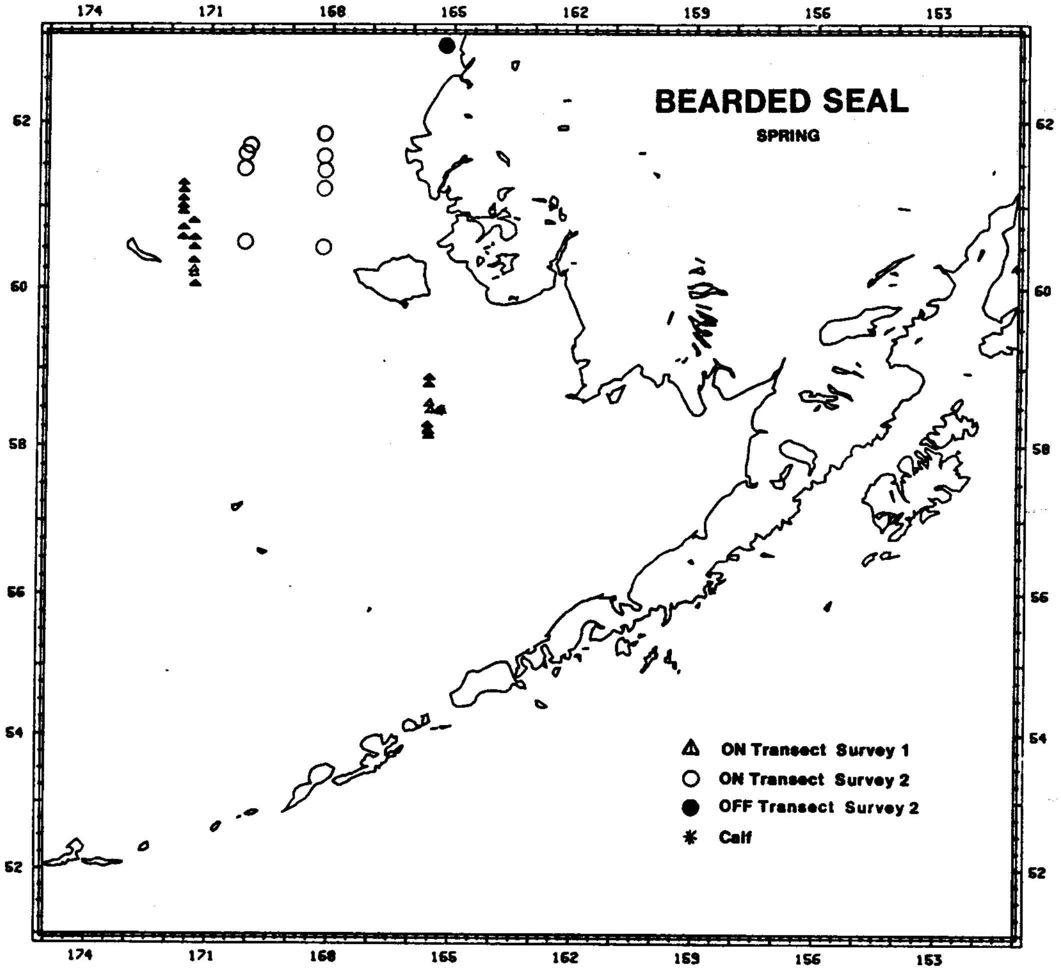


Figure 99. Total number of bearded seals seen by 1° block.



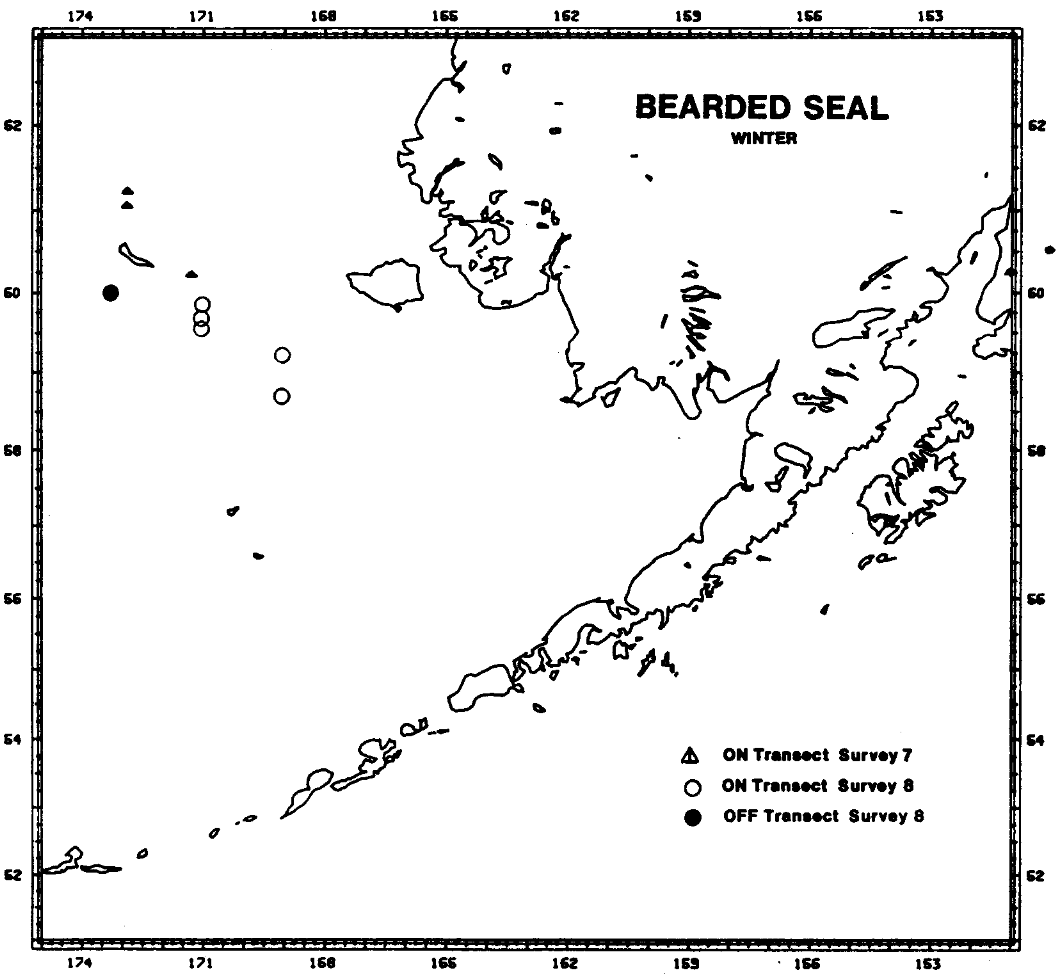


Figure 100. Locations of sightings of bearded seals during spring (top) and winter (bottom).

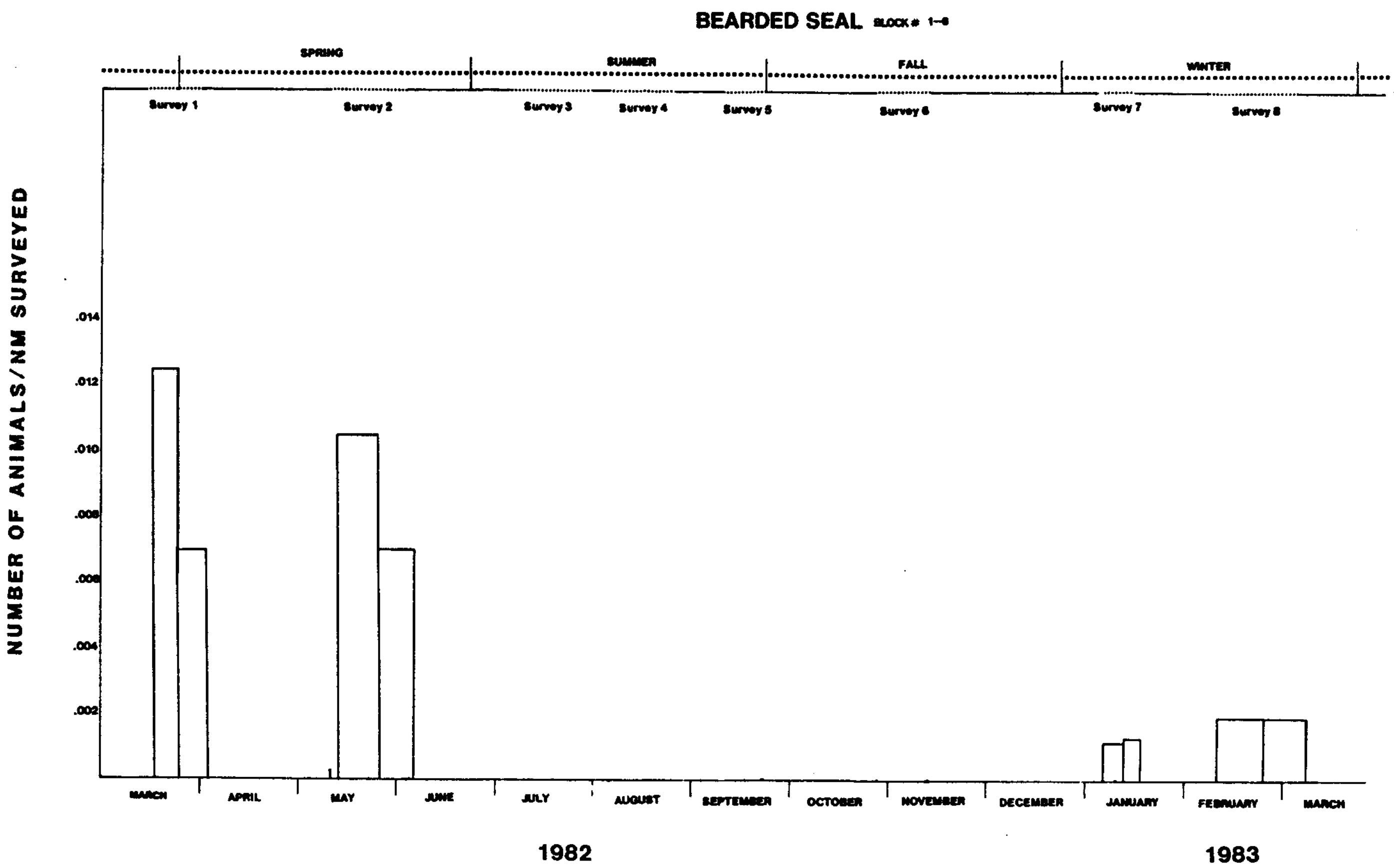


Figure 101. Indices of abundance of bearded seals by survey in blocks 1-6.

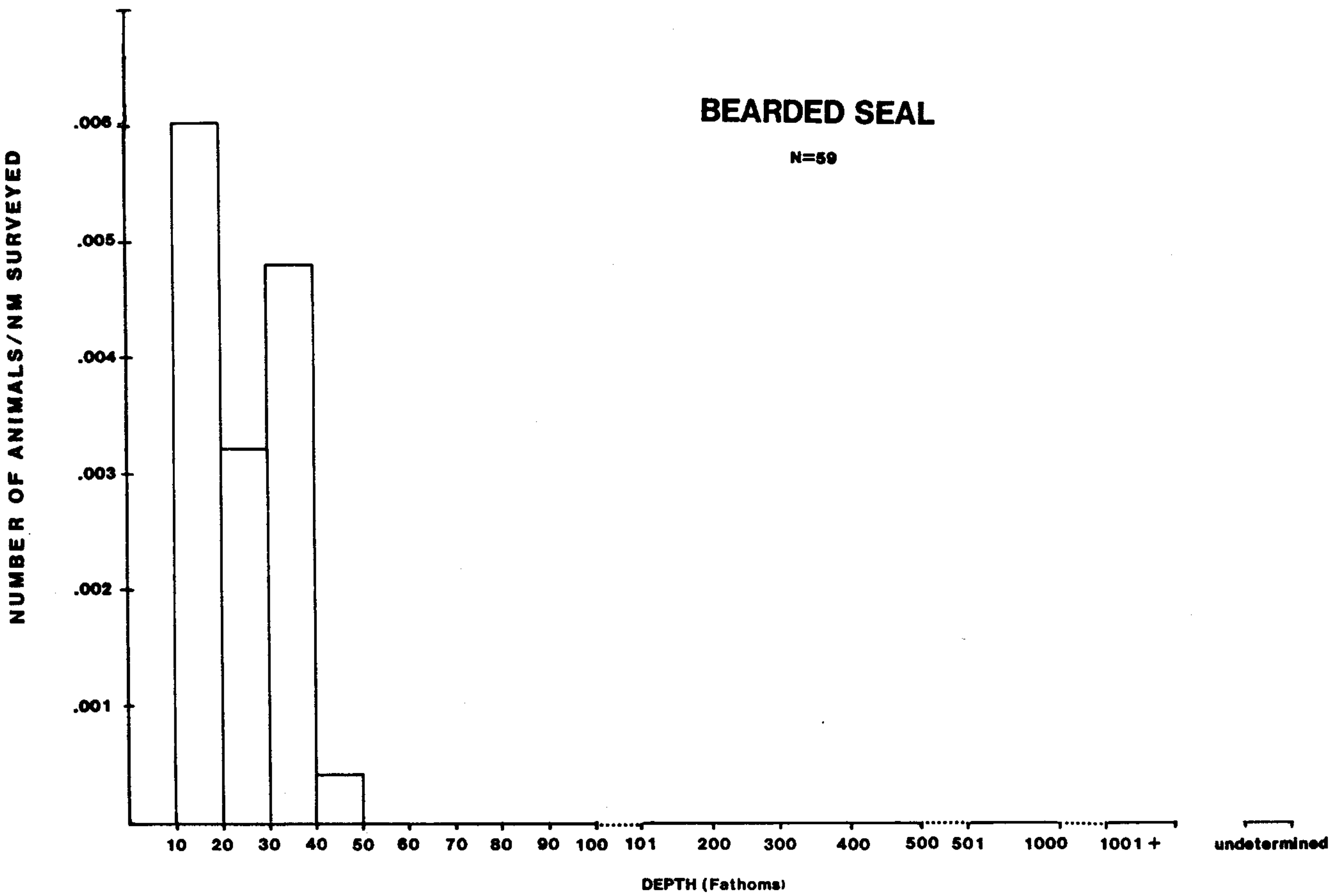


Figure 102. Indices of abundance of bearded seals by depth class.

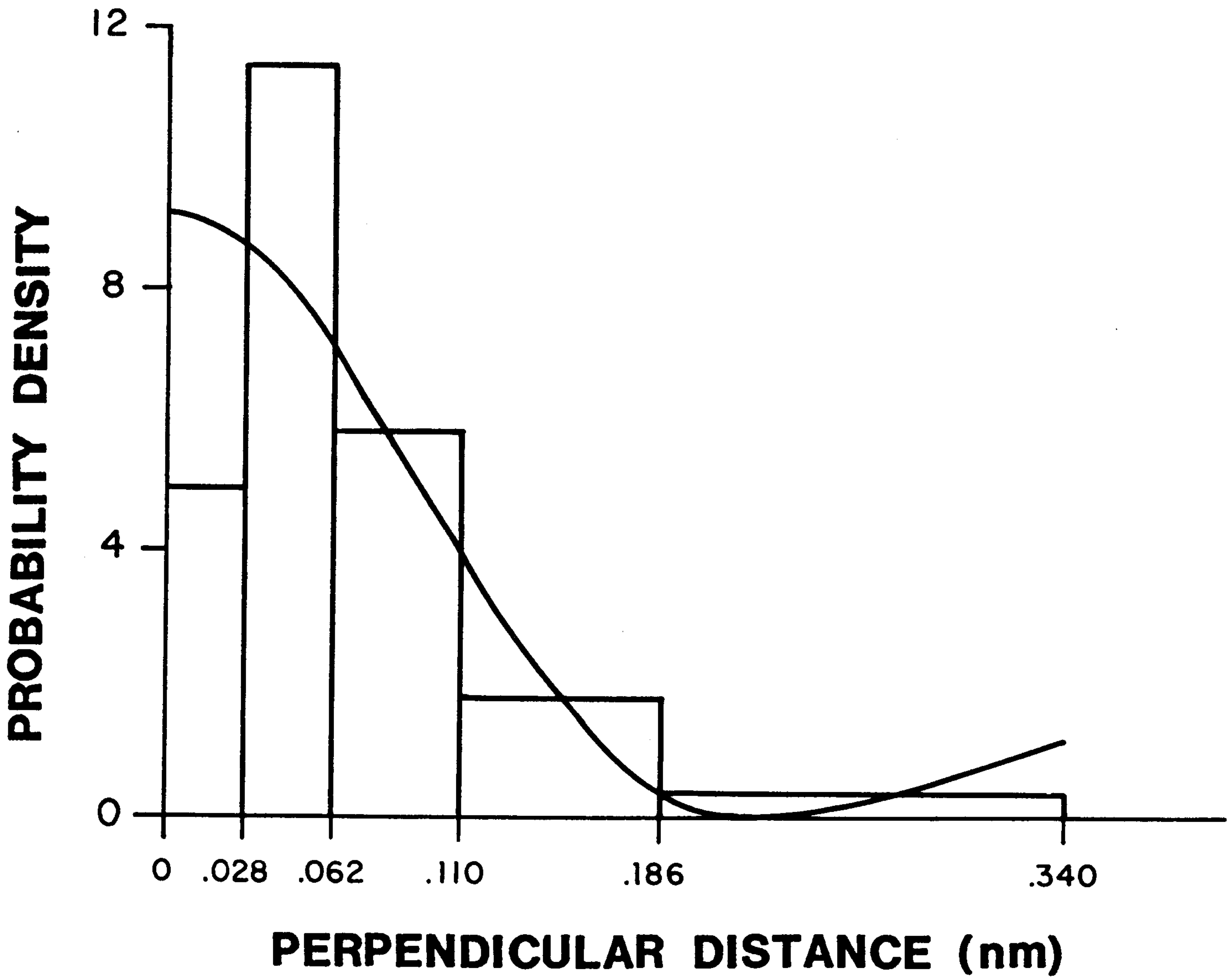


Figure 103. Perpendicular sighting distances truncated under the aircraft at 0.051 nm and the fitted Fourier Series model for bearded seals.

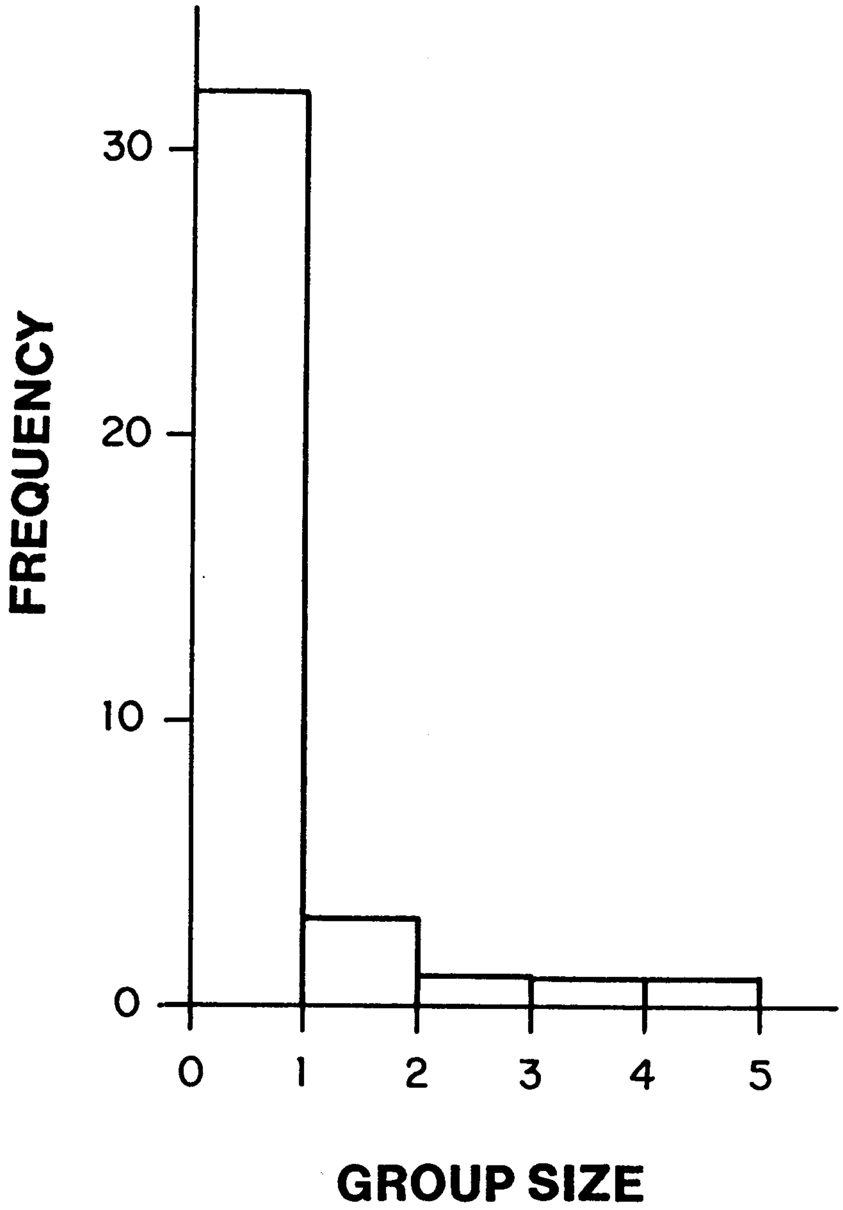


Figure 104. Size of groups of bearded seals.

to estimate that there were 18.16 $\pm$ 7.62 bearded seals per 1000nm^2 in blocks 1, 2, 3 and 6, all surveys combined (Table 10).

Northern Elephant Seal (Mirounga angustirostris)

The population of northern elephant seals has burgeoned following near-extinction in the late 19th century. Overall the species appears to be growing exponentially, at rates of about 11-15% per annum (Cooper and Stewart, 1983). At present its breeding range extends from Cedros, San Benitos, and Guadalupe islands, off Baja California, north to the Farallon Islands off San Francisco, California (Antonelis, Leatherwood and Odell, 1981; McGinnis and Schusterman 1981; Cooper and Stewart, 1983). Nonbreeding animals are often seen in waters as far north as Vancouver Island, Canada (Scheffer, 1958), and there are three still more northerly published records from Alaskan waters: the carcass of a subadult on Prince of Wales Island (Willett, 1943), and young males seen 4 July 1977 and July 1978 on Ugamak Island, in the southern end of Unimak Pass (D. Withrow, reported in Consiglieri and Braham, 1982:151, Table 5). Further, a single specimen was recovered from Dutch Harbor, Unalaska Island in 1981 (R. Nelson, ADF and G, pers. comm.). Distribution and habits of this species away from breeding and hauling areas are poorly known (McGinnis and Schusterman, 1981). There is no evidence to suggest that at present either of our study areas is of any importance to elephant seals. From known distribution and dispersal, however, it is reasonable to expect that those most likely to occur there would be adult males and one to three year old animals. It is also reasonable to speculate that if the population continues to increase as it has in recent years, then spring, summer, and autumn sightings in the Gulf of Alaska may become more common and that more individuals will enter the Bering Sea to feed.

Unidentified Pinnipeds

As discussed earlier, many pinnipeds seen from the altitude of the present surveys, particularly those in open water, could not be identified to species and were logged as "unidentified." Many of these probably could have been identified if there had been time to divert from track and/or decrease our altitude to examine animals more closely. However, as there was limited time to survey large areas for even the principal target species (the "endangered" whales) the degree of resolution in the pinniped data is less than we would have liked. The category "unidentified pinniped" is unlikely to include many, if any, Steller's sea lions as they are large and distinctive; however, it might include some fur seals and does include some phocids. The category "unidentified otariid" consists of young Steller's sea lions and fur seals. The category "unidentified phocids" includes harbor, largha, ringed, bearded and possibly ribbon seals.

In the Bering Sea there were 190 sightings (326 individuals) in which the animals were logged as unidentified pinnipeds. Of those, 3(12) were further classified to unidentified otariids (Figure 105) and 97(136) to unidentified phocids (Figure 106). The distribution of the latter is shown by season in Figure 107. Sightings of phocids from all surveys combined were adequate to support an estimate for blocks 1, 2, 3 and 6 combined of 26.62 ± 5.955 individuals/1000nm^2 (3,430 km^2) (see Figures 108 and 109 and Table 10).

In Shelikof Strait we saw 4 groups (4 individuals) of unidentified pinnipeds, including 3(3) unidentified otariids and 1(1) unidentified phocid, probably a harbor seal.

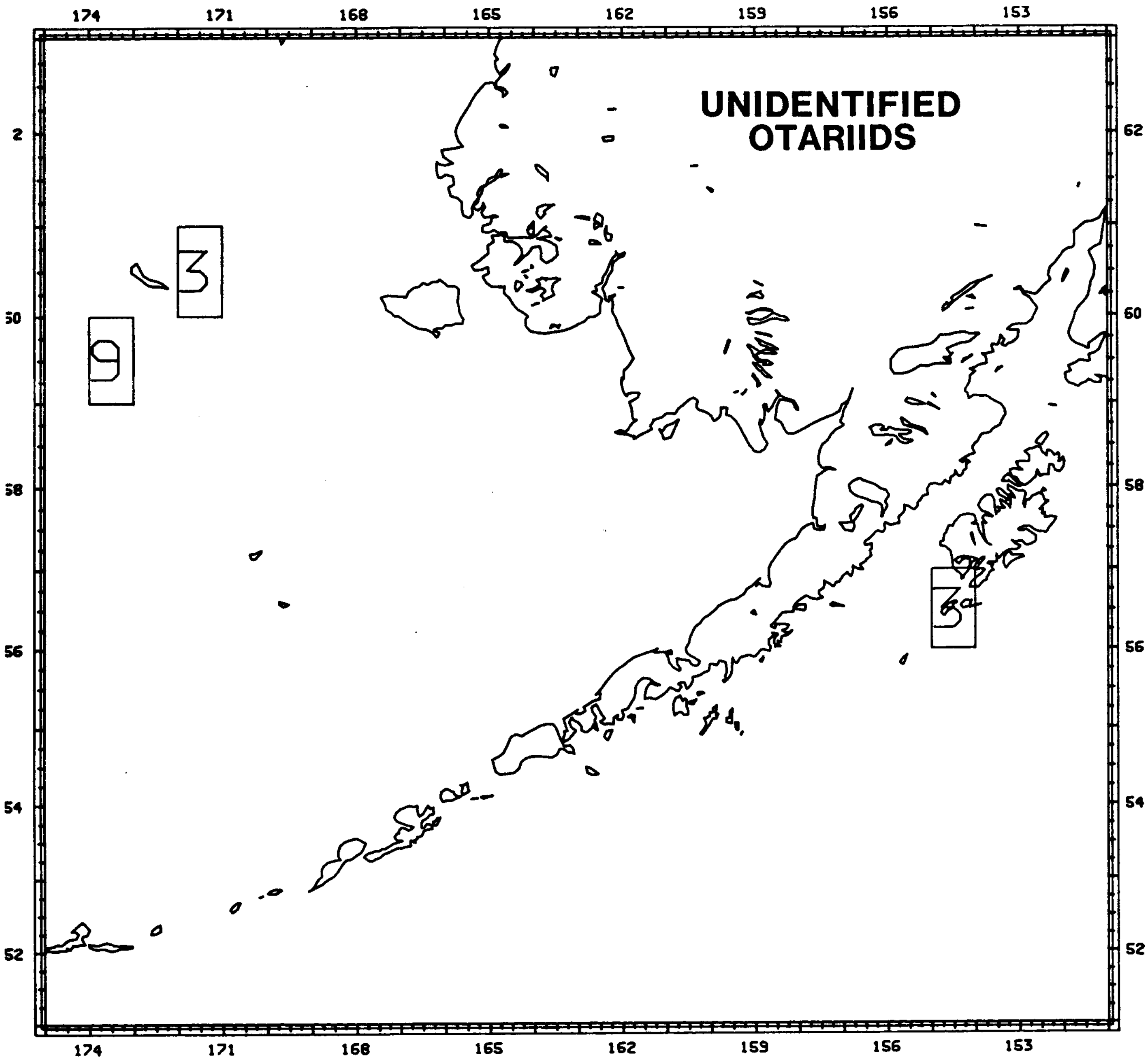


Figure 105. Total number of unidentified otariids by 1° block.

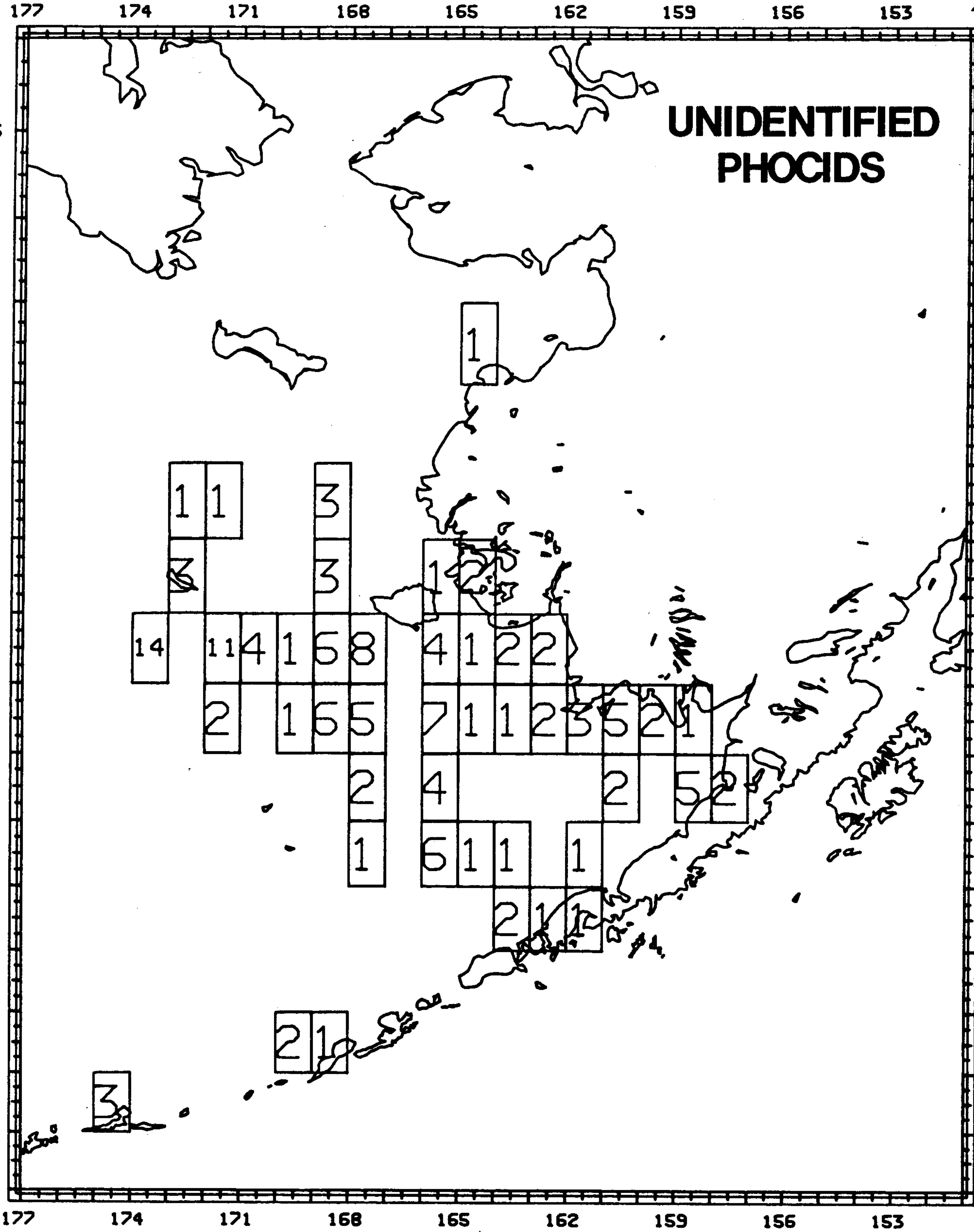


Figure 106. Total number of unidentified phocids by 1° block.

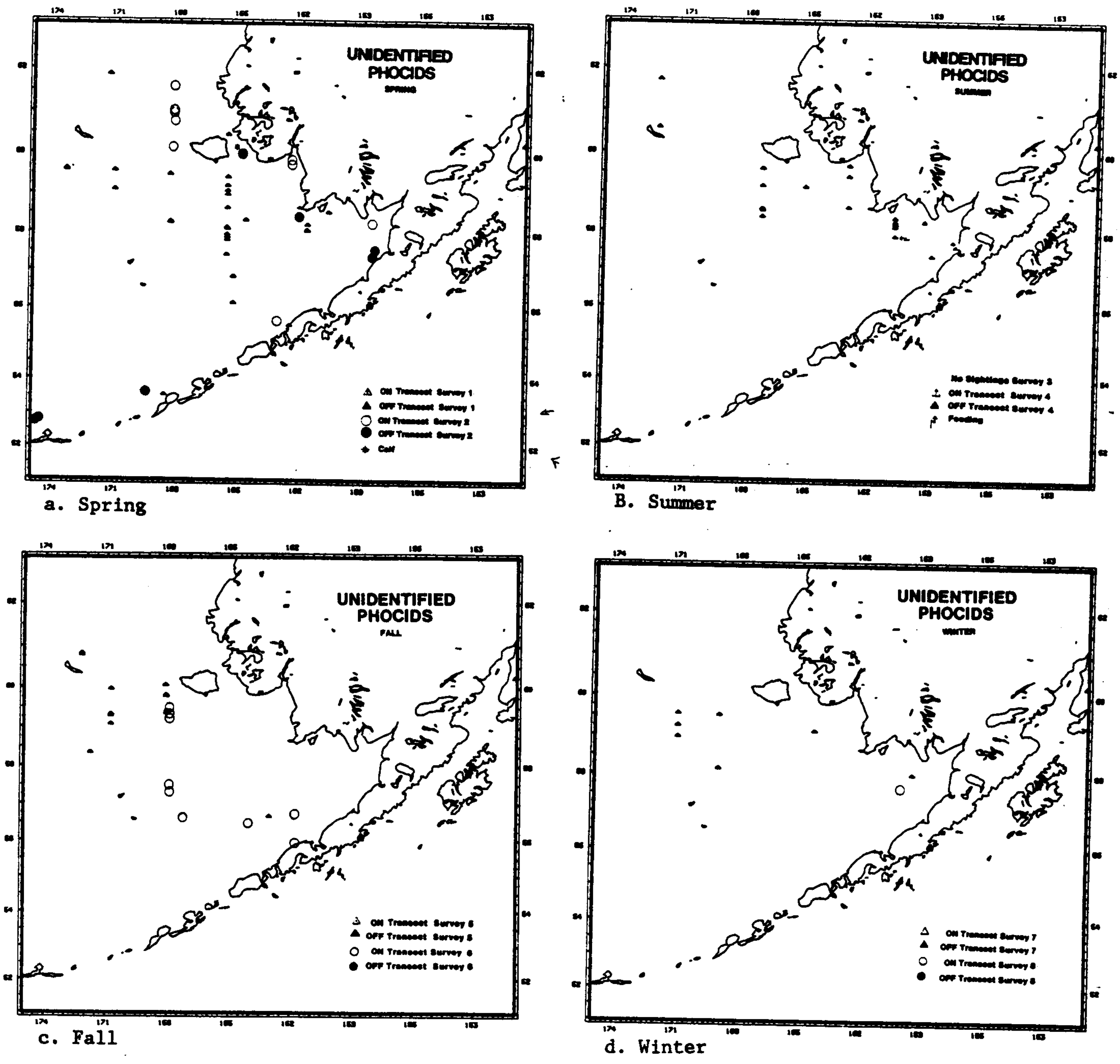


Figure 107. Distribution of sightings of unidentified phocids by season: a) spring, b) summer, c) fall, and d) winter.

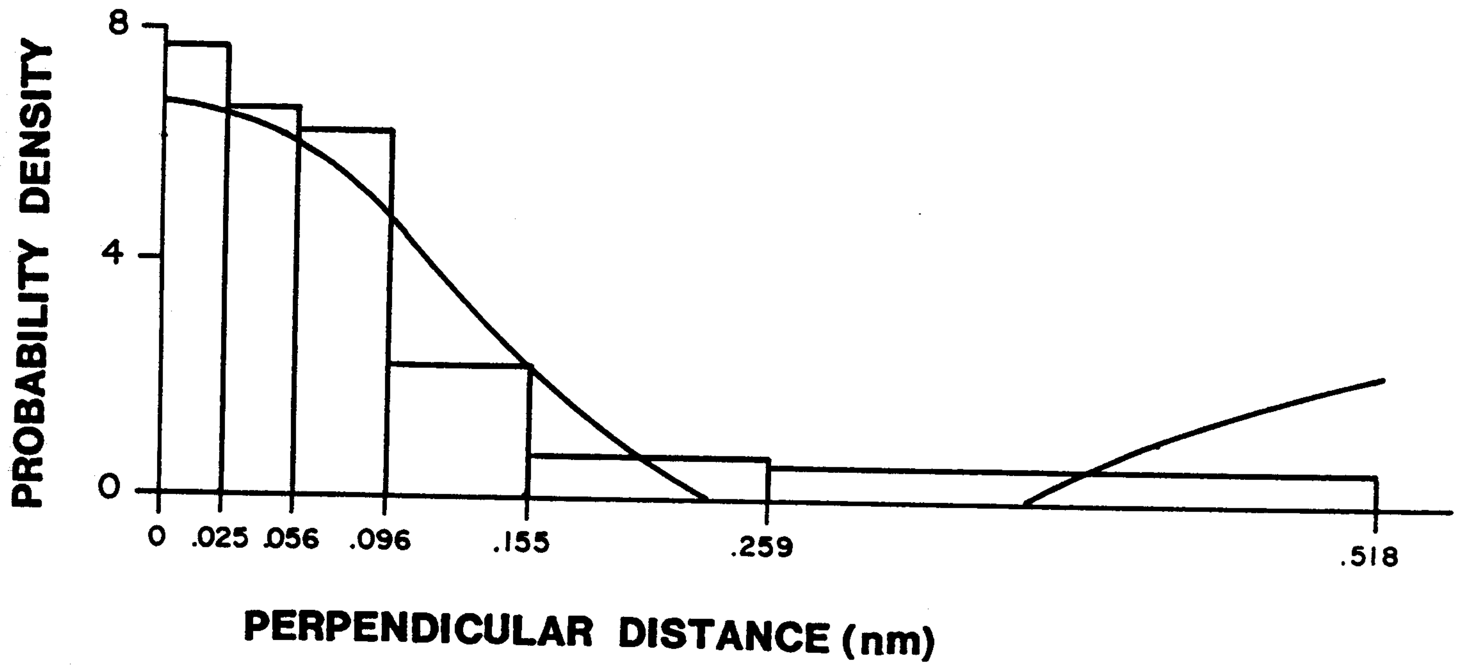


Figure 108. Perpendicular sighting distances truncated under the aircraft at 0.039 nm and the fitted Fourier Series model for unidentified phocids in blocks 1, 2, 3 and 6, all surveys.

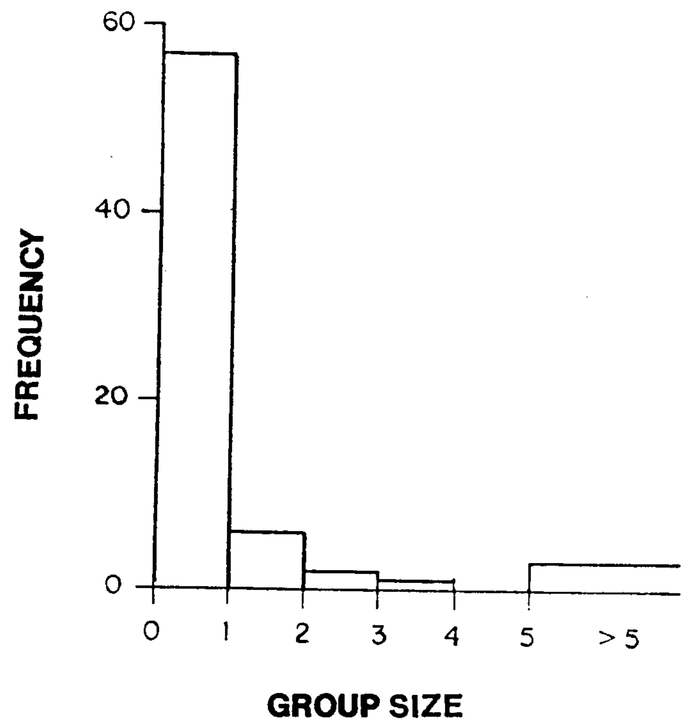


Figure 109. Distribution of sizes of groups of unidentified phocids, blocks 1, 2, 3 and 6, all surveys.

Sea Otter (_Enhydra lutris_)

The biology of the sea otter is well described (Kenyon, 1969, 1981). The species has been regarded to include up to three races, the northernmost of which, _Enhydra lutris lutris_, ranges from Prince William Sound to the Aleutian and Commander islands. The range formerly included the Pribilofs, as well, and a few otters have been seen there recently (Frost et al., 1982). At present, these putative races are often regarded as clinal variants rather than as races or subspecies (Kenyon, 1981). Sea otters are shallow-water animals rarely seen in water deeper than 30 fathoms (55 m). They usually are restricted to kelp beds and other near-shore environments, though in the shallow areas of the eastern Bering Sea and Bristol Bay they may seasonally range farther offshore. Those living north of the Alaska Peninsula and the Aleutians may be severely affected by the extent of sea ice and its effects on food availability (Schneider and Faro, 1975). The Alaskan population(s) currently includes an estimated 101,000 to 121,000 individuals (Johnson, 1976). Distribution and movements within the Bering Sea study area have been described by Schneider (1981).

Because they are small (less than about 147 cm and 45 kg), sea otters are often not clearly visible from survey altitudes such as ours. Further, since they generally occur in the narrow coastal band which our random transects sampled only slightly, they were unavailable for detection and counting during the majority of our survey effort. Therefore, sightings of sea otters on transects probably greatly underrepresent the population, though estimates extrapolated to larger areas based on these observed densities would likely be overestimates. Combined with the numerous sightings on transits and coastal surveys, however, sightings of sea otters during these surveys provide some useful documentation of sea otter distribution and relative abundance by season.

In the Bering Sea study area, sea otters were the third most abundant marine mammal (Figure 110), accounting for 180 sightings (over 1,256 individuals). Sightings in winter and spring were nearshore, except for 2 large individuals encountered in open water in central Bristol Bay in May (Figure 111). In summer the otters were more widely scattered; some were seen in deep water north of the Aleutians, near the Pribilofs, and between the Pribilofs and St. Matthew Island. By fall the otters had returned to the nearshore environment, except for solitary individuals east of St. Matthew Island, north of the Pribilofs and between St. Paul and St. George islands. This seasonality is reflected in Figure 112, in which the observed pulses in May through October were significantly affected by the tendency of the otters to occur more widely and in large "rafts" away from the kelp. There was a sufficient number of on-transect sightings (69) to support an estimate, using a generalized exponential model, for blocks 1, 2, 3 and 6, all surveys combined, of 376.6 ± 268.7 individuals/1,000nm^2 (Table 10, Figure 113a, 114a). We consider this estimate far too high. Nevertheless, it does demonstrate the abundance of sea otters in the Bering Sea/Bristol Bay region.

In Shelikof Strait we saw 94 groups of sea otters (1739 individuals) (Figure 110). Most were nearshore but some individuals were encountered in open water at all seasons (Figure 111). As in the Bering Sea, otters were seen with far greater frequency in spring through fall than at other times (Figure 115). The on-transect sightings (55) support an estimate of $2{,}064 \pm 784.6$ individuals/1,000nm^2 (Table 10, Figures 113b, and 114b). We also consider this estimate too high.

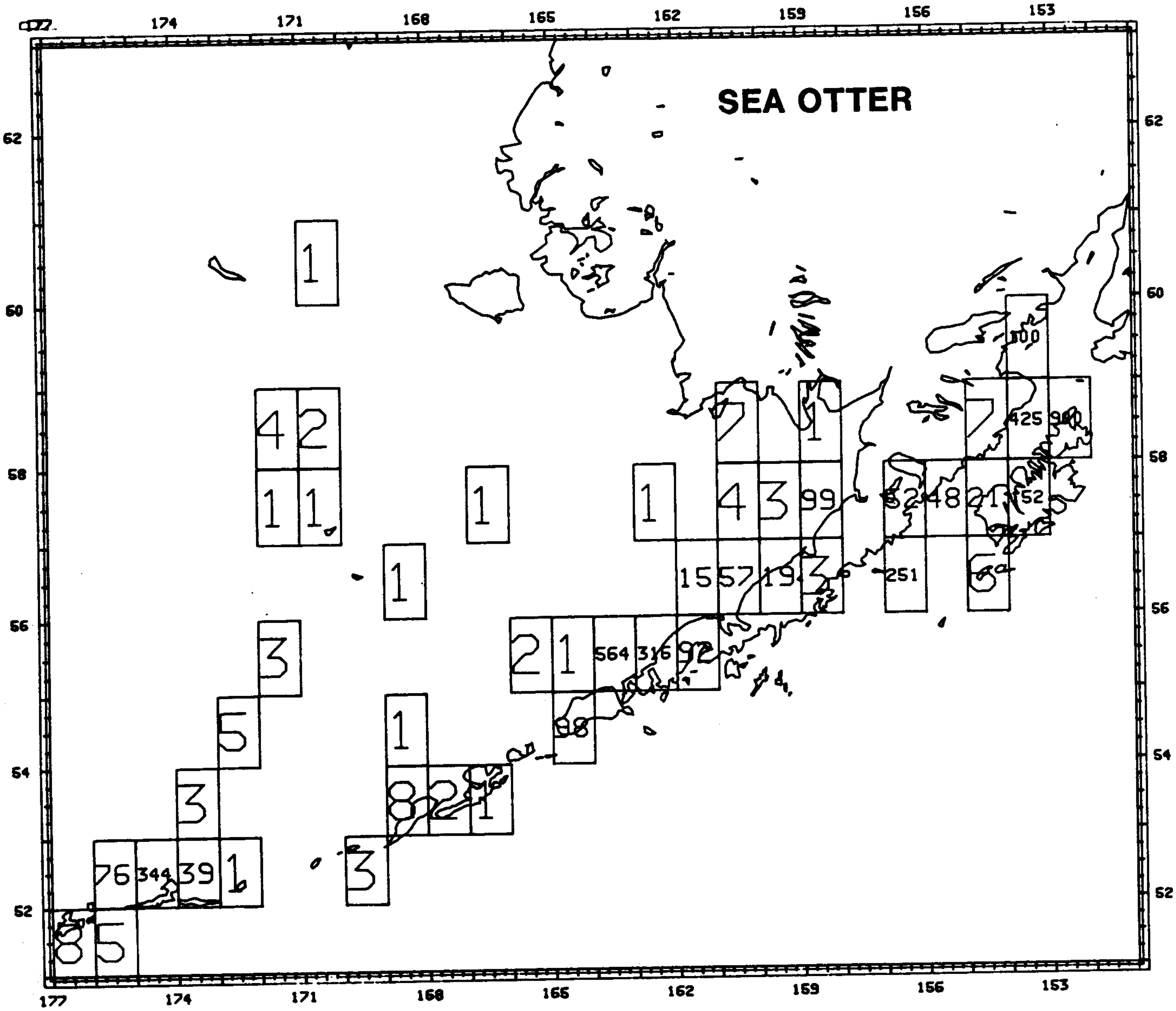


Figure 110. Total number of sea otters seen, by 1° block.

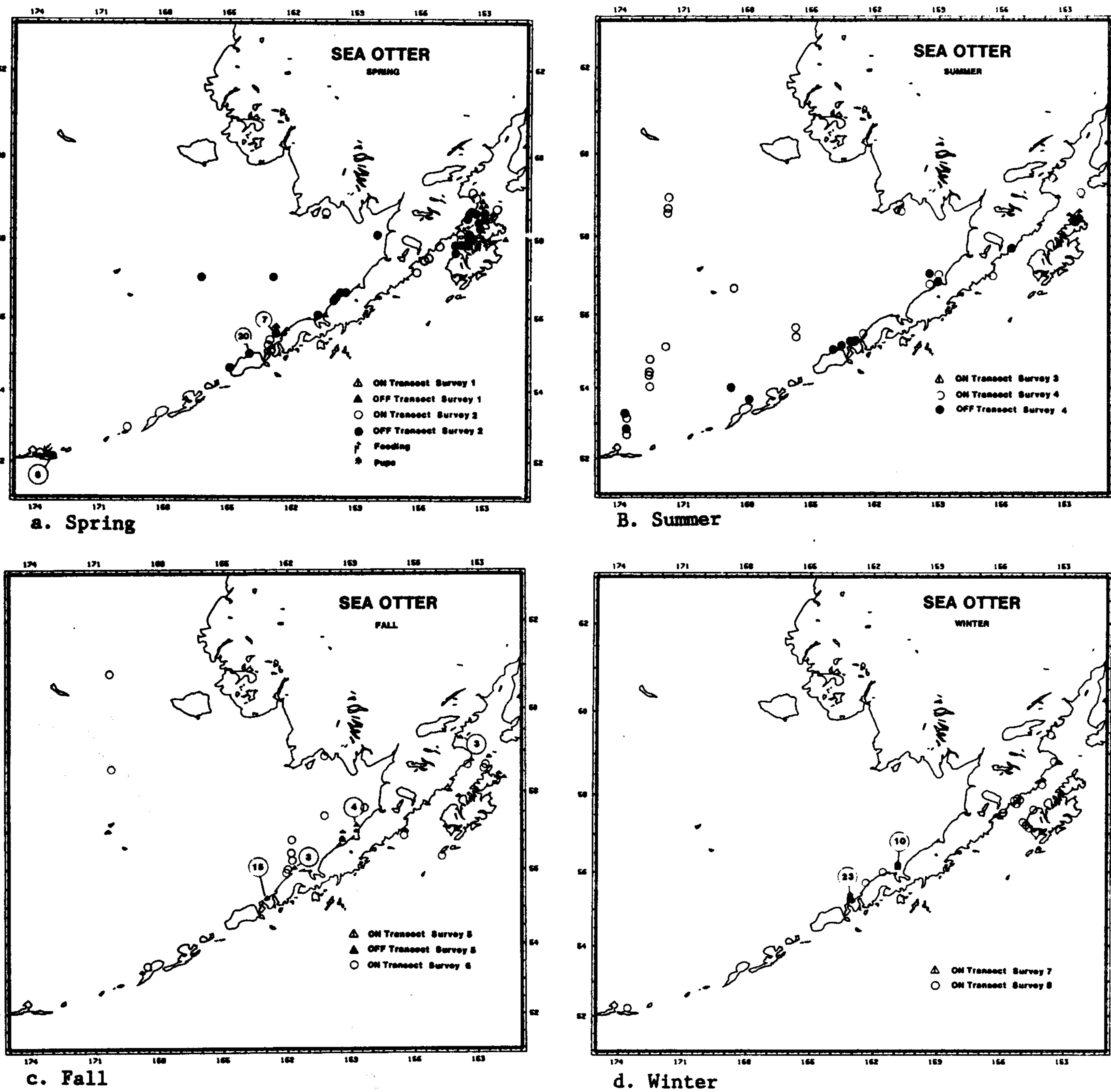


Figure 111. Distribution of sightings of sea otters by season: a) spring, b) summer, c) fall, and d) winter.

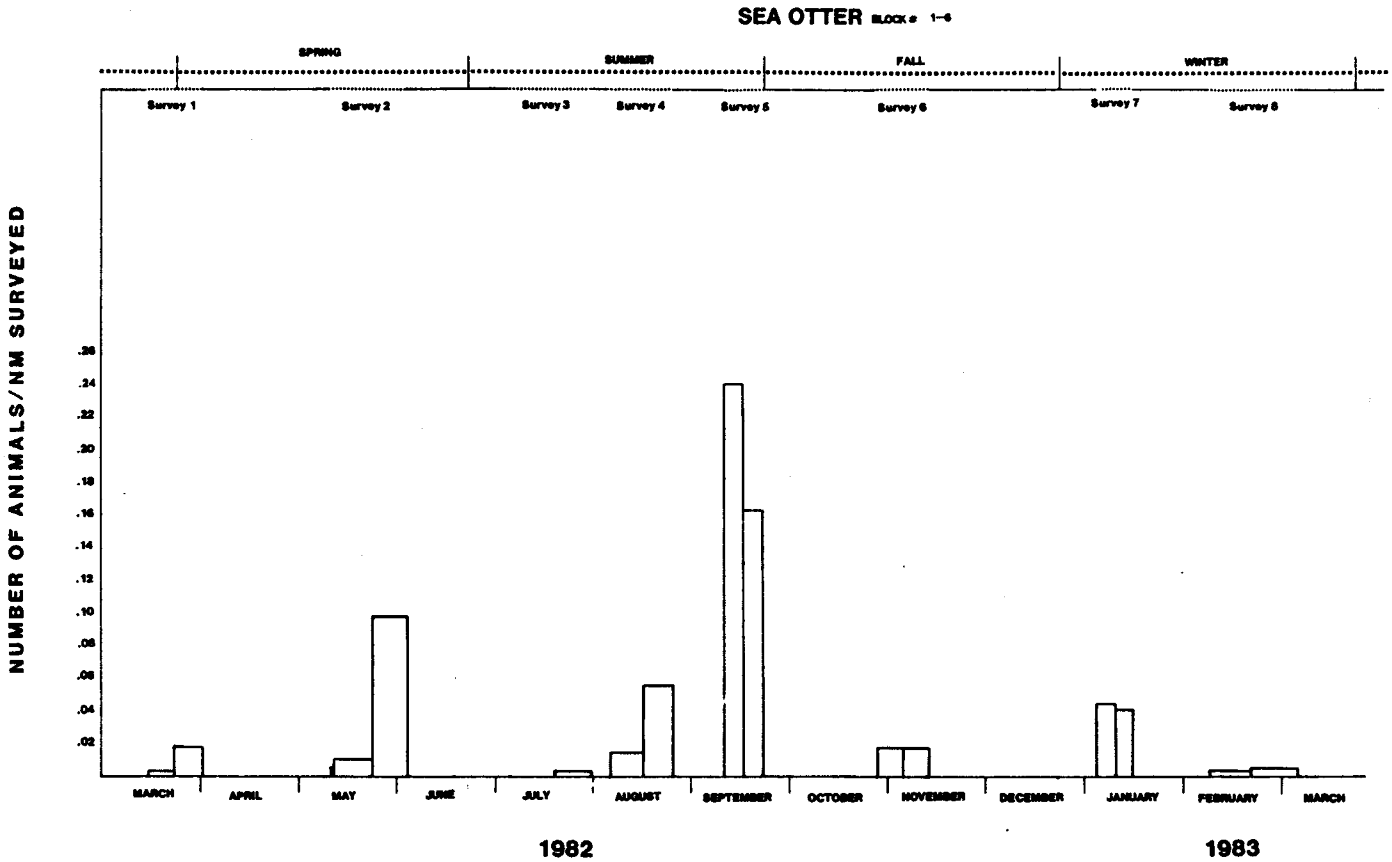


Figure 112. Indices of abundance of sea otters by survey, blocks 1-6.

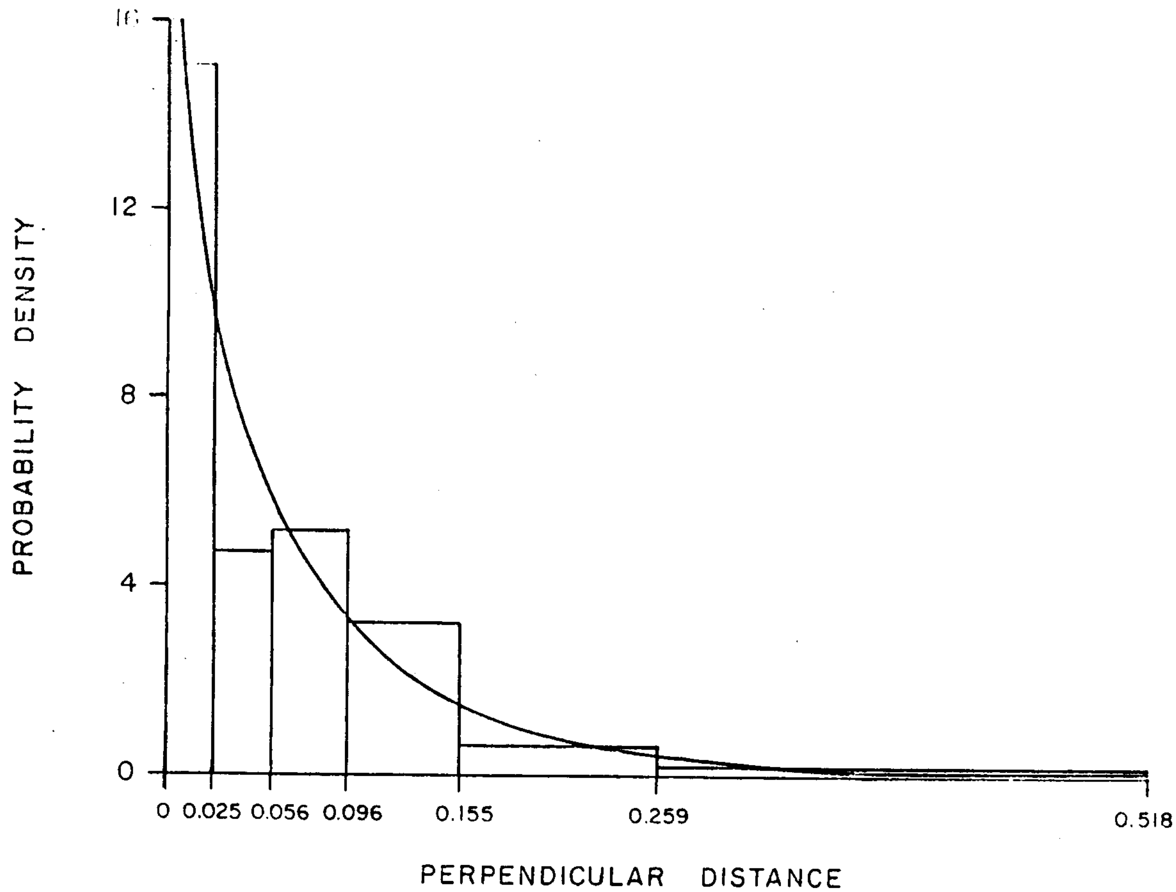


Figure 113a. Perpendicular distances truncated under the aircraft at 0.039nm and the fitted models for sea otters, a generalized for blocks 1, 2, 3, and 6, all surveys.

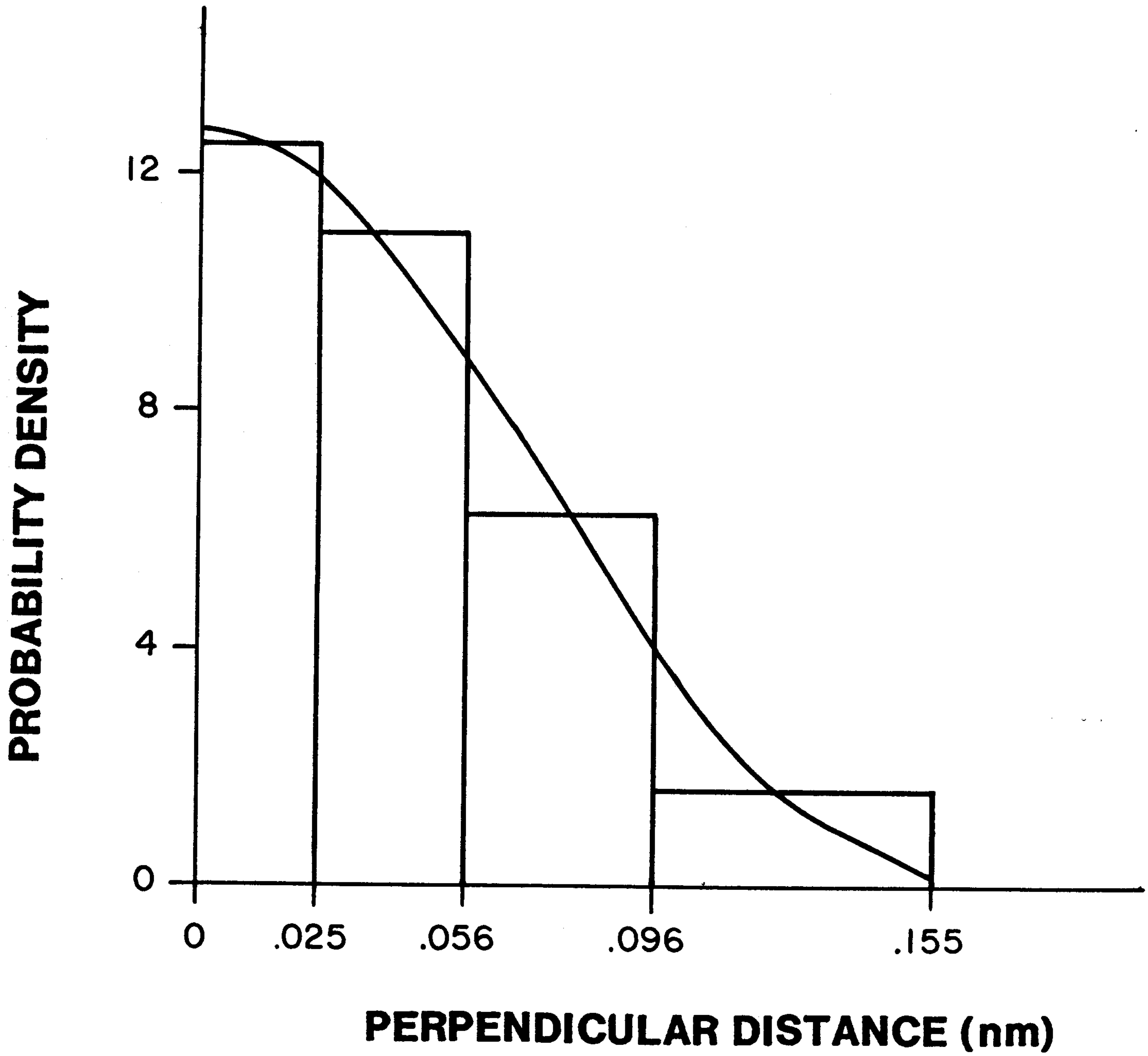


Figure 113b. The Fourier Series model for block 7, all surveys, of sea otters.

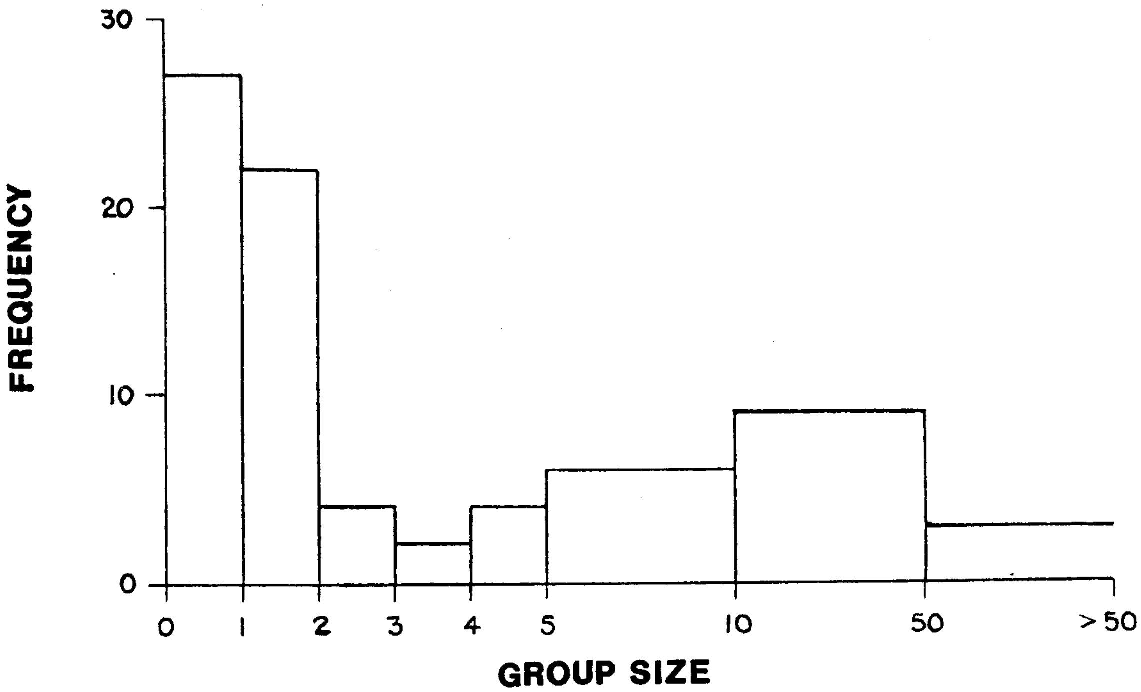


Figure 114a. Distribution of sizes of groups of sea otters in blocks 1, 2, 3, and 6.

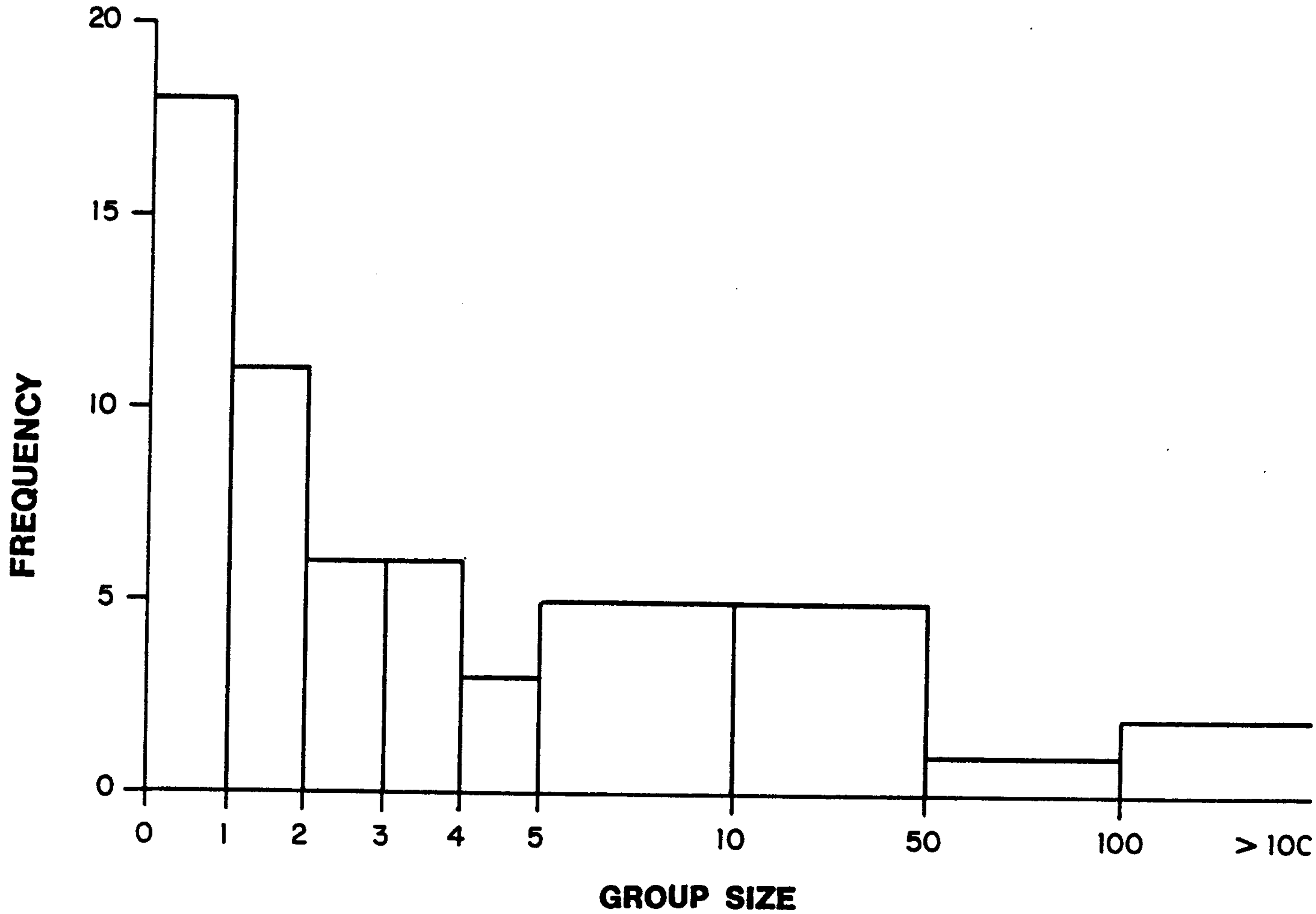


Figure 114b. Distribution of sizes of groups of sea otters in block 7.

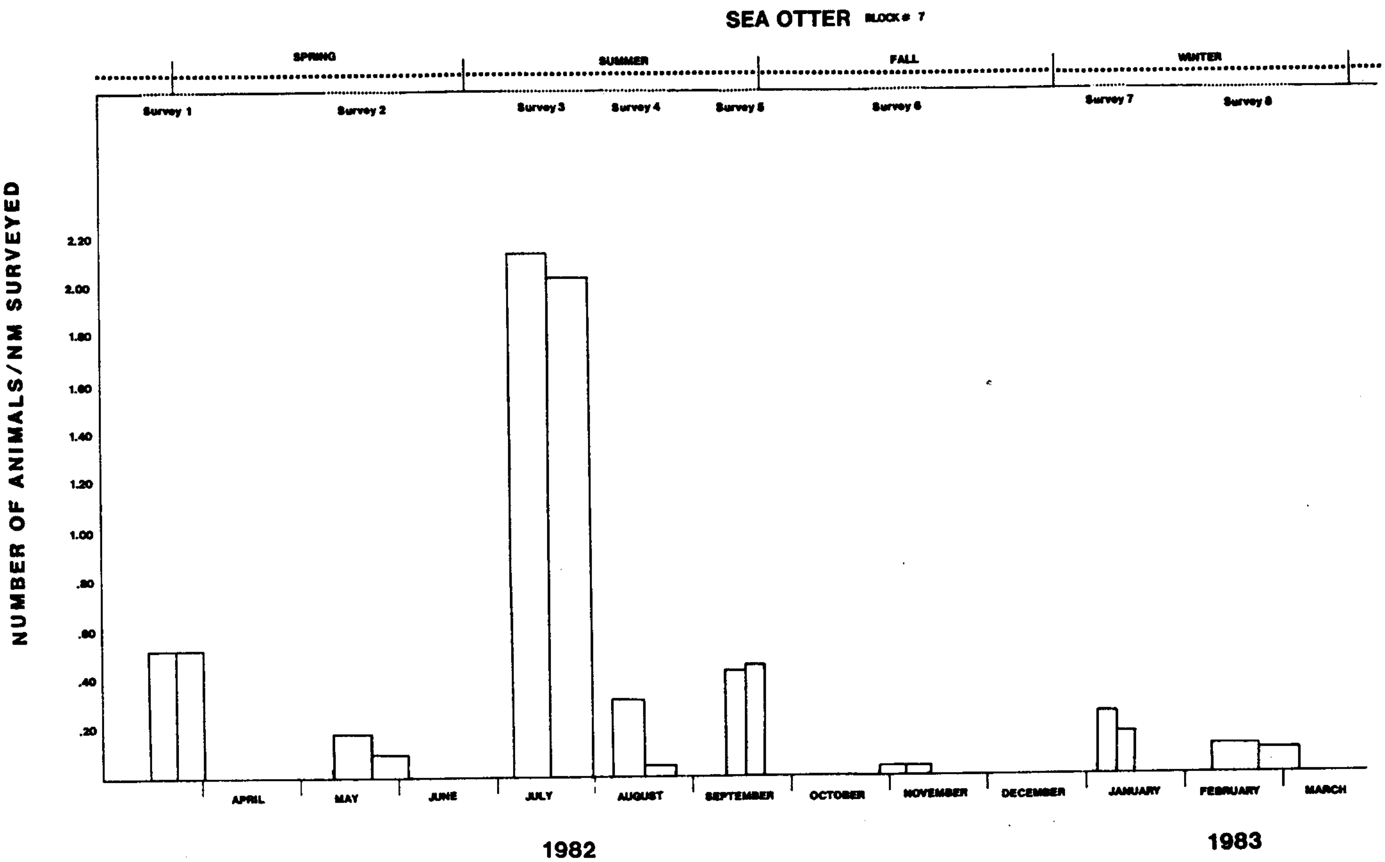


Figure 115. Indices of abundance of sea otters by survey, block 7.

In general, sea otters were in very shallow water less than 29 fathoms (53 m), though significant numbers of individuals were found to depths of 70 fathoms (128 m). The three peaks in distribution in water deeper than 70 fathoms (128 m) (Figure 116) result primarily from several large rafts seen between 52° and 56°N, above the Aleutian Islands, in summer.

Small pups were only observed during spring along the Aleutians and in Shelikof Strait but were likely missed much of the time. Pupping may occur in both study areas at any time of year though most births are in spring and summer (Kenyon, 1981).

Polar Bear (Ursus maritimus)

During the present surveys there were no sightings of polar bears within the study areas or on transects or connecting legs. However, during a transit flight on 10 February 1983 from Nome to the outer zone of block 2 we spotted a lone adult bear at 64°00.2'N, 168°42.2'W. When first seen, it was ambling on the ice with a heading of 060°, but it was obviously alarmed by the passage of the aircraft overhead and bolted briefly.

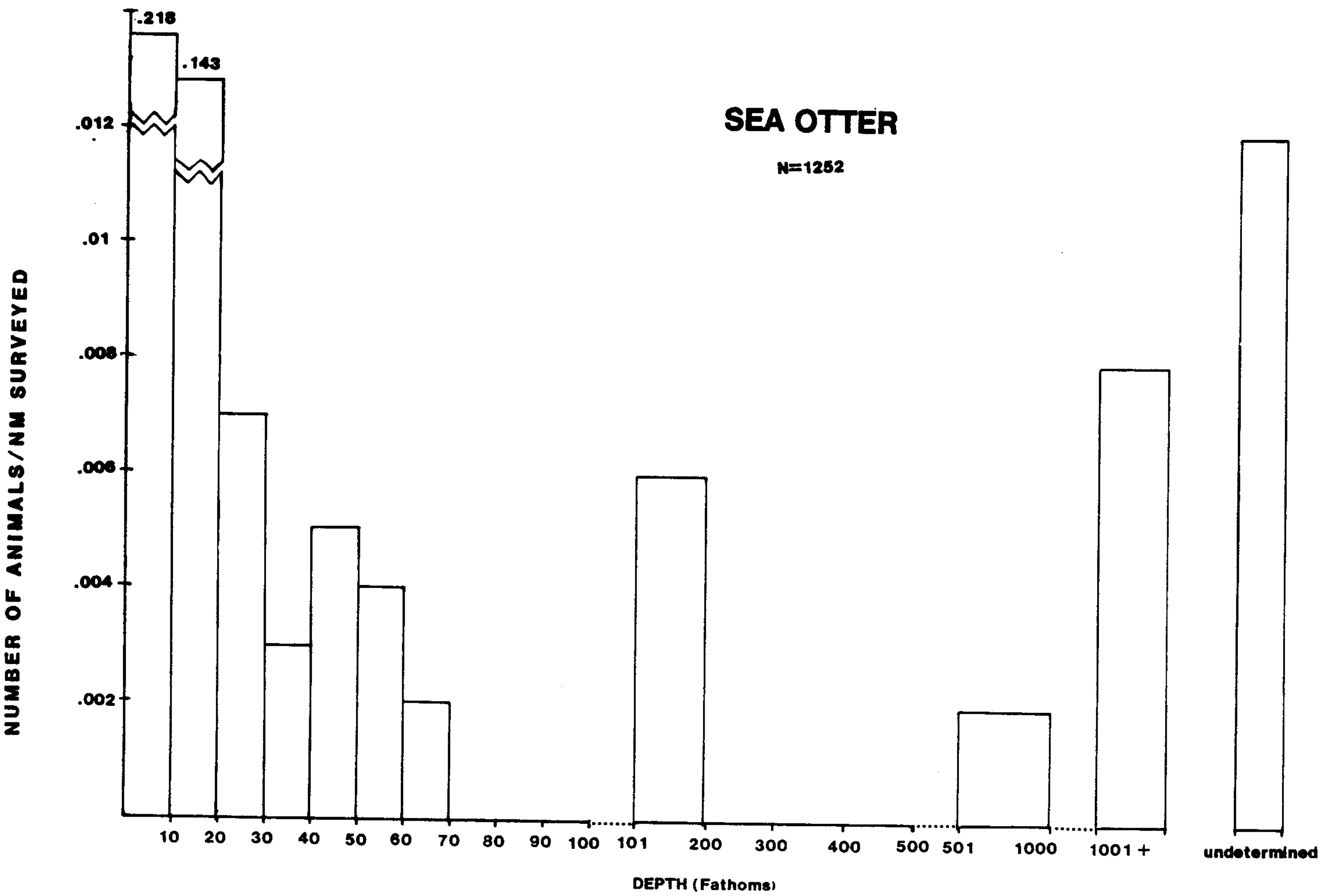


Figure 116. Indices of abundance of sea otters by depth class.

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APPENDIX I

DATA CODING SHEET

DATA CODING SHEET

Column	Entry	Explanation (or Example)
	Time (local)	2215.4 (The number following the decimal point indicates tens of seconds - i.e., .4=40, .5=50 sec. Round down, e.g., 46 sec.=.5).
	Latitude (all °N)	61°14.5'
	Longitude (all °W)	171°33.4'
	Reason for entry	01 = Start transect 02 = End transect 03 = Interrupt transect (e.g., over land, unacceptable environmental conditions) 04 = Break off transect (e.g., to investigate a sighting) 05 = Back on transect (follows 3 or 4) 06 = Sighting made from transect 07 = Sighting made off transect (during 03 or 04) 08 = Change in environmental conditions (weather, visibility, Beaufort, ice, water temp., etc) taken in field 09 = Start tally) in areas where sightings 10 = End tally) are too concentrated to allow logging of each group individually 11 = Change course - a significant alteration of course from base transect course. Repeat when you return to exact course. 12 = Position update 30 = Change in environmental condition added in laboratory (e.g. depth). 31 = Change indepth class taken accurately from chart (use 30 for interpolations).
	Sighting No.	Sequential for this flight (001....n)
	Species	01 = Blue Whale 02 = Fin Whale 03 = Sei Whale 04 = Brydes Whale 05 = Minke Whale 06 = Humpback Whale 07 = Unid. Rorqual 08 = Gray Whale 09 = Right Whale 10 = Bowhead Whale 12 = Unidentified Baleen Whale 13 = Sperm Whale 14 = Unidentified Large Whale

	15 = Pygmy Sperm Whale 16 = Dwarf Sperm Whale 17 = Either 15 or 16 18 = Beluga Whale 19 = Narwhal 20 = Killer Whale 21 = Pilot Whale 22 = False Killer Whale 23 = Risso's Dolphin 24 = Bottlenose Dolphin 25 = Goosebeaked Whale 26 = Unidentified Beaked Whale (describe in tentative identification in notes) 27 = Unidentified medium sized-whale 28 = Dall Porpoise 29 = Harbor Porpoise 30 = White-sided Dolphin 31 = N. Right Whale Dolphin 32 = Unidentified Dolphin/Porpoise 50 = Polar Bear 80 = Sea Otters 81 = Unidentified Pinniped 82 = Walrus 83 = Harbor Seal 84 = Larga Seal 85 = Ringed Seal 86 = Bearded Seal 87 = Ribbon Seal 88 = Unidentified Phocid 89 = Fur Seal 90 = Steller's Sea Lion 91 = Unidentified Otariid
Total number	9999 = No entry; if estimate is a range, list midpoint and state range under remarks. If midpoint is not whole number, round down (e.g.) 15-20 is recorded as 17, with 15-20 in remarks.
Sighting angle	(0-90°) As measured (inclinometer) or estimated. If estimated note in remarks.
Observer making sighting	01 = Leatherwood 02 = Everett 03 = Carter 04 = Carr 05 = Sinclair 06 = Derman 07 = Stewart 08 = Yochem 09 = Goodrich 10 = T. Leatherwood 11 = Kent 12 = Cubbage 13 = Owen 14 = Warkocewski 15 = Bowles

Appendix I cont'd

Cue	The cue which originally alerted observer to presence of the animals. 01 = Visible blow 02 = Body at surface 03 = Body of seal(s) on land or ice 04 = Body through water (the submerged body seen through water) 05 = Splash (whitewater) 06 = Surface disturbance or scar (ripples, footprint) 07 = Mud plume 08 = Breach 09 = Birds or fish 10 = Other (Describe in remarks) 11 = Flukes 12 = Vessel or other human activity 99 - No entry
Initial behavior	The behavior in which the animal was engaged at time of first detection 01 = Traveling slowly (straight line swim at speed of < 2 kts) 02 = Traveling quickly (straight line swim at speed of > 2 kts. 03 = milling (e.g., meandering or circling with no purpose discernible) 04 = resting (e.g., whale or dolphin in water making no forward progress, sleeping seal, rafting otter) 05 = Feeding (clear evidence of feeding) 06 = Mating 07 = Breaching 08 = Spy-hopping (pitch poling) 09 = Tail lobbing 10 = Flipper slapping 99 = Behavior indeterminable
Response to aircraft	1 = Yes 2 = No 9 = no entry
Swim Direction	The animals' swimming direction at time initially seen, read directly from Gyro (1-360). 999 = no entry; 555 = milling, no direction determined
No. of pups or calves	999 = no entry
Actual depth	in fms, rounded to even number. 9999 = no entry

Appendix I cont'd

Beaufort No.

No.	Sea condition	Wind velocity
0	Glassy	< 1 knot
1	Light ripple	1 < 6 knots
2	Small wavelets	4 > 6 knots
3	Scattered whitecaps	7 > 10 knots
4	Numerous whitecaps	11 > 16 knots
5	Many whitecaps	17 > 21 knots
6	All white caps	22 > 27 knots
7	Breaking waves	28 > 33 knots
8	High waves, blowing foam	34 > 40 knots

Weather

Definition of weather within likely survey strip (several nm of aircraft)

01 = Clear
02 = Partly cloudy
03 = Cloudy
04 = Overcast
05 = Light rain
06 = Heavy rain
07 = Patchy fog
08 = Heavy fog
09 = Haze
10 = Snow
99 = No entry

Visibility left

0 = Unacceptable
01 = < 1 but acceptable
02 = 1-2
03 = 2-3
04 = 3-5
05 = 5-10
06 = Unlimited
07 = 1-2 but with glare
08 = 2-3 " " "
09 = 3-5 " " "
(only if glare significantly affects sightability).

Visibility right

Same as visibility left.

Ice Type

0 = Open water, no ice in strip
01 = Grease ice
02 = Sheet ice
03 = Pancake ice
04 = Broken floes
05 = Floes/pack ice
06 = Pack ice
07 = Shore-fast ice

Appendix I cont'd

Percent cover	Percent of sea surface covered by ice
Altitude	In <u>feet</u>. 9999 = no entry
Depth class	01 = 0-10 fms 02 = 11-20 03 = 21-30 04 = 31-40 05 = 41-50 06 = 51-60 07 = 61-70 08 = 71-80 09 = 81-90 fms 10 = 91-100 11 = 101-200 12 = 201-300 13 = 301-400 14 = 401-500 15 = 501-1000 16 = > 1000 99 = no entry
Block -	Block of survey area
Zone -	Zone of survey area
Date -	Date data were taken
Linetype -	1 = random transect Connecting legs:- transect transect, 2 = shore-transect 3 = transits: shore line transits, legs outside study area, or other lines where airplane was not flown by survey standards.
Survey Number -	Number of survey, 1-8.

APPENDIX II

APPENDIX II

TABLE IIA1. Nautical miles searched on transects during Survey 1 by block and Beaufort scale, the number of zones surveyed in each block, the line length searched in blocks 1-6 as a proportion of the total, and the area of ocean in blocks 1-6 as a proportion of the total.

Beaufort scale	BLOCK 1	2	3	4	5	6	sub total	7	Total
	Line length searched in nautical miles								
0	12.4	295.9	313.1	-	-	-	621.4	-	621.4
1	208.1	-	30.2	7.2	-	11.9	257.4	18.2	275.6
2	74.7	-	63.8	215.7	4.2	21.8	380.2	63.3	443.5
3	53.5	-	43.7	16.7	22.2	28.7	164.8	77.7	242.5
4	7.3	-	45.5	35.7	36.6	116.2	241.3	97.0	338.3
5	2.0	-	104.5	6.0	80.6	149.6	342.7	30.5	373.2
6	-	-	103.5	46.2	57.8	30.5	238.0	-	238.0
7	-	-	-	-	8.2	-	8.2	-	8.2
total	358.0	295.9	704.3	327.5	209.6	358.7	2254.0	286.7	2540.7
No. of zones surveyed	4/4	3/4	4/4	3/4	4/4	4/4	22/24	6/6	28/30
Line length as proportion of total line length in blocks 1-6	0.16	0.13	0.31	0.15	0.09	0.16	1.00		
Area as proportion of total area of blocks 1-6	0.155	0.147	0.256	0.244	0.091	0.108	1.000		

TABLE IIA2. Sightings of marine mammals made on transects during Survey 1 by species code, species grouping, and survey block.

Species code	Species name	BLOCK 1	2	3	4	5	6	sub total	7	Total
02	Fin whale	0	0	1	0	0	0	1	0	1
03	Sei whale	0	0	1	0	0	0	1	0	1
05	Minke whale	0	0	1	0	0	0	1	0	1
07	Unid. rorqual	0	0	2	0	0	0	2	0	2
10	Bowhead whale	0	1	0	0	0	0	1	0	1
14	Unid. large whale	0	0	0	0	0	0	0	1	1
--	LARGE WHALES	0	1	5	0	0	0	6	1	7
18	White whale	0	2	0	0	0	0	2	0	2
20	Killer whale	0	0	1	0	2	0	3	0	3
--	OTHER WHALES	0	2	1	0	2	0	5	0	5
28	Dall's porpoise	0	0	0	1	0	1	2	1	3
29	Harbor porpoise	0	0	1	0	0	0	1	1	2
32	Unid. dolphin/porp.	0	0	0	0	0	0	0	2	2
--	DOLPHINS & PORPOISE	0	0	1	1	0	1	3	4	7
80	Sea Otter	0	0	0	0	1	2	3	8	11
82	Walrus	58	9	20	0	0	10	97	0	97
83	Harbor seal	0	0	0	0	0	1	1	1	2
86	Bearded seal	0	14	8	0	0	0	22	0	22
88	Unid. Phocid	4	2	16	0	0	2	24	0	24
--	PHOCIDS	4	16	24	0	0	3	47	1	48
89	Fur seal	0	0	0	0	0	3	3	1	4
90	Steller's sea-lion	0	0	4	0	1	1	6	4	10
91	Unid. Otariid	0	2	1	0	0	0	3	3	6
--	OTARIIDS	0	2	5	0	1	4	12	8	20
99	Unid. marine mammal	1	0	0	0	0	0	1	0	1
--	ALL MARINE MAMMALS	63	30	56	1	4	20	174	22	196

TABLE 1IB1. Nautical miles searched on transects during Survey 2 by block and Beaufort scale, the number of zones surveyed in each block, the line length searched in blocks 1-6 as a proportion of the total, and the area of ocean in blocks 1-6 as a proportion of the total.

Beaufort scale	BLOCK 1	2	3	4	5	6	sub total	7	Total
	Line length searched in nautical miles								
0	42.7	9.9	-	-	-	-	52.6	-	52.6
1	19.2	94.7	-	-	39.4	-	153.3	6.9	160.2
2	137.4	106.4	-	-	39.0	20.9	303.7	39.4	343.1
3	198.8	32.3	-	24.5	38.1	110.4	404.1	59.5	463.6
4	58.5	-	-	18.8	123.4	182.6	383.3	128.1	511.4
5	4.3	-	-	147.5	-	29.2	181.0	23.9	204.9
6	-	-	-	116.9	2.1	-	119.0	-	119.0
7	-	-	-	16.8	-	-	16.8	-	16.8
total	460.9	243.3	-	324.5	242.0	343.1	1613.8	257.8	1871.6
No. of zones surveyed	4/4	3/4	0/4	2/4	4/4	4/4	17/24	6/6	23/30
Line length as proportion of total line length in blocks 1-6	0.29	0.15	0.00	0.20	0.15	0.21	1.00		
Area as proportion of total area of blocks 1-6	0.155	0.147	0.256	0.244	0.091	0.108	1.000		

TABLE IIB2 Sightings of marine mammals made on transects during Survey 2 by species code, species grouping, and survey block.

Species code	Species name	1	2	3	4	5	6	sub total	7	Total
		BLOCK								
02	Fin whale	1	0	0	0	0	0	1	2	3
05	Minke whale	0	0	0	1	0	0	1	2	3
08	Gray whale	29	2	0	0	0	8	39	0	39
	LARGE WHALES	30	2	0	1	0	8	41	4	45
18	White whale	0	1	0	0	0	0	1	0	1
20	Killer whale	0	0	0	2	1	0	3	0	3
27	Unid. other whale	1	0	0	0	0	0	1	0	1
	OTHER WHALES	1	1	0	2	1	0	5	0	5
28	Dall's porpoise	0	0	0	0	2	0	2	8	10
29	Harbor porpoise	3	0	0	0	0	2	5	4	9
	DOLPHINS & PORPOISE	3	0	0	0	2	2	7	12	19
80	Sea Otter	1	0	0	0	2	5	8	9	17
81	Unid. pinniped	17	3	0	0	0	0	20	0	20
82	Walrus	12	3	0	0	0	17	32	0	32
83	Harbor seal	4	14	0	0	1	0	19	0	19
85	Ringed seal	0	3	0	0	0	0	3	0	3
86	Bearded seal	0	10	0	0	0	0	10	0	10
88	Unid. Phocid	3	5	0	0	0	0	10	0	10
	PHOCIDS	7	32	0	0	1	2	42	0	42
90	Steller's sea-lion	0	0	0	0	1	0	1	10	11
	OTARIIDS	0	2	5	0	1	4	12	8	20
	ALL MARINE MAMMALS	71	41	0	3	7	34	156	35	191

TABLE IIC1. Nautical miles searched on transects during Survey 3 by block and Beaufort scale, the number of zones surveyed in each block, the line length searched in blocks 1-6 as a proportion of the total, and the area of ocean in blocks 1-6 as a proportion of the total.

	BLOCK								
Beaufort scale	1	2	3	4	5	6	sub total	7	Total
	Line length searched in nautical miles								
0	-	-	-	-	-	-	-	-	-
1	-	26.3	40.2	-	-	-	66.5	21.5	88.0
2	2.4	23.8	135.0	-	-	-	161.2	0.3	161.5
3	4.5	45.3	224.4	-	-	-	274.2	27.7	301.9
4	19.3	91.8	54.3	-	-	-	165.4	48.2	213.6
5	5.8	-	-	-	-	-	5.8	33.3	39.1
6	-	-	-	-	-	-	-	6.5	6.5
7	-	-	-	-	-	-	-	-	-
total	32.0	187.2	453.9	-	-	-	673.1	137.5	810.6
No. of zones surveyed	1/4	2/4	3/4	0/4	0/4	0/4	6/24	4/6	10/30
Line length as proportion of total line length in blocks 1-6	0.05	0.28	0.67	0.00	0.00	0.00	1.00		
Area as proportion of total area of blocks 1-6	0.155	0.147	0.256	0.244	0.091	0.108	1.000		

TABLE IIC2. Sightings of marine mammals made on transects during Survey 3 by species code, species grouping, and survey block.

		BLOCK								
Species code	Species name	1	2	3	4	5	6	sub total	7	Total
00	Fin whale	0	0	1	0	0	0	1	2	3
05	Minke whale	0	0	1	0	0	0	1	0	1
28	Gray whale	0	0	0	0	0	0	2	0	2
14	Unid. large whale	0	0	0	0	0	0	0	1	1
	LARGE WHALES	2	0	2	0	0	0	4	3	7
28	Dall's porpoise	0	0	3	0	0	0	3	3	6
29	Harbor porpoise	0	0	0	0	0	0	0	2	2
32	Unid. dolphin/porp.	0	0	1	0	0	0	1	0	1
	DOLPHINS & PORPOISE	0	0	4	0	0	0	4	5	9
80	Sea Otter	0	0	0	0	0	0	0	6	6
81	Unid. pinniped	0	1	0	0	0	0	1	0	1
89	Fur seal	0	0	3	0	0	0	3	0	3
90	Steller's sea-lion	0	0	0	0	0	0	0	2	2
	OTARIIDS	0	0	3	0	0	0	3	2	5
99	Unid. marine mammal	0	0	1	0	0	0	1	0	1
	ALL MARINE MAMMALS	2	1	10	0	0	0	13	16	29

TABLE IID1. Nautical miles searched on transects during Survey 4 by block and Beaufort scale, the number of zones surveyed in each block, the line length searched in blocks 1-6 as a proportion of the total, and the area of ocean in blocks 1-6 as a proportion of the total.

	BLOCK								
Beaufort scale	1	2	3	4	5	6	sub total	7	Total
	Line length searched in nautical miles								
0	-	-	-	-	-	-	-	-	-
1	134.5	-	84.2	-	-	35.5	254.2	92.5	346.7
2	88.7	178.0	54.5	13.0	31.6	121.1	486.9	118.8	605.7
3	168.8	182.6	240.9	120.8	62.9	162.7	938.7	54.1	992.8
4	62.8	-	178.1	271.7	35.8	28.1	576.5	14.4	590.9
5	36.2	-	108.2	312.4	77.8	5.1	539.7	-	539.7
6	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-
total	491.0	360.6	665.9	717.9	208.1	352.5	2796.0	279.8	3075.8
No. of zones surveyed	4/4	4/4	4/4	4/4	4/4	4/4	24/24	6/6	30/30
Line length as proportion of total line length in blocks 1-6	0.17	0.13	0.24	0.26	0.08	0.13	1.00		
Area as proportion of total area of blocks 1-6	0.155	0.147	0.256	0.244	0.091	0.108	1.000		

TABLE IID2. Sightings of marine mammals made on transects during Survey 4 by species code, species grouping, and survey block.

Species code	Species name	BLOCK 1	2	3	4	5	6	sub total	7	Total
02	Fin whale	0	0	1	1	0	0	2	2	4
05	Minke whale	0	0	2	0	0	1	3	0	3
06	Humpback whale	0	0	1	0	0	1	2	0	2
14	Unid. large whale	1	0	0	0	0	1	2	0	2
--	LARGE WHALES	1	0	4	1	0	3	9	2	11
18	White whale	0	0	0	1	0	0	1	1	2
20	Killer whale	0	0	0	2	0	0	2	2	4
--	OTHER WHALES	0	0	0	3	0	0	3	3	6
28	Dall's porpoise	0	1	0	4	2	3	10	3	13
29	Harbor porpoise	5	3	2	1	0	2	13	1	14
--	DOLPHINS & PORPOISE	5	4	2	5	2	5	23	4	27
80	Sea Otter	4	0	3	7	2	4	20	3	23
83	Harbor seal	2	1	0	0	0	1	4	1	5
88	Unid. Phocid	9	2	7	0	0	0	18	0	18
--	PHOCIDS	11	3	7	0	0	1	22	1	23
89	Fur seal	0	0	1	1	0	0	2	0	2
90	Steller's sea-lion	0	0	0	0	0	0	0	4	4
--	OTARIIDS	0	0	1	1	0	0	2	4	6
99	Unid. marine mammal	1	0	0	0	0	0	1	0	1
--	ALL MARINE MAMMALS	22	7	177	1	4	13	80	17	97

TABLE IIE1. **Nautical miles searched on transects during Survey 5 by block and Beaufort scale, the number of zones surveyed in each block, the line length searched in blocks 1-6 as a proportion of the total, and the area of ocean in blocks 1-6 as a proportion of the total.**

	BLOCK								
Beaufort scale	1	2	3	4	5	6	sub total	7	Total
	Line length searched in nautical miles								
0	-	-	-	-	-	-	-	-	-
1	-	32.4	75.0	-	-	-	107.4	7.5	114.9
2	91.4	-	49.6	-	2.1	126.9	270.0	53.8	323.8
3	150.4	9.3	163.0	79.2	36.1	41.3	479.3	134.0	613.3
4	160.1	129.1	228.9	103.5	18.4	13.4	653.4	95.4	748.8
5	100.7	14.1	56.8	17.4	-	10.2	199.2	5.5	204.7
6	-	30.1	55.0	69.2	-	-	154.3	-	154.3
7	-	-	-	92.2	-	-	92.2	-	92.2
total	502.6	215.0	628.3	361.5	56.6	191.8	1955.8	296.2	2252.0
No. of zones surveyed	4/4	3/4	4/4	2/4	1/4	3/4	17/24	6/6	23/30
Line length as proportion of total line length in blocks 1-6	0.26	0.11	0.32	0.18	0.03	0.10	1.00		
Area as proportion of total area of blocks 1-6	0.155	0.147	0.256	0.244	0.091	0.108	1.000		

TABLE IIE2. Sightings of marine mammals made on transects during Survey 5 by species code, species grouping, and survey block.

Species code	Species name	1	2	3	4	5	6	sub total	7	Total
		BLOCK								
02	Fin whale	0	0	1	0	0	0	0	1	1
05	Minke whale	0	0	1	0	0	1	2	1	3
07	Unid. rorqual	1	0	0	0	0	0	1	0	1
--	LARGE WHALES	1	0	1	0	0	1	3	2	5
20	Killer whale	0	0	0	1	0	0	1	0	1
--	OTHER WHALES	0	0	0	0	0	0	1	0	1
28	Dall's porpoise	0	0	0	2	1	0	3	4	7
29	Harbor porpoise	1	1	0	0	0	0	2	6	8
--	DOLPHINS & PORPOISE	1	1	0	2	1	0	5	10	15
80	Sea Otter	5	0	0	0	1	40	46	11	57
81	Unid. pinniped	3	1	3	0	0	1	8	0	8
82	Walrus	9	0	2	1	0	1	13	0	13
83	Harbor seal	4	3	2	0	0	0	9	7	16
88	Unid. Phocid	0	2	8	0	0	1	11	0	11
--	PHOCIDS	4	5	10	0	0	1	20	7	27
90	Steller's sea-lion	0	0	0	2	0	4	6	9	15
91	Unid. Otariid	0	2	1	0	0	0	3	3	6
--	OTARIIDS	0	0	0	2	0	4	6	9	15
--	ALL MARINE MAMMALS	23	7	16	6	2	48	102	39	141

TABLE IIF1. Nautical miles searched on transects during Survey 6 by block and Beaufort scale, the number of zones surveyed in each block, the line length searched in blocks 1-6 as a proportion of the total, and the area of ocean in blocks 1-6 as a proportion of the total.

	BLOCK								
Beaufort scale	1	2	3	4	5	6	sub total	7	Total
	Line length searched in nautical miles								
0	42.5	13.5	-	-	-	-	56.0	-	56.0
1	8.2	13.8	-	-	-	-	22.0	20.2	42.2
2	83.2	118.2	194.2	-	-	62.1	457.7	29.3	487.0
3	269.0	179.1	223.7	10.7	55.9	81.3	819.7	93.5	913.2
4	126.1	78.8	227.9	180.1	67.7	87.1	767.7	56.7	824.4
5	37.7	42.4	37.1	168.7	108.2	53.0	447.1	43.0	490.1
6	7.2	-	-	-	-	-	7.2	-	7.2
7	-	-	-	-	-	-	-	-	-
total	573.9	445.8	682.9	359.5	231.8	283.5	2577.4	242.7	2820.1
No. of zones surveyed	4/4	4/4	4/4	2/4	4/4	3/4	21/24	6/6	27/30
Line length as proportion of total line length in blocks 1-6	0.22	0.17	0.26	0.14	0.09	0.11	1.00		
Area as proportion of total area of blocks 1-6	0.155	0.147	0.256	0.244	0.091	0.108	1.000		

TABLE IIF2. Sightings of marine mammals made on transects during Survey 6 by species code, species grouping, and survey block.

Species code	Species name	BLOCK								
		1	2	3	4	5	6	sub total	7	Total
05	Minke whale	0	0	1	1	0	0	2	2	4
07	Unid. rorqual	1	0	0	0	0	0	1	0	1
08	Gray whale	1	0	0	0	0	0	1	0	1
--	LARGE WHALES	2	0	1	1	0	0	4	2	6
18	White whale	1	0	0	0	0	0	1	0	1
20	Killer whale	0	0	0	0	0	2	2	0	2
27	Unid. other whale	1	0	0	1	0	0	2	0	2
--	OTHER WHALES	2	0	0	1	0	2	5	0	5
28	Dall's porpoise	0	0	1	0	1	3	5	1	6
29	Harbor porpoise	0	2	3	0	0	1	6	0	6
32	Unid. dolphin/porp.	0	0	0	1	0	0	1	0	1
--	DOLPHINS & PORPOISE	0	2	4	1	1	4	12	1	13
80	Sea Otter	5	1	1	0	1	5	13	5	18
81	Unid. pinniped	0	2	1	1	0	0	4	0	4
72	Walrus	58	0	0	0	0	0	57	0	57
83	Harbor seal	5	0	0	0	1	0	6	4	10
88	Unid. Phocid	0	0	6	1	0	3	10	0	10
--	PHOCIDS	5	0	6	1	1	3	16	4	20
90	Steller's sea-lion	0	0	0	0	0	1	1	11	12
--	OTARIIDS	0	0	0	0	0	1	1	11	12
99	Unid. marine mammal	1	0	0	0	0	0	1	0	1
--	ALL MARINE MAMMALS	72	5	13	5	3	15	113	23	136

TABLE 1IG1. Nautical miles searched on transects during Survey 7 by block and Beaufort scale, the number of zones surveyed in each block, the line length searched in blocks 1-6 as a proportion of the total, and the area of ocean in blocks 1-6 as a proportion of the total.

	BLOCK								
Beaufort scale	1	2	3	4	5	6	sub total	7	Total
	Line length searched in nautical miles								
0	288.1	284.6	328.7	-	-	21.6	923.0	-	923.0
1	52.9	-	-	78.9	-	-	131.8	13.0	144.8
2	-	120.0	8.3	139.9	4.5	-	272.7	10.8	283.5
3	17.8	16.3	29.3	204.8	10.8	29.1	308.1	142.4	450.5
4	75.8	-	56.7	64.1	184.3	133.1	514.0	37.3	551.3
5	36.6	-	284.8	13.8	53.1	111.7	500.0	27.8	527.8
6	-	-	6.0	20.0	-	57.3	83.3	-	83.3
7	-	-	-	-	-	-	-	-	-
total	471.2	420.9	713.8	521.5	252.7	352.8	2732.9	231.3	2964.2
No. of zones surveyed	4/4	4/4	4/4	3/4	4/4	4/4	23/24	5/6	28/30
Line length as proportion of total line length in blocks 1-6	0.17	0.16	0.26	0.19	0.09	0.13	1.00		
Area as proportion of total area of blocks 1-6	0.155	0.147	0.256	0.244	0.091	0.108	1.000		

TABLE IIG2. Sightings of marine mammals made on transects during Survey 7 by species code, species grouping, and survey block.

Species code	Species name	BLOCK 1	2	3	4	5	6	sub total	7	Total
05	Minke whale	2	0	0	0	0	0	2	0	2
18	White whale	17	1	0	0	0	0	18	0	18
20	Killer whale	0	0	0	0	1	1	2	0	2
26	Unid. Beaked whale	0	0	0	1	0	0	1	0	1
	OTHER WHALES	17	1	0	1	1	1	21	0	21
28	Dall's porpoise	0	0	0	11	1	1	13	5	18
29	Harbor porpoise	1	0	0	0	0	0	1	1	2
32	Unid. dolphin/porp.	0	0	0	0	0	0	0	2	2
	DOLPHINS & PORPOISE	1	0	0	11	1	1	14	8	22
80	Sea Otter	0	0	0	0	0	33	33	11	44
81	Unid. Pinniped	5	2	4	2	0	0	13	0	13
82	Walrus	14	27	6	0	0	1	48	0	48
86	Bearded seal	0	3	0	0	0	0	3	0	3
88	Unid. Phocid	1	0	0	0	0	0	1	0	1
	PHOCIDS	1	3	0	0	0	0	4	0	4
90	Steller's sea-lion	0	0	2	1	2	2	7	8	15
	ALL MARINE MAMMALS	40	33	12	5	4	38	142	27	169

TABLE IIH1. **Nautical miles searched on transects during Survey 8 by block and Beaufort scale, the number of zones surveyed in each block, the line length searched in blocks 1-6 as a proportion of the total, and the area of ocean in blocks 1-6 as a proportion of the total.**

	BLOCK								
Beaufort scale	1	2	3	4	5	6	sub total	7	Total
	Line length searched in nautical miles								
0	81.7	451.7	46.4	-	-	-	579.8	-	579.8
1	52.9	-	123.8	9.7	18.0	3.0	207.4	30.8	238.2
2	160.6	-	27.3	104.3	16.1	20.7	329.0	131.0	460.0
3	82.6	-	55.1	396.8	89.1	151.4	775.0	58.5	833.5
4	112.5	-	29.7	131.2	55.0	193.3	521.7	39.5	561.2
5	-	-	170.3	60.2	59.9	-	290.4	23.5	313.9
6	-	-	51.0	-	24.4	-	75.4	-	75.4
7	-	-	-	-	-	-	-	-	-
total	490.3	451.7	503.6	702.2	262.5	368.4	2778.7	283.3	3062.0
No. of zones surveyed	4/4	4/4	3/4	4/4	4/4	4/4	23/24	6/6	29/30
Line length as proportion of total line length in blocks 1-6	0.18	0.16	0.18	0.25	0.10	0.13	1.00		
Area as proportion of total area of blocks 1-6	0.155	0.147	0.256	0.244	0.091	0.108	1.000		

TABLE IIH2. Sightings of marine mammals made on transects during Survey 8 by species code, species grouping, and survey block.

Species code	Species name	BLOCK 1	2	3	4	5	6	sub total	7	Total
18	White whale	1	1	0	0	0	0	2	0	2
28	Dall's porpoise	1	0	0	3	1	1	6	7	13
29	Harbor porpoise	0	0	0	0	0	0	0	2	2
	DOLPHINS & PORPOISE	1	0	0	3	1	1	6	9	15
80	Sea Otter	0	0	0	0	1	2	3	14	17
81	Unid. Pinniped	2	1	4	0	0	1	8	0	8
82	Walrus	34	11	39	0	0	0	84	0	84
83	Harbor seal	0	0	0	0	0	0	0	1	1
86	Bearded seal	0	0	5	0	0	0	5	0	5
87	Ribbon seal	0	0	6	0	0	0	6	0	6
88	Unid. Phocid	2	0	5	0	0	0	7	0	7
	PHOCIDS	2	0	16	0	0	0	18	1	19
90	Steller's sea-lion	0	0	0	0	0	3	3	2	5
	ALL MARINE MAMMALS	40	13	59	3	2	7	124	26	150

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