AERIAL SURVEYS OF ENDANGERED CETACEANS AND OTHER MARINE MAMMALS IN THE NORTHWESTERN GULF OF ALASKA AND SOUTHEASTERN BERING SEA

by

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ABSTRACT

Aerial surveys were conducted in the northwestern Gulf of Alaska and southeastern Bering Sea to determine the abundance, distribution, and habitat use patterns of endangered cetaceans and other marine mammals. Seven, 7- to 20-day surveys were flown between April and December 1985 from a DeHavilland Twin Otter aircraft along almost 44,000 nmi (mean = 5,437 ± 1,972 SD) of randomly selected trackline stratified by water depth. Four species of cetaceans listed by the Federal Government as endangered were observed: gray (377 groups, 589 individuals), humpback (98, 185), finback (74, 149), and sperm (7, 23) whales. Sightings were also made of seven nonendangered species of cetaceans: minke (8, 8), Cuvier's beaked (1, 2), Baird's beaked (2, 9), belukha (6, 8), and killer (25, 67) whales, and Dan (50, 157) and harbor (1, 1) porpoises.

Most of the gray whales were observed during the April-May (12%) and November-December (87%) survey periods, which coincide with the spring and fall migrations through the study area. The spring migration route along the south side of the Alaska Peninsula was coastal from Seal Cape to Unimak Pass, although some animals were observed traveling along the continental shelf edge. Spring surveys were not conducted east of Seal Cape or along the north side of the peninsula. The fall migration route followed along the north side of the Alaska Peninsula from Ugashik Bay to Unimak Pass and coincided with the progressively narrowing O- to 40-m depth contour band. The fall route along the south side of the peninsula remained coastal until Seal Cape where it moved offshore toward the southwest end of Kodiak Island. Some whales were observed following the continental shelf edge toward Kodiak Island. Fifteen gray whales, including thirteen observed during a 1986 sea otter survey, were recorded summering in the study area, primarily north of the Alaska Peninsula (13 of 15 whales) in or near bays and large estuaries.

Most (90%) humpback whales were observed from June through August and the rest during October and November. All humpbacks were observed in the Shumagin Planning Area, where 66% of the survey effort occurred. Approximately 69% of the humpback whales were observed on the continental shelf, l% on the slope, and 30% in waters greater than 2,000 m deep. Humpbacks were repeatedly observed on Sanak Bank, Shumagin Bank, and an unnamed bank at longitude 158*W. These banks are near sharp relief where biological productivity was probably high and their repeated use by humpbacks suggests site fidelity. Humpback whale abundance was estimated at 333 ± 217 from the line transect procedure.

Finback whales were only observed during July and August, all in the Shumagin Planning Area. Approximately 90% of the finbacks were observed on the continental shelf and 10% on the slope. None were observed in waters greater than 2,000 m deep. Use of shelf and slope waters was not significantly different ($p > 0.05$), but 90% were observed near high relief areas between 45 m (25 fathoms) and 137 m (75 fathoms) deep. Finback whales were repeatedly observed near Lighthouse Rocks (157°25'W), suggesting site fidelity. Finback whale abundance was estimated at 184 ± 90 animals from the line transect procedure.

Sperm whales were only observed in the Shumagin Planning Area in waters 3,500-4,000 m deep, but too few were observed to derive an abundance estimate. Killer whale abundances were estimated for the St. George Basin (639 ± 476) and Shumagin (244 ± 136) planning areas only, since too few were encountered in the North Aleutian Basin.

Estimates for humpback, finback, and killer whales were not corrected for missed animals. Abundance was not estimated for the remaining nonendangered species because too few were observed, or, as in the case of the Dan porpoise, they could not be accurately observed at the altitude flown.

These results show that the project area is an important feeding ground for relatively large numbers of humpback and finback whales and lower numbers of gray and sperm whales. Moreover, the project area is a critical link in the gray whale migration route between seasonal ranges. The project area also supports a variety of other marine mammals both seasonally and annually.

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INTRODUCTION

Seven species of endangered whales seasonally inhabit the northwestern Gulf of Alaska and southeastern Bering Sea (Rice and Wolman 1982; Morris *et al.* 1983). Humpback (*Megaptera novaeangliae*), finback (*Balaenoptera physalus*), and right (*Balaena glacialis*) whales feed in both waters during the summer and early fall, while blue (*Balaenoptera musculus*), sei (*Balaenoptera borealis*), and sperm (*Physeter macrocephalus*) whales are more restricted to the North Pacific or the deeper western Bering Sea (Berzin and Rovnin 1966; Rice 1974). Gray whales (*Eschrichtius robustus*) pass through the Gulf of Alaska and eastern Bering Sea twice each year on their annual migration between breeding lagoons in Mexico and feeding grounds in the northern Bering and Chukchi seas (Braham 1984*b*). A few gray whales summer along the Alaska Peninsula (Gill and Hall 1983). Many of these species occur in the North Pacific and Bering Sea throughout the year (Brueggeman *et al.* 1984). Bowhead whales (*Balaena mysticetus*) winter in the Bering Sea but their range is beyond the study area, northwest of Bristol Bay (Brueggeman 1982).

Stocks of these whales were severely reduced by commercial whaling in the North Pacific Ocean and Bering Sea. Protection of the North Pacific right whale stock from commercial whaling began in 1937 and protection of the gray whale began in 1946, after both had been severely reduced by high-seas whaling in the 19th century (Townsend 1935). Only a few hundred right whales survive today (Rice 1974; Rice and Wolman 1982), while the gray whale population has apparently recovered to pre-exploitation levels (Gambell 1976; Reilly 1981; Rice and Wolman 1982).

The large-scale exploitation of these species began with the introduction of modern whaling methods after the turn of the century. Between 1912 and 1939, over 5,000 blue, finback, humpback, and sperm whales were taken from the northwestern Gulf of Alaska and southeastern Bering Sea by Alaska shore-based whaling stations (Brueggeman *et al.* 1984; Leatherwood *et al.* 1985; Reeves *et al. 1985).* After a brief respite during World War II, Soviet and Japanese pelagic whaling fleets further harvested blue and humpback whales from these waters until their protection in 1967 and finback and sei whales until their protection in 1976. Population levels of North Pacific rorquals presently range from approximately 870(1,200) of the estimated original numbers of humpback whales to 32-44% (14,620-18,630) of estimated original finback whales (Braham 1984*a*). The sperm whale, though listed as an endangered species, is commercially harvested by Japan in the North Pacific, where approximately 400 whales are annually taken from an estimated 472,100 animals composing the entire North Pacific stock (Ohsumi 1980; Braham 1984*a*; IWC 1986).

Nonendangered whales endemic to the northwestern Gulf of Alaska and southeastern Bering Sea include the minke whale (*Balaenoptera acutorostrata*), Stejneger's beaked whale (*Mesoplodon stejnegeri*), Cuvier's beaked whale (*Ziphius cavirostris*), Baird's beaked whale (*Berardius bairdii*), killer whale (*Orcinus orca*), harbor porpoise (*Phocoena phocoena*), and Dan porpoise (*Phocoenoides dalli*). population sizes for these species are unknown except for the Dan porpoise which is currently estimated at between 136,671 and 253,865 animals in the Gulf of

Alaska (Bouchet 1981). These cetaceans have not been specifically harvested by commercial whalers in the eastern North Pacific.

Other marine mammals common in these waters are the northern fur seal (*Callorhinus* w-sinus), northern sea lion (*Eumetopias jubatus*), harbor seal (*Phoca vitulina*), and sea otter (*Enhydra lutris*). The coast of the Alaska Peninsula and Aleutian Islands is the major breeding area for the latter three species, whereas the Pribilof Islands are the main breeding ground for the northern fur seal (Fiscus 1978; Kenyon 1982; Loughlin *et al.* 1984).

Information on marine mammal abundance, distribution, and habitat use patterns in the northwestern Gulf of Alaska and southeastern Bering Sea is incomplete. Most available information is derived from limited systematic surveys, opportunistic sightings, and historic whaling records. Aerial surveys and some vessel surveys have been conducted by the National Marine Mammal Laboratory (NMML) and other investigators (Braham *et al.* 1977; Rice and Wolman 1982; Leatherwood *et* al. 1983; Braham 1984*b*; Rugh 1984; Stewart *et al.* 1987) supported through the NOAA/MMS Outer Continental Shelf Environmental Assessment Program (OCSEAP). While these efforts have contributed substantially to a better understanding of the biology of these species, the results remain inconclusive because of the large area surveyed, difficult logistics, and the small number and sporadic distribution of many endangered cetacean and other marine mammal populations.

In 1985, we surveyed endangered cetaceans and other marine mammals in the northwestern Gulf of Alaska and southeastern Bering Sea in order to characterize their use of these areas. Our surveys were part of an OCSEAP study to determine the effect of proposed petroleum exploration and development on marine mammal populations in the Shumagin, North Aleutian Basin, and St. *George* Basin planning areas, as stipulated by the Marine Mammal Protection Act and the Endangered Species Act. Aerial surveys were conducted during six 20-day periods between June and December, and an additional 7-day survey was conducted during April-May by Donald K. Ljungblad and his staff from the Naval Ocean Systems Center, San Diego. Exact survey dates are included in Table 1. The primary objectives of the study were to

1) Characterize large cetacean abundance and habitat use in the Shumagin Planning Area twice each season (during the seven survey periods) from spring through early winter.

2) Define fall migration patterns of gray whales and their use of feeding areas in the St. George Basin and North Aleutian Basin planning areas.

3) Characterize large cetacean abundance and seasonal habitat use in the St. George Basin and North Aleutian Basin planning areas during June-July, November, and December surveys and make semiannual comparisons using available data from other sources.

4) Document sightings and behavior of other marine mammals encountered during the surveys.

Table I.-Aerial survey periods, 1985.

Survey number	Survey period	Actual survey date[a]
1[b]	April - May	28 April -4 May
2	June - July	24 June - 11 July
3	July - August	23 July -5 August
4	August	21 -31 August
5	October	13- 31 October
6	November	11 -24 November
7	December	2- 19 December

[a] Dates shown are first and last days of actual survey.
[b] Survey conducted by D. K. Ljungblad and staff at NOSC, San Diego.

STUDY AREA

The study area included the waters offshore of the Alaska Peninsula in the Bering Sea and the northwestern Gulf of Alaska (Figure 1). The southeastern Bering Sea is a sandy-bottomed shelf region less than 200 m deep. It is separated from the deep (2,500 m) Bering Sea basin by the shelf break that runs northwestward from Unimak Pass. In contrast, the continental shelf on the south side of the peninsula is rock-bottomed and has extensive reefs and island complexes. The shelf extends approximately 75 km from the coast before dropping precipitously into the 8,000-m-deep Aleutian Trench. Surveys were conducted as far as 325 km offshore of the Alaska Peninsula.

The oceanographic characteristics of Alaska Peninsula waters are primarily influenced by two major currents: the Alaska Coastal Current (ACC) and the Alaska Stream. The narrow ACC, driven by snowmelt and runoff, travels southwestward along the south side of the Alaska Peninsula. It then enters the Bering Sea through Unimak Pass (Royer 1981; Schumacher and Moen 1983) before flowing northeastward into Bristol Bay. According to Schumacher and Reed (1986), the islands and submarine canyons along the south side of the peninsula bifurcate the ACC and create mixing zones between the shelf and current waters. The much stronger Alaska

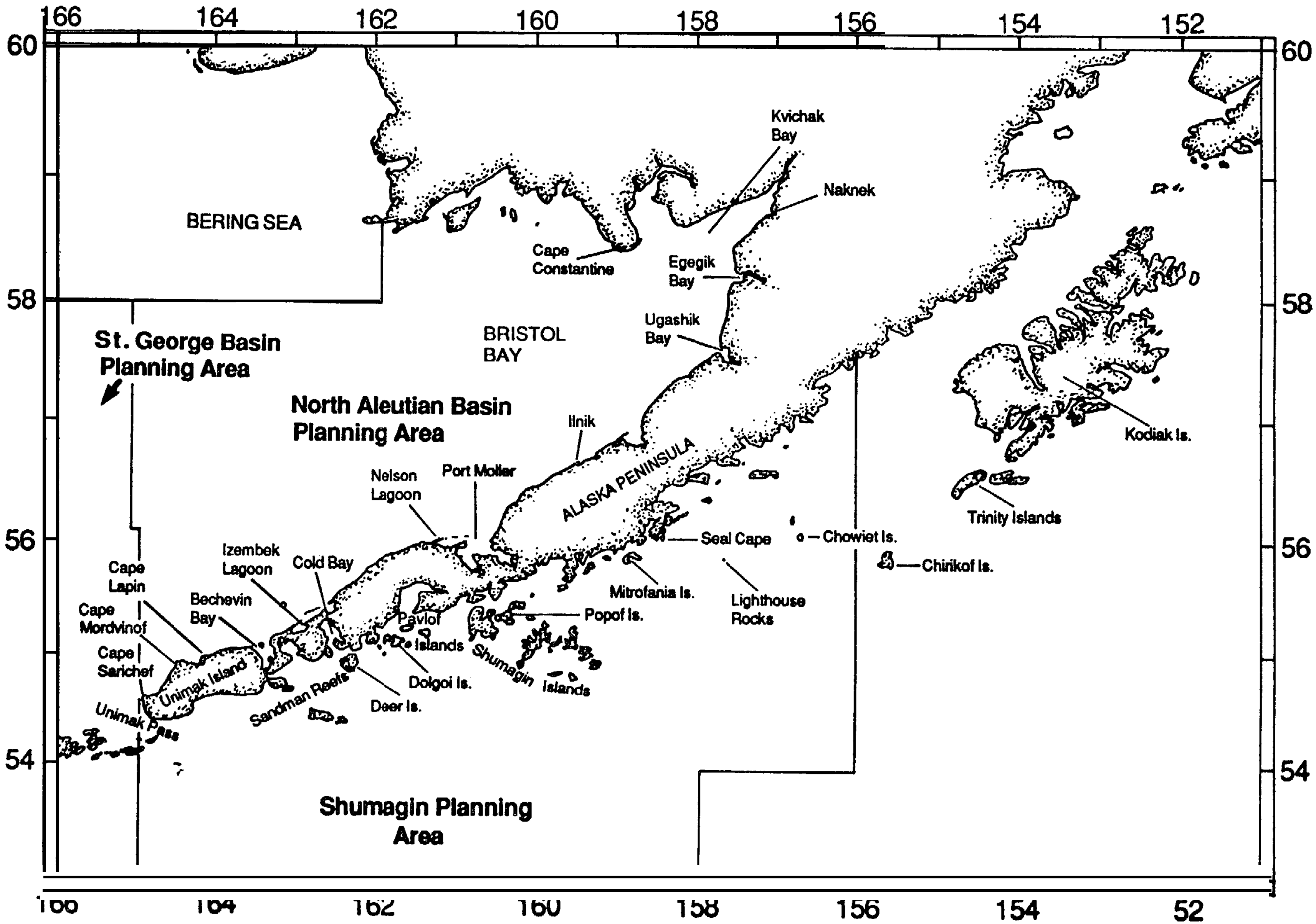


Figure 1.–Study area with place names mentioned in the text.

Stream flows southwestward along the edge of the continental shelf south of the peninsula. Part of this current diverges and travels through various Aleutian Island passes and mixes with Bering Sea waters (Favorite 1974). Both currents are influenced by the persistent and heavy winds typical of the Alaska Peninsula and the Aleutians. Monthly mean wind speeds, ranging between 24 and 29 km/hr, are highest and most persistent during winter when cyclonic storms are frequent. In turn, these currents and winds greatly influence the biological oceanography in the study area.

The northwestern Gulf of Alaska climate is maritime with little influence from continental air masses. Daily and seasonal temperature extremes are confined to fairly narrow limits and readings below -18°C (0°F) are very rare. Conversely, the Bering Sea is partially covered with sea ice from approximately October through June. Although the southern limit of the pack ice is north of the study area, shorefast ice reaches its southern limit approximately halfway down the Alaska Peninsula (Port Moller). During particularly cold years, fast ice may reach Unimak Island (Schneider and Faro 1975). Shorefast ice is present in the study area from approximately January through March.

METHODS

Survey Design and Procedures

The study area was stratified into three levels of survey effort: (1) planning area, (2) sampling block, and (3) water depth zone (Figure 2). The planning areas, which are federally delineated oil and gas lease sites, included the Shumagin unit (south of the Alaska Peninsula) and the North Aleutian Basin and St. George Basin areas (north of the Alaska Peninsula and eastern Aleutian Islands). Within these planning areas, 65 survey blocks, each 110 km long by 74 km wide, were uniformly distributed. There were 29 survey blocks in the Shumagin Planning Area, 20 in the North Aleutian Basin, and 16 in the St. George Basin. The blocks intersected three water depth categories: shallow, transition, and deep water. The shallow water zone, 0-200 m deep, corresponded to the outer continental shelf. The transition zone, 200-2,000 m deep, corresponded to the outer continental slope. The water depth beyond 2,000 m but within approximately 325 km of the coast represented the deep water zone. Survey blocks within each planning area were divided among the three zones so as to stratify the study area into habitats defined by water depth and geographic location.

For each survey period, blocks to be flown were randomly selected (without replacement) from all blocks in the planning area. Surveys were conducted in the Shumagin Planning Area during each period. On the other hand, the North Aleutian Basin and St. George Basin were surveyed only during the June-July, November, and December periods; a limited survey (173 nmi) was also conducted in the North Aleutian Basin during the August survey period. This schedule, developed by OCSEAP, was designed to correspond with the historic use of these areas by endangered whales. This includes spring through fall use in the Shumagin area and spring-early summer and late fall-early winter use in the North Aleutian Basin and St. George Basin areas.

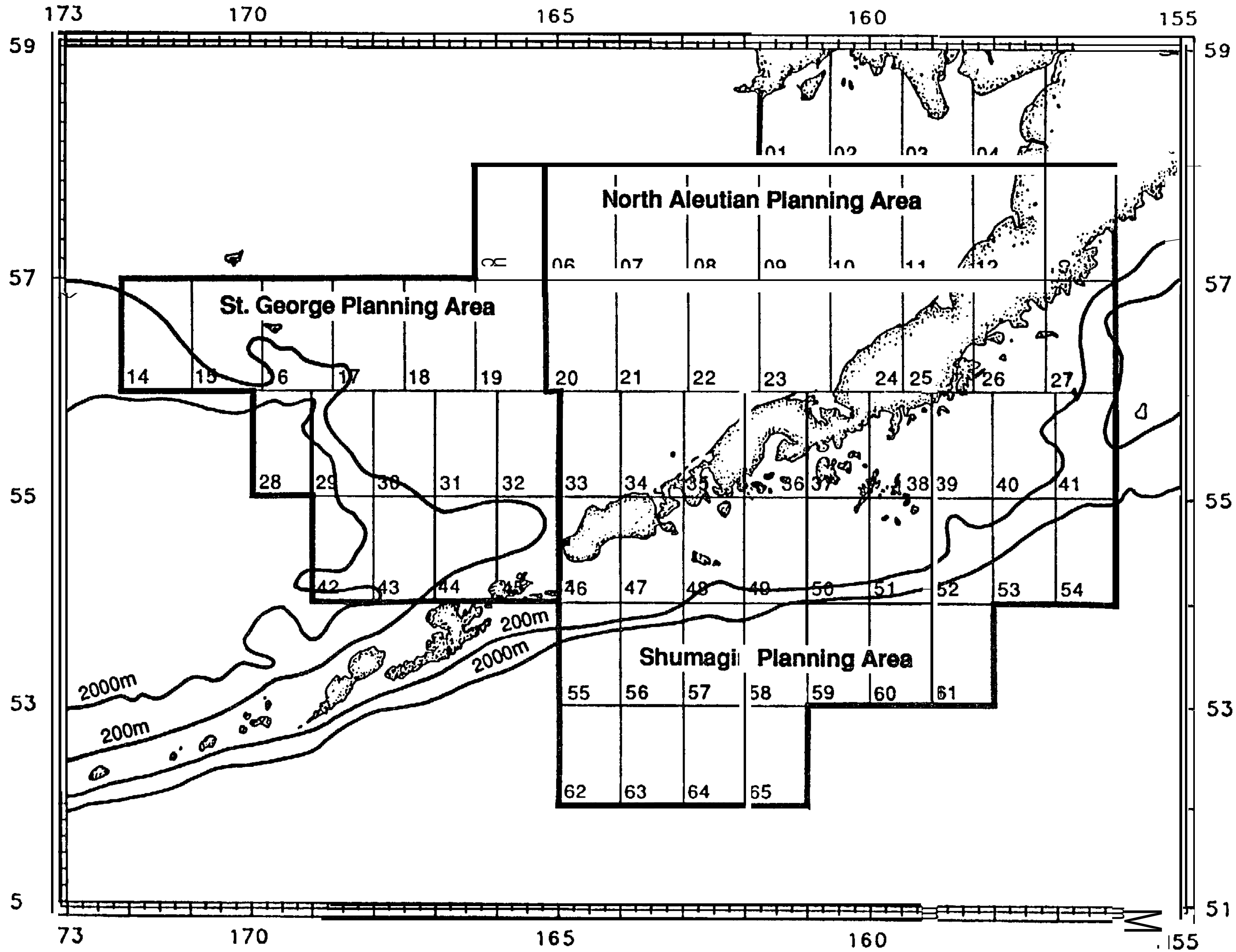


Figure 2.- Survey design.

Survey effort was recorded by planning area and water depth zone. The effort achieved for all surveys combined was a total of 540 hours of flight time, 60% of which was spent in the Shumagin Planning Area, 24% in the North Aleutian Basin, and 16% in the St. George Basin. Within these planning areas, approximately 76% of the effort was accomplished in the shallow water zone, 7% in the transition zone, and 17% in the deep water zone.

Aerial surveys were conducted along the transect lines uniformly distributed in each survey block (Figure 2). Each block contained ten transect lines, 110 km (60 nmi) long and spaced 7.4 km (4 nmi) apart, that were oriented in a north-south direction. These systematic transect lines were consecutively surveyed except for periods of unsuitable weather conditions. Transect lines were also surveyed when flying from Cold Bay (base of operations) to a sampling block, and these were termed random surveys. A third type of transect, termed a deadhead, was surveyed when flying between connecting systematic lines, when verifying a marine mammal sighting, or during non- or limited-effort transit flights. The latter type of survey provided information on species composition and distribution, but the data were not used to estimate population parameters since the effort was not constant. Surveys were occasionally conducted when sea state exceeded a Beaufort 4 or when ceiling height was below 90 m (300 ft), but these efforts were recorded as deadheads.

Surveys were conducted from a DeHavilland Twin Otter aircraft equipped with an auxiliary fuel tank to extend the potential flight duration to 10 hours. Surveys were flown at 230 m (750 ft), except when ceiling height forced the flight to a lower altitude. Air speed was maintained at 100 knots during all systematic and random transect flights. Air speeds greater or less than 100 knots occurred only during deadhead surveys or non-effort transit flights. Two observers, positioned on each side of the aircraft behind the pilot and copilot, relayed observations to a data recorder situated in the aft section of the aircraft. Observers viewed the survey area through bubble windows specially equipped on the aircraft to provide downward and forward visibility. A third observer rotated with the primary observers every 2 hours to reduce fatigue. The third or off-duty observer generally rested but also backed-up the others through a flat rear window during periods of frequent marine mammal encounters.

A Hewlett-Packard 85 computer, interfaced with the aircraft's Global Navigation System (GNS) and radar altimeter, provided the data recorder with an instantaneous readout of time, altitude, latitude, and longitude. The recorder combined these data with sighting and environmental information given by the observers. Sighting information included number of animals, group size, species, clinometer angle, behavior, direction of travel, number of calves, and whether the sighting was a duplicate. Duplicates were recorded when confirming a sighting. A group was defined as all animals within 3-4 body lengths of each other. Environmental information included sea state according to the Beaufort Wind Scale, with sea state descriptors (Black and Adams 1983), visibility, and glare. Visibility and glare descriptions are provided in Appendix C. Environmental conditions were evaluated by the observers at the beginning and end of each transect line or whenever conditions changed.

The April-May surveys were conducted by Donald K. Ljungblad and his staff at the Naval Ocean Systems Center (NOSC). Survey techniques were similar except north-south survey tracks were selected randomly within the area between Unimak Pass and the Shumagin Islands. Surveys were conducted from the same Twin Otter generally at an altitude of 230 m (750 ft) but which varied between 215 and 335 m (700 and 1,100 ft) depending on weather conditions. Data recording procedures and orientation of the observers in the aircraft were identical to those followed during the June-December surveys. Further information on the NOSC survey techniques can be found in Ljungblad *et* al. (1986).

Analytical Procedures

Marine mammal density and abundance were estimated from the line-transect procedure (Burnham *et al.* 1980). This procedure uses the perpendicular distances of animals from a survey trackline to determine a probability density function. The value of the function at the trackline (f(0)) is multiplied by the number of whales observed per distance of trackline to obtain the observed density. This procedure is the standard technique for estimating cetacean density and abundance. It must satisfy the following assumptions:

1) The area of interest is sampled randomly or the population is distributed randomly within the area.

2) All animals on the transect centerline are seen.

3) All measurements are made without error.

4) The animals do not move in response to the aircraft prior to being detected from it.

5) Sightings are independent events.

6) The size of a group of animals does not a.fleet its probability of being observed.

Steps were instituted during this study to minimize the violation of these assumptions. The first assumption was satisfied by randomly sampling survey blocks, since marine mammals are usually not randomly distributed.

The degree to which the second assumption was fulfilled is unclear; however, the following procedures and aircraft modifications were implemented to reduce this source of error: (1) bubble windows, constructed on each side of a high-winged aircraft, provided forward and downward visibility to the observers; (2) observers were constantly instructed to examine the trackline below and forward of the aircraft; and (3) pilots were instructed to alert observers to marine mammals detected on the trackline. Some whales that were below the surface were not detected by the observers. Species-specific information on respiration patterns is required to determine the proportion of missed or submerged whales. However, as various investigators have reported, respiration patterns are highly variable relative to behavior, sex, and age classes of animals. Because of this variability, it is not possible to calculate a meaningful correction factor. Hay (1982), however, reported that the proportion of animals missed can exceed the observed number by 50%.

The third assumption, that measurements are error-flee, relies upon accuracy in the two measurements needed to calculate a perpendicular distance: (1) altitude and (2) angle to animals. The altitude (in feet) was measured by a radar altimeter that was calibrated at the start of the surveys and directly linked to a portable computer for real-time measurements. The altitude was simultaneously recorded with the angle measurement of a sighting. Angles were obtained from clinometers and recorded to the nearest degree. While the altimeter values were accurate, the accuracy of the clinometer values decreased with increasing distance from the trackline. However, the influence of this error was reduced by truncating the tail of the sightability curve to calculate the f(0). The truncation process eliminates the furthest outlying sightings. These contribute little to the estimates of f(0) and density but often create problems for parametric and non-parametric estimation procedures. The outliers frequently cause difficulties such as a lack of fit for estimation models and necessitate adding terms in the Fourier series approach. A model with one or two terms is always preferred to one with four to six terms. Consequently, most estimation methods benefit from truncation of the data to eliminate outliers (Burnham *et* al. 1980).

The fourth assumption was almost certainly fulfilled since the speed of the airplane is great relative to the speed of the whales. The aircraft was moving at over 20 times the speed of the whales, and thus was fast enough to overcome the effects of any reaction of the whales to the aircraft.

The fifth assumption, that sightings are independent events, was generally met. Sightings were usually spaced at sufficient distances to reduce the likelihood that one sighting initiated the sighting of additional groups of whales. When multiple groups were tightly clustered, however, the independence of observations is uncertain. Failure to fulfill this assumption would affect only the sampling variance of the density estimate, rather than the density estimate itself (Burnham *et al. 1980).*

Lastly, the sixth assumption, that group size does not affect the probability of detection, was generally fulfilled. Because group sizes were typically small, the potential disparity in the probability of detecting different group sizes was substantially reduced. Larger groups have a higher probability of being observed than smaller groups. The result is an overestimation of mean group size and an underestimation of the mean number of groups per unit of area. Because group size was quite consistent within each species, observers were experienced at sighting whales, and individual animals were readily detected at 230 m (750 ft) altitude, group size did not substantially influence the probability of detecting a whale. Consequently, the line-transect procedure was suitable for estimating cetacean density and abundance for this study.

The probability density function of the perpendicular distances, f(x), was estimated from calculated distances and evaluated at zero (f(0)). (See Appendix A for a list of the basic notation used in the following calculations.) The following expression was used to calculate density:

$$D_i = \frac{n_i f(0)}{2L_i} \qquad \text{(Equation 1)}$$

where n_i is the number of groups of animals and L_i is the length of trackline searched in sampling block i. Only systematic and random trackline surveys were used to estimate density. The non-parametric Fourier-series estimator was used to calculate f(0). This method is recommended by Burnham *et al.* (1980) because it is a robust estimator of f(0) which is especially suitable to apply to marine mammal data. Program TRANSECT (Laake *et al.* 1979) was used to execute the calculations. The f(0) was determined for a set of perpendicular distances truncated at the tail of the sightability curve. K. Burnham (pers. commun.) recommended this procedure to reduce the variability of f(0) since the larger perpendicular distance values that compose the tail of the curve are less accurate and may represent a different sighting process.

Because survey effort was variable in each randomly selected sampling block, the following expression was used to calculate a weighted density of groups:

$$D_{wi} = \frac{\sum_{i=1}^{b} (L_i \; D_i)}{\sum_{i=1}^{b} L_i} \qquad \text{(Equation 2)}$$

where b is the number of sampling blocks surveyed. The weighted density was calculated for all sampling blocks surveyed in each of the three water depth zones. The total number of groups (G) in a planning area was calculated by summing the estimated abundance in each zone according to the following expression:

$$G = \sum_{i=1}^{3} (A_i \; D_{wi}) \qquad \text{(Equation 3)}$$

where A_i is the area of a planning area composed of one to three possible zones.

Because the group rather than the individual is the basic observation for marine mammals, the abundance estimate (N_G) is converted to an estimated number of individuals (N_I) by the following expression:

$$N_I = N_G \bar{K} \qquad \text{(Equation 4)}$$

where $\bar{K}$ is the average group size for a particular species of marine mammal.

An estimate of the sampling variance for density as derived by D. Chapman for this study is:

$$V(D_{wi}) = \left[\frac{\sum_{i=1}^{b} L_i (D_i)^2 - \dfrac{\left(\sum_{i=1}^{b} L_i D_i\right)^2}{\sum_{i=1}^{b} L_i}}{\left(\sum_{i=1}^{b} L_i\right)^2} \right] \left(\frac{B-b}{B-1}\right) \qquad \text{(Equation 5)}$$

where B is the total number of sampling blocks in a zone of a planning unit. The $\frac{B-b}{B-1}$ expression is a finite population correction factor.

The variance of the total number of individuals is then computed by the following expression:

$$V(N_I) = \sum_{i=1}^{3} \left[A_i^2 \, V(D_{wi})\right] f(0)^2 \, \bar{K}^2 \; +$$
$$\sum_{i=1}^{3} \left[A_i \, D_{wi}\right]^2 \, V\left[f(0)\right]^2 \, \bar{K}^2 \; + \qquad \text{(Equation 6)}$$
$$\sum_{i=1}^{3} \left[A_i \, D_{wi}\right]^2 \left[f(0)\right]^2 V(\bar{K})$$

where V f(0) was calculated from Burnham *et al. (1980)* and the $V(\bar{K})$ from the following equation:

$$V(K) = \frac{\sum_{i=1}^{G} K_i^2 - \frac{\left(\sum_{i=1}^{G} K_i\right)^2}{G}}{G(G-1)} \qquad \text{(Equation 7)}$$

where G is the number of groups of size K. The same sighting function (f(0)), and also the same mean group size ($\bar{K}$), are used for all sampling units within the three zones.

Approximately 95% confidence intervals were calculated for the estimate of abundances from the following formula:

$$N_I \pm 2\sqrt{V(N_I)} \qquad \text{(Equation 8)}$$

The number of whales missed during the surveys was not factored into the estimated density and abundance values. Missed animals include those at the surface but not seen by observers and those that were submerged. Corrections of aerial survey estimates for missed marine mammals based on dive-time data have not been derived because correction factors may be strongly influenced by behavior, group size, season, time of day, and many other biological and environmental factors. Pending availability of such correction factors, it is conservatively assumed that 50% of whales go undetected (H. H. Whitehead in Hay 1982).

RESULTS AND DISCUSSION

Species Composition and Effort

Sixteen species of marine mammals, including 1,274 cetaceans, 3,719 pinnipeds, and 4,463 sea otters were observed along 38,050 nmi of trackline surveyed in the Shumagin, North Aleutian Basin, and St. George Basin planning areas between April and December 1985 (Table 2). Approximately 63% of the marine mammals were encountered in the Shumagin area, 36% in the North Aleutian Basin, and 1% in the St. George Basin. Survey effort was correspondingly highest (66$10) in the Shumagin area, lowest in the St. George Basin (13%), and intermediate in the North Aleutian Basin (21%).

Four of the eleven species of cetaceans that we observed are listed by the federal government as endangered throughout their range. The survey recorded 589 gray whales, 185 humpback whales, 149 finback whales, and 23 sperm whales, which together accounted for almost 80% of the total number of cetaceans sighted. Of the seven nonendangered species, the

Table 2.–Species composition and number of marine mammals observed in the three planning areas, April-December 1985.

Species	Shumagin (25,059 nmi)[a]		North Aleutian Basin (8,061 nmi)		St. George Basin (4,930 nmi)		Total (38,050 nmi)	
	No.	Group	No.	Group	No.	Group	No,	Group
Cetacea								
Mysticeti								
Minke whale *(Balaenoptera acutorostrata)*	3 (l)[b]	3 (I)[b]	3	3	1	1	7 (1)	7 (1)
Finback whale *(Balaenoptera physalus)*	93 (56)	49 (25)	o	0	0	0	93 (56)	49 (25)
Humpback whale *(Megaptera novaeangliae)*	129 (56)	75 (23)	0	0	0	0	129 (56)	75 (23)
Gray whale *(Eschrichtius robustus)*	75 (116)	33 (40)	334 (64)	221 (43)	0	0	409 (180)	254 (83)
Unidentified baleen	33	24	14	9	1	1	48	34
Odontoceti								
Cuvier's beaked whale *(Ziphius cavirostris)*	2	1	0	0	0	0	2	1
Baird's beaked whale *(Berardius bairdii)*	5 (4)	1 (1)	0	0	0	0	5 (4)	1 (1)
Unidentified beaked whale	3 (1)	1 (1)	0	0	0	0	3 (1)	1 (1)
Sperm whale *(Physeter macrocephalus)*	23	7	0	0	0	0	23	7
Belukha whale *(Delphinapterus leucas)*	0	0	5 (3)	5 (1)	0	0	5 (3)	5 (1)
Killer whale *(Orcinus orca)*	32 (6)	11 (3)	1 (1)	1 (1)	27	9	60 (7)	21 (4)
Harbor porpoise *(Phocoena phocoena)*	1	1	0	0	0	0	1	1
Dan porpoise *(Phocoenoides dalli)*	71 (32)	25 (7)	21	7	33	11	125 (32)	43 (7)
Unidentified porpoise	8	5	6	6	10	7	24	16
Subtotal	478 (271)	234 (101)	384 (68)	252 (45)	72	29	934 (340)	515 (146)
Pinnipedia								
Otariidae								
Northern sea lion *(Eumetopias jubatus)*	2,997	171	341	19	4	2	3,342	192
Northern fur seal *(Callorhinus ursinus)*	4	3	4	1	10	6	18	10
Phocidae								
Harbor seal *(Phoca vitulina)*	282	54	53	3	0	0	335	57
Odobenidae								
Pacific walrus *(Odobenus rosmarus)*	0	0	24	18	0	0	24	18
Subtotal	3,283	228	422	41	14	8	3,719	277
Carnivora								
Mustelidae								
Sea otter *(Enhydra lutris)*	1,880	383	2,568	358	15	1	4,463	742
Total	5,639 (271)	844 (99)	3,374 (68)	651 (44)	101	38 (1)	9,113 (340)	1,532 (146)

[a] Total distance surveyed.

[b] Additional number or groups or animals observed on deadhead survey tracklines.

most abundant were the Dall porpoise (157) and killer whale (67). Fewer than 15 animals each were encountered of Cuvier's beaked whales, Baird's beaked whales, belukha whales, minke whales, and harbor porpoises. There were 76 unidentified cetaceans.

The richness of cetacean species was highest in the Shumagin Planning Area and lowest in the St. George Basin Planning Area (Table 2). Ten of the eleven species were observed in the Shumagin area, whereas five and three species were observed in the North Aleutian and St. George basins, respectively. All of the endangered whale species except the gray whale were recorded solely in the Shumagin area. Gray whales also occurred in the North Aleutian Basin. The Dan porpoise, killer whale, and minke whale were the only species found in all three planning areas. Belukha whale observations were confined to Bristol Bay in the North Aleutian Basin.

Four species of pinnipeds and 4,500 sea otters were also observed in the planning areas (Table 2). The northern sea lion was the most common pinniped, followed by the harbor seal, Pacific walrus, and northern fur seal. Large numbers of these species reproduce in rookeries distributed throughout the planning areas. Observations of pinnipeds and sea otters were incidental to those of cetaceans.

Survey effort in the planning areas totaled 38,050 nrni of systematic and random surveys and 5,634 nmi of deadhead surveys (Figure 3). Deadhead surveys were only used to describe marine mammal distribution, and they accounted for 338 (27%) cetacean observations. Systematic and random survey effort, the basis for the analysis, averaged 5,437 nmi (±1,972 SD) per survey period. Effort was highest during the June-July and July-August periods and lowest during the April-May period. The Shumagin Planning Area was surveyed during all seven periods and the effort averaged 3,580 nmi (±2,329 SD) (Figure 4). Effort averaged 2,016 nmi (±1,269 SD) for the four survey periods in the North Aleutian Basin, and 1,644 nmi (±767 SD) for the three survey periods in the St. George Basin. The total survey effort we achieved represents the highest intensity of coverage in these planning areas and it exceeds previous survey efforts (Leatherwood *et* al. 1983; Stewart *et al.* 1987) by at least a factor of three.

Viewing conditions during surveys primarily featured good to excellent visibility and Beaufort sea states of O to 3 (Figure 5). Good to excellent visibility conditions occurred during 86% of the total survey effort in the Shumagin Planning Area, 77% in the North Aleutian Basin, and 75% in the St. George Basin. The same visibility conditions were experienced in 76-92% of the effort in each of the seven survey periods (Table 3). Sea state, estimated according to the Beaufort Wind Scale, was between O and 3 during 78% of the total survey effort in the St. George Basin, 71% in the Shumagin area, and 57% in the North Aleutian Basin. Sea states were highest during the fall survey periods (particularly November) when Beaufort 4 and 5 conditions occurred during 43-63% of the total effort. During the spring and summer periods, sea states of these magnitudes prevailed during only 10% and 2670 of the total survey effort. Consequently, survey conditions were best during periods one through four (April-August), worst during period six (November), and intermediate during periods five and seven (October, December).

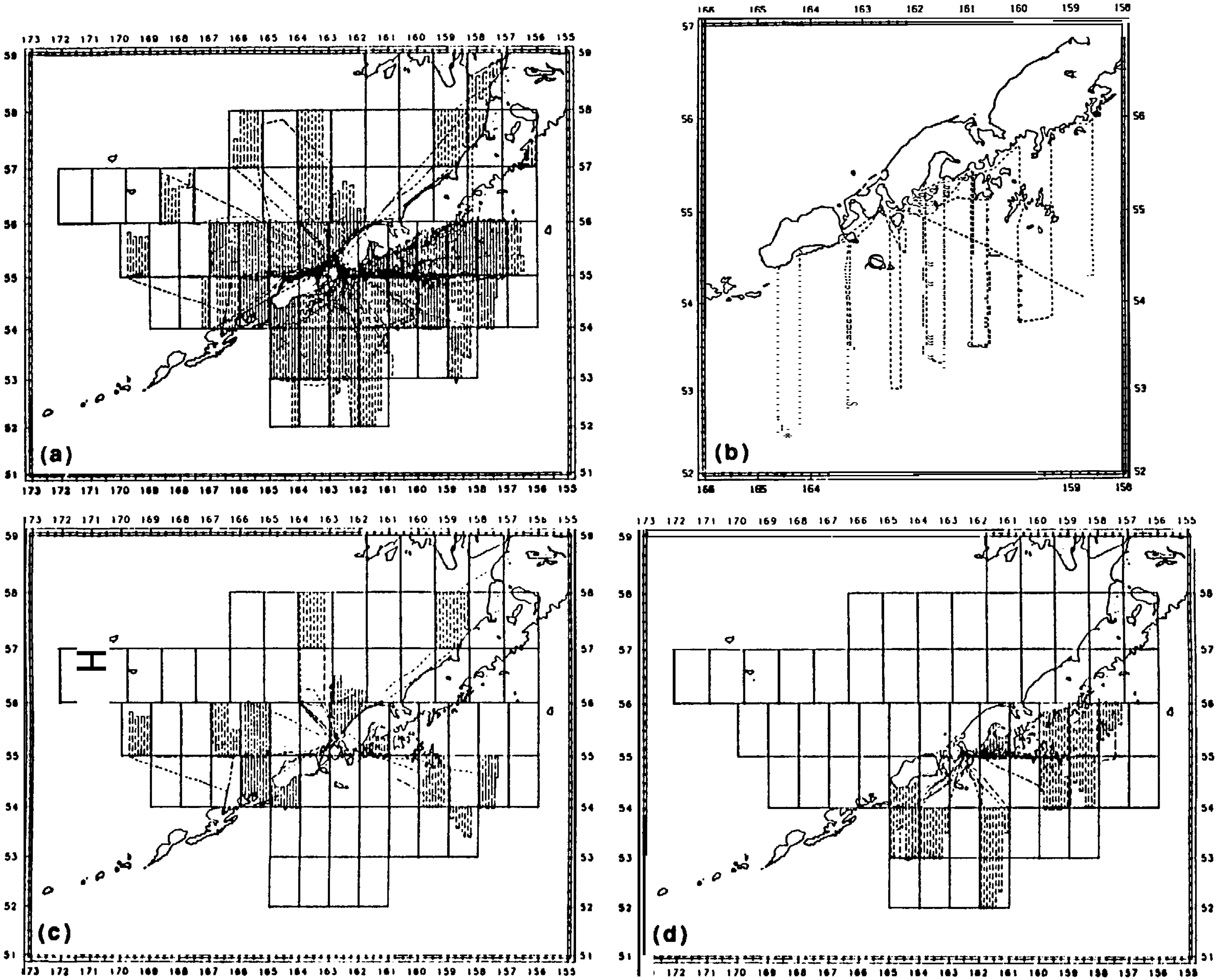


Figure 3.–Survey effort for April through December 1985 (a, total survey effort; b, April-May; c, June-July; d, July-August).

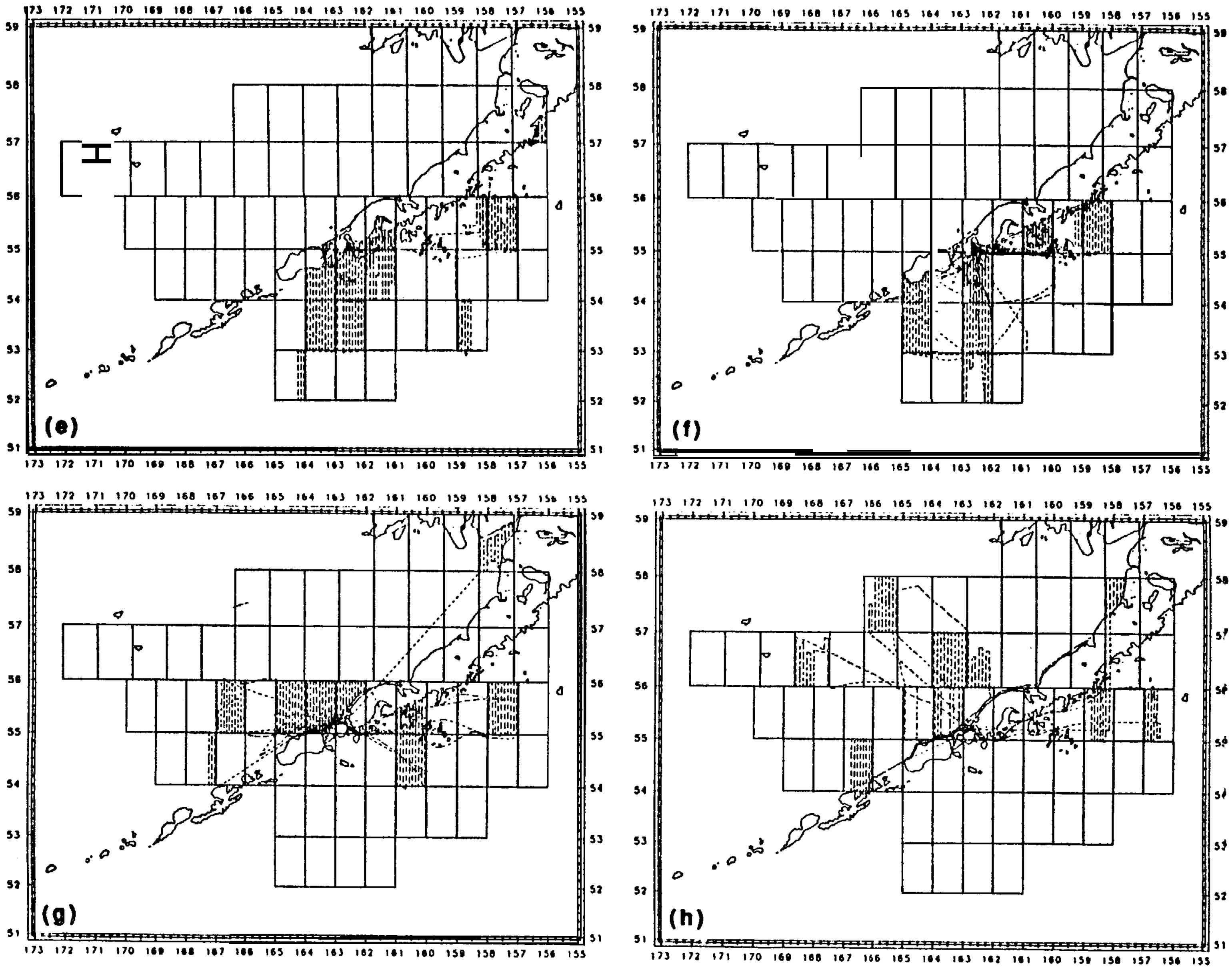


Figure 3 (continued).–Survey effort for Apri through December 1985 (e, August; f, October; g, November; h, December)

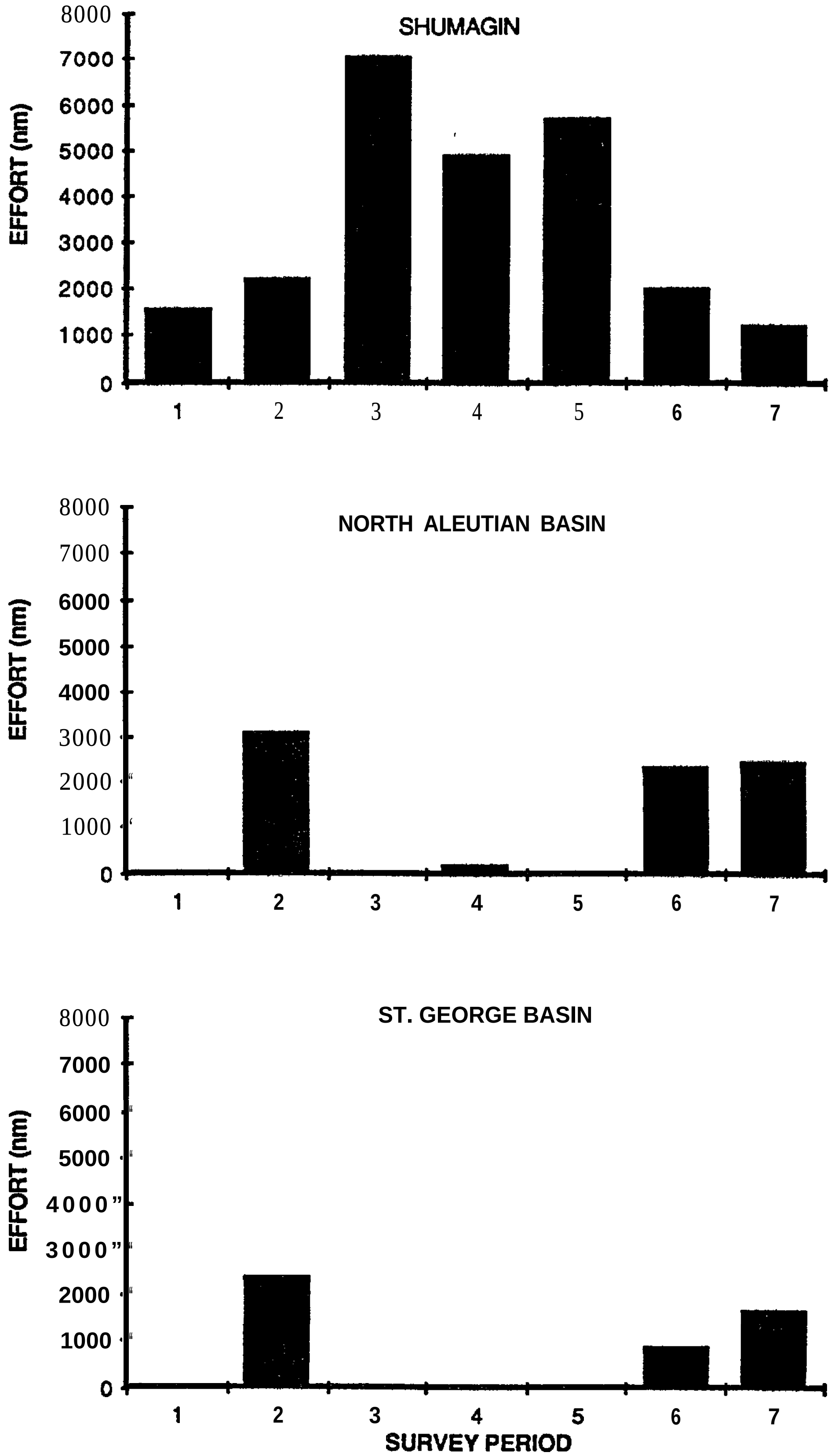


Figure 4.-Survey effort in the Shumagin, North Aleutian Basin, and St. George Basin planning areas, 1985.

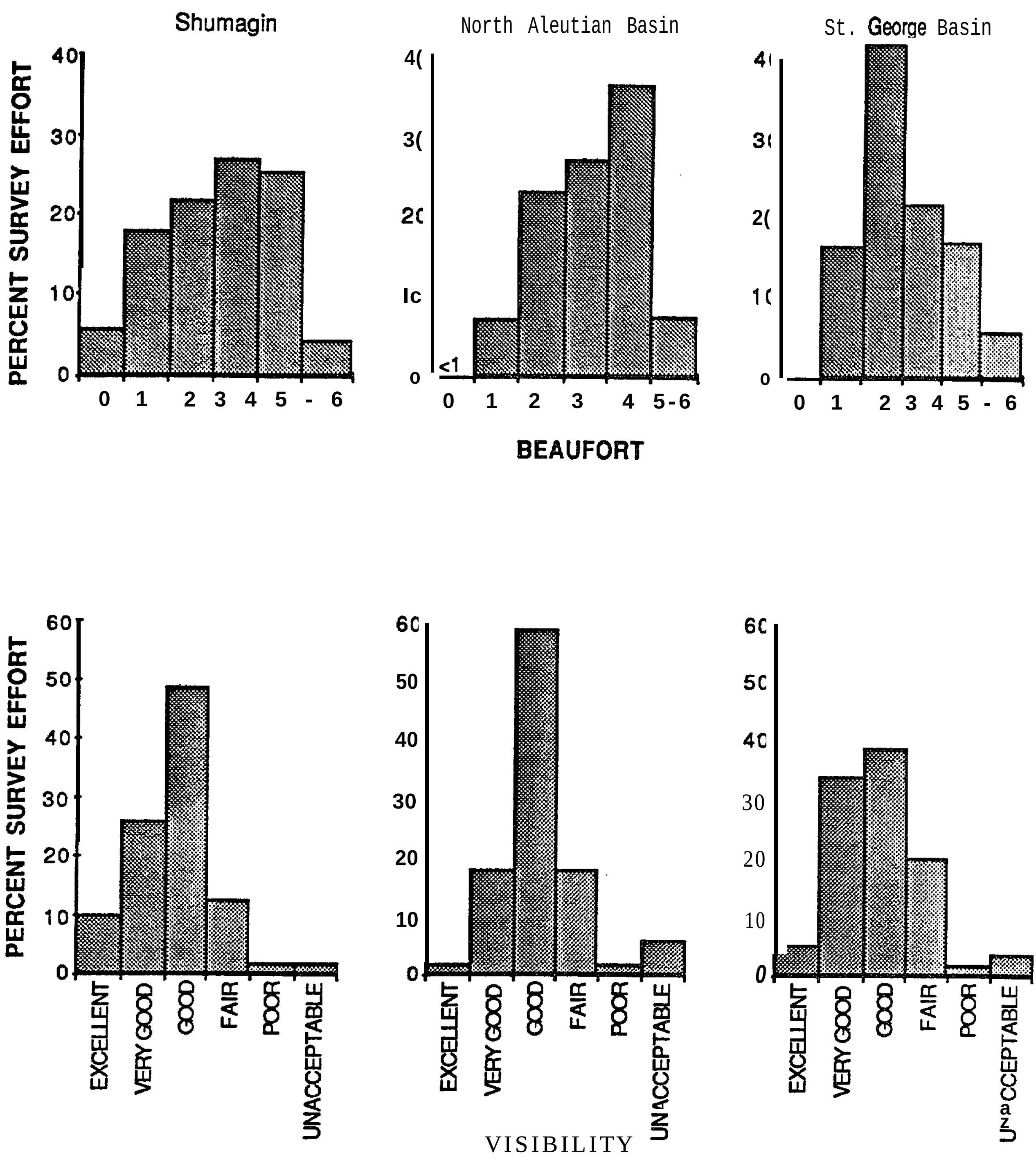


Figure 5.–Percentage of effort by Beaufort sea state and visibility in the Shumagin, North Aleutian Basin, and St. George Basin planning areas, 1985.

Table 3.–Survey conditions in the study area, April-December 1985.

Survey period[a]	Planning area[b]	Survey distance[c]	Visibility (percent)						Beaufort wind scale (percent)						
			UN	PO	FA	GO	VG	EX	0	1	2	3	4	5	6
1	Shumagin	1,576	0	0	19	18	21	42	17	25	21	11	9	17	0
2	Shumagin	2,205	1	1	7	53	36	2	3	28	27	29	13	0	0
	St. George	2,389	5	1	21	31	42	0	0	20	59	21	0	0	0
	North Aleutian	3,082	10	T[d]	19	52	18	1	0	12	25	34	26	3	0
	Subtotal	7,676	6	1	16	45	31	1	1	19	36	29	14	1	0
3	Shumagin	7,092	1	1	8	37	44	10	9	21	32	28	10	0	0
4	Shumagin	4,887	T	T	6	54	27	13	4	21	23	35	18	0	0
	North Aleutian	173	0	0	0	0	97	3	0	34	62	4	0	0	0
	Subtotal	5,060	T	T	6	53	29	13	4	22	24	34	17	0	0
5	Shumagin	5,860	1	1	24	48	18	9	1	13	15	23	35	12	1
6	Shumagin	2,201	0	T	12	84	5	0	0	T	4	14	79	3	0
	St. George	858	0	0	11	73	16	0	0	0	19	23	55	3	0
	North Aleutian	2,353	T	0	16	75	9	T	1	4	15	26	50	4	0
	Subtotal	5,412	T	T	14	78	8	T	T	2	11	20	63	3	0
7	Shumagin	1,238	T	1	9	74	16	T	0	T	18	48	33	1	0
	St. George	1,683	4	T	25	32	28	11	0	17	27	21	22	10	4
	North Aleutian	2,453	5	T	17	57	20	T	0	3	24	22	38	8	6
	Subtotal	5,374	4	1	17	53	21	4	0	6	24	27	32	7	4
Total	Shumagin	25,059	1	1	12	49	27	10	5	17	22	27	25	4	T
	St. George	4,930	4	1	20	38	33	4	0	16	41	21	17	4	1
	North Aleutian	8,061	6	T	17	59	17	1	T	7	23	27	36	5	2

[a] Survey period 1 =April-May, 2= June-July, 3= July–August, 4= August, 5= October, 6= November, and 7 =December.

[b] St. George Basin was surveyed during periods 2, 6, and 7. North Aleutian Basin was surveyed during periods 2, 4, 6, and 7.

[c] Distance (nmi) was calculated for only systematic and random surveys.

[d] T signifies <1 percent.

Gray Whale

The coastal habits of the eastern Pacific gray whale stock have made it the most studied mysticete. Gray whales were exploited to near extinction by commercial whalers in the mid-1800s and again in the 1900s (Reilly 1981). Since receiving protection in 1946, the stock has recovered to an estimated 17,000 animals (Rugh 1984), which is at or near the pre-exploitation level (Rice 1974; Rice and Wolman 1982). A limited number of gray whales are harvested annually by Soviet aboriginal whalers (IWC 1986).

The gray whale's annual cycle includes an 18,000 nmi migration between breeding lagoons along Baja California and feeding grounds in the Bering, Beaufort, and Chukchi seas. Nearly half of this annual cycle is spent in transit between the seasonal ranges (Mate and Harvey 1984). The migration route is coastal (Scammon 1874) even in Alaska, where shorter, open-water routes are available (Pike 1962; Rice and Wolman 1971; Braham 1984 b). Braham (1984*b*) has provided a comprehensive account of the gray whale migration in Alaska from a series of projects conducted by the National Marine Mammal Laboratory since 1975. While these projects and others (Gill and Hall 1983) have documented the spring migration along the north side of the Alaska Peninsula, the migration along the south side of the peninsula and the fall migration on both sides are incompletely understood.

Not all gray whales return each year to traditional feeding grounds in the high latitudes. Small numbers summer in areas between the seasonal ranges (Pike 1962; Rice and Wolman 1971; Hatler and Darling 1974; Patten and Samaras 1977; Sprague *et* al. 1978; Sullivan *et al.* 1983; Darling 1984; Sumich 1984), which include the lagoons and bays along the north shore of the Alaska Peninsula (Gill and Hall 1983). The percentage of the total population that feeds in these peripheral areas, as well as the location of important feeding areas in Alaska waters, is not fully known.

Our study confirms and clarifies the movement patterns of gray whales along the Alaska Peninsula during the spring and fall migrations. Furthermore, it defines additional summer feeding areas and confirms that gray whales use the peninsula's nearshore waters during the summer months.

Results

Number and distribution

A total of 337 groups of 589 gray whales were observed during four surveys in 1985 (Table 4). Eighty-seven percent of the groups were observed during November and December when 28% of the survey effort was conducted. These periods coincided with the gray whale fall migration in Alaska (Braham 1984*b*; Rugh 1984). Twelve percent of the sightings occurred during an April-May survey which corresponded to the spring migration. Only 4% of the 1985 survey effort was conducted at this time. Less than 1% (two whales) were observed during the summer. Another 15 groups were observed during sea otter surveys we conducted in 1986. Because seven of these sightings occurred during periods when gray whales were not observed

Table 4.–Effort (nmi) and number of gray whales observed in the study area, 1985 and 1986.

Period	Shumagin			North Aleutian Basin			St. George Basin			Total		
	Effort	No.	Group	Effort	No.	Group	Effort	No.	Group	Effort	No.	Group
1985												
April-May	1,576	21 (loo)	9 (30)	–[a]	–	–	–	–	–	1,576	21 (loo)	9 (30)
June-July	2,205	0	0	3,082	2	2	2,389	0	0	7,676	2	2
July-August	7,092	0	0	–	–	–	–			7,092	0	0
August	4,887	0	0	173	–					5,060	0	0
October	5,860	0	0	–	–	–	–	–	–	5,860	0	0
November	2,201	1	1	2,353	39 (12)	21 (lo)	858	0	0	5,412	40 (12)	22 (lo)
December	1,238	53 (16)	23 (10)	2,453	293 (52)	198 (33)	1,683	0	0	5,374	346 (68)	221 (43)
Subtotal	25,059	75 (116)	33 (40)	8,061	334 (64)	221 (43)	4,930	0	0	38,050	409 (180)	254 (83)
1986[b]												
1–15 Mar.		4	1		1	1		–	–		5	2
28 June-12 July		1 (1)	1 (1)		4 (5)	4 (3)		0	0		5 (6)	5 (4)
18 Aug.-1 Sept.		0	0		2	2		–	–		2	2
2-16 Oct.		0	0		0	0		–	–		0	0
Subtotal		5 (1)	2 (1)		7 (5)	7 (3)		0	0		12 (6)	9 (4)
Total		80 (117)	35 (41)		341 (69)	228 (46)		0	0		421 (186)	263 (87)

[a] Dash (–) signifies area not surveyed.
[b] Effort not available for 1986.

in 1985 (July and August), they have been added to this report to supplement the distributional information. Approximately 78% of all the gray whales were observed north of the peninsula and 22% south of it. No gray whales were observed in the St. George Planning Area.

Spring distribution.–A total of 39 groups of 121 gray whales were observed during the April-May survey period. Surveys were conducted only in the Shumagin Planning Area, where 1,576 nmi were surveyed in a 7-day period. An additional two groups of five whales were ‘incidentally recorded in March 1986 during sea otter surveys. One animal was observed along the north shore of Unimak Island on 11 March, the earliest recorded sighting of a g-ray whale in the Bering Sea (Braham 1984 b). The other four gray whales were observed in the Shumagin Islands on 14 March, Both 1986 groups were traveling toward their usual summer feeding grounds in the Bering Sea.

During the spring survey, gray whales were observed from Seal Cape to Unimak Pass (Figure 6). Ninety-two percent were found near (within 4 nmi) the mainland or nearshore islands. These results confirm that most gray whales travel in the nearshore waters south of the Alaska Peninsula. The remaining two groups were sighted considerably away from the mainland, one in the southern Shumagin Islands and the other in deep water 110 nmi (200 km) south of Unimak Island.

Fall distribution.–A total of 296 groups of 466 gray whales were observed during the November and December survey periods. Both periods coincide with the fall migration through Unimak Pass which peaks in late November-early December (Rugh 1984). The earliest sighting was 13 November. A total of 10,756 nmi of survey effort was achieved over all three planning areas. However, 2,541 nmi of this effort was achieved in the St. George Basin Planning Area, where no gray whales were observed. Only occasionally have gray whales been observed in the St. George Basin (Braham 1984*b*), and these were closer to the Pribilof Islands.

The distribution of whales north of the peninsula was coastal (Figure 6), with 69% within 2 nmi (3.7 km) of shore and 95% within 5 nmi (8.3 km) (Figure 7). The distribution from shore was not consistent as gray whales traveled toward Unimak Pass (Figure 8). From Ugashik Bay to Izembek Lagoon only 13% of 74 groups were within 1 nmi (1.85 km) of shore. Between Izembek Lagoon and Cape Mordvinof the percentage within 1 nmi increased to 36% (of 94 groups) and *between* Cape Mordvinof and Cape Sarichef it jumped to 67% (of 24 groups). All of these sightings, except one, were within the 40-m depth contour. One group of five whales was observed 17 nmi (31 km) north of Unimak Island.

The distribution of whales south of the peninsula was coastal between Deer Island and Seal Cape (Figure 6), although some whales were 12 nmi (22 km) off the mainland as they traveled between large islands. This suggests that migrating gray whales had a strong coastal affinity for islands as well as the mainland. However, the gray whales tended to become less coastal and more pelagic as they approached Kodiak Island from the Shumagin Islands. East of Seal Cape, ten groups of gray whales were observed 60 nmi (110 km) offshore between Chowiet Island and Lighthouse Rocks, traveling toward Kodiak Island. A group of seven was

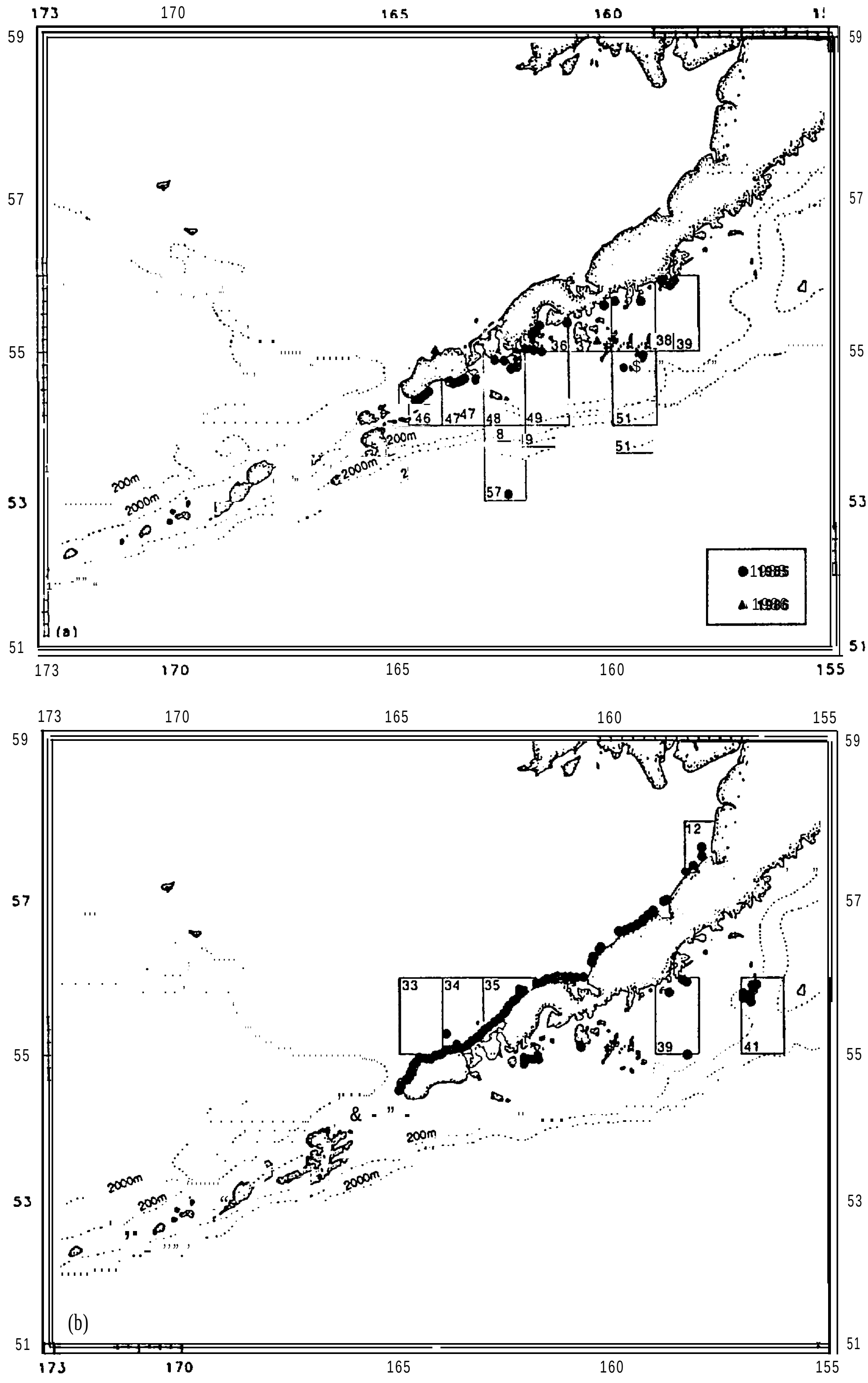


Figure 6.-Locations of gray whales observed in the study area in spring (a) and fall (b).

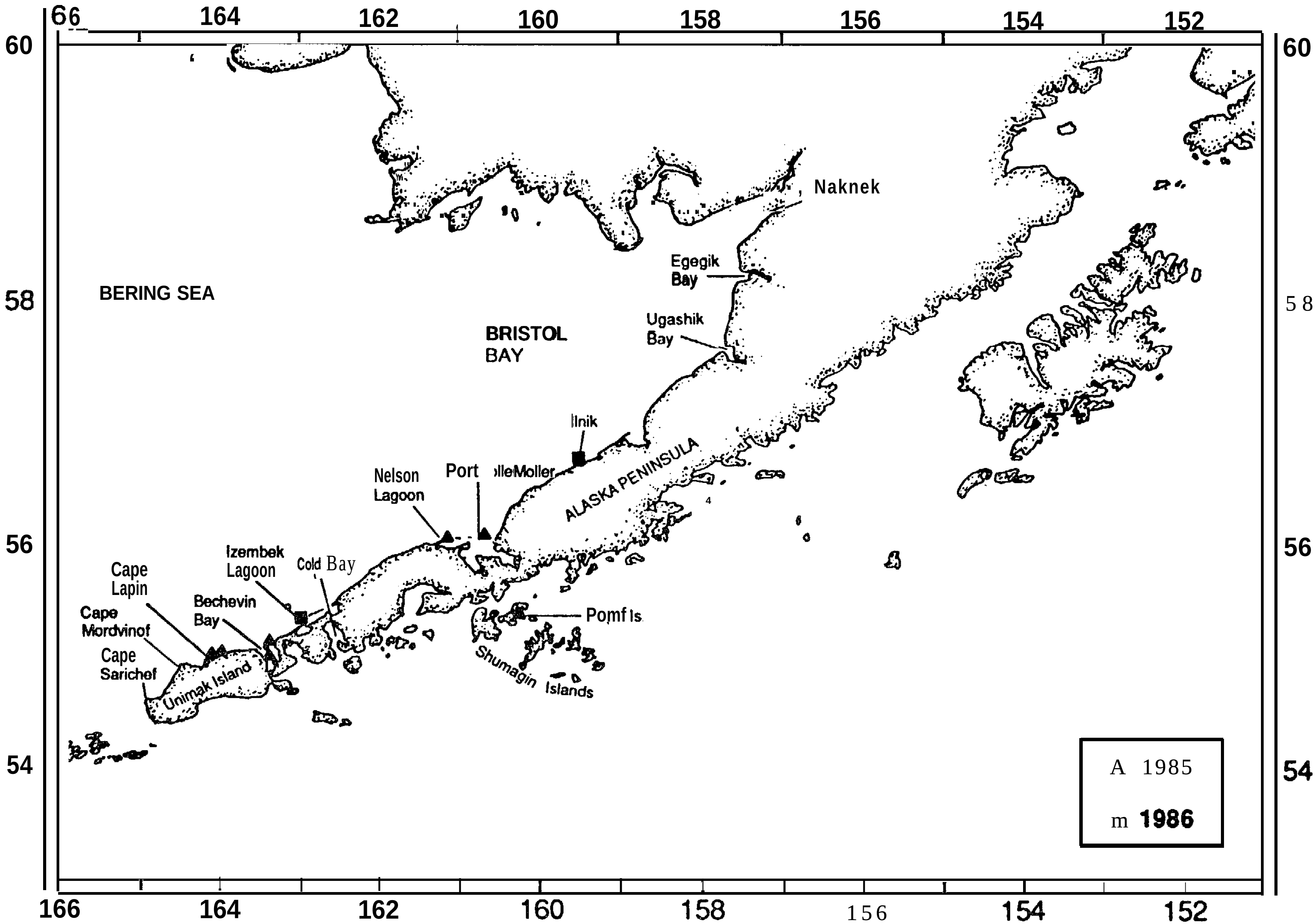


Figure 6. (continued) –Locations of gray whales observed in the study area during summer.

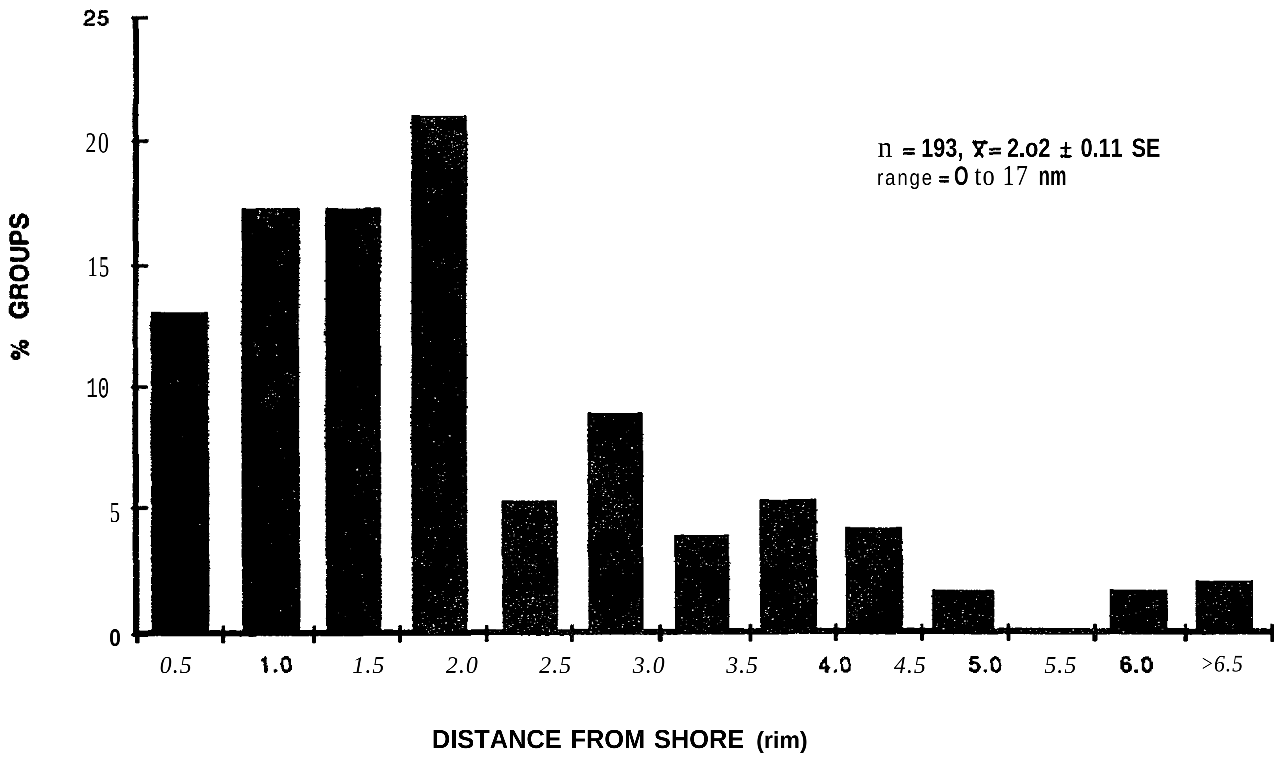


Figure 7.–Gray whale distance from shore along the north side of the Alaska Peninsula, fall 1985.

observed 60 nmi (110 km) south of Seal Cape traveling along the continental shelf edge, also toward Kodiak Island.

Summer Distribution. -Only two single gray whales were observed during the three summer survey periods in 1985 even though 17,439 nmi of effort were achieved in the Shumagin and North Aleutian planning areas during this period (Table 5, Figure 6). Surveys directed at sea otters in 1986 were more intense in the nearshore areas and yielded 11 groups of 13 whales. Eleven of the total thirteen groups observed in both years were found along the north shore of the Alaska Peninsula between Unimak Island and Ilnik. Ten of these groups were sighted in or near the confluence of estuaries (Figure 6). Gray whales were repeatedly observed in Bechevin Bay. In the Shumagin Planning Area a single whale was observed near Popof Island on 7 July 1986 and again on 9 July. No gray whales were observed in the St. George Basin Planning Area even though 2,389 nmi of trackline were flown.

Group size

Gray whale mean group sizes were significantly different ($p < 0.05$) between the spring and fall (Figure 9). Mean group sizes were greater during the spring (3.10 ± 0.46 SE) than during the fall (1.60 ± 0.06 SE). Small groups (l-2 animals) composed only 59% of the spring migrators compared to 84% for fall whales. These results do not concur with Herzing and

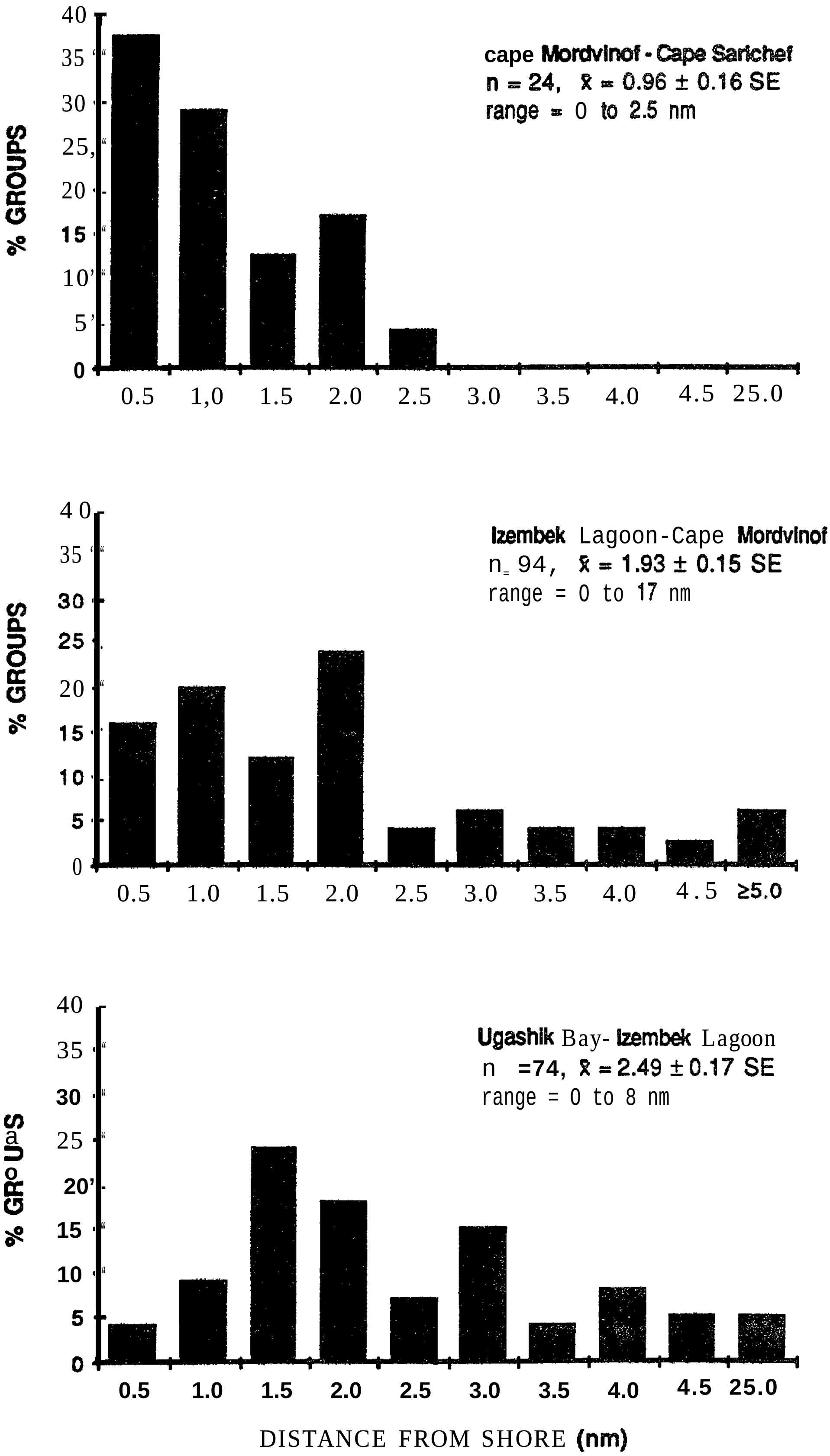


Figure 8.–Gray whale distribution from shore along segments off the north side of the Alaska Peninsula, fall 1985.

Table 5.–Summer g-ray whale sightings along the Alaska Peninsula during 1985 and 1986 aerial surveys.

Location	Date	Number	Groups
South side of Alaska Peninsula			
Popof Island	7 July 1986	1	1
Popof Island	9 July 1986	1	1
North side of Alaska Peninsula			
Unimak Island	29 June 1986	1	1
Unimak Island	21 August 1986	1	1
Bechevin Bay	29 June 1986	4	2
Bechevin Bay	21 August 1986	1	1
Izembek Lagoon	29 June 1985	1	1
Nelson Lagoon	8 July 1986	3	3
Port Moller	8 July 1986	1	1
Ilnik	6 July 1985	1	1
Total		15	13

Mate's (1984) findings from a 2-year study on the Oregon coast. In both years of their study, they found that small groups compose approximately 75% of the first-phase northward migrations and 50% of the southbound migrations. However, Herzing and Mate observed that significantly more small groups were recorded during the latter half of the first-phase northbound migration than during the earlier half Furthermore, they, as well as Rice and Wolman (1971), noted that large groups during the southward migration were observed more frequently in the middle of the migration period. Therefore, discrepancies between our respective data may be a result of the timing of our surveys. All of the summer sightings were either singles or pairs, with an average group size of 1.15 (±0.10 SE) animals.

Orientation and behavior

There was a significant (Rayleigh's test) tendency for traveling whales to be oriented in a direction consistent with their migration route during both the spring and fall survey periods (Figure 10). Gray whales traveling along the south side of the Peninsula during the April-May survey period were oriented generally to the southwest, or toward Unimak Pass. Even the single whale observed far offshore, although traveling northwest, was directly oriented toward

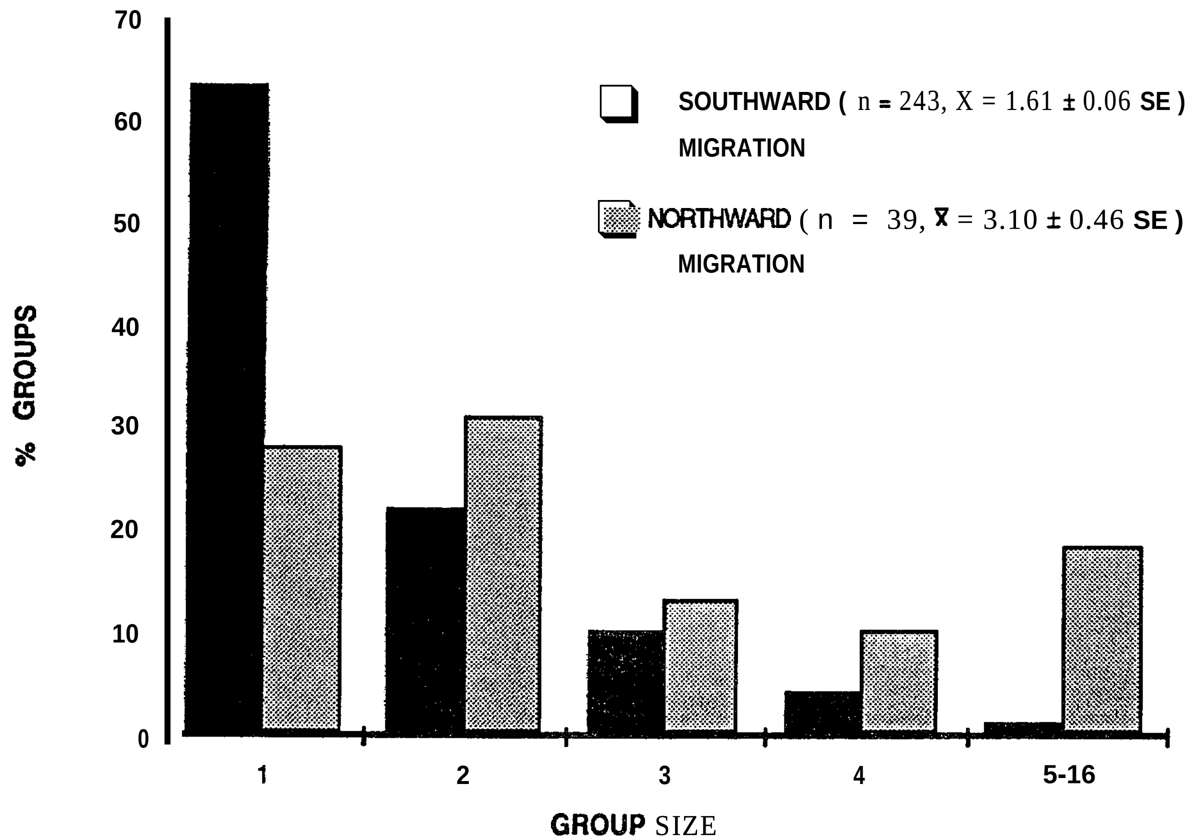


Figure 9.-Group sizes of gray whales migrating along the Alaska Peninsula, 1985,

Unimak Pass. Whales observed during the fall surveys were oriented west or southwest on the north side of the Alaska peninsula and generally northeast on the south side. There was not a significant directional tendency for whales observed during the summer, implying they were summer residents and not migrating.

Gray whale behavior observed during the spring and fall was consistent with migration activities: 81% of the spring whales and 9770 of the fall whales were traveling (Figure 1 l). The remaining whales for each season were either milling or breaching, none were observed feeding. In contrast, 42% of the summer whales were observed feeding, as shown by trailing mud plumes, 8% were milling, and 50% were traveling. These behavioral observations, coupled with the time of year they were observed and a lack of directional tendency, support observations by Gill and Hall (1983) and Braham (1984*b*) that a small contingent of whales remain along the north shore of the Alaska Peninsula each summer rather than follow the main herd north. In addition, a few whales summer south of the peninsula.

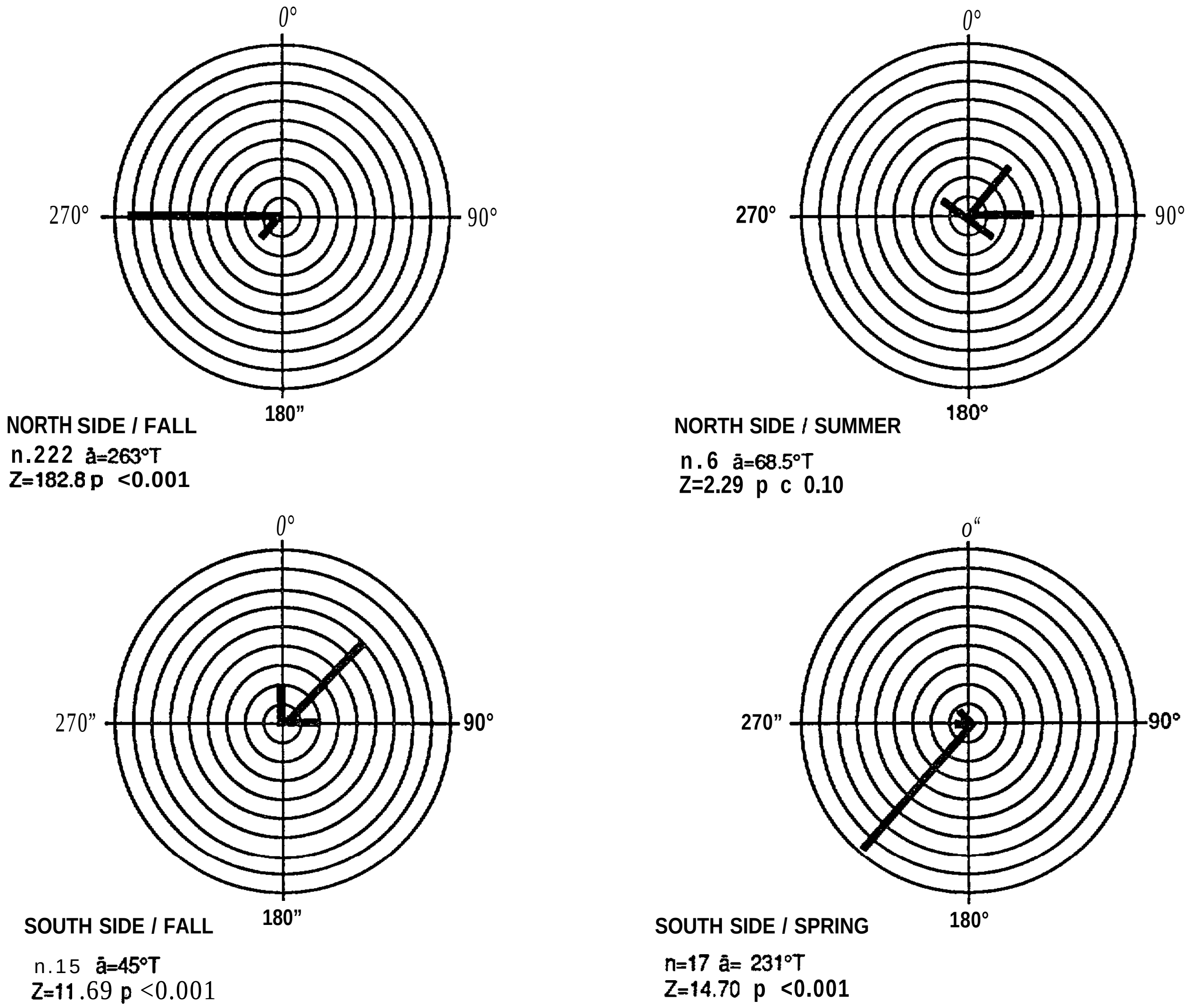


Figure 10.-Directional analysis of traveling gray whales, 1985 and 1986. Each concentric circle equals lo%.

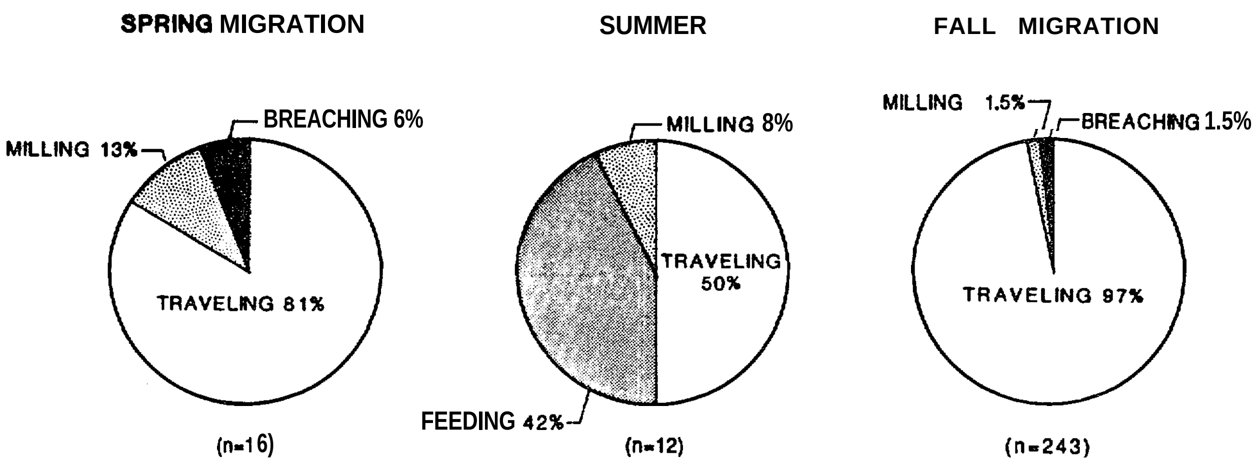


Figure il.-Observed gray whale behavior in the study area, 1985 and 1986.

Discussion

Spring migration

Our spring surveys (28 April-4 May) occurred during a period previously identified as the peak of the northbound migration (late April-early May) but prior to the arrival of cow-calf pairs (Hessing 1981). Since no calves were observed during our surveys, our descriptions concern the first wave of the bimodal (Herzing and Mate 1984) spring migration.

The spring migration along the south side of the Alaska Peninsula is coastal, at least between Seal Cape and Unimak Pass. Ninety-two percent of the northbound groups were within 4 nmi (7.4 km) of the peninsula coast or nearshore islands. Some of the whales apparently traveled the outer perimeter of large nearshore islands such as Deer and Dolgoi, even though it increased their travel distance. A group observed in the southern Shumagin Islands and another in pelagic waters 110 nmi (200 km) south of Cold Bay confirm that not all whales journey close to the coast. No whales were observed in offshore waters northeast of the Shumagin Islands because we did not survey east of Seal Cape, where whales traveling between Kodiak Island and the peninsula might be expected (Braham 1984*b*; Leatherwood *et al.* 1983). Therefore, the precise spring route between either Kodiak Island (or Shelikof Strait) and the peninsula remains unknown, but may be similar to the following description of the fall route.

Fall migration

Our fall gray whale observations largely confirm speculations by Braham (1984*b*) that the southbound migration along the north side of the Alaska Peninsula occurs farther offshore than the spring northbound migration. We observed 87% of 192 southbound groups beyond 0.5 nmi (0.9 km) from shore and 32% beyond 2 nmi (3.7 km). In contrast, Braham (1984*b*) reports that only 6 of 511 (1%) northbound whales traveling the north side of the Alaska Peninsula were observed beyond 0.6 nmi (1 km) from shore. However, 95% of our observations were still within 5 nmi (9 km) of shore and therefore the fall migration must be considered coastal.

The difference in the distance gray whales travel from the shore between the spring and fall seasons, at least north of the Alaska Peninsula, may reflect differing migration patterns across Bristol Bay. In the spring, northbound whales cross Bristol Bay from Egegik River west to Cape Constantine via lower Kvichak Bay (Gill and Hall 1983; Braham 1984*b*). Braham (1984*b*) suggests that the whales cross here to avoid shallow water and the extreme tidal fluctuations near the Naknek, Kvichak, and Nushagak rivers. Our 1985 fall surveys suggest that the route across Bristol Bay taken by southbound whales occurs farther southwest, because of the lack of whales sighted between Ugashik Bay and Kvichak Bay and because whales observed near Ugashik were among the furthest offshore. The reason for the difference may be that the Kvichak River and its tributaries discharge nearly twice as much sediment in fall as in spring (Bigelow *et al.* 1985) and thus create unfavorable conditions for migrating whales.

The whales moved closer inshore as they traveled down the peninsula. They closely followed the 0- to 40-m contour interval, even when it narrowed dramatically along Unimak

Island. Only 1 of 262 groups occurred outside of this band. Rugh (1984) also observed this shoreward trend on a November 1978 survey along the north side of Unimak Island. Rugh reported that only 5% of the whales he observed northeast of Cape Mordvinof were within 0.8 nmi (1.4 km) of the shore but 82% of the whales between Cape Mordvinof and Cape Sarichef were within this distance. Consequently, the coastal affinity of gray whales may be more a preference for shallow (<40 m) water than for simply being near land. This is perhaps most evident in the migration route between northern feeding grounds and northern Bristol Bay, where both the O- to 40-m contour interval and the distribution of migrating whales is widest (Braham 1984*b*).

Previous researchers have reported that the fall migration along the south side of Unimak Island was highly coastal (<2 nmi) (Rugh 1984). Our data suggest that once east of Unimak Island, whales move as far as 12 nmi (22 km) offshore as they pass through the Sandman Reefs and the Pavlov and Shumagin islands. East of the Shumagin Islands, whales were observed along the coast as far as Seal Cape and then were found offshore 60 nmi to the east near Lighthouse Rocks and Chowiet Island. These whales (10 groups) were traveling both toward Chirikof Island and the Trinity Islands. By "island-hopping" between Seal Cape and Kodiak Island, these whales would be able to maximize their travel in shallower waters. Alternately, a few whales may follow the Shumagin Islands out to the shelf edge and then travel the edge to Kodiak Island, as shown by a sighting near the edge. Apparently, it is not unusual for some gray whales to travel alternate routes. Darling (1984) observed gray whales migrating along the east side of Vancouver Island when most travel the west. Thus, based upon our results and others (Forsell and Gould 1981; Rugh 1984), we propose in Figure 12 a route for the fall migration of gray whales along the Alaska Peninsula.

No gray whales were observed in the St. George Basin Planning Area between Unimak Pass and the Pribilof Islands (Figure 6), even though a substantial survey effort was accomplished between the two areas during November and December. Thus, we cannot substantiate a fall migration from the Pribilof Islands to Unimak Pass even though gray whales have been observed near the Pribilof Islands in the past (Braham 1984*b*).

Summer

Previous researchers have noted that most gray whales observed feeding during migration were located near the mouths of rivers or estuaries (Nerini 1984) where, presumably, organically richer substrates exist. Ten of eleven whale groups observed during the summers of 1985 and 1986 along the north shore of the Alaska Peninsula were either within or near the confluence of an estuary. We observed gray whales on the north shore of Unimak Island, within Bechevin Bay, and near the confluences of Izembek Lagoon, Nelson Lagoon, Port Moller, and Ilnik. Gill and Hall (1983) described the importance of Nelson Lagoon to summering whales and observed gray whales at all major estuaries from Nelson Lagoon to Egegik, including Port Moller and Ilnik. Braham (1984*b*) reported summer sightings from Izembek Lagoon to Egegik and Leatherwood *et al.* (1983) recorded three sightings of gray whales apparently feeding near Nelson Lagoon on 24 September 1982. We found no previous reports of gray whales using the north shore of Unimak Island or Bechevin Bay during summer. Our results confirm that

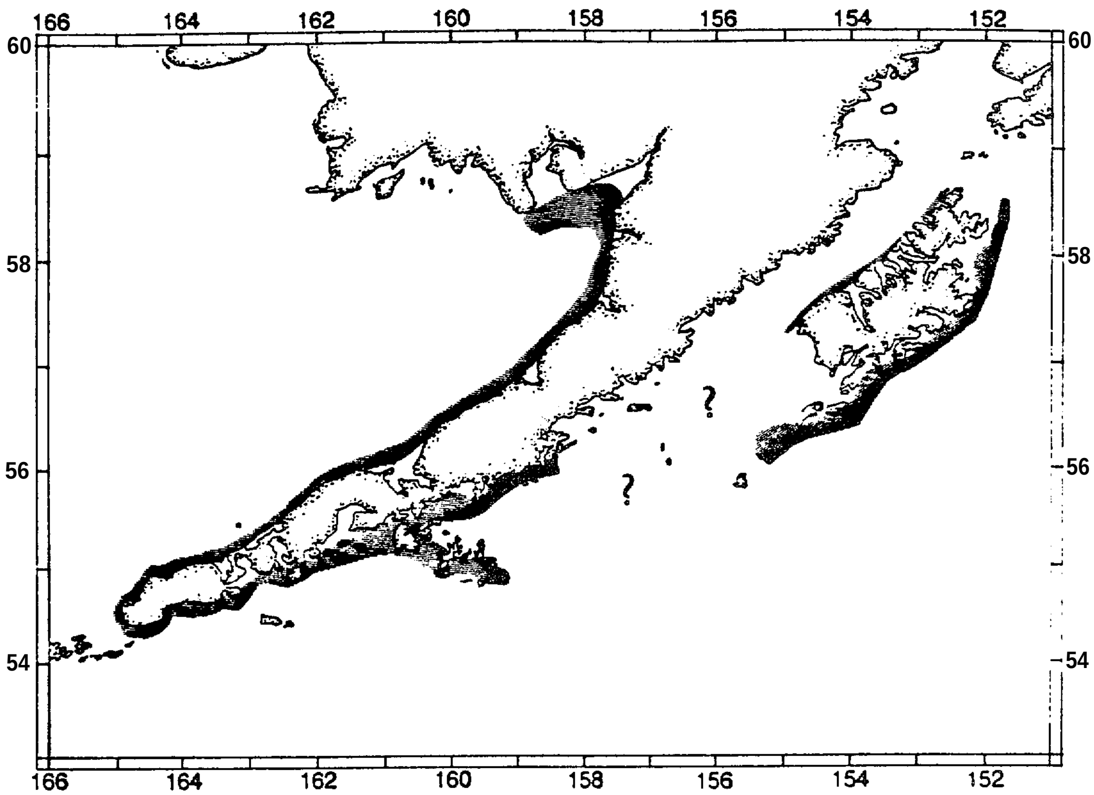


Figure 12a–Proposed spring migration route of gray whales along the Alaska Peninsula based upon data from Braham (1984), Leatherwood *et al.* (1983), and this study.

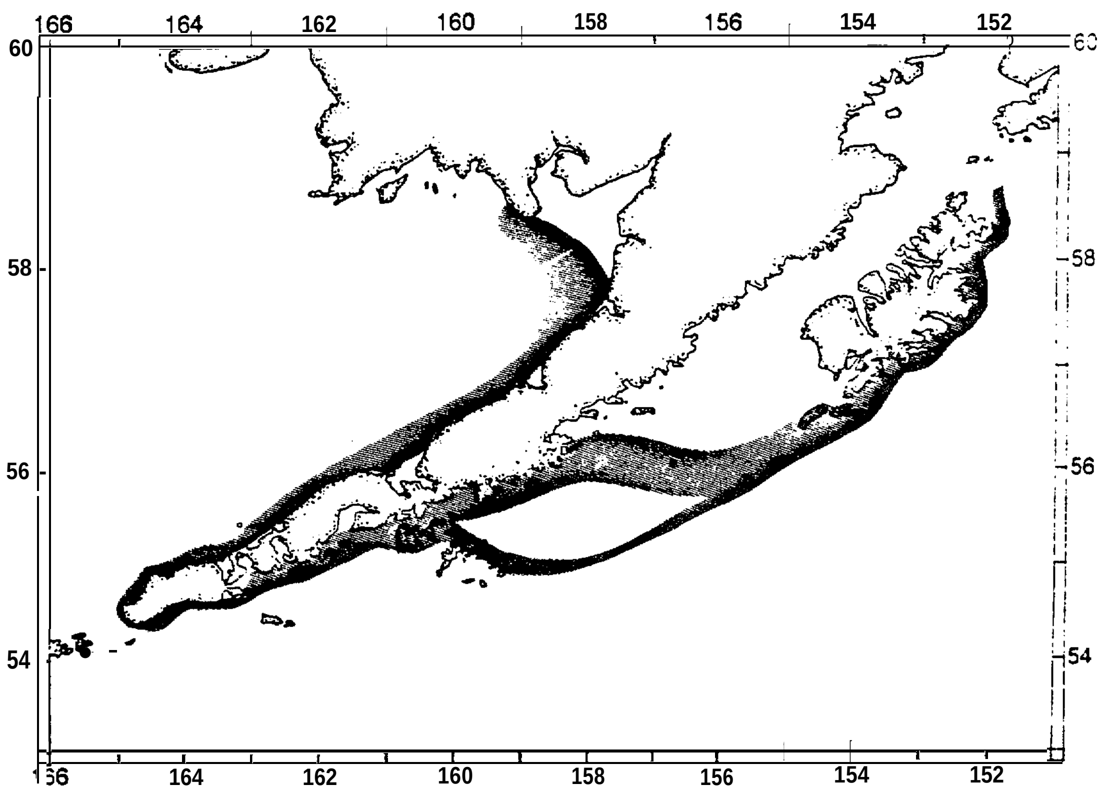


Figure 12b.–Proposed fall migration route of gray whales along the Alaska Peninsula based upon data from Forsell and Gould (1981), Rugh (1984), and this study.

almost every estuary on the north side of the Alaska Peninsula is important to summering gray whales.

There are few summer sightings from the south side of the Alaska Peninsula. The substrate on the shelf is largely rocky reef Also, the bays are rather deep and do not contain extensive shallow beds like the north side. The only reliable summer gray whale record we could find is a Platforms of Opportunity Program sighting of a group of two whales observed just south of Chowiet Island on 31 August 1984. Our sightings at Popof Island combined with this sighting indicate a few gray whales summer south of the peninsula.

Humpback Whale

The North Pacific humpback whale population was heavily exploited by commercial whalers until it received protection beginning in 1966 (Rice 1978*a*). The animal's slow swimming speed and coastal affinity made the humpback whale particularly vulnerable to exploitation by shore stations off Baja California, central California, British Columbia, and Alaska (Tonnessen and Johnsen 1982). Between 1912 and 1939, 3,083 humpback whales were harvested in Alaska by the Akutan and Port Hobron whaling stations (Reeves *et* al. 1985). Similarly high catches were reported for the other shore stations. By the early 1960s, the only area remaining in the North Pacific where large numbers of humpbacks congregated in the summer was near the eastern Aleutians and south of the Alaska Peninsula between 150° and 170W longitude (Berzin and Rovnin 1966). Japanese and Soviet pelagic whaling operations killed over 4,000 humpbacks in these areas between 1962 and 1965 (Rice 1978a). Present population estimates of the remaining North Pacific stock vary from 1,200 to over 2,100 whales (Darling 1983) for a species originally estimated to number 15,000 animals (Rice and Wolman 1982).

The North Pacific humpback whale population consists of three breeding stocks that summer in Alaska waters (Herman and Antinoja 1977) (Figure 13). The eastern stock migrates off the coasts of Canada and the United States from its breeding grounds in the bays and near the islands of Baja California and mainland Mexico. Animals from this stock summer in Alaska waters and off of California in the Farallon Islands. The central stock migrates from its breeding grounds in Hawaii to Alaska. Some interchange between Hawaiian and Mexican winter grounds has been revealed by recent photo identification studies (Darling and McSweeney 1985) and this suggests that the eastern and central stock may be one stock. The western or Asian stock is believed to migrate from breeding grounds near the Ryukyu, Benin, and Mariana islands, south of Japan, to northern feeding areas in the Sea of Okhtosk, Kamchatka Peninsula, Aleutian Islands, and Bering Sea (Kellogg 1929; Tomilin 1957; Berzin and Rovnin 1966).

Tagging and photo identification studies suggest that the summer feeding areas of these stocks may overlap in the waters surrounding the Alaska Peninsula and eastern Aleutian Islands. Eight whales tagged with discovery markers in waters off Japan were recovered in the eastern Aleutian Islands and near the Alaska Peninsula (Ivashin and Rovnin 1967; Ohsumi and Masaki 1975). Fluke pictures of whales wintering in Hawaii have been matched with whales

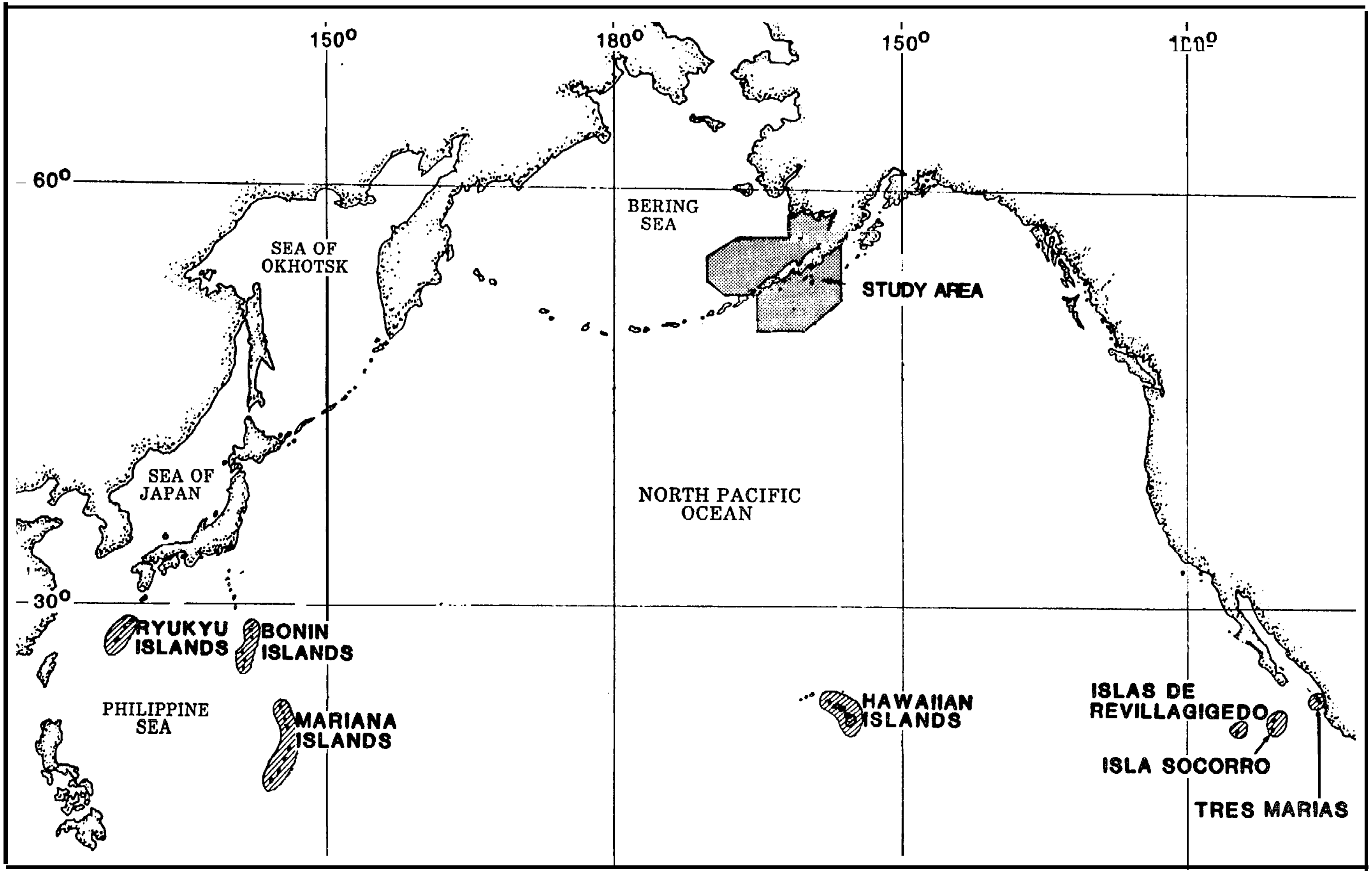


Figure 13.–Known winter breeding grounds of humpback whales and their relation to the study area.

summering in southeast Alaska, Prince William Sound, and the western Gulf of Alaska near Kodiak Island (Baker *et al.* 1986). In addition, whales wintering in Mexico have been matched with whales summering in southeast Alaska and Prince William Sound (Baker *et* al. 1986). While the information suggests the potential unique ecological importance of the waters bordering the Alaska Peninsula, confirmation of these associations has not been achieved because little effort has been directed at determining humpback whale use of these areas.

Rice and Wolman (1982) conducted 3,403 nmi of vessel survey east of the study area in the Gulf of Alaska between Cape Fairweather (138°W) and Chirikof Island (156°W), and reported observations of191 humpback whales. Leatherwood *et al. (1983)* conducted 28,743 nmi of aerial survey in Shelikof Strait, and the St. George Basin and North Aleutian Basin planning areas and reported 15 humpback sightings. Incidental sightings have been irregularly reported by other investigators (POP), but because there have been few sightings, no comprehensive information exists on humpback whale occurrences in the the Shumagin, St. George Basin, and North Aleutian Basin planning areas since the cessation of humpback whaling in 1966.

In this section, we document information on the abundance, distribution and habitat use patterns of humpback whales in these areas. This information will serve as a basis for future studies to determine interactions between different breeding stocks and to monitor the impacts of petroleum activities.

Results

Number and distribution

During the seven survey periods between April and December 1985, 98 groups representing 185 humpback whales were observed in the Shumagin Planning Area (Table 6). Humpbacks were not observed in the other two planning areas. Humpbacks were encountered during every survey period except April and December. Almost 90% of the whales were observed during the three June through August surveys, when approximately 57% of the total effort was accomplished. Fewer than 15 animals were observed in October or November. Humpbacks are reported to inhabit Alaska waters from approximately May to November, with peak numbers in June through August (Baker *et al.* 1985; Stewart *et al.* 1987). A small proportion of whales appears to overwinter in Alaska waters (Baker *et* al. 1985).

Humpback whales were widely distributed in the Shumagin Planning Area between 157° and 164°W (Figure 14). Chi-square analysis indicated that the whales were not uniformly distributed across the longitudes ($p < 0.05$) (Table 7). Approximately 67% of the groups were observed between 157° and 160°W, where 35% of the effort was achieved (Figure 15). Particularly large numbers ($p < 0.10$) of humpbacks were encountered between 158° and 160”W. Whales were encountered in this area during four of five June-to-November survey periods. Humpbacks were not observed in the extreme eastern or western portion of the Shumagin Area.

Humpbacks were encountered in all three water depth zones (Table 6). Approximately 67% were observed in the shallow zone, 1% in the transition zone, and 30% in the deep water

Table 6.–Survey effort (nmi) and number of humpback whales observed in the Shumagin planning area, April-December 1985.

	Shallow zone[a]			Transition zone[a]			Deep zone[a]			Total		
Survey period	Effort	Number	Group	Effort	Number	Group	Effort	Number	Group	Effort	Number	Group
April-May	773	0	0	186	0	0	617	0	0	1,576	0	0
June-July	1,316	46(19)	18(10)	292	1	1	597	0	0	2,205	47(19)	19(10)
July-August	4,621	18 (2)	12 (1)	582	0	0	1,889	0	0	7,092	18 (2)	12 (1)
August	3,132	20 (6)	16 (2)	416	0	0	1,339	28(22)	13 (7)	4,887	48(28)	29 (9)
October	3,977	0	0	431	0	0	1,452	9	9	5,860	9	9
November	1,991	7 (7)	6 (3)	153	0	0	57	0	0	2,201	7 (7)	6 (3)
December	1,105	0	0	133	0	0	0	0	0	1,238	0	0
Total	16,915	91(34)	52(16)	2,193	1	1	5,951	37(22)	13(7)	25,059	129(56)	75(23)

[a] Zones were defined as <200 m for shallow, 200-2,000 m for transition, and >2,000 m for deep. Numbers in parentheses equal additional individuals and groups counted on deadhead surveys.

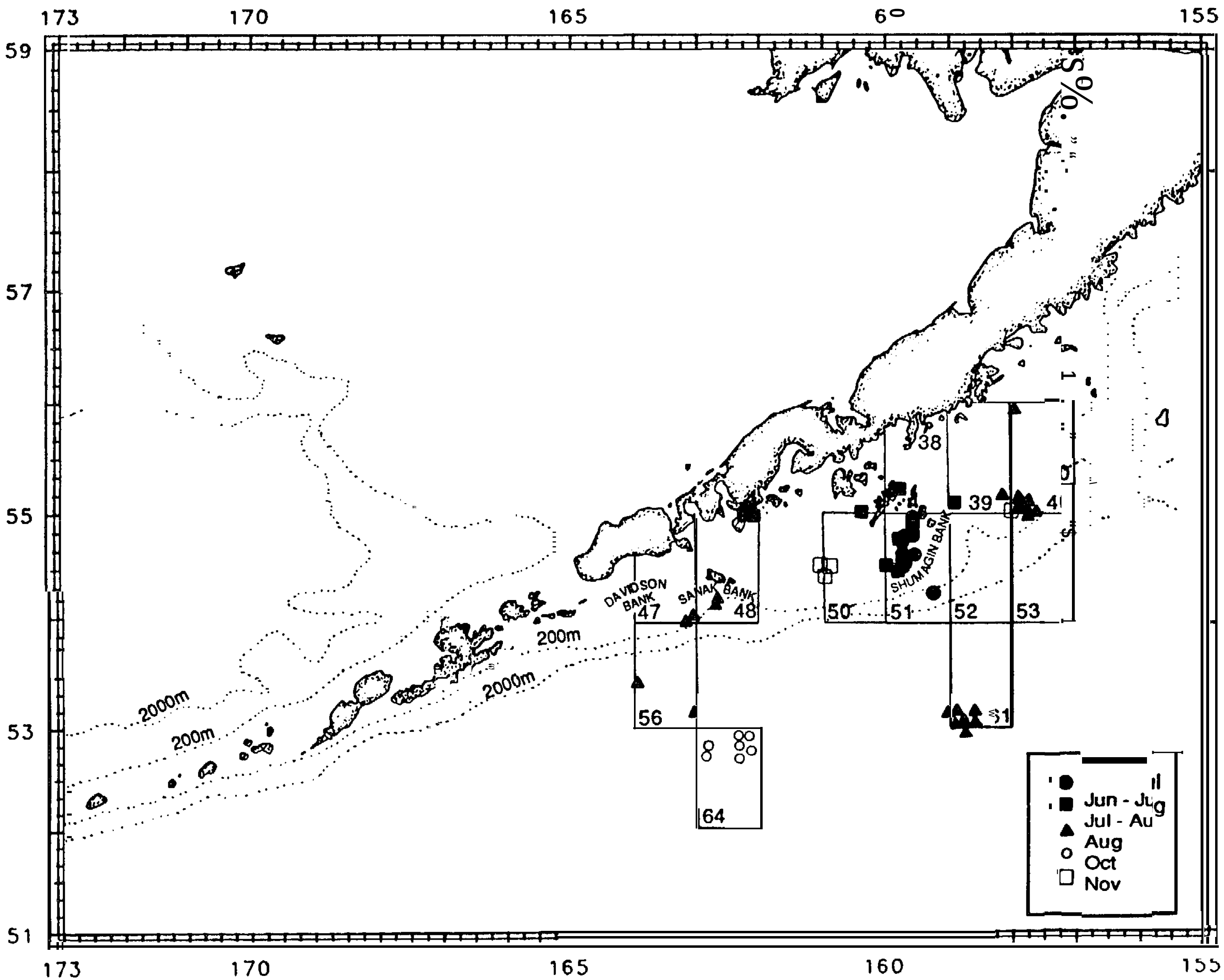


Figure 14.–Locations of humpback whales observed in the Shumagin Planning Area, 1985.

Table 7.-Relative occurrence of humpback whales by longitude degree in the Shumagin Planning Area.

Longitude	Percentage effort	Percentage occurrence	Preference[a]
164°-165°(W)	10.5	0.0	–
163°-1640	9.5	4.1	–
162°-1630	18.4	19.4	0
161°-1620	16.5	1.0	–
160°-1610	10.5	8.2	0
159°-1600	10.3	35.7	+
158°-1590	13.6	20.4	+
157°-1580	8.9	11.2	0
156°-1570	1.7	0.0	0
Total	99.9	100.0	
Total effort and number of groups	23,431 nmi[b]	98	

[a] – indicates significant avoidance, + indicates significant preference, and 0 indicates no selection ($p < 0.10$).

[b] Effort included distances surveyed during Beaufort O-4 and fair to excellent visibility conditions.

zone. Effort was highest in the shallow zone, lowest in the transition zone, and intermediate in the deep zone. Whales were observed in the shallow zone during four of the five June-to-November survey periods (Figure 16). They were much less frequently encountered in the other two zones except during August and October. Chi-square analysis indicated that use of the three zones by the whales was significantly different ($p < 0.05$; $X^2 = 32.74$) among the surveys (Table 8). Whale observations were higher than expected in the combined shallow-transition zones during the early to mid-summer periods, and higher than expected in the deep water zone during the late summer and early to mid-fall periods.

Group size

Group size averaged 1.72 (±0.14 SE) animals for the five survey periods (Figure 17). Approximately 96% of the groups included between one and three animals, but single animals were most common (63%). The largest group size included eight animals and was recorded during the June-July survey. Average group size among the survey periods was significantly different (p c 0.05), and it ranged between 1.00 and 2.47 animals. Tukey's multiple range test identified that the June-July average group size differed significantly ($p < 0.05$) from all other periods. Approximately 36% of the groups for this survey were singles, 11% pairs, 42% triads,

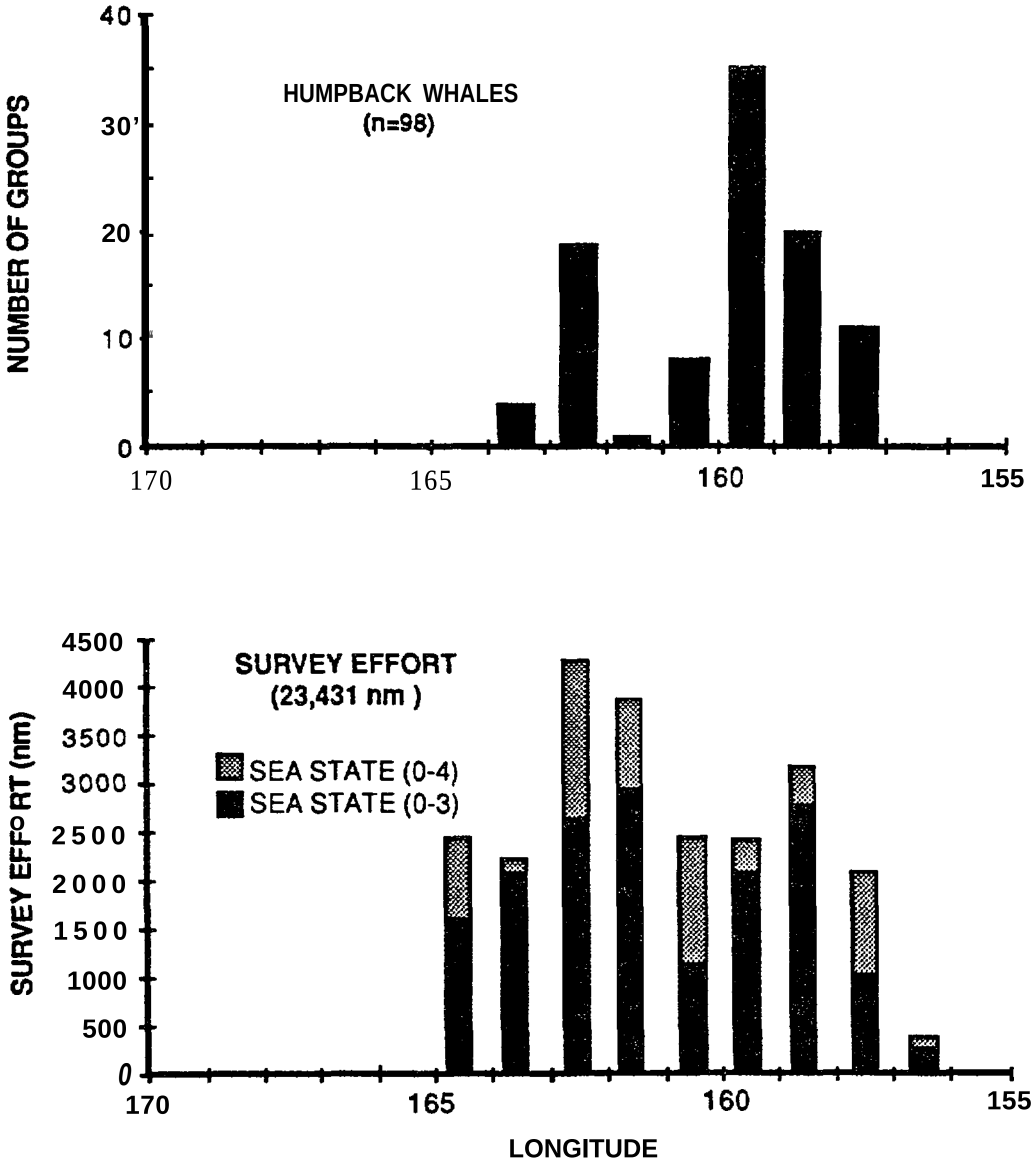


Figure 15.–Survey effort and number of humpback whales observed by longitude degree.

and the remainder were in groups of between four and eight animals. On the other hand, single animals were most common (>62%) in each of the other periods. While group sizes were usually small, 64% of the groups were in clusters ranging from 2 to 20 groups in a 3- to 4-nmi radius.

Orientation and behavior

The lack of a major movement pattern suggests that the majority of humpbacks observed in the Shumagin area were summering there. There was no consistent directional orientation ($p < 0.05$) in 53 humpbacks evaluated in the Shumagin area (Figure 18). This was found for humpbacks in each of the survey periods, except for humpbacks encountered in the deep water

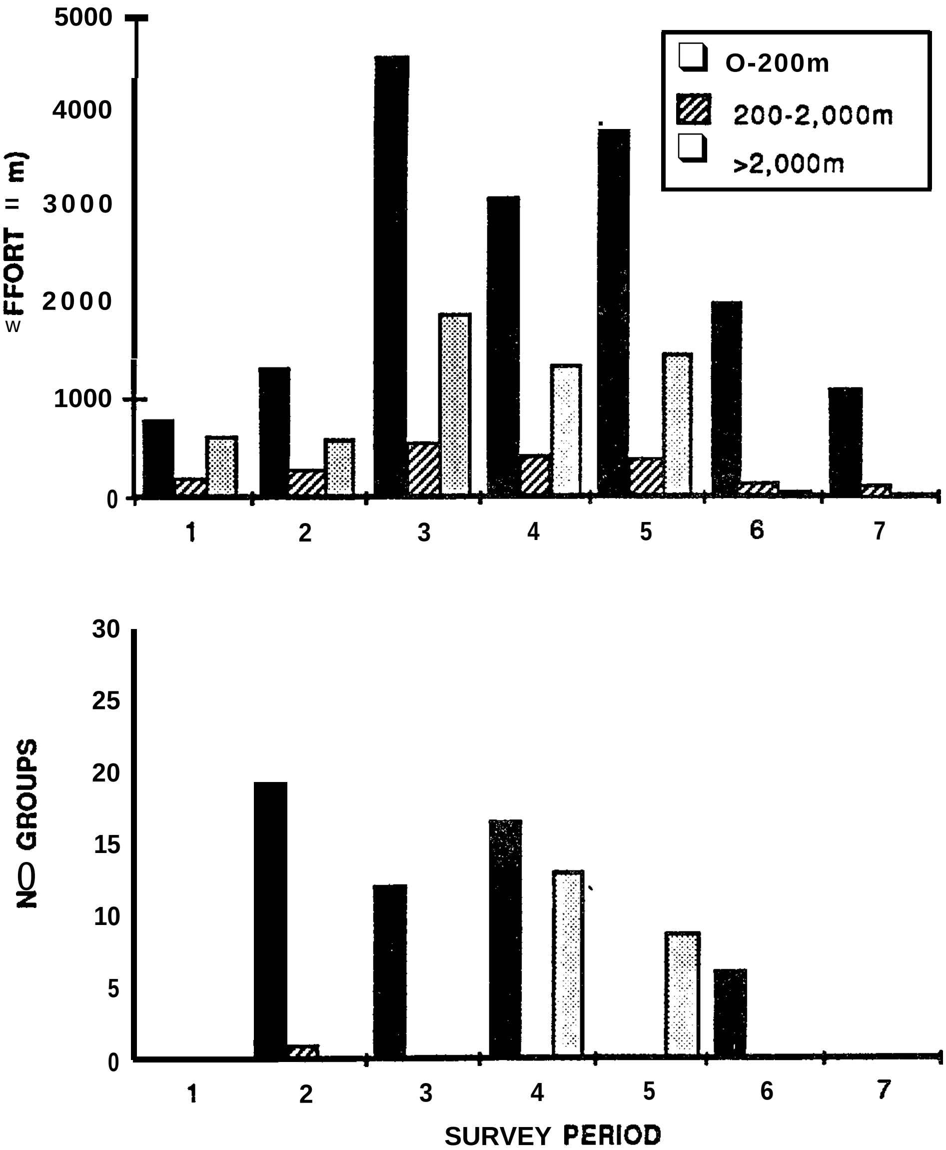


Figure 16.-Number of humpback whales observed in each water depth zone relative to survey effort.

zone. Of the 12 groups evaluated in this zone during the August (9) and October (3) periods, 83% were oriented in south (9) and southwest (1) directions. These southward-moving whales accounted for 32% of the 22 groups reported in August and all of the groups in October. Conversely, 93% of the 41 groups encountered in the shallow and transition zones were oriented in the west, north, and east cardinal directions.

The behavior of individual humpback whales was classified into one of five categories recorded incidental to the surveys (Figure 19). The predominant behavior of humpbacks was traveling, which was defined as a group of animals moving in essentially the same direction. The other categories of milling, feeding, breaching, and resting were infrequently observed for

Table 8.–Observed and expected number of humpback whale groups in each water depth zone.[a]

Zone	June-August			August			October-November			Total	
	Effort (nmi)	Observed	Expected	Effort (nmi)	Observed	Expected	Effort (nmi)	Observed	Expected	Effort (nmi)	Observed
Shallow-transition	6,810	31	22.7	3,549	16	21.1	6,553	6	12.2	16,912	53
Deep	2,486	0	8.3	1,339	13	7.9	1,509	9	2.8	5,334	22
Total	9,296	31	31	4,888	29	29	8,062	15	15	22,246	75
Chi-square			11.33			4.53			16.88		32.74

[a] Analysis was based on whales seen on systematic and random surveys. The shallow and transition water zones were combined as were also the June-July with the July–August and the October wit h the November to fulfill Cochran's (1954) assumption that no more than 20 percent of the expected frequencies should be less than five for the Chi-square analysis.

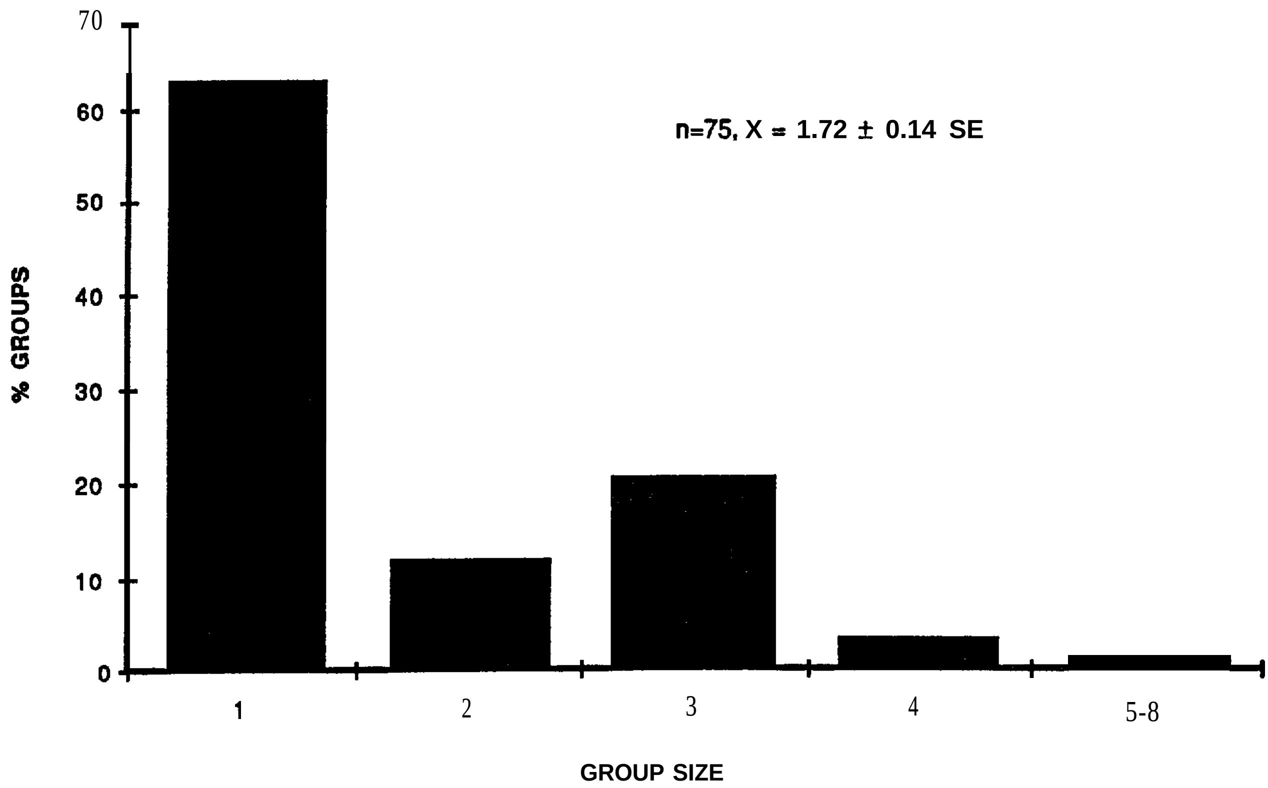


Figure 17.-Group size of humpback whales.

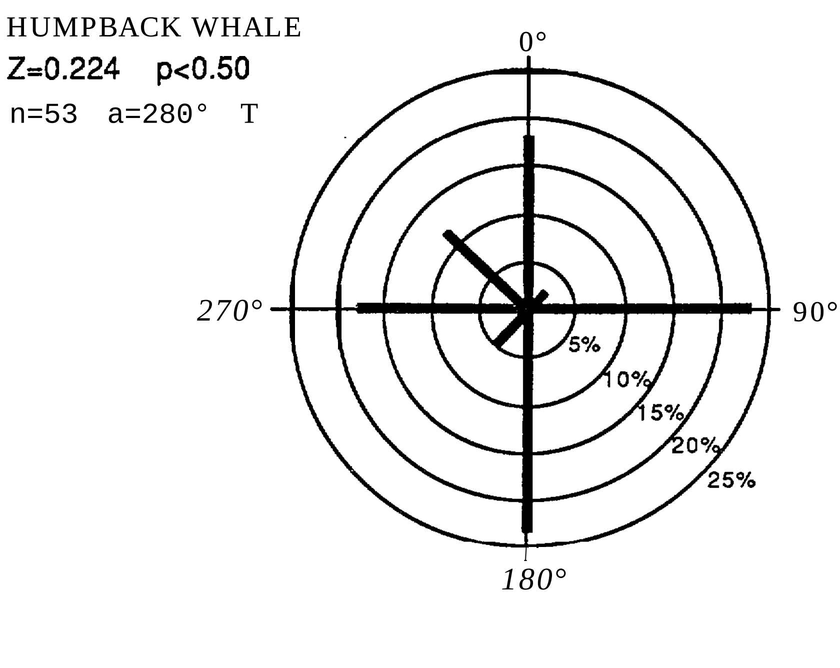


Figure 18.–Directional orientation of humpback whales.

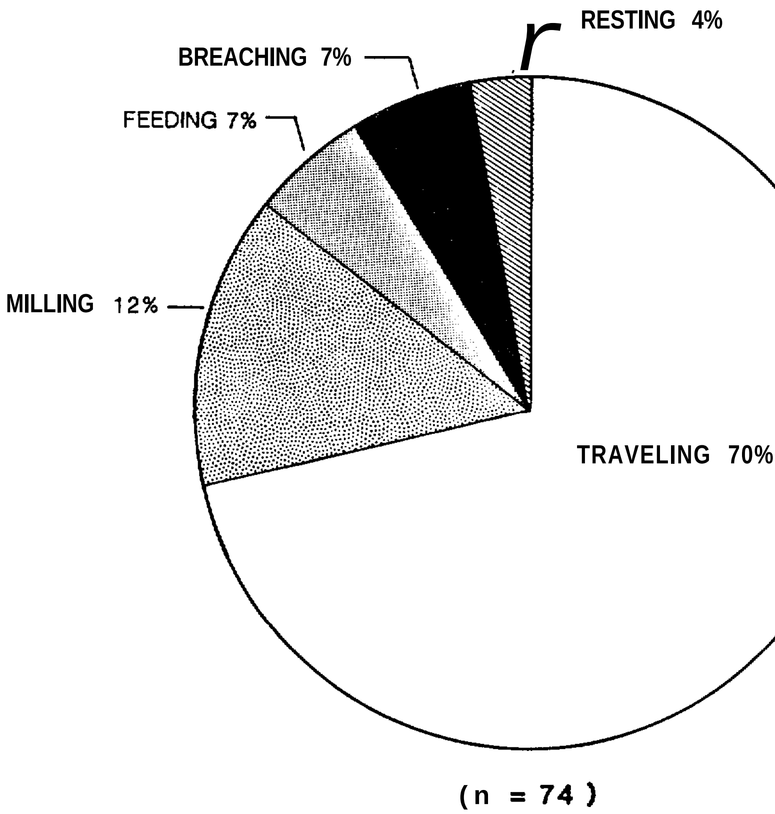


Figure 19.–Humpback whale behavior observed in Shumagin Planning Area, 1985.

humpbacks. Each of these categories made up less than 15% of the 74 groups of humpbacks included in the behavioral analysis. However, the ability of an observer to accurately evaluate behavior of whales from airplanes was limited by both the high survey altitude and the air speed.

Density *and abundance*

Humpback whale density and abundance estimates are provided in Table 9, Estimates were derived from systematic and random survey data for the three periods from June through August. These periods were chosen because almost 90% of the total 185 humpbacks were counted during these months, which corresponded to the reported peak period of humpback use in Alaska waters (Baker *et al.* 1985). The survey data were further screened to include only whales observed during good to excellent conditions and sea states between O and 2 Beaufort wind scale. Chi-square analysis indicated that observed numbers of whales were considerably fewer than the expected numbers during fair to poor visibility conditions and 3-5 Beaufort sea states ($p < 0.05$). Numbers of whales in the acceptable visibility and sea state categories were too few to analyze by individual viewing category, so the data were pooled into one category. Forty-three groups of humpbacks, observed along 7,581 nmi of trackline, were used for the density and abundance estimates.

Table 9.—Summary of statistics used in humpback whale density (n/nmi^2) and abundance estimates for Shumagin planning area.

Zone	Area (nmi^2)	Trackline length (nmi)	Number of groups	f(0)[a]	Density	Abundance	f(0)[b]	Density	Abundance
Shallow	21,855	5,117	22	1.405 (17.5)[c]	.006	131	1.327 (7.8)[c]	.006	123
Transition	6,501	626	1	—	.002	14	—	.002	14
Deep	24,960	1,838	11	—	.008	208	—	.008	196
Total number ± 95% confidence level						353 ± 255			333?217

[a] f(0) was derived from 34 perpendicular distances of humpback whale groups.
[b] f(0) was derived from 59 perpendicular distances pooled for humpback (34) and finback (25) whale groups (CV).
[c] Coefficient of variation ( ).

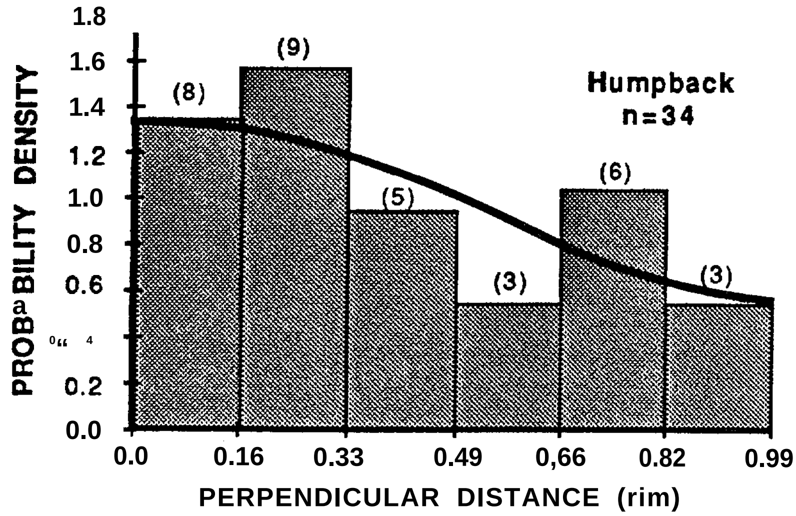
The f(0) was calculated two ways. In one method, the perpendicular distances obtained for humpback whales were used alone; in the other, these distances were combined with those of finback whales. The latter method was used to increase sample size, and it required that several assumptions be met. First, finback and humpback whales must have equal probabilities of detection. This could be an incorrect assumption if there are differences in blow characteristics, body size, and group size. The two species, however, have prominent blows, large body sizes (15 vs. 20 m), and generally small group sizes. Average group sizes for humpbacks (1.98) and finbacks (1.90) were not significantly different ($p < 0.05$). Average group size was calculated for whales encountered under the favorable conditions cited above, except that groups encountered in a Beaufort 3 sea state with good or better visibility conditions were included. The group sizes of these animals were not significantly different ($p < 0.05$) from those seen under Beaufort O-2 conditions, but were different from those associated with a Beaufort 4. While there are other biases, we felt the sightability of the two species was sufficiently similar to justify combining them to provide a second estimate of f(0). In addition, the f(0) values were not significantly different ($p < 0.05$) between these two species. Hay (1982) developed a combined humpback-finback whale f(0) to estimate their abundance in the North Atlantic Ocean, since he felt the two species usually had the same sighting cue.

The Fourier series fit of the perpendicular distances for humpback and combined humpback-finback sightings is given in Figure 20. The calculated perpendicular distances were used to estimate f(0) and to derive the Fourier series fit. The tails of the curves were truncated as recommended by Burnham (pers. commun.) to improve the fit by eliminating the highest distance estimates. These are generally the most difficult and least accurate to obtain from a survey platform. The truncation process reduced the perpendicular distance sample sizes from 43 to 34 groups (21%) for humpbacks and from 69 to 59 groups (15%) for combined humpback-finback distances. The f(0) values were similar and the associated coefficients of variation were small and ranged between 7.8 and 17.5%.

To construct the total density and abundance estimates, these values were determined for each zone and summed for the Shumagin Planning Area. The estimated f(0) and mean group size were assumed to be constant among zones since sample were too small to partition by zone. The resulting abundance estimates ranged from 333 ± 217 to 353 ± 255 humpback whales. These are minimum estimates, since they do not account for submerged animals.

Discussion

Our results show that humpback whale use of the Alaska Peninsula and eastern Aleutian Island waters has declined considerably since commercial exploitation commenced. While there are no pre-exploitation estimates, commercial whalers harvested over 7,000 humpbacks in these waters between 1912 and 1965 (Rice 1977; Reeves *et al.* 1985; Stewart *et* al. 1987). Commercial catches averaged over 1,000 whales each year in 1962 and 1963 (Rice 1978*a*). This value compares to only 185 whales we observed during approximately 38,050 nmi of aerial survey effort. Corresponding y, Stewart *et al. (1987)* reported that no humpbacks were observed during 3,690 nmi of aerial surveys on or near the whaling grounds hunted from the Akutan whaling station, where 1,510 whales were harvested between 1912 and 1939. Rice and



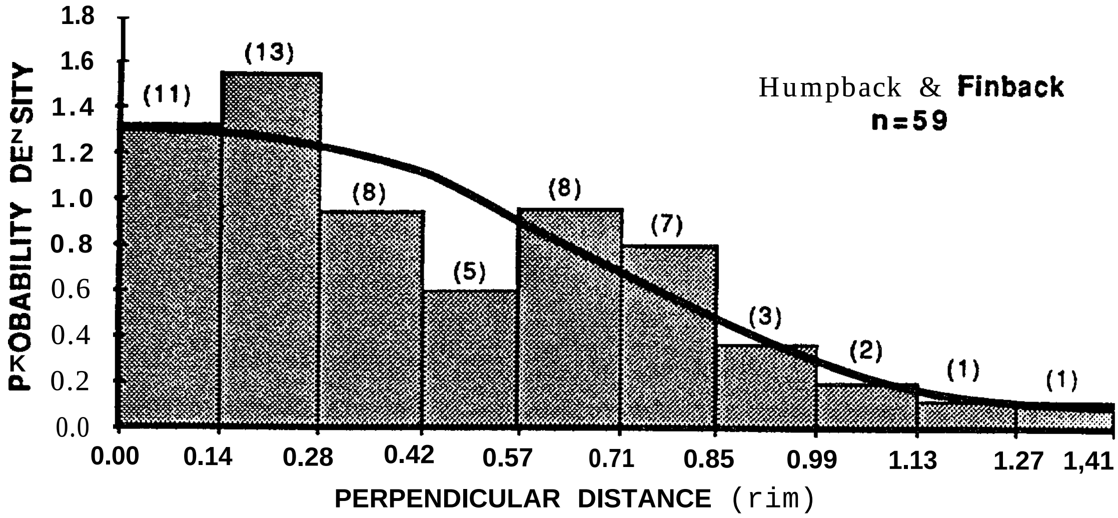


Figure 20.–Probability density function f(0) fit of the Fourier series to a histogram of sighting frequency and perpendicular distance for 34 sightings of humpback whales and 59 sightings of combined humpback and finback whales recorded on aerial transect surveys, 1985.

Wolman (1982) reported relatively few whales in the Kodiak area, where Port Hobron whalers took 1,573 humpbacks between 1926 and 1937. These findings suggest that humpback whale use of the area between Kodiak Island and Akutan Island, including the Alaska Peninsula, is substantially depressed from historic levels. Harvest records suggest that the waters north of the Alaska Peninsula did not support large numbers of humpback whales, which corresponds to our results and those of Leatherwood *et* al. (1983).

In our surveys, humpback whales occupied the Alaska Peninsula and eastern Aleutian Island waters from early July to mid-November, with the peak numbers occurring during July and August; surveys were not conducted during September. Similarly, whalers at the Akutan station harvested humpbacks from May through October (Brueggeman unpubl. data) and highest catches were from June through August (Stewart *et* al. 1987). This pattern of occupancy is also similar to southeast Alaska where Baker *et* al. (1985) reported that humpbacks arrived in June and numbers peaked in August and September. Whales occupying Prince William Sound arrived during late May-early June and stayed until October-November, when most began to move out of the Sound (Hall 1979). Consequently, our results show that the temporal pattern of use by humpbacks has not substantially changed from the initial period of humpback exploitation and the pattern is similar to other areas in southeast Alaska. Baker *et al.* (1985), however, reported that humpbacks were observed in southeast Alaska during December, when no humpbacks were observed in the study area.

The spatial distribution of humpbacks in the Alaska Peninsula and eastern Aleutian Island waters shows that the whales primarily are concentrated in the shallow shelf waters near islands and the shelf break. Townsend (1935) and Nishiwaki (1966) reported that humpback observation and catches by the Japanese in the North Pacific primarily occurred in these types of areas. Approximately 70% of the 98 groups of humpback whales that we observed were near island complexes or within 10 nmi of the shelf break in narrowly defined areas or banks (Table 10). These banks included Sanak Bank, Shumagin Bank, and an unnamed bank along 158°W longitude. Whales were repeatedly observed at Shumagin Bank (June-July, July-August) and the unnamed bank (August, November). No humpbacks were seen, however, on Davidson Bank, where large numbers of whales were harvested by Akutan whalers. Humpback whales in the Atlantic Ocean have been reported by Sutcliff and Brodie (1977) and Brodie *et* al. (1978) to feed most frequently along the edges of banks where prey concentrations are highest. A change in bathymetric relief on the shelf is often accompanied by a concentration of near-surface zooplankton, particularly when changes are abrupt (Sutcliff and Brodie 1977). The remaining 13 groups of whales that we observed on the shelf were distributed near clusters of islands where currents probably enhanced the productivity of prey. Consequently, these results show that humpbacks occurred in relatively narrow geographic areas associated primarily with oceanic banks and secondarily with island complexes.

The results also show that humpback whales have not reestablished use of Davidson Bank to the historic levels suggested by the Akutan whaling station harvest records. Approximately 4,371 nmi were surveyed in sampling blocks on and near this bank but no humpbacks were observed (Table 11). Moreover, the bank was surveyed during the four periods from June through October and the effort averaged 1,093 nmi per survey period. Given the extent of this survey effort, it is unlikely that the relative absence of humpbacks was simply a temporary variation in normal summer feeding patterns, Baker *et al.* (1986) reported that humpbacks in southeast Alaska showed strong fidelity to feeding sites. Individually identified whales, recognized from photos of flukes, repeatedly used the same feeding sites over several years. Furthermore, these feeding herds demonstrated strong geographic segregation. Consequently, our results coupled with surveys by Stewart *et al.* (1987) suggest that the intensive harvesting of whales on Davidson Bank may have depleted that feeding herd. Bockstoce (1978) and Rice (1978a) reported that harvests in southeast Alaska by the Tyee shore-based whaling station declined rapidly after one or two good seasons, suggesting that feeding herds specific to that area were depleted.

Table 10.–Number of humpback groups observed on or near areas of major relief changes or associated with island complexes.

Location	Number of groups	Range of distances of groups from major relief thange (nmi)[a]	Closest major contour interval (fathoms)	Distance between depths delineating major contour interval (nmi)
Sanak Bank	4	1-6	50-100	2
Shumagin Bank	26	0-5	50-100	8
Unnamed bank	12	1-1o	50-100	11
Near shelf edge	8	6-10	100-500	7
Islands complexes	18	–	–	–
Total	68			

[a] Minimum and maximum distances of groups of whales from 50-fathom or 100-fathom (near-edge) contour line.

Table Il.–Survey effort (nmi) on or near Davidson Bank in the Shumagin Planning Area, April-December 1985.

Sampling block	Survey period				
	June	July	August	October	Total
46	280	335	–	339	954
47	36	271	498	142	947
55	–	641	–	647	1,288
56	–	540	6 0	42	1,182
Total	316	1,787	1,098	1,170	4,371

In addition to whales encountered on or near the shelf, 29 groups were observed in deep water during the August and October surveys. Significantly, the direction of 10 of the 12 groups classified by orientation was primarily southward. While migrational movements to wintering areas seem unlikely during August, the high proportion (100%) of whales observed in October in deep water coupled with the southward orientation suggests these whales were migrating to the southern breeding grounds. The orientation included both a southwest direction toward the Asian breeding grounds and southern direction toward the Hawaiian breeding grounds.

Group sizes of humpback whales that we observed appeared to be smaller than reported in other surveys of humpbacks on the North Pacific feeding and breeding grounds. Rice and Wolman (1982) found that 37% of 83 groups of humpbacks surveyed in the Gulf of Alaska (east of Chirikof Island) were singles, 41% pairs, 11% triads, and 11% were in groups of 4 to 10 animals. Nemoto (1964) reported that 50% of 92 groups of humpbacks on the summer feeding grounds in the north Pacific were singles, 43% pairs, 3% triads, and 4% were in groups of four and five animals. We observed much higher proportions of singles (6396}, lower proportions of pairs (12%), higher proportions of triads (21%) and similarly low numbers of groups exceeding three animals. The observed differences are difficult to explain, but may be due to counting biases associated with the different survey platforms. Our aerial counts may have overestimated singles and underestimated pairs when compared to vessel counts reported by the other investigators. The results of the three data bases do support the conclusion that humpbacks occupy the summer feeding ground primarily in groups of one to two animals and seldom in groups exceeding five animals. Humpbacks on the winter breeding grounds in Hawaii occur in larger groups (32% were made up of at least three animals) since females are seen serially and simultaneously with multiple males, and males are seen serially with multiple females (Baker and Herman 1984; Herman and Antinoja 1977).

Humpback whale abundance in the Alaska Peninsula waters was estimated at 353 ± 255 and 333 ± 217 animals. These estimates were derived from identical databases, but the f(0) was calculated for humpback sightings alone to obtain the former estimate and for combined humpback and finback whale sightings to obtain the latter estimate. Although both estimates had relatively small coefficients of variation (CV) (36% vs. 33%), we believe the lower estimate is the best since the f(0) was based on the higher number of sightings and the CV was lower. Both estimates were derived from sighting data screened for visibility and sea state, and calculated by water depth zones. This screening reduced the sample size by 55% but correspondingly reduced the variability of the data. Consequently, the estimates were based on the data set with the fewest sources of bias. The estimates were reasonable since we observed 185 humpbacks, including 76 animals during one survey.

The size of the North Pacific humpback whale population is estimated at 1,200 whales (Rice and Wolman 1982), but the relative abundance of whales on the summer feeding grounds is incompletely understood. Estimates have been made for most of the historic summering areas in Alaska, except for the Alaska Peninsula and Aleutian Islands waters west of Chirikof Island and the Bering Sea (Table 12). Baker *et* al. (1985) estimated that 310 (270-372) humpbacks summered in southeast Alaska. Their estimate was based on a mark-recapture technique applied to photographic data on individually distinguished whales for 1981-1982. Rice and Wolman (1982) estimated 306 whales in the Gulf of Alaska east of Chirikof Island and an additional 58 whales in aggregation areas associated with the Gulf. The former estimate was derived from 25 groups of whales counted in 1980 along 3,106 nmi of strip transect line. The aggregation area estimate represented maximum counts of whales. Rice (pers. commun.)

Table 12.–Humpback whale estimates for the summer feeding areas in Alaska. The estimates represent minimum numbers except for southeast Alaska which is a total (surface and subsurface) estimate.

Area	Estimate (95% CI)	Method	Investigator
Southeast Alaska	310 (270-372)	Mark-recapture analysis of photographic data	Baker et al. (1985)
Gulf of Alaska	306”	Strip transect analysis from survey	Rice and Wolman (1982)
Prince William Sound	12’	Maximum count from vessel survey	Rice and Wolman (1982)
Yakutat Bay	13”	Maximum count from vessel survey	Rice and Wolman (1982)
Cape St. Elias-Middleton Island	13’	Maximum count from vessel survey	Rice and Wolman (1982)
Barren Islands	20”	Maximum count from vessel survey	Rice and Wolman (1982)
Alaska Peninsula	353 (±255)[b] 333 (±217)[b]	Line transect analysis from aerial surveys	Current study
Total	1,007 (750-1,286)’		

[a] Estimate based on density determined by strip transect procedure. Total number was determined by straight expansion of area surveyed to total study area. Sample size was too small to calculate confidence interval.

[b] The first estimate of 353 animals was calculated from f(0) derived from humpback whale sightings. The second estimate of 333 animals was calculated from f(0) derived from combined humpback and finback whale sightings.

[c] Numbers were based on the 333 humpback estimate for Shumagin because it had the lowest coefficient of variation.

believed that their estimate of 364 whales included the 40-60 humpbacks Baker *et al.* (1985) estimated for Prince William Sound. These estimates combined with our estimate of 333 (116-550) whales in the Alaska Peninsula waters provide a minimum abundance estimate of approximately 1,007 humpback whales (750-1,286) summering in Alaska waters.

This estimate for humpbacks summering in Alaska is approximate since there are several inherent biases. The estimates for the Alaska Peninsula and Gulf of Alaska do not account for submerged or missed whales. The Gulf of Alaska estimate does not include a variance component. Furthermore, the estimates may include duplicate counts of whales moving among the Alaska Peninsula, Gulf of Alaska, and southeast Alaska. The influence of this latter bias on the counts may be small, since Rice and Wolman (1982) and Baker *et* al. (1985) reported that humpbacks appear to form discrete feeding herds that have strong site fidelity and generally do not travel to other known feeding areas. Furthermore, all of the estimates except for Baker *et al.* (1985) were derived from summer counts (June-August) rather than counts taken in spring or fall, when animals are very mobile. While it is difficult to determine the effect of these biases on the estimate, the 1,007 animals is the best minimum estimate currently available for the Alaska region.

The North Pacific population estimate of 1,200 animals falls within the 750-1,286 range we calculated for humpbacks summering in Alaska. Since the range does not account for submerged or missed whales or whales summering outside Alaska waters, the current size of the North Pacific humpback whale population may exceed 1,200 animals.

Finback Whale

The size of the North Pacific finback whale population is estimated at between 14,620 and 18,630 animals, about 32-44% of the pre-exploitation population of between 42,000 and 45,000 animals (Rice and Wolman 1982; Braham 1984a). Finbacks were not commercially harvested until the advent of modern whaling because they were too fast for traditional whaling vessels of the early 1900s. Whaling for finbacks intensified in the mid-1900s after humpbacks became depleted (Rice 1974). Between 1958 and 1970, the eastern North Pacific stock of finback whales alone decreased 55% from approximately 20,000 to 9,000 animals (Rice 1974). Commercial whaling continued in the North Pacific until 1976 when the finback whale stock was protected by the International Whaling Commission.

North Pacific finback whales winter in subtropical to temperate waters and migrate in the spring to subarctic and arctic waters from the Gulf of Alaska to the Chukchi Sea (Nemoto 1959; Rice 1974). The Asian stock of finback whales migrates north along the Kurile Islands and southern Kamchatka to the Commander Islands where some move east to the Aleutian Islands and others pass north along the Asiatic coast, possibly to the Chukchi Sea (Berzin and Rovnin 1966). The eastern stock migrates off the Pacific Coast to the Gulf of Alaska and eastern Aleutian Island (Berzin and Rovnin 1966). Some of these animals migrate farther north into the Bering Sea and the Chukchi Sea. Tagging studies show that the two stocks intermingle along the Aleutian Islands. A finback whale tagged in 1955 north of Unalaska Island in the Bering Sea was killed in 1956 in the region of Kamchatka (Omura and Kawakami 1956).

The distribution of finback whales in the Gulf of Alaska and waters bordering the Alaska Peninsula is poorly understood. Between 1911 and 1937, commercial whalers harvested a large number of finbacks in these waters from shore-based operations, and during the 1950s and

1960s from Russian and Japanese factory whaling operations (Tonnessen and Johnsen 1982). Berzin and Rovnin (1966) reported that finbacks observed during a Russian scientific-exploration cruise from 1958 through 1964 and harvested from various whaling expeditions were widespread in the northern part of the Gulf of Alaska and east between the Trinity and Shumagin islands. Furthermore, they encountered few finback whales in Bristol Bay, but larger numbers on the Bering Sea side of the Aleutian Islands. Consequently, the Gulf of Alaska and Alaska Peninsula waters were important feeding grounds for the North Pacific finback whale population.

Recent surveys by Rice and Wolman (1982), Consiglieri and Braham (1982), and Leatherwood *et al.* (1983) found small numbers of finback whales widespread in these traditional summering areas. Their effort was, however, relatively low and the findings were incomplete. Their effort was particularly low in the waters bordering the Alaska Peninsula west of Chirikof Island to Unimak Pass and Bristol Bay. Consequently, finback whale distribution and abundance in this area is poorly understood.

In this section we document the distribution and abundance of finback whales in the Alaska Peninsula waters based on an intensive aerial survey. The information we report confirms and substantially expands the results from previous studies.

Results

Number and distribution

In the Shumagin Planning Area, 74 groups representing 149 finback whales were observed during the seven survey periods between April and December 1985 (Table 13). Finback whales were only observed during the July-August and August survey periods when 48% of the total effort was accomplished. Approximately equal numbers of whales were recorded during the two periods, but survey effort was 1.5 times higher in the July-August period. An aggregation of 19 large but unidentified whales observed during the November survey was suspected to be finbacks. No finbacks were observed in the other two planning areas.

Finback whales were not uniformly distributed ($p < 0.05$) in the Shumagin Planning Area (Figure 21). Seventy-three of the 74 total groups of finback whales were observed between 157° and 160°W longitude, where 34% of the total effort was accomplished (Figure 22). Particularly high numbers of finbacks were encountered in a 70-nmi band from 157° to 159°W ($p < 0.05$) (Table 14). Whales were repeatedly observed in this area during the July-August and August survey periods.

Finback whales were observed in two of the three water depth zones (Table 13). Approximately 90% of the finbacks were observed in the shallow zone, 10% in the transition zone, and none in the deep zone. A high proportion (>82%) of these whales was repeatedly observed during the two survey periods in the shallow water zone, where approximately 6570 of the effort was accomplished (Figure 23). Chi-square analysis indicated that use of the shallow and transition zones, however, was not significantly different ($p > 0.05$, $X^2 = 1.36$) (Table 15). No finbacks were observed in the deep water zone.

Table 13.–Survey effort (nmi) and number of finback whales observed in the Shumagin planning area, April-December 1985.

	Shallow zone[a]			Transition zone[a]			Deep zone[a]			Total		
Survey period	Effort	No.	Group	Effort	No.	Group	Effort	No.	Group	Effort	No.	Group
April-May	773	0	0	186	0	0	617	0	0	1,576	0	0
June-July	1,316	0	0	292	0	0	597	0	0	2,205	0	0
July–August	4,621	34 (24)	16 (11)	582	5 (8)	2 (3)	1,889	0	0	7,092	39 (32)	18 (14)
August	3,132	52 (24)	30 (11)	416	2	1	1,339	0	0	4,887	54 (24)	31 (11)
October	3,977	0	0	431	0	0	1,452	0	0	5,860	0	0
November	1,991	0	0	153	0	0	57	0	0	2,201	0	0
December	1,105	0	0	133	0	0	0	0	0	1,238	0	0
Total	16,915	86 (48)	46 (22)	2,193	7 (8)	3 (3)	5,951	0	0	25,059	93 (56)	49 (25)

[a]Zones were defined as <200 m for shallow, 200/2,000 m for transition, and >2,000 m for deep. Number in parentheses equals additional individuals and groups counted on deadhead surveys.

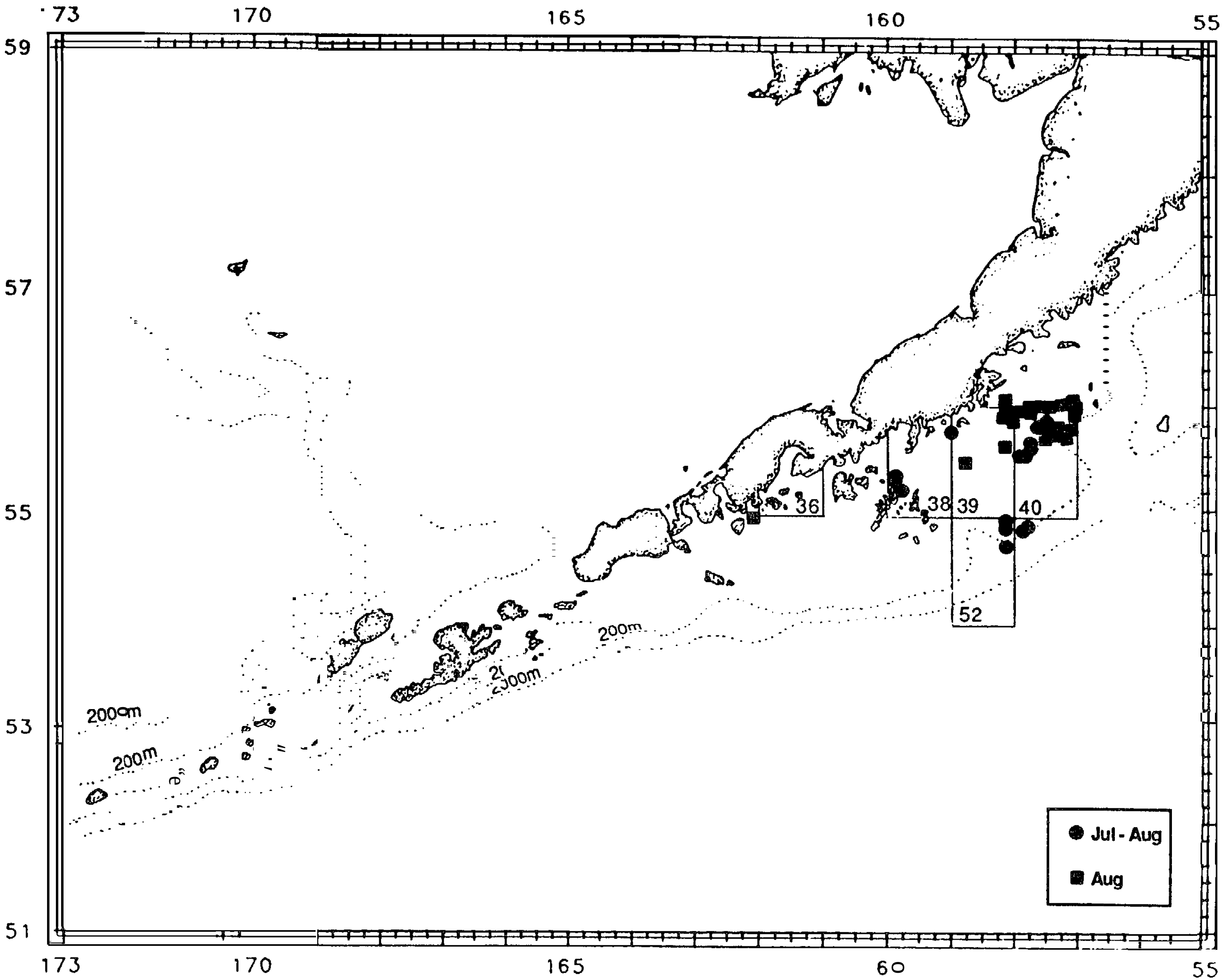


Figure 21.–Locations of finback whales observed in the Shumagin Planning Area, 1985.

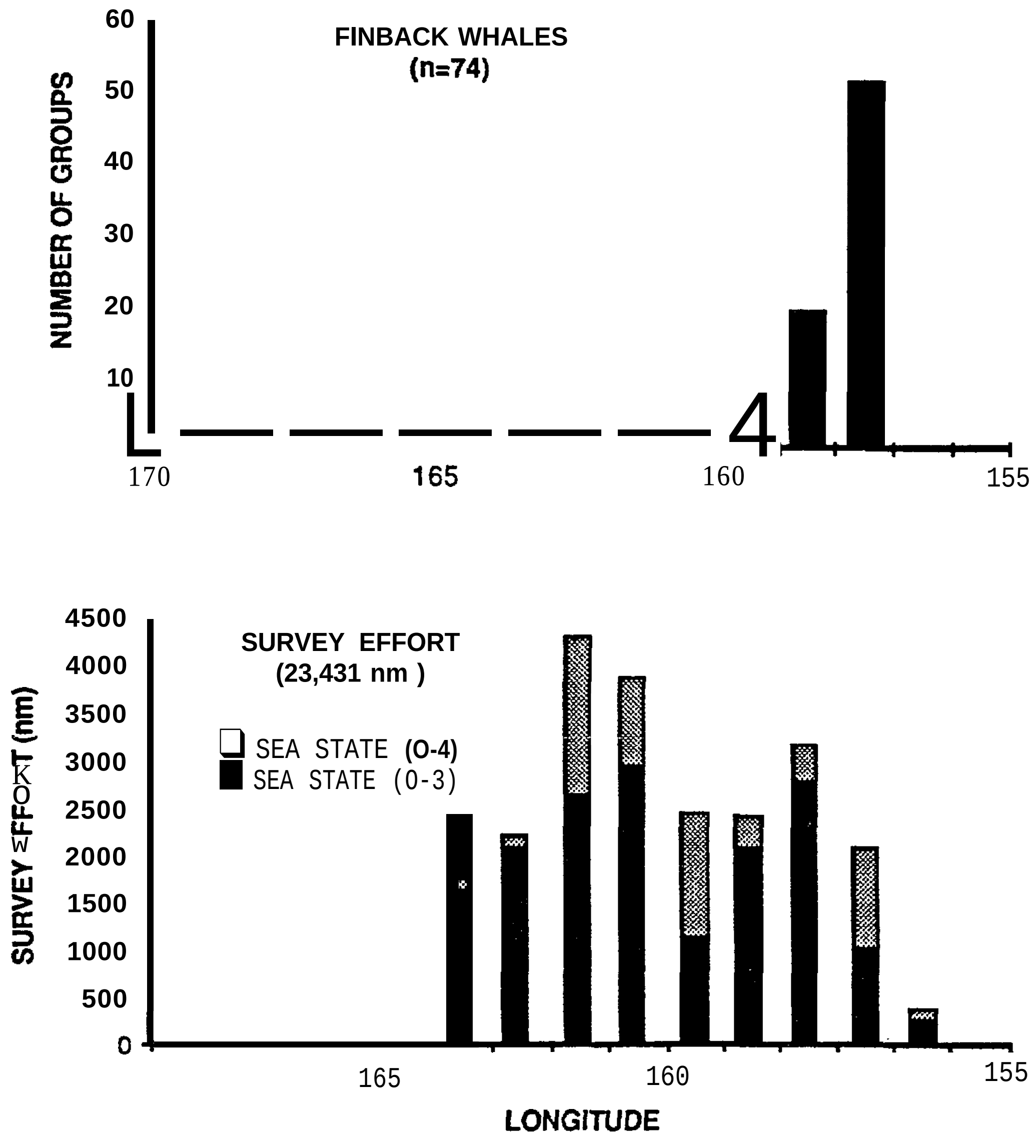


Figure 22.–Survey effort and number of finback whales observed by longitude degree.

Group size

Group size averaged 1.88 (±0.15 SE) animals for the two survey periods (Figure 24). Approximately 80% of the groups were composed of one or two animals, but single animals were the most common (45%). Fewer than 10% of the observations were in each of the remaining group size categories, which ranged from three to five animals. Average group size was not significantly different ($p < 0.05$) between the two survey periods. While group sizes were usually small, 86% of the 74 groups were in clusters ranging from 2 to 10 groups in a 3- to 5-nmi radius.

Table 14.-Relative occurrence of finback whales by longitude degree in the Shumagin Planning Area,

Longitude	Percentage effort	Percentage occurrence	Preference[a]
164°-165°(W)	10.5	0.0	
163°-1640	9.5	1.4	
162°-1630	18.4	0.0	
161°-1620	16.5	0.0	—
160°-1610	10.5	4.1	
159″-160°	10.3	25.7	+
158°-1590	13.6	68.9	+
157°-1580	8.9	0.0	—
156°-1570	1.7	- 00	0
Total	99.9	100.1	
Total effort and number of groups	23,431 nmi[b]	74	

[a] — indicates significant avoidance, + indicates significant preference, and O indicates no selection ($p < 0.10$).
[b] Effort included distances surveyed during Beaufort O-4 and fair to excellent visibility conditions.

Orientation and behavior

There was no consistent directional orientation ($p < 0.05$) of finbacks in the Shumagin area to suggest a major movement pattern (Figure 25). Finbacks were observed moving in a variety of directions during the two survey periods. While the whales were primarily observed traveling (98%), feeding activity may not have been detected by the aerial survey team (Figure 26). Finback whales feed by passing horizontally through the water and occasionally turning on their sides (Watkins and Schevill 1979), behavior which is difficult to distinguish from traveling.

Density and abundance

Finback whale density and abundance estimates and associated statistics are provided in Table 16. Estimates were derived for systematic and random surveys for the combined July-August and August periods. Finbacks were only encountered during these two periods, which correspond to the major period of use on these summer feeding grounds (Stewart *et al.* 1987). The survey data were screened to include only whales observed during good to excellent visibility conditions and sea states between O and 2 Beaufort wind scale. Chi-square analysis indicated that observed numbers of whales were considerably fewer than expected numbers for

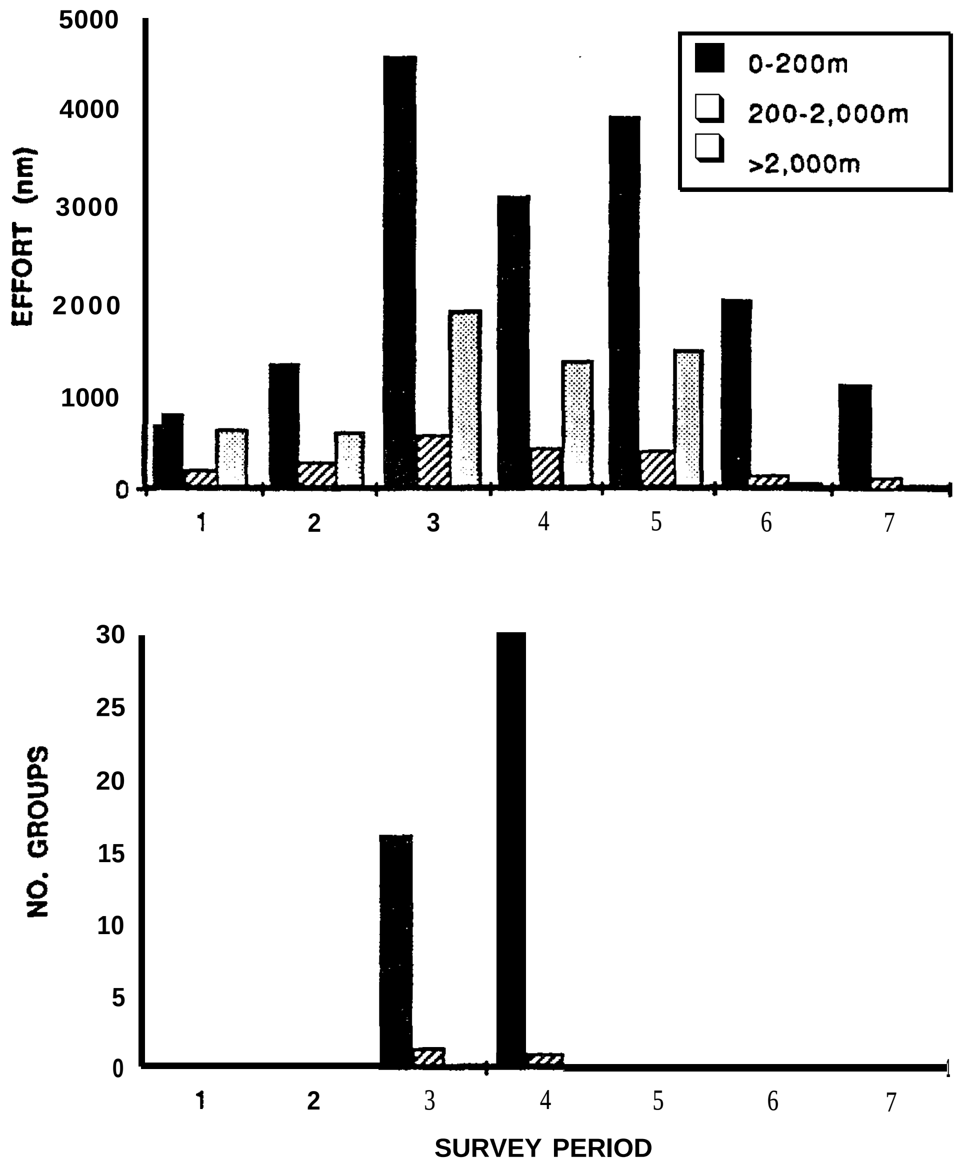


Figure 23.–Number of finback whales observed in each water depth zone relative to survey effort.

the other environmental conditions ($p < 0.05$). As with the humpback whales, the numbers of whales in the acceptable visibility and sea state categories were too few to analyze them by separate viewing categories, so the data were pooled into one category. Consequently, density and abundance estimates were derived from 25 groups of finback whales observed along 4,840 nmi of trackline.

The f(0) was calculated for perpendicular distances obtained for the finback whales and also for perpendicular distances obtained for finback and humpback whales combined. The justification for combining the distances of the two species is given in the preceding section on humpback whales. The Fourier series fits of the finback whale and the combined finback and

Table 15.–Observed and expected numbers of finback whale groups in each water depth zone.[a]

Zone	July-August Observed	Expected
Shallow	46	43.4
Transition	3	5.6
Total	49	49

[a] Analysis was based on whales seen on systematic and random surveys. Expected values were weighted by effort. The July-August and August surveys were combined to fulfill Cochran's (1954) assumption that no more than 20% of the expected frequencies should be less than five for the Chi-square analysis. Chi-square value equaled 1.36.

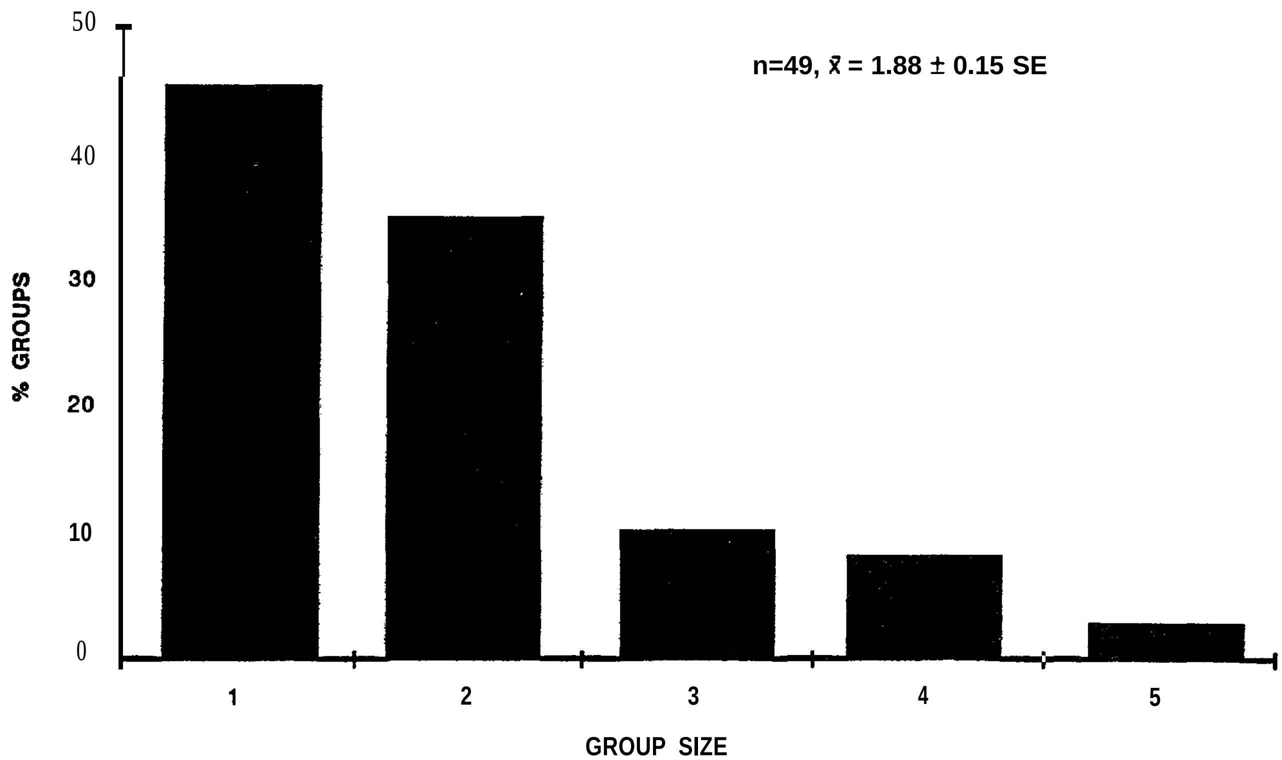


Figure 24.-Group size of finback whales.

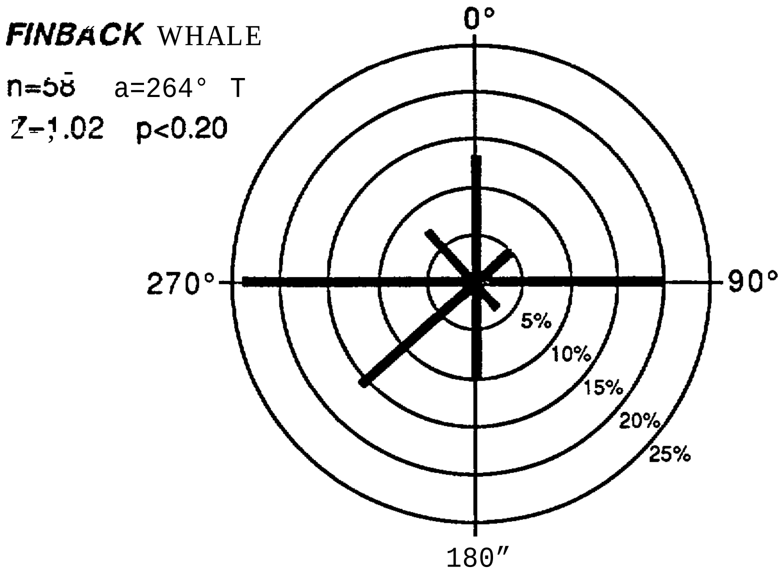


Figure 25.–Directional orientation of finback whales.

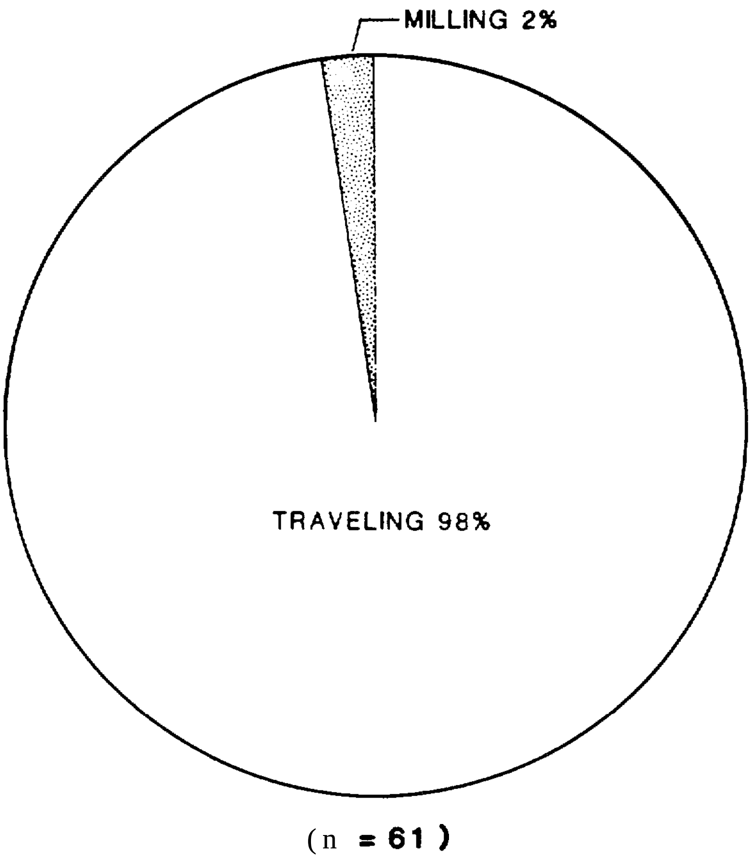


Figure 26.–Finback whale behavior observed in the Shumagin Planning Area, 1985.

Table 16.–Summary of statistics used in finback whale density (n/nmi^2) and abundance estimates for Shumagin planning area.

Zone	Area (nmi^2)	Trackline length (nmi)	Number of groups	f(0)[a]	Density	Abundance	f(0)[b]	Density	Abundance
Shallow	21,855	4,446	23	1.197 (15.6)[c]	0.006	129	1.327 (7.8)	0.006	143
Transition	6,501	394	2	—	0.006	37	—	0.006	41
Deep	24,960	1,585	0	—	o	0	—	o	0
Total number ± 95% confidence interval						166 ± 93			184 ± 90

[a] f(0) was derived from 25 perpendicular distances of finback whale groups.
[b] f(0) was derived from 59 perpendicular distances pooled for finback (25) and humpback (34) whale groups.
[c] Coefficient of variation ( ).

humpback whale perpendicular distances are given in Figure 27. The tails of the curves were truncated as recommended by K. Burnham (pers. commun.) to reduce variability. The truncation process reduced the perpendicular distance sample size for finback whales from 26 to 25 groups. The f(0) was 1.197 and the coefficient of variation was 15.6%. These values were similar to those developed for the combined finback and humpback whale sightings described previously.

To construct the total density and abundance estimates, these values were determined for each depth zone and summed for the Shumagin Planning Area. Since no finback whales were observed in the other two planning areas, these estimates were zero. The estimated f(0) and mean group size were assumed to be constant among the zones since the number of groups was too small to partition into zones. The resulting abundance estimates ranged from 166 ± 93 to 184 ± 90 finback whales. These are minimum estimates, since they do not account for submerged or missed animals.

Discussion

Our results show that finback whale use of the Alaska Peninsula and eastern Aleutian Islands has declined considerably since commercial exploitation commenced. Japanese commercial whalers alone harvested over 4,000 in or near these waters between 1945 and 1962 (Nishiwaki 1966). Catches in these areas ranged from 1,300-2,500 whales each year from 1954 to 1966 by all whalers (Tonnessen and Johnsen 1982). The 149 finbacks that we observed during approximately 43,700 nmi of aerial survey effort fall considerably below the average catch of finbacks 20 years ago. Others have also reported low numbers of finback whales in cetacean surveys. Stewart *et al.* (1987) observed only 11 finback whales during 3,690 nmi of aerial surveys on or near the former whaling grounds of the Akutan whaling station, where over 2,498 finbacks were harvested between 1912 and 1939. Rice and Wolman (1982) encountered 33 finback whales during 3,403 nmi of vessel survey effort in the Gulf of Alaska east of Chirikof Island, where the Port Hobron whaling station harvested over 464 finbacks between 1926 and 1937 (Reeves *et al.* 1985). These results show that while finback whales currently summer in the Gulf of Alaska and Alaska Peninsula waters, their use of the region is substantially below historic levels.

Finback whales were encountered in the Alaska Peninsula waters during the July-August and August surveys only, despite intensive survey effort during the other periods. Berzin and Rovnin (1966) reported that finback whales first arrived in the region of the eastern Aleutian Islands and Gulf of Alaska in April or May and departed in November. Hall (1979) observed finback whales in Prince William Sound from April to June and believed that they were primarily transients. Stewart *et al.* (1987) determined from the catch records of the Akutan whaling station that finback whales were taken in the Bering Sea and North Pacific near Akutan and Unalaska Islands from April through September, with peak catches occurring between July and early September. Consequently, the temporal distribution that we observed corresponds to the peak period of finback whale use in the Alaska Peninsula and adjoining waters. The absence of sightings during the other survey periods may be simply due to fewer numbers of whales. Our findings, however, do indicate that the temporal pattern of use by finback whales has not substantially changed from the historic one.

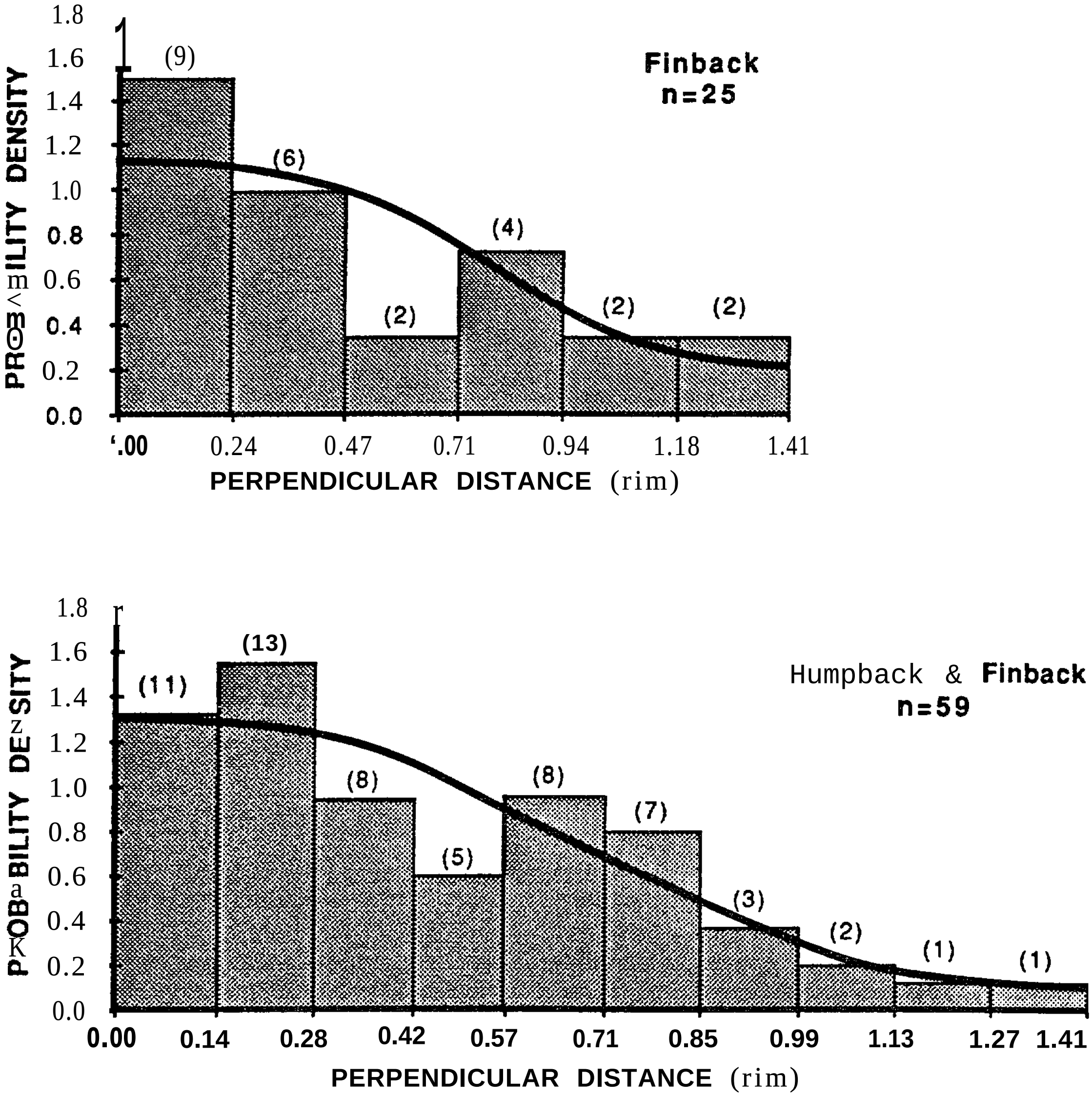


Figure 27.–Probability density function f(0) fit of the Fourier series to a histogram of sighting frequency and perpendicular distance for 25 sightings of finback whales and 59 sightings of finback and humpback whales combined recorded on aerial transect surveys, 1985.

The spatial distribution of finback whales in Alaska Peninsula waters was primarily on the continental shelf near areas of high bathymetric relief. Approximately 97% of the 74 groups of finback whales were distributed on or near (≤10 nmi) the 50-fathom (91-m) contour line (between 25 and 70 fathoms, or 46 and 128 m) and concentrated along the 158°W longitude line. This area, particularly southwest of the Semidi Islands where the largest aggregations of finback whales occurred, features sharp relief characterized by a deep canyon that bisects the shelf. Whales were repeatedly observed in this area during the two survey periods. Finback whales taken in the Gulf of Alaska by commercial whalers were also near areas of high relief where gyres, upwelling, and oceanic fronts provided high biological productivity (Uda 1954;

Berzin and Rovnin 1966; Shurunov 1970; Nasu 1974). Consiglieri and Braham (1982) similarly recorded that finback whales reported in the POP database primarily occurred in areas of upwelling along the continental slope and shelf in the western Gulf of Alaska to Unimak Pass. Several finback whales we observed were associated with island complexes, generally near areas of high relief except for the two finbacks by Deer Island.

The distribution of finbacks was very narrow, despite the broad spatial coverage achieved in the survey effort. These results suggest that finback whales, as we report for humpback whales, have not reinhabited some historically used areas since being depleted by commercial whalers. While large numbers of finbacks were historically taken by whalers off Davidson Bank (Reeves *et al.* 1985), no finback whales were recorded in this area during our surveys. Stewart *et al. (1987)* also found no finback whales associated with this bank following their aerial surveys. The narrowly defined areas where we did report finbacks may have been areas that whalers missed or hunted considerably less, possibly because of territorial boundary restrictions on access by foreign vessels (Rice, pers. commun.). Whales using these areas may display site fidelity similar to humpback whales (Baker *et al.* 1985).

The group sizes of the finback whales that we observed were generally similar to those reported by other investigators for the summer feeding grounds in Alaska. Rice and Wolman (1982) found that 47% of 15 groups of finback whales encountered in the Gulf of Alaska were singles, 20% pairs, and 33% were groups of three to five animals. Consiglieri and Braham (1982) similarly reported that 40% of 65 groups of finback whales recorded in the POP database for Alaska were singles, 25% pairs, and 35% composed groups of three or more whales. Single animals (45%) were most commonly observed during our surveys also, and groups exceeding three animals were relatively uncommon. We saw more pairs (35%) than reported by the other investigators but the difference was not substantial and may have been due to observer biases. In general, however, our results confirm that finback whales inhabit the summer feeding grounds in small groups. Small groups of finbacks (mean = 2.61) were also predominant on the North Atlantic summering grounds (Hay 1982).

Finback whale abundance in the Alaska Peninsula waters was estimated at 184 ± 45 and 166 ± 93 animals. We believe the higher estimate is the best, since the f(0) was based on the larger sample size derived from the combined finback and humpback sightings and the coefficient of variation was lowest (7.8% vs. 15.670). To reduce biases, the estimation process followed the same data screening procedure as described in the previous section on humpback whales. The estimates are reasonable since we observed 149 finbacks, including 78 during a single survey period. The estimates were not corrected for whales missed by the observers, so they are minimum numbers.

The size of the North Pacific finback whale population is estimated at 14,620-18,630 animals (Braham 1984a) but the number on the Alaska summer feeding grounds is unknown. Rice and Wolman (1982) estimated 159 finback whales in the Gulf of Alaska, east of Chirikof Island. Their estimate was derived from seven groups of whales recorded along 3,106 nmi of strip transect line. A confidence interval was not calculated because of the small sample size. Since there are no other estimates for these waters, we combined it with our estimate of 184

(94-274) whales in the Alaska Peninsula waters to provide a minimum abundance of 343 (253-433) finbacks summering in these Alaska waters. This estimate falls considerably short of the North Pacific population estimate of 17,000. Since finback whales summer in the Bering Sea (Brueggeman *et al.* 1984) and elsewhere in the northern waters (Berzin and Rovnin 1966), the total finback whale population would not be expected to summer in the Gulf of Alaska and Alaska Peninsula waters. There are no comparable estimates for the proportion of whales summering outside these waters.

Killer Whale

Killer whales are one of the most cosmopolitan of all the toothed cetaceans. They inhabit all oceans and major seas (Martinez and Klinghammer 1970; Dahlheim 1981) including the tropics (Dahlheim *et al.* 1982), but they are most common in the higher latitudes. There are no world or North Pacific estimates for the killer whale population.

Killer whales are distributed in the arctic and subarctic regions of Alaska. They occur seasonally and are possibly resident in the Gulf of Alaska and Bering Sea (Braham and Dahlheim 1982; Leatherwood *et* al. 1982; Brueggeman *et* al. 1984; Lowry *et al.* 1987), and some move into the Chukchi Sea when ice recedes (Scammon 1874; Cook 1926; Braham and Dahlheim 1982; Leatherwood *et al.* 1983). The most notable concentrations occur in the eastern Aleutian Islands (Murie 1959) and along the shelf edge northwest of Unimak Pass (Leatherwood *et* al. 1983). Approximately 100 whales have been estimated in each of southeast Alaska, Prince William Sound, and Shelikof Strait during the summer salmon migrations (Hall 1981; Leatherwood *et al.* 1983*a*). Except for a few incidental sightings, very little information exists on killer whale use of the waters bordering the Alaska Peninsula.

In this section we provide "information on the abundance, distribution, and habitat use patterns of killer whales in the planning areas.

Results

Number and distribution

Twenty-five groups of 67 killer whales were observed in the three planning areas between April and December (Table 17). Whales were observed during five of the seven survey periods. Counts were generally below ten animals for each period except in July-August and December when 20 and 27 whales (including those seen on deadhead) were recorded, respectively. Survey effort was highest for July-August but lowest for December. No whales were encountered during April or October, although approximately 7,500 nmi of trackline were surveyed.

Killer whales were widely distributed in the study area (Figure 28). They were observed in all three planning areas but the number of observations was variable. The highest number

Table 17.–Survey effort (nmi) and number of killer whales observed in the three planning areas, April-December 1985.

	Shumagin			North Aleutian Basin			St. George Basin			Total		
Survey Period	Effort	No.	Group	Effort	No.	Group	Effort	No.	Group	Effort	No.	Group
April-May	1,576	0	0	0	–[a]	–	0	–	–	1,576	0	0
June-July	2,205	12 (1)	5 (1)	3,082	0	0	2,389	0	0	7,676	12 (1)	5 (1)
July-August	7,092	15 (5)	5 (2)	0	–	–	0	–	–	7,092	15 (5)	5 (2)
August	4,887	5	1	173	0	0	0	–	–	5,060	5	1
October	5,860	0	0	0	–	–	0	0	0	5,860	0	0
November	2,201	0	0	2,353	1	1 (1)	858	0	0	5,412	1 (1)	1 (1)
December	1,238	0	0	2,453	0	0	1,683	27	9	5,374	27	9
Total	25,059	32 (6)	11 (3)	8,061	1 (1)	1 (1)	4,930	27	9	38,050	60 (7)	21 (4)

[a] Dash (–) signifies area was not surveyed.

[b] Number in parentheses indicates animals seen on deadhead transects.

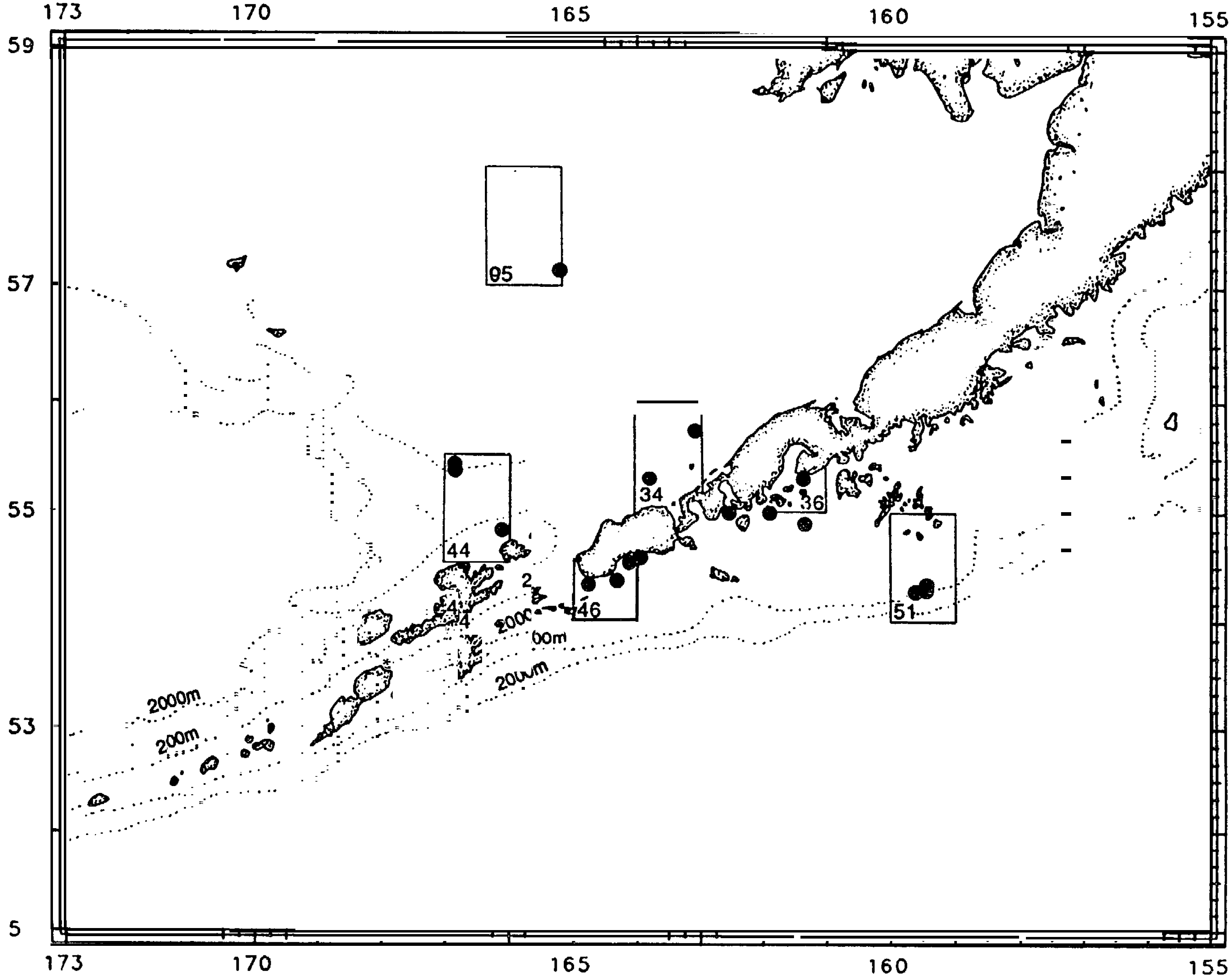


Figure 28.–Locations of killer whales observed in the study area, 1985.

of killer whales was encountered in the Shumagin area, where survey effort was highest. Slightly fewer whales were observed in the St. George Basin but effort was 8070 lower than in the Shumagin. Only two whales were recorded in the North Aleutian Basin, which was surveyed during four periods. Conversely, killer whales were recorded during two of three St. George Basin survey periods and during three of seven Shumagin area survey periods. Consequently, killer whale use of the planning areas was variable but highest in the Shumagin and St. George Basin planning areas.

Killer whales were associated with the shallow and transition water zones. Approximately 56% of the 21 groups were in shelf waters. These whales were primarily in the nearshore waters. Braham and Dahlheim (1982) reported that killer whales frequented the nearshore waters in the Gulf of Alaska. Moreover, Consiglieri and Braham (1982) found that killer whale sightings extracted from the Platforms of Opportunity Program (POP) for the Gulf of Alaska were almost exclusively on the continental shelf in water depths less than 200 m. The remaining 44% of the whales we observed during the surveys were on the slope near the edge of the continental shelf. No whales were observed in the deep water zone.

Group size

Group sizes of killer whales averaged 3.053 (±0.510 SE) and ranged from one to nine animals (Figure 29). Forty-three percent of the total groups were singles, 10% pairs, and 47% three or more animals. On five occasions, we observed two or more groups traveling together. Since killer whale pods are sets of closely related individuals which travel together in loosely formed groups, the clusters of groups we observed were probably members of the same pod (Ford and Fisher 1983).

Groups of the same pod maybe separated by as much as 4 nmi (7.3 km) (Martinez and Klinghammer 1970). By combining groups traveling together, the pod sizes averaged 4.79 (±1.25 SE) and ranged from 1 to 18 animals for our study area.

Orientation and behavior

There was no consistent directional orientation of killer whales to suggest a major movement pattern in the study area (Figure 30). The behavioral activity of the whales, however, was almost entirely observed as traveling. The movements may have been local rather than regional. One group of six killer whales was observed attacking a single northern sea lion. The whales encircled the sea lion and slapped it with their tails. We watched the attack for approximately 30 minutes but left before the confrontation ended.

-Density *and abundance*

Killer whale density and abundance estimates and associated statistics are provided in Table 18. Estimates were derived from systematic and random survey data for the Shumagin and St. George Basin planning areas. Estimates were not calculated for the North Aleutian Basin Planning Area because too few whales were observed in 1985. Only whales observed

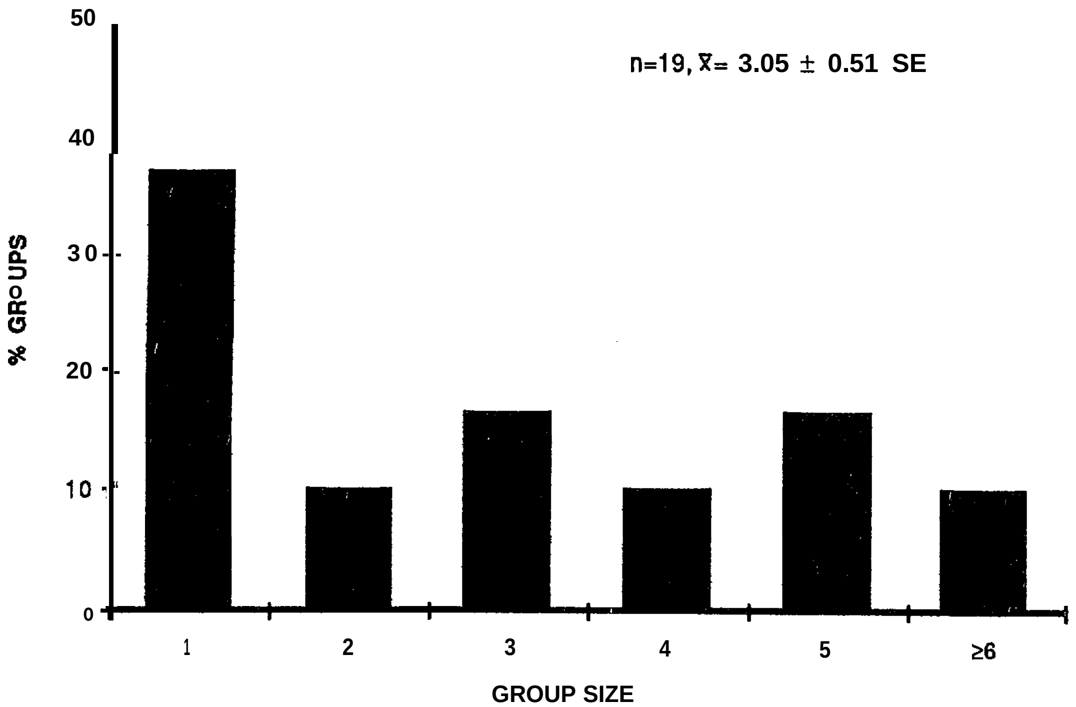


Figure 29.–Group sizes of killer whales observed in the Shumagin, North Aleutian Basin, and St. George Basin planning areas, 1985.

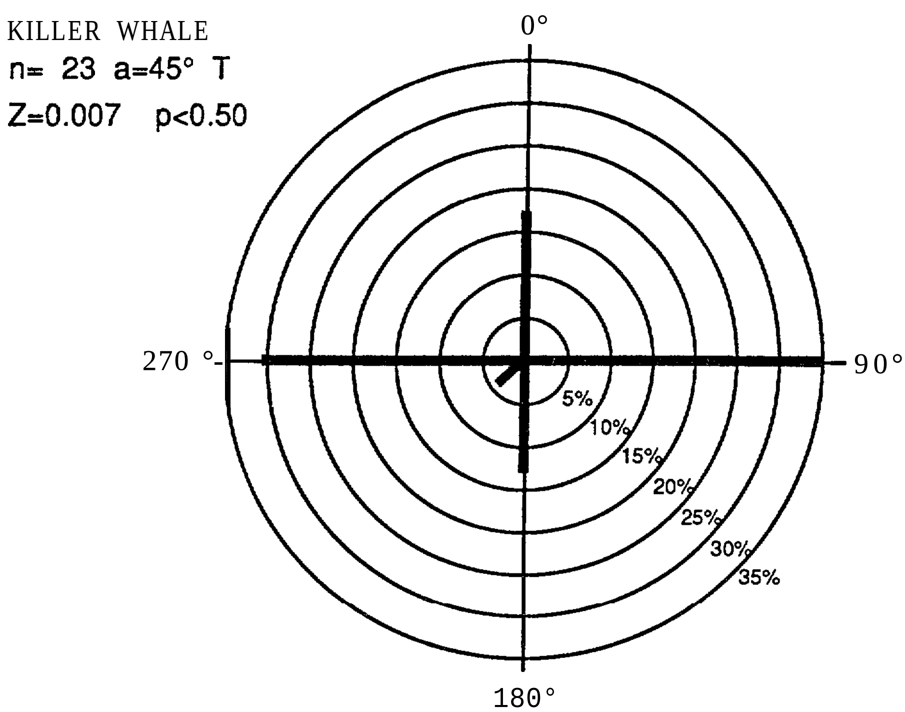


Figure 30.–Directional analysis of traveling killer whales in the Shumagin, North Aleutian Basin, and St. George Basin planning areas, 1985.

Table 18.–Summary of statistics used in killer whale density (n/nmi^2) and abundance estimates for the Shumagin and St. George Basin planning areas.[a]

Planning areas	Strata	Area (nmi^2)	Trackline length (nmi)	Number of Groups	f(0)[b]	Density	Abundance[c]
Shumagin	Shallow	21,885	7,459	8	3.306		119
	Transition	6,501	783	3			125
	Deep	24,960	2,374	0			0
Subtotal number ± 95% confidence interval							244 ± 136
St. George	All	35,441	2,246	8	3.306		639 ± 476
Total number ±95% confidence interval							883 ± 612

[a] St. George Basin estimate was pooled for all three zones because sample size was small. No estimate was derived for the North Aleutian Basin because numbers of observations were insufficient.

[b] f(0) was derived from 29 perpendicular distances.

[c] Alternative strip transect estimates were 243 ± 120 animals for the Shumagin and 634 ± 442 animals for the St. George Basin Planning Areas.

during good to excellent visibility conditions and sea states between O and 2 Beaufort wind scale were included in the analysis. These groups were pooled into one environmental condition category for analysis because there were too few whales recorded to stratify the results by each viewing condition. Eleven total groups in the Shumagin and eight groups in the St. George Basin planning areas were used for the density and abundance estimates.

Density and abundance estimates were derived from the line and strip transect procedures. The f(0) for the line transect procedure was estimated from 29 perpendicular distances of killer whales. Twelve of the 29 distances were extracted from aerial surveys conducted by Brueggeman *et al. (1984)* in the central Bering Sea. These survey procedures were similar to this study and both were conducted from aerial platforms flown at approximately identical altitudes. In addition, the average group sizes were not significantly different ($p < 0.05$). The pooled sighting data were fit to a Fourier series curve to estimate f(0) (Figure 31). The tail of the curve was not truncated because doing so produced a horizontal line. The horizontal line indicated that the probability of detecting a whale was 1.0 within a 0.61-nmi band or 0.305-nmi width per side (Figure 32). This relationship fulfilled the primary assumption for the strip transect procedure. The density, abundance, and associated variance were calculated from the strip transect procedure according to Method I described by Estes and Gilbert (1978). We applied a finite population correction factor to their formula (1) for calculating the variance of the density. This eliminated the need for the area correction factor in their formula (2) for calculating the variance of the abundance. The calculation procedure we followed is given in Appendix B.

Density and abundance estimates for the Shumagin Planning Area were determined for each depth zone and summed. The estimated f(0) and mean group size were assumed to be constant among zones. Density and abundance estimates for the St. George Basin Planning Area were not determined by depth zone but for the entire planning area. The resulting estimates for the Shumagin Planning Area ranged from 243 (±120 SD) using the strip transect method to 244 (±136 SD) using the line transect method. The strip estimates were much higher for the St. George Basin, ranging from 634 (±442 SD) to 639 (±476 SD). These are minimum estimates and do not account for submerged or missed animals.

Discussion

Since little is known about killer whales in the North Pacific and Bering Sea, it is difficult to compare our findings with others to reach conclusions. However, some general conclusions can be made about our results, though it must be recognized that the sample size is relatively small. Killer whales inhabited the planning areas from at least summer through early winter. Braham and Dahlheim (1982) suggested that portions of the killer whales inhabiting the Gulf of Alaska are year-round residents, while some move through the area to other locations. The whales we observed were widely distributed but generally associated with the nearshore water or edge of the continental shelf. These inshore waters likely contain shoaling fishes that Sleptsov (1961) found were common killer whale prey along the north side of the eastern Aleutian Islands and Alaska Peninsula. Sea otters, seals, and sea lions are also prevalent in these areas which, as we observed and others have reported, are prey to killer

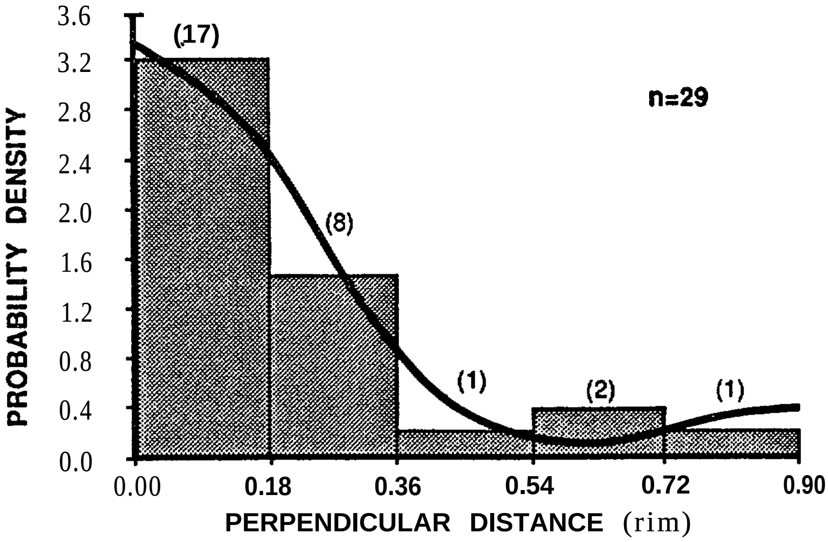


Figure 3 I.–Probability density function f(0) fit of the Fourier series to a histogram of sighting frequency and perpendicular distance for 29 sightings of killer whales recorded on aerial transect surveys, 1985.

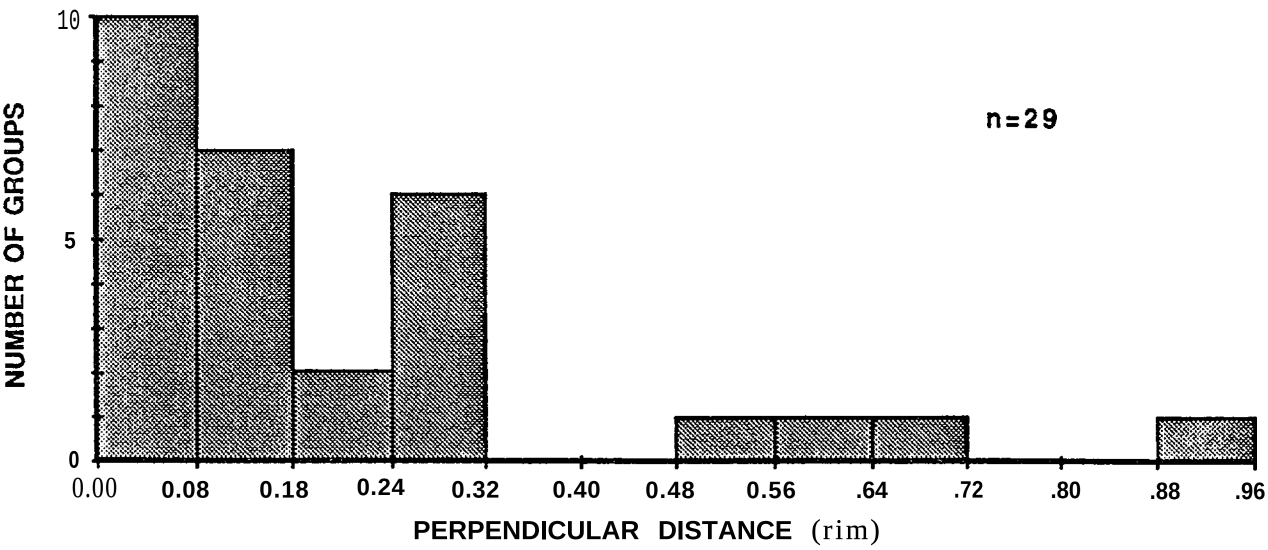


Figure 32.–Frequency histogram of perpendicular distances of killer whale sightings for determining strip width from aerial transect surveys, 1985.

whales (Scheffer and Slipp 1948; Tomilin 1957; Rice 1968; Lowry *et* al. 1987). The mean number of killer whales we estimated in the planning areas was 883 with a range of 271-1,495 animals. Our strip transect estimate fell within this range, The estimate is not unreasonable, considering the size of the planning areas and the high abundance of prey, relative to the previously stated estimates available for much smaller areas such as Prince William Sound and Shelikof Strait.

Sperm, Beaked, Belukha, and Minke Whales

Five species of medium-to-large whales were observed in the project area: (1) sperm, (2) Baird's beaked, (3) Cuvier's beaked, (4) belukha, and (5) minke whales (Figure 33). The number of observations recorded for each of these species was too small for detailed analysis. A brief description of our results, however, is provided below.

Sperm Whale

The sperm whale is the most abundant of the great whales. Their population has been estimated at 274,000 in the eastern North Pacific (Braham 1984*a*), although producing a reliable method for estimating sperm whale numbers has proven difficult (Ohsumi 1980). North Pacific sperm whales are classified as endangered, yet approximately 400 are harvested annually by Japanese whalers under special permit (IWC 1986). This number is down considerably from the 1960s and 1970s when annual harvests ranged from 7,000 to 16,000 (Ohsumi 1980). Nearly 269,000 sperm whales were killed in the North Pacific ii-em 1910 to 1976 (Ohsumi 1980). Approximately 1,000 sperm whales were taken by Alaska shore-based whaling stations operating from 1912 to 1939 (Reeves *et* al. 1985).

Sperm whales are characteristically found in pelagic waters near continental shelf edges (Berzin and Rovnin 1966; Leatherwood and Reeves 1982). They feed largely on squid, although deepwater bottom fish are common in their diet (Caldwell *et al.* 1966; Rice 1978*b*), especially in the eastern North Pacific (Okutani and Nemoto 1964). Males apparently dive deeper, presumably for squid, than the much smaller females (Lockyer 1976). Large bulls have been tracked to depths of 2,500 m (1,367 fathoms) (Leatherwood and Reeves 1982). Mature males are also found at higher latitudes than immature males and females (Pike and MacAskie 1969; Leatherwood and Reeves 1982) during the summer. The northern limit of females and immature males in the North Pacific is approximately 50°N (Berzin and Rovnin 1966; Pike and MacAskie 1969); therefore, only mature males regularly inhabit Alaskan waters. Over 90% of the sperm whales harvested at the Akutan and Port Hobron whaling stations in Alaska were males (Brueggeman, unpubl. data).

In 1985, seven groups of 23 sperm whales were observed in the Shumagin Planning Area (Table 2). One group of five was observed in July and the other six groups in August. The latter were traveling together in groups of one to seven whales. All 23 whales were observed beyond the continental slope in waters approximately 3,500-4,000 m (1,914-2,187 fathoms) deep (Figure 33). Previous studies in the Gulf of Alaska (Consiglieri and Braham 1982; Rice and Wolman 1982) also found most sperm whales near, but beyond, the shelf edge. Berzin and Rovnin (1966) indicated that concentrations of sperm whales are found where there is a large, rapid change in depth, such as occurs near a continental slope or seamount. All our sightings appeared to be groups of large animals that were probably males, which is consistent with reports that only males inhabit Alaskan waters.

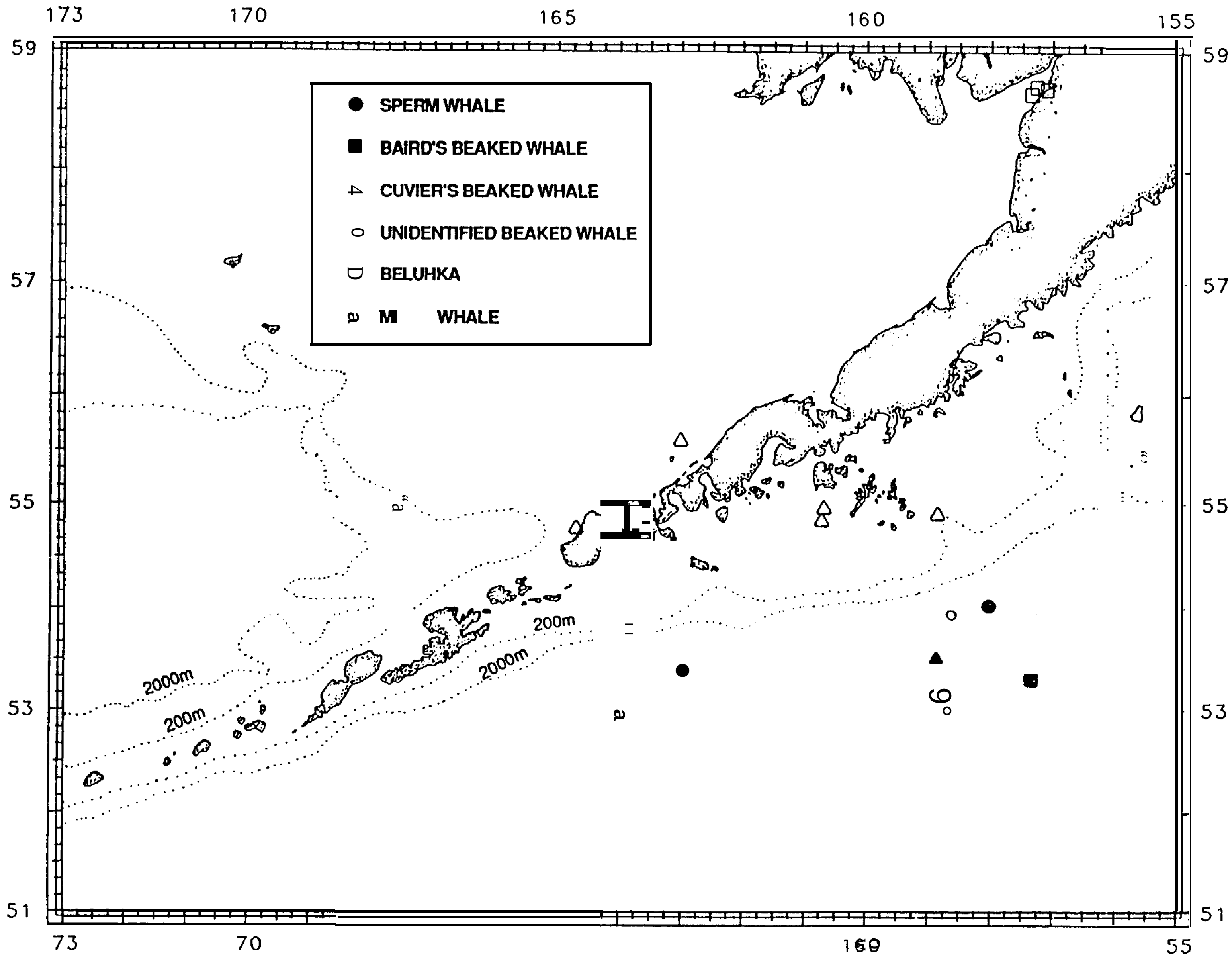


Figure 33.–Locations of the other medium-large whales observed in the study area, 1985.

Beaked Whales

Three species of beaked whales have been identified, usually from strandings, in Alaska waters (Leatherwood *et al.* 1982; 1983). The largest of these is the Baird's beaked whale, which reaches lengths of 12.8 m (42 ft) (Mitchell 1975). Baird's beaked whales have been commercially hunted only on an opportunistic basis in the eastern North Pacific (Leatherwood and Reeves 1982). They have, however, been exploited by small shore-based Japanese fisheries since World War II (Ohsumi 1975; Balcomb and Goebel 1977). Japanese whalers took 37 Baird's beaked whales in 1983 (IWC 1985). Cuvier's beaked whales are smaller, reaching maximum lengths of about 7 m (23 ft) and Stejneger's beaked whales reach 5.3 m (17.4 ft). Virtually nothing is known of the life histories of these two species. Baird's and Stejneger's beaked whales are confined to the North Pacific, including the Bering Sea (Leatherwood *et* al. 1982), while Cuvier's beaked whales are found in most oceans of the world (Moore 1963). Beaked whales are primarily found in pelagic water near shelf edges where they feed on squid and deepwater fish (Mitchell 1975).

Two species of beaked whales were observed in 1985 (Table 2). A group of two Cuvier's beaked whales and two groups of four and five Baird's beaked whales, respectively, were observed in pelagic waters of the Shumagin Planning Area during June and August. There were also two sightings of unidentified beaked whales. All five beaked whale observations were in waters between 4,800 and 5,500 m deep (Figure 33). Rice and Wolman (1982) observed a group of six Cuvier's beaked whales in about 5,400 m (2,952 fathoms) of water southeast of Kodiak Island. However, another Cuvier's beaked whale sighting by Rice and Wolman (1982) and one Baird's beaked whale sighting by Leatherwood *et* al. (1983) in the Gulf of Alaska and southeastern Bering Sea were in shallower waters of 1,110 m and 659 m, respectively.

Belukha Whale

Belukha or white whales are well-adapted for living in arctic waters with their all-white coloration, lack of a dorsal fin, and thick dermis and blubber layer (Leatherwood and Reeves 1982). Belukha whales are circumpolar with the North American arctic population estimated at 30,000 (Sergeant and Brodie 1975). In Alaska there are estimated to be between 150 and 300 belukhas in Cook Inlet and between 1,000 and 1,500 in Bristol Bay (Sergeant and Brodie 1975). These whales feed on a wide variety of fish and invertebrates, usually in waters less than 90 m (50 fathoms) deep (Dean and Douglas 1953). In Alaska, belukhas travel up rivers each summer to feed on returning salmon. This is most evident in the Kvichak River where belukhas have been considered a serious threat to commercial salmon fisheries (Fish and Vania 1971; Frost *et* al. 1984). Belukha whales were once harvested on a large scale, especially in the USSR where annual catches were 3,000-4,000 animals (Mitchell 1975). The annual world catch in recent years has been estimated at between 1,500 and 2,000 (IWC 1985; 1986). Most whales were taken by Denmark, followed by Canadian, Alaskan, and Siberian natives. The annual Alaskan harvest has ranged between approximately 170 and 354 from 1980 to 1984 (IWC 1986).

Five single belukhas were observed in November in Kvichak Bay near the mouth of the Kvichak River (Table 2, Figure 33). Another group of three whales was observed approximately

2 nmi up the Naknek River on the same date. Whales in Kvichak Bay were difficult to see because of muddy water conditions and scattered pancake ice. Belukhas are normally common in this area and reach high numbers there during annual salmon migrations (Fish and Vania 1971; Frost *et al.* 1984).

Minke Whale

Minke whales, the smallest of the baleen whales, are found worldwide. Today they are the mainstay of the whaling industry, since the stocks of larger whales are depleted. The annual take in Antarctica is around 6,000 animals and another 2,000-3,000 are taken in the rest of the world (IWC 1986). Korean and Japanese shore stations take nearly 800 each year from the North Pacific (IWC 1986). Scheffer (1976) estimated the species' world population at 340,000.

Minke whales are commonly found in Alaska during the summer. They are a coastal species usually occurring within the 200-m (109-fathom) depth contour (Tomilin 1957; Morris *et al.* 1983). Minke whales feed mainly on euphausids and schooling fish (Nemoto 1959; 1970). They are difficult to observe because of their small size (8-10 m) and low, inconspicuous blow (batherWood *et al.* 1982).

Minke whales were observed in all three planning areas (Table 2). Eight single animals were observed from July to late October. Six sightings were in shallow water (<200 m) and two in deep water (>1,000 m) (Figure 33). All whales observed were traveling. Nine additional singles were observed during sea otter surveys in 1986. Six were observed in the North Aleutian Basin Planning Area and three in the Shumagin Planning Area during June, July, August, and October. Aerial surveys in 1986 were flown 137 m (450 ft) lower in altitude than the 1985 surveys, which may have facilitated detecting minke whales.

Although all of the minke sightings were singles, three animals were observed within a 2-km radius of each other near the mouth of Cold Bay. Rice and Wolman (1982), Leatherwood *et al.* (1983), and Brueggeman *et al.* (1984) also observed a high occurrence of single minke whales in the North Pacific and Bering Sea. All 37 minke whales observed by Rice and Wolman (1982) in the Gulf of Alaska, 8 by Brueggeman *et al.* (1984) in the Bering Sea, and 39 of 46 (mean = 1.18) by Leatherwood *et al.* (1983) were singles. Furthermore, two cow-with-calf pairs were observed by Leatherwood *et al. (1983).* No calves were observed during our surveys.

Consiglieri and Braham (1982) reported that minke whales were virtually absent from the Gulf of Alaska by fall (October-December). Only three sightings recorded from the Platforms of Opportunity Program since 1958 were made during this period (Consiglieri and Braham 1982). Conversely, 7 of the total 17 (41%) sightings in this study during 1985 and 1986 were between 8 and 30 October. Leatherwood *et* al. (1983) and Brueggeman *et al.* (1984) observed minke whales during the fall, and even the winter, in the Bering Sea and Shelikof Strait. Consequently, minke whales are probably present in the Gulf of Alaska and Alaska Peninsula waters year-round in small numbers.

Dall Porpoise and Harbor Porpoise

Two species of small whales or porpoises were observed in the study area: Dan and harbor porpoises. The small size of these animals precluded an accurate census from the survey altitude we flew. The observations were, therefore, incidental to the endangered whale survey. A brief description of the survey results is provided below for each species.

Dall Porpoise

Dan porpoises are a ubiquitous delphinid endemic to the North Pacific. The population is estimated at over 1 million animals with as many as 250,000 in the Gulf of Alaska alone (Bouchet 1981). Dan porpoises are common both over the continental shelf and offshore but are found inshore more often during the summer (Hall 1979). They are taken both commercially and incidentally by Japanese fisheries. The 1983 commercial take was 12,766 porpoises and the incidental take, mostly by Japanese high-seas salmon drift net fisheries, was 3,082 (IWC 1985). The actual annual incidental takes, however, may reach 20,000 animals (NMML 1981).

Dan porpoises feed on schooling fish such as capelin, hake, arctic cod, and herring (Scheffer 1949, 1953; Sleptsov 1961), but squid maybe their principal food (Tomilin 1957; Pike and MacAskie 1969). Groups of Dan porpoises usually range from 2 to 10 animals, with a mode of about 4, although groups of over 200 have been reported (Morris *et al.* 1983).

In 1985, we sighted 50 groups of 157 Dan porpoises (Table 19) distributed throughout all three planning areas (Figure 34). The highest observed density (number per 1,000 nmi) of Dan pm-poises occurred in the St. George Basin Planning Area with 2.232 groups observed per 1,000 nmi surveyed. Densities in the other two planning areas were similar to each other: 0.998 groups per 1,000 nmi for the Shumagin and 0.869 groups per 1,000 nmi for the North Aleutian Basin. Densities by depth zone were examined in the Shumagin Planning Area. In the shallow water depth zone (<200 m) groups of Dall porpoises were encountered at a rate of 0.946 per 1,000 nmi. The densities in the transition (200-2,000 m) and deep (>2,000 m) water zones were much higher: 3.650 groups per 1,000 nmi and 3.193 groups per 1,000 nmi, respectively. This supports previous observations by other researchers (Morris *et al.* 1983; Leatherwood *et al.* 1983) that Dan porpoises are most abundant in deep pelagic waters and along continental shelf edges. We were not able to examine depth zone by season because of too few fall sightings in the Shumagin Planning Area.

Dan porpoises were observed during all survey periods except April-May and November (Table 19). Sixty-two percent (31) of the groups were observed during the summer survey periods, 10% in October (5), and 28% in December (14). An additional 26 groups of 44 individuals were sighted during the 1986 sea otter surveys, with all but one observed in the North Aleutian Planning Area. Ninety-six percent of these groups were observed between 29 June and 21 August. No Dan porpoises were observed in March during the sea otter survey and only a single animal was observed during October. Because all of the 1986 surveys were conducted in shallow water, the lack of spring and fall sightings perhaps suggests a seasonal inshore-offshore migration such as Leatherwood and Fielding (1 974) have described in southern

Table 19.–Survey effort (nmi) and number of Dan porpoises observed in the three planning areas.[a]

Period	Shumagin			North Aleutian Basin			St. George Basin			Total		
	Effort	No.	Group	Effort	No.	Group	Effort	No.	Group	Effort	No.	Group
April-May	1,576	0	0	0	–[b]	–	0	–	–	1,576	0	0
June-July	2,205	5	3	3,082	0	0	2,389	15	5	7,676	20	8
July-August	7,092	12	4	0	–	–	0	–		7,092	12	4
August	4,887	37 (32)	12 (7)	173	0	0	0	–		5,060	37 (32)	12 (7)
October	5,860	9	5	0	–	–	0	–	–	5,860	9	5
November	2,201	0	0	2,353	0	0	858	0	0	5,412	0	0
December	1,238	8	1	2,453	21	7	1,683	18	6	5,374	47	14
Total	25,059	71 (32)	25 (7)	8,061	21	7	4,930	33	11	38,050	125 (32)	43 (7)

[a] Number in parentheses is additional animals counted on deadhead surveys.
[b] Dash (–) signifies area was not surveyed.

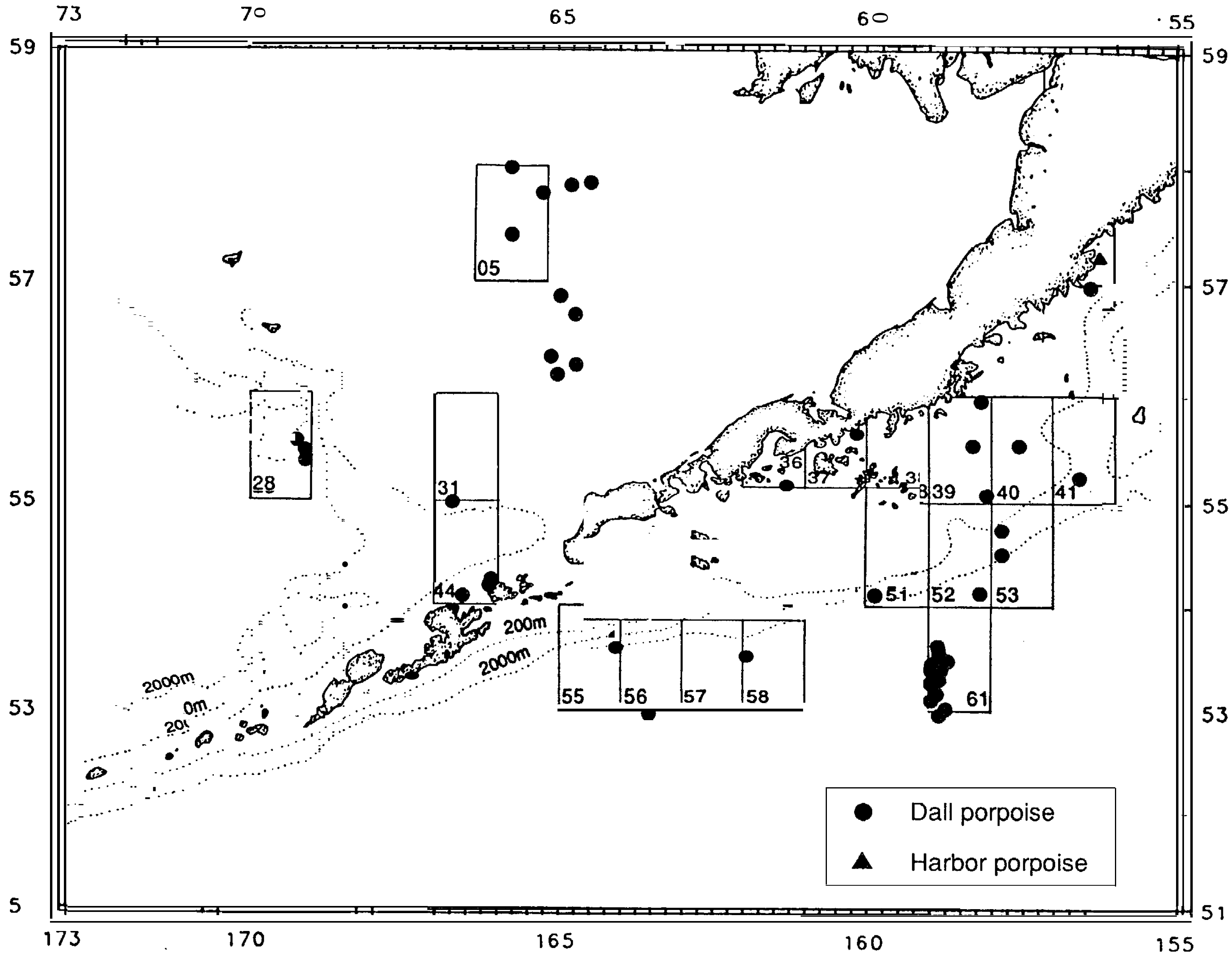


Figure 34.–Locations of Dall and harbor porpoises observed in the study area, 1985.

California. Others (Fiscus and Niggol 1965; Hall 1979) have also suggested a winter movement offshore.

Harbor Porpoise

Harbor porpoises are shy, inconspicuous delphinids which inhabit the coastal waters of the North Pacific and Bering Sea. They are generally found in waters less than 20 m (11 fathoms) deep (Leatherwood and Reeves 1978) and feed on a wide variety of schooling fish, including salmon (Tomilin 1957; Smith and Gaskin 1974). No population estimates exist for the North Pacific or the Bering Sea, except for Prince William Sound where Hall (1979) estimated a summer population of 946.

During 1985, we observed only one harbor porpoise (Figure 34). We attribute our lack of sightings to the difficulty of detecting these animals from the 230 m (750 ft) altitude flown during the endangered cetacean surveys. We saw a marked increase in the number of harbor porpoise sightings during the 1986 sea otter surveys, which were flown at 90 m (300 ft). Fifty-three groups composed of 94 individuals were observed during those surveys. Harbor porpoises were commonly sighted during all 1986 survey periods (March-October) and 70% were observed in the North Aleutian Planning Area. We also received reports of influxes of harbor porpoises at Nelson Lagoon during the sockeye salmon runs (M. Mack, pers. commun.). A more comprehensive analysis of the Dan and harbor porpoise data will appear in a later report which will combine the 1985 and 1986 survey results.

Unidentified Whales

Thirty-four groups of 48 unidentified baleen whales were recorded in the three planning areas (Table 2). The distribution of these animals is given in Figure 35. An additional 16 groups of 24 unidentified porpoises and 2 groups of 4 unidentified beaked whales were recorded during the surveys (Table 2).

Whales Expected But Not Observed in Study Area

Blue Whale

Blue, sei, and right whales historically inhabited the waters off the Alaska Peninsula and eastern Aleutian Islands, but none were observed during our surveys. The pre-exploitation size of the North Pacific blue whale population has been estimated at between 4,500 and 5,000 animals (Ohsumi and Wada 1972; Tillman 1975; Gambell 1976; Braham 1984a). Prior to receiving protection in 1967, the population was severely depleted by commercial whalers, using the modern whaling methods of the 1900s; blue whales were too swift and powerful for nineteenth century whalers to chase with their open boats and kill with their hand-thrown harpoons (Rice 1974; Tonnessen and Johnsen 1983). The current population size is estimated at 1,400-1,900 animals (Tillman 1975; Gambell 1976; Braham *1984a)*, and the data indicate that the North Pacific population has increased since receiving protection (Ohsumi and Wada 1972).

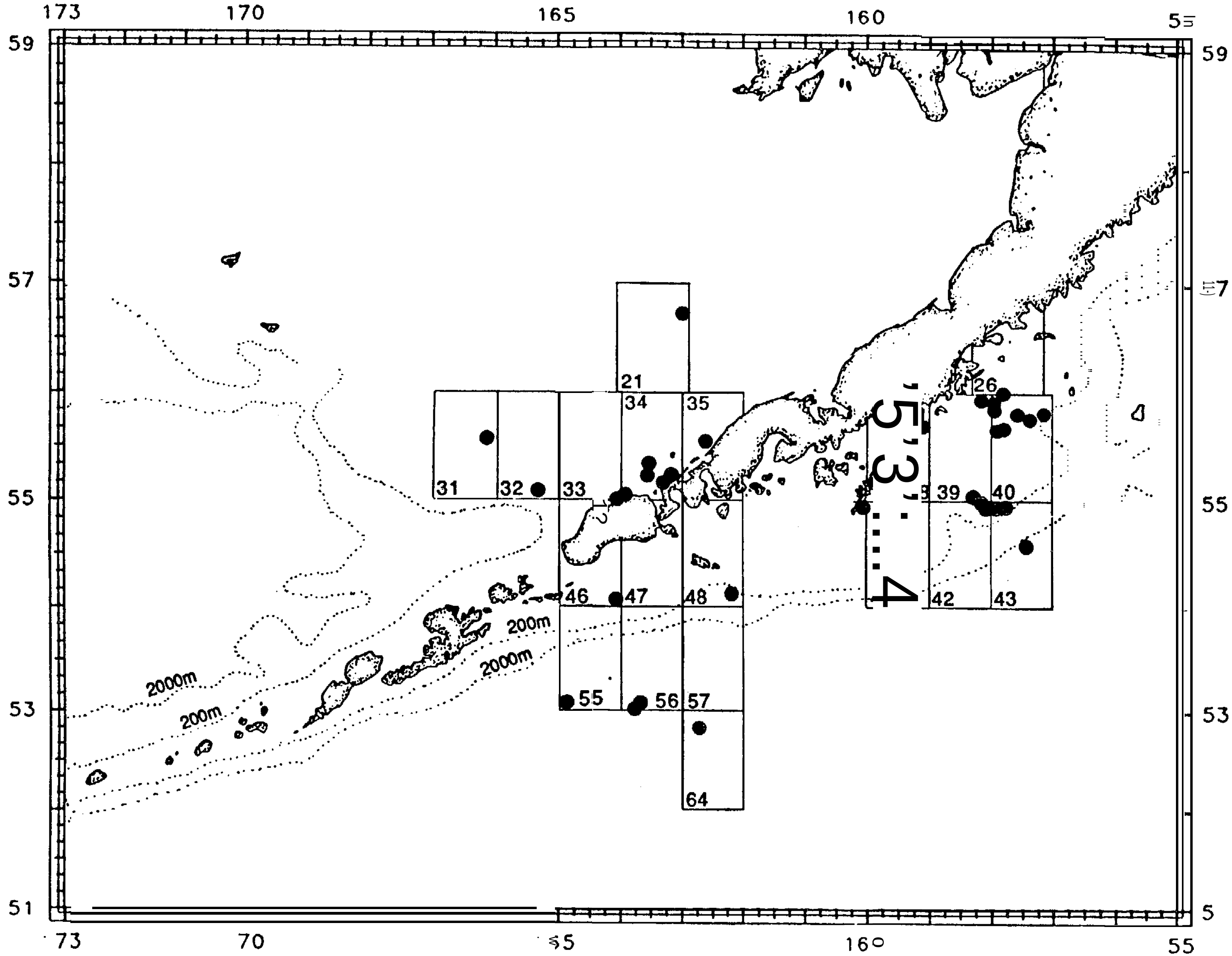


Figure 35.-Locations of unidentified baleen whales observed in the study area, 1985.

The commercial catch records from the shore-based stations operating off Akutan Island and Sitkalidak Island (Port Hobron, near Kodiak Island) show that substantial numbers of blue whales were harvested between 1917 and 1939 (Brueggeman *et al.* 1985). A total of 835 blue whales were harvested off Akutan and 218 blue whales were harvested off Sitkalidak Island. No whales were taken in the Bering Sea from the Akutan station, which supports the contention that few blue whales occur north of the Aleutians and Alaska Peninsula (Nishiwaki 1966). The majority of the blue whales harvested were located within the boundaries of the area we surveyed.

The absence of sightings b-em our surveys suggests that the number of blue whales using the Alaska Peninsula and eastern Aleutian Island waters is small, and the population has not recovered from commercial exploitation.

Sei Whale

The pre-exploitation sei whale population for the North Pacific was estimated at 45,000 whales (Ohsumi and Fukuda 1975; Braham 1984a). The sei whale was not heavily harvested in the North Pacific until around 1963 when the finback and blue whale stocks were severely depleted. Sei whale catches by Japanese and Soviet fleets in the North Pacific and Bering Sea increased from 260 animals in 1962 to over 4,500 animals in 1968 and 1969 after which catches declined rapidly until the species received protection in 1976 (Mizroch *et cd.*, 1984). The current sei whale population size in the North Pacific is estimated between 22,000 and 37,000 animals (Braham 1984*a*).

The summer feeding grounds of the sei whale include the boundaries of the project area (Nishiwaki 1966). Rice (1974) reported that sei whales rarely occur north of the Aleutian Islands. Catch locations of almost 900 sei whales harvested east of 180° by the Japanese between 1952 and 1962 show that the animals were widely distributed along the south side of the Alaska Peninsula and Aleutian Islands (Nishiwaki 1966). Recent surveys of this area by Rice and Wolman (1982) yielded no sei whale sightings, while Leatherwood *et al.* (1983) found one sei whale in the southwestern Bering Sea.

The absence of sei whale sightings during our surveys and those of other investigators, suggests that few sei whales summer in the project area. Sei whales, however, may have been unnoticed during the surveys since they travel in small groups (Tomilin 1957) which are difficult to detect from an airplane, and they are not readily distinguished from finback whales. While these factors may account for some missed sei whales, the results support the conclusion that sei whales are not abundant in the project area.

Right Whale

During the 19th century, commercial whalers almost completely exterminated the North Pacific right whale population (Rice 1974). An estimated 15,451 right whales were taken in the North Pacific between 1935 and 1969 (DuPasquier 1986). The intensity of the hunt was so great that between 1846 and 1851 an estimated 300-400 ships were taking right whales on the

Kodiak Grounds (Gilmore 1978). An indication of how close the whalers came to exterminating the population is that only 24 right whales are know to have been killed in Alaska and British Columbia between 1905, when modern whaling methods were introduced on the West Coast, and 1935, when the species was protected (Rice 1974). Although scattered sightings of right whales have been recorded since 1937 (Nasu 1960, 1963; Omura *et al.* 1969; Pike and MacAskie 1969; Brueggeman *et* al. 1984; Scarff 1986), the North Pacific population has never recovered from exploitation and is presently estimated to number 100-200 animals (Tillman 1975; Gambell 1976; Wada 1979).

The project area occurs within the historic summer range of right whales in the eastern North Pacific Ocean (Townsend 1935). Right whales summered primarily north of 50"N but were particularly abundant in the "Kodiak Grounds" which encompassed the Gulf of Alaska from Vancouver Island to the eastern Aleutians (Scammon 1874; Townsend 1935; Berzin and Rovnin 1966; Rice 1974). Some whales also frequented the Bering Sea, primarily in the southeastern corner from Alaska to St. Matthew and Nunivak islands (Townsend 1935; Berzin and Rovnin 1966; Berzin and Doroshenko 1982).

Right whales have been harvested or sighted in the region of the study area since the period of heavy exploitation in the 1800s. Shore-based whaling stations at Akutan Island and Port Hobron harvested 20 right whales between 1917 and 1935 (Brueggeman *et al.* 1986). Nine additional right whales were harvested by the Japanese by special permit during 1961, 1962, and 1963 off Kodiak Island and north of the eastern Aleutian Islands (Omura *et al.* 1969). Seventeen more right whales were observed during Japanese sighting cruises north of 50°N and east of 180°W between 1965 and 1979 (Scarff, 1986). There have been no confirmed sighting of right whales in the region of the study area since the 1970s, although Brueggeman *et al.* (1984) observed two right whales in the Bering Sea northwest of St. Matthew Island in 1983.

The absence of sightings, combined with the intensive effort of our surveys, confirms that right whales have not recovered from commercial exploitation.

SUMMARY AND CONCLUSIONS

Four of seven endangered cetaceans which historically occurred in the northwestern Gulf of Alaska and southeastern Bering Sea were encountered during seven aerial surveys conducted from April through December in these waters during 1985 (Table 20). Humpbacks were present from June to November, finbacks June to August, and sperm whales during July and August. Humpback and finback whales were observed feeding in the study area and sperm whales were presumed to also be feeding. Gray· whales were observed migrating through the study area in April and May, and November and December. Small numbers were also observed feeding in the study area during June through August. We estimated that 333 ± 217 humpbacks and 184 ± 90 finbacks summered in the study area. These estimates are conservative since they were not corrected for missed animals. There were too few sperm whales observed and gray whales were too transitory to develop abundance estimates. Although we did not observe blue, sei, or right

Table 20.-Survey periods cetaceans were observedin the study area, 1985.

Species/status	Apr-May	Jun-Jul	Jul-Aug	Aug	Ott	Nov	Dec
Endangered species							
Humpback whale		x	x	x	x	x	
Finback whale			X	x			
Gray whale[a]	x	x				X	x
Sperm whale			X	x			
Other cetaceans							
Minke whale		x	x		x		
Cuvier's beaked whale		x		x			
Baird's beaked whale				x			
Belukha whale						x	
Killer whale	x	x	x			x	x
Harbor porpoise			x				
Dan porpoise	x	x	x	x			x

[a] Gray whales were also observed during the months of March, June, July, and August during 1986 sea otter surveys.

whales, these species historically summered in the project area but were exploited to such low levels that the likelihood of encountering them was small.

Seven species of whales that are not listed as threatened or endangered by the Federal Government were also observed in the study area. Killer whales and Dan porpoises were observed essentially throughout the entire survey period which suggested that these species are probably year-round residents. We estimated that 883 ± 612 killer whales occurred in the study area. No estimate was developed for Dan porpoises since the survey altitude was too high for accurately detecting this species. Other cetaceans observed included minke, beaked (Cuvier's, Baird's), and belukha whales and harbor porpoises, but too few of these species were observed to estimate abundances.

The species of cetaceans observed in the project area were unequally distributed among the three planning areas. Humpback, finback, and sperm whales were recorded only in the Shumagin Planning Area. Gray whales occurred in the Shumagin and North Aleutian Basin during the migration periods. Gray whales also summered in both planning areas, although 13 of the 15 animals were in the North Aleutian Basin.

These observed distributions are generally more restrictive than has been historically reported. Berzin and Rovnin (1966) and Nishiwaki (1966) reported that relatively large numbers of finback and humpback whales were harvested or sighted in areas of the Bering Sea corresponding to the St. George and North Aleutian Basin planning areas, as well as the Shumagin region of the North Pacific, by Japanese and Russian whaling fleets between 1958 and 1964. More recently, Leatherwood *et al.* *(1983)* observed small numbers of humpbacks in the St. George Basin and finbacks in both the St. George and the North Aleutian basins. Braham (1984*b*) reported that gray whales seen near the Pribilof and St. Matthew islands may demonstrate that not all whales strictly follow the coastline past Unimak Pass but may move offshore through the St. George Basin. These observations identify a wider distribution than we report for humpback, finback, and gray whales. However, our finding that sperm whales do not summer north of the Alaska Peninsula or the eastern Aleutians coincides with the historic distribution of sperm whales (Berzin and Rovnin 1966). While our results generally confirm findings of other investigators, they also indicate that finback and humpback whales have not reinhabited the summer feeding grounds to historic levels.

Of the seven nonendangered species of whales, minke and killer whales and Dan porpoises were generally widespread in all three planning areas. Gross densities (number per nmi) not adjusted for visibility or sea state suggest that the St. George Basin supports the highest densities of these three species. The North Aleutian Basin had the lowest densities of killer whales and Dan porpoises, whereas the Shumagin Planning Area had the lowest density of minke whales. Of the remaining four species, all but the belukha whale were recorded in the Shumagin Planning Area. Belukhas were found only in the North Aleutian Basin. The observed distributions of these species generally agree with findings of other investigators (Leatherwood *et al.* 1983); however, a summary of beaked whale stranding and sighting records by Leatherwood *et al.* *(1983)* showed Baird's and Cuvier's beaked whales occurring in both Bering Sea planning areas. Furthermore they reported relatively large numbers of harbor porpoises in these two planning areas. Consequently, our findings combined with those of other investigators show that beaked and minke whales probably occur in all planning areas in small numbers. Dan porpoises, harbor porpoises, and killer whales are similarly widespread but occur in much larger numbers. Belukhas are primarily found in eastern Bristol Bay.

The distribution of whales in the planning areas generally corresponded to their feeding habits. The endangered species of whales were primarily distributed on the outer continental shelf. Gray, humpback, and finback whales predominantly occurred on or near the shelf waters while sperm whales occurred in deep water outside the shelf. Grays migrated in the nearshore waters less than 40 m deep, while those summering in the study area were generally occurred in bays, lagoons, or nearshore waters. This coastal affinity has been reported in other investigations of gray whales, which typically feed on benthic organisms in shallow waters (<60 m).

While some overlap occurred between distributions of humpback and finback whales, the two species generally used separate feeding areas and geographic ranges. Humpback and finback whales were generally associated with areas of sharp relief near the 50-fathom (91-m) contour on the shelf. Humpbacks were closely associated with oceanic banks while finbacks were more associated with the sharp relief of submarine canyons. (Both of these high relief areas create upwelling which typically supports high production of the zooplankton and fish that humpback and finback whales prey upon.) Furthermore, humpback distribution tended to be greater to the west of the Shumagin Islands, whereas finback distribution was greater to the east.

Sperm whales occurred outside the shelf area in waters exceeding 3,000 fathoms (5,487 m). Sperm whales feed on squid, which are commonly associated with deeper water. Consequently, these four species appeared to partition their use of habitats in the project area.

The nonendangered species distributed themselves somewhat differently among the three water depth zones. The beaked whales occurred exclusively in the deep water zone outside the shelf, where they feed on pelagic schooling fishes. Conversely, killer whales were observed primarily on the shelf, where they feed on pinnipeds and fishes typically associated with nearshore areas. Dan porpoises were encountered in all three zones, a finding which suggests that this species is a more generalistic feeder than the other species. Braham *et al.* (1983) and Leatherwood *et al.* (1983) identified a similarly wide distribution of this species but reported that Dan porpoises were most abundant in deep pelagic water and in areas along the outer continental shelf break. Minke whales were also widely distributed in the three zones. Other investigators report that minke whales inhabit both shallow shelf waters and deep waters (Fiscus *et* al. 1976; Leatherwood *et al.* 1983) but tend to be more prevalent on the shelf waters (Braham *et al.* 1982). Lastly, both harbor porpoises and belukha whales occurred on the shelf in nearshore areas. Belukhas were associated with mouths of rivers in eastern Bristol Bay, where they feed on fish, while the single harbor porpoise observed during our surveys was close to shore. A subsequent sea otter survey conducted in 1986 recorded 53 total groups of harbor porpoises in the shallow shelf waters. Leatherwood *et* al. (1983) similarly reported high occurrences of harbor porpoises on the shelf waters. These results show that cetaceans occurred across all three water depth zones, but the areas on or near the shelf supported the highest diversity of whales.

In conclusion, the results show that a variety of cetaceans inhabit the study area both seasonally and annually. The four endangered species use the area seasonally for feeding and during migration periods, The North Aleutian Basin serves primarily as a migration corridor for gray whales while the Shumagin Planning Area is an important feeding area for humpback, finback, and to a lesser degree, sperm whales. There were no observations of these species in the St. George Basin, although finback whales historically migrated through this basin. The nearshore areas of the North Aleutian Basin and Shumagin planning areas provided important habitat to migrating gray whales. Furthermore, these nearshore areas and bays were important feeding habitat for small numbers of gray whales, particularly in the North Aleutian Basin. Conversely, the high relief areas associated with the oceanic banks and submarine canyons near the outer continental shelf on the Shumagin Planning Area were important habitat to humpback and finback whales. These two species also fed around the island complexes in the planning areas. Sperm whales were outside the shelf in deep waters south of the Alaska Peninsula. Gray whales were probably the most abundant species, although they were primarily transitory. Of the endangered whales feeding in the study area, humpbacks represented the highest number, followed by finbacks and then sperm whales.

The seven nonendangered species inhabit the study area seasonally and some probably annually. Our results combined with others indicate that killer whales, minke whales, Dan porpoises, and harbor porpoises annually occupy the study area. Minke whales and Dan porpoises were probably the most widespread species in the three planning areas, while killer whales and harbor porpoises were more restricted to the shallow shelf waters. Too few belukhas and beaked whales were observed to derive conclusions; however, large concentrations of belukhas are known to summer in eastern Bristol Bay and probably small numbers of beaked whales summer throughout the deeper waters in all three planning areas.

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APPENDIX A

Statistical abbreviations.

$\bar{a}$	Sampling mean of measurements on a circular scale
A_i	Area of planning area i
B	Number of sampling blocks available for survey
b	Number of sampling blocks surveyed
D_i	Density estimator of animal groups in sampling block i
D_{wi}	Weighted density estimator of animal groups in sampling block i
f(o)	Probability density function at zero distance from the trackline
f(x)	Probability density function of perpendicular distances
G	Number of animal groups
$\bar{k}$	Average group size
K_i	Number of animals in group i
Li	Length of trackline searched in sampling block i
n_i	Number of animal groups in sampling block i
N_G	Estimated number of animal groups in study area
N_I	Estimated number of individual animals in study area
$V(D_{wi})$	Sampling variance of weighted density
$V(N_I)$	Sampling variance of estimated number of individuals in study area
V [f(0)]	Sampling variance of the probability density function of zero distance from the trackline
z	Test statistic for circular data

APPENDIX B

Strip transect procedure followed for calculating killer whale density, abundance, and associated variance.

Estimated density: $D_i = \frac{\Sigma n_i}{\Sigma x_i}$

where:

n_i = number of groups in box i of zone i

x_i = area of strip in box i of zone i

Estimated number of groups: $N_G = \sum_{i=1}^{3} A_i D_i$

where: A_i = area of zone i

Estimated number of individuals: $N_I = N_G \bar{k}$

where: $\bar{k}$ = mean group size

Estimated variance for density of groups:

$$V(D_i) = \left[\left[\sum_{i=1}^{b} (ni/xi) - D_i \Sigma n_i\right] / (b-1) \Sigma x_i\right] * \frac{B-b}{B-1}$$

where:

b = number of boxes surveyed in zone i

B . number of boxes in zone i

Estimated variance for number of individuals:

$$V(N_I) = \sum_{i=1}^{3} [A_i^2 V(D_i)] \bar{k}^2 + \sum_{i=1}^{3} [(A_i D_i)^2 V(\bar{k})]$$

$$- \sum_{i=1}^{3} [A_i^2 V(D_i)] V(\bar{k})$$

95 percent confidence interval $N_I \pm 2\sqrt{V(N_I)}$

APPENDIX C

Visibility and glare criteria.

Table C-1. Criteria used to determine relative visibility.

Visibility	Highest Allowed Beaufort Sea State	Descriptors
Excellent	1	Calm and clear
Very Good	2	Surface ripple, some glare.
Good	4	Light chop, glare, fog
Fair	5	Chop, glare, shadows, fog but all animals on line visible
Poor	5	Same as Fair only some animals on line obscured
Unacceptable	--	Survey tract obscured

Table C-2. Criteria used to classify glare.

Glare Number	Percent area obscured by sun reflection, fog, or moisture on window surface
1	1 - 10 percent
2	11 - 25 percent
3	26 - 50 percent
4	51 - 75 percent
5	76 - 100 percent

APPENDIX D

Record of whales encountered in southeastern Bering Sea and northwestern Gulf of Alaska during April-December 1985.

Month /Day/Year	Number	Species[a/]	Latitude	Longitude
7/02/85	1	BA	5500N	16735W
7/02/85	1	BA	5446N	16435W
7/02/85	1	BA	5446N	16435W
7/03/85	1	BA	5535N	16258W
7123185	1	BA	5259N	16351W
10 /30/85	1	BA	5459N	16045W
10 I30I85	1	BA	5458N	16044W
10 I30I85	1	BA	5458N	15855W
6/28/85	5	BB	5418N	15727W
8/26/85	4	BB	5308N	15855W
7/24/85	3	BP	5459N	15809W
7/24/85	1	BP	5456N	15809W
7/24/85	2	BP	5444N	15809W
7/24/85	3	BP	5444N	15809W
7/24/85	2	BP	5444N	15808W
7/24/85	3	BP	5444N	15808W
7/24/85	3	BP	5444N	15809W
7/26/85	1	BP	5511N	15945W
7/26/85	1	BP	5517N	15949W
7/26/85	1	BP	5517N	15951W
8/ 2/85	3	BP	5546N	15858W
8/ 2/85	2	BP	5535N	15757W
8/ 2/85	4	BP	5534N	15757W
8/ 2/85	2	BP	5534N	15757W
8/ 2/85	3	BP	5534N	15751W
8/ 2/85	3	BP	5534N	15754W
8/ 2/85	2	BP	5533N	15754W
8/ 2/85	2	BP	5539N	15745W
8/ 2185	1	BP	5536N	15747W
8/ 2/85	2	BP	5550N	15739W
8/ 2185	4	BP	5551N	15733W
8/ 2/85	1	BP	5550N	15733W
8/ 2/85	3	BP	5549N	15733W
8/ 2/85	2	BP	5548N	15731W
8/ 2/85	2	BP	5548N	15731W
8/ 2/85	3	BP	5548N	15731W
8/ 2/85	4	BP	5548N	15731W
8/ 2/85	3	BP	5551N	15730W
8/ 2/85	2	BP	5551N	15730W
8/ 2/85	1	BP	5552N	15730W
8/ 4/85	1	BP	5455N	15752W
8/ 4/85	1	BP	5456N	15744W
8/21/85	2	BP	5548N	15703W

[a/] Species Codes:

BA=Minke whale
BB=Baird's Beaked whale
BP= Fin whale
DL=Belukha whale
ER=Gray whale
MN=Humpback whale
OO=Killer whale
PC=Sperm whale
PD=Dall 's porpoise
PP=Harbor porpoise
ZC=Cuvier's Beaked whale

Month/Day/Year	Number	Species	Latitude	Longitude
8/21/85	2	BP	5558N	15703W
8/21/85	6	BP	5600N	15703W
8/21/85	2	BP	5603N	15704W
8/21/85	1	BP	5604N	15706W
8/21/85	4	BP	5547N	15709W
8/21 /85	1	BP	5544N	15715W
8/21/85	2	BP	5547N	15715W
8/21/85	2	BP	5547N	15715W
8/21/85	1	BP	5548N	15715W
8/21/85	2	BP	5602N	15716W
8/21/85	2	BP	5549N	15721W
8/21/85	1	BP	5548N	15715W
8/21/85	2	BP	5547N	15716W
8/21/85	1	BP	5547N	15721W
8/21 /85	1	BP	5547N	15721W
8/27/85	2	BP	5556N	15757W
8/27/85	1	BP	5600N	15745W
8/27/85	1	BP	5600N	15745W
8/27/85	2	BP	5558N	15745W
8/27/85	2	BP	5557N	15745W
8/27/85	1	BP	5547N	15739W
8/27/85	2	BP	5548N	15739W
8/27/85	4	BP	5559N	15739W
8/27/85	2	BP	5600N	15739W
8/27/85	2	BP	5600N	15739W
8/27/85	1	BP	5600N	15739W
8/27/85	1	BP	5600N	15733W
8127/85	1	BP	5544N	15733W
8/27/85	2	BP	5546N	15736W
8/28/85	2	BP	5459N	16209W
8/28/85	1	BP	5551N	15803W
8/28/85	2	BP	5551N	15803W
8/28/85	1	BP	5551N	15803W
8/28/85	1	BP	5603N	15809W
8128/85	1	BP	5601N	15809W
8/28/85	1	BP	5558N	15809W
8128/85	1	BP	5558N	15809W
8/28/85	4	BP	5557N	15809W
8/28/85	2	BP	5553N	15809W
8/28185	5	BP	5538N	15809W
8/30/85	1	BP	5528N	15844W
11/12/85	1	DL	5839N	15719W
11/12/85	1	DL	5839N	15719W
11/12/85	1	DL	5840N	15719W
11/12/85	1	DL	5840N	15719W
11/12/85	1	DL	5840N	15719W
11/12/85	3	DL	5843N	15700W
4/28/85	2	ER	5440N	16326W
4/28/85	1	ER	5437N	16340W
4/28/85	4	ER	5423N	16434W
4128/85	8	ER	5425N	16433W
4/28/85	7	ER	5425N	16432W
4128/85	2	ER	5426N	16427W
4/28/85	1	ER	5427N	16424W
4/28/85	16	ER	5428N	16421W

Month/Day/Year	Number	Species	Latitude	Longitude
4/28/85	2	ER	5430N	16419W
4/28/85	1	ER	5438N	16343W
4/28/85	5	ER	5438N	16341W
4/28/85	4	ER	5438N	16339W
4/28185	4	ER	5438N	16333W
4/28/85	1	ER	5439N	16330W
4/28/85	3	ER	5440N	16309W
4/28/85	4	ER	5457N	16244W
5/ 1/85	1	ER	5453N	16212W
5/ 1/85	1	ER	5451N	16213W
5/ 1/85	5	ER	5449N	16216W
5/ 1/85	1	ER	5448N	16217W
5/ 1/85	1	ER	5308N	16227W
5/ 1/85	3	ER	5454N	16227W
5/ 1/85	2	ER	5500N	16213W
5/ 1/85	7	ER	5503N	16201W
5/ 1/85	2	ER	5506N	16156W
5/ 1/85	3	ER	5513N	16151W
5/ 1/85	2	ER	5515N	16150W
5/ 1/85	3	ER	5517N	16148W
5/ 1/85	7	ER	5502N	16146W
5/ 3/85	2	ER	5525N	16059W
5/ 3/85	1	ER	5502N	16140W
5/ 3/85	2	ER	5503N	16200W
5/ 4/85	2	ER	5538N	16009W
5/ 4/85	1	ER	5540N	15958W
5/ 4/85	2	ER	5458N	15918W
5/ 4/85	3	ER	5543N	15922W
5/ 4/85	2	ER	5556N	15853W
5/ 4/85	2	ER	5555N	15839W
5/ 4/85	1	ER	5558N	15834W
6/29/85	1	ER	5516N	16258W
7/06/85	1	ER	5634N	15946W
11/13/85	1	ER	5509N	16315W
11/14/85	1	ER	5504N	16353W
11/14/85	4	ER	5550N	16215W
11/16/85	1	ER	5503N	16344W
11/16/85	1	ER	5505N	16343W
11/16/85	1	ER	5504N	16348W
11/16/85	1	ER	5504N	16350W
11/16/85	1	ER	5504N	16348W
11/16/85	2	ER	5504N	16349W
11/16/85	1	ER	5505N	16352W
11/16/85	1	ER	5501N	16400W
11/16/85	1	ER	5522N	16300W
11/16/85	1	ER	5520N	16258W
11/16/85	1	ER	5552N	16154W
11/16/85	1	ER	5511N	16045W
11/21/85	2	ER	5502N	16352W
11/21/85	1	ER	5501N	16401W
11/21/85	7	ER	5501N	16410W
11/21/85	1	ER	5501N	16407W
11/21/85	1	ER	5502N	16355W
11/23/85	1	ER	5513N	16307W

Month/Day/Year	Number	Species	Latitude	Longitude
11/24/85	4	ER	5505N	16349W
11/24/85	3	ER	5506N	16350W
11/24/85	1	ER	5506N	16350W
11/24/85	3	ER	5515N	16332W
11/24/85	1	ER	5515N	16325W
11/24/85	1	ER	5515N	16316W
11/24/85	1	ER	5515N	16311W
11/24/85	2	ER	5516N	16302W
11/24/85	1	ER	5517N	16303W
11/24/85	2	ER	5517N	16302W
11/24/85	1	ER	5517N	16302W
11/24/85	1	ER	5517N	16301W
11/24/85	1	ER	5518N	16301W
12/02/85	1	ER	5518N	16303W
12/02/85	1	ER	5520N	16302W
12/02/85	1	ER	5520N	16301W
12/02/85	3	ER	5518N	16303W
12/02/85	3	ER	5519N	16303W
12/05/85	3	ER	5500N	16201W
12/05/85	1	ER	5456N	16159W
12/05/85	2	ER	5455N	16159W
12/05/85	2	ER	5459N	16153W
12/05/85	3	ER	5459N	16150W
12/05/85	1	ER	5459N	16150W
12/05/85	1	ER	5500N	16143W
12/05/85	2	ER	5502N	16143W
12/05/85	1	ER	5559N	15823W
12/05/85	4	ER	5557N	15815W
12/05/85	3	ER	5500N	15815W
12/05/85	1	ER	5551N	15845W
12/05/85	1	ER	5551N	15845W
12/05/85	1	ER	5546N	15912W
12/06/85	4	ER	5511N	16307W
12/06/85	1	ER	5513N	16311W
12/06/85	1	ER	5514N	16313W
12/06/85	2	ER	5502N	16357W
12/06/85	3	ER	5520N	16351W
12/06/85	2	ER	5507N	16351W
12/06/85	1	ER	5505N	16351W
12/06/85	1	ER	5504N	16351W
12/06/85	2	ER	5504N	16351W
12/06/85	6	ER	5506N	16348W
12/06/85	2	ER	5501N	16358W
12/06/85	1	ER	5501N	16358W
12/06/85	1	ER	5501N	16358W
12/06/85	1	ER	5503N	16345W
12/06/85	1	ER	5504N	16345W
12/06/85	3	ER	5504N	16345W
12/06/85	1	ER	5505N	16345W
12/06/85	1	ER	5505N	16345W
12/06/85	2	ER	5504N	16342W
12/06/85	2	ER	5504N	16342W

Month/Day/Year	Number	Species	Latitude	Longitude
12/06/85	3	ER	5504N	16340W
12/06/85	2	ER	5515N	16309W
12/06/85	4	ER	5514N	16309W
12/06/85	1	ER	5514N	16309W
12/06/85	3	ER	5512N	16312W
12/06/85	2	ER	5512N	16312W
12/06/85	1	ER	5512N	16312W
12/06/85	3	ER	5512N	16311W
12/13/85	1	ER	5508N	16319W
12/13/85	2	ER	5509N	16322W
12/13/85	1	ER	5508N	16323W
12/13/85	1	ER	5505N	16333W
12/13/85	1	ER	5505N	16335W
12/13/85	1	ER	5504N	16338W
12/13/85	3	ER	5505N	16339W
12/13/85	2	ER	5504N	16339W
12/13/85	1	ER	5505N	16342W
12/13/85	1	ER	5505N	16344W
12/13/85	1	ER	5505N	16347W
12/13/85	1	ER	5505N	16349W
12/13/85	4	ER	5504N	16352W
12/13/85	2	ER	5504N	16352W
12/13/85	1	ER	5503N	16356W
12/13/85	2	ER	5502N	16359W
12/13/85	1	ER	5502N	16359W
12/13/85	4	ER	5501N	16401W
12113185	1	ER	5501N	16401W
12/13/85	1	ER	5501N	16402W
12/13/85	1	ER	5500N	16403W
12/13/85	1	ER	5500N	16404W
12113185	2	ER	5459N	16405W
12/13/85	2	ER	5459N	16405W
12/13/85	2	ER	5459N	16411W
12/13/85	2	ER	5458N	16411W
12/13/85	1	ER	5458N	16412W
12/13/85	1	ER	5457N	16413W
12/13/85	1	ER	5457N	16415W
12/13/85	1	ER	5457N	16416W
12/13/85	1	ER	5456N	16417W
12/13/85	1	ER	5456N	16419W
12/13/85	2	ER	5456N	16422W
12/13/85	2	ER	5456N	16424W
12/13/85	2	ER	5456N	16424W
12/13/85	1	ER	5456N	16425W
12/13/85	1	ER	5456N	16426W
12/13/85	3	ER	5452N	16437W
12/13/85	2	ER	5450N	16436W
12/13/85	1	ER	5450N	16435W
12/13/85	1	ER	5450N	16435W
12/13/85	1	ER	5452N	16434W
12/13/85	3	ER	5448N	16439W
12/13/85	1	ER	5447N	16440W
12/13/85	2	ER	5447N	16440W

Month/Day/Year	Number	Species	Latitude	Longitude
12/13/85	1	ER	5446N	16441W
12/13/85	1	ER	5446N	16441W
12/13/85	3	ER	5446N	16441W
12/13/85	2	ER	5444N	16442W
12/13/85	4	ER	5443N	16443W
12/13/85	2	ER	5442N	16443W
12/13/85	1	ER	5442N	16443W
12/13/85	3	ER	5442N	16443W
12/13/85	1	ER	5441N	16444W
12/13/85	2	ER	5441N	16444W
12/13/85	3	ER	5441N	16444W
12/13/85	2	ER	5441N	16444W
12/13/85	1	ER	5440N	16444W
12/13/85	4	ER	5440N	16444W
12/13/85	3	ER	5440N	16445W
12/13/85	1	ER	5440N	16445W
12/13/85	2	ER	5439N	16447W
12/13/85	1	ER	5439N	16450W
12/13/85	2	ER	5439N	16451W
12/13/85	2	ER	5438N	16453W
12/13/85	1	ER	5438N	16453W
12/13/85	2	ER	5437N	16455W
12/13/85	3	ER	5436N	16456W
12/13/85	2	ER	5436N	16457W
12/13/85	2	ER	5436N	16458W
12/13/85	5	ER	5436N	16458W
12/13/85	3	ER	5435N	16459W
12/13/85	3	ER	5434N	16501W
12/14/85	1	ER	5511N	16310W
12/14/85	1	ER	5511N	16310W
12/14/85	1	ER	5511N	16312W
12/14/85	2	ER	5510N	16312W
12/14/85	1	ER	5506N	16324W
12/14/85	1	ER	5506N	16327W
12/14/85	1	ER	5506N	16327W
12/14/85	1	ER	5505N	16327W
12/14/85	1	ER	5552N	16206W
12/14/85	1	ER	5548N	16208W
12/14/85	1	ER	5547N	16210W
12/14/85	2	ER	5545N	16214W
12/14/85	2	ER	5544N	16215W
12/14/85	2	ER	5532N	16231W
12/14/85	1	ER	5531N	16235W
12/14/85	1	ER	5531N	16236W
12/14/85	1	ER	5530N	16240W
12/14/85	2	ER	5526N	16249W
12/14/85	1	ER	5523N	16254W
12/14/85	2	ER	5519N	16301W
12/14/85	1	ER	5517N	16305W
12/14/85	1	ER	5513N	16313W
12/14/85	3	ER	5513N	16313W
12/14/85	1	ER	5510N	16318W
12/15/85	2	ER	5527N	16237W

Month/Day/Year	Number	Species	Latitude	Longitude
12/15/85	1	ER	5532N	16232W
12/15/85	1	ER	5532N	16232W
12/15/85	1	ER	5533N	16231W
12/15/85	1	ER	5533N	16231W
12/15/85	1	ER	5534N	16230W
12/15/85	1	ER	5534N	16229W
12/15/85	1	ER	5534N	16229W
12/15/85	1	ER	5535N	16228W
12/15/85	1	ER	5535N	16228W
12/15185	1	ER	5538N	16224W
12/15/85	2	ER	5539N	16222W
12/15/85	1	ER	5540N	16221W
12/15/85	1	ER	5540N	16220W
12/15/85	2	ER	5542N	16218W
12/15/85	1	ER	5544N	16215W
12/15/85	2	ER	5545N	16213W
12/15/85	2	ER	5548N	16206W
12/15/85	1	ER	5548N	16206W
12/15/85	1	ER	5549N	16203W
12/15/85	1	ER	5549N	16202W
12/15/85	1	ER	5550N	16159W
12/15/85	1	ER	5557N	16143W
12/15/85	1	ER	5557N	16136W
12/15/85	1	ER	5557N	16136W
12/15/85	1	ER	5557N	16135W
12/15/85	1	ER	5557N	16135W
12/15/85	1	ER	5558N	16131W
12/15/85	1	ER	5558N	16130W
12/15/85	1	ER	5559N	16125W
12/15/85	1	ER	5559N	16118W
12115/85	1	ER	5600N	16117W
12/15/85	1	ER	5602N	16107W
12115/85	1	ER	5602N	16105W
12/15/85	1	ER	5602N	16102W
12/15/85	2	ER	5603N	16056W
12/15/85	1	ER	5603N	16053W
12/15/85	2	ER	5603N	16050W
12/15/85	1	ER	5603N	16036W
12/15/85	3	ER	5618N	16021W
12/15/85	1	ER	5620N	16019W
12/15/85	2	ER	5624N	16013W
12/15/85	1	ER	5624N	16012W
12/15/85	1	ER	5636N	15945W
12/15/85	2	ER	5636N	15945W
12/15/85	1	ER	5637N	15942W
12/15/85	2	ER	5637N	15941W
12/15/85	1	ER	5637N	15940W
12/15/85	2	ER	5639N	15935W
12/15/85	3	ER	5640N	15931W
12/15/85	1	ER	5644N	15922W
12/15/85	1	ER	5644N	15921W
12/15/85	1	ER	5645N	15918W
12/15/85	1	ER	5646N	15917W

Month/Day/Year	Number	Species	Latitude	Longitude
12/15/85	2	ER	5649N	15907W
12/15/85	1	ER	5649N	15906W
12/15/85	2	ER	5650N	15904W
12/15/85	2	ER	5651N	15901W
12/15/85	1	ER	5700N	15842W
12/15/85	1	ER	5659N	15844W
12/15/85	1	ER	5718N	15815W
12/15/85	2	ER	5724N	15808W
12/15/85	3	ER	5738N	15754W
12/15/85	1	ER	5734N	15754W
12/16/85	1	ER	5511N	16315W
12/16/85	1	ER	5510N	16316W
12/16/85	1	ER	5510N	16316W
12/16/85	1	ER	5510N	16314W
12/16/85	1	ER	5509N	16317W
12/16/85	1	ER	5509N	16317W
12/16/85	2	ER	5505N	16330W
12/16/85	2	ER	5505N	16330W
12/16/85	1	ER	5505N	16331W
12/16/85	1	ER	5505N	16343W
12/16/85	1	ER	5505N	16343W
12/16/85	1	ER	5505N	16347W
12/16/85	1	ER	5504N	16350W
12/16/85	1	ER	5504N	16351W
12/16/85	1	ER	5504N	16351W
12/16/85	1	ER	5504N	16352W
12/16/85	1	ER	5503N	16354W
12/16/85	1	ER	5503N	16354W
12/16/85	1	ER	5503N	16355W
12/16/85	2	ER	5502N	16356W
12/16/85	1	ER	5501N	16400W
12/16/85	1	ER	5500N	16401W
12/16/85	2	ER	5459N	16403W
12/16/85	1	ER	5501N	16357W
12/16/85	1	ER	5501N	16359W
12/16/85	1	ER	5500N	16400W
12/16/85	1	ER	5459N	16403W
12/16/85	1	ER	5459N	16405W
12/16/85	2	ER	5459N	16407W
12/16/85	1	ER	5459N	16409W
12/16/85	1	ER	5459N	16409W
12/16/85	1	ER	5459N	16410W
12/16/85	1	ER	5459N	16410W
12/16/85	1	ER	5459N	16411W
12/16/85	2	ER	5457N	16413W
12/16/85	1	ER	5459N	16421W
12/16/85	1	ER	5459N	16426W
12/16/85	1	ER	5457N	16427W
12/16/85	1	ER	5457N	16427W
12/16/85	1	ER	5524N	16256W
12/16/85	1	ER	5523N	16255W
12/17/85	1	ER	5557N	15822W
12/17/85	4	ER	5550N	15657W

Month/Day/Year	Number	Species	Latitude	Longitude
12/17/85	3	ER	5548N	15657W
12/17/85	1	ER	5543N	15651W
12/17/85	3	ER	5557N	15645W
12/17/85	1	ER	5549N	15645W
12/17/85	1	ER	5552N	15643W
12/17/85	3	ER	5556N	15640W
12/17/85	1	ER	5557N	15640W
12/17/85	4	ER	5552N	15639W
12/19/85	1	ER	5510N	16323W
12/19/85	3	ER	5508N	16339W
12/19/85	2	ER	5503N	16352W
12/19/85	2	ER	5503N	16352W
12/19/85	3	ER	5503N	16353W
12/19/85	1	ER	5503N	16355W
12/19/85	1	ER	5502N	16358W
7/04/85	1	MN	5421N	15915W
7104/85	1	MN	5456N	15933W
7/04/85	1	MN	5456N	15933W
7/04/85	2	MN	5456N	15933W
7/04/85	2	MN	5454N	15933W
7104/85	2	MN	5451N	15933W
7/04/85	1	MN	5449N	15932W
7/04/85	4	MN	5437N	15933W
7/04/85	3	MN	5433N	15939W
7/04/85	3	MN	5433N	15939W
7/04/85	3	MN	5433N	15939W
7/04/85	3	MN	5433N	15939W
7/04/85	3	MN	5433N	15939W
7/04/85	3	MN	5435N	15942W
7/04185	2	MN	5436N	15942W
7/04/85	4	MN	5436N	15942W
7/04/85	2	MN	5436N	15942W
7104/85	2	MN	5436N	15942W
7/04/85	1	MN	5436N	15942W
7104/85	1	MN	5436N	15942W
7/04/85	1	MN	5436N	15942W
7104185	1	MN	5437N	15939W
7/04/85	3	MN	5444N	15945W
7/04/85	1	MN	5438N	15945W
7/04/85	3	MN	5437N	15945W
7/04/85	3	MN	5437N	15945W
7/04/85	8	MN	5435N	15945W
7104185	1	MN	5435N	15945W
7/04/85	1	MN	5433N	15945W
7/25/85	3	MN	5459N	16204W
7/25/85	2	MN	5501N	16211W
7/25/85	2	MN	5504N	16206W
7/26/85	2	MN	5509N	15945W
7/28/85	1	MN	5459N	16024W
7/28/85	1	MN	5508N	15851W
7/29/85	1	MN	5459N	16209W
7/29/85	1	MN	5459N	16209W
7/29/85	3	MN	5434N	15945W

Month/Day/Year	Number	Species	Latitude	Longitude
7/29/85	1	“MN	5434N	15945W
7/29/85	1	MN	5434N	15945W
7/29/85	1	MN	5445N	15945W
7/29/85	1	MN	5435N	15957W
8/22/85	1	MN	5410N	16239W
8/22/85	2	MN	5410N	16241W
8/23/85	1	MN	5330N	16357W
8/25/85	4	MN	5508N	16208W
8/25/85	1	MN	5400N	16309W
8/25/85	2	MN	5312N	16303W
8/25/85	1	MN	5404N	16303W
8/26/85	3	MN	5309N	15857W
8/26/85	1	MN	5308N	15857W
8/26/85	1	MN	5259N	15851W
8/26/85	3	MN	5309N	15851W
8/26/85	7	MN	5254N	15843W
8/26/85	2	MN	5254N	15843W
8/26/85	2	MN	5254N	15843W
8/26/85	3	MN	5254N	15843W
8/26/85	6	MN	5254N	15843W
8/26/85	1	MN	5254N	15843W
8/26/85	1	MN	5300N	15839W
8/26/85	4	MN	5300N	15839W
8/26/85	3	MN	5301N	15839W
8/26/85	2	MN	5301N	15839W
8/26/85	1	MN	5303N	15839W
8/26/85	3	MN	5310N	15833W
8/26/85	3	MN	5310N	15833W
8/26/85	1	MN	5302N	15833W
8/27/85	3	MN	5557N	15757W
8/27/85	1	MN	5503N	15757W
8/27/85	2	MN	5506N	15751W
8/27/85	1	MN	5505N	15745W
8/27/85	1	MN	5504N	15745W
8/27/85	1	MN	5503N	15745W
8/27/85	1	MN	5503N	15745W
8/27/85	1	MN	5501N	15745W
8/27/85	2	MN	5501N	15739W
8/27/85	1	MN	5504N	15741W
8/28/85	1	MN	5459N	16209W
8/28/85	1	MN	5459N	16209W
8/28/85	1	MN	5508N	15809W
10/24/85	1	MN	5248N	16203W
10/24/85	1	MN	5252N	16209W
10/24/85	1	MN	5252N	16209W
10/24/85	1	MN	5255N	16209W
10/24/85	1	MN	5256N	16209W
10/24/85	1	MN	5255N	16215W
10/24/85	1	MN	5244N	16215W
10/26/85	1	MN	5249N	16245W
10/26/85	1	MN	5243N	16245W
11/10/85	1	MN	5505N	15745W
11/11/85	1	MN	5426N	16057W

Month/Day/Year	Number	Species	Latitude	Longitude
11/11/85	1	MN	5426N	16057W
11/11/85	1	MN	5426N	16057W
11/11/85	1	MN	5425N	16057W
11/11/85	2	MN	5424N	16057W
11/11/85	4	MN	5423N	16100W
11/11/85	1	MN	5424N	16059W
11/11/85	2	MN	5425N	16059W
7/03/85	1	00	5500N	16157W
7/03/85	2	00	5500N	16157W
7/03/85	1	00	5500N	16157W
7/04185	1	00	5419N	15927W
7104185	4	00	5421N	15927W
7/04/85	4	00	5419N	15939W
7/23/85	2	00	5459N	16233W
7/25/85	5	00	5419N	16445W
7/25/85	1	00	5421N	16421W
7/25/85	3	00	5430N	16409W
7/25185	3	00	5430N	16410W
7/25/85	1	00	5517N	16121W
8/ 4/85	5	00	5448N	16123W
8/25/85	5	00	5508N	16109W
11/13/85	1	00	5539N	16303W
11/14/85	1	00	5522N	16345W
12/13/85	1	00	5448N	16645W
12/13/85	3	00	5448N	16645W
12/13/85	1	00	5448N	16645W
12/13/85	3	00	5449N	16645W
12/13/85	6	00	5419N	16609W
12/13/85	9	00	5419N	16609W
12/13/85	1	00	5419N	16609W
12/13/85	2	00	5419N	16609W
12/14/85	1	00	5710N	16515W
7124/85	5	Pc	5409N	15809W
8/25185	5	Pc	5333N	16303W
8125/85	2	PC	5333N	16303W
8/25185	2	PC	5333N	16303W
8/25/85	1	PC	5333N	16303W
8/25/85	7	PC	5333N	16303W
8/25/85	1	PC	5333N	16303W
6/28/85	2	PD	5430N	15751W
6/28/85	2	PD	5444N	15751W
7/01/85	6	PD	5406N	16632W
7/02/85	4	PD	5532N	16909W
7/02/85	2	PD	5525N	16903W
7102/85	2	PD	5522N	16903W
7/02/85	1	PD	5500N	16742W
7/04185	1	PD	5406N	15951W
7/24/85	5	PD	5410N	15809W
7/27/85	2	PD	5335N	16157W
7/28/85	1	PD	5501N	16117W
8/ 2/85	4	PD	5532N	15733W
8/26/85	1	PD	5328N	15857W
8/26/85	1	PD	5325N	15857W

Month/Day/Year	Number	Species	Latitude	Longitude
8/26/85	2	PO	5317N	15857W
8/26/85	7	PD	5307N	15857W
8/26/85	7	PD	5259N	15851W
8/26185	8	PC)	5309N	15854W
8/26/85	1	PD	5320N	15850W
8/26/85	4	PD	5325N	15851W
8/26/85	4	PD	5325N	15851W
8/26/85	5	PD	5332N	15851W
8/26/85	6	PD	5332N	15851W
8/26/85	1	PD	5336N	15851W
8126/85	2	PD	5339N	15851W
8/26/85	2	PD	5341 N	15851W
8/26185	8	PD	5330N	15845W
8/26/85	1	PD	5302N	15845W
8/27/85	4	PO	5658N	15626W
8/28/85	2	PD	5557N	15809W
10/19/85	2	PD	5339N	16403W
10/19/85	1	PD	5258N	16332W
10/29/85	3	PD	5536N	16009W
10/30/85	1	PD	5532N	15815W
10/30/85	2	PD	5505N	15803W
12/13/85	3	PD	5414N	16605W
12/13/85	2	PD	5411N	16607W
12/13/85	5	PD	5459N	16639W
12/14/85	4	PD	5642N	16445W
12/14/85	3	PD	5651N	16502W
12/14/85	2	PD	5743N	16515W
12/14/85	2	PD	5748N	16449W
12/14/85	1	PD	5749N	16429W
12/16/85	2	PD	5614N	16503W
12/16/85	6	PD	5625N	16507W
12/16/85	5	PD	5759N	16543W
12/16/85	1	PD	5728N	165431
12/16/85	3	PD	5618N	16443W
12/17/85	8	PD	5515N	15633W
8/27/85	1	PP	5713N	15617W
8126/85	2	ZC	5329N	15857W