CALIFORNIA GRAY WHALE (*ESCHRICHTIUS ROBUSTUS*)

FALL MIGRATION THROUGH

UNIMAK PASS, ALASKA, 1977

by

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ABSTRACT

California gray whales were censused from 20 November to 9 December 1977 as they passed Cape Sarichef, Unimak Island, Alaska, on their fall migration out of the Bering Sea. During 82.5 hours of systematic observations, 2,055 southbound whales were sighted. Assuming no diurnal variation in rates of movement, 11,179 ± 878 whales passed during the study period. Adding an estimated 3,920 ± 1,463 whales for sightings missed before and after the survey, based on the distribution of rates of sightings, approximately 15,099 ± 2,341 gray whales left the Bering Sea through Unimak Pass. The east shore of this pass is undoubtedly the principal migratory corridor (71% of the sighted whales passed within 730 m of the shore). Peak counts occurred on 22 and 23 November when a maximum rate of 52.8 per hour was reached. Correlating this peak with the peak in counts at Point Loma, California, on 11 January 1978, allowed us to calculate a mean travel speed of 4.3 km/hr along the coastal contour.

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INTRODUCTION

The timing and location of the California gray whale's (*Eschrichtius robustus*) fall migration out of the Bering Sea have been speculated on since Scammon (1874) described their general route. Pike (1962) assumed the whales left the Bering Sea in November and December based on a letter from G. T. Bush of the US Coast Guard at Cape Sarichef in 1962 describing some 200 gray whale sightings along the shore there principally between 5 and 15 December. We conducted vessel and helicopter surveys in the eastern Aleutian Islands and along the western Alaska Peninsula coast on 21 - 25 October 1976 (Braham, Everitt, Krogman, Rugh, and Withrow, 1977) but found no gray whales. From these records we estimated that the peak of the whale migration should occur in late November or early December.

Scammon (1874) assumed that the gray whale "follows the general trend of an irregular coast..." (p. 32). This tendency to follow the coastline during the spring was demonstrated by Pike (1962) as far north as Dixon Entrance, British Columbia. Evidence also comes from fall sightings of gray whales at Yakutat Bay and on the southwest side of Kodiak Island by personnel of the National Marine Fisheries Service and the Alaska

Department of Fish and Game (MacIntosh and Calkins pers. comm.) and in the spring by Wilke and Fiscus (1961). The fall migration probably is as coastal as the spring migration (Braham, 1978). Whales passing into or out of the Bering Sea would then be most likely to use the easternmost passes,as described by Ichihara (1958), Pike (1962), Rice and Wolman (1971), and later by Gilmore (1978), though use of passes to the west has been hypothesized (Gilmore 1968). The lack of sightings to the west of Unimak Pass and the many sightings along the north coast of the Alaska Peninsula (Braham et al. 1977) encouraged us to survey Unimak Pass, as that seemed the most probable route for gray whales exiting the Bering Sea.

METHODS

A single observer (Rugh) maintained systematic watches for gray whales during daylight hours at Cape Sarichef from 20 November to 9 December 1977. The observation point, used consistently throughout this study, was 30.5 m above sea level on the bluff directly west of the US Coast Guard Station. The viewing area covered an arc of 150°, which meant a surface area of 12 km^2 when 3 km is considered the outer limit of visibility. During the 17 days of observation, the average time on watch was 4.9 hours per day (range 1.3 to 7.0 hr/day). There were never more than 7.5 hours of daylight during any one day of the study period. Each passing whale was recorded when it crossed an imaginary line extending 70°W of N from the observation point. Notes were made on timing, pod size, direction of movement, size of individuals, distance from shore (in degrees below the horizon measured with inclinometer), and significant behaviors. Photographs, notes, and sketches were made to identify characteristic markings of individuals. Every half hour environmental conditions were recorded.

STUDY AREA

Cape Sarichef on Unimak Island, Alaska, was selected because it is a promontory from which gray whales could be easily watched during their southbound migration through Unimak Pass (Fig. 1). The US Coast Guard/ LORAN Station at Cape Sarichef provided a convenient support facility. The cape is the westernmost point of Unimak Island (54°36'N, 164°56'W)--the western end of the land mass separating the eastern Bering Sea from the North Pacific Ocean. False Pass is the only pass to the east, but breakers and depths of less than 4 m at the north entrance apparently discourage whales from using it as a route.

During the study period from 20 November to 9 December, temperatures ranged from -5° to +6°C (mean 0°C) and winds rose to velocities over 90 km/hr (mean 33 km/hr). The wind was from the north and northeast 92% of the recorded time. During observation periods, overcast and partly cloudy conditions were noted 70% of the time; precipitation occurred in the form of rain, sleet, or snow 7% of the time.

RESULTS AND DISCUSSION

Census

A total of 2,163 gray whales were counted going south and 108 going north during 82.5 hours of systematic observations from Cape Sarichef. Subtracting northbound from southbound sightings (it was assumed all of these whales eventually went south) gave a net total of 2,055 migrating whales (Table 1). The mean number of whales-per-hour was calculated for each day and multiplied by 24 hours (we assumed no diurnal variations in our estimate that 11,179 whales passed).

A 95% confidence interval was determined _a. posteriori_ by using southbound counts from each 15 min interval with each day treated as a separate domain(j). The sum of the daily variances (Σ var $(\hat{y}_j)$) equals the variance for the estimated total number of whales $(\hat{y})$ passing during the study period. Therefore, the confidence interval was estimated as $\hat{y} \pm t_a \sqrt{\text{var}\ (\hat{y})}$ where t_a = 2.093 from a t-distribution table for a = 20 (number of days) and $\text{var}(\hat{y}) = \Sigma\ \text{var}\ (\hat{y}_j)$. Utilizing Cochran's (1963) techniques for estimating the standard error of totals over subpopulations (domains), each var $(\hat{y}_j)$ was calculated as $(N_j^2)(\text{var}(\bar{y}_j))$ for N_j = 96 (number of intervals per domain), where var $(\bar{y}_j)$ was based on $s_j^2/n_j(1 - n_j/N_j)$, s_j is the standard deviation for each day, and n_j is the number of sampled periods per day. Values for unsampled domains were estimated by using $(\Sigma y_1\ \Sigma y_3\ /n_1+n_3)$ where j = 1 and 3 are days neighboring the unsampled domain (j = 2). The variance for unsampled domains was estimated by treating neighboring days as representative of the missing day, letting $n_2 = n_1+n_3$. Therefore 11,179 ± 878 gray whales passed Cape Sarichef between 20 November and 9 December.

TABLE 1.--Summary of gray whale counts from Cape Sarichef, Alaska, 20 November to 9 December, 1977.

Date		Whale count	Hours of watch	Whales per hour	Whales per 24-hour
November	20	27	1.25	21.6	518.4
	21	93	4.25	21.9	525.2
	22	249	5.00	49.8	1195.2
	23	277	5.33	52.8	1266.3
	24	196	5.00	39.2	940.8
	25	238	7.00	34.0	816.0
	26	189	5.50	34.4	824.7
	27	110	4.00	27.5	660.0
	28	44	2.00	22.0	528.0
	29	--	no watch	----	est. 425.6
	30	89	5.50	16.2	388.4
December	1	81	5.00	16.2	388.8
	2	87	5.25	16.6	397.7
	3	--	no watch	----	375.5
	4	89	6.00	14.8	356.0
	5	71	4.00	17.7	426.0
	6	94	7.00	13.4	322.3
	7	73	6.00	12.2	292.0
	8	--	no watch	----	est. 276.6
	9	48	4.50	10.7	256.0
Total		2,055	82.5		11,179

Coast Guard personnel at Cape Sarichef first sighted whales in late October (treated here as one whale for 31 October); by 12-13 November "lots" of whales were seen (treated here as five whales per hour). Using these accounts and our data for 20-23 November, we applied theoretical distributions which enabled us to estimate the number of whales passing prior to our survey. An exponential curve fit these points well ($r^2 = 0.96$) based on $\hat{y} = 0.05e^{0.3x}$ with an estimated 1,709 whales for 31 October to 20 November. A power curve fit even better ($r^2 = 0.98$), based on $\hat{y} = 0.04x^{2.17}$ though with a dramatically higher estimate of 3,895 whales. The mean of these two estimates, 2,802, approached the estimate from the best curvilinear fit drawn graphically (Fig. 2) to approximate the count distribution (2,621). Therefore we may estimate 2,802 ± 1,093 whales passed before our survey began. (In all cases referring to population estimates, $\hat{y}$ is the estimated number of whales passing on day x).

Similarly, applying a linear regression ($\hat{y} = 17.42 - 0.85x$; $r^2 = 1.00$) to data for 2-9 December (excluding the anamolous 5 December count) allowed us to estimate that 1,487 whales passed after the survey was terminated (including the 5 December value merely adds three whales to this estimate). A second order polynomial equation ($\hat{y} = 16.58 - 0.03x - 0.06x^2$) also approximated the distribution of counts after 9 December ($r^2 = 0.90$). By this method we calculated that 748 whales had passed. Using both of these estimates, we approximated that 1,118 ± 370 whales went through Unimak Pass after the end of our survey.

Adding the estimated 2,802 ± 1,093 whales passing prior to our survey, and the 1,118 ± 370 passing after our survey to the 11,179 ± 878 estimated during the survey resulted in a total of 15,099 ± 2,341 gray whales migrating out of the Bering Sea.

Rice (1975) estimated that 11,000 (± 2,000) gray whales pass the counting stations in California (based on an assumed constant day and night travel rate). Presumably all whales swim south of the Alaska Peninsula in the fall, but it seems unlikely that the entire population continues to the southern extension of their migratory route. Hatler and Darling (1974) observed gray whales off Vancouver Island, British Columbia, most of the winter. Other sporadic sightings made between California and British Columbia suggest that some animals do not complete their southern migration. There is also evidence that a portion of the population does not go as far north as the Bering Sea (Pike 1962; Hatler and Darling,1974), but the size of this portion and how much it might affect a total population estimate of 15,000 is unknown.

Evidence from sightings in California shows that the gray whale population has stabilized since 1960 following its rise from exploitation levels in the late 1800's (Rice, 1975). Henderson (1972) estimated that the population prior to the period of commercial harvesting was not more than 15,000, an estimate also used by Rice (1975), though considerably less than Gilmore's (1955) 25,000. This 15,000 figure matches our estimate of the present gray whale population of 15,099 animals, though we have not included an estimate of the number of whales that stay south of the Bering Sea in the summer.

Sightability of Whales

Seven categories of visibility were devised, from excellent to unacceptable, combining all factors bearing on the observer's ability to sight a surfacing whale within the 12 km^2 viewing area. If counts were strictly dependent on visibility, time spent during good to excellent conditions should have resulted in higher counts than during poor conditions. Kendall's Test for Independence (Hollander and Wolfe, 1973), applied to counts categorized by visibility through the season, showed no significant correlation ($P = 0.14$). Therefore all visibility categories could be treated equally. When the observer was convinced whales could pass unseen, the visibility was considered unacceptable and the systematic watch suspended.

Whale counts were compared on a per minute basis as a function of time from the beginning of each watch period ($n = 49$ for the first 30 minutes, dropping to 26 at 120 minutes). The per minute averages were tested for a decrease in counts that might have been related to observer fatigue through the two-hour watch period. A low slope coefficient ($r^2 = 1.56 \times 10^{-6}$) indicated no correlation between time of watch and whale counts; therefore no correction factor was necessary.

Whales were visible to the observer for an average of 19.5 ± 1.9 sec, established by multiplying the mean number of blows observed per whale, 3.9 ± 0.3 ($n = 247$), and the mean time at the surface, 5.0 ± 0.1 sec ($n = 292$). Surface times were measured between the blow and the submergence of the caudal ridge or fluke. These timings ranged from 1.4 to 9.2 sec. On calm days when spray from a blow would hover, a whale's presence would be recognized for even longer periods. Southbound whales that did not deviate from their course were seen up to eleven times each. A whale could be followed for potentially longer periods, but during this census emphasis was placed on counts. Whales were identified by single blows only 3.2% of the time, suggesting small likelihood of "zero blows", that is, whales passing without being recorded.

Distance from shore

Distance offshore was recorded for each whale by measuring its angle below the horizon with a handheld inclinometer. These angles were converted to meters offshore and corrected for the distance to the outermost rocks along the shore. All whale sightings occurred within twelve distance sectors, including the most distant (1.6 to 3.0 km).

Of all the southbound whales sighted, only 29% were more than 730 m offshore (sectors 1 and 2) compared to 64% off Granite Canyon and 89% off Point Loma, California (Rice, pers. comm.). The whales apparently follow the shore of Unimak Island much more closely than the shores of California, perhaps related to the way the Alaska Peninsula obstructs the general orientation of their route.

The distribution of sightings offshore of Cape Sarichef was more a function of whale distribution than of visibility decreasing with distance. No differences between counts made in excellent versus poor conditions was evident when plotted against distance offshore ($P < 0.001$; Kendall's Test for Independence). Also, when the surf was high, one would have expected whales to be less visible farther offshore. The data show, however, that when the surf was less than 2 m high, 22% of the sightings were more than 730 m offshore compared to 72% when the surf was high (Fig. 3). High surf conditions shifted whale distribution seaward, presumably because of the increase in noise or the dangers of the nearshore surf. During calm weather whales passed very close to the rocky shore, some as close as 13 m.

Seventy-three percent (73%) of the whales within 50 m of shore were yearlings or small whales, whereas beyond 100 m 77% of the whales were medium to large. Leatherwood (1974) also observed no yearlings in offshore areas off southern California.

Relative Whale Sizes

Whenever conditions allowed, whale sizes were estimated and recorded. A total of 553 animals were categorized, of which 13% were large, 57% medium, 25% small (presumably 2-3 year olds), and 5% were yearlings. Large whales decreased in occurrence as the season progressed while yearlings became more common; most yearlings (93%) passed during the first week of December. Medium and small whales showed no distinct temporal trend during the study.

Using a least squares procedure, a polynomial equation ($\hat{y} = 4.31 - 2.93x + 0.44x^2 - 0.01x^3$) was applied to the data to approximate the percentage distribution of yearling sightings ($\hat{y}$) versus time (x). From this relation, the number of yearlings passing each day during the study period was estimated (using only $\hat{y} > 0$ for 26 November to 9 December). The sum of these estimates, 337 yearlings, is 3.0% of the population passing during the survey (11,179).

Pod Sizes

There was no apparent change in pod size through time ($r^2 = 0.17$), the mean size being 1.95 ± 0.07 whales and maximum 9 (for 1,253 pods). Only those groups traveling close enough together to allow frequent contact were considered pods. Although many whales traveled in loose association, they appeared haphazardly arranged relative to the discrete pods which swam and surfaced together.

Course Deviations

Not all whales were strictly southbound. Course deviations were noted on 171 occasions involving 324 whales, which is 12% of the whales passing Cape Sarichef. These deviations increased through time indicating a greater percentage of casual travelers later in our survey. Initially only 2.2% of the sightings were recorded as other than southbound; by the end of the study period, this occurred with 29.2% of the sightings. Most (61%) of the deviations were northbound whales (it was assumed all whales turned south eventually). It was likely, then,that whales intent on getting tc the winter breeding lagoons, such as pregnant females, would have been at the front of the migration, making few diversions while enroute. Later whales may have been more involved in social interactions and were less likely to reach California that year.

Diurnal Variations

Whale counts were categorized by time of day to test for diurnal variations. Time was adjusted relative to the position of the sun (daylight hours became increasingly fewer as the study progressed). Data for each 15 min interval were divided by the total estimate for the respective day in order to remove seasonal variations in numbers of whales passing the observation point. Mean values show no apparent pattern (Table 2). No regression can be found in counts from dawn to noon (r^2 = 0.05) nor from noon to dusk (r^2 = 0.15). Cumulative twilight data (adding dawn and dusk figures) also show no trend in counts relative to light level (r^2 = 0.09).

If whales slowed down with increased darkness, their surface timings might have increased; that is, with slowed movement, we may expect whales to spend more time at the surface with each blow. Using cumulative dawn and dusk data to increase the sample size, surface timings were compared as a function of light. No statistically significant regression was apparent (r^2 = 0.50).

If whales slowed their rate of travel at night, there might have been an increase in the number of deviations from a strictly southbound course. That is, with decreased light levels, we might expect a greater incidence of whales swimming north, traveling irregularly, or engaging in social interactions. Using pooled dawn and dusk data in the same manner as for surface timings, we found no significant trends in direction of travel (r^2 = 0.53) with decreases in light.

TABLE 2.--Mean counts of whales ($\bar{x}_1$) distributed through the day as observed from Cape Sarichef, Alaska, 20 November to 9 December 1977. Counts are corrected ($\bar{x}_2$) to remove seasonal variation by dividing each value by the estimated total for the respective day. Values for (n) indicate number of data points. The standard deviation (S.D.) is based on the corrected values for each day.

	$\bar{x}_1$	$\bar{x}_2$	n	S.D.
	5.0	0.46	1	-
	4.7	1.98	3	0.94
-4 hr				
	4.5	0.99	6	0.92
	5.7	1.24	9	0.49
	4.5	1.16	11	0.53
Sunrise				
	5.5	1.00	12	0.90
-3 hr				
	5.8	1.30	16	1.14
	5.3	1.26	10	0.52
	5.8	1.00	12	0.85
	4.4	1.24	18	1.22
-2 hr				
	7.4	1.22	13	1.22
	12.8	1.20	7	0.22
	8.3	1.09	7	0.36
	10.2	1.08	6	0.61
-1 hr				
	7.0	1.23	7	0.74
	9.7	0.72	6	0.70
	7.9	0.35	10	0.66
	5.9	1.27	11	1.03
Noon				
	7.1	0.86	10	0.59
	7.4	1.61	12	1.17
	7.0	1.21	12	0.87
	7.0	1.58	11	0.98
+1 hr				
	7.1	1.37	12	0.94
	6.2	0.91	12	0.85
	9.2	1.80	18	2.85
	7.2	1.23	9	0.77
+2 hr				
	6.2	1.59	12	1.39
	5.2	0.99	13	0.79
	7.1	1.30	13	0.89
	5.6	0.80	12	0.58
+3 hr				
	5.9	1.00	13	0.64
Sunset				
	7.5	0.78	5	0.48
	8.4	0.80	3	0.70
	7.0	0.49	2	0.69
+4 hr				
	5.0	1.55	1	-

Although Gilmore (1960) and Adams (1968) used arbitrary correction factors to estimate nocturnal rates (50% and 70% respectively), and Hubbs and Hubbs (1967) as well as Ramsey (1968) believed there was some evidence of diurnal variations in rates of movement, we found no evidence to reject the hypothesis that nighttime travel rates equal daytime rates. Cummings et al. (1968), Rice and Wolman (1971), IWC (1976 and 1977), and Leatherwood (pers. comm.) have also found no apparent differences between day and night rates of travel.

Rate of Travel

Distinct peaks in whale counts were observed at Cape Sarichef on 23 November 1977 and at Point Loma on 11 January 1978 (D. Rice, pers. comm.) with rates of 53 and 48 whales per hour respectively. The shortest possible route between these points across the Pacific Ocean is 4,413 km (2,383 nm). A route following the coastal contour is 5,056 km (2,730 nm). The pelagic route, only 643 km shorter, is not especially advantageous if gray whales rely on coastal features for guidance while migrating (Gilmore, 1960; Pike, 1962). Coastal sightings, referred to earlier, allow us to assume the coastal contour is the preferred migratory route.

In order to cover the 5,056 km between Cape Sarichef and Point Loma in 49 days, whales must have averaged 4.3 km/hr. But if traveling rates dropped at night to 50% of daytime rates (Gilmore, 1960), an average of 5.9 km/hr must have been maintained during daylight hours (47% of this portion of their migration occurred during the day calculated from average sunrise and sunset timings for Cape Sarichef and Point Loma plus two hours of twilight per day). If no travel occurred at night, the whales would have averaged 9.1 km/hr.

Wyrick (1954) and Cummings et al. (1968) calculated gray whale travel rates at 8.5 and 10.2 km/hr respectively for observation periods of less than three hours per whale. Rice and Wolman (1971) estimated speeds of 7 to 9 km/hr. Leatherwood (1974) calculated a mean rate of 2.8 km/hr based on two to three days of observation, but this was for northbound whales which travel slower than southbound whales. Pike (1962) estimated speeds of 3.7-7.4 km/hr from sightings made between British Columbia and San Diego, California. Our estimated rate of 4.3 km/hr for a 49 day period matches Pike's calculation well. It is evident that the greater the distance used to calculate the rate of migrating whales, the slower the average speed will be --which may be related to deviations in the migration either when whales use detours or when they spend time involved in non-migratory activity. It seems evident there is adequate time for whales to use a course following the coastal contour rather than a direct, pelagic route. From these calculations, it is not evident, however, as to whether or not there is a reduced rate at night.

CONCLUSION

On the basis of 82.5 hours of observations and 2,163 gray whale sightings made from Cape Sarichef at the west end of Unimak Island, Alaska, it is estimated that 11,179 ± 878 whales migrated south out of the Bering Sea between 20 November and 9 December 1977. Combined with extrapolations for whales passing prior to the survey (2,802 ± 1,093) and after the survey (1,118 ± 370), these data resulted in a total population estimate of 15,099 ± 2,341 gray whales exclusive of those that did not migrate into the Bering Sea in the spring. No correction factors for visibility, observer fatigue, or diurnal variations in net rates of movement appear to be necessary. This population estimate equals the estimate made by Henderson (1972) for the original stock size.

We have delineated the time frame of the migratory exit from the Bering Sea as being from early November to late December; an estimated 74% of the whales passed between 20 November and 9 December.

The principal migratory corridor was through Unimak Pass with 71% of the whales sighted within 73 m of the west shore of Unimak Island.

It was approximated that 3.0% of the whales were yearlings. Small whales tended to follow the coast more closely than larger whales.

The mean pod size was 1.95 ± 0.07 whales with no apparent seasonal trend.

Course deviations (12% of the recorded sightings turned from a south-bound migratory course) increased throughout the study period indicating that the whales most likely to reach the breeding lagoons in Baja California were already at the front of the migration in Unimak Pass.

Gray whales appear to select a coastal route on their migration from the Bering Sea to Baja California. Between Cape Sarichef and the counting station at Pt. Loma, California, this would mean 5,056 km, which was covered in 49 days at an average rate of 4.3 km/hr.

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FIGURE 1.--Study area at Unimak Pass. The observation point was located at Cape Sarichef on Unimak Island, Alaska.

FIGURE 2.--Distribution of counts of gray whales migrating south past Cape Sarichef, Alaska, November and December, 1977. Areas to the left of 20 November and to the right of 9 December are extrapolated.

FIGURE 3.--Density distribution of gray whales offshore of Cape Sarichef, Alaska, 20 November to 9 December 1977. Sightings occurring during surf conditions greater than 2 m are indicated by the dashed line.

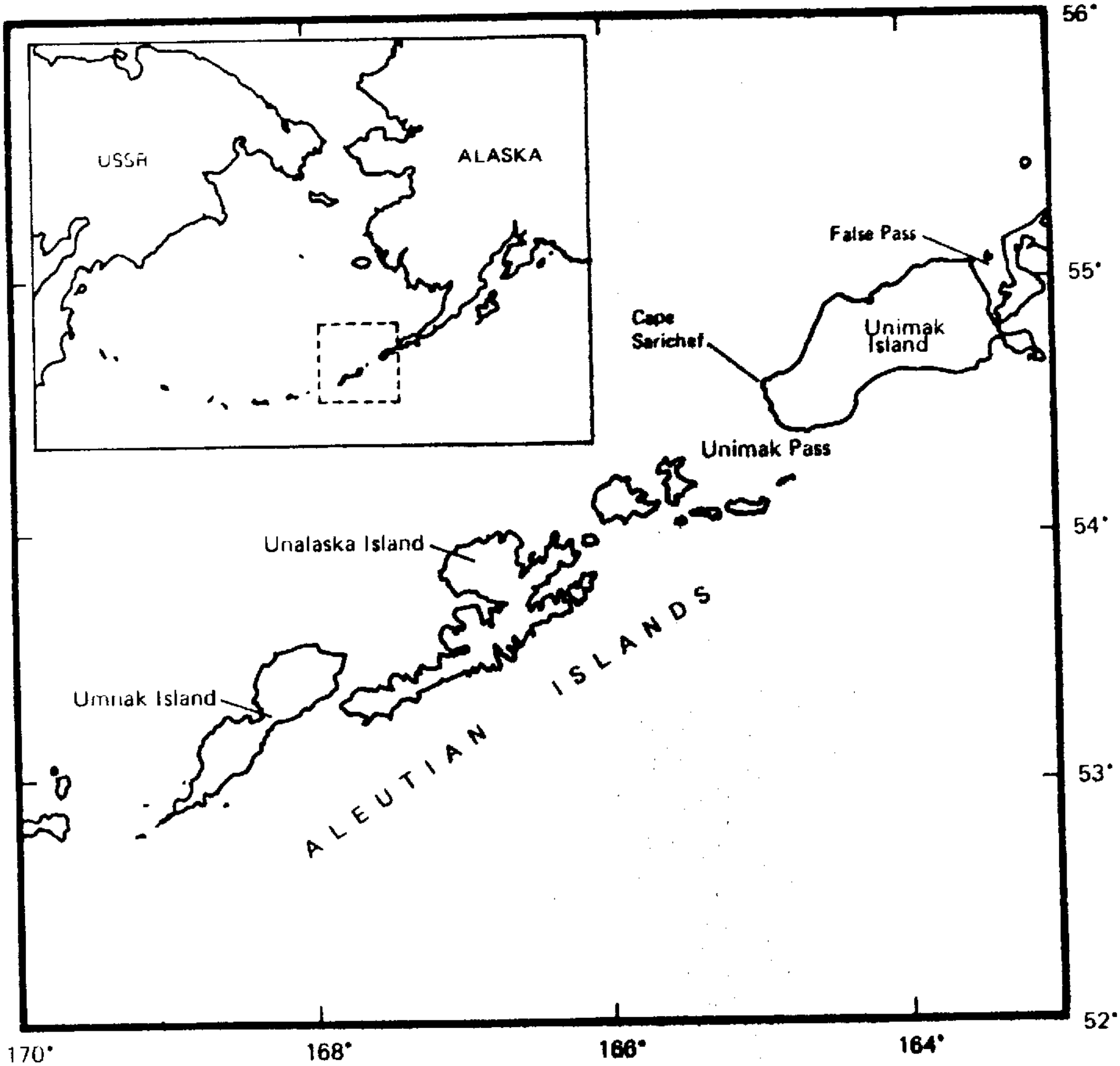
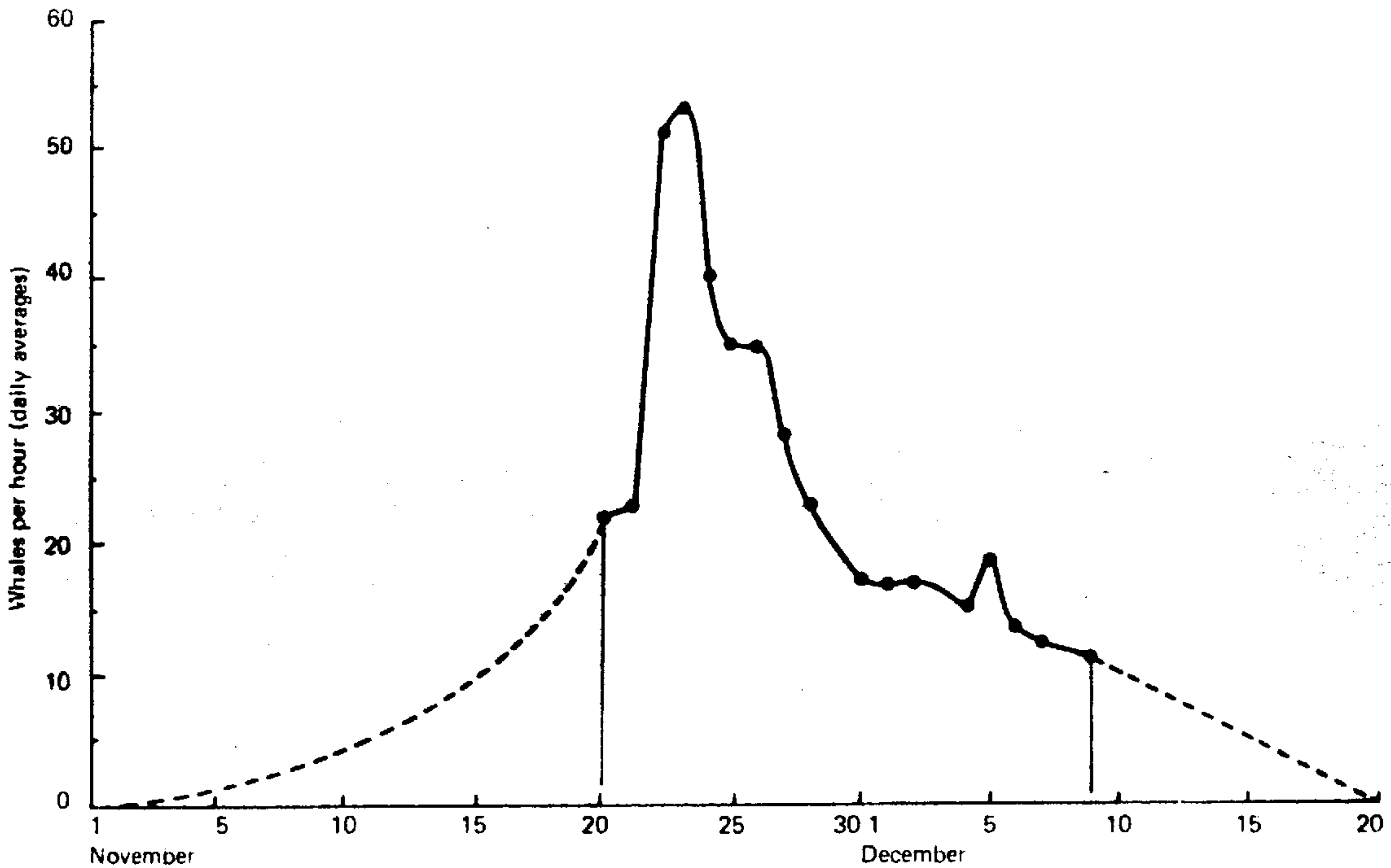
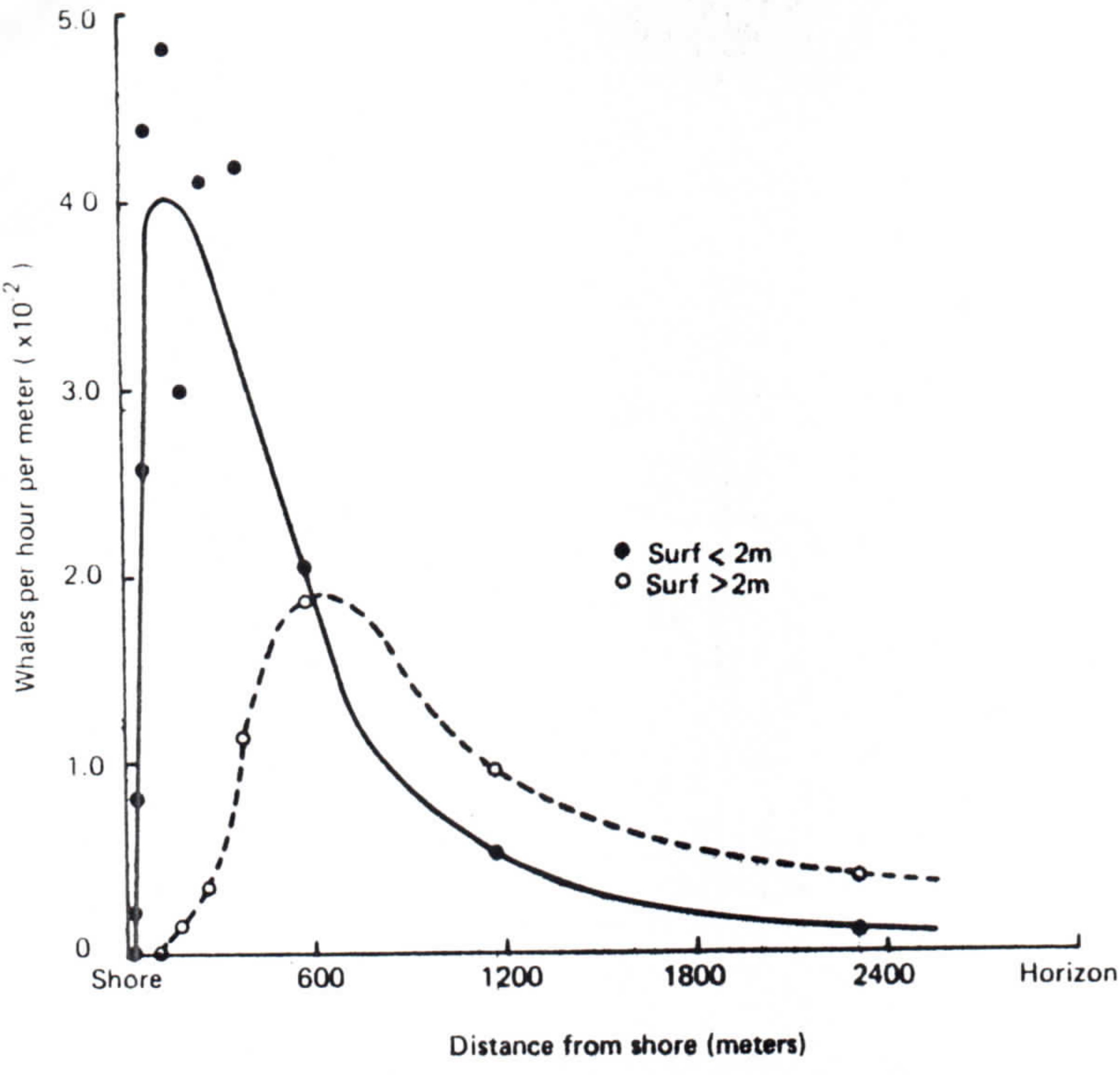


Fig. 1 (Rugh/Braham)


Whales per hour (daily averages)
60
50
40
30
20
10
0
1
5
10
15
20
25
30 1
5
10
15
20
November
December


5.0
4.0
3.0
2.0
1.0
0
Whales per hour per meter (x10⁻²)
Surf < 2m
Surf >2m
Shore
600
1200
1800
2400
Horizon
Distance from shore (meters)

[illegible]