13

Gray Whale Migrations along the Oregon Coast, 1978–1981

Denise L. Herzing and Bruce R. Mate

Introduction 289
Methods 290
Study Area 290
Field Study 290
Analysis 291
Results 292
Migratory Timing 292
Uncorrected Estimates 295
Pod Size 296
Distribution Relative to Shore 297
Pod Size versus Distribution Relative to Shore 298
Aerial Surveys 299
Discussion and Conclusions 301
Migratory Timing 301
Pod Size and Distribution Relative to Shore 302
Population Size 304
Estimates of Calf Production 304
Summary 306
References 306

Introduction

Studies of gray whale (*Eschrichtius robustus*) movements along the eastern Pacific coast of North America previously have emphasized the fall (southward) migration, primarily to develop abundance estimates. No previous studies have monitored fall and spring migrations continuously from the same location. This chapter reports a 3-year study (1978–1981) designed to document migratory timing, pod-size frequency, and distribution relative to shore of gray whales during their fall and spring migration along the Oregon coast. Estimates of abundance were made for comparison with those from other studies.

ISBN 0-12-389180-9

Methods

STUDY AREA

Gray whales were observed from November through May, 1978–1981, from the Yaquina Head Lighthouse, located on a rocky headland 4.8 km north of Newport, Oregon (44°41′N, 124°05′W) (Fig. 1). From the observation platform 50 m above sea level, visibility extends 35 km to the horizon. Prevailing winds are from the southwest in the fall and winter and from the northwest in spring and summer. The 10- and 20-fathom contours are parallel to shore at distances of 0.8 and 2.4 km, respectively, from Yaquina Head.

FIELD STUDY

During the 1978–1979 pilot study, five observers counted whales on 3 predetermined days each week from late November to the end of May. These counts were used

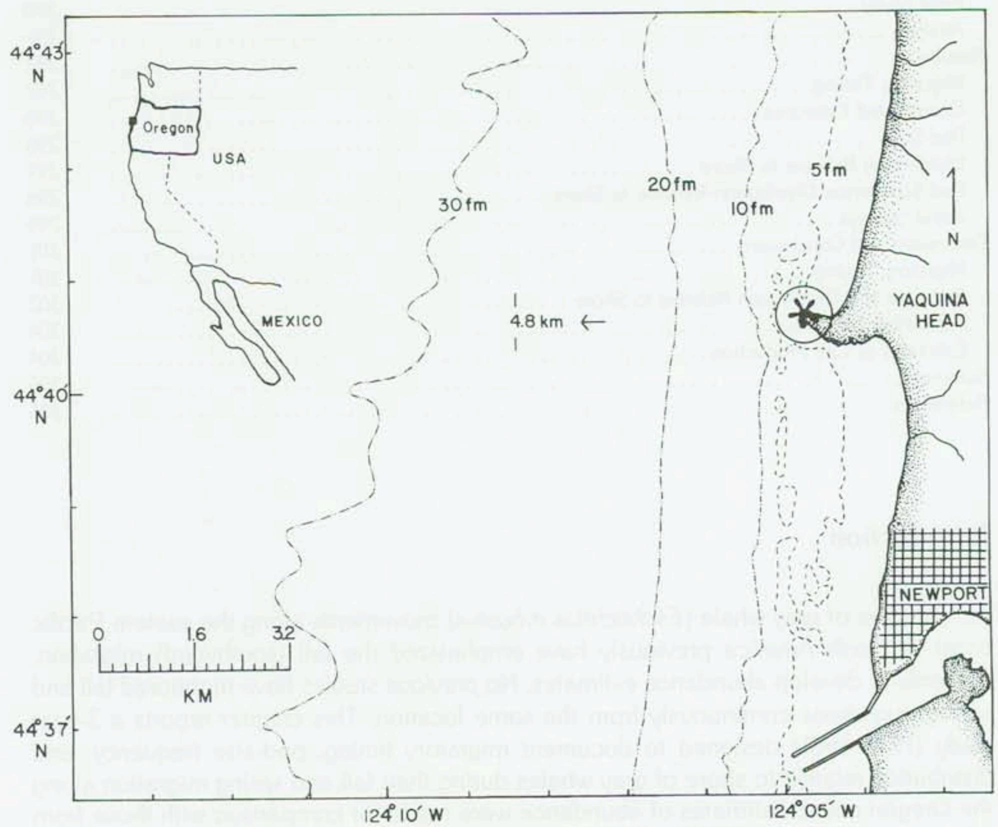

Fig. 1. *Location of study site at Yaquina Head, Oregon.*

to determine migratory timing and to develop methods suitable for the more complete studies which followed in 1979–1980 and 1980–1981. To eliminate interobserver bias, D. Herzing was the sole observer in 1979–1980 and 1980–1981.

Observations were made during five 0.5-hr periods alternated with 0.5-hr rest periods throughout morning hours, generally 0800–1300. Observers recorded the following: (1) viewing conditions, which were monitored by subjectively estimating Beaufort sea state; (2) pod size, which was estimated by continuously observing whales as they entered and passed through the study area, thus allowing multiple surfacing sequences to be observed; (3) distances of whales from shore for each sighting (in 1979–1980 and 1980–1981 only), which were calculated from vertical angles to whales as they passed directly off the lighthouse perpendicular to the coastline (measured with a clinometer) and from the known elevation of the observation platform. Distance-to-whale sightings were grouped as occurring 0–1.6 km, 1.6–3.2 km, and 3.2–4.8 km from shore. We arbitrarily limited our observations to within 4.8 km.

To determine the relative distribution of gray whales migrating within and farther than 4.8 km from shore, in January 1981 16 aerial surveys were flown perpendicular to the coast, extending to 32 km offshore. Flying at 600-m elevation in a Cessna 182, two observers, one on each side of the aircraft counted gray whales within 1.6 km of the aircraft trackline. The strip was defined by strut-mounted streamers. Distance from shore was calculated from flying time and airspeed. Flights were made on calm weather days when winds were negligible. Counts were made on both inbound and outbound transects. Inbound transects were moved a sufficient distance northward of outbound transects to avoid duplicate sightings. As we were interested only in the relative distribution of whales from shore, uniform sightability throughout the transect width was not necessary. We recognized that large groups may be easier to see than are individuals and thus the technique may be biased if group size is correlated with distance from shore.

ANALYSIS

Daily estimates of the number of whales passing through the study area were made from shore observations when the sea state was recorded as Beaufort 3 or less (winds <10 knots, occasional white caps) and visibility extended to a minimum of 4.8 km offshore (as determined by clinometer). Such weather conditions are well within Reilly's (1981) categories of "excellent to fair" visibility, under which no significant interference with shore censusing of gray whales from the weather was demonstrated; therefore data in the Oregon study were uncorrected for weather-related visibility categories.

Daily estimates of the numbers of animals passing the study site for 1979–1980 and 1980–1981 were calculated by multiplying the average number of whales observed per hour by 24 hr. Because Reilly (1981) found no significant difference between mean hourly migration rates or between morning versus afternoon migration rates and since no conclusive data exist that demonstrate a significant difference between day and night rates, all hourly rates in the Oregon study were assumed to be equivalent throughout a 24-hr period. Estimates were interpolated for unobserved days by following the linear trend of the migration immediately before and after the unobserved period. All daily estimates were summed to produce an estimate of the total number of whales passing through the study area. Ninety-five percent confidence limits were calculated by

$$\bar{P} \pm t \frac{S\bar{p}}{\sqrt{n}}$$

where $\bar{P}$ = mean estimate, $S\bar{p}$ = SD of the mean, n = sample size, t = Student's T value for $\alpha = .05$ [following Sokal and Rohlf (1969)].

During the pilot study in 1978–1979, estimates of whales passing per hour were averaged weekly and interpolated as above. However, because of observer variation and less accurate methods of calculating distance, data from the pilot study were not used to produce population estimates but only to compare the timing of migratory phases in subsequent years.

For testing purposes we divided the migration into southward and northward, and subdivided northward into that portion without calves (Phase A) and that with calves (Phase B). A G test of independence was used to compare pod size and distribution relative to shore between (1) the southward and Phase A migration, (2) the early and late Phase A migration.

Results

MIGRATORY TIMING

Gray whales migrated along the Oregon coast in three discernible phases (Fig. 2a,b,c): the fall/southward migration which occurred from early December to mid-February; the first portion of the spring/northward migration when calves were not present, which occurred from mid-February through April and is referred to as northward/Phase A; and the second portion of the spring/northward migration, composed primarily of cows with calves, which occurred from late April through May and is referred to as northward/Phase B or the cow/calf migration. The migration timing and peak migration rates for three annual migration cycles are shown in Table I.

Southward

The first southbound migrants were observed in early December. Maximum numbers of whales passed during the first week in January (maximum daily averaged rate was 29 whales/hr) with 90% of the animals passing between December 19 and January 23. Rates gradually declined to zero by mid-February, after which no further whales were observed until the onset of the northward migration.

Northward/Phase A

The northward migration began during the last week in February, and the rate of northbound migrants during Phase A peaked during mid-March (e.g., to a maximum daily average of 14 whales/hr in 1980–1981). After that, rates gradually declined to zero

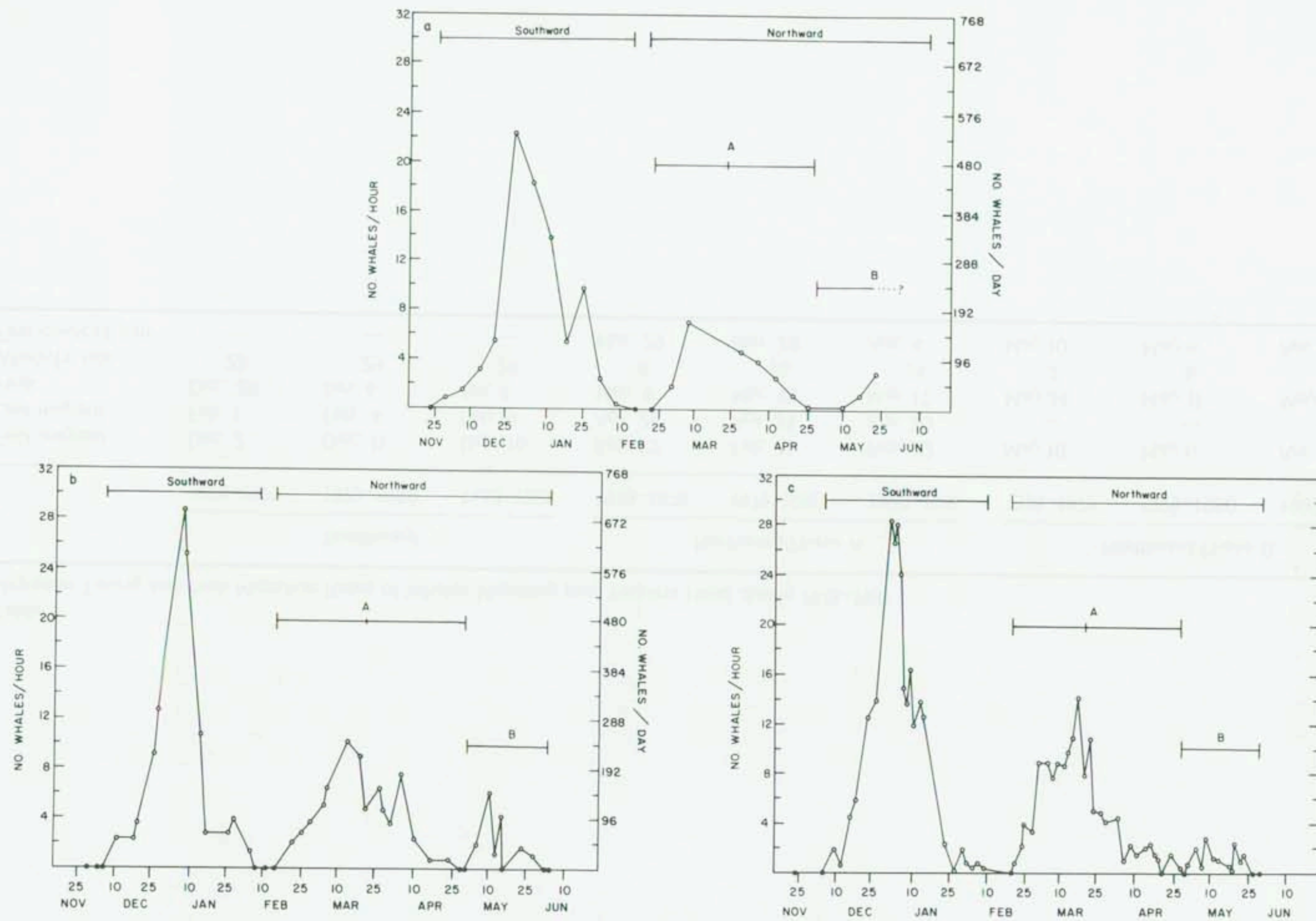

Fig. 2. *Temporal distribution of migrating gray whales during southward and northward/Phase A and B migrations, 1978–1981. Points on the graph denote weekly averages during 1978–1979 (a) and actual observation days during 1979–1980 (b), and 1980–1981 (c).*

Table 1
Migration Timing and Peak Migration Rates of Whales Migrating past Yaquina Head during 1978–1981

	Southward			Northward/Phase A			Northward/Phase B		
	1978–1979	1979–1980	1980–1981	1978–1979	1979–1980	1980–1981	1978–1979	1979–1980	1980–1981
First migrant	Dec. 2	Dec. 11	Dec. 10	Feb. 27	Feb. 21	Feb. 22	May 10	May 6	Apr. 24
Last migrant	Feb. 1	Feb. 4	Feb. 9	Apr. 26	Apr. 24	Apr. 20	—	—	—
Peak	Dec. 28	Jan. 6	Jan. 1	Mar. 8	Mar. 15	Mar. 17	May 24	May 11	May 8
Whale/hr rate	22	29	29	8	10	14	3	6	3
First cow/calf pair	—	—	—	Mar. 29	Mar. 28	Apr. 4	May 10	May 6	Apr. 24

by the end of April. These sightings included a single cow/calf pair in late March or early April of each year.

Northward/Phase B

Cows with calves began migrating past the study area in late April. During Phase B the rate of whale passage increased in early May (e.g., to a maximum daily averaged rate of 6 whales/hr in 1979–1980) and this portion of the migration was composed principally of cows with calves (73% in 1979–1980 and 79% in 1980–1981). Single animals either traveling alone or in the presence of a cow/calf pair were observed through mid-May, after which 100% (of the whales observed) were cow/calf pairs.

UNCORRECTED ESTIMATES

Table II summarizes the estimates of the number of whales in each migratory phase for 1979–1980 and 1980–1981. We estimated that in the 1979–1980 annual migration, 11,962 whales passed southward (based on 253 sightings), 7,340 passed northward during Phase A (159 sightings), and 1,464 passed northward during Phase B (57 sightings). In the 1980–1981 annual migration, an estimated 13,627 whales passed southward (653 sightings), 8,020 passed northward during Phase A (333 sightings), and 945 passed northward during Phase B (76 sightings). If the observed percentages of cow/calf pairs (73 and 79%) are applied to the total estimated number of whales passing during northward/Phase B (1,464 and 945), an estimated 534 calves passed Yaquina Head from late April through May during 1979–80, and 373 during the same period in 1980–1981.

Table II
Number of Whales Observed, Estimated Number of Whales Passing Yaquina Head, and Cow/Calf Composition, 1979–1981[a]

	Southward		Northward/Phase A		Northward/Phase B	
	1979–1980	1980–1981	1979–1980	1980–1981	1979–1980	1980–1981
Number of whales observed	253	653	159	333	57	76
Estimated number of whales within 4.8 km	11,962	13,627	7,340	8,020	1,464	945
95% upper confidence limit	18,274	18,571	12,657	12,264	3,427	2,179
95% lower confidence limit	5,550	8,583	2,023	3,776	—	—
Percentage of cow/calf pairs	—	—	—	—	73	79
Estimated number of calves	—	—	—	—	534	373

[a]All dashes mean not applicable.

The estimates given above were not considered total population estimates because they did not include: (1) estimates of the number of whales unobserved because they passed prior to or after the study; (2) estimates of the percentage of whales that traveled outside the 4.8-km observation area; and (3) corrections for probable errors in the estimated pod size.

POD SIZE

As the direction of migration changed from south to north, a general trend of decreasing pod size was observed (Fig. 3a,b). During this transition in the 1979–1980

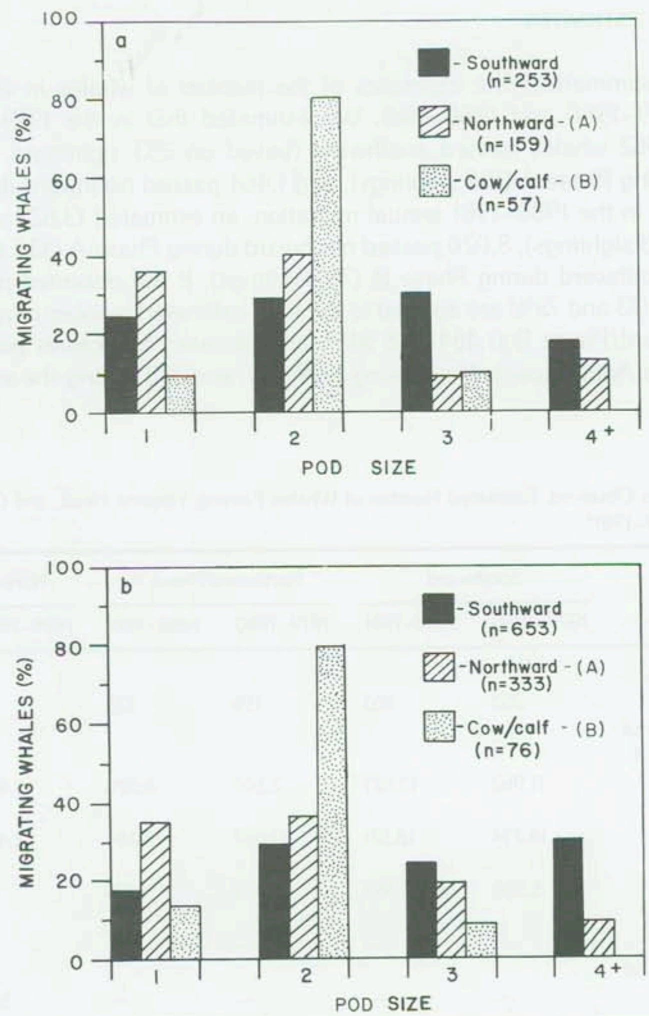

Fig. 3. *Distribution of pod sizes passing Yaquina Head in the three migration phases, (a) 1979–1980, (b) 1980–1981.*

Table III
Percentages of Whales in Small (Singles and Pairs) and Large (Three or More) Groups During Each Migratory Phase, 1979–1980/1980–1981

Pod size	Southward	Northward/Phase A	Northward/Phase B
Small (1–2)	52/47	77/71	90/92
Large (3+)	48/53	23/29	10/8

season there was a significant (α = .01, G = 32.070) increase in the percentage of whales recorded as singles or pairs, from 52% (southward) to 77% (northward/Phase A), and a decrease in the percentage of whales observed in pods of three or larger, from 48% (southward) to 23% (northward/Phase A) (Table III). Further analysis between early and late Phase A revealed that small pods (1–2) were found in a significantly (α = .01, G = 31.956) greater percentage during late Phase A. Thus the change in the late portion of the Phase A migration largely accounts for the observed changes in pod size between the southward and northward/Phase A migrations. Similar trends were observed during the 1980–1981 season. By the time the cow/calf migration (Phase B) had begun in 1980 and 1981, more than 90% of all observed whales were recorded as single animals or pairs.

During the southward migration, 80% of pods composed of four or more whales migrated past Yaquina Head in mid-season (late December to early January), while singles, pairs, and trios were observed regularly from the beginning of December through the end of January. During the northward/Phase A migration, 90% of pods of four or more whales migrated in the beginning of the season (late February to mid-March), and smaller pod sizes were observed throughout the northward movement. At the onset of the cow/calf migration, singles, pairs, cow/calf pairs, and trios (always including a calf) were observed, but by mid-May only cow/calf pairs were observed.

DISTRIBUTION RELATIVE TO SHORE

Over 50% of all whales observed during both the southward and northward/Phase A migrations traveled between 1.6 and 3.2 km offshore (Fig. 4a,b). However, a general trend of decreasing distance of whales from shore was observed as the migration direction changed from south to north. For instance, during this transition in the 1979–1980 season there was a significant (α = .01, G 22.826) increase in the percentage of whales observed less than 1.6 km from shore, from 20% (southward) to 40% (northward/Phase A), and a decrease in the percentage of whales observed further than 3.2 km from shore, from 20% (southward) to 9% (northward/Phase A). Furthermore, analysis between early and late Phase A revealed that a significantly (α = .01, G = 39.652) greater percentage of whales traveled closer to shore in the late than in the early Phase A, which probably accounts for most of the observed difference between the southward and northward/Phase A migrations. Similar trends were observed during the 1980–1981 season. During the cow/calf (Phase B) migration, over 97% of all whales observed traveled within 0.8 km of shore during both years, well within the 1.6-km category.

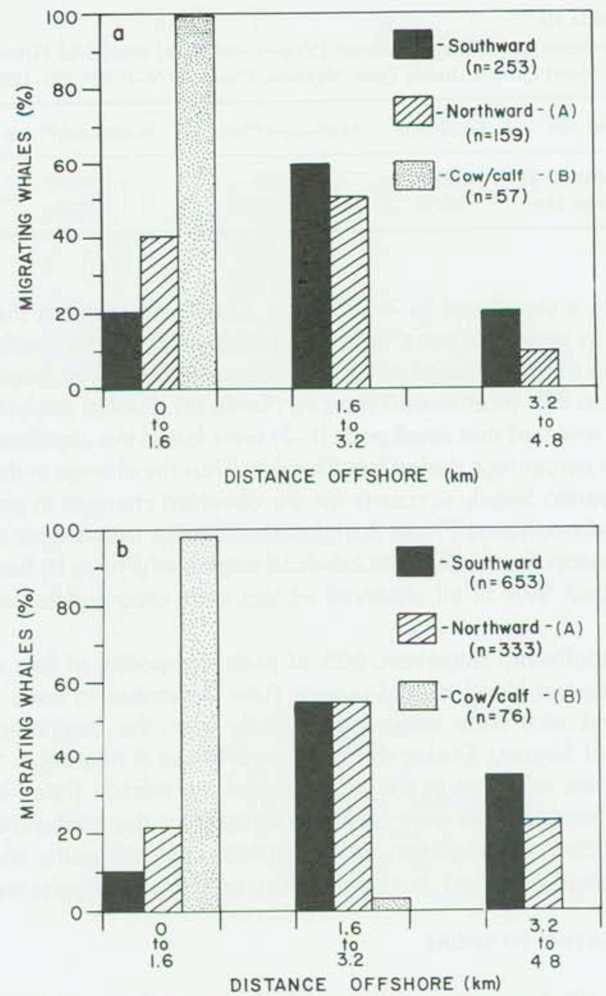

Fig. 4. *Distribution relative to shore of whales in the three migration phases. (a) 1979–1980. (b) 1980–1981.*

POD SIZE VERSUS DISTRIBUTION RELATIVE TO SHORE

Except for the Phase B migration, the majority of all sightings for all pod sizes were made in the 1.6- to 3.2-km region (Fig. 5a,b). During the combined southward and northward/Phase A migrations there was a significantly (α = .01, G = 33.702) smaller percentage of pods of four or more whales observed within 1.6 km than observed between 3.2 and 4.8 km (e.g., 8 versus 30% in 1979–1980). Further analysis between early and late Phase A revealed that a significantly (α = .01, G = 27.146) greater percentage of (1) small pods were observed closer to shore during late Phase A than during early Phase A, and (2) large pods were observed father from shore during early Phase A than during late Phase A. These changes within Phase A reemphasize the

(1981) estimate of a rate of 4.6% of calf production from Unimak Pass, Alaska. These calf production rates are much lower than the 13% that Rice and Wolman (1971) have estimated. Lower calf production rates may be due to a variety of factors.

Swartz and Jones (1983) estimated a 5.3% mortality rate for calves from the time of birth and initial lagoon occupation through departure from the lagoon. Following the departure of calves from the lagoons to a central point in California a second critical period is suggested. Poole (1984) estimated a total mortality rate of 25% for calves from their birth in the lagoon to their migration off central California. Such a high mortality seems unlikely in view of the extremely small number of dead calves found along California and Oregon beaches (Scientific Event Alert Network).[1] Poole (1984) discusses observations of a high number of dead calves found in a single spot along the northern Baja coast. Such high numbers of unreported calves may indicate that calves dying after leaving the lagoons in Mexico and washing up on shore in Baja would normally remain undetected and therefore not be considered in estimations of calf mortality rates. Twenty-one percent of Phase B migrants off the Oregon coast in 1981 were single whales either traveling alone or in the presence of a cow/calf pair. An unknown number of these may have been postpartum females that had lost their calves. Even if all Phase B single whales were postpartum females, it would account for only a maximum of 198 additional calves, a total of 571 calves, still only slightly more than half of the estimated production of 1,051 calves.

As a result of their extremely close proximity to shore and distinctive behavior, it is unlikely that large numbers of calves passed Yaquina Head undetected during the study period. No correction factors exist for whales outside the 4.8-km viewing area during Phase B, but the 3% found in the 1.6- to 3.2-km region in 1981 and the 0% found in the 3.2- to 4.8-km region in 1980 and 1981 suggests the number traveling outside 4.8 km would be very small. Poole (Chapter 16, this volume) observed all of the cow/calf pairs at Pt. Piedras Blancas, CA within 400 m of shore during aerial surveys, indicating that most, if not all of the cow/calf pairs travel very close to shore.

Another explanation for low calf numbers during this study may be that a significant proportion of cow/calf pairs had not yet reached the study area before termination of the study. Swartz and Jones (1980b) reported that females with calves may remain at the lagoon entrances through late May and early June. These late migrant cow/calf pairs and others still migrating along southern California would be undetected along central California and Oregon before late May. Many whales including cow/calf pairs may spend the entire summer along the Baja California and southern Oregon coasts and never migrate past the Oregon study site. Summering whales including cow/calf pairs have been noted along the Baja coast, (A. Aguayo, personal communication), the Oregon coast (J. Sumich, personal communication), and along Vancouver Island, British Columbia, Canada (Darling, 1977). Numbers of whales summering along the California coast are unknown. Using our uncorrected Oregon estimates of 8,804 northbound migrants in 1979–1980 and 8,965 in 1980–1981 as a comparison with 11,962 southbound

[1]Scientific Events Alert Network, National Museum of Natural History MRC 129, Smithsonian Institution, Washington, D.C.

migrants in 1979–1980 and 13,627 in 1980–1981, we estimate that 3,000 to 4,500 southbound migrants are unaccounted for on the return migration northward. These discrepancies and the low number of calves may be partially explained by the summering behavior of gray whales as well as higher mortality rates of calves during their northward migration.

Summary

To determine the temporal and spatial distribution and pod size of the California gray whale *Eschrichtius robustus* along the Oregon coast, whale movement was monitored from November through May during 1978–1981. Primary observations were made from shore, and supplemental observations were from aerial surveys. The migration occurred in three major phases: (1) southward migration (early December to mid-February) which peaked in early January at a maximum rate of 29 whales/hr; (2) northward/Phase A migration (mid-February through April) which did not include calves and peaked in mid-March at a maximum rate of 14 whales/hr; (3) northward/Phase B (cow/calf) migration (late April through May) which peaked in mid-May at a maximum rate of 6 whales/hr. Over 50% of all whales in the combined southward and northward/Phase A migrations passed by Yaquina Head between 1.6 and 3.2 km from shore. Pod size decreased and whales moved progressively closer to shore throughout the northward migration. The cow/calf migration was characterized by a high percentage of singles and pairs (90%) and travel within 1.6 km of shore (97%). In the 1980–1981 season, an estimated 15,462 whales migrated past Yaquina Head during the southward migration. Discrepancies in the estimated number of calves and total estimated number of whales passing south and north by Oregon may be attributable to late migrants, animals summering south of the study area, and higher mortality rates of calves during their northward migration.

Acknowledgments

Special thanks to Robin Brown, Jim Harvey, and Jim Sumich for their suggestions and field assistance, to Dr. Debbie Duffield and Dr. Bernd Würsig for reviewing this manuscript, to Nancy Brown for typing, to the U.S. Coast Guard for the use of Yaquina Head Lighthouse, and to the many friends and volunteers who contributed time and energy. We are grateful for the support of the Office of Naval Research (Grant no. 700014-79-C-004) and the Oregon State University Foundation.

References

Darling, J. D. (1977). Aspects of the behavior and ecology of Vancouver Island gray whales, *Eschrichtius glaucus* (Cope). M.A. Thesis, University of British Columbia, Vancouver, Canada.

Hall, J. D., Harrison, C. S., Nelson, J., and Taber, A. (1977). The migration of California gray whales into the Bering Sea. *Proc. Conf. Biol. Mar. Mammal., 2nd,* (Abstr.), p. 8.

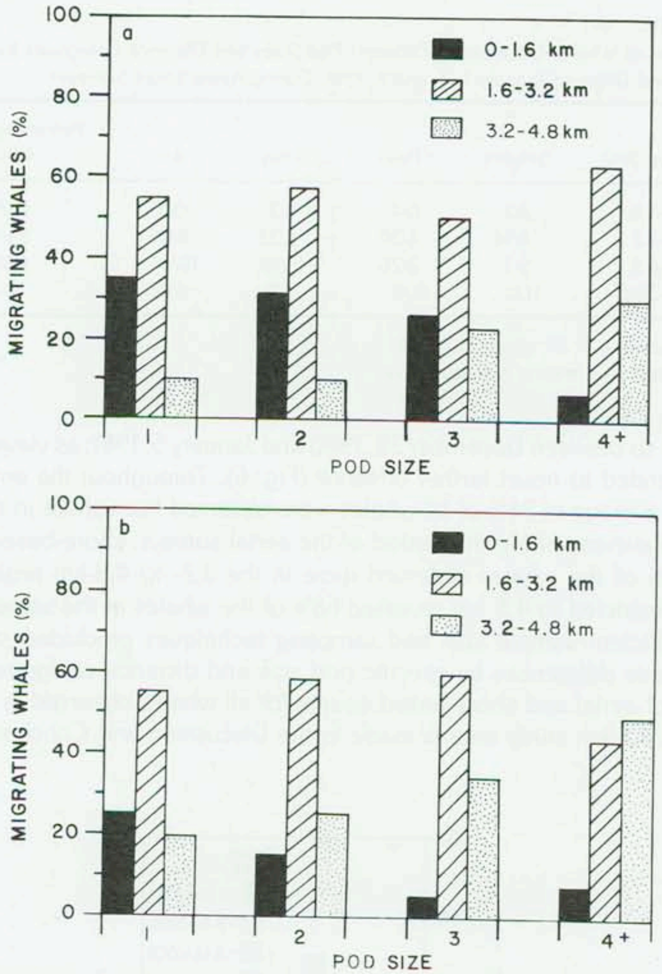

Fig. 5. *Distribution relative to shore of pod sizes for the combined southward and northward/Phase A migrations. (a) 1979–1980. (b) 1980–1981.*

apparent interrelationship of pod size, distribution relative to shore, and migration timing. Similar trends were observed in the 1980–1981 season.

AERIAL SURVEYS

The pod size and distribution relative to shore of migrating gray whales as determined during 16 aerial transects and shore surveys on January 1, 2, and 4, 1981 are summarized in Table IV. Of the 87 whales observed during the aerial transects, 34 (39%) were beyond the 4.8-km boundary, 23 of which were singles or pairs. During aerial surveys to 32 km offshore, whales were seen as far as 20 km from shore. Shore-based observations revealed that 80% of all pods of 4 or more whales that migrated past the

Table IV
Numbers of Whales Observed in Different Pod Sizes and Distance Categories for the Combined Dates of January 1, 2, and 4, 1981, During Aerial/Shore Surveys[a]

Distance (km)	Singles	Pairs	Trios	4+	Percentage within 4.8 km
0–1.6	2/3	0/4	0/3	0/10	3/9
1.6–3.2	8/14	4/20	3/33	0/39	29/45
3.2–4.8	9/3	2/26	15/18	10/64	68/46
4.8–32.0	11/0	12/0	3/0	8/0	—/—[b]

[a]Aerial, $n = 87$; shore, $n = 237$.
[b]Dash (—) means not applicable.

study site did so between December 28, 1980 and January 5, 1981; as viewed from shore, large pods tended to travel farther offshore (Fig. 6). Throughout the entire southward migration an average of 36% of all whales were observed from shore in the 3.2- to 4.8-km region. However, during the period of the aerial surveys, shore-based observations indicated 46% of the whales observed were in the 3.2- to 4.8-km region, and aerial survey data restricted to 4.8 km revealed 68% of the whales in the same region. Problems of insufficient sample size and sampling techniques precluded statistical comparison of these differences by specific pod size and distance categories. However, a comparison of aerial and shore-based counts for all whales observed in each distance region of the 4.8-km study area is made in the Discussion and Conclusions section.

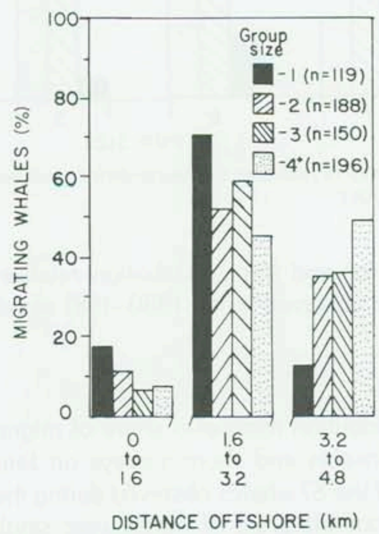

Fig. 6. *Distribution of pod sizes in each distance category during the southward migration in 1980–1981.*

Hessing, P. (1981). Gray whale, (*Eschrichtius robustus*), migration into the Bering Sea, Spring 1981. Final Report. NOAA/OMPA Contract: NA 8IRGA 00080.

Poole, M. M. (1984). Preliminary assessment of annual calf production of the California gray whale, *Eschrichtius robustus*, from Pt. Piedras Blancas, California. *In* "Cetacean Reproduction: Estimating Parameters for Stock Assessment and Management" (W. Perrin, R. D. Brownell, Jr., and D. DeMaster, eds.). La Jolla, California. (in press)

Reilly, S. B. (1981). Population assessment and population dynamics of the California gray whale (*Eschrichtius robustus*). Ph.D. Thesis, University of Washington, Seattle.

Reilly, S. B., Rice, D. W., and Wolman, A. A. (1980). Preliminary population estimates for the California gray whale based on Monterey shore censuses, 1967–68 to 1978–79. *Rep. Int. Whal. Commn.* **30,** 359–368.

Rice, D. W. and Wolman, A. A. (1971). The life history and ecology of the gray whale, *Eschrichtius robustus*. *Spec. Publ.—Am Soc. Mammal.* **3,** 1–142.

Rice, D. W., Wolman, A. A., Withrow, D. E., and Fleisher, L. A. (1981). Gray whales on the winter grounds in Baja California. *Rep. Int. Whal. Commn.* **31,** 477–489.

Sokal, R. R., and Rohlf, E. J. (1969). "Biometry: The Principles and Practices of Statistics in Biological Research." Freeman, San Francisco, California.

Sund, P. N., and O'Connor, J. L. (1974). Aerial observations of gray whales during 1973. *Mar. Fish. Rev.* **36**(4), 51–52.

Swartz, S. L., and Jones, M. L. (1980a). "Gray Whales, *Eschrichtius robustus*, during the 1977–1978 and 1978–1979 Winter Seasons in Laguna San Ignacio, Baja California Sur, Mexico." U.S. Dept of Commerce Report to the Marine Mammal Commission. NTIS PB80-202989.

Swartz, S. L., and Jones, M. L. (1980b). "Gray Whales, *Eschrichtius robustus*, during the 1980 Winter Season in Laguna San Ignacio, Baja California Sur, Mexico." Submitted to the July 1980 meeting of the International. Whaling Commission.

Swartz, S. L., and Jones, M. L. (1983). Gray whale calf mortality and production in the winter range. *Rep. Int. Whal. Commn.* **33,** 503–507.

Discussion and Conclusions

MIGRATORY TIMING

Southward

Southward migration along the Oregon coast was similar in duration but approximately 1 month later (early January) than the southward migration at Unimak Pass, Alaska (late November/early December). The southward migration lasted 2 months in both Oregon and Alaska. Ninety per cent of the observed gray whales migrated past Oregon between December 19 and January 23. Rugh (Chapter 10, this volume) reported 90% of the observed whales in Alaska passed between November 19 and December 23. Peak migration dates along Oregon occurred approximately 1 week prior to the average peak passage date (January 9) off Monterey, California (Reilly, 1981).

Observed peak passage dates varied slightly for the 3 years studied along the Oregon coast. For each consecutive year (1977, 1978, 1979) the peak passage date was later, both at Unimak Pass, Alaska and at Monterey, California (Chapter 10, this volume). Rugh suggests such variation may correspond to changes in environmental features such as ice development in northern feeding grounds.

The maximum passage rate of 52 whales/hr observed at Unimak Pass, Alaska (Chapter 10, this volume) was higher than the 29 whales/hr observed along the Oregon coast and the 30 whales/hr reported by Reilly (1981) for Monterey. As whales travel south, they may change rates of travel relative to sex, age, and reproductive status, or they may travel farther offshore (out of view) as suggested by our aerial surveys along the Oregon coast, thus accounting for lower passage rates from shore observations at lower latitudes.

Northward/Phase A

In 1981, peak passage of the Phase A migration occurred along the Oregon coast in mid-March, 2 weeks later than Poole's (Chapter 16, this volume) observations of peak passage in late February off Point Piedras Blancas, California. Rugh (Chapter 10, this volume) reported no whales observed northbound through Unimak Pass, Alaska between January 2 and March 22, 1980. Hall *et al.* (1977) surveyed northbound gray whales between April 7 and May 26, with only a few cow/calf pairs sighted. Recent studies at Unimak Pass in 1981 indicated peak passage of the Phase A migration to be April 27 (Hessing, 1981), which would indicate an approximate lag of 4–5 weeks between the beginning of the northward/Phase A in Oregon and in Unimak Pass, Alaska.

Unlike the rapid increase in whale-passage rate observed during the southward migration, the northward/Phase A migration was characterized by a gradual increase to 14 whales/hr in mid-March and a gradual decrease to 0 whales/hr by late April. Gradual changes in Phase A rates were also observed along central California with a higher observed daily passage rate of 18.5 whales/hr (Chapter 16, this volume). Poole also reported his first sighting of a cow/calf pair at the end of March in 1980 and in early April in 1981, the same as observed in Oregon.

Northward/Phase B

The peak passage rate during the cow/calf migration was lower and therefore less conspicuous along Oregon in 1981 than in 1980. In 1980, this peak rate occurred 2 weeks later (mid-May) than the late April peak at Point Piedras Blancas, California (Chapter 16, this volume). Hessing (1981) reported a peak in cow/calf migration at Unimak Pass, Alaska on June 4, approximately 4 weeks following the cow/calf peak along the Oregon coast. Swartz and Jones (1980a) reported two "departure waves" of gray whales from San Ignacio Lagoon in Baja, California: (1) Whales without calves decreased after mid-February and declined to zero by mid-March, and (2) cow/calf pairs declined after an early April peak. If these two waves of departure from the lagoon are representative of departure of whales from waters outside the lagoon as well, they may correspond to Phases A and B. However, as these dates are only 1 month before those phases peak along the Oregon coast, it seems unlikely.

The most recent attempts to thoroughly census the major calving and breeding lagoons in Baja (Rice *et al.*, 1981) produced estimates well below half the estimated southbound population. Thus it appears most whales are outside the lagoon at any particular time. Some may enter a lagoon and soon leave, as indicated by some the short residency times found by Harvey and Mate (Chapter 24, this volume). Thus departure dates from the lagoons may not be representative of the beginning of northward movement for the population in general.

Some whales may never get far enough south to enter a lagoon before they turn around again to head north. Mate and Harvey (Chapter 25, this volume) also reported a single whale, radio-tagged in San Ignacio Lagoon in late February, which passed Oregon in early May towards the end of Phase A (2 months enroute). Late Phase A along the Oregon coast may include whales from the initial departure wave reported from San Ignacio Lagoon by Swartz and Jones (1980a), indicating a 5- to 6-week migration period between Mexican lagoons and the central Oregon coast.

POD SIZE AND DISTRIBUTION RELATIVE TO SHORE

Southward

The changes in pod size observed throughout the southward migration along the Oregon coast may be explained by the temporal segregation of different age/sex and reproductive classes as reported by Rice and Wolman (1971): pregnant females migrate first, followed by nonpregnant females, adult males, and immatures. They also reported that single whales passed early, large groups passed mid-season, and pod size decreased through the end of the migration. Rugh (Chapter 10, this volume) reported temporal–size segregation at Unimak Pass with large whales (presumably pregnant females with greater motivation for leaving northern feeding areas than other age/sex classes) migrating earlier, and small whales migrating later.

Reilly (1981) reported that pod size was related to distance from shore with larger pods occurring farther from shore. He further identified the middle of the southward migration (December 30 to January 18) as having more animals farther from shore, corresponding to the middle part of the Oregon southward migration when the majority of the large pods traveled farther offshore. Shore-based observations along Oregon concluded that large pods travel more frequently in the 3.2- to 4.8-km region than do small pods. However, aerial surveys revealed numerous single and paired whales beyond 4.8 km and a higher percentage of whales within the 3.2- to 4.8-km region than did shore-based observations. This established that smaller pod sizes pass the study site unobserved from shore in the 3.2- to 4.8-km region as well as outside the 4.8-km viewing area. With a reduced probability of sighting small pods with increasing distance, then the conclusion from shore-based observations that large pods are the predominant pod size in that region may be incorrect.

Migration through water less than 90 m in depth was characteristic along Oregon as well as at other study sites. The maximum distance gray whales traveled from shore along the Oregon coast was 20 km (90-m water depth); but the majority of whales were observed between 1.6 and 3.2 km (40–60 m). Although Unimak Pass is from 18.5 to 48.2 km wide, Rugh (Chapter 10, this volume) reported that all gray whales observed from shore and by plane were within 3.7 km of Unimak Island in water less than 75 m deep; 79% of these traveled within 1 km (20-m depth). Ninety per cent of the whales off Yankee Point, California were observed within 1.6 km of shore (Sund and O'Connor, 1974), well within the 90-m depth contour.

Northward/Phase A

Changes in pod size observed within Phase A also correspond to trends reported by Rice and Wolman (1971) during the northbound migration along the California coast, where large groups of mature whales migrated early and smaller pods of immature whales migrated later. Poole (Chapter 16, this volume) also reported smaller whales nearer to shore throughout this period. During Phase A, whales migrating along the central California coast moved closer to shore in the later half of the migration (Chapter 16, this volume), corresponding to late Phase A along Oregon during which a significant decrease in pod size and the distance whales migrated from shore was observed. This period corresponds with immature whale migration and suggests that smaller animals show a strong preference for migrating close to shore.

Northward/Phase B

The cow/calf migration was characterized by migration extremely close to shore. Poole (Chapter 16, this volume) observed that over 90% of Phase B whales along central California traveled within 200 m of shore, similar to the observations along the Oregon coast where 90% were found within 800 m. Hessing (1981) reported that after May 21, no whales were seen farther offshore than 800 m and within the last 3 weeks of migration 90% of all whales traveled within 100 m of shore. Rice and Wolman (197i) did not see cow/calf pairs during their shipboard observations off central California through April and postulated that these animals migrated farther offshore than the rest of the migration. This study and others cited in this chapter reveal that cow/calf pairs migrate later than the majority of the population and display a strong tendency to travel extremely close to shore. Rice and Wolman's surveys may have been too early in the season or too far offshore to discern this migratory phase.

POPULATION SIZE

An estimated 11,962 and 13,627 whales passed through the Yaquina Head study area during the southward migration in 1979–1980 and 1980–1981, respectively. These shore estimates were (1) not corrected for weather-related sightability, which was assumed equal during all observation days, based on Reilly's (1981) visibility correction data, (2) not corrected for portions of the migration before or after the observation study period (rather, it was assumed that the census began and terminated well before and after the majority of migrants had passed), and (3) not corrected for animals moving outside the 4.8-km outer boundary of the study area. We attempted a correction for the latter during the short period of December 28, 1980 to January 5, 1981, when aerial surveys revealed 39% of the whales were passing beyond 4.8 km. This resulted in an additional 1,835 whales being added to the estimated 4,705 whales passing through the study area during that time, increasing out initial estimate of 13,627 for 1980–1981 to 15,462. Assuming that our sightability bias for underestimating pod size (especially of single whales) at increasing distance is real, we could apply the corrections developed by Reilly (1981) for northern California to our shore-based data. Reilly found that 35% of the single animals were missed by shore counts, pairs and trios were accurately identified, and pods of four or larger were underestimated by 33%. Thus, if we applied these correction factors to the proportion of whales in each pod size throughout the entire southward migration, the result would be an increase in the total estimated number of whales passing Oregon from 15,462 to 17,671 whales. These corrected estimates are close to those for Alaska of 16,928 whales in 1978 (Chapter 10, this volume), to the central California estimates of 16,304 whales (Reilly *et al.*, 1980) and 15,640 (Poole, 1984) in 1981.

ESTIMATES OF CALF PRODUCTION

We estimated that 534 and 373 calves passed Oregon during Phase B in 1980 and 1981, respectively. Swartz and Jones (1983) have estimated the annual calf production at 6.8% of the population. When this figure is applied to our own best estimate of 15,462 (excluding Reilly's correction for sightability), calf production is estimated at 1,051 individuals. We therefore estimated that when we stopped surveying in late May that approximately 500–700 calves either had died, had moved past offshore beyond our view, or were still south of the study site. However, using the uncorrected estimate of 11,962 whales passing Yaquina Head, Oregon and 534 estimated calves from that population, a calf production rate of 4.7% is estimated in agreement with Poole's (1984) estimate of calf production of 4.7% off Pt. Piedras Blancas, California and Hessing's