Behavior of individually-identified sei whales *Balaenoptera borealis* during an episodic influx into the southern Gulf of Maine in 1986

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Abstract.—Sei whales *Balenoptera borealis* are noted for major fluctuations in distribution, often in response to local availability of prey. An influx of sei whales occurred in the southern Gulf of Maine during summer 1986. Forty-seven individuals (including four mothers with calves) were photographically identified using natural markings, including dorsal-fin notches, placement of small circular scars on the animal's flank, and natural variation in dorsal-fin shape and pigment swaths along the dorsal surface behind the blowholes. Seventeen of these whales (36.1%) were photographed on more than one day, and the period between first and last sighting of individuals ranged from one to 66 days. Only six animals were sighted in more than one region in the southern Gulf of Maine. Observed behavior included traveling, nearsurface skim feeding, lunge feeding, and (rarely) "milling" or breaching. Group sizes were small and variable. Two individuals were matched to photographs taken in other regions in or near offshore Gulf of Maine waters. We hypothesize that the southern Gulf of Maine represents a short-term feeding site. The occurrence of individuals without sufficient marks for individual recognition suggests that photoidentification is of limited value in the study of this species.

Most species of baleen whales undertake seasonal migrations between high-latitude feeding grounds and warmer breeding areas (Kellogg 1929, Slijper 1962, Mackintosh 1965). Populations often show annual variations in local spatial distribution within these areas (Wursig et al. 1985). While the factors causing these variations are not well defined for breeding grounds, it has been suggested that they are explained on feeding grounds by differences in prey distribution (Whitehead and Carscadden 1988, Payne et al. 1990). Because of the energetic demands upon large whales (Lockyer 1981) and the unpredictable distribution of their prey, such areal variation would be expected if the animals were seeking to maximize their feeding efficiency.

Sei whales *Balaenoptera borealis* have been reported to have greater variation in distribution on their feeding grounds than most baleen whale species (Horwood 1987). Sei whales have been reported in considerable numbers for brief periods outside of their regular range in Norway (1885, 1898, and 1919), Finland (1885), and Scotland (1906) (Tomilin 1957, Jonsgard and Darling 1977). Ingebrigtsen (1929) reported large annual changes in distribution off the Faroe Islands. These changes are hypothesized to be related to local increases in planktonic productivity (International Whaling Commission 1977, Horwood 1987).

Sei whales off the northeastern United States and southeastern Canada have been little studied. Mitchell and Chapman (1977) hypothesized

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the existence of a "stock" of sei whales centered around Nova Scotia. During the spring these animals are thought to occur on the southern edge of George's Bank (Mitchell and Chapman 1977, CETAP 1982). During June and July, they move north to the southern Scotian Shelf, then onto Brown's, Bacarro, and Roseway Bank from August to October (Sutcliffe and Brodie 1977). The lack of sightings in these areas, plus late-winter/early-spring strandings in South Carolina, Louisiana, and Mississippi suggest a southward movement after October (Mead 1977). The inshore waters of the southern Gulf of Maine are rarely used by sei whales (CETAP 1982, Payne et al. 1990).

In this paper, we report on the photoidentification, occupancy patterns, surface behavior, and social behavior of individual sei whales found in the Gulf of Maine during an unexpected summer influx of this species in 1986, documented through daily shipboard surveys. We also report results of photographic identification of individual sei whales, and evaluate the feasibility of such techniques for investigations of this species.

Methods

Non-systematic surveys of the southern Gulf of Maine were conducted daily (weather permitting) from mid-April through October on commercial whale-watching and research vessels operating out of Provincetown and Gloucester, Massachusetts during 1980–91. In 1986, the only year of sei whale abundance, the number of vessels collecting data varied. There were usually six to nine 4-hr cruises daily from each port. Vessels were 18–30 m long diesel-powered whale-watching vessels and 6.7–14 m long research vessels powered by sail, diesel, or outboard engines. Whale-watch cruises were typically 4–5 hr in duration, while research-vessel cruises often lasted from dawn until dusk.

Search effort by whale-watching vessels was concentrated on the southern and northern edges of Stellwagen Bank and the southern edge of Jeffrey's Ledge because of the concentrations of whales there (Fig. 1). Stellwagen Bank is a shallow glacial deposit with a sand substrate, at 20–40 m. Southern Jeffrey's Ledge has a mean depth of 48 m, and is a mixture of sand, gravel, and rocks. Depths surrounding both areas extend to 182 m. In both areas there is upwelling, caused by steep topography which enriches the biological productivity of the area, providing food for whales (Kenney and Winn 1986).

For each sighting data included location, direction and speed of animal movement (based on LORAN-C readings taken every 5–10 min), environmental conditions, behavioral information including respiration intervals (to the nearest second) of individuals recognizable by natural marks, notable non-respiratory surface behavior, and associations among whales. Two or more whales were considered associated if they were in close proximity and consistently coordinated in the timing and direction of their surfacings.

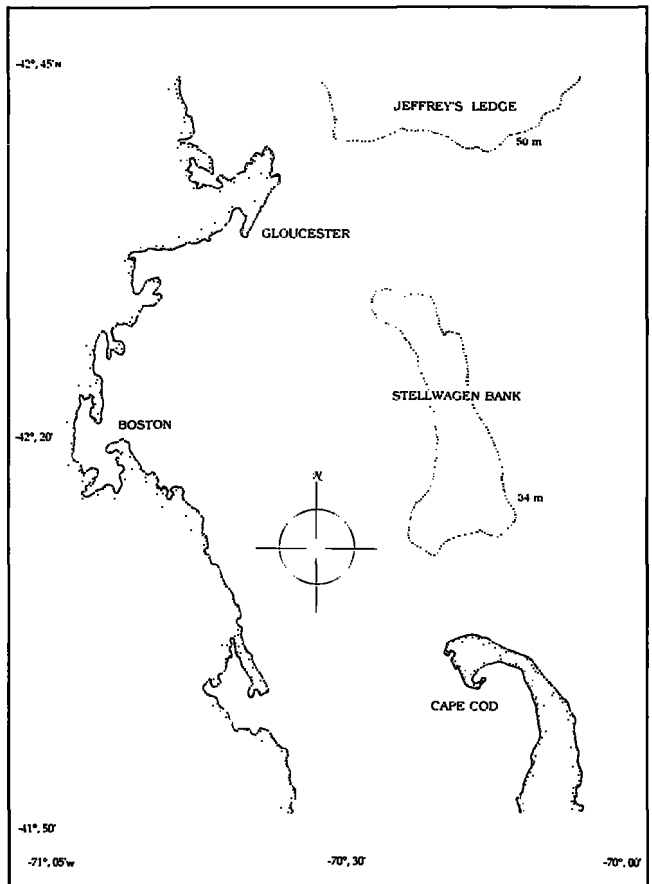

Figure 1
Study area in the Gulf of Maine.

Cow/calf pairs were treated as single animals for an analysis of occupancy periods (the time between first and last sighting), assuming that the calf's movements are determined by those of its mother. Calves were designated based on the animal being considerably smaller than any other animals, and on the continuous association between two individuals for at least 30 min or on more than one day. Personnel were experienced in observing mother-calf pairs of humpback *Megaptera novaeangliae* and fin *Balaenoptera physalus* whales. To determine mean associated group size, mother and calf pairs were counted as two individuals.

Fecal samples were scooped from the surface in a 5-gallon bucket on two days in August 1986 near northern Stellwagen Bank. The material was frozen until

examination. Prey remains were identified to species by staff of Allied Whale at the College of the Atlantic, Bar Harbor, Maine.

High-speed (ISO 400) black-and-white film was used in 35 mm single-lens reflex cameras equipped with telephoto lenses (range 200–400 mm) to photograph whales. When possible, three regions were photographed on each side of a whale: between the tip of the snout and the blowhole, the flank between the blowhole and dorsal fin, and the dorsal fin.

Photos were classified as matchable or unmatchable based on the same criteria defined by Seipt et al. (1990) for fin whale photoidentification. Unmatchable photos had poor focus, were not perpendicular to the whale, or were too far from the whale to distinguish marks clearly (generally photos taken at distances >100 m from the whale). For photos judged matchable, a whale was classified as a unique individual based on the presence of one or more of the following characters: recognizable scars, a distinctive dorsal-fin shape (including dorsal-fin notches), or detectable pigmentation on the flank between the blowhole and dorsal fin. If at least one of these features was not present in a photograph, it was discounted.

Matches of individual whales were made within independent photographic collections of the Atlantic Cetacean Research Center (Gloucester MA), the Center for Coastal Studies (Provincetown MA), and the Cetacean Research Unit (Gloucester MA) by personnel experienced in photo-identifying individual humpback or fin whales. The independent catalogs of identified whales from each organization were compared, with matches being confirmed by both other groups, resulting in a single collective catalog of identified whales. Only matches agreed upon by all parties were accepted.

In order to examine long-range movements of sei whales, photographs were solicited from researchers working in the Gulf of Maine for comparison with the unified catalog described above. Each set of photographs obtained in different geographic areas or years were treated separately.

Data for this study were stored on PC-based microcomputers and statistical analyses were performed using SPSS (1989) statistical software package for PC's, including calculation of mean values and standard deviations. A two-tailed t-test was used to compare mean values for associated group sizes between different parts of the study area, and a χ^2 test was used to test potential differences in group sizes when a mother-calf pair was present in the group (Zar 1984).

Results

Photoidentification

A total of 240 sei whale sightings took place between 29 June and 20 September 1986. Photographs were taken on 182 sightings (75.8%). In 51 photographed sightings (28.0% of all photographed sightings) the animal could not be reliably identified because of poor photographic quality.

Photoidentification of some individual sei whales was possible using variation in dorsal-fin shape, placement of small circular scars on either flank, and light pigment swaths behind the dorsal fin (Fig. 2). A total of 47 identifiable non-calf sei whales and 4 calves were photographed; of these, 19 were identifiable based on notches in their dorsal fin alone, 4 based on the locations of small circular scars on the flanks, and 10 based on both distinctive dorsal fins and circular scars. No attempt was made to photoidentify calves. Twelve whales were identified based on dorsal-fin shape and pigment swaths behind the blowhole. One sei whale was missing its dorsal fin, and one had a large white scar visible on the lower portion of its right caudal peduncle. In 12 cases, animals did not have distinctive marks by which they could be identified reliably.

Occurrence and occupancy

The 47 individual sei whales were sighted on as few as 1 and as many as 15 separate days ($\bar{x}$ 2.4, SD 3.0) (Fig. 3). Seventeen individuals (36.2%) were observed on more than one day; the mean period for resighted animals between first and last sighting was 26.8 days (SD 24.1, median 20.0). No individual sighting record spanned more than 66 days from first to last sighting.

Twenty-six individuals (55.3%) were initially photographed on southern Stellwagen Bank, 15 (31.9%) on northern Stellwagen Bank, 4 (8.5%) on Jeffrey's Ledge, 1 (2.1%) in Massachusetts Bay (west of Stellwagen Bank), and 1 (2.1%) in the Great South Channel. Only 6 animals out of the 17 resighted were photographed in more than one of these areas. Of these, four were first seen on southern Stellwagen and subsequently moved north on the Bank; one animal showed the reverse pattern. The remaining one was first photographed on southern Jeffrey's Ledge and later resighted on northern Stellwagen Bank. One of these whales moved between northern and southern Stellwagen Bank at least five times; this individual also had the greatest number of sightings (15) and the longest period between first and last sighting.

Behavior and movement patterns

A total of 752 respiration intervals were recorded during 53 sei whale sightings (from at least 15 different individuals). Inter-respiration intervals showed a range of 2–928 sec, with a mean of 60.8 sec (SD 78.0 sec). The most common respiratory pattern was a single breath followed by a short dive of 45–90 sec. On only four sightings did the whales submerge for prolonged dives of 6–11 min, and they did so repeatedly within the observation.

The regular breath intervals and lack of prolonged dives often appeared associated with near-surface feeding. In the most common feeding behavior, sei whales would take a breath and then roll 45–90° around their longitudinal axis while ~3 m below the surface. The mouth was often slightly open as the animal swam forward. There were four observations of lunge feeding, when the whale rapidly surfaced with its mouth opened. During lunges, no rolling was observed. On one of four occasions of lunging, the same individual alternated lunges with the more common nearsurface feeding behavior.

During feeding and swimming, the whales often remained in an area of ~0.5 km^2 for over an hour. Whales would either change swimming direction with each breath, or travel in a straight line for 10 min or less before reversing, resulting in minimal net movement at the surface.

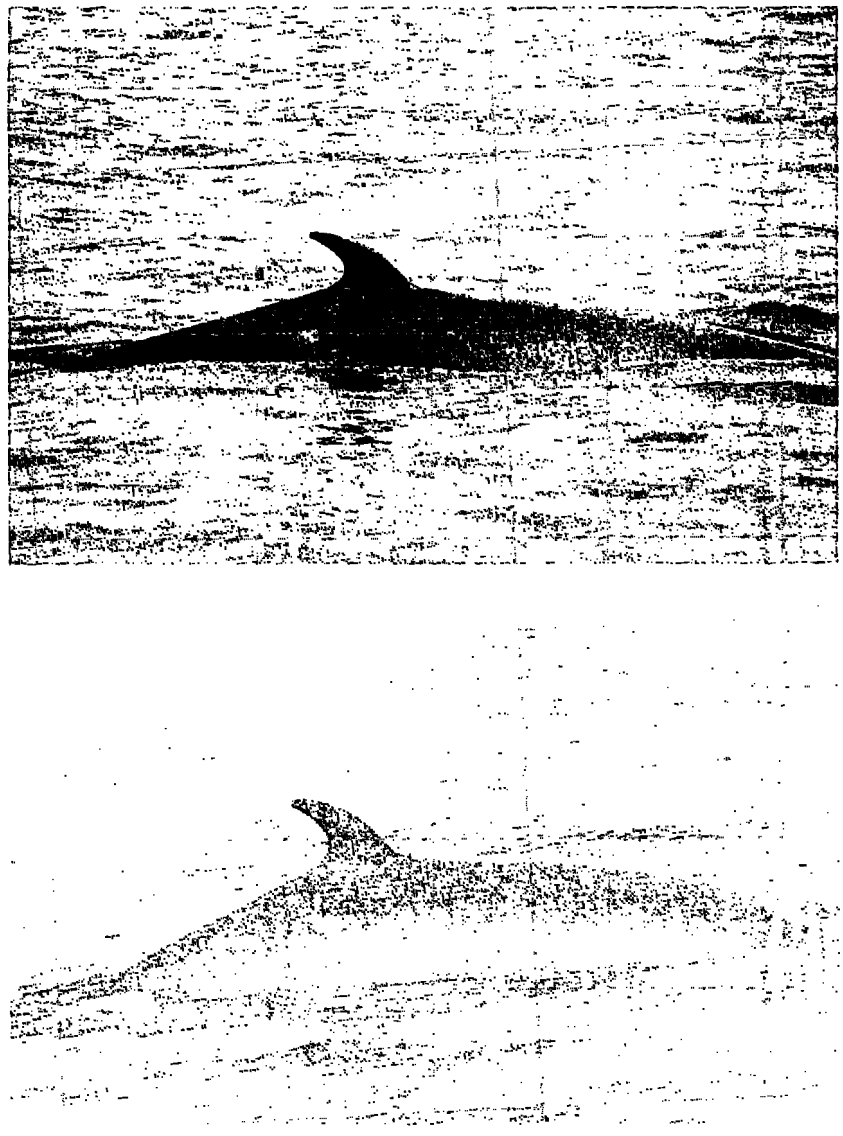

Figure 2

Photographic match of sei whale *Balaenoptera borealis* #22, utilizing both circular scars and dorsal-fin notches as aids in identification. Note the pattern of circular scars below the dorsal fin, particularly the large circular scar below and immediately posterior to the dorsal fin, and the slightly blunted tip of the fin itself. Top photograph was taken 10 August 1986, bottom photograph on 22 August 1986.

Defecations were observed nine times. Feces were bright red and contained chunks of particulate matter. Only mandibles from the copepod *Calanus finmarchicus* were subsequently identified in fecal material.

While feeding and traveling comprised most of the behavioral events (both time and number), milling (at least three socializing with one another while moving in apparently random directions, rolling, and remaining on the surface continually for over 10 min) was seen four times. This was always associated with one whale leaving the group either during or immediately after the milling period. Breaching was seen once, when a single animal breached twice in rapid succession.

Social behavior

Sei whales were seen in groups of 1—6 individuals. Mean group size was 1.8, and was the same on both

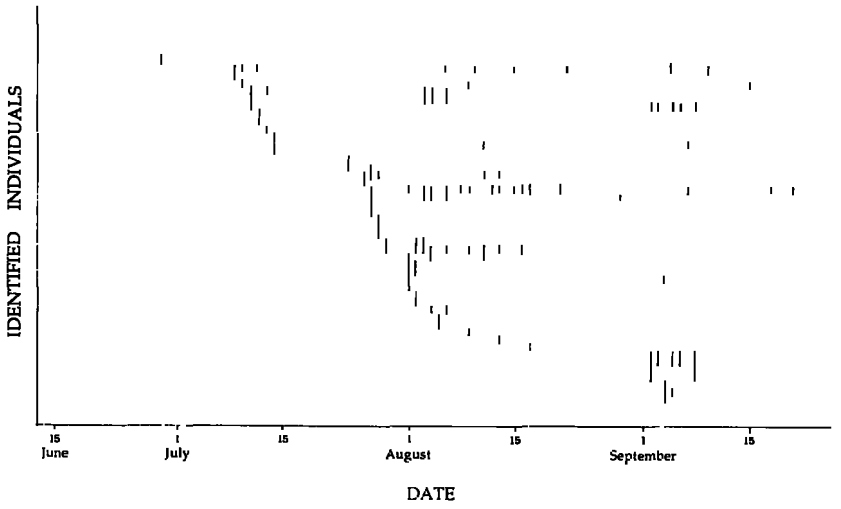

Figure 3

Occurrence of individual sei whales *Balaenoptera borealis* in the southern Gulf of Maine during 1986. Individual whales are ordered (top to bottom) by date of first sighting; each row of marks represents the dates on which one individual was seen during the year. Vertical marks represent single whales.

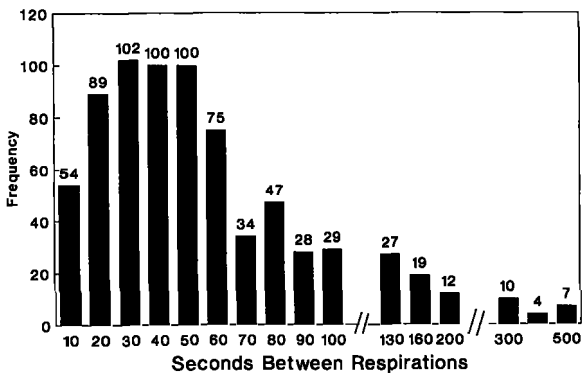

Figure 4

Histogram showing the distribution of breath intervals (sec) from sei whales *Balaenoptera borealis* recorded during 52 sightings in the 1986 season on northern Stellwagen Bank. Note the scale change for the longer breath intervals due to their infrequent occurrence.

northern and southern Stellwagen Banks, where most observations took place (two-tailed t-test, p 0.93, 1 df). Resightings of individual animals on successive days were recorded 14 times. In cases where all members of an associated group were photoidentified, only one pair of animals was seen together on two days; one whale from this pair was later sighted with a different associate two days later. These data indicate that individual associations were transient, generally lasting less than 24 hr.

Of 13 cow/calf pairs, 3 (23.0%) were associated with 1 or more other whales, while 48 (51.6%) of the 93 non-calf groups involved 2 or more whales. Frequency of association with another whale was not statistically significant between groups with and without mother-calf pairs (χ^2 3.7, p 0.06, 1 df). Cow/calf pairs were never seen with more than one associate.

Comparisons with other data sets

Sei whales identified in the southern Gulf of Maine in 1986 were compared with one 1984 photograph from Georges Bank (Atlantic Cetacean Research Center), one from Stellwagen Bank in 1987 (Plymouth Marine Mammal Center), one from Jeffrey's Ledge in 1988 (Cetacean Research Unit), three from the Scotian Shelf in 1988 (Atlantic Cetacean Research Center and Nancy Miller), and four from the Scotian Shelf in 1989 (New England Aquarium). There were two matches. Sei whale 33 was photographed on 11 June 1984 between Wilker's and Oceanographer's Canyon on the southern edge of Georges Bank (40°05'N, 68°19'W), 176nmi from the 1986 sighting; sei whale 19 was photographed on 28 August 1989 on the Nova Scotian Shelf (42°57'N, 65°09'W), 211nmi from its 1986 sighting.

Discussion

Photoidentification of individual animals has been accomplished for numerous baleen and toothed whales (Katona et al. 1980, Dorsey 1983, Agler et al. 1990, Seipt et al. 1990). Our results indicate that some sei whales can be identified using variations in natural markings. Dorsal-fin shape, natural pigment patterns, and scarring were all useful features. The presence of circular scars along the flank—hypothesized to be caused by small sharks (Shevchenko 1977), lampreys, or pathogenic microorganisms (Tomilin 1957, Rice 1977)—and dorsal-fin notches (unknown origin) both facilitated identification of the individuals. While these techniques work within a single season, the possibility of acquiring new dorsal-fin notches, new scars, or

having scars change with age (Shevchenko 1977) might make identification over a prolonged period difficult.

The lack of distinctive markings on some individuals indicates that while photoidentification is useful in studies of sei whales, it is not likely to allow identification of all members of the population. Because we were unable to determine the sex and/or age of the animals involved, it is impossible to indicate whether distinctive markings were related to age or sex.

The photographic matches of sei whales in the southern Gulf of Maine to both Georges Bank and the Scotian Shelf lend some support to the idea that whales in the 1986 influx were from the closest-known geographic stock. However, given the dearth of knowledge concerning the biogeography of this species, and Brown's (1977) record of a sei whale moving 4000 km in 10 days, many or all of the animals reported here may come from other locations in the North Atlantic. During the year of the southern Gulf of Maine influx, abnormally high levels of *Calanus finmarchicus* were present on Stellwagen Bank (Payne et al. 1990). Our findings therefore lend support to the hypothesis that sei whales show annual areal fluctuations to take maximal advantage of changes in local productivity throughout their range. Whether each individual independently found the increased copepod productivity, or whether social factors were involved in the influx, remains an open question which our data do not address.

Most of the sei whales in 1986 were seen during late July and early August, with a secondary peak in early September (Fig. 3). This suggests that the local productivity provided a brief stop-over point during the summer feeding season. Repeated resightings of a few individuals during the study suggest that a small number of animals found prey levels adequate to allow a prolonged occupancy period.

Observed behavior of sei whales was similar to that previously described (Tomilin 1957, International Whaling Commission 1977, Horwood 1987). The relatively small variation around the mean breath interval shows a departure from the standard balaenopterid pattern of hyperventilation, e.g., several breaths taken in rapid succession followed by a longer diving period (Gunther 1949, Leatherwood et al. 1976). The rolling we observed during apparent feeding behavior differs from that described by Tomilin (1957) who did not observe this species roll during feeding.

Social groups observed in this study are similar to those reported by studies of other balaenopterids, with individuals being sighted either alone or in small groups (Nemoto 1964, Dorsey 1983, Whitehead and Carlson 1988). Lockyer (1977) reported a mean associated group size of 2.4, slightly higher than the 1.8 reported here. Since she did not define an associated group, however, direct comparisons are difficult. Further, if there is a correlation between the associated group-size and prey patch-size (such as that described for humpback whales by Whitehead 1983), it is possible that the larger group size observed could be explained by the more productive Antarctic waters. Our limited data also suggest that, as in other baleen whales, cow/calf pairs were more solitary than other animals, both in frequency of association with other individuals and in overall group size. This has previously been documented in humpback whales (Clapham and Mayo 1987), gray whales *Eschrichtius robustus* (Swartz 1986), and right whales *Eubalaena australis* (Payne 1986).

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