Abstract.—Between 1980 and 1987 in Massachusetts Bay, 156 individual fin whales *Balaenoptera physalus* were photographically identified using variations in natural markings and scars. Of these, 98 (62.8%) were observed more than once, and 70 (44.9%) were photographed in 2 to 8 different years. On average, 49.2% of whales seen in a year were resighted at least once during that year, and 44.5% were observed the following year. Within a year, the observed occupancies (the period between first and last sighting) of resighted individuals varied from 1 to 197 days (mean 46.1), while the number of separate days on which individuals were sighted ranged from 1 to 12 days (mean 2.5). However, given the strong bias in photographic effort towards other species in the region, it is likely that rates of within-season occurrence and annual return are considerably underrepresented in the data. Overall, the results suggest some similarity between the population characteristics of fin whales and those of the sympatric humpback whale *Megaptera novaeangliae*, although data from whaling catches and from radio telemetry point to the existence of major differences between the two species.

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Population Characteristics of Individually Identified Fin Whales *Balaenoptera physalus* in Massachusetts Bay

Irene E. Seipt
Phillip J. Clapham
Charles A. Mayo
Mary P. Hawvermale

Cetacean Research Program, Center for Coastal Studies
Box 1036, Provincetown, Massachusetts 02657

In recent years, techniques for the identification of individual cetaceans using variations in natural markings and scars have permitted investigations of the biology and behavior of many species (recently summarized in Hammond et al. 1990). Some of these studies have yielded detailed descriptions of the structure and patterns of migratory movement of some populations. Until recently, similar studies of fin whales *Balaenoptera physalus* had been hampered by the lack of a technique with which to reliably identify individual whales, and by the tendency of observers to concentrate on more accessible species whose ranges overlap that of the fin whale.

As a result, the high-latitude distribution of the fin whale remains poorly understood despite extensive hunting this century. On the one hand, whaling data and information from some radio telemetry studies have shown that fin whales sometimes undertake extensive movements. For example, a whale radio-tagged by Watkins et al. (1984) travelled 1700 km across the Irminger Sea in 9.5 days. Discovery tag returns suggest that Antarctic fin whales, at least over the course of several seasons, may have high-latitude ranges that encompass as much as 90 degrees of longitude (Brown 1962). In contrast to this, a whale tagged by Watkins et al. (1981) in Prince William Sound, Alaska, exhibited short-term site fidelity, remaining in a restricted area for at least 28 days. At a broader level, whaling data led Sergeant (1977) to characterize the composition of the North Atlantic fin whale population as a "patchy continuum." Mitchell (1974) believed that some spatial separation of stocks existed, but that different populations moved latitudinally with the seasons, with some whales moving south in winter to occupy the summering areas of others. Data from CeTAP (1982) generally support this idea of a seasonal shift in the population.

Mayo (1982) and Mayo et al. (1985) presented a technique for the identification of individual fin whales using variations in natural features as well as prominent scars. This technique has since been adopted by a number of observers in the western North Atlantic (Clapham 1987, Agler et al. 1990), and has been used by us to study the population characteristics of fin whales observed in Massachusetts Bay during the period 1980–87. We present here the results of this study, including evidence that fin whales on a high-latitude feeding ground exhibit patterns of seasonal occurrence and annual return that are in some respects similar to those shown for humpback whales *Megaptera novaeangliae*.

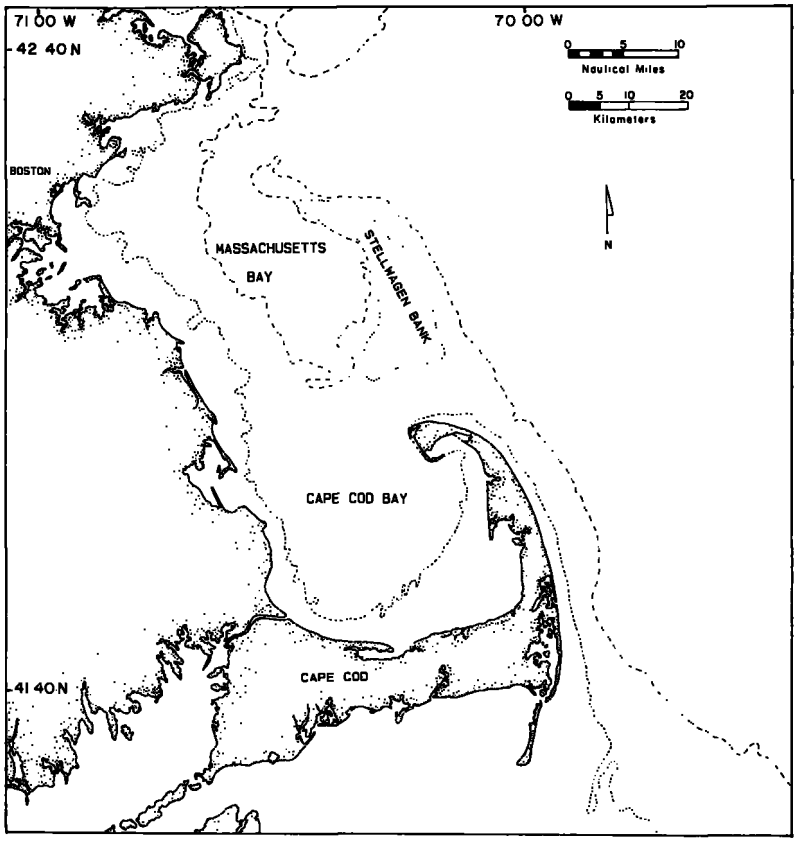

Figure 1
Fin whale study area.

Methods

The observations in this study were conducted in the coastal region dominated by Massachusetts Bay and Cape Cod Bay (Fig. 1) between the years 1980 and 1987 inclusive. Observations were made from 30-m commercial whalewatching vessels operating between April and October of each year from Provincetown, Massachusetts. Beginning in the autumn of 1983, additional cruises were made from a 12-m diesel-powered research vessel and, beginning in the autumn of 1985, from a 14-m auxiliary ketch. The total number of cruises conducted during the study period was 5979, 97% of which were made by whalewatching vessels.

Search patterns were in most cases non-random and non-systematic. This was particularly true of the whalewatching vessels, where search tracks were decided by the captains based upon where most whales had been seen the previous day or trip. Search effort directed specifically at fin whales varied considerably. Because humpback and (during the spring) right whales *Eubalaena glacialis* were preferred by the whalewatching vessels, opportunities to obtain usable photographs of fin whales occurred only incidentally except during periods when the preferred species were less abundant or absent. An exception were four fin whales that exhibited large, permanent scars that were easily noticeable from a distance of 100 m or more. Because these whales were among the few that could be readily recognized by all observers in the field, they were much more likely to be photographed, and confirmation of identity could be achieved with poorer quality photographs than those taken of unscarred whales.

Individual fin whales were identified using variations in natural markings, as described in Clapham (1987), Hawvermale (1987), and Agler et al. (1990). Major features used included the shape of the dorsal fin, the light-colored wash of pigment on the right side of the head (the "blaze"), and the V-shaped pattern of light pigment behind the blowholes and extending down both sides of the whale (the "chevron"). Scars were also used. A full definition of features and a description of the technique can be found in Agler et al. (1990).

Fin whales exhibit asymmetry in their coloration, with greater variability in features on the right side of the head than the left; consequently, while some whales were identified using both right and left sides, an individual was not considered matchable if only the

left side was photographed. Because fin whales generally have less marked variations in their features than do humpback or right whales, and because a series of photographs of high quality are generally required to successfully identify an individual, we adopted a conservative approach in our matching: only photos of excellent quality were used, and a match was considered confirmed only if three features were common in photographs of both sightings.

Photographs were taken with a 35-mm camera equipped with a 200-mm, 300-mm or 400-mm lens, power winder, and recording databack. Kodak Tri-X or T-Max film (both rated at ISO 400) was used. Copies of photographs were sent to the North Atlantic Fin Whale Catalogue at College of the Atlantic in Bar Harbor, Maine, for analysis of the movement of individual whales outside our study area.

Definitions

The following terms are used in this report:

Occupancy The sum of the resighting intervals of an individual whale within years, i.e., the number of days between the first and last sighting of a whale in a particular year. We do not assume that an individual was necessarily present in the study area for all or part of the period between sightings.

Occurrence The temporal distribution of an individual whale in the study area, expressed as the total number of separate days on which the whale was observed.

Resighting interval The interval, in days, between successive sightings of an individual whale within a particular year.

Results

During the period 1980–87, a total of 156 fin whales were individually identified. While many other animals were photographed, this number represents only those whales that were sufficiently well-marked and well-photographed to ensure that the file contained no duplicates. A total of 98 individuals (62.8%) were observed more than once, 70 (44.9%) of which were photographed in more than one year. The photographs shown in Figure 2 provide one example of the features used to identify an individual whale in two different years.

Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

While fin whales were sometimes observed between the beginning of November and the end of February, none were photographed during this period in any year. (In 1979, only two fin whales were photographed, both of which were subsequently resighted).

Table 1 shows the number of individuals observed for each year of the study period, the percentage of these animals that were photographed on more than one day in that year, and that were reidentified in each subsequent year. The occurrence of identified fin whales during 1987 (the year with the largest number of cruises) is shown in Figure 3. This temporal distribution is broadly representative of other years with a similar level of effort. Table 2 summarizes resighting intervals, grouped by 10-day periods, for 1985, 1986 and 1987 combined (the 3 years with the greatest vessel effort).

Occupancy was calculated for each whale that had been observed more than once in a year (individuals seen only once or not at all in the year were excluded). Observed occupancies ($n = 159$, including two or more occupancy periods for individuals who were resighted in more than one year) ranged from 1 to 197 days (mean 46.1 days, SD 47.407). The mean number of days in a year that individual fin whales were photographed (occurrence) was calculated (including individuals observed on only one day, but excluding individuals not observed in the year). Observed values ($n = 264$) ranged from 1 to 12 days (mean 2.5 days, SD 2.011).

Of the 70 individual fin whales photographed in more than one year, 26 were observed in 2 years, 15 in 3 years, 14 in 4 years, 7 in 5 years, 3 in 6 years, 3 in 7 years, and 2 in 8 years. (These figures include the two individuals identified in 1979.) Table 3 summarizes the sighting histories of these whales.

Discussion

A major problem confounding interpretation of the data presented here is the relatively low level of effort involved in this study. An appreciation of the difference in effort directed at fin whales and at humpback whales (the whalewatching vessels' preferred species) can be gained by comparing the respective ratios of sightings to individual identifications, i.e., the total number of whales recorded (whether photographed or not) versus the number of sightings for which not only was a photograph taken, but where the photograph was good enough to positively identify the individual. For humpback whales, this ratio is consistently about 1.2:1 for all years. For fin whales, however, the ratio ranged from 11:1 in 1986 (a year with unusually low numbers of humpback whales) to 83:1 in 1981. The mean for all years was 32:1. These ratios reflect two factors. Firstly, far fewer fin whales were approached than hump-

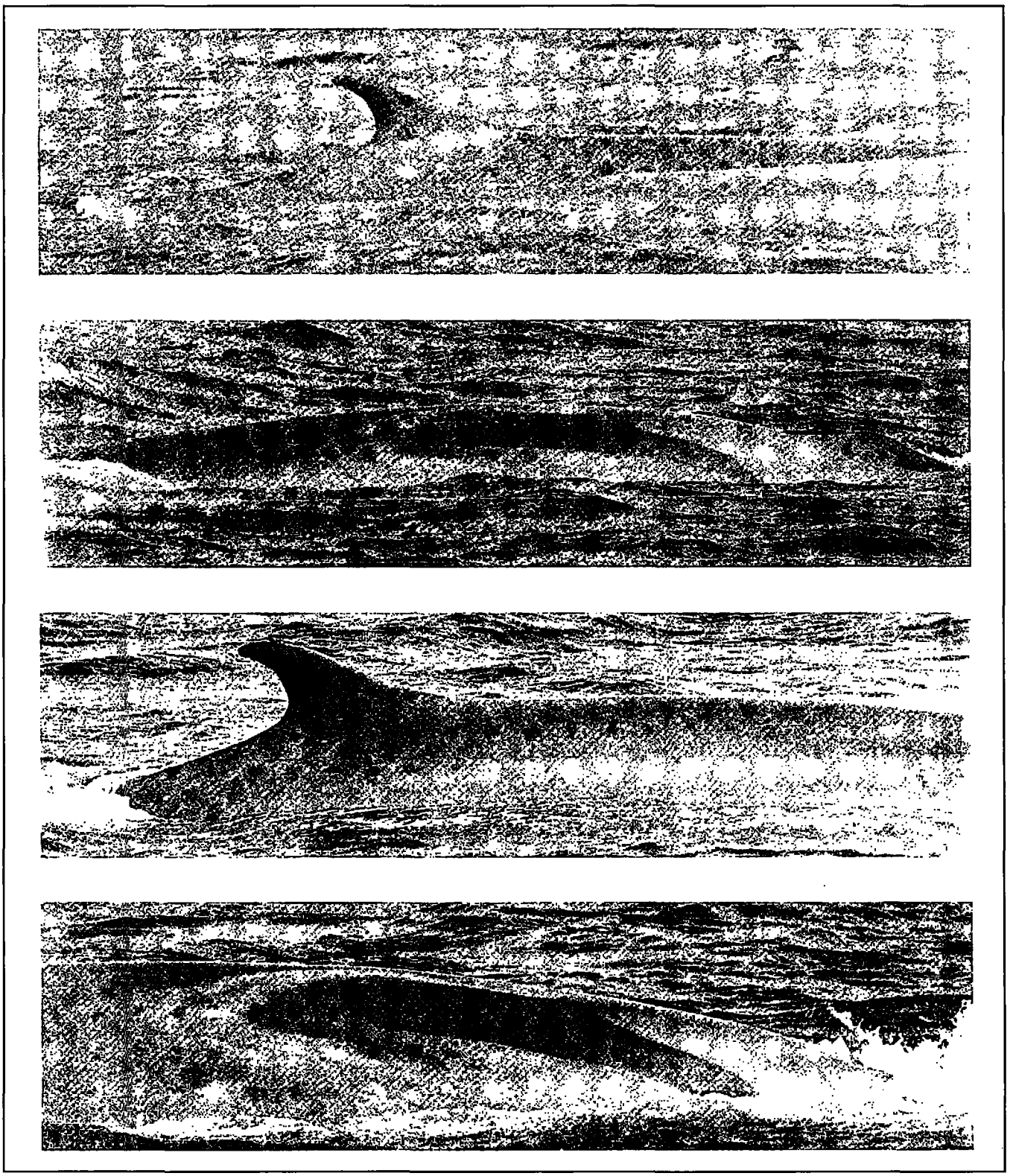

Figure 2

An example of a year-to-year match of an individual fin whale in Massachusetts Bay. The photos show catalogue number 0143 in 1983 (top two photos) and in 1987 (bottom two photos).

Table 1

The number of individual fin whales (n) identified in Massachusetts Bay for each year of the study period, and the percentage of those individuals that were reidentified within the same year, and in each subsequent year. For example, of the 22 individuals identified in 1981, 50.0% were seen more than once that year, 59.1% were reidentified in 1982, and 50% in 1983. The mean of all same-year resightings is 49.2%. The mean of all consecutive year values (e.g., 1980–81, 1981–82) is 44.5%.

	1980	1981	1982	1983	1984	1985	1986	1987
1980 $n = 21$	33.3%	38.9%	38.9%	50.0%	44.4%	33.3%	66.7%	61.1%
1981 $n = 22$		50.0%	59.1%	50.0%	40.9%	45.5%	40.9%	45.5%
1982 $n = 38$			42.1%	42.1%	39.5%	42.1%	47.4%	47.4%
1983 $n = 33$				48.5%	42.4%	36.4%	54.5%	60.6%
1984 $n = 38$					50.0%	36.8%	44.7%	50.0%
1985 $n = 31$						58.1%	54.8%	51.6%
1986 $n = 67$							52.2%	37.3%
1987 $n = 64$								59.0%

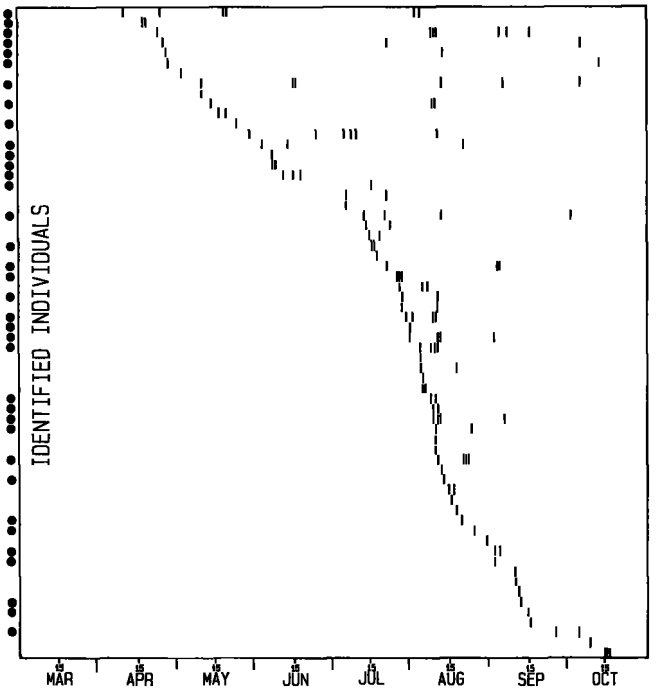

Figure 3

Observed temporal occurrence of individual fin whales in Massachusetts Bay during 1987. 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. A black dot to the left of the vertical axis signifies that the individual concerned had been observed in at least one previous year of the study period.

Table 2

Resighting intervals, grouped by 10-day periods, of individual fin whales photographed in Massachusetts Bay for the three years 1985, 1986 and 1987 combined. The zero-interval category encompasses whales that were observed only once during a year.

Interval (days)	No. of intervals
0	81
1–10	146
11–20	24
21–30	14
31–40	9
41–50	6
51–60	4
61–70	2
71–80	2
81–90	2
91–100	2
101–110	0
111–120	0
121–130	0
131–140	0
141–150	0
151–160	1
161–170	1
171–180	1

Table 3

Sighting histories of individual fin whales observed in Massachusetts Bay in more than one year of the study. O = observed. Note: 0180 and 0394 were also observed in 1979.

No.	1980	1981	1982	1983	1984	1985	1986	1987	No.	1980	1981	1982	1983	1984	1985	1986	1987
0017	O	O	O	O		O	O	O	0227			O	O			O	
0027	O	O	O	O	O	O		O	0228			O	O			O	
0045	O					O	O		0230			O		O			
0061	O	O		O			O	O	0232			O				O	
0062		O	O			O	O		0233			O		O	O		O
0064	O				O		O	O	0241			O	O				O
0068	O		O						0261	O		O				O	O
0069	O			O				O	0266			O		O	O		
0081	O	O	O	O	O	O	O	O	0267			O	O		O	O	O
0086	O			O	O			O	0275			O			O	O	O
0089	O	O		O	O	O	O	O	0281			O		O		O	O
0090		O	O						0286			O					O
0093	O		O		O		O		0287				O	O			
0096	O							O	0299				O		O		
0110	O	O							0303				O		O	O	
0113				O			O		0318				O	O			
0114	O					O	O		0319				O	O		O	O
0126		O	O		O	O			0322				O	O		O	O
0131		O					O		0334				O			O	O
0137	O				O		O		0357					O		O	
0141		O	O						0367					O	O	O	O
0143		O	O	O			O	O	0391					O		O	O
0146		O	O	O	O	O		O	0394					O	O	O	O
0174		O	O		O	O			0420					O		O	
0179	O	O		O			O		0434					O		O	
0180		O	O	O	O	O	O	O	0443					O		O	O
0183		O	O	O	O			O	0452					O	O		
0189		O	O	O	O	O		O	0512						O	O	
0213			O	O		O	O	O	0520						O	O	O
0215			O	O	O	O		O	0521						O		O
0218			O		O				0542						O	O	
0222	O		O	O	O		O	O	0575							O	O
0224			O				O		0582							O	O
0225			O			O	O		0584							O	O
0226			O	O			O		0592							O	O

backs. Furthermore, while a humpback can often be recognized from a single poor-quality photograph, identification of most individual fin whales requires a series of high-quality photographs which must be taken from approximately the same position relative to the whale.

Despite this, the frequency with which individual fin whales were resighted is high. Roughly half of the fin whales seen in one year were seen again the same season, and about half were also resighted the following year. Resighting intervals provide some evidence for a degree of residency on the part of some whales, and of bimodal occupancy by others. However, the many gaps in the sighting histories of individuals are difficult to interpret. Do the gaps represent whales that were resident in the area for extended periods but were not photographed, or do they indicate movement to other areas between sightings? At this point, we can say only that, given the obvious bias in effort, it seems likely that rates of within-season occurrence and annual return of fin whales in Massachusetts Bay are considerably under-represented in our data. When only 1 out of every 83 fin whales sighted is identified (as occurred in 1981), it is unlikely that even an individual which remained in the area for many weeks would be recaptured more than a few times. This is supported by the fact that the subset of individuals towards which there was clear observer bias—those bearing large, prominent scars—were among the most frequently observed animals during this study. For example, whale number 0081, named "Braid" (an animal with very large propeller scars on its left side), was observed in all 8 years, with a mean occupancy of 116 days, and mean occurrence of 6 days.

It is clear, however, that many of the gaps in our sighting histories of individual whales represent real absences from the area. Resightings of individuals outside our study area confirm that the summer ranges of these whales are often, if not regularly, extensive. In a preliminary analysis of photographs from the North Atlantic Fin Whale Catalogue, Agler et al. (1990) report a number of instances of movement of individuals between Massachusetts Bay and the waters of Maine and the Bay of Fundy. It is possible that some individuals undertake extensive movements outside the Gulf of Maine, but the current lack of observer effort beyond this region precludes investigation of this idea.

From the regional perspective of this study, it is tempting to compare the results reported here with the much more complete information available on Gulf of Maine humpback whales and to conclude that the two populations are broadly similar in their patterns of occurrence and distribution. The annual return rate of humpback whales to Massachusetts Bay is extremely high, with as many as 85% of individuals observed in one year returning the next (Mayo 1983, Mayo et al. 1988). While no individual humpback remains in Massachusetts Bay for an entire season, many appear to spend prolonged periods in the area between making wider forays elsewhere in the Gulf of Maine (Clapham and Mayo 1987, Mayo et al. 1988). Other humpbacks are observed less often, and presumably frequent other habitats for much of the year, a fact which reflects considerable variation among individuals. It is also clear that overall individual fidelity to the Gulf of Maine is maternally directed (Clapham and Mayo 1987).

It is not unreasonable to expect that fin whales might exhibit similar patterns of occurrence. Given that the distribution of fin and humpback whales in high latitudes must be predominantly related to the distribution of their prey (Payne et al. 1986), it is to be expected that the occurrence of both species should be characterized by individuals returning repeatedly, both during a season and from year to year, to consistently productive habitats such as Massachusetts Bay. From the standpoint of energetics, it would make little sense for an individual to abandon an area of high productivity and search elsewhere if the resources found in the former habitat were adequate for its needs, although it is possible that, as suggested by Watkins et al. (1984), social imperatives play an important role in the movement of individuals.

Overall, the data presented here suggest that there are more similarities than differences in the high-latitude population characteristics of humpback and fin whales, although data from other sources suggest that significant differences between the two species do exist. In addition to the above-mentioned studies which documented extensive movements on the parts of individuals (Brown 1962, Mitchell 1974, Watkins et al. 1984), other observers have noted evidence for spatial segregation by length in certain areas (Mackintosh 1942, Mitchell 1974, Rorvik et al. 1976, Sergeant 1977), a phenomenon that has not been demonstrated for humpbacks. Our own data are regional in nature and do not permit us to address these broader questions of population structure at the oceanic level. However, with increased photographic effort in other areas, studies based upon the identification of individual fin whales should provide clearer insights into the population biology of this species in the North Atlantic.

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