Population identity of humpback whales (*Megaptera novaeangliae*) in the waters of the US mid-Atlantic states

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ABSTRACT

In recent years, humpback whales (*Megaptera novaeangliae*) have been observed in the waters of the US mid-Atlantic states (USMA; New Jersey to North Carolina), notably in winter. The level of the mortality in this area (52 recorded deaths from 1990-2000), makes it important to understand the nature and population identity of this aggregation. Of the approximately 100 humpback whales documented in this study, photographs of 41 (live or dead) were of sufficient quality to be compared to catalogues from the Gulf of Maine (GOM, the closest feeding ground) and elsewhere in the North Atlantic. Of 22 live whales, 10 (45.5%) matched to the GOM, 5 (22.7%) to Newfoundland and 1 (4.5%) to the Gulf of St Lawrence (GSL). Of 19 dead whales, 6 (31.6%) were known GOM whales. Although the population composition of the USMA is dominated by GOM whales, lack of recent photographic effort in Newfoundland makes it likely that the observed match rates under represent the true presence of Canadian whales in the region. Length data from 48 stranded whales (18 females, 22 males and 8 of unknown sex) suggest that 39 (81.2%) were first-year animals, 7 (14.6%) were immature and 2 (4.2%) were adults. However, sighting histories of five of the dead whales indicate that some were small for their age and histories of live whales further indicate that the population contains a greater percentage of mature animals than is suggested by the stranded sample. The authors suggest that the study area primarily represents a supplemental winter feeding ground that is used by humpbacks for more than one purpose. From a management perspective, although the only successful matches of mortalities to date have been to the GOM, the observed mixing of live whales from different summer stocks might suggest that the high numbers of mortalities occurring there may not be impacting this single stock alone. Although further data are required before conclusions can be drawn, the mortality rate may be significant for the GOM population and this warrants further investigation.

KEYWORDS: HUMPBACK WHALE; NORTH ATLANTIC; POPULATION IDENTITY; MIGRATION, MORTALITY; STRANDINGS

INTRODUCTION

In summer, humpback whales (*Megaptera novaeangliae*) in the North Atlantic are distributed from the eastern coast of the USA north to the waters of the Arctic (Clapham and Mead, 1999; Smith *et al.*, 1999; IWC, 2002). Individual whales show strong fidelity to specific feeding grounds within this range, including the Gulf of Maine, Newfoundland/Labrador, the Gulf of St Lawrence, Greenland, Iceland and Norway (Katona and Beard, 1990; Smith *et al.*, 1999). This fidelity is maternally directed (Clapham and Mayo, 1987) and in some areas persists for long enough to be reflected in the genetic structure of the population (Larsen *et al.*, 1996). Despite this strong segregation, whales from all of the known feeding grounds migrate to a common winter breeding range in the West Indies, where they mate and calve (Palsbøll *et al.*, 1997). It is generally believed that the majority of whales engage in this seasonal migration; however humpbacks have also been observed at high latitudes during winter (Charif *et al.*, 2001; J. Robbins, unpublished data).

In recent years, the occurrence of humpback whales has been documented from the coastal waters of the US mid-Atlantic states (hereafter USMA) from New Jersey to North Carolina (e.g. Swingle *et al.*, 1993; Wiley *et al.*, 1995). Most records are for the January to April period, although occasional sightings are made in the summer. Recorded mortalities are relatively high in the USMA compared to other coastal waters. Between 1990 and 2000 there were 52 reported deaths (Wiley *et al.*, 1995; Waring *et al.*, 2000). Of these, the cause of death could not be determined for 39 (75%). For the remaining 13, 11 were identified as being due to entanglements in fishing gear or collisions with vessels, whereas two showed no signs of human-induced mortality.

Knowledge of the origin of the USMA animals is important since managers must assign anthropogenic mortalities to the correct management stock in order to assess status. The closest feeding aggregation to the USMA is the well-studied Gulf of Maine aggregation that is considered a separate management unit by the US National Marine Fisheries Service (NMFS; Waring *et al.*, 2000). The implications for management will differ if all mortalities in the USMA are from this aggregation or from two (or more) aggregations.

In order to investigate the origin of the USMA animals, identifying photographs of living and dead USMA humpback whales were compared to catalogues from the Gulf of Maine, Newfoundland and other areas of the North

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Atlantic. In addition, patterns of occurrence were combined with available life history data of matched individuals to gain insight into the question of habitat use by humpback whales in the USMA.

MATERIALS AND METHODS

The USMA study area is shown in Fig. 1.

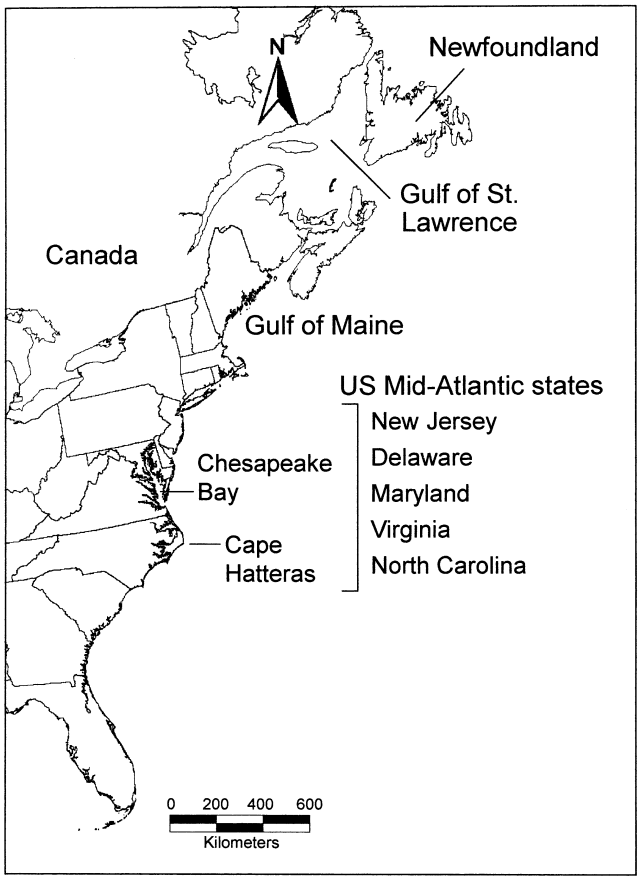

Fig. 1. Study area, in relation to other major regions mentioned in this report.

Observations of live humpback whales derive from a combination of sporadic vessel surveys (particularly in 1993 and 1994) directed at this or other species in the study area and whalewatching excursions based in Virginia Beach, VA and Cape May, NJ. Data collected included date, time, location and behaviour; where possible, photographs were taken for the purpose of individual identification. In the case of dead animals, information was collected by various researchers who responded to the stranding events. Where possible, data on the length and sex of the animal were obtained.

All available photographs of humpback whales observed either alive or dead in this area were included in this study. Most of the images were collected in the Mid-Atlantic Humpback Whale Catalogue (MAMNC) curated by the Virginia Marine Science Museum in Virginia Beach, VA (Swingle and Barco, 2000). Individual humpback whales were identified and catalogued using variations in the ventral fluke pattern and/or in the shape, size and scarring of the dorsal fin (Katona and Whitehead, 1981). These samples include, but are not limited to, those described in Wiley *et al.* (1995) and Swingle *et al.* (1993).

Each fluke photograph was compared to two large ocean-wide catalogues: the North Atlantic Humpback Whale Catalogue (NAHWC) and the collection from the Years of the North Atlantic Humpback (YONAH) project. The NAHWC includes photographs of 5,341 individuals, with observations dating from 1968 to the present. The YONAH collection includes 2,998 individuals, with the great majority photographed during a two-year ocean-basin-wide collaborative study in 1992 and 1993 (Smith *et al.*, 1999). Both catalogues include photographs from all studied areas of the North Atlantic, including the Gulf of Maine, the Gulf of St Lawrence, Newfoundland, Labrador, West Greenland, Iceland, Norway and the West Indies. Both catalogues are curated by the College of the Atlantic in Bar Harbor, Maine.

In addition to the oceanic catalogues described above, photographs in this study were compared to two regional Gulf of Maine catalogues. While these catalogues overlapped with the oceanic collections to some degree, they contained more recent coverage and more detailed information on the individual animals in that region. Regional catalogues also maintained photographic coverage of the dorsal fin that was an additional source of potential matches to USMA photographs. Gulf of Maine researchers collaborate to identify new additions to the population, but maintain separate photographic catalogues and archives that differ in their underlying levels of effort and geographic coverage. In this study, comparisons were made to a catalogue curated by the Center for Coastal Studies (CCS) in Provincetown, Massachusetts and to one curated by the Whale Center of New England (WCNE) in Gloucester, Massachusetts. The CCS catalogue includes photos of 1,273 individuals sighted from 1975 to the present, including directed effort throughout the Gulf of Maine. The WCNE collection includes 1,419 individuals, with the earliest observations from 1974.

Animals deemed less likely to be successfully matched to high latitude catalogues due to low image quality or animal distinctiveness were excluded from the matching effort with the NAHWC and GOM catalogues. In the case of stranding documentation, the condition of the carcass was also considered. However, all available photographic documentation, regardless of feature or quality, was used to establish within- and between-year resightings of individuals in the USMA.

Exact or minimum ages of USMA animals were determined based on previous sightings in other regions. An exact age was known for animals first catalogued as calves. Animals without a known year of birth were assigned a minimum age by assuming that the whale was at least one year old the first time that it was sighted. Female humpback whales in the Gulf of Maine have been shown to reach sexual maturity at an average age of five years (Clapham, 1992), a figure that corresponds well with findings for both male and female humpback whales in the Southern Hemisphere (Chittleborough, 1965). Animals known to be less than five years old were considered to be juvenile, while those known to be at least five years old were considered to be sexually mature. A maturational class could not be confidently assigned to whales that were not seen as calves and who were first catalogued less than four years before the study period. For stranded animals, age class was also inferred from body length. Animals less than 9.9m were considered to be dependent or newly independent animals born the previous winter. Males between 10.0 and 11.5m and females between

10.0 and 11.9m were considered to be independent but sexually immature. Males greater than 11.5m and females in excess of 11.9m were considered to be sexually mature (Clapham and Mead, 1999).

The sex of live animals was determined by molecular genetic analysis of skin samples collected by biopsy techniques, either in the USMA or the Gulf of Maine (Bérubé and Palsbøll, 1996a; b; Palsbøll *et al.*, 1997). The sex of dead whales was determined by direct examination of the genital area and/or reproductive organs.

For the purpose of discussing temporal distribution of records, the seasons were defined as follows: spring = April-June; summer = July-September; autumn = October-December; and winter = January-March.

RESULTS

Strandings[1]

Of 52 known humpback whale mortalities in the USMA between 1990 and 2000, 32 were from North Carolina, 13 from Virginia, 3 from Delaware and 2 each from Maryland and New Jersey. These are summarised by year in Fig. 2 and by month in Fig. 3. In addition, one individual originally photographed in the Gulf of Maine in the winter of 2000 stranded in Virginia in April of 2001. This whale was not included in stranding analyses (Table 1), but was included in the matching analyses (Tables 4 and 5).

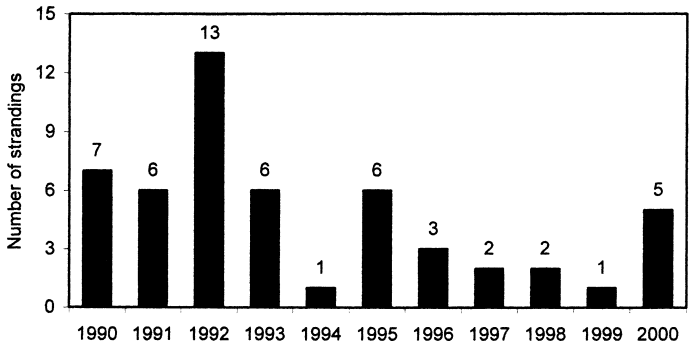

Fig. 2. Yearly frequency of humpback whale strandings in the US mid-Atlantic (NJ-NC) from 1990-2000 ($n = 52$).

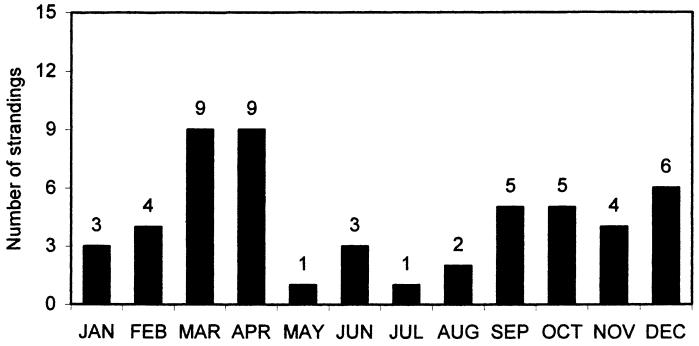

Fig. 3. Monthly frequency of humpback whale strandings in the US mid-Atlantic (NJ-NC) from 1990-2000 ($n = 52$).

Strandings occurred in all years, although there was a noticeable peak of 13 animals in 1992. They were also distributed throughout the year, with a peak in late winter/early spring and the fewest strandings (eight) in summer. In 48 cases, there was information on the sex and/or length of the stranded animal; these are summarised by sex and age class (inferred from length) in Table 1. The sex ratio of stranded whales did not differ significantly from parity ($\chi_2 = 0.20$, df = 1, $p = 0.65$). Judged by length data alone, the majority (39, or 81.2%) would be considered first-year whales, including eight animals that were likely to have been dependent (unweaned) calves. Seven (14.6%) would be considered sexually immature, while only two (4.2%) were large enough to be defined as adults. However, five animals had a prior sighting history from the Gulf of Maine with which to evaluate these length-based determinations. One 7.2m female was first documented as a calf and was therefore known to have died in the spring of her second year. Another male was known to have been at least four years old, despite a measured length of only 9.9m. The exact age of the remaining three animals was unknown, but they were at least near the end of their second year (9.5m male) or the beginning of their third year (8.9m female, 11.1m male) when their carcasses were recovered. Based on carcass length alone, all but the last animal listed would have been considered first-year whales. In addition, necropsy reports of some animals indicated the presence of partially digested fish and/or fish bones and otoliths in the stomachs of stranded whales.

Table 1

Strandings of humpback whales in the US mid-Atlantic, 1990 to 2000, by sex and age class. Age class was inferred from length, as described in Methods. However, some designations are known from sighting history data to be inaccurate (see text).

Age class	Male	Female	Unknown	Total	
1st-year whale	17	16	6	39	81.2%
Immature	4	2	1	7	14.6%
Mature	1	-	1	2	4.2%
Total	22	18	8	48	100.0%

Live whale sightings[1]

Most sightings of live whales were documented in Virginia, which was the focus of most of the sighting effort. However, sightings were also made in New Jersey and North Carolina. Humpback whales were sighted in all seasons, but predominated between January and March. Of the 58 live whales seen, 43 were sighted in winter, primarily in Virginia and North Carolina, 6 were sighted in spring, 12 were observed in summer, primarily off New Jersey and 3 were observed in the autumn. Four whales were sighted in two seasons, one was observed in three seasons. In addition to identifying photographs, whale watch interpreters in Virginia have often noted observing whales with extended ventral grooves surfacing with mouths partially open (Virginia Marine Science Museum, unpublished data).

Thirteen individuals were documented in the USMA region in multiple years. Eleven were sighted in two years, while two were sighted in three years. Most ($n = 8$) re-sightings were limited to consecutive years. However, animals were also found to return 2 ($n = 2$), 3 ($n = 2$), or 6 years ($n = 1$) after their initial sighting.

Exact or minimum ages were available for ten individuals previously documented in other regions. The only live whale first documented as a calf was subsequently sighted in the USMA at the age of seven. The average minimum age of the remaining sample was 3.7 years ($n = 14$, range = 1-6 yrs). When exact and minimum age data were combined, four sightings (26.7%) involved animals that had exceeded the average age of sexual maturity (five years). An additional

[1] The complete set of stranding and sightings data are available from the author or the Office of the Journal.

five sightings involved animals that were at least four years old at the time. As females in the Gulf of Maine have been sighted with calves as early as the age of five, it is conceivable that some of those animals might also have reached sexual maturity.

The sex of 10 USMA whales was determined from molecular genetic analysis of biopsy samples; seven were females and three were males.

Results of photographic matching

A minimum of 44 animals were documented alive in the USMA between 1990 and 2000. Because some individuals were represented only by dorsal fin and others only by fluke photographs, it is likely that some, but not all, animals were catalogued more than once. If however, all of the dorsal fins were different from the flukes, there were as many as 58 unique individuals in the dataset. After rejection of poor quality photographs, 22 unique animals could be identified by fluke pattern. Of the 52 stranded whales, 19 had fluke images of adequate condition for identification.

Sightings information on matched live and dead whales is summarised in Tables 2 and 3, respectively. Three additional Gulf of Maine matches to live whales were made on the basis of dorsal fin photographs; however, these are not included in Tables 2-5 because this feature was not available for matching to catalogues from other feeding grounds. A summary of the number of individuals identified, by state, is given in Table 4. Fluke photographs from 41 individual humpback whales (22 living and 19 dead) were deemed suitable for comparison to other catalogues from the North Atlantic. As shown in Table 5, 20 (14 live and 6 dead) of the 41 individuals were matched to the following areas: Gulf of Maine (16; 39.0%), Newfoundland (5; 12.2%) and the Gulf of St Lawrence (1; 2.4%). Two live whales were matched to both the Gulf of Maine and Newfoundland making a total of 22 matches of 20 individuals. One Gulf of Maine whale was also seen in the West Indies (on Silver Bank) three years prior to its sighting in the USMA.

DISCUSSION

Habitat use and population composition

Swingle *et al.* (1993) presented data on sightings of humpback whales feeding in the nearshore waters of Virginia during the winters of 1991 and 1992. They suggested that the increase in records of this species from the USMA was a recent phenomenon and was not likely due to increased observer coverage. A similar conclusion was reached by Wiley *et al.* (1995), who reviewed stranding records of humpback whales along the USMA coastline. They found records of 30 strandings from 1985-1992, with the highest number in North Carolina and the greatest density of strandings occurring in an area from the Chesapeake Bay to Cape Hatteras. Four of the strandings occurred from 1985-1989 (0.8/year) while the remaining 26 were reported from 1990-1992 (8.7/year). Wiley *et al.* (1995) argued that, since large whale strandings are unlikely to escape public notice, the dramatic increase in such events was real and probably reflected an increase in the use of these waters by the species. They considered the possibility that a winter concentration of humpback whales that had always been present in offshore waters had moved inshore in recent years, but noted that this was not supported by data from systematic aerial and shipboard surveys of the region (CeTAP, 1982).

Table 2

Summary of the sighting histories of live whales matched by fluke to high-latitude areas. HWC = North Atlantic Humpback Whale Catalogue number; GOM = Gulf of Maine; NFD = Newfoundland; GSL = Gulf of St Lawrence; * = exact date unknown.

	Mid-Atlantic US sightings			High Latitude matches		
HWC No.	ID	State(s)	Year(s)	ID	Area	Year(s)
0984	MAMNCLI001	NJ, VA	1990, 92, 93	EL CID	GOM	1990
3792	MAMNCLI008	VA	1992, 93	Y2657	NFD	1993
3791	MAMNCLI014	NC	1993	NONE	NFD	1994
3690	MAMNCLI058	NJ	1992, 93	BORDER	NFD/GOM	1990, 92/91
7044	MAMNCLI015	NJ, NC, VA	1993, 94	AETNA	GSL	1991, 93
8243	MAMNCLI019	NJ, NC	1992, 94	PUMICE	GOM	1997, 98
3715	MAMNCLI026	NC	1994	NONE	NFD	1991
3680	MAMNCLI032	VA	1993, 95	JETTY	NFD/GOM	1990/ 92, 93
8250	MAMNCLI034	NC	1994	CAMELOT	GOM	1995
8111	MAMNCLI038	VA	1995	HAWKSBILL	GOM	1992, 93, 98
8094	MAMNCLI047	VA	Winter 1999*	SWAN	GOM	1992, 97, 98, 99
8244	MAMNCLI044	VA	Winter 1999*	NIKE	GOM	1994, 98, 99
8252	MAMNCLI045	VA	Winter 1999*	DENALI	GOM	2000
8262	MAMNCLI060	NC	2000	CHARYBDIS	GOM	2000

Table 3

Summary of the sighting histories of dead whales matched by fluke to high-latitude areas. GOM = Gulf of Maine. * This GOM whale is the only 2001 stranding included here. It was not included in data presented in Table 1.

	Mid-Atlantic US sightings			High Latitude matches		
HWC No.	Field number	State(s)	Date	ID	Area	Year(s)
830	13-2-90-DC-W	NC	5 Feb. 1990	COBWEB	GOM	1989
832	VMSM 19901013	VA	19 Nov. 1990	BUBBLES	GOM	1990
996	92-MM-AO-MN-05	MD	16 Apr. 1992	CHOPPER	GOM	1991
887	93-MM-AO-MN-02	DE	6 Mar. 1993	THUNDERBIRD	GOM	1990, 92
8285	VMSM 19961010	VA	2 Apr. 1996	DEXTRA	GOM	1995
8264*	VMSM20011038	VA	9 Apr. 2001	INLAND	GOM	2000

Table 4

Summary of live and dead humpback whales individually identified from fluke photographs taken in the US mid-Atlantic, by state. States are listed from North to South. NJ = New Jersey; DE = Delaware, MD = Maryland; VA = Virginia; NC = North Carolina. * There were five cases in which an individual whale was observed in the waters of more than one state, including one animal seen in three states.

Type	*n*	NJ	DE	MD	VA	NC
Live animals*	22	8	0	0	11	9
Dead animals	19	1	1	1	7	9
Total	41	9	1	1	18	18

Table 5

Summary of fluke matches of live (n =14) and dead (n = 6) humpback whales photographed in the US mid-Atlantic. One Gulf of Maine whale was also seen in the West Indies (on Silver Bank) three years prior to its sighting in the mid-Atlantic. Percentages likely represent minimum figures for match rates; see text for discussion of biases. *Two whales were observed in both the Gulf of Maine and in Newfoundland resulting in 16 matches with 14 individuals.

Type	*n*	Gulf of Maine	Newfoundland	Gulf of St Lawrence
Live animals*	22	10 (45.5%)	5 (22.7%)	1 (4.5%)
Dead animals	19	6 (31.6%)	0	0
Total	41	16 (39.0%)	5 (12.2%)	1 (2.4%)

The data presented in this study can add little to the above discussion. Whether the appearance of humpback whales in the USMA coastal waters reflects population expansion in the North Atlantic, notably in the Gulf of Maine and off Atlantic Canada, is unclear. However, given the estimated population growth rate of 6.5% in at least the former region during the 1980s (Barlow and Clapham, 1997), this is not an unreasonable explanation.

Existing data continue to support the hypothesis that humpback whales use the USMA waters primarily during the winter, with some additional occupation at other times of year. The relative paucity of humpback whales in much of the region during summer was confirmed by systematic aerial surveys conducted by the Northeast Fisheries Science Center in 1995 and 1998. These surveys covered the region from Cape Hatteras, North Carolina north to New Jersey and found no humpback whales on the continental shelf (D. Palka and G. Waring, unpublished data).

Both previous studies from this region (Swingle *et al.*, 1993; Wiley *et al.*, 1995) used body length data from strandings as well as visual estimates of length from live whale observations to suggest that local population composition was heavily biased towards sexually immature animals. Of 25 stranded humpbacks from 1985-1992 for which body length was measured, all were below mean lengths for sexual maturity (11.6m for males and 12.0m for females). Seventeen of the 25 were between 8.0 and 9.9m in length and were thus considered by Wiley *et al.* (1995) to be newly independent (i.e. animals at the end of their natal year and recently separated from their mothers); this is in agreement with more recent work defining length at birth and independence in this species (Clapham *et al.*, 1999).

In contrast, the data reported here tell a somewhat different story about the composition of the USMA animals. Assuming that the average age at attainment of sexual maturity is five years (Clapham, 1992), at least 26.7% of the live whales previously catalogued outside of the region were likely to have been reproductively mature when seen in the USMA based upon the length of their sighting histories. It should be noted that this sample may not be representative of the USMA animals since the likelihood of cataloguing an individual increases over time. However, the documentation of calves is not subject to the same bias, and the only live whale first seen at that age was known to be seven years old at the time of its USMA sighting.

It is not known whether the presence of older whales in the sample represents a change in the composition of the population or is an artifact of the different methodologies employed. In the case of free-ranging whales, visual size estimates have not been tested on a sample of known-age whales, and their subjectivity can produce unreliable results, even among experienced observers. It is also possible that the USMA whales may be physically small for their age. In this study, stranded animals with previous sighting histories were found to be older than their carcass lengths suggested. Under-development, particularly for females, may reduce reproductive fitness and might explain the presence of animals of reproductive age outside the breeding range in winter.

Taking all the data together, we suggest that the USMA waters represent a supplemental feeding ground which may be used by juvenile as well as mature humpback whales primarily in winter but also at other times of the year. That some individuals were observed in more than one year indicates repeated use of this habitat. The occurrence in the stranded sample of apparently yearling whales might indicate that the area (or somewhere nearby) constitutes a place where some mothers wean and separate from their calves; however, there is no way to test this hypothesis at present. The presence of other small animals may reflect overwintering by whales that, while not yearlings, are not yet sexually mature and thus have less reason than adult humpback whales to undertake the migration to tropical breeding areas. However, there is little data on residency times of individuals to confirm that overwintering takes place.

The adults observed in the study area might be passing through on their migration to or from the West Indies, or they may be whales that have chosen to remain in higher latitudes rather than migrating south. However, this question cannot be resolved at present. Neither the available individual USMA residency data nor the available high latitude sightings data preclude either possibility.

Population identity

Gulf of Maine

Of the four western North Atlantic feeding stocks (Gulf of Maine, Newfoundland/Labrador, Gulf of St Lawrence and West Greenland), the Gulf of Maine is geographically the closest to the study area and might be expected to provide most or all of the USMA animals.

The observed rates of exchange between the USMA and the Gulf of Maine (45.5% for live whales and 31.6% for stranded animals) are indeed high, exceeding exchange rates documented among the major known North Atlantic feeding grounds by more than an order of magnitude. For example, of 1,082 Gulf of Maine humpbacks compared to other North Atlantic regions through the end of 2000, only 12 (1.1%) were also recorded off Newfoundland and 22 (2.0%) in the Gulf of St Lawrence (J. Allen, unpublished data). Furthermore, the magnitude of exchange reported here should be considered a minimum estimate. USMA individuals cannot be excluded from the Gulf of Maine aggregation just because they were not successfully matched

to the catalogue. Despite the fact that sampling occurs throughout the Gulf of Maine, sightings effort in Massachusetts Bay, in particular, has been substantially higher than in other regions. Individuals that consistently use other areas of the Gulf of Maine would therefore have been less likely to be sighted and catalogued. Gulf of Maine sightings of matched USMA whales occurred primarily within areas of the highest GOM sighting effort, suggesting that effort may have played a role in the matching results. Effort may also explain why the fluke-based match rate was lower for USMA stranded whales than for live whales; because the likelihood of detecting a Gulf of Maine whale increases with time, it is conceivable that fewer were matched because fewer opportunities existed to sample them alive.

Atlantic Canada

In addition to the expected Gulf of Maine matches, it was somewhat surprising to also find several matches to Atlantic Canada (five to Newfoundland and one to the Gulf of St Lawrence) in the sample. Although these six matches represent only 27.3% of the sample of live whales, this greatly exceeds the among-feeding-grounds match rates noted above.

Furthermore, there is good reason to believe that the observed match rate significantly under-represents the true presence of Canadian whales in the study area. Although photo-identification effort has been relatively constant in the Gulf of St Lawrence, such effort in Newfoundland was drastically reduced after 1993 following completion of the YONAH project. Indeed, all five matches to Newfoundland were observed there prior to 1995; of the ten live whales matched to the Gulf of Maine, six (60.0%) had sighting histories which predated 1994.

An additional bias relates to the age of animals found off the USMA. Although it is clear from the sighting histories of some of the known Gulf of Maine whales in the sample, that a range of age classes is represented in the region, the body length data from stranded animals leave little doubt that many of the whales occurring there are juveniles (i.e. younger than five years of age). Given the lack of photo-identification effort in Newfoundland after 1993, only older whales photographed in the USMA would be matchable to that area of Canada. Put another way, there was virtually no sample of Newfoundland whales to match to after 1993, thus any young animals from that area photographed off the USMA in subsequent years would necessarily have been of unknown origin.

CONCLUSION

Whatever the true representation of Canadian whales in the study area, it is apparent that the waters of the USMA are a mixing area for humpback whales from different summer feeding grounds. Although the parallels can be taken only so far, a similar situation appears to exist for harbour porpoises (*Phocoena phocoena*) in this area. Recent genetic studies have suggested that porpoises found off the USMA have more than a single stock origin, with some animals perhaps coming from as far away as Greenland (Rosel *et al.*, 1999). However, since the genetic analysis was based upon the frequency distribution of mitochondrial DNA haplotypes in a relatively small sample (rather than on resightings of identified individual porpoises), this conclusion must remain tentative pending further research.

Management implications

The mixing of humpback whales from different feeding stocks in the study area will mean that the mortalities occurring there will have a lower population impact than if all whales came from a single population. The significance of this will depend on whether whales from each feeding stock are equally likely to die in the study area, a question which cannot be addressed with the existing data. Although the only matches to dead whales were to the Gulf of Maine, the biases noted above —regarding both sampling effort elsewhere and the age of the animals in question —make establishing matches to other regions less likely.

In this context, it is worth noting that a humpback whale that stranded in Brooklyn, New York on 5 September 1991 was photographed alive off Newfoundland the previous year (J. Allen and R. Seton, unpublished data). Since the stranding location is not part of the USMA, this whale was not included in the sample used here. However, New York abuts the northern margin of the study area; thus, the presence of a Canadian whale there lends support to the idea that USMA mortalities may involve more than a single population.

The impact of USMA mortalities on the feeding populations concerned cannot be reliably assessed at present. To do this would require the ability to assign mortalities to the different feeding aggregations and also to have reliable and reasonably precise estimates of abundance for those stocks. There is no current estimate for Newfoundland or the Gulf of St Lawrence, although older data from the YONAH project indicate that at least the former population is 'large' (Smith *et al.*, 1999). The Gulf of Maine population was recently estimated from line transect data at 816 (CV = 0.45, Clapham *et al.*, 2001), not statistically different from the YONAH estimate of 652 (CV = 0.29). Both estimates are subject to possible negative biases (IWC, 2002).

There are no data on population growth rates for humpback whales off Atlantic Canada. The Gulf of Maine population was growing at an estimated rate of 6.5% in the 1980s and early 1990s (Barlow and Clapham, 1997), which is close to the theoretical maximum for this stock. However, an updated recent analysis of photo-id data from 1992-2000 found that population growth had declined during the period 1992-1995; this was linked to a major decrease in calf survival estimates (Clapham *et al.*, 2001). If this decrease was real, it may be partly related to the high mortality among young whales in the USMA. However, as noted by Clapham *et al.* (2001), the decline in calf survival and in apparent population growth rate coincided exactly with a shift in humpback whale distribution away from intensively studied areas; thus, the decline may be at least partly an artifact of this distribution shift. Further analysis of survival and population growth in the Gulf of Maine will require additional years of photo-id data.

In order to determine whether the observed level of mortality in the USMA represents a potentially serious issue for the Gulf of Maine feeding aggregation, further study in the USMA region, including continued monitoring of mortalities, should be a high priority for management.

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