A note on the comparison of humpback whale tail fluke catalogues from the Sultanate of Oman with Madagascar and the East African mainland

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ABSTRACT

The photo-identification catalogue of humpback whale tail flukes from Oman was compared with those from Antongil Bay, Madagascar and study sites in South Africa and Mozambique collectively termed the 'East African Mainland'. No matches were found, supporting other lines of evidence that the humpback whales studied off the coast of Oman form part of a discrete Arabian Sea population, which adheres to a Northern Hemisphere breeding cycle, and has little or no ongoing exchange with the nearest neighbouring populations in the southern Indian Ocean. While the sample size from Oman is small, and low levels of ongoing exchange might not be detected in this type of catalogue comparison, the study nonetheless emphasises the need to pursue research and conservation efforts in the known and suspected range of the Endangered Arabian Sea humpback whale population.

KEYWORDS: HUMPBACK WHALE; SOUTHERN HEMISPHERE; INDIAN OCEAN; ARABIAN SEA; PHOTO-ID

INTRODUCTION

The humpback whale (*Megaptera novaeangliae*) is a cosmopolitan species found in all of the major oceans (Clapham and Mead, 1999). All known populations, with the exception of the population in the Arabian Sea (Minton *et al.*, In press), migrate between breeding grounds in tropical waters and feeding grounds in productive temperate or polar waters.

Soviet whaling data, observations from merchant vessels and recent research (primarily along the coast of Oman) include records of humpback whales from every month and strongly suggest the presence of a resident population in the western Arabian Sea with confirmed historical records indicating a distribution in Yemen, Southern Oman, Iran, Pakistan and India (Brown, 1957; Mikhalev, 2000; Minton *et al.*, 2008; Reeves *et al.*, 1991; Slijper *et al.*, 1964; Wray and Martin, 1983; Yukhov, 1969). These locations are well within the Northern Hemisphere, but offer no feasible migration routes to any of the known Northern Hemisphere humpback whale feeding grounds. Data on reproductive parameters collected during illegal Soviet whaling operations in 1966, as well as observations of calves and recordings of humpback whale song off the coast of Oman, indicate that this population adheres to a Northern Hemisphere breeding cycle, with peak calving taking place between January and May (Mikhalev, 2000; Minton *et al.*, In press).

Recent research has confirmed the continued presence of humpback whales off the Gulf of Oman and Arabian Sea coasts of Oman (e.g. Minton *et al.*, In press). Only limited incidental observations of the species have been recorded for some areas within the remainder of the suspected range. Re-sightings of photographically identified individuals off the coast of Oman in early autumn and late spring provide further evidence of year-round residency (Minton *et al.*, In press). Mark-recapture estimates using three different pairings of tail fluke photographs collected in Oman in two main research areas in the Arabian Sea over a period of four and a half years yielded a population estimate of 82 individuals (95% CI=60-111). However, sample sizes were small and there are various sources of possible negative bias, including insufficient spatial and temporal coverage of the population's suspected range (Minton *et al.*, In press).

Genetic analyses of tissues sampled from live and dead humpback whales in Oman and elsewhere in the Western Indian Ocean provide further evidence for a discrete Arabian Sea sub-population (Pomilla *et al.*, 2006; Rosenbaum *et al.*, 2009). Although this study showed that this sub-population clearly originated from the larger Southern Hemisphere population, analyses of maternally inherited mitochondrial (mt) DNA and nuclear microsatellites confirm genetic differentiation from all other Southern Hemisphere populations including those wintering off Madagascar, the Comoros Islands and Mozambique, and no evidence of current exchanges with these neighbouring areas (Pomilla *et al*., 2006; Rosenbaum *et al*., 2009).

The humpback whales in Antongil Bay in Madagascar and the waters of Mozambique and South Africa represent the best studied breeding stocks within feasible migration

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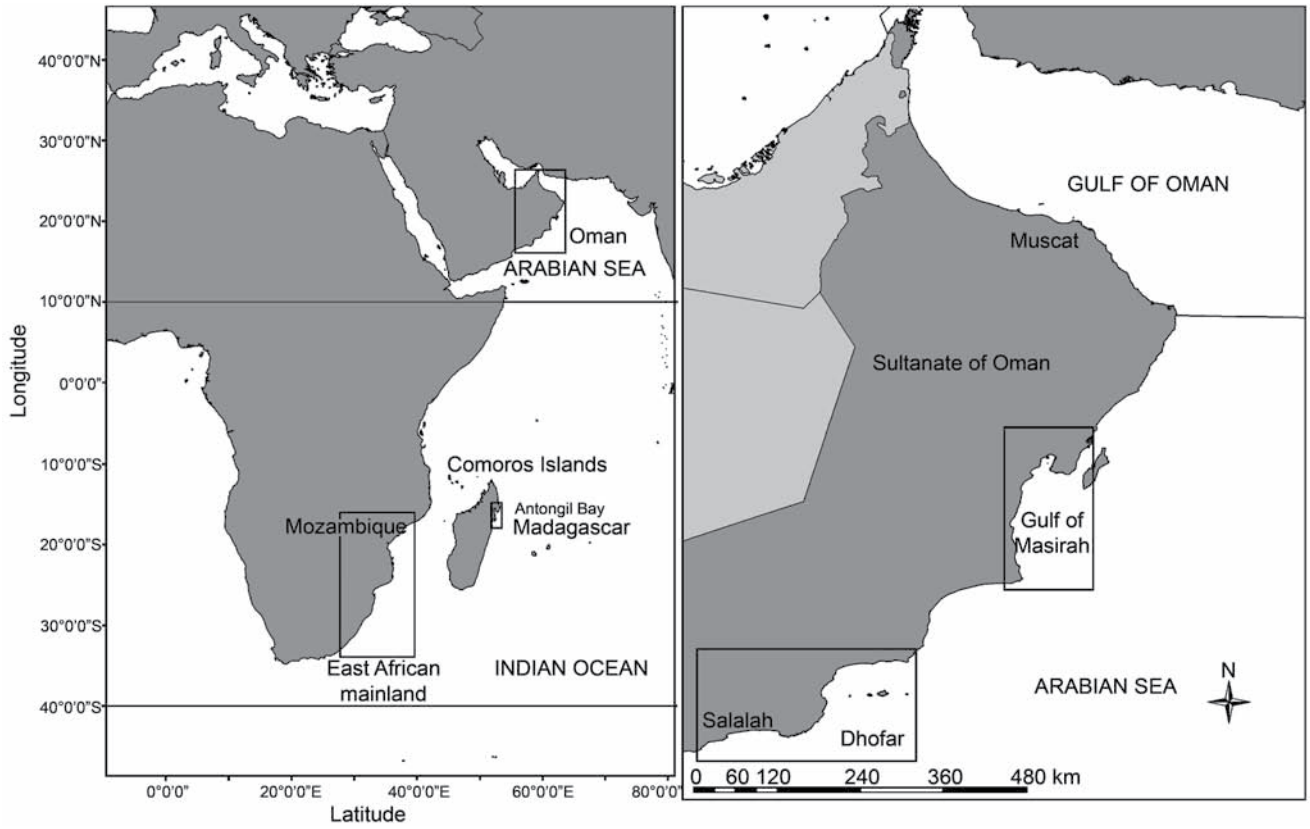

Fig. 1. Left: Three main sampling areas, Oman (breeding and feeding area X), Madagascar (breeding area C3) and the East African Mainland (breeding area C1). Right: Sultanate of Oman, with two main humpback whale survey areas highlighted.

Table 1

(a) Oman (Pop X), (b) Madagascar (BS C3) and (c) East African Mainland (BS C1S) samples with effort by date ranges and number of days on which photographs were collected and samples of individual identifications, ***n***, before and after filtering for quality. Note that in Oman and Madagascar, almost every day between the start and end date was spent observing whales, while in the East African mainland (EAM), the number of survey days are indicated to give a more accurate indication of effort between start and end dates.

Dates of IDs	2000	2001	2002	2003	2004	2005	2006
(a) Oman							
Survey periods	15-24 Jan. 8-21 Feb. 15-17 Oct.	9-22 Feb. 4-27 Oct.	10 Feb.- 2 Mar. 24 Oct.-7 Nov.	24 Feb.-19 Mar. 15-17 May	4-29 Mar. 4-29 Nov.	No obs	12-28 Feb.
n - all	8	15	23	8	15	0	4
quality filtered	7	14	20	5	13	0	3
(b) Madagascar							
Start date	17 Jul.	10 Jul.	22 Aug.	11 Jul.	10 Jul.	13 Jul.	16 Jul.
End date	17 Sep.	14 Sep.	11 Sep.	9 Sep.	5 Sep.	5 Sep.	4 Sep.
n - all	122	184	24	161	179	170	181
quality filtered	89	159	16	126	151	144	158
(c) East African mainland							
Start date	Jun.	Jun.	4 Jul.	3 Jun.	1 Sep.	25 Jun.	4 Jun.
End date	Jul.	6 Nov.	6 Dec.	28 Oct.	30 Sep.	17 Nov.	12 Nov.
No. of survey days	3	17	29	52	7	58	48
n - all	4	38	69	147	28	157	129
quality filtered	3	24	49	115	21	134	112

range from Oman. As such, the comparison presented here is intended to provide further understanding of the status of the Oman/Arabian Sea population. Comparisons of photo-identification material from Oman and Zanzibar have been carried out previously and no links between these areas were found (Minton *et al*., In press).

METHODS

Oman (known as feeding/breeding population X by the IWC Scientific Committee - e.g. IWC, 2007)

Photographs were collected using standard procedures during small-boat surveys that were conducted over a period of six years in two main locations: the Gulf of Masirah and

Dhofar (both on the Arabian Sea coast of Oman - see Fig. 1). Surveys were designed to target areas where published (Mikhalev, 2000) and unpublished records (held by the authors) indicated potentially higher abundance of humpback whales. Survey timings are detailed in Table 1. Additional photos were taken during incidental sightings and entanglements in the Muscat region, Gulf of Oman (Minton *et al.*, In press).

Madagascar (known as Breeding Stock C3 - e.g. IWC, 2007)

Madagascar (breeding stock C3) data were collected from Antongil Bay, Madagascar (Fig. 1). Standard procedures were used for identification photography (see Cerchio *et al.*, 2008a). Individual identification photographs used in this analysis were collected from 2000 to 2006 during yearly research field seasons of the Cetacean Conservation and Research Program (CCRP).

East African mainland (known as Breeding Stock C1 - e.g. IWC, 2007)

The photographs collected from the East Coast of South Africa (east of 20ºE) and Mozambique were grouped together in one catalogue as the coasts of both countries are thought to comprise one breeding sub-stock (C1). For convenience, these areas were collectively termed the 'East African Mainland' to differentiate from the Madagascar and Western Indian Ocean island sub-stock. These photos were collected during both whale watch tourism operations and research cruises conducted between 2000 and 2006. Data used in this analysis were collected entirely from sub-region C1S (south of 15°S), with the vast majority (93%) collected off northern KwaZulu Natal and the Eastern Cape, South Africa (Cerchio *et al.*, 2008b).

Photographic comparison procedure

Photographs were compared on a computer screen, and the best representative photograph for each individual whale was chosen for each single survey day. Scanned and digital images were referenced with relevant sighting data in a customised Microsoft *Access* database. Customised forms and queries allowed for comparison of images permitting completion of within-year and between-year matching. Three separate regional catalogues were compiled for Oman and breeding stocks C1 and C3. Additional details of these matching procedures can be found in Cerchio *et al.* (2008b) and Minton *et al.* (In press). The finalised catalogues for each region, consisting of the best quality photograph of each individual identified, were merged into an inter-regional database, facilitating comparison between regions. All matching was completed by researchers with suitable experience in humpback whale photo-identification. All detected matches were confirmed by two other researchers. All photographs used in the comparison were rated for quality on a five-level scale: excellent, good, fair, poor, and not useable, in keeping with 'overall quality' criteria described by Friday *et al.* (2000). Photos of all qualities were compared; however, only photos of a quality of 'fair' or better were considered suitable for mark-recapture procedures and are thus reported (Table 1).

RESULTS

Table 1 shows the total number of photographs collected in Oman, Madagascar and the East African Mainland per year. The finalised catalogues from all three regions through 2006 included a total of 68 tail fluke photos for Oman, 1,041 photos for Madagascar and 559 for the East African Mainland (note that these totals are not the sums of the totals collected each year in Table 1; a number of individuals in each region were photographed more than once between years and are only counted once in the totals above). There were no matches found between Oman and either of the other two regions.

DISCUSSION

The complete lack of recaptures between Oman and either Madagascar or East African mainland suggests little to no exchange between the Arabian Sea population and these southern West Indian Ocean populations. It is important to bear in mind that a comparison of the photo-ID catalogues from breeding stock C1 (458 individuals identified by photos of acceptable quality) and breeding stock C3 (842 individuals of acceptable quality) yielded only one match (two if a poor quality match is included; see Cerchio *et al.*, 2008b). This small recapture rate between C1 and C3 is apparently due to relatively large population sizes combined with a low level of exchange. Given the much smaller sample size from Oman, we recognise that an equivalent exchange as that detected between C1 and C3 would not expect to be detected in this comparison. At the same time, however, mark-recapture estimation for C3 yielded best estimates of abundance in excess of 6,000 individuals (Cerchio *et al.*, 2008a) and line transect estimation for C1 yielded estimates of abundance of 5,965 (CV=0.17) (Findlay *et al.*, In press). As such, the number of individuals represented in the C1 and C3 catalogues represent a smaller percentage of the C1 and C3 populations, while the 68 individuals in the Oman catalogue may represent as much as 90% of the total population off the Coast of Oman. Furthermore, the finding of no recaptures of individuals corroborates the conclusions of genetic comparisons (Pomilla *et al.*, 2006; Rosenbaum *et al.*, 2009) that indicate greater differentiation between Arabian Sea and southern West Indian Ocean populations than between the southern populations. Given the observed genetic differentiation, and lack of recaptures here, we believe there can be no substantial mixing between Oman and other populations, and probably no recent exchange at all.

It is also important to bear in mind that the Oman Photo-ID catalogue does not include any individuals photographed outside of Oman in other parts of the Arabian Sea humpback whale population's suspected range. It is possible that whales in the more southern reaches of the Arabian Sea (e.g. those detected historically in the Gulf of Aden or Sri Lanka) have higher exchange rates with C1 or C3 populations. There has also been speculation that observations of whales in Tanzania, Kenya, and the Seychelles may include whales that move between the Arabian Sea and Southern Indian Ocean, but there is no evidence for this to date, and most observations in those areas appear to be of singing males or females with calves in August-September, which would be more in keeping with a Southern Hemisphere breeding cycle (e.g. Weru, 2001; P. Berggren, pers. comm. and C. Anderson, pers. comm.) rather than the Northern Hemisphere breeding cycle of Oman's whales. A comparison of the Oman catalogue with fluke and dorsal fin photographs taken in Zanzibar between 2000 and 2002 did not yield any matches (Minton *et al.*, In press). Another comparison between these regions with a larger and more recent sample from Zanzibar is planned, but no other catalogues are available to the authors knowledge.

Until further research is conducted in these areas, the results of this comparison, taken together with the results of genetic analysis and the proven year-round residence of

whales off the coast of Oman, provide strong evidence for the discrete nature of the population of humpback whales off the coast of Oman. This further justifies the recent International Union for Conservation of Nature (IUCN) Red List designation of the Arabian Sea population of humpback whales as 'endangered' (Minton *et al.*, 2008). It also provides further indication that this population requires continued research and conservation efforts in order to more accurately assess population size and possible threats. There is an urgent need to further investigate the distribution and range of the Arabian Sea population by surveying other areas of the population's historic range, which may extend to Yemen, Iran, Pakistan and India (Minton *et al.*, 2008). Furthermore, as research is conducted in these areas, further photographic comparisons should take place between these new areas and the animals photographed off the coast of Oman.

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REFERENCES

Brown, S.G. 1957. Whales observed in the Indian Ocean. Notes on their distribution. *Mar. Obs.* 27(177): 157-65.

Cerchio, S., Ersts, P., Pomilla, C., Loo, J., Razafindrakoto, Y., Leslie, M., Andrianrivelo, N., Mindon, G., Dushane, J., Murray, A., Collins, T. and Rosenbaum, H.C. 2008a. Revised estimation of abundance for breeding stock C3 of humpback whales, assessed through photographic and gentypic mark-recapture data from Antongil Bay, Madagascar, 2000-2006. Paper SC/60/SH32 presented to the IWC Scientific Committee, June 2008, Santiago, Chile (unpublished). 20pp. [Paper available at the Office of this Journal].

Cerchio, S., Findlay, K., Herman, O., Ersts, P., Minton, G., Bennet, D., Meyer, M., Razafindrakoto, Y., Kotze, D., Oosthuizen, H., Leslie, M., Andrianarivelo, N. and Rosenbaum, H.C. 2008b. Initial assessment of exchange between breeding stocks C1 and C3 of humpback whales in the western Indian Ocean using photographic mark-recapture data, 2000-2006. Paper SC/60/SH33 presented to the IWC Scientific Committee, June 2008, Santiago, Chile (unpublished). 15pp. [Paper available at the Office of this Journal].

Clapham, P.J. and Mead, J.G. 1999. *Megaptera novaeangliae*. *Mamm. Species* 604: 1-9.

Findlay, K., Meyer, M., Elwen, S., Kotze, D., Johnson, R., Truter, P., Uamusse, C., Sitoe, S., Wilke, C., Kerwath, S., Swanson, S., Staverees, L. and van der Westhuizen, J. In press. Distribution and abundance of humpback whales, *Megaptera novaeangliae*, off the coast of Mozambique, 2003. *J. Cetacean Res. Manage.* (*special issue*). 39pp.

Friday, N., Smith, T., Stevick, P. and Allen, J. 2000. Measurement of photographic quality and whale distinctiveness for the photographic identification of humpback whales. *Mar. Mammal Sci.* 16(2): 355-74.

International Whaling Commission. 2007. Report of the Scientific Committee. Annex H. Report of the Sub-Committee on Other Southern Hemisphere Whale Stocks. Appendix 1. Agenda. *J. Cetacean Res. Manage. (Suppl.)* 9:206-07.

Mikhalev, Y.A. 2000. Whaling in the Arabian Sea by the whaling fleets *Slava* and *Sovetskaya Ukraina*. pp.141-81. *In*: Yablokov, A.V., Zemsky, V.A. and Tormosov, D.D. (eds). *Soviet Whaling Data (1949-1979)*. Centre for Russian Environmental Policy, Moscow. 408pp.

Minton, G., Collins, T., Findlay, K., Baldwin, R., Ersts, P., Rosenbaum, H., Berggren, P. and Baldwin, R.M. In press. Seasonal distribution, abundance, habitat use and population identity of humpback whales in Oman. *J. Cetacean Res. Manage. (special issue)*: 35pp.

Minton, G., Collins, T., Pomilla, C., Findlay, K., Rosenbaum, H., Baldwin, R. and Brownell, R.L., Jr 2008. *Megaptera novaeangliae* (Arabian Sea sub-population). *In*: IUCN (eds). *2009 IUCN Red List of threatened species*. [See *http://www.iucnredlist.org/details/132835*].

Pomilla, C., Best, P.B., Findlay, K.P., Collins, T., Engel, M.H., Minton, G., Ersts, P., Barendse, J., Kotze, P.G.H., Razafindrakoto, Y., Ngouessono, S., Meyer, M., Thornton, M. and Rosenbaum, H.C. 2006. Population stucture and sex-biased gene flow in humpback whales from Wintering Regions A, B, C and X based on nuclear microsatellite variation. Paper SC/A06/HW38 presented to the IWC Workshop on Comprehensive Assessment of Southern Hemisphere Humpback Whales, Hobart, Tasmania, 3-7 April 2006 (unpublished). 22pp. [Paper available from the Office of this Journal].

Reeves, R.R., Leatherwood, S. and Papastavrou, V. 1991. Possible stock affinities of humpback whales in the northern Indian Ocean. pp.259-70. *In*: Leatherwood, S. and Donovan, G. (eds). *Cetaceans and cetacean research in the Indian Ocean Sanctuary: Marine mammal technical report number 3*. UNEP, Nairobi, Kenya. United Nations Environment Programme, Marine Mammal Technical Report Number 3.

Rosenbaum, H.C., Pomilla, C., Mendez, M.C., Leslie, M.C., Best, P.B., Findlay, K.P., Minton, G., Ersts, P.J., Collins, T., Engel, M.H., Bonatto, S., Kotze, D.P.G.H., Meyer, M., Barendse, J., Thornton, M., Razafindrakoto, Y., Ngouessono, S., Vely, M. and Kiszka, J. 2009. Population structure of humpback whales from their breeding grounds in the South Atlantic and Indian Oceans. *PLoS ONE* 4(10). e7318. doi: 10.1371/journal.pone.0007318.

Slijper, E.J., van Utrecht, W.L. and Naaktgeboren, C. 1964. Remarks on the distribution and migration of whales, based on observations from Netherlands ships. *Bijdr. Dierkd.* 34: 3-93.

Weru, S. 2001. Rapid baseline survey of large marine animals, with special emphasis on humpback whales, in Kenya. *KWS Technical Series*. [Available from: *werus@africaonline.co.ke*].

Wray, P. and Martin, K.R. 1983. Historical whaling records from the western Indian Ocean. *Rep. int. Whal. Commn* (*special issue*) 5: 213-41.

Yukhov, V.L. 1969. Observations of cetaceans in the Gulf of Aden and the northwestern part of the Arabian Sea. pp.327-28. *In*: Arsenev, V.A., Zenkovich, B.A. and Chapskii, K.K. (eds). *Marine Mammals*. Akad. Nauk., Moscow. [Original in Russian, this article translated by S. Pearson, National Marine Mammal Lab., Seattle, USA].

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