Preliminary comparison of humpback whale photographic identifications indicates connectivity between Reunion (BS C4) and Madagascar (BS C3)

DULAU-DROUOT V.[1], CERCHIO S.[2], JOUANNET V.[1], ERSTS P.[3], FAYAN J.[4], BOUCAUD V[1]. ROSENBAUM H.[2]

[1] *GLOBICE Reunion, 30 chemin Parc Cabris, Grand Bois, 97410 Saint Pierre, La Reunion, France.* globice@globice.org
[2] *Wildlife Conservation Society, Ocean Giants Program, 2300 Southern Blvd., Bronx, NY 10460-1099, USA.*
[3] *American Museum of Natural History, Center for Biodiversity and Conservation, 79th Street and Central Park, West, New York, NY 10024, USA.*
[4] *Brigade Nature Ocean Indien/ONCFS 12 allée de la Forêt, Parc de la Providence, 97400 Saint Denis, La Réunion, France.*

ABSTRACT

We report on the first movement of humpback whales between Reunion (C4) and Madagascar (C3) in the south-western Indian Ocean (Breeding stock C) using photographic identification of individual fluke. The inter-regional catalogue included 1021 individuals from Antongil Bay, Madagascar (2000-2006) and 320 individuals from Reunion (2001-2010). Comparisons are still ongoing, but so far, 3 inter-regional recaptures have been reported, indicating some connectivity between C3 and C4 sub-stocks.

INTRODUCTION

Humpback whales, *Megaptera novaeangliae*, undertake annual migration between high latitude summer feeding areas and low-latitude winter breeding areas (Dawbin, 1966). The International Whaling Commission designated seven breeding population (stocks A-G) in the southern hemisphere (IWC, 1998). The south-western Indian Ocean is considered breeding stock C, and has been sub-divided into 3 major subpopulations (IWC, 2000): C1, along the east coast of South Africa to Mozambique (further subdivided into regions C1S and C1N, IWC 2006); C2, central Mozambique channel islands (Comoros, Aldabra, Eparses islands); and C3, coastal waters of Madagascar (Fig.1). The possibility of a further breeding sub-region, C4, including Reunion and Mauritius islands, has been proposed (IWC, 2006). However, because limited data were available, humpback whales from this region were not considered in the Comprehensive Assessment of breeding stock C conducted recently by the IWC Scientific Committee (IWC, 2010). A cetacean research program implemented since 2004 in Reunion (C4) confirms the presence of both new-born calves, male singers, and competitive groups from June to late October, suggesting this oceanic island represents a breeding area for the species (Dulau *et al*., 2008). A significant increase in the number of humpback whales wintering off Reunion has been observed since 2007 (Dulau *et al*., submitted), resulting in increased photographic identification data being collected in 2008-2010. Following the recommendations of the IWC scientific committee, encouraging C4 data to be processed for a better understanding of stock structure (IWC, 2008), an inter-regional fluke catalogue was created to allow systematic matching of the Reunion catalogue with Madagascar (C3). Preliminary results of this comparison work are reported here.

MATERIAL AND METHODS

Standard procedures were used to collect humpback whale photographic data, using digital cameras. Pictures of the ventral side of the fluke and, whenever possible, both sides of the dorsal fin were taken. However, only individual identifications from fluke photographs have been used in this study. An inter-regional catalogue was created by combining datasets from the two survey regions described below.

Madagascar (C3)

Madagascar data were collected from Antongil Bay, located on the northeast coast of Madagascar (Fig 1.). The bay is relatively shallow and extends approximately over 1800km². Data used in this study were collected over 8 years, from 2000 to 2006. Dedicated boat surveys were conducted from mid-July to mid-September every year, when the highest concentration of humpback whales occurs in the area. The distribution of effort was fairly consistent (Table 1), with an average of 33 days sampled every austral winter (excepted in 2002 where 12 sampling days were achieved).

Reunion island (C4)

Reunion data were collected in coastal waters, primarily off the western and southern coast of the island. Being a young oceanic island, the shelf is very narrow and depth increases rapidly near the shore, down to 300m. Humpback whale sightings mainly occur in waters less than 100m in depth, representing an area of around 350 km² around the island. Photo-identification survey work started in 2004 and is still underway. However, some fluke photographs were available from previous years (2001-2003) and, although not associated with effort data, were included in the catalogue. Therefore, Reunion's catalogue included photographs spanning a 10 year period, from 2001 to 2010. Dedicated survey effort was not consistent throughout the years and significantly increased in 2008-2010 (Table 2).

Photographic comparison procedure

A distinct catalogue was first created for Reunion and Madagascar regions separately. A single representative fluke photograph was chosen to represent an individual, except in cases where multiple pictures were needed to allow a complete identification. All photographs were rated for quality on a five-level scale: excellent, good, fair, poor, and not useable. This latter category was then discarded from the comparison process. Flukes were classified into 5 categories, according to the pigmentation pattern.

Within and between-year comparisons were first undertaken for each region, within separate regional database catalogues. Each individual identification was then assigned a regional reference name. This prevents double counting individuals observed several times in the same region and allows establishment of individual sample sizes for each region. The two separate regional catalogues from Reunion and Madagascar were then combined to create an inter-regional catalogue. The separate regional catalogues and the finalized inter-regional catalogue were generated from a customized MS Access database template developed and used in previous regional comparison studies (Cerchio *et al.,* 2008; Minton *et al*., 2008). Standardised forms enable systematic comparisons of the photographs. Each individual from the Reunion catalogue was compared to all individuals from the Madagascar catalogue falling into the same pigmentation category and the adjacent ones (ex: flukes from category 3 are compared to the categories 3, 2 and 4). Between-region matching was performed by the same person (VJ) and all matches (as well as flagged "possible matches") were validated by researchers with experience in humpback whale photo-identification (VD and SC).

RESULTS

Table 3 provides the number of individuals photographically identified by year per region, as included in the finalised inter-regional catalogue. The sample size was 320 different individuals for Reunion (from 602 corresponding observations on separate days). This represents all useable qualities (poor to excellent). For Madagascar there were 812 different individuals (in 843 observations) after filtering out poor quality photos. As a standard procedure with this dataset, poor quality photos are filtered out from mark-recapture analyses in order to reduce error associated with false negatives (Cerchio *et al.* 2009); however, the Reunion photographs have not yet been filtered for equivalent quality scores for this preliminary report.

The matching of the inter-regional catalogue is still in process. To date, 173 individuals from Reunion have been compared to the Madagascar catalogue, and there are still 147 individuals to be matched. Thus far, the comparison revealed 3 recaptures between Reunion and Madagascar (Table 4, Figure 2). Interestingly, the 3 captures all had similar temporal intervals, being first captured in Madagascar in 2000, 2001 and 2002, respectively, and recaptured in Reunion in either 2008 or 2010 (Table 4). Therefore there was a temporal consistency in individual recaptures, with a time interval of 7 to 8 years. Although these are preliminary results, as matching between the Reunion and Madagascar catalogues is still ongoing, these inter-regional recaptures represents the first records of connectivity between breeding stock C3 and C4.

Sighting histories of whales involved in interchanges between C3 and C4 are presented in Table 5. The two whales captured in 2000 and 2001 in Madagascar and recaptured in Reunion in 2008 were sighted only once in each area (no within or between year recaptures in either region). The third whale was recaptured within-years in both regions. It was photographically captured on 3 sampling days in Madagascar in 2002, and on 10 sampling days in Reunion in 2010. Its minimum occupancy time was 6 days in Madagascar and 41 days in Reunion, where it was sighted from mid-August to early October in different group types (Table 5). It is worth mentioning that while in Reunion, this individual escorted the same mother and calf pair over a month period, and thus its sex is suspected to be male. A biopsy sample has been collected from that individual in Reunion, although genetic data are not available yet. Sexes for the other recaptured individuals have not yet been assessed as of the writing of this preliminary report.

DISCUSSION

This paper presents the first attempt of systematic comparisons between Reunion and another sub-stock of the south-western Indian Ocean and documents the first time movements of individual humpback whales between the proposed breeding sub-stock C4 and sub-stock C3. The flukes photograph dataset from Madagascar (C3) has previously been compared to other sub-stocks, demonstrating exchanges with East Africa Mainland (C1-C3: 2 recaptures; Cerchio *et al*., 2008) and Mayotte and Geyser-Zélée Complex (C2-C3: 4 recaptures by flukes, and an additional 4 by molecular, and 1 by dorsal fin; Ersts *et al*. in press). The completion of this work will allow us to asses the degree of connectivity between C4 and C3, compared to other sub-stocks.

These primarily results are encouraging, and several improvements will be made in the combined dataset and completed analysis so that we can assess the probability of individual capture and exchange between the regions within a mark-recapture framework. Reunion data presented in this paper have not yet been filtered for quality, and this will have to be

undertaken in a consistent manner so that the two datasets are comparable in order to assess capture probabilities. Furthermore, although the temporal coverage was consistent every winter season, yearly survey effort and sample size in Reunion varied substantially. This was due to an increased survey effort deployed in response to a documented increase in the number and frequency of humpback whales off Reunion in recent years (Dulau *et al*., submitted). It might be necessary to discard early year Reunion data with non-comparable effort (e.g., 2001 to 2006 or 2007) in order to conduct an analysis of inter-regional exchange (as done for some sample years in Cerchio et al. 2008 for an assessment of exchange probability between Madagascar and East Africa Mainland).

Despite the limitations of the preliminary data presented here, it is clear that there is some connectivity between Madagascar and Reunion. Already, these preliminary results suggest that the connection between C3 and C4 may be more extensive than that between C3 and C1, since only 2 matches were made with C1 despite it was represented by a much larger sample of 564 individuals (Cerchio *et al*. 2008). Data from C3 all came from Antongil Bay, located on the east coast of Madagascar, therefore exchanges with C4 might be facilitated due to the absence of geographic boundaries. Furthermore, it is interesting to note a temporal consistency in the captures observed thus far between stock C4 and C3, with first captures occurring in Madagascar in three consecutive years (2000, 2001, 2002) and subsequent recaptures occurring in Reunion after a consistent and relatively long time interval of 7 to 8 years. These recent inter-regional recaptures in C4, together with the recent increase in whale numbers wintering in Reunion might suggest a range expansion of whales from C3 to new migratory destinations such as Reunion (located 700km east of Madagascar). Although this is currently speculative, we will seek to test this hypothesis in subsequent analyses. The relatively high occupancy time and the first reports of inter-annual recaptures between 2009 and 2010 in Reunion (Dulau *et al*., submitted) also suggests that some degree of site fidelity may have started to occur. Humpback whales within the range of breeding stock C could be investigating and occupying new habitats or re-occupying historical ones as a result of population increase. It should be emphasized, that these results represent movements of only 3 individual whales so far, thus a small portion of the population migrating to Reunion and Madagascar, and might not be representative of a general pattern. Furthermore, data from Madagascar came from only one location, Antongil Bay, and the possibility of heterogeneity across sub-regions within Madagascar has not yet been evaluated. The continuation of research effort in Reunion (C4) and the enhancement of comparison work at a regional level, together with a statistic mark-recapture approach, should provide valuable insights towards the validation of the hypothesis of a spatial range expansion over time.

ACKNOWLEDGEMENTS

We thank the Conseil Régional de la Réunion and DIREN-Reunion for having funded part of this study. Data collection in Reunion would not have been possible without the active participation of GLOBICE volunteers. We are also grateful to BNOI, Croisière &Découvertes, Excelsus Diving Center and private boat owners for providing survey plateforms in Reunion. For Madagascar project, we are grateful to the staff of the WCS/AMNH New York and WCS Madagascar Country Programs, in particular Yvette Razafindrakoto, Norbert Andrianarivelo, Matt Leslie, George Amato, Rob DeSalle, Eleanor Sterling, Helen Crowley and Matthew Hatchwell, and all the summer interns, students, volunteers and research assistants who have contributed to field and laboratory work.. Many other individuals were involved and helped throughout the years of this study from the WCS Madagascar Country Program, WCS Marine Program, AMNH Center for Biodiversity and Conservation and AMNH Conservation Genetics Program. Funding for development of the

Access database and matching platform and the collation of the Madagascar catalog was provided from grants and awards to WCS and AMNH.

LITERATURE CITED

Best, P. B., Findlay, K. P., Sekiguchi, K., Peddemors, V. M., Rakotonirina, B., Rossouw, A., and Gove, D. 1998. Winter distribution and possible migration routes of humpback whales Megaptera novaeangliae in the southwest Indian Ocean. *Mar. Ecol. Prog. Ser.* 162:287-299.

Cerchio, S., Findlay, K. P, Ersts, P.J., Minton G., Bennet D., Meyer M., Razafindrakoto Y., Kotze D., Oosthuizen H., Leslie M., Andrianarivelo N., & Rosenbaum H. 2008. Initial assessment of exchange between breeding stocks C1 and C3 of humpback whales in the western Indian Ocean using photographic markrecapture data, 2000-2006. IWC Scientific Committee SC/60/SH33.

Cerchio, S., Ersts, P.J., Pomilia C., Loo, J., Razafindrakoto Y., Leslie M., Andrianarivelo N., Minton G., Dushane, J., Murray, A., Collins T., Rosenbaum H. 2009. Updated estimated of abundance for humpback whale breeding stock C3 off Madagascar, 2000-2006. IWC Scientific Committee SC/61/SH7.

Dawbin WH. 1966. *The seasonal migratory cycle of humpback whales*. In: Norris KS. (ed.) *Whales, Dolphins, and Porpoises.* Berkeley: University of California Press. pp 145–70.

Dulau-Drouot, V., Boucaud, V. & Rota, B. (2008) Cetacean diversity off La Réunion island (France). *Journal of Marine Biology Association of UK,* 88(6) : 1263–1272.

Dulau-Drouot V., Boucaud V., Fayan J., Mouysset L. *Submitted* . Trend and residency pattern of humpback whales in Reunion Island. Submitted to the *Journal of Cetacean Research and Management*

Ersts, P.J., Pomilla, C., Kiszka, J., Cerchio, S, Rosenbaum, H.C., Vély, M, Razafindrakoto, Y, Loo, J., Leslie, M. and Avolio, M. In press. Observations of individual humpback whales utilizing multiple migratory destinations in the southwestern Indian Ocean. African J. Mar. Sci.

IWC. 1998. Report of the Scientific Committee. Annex G. Report of the Sub Committee on the Comprehensive Assessment of Southern Hemisphere Humpback Whales. *Rep. Int. Whal. Commn.* 48: 170-18.

IWC 2000. Report of the Sub-Committee on In-Depth Assessments. Report of the International Whaling Commission #52.

IWC. 2006. Report of the Workshop on the Comprehensive Assessment of Southern Hemisphere Humpback Whales. Paper SC/58/Rep 5 presented to the IWC Scientific Committee, May 2006 (unpublished).

IWC. 2008. Annex H: Report of the sub-committee on other Southern Hemisphere Whale Stocks. *J. Cetacean Res. Manag. (Suppl.)* 10:207-224.

Minton G., Cerchio, S., Collins,. Ersts, P. Findlay K.P., Pomilia, C., Bennet, D. Meyer M.A., Razafindrakoto, Y., Kotze, P.G.H., Oosthuizen, W.H., Leslie M., Andrianarivelo, N., Baldwin, R., Ponnampalam, L., & Rosenboom, H. 2008. Comparison of humpback whlae tail fluke catalogues from the Sultanate of Oman (Breeding and Feeding area X) with Madagascar (BS C3) and the East African Mainland (BS C1). IWC Scientific Committee SC/60/SH43

Table 1. Yearly survey effort conducted from 2000 to 2006 in Antongil Bay, Madagascar.

	2000	2001	2002	2003	2004	2005	2006
Start date	17 July	10 July	22 Aug	11 July	10 July	13 July	16 July
End date	17 Sept	14 Sept	11 Sept	9 Sept	5 Sept	5 Sept	4 Sept
Duration	62	66	20	60	59	56	52
Daily surveys	37	35	12	34	34	28	37

Table 2. Yearly survey effort conducted from 2004 to 2010 in Reunion.

	2004	2005	2006	2007	2008	2009	2010
Start date	21 June	4 June	4 June	7 June	5 June	7 June	2 June
End date	31 Oct	28 Oct	29 Oct	21 Oct	29 Oct	31 Oct	31 Oct
Duration	132	146	147	136	146	146	151
Daily surveys	28	36	42	53	92	108	141

Table 3. Number of individuals identified in Madagascar and Reunion included in the inter-regional catalogue. Madagascar numbers are after filtering out poor quality photographs, whereas Reunion numbers include all qualities. "Total" represents the overall total of different individuals after recaptures between years are accounted for.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Madagascar	89	159	16	126	151	144	158					812
Reunion		1	2	10	2	0	1	15	86	83	120	320

Table 4. Number of recaptures found between Madagascar (C3) and Reunion (C4).

	Reunion		
	2008	2009	2010
Madagascar			
2000	1		
2001	1		
2002			1

Table 5. Sighting history of whales involved in interchanges between Madagascar (C3) and Reunion (C4)

Individual references	Date	Site	Group type	Comment
TF-MAD-00-007 / TF-REU-08-172	22/07/2000	Antongil Bay (C3)		
	19/08/2008	Reunion (C4)	Competitive group (N=6)	
TF-MAD-01-182 / TF-REU-08-181	05/09/2001	Antongil Bay (C3)		
	01/08/2008	Reunion (C4)	Pair	
TF-MAD-02-023 / TF-REU-10-329	02/09/2002	Antongil Bay (C3)		
	06/09/2002	Antongil Bay (C3)		
	07/09/2002	Antongil Bay (C3)		
	22/08/2010	Reunion (C4)	Mother-calf-Escort	Escort of ind.# TF-REU-08-329
	07/09/2010	Reunion (C4)	Mother-calf-Escort	Escort of ind.# TF-REU-08-329
	08/09/2010	Reunion (C4)	Mother-calf-Escort	Escort of ind.# TF-REU-08-329
	12/09/2010	Reunion (C4)	Mother-calf-Escort	Escort of ind.# TF-REU-08-329
	17/09/2010	Reunion (C4)	Mother-calf-Escort	Escort of ind.# TF-REU-08-329
	21/09/2010	Reunion (C4)	Mother-calf-Escort	Escort of ind.# TF-REU-08-329
	26/09/2010	Reunion (C4)	Singleton	
	28/09/2010	Reunion (C4)	Competitive group (N=5)	
	01/10/2010	Reunion (C4)	Group of 4 including a calf	mother of the calf: ind. # TF-REU-08-345)
	02/10/2010	Reunion (C4)	Singleton	

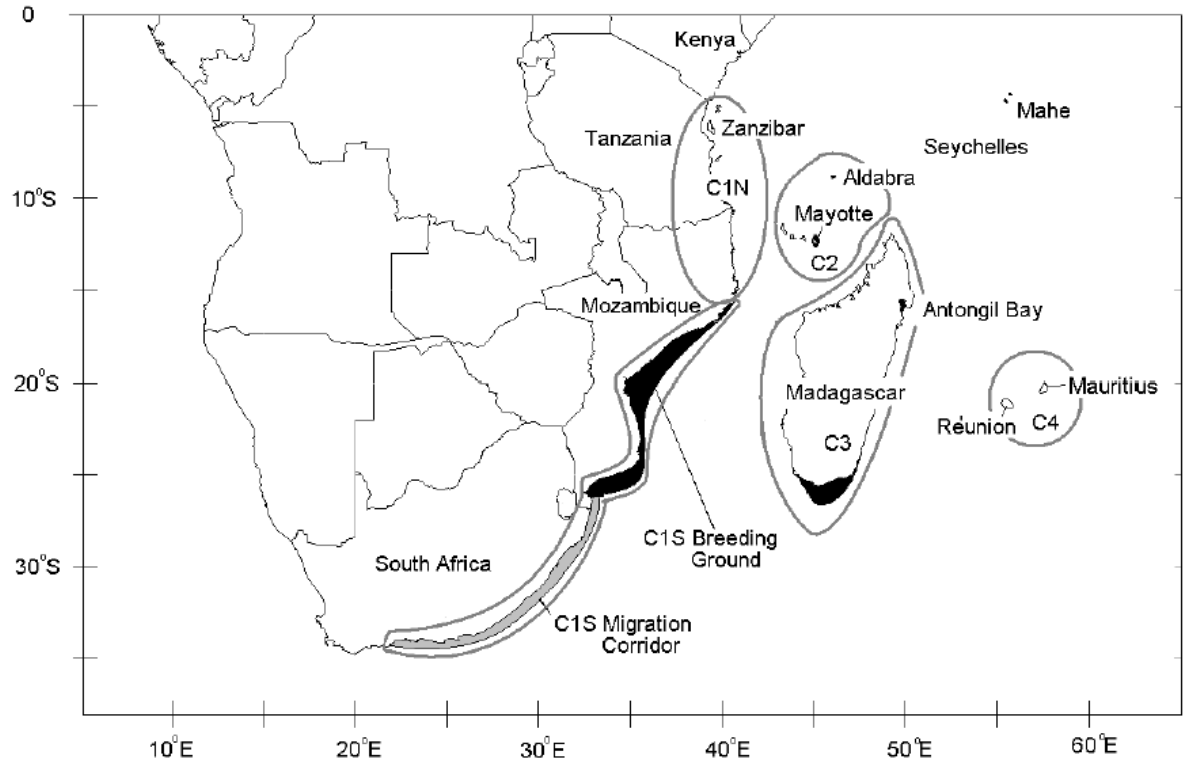

Figure 1. Sub-stock division Southern Hemisphere breeding stock C, as proposed in IWC (2006).