MARINE MAMMAL SCIENCE, 23(2): 453–463 (April 2007)

DOI: 10.1111/j.1748-7692.2007.00116.x

MIGRATORY DESTINATIONS OF HUMPBACK WHALES FROM THE MAGELLAN STRAIT FEEDING GROUND, SOUTHEAST PACIFIC

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Historical summer feeding and winter breeding grounds of humpback whales in the southeast Pacific humpback whales (*Megaptera novaeangliae*) have been recorded in the west of the Antarctic Peninsula during the austral summer and off Ecuador and Colombia during the austral winter (Kellogg 1929, Mackintosh 1965, Flórez-González *et al*. 1998, Scheidat *et al*. 2000, Félix and Haase 2001). In recent years, southeast Pacific humpback whales have been found further north, off Panama and Costa Rica during the austral winter (Acevedo and Smultea 1995; Flórez-González

et al. 1998; Rasmussen, personal observation), in areas also frequented by northeast Pacific humpback whales during the boreal winter (Steiger *et al*. 1991). Furthermore the species has recently been observed feeding in the Magellan Strait, Chile, during the austral summer and fall (Gibbons *et al*. 2003, Acevedo *et al*. 2004, Acevedo *et al*. 2006).

Migratory connections have been established between the feeding area in the Antarctic Peninsula and wintering destinations off Ecuador and Colombia using photo-identification (Stone et *al*. 1990, Garrigue *et al*. 2002, Stevick *et al*. 2004) and genetic analyses (Olavarría 1999, Caballero *et al*. 2000, Olavarría *et al*. 2000), and the wintering grounds off Panama and Costa Rica using photo-identification (Rasmussen *et al*. 2004). The migratory destination(s) for the Magellan Strait humpback whales has not, however, been previously documented. Here we present the first evidence of a migratory connection between the Magellan Strait feeding area and wintering grounds off both the northwest coast of South America and the southwest coast of Central America.

Individual humpback whales can be identified from photographs of unique pigmentation patterns on the ventral side of the fluke (Katona *et al*. 1979). Photo-identification catalogs have been compiled for Panama/Costa Rica, northern Colombia, Ecuador, and the Antarctic Peninsula. For two of the areas, Ecuador and Antarctic Peninsula, two catalogs exist. Photographs were taken from research and whale-watching vessels between 1991 and 2004 in wintering areas and Antarctica, and between 2003 and 2005 in the Magellan Strait. The areas sampled are described in Table 1 and illustrated in Figure 1. The comparison of the Magellan Strait humpback whale catalog and the other catalogues was undertaken manually (as a pairwise visual comparison) and with assistance of computer software (Oyarzo 2004) modified by the CEQUA researchers. Low-quality photographs were discarded, as were duplicates of whales that appeared in both Ecuadorian catalogs or in both Antarctic Peninsula catalogs. The total number of individual whales from all catalogues was thus reduced from 1,835 to 1,600. Matches with Magellan Strait whales were confirmed by members of CEQUA and by a member of the other research group from which the match was found.

Whales identified in the Magellan Strait ($n = 62$) were not resighted in the Antarctic Peninsula ($n = 508$). The absence of matches between these humpback whale aggregations suggests that these represent two discrete feeding populations. The comparison of Magellan Strait humpback whales with individuals from wintering areas ($n = 1{,}030$) revealed eight matches (Fig. 2), five with Ecuador and one with each of Colombia, Costa Rica, and Panama. The seven whales sighted in Ecuador, Colombia, and Costa Rica were sighted only once in these areas. Six of these seven whales were observed in two consecutive summer feeding seasons in the Magellan Strait. The remaining individual was sighted there only once (Table 2).

The individual photo-identified in both Magellan Strait and Panama was a male, as indicated by molecular methods (Gilson *et al*. 1998). This whale was seen in three consecutive seasons in the Magellan Strait (late summer 2003, 2004, 2005) and in both interceding winters in Panama (2003 and 2004). This finding is the first evidence of two complete migration events between feeding and breeding grounds in

Table 1. Number of southeast Pacific humpback whales identified by photographs of flukes.

Curator	Number of photos		Sampling years	Location	Country/general area
	Available	Examined			
Cascadia Research Collective (CRC)	43	37	2001–2003	Papagayo Gulf, Drake's Bay, and Dulce Gulf	Costa Rica
			2002–2004	Chiriqui Gulf	Panama
Fundación Ecológica SENTIR	66	66	2000–2002	Coqui Cove	Northern Colombia
Pacific Whale Foundation–Ecuador (PWF-EC) and	1,108	927	1996–2004	Machalilla National Park	Ecuador
Fundación Ecuatoriana para el Estudio de Mamíferos Marinos (FEMM)			1991–1997 and 2000	Machalilla National Park	
			2002–2004	Salinas	
Fundación Centro de Estudios del Cuaternario (CEQUA)	67	62	2003–2005	Magellan Strait and adjacent waters	Chile
Instituto Antártico Chileno (INACH) and	551	508	1994–1999	Western Antarctic Peninsula	Antarctic
Projecto Baleias/PROANTAR			1994 and 1998–2003	Western and Eastern Antarctic Peninsula	
Total photos	1,835	1,600			

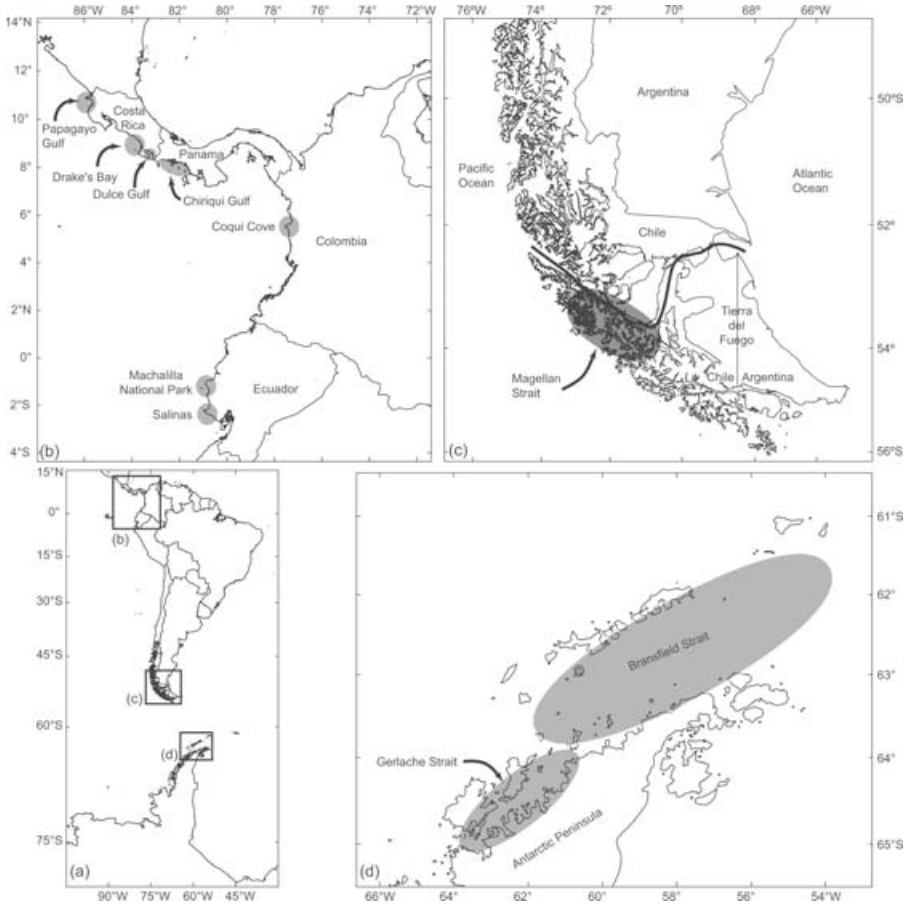

Figure 1. Location (a) of major areas where photo-identification was conducted, including details on sampling location at wintering grounds (b) and feeding areas (c, d). Shaded ellipses delimit the main areas where photo-identification was carried out. Lane shows in (c) the extent of the Magellan Strait.

any Southern Hemisphere population. Moreover, the whale was observed very close temporally and geographically in both migration destinations, suggesting that site fidelity occurs in both winter breeding and summer feeding grounds. Strong maternally directed fidelity to specific feeding grounds has been demonstrated elsewhere in the world (*e.g.*, the Gulf of Maine, Clapham *et al*. 1993).

Humpback whales from Magellan Strait show a higher exchange rate (measured as the Interchange Index [Baker *et al*. 1985, Urbán *et al*. 2000]) with the Panama/Costa Rica regions (0.87) than with the Ecuador (0.09) and north of Colombia (0.24), although a goodness-of-fit test showed the observations were not significantly different from the expectation ratio ($\chi^2 = 0.57$, df $= 2$, $P > 0.05$). However, when frequencies of matches obtained between the Magellan Strait and the areas surveyed off

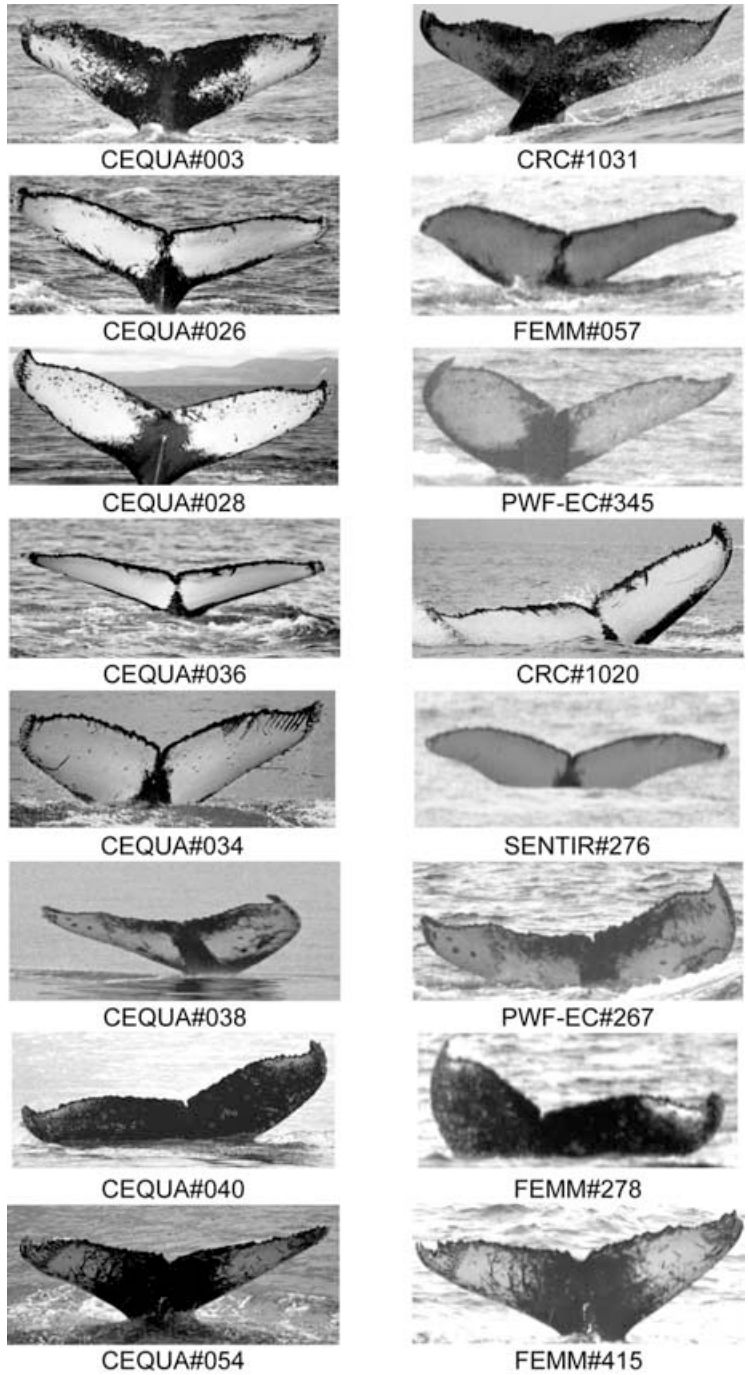

Figure 2. Photographs of individual humpback whales matched between the Magellan Strait and wintering grounds in the Eastern South and Equatorial Pacific Ocean. See Table 2 for information on field data.

Table 2. Photograph matches between humpback whales from the feeding area in the Magellan Strait and wintering grounds off the Southeast and Equatorial Pacific.

Magellan Strait				Wintering grounds		
Whale ID	Summer 02/03	Summer 03/04	Summer 04/05		Whale ID	Date
CEQUA#003	21/03/2003	12/02/2004	10/02/2005	Panama	CRC#1031	03/09/2003 07/09/2004
CEQUA#026	—	30/12/2003	14/01/2005	Ecuador	FEMM#057	20/08/1995
CEQUA#028	—	09/01/2004	13/01/2005	Ecuador	PWF-EC#345	30/08/2003
CEQUA#036	—	11/02/2004	15/01/2005	Costa Rica	CRC#1020	22/08/2002
CEQUA#034	—	11/02/2004	09/02/2005	Colombia	SENTIR#276	22/08/2001
CEQUA#038	—	11/02/2004	06/02/2005	Ecuador	PWF-EC#267	09/09/2003
CEQUA#040	—	12/02/2004	14/01/2005	Ecuador	FEMM#278	17/08/2002
CEQUA#054	—	—	19/12/2004	Ecuador	FEMM#415	12/07/2004

Ecuador, Colombia, and Panama/Costa Rica were compared using a test of proportion (comparing more than two proportion [Zar 1984]), a highly significant difference was found ($\chi^2 = 11.43$, df $= 2$, $P < 0.05$). If the same analysis was conducted by grouping the closest breeding grounds according to geographic distance (a northern area grouping northern Colombia/Panama/Costa Rica and a southern area containing only Ecuador), both the Interchange Index analysis (northern $= 0.47$, southern $= 0.10$; $\chi^2 = 4.57$, df $= 1$, $P < 0.05$) and frequencies of matches ($\chi^2 = 6.77$, df $= 1$, $P < 0.05$) showed a closer relationship between the Magellan Strait feeding area and the northern breeding grounds.

Despite the small sample size of matches among regions and of most catalogs, the multiple sightings of one individual (CEQUA#003-CRC#1031) in both the Magellan Strait and Panama (separated by *ca.* 6,500 km) highlight the importance of Panama as a migratory destination for at least some of the humpback whales that feed in the Magellan Strait. Furthermore, although it is not possible to rule out that Ecuador, and probably southern Colombia, Gorgona Island, also constitute migratory destinations for the Magellan Strait humpback whales, matches between these areas may represent animals in transit to or from more northern destinations located off Panama and/or Costa Rica.

We hypothesize that southeast Pacific humpback whales migrate from their northernmost feeding area (Magellan Strait) primarily to the northernmost wintering areas (northern Colombia, Panama, and Costa Rica), whereas those from the southern feeding area near the Antarctic Peninsula winter mainly off Ecuador and southern Colombia, as documented by Stone *et al*. (1990), Garrigue *et al*. (2002), and Stevick *et al*. (2004). A similar migratory pattern seems to occur in the northeast Pacific humpback whale population, linking the southernmost wintering area in Panama/Costa Rica with the southernmost feeding area off California (Calambokidis *et al*. 2000). Such a possible sub structure within the southeast Pacific population has important implications for the management and assessment of population trends, given it is assumed by the International Whaling Commission (IWC) to be a panmictic breeding population, located mainly off Ecuador and Colombia (Gorgona Island), which migrates south to feed in two areas, Antarctic Peninsula and Magellan Strait (IWC 2005).

Although the observations presented here confirm a link between Magellan Strait and Panama/Costa Rica humpback whales, further research is needed to support the hypothesis that the northernmost wintering grounds for the southeastern Pacific population constitute the primary destination of the whales feeding in the Magellan Strait area. It is necessary to include the arguably largest breeding ground in the southeastern Pacific, Gorgona Island, southern Colombia (Flórez-González 1991). However, given that it is highly likely that humpback whales migrating to northern wintering grounds pass through Ecuador and Colombia, satellite tagging seems to be the most adequate technique to address this question.

ACKNOWLEDGMENTS

The CEQUA researchers thank the Directors of the Fundación Centro de Estudios del Cuaternario (CEQUA) and the Instituto Antártico Chileno (INACH) for providing funding and

constant support in the Magellan Strait and Antarctic Peninsula surveys, as well as Nautilus & Sermares Ltd. for support of our surveys in the Magellan Strait. They also thank A. Larrea, R. Ritter, F. Sepúlveda, S. Vasquez, J. Cabellos, J. Plana, E. Newcombe, C. S. Baker, and P. J. Clapham for various support (field assistance, laboratory analysis, and manuscript review). The study in Ecuador by Fundación Ecuatoriana para el Estudio de Mamíferos Marinos (FEMM) is supported by the Whale and Dolphin Conservation Society (WDCS). The Machalilla National Park researcher is supported by the Pacific Whale Foundation-Ecuador and she thanks whale-watching operators and naturalist guides. The Projeto Baleias/Brazilian Antarctic Program was funded by the Brazilian Council for Scientific and Technological Development (CNPq), the Ministry of Environment (MMA), and the Inter-ministerial Commission for the Resources of the Sea (CIRM)/Brazilian Navy. They thank the crews of the *NApOc Ary Rongel* and colleagues of the Projeto Baleias who helped in the field. Cascadia Collective Research thanks L. May-Collado, F. Garita, and L. K. and D. Bell who assisted in the field in Costa Rica and Panama.

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Received: 20 June 2006
Accepted: 12 October 2006