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## Feeding grounds of the western South Atlantic humpback whale population

M. H. ENGEL

Instituto Baleia Jubarte,  
Rua Barão do Rio Branco, 26,  
Centro, 45900–000 Caravelas, Bahia, Brazil  
E-mail: marcia.engel@baleiajubarte.org.br

A. R. MARTIN

British Antarctic Survey,  
Natural Environment Research Council,  
High Cross, Madingley Road,  
Cambridge CB3 0ET, United Kingdom

The breeding and feeding grounds of most humpback whale populations are well known. Their preference for shallow, subtropical waters in winter, where they calve and mate (Clapham 1996), often brings them close to coasts or ship traffic, and their blows are readily seen in such relatively calm seas. Summer feeding grounds are mainly known through the activities of 20th-century whalers, who quickly discovered that this species was predictably found in discrete geographical patches, often on shelves around oceanic islands at cold-temperate and subpolar latitudes (Mackintosh 1965).

Although breeding and respective feeding grounds have been paired in most Northern Hemisphere populations, there is considerable uncertainty about the migratory destination of many Southern Hemisphere breeding populations. Much less research effort has been focused on these whales, especially using the techniques that have produced most relevant results in the north—satellite-tracking, photographic matching, and genetics.

The South Atlantic Ocean has two discrete humpback whale breeding grounds—one on each continental margin (Brazil and West Africa)—and many suitable high-latitude areas to which they could migrate in summer for feeding (Mackintosh 1965, IWC 1998). These include the Antarctic Peninsula, where the species is common, South Georgia, where humpbacks were the early focus of whaling a century ago, and several subantarctic island groups that receive few ship visits—South Orkney, South Shetland, South Sandwich, and Bouvet. Additionally, offshore areas have yielded humpbacks to whaling expeditions, though whether these animals were on migration or not is unclear. Similarities in the song of humpback whales off Brazil and Gabon indicate an acoustic link between animals in these areas (Darling and Sousa-Lima 2005). The mechanism of this information transfer is unknown and, due to the possibility of long-distance sound propagation at sea, does not necessarily involve close physical proximity of whales from the two populations.

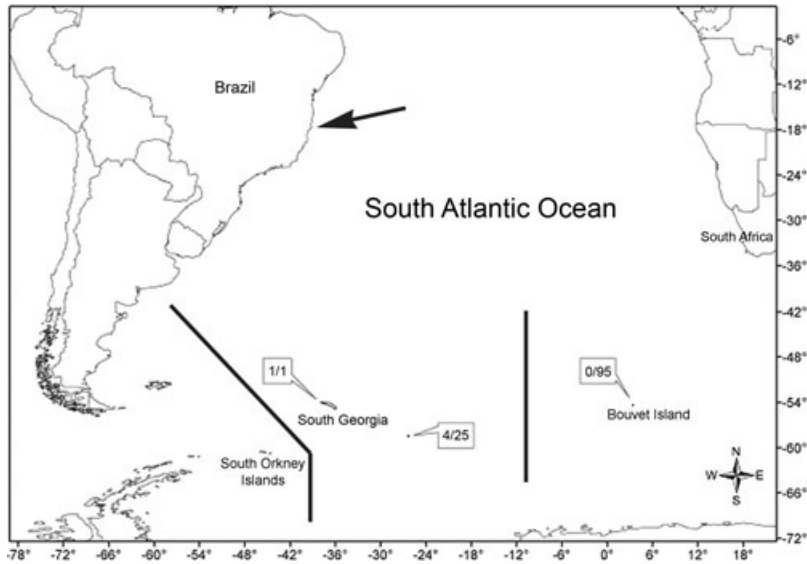


Figure 1. Map of the South Atlantic Ocean showing putative boundaries of humpback whale summer distribution based on current knowledge (Stevick *et al.* 2006, Zerbini *et al.* 2006, this study). The large arrow shows the main breeding site of the western population and near the Abrolhos Bank off Brazil. Solid black lines illustrate the approximate location of boundaries between the three feeding stocks in this region. Numbers in boxes show the numbers of photo-id matches between that location and Brazil, and the sample size. The unlabelled locations are Shag Rocks (1/1) and South Sandwich Islands (4/25).

The population of humpbacks breeding off the coast of Brazil (principally in latitudes 12°S–19°S, including a concentration on Abrolhos Bank) (Engel 1996, Martins *et al.* 2001) is one of seven recognized in the Southern Hemisphere (IWC 1998). Animals begin to aggregate here in June, are at their highest density in August/September, and most have moved away by November. The possibility of this population migrating to the Antarctic Peninsula was discounted when no photographic matches were made between the extensive fluke-photo catalogs of each area (Stevick *et al.* 2004) and because of significant mtDNA differences between populations off Brazil and the Antarctic Peninsula (Engel *et al.* 2008). First positive indications of where these whales migrate to feed were provided by a single photographic match between Abrolhos Bank (18°S, 39°W) and Shag Rocks (53.5°S, 41.6°W), west of South Georgia (Stevick *et al.* 2006) and three satellite-tagged animals that left the Brazilian coast heading in the direction of the South Sandwich islands (SSI), one of which reached the archipelago and remained in the vicinity for 10 wk (Zerbini *et al.* 2006). Further support was provided by the discovery that the mtDNA haplotypes of two whales sampled near South Georgia were known only from the Brazilian breeding population (Engel *et al.* 2008). The islands of the Scotia Arc (Fig. 1) therefore appear to form at least part of the summer range of this population. However, doubt remains about whether this area is the main feeding ground, partly because relatively few humpbacks have been encountered in the region

in recent decades (Moore *et al.* 1999, Rossi-Santos *et al.* 2007). Despite an almost complete cessation of humpback whaling here by 1950 (only *ca.* 55 were taken in the South Georgia region after this date), the numbers seen from ships and land appear not to match the large and increasing Brazilian breeding population, estimated at 6,251 (CV = 0.16) whales in 2005 (Andriolo *et al.* 2006).

To address this question, photographs of humpback whale flukes were obtained from two subantarctic areas that have few human visitors and could potentially be major summering grounds for Brazilian-breeding humpbacks—the SSI (58°S, 27°W) and the nearest subantarctic island to the east, Bouvet Island (54°S, 3°E). These whales were then compared with the catalogue of whales photographed off Brazil, which is maintained by the Instituto Baleia Jubarte.

Photographs of 25 humpback whales from coastal waters off the SSI in January/February 2006 and 96 from Bouvet Island (BI) in the 2005/2006 and 2006/2007 seasons were compared with each other and with the Brazilian catalog, which comprises 2,597 individuals photographed off Brazil between 1989 and 2006.

The selection of photographs for the Brazil catalog followed standard international protocols (Katona and Beard 1990, Rosenbaum *et al.* 1995, Calambokidis *et al.* 2001). All photographs were compared by at least two trained persons, and a third was consulted in the event of ambiguity.

Four matches ( $4/25 = 16\%$ ) were found between SSI and Brazil, a rate not significantly lower than that obtained for new whales photographed off Abrolhos Bank in 2004 ( $63/354 = 17.8\%$ ) (Fisher's exact test  $P = 0.55$ ). Three animals were seen only once on Abrolhos bank (no. 1078: 2001, no. 1356: 2002, no. 1814: 2004), two of them in groups containing calves. Whale no. 715 was recorded at Abrolhos Bank in 1999, 2005, and 2006; in the latter year it was also seen at SSI. The longest interval between matches was 7 yr and the shortest was 6 mo. No matches were obtained between Bouvet and Brazil or between Bouvet and SSI. The proportions of matches between the Brazil catalog and each of the samples from SSI and Bouvet are significantly different (Fisher's exact test  $P = 0.002$ ), indicating that whales occurring at the SSI and BI are not from the same population.

The lack of any matches between the Brazilian catalog and the large Bouvet sample strongly indicates that this area is not used by the western South Atlantic breeding population. Although no comparison has yet been made of humpback whale flukes in the Bouvet sample and from the West African breeding grounds, satellite-tracking results have demonstrated that at least some humpbacks from West Africa do indeed migrate to the Bouvet area after the breeding season (Rosenbaum and Mate 2006).

In contrast, the discovery of four matches between the Brazilian catalogue and the sample of 25 whales from the SSI—a similar probability to that of matching new Brazilian photos with existing animals in the catalog—is consistent with all the animals feeding there having been born off Brazil. Although Bouvet and SSI are separated by only 1,850 km, and the great-circle distance to Bouvet from Abrolhos is only 19% greater than to SSI (involving a migrational bearing change of 2°), there appears to be a line between the two that is not normally crossed by this species, probably between 0° and 20°W.

Humpback whales were taken by whalers at the SSI to a limited extent in the early part of the 20th Century (Tønnessen and Johnsen 1982), but no land station was established there because of the persistently bad weather encountered and the lack of a natural harbor. No human habitation has been established in the archipelago, and the rough seas discourage visitors, who can only reach it by ship. Nevertheless, SeaWiFS satellite images reveal consistently high densities of primary productivity (chlorophyll a) in summer around, and to the east of, the islands (NASA 2008), and very large populations of krill-eating penguins (mostly chinstrap penguins *Pygoscelis antarctica*; Convey *et al.* 1999) demonstrate the abundance of the preferred Southern Ocean baleen whale prey here. Although no estimates of humpback whale density at the SSI are available, the relative ease with which 25 humpbacks were photographed, together with the tracking results of Zerbini *et al.* (2006), indicates that substantial numbers, and plausibly thousands of whales forming the majority of the population breeding off Brazil, may feed here at some stage during summer in the early 21st century. With coastal waters of South Georgia supporting very few humpbacks in recent years (Moore *et al.* 1999, Rossi-Santos *et al.* 2007), in contrast to a century ago at the start of commercial whaling when the species was abundant (Tønnessen and Johnsen 1982), the focus of the summer distribution of this population appears to have changed, and may have shifted some 750 km to the southeast.

Based on a combination of recent and older data from several sources (Reilly *et al.* 2004, Zemsky *et al.* 1996, Kasamatsu *et al.* 1996, Zerbini *et al.* 2006), another humpback “hotspot” is thought to occur far offshore to the north and northeast of South Georgia. This area is en route between Abrolhos and the eastern Scotia Sea and, as tracking results have shown (Zerbini *et al.* 2006), whales may either pause here on their way south or remain for longer periods.

The location of the line dividing the summer distribution of this population from the adjacent one to the southwest (western Antarctic Peninsula and South Shetland Islands) is insufficiently understood, but may be at the eastern end of the South Scotia Ridge at about 40°W (Fig. 1). Evidence for this is based on two photo-id matches linking the South Orkney Islands with areas to the west (South Shetland Islands and Ecuador), and none with areas to the east,<sup>1</sup> and tracking data for animals summering around the Peninsula (Dalla Rosa *et al.* 2008).

In conclusion, the feeding grounds for western South Atlantic humpback whales appear to be centered on the Scotia Sea, bounded to the East by the South Sandwich Islands, and to the northwest by the shelf around Shag Rocks (44°W), some 265 km west of South Georgia. A boundary between the foraging areas of this population and its neighbor in the eastern South Atlantic occurs at an unknown longitude between the SSI and Bouvet Island. Whales around the South Orkney Islands appear to be from a separate population. Our increasing knowledge of Southern Ocean partitioning by humpback whale populations has clear implications for understanding their current role in its krill-based ecosystem. Additionally, it allows much greater understanding of which populations were affected by the various

<sup>1</sup>Personal communication from J. Allen, Antarctic Humpback Whale Catalogue, Allied Whale, College of the Atlantic, Bar Harbor, ME, 20 May 2008.

20th-century whaling operations, and how they have responded to five decades of protection.

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