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Movements of satellite-monitored humpback whales, *Megaptera novaeangliae*, from the Cook Islands

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Humpback whales (*Megaptera novaeangliae*) undertake extensive seasonal migrations from summer feeding areas in high latitudes to winter mating and calving grounds in tropical waters (Clapham and Mead 1999). In the Southern Hemisphere, seven populations are recognized by the International Whaling Commission (IWC). These breeding stocks are designated by the letters A to G, and they have migratory connections to feeding grounds in the Antarctic (IWC 1998); the latter areas were previously used by the IWC as management units, and were labeled Areas I

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to VI (Donovan 1991). The relationship between these feeding and breeding areas is known with varying degrees of certainty. For example, there is a clear migratory connection between eastern Australia (breeding stock E) and Area V to the south; similarly, there is good evidence from Discovery marks linking western Australia (breeding stock D) with Area IV (Chittleborough 1965).

Feeding ground connections with breeding areas in Oceania are among the poorest known, as is the degree of movement between different areas in the southwestern South Pacific. Photo-identification studies have shown limited exchange among major island groups including New Caledonia, Tonga, Vanuatu, the Cook Islands, and French Polynesia (Garrigue *et al*. 2002, in press).

Whales found around the Cook Islands are currently considered by the IWC to be part of Breeding Stock F (IWC 2006); however, very little is known about the winter movements of these animals, and there is no information regarding where they feed in the Antarctic. Hauser *et al*. (2000) presented limited information on population characteristics of Cook Island humpbacks, derived from a preliminary photo-identification study off Rarotonga and two other islands in the southern Cooks. Although there is no current abundance estimate, the Cook Islands aggregation appears to be small and transient, and recent photo-identification matches have shown connections with other areas (principally Tonga, Garrigue *et al*. 2002).

In this study, we report the movements of seven whales satellite-tagged in the Cook Islands, including the first documented migration to an antarctic feeding ground. In September 2006 and 2007 we attached Argos satellite-monitored tags to eight humpback whales of various sex and behavioral classes (Table 1). All whales were tagged in the nearshore waters of Rarotonga (the largest island in the Cooks group). The tags consisted of the implantable model (Mold 177) of the SPOT3 (2006) and SPOT5 (2007) transmitters manufactured by Wildlife Computers (Redmond, WA). Transmitters were attached to a stainless steel anchoring system equipped with foldable barbs and a triangular sharp tip (Fig. 1). They were duty cycled to transmit every third day in 2006 and, in 2007, every day during September–October, and every other day from November on. The transmitters were implanted into the

Table 1. Satellite transmitters deployed on humpback whales in the Cook Islands in 2006 and 2007.

PTT ID number	Deployment date	Tag longevity (d)	Locations received	% of classes 1, 2, 3 quality	Sex/behavior class
22854	10 September 2006	135	32	7	F with calf
27262	19 September 2007	10	35	37	M escort to mother/calf
37232	18 September 2007	9	28	57	F with calf and escort
37233	19 September 2007	11	38	63	F with calf and escort
37234	20 September 2007	10	38	39	M in competitive group
37236	20 September 2007	15	27	19	F with calf
37277	21 September 2007	4	11	64	Unknown
37282	25 September 2007	25	63	43	F with calf and escort

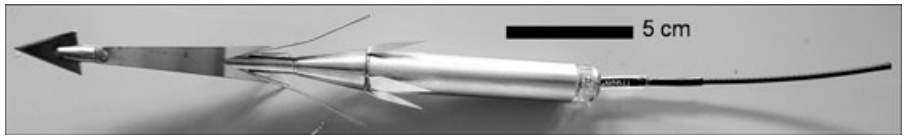

Figure 1. Satellite transmitter (Wildlife Computers implantable SPOT3/4) deployed in humpback whales in the Cook Island.

left or right flank of the whales from about 1–2 m ahead to the same level of the dorsal fin and usually within 2 m from the midline of the whale's body. Maximum penetration depth of the transmitters was approximately 17 cm. Tag deployment was accomplished with an 8-m pole deployed from a small motor boat, using the technique described in Heide-Jorgensen *et al*. (2003) and Zerbini *et al*. (2006). No noticeable immediate posttagging reaction was observed for four individuals, an increase in swimming speed was recorded for three, and a slight tail slap was seen for another whale.

In plotting the subsequent track of the tagged whales, we used all Argos locations of qualities 3, 2, 1, 0, A, and B, in order of accuracy (Argos 1990) when looking at fine-scale movements in the wintering grounds. Argos locations were filtered using the R-function Trip (Sumner 2006) in order to remove locations that implied unrealistic movements. Removal occurred if travel speed between two consecutive locations exceeded 12 km/h. This value was selected based on maximum speeds reported for humpback whales (*e.g.*, Tyack 1983, Mate *et al*. 1998). When looking at movements in the migratory routes and putative feeding destinations, average daily positions were computed from all location qualities (*e.g.*, Zerbini *et al*. 2006). There were instances where only a single poor-quality location per day was available for two consecutive days; in such cases, the locations were averaged.

Data on deployments of the seven tags are summarized in Table 1. The single 2006 tag (ID number 22854), deployed on a female with calf on 10 September, initially transmitted for 9 d, during which the whale remained in the vicinity of Rarotonga, circling the island several times at distances of up to 20 km from shore. On 25 September, the tag fell silent for 3 mo, but resumed transmissions on 24 December, at which point the whale was approximately 3,000 km south of French Polynesia and heading towards Antarctica (Fig. 2). The tag continued to transmit for another 31 d, during which the whale migrated steadily south or southeast, covering an average of 80.7 km/d. The last position was recorded on 23 January 2007 at 65°06′S, 126°57.1′W, approximately 900 km north of West Antarctica and the Amundsen Sea. This location is still within the IWC management region known as Area VI, but is only 315 km west of the boundary with Area I. The total point-to-point distance between the whale's original position at tagging off Rarotonga to its last transmission location was approximately 5,400 km. Unlike humpback whales in the South Atlantic, which show a reduction in speed and begin moving in a more erratic fashion once they cross the Antarctic Polar Front (presumably because they start feeding; Zerbini *et al*. 2006), whale 22854 continued to move steadily south towards the ice-edge (Fig. 2).

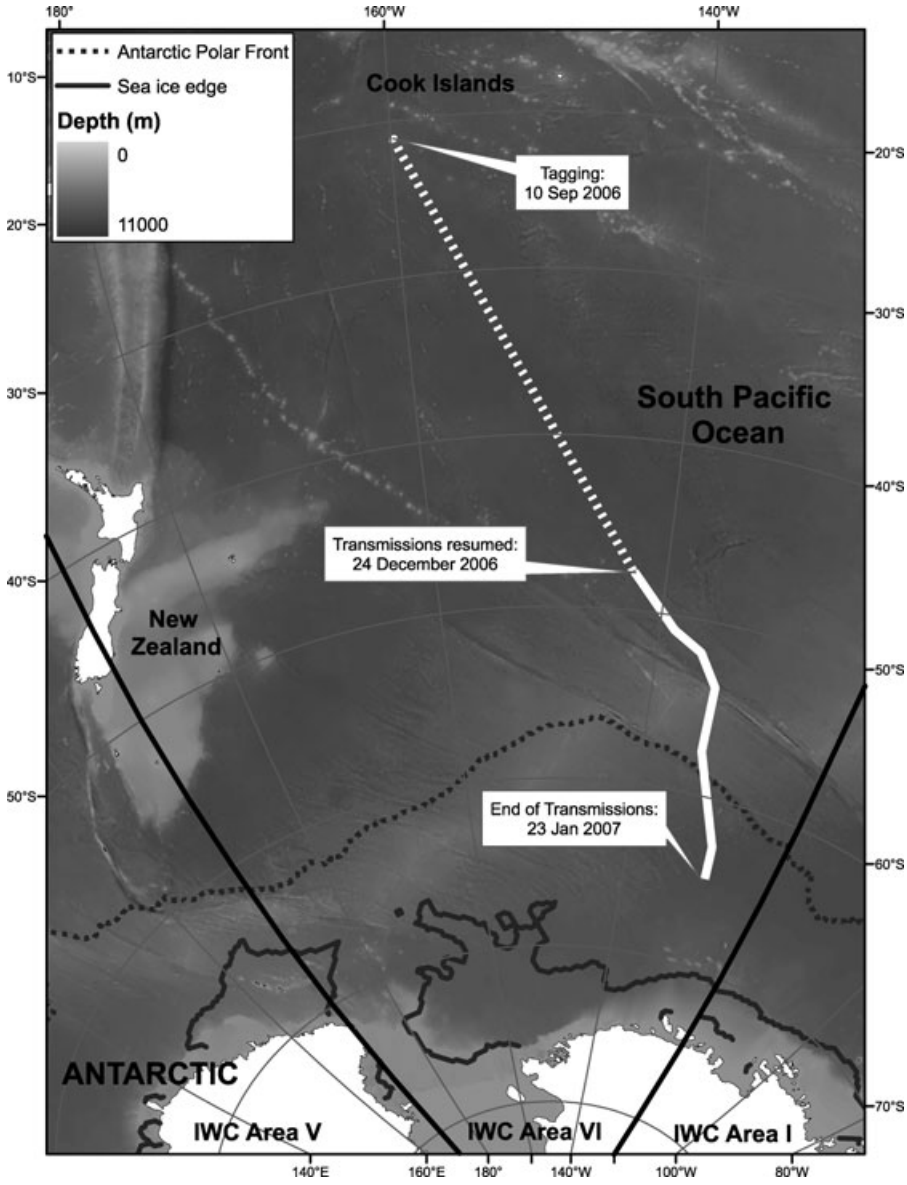

Figure 2. Satellite-monitored track of humpback whale 22854 tagged off Rarotonga in 2006 and traveling from the Cook Islands to the Antarctic in 2006/2007. The dotted white line represents the inferred track between 19 September and 24 December 2006 and the solid line the track during the period of transmissions. The sea ice edge corresponds to January 2007 (Fetterer *et al*. 2002, updated 2009), the Antarctic Polar Front representation is equivalent to Moore *et al*. (1999) and the IWC Management Areas are illustrated as in Donovan (1991).

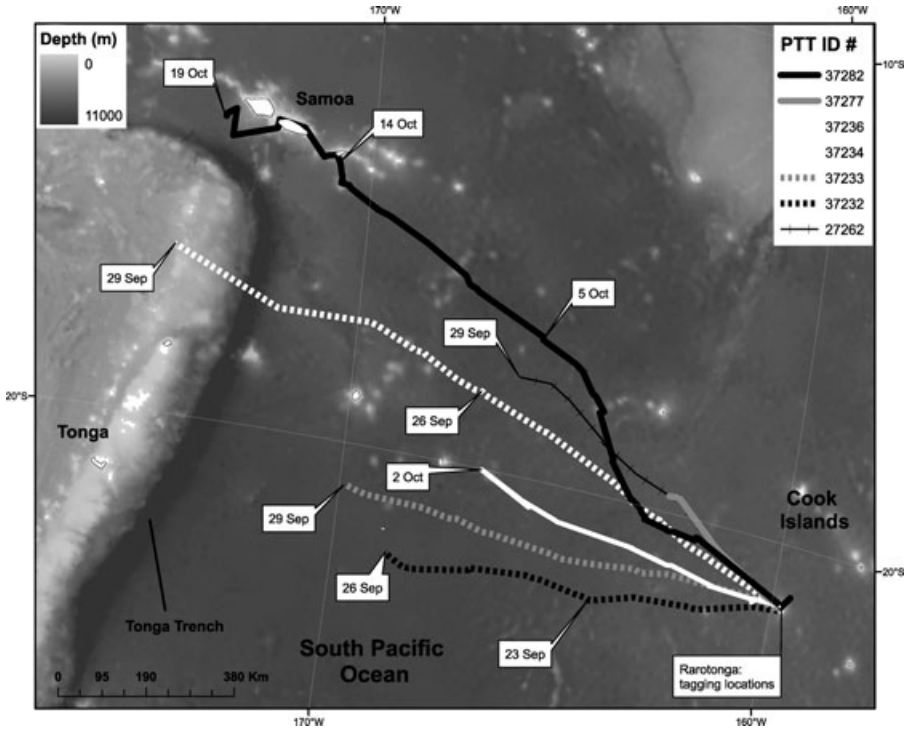

Figure 3. Satellite-monitored tracks of humpback whales tagged off Rarotonga, 2007.

The seven 2007 tags transmitted for periods ranging from 4 to 25 d, giving a total of 240 locations; the whales' tracks are shown in Figure 3. All of the whales traveled away from Rarotonga on a relatively narrow range of headings from west to northwest. Average travel rate of these individuals was 130 km/d (range 104–157 km/d). These travel rates are comparable to migrating humpback whales in other oceans (Mate *et al*. 1998, Zerbini *et al*. 2006, Lagerquist *et al*. 2008). Two whales reached and crossed the Tonga Trench, and one of these spent 5 d in the coastal waters of American Samoa and then Samoa before continuing west.

The 5,400 km track of the 2006 whale represents the first confirmation of the migratory destination of a whale from the Cook Islands, and implies that at least some humpbacks wintering in this region (IWC Breeding Stock F) feed in the waters of IWC Area VI. However, given that the whale's last recorded location was only about 315 km from the Area VI/Area I boundary, some interchange between these two management areas appears likely. The whale appeared to still be migrating at the time the last transmission was received, suggesting that it had not yet reached its summer feeding ground. This is consistent with the distribution of humpback whales in high latitudes of the Antarctic Ocean near 120–130°W. Sightings of humpback whales recorded during the IWC IDCR/SOWER cruises within this longitudinal sector of the Antarctic were concentrated south of 65°S (Branch, in press).

The 2007 tagging results reinforced the connection between the Cook Islands and Tonga, as well as with Samoa/American Samoa. To date, photo-identification comparisons have found 11 matches between the Cook Islands and Tonga, and one with American Samoa (Garrigue *et al*., in press). However, while these matches demonstrated interarea connections, the wide temporal spacing between resightings make them uninformative with regard to routes traveled. Accordingly, the most interesting aspect of the 2007 tracks was the consistency with which all the whales went west or northwest. Prior to this study, the only indication of the movements of whales from Rarotonga came from between-year photo-identification and genotype matches to areas that lie both west (Tonga, New Caledonia) and east (French Polynesia) of the Cook Islands (Garrigue *et al*., in press; Hauser *et al*., unpublished data). From this, one might have expected the whales to exhibit movements in several opposing directions, but this was not the case. The consistent movement toward Tonga and Samoa suggests that whales arrive in the Cook Islands from somewhere in the east and continue a westerly/northwesterly sweep through the region before (presumably) turning toward Antarctica when they are ready to migrate at the end of the winter. This westerly movement through island groups has also been observed in the West Indies (Mattila *et al*. 1989).

Unfortunately, none of the 2007 tags continued to transmit until the whales began their southerly migration, so we know neither where this migration begins nor the routes taken. The movements of the 2006 whale are not informative in this regard because of the 3-mo break in transmissions. If this whale, like the others, went northwest towards Tonga before beginning its journey back to the feeding grounds, then its migratory track would have been approximately southwest, which would represent something of a reversal in movement. Why Cook Islands whales proceed west before turning in a more southerly direction to migrate is not clear. They may be visiting preferred breeding habitats prior to migration, and/or are seeking some prominent oceanic features by which to navigate over the great distances to Antarctica as observed in other regions (*e.g.*, Mate *et al*. 1998).

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