Movements of satellite-monitored humpback whales from New Caledonia and the Cook Islands

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ABSTRACT

Knowledge of the local and migratory movements of humpback whales from New Caledonia and the Cook Islands is very limited. To investigate this topic, we attached satellite-monitored tags to 12 whales off southern New Caledonia and six off Rarotonga in the Cooks. Tag longevity ranged from 4 to 52 days. The humpbacks from New Caledonia generally moved to the south or southeast, with at least seven whales spending time in a previously unknown sea mount habitat named Antigonia Reef before continuing on, generally towards Norfolk Island, New Zealand or the Tonga Trench. However, one female with a calf traveled the entire length of the west coast of New Caledonia and west towards the Chesterfield Reefs (a 19th century Yankee whaling ground). None of the New Caledonia whales traveled to eastern Australia, which is broadly consistent with the low rate of interchange observed from photo-identification comparisons between these two areas. The connections between New Caledonia and New Zealand, together with the relatively low numbers of whales seen in both these places, supports the idea that whales from these two areas constitute a single population that remains small and unrecovered, and which is for the most part separate from the large, increasing stock off eastern Australia. All of the Rarotonga whales traveled west or northwest to or across the Tonga Trench, suggesting that humpbacks sweep through the Cook Islands from somewhere in eastern Oceania and move west before they initiate the southward migration to the Antarctic.

INTRODUCTION

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 breeding populations are recognized by the International Whaling Commission (IWC). These are designated by the letters A to G, and they have migratory connections to feeding grounds in the Antarctic; the latter areas were previously used by the IWC as management units, and were labeled Areas I to VI. The relationship between these feeding and breeding areas is known with varying degrees of certainty. For example, there is a clear migratory connection between East Australia (breeding stock E) and Area V to the south; similarly, there is good evidence linking West Australia (breeding stock D) with Area IV.

Feeding ground connections with breeding areas in Oceania are less clear, 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, 2008a). However, the primary migratory destination and winter movements of whales from these locations remains largely unknown.

Given the relative proximity of New Caledonia to East Australia, a logical hypothesis is that whales from the former region migrate along the Australian coast to the Antarctic (Area V). However, a recent study by Garrigue *et al.* (2008a)

found only four matches (out of 1,398 photo-identified individuals) between these two areas. In addition, the two populations exhibit major differences in size and apparent recovery: while the humpback whales off East Australia are numerous and increasing at consistently high rates (Noad *et al.* 2008), the New Caledonia population is small and relatively static. Garrigue *et al.* (2004) used photo-identification and gametic mark-recapture to estimate the population at 327 (CV=0.11) and 379 (CV=0.30), respectively, and they suggested that New Caledonia represents a relatively discrete stock that has only minimal interchange with Australia.

The great majority of sighting effort in New Caledonia has been in the large southern lagoon (Garrigue & Gill 1994, Garrigue *et al.* 2001); consequently, little is known about the local movements of these animals through the waters adjacent to the main island.

Even less is known about humpback whales in the Cook Islands. Hauser *et al.* (2000) presented limited information on some population characteristics, derived from a preliminary study off Rarotonga and two other locations in the Southern Cooks group; although there is no abundance estimate, the population appears to be small and transient, and recent photo-identification matches have shown connections with other areas (principally Tonga) (Garrigue *et al.* 2002). The only information on the migratory destination of Cook Islands whales comes from a single animal (a mother) that was satellite-tagged off Rarotonga in 2006/07, and which traveled more than 3,000 km south to a location north of the Amundsen Sea (SC/59/SH16).

In order to investigate movements within and beyond Oceania, we attached satellite-monitored transmitters to 18 humpback whales from New Caledonia and the Cook Islands in the austral winter of 2007. The results of this tagging show consistent westward or northwestward movements by whales from Rarotonga, as well as differing directions of travel and use of an offshore seamount reef system by the New Caledonia animals. They also confirm migratory movements between New Caledonia and New Zealand, and the low rate of exchange documented between the former area and eastern Australia.

METHODS AND MATERIALS

In August and September 2007, we attached Argos satellite-monitored tags to 20 humpback whales of various sex and age classes; two of the tags (both deployed in the Cook Islands) never transmitted, leaving 18 that worked for varying periods of time (12 in New Caledonia and six in the Cooks). The tags consisted of the implantable model of the SPOT 5 transmitter manufactured by Wildlife Computers (Redmond, Washington, USA). Transmitters were attached to a stainless steel anchoring system equipped with foldable barbs and a triangular sharp tip, and were duty cycled to transmit every day during August-October and every other day as of November. They were also programmed to provide a daily maximum of 300 transmissions during two periods of the day: 03:00-9:00 and 15:00-21:00 GMT. The transmitters were implanted into the left or right flank of the whales in the vicinity of the dorsal fin; the attachment was accomplished by hand with an 8-meter pole deployed from a motor boat, using the technique described by Heide-Jørgensen *et al.* (2006) and Zerbini *et al.* (2006).

In plotting the subsequent track of the tagged whales, we used all Argos locations 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 12km/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 one poor quality location was available in a given day for two sequential days. These were therefore averaged.

Tagged humpback whales were individually identified using variation in ventral fluke patterns (Katona *et al.* 1979), and these photos were compared to existing local catalogues for information on sex and resighting history, where known.

RESULTS

As noted above, 20 whales were tagged during the study, although two of these tags (both in Cook Islands) did not function, and are therefore not included here. An overview of the movements of the remaining 18 whales is shown in Figure 1. Further details are given below.

New Caledonia

Data on deployments of the 12 tags from New Caledonia are summarized in Table 1. All the tagged whales were known or judged from size or behavior to be adults. Fluke photos revealed that six of the whales had been previously identified in New Caledonia; two were sighted earlier in 2007 prior to the tagging program, while the other four had been encountered in previous years. One of these (a male) was observed in nine different years. Whales were tracked for between one and 52 days (mean = 22.5 days, Table 1). A total of 924 locations were received.

All the whales were tagged in the same area and except one they all travelled in a general S-SE direction with individual variation. Tracks of the 12 tagged whales are shown in Figures 2 and 3; the latter gives more detail on movements around New Caledonia.

Whale #24638, a mother accompanied by a calf, stayed in the southern part of the lagoon including off Isle des Pins for eight days after tagging. She then moved to the great northern lagoon at the opposite side of the island, navigating outside the western fringing barrier reef in the open ocean and following the reef for four days and over more than 400 km. The whale spent ten days milling around in the northern lagoon before headed southwest and then west for another 300 km until she reached Landsdowne Bank (east of the Chesterfield Reefs) where she remained for at least the next 24 hours, at which point transmissions ceased.

Whale #24639 was already known to be male from genetic sexing of a biopsy sample taken in a previous year. This whale spent two days in the western part of the lagoon before coming back to the southern part, where he remained for two to three weeks. During this time, he moved back and forth between the southern part of the lagoon and two seamounts known as Banc de La Torche and Antigonia, situated respectively 15 and 60 nm from the Isle des Pins. After this, the whale navigated in a southeasterly direction for nine days before going southwest for two days to reach Raoul Island in the Kermadec group. There, he remained for at least seven days before the end of transmissions.

Whale #24641 travelled southeast to Antigonia Reef where it stayed for ten days before coming back to the area of the other seamount.

Whale #24642 followed a southeasterly direction, moving back and forth between the two seamounts for two weeks. It then travelled in a south or southeasterly direction for the three remaining days of transmissions.

Whale #26712 spent two days milling around in the southern lagoon before starting to move southeast to the two seamounts, Banc de la Torche and then Antigonia where it spent a few days. It left Antigonia heading in a southeasterly then southerly direction for five days until it reached vicinity of Norfolk island. It remained at Norfolk for at least a week before transmissions ceased.

Whale #27258 remained in the lagoon for four days then travelled in the direction of Antigonia.

Whale #27259 was a mother accompanied by a calf. After tagging the whale milled around for the day; for the next two days it travel southeast to Antigonia where she stayed for two days. She then left the seamount and travelled SSW then south. The whale passed 70 km to the west of Norfolk Island but did not stop there, and instead travelled 970 km over the next nine days. She then moved erratically for the next 19 days in an area named Basin de La Gazelle on the West Norfolk Ridge before starting to move southeast until she reached the north coast of New Zealand. There, she followed

the east coast to the Bay of Plenty over the next eight days.

Whale #33000 travelled in the direction of Antigonia.

Whale #33001 travelled in a southeasterly direction through Banc de La Torche and Antigonia but maintained this direction for 13 days before transmissions ceased.

Whale #37229 also travelled southeast for 12 days. The animal then milled around for six days before moving once more east/southeast for four days.

Whale #37230 was encountered with a small calf. The mother milled around in a protected area of the southern lagoon for four days. After this, she left the lagoon to travel northeast along the eastern coast of New Caledonia, probably outside of the barrier reef. After two days of transit, she then entered the eastern lagoon and changed direction, travelling southeast inside the lagoon back to the southern lagoon, where she arrived two days later. She remained in the southern lagoon for another 11 days before travelling southeast in the direction of the seamounts. The whale went back and forth between these seamounts and the southern lagoon for the next 12 days, then moved back to Antigonia where she stayed for the eight remaining 8 days of transmissions.

Cook Islands

Data on deployments of the six functional tags in the Cook Islands are summarized in Table 2. The tags transmitted for periods ranging from six to 25 days (mean = 12.3 days), giving a total of 205 locations; the whales' tracks are shown in Figure 4. All of the whales traveled away from Rarotonga on a relatively narrow range of headings of west to northwest. Two reached and crossed the Tonga Trench, and one of these spent some time off American Samoa and then Samoa before apparently heading offshore.

The shorter attachment times of the tags relative to those in New Caledonia was due to Air New Zealand losing the damn tagging pole, thus necessitating creation of an improvised and less effective means of deployment (a wooden pole).

DISCUSSION

New Caledonia

Intra-island movements, and a new habitat

The tagging in New Caledonia revealed the existence of a previously unknown offshore habitat at Antigonia Seamount. Whales also used Banc de la Torche, but this area was known from previous work (Garrigue, unpublished data). That Antigonia is important to the population is suggested by the fact that at least seven of the 12 tagged whales spent some time there, and the final transmissions of the tags on three others placed them close to this location. A few seamounts occur close to the southern lagoon but only Antigonia was used by the tagged whales. Whether this area is in use the entire season, or is used as a departure point for a southward migration, remains to be investigated.

Our discovery of this new habitat may have implications for the estimation of abundance of the New Caledonian population, since previous estimates have been based on mark-recapture data collected primarily in the southern lagoon (Garrigue *et al.* 2004). This area has been the focus of sampling because it was considered the main breeding area of the population; however, given the new results it is possible that previous estimates were based on an incomplete coverage of the wintering range of this stock.

Most of the whales moved south after being tagged. This was expected because tagging took place late in the season when the whales leave the southern lagoon. Although whales are occasionally observed as late as November, the peak of the season is considered to be in August (Garrigue et al. 2001).

The tagging also showed movements along both the eastern and western coasts of New Caledonia by two whales, both

of them mothers with accompanying calves. Previous studies of humpback whales in New Caledonia concluded that whales could be found all around the island (Garrigue and Gill 1994) but that the highest density of whales occurred in the southern lagoon where most breeding behavior is believed to occur (Garrigue 2005). These studies also suggested that some areas, such as the lagoon of the east coast, could be preferentially used by mothers and calves as a resting area far from competitive group activity (Garrigue, 2005).

The longest distance travelled around the island was by the two mothers noted above. The whales' ability to utilize the western lagoon is thought to be very limited; for a few hundred kilometers, the fringing barrier reef comes close to land and prevents any use of the lagoon which is only a few meters' deep and sometimes closed off by reticulated reef. This explains why humpback whales are rarely observed on the west coast, as few people venture outside the reef to the deeper waters which the whales have to use in transit. By following the reef on the seaward side the whales would eventually enter the huge northern lagoon; this is a remote area with few human inhabitants, and opportunistic sightings are inevitably very rare.

Implications for population structure

The movements of humpback whales monitored during this study have implications for stock structure. The humpback whales from New Caledonia are believed to be part of the Area V population (Garrigue and Gill 1994). Previously proposed migration routes involved tracks which followed the eastern coast of Australia or passed by New Zealand; however, this question was never resolved as none of the Discovery tags deployed in the vicinity of the Loyalty Islands (east of New Caledonia) were ever recovered (Dawbin 1964). Of the 12 satellite-monitored whales, only one (#24638) moved in a westerly direction, reaching Landsdowne Bank in the direction of Chesterfield Reefs. Dawbin & Falla (1949) considered that the Chesterfields, situated in the Coral Sea northwest of New Caledonia (about 17˚ to 22˚S; 157˚ to 163˚E), were the breeding ground of humpback whales passing the eastern coast of Australia. This opinion was based upon Townsend's (1935) charts in which the Chesterfield reef complex was identified as an important Yankee whaling ground. Unfortunately, tag transmissions ceased after 26 days; if the whale continued on its last recorded course it would have eventually reached the eastern Australian coast. Photo-identification has shown only limited exchange between New Caledonia and the eastern coast of Australia, with only four matches between the two areas out of a total of 1398 photographed individuals (Garrigue *et al.* 2007, 2008b). Furthermore, the relative size of the two populations is markedly different, with the New Caledonia group being much smaller than the apparently burgeoning Australian stock.

All the other whales (seven individuals) whose tags were still working when they began their southern migration headed generally south. Two whales were tracked until they reached New Zealand. One (#27259) passed along the northeastern coast of the North Island to the Bay of Islands, while the second (#24639) went to Kermadec Island. Three other tags stopped transmitting with the whales concerned heading in the direction of New Zealand (#26712 at 670 km distance, #33001 at 630 km, and #37229 at 460 km). Together, these provided the first evidence of migratory routes followed by humpback whales wintering in New Caledonia.

Connections between New Caledonia and New Zealand (n = 2 matches) have previously been established by photo-identification (Garrigue *et al.* 2000, Constantine *et al.* 2007) but never in the same year. Comparison of photographic data collected in 2006 allowed the identification of a whale first observed in August in the southern lagoon of New Caledonia and photographed a month later off Norfolk Island (Paton *et al.* in review). To date, there has also been one photo-identification match between New Caledonia and the island of Vanuatu, and 11 matches with Tonga (Garrigue *et al.* 2008a).

The New Zealand population was considerably depleted by commercial whaling. The last shore whaling stations closed in 1964 following a population collapse, largely precipitated by huge illegal Soviet catches in Areas V and VI. Although sightings of humpbacks off New Zealand have increased in recent years (Childerhouse and Gibbs 2005), the population remains small. This stands in sharp contrast to the high recovery rate of the eastern Australian population (Noad *et al.* 2008). The small sizes of the New Caledonian and New Zealand populations suggest a connection between the two regions, and this is reinforced by the tagging results reported here. It is also supported by recent genetic analysis of humpback whales from New Zealand: this revealed 20 different mtDNA haplotypes, all of which had previously been found in New Caledonia (Olavarria *et al.* 2006).

The direction taken by the tagged whales suggests that the southbound migration follows the same pattern that Dawbin

(1966) described (in reverse) for the northbound migration. This could reinforce the hypothesis that two different streams of humpback whales passed by New Zealand, as proposed in Franklin *et al.* (2008).

Cook Islands

The tagging results from the Cook Islands reinforced a previously known connection between this region and Tonga, as well as Samoa/American Samoa. To date, photo-identification comparisons have found eight matches between the Cooks and Tonga, one with American Samoa, and one with Niue (Garrigue *et al.* 2002, 2008a).

Perhaps the most interesting aspect of the Cook Island whales' tracks was the consistency with which all went west or northwest. Prior to this study, the only indication of the movements of whales from Rarotonga came from photo-identification matches to areas that lie both west (Tonga, New Caledonia) and east (French Polynesia) of the Cooks. From this, one might have expected the whales to exhibit movements in several opposing directions, but this was not the case. The consistent movement towards Tonga and Samoa suggest that whales arrive in the Cooks from somewhere in the east and continue a westerly/northwesterly sweep through western Oceania before (presumably) turning towards the Antarctic when they are ready to migrate at the end of the winter. This westerly movement through island groups has also been observed among humpback whales in the West Indies (Mattila *et al.* 1989).

Unfortunately, none of the tags continued to transmit until the Cook Islands whales began their southerly migration, so we do not know where this migration begins, or the routes taken. The movements of the one humpback whale tagged off Rarotonga in 2006 (shown here again in Figure 5) are not informative in this regard; its track is unknown between tagging in the Cooks and a location 3000 km SSE where the tag resumed transmission after a silence of three months (SC/59/SH16). Consequently, we can only speculate about its movements in between; however, if this whale, like the others, went northwest towards Tonga before beginning its journey back to the feeding grounds, then its migratory track to Antarctica would have to 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, unless they are visiting preferred breeding habitats prior to migration, and/or using some prominent oceanic features by which to navigate over the great distance to the Antarctic.

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Table 1. Satellite transmitters deployed on humpback whales in New Caledonia in 2007.

Tag number	Date of deployment	Position of deployment	Tag longevity (days)	Number of locations received	% of classes 1, 2, 3 quality	Sex
24638	20 Aug 07	22˚27.69'S 166˚50.24'E	26	83	50	F with calf
24639	01 sept 07	22˚23.78'S 166˚46.68'E	44	113	37	M
24641	27 Aug 07	22˚31.67'S 167˚05.10'E	13	84	52	
24642	10 Sept 07	22˚39.85'S 167˚05.65'E	19	59	19	
26712	27 Aug 07	22˚44.69'S 167˚05.15'E	22	88	39	
26715	01 Sept 07	22˚23.44'S 166˚47.38'E	1	9	33	
27258	03 Sept 07	22˚26.30'S 166˚54.89'E	5	16	13	M
27259	10 Sept 07	22˚27.35'S 166˚59.88'E	52	237	35	F with calf
33000	03 Sept 07	22˚25.81'S 166˚54.09'E	7	22	23	
33001	08 Sept 07	22˚29.70'S 166˚56.65'E	14	34	24	
37229	10 Sept 07	22˚39.39'S 167˚06.24'E	23	70	31	F
37230	11 Sept 07	22˚28.85'S 166˚56.54'E	44	109	44	F with calf

Table 2. Satellite transmitters deployed on humpback whales in the Cook Islands in 2007.

Tag number	Date of deployment	Position of deployment	Tag longevity (days)	Number of locations received	% of classes 1, 2, 3 quality
37232	9/18/2007	21 11.90'S 159 47.712'E	9	28	57
37233	9/19/2007	21 12.97'S 159 50.1852'E	11	38	63
37234	9/20/2007	21 11.11'S 159 47.2092'E	10	38	39
37236	9/20/2007	21 16.93'S 159 45.1458'E	15	27	19
37277	9/21/2007	21 11.61'S 159 48.5082'E	4	11	64
37282	9/25/2007	21 00'S 160 36'E	25	63	43

Figure 1. Overview of satellite-monitored tracks of humpback whales tagged in New Caledonia and the Cook Islands.

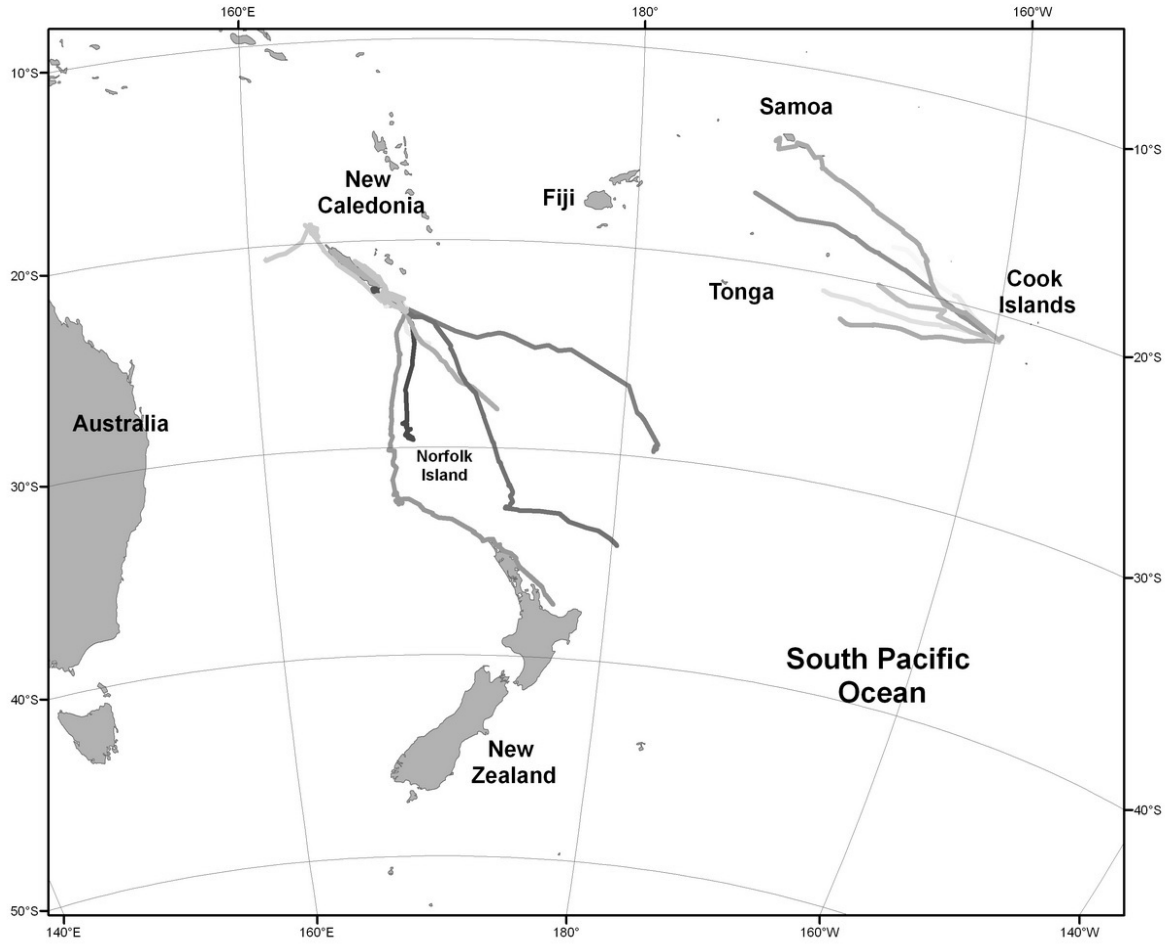

Figure 2. Satellite-monitored tracks of humpback whales tagged in New Caledonia.

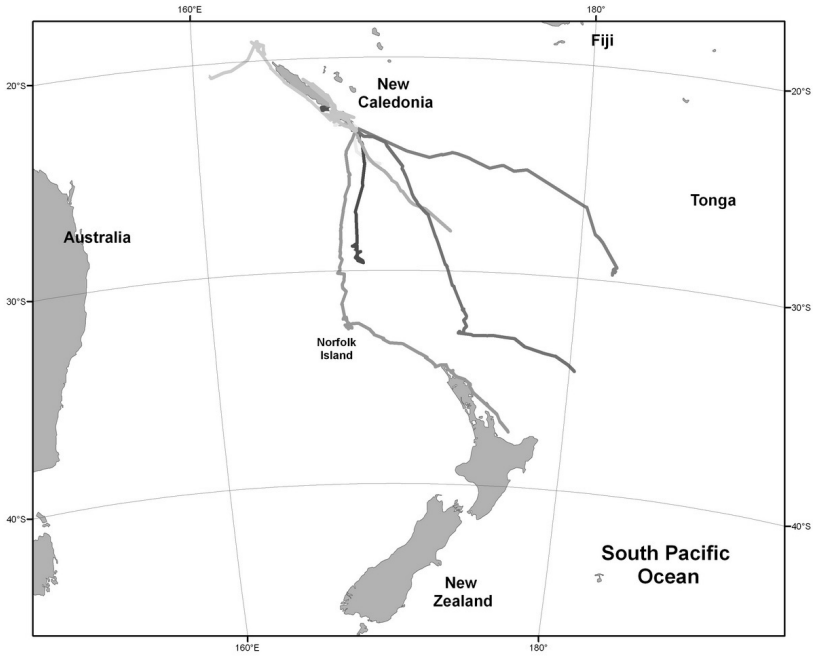

Figure 3. Local movements of tagged humpback whales in New Caledonia waters.

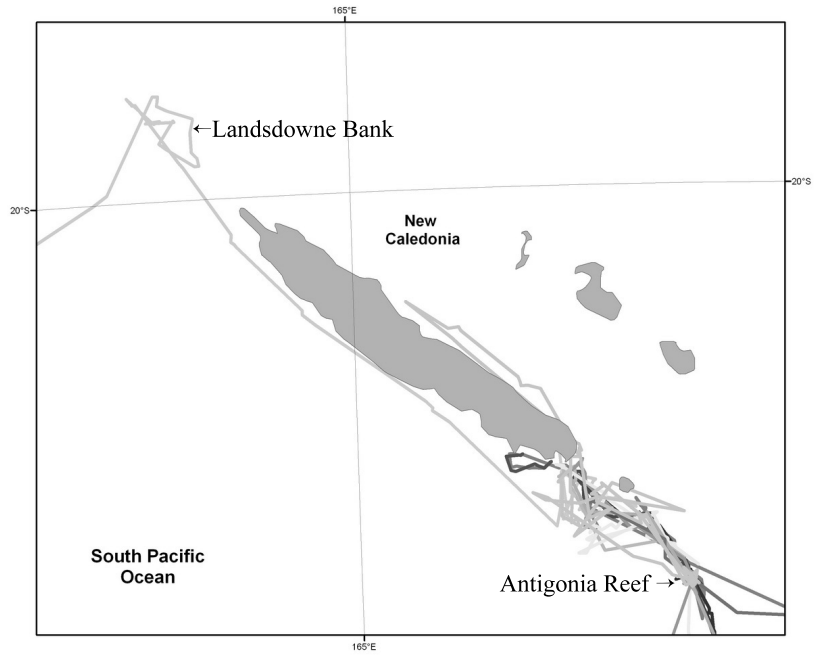

Figure 4. Satellite-monitored tracks of humpback whales tagged off Rarotonga, Cook Islands, 2008.

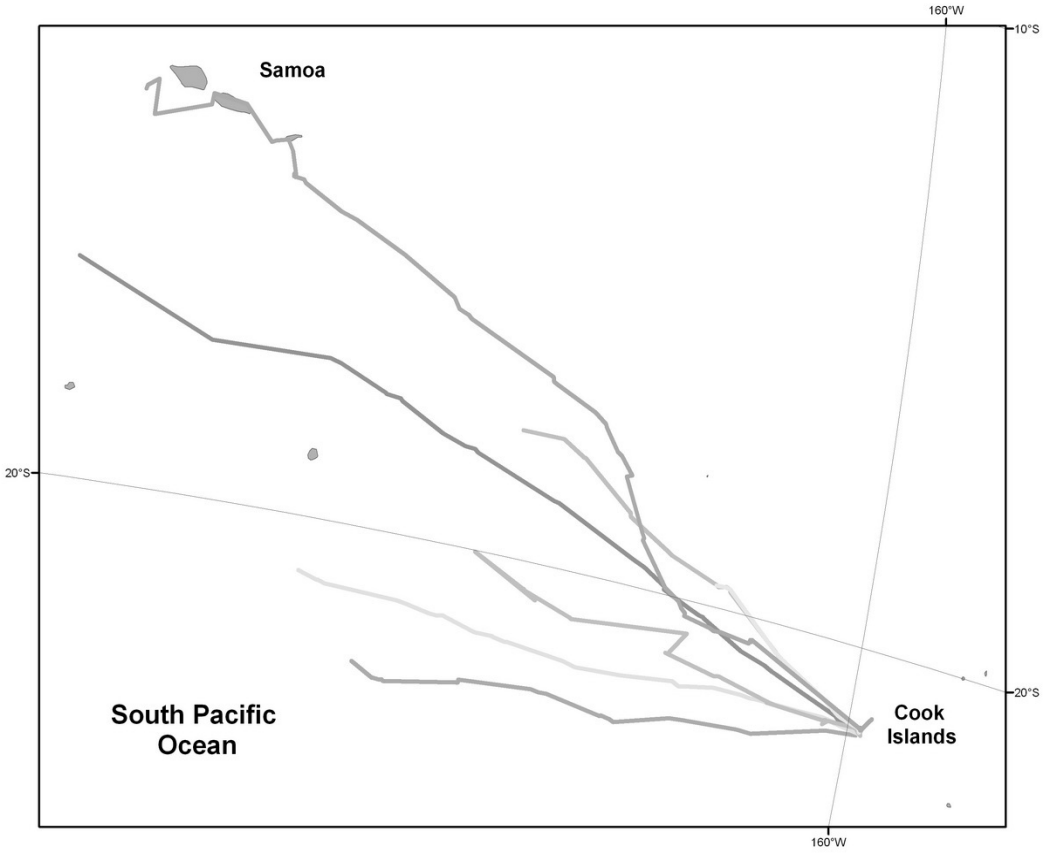

Figure 5. Track of a humpback whale from the Cook Islands to the Antarctic in 2006/07 (from SC/59/SH 16). Note: because the tag was silent for three months, the first half of the line is not a real track, but merely connects the point of tagging to the location where the tag resumed transmission in late December 2006. The whale's actual route over this period is unknown.