Satellite tracking of Australian humpback (*Megaptera novaeangliae*) and pygmy blue whales (*Balaenoptera musculus brevicauda*)

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ABSTRACT

This paper describes three datasets derived from the deployment of satellite tags on pygmy blue whales off south-western Australia and on humpback whales off Evans Head, eastern Australia and the Kimberley coast, north-western Australia. A total of 41 tags were deployed (3 pygmy blue whales, 38 humpback whales) which provided 910 days of location data (over 3,000 individual locations), and the whales were tracked for over 49,000km. These datasets will be used to define the spatial and temporal migratory behaviour of these whales in Australian waters and beyond.

KEYWORDS: SATELLITE TRACKING, HUMPBACK WHALE, PYGYMY BLUE WHALE, STOCK D, STOCK E, AREA IV AREA V, ANTARCTICA

INTRODUCTION

Satellite telemetry has been used routinely in wildlife biology for nearly two decades and has been applied successfully in studies of many marine organisms including penguins, albatrosses, seals and even sharks e.g. (Bonadonna *et al.*, 2000; Gifford *et al.*, 2007; Jouventin *et al.*, 1994; Weimerskirch *et al.*, 1993). The use of this technology in understanding the migration of large whales has, however, lagged behind other taxa largely due to the inability to catch and attach tags to such large species. It is only relatively recently that research groups developed reliable tags that can be implanted into free-ranging whales (e.g. Gales *et al.*, 2009; Heide-Jorgensen *et al.*, 2001; Mate *et al.*, 2007). Such tags have now been used in studies of many large whales species such as blue (Heide-Jorgensen *et al.*, 2001; Mate *et al.*, 1999), humpback (Dalla Rosa *et al.*, 2008; Gales *et al.*, 2009; Lagerquist *et al.*, 2008), sei (Olsen *et al.*, 2009), right (Baumgartner & Mate, 2005), bowhead (Mate *et al.*, 2000) and minke whales (Heide-Jørgensen *et al.*, 2001), although large scale deployments are still rare.

Satellite tracking studies of whales in Australian waters are few and therefore the movement patterns and migratory routes of Australian whales are generally poorly described. The two most significant deployments occurred very recently. In 2008, Gales *et al.* (2009) deployed 16 tags on humpback whales migrating south off New South Wales. And in the same year five tags were attached to five long-finned pilot whales prior to their release after stranding in north-western Tasmania (Gales, R. *et al.*, DPIPWE, in prep).

Here we briefly describe the deployment of satellite tags on southbound Stock D (west Australian) humpback whales, northbound Stock E (east Australian) humpback whales and on pygmy blue whales in the Perth Canyon off Western Australia. These studies aimed to describe the migratory pathways of humpback and blue whales migrating along the coast of Australia and to identify possible calving areas for the eastern Australian humpback whales which have yet to be clearly identified. Activities associated with industrial and domestic developments, shipping, and oil and gas exploration are increasing on both the eastern and western coasts of Australia. This, together with the rapidly increasing humpback whale populations on both coasts (Hedley *et al.*, 2009; Noad *et al.*, 2008), suggests anthropogenic disturbance will become more common and thus knowledge of the temporal and spatial specific movements of these whales will become of greater interest and value to conservation managers and other stakeholders.

METHODOLOGY

The tags consisted of a custom-designed, implantable housing that contained Wildlife Computer (Redmond, Washington, USA) Spot 5 transmitters. The tags are designed to implant up to a maximum of 290mm into the back of the whale (generally just forward and to the left or right side of the dorsal fin). The front 80mm of the tag disarticulates from back section of the tag post-deployment; a flexible 5mm multi-braided stainless steel wire maintains a coupling between the two parts. The tag is designed to penetrate beneath the skin and hypodermis and anchor the tag within the variable muscle and connective tissue matrix that underlies the blubber. Retention of the tag is maintained through two actively sprung plates, and a circle of passively deployed 'petals'. All external components of the tag are built from stainless steel and the tag is surgically sterilised prior to deployment (for photographs see Gales *et al.*, 2009).

Each tag is deployed with the use of a compressed air gun (modified ARTS) set at pressure of between 7.5 and 10 bar. A projectile carrier is attached to the rear of the tag by some retention teeth and is fired at the whale from the bow-sprit of a 5.8m rigid-hulled inflatable boat at a range of 3-8m. The rapid deceleration of the tag and carrier as they strike the whale leads to the withdrawal of the retention teeth that hold the tag to the projectile carrier and their subsequent disengagement. Once deployed, each tag turns on during the subsequent dive of the whale. They will then transmit upon each initial surfacing, and each 30 seconds of subsequent 'dry time' (if surface time >30sec). When first deployed the tags will run from the time they are turned on until 00:00 hrs UTC. They then transmit on a 6hr on, 18hr off duty cycle until the tag falls off the whale, malfunctions or the single AA lithium battery is exhausted.

Argos locations were filtered using the Speed-Distance-Angle function in the R package (R Development Core Team, 2007) 'argosfilter' (Freitas *et al.*, 2008) which has been designed specifically for the tracking data from marine mammals and is based on the algorithm developed by McConnell *et al.* (1992). This function will remove locations from the data set based on unrealistic swimming speeds, distances between successive locations and turning angles. The conservative default settings (maximum swimming speed of 7.2 km/h) were used for mapping purposes; more careful application of this filter will be applied for later analyses.

Skin biopsies were collected for genetic analyses. These were collected using a biopsy dart fired from a modified .22 Paxarms system (Krutzen *et al.*, 2002). Biopsies were usually collected simultaneously with the deployment of the satellite tag. Biopsies were stored in 70% ethanol and DNA subsequently extracted using either a salting-out protocol (Aljanabi & Martinez, 1997) or by using a the Tissue DNA purification kit for the Maxwell 16 DNA extraction robot (Promega Corporation). The sexes of the tagged whale were determined using a 5' exonuclease assay of the polymorphisms in the sex-linked Zinc Finger genes as described by Morin et al. (2005).

RESULTS

In April 2009 three tags were deployed on pygmy blue whales (*Balaenoptera musculus brevicauda*) off the Perth Canyon, Western Australia (~32.0^{o}S, 115.0^{o}E). The longevity of these tags ranged from eight to 137 days and the distances these whales were tracked ranged from 260 to 6,200 km (Table 1, Figure1). The whale with the greatest tag life was tracked from the Perth Canyon north along the western coast of Australia; it then passed through the Savu Sea and Wetar Basin and then entered the Banda Sea east of the Indonesian island of Wetar.

In June 2009 15 tags were deployed on humpback whales (*Megaptera novaeangliae*) migrating north off Evans Head, New South Wales (~29.0^{o}S, 153.5^{o}E). Thirteen of these tags were deployed successfully; one was damaged on deployment by the biopsy (88749) dart and one did not implant well (88752; see Table 1). The longevity of the well deployed tags ranged from fifteen to 60 days and the distances these whales were tracked ranged from 930 to 3,400km (Table 1, Figure 2). For five of the thirteen whales the last recorded location was the most, or very near to the most northerly location. For the remaining whales the last location was south of the northern most location and for seven of these whales the last location was greater than 50 km south of the most northerly location. These data suggest that this data set has captured the northern extent of the migratory path for many of the tagged whales.

In late August and early September 2009 23 tags were deployed on female humpback whales (accompanied by a calf) between Camden Sound (~15.4^{o}S, 124.4^{o}E) and Pender Bay off the Kimberley region of Western Australia. The longevity of the tags ranged from zero to 108 days and the distances these whales were tracked ranged from zero to 6,600km (Table 1, Figure 3). The whale with the greatest tag life was tracked from its winter calving ground off Western Australia to its feeding grounds off Eastern Antarctica.

Figure 4 shows a comparison of tag survival from the two humpback whales deployments described here and also from the deployment of 16 tags on southbound humpback whales off Eden, southern New South Wales (Gales *et al.*, 2009).

Tag survival is highly variable within each deployment but the tag performance in the Kimberley and Evans Head deployments was significantly lower than for the Eden deployment ($\chi 2=11.6$, df=2, $p<0.01$).

DISCUSSION

This paper provides a basic summary of three deployments of satellite tags on large baleen whales in Australian waters. Despite the highly variable performance of these tags the data have provided significant insights into the movement and migratory behaviour of the whales and will be analysed in detail in later papers.

The data from the tagged blue whales provided the first definitive link between the blue whales that feed off the Perth Canyon (Bannister *et al.*, 2006; Branch *et al.*, 2007; Jenner *et al.*, 2008) and those that occur around Indonesia (Branch *et al.*, 2007). This is movement is concordant with the proposed 'Tasmania to Indonesia' population described by Branch *et al*. (2007). A larger deployment is planned for March/April 2011 and these data, together with acoustic data collected from south-western and north-western Australia, will contribute significantly to defining the spatial and temporal migratory behaviour of pygmy blues off Western Australia and beyond.

The data from the Evans Head deployment on northbound humpback whales provides the first detailed movement data of this species in their proposed calving area around the southern Great Barrier Reef. These data are now being analysed in conjunction with opportunistic sightings data to assist in the identification of the as yet poorly defined calving area for this population (Smith, J. *et al.* in prep.).

Despite the poor tag survival statistics, the Kimberley deployment has provided the most detailed movement data for humpback whales off north-western Australia to date. These data together with extensive boat-based and aerial survey data from the region are now being analysed to accurately describe the migratory movements of this species in north-western Australia. They will be you used to assess the potential impacts of existing and proposed industrial developments in this region and develop methods and practices to mitigate any such impacts. This dataset has also revealed a previously unrecognised migratory behaviour - two of the four whales that provide location data south of Exmouth Gulf, deviated from the expected migratory route close to the coast of Western Australia and were tracked 1,200km into the Indian Ocean (Figure 3). It is possible that such whales divert from the most direct route to their Antarctic feeding grounds, to exploit temperate foraging areas (Stamation *et al.*, 2007). Such behaviour was also revealed by Gales *et al.* (2009) who showed a significant proportion of Eastern Australian humpback whale utilise productive waters off Fiordland, New Zealand and north-eastern Tasmania before continuing their migration to Antarctic waters.

Tag performance remains highly variable and this also appears to be characteristic of deployments conducted by other research groups (e.g. Mate *et al.*, 2007; Zerbini *et al.*, 2006). The cause of this variability will be difficult to determine particularly if it is due to the physiological reaction to the implanted tags by individual whales. Tag performance also seems to vary between deployments and the tag performance from Evans Head and Kimberley was lower that that for the Eden deployment in 2008. We suspect the cause of this more rapid rate of tag failure closure to the calving regions is either due to the greater probability of tag damage due to contact between whales or that the whales are in shallow water and damage the tags through contact with the sea floor. When similar tags have been deployed on whales in or close to deep water the tag longevity has been greater (Gales *et al.*, 2009; Zerbini pers. comm.). Tag failure was particularly rapid for tags deployed in the Camden Sound region of the Kimberley where whales are frequently seen with mud on their rostrum, dorsal fin or tail after rolling on the sea floor. Following evidence of rapid tag failure in the Kimberley deployment, two tags were fitted with stainless steel rings around the water switch (which is embedded in epoxy resin) and these tags (96382 & 96389) performed well above average for this deployment (see Table 1).

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Table 1. Summary of satellite tracking data from deployments on pygmy blue whales off Western Australia and on humpback whales off Evans Head, New South Wales and the Kimberley coast of Western Australia.

Deployment	Whale species	Tag	Sex	Start Date	Last Date	Longevity (days)	No. of days of locations	No. of locations	Total distance travelled (km)
Perth Canyon	Blue	88731	Male	8/04/2009	15/04/2009	8	8	39	259.3
Perth Canyon	Blue	88739	Male	4/04/2009	18/08/2009	137	125	330	6,217.9
Perth Canyon	Blue	88740	Female	6/04/2009	4/05/2009	29	29	155	1,647.8
Subtotal						**174**	**154**	**485**	**8,125.0**
Evans Head	Humpback	88730	Male	28/06/2009	11/08/2009	45	45	150	2,354.6
Evans Head	Humpback	88734	Female	26/06/2009	21/07/2009	26	26	125	1,428.6
Evans Head	Humpback	88736	Male	29/06/2009	13/07/2009	15	15	74	1,076.3
Evans Head	Humpback	88737	Male	29/06/2009	19/07/2009	21	21	99	1,468.5
Evans Head	Humpback	88742	Male	27/06/2009	17/07/2009	21	21	89	1,254.6
Evans Head	Humpback	88747	Unknown	24/06/2009	7/07/2009	14	14	71	933.4
Evans Head	Humpback	88748	Unknown	24/06/2009	28/07/2009	35	34	128	2,221.8
Evans Head	Humpback	88749	Unknown	24/06/2009	24/06/2009	1	0	0	0.0
Evans Head	Humpback	88750	Male	26/06/2009	25/07/2009	30	27	43	1,252.4
Evans Head	Humpback	88751	Male	27/06/2009	18/07/2009	22	21	85	1,337.4
Evans Head	Humpback	88752	Male	27/06/2009	29/06/2009	3	3	5	-
Evans Head	Humpback	88753	Unknown	24/06/2009	22/07/2009	29	29	144	1,259.5
Evans Head	Humpback	88754	Female	27/06/2009	25/08/2009	60	59	214	3,422.0
Evans Head	Humpback	88755	Male	25/06/2009	4/08/2009	41	32	52	1,659.4
Evans Head	Humpback	88756	Male	29/06/2009	24/07/2009	26	24	74	1,295.5
Subtotal						**389**	**371**	**1,353**	**20,964.0**
Kimberley	Humpback	96379	Female	29/08/2009	29/08/2009	1	1	10	18.6
Kimberley	Humpback	96381	Female	26/08/2009	26/08/2009	2	2	22	39.1
Kimberley	Humpback	96382	Female	2/09/2009	18/12/2009	108	69	251	6,641.0
Kimberley	Humpback	96383	Female	5/09/2009	5/09/2009	1	1	4	-
Kimberley	Humpback	96384	Female	27/08/2009	20/09/2009	25	25	141	1,487.7
Kimberley	Humpback	96387	Female	5/09/2009	5/09/2009	1	1	1	-
Kimberley	Humpback	96388	Female	29/08/2009	2/09/2009	5	5	37	374.2
Kimberley	Humpback	96389	Female	3/09/2009	6/10/2009	34	31	91	2,636.7
Kimberley	Humpback	96391	Female	6/09/2009	11/10/2009	36	36	208	2,382.6
Kimberley	Humpback	96392	Female	26/08/2009	26/08/2009	0	0	0	-
Kimberley	Humpback	96393	Female	4/09/2009	9/09/2009	6	6	28	394.5
Kimberley	Humpback	96394	Female	2/09/2009	2/09/2009	0	0	0	-
Kimberley	Humpback	96396	Female	25/08/2009	29/08/2009	5	5	26	225.7
Kimberley	Humpback	96397	Female	30/08/2009	30/08/2009	1	1	12	16.4
Kimberley	Humpback	96399	Female	31/08/2009	9/09/2009	10	7	15	456.9
Kimberley	Humpback	96400	Female	30/08/2009	11/11/2009	74	30	167	3,178.9
Kimberley	Humpback	96402	Female	1/09/2009	1/09/2009	0	0	0	-
Kimberley	Humpback	96406	Female	26/08/2009	26/08/2009	1	1	1	-
Kimberley	Humpback	96407	Female	4/09/2009	11/09/2009	8	8	44	337.4
Kimberley	Humpback	96408	Female	30/08/2009	17/09/2009	19	19	115	937.4
Kimberley	Humpback	96409	Female	1/09/2009	1/09/2009	1	1	7	6.5
Kimberley	Humpback	96410	Female	2/09/2009	7/09/2009	6	6	27	340.0
Kimberley	Humpback	96411	Female	4/09/2009	11/09/2009	8	8	43	479.9
Subtotal						**355**	**263**	**1,256**	**19,953.5**
Total						**910**	**788**	**3,094**	**49,042.5**

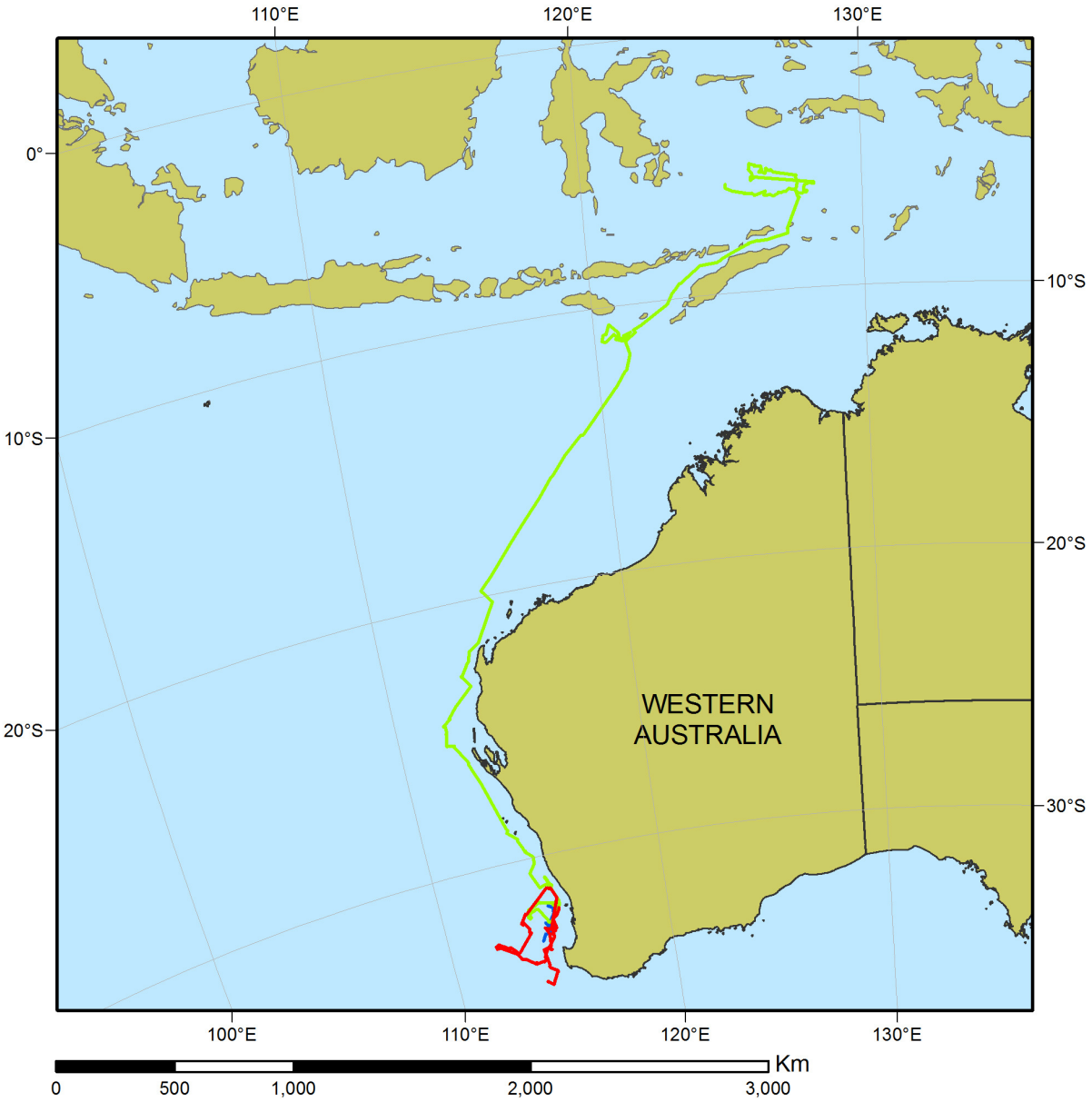

Figure 1. Individual movements of three pygmy blue whales tagged off the Perth Canyon, Western Australia in April 2009. The tag with the greatest longevity provided location data until August 2009 (see Table 1).

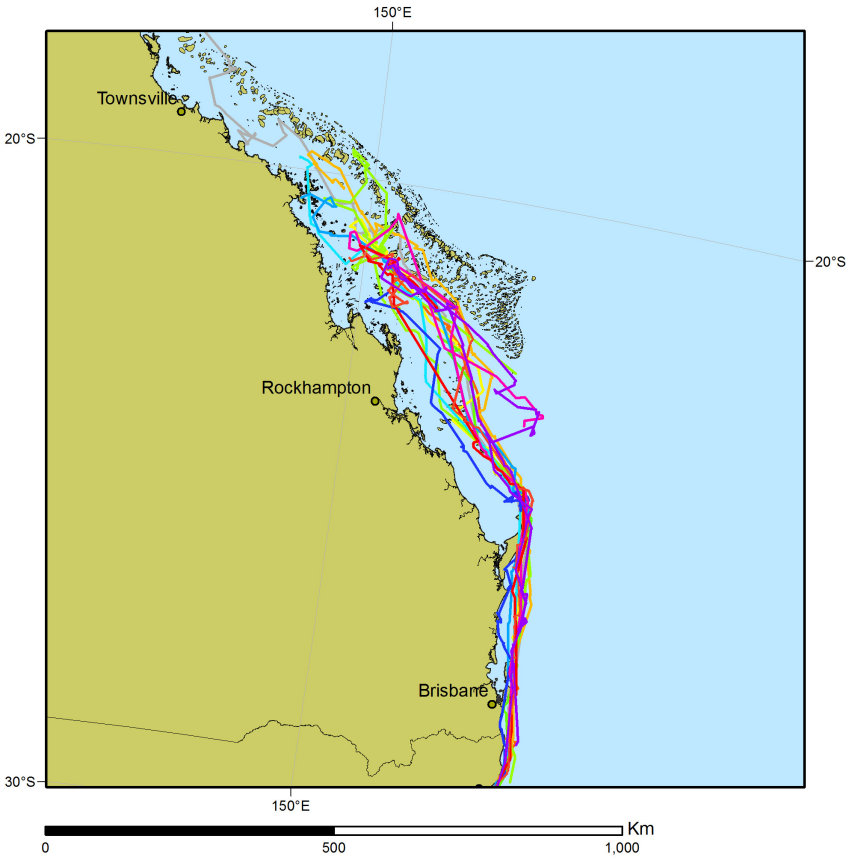

Figure 2. Individual movements of 15 humpback whales tagged off Evans Head, NSW in June 2009.

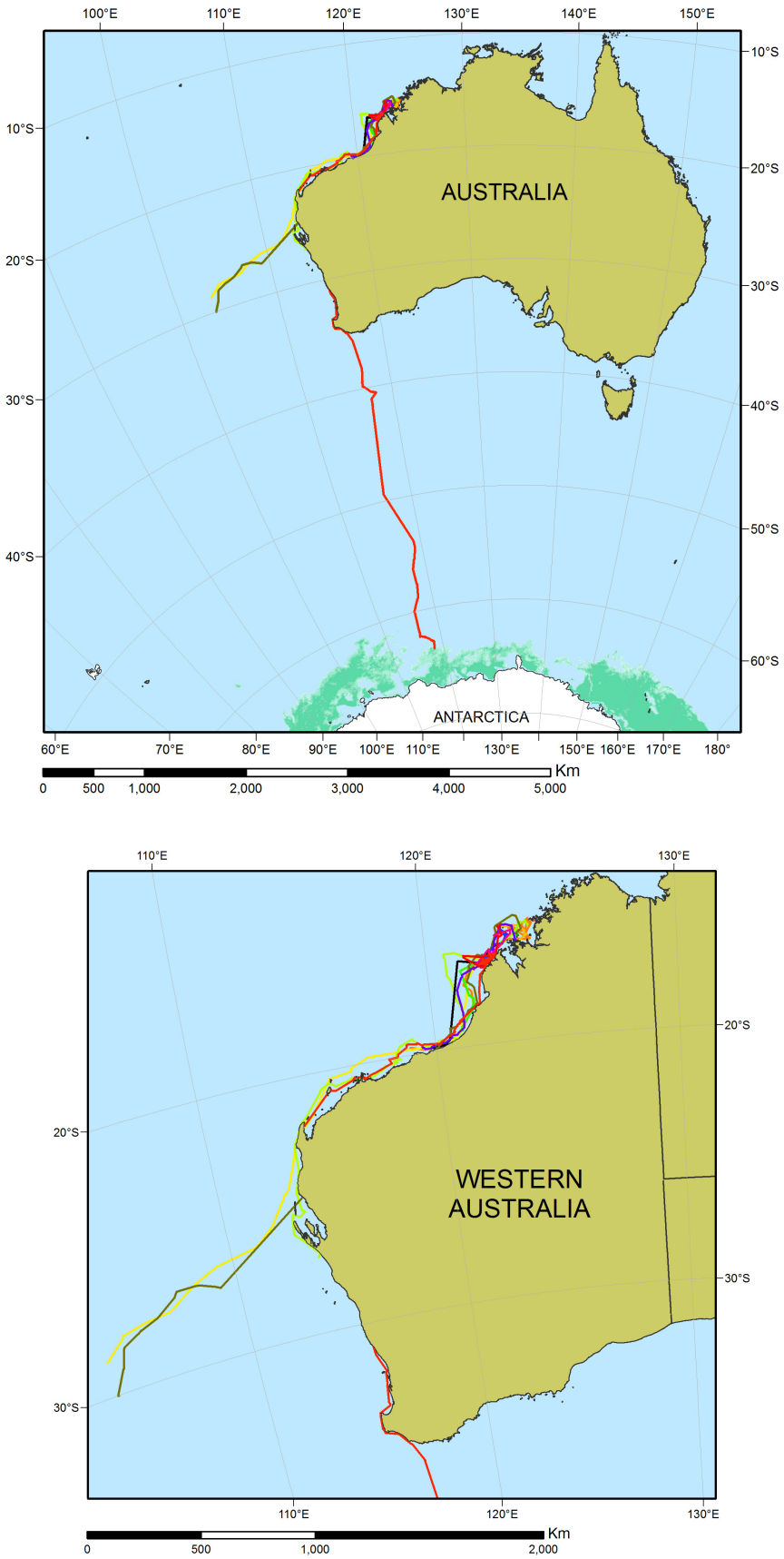

Figure 3. Individual movements of 23 southbound humpback whales tagged between Camden Sound and Pender Bay, Western Australia late August and early September 2009.

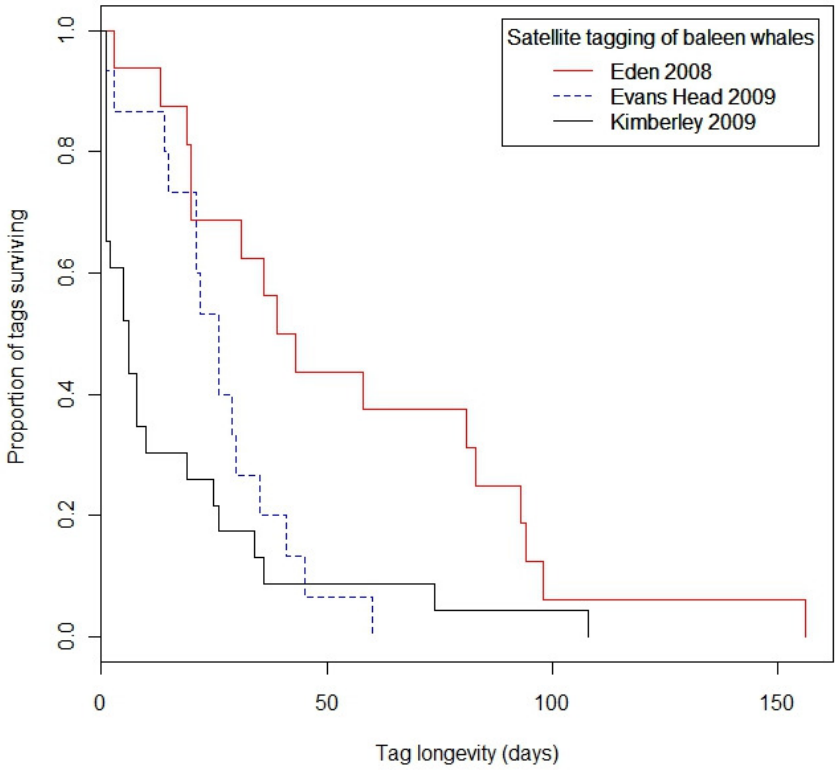

Figure 4. Survival analysis of satellite tags on humpback whales from three deployments – Eden 2008, Evans Head 2009 and Kimberley 2009 (see Table 1).