Satellite tracking of southbound East Australian humpback whales (*Megaptera novaeangliae*): challenging the feast or famine model for migrating whales

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ABSTRACT

We attached satellite tags to 16 humpback whales off South Eastern Australia in October/November 2008. The tags transmitted for an average of 55 days (range: 3-156 days) and provided data on migratory movements between Australia and the Antarctic feeding grounds. While the dispersal into the Southern Ocean was generally consistent with movements determined from historical discovery marks, unexpected findings included an eastwards migration of eight whales to SW New Zealand, regular feeding in temperate latitudes (areas of high productivity) and a migration of one whale into Area IV. A full analysis of these data, with a focus on habitat utilization, will be developed.

KEYWORDS: HUMPBACK WHALES, SATELLITE TRACKING, AREA V, ANTARCTICA, FEEDING

INTRODUCTION

Southern Hemisphere humpback whales (*Megaptera novaeangliae*) are a highly migratory species that forage seasonally in energy-rich, high latitude habitats and undertake extensive movements to low latitude, coastal waters for calving and mating (Dawbin, 1966). Our understanding of the coarse-scale spatial and temporal patterns of these seasonal movements has been historically informed from data collected during coastal and pelagic whaling, and in particular from the deployment and recovery of discovery marks (e.g. Chittleborough, 1965). More recently, the use of photographic identification of individual whales (e.g. Franklin *et al.*, 2007) and genetic analyses (e.g. Albertson-Gibb *et al.*, 2008) have further informed patterns of population structure among the low latitude breeding aggregations. Perhaps the most data-rich and spatially resolved contribution to understanding these movement patterns has been through some very recent successes in the application of satellite telemetry technologies (e.g. Dalla Rosa *et al.*, 2008; Lagerquist *et al.*, 2008; Zerbini *et al.*, 2006).

Currently the IWC recognises seven distinct breeding aggregations (Breeding Stocks A –G) distributed around lower latitude coastal regions in the Atlantic, Indian and Pacific Oceans (IWC 1998). The IWC also designates six areas (Area I – VI) that divide up the circumpolar Southern Ocean waters where these putative populations seasonally migrate and feed. Discovery mark, photo-identification, genetic and recent satellite telemetry studies have begun to resolve some of the linkages between Areas I – VI and Breeding Stocks A – G, as well as to suggest levels of exchange between, and sub-structure within, the Breeding Stocks.

Humpback whales that breed off eastern Australia belong to Breeding Stock E. This stock is believed to be sub-structured to an unquantified degree with breeding aggregations off NE Australia (E1), and others around islands and reefs in the SW Pacific (E2, E3) (ref). Our understanding of linkages to feeding grounds is primarily derived from discovery mark data (ref) (Figure 1), and some photo-identification data (Franklin et al), and suggests that Area V is the primary feeding destination.

Here, we report results of a study into the linkages between breeding and feeding habitats for eastern Australian humpback whales.

METHODOLOGY

Between 24th October and 1st November 2008 16 satellite-linked radio tags were attached to humpback whales as they migrated south along the coast near Eden, New South Wales, Australia (37.15S, 150.07E). The tags consisted of a custom-designed, implantable housing that contained Wildlife Computer (Redmond, Washington, USA) Spot 5 transmitters (Figure 2). 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) (Figure 3). 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' (See figure 2 for details). All external components of the tag are built from stainless steel and the tag is surgically sterilised prior to deployment.

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

Table 1 summarises the deployment statistics on the 16 tagged whales. The tags provided locations from between 3 and 156 days with an average of 55.4 days. The 3 day duration was due to a very shallow deployment when we tried a lower deployment pressure of 7.5 bar.

Tags remained attached on eight whales long enough to fully describe their transit from Eden to the Antarctic feeding grounds. The migratory patterns from these whales, and those for which partial transits were measured can be divided into three main migratory routes (Figure 4);

- Eden – SW New Zealand – Area V (n = 2 full migration; n = 6 partial migration)
- Eden – E Tasmania – Area V (n = 5 full migration; n = 5 partial migration)
- Eden – NW Tasmania – Area IV (n = 1 full migration)

The rates of transit from the tagging location to the Antarctic waters were variable. Figure 5 represents the relative rates of travel between derived locations, and Figure 6 represents the aggregated time spent within grids of 0.5^{o} by 0.5^{o}. The large amount of time spent in the Eden region is clearly an artefact of the concentration of tagging effort, but a general habitat usage pattern is evident in these figures showing a decrease in transit rate, and commensurate increase in time within a grid in the areas of eastern Bass Strait, NE Tasmania, SW New Zealand and the southern migratory extreme of the high latitude waters. Passage between these regions was generally directional with consistent speed.

The southern limit of migrations was generally characterised by the extent of the seasonal ice edge. Figure 7 demonstrates the distance to the ice edge of each whale at the time the location was acquired.

DISCUSSION

This study demonstrates a high level of linkage between breeding aggregations of east Australian humpback whales (Breeding Stock E) and humpback whales that feed in Area V. Although the sample size of tracked whales from Eden to their feeding destinations was relatively small (N = 8), the one whale that migrated SW from Tasmania and was likely feeding in Area IV suggests that mixing of humpbacks that breed on the east (Breeding Stock E) and west coasts (Breeding Stock D) of Australia may be substantial. It is not possible to speculate on exchange between the breeding aggregations on the basis of our data.

Perhaps the most surprising aspect of our study is the degree to which some humpback whales aggregate in defined areas within their temperate, migratory habitats. In eastern Bass Strait, NE Tasmania and SW New Zealand some whales paused their migratory progression and spent days to weeks with the region. Humpback whales have been regularly observed feeding on small schooling fish in the seasonally productive waters off Eden (Stamation *et al.*, 2007); indeed seven of the whales we tagged were feeding at the time of tagging. Figure 8 demonstrates that the waters in which some whales delayed their migration are relatively productive compared to other adjacent areas. We suggest that the whales specifically target these waters in order to feed, and in so doing supplement their energetic requirements during migration. The proportion of whales that utilise such a strategy is unknown, and the degree to which supplementary feeding may contribute to annual energy budgets is also unknown. Further elucidation of these meso-scale movements, and seasonal behaviours within migratory, breeding and feeding habitats will be required to more fully understand the importance of transitory feeding episodes.

The tracks acquired in this study include substantial periods during which we presume the tagged whales are feeding within their Antarctic habitats. Further analyses will be conducted to investigate finer-scale relationships between the whale behaviour (inferred from daily movement patterns) and the biological and physical environment.

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Table 1. Summary of satellite tracking data from 16 humpback whales tagged off Eden, New South Wales, Australia.

Tag	Start Date (UTC)	Latest Date (UTC)	No. of days	Number of locations	Pod composition	Age	Sex	Resighted post deployment?
88733	23/10/2008	4/12/2008	43	363	Mother, Calf and Escort	Mother with Calf	Female	No
88735	24/10/2008	1/12/2008	39	272	2 Adults, 1 Subadult and Calf	Adult	Unknown	No
88732	23/10/2008	27/11/2008	36	258	3 Adults, 1 Subadult and Calf	Adult	Male	No
88723	23/10/2008	13/01/2009	83	693	4 Subadult	Subadult	Male	No
88743	24/10/2008	5/11/2008	13	109	1 Adult and 1 Subadult	Subadult	Male	No
88746	24/10/2008	12/11/2008	20	138	2 Adults	Adult	Male	No
88744	25/10/2008	27/10/2008	3	21	1 Adult	Adult	Male	No
88718	24/10/2008	24/01/2009	93	992	5 Adults	Adult	Male	Yes: after 1 day & 41 days
88745	25/10/2008	12/11/2008	19	99	2 Adults	Adult	Male	No
88725	25/10/2008	13/01/2009	81	843	3 Adults	Adult	Male	No
88738	27/10/2008	23/12/2008	58	646	Mother, Calf and Escort	Escort	Male	Yes: after 20 days
88722	28/10/2008	16/11/2008	20	125	5 Adults	Adult	Female	No
88729	29/10/2008	3/02/2009	98	1160	mother and calf	Mother	Female	No
88717	30/10/2008	29/11/2008	31	145	Mother and Calf	Mother	Female	No
88728	31/10/2008	1/02/2009	94	1282	Mother and Calf	Mother	Female	No
88741	31/10/2008	4/04/2009	156	1963	4 Adults	Adult	Female	No

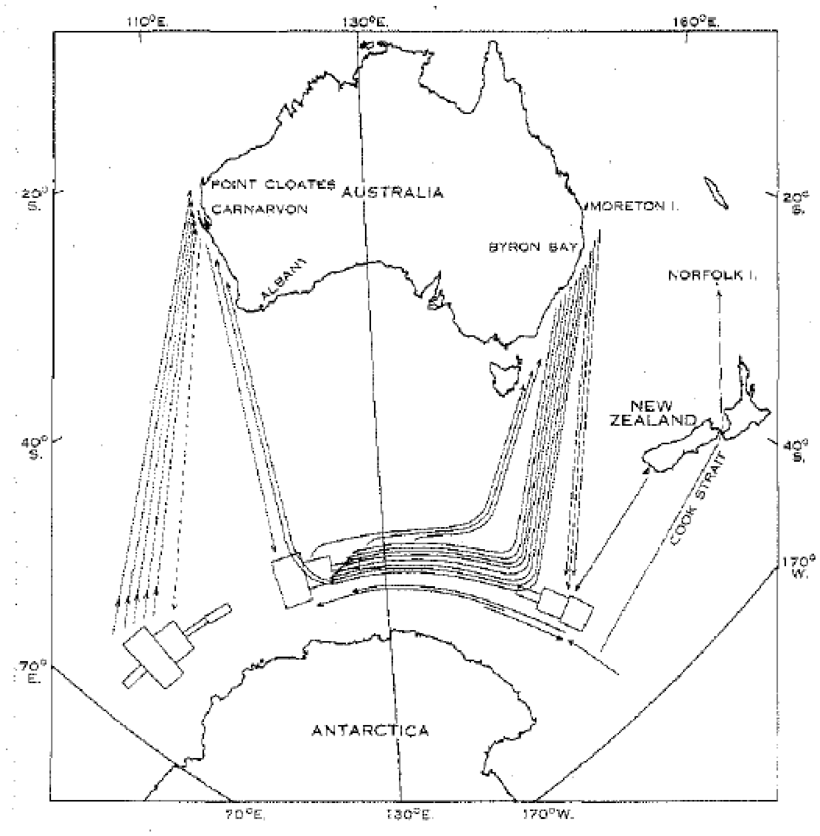


Fig. 1.—Individual movements (simplified) by 27 marked whales whose recapture provided evidence of migrating behaviour in 1958–59. Rectangles indicate location of Antarctic humpback whale catch in February 1959.

Figure 1. Individual movements of eastern and western Australian humpback whales determined from discovery mark data (From: Chittleborough, 1965).

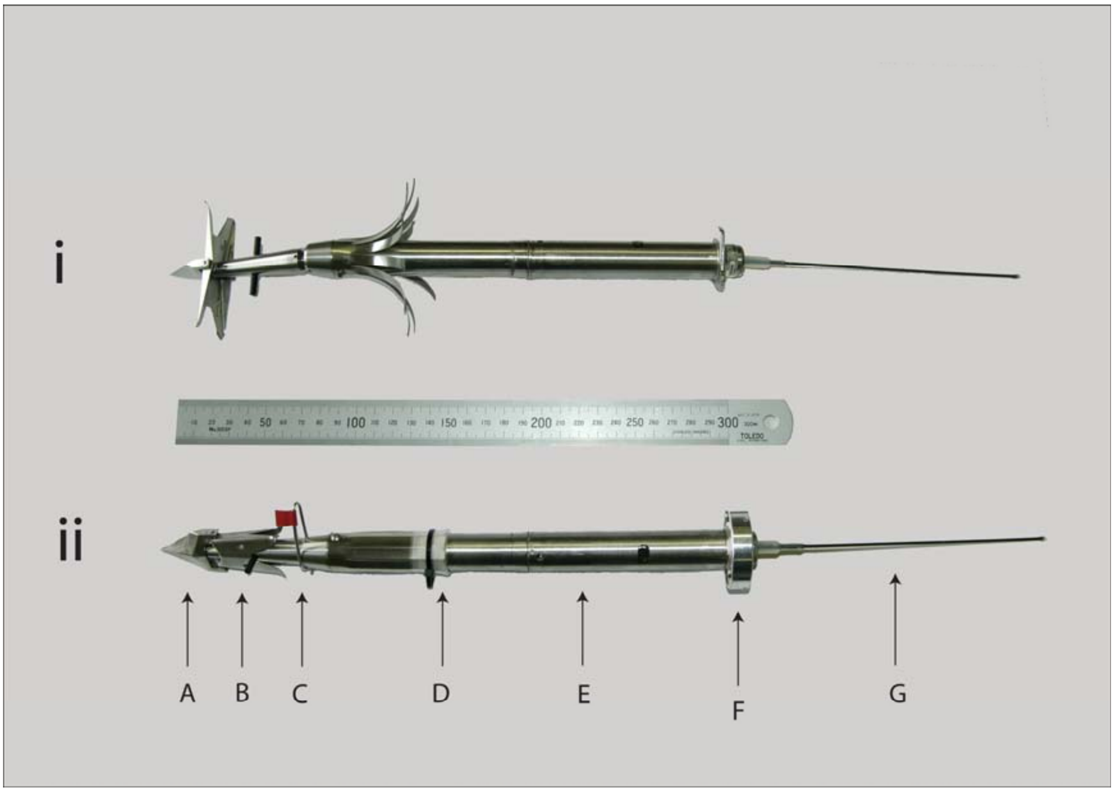


Figure 2. /Details of the satellite tag in post deployment mode (i) and pre-deployment mode (ii). Components are: A – Sharp, triangular arrow head; B – Holding flaps in pre-deployment position; C- Articulation point of the head and body of the tag; D – Holding ‘skirt’ of tag held down with dissolvable tape; E – body of the tag holding electronics and battery; F – Stopping plate (with detachable component: G – Aerial.

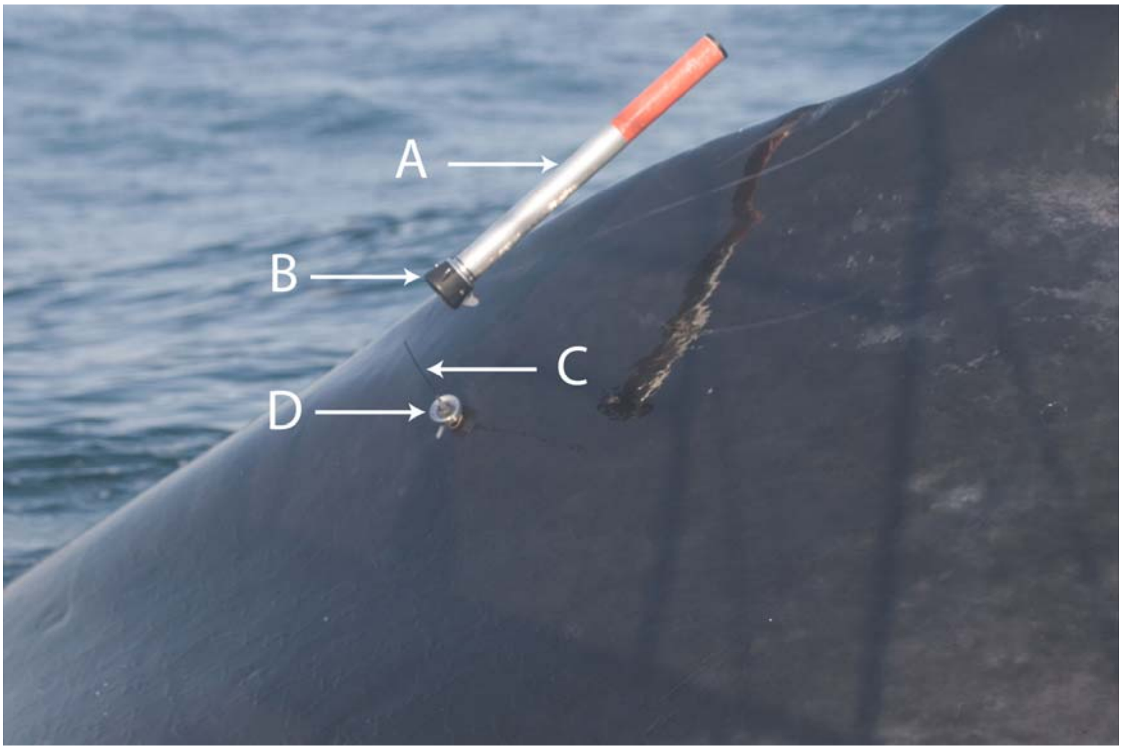


Figure 3. : Deployment of a tag immediately post-implantation showing; A – Tag-holding projectile; B; Projectile attachment mechanism; C: Aerial; D – implanted tag.

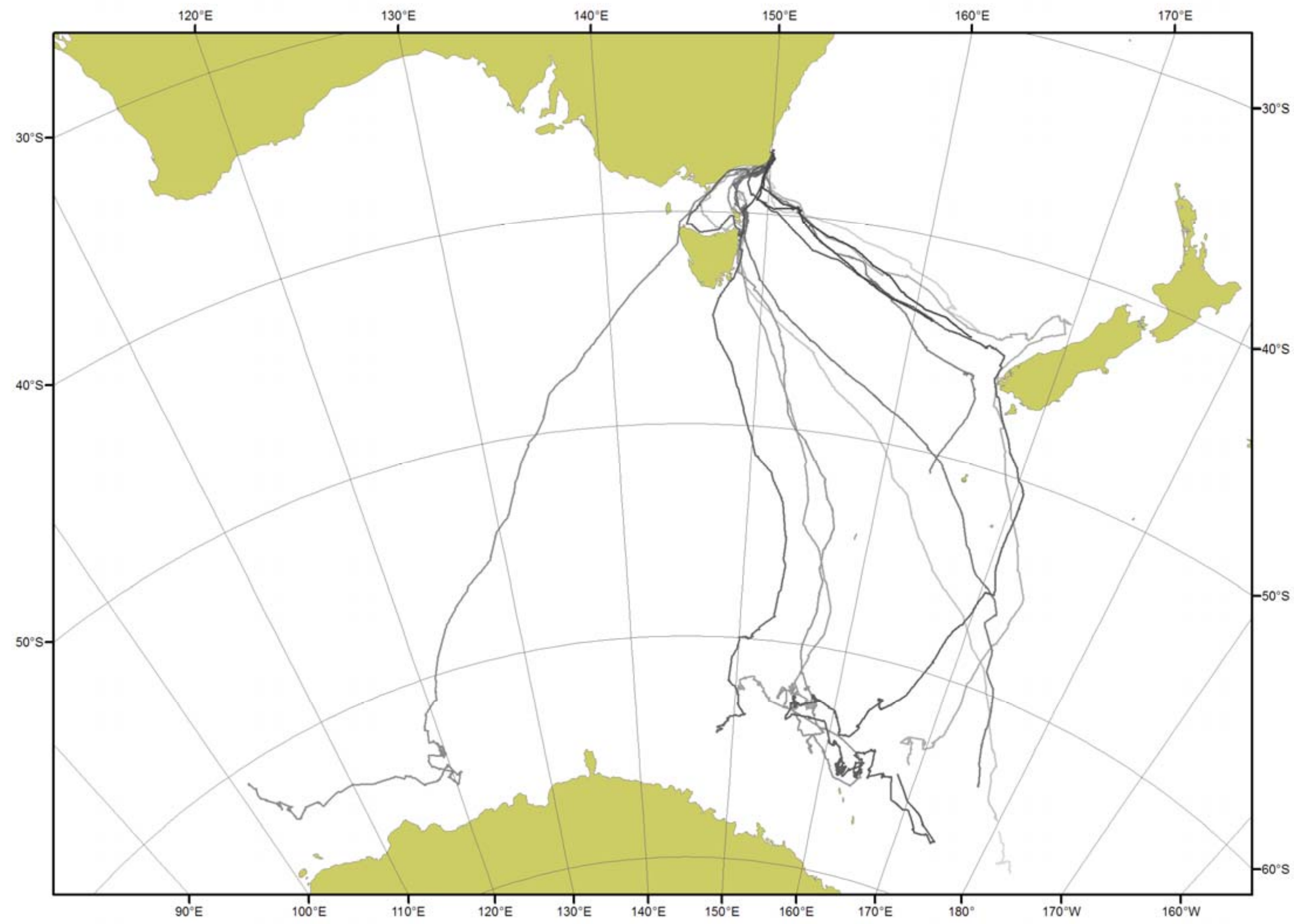


Figure 4. Map showing the individual tracks of the sixteen humpback whales tagged near Eden, NSW in late October and early November 2009

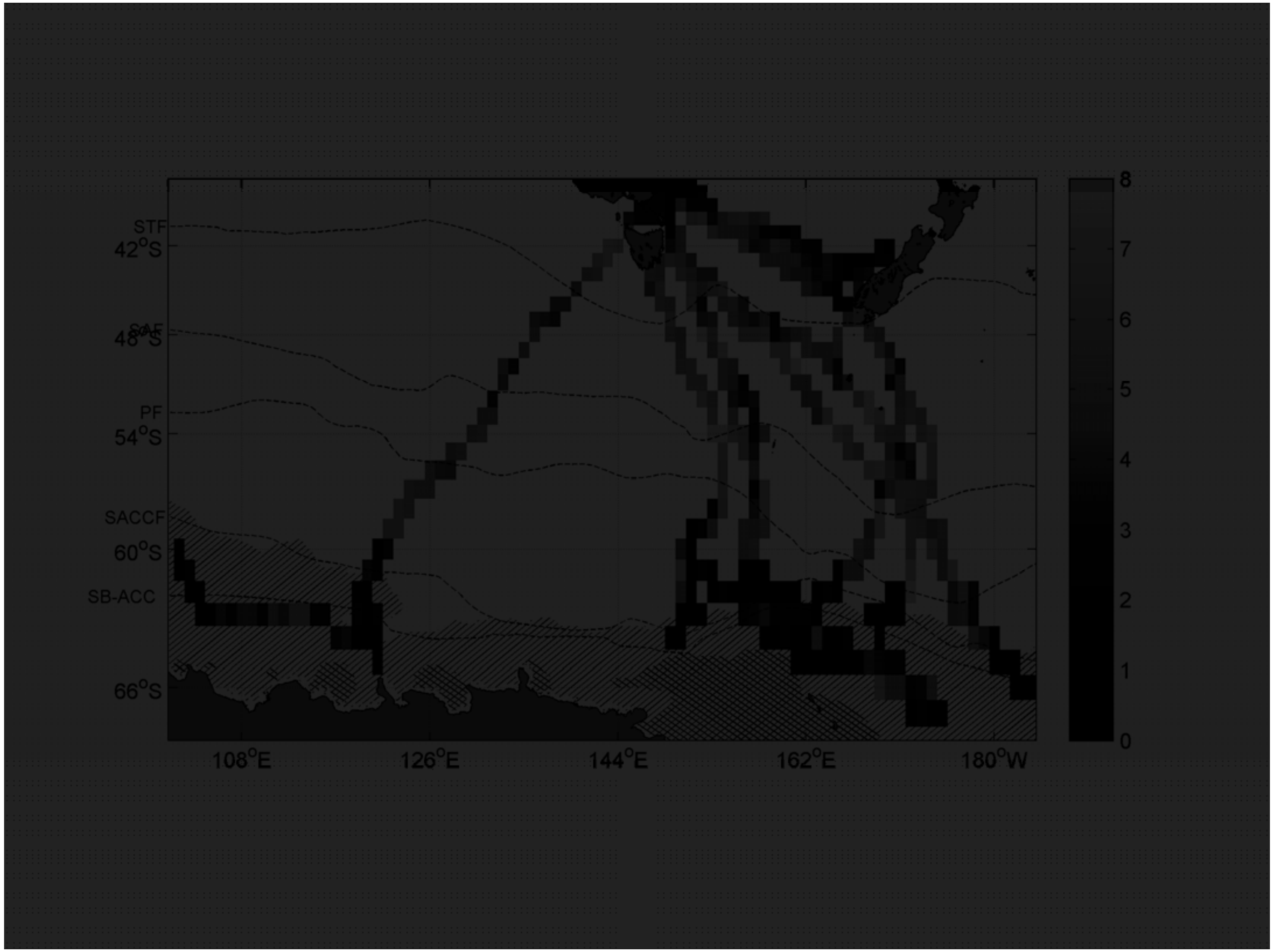


Figure 5: Map showing relative rates of travel in km/hr

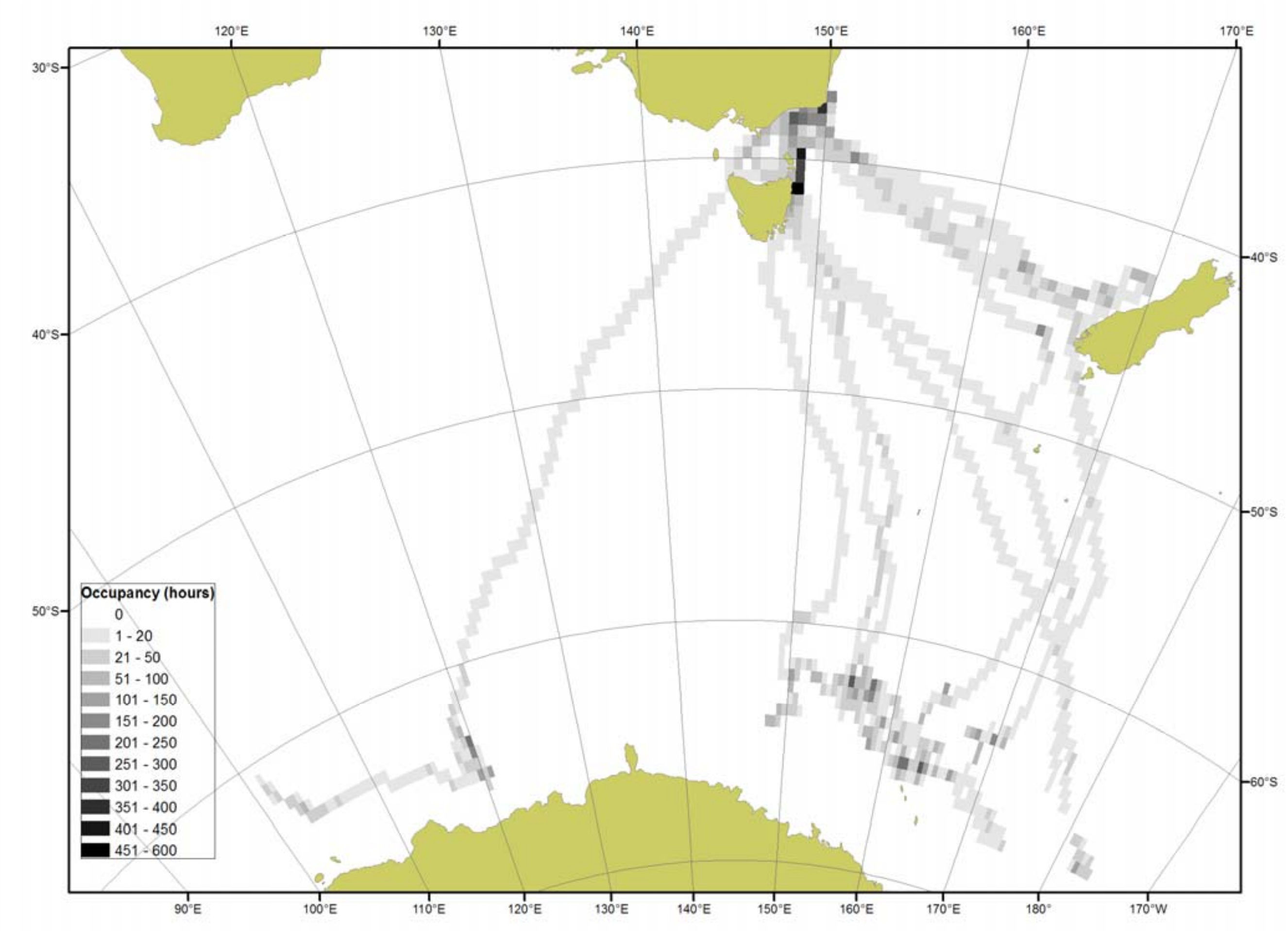
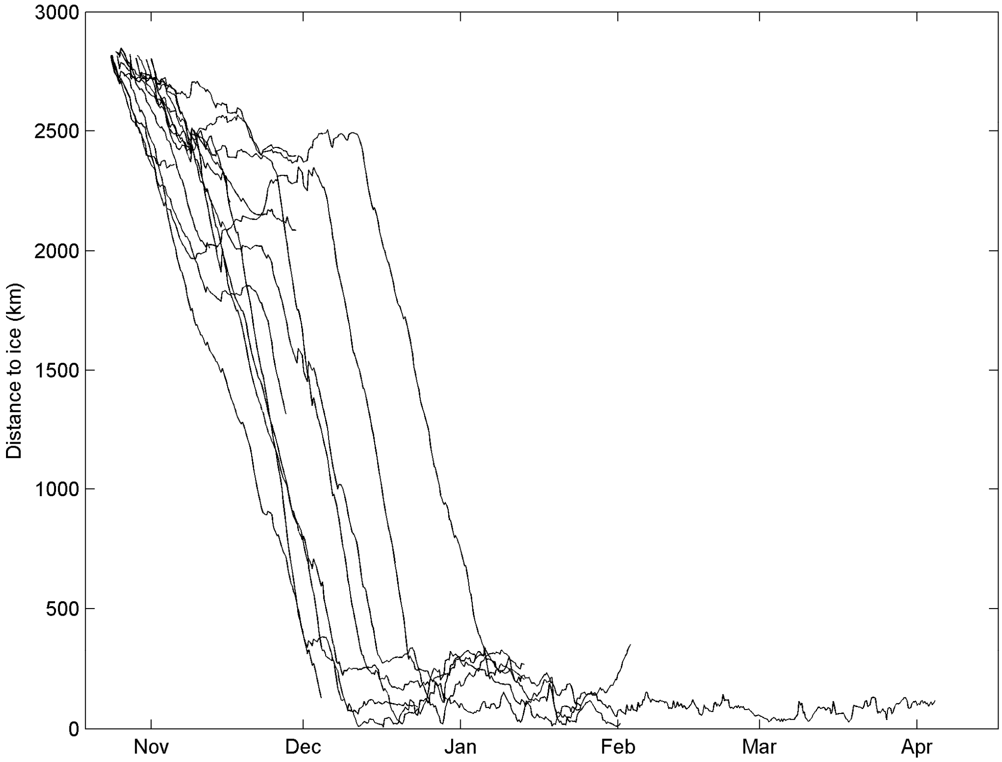


Figure 6. Map showing accumulated time spent in 0.5° by 0.5° squares by the sixteen tagged humpback whales.



Months from November 2008 to April 2009

Figure 7: Graph showing distance to ice edge over the duration of the deployment.