Cruise report of the 2013 Antarctic blue whale voyage of the Southern Ocean Research Partnership

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ABSTRACT

The ultimate objective of the Antarctic Blue Whale Project (an initiative of the Southern Ocean Research Partnership (SORP) is to estimate the circumpolar abundance of Antarctic blue whales (*Balaenoptera musculus intermedia*). A mark-recapture approach can deliver a precise estimate with reasonable effort if the sighting rate of blue whales can be elevated relative to line-transect surveys using passive acoustic methods. The Australian Government chartered the 65-m *FV Amaltal Explorer* to conduct a 47-day voyage to Antarctic waters focussing on an area south of 60°S between 135° E and 170° W. An acoustic tracking system using DIFAR sonobuoys operated continuously during the voyages recording 626 hours of audio, while acousticians processed 26,545 Antarctic blue whale calls all in 'real-time'. During the voyage 51 groups of vocalising blue whales were acoustically 'targeted' which led to 33 visual sightings of groups of one or more whales. Photograph-identification data were collected for 50 individuals (33 left flank; 44 right flank; 33 left and right flanks) from 33 groups. The 23 biopsy samples collected showed a strong male bias (0.79) although some samples may be duplicates. Two satellite tags were deployed on Antarctic blue whales; this has not been achieved previously. This voyage has shown that acoustic tracking can increase the sightings rate of blue whales and should be employed on future voyages contributing to the Antarctic Blue Whale Project.

Introduction

From the late 19th through to the mid 20th century over one third of a million blue whales (*Balaenoptera musculus*) were killed in the Southern Hemisphere (Clapham & Baker, 2002), first by shore-based operations and then by the pelagic catcher and factory ships.Close to extinction, in 1964 the International Whaling Commission banned the hunting of blue whales although they were still caught by illegal Soviet whaling operations until 1973 (Branch et al., 2004). Today, the blue whale is classified as critically endangered by the International Union for Conservation of Nature and is of global interest as one of the most at risk baleen whale species in the Southern Ocean.

Our understanding of the impact of the whaling era on the Antarctic blue whale (*Balaenoptera musculus intermedia*) is predominantly based on two sources of information: catch data derived from the logbooks of whaling vessels and from circumpolar cetacean sightings surveys. Circumpolar sighting surveys were initiated in 1978 as the International Decade of Cetacean Research (IDCR) and later Southern Ocean Whale Ecosystem Research (SOWER) initiatives (Branch & Butterworth, 2001). The IDCR/SOWER surveys usually involved two ships conducting line-transect surveys from the Antarctic ice-edge north to 60°S. These vessels conducted three circumpolar surveys (CPI, CPII and CPIII) that were completed in 2004, although further regional surveys went on until 2010. While the catch data can provide yearly catch distribution and magnitude as well as often detailed information on the animals caught (including size, sex, pregnancy status, stomach contents etc.), the data from sightings surveys can generate estimates of circumpolar abundance, trends and distribution.

The low sighting rates of Antarctic blue whales from the IDCR/SOWER surveys generated abundance estimates with low precision which in turn hampered early efforts to assess population trend (Branch & Butterworth, 2001; Gerrodette, 1995). Later, Branch et al. (2004) estimated trend using catch and sightings data in a Bayesian modelling framework which estimated that the circumpolar Antarctic blue whale population decreased from pre-exploitation abundance of 239 000 (95% Bayesian interval of 202,000 – 311,000) to a low of around 360 individuals (95% Bayesian interval of 150 – 840) in the early 1970s. This represents a population decline of greater than 99%. This study also determined that from the lowest abundance the population had increased at a mean rate of 7.3% per year (95% CI 1.4-11.6%) and the estimated abundance in 1996 was 1,700 individuals (CV = 0.51, 95% CI 860 – 2,900).

In 2009 the Japanese Government indicated the 2009/10 would be the last SOWER survey after 32 years of effort covering some 216,000 nm and 4,100 vessel-days (International Whaling Commission, 2009). With the cessation of the SOWER surveys there are now no large scale, formal cetacean sightings surveys operating in Antarctic waters and no strategy to monitor the recovery or otherwise of Antarctic blue whales.

The Southern Ocean Research Partnership (SORP) program was initiated within the International Whaling Commission to promote collaborative cetacean research through coordination, cooperation and data sharing between research groups and national Antarctic programs (SORP, 2009). Six projects were initially proposed (Childerhouse, 2010) including the Antarctic Blue Whale Project. This project's ultimate objective is to assess the status of Antarctic blue whales through the delivery of a new, precise circumpolar abundance estimate. This ambitious and long-term goal, however, first required an assessment of the most appropriate survey method for this subspecies. Kelly et al. (2013) estimated the expected precision of abundance from 6 or 12 year line-transect (LT) or mark-recapture (MR) surveys based upon the projected numbers of encounters as a function of abundance and survey method. The study found LT and MR performed similarly but MR was deemed a more pragmatic approach as data collection can be more flexible and opportunistic. However, a MR approach would be dependent upon an encounter rate enhanced by passive acoustic tracking (Kelly et al., 2013; Peel et al., 2013).

In 2012 two voyages were conducted off western Victoria, Australia that attempted to assess the effectiveness of passive acoustics for tracking and locating blue whales (Miller, 2012; Miller et al., 2012). The promising results from these voyages led, in 2013, to the first dedicated Southern Ocean voyage of the Antarctic Blue Whale Project (Wadley et al., 2012). The principal objectives of this voyage were: to assess and refine passive acoustic methods for locating Antarctic blue whales; to collect photographic data and biopsies for individual identification of blue whales; to deploy satellite tags to describe the movement and behaviour of blue whales; and to collect distance sampling data for regional abundance estimate of cetacean species.

Methods

The methods employed on the voyage are presented in brief here; for further details refer to the voyage's Science Plan (Double et al., 2013). Also see Miller at al. (2013a; 2013b), Olson et al. (Olson et al., 2013a; Olson et al., 2013b) and Andrews-Goff et al. (2013) for further information on acoustic tracking, photo-identification and satellite tracking respectively.

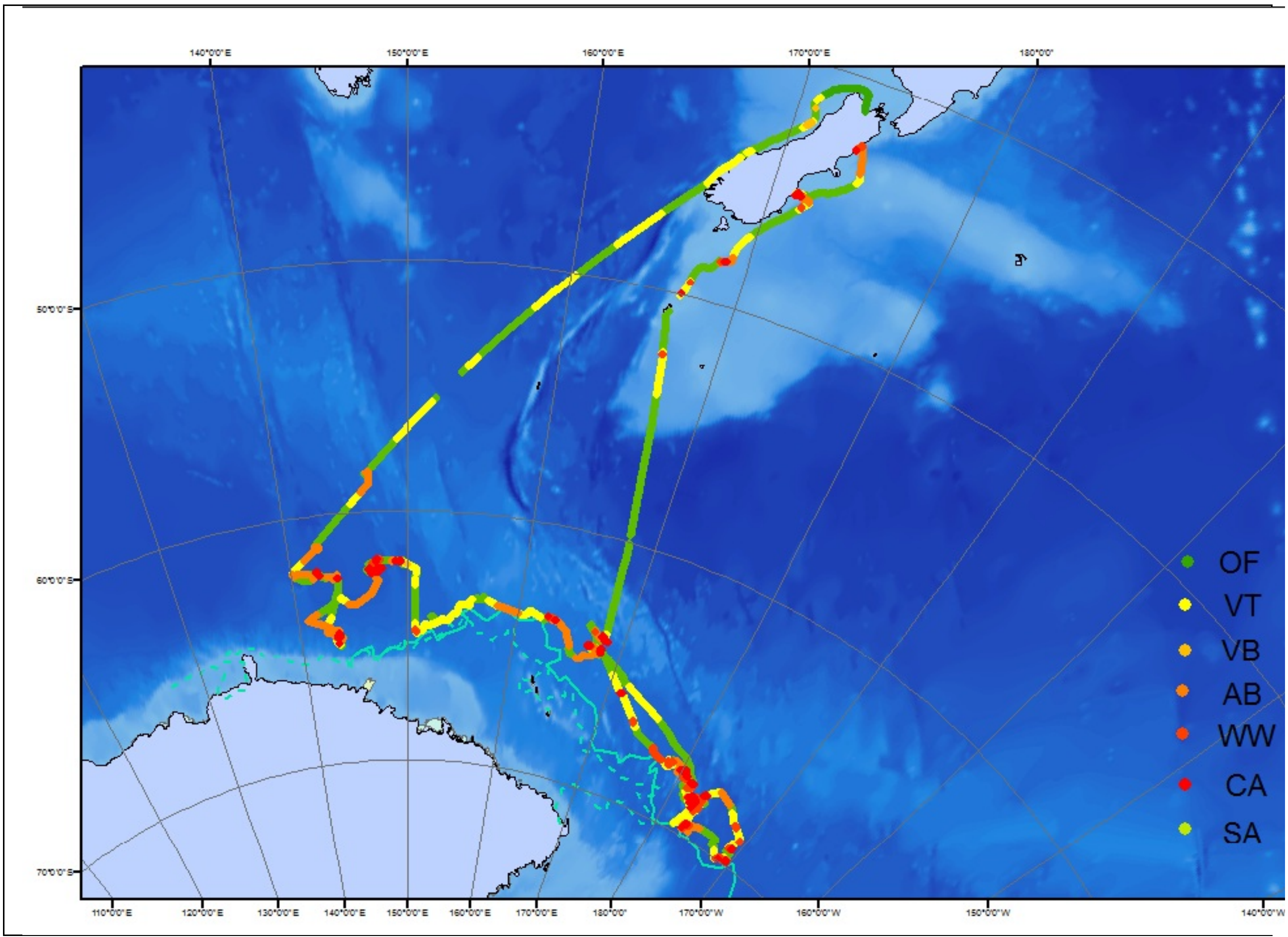

Figure 1. The Antarctic Blue Whale Voyage ship track detailing associated observational modes (see Table 1). The maximum (7/3/2013) and minimum (15/2/2013) ice extent (from satellite data) during the voyage is represented by the solid and dashed lines adjacent to the Antarctic coastline. On the transit south and north the vessel went to the west and east of New Zealand's South Island respectively.

The survey region (south of 60°S between 135°E–170°W, Figure 1) was identified prior to the voyage based on an examination of catch, sightings and acoustic data that suggested the area may have a higher density of blue whales than the circumpolar average (Kelly et al., 2013).

The Australian Government chartered the 65 m *FV Amaltal Explorer* for the inaugural Southern Ocean voyage of the Antarctic Blue Whale Project. This ship is a Class 1D (second lowest ice rating) factory stern-trawler registered in and operated from New Zealand. Three rigid hull inflatable boats (RHIB) were taken south on this voyage of which the primary research vessel was *Remora*; a 6.3m Naiad with a bowsprit for biopsying and tagging. For this voyage the ship had 13 crew members while the 15-person research team included scientists, a doctor and voyage managers. Members of the research team were assigned to one or more task-orientated groups: leadership; acoustics; observations and small-boat.

During the voyage the ship operated under seven specific survey modes (see Table 1).

All events occurring during any one of these modes such as sightings, biopsy attempts, boat launches, sonobuoy deployments were recorded in a customized data entry program Logger[1] along with weather and effort data.

The acoustics team typically operated 24 hours a day for the duration of the voyage with the primary task of detecting, tracking and targeting blue whales. DIFAR Sonobuoys were deployed at 30 nmi intervals, or more frequently when needed for tracking and targeting pods. For a detailed description of the acoustic system and the specific methods employed by the acoustic team see Miller et al. (2013a).

Visual surveys were conducted during daylight hours by observers on the open-air flying bridge or in the enclosed bridge depending on weather conditions. Observers on the flying bridge were stationed in one of two viewing boxes that provided seating, a wind break, and a small shelf with a radial angle board that was used to determine the angle to whale sightings. Observers alternated between searching with and without 7X binoculars. For each cetacean sighted the distance and angle relative the ship's course were estimated using reticle binoculars and angle boards mounted on the viewing boxes or on the bridge. The visual surveys were curtailed when wind speeds were greater than 35 kts (approx. Beaufort 8) but acoustic searches occurred in all weather conditions.

Upon sighting suspected blue whales, the vessel was guided towards the whale by a member of the research team for species identification and to biopsy and to obtain images for photo-identification. The location of the whale was determined accurately using a photogrammetric measurement system described by Leaper & Gordon (2001). During sightings a commentary on surfacing events and other behaviours were logged on a voice recorder (see Double et al., 2013). When possible both sides of each whale were photographed using high resolution digital SLR cameras with image-stabilized zoom lenses. Photographs and associated records were archived at the end of each day for later quality control and reconciliation (Olson et al., 2013b).

When weather conditions permitted *Remora* was launched to collect photo-identification data, biopsies and to deploy satellite tags on blue whales. Biopsies were collected from humpback whales opportunistically. On *Remora* biopsies were collected using a modified .22 Paxarms rifle (Krutzen et al., 2002); when *Remora* could not be launched biopsies were collected from the bow of *Amaltal Explorer* using both Paxarms and Larsen rifles (Larsen, 1998). Biopsy samples were split between All Protect (Qiagen), 70% ethanol, and freezing in liquid Nitrogen. DNA was subsequently extracted using a Tissue DNA purification kit for the Maxwell 16 DNA extraction robot (Promega Corporation). The sexes of the tagged whales were determined using a 5' exonuclease assay of the polymorphisms in the sex-linked Zinc Finger genes as described by Morin et al. (2005).

Satellite tagging was not a high priority on this voyage because of the focus on acoustic tracking and MR data. However, tagging was attempted to assess its feasibility in addressing the goals of the Antarctic Blue Whales Project related to population structure, movement and feeding behaviour. The satellite tags employed comprised of a custom-designed, anchor section (Gales et al., 2009) joined to a stainless steel housing containing the Spot 200 transmitter manufactured by Wildlife Computers (Redmond, Washington, USA). Tags were duty cycled to a three hour on, three hour off transmission period at a 30 second repetition rate (Andrews-Goff et al., 2013).

[1] Logger was developed by the International Fund for Animal Welfare to facilitate benign research

Table 1. Description of the modes of operation and associated activities during the voyage.

Mode	Hours of Operation	Activities	Weather conditions	Who is 'guiding' the ship?
Visual Transect (VT or VT-BO) or Acoustic Bearing (AB) or Visual Bearing (VB)	Daylight hours	Acoustics team deploying sonobuoys and listening for blue whales. Observing team on Flying Bridge and/or Bridge	Observing on the Flying Bridge will occur for < Beaufort 5. Bridge only > Beaufort 5. No sightings > Beaufort 6. Acoustics will occur when Beaufort <7, unless otherwise unsafe to deploy sonobuoys	Acoustics team according to their tracking and targeting protocols or if whale sighted without acoustics bearing then the sightings team will guide the vessel. In the event no blue whales detections the vessel will be directed by the spatial model i.e., heading back towards or along the sea ice boundary
With Whales (WW)	Daylight hours	Once sighting is confirmed as a blue whale then observation team switches to WW mode and starts video tracking Decision required whether to switch to Close Approach, Small Boat or Survey Aggregation mode	likely < Beaufort 6	Ship guide - an observer on the gantry (on the mast above the flying bridge)
Close approach (CP)	Daylight hours	Decision required whether Photo-ID only or Biopsy and Photo-ID Potentially collecting photo-ID and biopsies from bow Remaining observing team will maintain observations from the Flying Bridge Acoustics team deploying sonobuoys and listening for blue whales, as required	likely < Beaufort 6	Ship guide - an observer on the gantry (on the mast above the flying bridge)
Small boat (SB)	Daylight hours	Potentially collecting photo-ID and biopsies from bow Biopsies and photo-ID may also be captured from the ship	likely < Beaufort 5	Ship guide - an observer on the gantry (on the mast above the flying bridge) Ship must remain in visual contact with small boat
Survey Aggregation (SA)	Daylight hours	The aim is to estimate the extent and numbers of whales within an aggregation. This survey mode will only be undertaken when it is not possible to approach individuals for photo-id or biopsy either with AE or the small boat This will be based on short track lines within the aggregation area.	likely > Beaufort 6	Lead observer will design small scale tracklines within a limited area of the aggregation
Acoustics only (AO)	Outside daylight hours	Acoustics team deploying sonobuoys to locate new, or remain with blue whales	Up to Beaufort 7, unless otherwise unsafe to deploy sonobuoys	Acoustics team according their tracking and targeting protocols.

Results and Discussion

The voyage departed from Nelson, New Zealand on the 30th January and returned to the same port on March 17th 2013 (47 days). Twenty-nine days were spent in the designated study area south of 60°S, from 135°E-170°W. The 3,620 km transit to the western part of the survey area took nine days. During the 29 days spent south of 60°S the *FV Amaltal Explorer* covered approximately 10,595 km. The transit north took nine days and covered 2,785 km. The time spent and distance covered in each of the survey modes is presented in Table 2.

For a detailed treatment of recommendations to improve methods, operations and equipment on future voyages see Barlow et al. (2013).

Table 2. Visual survey effort by different modes on Transit to 60°S and south of 60°S.

	Transit to 60°S		South of 60°S	
Survey modes	**Dist (km)**	**Time (hours)**	**Dist (km)**	**Time (hours)**
AB – Acoustic Bearing	126	7	2045	107
BO – Bridge Only	380	21	590	35
CA – Close Approach	0	0	867	72
OF – Off Effort	1686	94	4517	396
SA – Survey Aggregation	0	0	89	5
VB – Visual Bearing	30	2	50	3
VT – Visual Transect	693	35	1882	94
WW – With Whales	0	0	555	30

Blue whale acoustics, sightings and photo-identification

A total of 361 sonobuoys were deployed both in transit to and within the survey area yielding 734 hours of acoustic recordings (see Table 3 for summary of acoustic data from south of 60°S). From these recordings 26,545 whale calls were analysed in real time. Fifty-one singletons or groups of calling whales were 'targeted' by the ship of which 32 were sighted or led to sightings of blue whales close to the targeted singing whales. On thirteen occasions the targeting was aborted due to ice, weather, operational reasons, or to targeting a group of calling whales thought to be nearer to the ship. Six whales were not sighted because they either stopped singing (n=5) or were moving too fast to be approached by the ship (n=1; see Table 3).

Vocalisations of Antarctic blue whales were first detected during transit on 3rd February 2013 (sonobuoy #22, 51.95°S, 157.55°E) and were audible on all sonobuoys deployed south of 52°S. Initial analyses suggest that Antarctic blue whale vocalisations were audible from the west (62°S, 140°E) and central regions of the survey area (64°S, 170°E) at a distance of approximately 600 nmi. If these preliminary results are found to be valid, then these recordings indicate an extremely long detection range even when using hydrophones deployed near the sea surface.

Table 3. Acoustic tracking and targeting metrics of Antarctic blue whales calls south of 60°S.

Measure	**South of 60°S**
Sonobuoys deployed	260
Number of failed buoys	31
Audio recorded (hours)	564.4
Audio from 2 simultaneous buoys (%)	58.1%
ABW calls analysed in real time	26,006
Triangulated locations	3,146
Targets pursued	51
Targets successful	24
Associates of targets successful	8
Targets aborted	13
Targets missed	6
Visual survey hours	346.6
Visual survey distance (km)	6,078

Thirty-nine groups of blue whales were sighted south of 60° during the voyage. All of these groups were acoustically targeted whales or whales closely associated with targeted whales (see Table 3). The estimated pod size ranged from one to five individuals (mean=2.15). The geographical distribution of blue whale sightings is presented in Figure 2. The radial distances to initial sightings of blue whales are shown in Figure 3. The large number of close sightings can partly be explained by acoustic tracking to locate animals in poor weather conditions and overnight.

Thirty-three groups of blue whales, composed of an estimated 82 individuals, were approached for photo-identification; 75 individuals were photographed. A total of 50 blue whales were individually identified (33 left flank; 44 right flank; 33 left and right flanks). The geographic distribution of individually indentified whale is shown in Figure 4. Twenty-five whales were either not photographed well enough for reliable individual identification or were found to be resights within the voyage (see Olson et al., 2013b). Identification photographs will be uploaded into the internationally collaborative Southern Hemisphere Blue Whale Catalogue (Galletti Vernazzani & Olson, 2012).

During the transit south and north past New Zealand's South Island (see Figure 1) there were nine sightings of blue whales and a further four groups heard, targeted and subsequently sighted. New Zealand-type blue whale calls were recorded on 44 of 61 sonobuoys deployed around the South Island of New Zealand and subantarctic waters south of New Zealand (between 155 to 175°E longitude and 41 to 54°S latitude). The calls recorded were first described by Kibblewhite et al. (1967) and were later presumed to be blue (McDonald et al., 2009; McDonald et al., 2006). However, this may be the first time the calls have been recorded with simultaneous visual sightings of blue whales; see Miller et al. (2013b). (2013b). Fourteen blue whales were photo-identified off the South Island during the transits, 9 from the west coast in January and 5 near the east coast in March (seeOlson et al., 2013a).

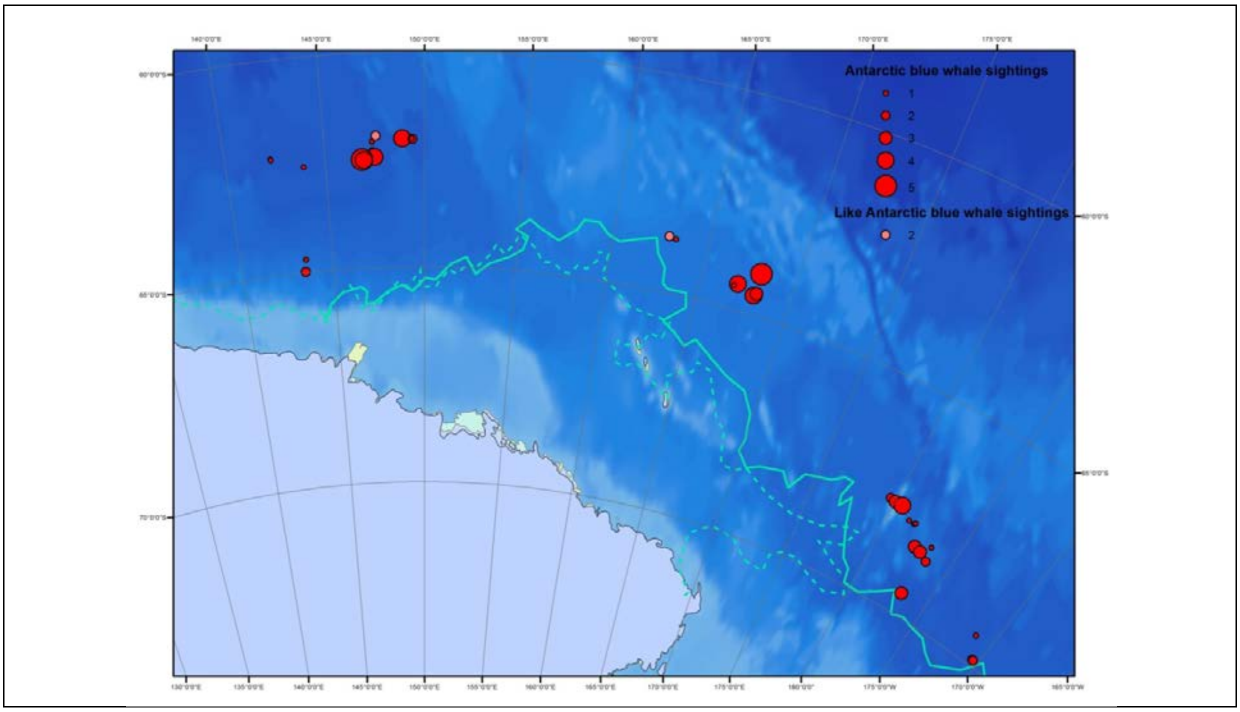

Figure 2. Distribution of Antarctic blue whale sightings throughout the voyage. The maximum (7/3/2013) and minimum (15/2/2013) ice extent (from satellite data) during the voyage is represented by the solid and dashed lines adjacent to the Antarctic coastline.

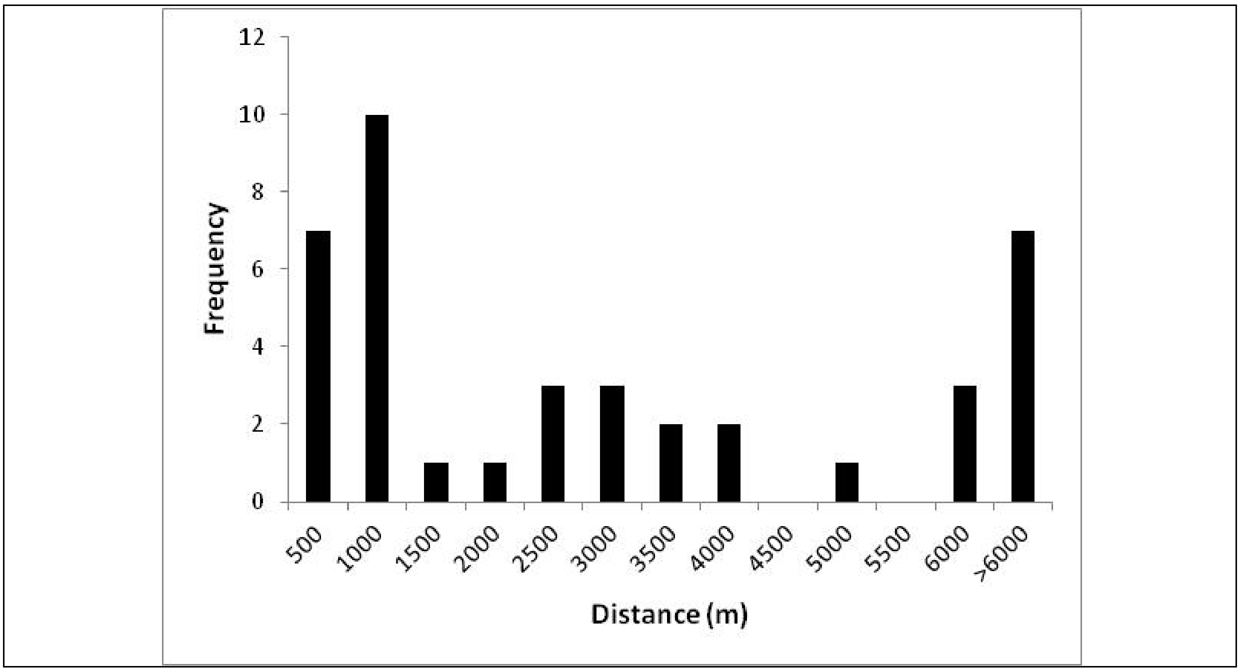

Figure 3. Distribution of radial distances to initial sightings of blue whales. The horizon was at approximately 12 km. Sightings greater than 6 km (less than 0.1 binocular reticles) were pooled in this figure.

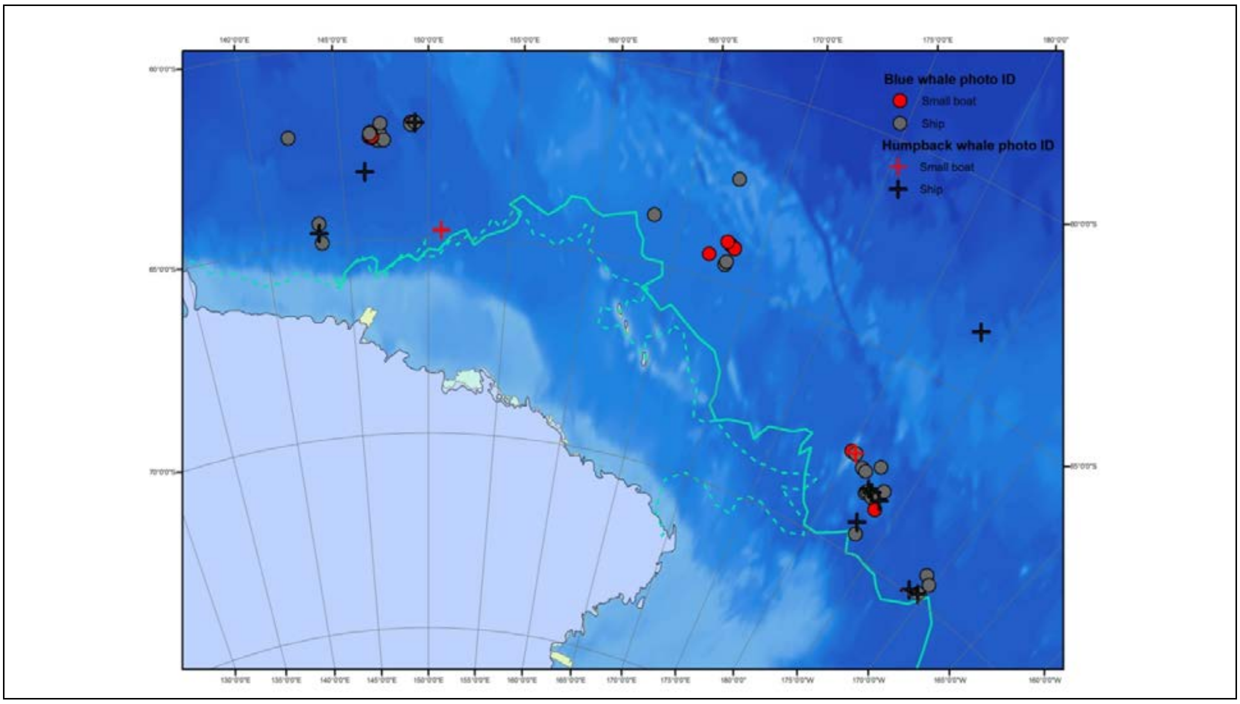

Figure 4. Distribution of Antarctic blue and humpback whale photo IDs collected from the ship and small boat throughout the voyage. The maximum (7/3/2013) and minimum (15/2/2013) ice extent (from satellite data) during the voyage is represented by the solid and dashed lines adjacent to the Antarctic coastline.

Biopsies and satellite tagging

Biopsy samples from 23 whales were obtained from the *FV Amaltal Explorer* (n=10) and the *Remora* (n=13) using the Larsen and Paxarms rifles respectively. The geographic distribution of the samples is given in Figure 5. It is likely at least five whales were biopsied more than once; the total number of whales sampled will be determined definitively by genotyping. Most Antarctic blue whale samples included sufficient tissue to be divided and preserved in three ways to maximise analysis potential (All Protect, 70% ethanol, and freezing in liquid Nitrogen). These samples will be used to generate mitochondrial DNA sequences and individually-specific microsatellite and/or SNP genotypes for MR analyses. The specific genetic methods will be determined in the near future by a Technical Committee of the Antarctic Blue Whale Project. Subsamples of all biopsies will be submitted to the IWC-endorsed repository for blue whales genetic samples at the NOAA Southwest Fisheries Science Center, La Jolla, California (International Whaling, 2012).

Two satellite tags were deployed on blue whales in Antarctic waters which to our knowledge has not been achieved previously. The tags collected movement data for 14 and 74 days tracking each whale over 1,433 and 5,300 kilometres respectively. The satellite tag-derived movements showed one travelled northwards and then west, approximately parallel to the polar front while the other travelled southeast at greater average speed (see Figure 6). Both whales performed long scale movements interspersed with patches of searching, often in close association with the ice edge. Details on tag performance and the movements of each whale can be found in Table 4. See Andrews-Goff et al. (2013) for further details.

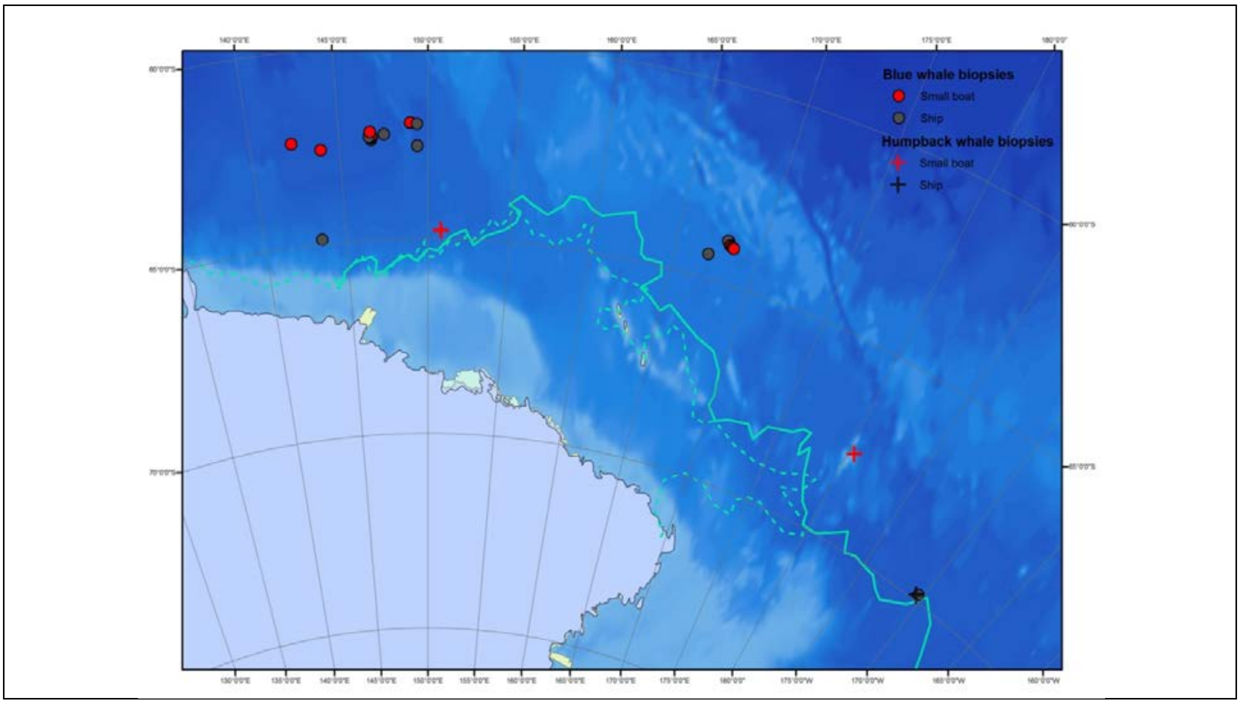

Figure 5. Distribution of Antarctic blue and humpback whale biopsies collected from the ship and small boat throughout the voyage. The maximum (7/3/2013) and minimum (15/2/2013) ice extent (from satellite data) is represented by the solid and dashed lines adjacent to the Antarctic coastline.

Generally blue whales encountered south of 60^{o}S were more evasive of the RHIB than the ship even though the ship was considered to be noisy (see Barlow et al., 2013). Therefore, as the voyage progressed the ship was used more frequently to obtain photographs and biopsies. On future blue whales voyages it should not be assumed that a RHIB is a more effective platform for photographs and biopsy samples than a manoeuvrable ship.

Eight biopsies were collected opportunistically from humpback whales but this activity was a lower priority on this voyage (Figure 5).

Approximately thirty hours of detailed behavioural data were collected to investigate the context of calling behaviour and obtain accurate locations of whales that may be used for source level measurements. These data were collected from 25 encounters varying from less than ten minutes to over four hours (with an average of approximately one hour). However, the data were usually collected following close approaches by the ship and may not be representative of undisturbed behaviour. For future voyages it would be beneficial to stand off the whales for a time to collect these data appropriately.

Cetacean sightings data

Sightings of all cetaceans and the 40 sightings of Antarctic blue whales are listed in Table 5.
In total there were 596 sightings of an estimated 1,821 individual cetaceans. Confirmed sightings of 11 cetacean species were recorded.
Although distance-sampling methods were employed on this voyage it is unlikely these data can be used to estimate regional abundance of cetaceans because the trackline of the ship was influenced greatly by the acoustic targeting of blue whales. Also the distribution of blue whales may not be independent of the distribution of other cetacean species. For example a preliminary analysis indicated 70% (235/337) of fin whales sighted were within 30 km of the nearest blue whale sighting,

although there appeared to be some separation in the species distribution at smaller spatial scales (only 3% of fin whales encountered were within 5 km of the nearest blue whale). In contrast humpback whales (238 groups sighted) showed less association with blue whale sightings (Figure 7). Only 45% of humpback whale individuals sighted (215/475) were within 30 km of blue whales with a median group distance of 42 km from the nearest blue whale sighting. Humpback whales are the only species for which it may be possible to estimate a detection function related to perpendicular distance.

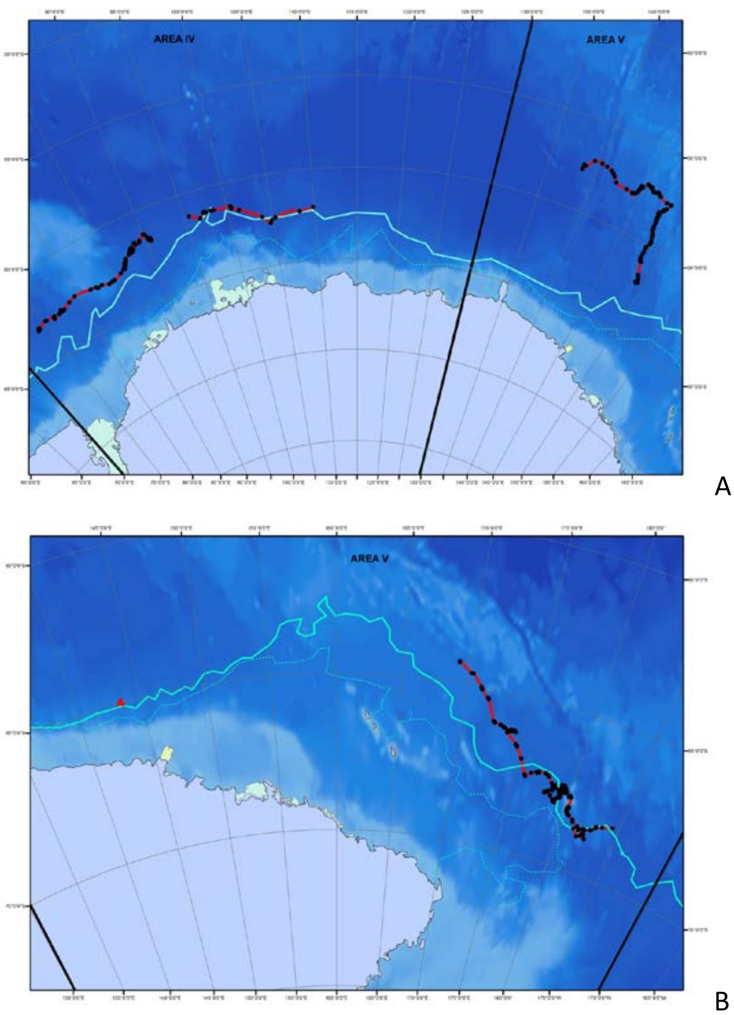

Figure 6. Satellite tag derived movements of two Antarctic blue whales tagged during the voyage. Both tracks were filtered and smoothed using the CRAWL package implemented in R (http://cran.r-project.org/). A) Ice extent upon deployment (14/2/2013) and termination of the tracking period (29/4/2013) is represented by the solid and dashed lines adjacent to the Antarctic coastline. B) Ice extent upon photo identification (red triangle - 9/2/2013) and termination of the tracking period (21/3/2013) is represented by the solid and dashed lines adjacent to the Antarctic coastline.
Blue whale behavioural data

Table 4. Tag performance and movement summaries calculated from filtered (SDA filter – Freitas et al. 2008) and smoothed (CRAWL – Johnson et al. 2008) Argos location data transmitted by two tagged blue whales.

	PTT 123223 (*"Markus"*)	**PTT 121205 (*"Henry"*)**
Sex	Female	Male
Date deployed	14/02/2013	8/03/2013
Track duration	74 days (40 days of locations data)	14 days
Location deployed	62.00°S, 149.01°E	64.04°S, 168.29°E
Photo identification date	NA	9/02/2013
Photo identification location	NA	64.97°S, 143.47°E
Locations per day (mean ± se; range)	7.75 ± 0.90; 1 - 20	12.07 ± 1.58; 3 - 25
Track distance	5300km	1433km
Distance per day (mean ± se)	80.13 ± 7.74km	102.37 ± 9.94km
Speed (mean ± se; max)	3.90 ± 0.16 kmh^{-1}; 34.09 kmh^{-1} max	5.86 ± 0.31 kmh^{-1}; 26.04 kmh^{-1} max
Locations per day (mean ± se; range)	7.75 ± 0.90; 1 - 20	12.07 ± 1.58; 3 - 25
Last transmission date	29/04/2013	21/03/2013
Last transmission location	62.96°S, 73.95°E	68.18°S, 175.59°W

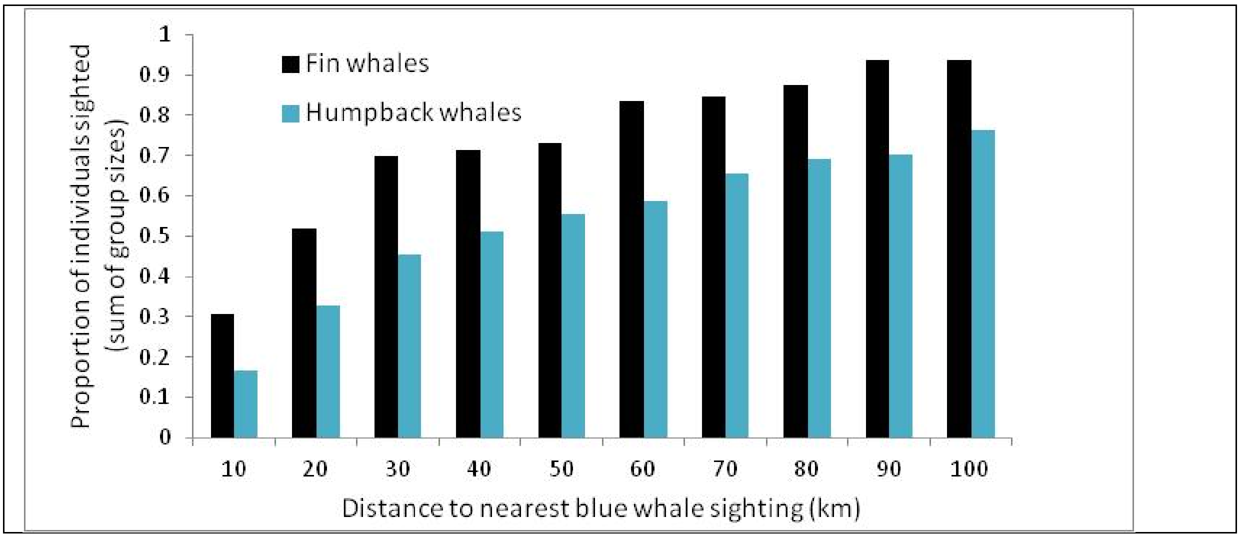

Figure 7.Proprtions of fin and humpback whale sightings within each distance category from the nearest blue whale sighting .

Table 5. Summary of cetacean sightings during the Antarctic blue whale voyage 2013.

Species	Sightings	Individuals
Blue whale	39	84
Like blue whale	7	9
Pygmy blue whale	9	17
Like pygmy blue	1	1
Fin whale	61	341
Like fin whale	8	31
Humpback whale	238	475
Like humpback whale	67	110
Right whale	2	3
Sei whale	4	4
Minke whale	7	8
Like minke	16	37
Sperm whale	7	7
Like sperm whale	4	4
Killer whale	5	59
Pilot whale	2	7
Like pilot whale	1	30
S Bottlenose whale	1	1
Ziphiidae	1	10
Common dolphin	5	75
Cruciger dolphin	4	32
Dusky dolphin	5	157
Unid large baleen	55	93
Unid large whale	21	45
Unid whale	3	5
Unid small whale	10	10
Unid whale/dolphin	1	2
Unid dolphin	8	167
Unid small cetacean	4	7

Conclusions

1. DIFAR sonobuoys allowed the detection of aggregations of blue whales from hundreds of kilometres away and provided a bearing to the aggregation. This was a highly effective tool to improve the encounter rate for efficient photographic and biopsy sampling.
2. Photo-Identifications and biopsies were collected from both the ship and RHIB. Individual Antarctic blue whales were approached more easily with the ship, but in high-density areas the most efficient sampling was using both the ship and the RHIB.
3. Antarctic blue whales were successfully satellite tagged but were evasive in the presence of the RHIB.
4. The distributions of other whale species, particularly fin whales, were highly correlated with the distribution of blue whales so acoustically-directed search for blue whales was not random with respect to the distribution of other baleen whales. The estimation of regional abundance for other species from visual distance sampling data (Objective 4) on such voyages may not be appropriate.
5. Both acoustic detections and satellite tag deployments indicated that Antarctic blue whale distribution extends north of 60°S in late summer, which has not been shown in previous survey data.
6. The biopsy samples showed a strong bias towards males. This may be related to acoustic tracking, segregation with respect to ice or behavioural differences between sexes. The possible causes of the sex bias in sampled whales will be investigated further.

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