REPORT OF THE 2013/14 SOUTH AFRICAN ANTARCTIC BLUE WHALE SURVEY, 000° - 020°E

Ken Findlay[1*], Meredith Thornton[1], Fannie Shabangu[1,2], Kirsty Venter[1], Ian Thompson[1] and Ove Fabriciussen[1]

Mammal Research Institute Whale Unit, University of Pretoria. [c/o Iziko SA Museum, PO Box 61, Cape Town 8000, South Africa]

Fisheries Branch, Department of Agriculture, Forestry and Fisheries, Foreshore, Cape Town, South Africa

* Corresponding author: kenfin@mweb.co.za

ABSTRACT

The South African Antarctic Blue Whale Project proposed two major research objectives during the 2013/2014 South African National Antarctic Expedition (SANAE) 53 cruise to Queen Maud Land coastal region on the *SA Agulhas II*. An Autonomous Acoustic Recorder (AAR) mooring deployment was carried out on the Maud Rise at 65°00S; 002°30'E in water depths of 1200m to investigate the seasonality of blue whales in this region over the next year. An ice-edge line-transect survey was proposed across the ice-edge region between 000° and 020°E. A total of 82 hours of survey effort (859 n miles) was carried out in an easterly direction although poor sighting conditions towards the end of the survey resulted in the termination of the survey at 017°30'E, whilst 11.9 hours (139 n miles) of search effort was undertaken during the transits to and from the survey area. Weather and sighting conditions encountered during the survey ranged from poor to excellent, with predominantly fog and wind accounting for poor sighting conditions, while ice conditions were highly dynamic. A total of 213 sightings of an estimated 451 cetaceans was sighted by the whale research team during the research effort on the survey. The most commonly encountered whales were minke whales (93 groups of 238 individuals), all of which were identified as Antarctic minke whales, and ninety five percent of which were to the east of 008°E. Seventeen groups of 26 blue whales (all identified as Antarctic blue whales (*B. m. intermedia*)) were encountered on the cruise, with one sighting of two individuals made during research effort by other observers and two sightings of two individuals made outside of research effort. Biopsies were collected from four individual blue whales, while at least 16 blue whales are believed to have been adequately photographed. Calibrated 38 and 120kHz acoustic echo-sounders were operated from the survey vessel define distributions of Antarctic krill (*Euphausia superba*) and other whale prey species across the survey area. The relatively high numbers of blue whales sighted on this survey re-enforces the perception that the 000-020°E region of the Queen Maud Land coast is a hotspot for Antarctic blue whales.

INTRODUCTION

Two subspecies of blue whales occur in the Southern African and the associated Antarctic region, the Antarctic (or true) blue whale (*Balaenoptera musculus intermedia*) and the pygmy blue whale (*B. m. brevicauda*) (Mackintosh, 1942; Ichihara, 1966; Best, 2007). These two subspecies appear to have largely discrete distributions in summer, with Antarctic blue whales found south of 55˚S, while pygmy blue whales are found to the north of 55˚S. Some 360,000 blue whales were whaled from the Southern Hemisphere last century (Clapham and Baker, 2002), and evidence for the annual migrations of Antarctic blue whales from high latitude feeding areas (summer) to low latitude mating and calving areas (winter) largely arises from the timing of catches at different latitudes (Mackintosh & Wheeler 1929; Mackintosh 1942). Branch *et al.* (2004) have estimated that catches of Antarctic blue whales last century reduced the Southern Ocean population from 239,000 (95% interval 202,000 – 311,000) to a low of 360 (150-840) animals.

Despite a low abundance (at 1700 individuals (95% Bayesian interval 860–2900)) in Antarctic waters south of 60˚S in 1996, Branch *et al.* (2004) have shown an increase of Antarctic blues of 7.3% per year (95% interval 1.4–11.6) from the International Whaling Commission (IWC) International Decade of Cetacean Research (IDCR) and Southern Ocean Whale Ecosystem Research (SOWER) programmes (1968 – 2001). This population estimate of Branch *et al.* (2004) does not however include the relatively high numbers of blue whales sighted on the SOWER cruises in the Antarctic region south of Africa (000-070°E, or the IWC's Area III) in more recent years (2003-2010). The 221 sightings made during the IDCR / SOWER cruises over the last 30 years shows a strong concentration of blue whales between 000° and 020°E and in the narrow band between 67°S and the ice edge (see Ensor *et al.*, 1997; 1998; 1999; 2000; 2001; 2003; 2004; 2005; 2006; 2007; 2008 and 2009). Furthermore, of the 207 individual Antarctic blue whales identified photographically on the IWC IDCR / SOWER cruises over the last 15 years, 157 whales (76%) have been identified from Area III (Olson, 2009) with six re-sightings of whales recorded across years. Both the 2005-2006 and 2006-2007 cruises were in Area III, and Olson (2009) reported that the re-sighted individuals within years during the 2005-2006 (11%), 2006-2007 (17%) and 2008-2009 (20%) seasons imply that blue whales exhibit some degree of residency within this region during the summer season. Such residency patterns are in stark contrast to the marked movement of certain individuals apparent from other photo-identification (Olsen 2009), genetic (Sremba *et al.*, 2013) or *Discovery* mark data (Branch *et al.*, 2007). Just as with the photo-identification data, genetic identification samples collected on the IWC SOWER cruises are heavily biased towards the this Antarctic region to the south of South Africa as 127 samples (of a total of 218) are from the area of interest (Sremba *et al.*, 2013).

Furthermore, substantial historical, austral winter catches of probable Antarctic blue whales were made off the southwest African coast (7,969 off Saldanha Bay, 1,665 off Namibia and 1,917 off Angola (Best 1994)), and the waters off Namibia are the only potential breeding ground for Antarctic blue whales identified to date (Best, 1998). Although no links between these Antarctic feeding and the Southern African west coast breeding areas have been established, their proximity would suggest migration ties between these regions. Such ties may be identified through the collection of individual identification markers (either as photo-identified natural marks or as genetic markers).

Although sightings of blue whales outside of the Antarctic hotspot are few (only a handful of sightings have been made off the South African coast in the last 40 years), large baleen whale species have some of the loudest calls in nature (Antarctic blue whale calls have source levels of 189 dB re 1 µPa at 1m), that can be detected at considerable distances from the caller depending on source intensity, oceanographic conditions and the location of the recording device in relation to the sound channel (Širovic *et al.*, 2007; Stafford *et al.* 1998; Samaran *et al.*, 2010). Such calls make acoustic monitoring of the population possible over a wider area and with greater efficiency than visual detection (see Mellinger *et al.* 2007). Autonomous Acoustic Recorder (AAR) devices are designed to sub-sample the acoustic environment on a 24-hr basis and provide data on the presence of acoustically active individuals (as individual calls and the energy within the background noise spectra), while source levels detected by such instruments could possibly be used to derive estimates of the distance of incoming calls, and hence determine the radial location of callers. Over longer spatial or temporal scales, studies of migrations, peak relative abundance, and seasonality may be particularly facilitated through the use of AAR instruments.

These concentrations of blue whales provide an excellent opportunity for South Africa to instigate a long-term feeding ground study on the species, including initially estimating abundance, and investigating distributions and migrations, and thereafter leading in the longer term to investigating both population trends of blue whales, and krill predator dynamics of blue and other baleen whale species. This study proposes the use of AAR instrumentation across the migration range of the species to investigate seasonal distribution and relative abundance patterns.

PROPOSED RESEARCH METHODOLOGY

The South African National Antarctic Programme (SANAP) funded "South African Blue Whale Project" (SABWP) initiated by the Mammal Research Institute Whale Unit of the University of Pretoria proposed two major research objectives during the 2013/2014 SANAE 53 cruise. Research was carried out under Environmental Evaluation Decision 14/12/16/5/1 in accordance with Article 2(1) (Environmental Impact Assessment) of the Protocol on Environmental Protection (PEP), 1991, under the South African National Antarctic Programme.

Deployment of Autonomous Acoustic Recorder Mooring

The Autonomous Acoustic Recorder Mooring was deployed on 12 January at position 65°00'S; 002°30'E on the Maud Rise. This AAR will record 25 minutes of each hour every day until February 2015 when the mooring (and archive acoustic data) will be recovered and in all likelihood be re-deployed for a further year.

Visual line - transect abundance and distribution survey of whales, photo-identification and genetic marker sampling and echo-sounder surveys of krill

This component of the proposed research aimed to i) estimate the abundance of blue whales in the ice-edge region through line transect distance sampling, ii) to define the distribution of animals in association with environmental and biological parameters such as prey availability and iii) to collect individual identification material (photo-identification of natural marks and collection of skin biopsies for genetic marking) for identification of movement patterns and mark-recapture estimation of population size. The proposed line-transect survey required a pre-determined saw-tooth track design to be steamed for sixteen hours per day from the ice edge to 67˚S and between 000˚E and 020˚E. At the end of each day's survey the vessel drifted and the survey track was commenced at the start of the following day's research. Whilst northern waypoints were fixed, the southern waypoints were ice-edge dependent. Trackline design protocol in association with the ice edge was based on that utilised by the IWC IDCR and SOWER cruise protocols (IWC, undated). Research was planned for 16 hours per day (05h00 - 21h00) under acceptable weather conditions (wind speeds of less than 25 knots and adequate visibility), with at least four observers on watch at all times All search effort and all species encountered were logged, as were hourly sighting and weather conditions. Searching was carried out using binoculars and the naked eye, and at each sighting a suite of data was collected, including Global Positioning System (GPS) position of the vessel and the estimated distance and bearing from the vessel to the sighting. Such distances were generally measured through triangulation of multiple bearings from the vessel as it traversed the trackline, although other techniques such as distance photography were utilised. All searching was carried out in passing mode with closing of potential blue, right and killer whale sightings for photo-identification and group size confirmation at the discretion of the senior scientist on watch, including decisions on the feasibility of small-boat work. After completion of data collection (either from the ship or the small boat) the vessel returned to the trackline by the shortest available route, and continued the survey immediately once back on the trackline.

Depending on whether weather conditions allow the use of a small boat, the ship's fast rescue boat, was deployed by the ship's crew for approach of blue whales. Individual identification photographs were taken with a Canon EOS7D and 100-400mm lens, a Nikon with a 100-300mm lens and a Canon 5D with a 150-500mm lens; the target areas being the left and right lateral views of the body in the dorsal fin region. Skin biopsy collection of genetic samples was attempted using a crossbow with all biopsy heads having been cleaned by washing in bleach, flamed and sterilised in alcohol prior to each use. When small-boat work was not possible whales were photographed from the bow or Monkey Island of the *SA Agulhas II*. No genetic sampling was attempted from the *SA Agulhas II*. All approaches of whales were carried out under permit RES2014/61 issued by the Director: Biodiversity and Coastal Research, Branch Oceans and Coasts, Department of Environmental Affairs(DEA) in terms of Section 79 of the Marine Living Resources Act of 1998 (Act No. 18 of 1998).

The *SA Agulhas II* 38 and 120 kHz acoustic echo-sounders were operated to monitor the water column for Antarctic krill (*Euphausia superba*) and other whale prey species. To convert the acoustic strength into numbers and biomass, a*d hoc* target identification sampling using the standard 2 m^2 Methot ichthyoplankton net was carried out (on acoustic targets of suitable strength) with plankton species composition, length frequencies and mass measurements being undertaken on small amounts of krill (about 100 individuals) thereafter.

CRUISE NARRATIVE

The proposed SANAE 53 voyage could be divided into three legs (Figure 1) including

1. the Southward Logistic Cruise Transit from Cape Town to Penguin and Akta Buktas on the Queen Maud Land coast on a transit of the Good Hope Line;
2. the Research leg (which incorporated the transit to South Thule and South Georgia, the iron and associated research on the second transit of the Good Hope line (eight oceanographic stations) being conducted between 44° and 60°S and the whale research component in the ice-edge region between 000° and 020°E) and
3. the northward Logistic Cruise Transit from Penguin and Akta Buktas to Cape Town which incorporated a further transit of the Good Hope Line.

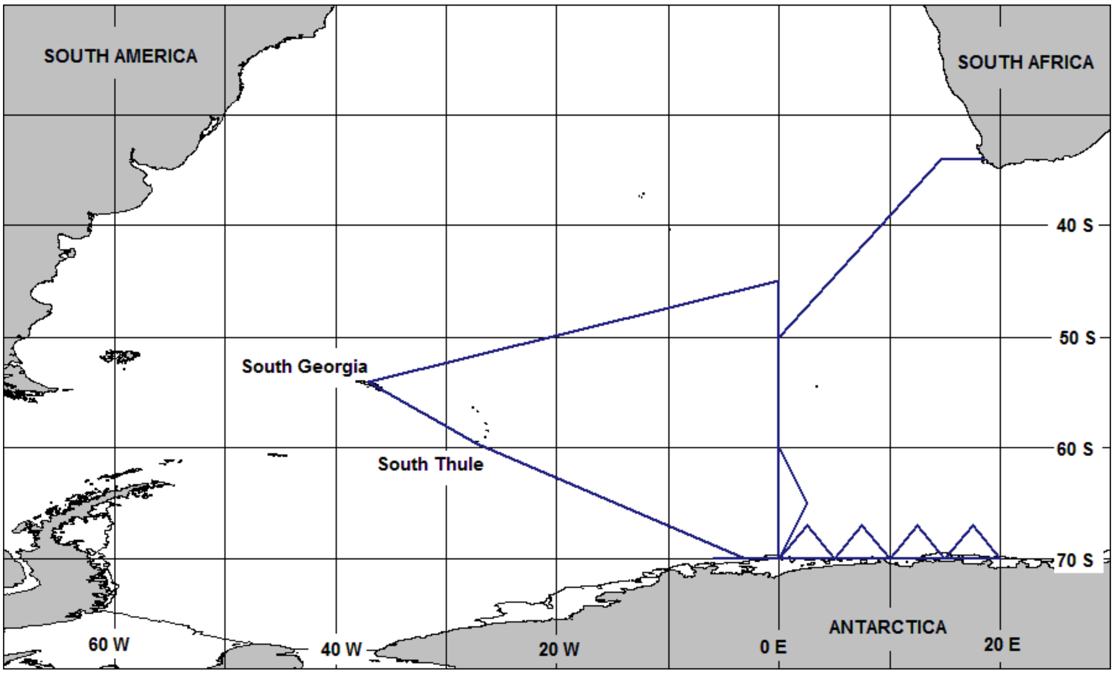


Figure 1. The Proposed SANAE 53 cruise track, showing the transit from Cape Town to Penguin and Akta Buktas and the Good Hope Line, the transit to South Georgia, the Iron Research leg on the Good Hope Line, the Whale Research transects and the transit from Penguin and Akta Buktas to Cape Town.

The planned dates of the Research Leg extended from 26 December 2013 to 2 February 2014 when the ship was to depart from and return to Penguin Bukta respectively. Severe ice concentrations encountered on the Southward Logistic Transit for an estimated 14 days delayed the start of the Research Leg by five days so that the vessel departed Penguin Bukta on 30 December for South Thule Island[1]. South Thule was reached on 04 January 2014 and after completion of the weather service programme the ship departed for South Georgia. A shore visit on South Georgia took place on 06 January and the ship departed immediately thereafter on the transit to the Good Hope Line for proposed iron and associated research.

Fuel consumption during the ice navigation on the Southward Logistic Transit resulted in some limitations in the distances that could be covered during the Research Leg. Various options for alleviating these limitations were considered and on 07 January a decision was made to proceed directly to the Whale Research component of the cruise and the Whale Research component was initiated on 12 January.

The Autonomous Acoustic Recorder Mooring was deployed in calm conditions between 06h00 and 11h00 on 12 January at position 65°00’S 002°30’E on the Maud Rise. Thereafter the vessel transited south to the proposed start of the visual line-transect survey at position 68°30’S, 000°E. Training of observers was carried out prior to the survey commencement, including a short course on whale identification and practical survey training while the vessel was in transit on both 11 and 12 January.

Whilst the original survey design called for eight transects between 000° and 020°E out to approximately 120 n miles from the ice edge, prior information on blue whale distribution from IWC SOWER cruises and the poorer weather expected away from the ice-edge resulted in the design being modified to sixteen transects out to 60 n. miles from the ice-edge (where Kasamatsu *et al.* (2000) report the highest densities of blue whales). This modified design corresponds to the southern stratum surveys carried out on the IWC IDCR and SOWER cruises. The survey started at 05h00 on 13 January at the ice edge at 68°39’S 000°E. The visual line transect was then undertaken in an easterly direction over the next 9 days, with the survey waypoints and the timing of their arrival provided in Table 2.

The ice conditions encountered during the survey were particularly dynamic and some alterations to the proposed cruise track were necessary to accommodate this. Thick fog encountered at the ice edge in the region of 017°30’E required the survey to be suspended at 05h00 on 21 January and the vessel drifted off - effort until this lifted partially at 18h00 when survey effort resumed. The weather for the following day was predicted to be similar and it was decided to terminate the survey at 017°30’E. This decision meant that Whale Research could be carried out on the return transit through a high density blue whale area on 22 January and encountered blue whales could be approached for biopsy and photo-identification sampling and krill trawls could be conducted on this transit. Some 35 n. miles of trackline covered during poor sighting conditions on 20 January were resurveyed westwards until 21h00 on 21 January at which time the vessel proceeded westwards on the transit to Penguin Bukta. The vessel transited the research area along the ice edge on 22 January, although the marked northward movement of the ice edge (which coincided with the northward shift in ice conditions encountered during the survey) on the return transit must be noted. Penguin Bukta was reached on 24 January.

RESULTS

All results presented here are deemed preliminary as the data have not been through a final validation screening.

Deployment of Autonomous Acoustic Recorder Mooring

The Autonomous Acoustic Recorder Mooring was deployed without problems between 06h00 and 11h00 on 12 January at position 65°00’S; 002°30’E on the Maud Rise.

Visual line - transect abundance and distribution survey of whales and echo-sounder surveys of

[1] The efforts of the Captain and crew of the *SA Agulhas II* in recovering time and distance while at Penguin Bukta and en route to South Thule is gratefully acknowledged.

krill

The northerly position of the ice edge in the region of 68°S across the survey area between 000°and 020°E necessitated considerable alteration to the originally proposed cruise track design, although the distance to be surveyed remained as proposed. The modified cruise track design (shown as the planned Waypoints in Table 1) was further modified on an *ad hoc* basis as ice conditions demanded.

Ice conditions during the line transect survey

The ice edges encountered at 000°E, 002°30’E and 005°E were 9, 10 and 8 n miles further south respectively than expected from the satellite ice chart so that southward transects to the ice edge had to be incorporated at these positions. The ice edges at 007°30’E, 010°E and 12°30’E were approximately 8, 13 and 24 n. miles further north than expected from the ice charts showing continued northward movement of the ice edge during the survey. The transects were shifted northwards by 10 n. miles and 15 n. miles at 013°45’E and 016°15’E respectively (Table 1) and despite such shifts the ice edge was still 14 n. miles north of its expected position at the 15°E waypoint. The ice edge at 017°30’E was four miles south of its expected position with the 15 n mile northward shifts of transects in this region. A marked northward movement of the ice edge was noted as the vessel transited the research area along the ice edge on 22 January when certain of the transects surveyed the previous week were ice covered (see TR effort in Figure 2).

Searching Effort

All observation effort was carried out from the Monkey Island some 30.55 metres above sea level. It should be noted that the requested alterations to the top observation platform originally made in May 2012 were not carried out despite considerable discussion during the planning stages of the cruise and the Top Observation Platform of the *SA Agulhas II* was deemed unsuitable for observations. Two observation platforms were consequently utilised on the Monkey Island. A last minute transfer of the open and exposed whale observation box from the *FRS Algoa* prior to departure of the *SA Agulhas II* provided the primary platform on the starboard bridge wing. All survey effort from this Whale Box platform (classified as P1 effort) carried out on the survey transects was carried out in passing mode in that all whale groups were passed except closing / approaches on blue and killer whale sightings, and was categorised as primary passing effort. However, binocular vibration associated with wind buffeting during headwinds encountered on this platform compromised survey of the horizon and a second platform, the Glass House, situated directly above the bridge was utilised under headwind conditions or when steaming was carried out through limited visibility conditions. All effort from the Glass House platform was categorised as secondary passing effort (P2), despite sighting conditions from within the Glass House platform being within acceptable sighting conditions at certain times.

A total of 82 hours of survey effort was carried out during the 9 day line-transect survey with a further 11.9 hours of search effort undertaken during the transits to and from the survey area (Table 2). A further 40.3 hours were spent confirming and closing on whale groups, including blue whales, other large baleen whales (up until the species identification had been made) and killer whales. Some 27.5 hours were spent drifting in poor weather / sighting conditions unsuitable for survey. A total of 859 n miles was estimated to have been searched during the line transect survey between 13 and 21 January with a further 139 n miles surveyed in transit to or through the research area on 12 January and 22 January. A breakdown of the research activities of the vessel over the 13 to 22 January period is provided in Table 3, while Figure 3 provides the distribution of survey effort undertaken from the *SA Agulhas II* during the Antarctic blue whale survey. It should be noted that P2 effort was carried out under acceptable sighting and visibility conditions at certain times particularly when headwinds precluded the use of the exposed Whale Box. The spread of the research effort across the survey area and eastward progress of the survey was clearly dependent on both weather conditions and the availability of blue and other target species whales, with drifting in poor weather accounting for most of the research time on 21 January and some of the available time on 13 and 14 January. Small-boat work (reflected in Table 2 as a component of the confirmation time) accounted for a total of 8% of the total research time.

Table 1. A total of 160 hours (16 hours per day between 05h00 and 21h00 for 10 days between 13 January and 22 January inclusive) were available for the line-transect research operations. Planned and actual positions of waypoints and the time of arrival at each waypoint during the visual line transect survey.

Waypoint	Planned Position		Actual Position		Timing of Arrival at Longitude
			Latitude	Longitude	Date - Time
1	68°30’ S	000° E	68°39’ S	000° E	2014/01/13 – 05:00
2	67°36.5’ S	001°15’ E	67°36.5’ S	001°15’ E	2014/01/13 - 11:11
3	68°15’ S	002°30’ E	68°33.6’ S	002°30’ E	2014/01/14 - 11:04
4	67°16’ S	003°45’ E	67°16’ S	003°45’ E	2014/01/15 - 05:01
5	68°00’ S	005°00’ E	68°08’ S	005°00’ E	2014/01/15 - 11:57
6	67°00’ S	006°15’ E	67°00’ S	006°15’ E	2014/01/16 - 07:21
7	68°00’ S	007°30’ E	67°50’ S	007°30’ E	2014/01/16 - 15:23
8	67°00’ S	008°45’ E	67°00’ S	008°45’ E	2014/01/17 - 07:33
9	68°00’ S	010°00’ E	67°43’ S	010°00’ E	2014/01/17 - 13:06
10	67°00’ S	011°15’ E	67°00’ S	011°15’ E	2014/01/17 - 20:51
11	68°00’ S	012°30’ E	67°35’ S	012°30’ E	2014/01/18 - 14:27
12	67°00’ S	013°45’ E	67°00’ S	013°45’ E	2014/01/18 - 17:07
13	68°00’ S	015°00’ E	67°35’ S	015°00’ E	2014/01/19 - 17:42
14	67°07’ S	016°15’ E	67°07’ S	016°15’ E	2014/01/20 - 12:50
15	68°10’ S	017°30’ E	67°48’ S	017°30’ E	2014/01/21 - 07:12
16	67°15’ S	018°45’ E	-	-	
17	68°17’ S	020°00’ E	-	-	

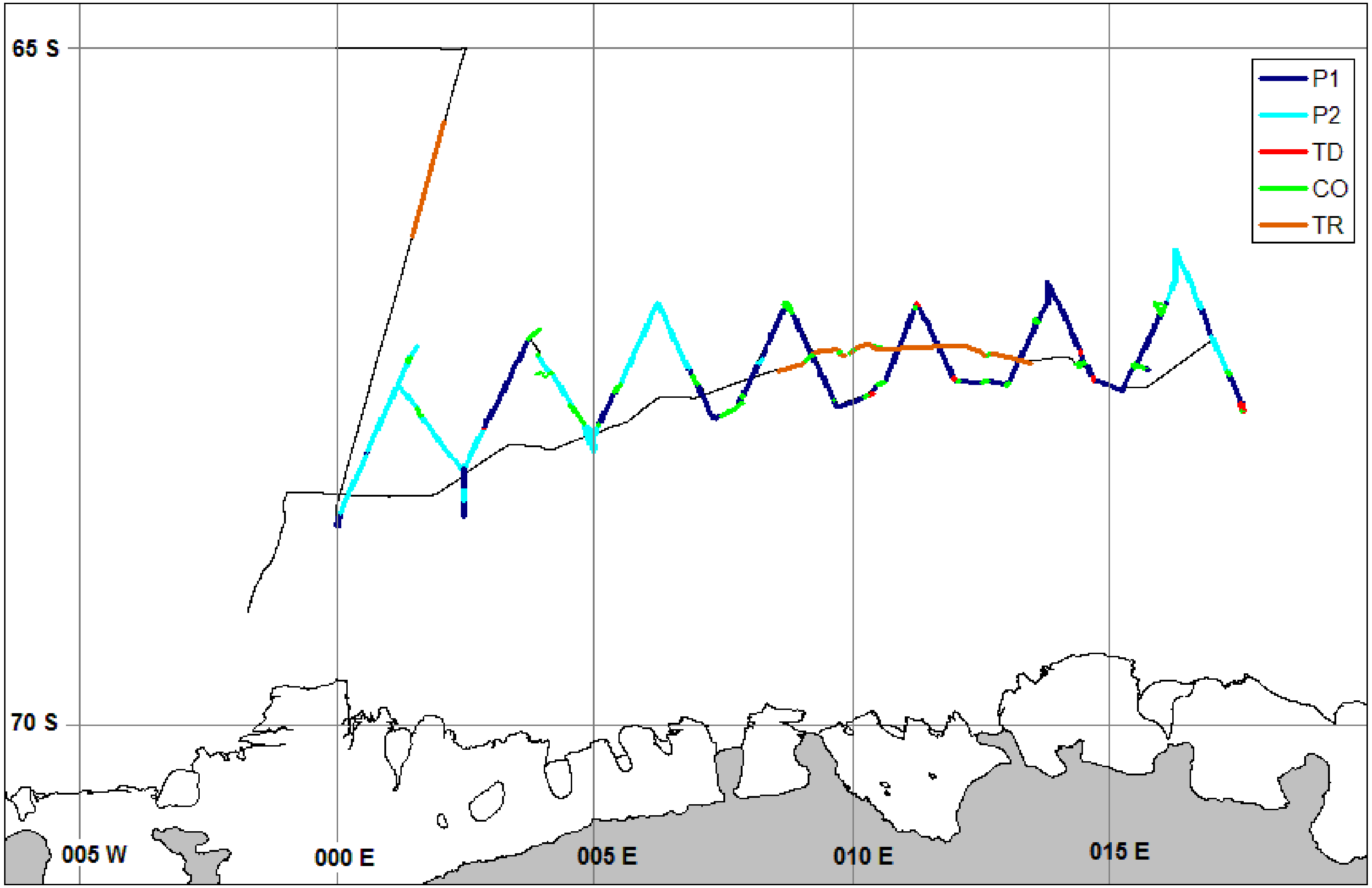


Figure 2. Distribution of Survey Effort undertaken from the *SA Agulhas II* during the Antarctic blue whale survey. P1 = Primary Survey Effort; P2 = Secondary Survey Effort; TD = Passage steamed on the Trackline without Survey Effort: CO = Confirmation of Whale Groups (including small boat operations) and TR = Survey Effort during transit to and from the Research Area.

Table 2. Allocation of available research time to research activities each day between 12 January and 22 January (P1 = Primary Survey Effort; P2 = Secondary Survey Effort; CO = Confirmation of whale groups; DR = Drifting off effort; TD = Steaming on the transect line off effort).

Date	**P1**		**P2**		**TR**		**CO**		**DR**		**TD**		**Total Time**	**Total Distance on Effort (P1/P2/TR)**
	Time	**Distance**	**Time**	**Distance**	**Time**	**Distance**	**Time**	**Distance**	**Time**	**Distance**	**Time**	**Distance**		
12/01/2014					3.59	48.52							15.99	48.52
13/01/2014	0.68	6.40	6.97	78.99			0.54		7.80				16.00	85.39
14/01/2014	6.77	71.35	9.01	89.13			1.13						16.90	160.48
15/01/2014	5.98	32.15	4.08	46.95			5.95						16.00	79.10
16/01/2014	4.36	43.31	5.24	59.70			5.89		0.13		0.38	4.43	16.00	103.01
17/01/2014	12.01	131.59					3.08		0.10		0.71	17.64	15.90	131.59
18/01/2014	5.70	54.46	0.38	4.74			6.46		3.5			0.78	16.03	59.20
19/01/2014	7.79	86.61	0.10	0.68			5.26		1.01		1.75	1.15	15.91	87.29
20/01/2014	3.82	43.01	6.45	73.63			4.70		1.03				16.01	116.64
21/01/2014	1.98	22.10	1.22	13.99			0.12		12.61				15.93	36.09
22/01/2014					7.51	90.29	7.19		1.29				15.99	90.29
Total	49.10	490.98	33.45	367.80	11.09	138.81	40.30		27.48		2.84	24.00	176.66	997.59

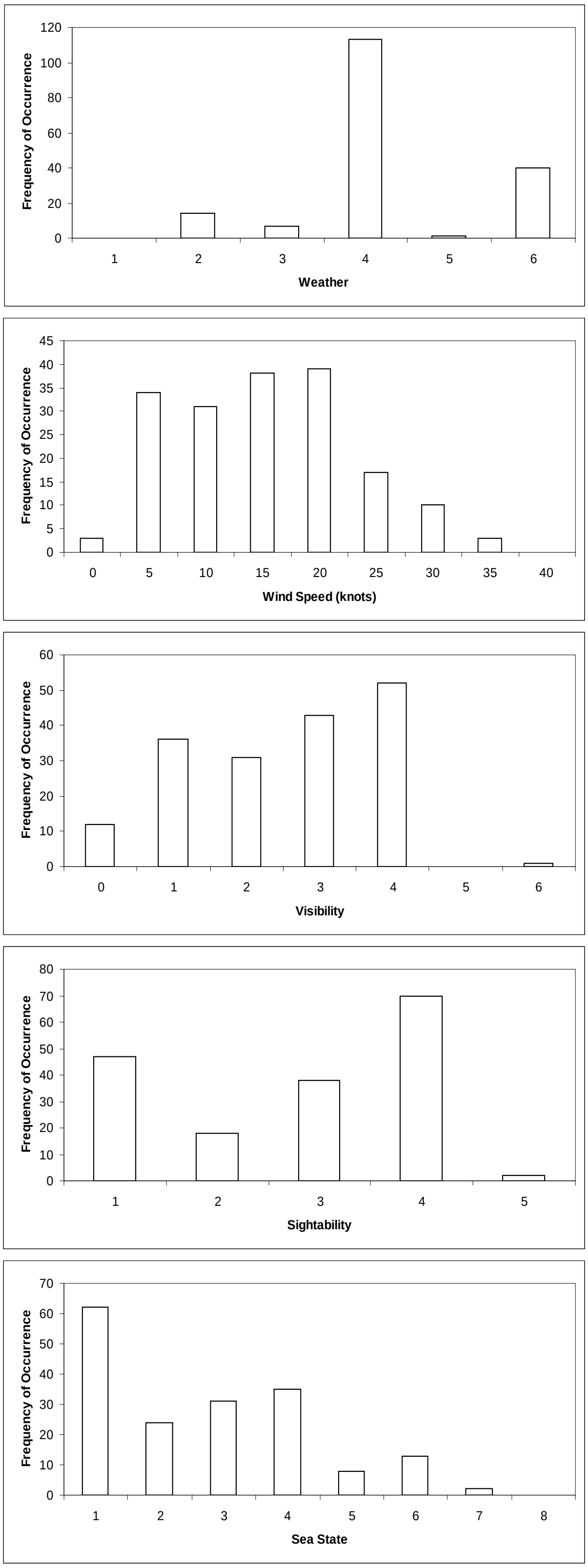
Weather Conditions

Weather conditions encountered during the survey ranged from poor to excellent, with predominantly fog and wind accounting for poor sighting conditions. Figure 3 shows the frequencies of occurrence of weather conditions, wind speeds, visibility estimates, sightability estimates and sea states experienced over the survey period. Estimates of sightability are a subjective measure of the overall conditions for spotting whales ranging from 1 as very poor to 5 as excellent, while visibility was defined as the maximum distance at which a humpback whale blow could be sighted. Weather conditions were predominantly overcast or foggy with few hours of partial sun. The lack of contrast resulting from cloud conditions and very calm seas on the afternoon of 20 January resulted in poorer sightability conditions being experienced then (animals were largely cued by body rather than blow during this period). Wind speeds were generally less than 24 knots, which is the upper limit of wind speed conditions utilised for survey in the IWC IDCR / SOWER surveys in the ice-edge region. Visibility and sightability ranged considerably dependent on the fog conditions. It is consequently recommended that the analyses of effective search widths take these into consideration as effective search widths under poorer conditions are likely to be narrower and will likely bias survey estimates upwards.

Sightability is the best overall index of sighting conditions and sightability estimates made during the cruise are plotted in Figure 4, while Table 3 provides the frequencies of estimates of sightability experienced at the beginning of each hour's observation effort on each day of the visual line transect survey. Apart from the first two transects between 000°E and 002°30'E when poor conditions were experienced across most of the transects on 13 and 14 January (see Table 3), acceptable sightability conditions were spread across most of the survey area as shown in Figure 4. No surveying was carried out for most of 21 January when the ship drifted due to limited visibility conditions resulting from fog.

Table 3. Sightability conditions (ranging from 1 = Poor to 5 = Excellent) experienced at the beginning of each hours observation effort on each day of the visual line transect survey. This Table assumes that the sightability conditions recorded on the hour have continued for the following hour.

Date	Avail. Time (hrs)	Sight 1 Time (hrs)	Sight 2 Time (hrs)	Sight 3 Time (hrs)	Sight 4 Time (hrs)	Sight 5 Time (hrs)
13-Jan	16	13	1	2		
14-Jan	16	8	1	3	4	
15-Jan	16	1		2	13	
16-Jan	16	1	4	7	4	
17-Jan	16		1	4	10	1
18-Jan	16		2	5	9	
19-Jan	16	3	1	3	8	1
20-Jan	16	4	2	6	4	
21-Jan	16	11	1	3	1	
22-Jan	16		1	2	13	
Total	160	41	14	37	66	2



Weather Codes

01: Blue sky 02: Partly cloudy

03: Cloudy 04: Overcast

05: Rain 06: Fog

The estimate of the maximum distance a humpback whale blow could be seen in n.miles.

1: Very poor 2: Poor

3: Moderate 4: Good

5: Excellent

0: Calm 1: Very Light

2: Light Breeze 3: Gentle Breeze

4: Moderate Breeze 5: Fresh Breeze

6. Strong Breeze 7: Near gale

Figure 3. Frequencies of occurrence of weather, wind speed, visibility, sightability and sea state estimates recorded at each hour during the Antarctic blue whale survey (including times when survey effort was not carried out).

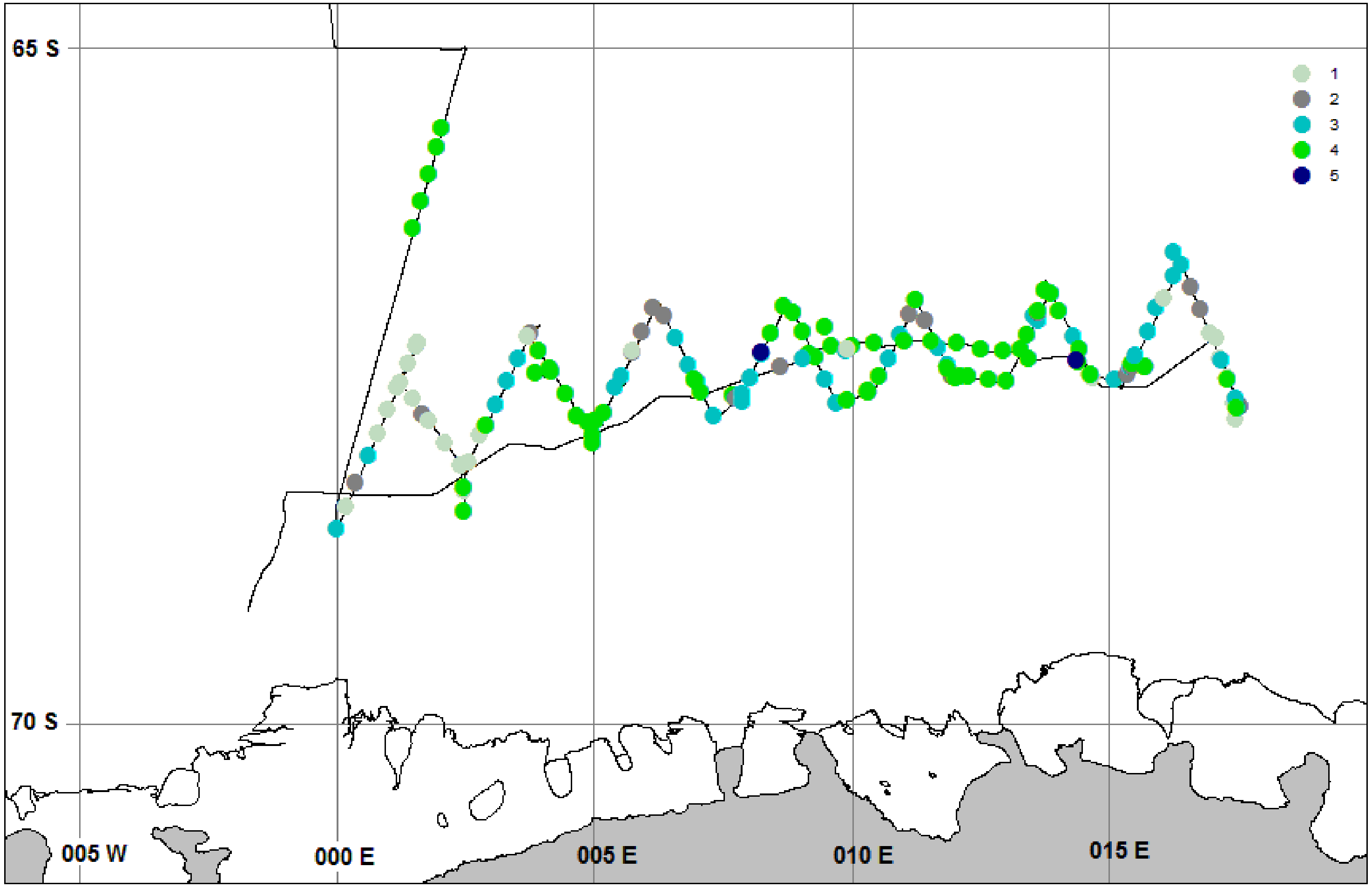


Figure 4. Sightability conditions recorded from the *SA Agulhas II* during the Antarctic blue whale survey at each hour of the survey period (including times when survey effort was not carried out). 1: Very poor, 2: Poor 3: Moderate 4: Good and 5: Excellent.

Whale Sightings

A total of 213 sightings of an estimated 451 cetaceans were sighted by the Whale Research Team during the research effort on the survey (Table 4), while a further 2 blue whales not sighted by the observers were reported by the ornithologist team working on the bridge, once the whales were aft of the visual survey area.

Table 4. The numbers of groups and individuals of different whale species sighted from the *SA Agulhas II* during the Antarctic blue whale survey. These include whales sighted during survey effort carried out during transit to and from the survey transects.

Species	Number of groups sighted during research effort	Number of individuals sighted during research effort	Number of groups sighted outside of research effort	Number of individuals sighted outside of research effort
Blue	14 (+1)	22 (+2)	2	2
Fin	14	31		
Sei	2	6		
Humpback Whale	21	39		
Like Humpback Whale	3	4		
Unid. Large Baleen Whale	12	18		
Minke	93	238		
Like Antarctic Minke Whale	3	7		
Like Minke Whale	2	3		
Sperm	13	14		
Unid. Large whale	4	5		
S. Bottlenose Whale	8	22		
Like S. Bottlenose Whale	1	1		
Killer Whale	3	14		
Unid. Small Whale	5	7		
Unid Whale	11	12		
Unid. Dolphin	1	4		
Unid. Small Cetacean	1	2		

The blue whale sighting in brackets was made by the ornithologist team working on the bridge, once the whales were aft of the visual survey area.

The exposed Whale Box was utilised for observations whenever possible although observations were carried out from the Glass House in acceptable sighting conditions when headwinds compromised observations from the Whale Box due to binocular vibration (in such cases probabilities of sighting were believed to be considerably higher from the Glass House despite searching though window panes). The distribution of sighting angles off the bow (Figure 5) shows some slight bias in sightings to the starboard side of the vessel presumably reflective of the position of the Whale Box observation platform on the starboard bridge wing. Such bias may require consideration in the determination of effective search widths in distance and density estimation.

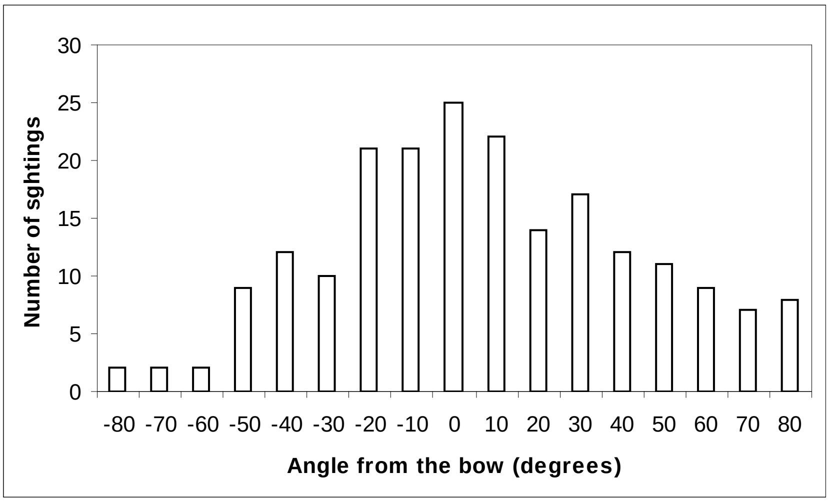


Figure 5. The distribution of sighting angles from the port beam (-90 degrees) to the starboard beam (+90 degrees).

Distributions of sightings

The distributions of cetacean sightings made during the Antarctic blue whale survey (including transits) are shown in Figure 6 to Figure 10.

As expected, the most commonly encountered whales were minke whales (93 groups of 238 individuals), all of which have been identified as Antarctic minke whales (*Balaenoptera bonaerensis*). No dwarf minke whales (*B. acutorostrata*) were identified, although the lack of closing where the probabilities of identification of the dwarf form would be higher must be noted. Group sizes of minke whales were estimated at between one and 12 individuals. Ninety five percent (225 of 238 individuals) of minke whale encounters were to the east of 008° E. Whilst the minke whale distribution shown in Figure 7 appears uniform to the east of this point, researchers noted that minke whale sightings tended to be aggregated with seven major areas (in the regions of longitudes 008°45’E; 009°48’E; 11°06’E; 12°24’E; 13°15’E; 14°03’E; 15°42’E) where minke whale encounters appeared higher. At this stage it is uncertain if this results from prey distribution, although number of sightings of minke whales involved what is believed to be feeding individuals with numerous head lunges and breaches observed during these encounters.

Based on their body shape, all blue whales were identified as Antarctic blue whales (*B. m. intermedia*). Seventeen groups of 26 blue whales were encountered on the cruise, with one sighting of two individuals made during research effort by other observers and two sightings of two individuals made outside of research effort. Sizes of observed blue whale groups ranged between one and three (seven singletons; seven pairs and one group of three, although one singleton joined a pair during the observation). One blue whale was encountered within a group of three fin whales and one pair was believed to comprise an adult and juvenile whale. Blue whale sightings appeared to be aggregated around 007°30’, 010° and 015°E.

Two individuals appeared to be feeding in association with the drifting vessel early in the morning of 20 January and duty crew suggested they had been alongside the vessel for three to four hours. Both of these individuals were later seen feeding alongside the small boat.

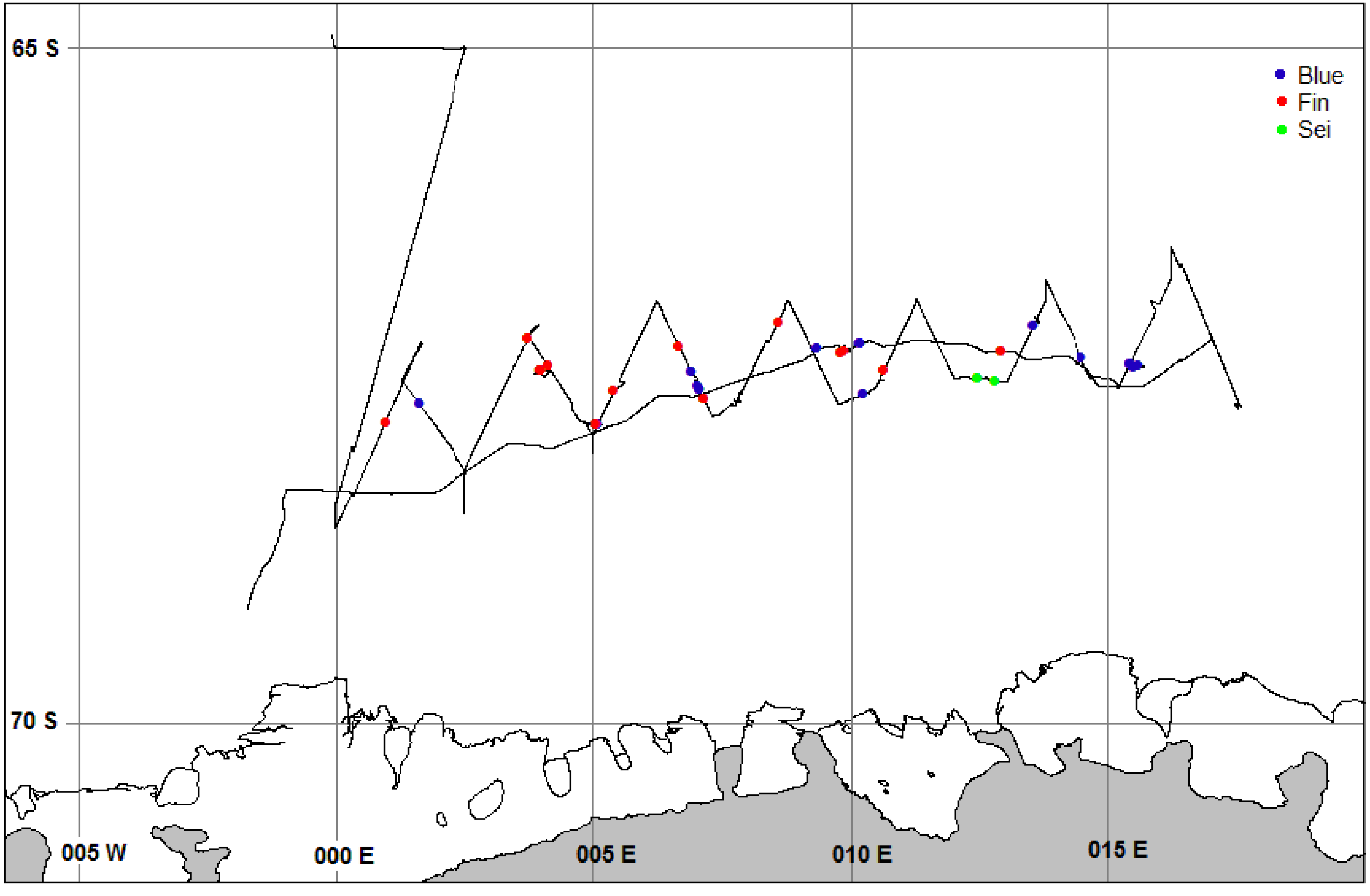


Figure 6. The distribution of blue whales, fin whales and sei whales sighted from the *SA Agulhas II* during the Antarctic blue whale survey

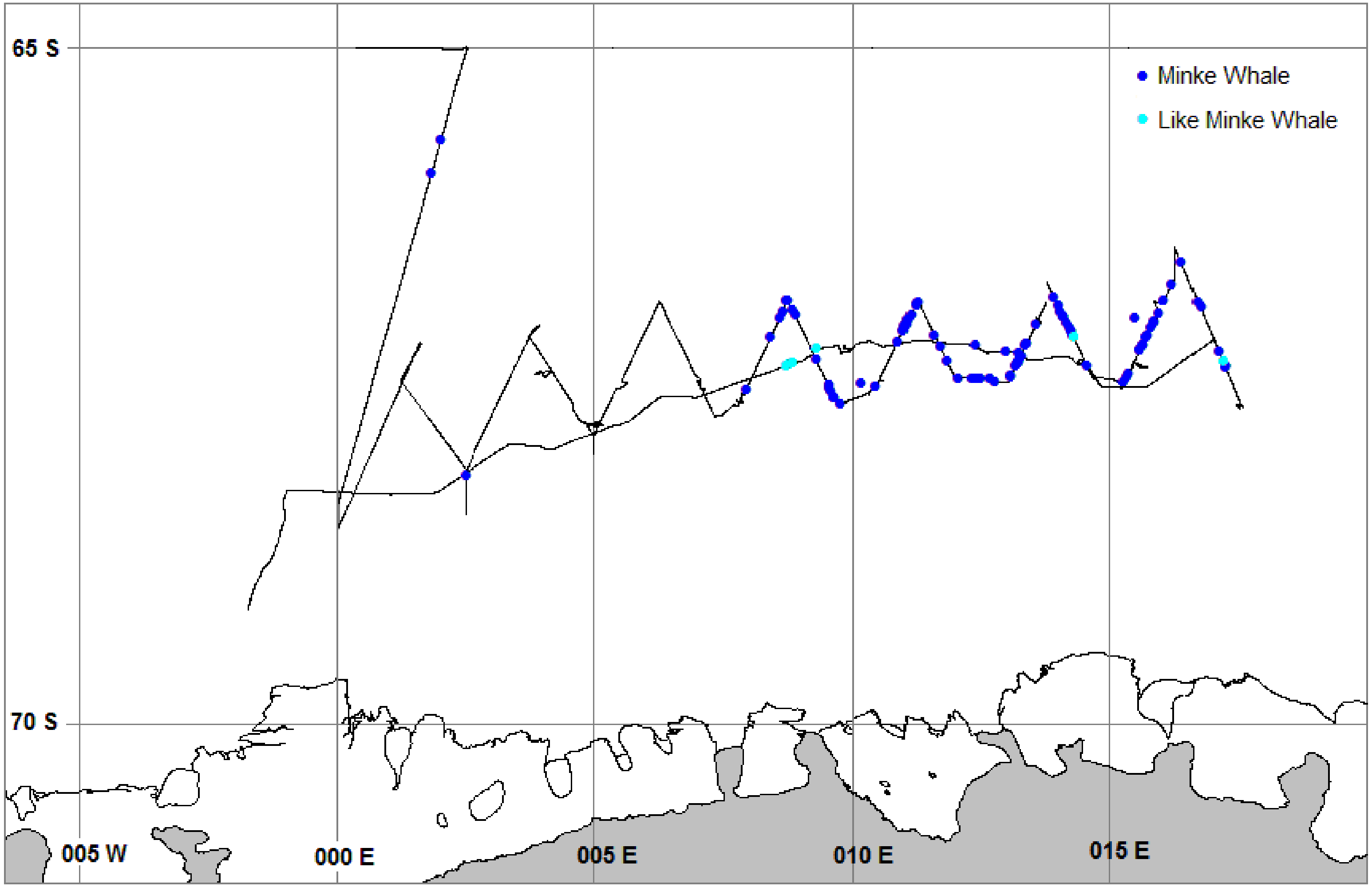


Figure 7. The distribution of minke whales and “like minke whales” sighted from the *SA Agulhas II* during the Antarctic blue whale survey

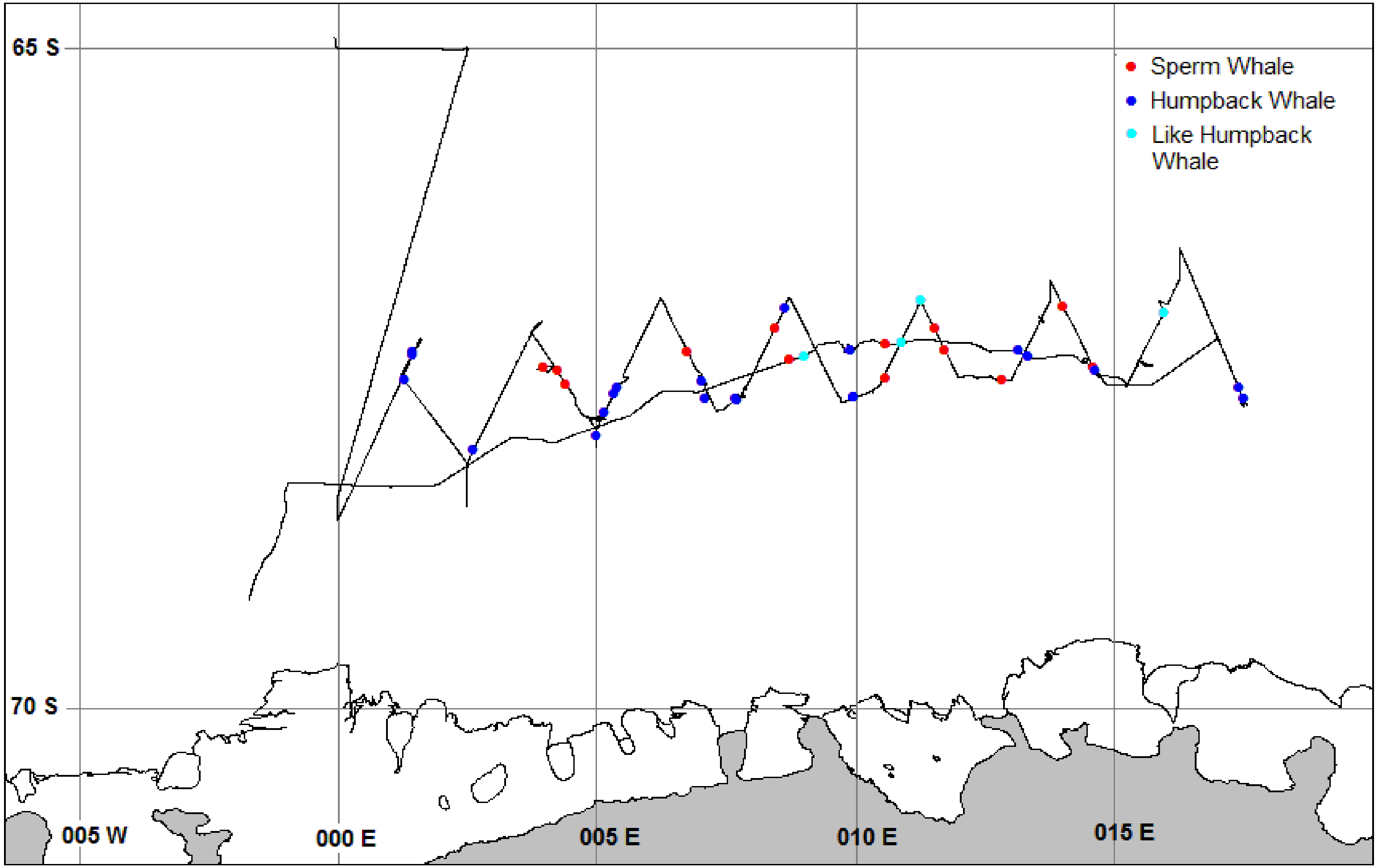


Figure 8. The distributions of sperm whales, humpback whales and "like humpback whales" sighted from the *SA Agulhas II* during the Antarctic blue whale survey.

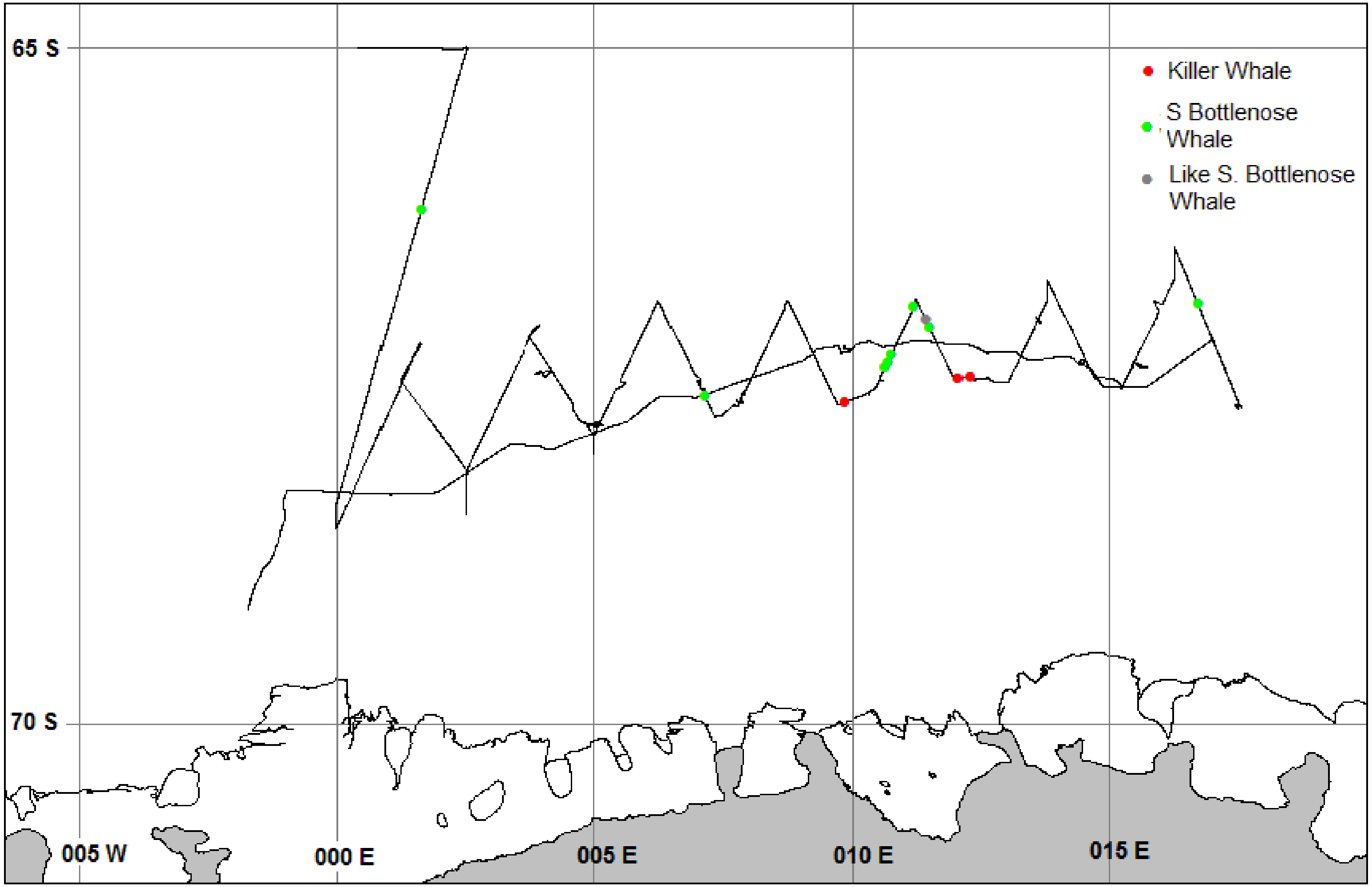


Figure 9. The distributions of killer whales, southern bottlenose whales and “like southern bottlenose whales” sighted from the *SA Agulhas II* during the Antarctic blue whale survey.

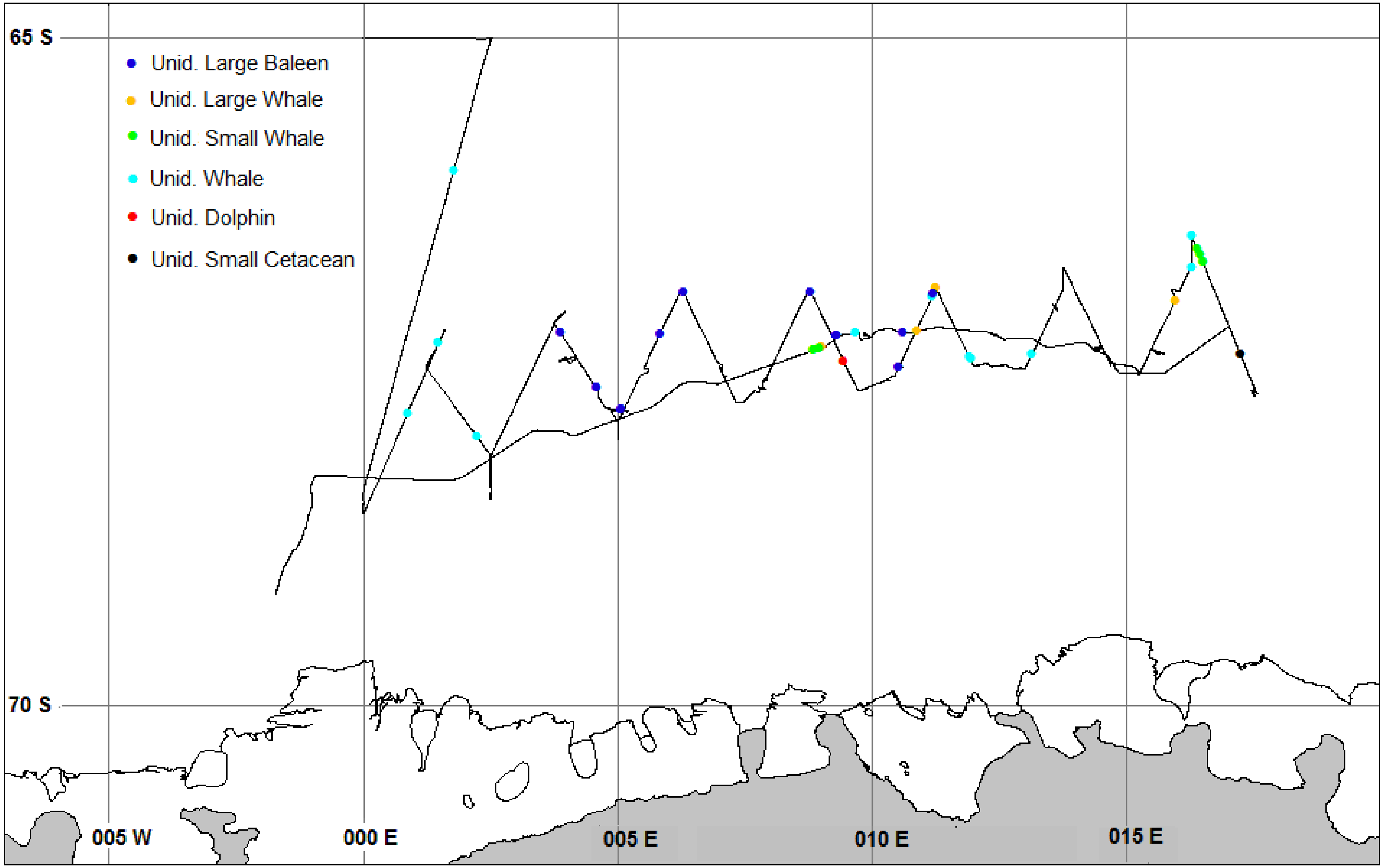


Figure 10. The distributions of unidentified cetaceans sighted from the *SA Agulhas II* during the Antarctic blue whale survey.

Interestingly high numbers of fin whales (14 groups of 31 animals) were encountered on the survey, the majority of which (26 of 31 animals sighted or 84%) were to the west of 010°E. Distribution of sighted groups ranged from the ice edge out to the northern limits of the transects. Group sizes ranged between one and four, with a mean group size of 2.2

The low numbers of humpback whales encountered on this survey were surprising given that humpbacks have been the most commonly sighted species in recent IWC SOWER cruises to this area. Twenty one sightings of 39 humpback whales and three sightings of four "like humpback whales" were distributed across the longitudinal range of the survey area, the majority of which were close to the ice edge. Group sizes ranged between 1 and 5 with a mean group size of 1.9.

Two groups of six sei whales were recorded on 18 January in the vicinity of the ice edge.

All three killer whale sightings (of an estimated 14 individuals) were made in association with the ice edge and approach of these groups suggested that they were patrolling the ice edge in loosely dispersed groups.

Apart from one group of unidentified dolphins, one group of unidentified small whales and eight groups of 22 southern bottlenose whales, no smaller cetaceans were sighted during the survey.

Small-boat work

Approaches of blue whale groups were carried out on eight occasions (see Table 5 below). Approaches were generally most successful in calm conditions when whales were approached slowly and feeding whales on 20 January appeared to show little response to the boat even after biopsy. Once approached at high speeds, whales became skittish and ran at high speed speeds after two or three surfacing bouts. The small-boat work carried out during this survey re-enforced the ease of small-boat work within the ice-edge region of the Antarctic where sea conditions may be considered relatively calm and conditions for use of the small boat were relatively benign.

Table 5. Results of small boat approaches on blue whales carried out from the *SA Agulhas II* during the Antarctic blue whale survey.

Day	Sighting Number	Group size	Time Launched	Time Recovered	Sea State	Speed of Approach	Photograph and Biopsy Opportunity
16 Jan	005	1	11:00:00	12:48:00	03	Rapid	Poor
16 Jan	013	2	16:42:00	18:00:00	02	Rapid	Poor
17 Jan	023	2	14:12:00	15:54:00	01	Slow	Good
18 Jan	033	1	19:12:00	20:20:00	03	Slow	Excellent
19 Jan	014	1	11:06:00	13:06:00	02	Slow	Good
19 Jan	022	1	19:48:00	21:00:00	01	Slow to Rapid	Fair
20 Jan	002	1	05:12:00	07:24:00	01	Slow	Excellent
20 Jan	001	1				Slow	Excellent
22 Jan	011	1	12:54:00	14:25:00	04	Slow to Rapid	Poor
22 Jan	012	2					

Sighting numbers 011 and 012 of 22 January merged prior to the small boat approach.

Interception of whale groups by SA Agulhas II

Five groups of blue whales were approached by the ship when weather conditions were considered too inclement for small-boat work, while Groups 11 and 12 (merged) of 22 January were photographed from the *SA Agulhas II* followed by a biopsy sampling attempt from the small boat. Group 3 of 20 January was not approached for photo-identification as it was assumed to comprise at least two of the animals successfully approached by small boat within the previous hour.

Of the three groups of killer whales approached by the *SA Agulhas II* for photo-identification only one group could be adequately photographed.

Whist the officers on watch must be commended for their attempts to approach whales closely for photo-identification, the slow manoeuvrability and acceleration of the *SA Agulhas II* in relation to the speed and manoeuvrability of blue or killer whales meant that small-boat work greatly facilitated photo-identification and biopsy research. Biopsy attempts would not have been possible from the *SA Agulhas II*.

Summary of Photo-identification and biopsy sampling results

Results of photo-identification and biopsy sampling of blue whales are summarised in Table 6 below. A total of four blue whales were successfully biopsied from 8 biopsy shot attempts and at least 16 animals are believed to have been adequately photographed by the three camera systems from either the small boat or the *SA Agulhas II*. However, the estimated 3150 images taken of the left and right dorsal flank aspects of blue whales (including distant images) still require collation for quality control and assignment to particular individuals. One photographed blue whale appeared to have marked propeller scars across its back, making it particularly identifiable in photo-identification studies (0 below). Importation of biopsy samples from the high Seas into South Africa was carried out under CITES Permit Number 138008 dated 29/10/2013.

One group of Type B killer whales was adequately photographed from the *SA Agulhas II*, the animals showing the large eye patch and yellowish diatom film of this type. Other groups were too evasive for adequate photo-identification.

Table 6. Summary of photo-identification and biopsy sampling of blue whales carried out from the *SA Agulhas II* during the Antarctic blue whale survey.

Date	Sight. No.	Group size	Confirmation		Approach By	Identification Photographs			Photo Form	Biopsy	Biopsy Form
			Start	End		MRI Canon	MRI Nikon	KF Canon			
14/01/2014	002	2	06:19:00	07:17:00	Ship	Nil	6265-6269	Nil	ID001	N	N/A
15/01/2014	010	2	13:53:00	15:22:00	Ship	1607-1680	Nil	2099-2124	ID002	N	N/A
15/01/2014	011	1	15:42:00	17:37:00	Ship	1681-2246	6271-6462	2126-2312	ID003	N	N/A
16/01/2014	005	1	10:27:00	12:48:00	FRB	2290-2309	Nil	Nil	ID004	N	N/A
16/01/2014	007	1	13:19:00	13:19:00	-	Nil	Nil	Nil	N/A	N	N/A
16/01/2014	013	2	16:18:00	17:59:00	FRB	2345-2469	6497-6717	2508-2647	ID005	N	N/A
16/01/2014	014	2	18:26:00	19:18:00	Ship	2470-2566	6717-6907	2659-2741	ID006	N	N/A
17/01/2014	023	2	13:50:00	15:50:00	FRB	2883-2920; 2920-3006	7064	2816-2835	ID007, ID008	Y/4M	BY001
18/01/2014	033	1	18:43:00	20:44:00	FRB	3519-3527; 3529-3588	7582-7621	2969-2978	ID009	Y	BY002
19/01/2014	014	1	10:30:00	13:34:00	FRB	3710-3796; 3797-3904	7622-7655; 7656- 7852	2981-2994	ID010	M	BY003
19/01/2014	022	1	19:23:00	21:00:00	FRB	3929-3947; 3948-3587	7854-7874	Nil	ID011	N	N/A
20/01/2014	001	1	05:00:00	08:03:00	FRB	4107-4191	Nil	2996-3017; 3096-3158	ID012	Y	BY004
20/01/2014	002	1	05:00:00	08:03:00	FRB	4016-4105	Nil	3019-3094	ID013	Y	BY005
20/01/2014	003	3	08:14:00	08:20:00	-	Nil	Nil	Nil	N/A	N	N/A
22/01/2014	011	1	11:52:00	16:10:00	Ship / FRB	4264-4569	7904-8019	3166-3276	ID014	N	N/A
22/01/2014	012	2			Ship / FRB	With above	With above	With above	With above	N	N/A
22/01/2014	019	2	17:42:00	19:08:00	Ship	4637-4647			ID015	N	N/A

Sighting #2 approached before sighting #1 on 20 January.

Krill echo-sounder surveying and krill sampling

A report of the krill surveying and sampling has been prepared by PhD candidate Mr. Fannie Shabangu and is provided as Appendix II

In summary, continuous acoustic traces from the calibrated 38 and 120 kHz echo sounders were logged over the extent of the visual line transect survey for post survey analyses of krill densities. A dedicated acoustic watch was routinely kept to identify trawlable aggregations of krill for target verification. Three suitable krill aggregations were targeted for 20 minutes each using the 2 m^2 Methot plankton net and total samples (of approximately 0.5 kg; and less than 2 kg for the first two samples respectively; no plankton were recorded in the third sample) were investigated for species identification and length measurements, with approximately 100 individuals being measured in each sample.

Good acoustic data were collected across the survey area and active acoustic data collection did not interfere with any instruments or operations aboard the vessel. Relative target strength will be compared to observed whale densities.

DISCUSSION

Deployment of Autonomous Acoustic Recorder Mooring

Although the mooring deployment on the Maud Rise was proposed as early as possible on the cruise and potentially on the Southward Transit Leg, prevailing ice conditions meant that the open water required for the mooring deployment was only accessible after the passage of the *SA Agulhas II* through this region. The mooring was consequently deployed midway through the cruise on 12 January. A second proposed mooring site had originally been identified in shallow water on the Astrid Ridge (68°25’S 011°00’E); however a mooring deployment would not have been possible at this position as it remained under sea ice for the duration of the cruise.

The deployment of the mooring on the Maud Rise was greatly facilitated by the benign weather and sea conditions experienced on the day allowing the deployment to be executed without any complications. Spooling out of the riser line was carried out by hand and would have been difficult under adverse conditions. Mooring recovery (and particularly of the Dyneema riser line) will need to be carried out onto a deck mounted winch drum that will allow the riser line to be immediately redeployed once the batteries and hard drive of the recording instrument and the batteries of the acoustic transponder have been replaced.

Interrogation of the acoustic transponders was carried out from four locations immediately after their deployment. Considerable variation in slant ranges were obtained, some of which were considered infeasible. The best estimate of the water depth and consequent instrument depth places the instrument at about 185m deep – well within the 300m depth limitation of the instrument. The AAR will run until 15 February 2015 and will consequently be best recovered on the return transit from SANAE in February 2015.

The possibility of short term deployments of shallow water short-term AAR moorings at Penguin Bukta require consideration particularly if the *SA Agulhas II* visits the bay twice within a season. Early season deployment and late season recovery in shallow (less than 200m) water depths could allow for a low cost shallow mooring to be deployed at the ice shelf edge with a low risk of ice induced damage / removal.

Visual line - transect abundance and distribution survey of whales

Selection of a visual line transect survey approach over a mark-recapture approach for estimating blue whale abundance

Kelly *et al.* (2012) argue that a line-transect approach alone is not a realistic option to obtain a precise circumpolar abundance estimate of Antarctic blue whales and that a mark-recapture approach using both visual and passive acoustic survey to target blue whales hotspots over a ten year duration would provide a viable estimate of abundance. However such an approach requires a) a considerable investment in “disposable” passive acoustic hardware, b) a multi-season survey approach and c) confidence that once encountered, Antarctic blue whales could be adequately approached with the available vessel for photo-identification and genetic sampling. Given these considerations, the South African blue whale survey adopted a multi-disciplinary approach of a visual line-transect survey for encountering animals with mark-recapture photo-identification and genetic sampling of animals once encountered within the 0-20°E blue whale hotspot. This approach also allows for distributional analyses in relation to environmental and biotic factors across a range of species. The survey protocols largely followed those of the IWC SOWER surveys that traversed this region in 2004/05 (Ensor *et al.*, 2005); in 2005/06 (Ensor *et al.* 2006) and in 2006/07 (Ensor *et al.* 2007).

Schedule and Survey Design of the Cruise

The original survey design across a latitudinal band 120 n miles from the ice edge was informed by distribution patterns of blue whales sighted on IWC SOWER cruises, although this was modified to a 60 n mile latitudinal band on the basis of whale distributions in relation to the ice edge (see Kasamatsu *et al.* 2000) and the probabilities of more inclement weather with distance from the ice edge.

Dynamic ice conditions across the study area required considerable further modification of this 60 n mile latitudinal band survey design. As the survey was originally planned for a week to ten days later than it was actually carried out, a southward retreat of the ice edge would have been expected over the ten days and the survey region would have been expected to be slightly further south. However the marked northward movement of the ice edge during the survey was surprising and may have resulted in a more northern survey area if the original survey timing had been in place. A detailed ice-edge configuration will be obtained from satellite imagery (once internet bandwidth is available in Cape Town) and will be used to define the survey area in association with the *in situ* ice-edge waypoints achieved during the survey.

The decision to terminate the survey at 017°30'E reflected both the predicted poor weather for 22 January and the balance in line transect and mark-recapture samples. There were opportunities for approaching five blue whales during the transit on 22 January and adequate photos appear to have been obtained for at least four of these. No biopsy samples could be collected.

Survey Effort

The Whale Box transferred from the *FRS Algoa* at the last minute before the cruise was not entirely suitable as a sighting platform, due to a) its position on the starboard bridge wing and some obstruction of the port beam view, and b) its exposed nature which resulted in considerable binocular vibration in headwinds. It is strongly recommended that modifications to the mammal / seabird observation areas on either the top observation deck or the Glass House / Monkey Island deck be carried out well prior to future surveys. Such modifications need to consider a) any obstruction of the observation view from, and b) the exposure in, the observation platform.

The almost 1000 n miles of achieved survey effort is high for the 11 days available, considering that over 40 hours were utilised for confirmation of whale groups and a further 6 hours and over 12 hours were utilised for deployment of moorings and transits respectively. As discussed above, exposure required observations to be carried out from within the Glass House at times and observations were carried out under poor sighting conditions due to the need to maintain progress with the survey schedule, particularly within the first day of the survey (when a half day had been lost on 12 January to transit from the mooring position to the start of the survey transects). It is strongly recommended that the secondary survey (P2) effort carried out from the Glass House requires stratification by weather or sightability conditions to determine the extent of P2 effort carried out under acceptable survey conditions. P2 survey effort carried out under sightability indices of 1 should be discarded in the line transect abundance estimation or at minimum analysed separately to allow for the reduced effective search widths and lower densities resulting from such conditions.

The rotation schedule of the two observer teams (of four observers each) was kept short (to a maximum of two and a half hours) to allow for rest, recovery from cold exposed conditions and alignment with meal times. Small-boat work was carried out by the off-effort team without significant survey disruption, with the on-effort team attempting to photograph animals during the identification confirmation process.

Whale Sighting Density and Distribution

The relatively high numbers of blue whales sighted on this cruise re-enforces the perception that the 000-020°E region of the Queen Maud Land coast is a hotspot for Antarctic blue whales. Although sighting densities of blue whales are lower than those recorded on the IWC SOWER surveys of 2004/05; 2005/06 and 2006/07 (Ensor *et* *al.* 2005, 2006 2007) in terms of effort distance, the number of sightings by days of survey are comparable with those of the SOWER surveys.

Distributions of baleen whales in Antarctic waters are presumably defined by prey availability and differences in distribution patterns might well be linked to selectivity of different prey species or size classes. Initial review of the distributions of sightings of the baleen whale species suggests that there is some spatial segregation of species across the survey area. The suggestion of clumping of blue whale sightings is similar to that recently found by Miller (pers. comm.) where acoustic detections of Antarctic blue whales to the south of Australia showed strong aggregations of whale groups. The marked longitudinal distributions of both fin whales to the west of 010°E and minke whales to the east of 008° E surprising, as is the southerly distribution of fin whales which Kasamatsu *et al.* (1996) found to be distributed further from the ice edge than found in this survey. Despite Kasamatsu *et al.* (2000) finding an interrelationship between distributions of minke and blue whales, and of minke and killer whales no such patterns were evident in these (albeit very limited) survey data, although all three killer whale sightings were at the ice edge and to the east of 009°E.

Of particular interest in the future analyses of these data is the interrelationship between what appear as patchy whale distributions and relative prey abundance as defined through echo-sounder surveys of krill prey. Primary productivity studies carried out during the whale survey by Emma Bone and Luke Gregor could take these analyses to a further trophic level.

Photo-identification and genetic marker sampling

No biopsy sampling could be carried out from the *SA Agulhas II* due to both limited maneuverability and acceleration and the inability to recover biopsy darts from the sea surface after sampling. Photo-identification of blue whales from the *SA Agulhas II* was difficult due to the range and orientation of the whales' avoidance of the vessel.

The value of the small-boat work in the collection of photo-identification and biopsy samples cannot be underestimated. Small boat approaches of blue whales were carried out relatively easily, although the need for slow quiet approaches was clearly evident. Once the blue whales had started running, approaches close enough for biopsy (with a crossbow) were almost impossible.

The use of two cameras operating concurrently with biopsy sampling in the small boat proved to be the optimal method for achieving good quality photographs and biopsy samples. The relatively low number of biopsy samples obtained may reflect the range of the crossbow and it is recommended that a longer range "Larsen Gun" be utilised in the future to increase both range and accuracy.

Echo-sounder surveys of krill

Although time precluded further Methot net sampling of krill swarm structure, the echo-sounder krill surveys were an extremely valuable component to the whale survey. More net sampling time is recommended for future studies if more accurate krill abundance and distribution estimation outputs are to be obtained. It is recommended that a dedicated acoustic team form part of any future such surveys in Antarctic waters.

ACKNOWLEDGEMENTS

The researchers thank the Captain and crew (in particular the Chief Mate, Bosun and Deck Crew) of the *SA Agulhas II* for their dedicated contributions to the success of this survey. We thank the UCT Oceanography team for able assistance in conducting the sighting survey. Loan of equipment from the Division Oceans and Coasts of the Department of Environmental Affairs is gratefully acknowledged, whilst the Southern Ocean Research Partnership and the International Whaling Commission Secretariat are thanked for ideas and data utilised in cruise planning. The South African National Antarctic Programme (SANAP) is acknowledged for funding of the South African Blue Whale Project and the Department of Environmental Affairs is acknowledged for all assistance in cruise planning and execution.

LITERATURE CITED

Best, P.B. 1994. A review of the catch statistics for modern whaling in Southern Africa, 1908-1930. *Reports of the International Whaling Commission*, 44: 467–485.

Best, P.B. 1998. Blue whales off Namibia – a possible wintering ground for the Antarctic population. Document SC/50/CAWS14 submitted to the IWC Scientific Committee.

Best, P.B. 2007. *Whales and dolphins of the Southern African subregion*. Cambridge University Press, Cape Town, South Africa.

Branch, T.A., Matsuoka, K. & Miyashita, T. 2004. Evidence for increases in Antarctic blue whales based on Bayesian modelling. *Marine Mammal Science*, 20, 726–754.

Branch, T.A., Stafford, K.M., Palacios, D.M., Allison, C., Bannister, J.L., Burton, C.L.K., Cabrera, E., Carlson, C.A., Galletti Vernazzani, B., Gill, P.C., Hucke-Gaete, R., Jenner, K.C.S., Jenner, M.-N.M., Matsuoka, K., Mikhalev, Y.A., Miyashita, T., Morrice, M.G., Nishiwaki, S., Sturrock, V.J., Tormosov, D., Anderson, R.C., Baker, A.N., Best, P.B., Borsa, P., Brownell Jr, R.L., Childerhouse, S., Findlay, K.P., Gerrodette, T., Ilangakoon, A.D., Joergensen, M., Kahn, B., Ljungblad, D.K., Maughan, B., McCauley, R.D., McKay, S., Norris, T.F., Oman Whale and Dolphin Research Group, Rankin, S., Samaran, F., Thiele, D., Van Waerebeek, K. and Warneke, R.M. 2007. Past and present distribution, densities and movements of blue whales in the Southern Hemisphere and northern Indian Ocean. *Mammal Review* 37 (2): 116-175.

Clapham PJ. and Baker CS. 2002. Modern whaling. In: W.F. Perrin B. Würsig and J.G.M. Thewissen (eds.) *Encyclopedia of Marine Mammals.* Academic Press New York.

Ensor P, Minami K, Morse L, Olson P, Sekiguchi K. 2008. 2007–2008 International Whaling Commission-Southern Ocean Whale and Ecosystem Research (IWC-SOWER) cruise. Document SC/60/IA1 submitted to the IWC Scientific Committee.

Ensor, P., Findlay, K. P., Hucke-Gaete, R., Kleivane, L., Komiya, H., Ljungblad, D., Marques, F., Muira, T., Sekiguchi, K. and Shimade, H. 2000. 1999-2000 IWC-Southern Ocean Whale and Ecosystem research (IWC-SOWER) Antarctic Cruise, Areas I and II. Document SC/60/IA1 submitted to the IWC Scientific Committee.

Ensor, P., Findlay, K., Hara, T., Hedley, S.L., Pitman, R., Sekiguchi, K., Tsurui, T. and Yamagiwa, D. 1997. 1996-97 IWC-Southern Ocean Whale and Ecosytem Research (IWC-SOWER) Antarctic Cruise, Area II. Document SC/49/SH7 submitted to the IWC Scientific Committee.

Ensor, P., Findlay,K., Friedrichsen, G., Hirose, K., Komiya, H., Morse, L., Olson, L., Sekiguchi, K., Waerebeek, V. and Yoshimura , I, 2005. 2004-2005 International Whaling Commission-Southern Ocean Whale and Ecosystem Research (IWC-SOWER) Cruise, Area III. Document SC/57/IA1 submitted to the IWC Scientific Committee.

Ensor, P., H. Komiya, P. Olson, K. Sekiguchi, and K. Stafford. 2006. 2005-2006 International Whaling Commission- Southern Ocean Whale and Ecosystem Research (IWC-SOWER) cruise. Document SC/58/IA1 submitted to the IWC Scientific Committee.

Ensor, P., K. Matsuoka, F. Marques, T. Miura, H. Murase, R. Pitman, K. Sakai and K. Van Waerebeek, 2001. 2000-2001 International Whaling Commission - Southern Ocean Whale and Ecosystem Research (IWC-SOWER) Circumpolar Cruise, Area V, VI and I. Document SC/IA/5 submitted to the IWC Scientific Committee.

Ensor, P., Komiya, H., Beasley, I., Fukutome, K., Olson, P. and Tsuda, Y. 2007. 2006-2007 International Whaling Commission—Southern Ocean Whale and Ecosystem Research (IWC-SOWER) Cruise. Document SC/59/IA1 submitted to the IWC Scientific Committee.

Ensor, P., Komiya, H., Kumagai, S., Kuningas, S., Olson, P. and Tsuda, Y. 2009. 2008-2009 International Whaling Commission-Southern Ocean Whale and Ecosystem Research (IWC-SOWER) Cruise. Document SC/61/IA19 submitted to the IWC Scientific Committee.

Ensor, P., Matsuoka, K., Hirose, K., Ljungblad, D., Minami, K., Olson, P., Rankin, S., Stevick, P., Tsunekawa, M. and Ugarte, F. 2003. 2002-2003 International Whaling Commission-Southern Ocean Whale and Ecosystem

Research (IWC-SOWER) Circumpolar Cruise, Area V. Document SC/55/IA1 submitted to the IWC Scientific Committee.

Ensor, P., Matsuoka, K., Komiya, H., Ljungblad, D., Miura, T., Morse, L., Olson, P., Olavarria, C., Mori, M. and Sekiguchi, K. 2004. 2003- 2004 International Whaling Commission-Southern Ocean Whale and Ecosystem Research (IWC-SOWER) Circumpolar Cruise, Area V. 68pp. Document SC/56/IA13 submitted to the IWC Scientific Committee.

Ensor, P., Pastene, L.A., Cawthorn, M., Findlay, K., Hedley, S.L., Iwakami, H., Kleivane, L., Pitman, R., Tsurui, T. and Sakai, K. 1998. 1997-98 IWC-Southern Ocean Whale and Ecosytem Research (IWC-SOWER) Antarctic Cruise, Area II. Document SC/50/Rep1 submitted to the IWC Scientific Committee.

Ensor, P., Sekiguchi, K., Doherty, J., Kleivane, L., Ljungblad, D., Marques, F., Matsuoka, K., Narita, H., Pitman, R. & Sakai, K. 1999. 1998–1999 IWC-Southern Ocean Whale and Ecosystem Research (IWCSOWER) Antarctic Cruise, Areas III and IV. Document SC/51/Caws6 submitted to the IWC Scientific Committee.

Ichihara, T. 1966. The pygmy blue whale, *Balenoptera musculus brevicauda*, a new subspecies from the Antarctic. In *Whales, Dolphins and Porpoises*. Norris, K.S. Ed. Berkeley and LA, Uni Cal. P 79-113.

Kasamatsu F, Joyce G, Ensor P, and Mermoz J (1996) Current occurrence of baleen whales in Antarctic waters. *Rep Int. Whaling Comm* 46: 293-304.

Kasamatsu, F., Matsuoka. K. and Hakamada, T. 2000. Interspecifc relationships in density among the whale community in the Antarctic. *Polar Biol.* (2000) 23: 466-473

Kelly, N., Miller, B., Peel, D., Double, M. and De La Mare, W. 2012. Strategies to obtain a new circumpolar abundance estimate for Antarctic blue whales: survey design and sampling protocols. Document SC/64/SH10 submitted to the Scientific Committee of the International Whaling Commission.

Mackintosh, N.A. and Wheeler, J.F.G. 1929. Southern blue and fin whales. *Discovery Reports* 1, 257–540.

Mackintosh NA. 1942. The southern stocks of whalebone whales. *Discovery Reports* 22: 197-300.

Mellinger, D.K., and C.W. Clark (2000): Recognizing transient low-frequency whale sounds by spectrogram correlation *Journal of the Acoustical Society of America* 107(6), 3518–3529.

Mellinger, D. Stafford, K.M., Moore, S.E., Dziak, R. and Matsumo, H. 2007. An Overview of Fixed Passive Acoustic Observation Methods for Cetaceans. *Oceanography* 20(4): 36-45.

Miller, B. Personal Communication. Australian Antarctic Division, Kingston, Hobart. 2013.

Olson, P. 2009. Blue whale photo-identification from IWC IDCR/SOWER surveys. Paper SC/61/SH19 presented to the IWC Scientific Committee, May 2009, Madeira.

Samaran, F., Adam, O. and Guinet, C. 2010. Detection range modelling of blue whale calls in the Southwestern Indian Ocean. *Applied Acoustics* 71: 1099-1106.

Samaran, F., K. Stafford, J. Gedamke, I. Van Opzeeland, B. Miller, A. Olivier, M. Baumgartner, S. Mussoline, and P. Guillaume. Report on the use of passive acoustic data to study distribution, seasonal presence, and population trends of blue and fin whales in the Southern Ocean. In: Annual Report of the Southern Ocean Research Partnership (SORP) 2011/12. Editor: E. Bell. Report to the 64th Scientific Committee of the International Whaling Commission. SC64/O13. pp. 13-37.

Širovic, A., J.A. Hildebrand, and S.M. Wiggins. 2007. Blue and fin whale call source levels and propagation range in the Southern Ocean. *Journal of the Acoustical Society of America* 122:1,208–1,215.

Sremba A.L., Hancock-Hanser B., Branch T.A., LeDuc R.L., Baker C.S. (2012) Circumpolar Diversity and Geographic Differentiation of mtDNA in the Critically Endangered Antarctic Blue Whale (*Balaenoptera musculus intermedia*). *PLoS ONE* 7(3): e32579. doi:10.1371/journal.pone.0032579.

Stafford, K.M., C.G. Fox, and D.S. Clark. 1998. Long range detection and localization of blue whale calls in the northeast Pacific using military hydrophone arrays. *Journal of the Acoustical Society of America* 104:3,616–3,625.

APPENDIX I - ACOUSTIC TRANSDUCER CALIBRATION AND ANTARCTIC KRILL (*EUPHAUSIA SUPERBA*) SURVEY AND SAMPLING

Mr Fannie Shabangu, PhD Candidate Mammal Research Institute, University of Pretoria / Department of Agriculture, Forestry and Fisheries.

Introduction

Distributions and density of baleen whales in Antarctic waters could be dependent on, or regulated by the distribution and abundance of prey species. Antarctic krill (*Euphausia superba*) is an important prey item of blue whales, and the distribution of blue whales may be closely associated with that of this shrimp-like crustacean. To verify the whale - prey relationship, acoustic data to estimate the krill distribution were recorded from the ship's calibrated Simrad EK60 38 and 120kHz echo sounder transducers installed on the drop keel of the *SA Agulhas II* over the extent of the visual line transect survey.

Calibration process

Calibration is the process of establishing a relationship between a measuring device and the unit of measure with a known performance output. The Simrad EK60 38 and 120kHz echo sounders were calibrated in Penguin Bukta (70° 16.291'S, 03° 04.133'W), on the afternoon of the 29th of December 2013. Both the on-axis sensitivity of the general-purpose transceiver (GPT) and the beam parameters of the ES38B and ES120-7C split-beam transducers were determined by using a 38.1mm diameter tungsten carbide (WC) standard sphere suspended beneath the vessel from three manual fishing reels with one and two reels being mounted on the port and the starboard gunwales respectively. The calibration was performed with the transmit power set at 2 and 0.5 kW for the 38 and 120kHz transducer respectively, a pulse duration of 1.024ms was used for both transducers. The environmental conditions at the calibration site were acceptable, the wind speed was 13.9 knots and wind direction was 131.8°; these measurements being obtained from the ship's Scientific Data System. The water depth at the calibration site was 178m, and wave height was estimated to be 0.75m. The water temperature of -1.43°C and salinity of 34.22ppt at the calibration depth were obtained from a CTD dip, the sound speed was calculated at depth to be 1445.3m/s, and the absorption coefficients were 9.82 and 24.2dB/km for the 38 and 120kHz transducer respectively. These environmental parameters were applied to both transducers during calibration.

A 60m line was rigged under the vessel prior to vessel resting on the ice edge and fastened to the gunwales. The 38.1mm WC sphere (target strength: -41.92dB at 38kHz and -40.02dB at 120kHz) was thoroughly immersed in a dishwashing liquid to prevent formation of air bubbles that might otherwise affect the calibration results. The sphere was then attached to the three monofilament nylon suspension lines and was lowered carefully from the forward reel position on the starboard gunwale. An additional weight was secured approximately 3m below the sphere (prior to deployment) to improve stability and control during the calibration exercise (Figure A1). Once the sphere was detected on the transducer beam, it was moved across all quadrants of the split beam transducers (Figure A2a and A3a). One team member on each side of the deck throughout the calibration procedure manually raised or lowered the sphere as requested by the scientist in the lab via UHF radio.

Survey methods

Continuous acoustic traces from both the 38and 120kHz echo sounders were logged over the extent of the visual line transect survey for post survey analyses of krill densities. Furthermore an acoustic watch was routinely kept by Mr Fannie Shabangu to identify aggregations of krill. Suitable krill targets were sampled using a 2m^2 Methot net for species identification and length measurements.

Preliminary results and discussion

The calibration of transducers produced satisfactory results that conformed to the manufacture's specifications, and the root mean squares were well below 0.4 (Tables 1 and 2). The GPT settings used during the survey are also given in Tables 1 and 2. The two starboard quadrants of the 38kHz were not tracking as expected, and also the edges of the port quadrants of the 38kHz were weak or unresponsive as depicted by the EK60 model (Figure

A2b). All the quadrants of the 120kHz transducer were working perfectly, and tracked well when the calibration sphere was moved around them and the EK60 model confirms this (Figure A3b).

The 120 kHz is the optimal frequency for krill detection, and these data will be used assessing the stock as further post-processing of the acoustic data is still to be conducted. Good acoustic data were collected from this survey and active acoustic data collection did not interfere with any instruments or processes aboard the vessel.

Large swarms of krill were observed during different times of the day. The deployment and retrieval of the $2m^2$ Methot net was smoothly conducted by the vessel crew and two samples (of approximately 0.5kg; and less than 2kg) were sub-sampled for species identification and length measurements. No plankton were found in the third sample attempt. All size ranges of Antarctic krill were present in the two net samples (Figure A4). Blue whales and other marine mammals were visual observed to feed on krill. More net sampling times are recommended for future studies if more accurate krill abundance and distribution estimation outputs are to be obtained.

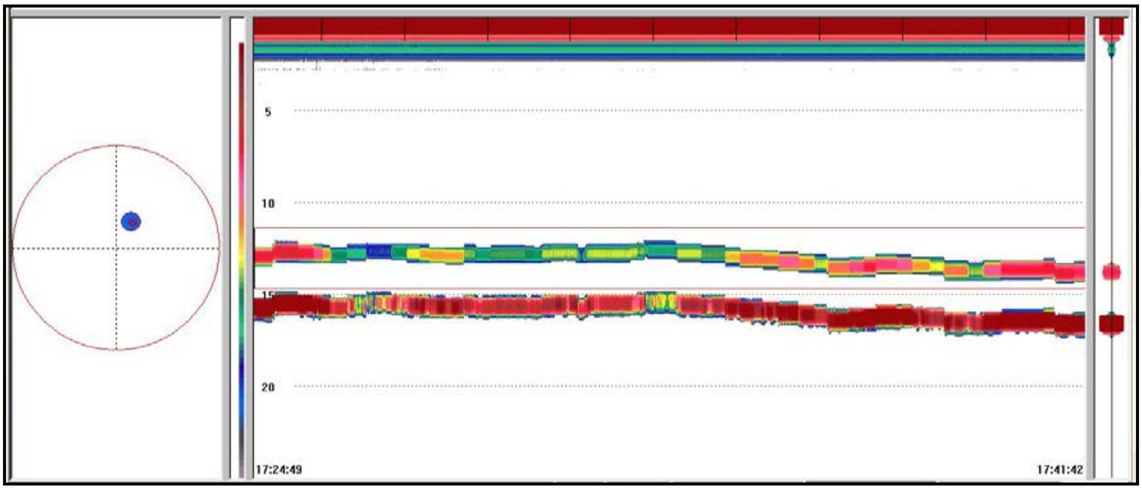


Figure A1. Transducer calibration process. The left wind shows all the transducer quadrants with the position of the sphere in the beam; the sphere was located on the starboard forward quadrant at the time of saving this window. The right window, the top track is the calibration sphere echo and the bottom track is the echo of the suspended weight.

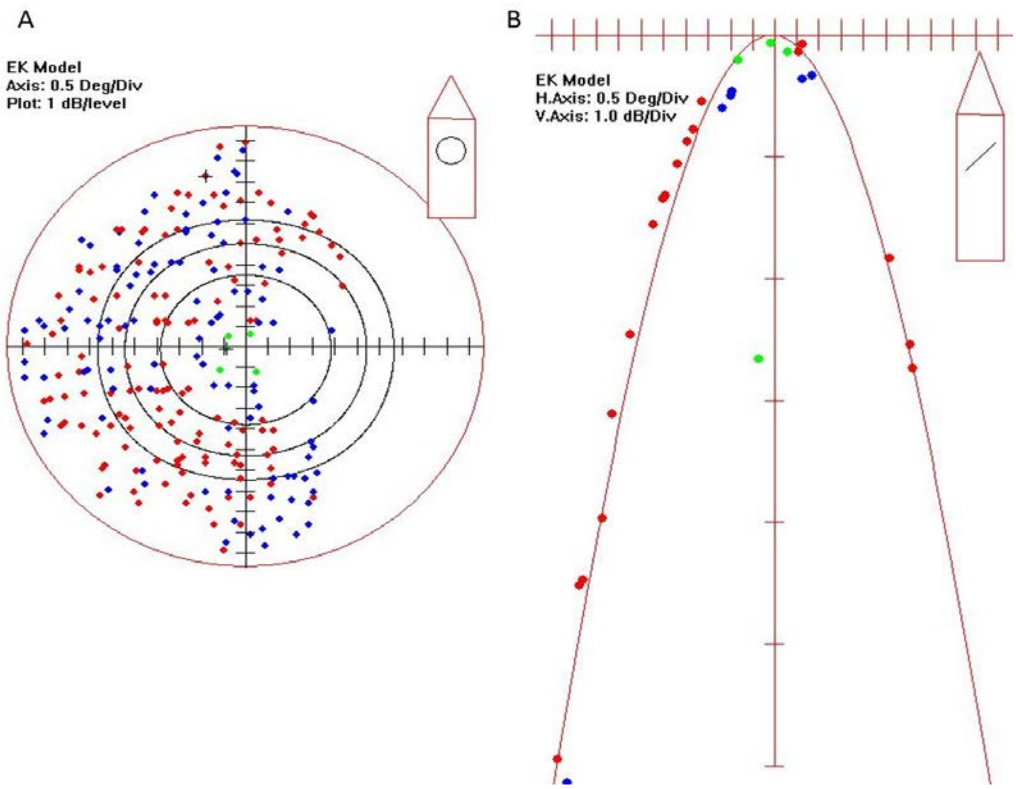


Figure A2. The polar (A) and 45° (B) EK60 beam model plots for the 38 kHz transducer showing all the points in each quadrant tracked by the calibration sphere.

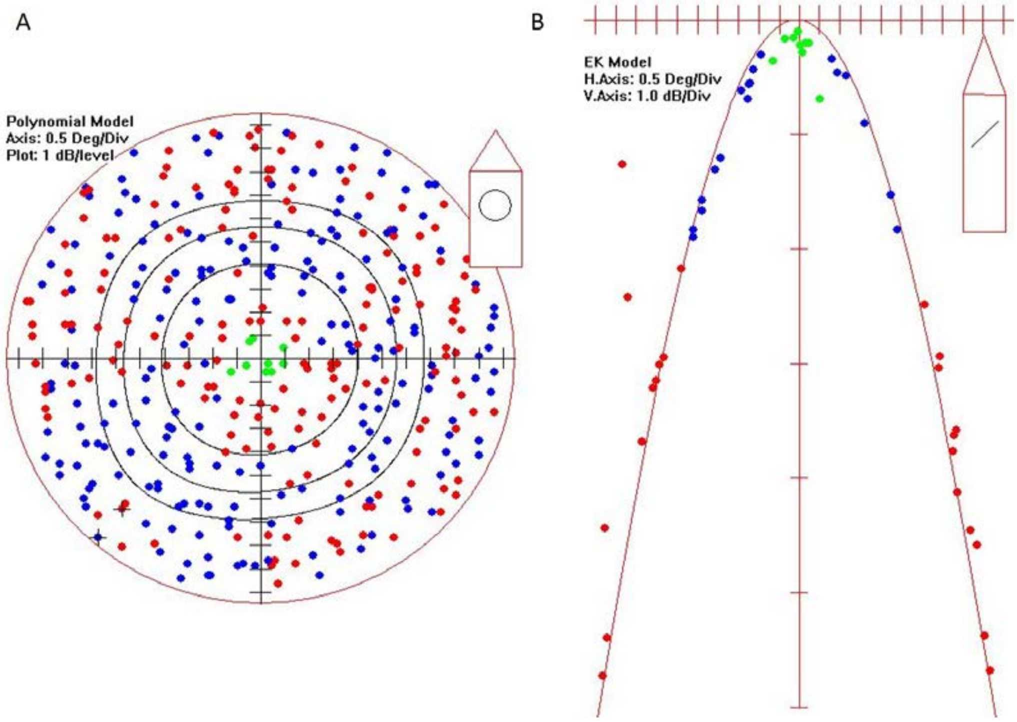


Figure A3. The polar polynomial and 45° EK60 beam model plots from the 120 kHz transducer showing all points in each quadrant tracked by the calibration sphere.

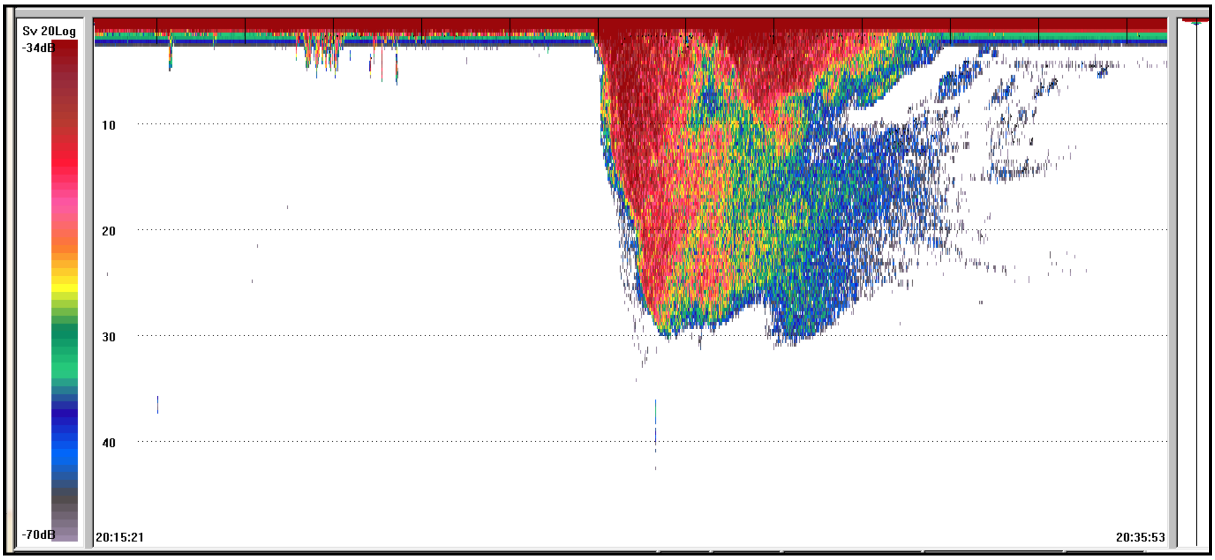


Figure A4. Echogram showing a dense swarm of krill observed at night during this survey.

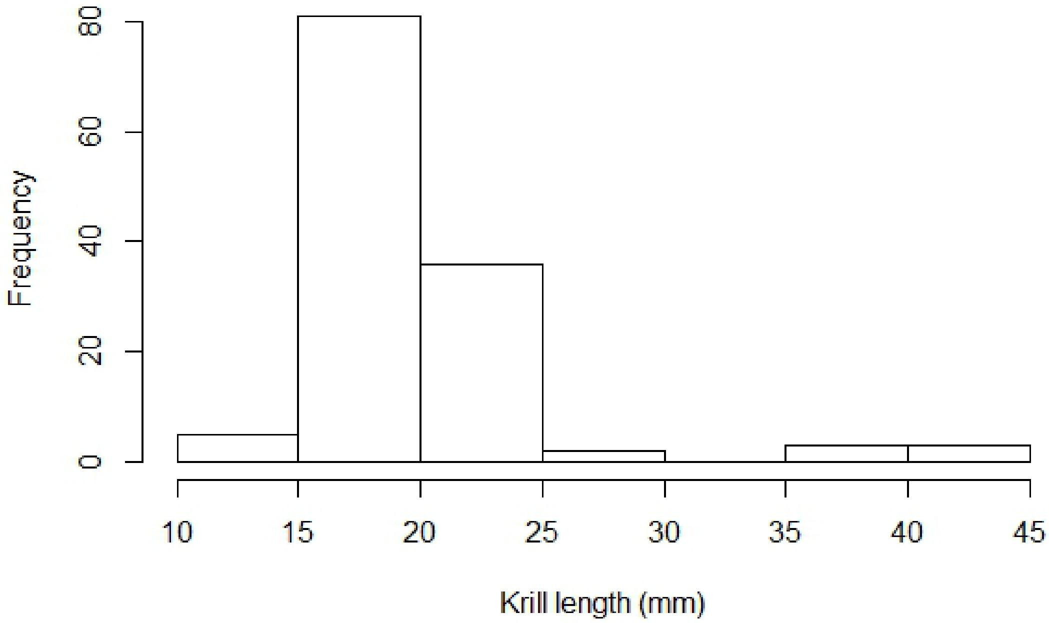


Figure A5. Length-frequency distribution of 130 Antarctic krill (*Euphausia superba*) from one of the net samples.

Table A1. The 38 kHz EK60 transceiver settings applied after the calibration procedure and used during the survey.

```
Calibration  Version   2.1.0.12

Date:  2013/12/29

Comments: Penguin
Penguin Bukta SA Agulhas II Calibration

Reference Target:
  TS                     -41.90 dB       Min. Distance          10.00 m
  TS Deviation             5.0 dB        Max. Distance          15.00 m

Transducer:  ES38B  Serial No.
  Frequency               38000 Hz       Beamtype                 Split
  Gain                    26.50 dB       Two Way Beam Angle    -20.6 dB
  Athw. Angle Sens.          21.90       Along. Angle Sens.       21.90
  Athw. Beam Angle        7.10 deg       Along. Beam Angle     7.10 deg
  Athw. Offset Angle      0.00 deg       Along. Offset Angle   0.00 deg
  SaCorrection             0.00 dB       Depth                  0.00  m

Transceiver:  GPT  38 kHz 009072060466 1-1 ES38B
  Pulse Duration          1.024 ms       Sample Interval     0.185    m
  Power                    2000  W       Receiver Bandwidth    2.43 kHz

Sounder Type:
  EK60 Version  2.4.3

TS Detection:
  Min. Value              -50.0 dB       Min. Spacing             100 %
  Max. Beam Comp.           6.0 dB       Min. Echolength           80 %
  Max. Phase Dev.              8.0       Max. Echolength          180 %

Environment:
  Absorption Coeff.   9.8 dB/km          Sound Velocity     1445.3 m/s

Beam Model results:
  Transducer Gain    = 26.70 dB          SaCorrection        = -0.37 dB
  Athw. Beam Angle   = 6.65 deg          Along. Beam Angle   = 6.32 deg
  Athw. Offset Angle =-0.00 deg          Along. Offset Angle=-0.08 deg

Data deviation from beam model:
  RMS =     0.35 dB
  Max =     0.78 dB  No. =     88  Athw. = -0.9 deg  Along =  4.1 deg
  Min =    -2.61 dB  No. =      1  Athw. = -0.4 deg  Along = -0.1 deg

Data deviation from polynomial model:
  RMS =     0.32 dB
  Max =     0.73 dB  No. =     88  Athw. = -0.9 deg  Along =  4.1 deg
  Min =    -2.46 dB  No. =      1  Athw. = -0.4 deg  Along = -0.1 deg
```

Table A2. The 120 kHz EK60 transceiver settings applied after the calibration procedure and used during the survey.

```
Calibration  Version   2.1.0.12

Date:  2013/12/29

Comments:
Penguin Bukta SA Agulhas II Calibration

Reference Target:
  TS                   -40.02 dB      Min. Distance        10.00 m
  TS Deviation            5.0 dB      Max. Distance        15.00 m

Transducer:  ES120-7C  Serial No.
  Frequency            120000 Hz      Beamtype              Split
  Gain                 27.00 dB       Two Way Beam Angle  -21.0 dB
  Athw. Angle Sens.       23.00       Along. Angle Sens.     23.00
  Athw. Beam Angle     7.00 deg       Along. Beam Angle   7.00 deg
  Athw. Offset Angle   0.00 deg       Along. Offset Angle 0.00 deg
  SaCorrection          0.00 dB       Depth               0.00  m

Transceiver:  GPT 120 kHz 0090720674c2 2-1 ES120-7C
  Pulse Duration       1.024 ms       Sample Interval    0.185   m
  Power                  500  W       Receiver Bandwidth  3.03 kHz

Sounder Type:
  EK60 Version  2.4.3

TS Detection:
  Min. Value           -50.0 dB       Min. Spacing           100 %
  Max. Beam Comp.        6.0 dB       Min. Echolength         80 %
  Max. Phase Dev.          8.0        Max. Echolength        180 %

Environment:
  Absorption Coeff.  24.2 dB/km       Sound Velocity    1445.3 m/s

Beam Model results:
  Transducer Gain    = 26.30 dB       SaCorrection        = -0.34 dB
  Athw. Beam Angle   = 6.47 deg       Along. Beam Angle   = 6.51 deg
  Athw. Offset Angle =-0.05 deg       Along. Offset Angle=-0.05 deg

Data deviation from beam model:
  RMS =     0.31 dB
  Max =     3.53 dB   No. =   128  Athw. = -2.9 deg  Along = -3.2 deg
  Min =    -0.61 dB   No. =    96  Athw. =  4.8 deg  Along = -0.7 deg

Data deviation from polynomial model:
  RMS =     0.25 dB
  Max =     3.02 dB   No. =   128  Athw. = -2.9 deg  Along = -3.2 deg
  Min =    -0.61 dB   No. =   127  Athw. = -3.4 deg  Along = -3.9 deg
```