Final report for a survey of cetaceans in the eastern Great Australian Bight
26th April – 8th May 2013
by
The International Fund for Animal Welfare
and
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SUMMARY

The eastern Great Australian Bight (GAB) upwelling area off the coast of South Australia is severely data deficient in terms of both understanding cetacean biodiversity and oceanographic fluctuations between years. The Australian Government opened two lease areas for oil and gas exploration in 2010 and in response to this, International Fund for Animal Welfare (IFAW) Oceania undertook a visual/acoustic survey of the licenced area for marine mammals in April/May 2013. The objective of the work was to provide initial baseline data on the presence, diversity and distribution of cetaceans in this poorly studied area and this is the first systematic vessel-based research survey of the region conducted during this time of year. The survey site covered 15,130 km^2 and included shelf, slope and abyssal habitats. During 1100 km (220 hours) of survey effort, 20 sightings were made of four species of cetaceans (pilot whale, common dolphin, bottlenose dolphin and Shepherd's beaked whale) and one species of seal. In addition, sperm whales were also detected acoustically, usually in waters deeper than 1000 m, and although there were no sightings during vessel surveys, the aerial surveys conducted of the same area reported two sightings of three individual sperm whales (see Appendix II). Odontocete clicks, whistles and pulsed calls were detected throughout 32% of the study site and were mainly concentrated around the continental slope between depths of 200 m and 3000 m. The peak in detections was situated within the planned seismic survey area and over the slope, areas that were also found to have low ambient noise levels during the course of the study. The majority of acoustic detections were made during hours of darkness, highlighting an inherent weakness in surveys relying on visual techniques alone. Baleen whales were not seen or heard throughout the survey, nor were they encountered during consecutive aerial surveys. These results suggest the proposed seismic survey will be both spatially and temporally proximate to aggregations of whales including sperm whales, pilot whales and Shepherd's beaked whales, a species that may have only been previously seen alive at sea on fewer than ten occasions worldwide. As such, it is recommended that visual and acoustic surveys for cetaceans be conducted over multiple years to gain a better understanding of presence, diversity and distribution in this area, to better inform future decisions around industrial development and conservation.

1. INTRODUCTION

The eastern Great Australian Bight (GAB) upwelling area off South Australia is severely data deficient both in terms of understanding upwelling fluctuations from year to year and in terms of cetacean biodiversity. The Australian Government opened two lease areas for oil and gas exploration in 2010 (EPP-41 and EPP-42). Presently, one petroleum exploration company has applied for permission under the Environment Protection Biodiversity Conservation (EPBC) Act to conduct seismic testing in this area during the months of March to May. This time of year is considered a "shoulder season" between blue whale feeding aggregations in the summer months and the migration of southern right whales to calving and breeding grounds in winter months.

This area includes the Kangaroo Island pool and canyons, a key ecological feature and a conservation site of regional priority in the south-west marine bioregional plan (SEWPaC, 2012a). The Government's protected matters search tool reveals that the area represents habitat for 28 species of cetacean including sperm whales, fin and sei whales. South Australian waters also encompass a worldwide hotspot in terms of beaked whale species diversity and one of only three recognised feeding areas for the endangered blue whale in Australian waters. Survey effort is severely lacking in this area, particularly during the months of March to May. Scientific data regarding the diversity, distribution and presence of cetacean species are urgently needed in this oil and gas development area and Australian waters more generally in order to inform conservation management and decisions on industrial activity in the area.

The field work conducted in 2013 was the first systematic vessel-based research survey of the area during these months. The objective of the work was to conduct visual and acoustic research for cetaceans in the waters of the eastern GAB upwelling area, providing initial baseline data on presence, diversity and distribution in this poorly studied area.

1.1 Baleen whales

Blue whales, thought to be pygmy blue whales (*Balaenoptera musculus brevicauda*), aggregate off southern Australia each austral summer (November to May) to feed on euphausiid (krill) swarms (*Nyctiphanes australis*) in the seasonal cold water upwelling (Gill *et al*., 2011). Gill and colleagues (2011) describe the presence of complex cross-shelf canyons in this area as being similar to those linked to the upwelling along the Bonney Coast, and propose that the nutrient-rich waters of the Kangaroo Island pool influence both blue whale and krill distribution in this area. During aerial surveys conducted in 2003, blue whales were observed feeding along the outer shelf to the south and west of Kangaroo Island, confirming that the blue whale feeding ground in this region was larger than previously thought (Morrice *et al*., 2004). The exact timing of blue whale presence in the area is highly variable, as is the upwelling which is thought to drive prey availability and distribution in the region (Gill *et al*., 2011).

Southern right whales (*Eubalaena australis*) migrate to calving and breeding grounds in southern Australian waters during the austral winter each year. These whales occupy coastal waters from May to October and female southern right whales exhibit high site fidelity during calving years (Pirzl, 2008). The exact migratory routes of southern right whales from Antarctic to Australian waters remain unknown. However, it is recognised in the Conservation Management Plan for the Southern Right Whale 2011-2016 (SEWPaC, 2012b) that habitat connectivity between calving areas is of importance to the recovery of this endangered whale species. It is likely that pregnant southern right whales migrating to nearby calving grounds at Sleaford Bay would travel through the area to the west of Kangaroo Island on their migratory path.

Although sighted on previous occasions, data regarding distribution, abundance, movement patterns and habitat use of fin whales (*Balaenoptera physalus*) and sei whales (*Balaenoptera borealis*) in this area are deficient due to a lack of survey effort. Observations have been made of both fin and sei whales feeding alongside blue whales nearby in the Bonney Upwelling (Gill, 2002).

Large whales are subject to a wide range of anthropogenic impacts. From the late 1700s to as recently as 1978, southern right, humpback, sperm and blue whales all suffered some degree of population depletion by whaling carried out in Australian waters. The extent to which pygmy blue whales were impacted by the whaling activity that pushed Antarctic blue whales (*B. m. intermedia*) to the brink of extinction (with as few as 150 individuals remaining in 1973; Branch *et al*., 2004) is still not fully understood. Since the IWC moratorium on whaling came into effect in 1986, other anthropogenic activities continue to threaten the recovery of large whales. Entanglement in fishing gear for example is a major source of non-natural mortality (Perrin *et al*., 1994; Volgenau *et al*., 1995) and ship strike poses a threat to all species of great whales, especially from large, fast commercial vessels such as container ships (Clapham *et al*., 1999). Noise pollution is a growing issue in the waters around Australia (see Erbe, 2013, for a review). Shipping traffic is steadily increasing as are the number of seismic surveys, due to the dramatic increase in offshore oil and gas development in recent years.

Baleen whales are known to produce numerous types of low frequency signals (see for example, Cummings *et al*., 1986; Edds, 1988; McDonald *et al*., 2001; Thompson *et al.,* 1996), mostly below 50 Hz. Off Madagascar and Western Australia, regionally distinctive sounds are produced by suspected pygmy blue whales with differing frequencies and sound production patterns (Ljungblad *et al*., 1998; McCauley *et al*., 2000) and recently, the vocal repertoire of southern right whales in New Zealand waters has been described (Webster and Dawson, 2011). With limited knowledge of sei and fin whale vocalisations and increasing evidence suggesting that song patterns from blue whales can be used to distinguish between stocks (McDonald *et al*., 2006), efforts to describe the vocalisations of baleen whales are particularly important.

1.2 Beaked whales

The beaked whales are one of the least known families of cetaceans. They are particularly difficult to study, because they are deep divers with an oceanic distribution. They are also very difficult to detect visually at sea (Barlow *et al.,* 2006). In recent years, there has been increasing evidence that they are vulnerable to anthropogenic sounds, particularly seismic airguns and military mid frequency sonar (2-10 kHz) (e.g. Tyack *et al*., 2011; DeRuiter *et al.,* 2013). In the past 40 or so years, over 40 mass strandings have been reported world-wide (probably representing a small proportion of all beaked whale strandings). Some of these were concurrent with naval exercises and the use of active sonar, and the overall pattern of strandings has led to increasing concerns that certain high intensity sounds may result in the death and injury of beaked whales (Cox *et al*., 2006).

Beaked whales are known to be difficult to observe at sea (e.g. Barlow *et al.,* 2006), so improved systems for detecting beaked whales, for example using passive acoustic techniques, have intrinsic value. Beaked whales have been found to use relatively high frequency echolocation (up to 50 kHz or more) and non–echolocation sounds in the region of up to at least 16 kHz. Some of these vocalisations appear to be quite distinctive from those of other cetaceans (Johnson *et al*., 2004; Zimmer *et al*., 2005); a very positive finding in terms of the viability of identification of beaked whales by acoustics.

The SEWPaC cetacean report card for the south-west region (SEWPaC, 2012c) details the occurrence of beaked whales in the region; "*Information is limited on the ecology of beaked whales, and most information about the species group has been gleaned from stranded specimens (MacLeod & Mitchell 2006). Beaked whales are generally found in deep water offshore around seamounts and canyons. They dive for long periods and are rarely observed. South-west Australia has been listed as one of the key areas for beaked whales worldwide, particularly Hector's, Andrew's and Cuvier's beaked whales (MacLeod & Mitchell 2006), while the most common beaked whale to strand in South Australia is the strap-toothed beaked whale (Kemper 2008)*." In 2012, six rarely-seen Shepherd's beaked whales (*Tasmacetus shepherdi*) were sighted in this area (BWS, 2012) and a sighting of this species was also documented further east in the Bonney Upwelling (Miller *et al*., 2012). Based on historical data, eight species of beaked whale may occur in the area and a number of sightings of groups of Arnoux's beaked whales (*Berardius arnuxii*) have been reported in the past (Kemper, *pers. comm*.).

Current information on beaked whale distribution is sparse, but they "seem to be most common in slope waters and around offshore volcanic islands" (Kaschner, 2007). Certainly, many of the recent strandings have been in areas with abrupt undersea topography (e.g. Hellenic Trench, Greece, the Canary Islands and Galápagos Islands; Frantzis, 1998; Podestà *et al*., 2006; D'Amico *et al*., 2009). The physical basis for the association probably lies in the effects of topography on the water column and the way it concentrates nutrients and prey. A better understanding of the preferred habitats of these whales will support measures to protect them.

1.3 Sperm whales

Sperm whales (*Physeter macrocephalus*) are the largest of the toothed whales and have been recorded off all Australian states (Bannister *et al*., 1996). Sperm whales are deep diving cetaceans that forage for oceanic cephalopods for prolonged periods and are usually found in deep waters (>200 m) in pelagic habitats. In Australia, key locations for sperm whales include the area between Cape Leeuwin and Esperance, Western Australia, close to edge of continental shelf; southwest of Kangaroo Island, South Australia; off the Tasmanian west and south coasts; off New South Wales, including Wollongong; and off Stradbroke Island, Queensland (Bannister *et al*., 1996). Sperm whales were hunted commercially in Australia until 1978 and the only systematic survey for these whales was conducted in the late 1960s; as a result the current population status is not known (SEWPaC, 2012d).

Sperm whales produce very distinctive, loud and regular characteristic broadband clicks at a rate of about one per second during most of their deep dives. Between dives they may spend only short periods (about 10 minutes) at the surface. These characteristics make sperm whales well-suited to acoustic surveying, but more difficult to survey visually. Sperm whale clicks can easily be detected and analysed with available software allowing the location of the whale to be determined (Gillespie and Leaper, 1997).

1.4 Other odontocetes

Pilot whales

Both short-finned (*Globicephala macrorhynchus*) and long-finned pilot whales (*Globicephala melas*) are found in Australian waters, although the latter appears to occur exclusively south of 27°S (Ross, 2006). These gregarious delphinids are highly social animals and are typically observed in smaller groups of 10 to 50 although they are also seen in large pods from hundreds to thousands (Bannister *et al*., 1996). Pilot whales have been widely recorded in the waters off Australia and the short-finned species is found in tropical (22-32°C) to temperate (10-22°C) oceanic waters and the long-finned in temperate (10-20°C) and deep, sub-Antarctic (1-8°C) waters. Long-finned pilot whales also appear to favour areas of higher productivity along continental slope waters, apparently moving into shallower shelf waters (<200 m) to hunt for prey (Ross, 2006). Neither short-finned nor long-finned pilot whales have been systematically surveyed in Australian waters despite the numerous sightings.

Bottlenose dolphin

Historically, all bottlenose dolphins in Australia were recognised as *Tursiops truncatus*. More recently, *Tursiops aduncus* have been confirmed off eastern and western Australia (see Möller & Beheregaray, 2001 and Krützen *et al*., 2004) and *Tursiops australis* off south eastern and southern Australia (Charlton-Robb *et al*., 2011). Molecular and morphological differences are well described, but biological and habitat preference information is limited for bottlenose dolphins inhabiting Australian waters, although they are known to be abundant and widely distributed in both coastal and offshore waters (Ross, 2006).

Common dolphin

Short-beaked common dolphins (*Delphinus delphis*) are poorly studied in Australian waters and so information about their ecology, distribution and abundance is currently lacking (Ross, 2006). In South Australia, Gulf St. Vincent is recognised as a key locality for this dolphin species; it is suspected that this is due to high prey availability or because the shallow, sheltered waters provide protection from the many deep-water predators in this area (Filby *et al*., 2010). Bycatch of common dolphins in purse-seine fisheries, such as the South Australian Sardine Fishery, has been identified as a serious cause of mortality likely to be impacting these dolphins at a population level (Bilgmann *et al*., 2008).

1.5 Aims

The primary purposes of this survey were to:

- Collect baseline visual and acoustic data for cetaceans in the eastern GAB upwelling area during April and May (a season with little previous survey effort).
- Collect photographic identification data on priority species (see Appendix I) in order to support local photo-ID catalogues and to further understanding of which populations utilise this upwelling area.
- Investigate the importance of slope waters for all species.

2. METHODOLOGY

The research was conducted in the eastern Great Australian Bight from the 26th April to the 8th May 2013 in a 15,130 km^2 offshore area located to the south of Spencer Gulf and limited by the most western tip of Kangaroo Island (Figure 1). The survey was carried out from the 19 m sailing catamaran *SV Pelican* with a team of 13 personnel; seven scientific staff, five crew and one cinematographer. When sailing was not possible, twin 50 HP diesel sail drive engines provided auxiliary power.

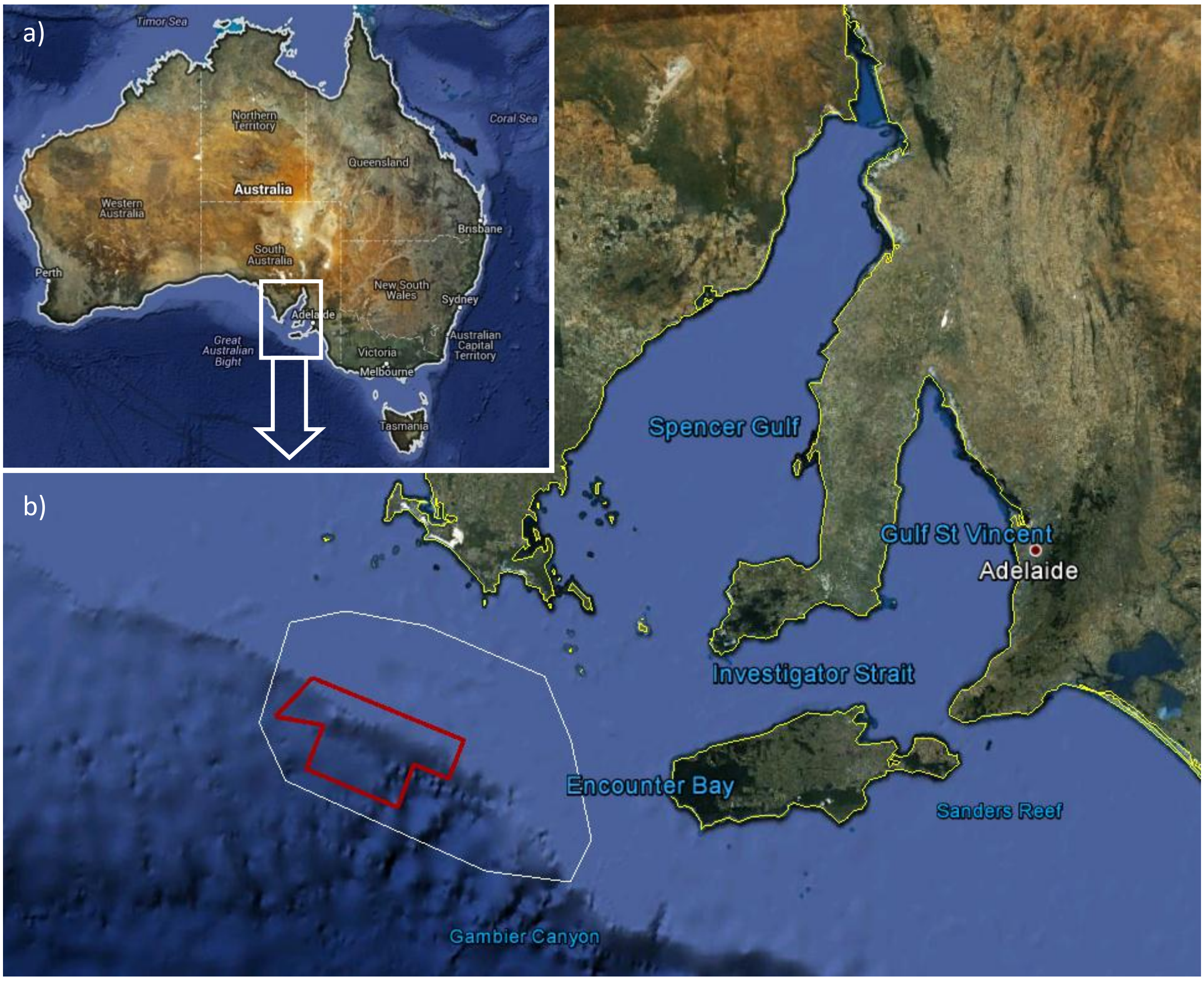

Figure 1. a) Map showing the location of the survey area. b) Detailed view of survey area (white polygon) and the planned seismic area (red polygon). Bathymetry from Google Earth.

Survey track lines were designed using the programme Distance 6.0 (RUWPA, University of St Andrews) in order to provide an equal coverage probability within the area. Tracks were designed in an adjusted angle zigzag mode to be perpendicular to bathymetry contours and oriented towards the direction of the prevailing wind to facilitate sailing. Total length of the track was of 314 nm (see Figure 2).

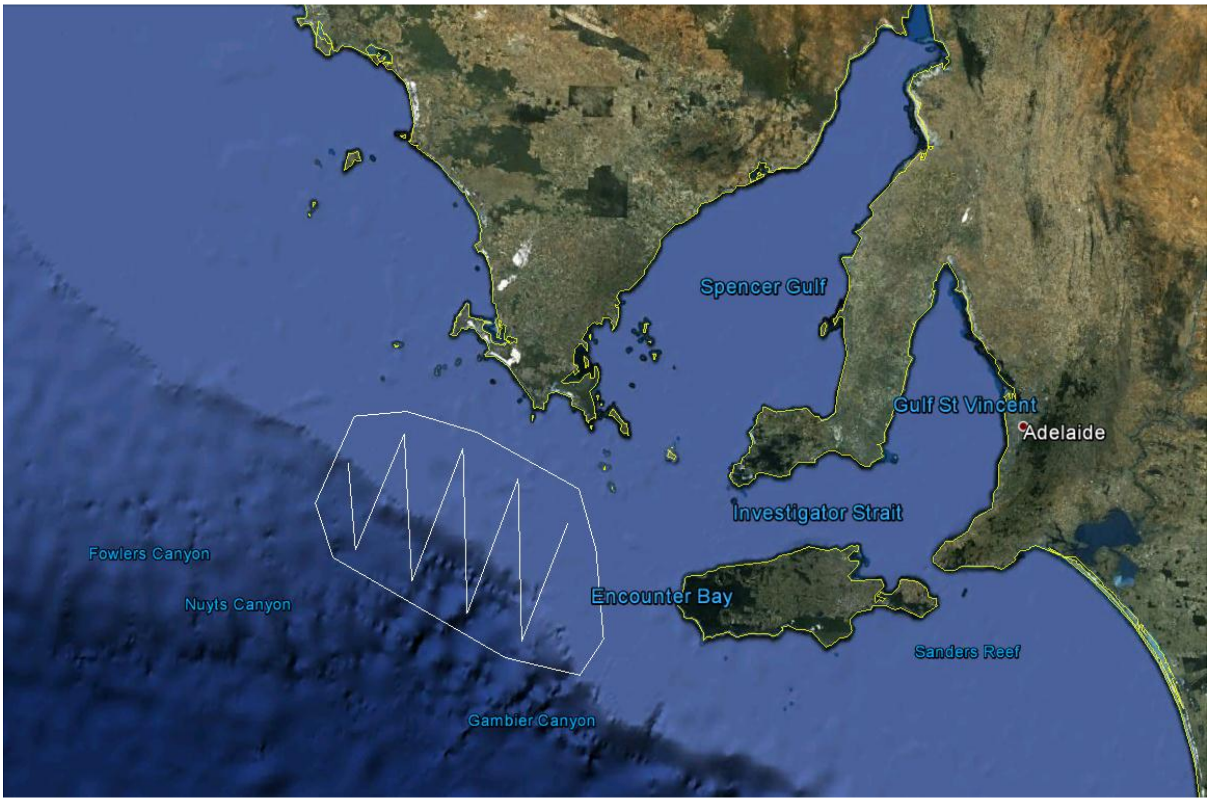

Figure 2. Planned adjusted angle zigzag track lines designed using the programme Distance. The external polygon shows the study site with a 10 km margin to allow for sail changes on the approach to any given track line.

Acoustic monitoring was carried out 24 hours a day and visual surveying conducted during daylight hours and favourable conditions. All times are reported in coordinated universal time (UTC).

2.1 Visual survey

Visual observations were conducted during daylight hours when sea conditions were appropriate (below sea state four). When on effort and weather permitting, two observers positioned on the *SV Pelican* cabin roof with an eye height of approximately 5.6 m scanned the sea surface ahead of the vessel using the naked eye and/or binoculars. One observer scanned from 0-180 degrees, and the other from 180-360 degrees; however both observers focused the majority of their effort ahead of the vessel at the trackline. In higher sea states, visual observation took place from deck.

Sighting information was logged to a database via the Logger software (IFAW) and included the angle and distance to the animal, species, group size and behaviour. Angle was determined using an angle board placed in front of observers while distance to the animals was estimated using reticulated binoculars. Environmental variables such as wind speed (knots), wind direction, sea state, wave and swell height, sea surface temperature (°C) and survey effort (numbers and positions of observers) were logged hourly or when conditions changed. GPS and AIS data were also logged automatically to the same database, including date, time and vessel position (lat-long).

Effort status was also logged and it was classified into three categories:

1) Passage: when transiting towards or away from the survey area.

2) Track: when following track lines within the survey area.
3) With animals: when normal survey effort was interrupted to approach animals.

In each category one of these options was selected: survey, visual survey, acoustic survey or visual and acoustic.

2.2 Acoustic survey

Acoustic surveys were conducted under sail, motor or motor/sail at 5-8 knots, a speed that allowed the hydrophone array to stream while reducing strum and excessive strain. A 300 m hydrophone array was towed from the *SV Pelican* at all times when water depth was sufficient. The array consisted of a tow cable and an oiled-filled tail, both containing different hydrophone elements: two low frequency elements (flat response within 1.5 dB from 10 Hz to 15 kHz) 100 meters apart and two broadband elements (2 kHz to 200 kHz) spaced 0.25 m apart (see Figure 3). The pairs of hydrophones were used in order to obtain range and bearing information to animal vocalisations. The two low frequency hydrophones were primarily used to collect data on baleen whales while the two broadband elements were used to detect beaked whales, sperm whales and dolphin clicks and whistles.

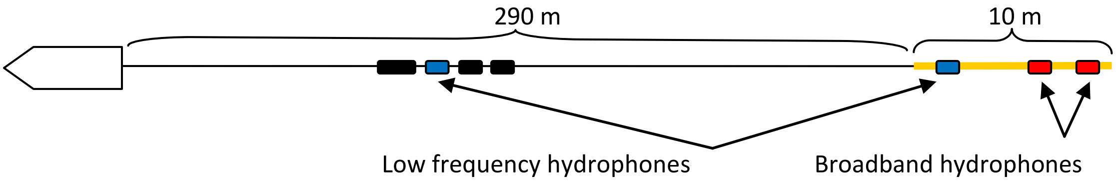

Figure 3. Details of the hydrophone and arrangements of the elements.

Continuous stereo recordings were made at sampling rates of 48 kHz (from the low frequency elements) and 192 kHz (from the broadband elements) via a bespoke Seiche buffer box passing signals to an RME Fireface sound card and an NI-6251 data acquisition card respectively. The entire system was capable of detecting signals from 10 Hz to 200 kHz. For the bandwidths of interest for baleen whale vocalisations (10 to 8000 Hz) and beaked whale clicks (25 to 50 kHz), the response of the system was approximately flat.

Recordings were made using Pamguard v1.12.05 (Passive Acoustic Monitoring Guardianship, www.pamguard.org) and Logger 2010 (IFAW), being written to disk as two-channel 16-bit wav files. Different Pamguard modules were employed in real time throughout the survey; a click detector module, which used the broadband signals to monitor and record odontocete clicks including beaked whales, and a spectrogram module, which monitored dolphin whistles. A separate click detection software, Rainbow Click (IFAW), was also run continuously to log sperm whale and dolphin click trains in the audio range (2 to 24 kHz). In addition, the hydrophone array was monitored aurally for two minutes every 15 minutes in order to detect vocalisations and check the acoustic system was operating correctly. All vocalisations heard during those listening stations were noted in a Logger database classifying them into different categories: odontocetes clicks, odontocete whistles, sperm whale clicks, sperm whale codas and baleen whale moans. Background noise, such as water flow and ship noise (from either *SV Pelican* or other vessels) was also logged. For every vocalisation heard, a score (one to five, five being the highest) was attributed depending on the relative intensity of the sound.

Baleen whales

Analysis of the low frequency recordings sampled at 48 kHz was carried out using XBAT Extensible Bioacoustics Tool (Cornell University). Audio data were visually analysed by scanning spectrograms. For every vocalisation detected, and after aural confirmation, start and end frequencies and times were logged.

Beaked whales

A beaked whale click detector mode was run continuously in real time using Pamguard software and was checked periodically for any possible detections. Beaked whale clicks have the distinctive form of a relatively long duration (~200 µs) FM upsweep with dominant energy between 25 and 50 kHz (Johnson *et al*., 2004; Johnson *et al*., 2006; Gillespie *et al*., 2009) making it possible to detect and extract potential beaked whale clicks from background noise using click detection algorithms.

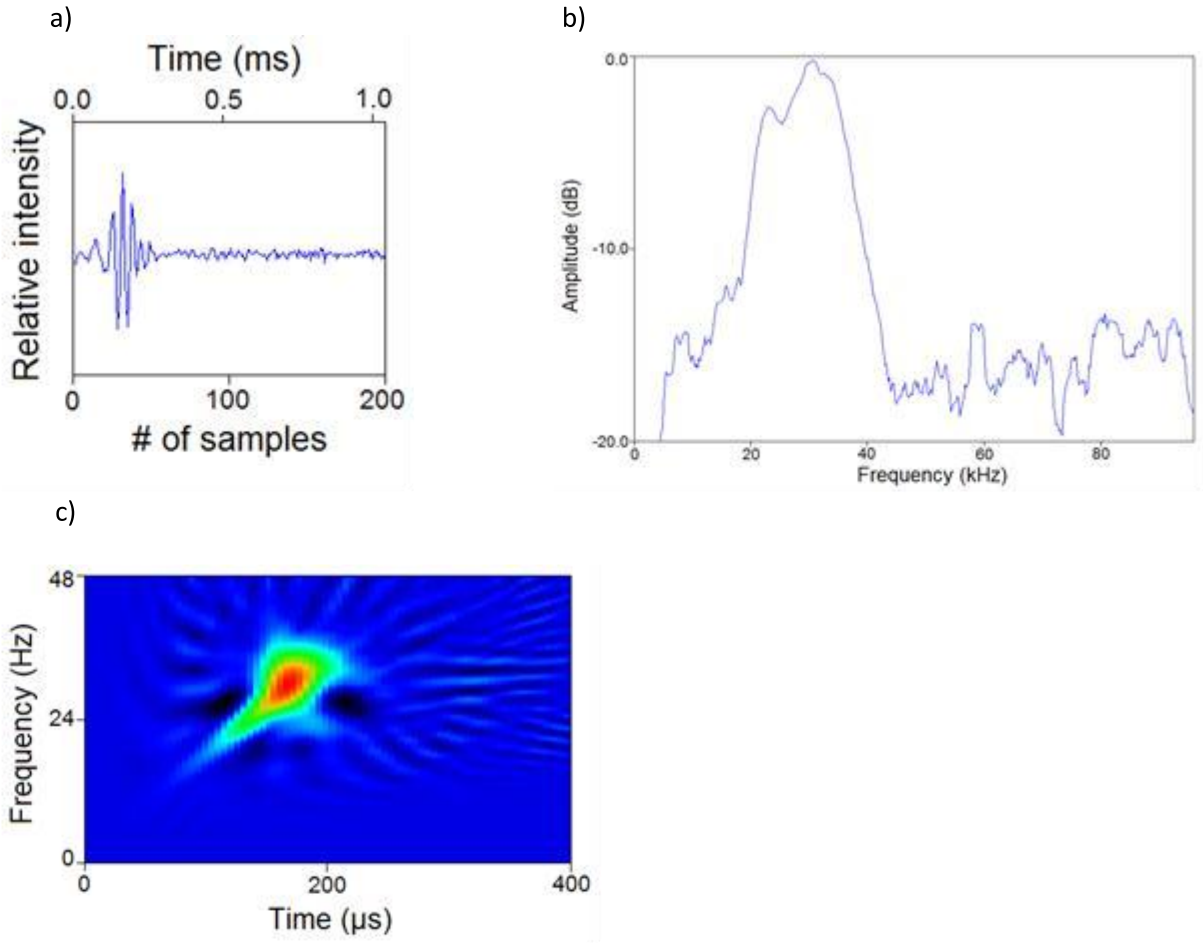

Figure 4. Typical features of a beaked whale click. Waveform (a), power spectrum (b) and time-frequency Wigner plot (c).

Post-survey, a more thorough analysis was conducted of potential beaked whale clicks using Pamguard software. Each click was manually inspected by an analyst to remove any false detections and separate the clicks into acoustic events. Candidate beaked whale clicks were classified with a subjective measure of confidence (possible, probable or definite) according to how well they conformed to the parameters displayed in Figure 4. A second analyst independently confirmed these events.

Sperm whales

In addition to the automated detection of sperm whales using Rainbow Click, data logged from the aural listening stations were analysed post-survey to confirm sperm whale detections and separate them into different acoustic events. Recordings of every event were inspected again and sperm whale group size was estimated as one, two or three or more animals.

Background noise levels

Background noise levels were measured for all 48 kHz recordings made during the survey using the Noise Monitor module in Pamguard.

3. RESULTS

A total of 1099 km (220 hours) of research effort was undertaken in the eastern Great Australian Bight waters over nine days (Table 1). *SV Pelican* left North Haven, South Australia, on 26th April and arrived at the survey area two days later after a stop at Marion Bay (Investigator Strait) to wait for weather conditions to improve. From 28th April until 8th May, the survey was conducted continuously except for one day when weather conditions were inclement.

Table 1. Summary of research effort from 26th April to 8th May 2013.

Effort status	Nautical miles	Kilometres	Time (hh:mm)
Passage	189	350	34:37
Passage + acoustic	142	264	28:42
Passage + visual	50	93	13:46
Passage + acoustic + visual	53	99	10:10
Track + acoustic	394	730	77:57
Track + visual	17	31	2:55
Track + acoustic + visual	242	449	46:04
With animals	7	13	2:29
Other	4	7	1:02
Total track	1099	2036	220:02

Sea state and weather conditions limited the amount and type of survey effort planned pre-survey. Therefore, all tracks were designed considering short-term weather forecasts to provide maximum coverage.

The pre-designed track lines designed in Distance were completed first (Figure 5; orange track). A secondary track designed in Distance was completed (Figure 5; black track) covering the whole area with a wider adjusted-angle. Most of the acoustic detections and sightings occurred around the continental slope between 200 and 2000 m; therefore two additional sets of tracks were undertaken in this area (Figure 5; red track) in order to provide more detailed information on those species inhabiting the slope habitat. As this part of the survey was conducted during poor weather conditions, it was not possible to design the tracks in Distance (namely with random start points and equal-coverage probability); rather these tracks were generated making the best of the prevailing winds.

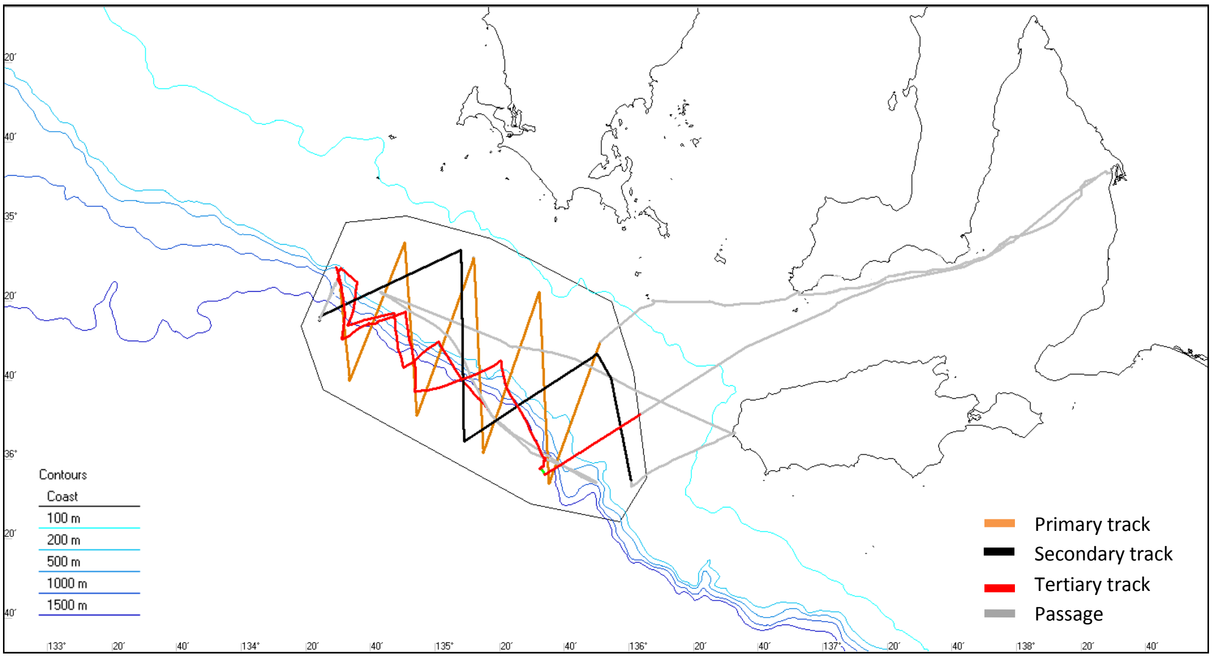

Figure 5. Track lines made by *SV Pelican* during the survey; primary track (orange), secondary track (black) and tertiary tracks (red). Grey lines are transiting tracks.

3.1 Sightings

Visual observations were strongly influenced by the sea state which was on average three (large wavelets with scattered whitecaps) with swells of one to five metres for most of the survey (Figure 6). These environmental conditions decreased the probability of detecting animals visually.

A total of 20 sightings were made of four species of cetaceans and one species of seal (Table 2); the species most often encountered during the entire survey was the short-beaked common dolphin. Three cetacean species and one seal species were sighted within the main survey block; the most commonly encountered cetacean being the pilot whale. Within the planned seismic survey area, pilot whale encounters were the most numerous followed by fur seals (Figure 7).

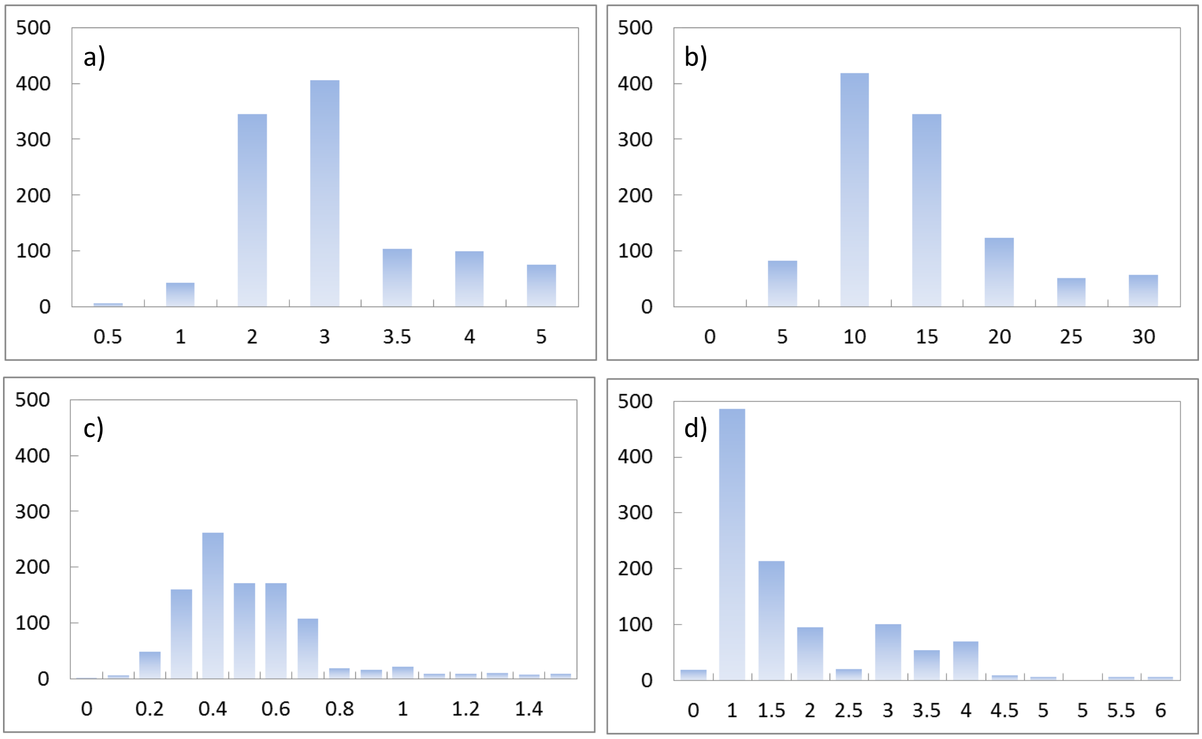

Figure 6. Interpolated frequency plots summarising environmental conditions experienced throughout the survey based on hourly logs of environmental data. a) Sea state, b) wind speed (knots), c) wave height (m) and d) swell height (m).

Table 2. Summary of marine mammals encounters during the survey.

Species	Number of encounters	Mean group size	Min. & max. group size
Pilot whale *Globicephala* sp.	3	27	4-60
Shepherd's beaked whale *Tasmacetus shepherdi*	1	3	3
Short-beaked common dolphin *Delphinus delphis*	7	30	2-30
Bottlenose-dolphin *Tursiops* sp.	2	5	3-10
Fur seal *Arctocephalus* sp.	5	2	1-2
Unidentified dolphin	2	2	1-2

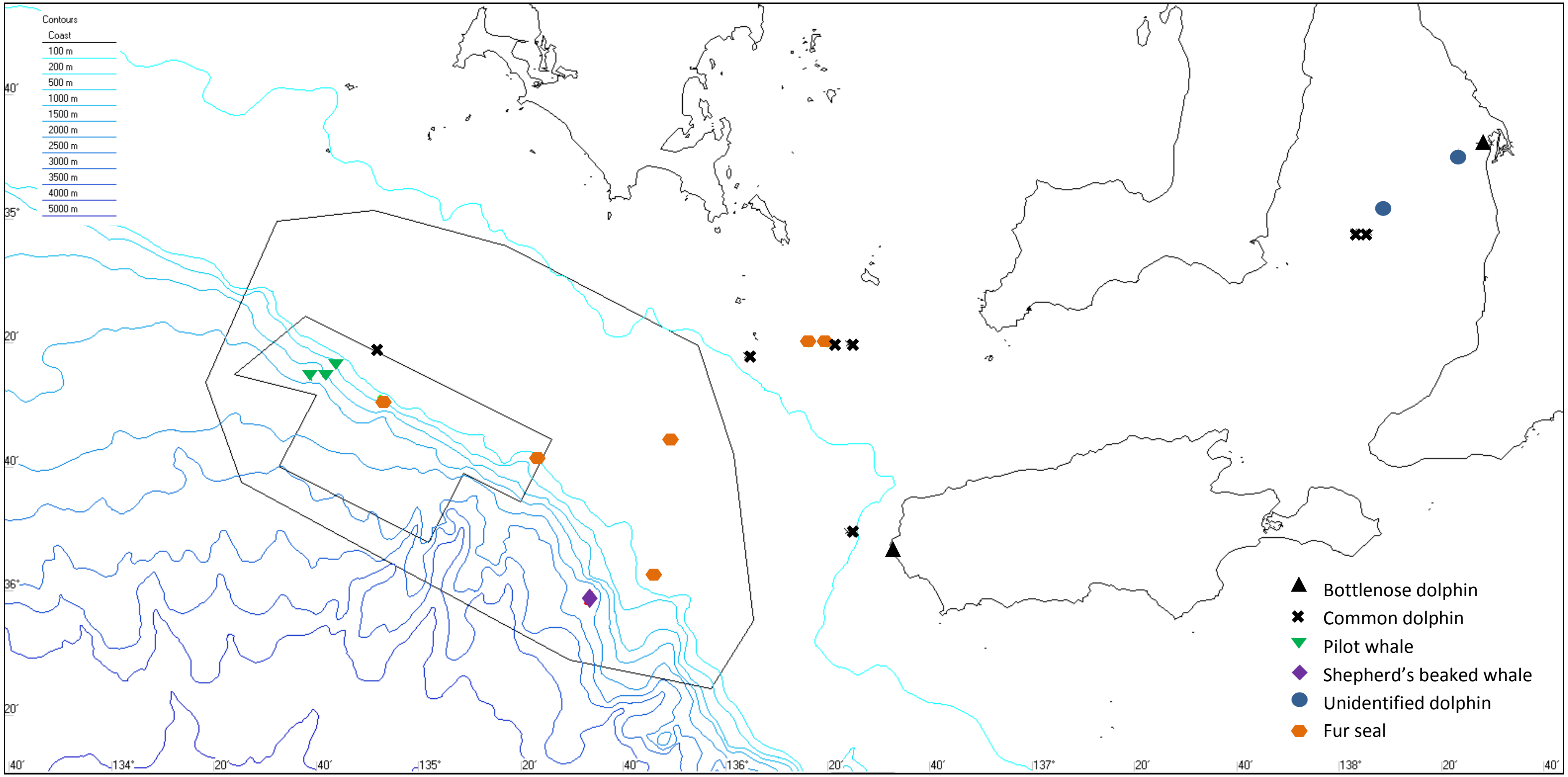

Figure 7. Map summarising marine mammals sighted during the survey. Study area (larger polygon) and planned seismic area (smaller polygon) are shown.

3.2 Acoustic detections

Odontocete acoustic detections were mainly concentrated around the continental slope between depths of 200 m and 3000 m. The hydrophone was monitored throughout the survey at 15 minute intervals. Odontocete whistles, clicks and pulsed calls were heard during 32% (*n*=201) of these 635 'listening stations'. Of these acoustic encounters, over half were reported to be probable pilot whales (*n*=104). The peak in the proportion of detections was situated within the planned seismic survey area and over the slope (Figure 8). The majority of acoustic detections (63%, *n*=127) were made during hours of darkness (specifically between 17:00 and 07:00).

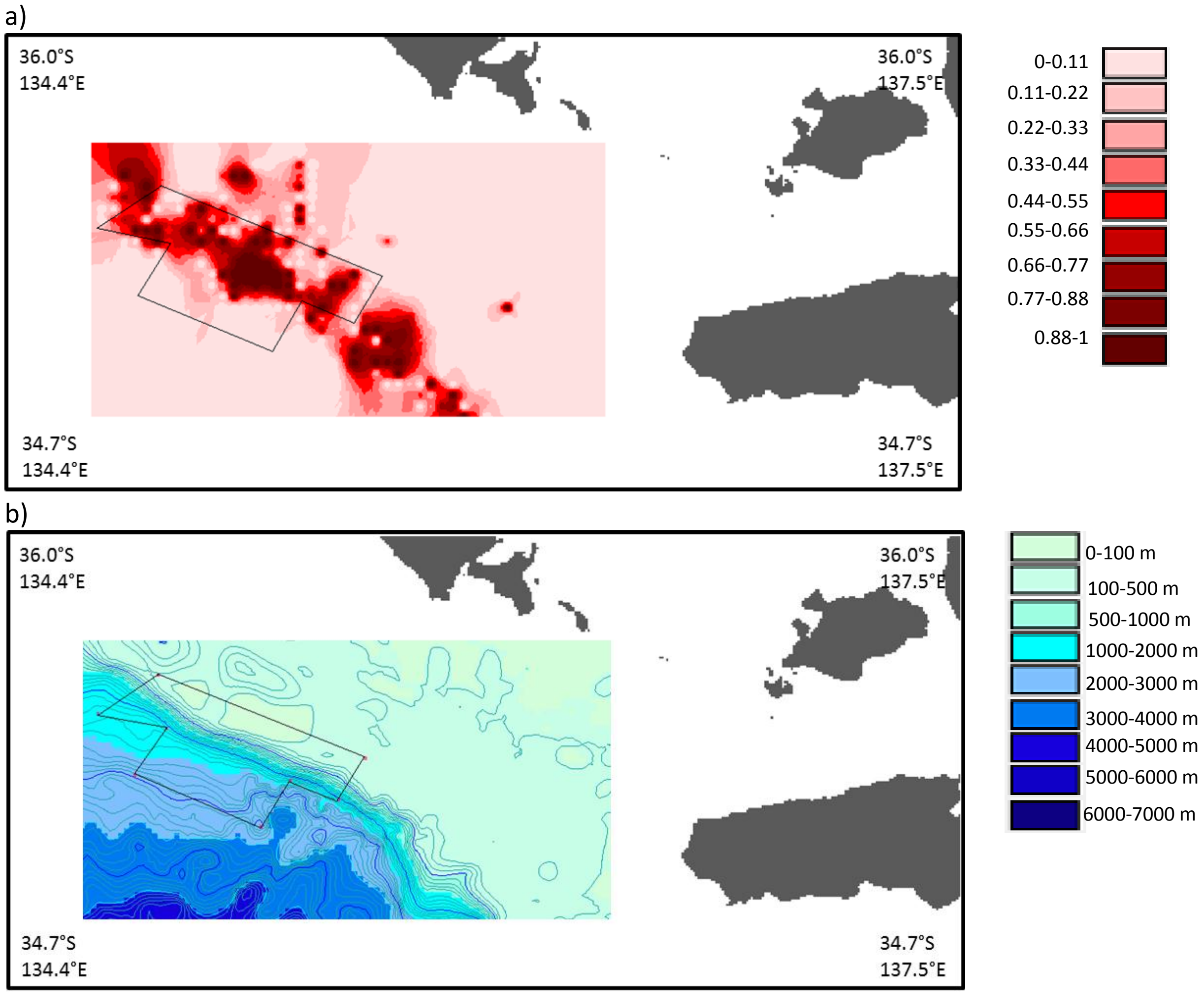

Figure 8. a) A 'heat' map showing the proportion of listening stations with acoustic detections of odontocetes (delphinids and sperm whales). The map was configured by splitting the survey area in to a 0.05 degree grid and interpolating between the points. b) Depth contours demonstrating that the peak in the proportion of detections was situated over the slope.

3.3 Sperm whales

There were a total of seven separate acoustic detections of sperm whales, accounting for the detection of at least 11 individuals. Of these, 71% were made in depths greater than 1000 m (Figure 9). Most of the detections were of relatively small groups (two individuals or fewer). Of the seven acoustic detections, five were made during hours of darkness and although two of these detections occurred in daylight hours, poor weather conditions prevented efforts to track the animals for photo-identification. In addition to the acoustic detections, three individual sperm whales were seen on 6th May from a concurrent aerial survey (see Appendix II) over the proposed seismic survey area. It is thought at least two of these animals were subsequently detected acoustically during the night of the 6th May.

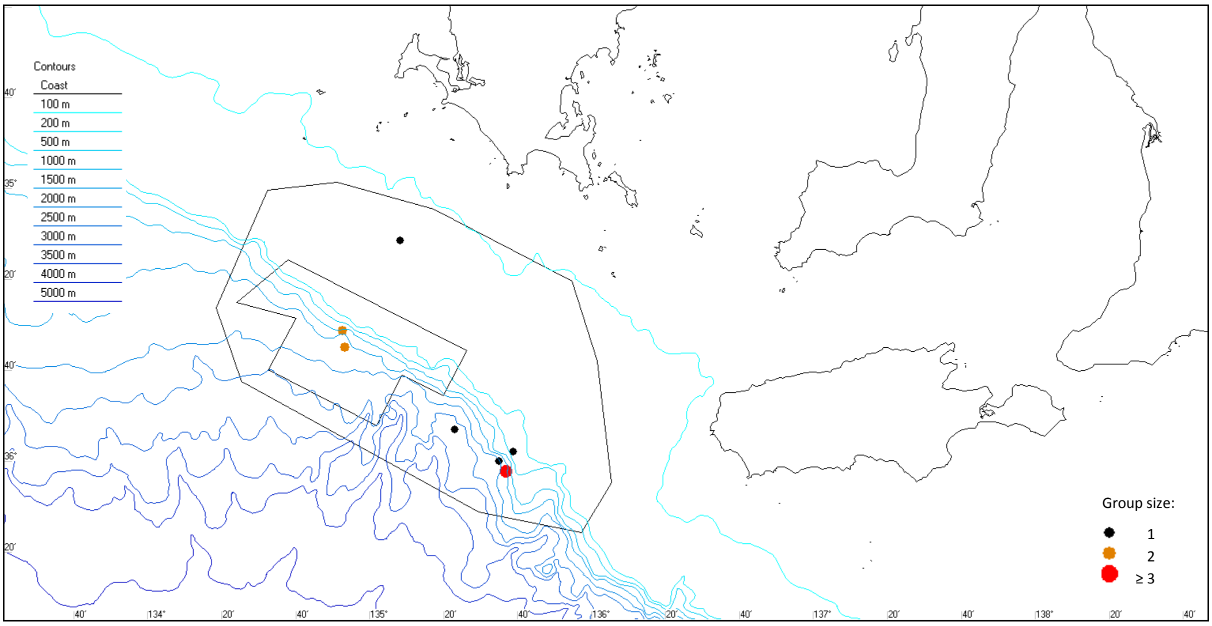

Figure 9. Map showing acoustic detections of sperm whales (and group size) within the study area.

3.4 Baleen whales

Post-survey analysis of the low frequency recordings revealed a constant flow noise (from the movement of the vessel and hydrophone through the water) from 10 – 50 Hz, limiting the ability to detect baleen whale vocalisations found within these frequencies. Although it is possible to detect vocalising baleen whales whilst underway (for example, Boisseau *et al*., 2008), it is possible that in this study flow noise reduced the ability to detect vocalising whales that may have been present. Baleen whale calls were not detected, and concurrent aerial surveys during the study period did not encounter any baleen whales.

3.5 Beaked whales

On 6th May a group of three Shepherd's beaked whale (*Tasmacetus shepherdi*) was sighted at 09:12 local time in a water depth of 2000-2500 m (Figure 7). The encounter lasted 2 hours and 6 minutes with an average dive time of 10-15 min and no apparent deep dives (as described, for example, in certain *Ziphius* and *Mesoplodon* species; Tyack *et al*., 2006), indicating that the group was not feeding and was possibly milling at the surface. Species identification was made later using photographs taken during the encounter. Shepherd's beaked whale is the only species of ziphiid with a full set of functional teeth (17 to 27 pairs in both upper and lower jaws; Oliver, 1937). Adult males also have a pair of tusks at the tip of the lower jaw, and at least one male was among the group, identified in one of the pictures (Figure 10c) by a tooth visible in the lower jaw. Distinctive features of the species can be seen in Figure 10. No obvious beaked whale vocalisations were noted during the encounter. Detailed post-process analysis of the recordings running from one hour prior to the first sighting to one hour after the final sighting did not reveal any vocalisations that might be ascribed to these beaked whales. This may be explained by the fact that the whales did not appear to be making characteristic long deep foraging dives during which echolocation clicks have previously been described in several species of beaked whale.

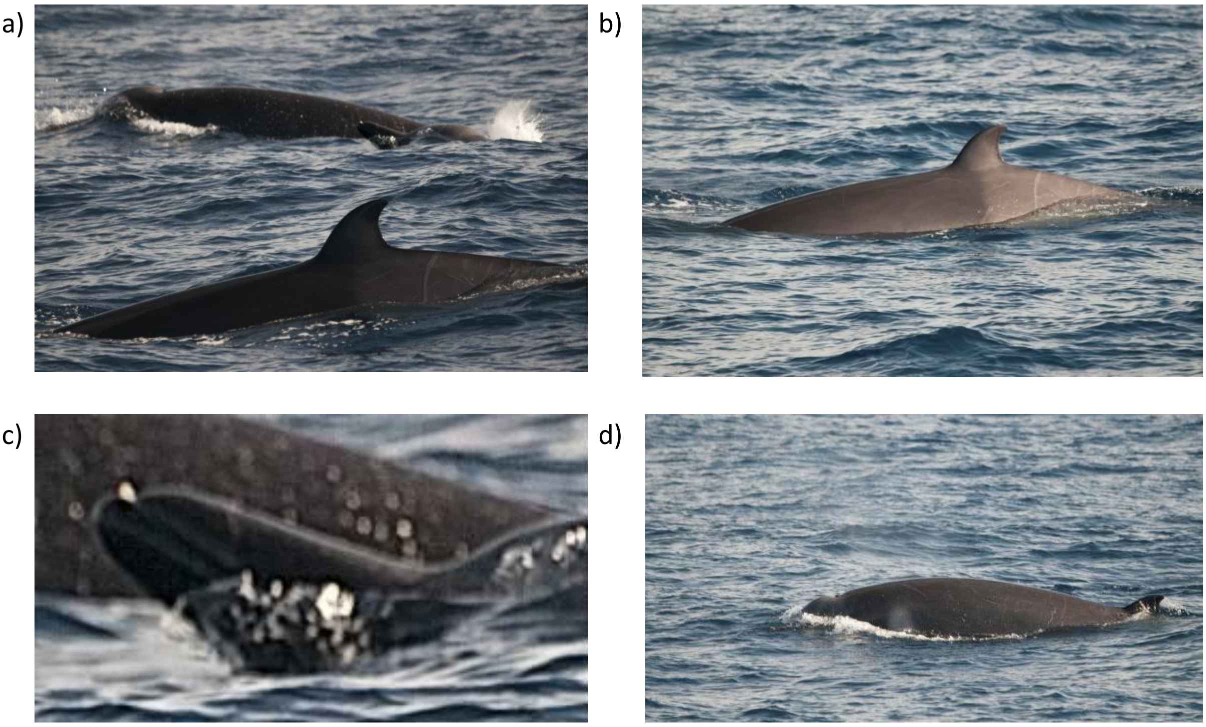

Figure 10. Photographs of the Shepherd's beaked whale group encountered on 6th May. Diagnostic features include, a) rounded melon and pale head patch; b) small falcate dorsal fin set far back and creamy-white side after dorsal fin; c) prominent beak and a pair of apical teeth protruding from the lower jaw in males; d) forward-centred pale shoulder mark above pectoral fins.

3.6 Background noise

During the course of the survey, measurements averaged over 10 minutes of relative ambient noise levels were made from the low-frequency hydrophone elements as third octave bands up to 48 kHz. The third-octave band values were averaged to generate a 'heat-map' (Figure 11). As expected, background noise levels tended to be higher in shallower waters due to 'cylindrical' spreading, a simple approximation for spreading loss in a medium with upper and lower boundaries (the sea surface and sea bed respectively). The influence of sea-bed noise, for example snapping shrimp and shifting rocks, is also likely to be more conspicuous in shallower waters. Conversely, in deeper waters sound waves are less constrained and propagate away from a source uniformly in all directions. In general, the slope waters were relatively quiet in terms of ambient noise during the course of this study.

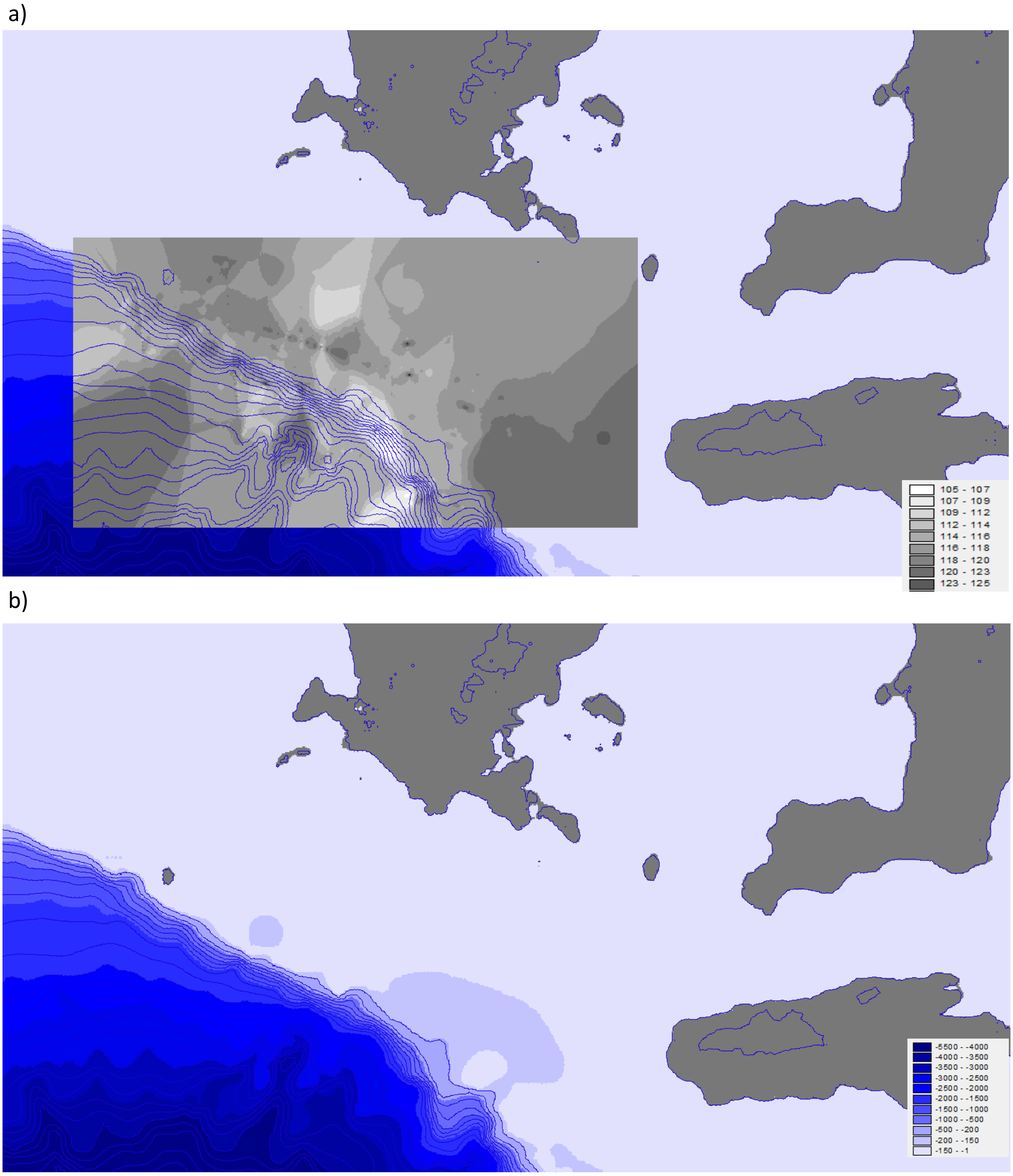

Figure 11. a) Relative ambient noise levels (dB) throughout the study area. The map was configured interpolating between 10 minute measurements and averaging all third-octave bands up to 48 kHz. b) Depth contours (m) demonstrating how the slope waters represented a relatively quiet region during the course of this study.

4. DISCUSSION

This short survey from *SV Pelican* was conducted during autumn months in latitudes of 35 degrees and higher in an area with limited previous systematic survey effort. The weather at times reduced the likelihood of observing marine mammals and this may have influenced the relatively low sighting rate. Acoustic survey techniques are less influenced by sea state, and 60 acoustic detections were made despite only 14 of these (23%) corresponding with a sighting of a cetacean. To illustrate the importance of sea state for sighting success, the only cetacean sighting that took place without a prior acoustic detection was of Shepherd's beaked whales when the sea was at its lowest level (sea state < 1 with a swell height of 0.5 m and a wave height of 0.2 m) at the end of the survey. Relying on visual techniques alone would have resulted in at least 46 groups of cetaceans passing undetected in this area, a result of some note given that currently mitigation efforts in Australian waters have focused almost solely on visual techniques (e.g. Marine Mammal Observers) and an acoustic dimension is not included (e.g. Passive Acoustic Monitoring), despite the guidelines allowing this possibility.

4.1 Baleen whales

The intensity of the annual upwelling driven by prevailing south-easterly winds in southern Australia is highly variable and difficult to predict from year to year. As discussed, these upwellings strongly influence prey abundance and corresponding pygmy blue whale aggregations in this area. As such, the presence of blue whales in this region will vary in accordance with the intensity and timing of upwelling (Gill *et al*., 2011). Reports from the Integrated Marine Observing System (IMOS) for 2013 indicate that the usual November to April upwelling for the nearby Bonney Coast was relatively weak until the first significant upwelling in March (IMOS, 2013). This could possibly provide an explanation for the lack of pygmy blue whale detections in the region this year and during this survey. Consecutive aerial surveys flown during the study period similarly did not result in any baleen whale sightings.

The paucity of data relating to migration routes for southern right whales from Antarctic feeding grounds to Australian breeding grounds makes predictions of timing or locations for southern right whale encounters in offshore waters challenging. However, coastal sightings of southern right whales are frequently made during the months of April and May in South Australia and the earliest sighting for 2013 was actually on 29 March at Boomer Beach (Pippos, *pers. comm*.), approximately 160 nautical miles east of this survey area.

Given that seismic surveying is planned for this area and the timing of this could overlap with the presence of foraging pygmy blue whales and/or migrating southern right whales, it is recommended that several years of baseline data be gathered to further elucidate endangered baleen whale habitat use in the survey area. Noise from seismic surveys utilising airguns has peak frequencies that overlap with the acoustic signals and estimated hearing ranges of baleen whales (Weir, 2008a). Seismic surveys have been documented to ensonify an area of 300,000 km^2 (IWC, 2005), raise the background noise levels by 20 dB (IWC, 2005) for months at a time and be heard up to 4,000 km from their source (Nieukirk *et al*., 2012). As blue and fin whales may communicate over vast distances of at least 400 km (Spiesberger & Fristrup, 1990) masking of biological sounds and impacts on intra species communication are likely. Furthermore, the population of southern right whales in this area are from the distinct southeast population (AMMC, 2009) which is showing little evidence of increase, unlike the southwest population. Without evidence of recovery, this population could be more vulnerable to the impacts of anthropogenic noise.

Baleen whale acoustics

Blue whale calls recorded to date off the Antarctic Peninsula, Madagascar and Western Australia are characterised by maximum frequencies of 28 Hz (Rankin *et al.*, 2005; Širovic *et al.*, 2004; Ljungblad *et al.*, 1998). Southern right whales produce various types of calls, some of lower frequencies from 20-60 Hz and others up to 1 kHz. From quiet research vessels, such as IFAW's Song of the Whale, it has previously been possible to detect baleen whale calls while under engine at moderate speeds averaging 6 knots (Boisseau *et al.*, 2007). However, on other vessels, propeller and flow noise are often a challenge when collecting baleen whale vocalisations. With this in mind the research team planned to heave to at the end of each transect to make recordings free from or with reduced flow noise. However, operational issues made this impractical and therefore constant flow noise ranging from 10-50 Hz was present in the dataset presented here; meaning any blue or right whale calls below 50 Hz could have been masked. As the likelihood of detecting baleen whale vocalisations was limited by flow noise it cannot be assumed that blue whales were not present in the area from the results of this analysis. Southern right whale calls typically contain energy in frequencies higher than 50 Hz; however, no detections were made during this survey.

Overall, the problems associated with flow noise may impact the use of passive acoustic monitoring for baleen whales during vessel-based surveying. There are methodological adaptations which can be utilised to eliminate flow noise while using towed hydrophone arrays. For example, fairings can be attached to a hydrophone cable which would assume a streamlined shape when towed and thus reduce flow noise and cable strum; however these are often avoided due to the increased risk of entanglement with, for example, fishing gear. Even at relatively slow speeds where flow noise may be less of a hindrance, propeller noise generated by the vessel will mask detections of low frequency species unless the vessel has been specifically designed to avoid this. As an alternative, remote data loggers or DIFAR buoys can be utilised to detect baleen whales acoustically, eliminating the issues with flow and propeller noise; however careful placement of these would be needed in order to cover the entire limits of the survey area.

4.2 Beaked whales

The sighting and positive identification of a group of three Shepherd's beaked whales during this survey is very significant, as this is only the second documented sighting of this rarely-seen species of beaked whale within the survey area. There have been four other observations of this species from recent vessel-based surveys in New Zealand and southern Australia (2008 and 2012 respectively). These sightings resulted in detailed descriptions of the physical appearance and some insight into habitat preferences of this species (Donnelly *et al*. 2012). All previous sightings by Donnelly and colleagues occurred near the continental shelf break and within or adjacent to deep waters (>900 m), which is consistent with the sighting from this survey. Continental slope waters, deep canyons and seamounts are all habitats that feature the complex topography associated with beaked whale occurrence (Kaschner, 2007). It is possible that these underwater features offer ideal foraging conditions for beaked whales and that the Kangaroo Island canyons, a small group of narrow, steep-sided canyons, may provide such suitable habitat. Further surveys will be needed to confirm whether indeed this area is a key habitat for beaked whales.

Beaked whales are the group of whales thought to be most susceptible to the negative impacts of manmade noise. Strandings of beaked whales have been linked to the use of military mid-frequency sonar (e.g. Fernández *et al*., 2005; Cox *et al.,* 2006; Rommel *et al*., 2006) and a recent study demonstrated a strong behavioural response (DeRuiter *et al.*, 2013). It is thought that other noise sources such as shipping and seismic testing may affect this acoustically sensitive group of whales. The numerous reports of beaked whale strandings near naval exercises involving use of mid-frequency sonar suggest a need for caution in conducting seismic testing in areas occupied by beaked whales until more is known about effects of seismic surveys on those species (Hildebrand, 2005).

Beaked whale acoustics

The lack of beaked whale detections in what seems to be a hotspot habitat for this cetacean group could be explained by the difficulties in detecting their clicks. Studies of other beaked whale species, notably Cuvier's and Blainville's beaked whales (Johnson *et al*., 2004; Johnson *et al*., 2006; Tyack *et al*., 2006) have suggested ultrasonic frequency-modulated clicks with most energy between 20 and 50 kHz are typically only produced during deeper dives (foraging clicks are often only reported when the depth of a dive exceeds 200 m). As these clicks have relatively low source levels and are mostly produced when the animal is oriented downwards, the likelihood of detecting a beaked whale acoustically is lower than for more vocally active species, such as sperm whales. However, acoustic techniques tend to be more successful than visual surveying for detecting beaked whale presence. Detection likelihood can be improved by adjusting the survey protocol (for example, slower survey speed and deeper hydrophone elements), an option not available for this survey aimed primarily at documenting and recording all marine mammal species.

During the Shepherd's beaked whale encounter, no apparent deep dives were observed; all dive times were shorter than 15 minutes. It has been suggested that vocally-active foraging deep dives (of 40 to 60 minutes) are usually interspersed with vocally-inactive shallow dives (of 9 to 15 minutes; Tyack *et al*., 2006). As such it is possible that this surface-active group was not vocalising throughout the encounter. However, it should be noted that nothing is currently known about the acoustic behaviour or the vocal repertoire of this species, and it is quite possible that the behaviour of Shepherd's beaked whales may differ from the types of behaviour documented for the better studied species such as Cuvier's and Blainville's beaked whales in the northern hemisphere.

4.3 Sperm whales

At least 11 individual sperm whales were detected acoustically during this study; in addition three individuals were observed during an aerial survey of the planned seismic survey area on 6th May (see Appendix II). As would be expected, all detections occurred in waters deeper than 200 m with most detections (71%) taking place in waters deeper than 1000 m. It is also of note that of the seven acoustic detections, five (71%) were made during hours of darkness. Within the large study area shown in Figure 1, there was a total of 1568 km of trackline undertaken. Thus, the acoustic density of sperm whales was at least 0.35 animals per 1000 km^2 (assuming an estimated strip half-width of 10 km). When considering only those sections of track representing suitable sperm whale habitat, namely waters deeper than 200 m, the acoustic density was 0.72 animals per 1000 km^2. This is comparable with acoustic density estimates for other regions recognised as important sperm whale habitats; for example, 0.16 in the Tongue of the Ocean, Bahamas (Ward *et al.*, 2012), 0.23 for the Ionian Sea, Greece, 0.34 for the Hellenic Trench (south of Crete) and 1.96 for the southwest Mediterranean (Lewis *et al.*, in prep.), 0.52 to 2.05 for the Faroe Shetland Channel off Scotland (Hastie *et al.*, 2003), 1.26 to 2.86 for the eastern temperate North Pacific (Barlow & Taylor, 2005) and 3.6 in French and Spanish waters (Swift *et al.*, 2009).

Sperm whales are currently listed as a migratory species in Australia under the EPBC Act and globally as Vulnerable under the IUCN red list. They are listed as Endangered Migratory Species under Appendix 1 of the Bonn convention. Sperm whales have been recorded from the waters of all Australian states (Bannister *et al.*, 1996) and it is possible that sperm whales in Australian waters represent severely fragmented populations. The sperm whale detections in this study are striking as despite having a status of Insufficiently Known (K) under the Australian Action Plan (Bannister *et al*., 1996), the Action Plan elaborates that sperm whales will remain, "status indeterminate until surveys conducted, particularly off south-west Australia". Our detections support the suggestion in the Action Plan document that the waters to the south-west of Kangaroo Island may contain a 'concentration' of sperm whales and this study provides novel data on the distribution of this species. Further research on sperm whale distribution is urgently needed; perhaps the most detailed report on sperm whale distribution in Australian waters is based on aerial surveys conducted almost fifty years ago, between 1963 and 1965 (Bannister, 1968).

4.4 Other odontocetes

Pilot whales were sighted on three occasions, often in large widespread groups. Although these encounters took place on separate days, they were all within 10 km of each other over the slope waters of the proposed seismic survey site. In addition to these sightings, their characteristic vocalisations were heard repeatedly during the survey, with 17% of all listening posts containing pilot whale vocalisations. A majority (61%) of all detections were made in darkness, in keeping with the suggestion that pilot whales may forage primarily at night when they would be more vocally active (Mate, 1989; Shane, 1995; Gannier, 2000). As the longest of these nocturnal acoustic encounters with pilot whales lasted over eight hours, it seems likely that some of the groups were very large and widespread. This study provides novel information on pilot whale distribution in waters of the Great Australian Bight.

Common dolphins were also encountered during the survey; all sightings were made in waters less than 200 m deep. Common dolphins have been encountered off all Australian states with apparent concentrations in the southern south-eastern Indian Ocean and in the Tasman Sea, but are rarely seen in northern Australian waters (Ross, 2006). Neither the extent of occurrence nor the area of occupancy of the common dolphin has been estimated in Australia, but due to its offshore distribution, it is unlikely that common dolphin populations are severely fragmented in Australia.

4.5 Implications for seismic surveying

The EPBC Act Policy Statement 2.1 (interaction between offshore seismic exploration and whales; DEWHA, 2008) stipulates that in situations involving biologically important habitats, explicit justification for why any proposed survey should take place should be provided. For any potential seismic survey, it will be necessary to implement more extensive measures, such as greater precaution zones and additional marine mammal observer coverage. In those areas where the likelihood of encountering whales is “moderate to high”, the application of additional measures is necessary to ensure that impacts and interference are avoided and/or minimised. Moderate to high likelihood is defined for seismic surveys as being, “spatially and/or temporally proximate to aggregation areas, migratory pathways and/or areas considered to provide biologically important habitat”. Although the definition is vague, this study suggests Commonwealth Petroleum Exploration Permit Areas EPP-41 and EPP-42 will be both spatially and temporally proximate to aggregations of whales including sperm whales, pilot whales and Shepherd’s beaked whale, a species that may have only been seen alive at sea on fewer than ten occasions (Mead, 2009). As such, the application of additional mitigation measures will be required for any seismic survey in this area. Conducting seismic surveys during a different time of year would not only overlap with peaks in blue whale and southern right whale presence, but would also not necessarily avoid potential disturbance of odontocetes, as the deep-diving species encountered in this study are quite likely to be found in the area year round. Species, such as the beaked whales, which appear to be found in small, possibly genetically isolated, local populations and are resident year round (Wimmer & Whitehead, 2004; Balcomb & Claridge, 2001) may be particularly vulnerable to disturbance and population level impacts. Sperm whales also exhibit some evidence of year-round residency in other areas (see for example, Lettevall *et al*., 2002).

It is increasingly clear that loud underwater noise has the potential to disturb and harm marine life both directly and indirectly in the short term, with potential changes at the population level and across generations in the longer term. This appears to be the case for the cetacean species encountered in this study. For example, Jochens *et al*. (2008) demonstrated that sperm whales reduced foraging activity by between 20-60% during full array seismic activity. In the presence of operating seismic airguns, sperm whales were shown to reduce swimming effort on foraging dives, reduce buzz rates (used to home in and capture prey), and remain at the surface apparently waiting for airguns to stop before beginning foraging dives (Tyack, 2009). Other studies have shown a reduction in the number of fluke strokes and swimming effort while sperm whales were foraging, even in response to distance airgun sounds (IWC, 2007). Although there are no specific reports pertaining to the rarely-seen Shepherd’s beaked whale, other ziphiids are known to be particularly vulnerable to loud mid-frequency anthropogenic sounds, as evidenced by the growing number of mass strandings associated with military sonar (Fernandez *et al*., 2005; Cox *et al.*, 2006; Rommel *et al*., 2006). There have been reported cases of beaked whale strandings in the proximity of seismic operations, although no conclusive link has been made (Hildebrand, 2005). However, this may in part be because knowledge of beaked whale distribution and abundance is so limited that combined with the inherent problems of studying such elusive whales, data on the impacts of seismic activities on beaked whales are limited compared to some other cetaceans. For pilot whales, temporary avoidance response has been noted during seismic airgun testing (Weir, 2008b) and during the start-up of airguns (Stone & Tasker, 2006). In addition, sightings by MMOs (Marine Mammal Observers) of pilot whales in waters subject to seismic exploration around the British Isles have declined since 1998 (Stone, 2003).

The impact on cetaceans of any proposed seismic activity will depend on a number of factors including: source level and frequency; distance from the source; water depth; substrate; ambient noise environment; species concerned and their ecology and behavioural state. For example, the relative strength of seismic pulses arriving via different pathways vary with the distance from source and depth of diving sperm whales, but absolute received levels can be as high at 12 km as they are at 2 km (Madsen *et al*., 2006). The level of risk reduction, if any, is not known for most current mitigation measures employed during seismic surveys. A common mitigation practise is to use observer MMOs to detect marine mammals visually close to the seismic operation; however, the likelihood of seeing a cetacean diminishes rapidly with degrading sea state and light conditions. As over 60% of the acoustic detections of odontocetes in this study were made during hours of darkness, it is apparent that mitigation techniques relying on visual techniques alone for detecting the presence of mammals are flawed. It seems the most effective mitigation of the effects of seismic surveys is by avoiding biologically important areas, conducting fewer surveys and/or decreasing the intensity or duration of sound during the surveys.

4.6 Future research

The data presented provide novel information on several species of marine mammal off southern Australia and highlight the intrinsic value of scientific research in those areas for which few data exist. Although only a short survey, this study improves the knowledge of cetacean distribution in the shoulder season of April and May that has received very little prior research effort. Even outside of this shoulder season, much of the publicly available information regarding cetacean distribution off southern Australia is patchy; for example, the most recent sperm whale sightings near Kangaroo Island stored on the OBIS-SEAMAP database are from 1980 (data from the National Whale and Dolphin Sightings and Strandings Database and courtesy of the Australian Antarctic Data Centre). Indeed, for sperm whales off Western Australia, an apparent decline off Albany has recently been noted despite the cessation of whaling over 30 years ago, with implications for the management of sperm whales not just in Australian waters but worldwide (Carroll *et al*., 2013).

The lack of publicly available baseline data off southern Australia is of concern, particularly in light of increasing interest in seismic surveying in this region. While this study provides some insight into cetacean presence, the highly variable seasonal upwelling and resulting prey availability fluctuations are likely to impact cetacean presence, diversity and distribution from year to year in this area. Consequently, it is recommended that systematic visual and acoustic surveys be conducted over multiple years to better determine the importance of this area to a range of cetacean species.

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APPENDIX I: Priority list of cetacean species found in southern Australia

Species	Priority	EPBC Act Listing Status
Pygmy Blue whale (*Balaenoptera musculus brevicauda*)	High	Endangered
True Blue whale (*Balaenoptera musculus intermedia*)	High	Endangered
Southern right whale (*Eubalaena australis*)	High	Endangered
Humpback whale (*Megaptera novaeangliae*)	High	Vulnerable
Fin whale (*Balaenoptera physalus*)	High	Vulnerable
Sei whale (*Balaenoptera borealis*)	High	Vulnerable
Sperm whale (*Physeter macrocephalus*)	High	Migratory
Gray's beaked whale (*Mesoplodon grayi*)	High	-
Andrew's beaked whale (*Mesoplodon bowdoini*)	High	-
True's beaked whale (*Mesoplodon mirus*)	High	-
Gingko-toothed beaked whale (*Mesoplodon ginkgodens*)	High	-
Cuvier's beaked whale (*Ziphius cavirostris*)	High	-
Hector's beaked whale (*Mesoplodon hectori*)	High	-
Shepherd's beaked whale (*Tasmacetus shepherdi*)	High	-
Arnoux's beaked whale (*Berardius arnuxii*)	High	-
Blainville's beaked whale (*Mesoplodon densirostris*)	High	-
Strap-toothed beaked whale (*Mesoplodon layardii*)	High	-
Southern bottlenose whale (*Hyperoodon planifrons*)	High	-
Long-finned Pilot whale (*Globicephala melas*)	High	-
Short-finned pilot whale (*Globicephala macrorhynchus*)	High	-
Indo-Pacific bottlenose dolphin (*Tursiops aduncus*)	High	Migratory
Bottlenose dolphin (*Tursiops truncatus*)	High	-
Antarctic minke whale (*Balaenoptera bonaerensis*)	Medium	Migratory
Dwarf minke whale (*Balaenoptera acutorostrata*)	Medium	-
Bryde's whale (*Balaenoptera edeni*)	Medium	Migratory
Pygmy sperm whale (*Kogia breviceps*)	Medium	-
Dwarf sperm whale (*Kogia sima*)	Medium	-
Killer whale (*Orcinus orca*)	Medium	Migratory
False killer whale (*Pseudorca crassidens*)	Medium	-
Dusky dolphin (*Lagenorhynchus obscurus*)	Medium	Migratory
Risso's dolphin (*Grampus griseus*)	Medium	-
Common dolphin (*Delphinus delphis*)	Medium	-
Southern right whale dolphin *(Lissodelphis peronii*)	Medium	-

APPENDIX II: SUMMARY OF FINAL REPORT FOR 2013 IFAW AERIAL SURVEYS: SOUTH AUSTRALIA

Final Report for 2013 IFAW Aerial Surveys: South Australia

BPM-NSW-13-IFAW Aerial Surveys-Final Report-v1.1

25-06-2013

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Executive Summary

The International Fund for Animal Welfare (IFAW) contracted Blue Planet Marine (BPM) to conduct five aerial surveys off Kangaroo Island/the Eyre Peninsula during April and May 2013. The primary purpose of the surveys was to assess the diversity and distribution of cetaceans, with a focus on great whales (e.g. baleen whales plus sperm whale), and in particular blue whales. There was no attempt, and the survey was not designed, to obtain abundance estimates of any species.

There were five survey replicates flown, all in April and May 2013. All flights left Parafield Airport, Adelaide, transited to Port Lincoln Airport to refuel, and then conducted the survey. The return flight was in the reverse order. The total flight time over the five surveys was 27 hrs 41 mins and averaged 5 hrs 32 mins per survey. Total time over the survey area was 10 hrs 34 mins and averaged 2 hrs 7 mins per survey. Three surveys were conducted while IFAW personnel were on a chartered vessel in the area. All flights were conducted in accordance with required safety procedures and there were no health or safety issues during the survey.

There were 12 confirmed sightings of cetaceans over the five surveys representing 11 different pods, with one of those sightings/pods observed outside the survey area while in transit. Of the 11 pods observed, two were identified as sperm whales, three as dolphins (species not determined), and six as unidentified small odontocetes.

Introduction

The International Fund for Animal Welfare (IFAW) contracted Blue Planet Marine (BPM) to conduct five aerial surveys off Kangaroo Island/the Eyre Peninsula during April and May 2013. The primary purpose of the surveys was to assess the diversity and distribution of cetaceans, with a focus on great whales (e.g. baleen whales plus sperm whale), and in particular blue whales. There was no attempt, and the survey was not designed, to obtain abundance estimates of any species.

This is the final report for the aerial surveys.

Methods

The aerial survey design and methods are detailed in Appendix A.

Results & Discussion

Flight details

There were five survey replicates flown, all in April and May 2013 (Table 1). All flights left Parafield Airport, Adelaide, transited to Port Lincoln Airport to refuel, and then conducted the survey. The return flight was in the reverse order. The transect pattern for each survey was the same except that after the first survey transect 2 was extended to provide greater coverage of the south west corner of the survey area (see Appendix A for details and Appendix B for the trackline of each survey). The time spent over the survey area was influenced by whether the aircraft went off transect and primary effort to investigate a sighting off the trackline. The total flight time was also influenced by restricted airspace around the RAAF Base Edinburgh located near to Parafield Airport.

Table 1: Summary of flight details.

Survey	Date	Total flight time	Time over survey area	Sighting conditions	No. sightings in the survey area		No. sightings outside the survey area	
					Great whales	Other cetaceans	Great whales	Other cetaceans
1	6.4.13	05:34	02:30	Good	0	2	0	0
2	16.4.13	05:24	02:00	Good	0	5[1]	0	1
3	28.4.13	05:06	01:44	Fair	0	1	0	0
4	30.4.13	05:29	02:03	Good	0	0	0	0
5	6.5.13	06:08	02:17	Good	2	1	0	0

[1] For one pod there were two sightings as it was seen on both sides of the aircraft at the same time.

Initially, four surveys were planned and IFAW requested that two surveys were conducted while IFAW personnel were on a chartered vessel (*S/V Pelican*) in the area between the 24th April and the 9th May. The first three surveys were evenly spaced over time. The fourth survey was conducted shortly after on the 30th April as the weather conditions were not forecast to be favourable beyond then and the fifth survey had not been approved by IFAW. Surveys 3, 4 and 5 were all conducted when the *S/V Pelican* was in the area.

Sighting details of cetaceans

There were 12 confirmed sightings of cetaceans over the five surveys representing 11 different pods, with one of those sightings/pods observed outside the survey area while in transit. Of the 11 pods observed, two were identified as sperm whales (Figure 1), three as dolphins (species not determined), and six as unidentified small odontocetes (Table 2). Note that the survey protocol means that the aircraft only deviated from the transect to investigate sightings of great whales which explains why other cetaceans were not identified to a species level. The distribution of cetacean sightings is shown in Figure 2 and Figure 3. Each sighting is shown with the survey number/sighting. The details for all sightings, including other marine fauna as well as vessels, are shown in Appendix C.

Figure 1: Photograph of a Sperm whale (survey 5, sighting B).

Table 2: Summary of confirmed cetacean sightings.

Survey	Time	Sighting	Species	Composition	Position
1	14:02	F	Small odontocetes	~50	-35° 40' 17", 135° 14' 30"
1	14:13	G	Small odontocetes	100+	-35° 43' 14", 135° 20' 51"
2	11:32	A	Small odontocetes	~10	-34° 54' 01", 135° 17' 13"
2	12:26	B/C	Dolphins	80+	-35° 28' 20", 134° 47' 24"
2	12:27	D	Dolphins	~20	-35° 29' 16", 134° 46' 49"
2	13:00	E	Small odontocetes	~12	-35° 31' 30", 135° 02' 21"
2	13:35	G	Dolphins	~20	-35° 42' 10", 135° 13' 22"
3	15:09	B	Small odontocetes	5+	-35° 45' 41", 135° 19' 43"
5	13:57	A	Small odontocetes	~12	-35° 26' 21", 134° 48' 23"
5	14:44	B	Sperm whales	2	-35° 36' 36", 134° 58' 28"
5	14:45	C	Sperm whale	1	-35° 41' 21", 134° 54' 55"

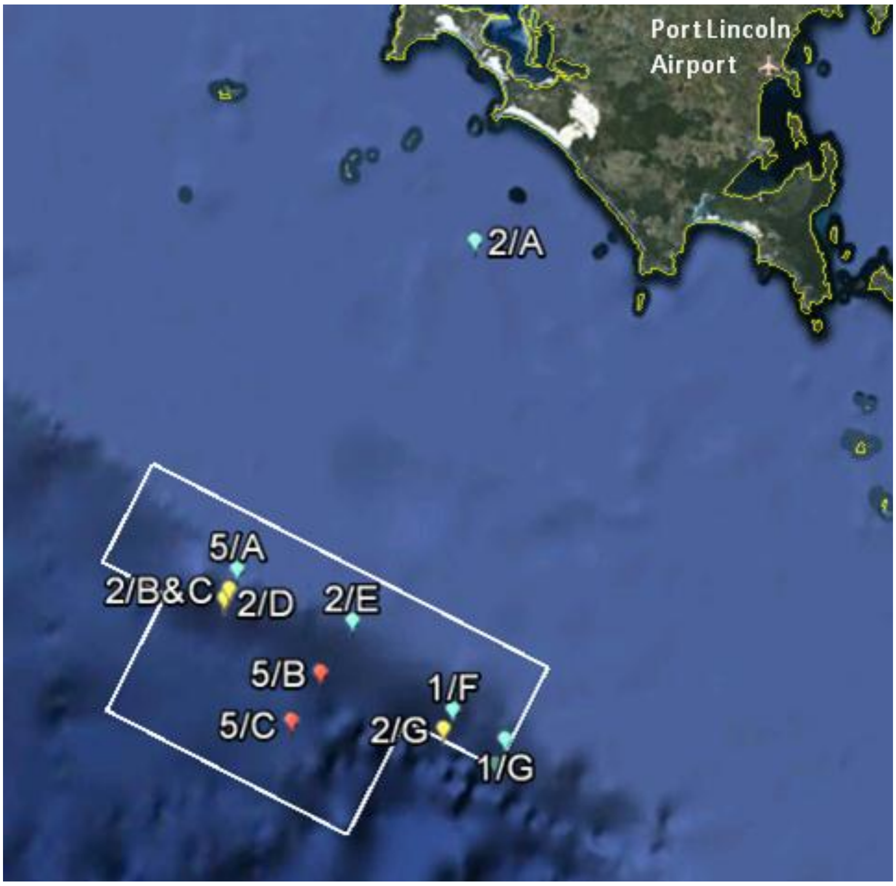

Figure 2: Google Earth image showing all cetacean sightings.

(Note: Each sighting is shown with the survey number/sighting. Light blue - small odontocetes, yellow - dolphins, red - sperm whales)

Figure 3: Google Earth image showing cetacean sightings in the survey area.

(Note: Each sighting is shown with the survey number/sighting. Light blue - small odontocetes, yellow - dolphins, red - sperm whales)

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Appendix A: Aerial Survey Design and Survey Area

IFAW provided BPM with the co-ordinates for the corner points of the survey area (Table 1). A map of the survey area and location relative to the mainland is shown as the white polygon in Figure 1.

Table 1: Survey area co-ordinates

Latitude	Longitude
35 15 30.45 S	134 38 14.47 E
35 35 42.46 S	135 26 03.11 E
35 45 38.01 S	135 19 50.12 E
35 40 59.07 S	135 08 43.93 E
35 52 13.82 S	135 01 37.77 E
35 39 50.27 S	134 32 25.09 E
35 28 27.39 S	134 39 41.55 E
35 25 11.65 S	134 32 03.50 E

Figure 1: Survey area location

Survey Design

The key focus of the survey was to locate and identify great whales (e.g. baleen whales plus the sperm whale) within the target area. An abundance estimate was not required and therefore the double-platform observer configuration typically used for mark-recapture based abundance estimates (as in Buckland et al. 2001) was not utilised. The survey employed a combination of line-transect methods and off-transect identification verification of sightings of great whales.

Initial design

It was considered that transects spaced approximately 12 km apart would provide good coverage. Given the area to be covered we were able to fit in eight transects with that spacing, and approximately perpendicular to the depth contours (Figure 2). Each transect extended approximately 5 km beyond each end of the target area to provide a 'buffer zone' before the line turn during which observers would go 'off-effort' to manage fatigue. For all flights, transects were flown in order from 1 to 8.

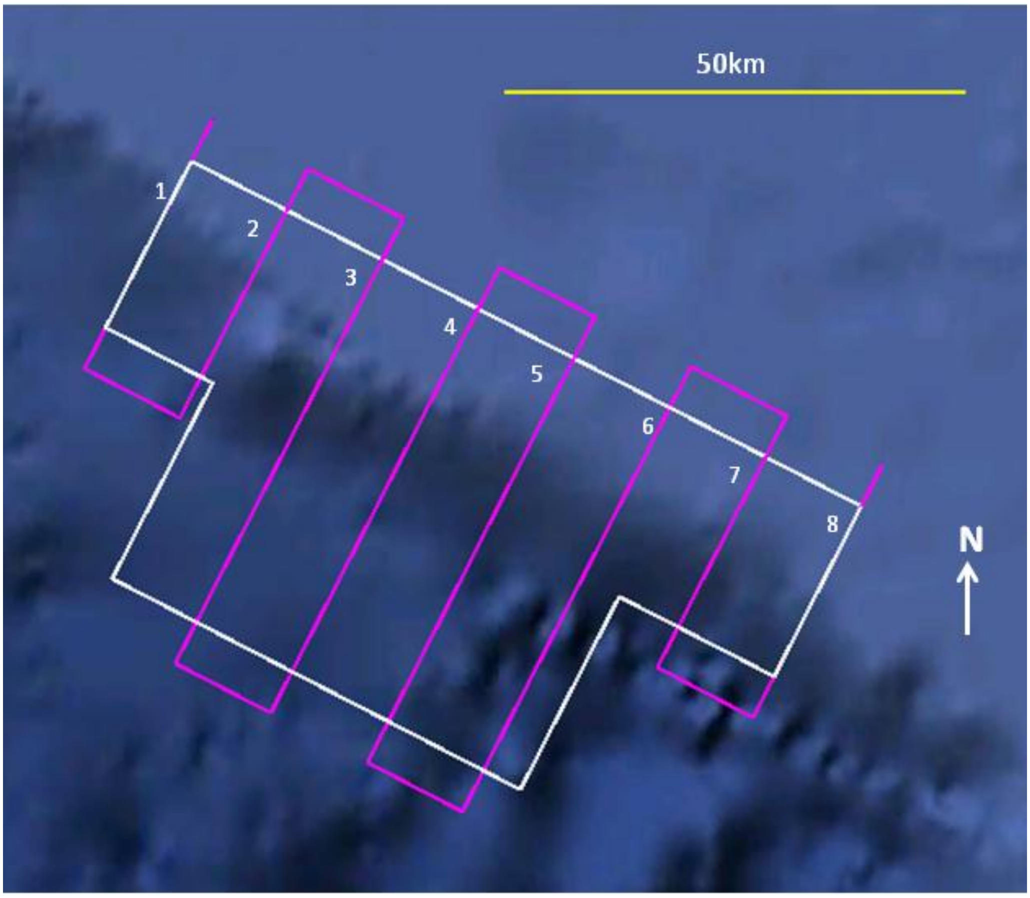


Figure 2: Initial survey design

Subsequent modifications

After the first survey flight we made two modifications to the survey design. We realised that the south-west corner of the survey area was not being covered adequately so transect 2 was extended to the south-west to match the length of transects 3-6. The 5 km buffer zone at the end of each transect was shortened to reduce the amount of time spent outside the survey area during turns. In general, the line turn to the next transect began as soon as the edge of the survey area was reached.

Thus, transects 1, 7, 8 were approximately 21 km in length, and transects 2 - 6 approximately 45 km in length (excluding line turns).

Survey Methods

Personnel

For each survey there was one pilot and two observers.

Equipment

Aerial surveys were conducted using a Cessna 337TM high-wing, twin engine aircraft. Observers wore appropriate Personal Protective Equipment (see the HSE section below). Other equipment used by the observers included:

- A handheld Garmin GPS to record the flight path and waypoints of sightings;
- A marine VHF radio to communicate with IFAW personnel on the charter vessel *S/V Pelican*;
- An inclinometer each to assist in estimating distances to sightings from the aircraft; and
- A microtrack to record flight and sighting information during the survey.

Flight plan & procedures

Flights were to take place in April and May with at least two flights requested while IFAW personnel were on a chartered vessel in the area between the 24th April and the 9th May. We attempted to spread the flights evenly through the survey period, depending on availability of personnel and weather conditions. Ideally, surveys should be conducted on days with wind speed less than 12 knots and with clear sighting conditions to maximise whale and marine megafauna detection. During the survey period, the aircraft was housed at Parafield Airport, Adelaide. For safety reasons, the aircraft did not fly direct to the survey area from Parafield but flew via Port Lincoln Airport where it would refuel. From Port Lincoln the aircraft would fly to the north west corner of the survey area and begin observations on transect 1. The survey would finish at the end of transect 8 in the north east corner of the survey area before flying back to Port Lincoln to refuel, and then return to Parafield Airport. As we were not obtaining abundance estimates of any cetacean species, randomisation of the survey start point between flights was not necessary and therefore the most cost effective route of transects was flown.

While on transect, surveys were flown at an altitude of 457 m and at a speed of approximately 240 km per hour. These values are based on the methods of Gill *et al* (2011) for blue whale surveys off Victoria. Given the safe flying range of the aircraft and that it was over water, it was agreed with IFAW that the aircraft would deviate from the trackline only to investigate sightings of great whales (e.g. baleen whales plus sperm whale), and not other cetaceans. A waypoint will be taken prior to leaving the trackline so that the aircraft can resume the trackline at the same location.

After the first survey the question arose as to how much time should be spent off-transect to confirm a sighting of a great whale? Given that one of the primary objectives of the survey was to map the distribution of blue whales we used the following rule; that the minimum time should be 7 minutes and the maximum time 15 minutes (with the actual time spent at the discretion of the survey leader). These times are taken from a study of tagged blue whales where the average dive time was 6.6 minutes and the longest dive time was 14.7 minutes (Croll *et al*. 2001).

Observations

The two observers were seated on opposite sides of the aircraft, allowing each observer to scan from as close to the trackline as is practicable to as far as conditions will allow. In good sighting conditions, great whales can be seen up to six or more kilometres away at that survey altitude. With tracklines approximately 12 km apart there was good coverage over the survey area. There is a 'blind strip' directly beneath the aircraft of approximately 600 m width that will not be visible to observers. Both observers scanned their sector continuously when on transect. Any opportunistic sightings made when off transect were also recorded.

The following variables were recorded by the survey leader:

- Before takeoff -
  - Date and time;
  - Wind speed;
  - Wind direction;
  - Cloud cover (oktas); and
  - Visibility
- Close to survey area and whenever conditions change during transects -
  - Beaufort Sea State;
  - Glare;
  - Cloud cover; and
  - Turbidity.
- Effort -
  - Number and names of observers plus any other extra observers present;
  - Start time of transect;
  - Transect number;
  - Direction;
  - End time transect;
  - Leaving transect (e.g. to go to a sighting off the trackline);
  - Resume transect (e.g. when returning to the trackline at the same point that the transect was left); and
  - Position (where left or elsewhere).
- When a sighting of a whale is made, the observer will record the following information:
  - Side of aircraft;
  - Time;
  - Angle of inclination (or GPS waypoint number if off trackline);
  - Species;
  - Number of animals;
  - Presence of calves;
  - Behaviour (e.g. travel, feed, log, social, mill) and/or activity (e.g. dive, splash, blow);
  - Position (e.g. surface, below surface);
  - Direction of travel;
  - Presence of krill and;
  - Any other relevant information (e.g. other species present such as sea birds, etc.).

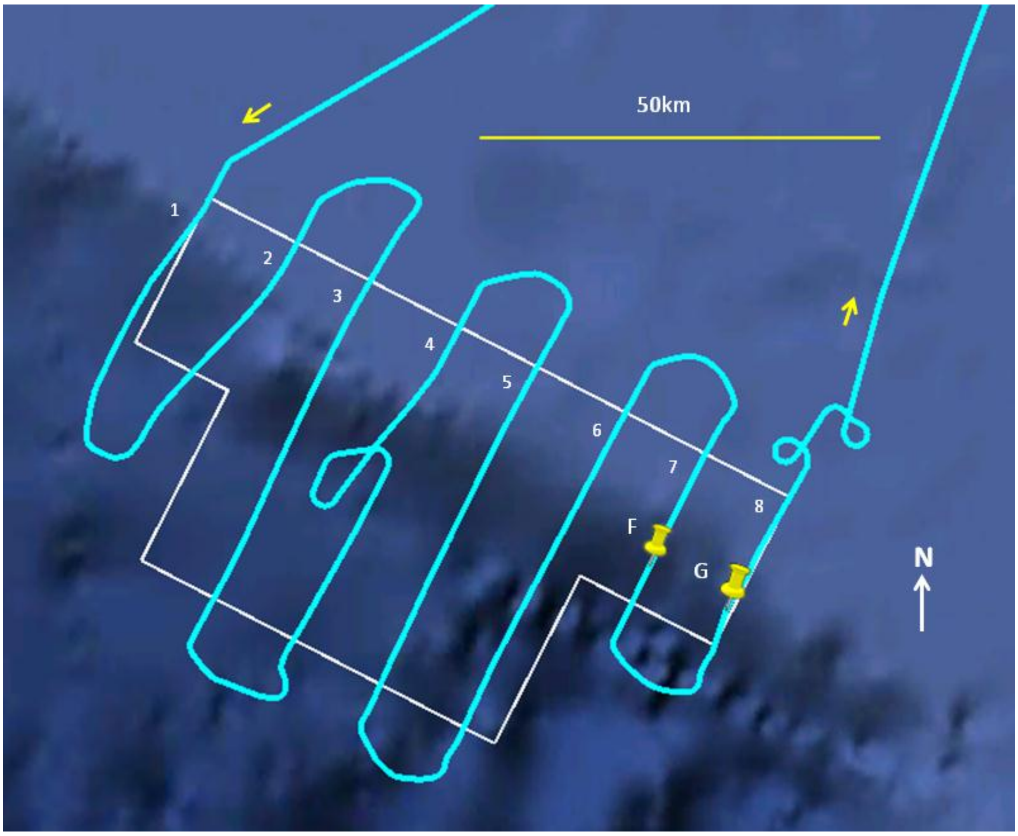
Many species of marine mammal have been recorded in South Australian waters including dolphins, whales and pinnipeds. It was recognised that at 457m altitude, species identification is unlikely for the smaller species and therefore only the presence of unidentified small cetaceans will be recorded if sighted. However, attempts were made to identify to species whenever possible. As the targets of this survey were great whales, 'off-effort' deviations from the trackline were only be made for suspected sightings of large cetaceans to confirm species identification, pod composition and behaviour.

Appendix B: Survey tracklines & sightings

The images below were taken from the individual interim reports for each survey and show the trackline over the survey area and sighting locations of cetaceans. Refer to Table 2 in the body of the main report for details of sightings. For each image the direction of flight, the transect number, direction of North, and a 50 km scale are also shown.

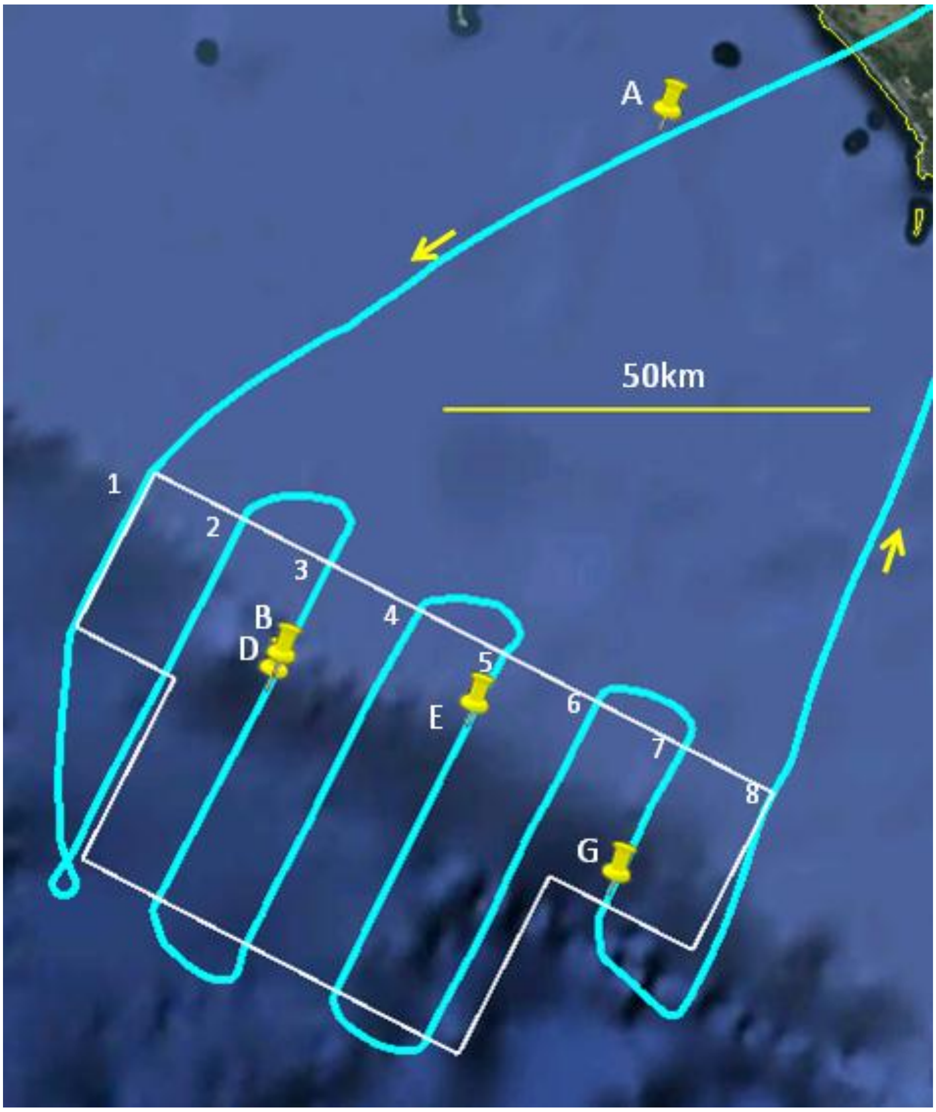
Survey 1 - 6th April 2013

During the flight, the survey leader noticed that the first two transects were flown off course. This was subsequently corrected. The deviation off the trackline in transect 4 was to investigate a possible whale sighting which was not confirmed and therefore doesn't appear on the Figure. The deviation just to the north of transect 8 was to investigate two large schools of fish as their large size and associated water disturbance indicated the possibility of a feeding whale below.

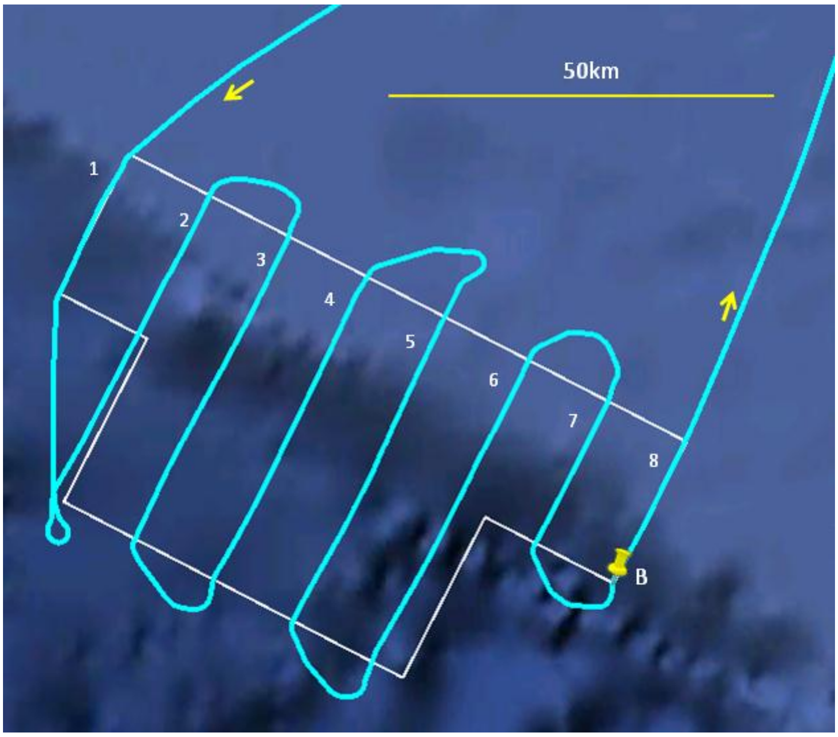


Survey 2 - 16th April 2013

Note that transect 2 has been extended to the south west for this and all subsequent flights. Transect 8 was flown slightly off course to avoid rain at the southern end.

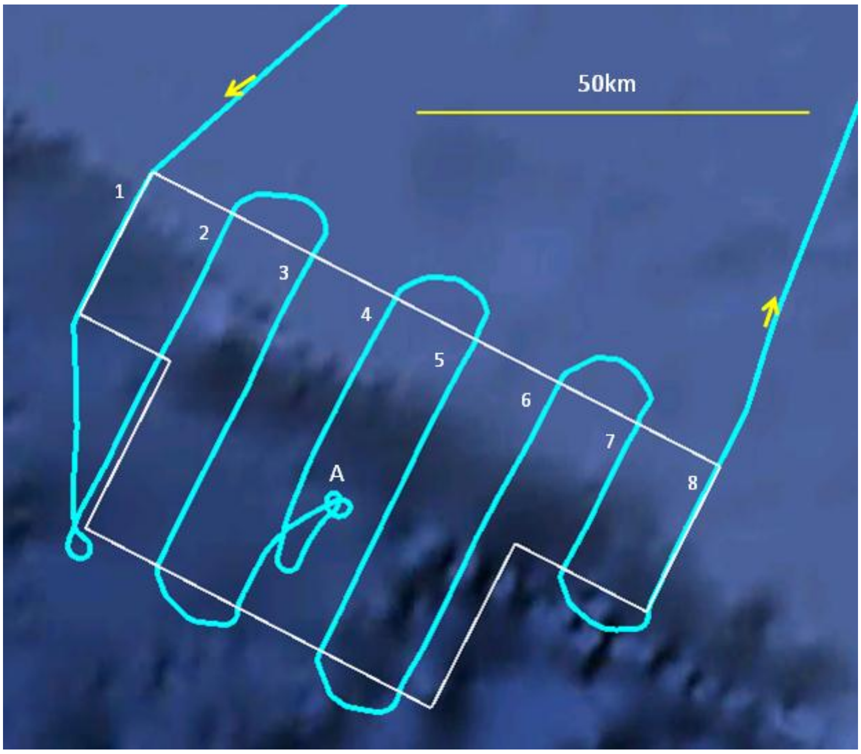


Survey 3 - 28th April 2013



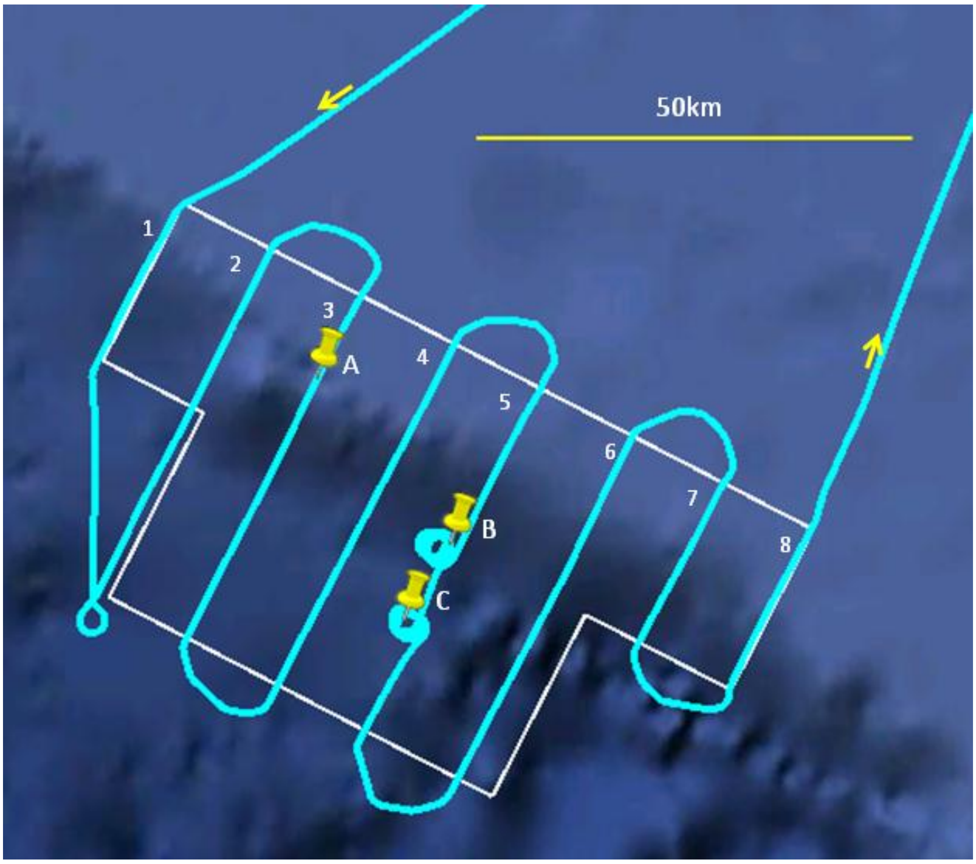
Survey 4 - 30th April 2013

Transect 4 was broken for a flyover and to communicate with the *S/V Pelican* (Sighting A).



Survey 5 - 6th May 2013

The deviations off the trackline in transect 5 were to investigate sperm whale sightings.



Appendix C: All sightings

The table contains position and description for all sightings.

Survey	**Sighting**	**Position**	**Description**
1	A	-35° 35' 30", 134° 42' 39"	Cargo ship
1	B	-35° 35' 39", 134° 51' 39"	Unconfirmed whale
1	C	-35° 50' 30", 134° 59' 27"	Fish school
1	D	-35° 33' 51", 135° 10' 00"	Shark
1	E	-35° 38' 00", 135° 15' 52"	Fish school
1	F	-35° 40' 17", 135° 14' 30"	Small odontocetes
1	G	-35° 43' 14", 135° 20' 51"	Small odontocetes
1	H	Not recorded	Fish school
1	I	-35° 16' 37", 135° 35' 57"	Fishing boats
2	A	-34° 54' 01", 135° 17' 13"	Small odontocetes
2	B/C	-35° 28' 20", 134° 47' 24"	Dolphins
2	D	-35° 29' 16", 134° 46' 49"	Dolphins
2	E	-35° 31' 30", 135° 02' 21"	Small odontocetes
2	F	-35° 29' 10", 135° 14' 28"	Fauna (poss seal or shark)
2	G	-35° 42' 10", 135° 13' 22"	Dolphins
2	H	-35° 16' 07", 135° 35' 32"	Fishing boat
3	A	-35° 47' 10", 135° 18' 59"	Cargo ship
3	B	-35° 45' 41", 135° 19' 43"	Small odontocetes
4	A	-35° 39' 31", 134° 48' 59"	S/V Pelican (position is where the aircraft left the trackline to fly over)
4	B	-35° 25' 32", 135° 06' 15"	Cargo ship
5	A	-35° 26' 21", 134° 48' 23"	Small odontocetes
5	B	-35° 36' 36", 134° 58' 28"	Sperm whales
5	C	-35° 41' 21", 134° 54' 55"	Sperm whale
5	D	-35° 26' 08", 135° 05' 52"	Cargo ship