Report of a passive acoustic survey for cetaceans over Portuguese submarine canyons conducted from R/V *Song of the Whale*

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Report prepared by:
Anna Cucknell, Conor Ryan, Miriam Romagosa, Oliver Boisseau, Anna Moscrop & Richard McLanaghan
Marine Conservation Research International
1 High Street
Kelvedon
Essex CO5 9AG, UK

Email: MCRinfo@mcr-team.co.uk

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EXECUTIVE SUMMARY

The research vessel *Song of the Whale* transited through Portuguese waters between the 30th May and 3rd June 2013 *en route* to the Mediterranean Sea. An opportunistic passive acoustic survey was conducted over four submarine canyons off the southwest of Portugal, which had been identified as being of particular interest for cetaceans. This research cruise was funded by the International Fund for Animal Welfare (IFAW) and undertaken following discussion with Ricardo Antunes (University of St Andrews) and José Vítor Vingada, Department of Biology, University of Minho, Portugal. The survey focused on beaked whales, as deep submarine canyon systems are known to be important to Ziphiidae; however all cetacean sightings and detections were recorded. On this occasion, no sightings or acoustic detections of beaked whales were reported, however four cetacean species were sighted: striped, common and Risso's dolphins and fin whales. This survey, although limited by time constraints, aimed to provide novel data on the presence of cetaceans in offshore Portuguese waters in order to inform management and conservation of this area and its marine mammal species.

INTRODUCTION

Beaked whales (Family Ziphiidae) carry out prolonged deep dives lasting for up to one hour at a time (Barlow *et al*., 2013), therefore they are difficult to detect by visual means, which is compounded by their cryptic surfacing behaviour. It is increasingly recognised that passive acoustic monitoring is an effective means for detecting beaked whales, taking advantage of their distinctive echolocation clicks (Barlow *et al*., 2013). Submarine canyons are known to provide important habitat for beaked whales as they support aggregations of their preferred prey (squid and deep-sea fish), afforded by increased upwelling and hence elevated productivity (Becker *et al.*, 2012; Hooker *et al.* 1999). To the southwest of Portugal, several deep submarine canyons extend from the abyssal plain towards the coast. There have been few dedicated marine mammal offshore surveys conducted in the area; therefore more information is required in order to assess whether they support beaked whales, a taxon whose species mostly remain 'Data Deficient' on the IUCN Red List. *En route* to the Mediterranean Sea, the R/V *Song of the Whale* team conducted a passive acoustic and opportunistic visual survey of four submarine canyons off the southwest coast of Portugal (Figure 1). This particular area is currently under consideration for designation as a Natura 2000 site for cetaceans in offshore areas. It is hoped that this survey will provide additional data to help inform decision making regarding the designation of MPA boundaries and the development of protection measures for the species found within these waters.

METHODOLOGY

R/V *Song of the Whale* arrived in Portuguese waters on the 30th May after a passage from the UK. R/V *Song of the Whale* is a 21 metre auxiliary-powered cutter-rigged sailing research vessel, owned by the International Fund for Animal Welfare and operated by Marine Conservation Research Ltd (MCR Ltd). The SOTW team spent four days in Portuguese waters, leaving on 3rd June 2013 bound for the eastern Mediterranean Sea. Pre-determined track-lines were laid out to cover the deepest parts

of four target canyons, beginning and ending at the 100 m and 2000 m contours respectively (figure 1).

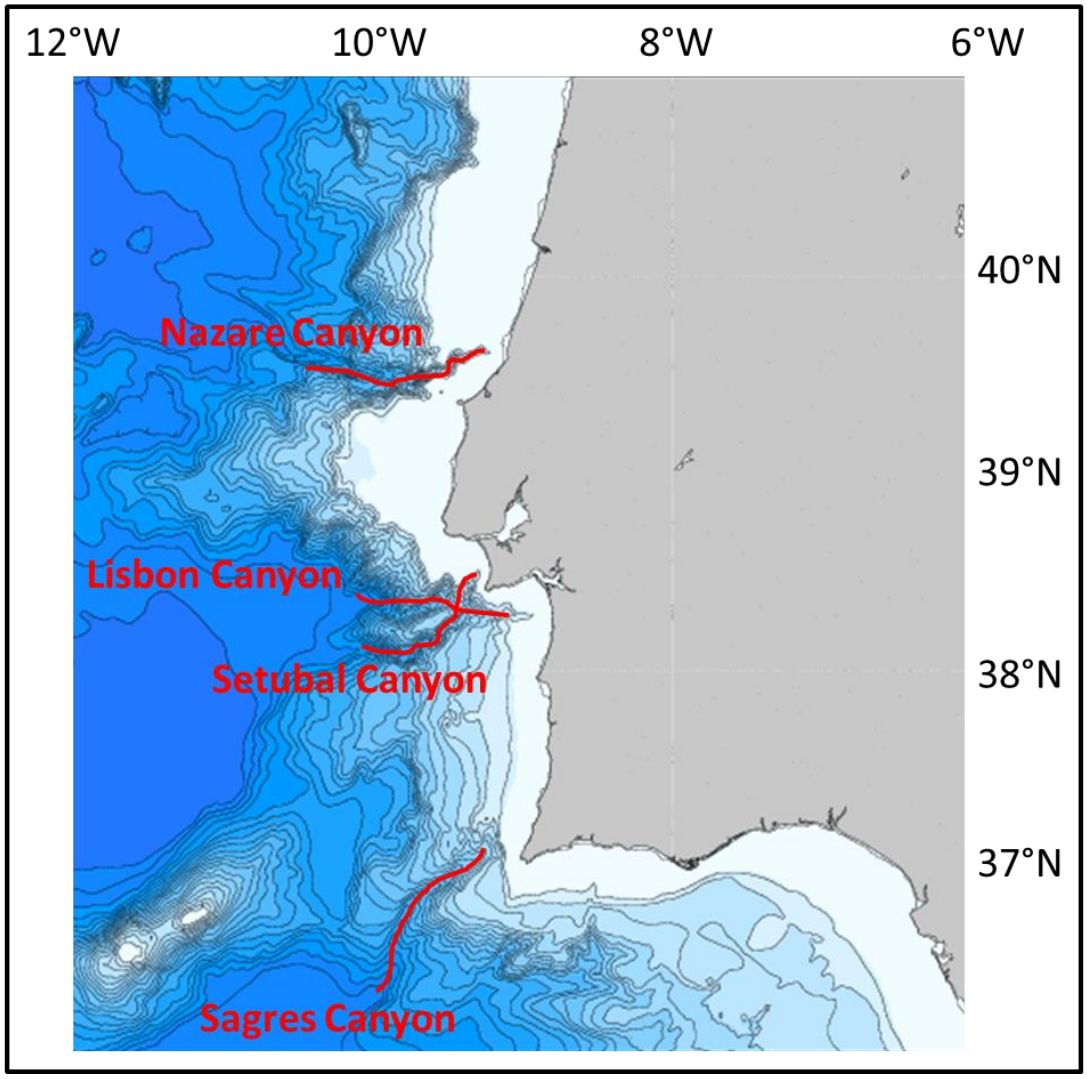

Figure 1: The four canyons off the Portuguese coastline which were surveyed by R/V Song of the Whale on the passage to the Eastern Mediterranean (image made using Sea Turtle www.seaturtle.org).

A single hydrophone array was towed under sail, motor or motor/sail at a speed between a minimum of 5 knots and a maximum of 8 knots (to reduce cable strum and keep the arrays at depth). During daylight hours and in sea states below four, a single visual observer with binoculars kept watch for cetaceans from a sighting platform that provided an eye height of 5.5 m above sea level. Observers were prompted by acoustic cues and/or deck observers. In higher sea states, observers kept a lookout from deck. Sightings were logged to a database via the Logger 2010 software (IFAW). Environmental, GPS and true heading data were logged automatically to the same database, including date, time, vessel position (lat-long), sea surface temperature (°C) and wind speed (knots). Manual records of other environmental variables (such as sea state, wave and swell height) and survey effort (numbers and positions of observers) were made hourly.

Acoustic sampling was primarily conducted using a 400 m towed three-element broadband hydrophone array. Continuous stereo recordings were made at sampling rates of both 48 kHz and 192 kHz via bespoke buffer boxes passing signals to NI-6251 and fireface data acquisition cards respectively. The system was capable of detecting beaked whale clicks (25 to 50 kHz) and other mid-frequency odontocetes including sperm whales and most delphinids. Recordings were made using Pamguard (www.pamguard.org) and written to disk as two-channel 16 bit wav files. Additionally Pamguard continuously ran several automated detection modules including a click detection module to log odontocete click trains (2 to 55 kHz) and a whistle detection module to detect frequency modulated calls produced by odontocetes. Two-minute listening stations were carried out at 15 minute intervals during which cetacean clicks or whistles were logged (to species level where possible). Noise from the research vessel, other vessels and water-noise were recorded as a categorical index: 0= no noise, 1= faint noise, 2= noise becoming clear, 3= noise clearly audible, 4= noise becoming loud, 5= nothing else heard but noise. The same scale was used for cetacean detections.

A more thorough investigation of potential clicks was conducted post-survey. Initially, the files created in the field using varying trigger thresholds were analysed using a basic click detection algorithm. Following this first pass, the click files were regenerated using the original recordings and those settings perceived to be most suited for the acoustic environment of this survey. During this second pass, an enhanced frequency sweep algorithm was used in Pamguard to identify those waveforms with more than five zero crossings, a useful diagnostic test to differentiate beaked whale clicks from those of other odontocetes. Candidate beaked whale clicks were selected if they had significant energy in the 25 to 50 kHz energy band, had a waveform resembling that of published data for other beaked whale species, had an upswept narrowband structure revealed in a Wigner plot and formed part of a click train, i.e. with similar bearings and regular inter-click intervals. Potential beaked whale clicks were classified with a subjective measure of confidence (possible, probable or definite) according to how well they conformed to these parameters. The data were analysed in two separate passes. The occurrence of other non-ziphiid clicks was also logged.

RESULTS

The survey covered 628 nm in Portuguese waters, of which 497 nm were with at least acoustic effort and 109 nm also included visual observations (Table 1 and Figure 2).

Table 1: Effort status of R/V Song of the Whale throughout Portuguese waters.

	Nautical miles	**Time (hh:mm:ss)**
Total Track	627.9	101:45:24
Track	68.2	11:52:16
Track with acoustic effort	444.1	71:53:53
Track with visual effort	60.2	09:01:42
Track with acoustic and visual effort	51.2	07:48:47
With Animals	1.6	00:19:50
Other (Engine checks etc.)	2.6	00:48:33

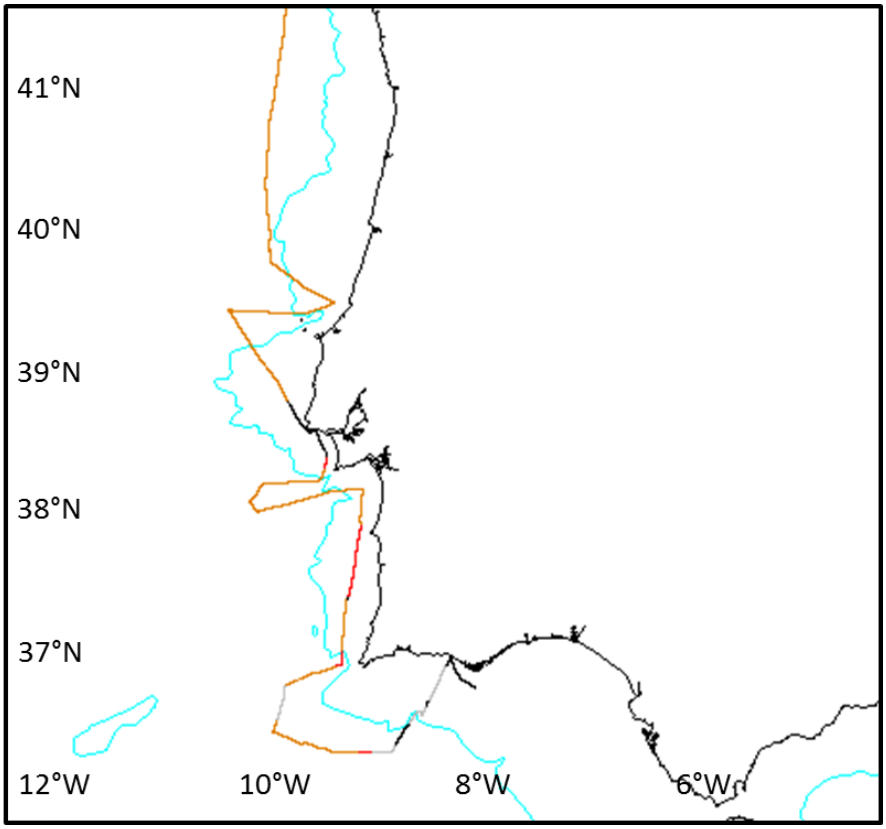

Figure 2: Map showing the research effort by *RV Song of the Whale*. The black lines indicate track without effort, orange lines show acoustic effort only, grey lines show visual effort only and the red lines show acoustic and visual effort.

Acoustic Data

Odontocete clicks and whistles were heard along most of the track off the Portuguese coastline (Figure 3), with sperm whale detections in two groups: one in the Lisbon canyon south of Setubal and the other in the deep water off southern Portugal (Figure 4).

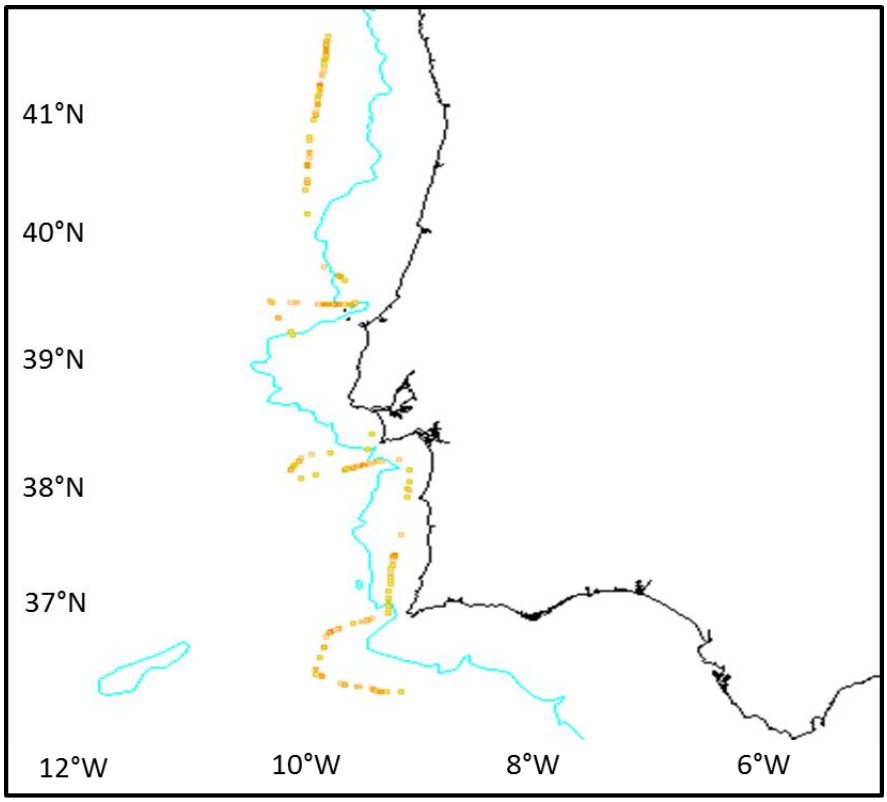

Figure 3: A map displaying the listening stations where odontocetes were heard (both clicks and whistles). The darker the colour the louder the detection.

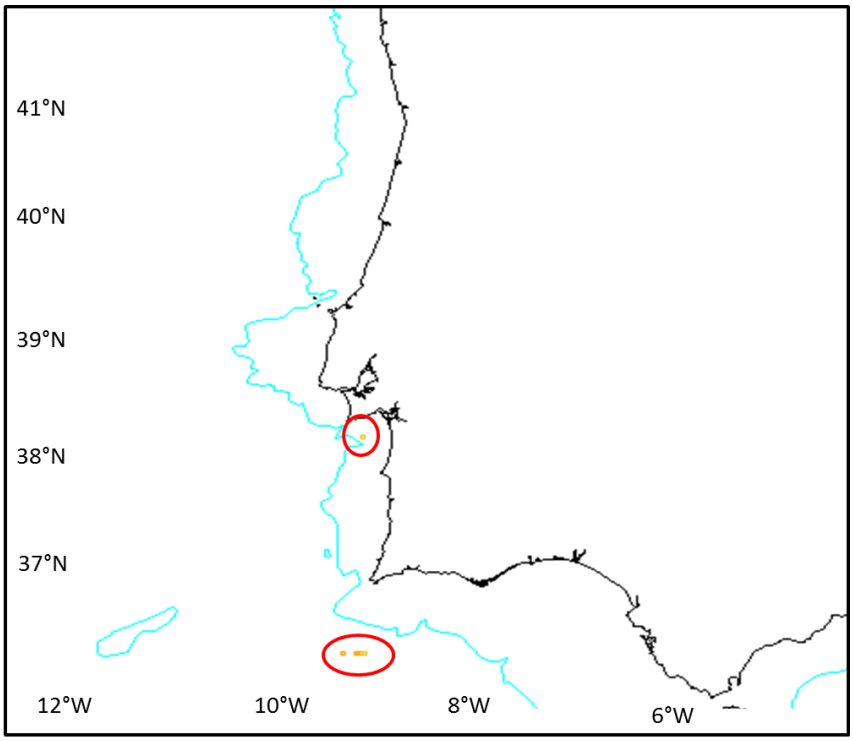

Figure 4: A map displaying the listening stations where sperm whale clicks were heard with each grouping of clicks circled in red. The darker the colour the louder the detection.

Detailed acoustic analysis (by two independent, experienced operators) of the high frequency recordings were made post-survey in order to establish if any beaked whale clicks were recorded. It was confirmed that there were no beaked acoustic detections.

Sightings

Opportunistic visual survey effort was carried out during daylight hours only, from the A-frame (giving an eye height of approximately 5 m) or from the deck during rough seas. The distribution of cetacean sightings in relation to depth contours is presented in Figure 5. The most commonly sighted cetacean was the common dolphin (*Delphinus delphis*) with 12 groups, ranging from one to 100 in size (Table 2). The next most abundant cetacean species observed was the striped dolphin (*Stenella coeruleoalba*), with four groups ranging in size from five to 30. Three sightings were recorded of fin whales (*Balaenoptera physalus*), with group sizes ranging from one to four. A single sighting of between five and eight Risso's dolphins (*Grampus griseus*) was recorded in association with striped dolphins. A strong tendency for mixed striped/common dolphin groups was noted: all of the groups numbering greater than 15 individuals comprised of both species. For five, or 20% of sightings, it was not possible to determine species with confidence; these were all recorded as 'dolphin species'.

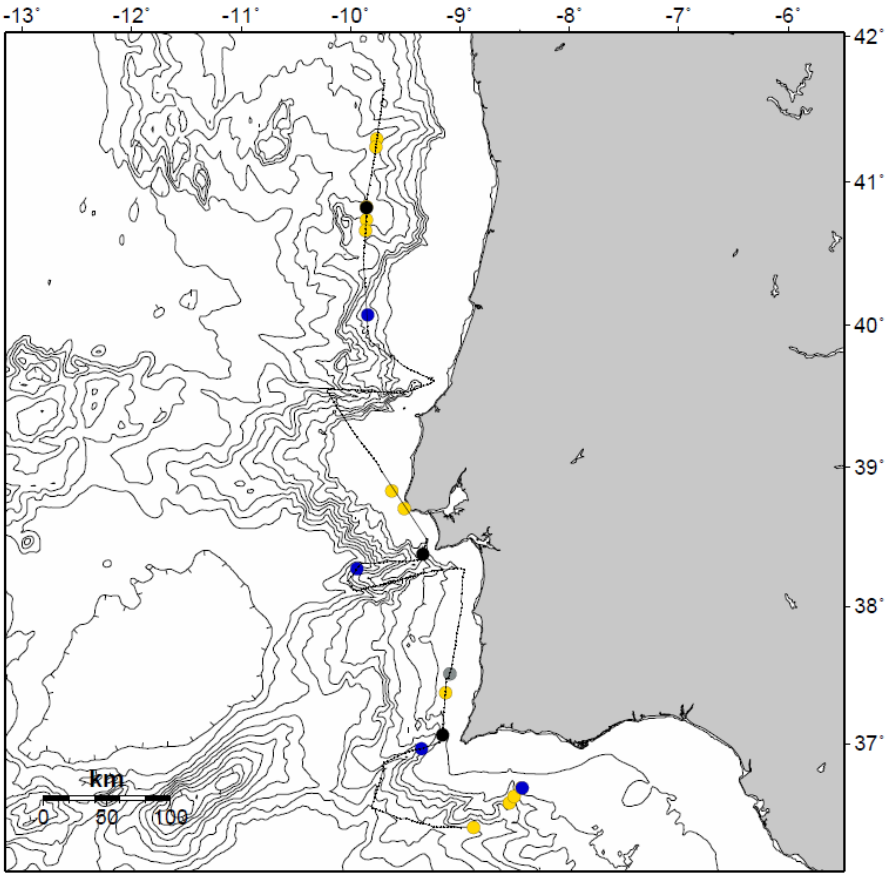

Figure 5: Map showing the distribution of cetacean sightings, with the track followed by R/V Song of the Whale shown as black dots. Yellow=common dolphin; blue=striped dolphin; black=fin whale; grey=Risso's dolphin.

Table 2: The date, time, location, species and group size of all cetacean sightings during the survey and passage through Portuguese waters (those sightings with calves present are marked with *).

Time (UTC)	Latitude	Longitude	Species	Min No	Max No	Platform
30/05/2013 02:19	41.52408	-9.71365	Unidentified Dolphin	1	1	Deck
30/05/2013 04:48	41.30085	-9.75868	Common dolphin	15	25	Deck
30/05/2013 05:26	41.24607	-9.7688	Common dolphin	5	5	Deck
30/05/2013 09:32	40.83123	-9.855	Common dolphin	8	10*	Deck
30/05/2013 09:36	40.82453	-9.8554	Fin whale	2	2	Deck
30/05/2013 10:23	40.7407	-9.85638	Common / Striped dolphins	8	10	Deck
30/05/2013 11:06	40.6655	-9.86293	Common / Striped dolphins	20	30	Deck
30/05/2013 16:05	40.07747	-9.84208	Common / Striped dolphins	30	40	Deck
31/05/2013 15:16	38.83063	-9.62098	Common dolphin	12	15*	Deck
31/05/2013 16:58	38.7037	-9.50838	Common dolphin	1	1	Deck
01/06/2013 14:19	38.37597	-9.33807	Fin whale	4	5	Deck
01/06/2013 18:55	38.2715	-9.9406	Striped dolphin	5	5	Deck
02/06/2013 11:59	37.666	-9.05328	Unidentified Dolphin	1	1	A-Frame
02/06/2013 13:19	37.5099	-9.09335	Risso's dolphin	5	8	Deck
02/06/2013 14:50	37.37382	-9.13275	Common dolphin	10	12	A-Frame
02/06/2013 17:24	37.06405	-9.15987	Fin whale	1	1	A-Frame
02/06/2013 19:09	36.9639	-9.35283	Striped dolphin	15	20	Deck
03/06/2013 02:27	36.46058	-9.5832	Unidentified Dolphin	3	6	Deck
03/06/2013 09:02	36.38427	-8.87355	Common dolphin	6	7	A-Frame
03/06/2013 12:31	36.564	-8.54987	Common dolphin	5	7	Deck
03/06/2013 13:06	36.61315	-8.5051	Common dolphin	15	20	A-Frame
03/06/2013 13:42	36.66587	-8.45277	Unidentified Dolphin	5	6	A-Frame
03/06/2013 13:47	36.67297	-8.44453	Unidentified Dolphin	4	4	A-Frame
03/06/2013 13:50	36.67688	-8.44002	Common / Striped dolphins	100	150	A-Frame
03/06/2013 13:55	36.67608	-8.43122	Striped dolphin	12	20*	A-Frame

DISCUSSION

Submarine canyons have been recognised as important habitats in the marine environment and have been shown to have higher primary production than surrounding areas (Hooker *et al*., 1999), as well as being linked to key feeding areas for cetaceans. Canyons are preferred fishing sites and tend to concentrate pollutants and debris (Richter *et al.,* 2009). Submarine canyons are also the typical habitat of beaked whales, a group of species that is particularly sensitive to disturbance by anthropogenic noise, particularly to high intensity sound sources (see, for example, Cox *et al*., 2006;

Barlow and Gisiner, 2006; Pirotta *et al*., 2012). Due to their biological importance and the potential for impact from anthropogenic activities, submarine canyons are prime candidates for Marine Protected Area status.

The Portuguese continental shelf includes several submarine canyons which being close to the coast and in proximity to important harbours (e.g. Peniche), industrial sites (e.g. Setubal) and naval bases (e.g. Lisbon), make them vulnerable to the impact of anthropogenic activities. Occasional beaked whale strandings along the coast suggest that these species may occur in the submarine canyons of the Portuguese continental shelf, but this has not been confirmed by dedicated surveys. This short, dedicated acoustic survey (with opportunistic visual effort) did not detect any beaked whales either acoustically or visually. As beaked whales are inconspicuous cetacean species that spend long periods submerged, sighting beaked whales can be very challenging and detection is greatly enhanced by using acoustic detection of their vocalisations (Barlow *et al*., 2013). However, it should be noted that this was a short study, with very limited effort and the lack of sightings and acoustic detections reported should not be interpreted to mean that there are no beaked whales present within this canyon network. Indeed a recent study demonstrated that beaked whales are detectable for just 20 – 30% of the time using passive acoustic monitoring (Barlow *et al.* 2013), therefore greater acoustic survey effort, in addition to the planned aerial surveys, will be required to determine the status of beaked whales in the Portuguese canyon system.

There were four species of cetacean seen and / or acoustically detected during the study including common, striped and Risso's dolphins as well as fin whales. Common and striped dolphins were found in associated pods for 31% and 57% of their sightings respectively. Common dolphins are present in both neritic and oceanic habitats (Pusineri *et al*., 2007), whereas striped dolphins tend to be more oceanic in range, however while offshore they both prey mostly on pelagic animals, having been reported to forage primarily on fish and cephalopod species (Silva, 1999; Rinelstein *et al*., 2006). Even though both species share similar prey sources, it seems associations between the species may be beneficial.

Risso's dolphins, a deep water species often found in waters over 600 metres in depth (Cañadas *et al*., 2002), were sighted on only one occasion during the survey in Portuguese waters, on the upper continental shelf. Baumgartner (1997) found five to six times more sightings on steep slopes of the upper continental shelf when surveying the Gulf of Mexico, with their presence in deep water areas around the world thought to be due to the oceanographic mechanisms concentrating their prey in these areas (Spitz *et al*., 2011; Cañadas *et al*., 2002; Baumgartner, 1997).

Three sightings of fin whales were made, with groups of one to four individuals observed. All sightings were situated over steep slope areas. Fin whales have been documented to occur worldwide in offshore waters, having a catholic diet, preying mostly on crustaceans and fish (Reilly *et al*., 2013). Although these whales were found very close to Mediterranean waters, it is believed, from genetic analysis, that the North Atlantic and Mediterranean fin whales are genetically distinct (Bérubé *et al.* 1998) and therefore the animals seen during this study are assumed to be from the North Atlantic population. Although there is evidence that some of the population of fin whales migrate between northern latitudes for feeding in summer months and southern latitudes for breeding in winter months, from acoustic analysis it seems there is also year around presence of fin

whales in all of their range (Clark, 1995). Acoustic and stable isotope based studies have indicated some exchange between fin whales in the south-western Mediterranean Sea and adjacent North Atlantic waters (Castellote *et al*. 2012; Ryan *et al.* 2013). Although the IWC considers two separate management units based on genetic analyses (Béurbé *et al.* 1998), the extent to which these populations mix is subject to controversy (see Notarbartolo di Sciara *et al.* 2003, Giménez *et al.* 2013, Castellote *et al.* in press).

Throughout the acoustic survey sperm whales were present in two areas: close into the coast by Sebutal in the Lisbon canyon, and off southern Portugal. Sperm whales occur in deep water habitats due to their primary prey of cephalopods, however existing so close to the coast by Sebutal could make them vulnerable to human activities, including offshore developments, ship strikes and fishing pressure.

The information gathered by this very short survey provides some additional data on the presence and distribution of cetaceans in Portuguese continental waters, but it could also be used to support future proposals for protection of the important habitats of the submarine canyons.

Conservation measures are required to minimise risk of population decline, but the status of marine mammals in the ACCOBAMS agreement region and the relative impact of anthropogenic threats on different species and geographic zones are poorly known. Such knowledge is vital to help design and implement adequately targeted conservation strategies which, due to the mobility of most species concerned, must extend across international boundaries.

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