Final report for a survey of cetaceans in the Azores, Portugal, conducted from R/V *Song of the Whale* 5th April – 8th May 2012 by the International Fund for Animal Welfare and Marine Conservation Research International

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SUMMARY

This report summarises research conducted from R/V *Song of the Whale* (SOTW) in the spring of 2012 around the Azores archipelago whilst *en route* from the UK to the USA. The aim of this survey was to build upon recent research effort on the vocalisations of both baleen and beaked whales as part of on-going work to develop acoustic detection systems. The *Song of the Whale* team conducted 34 days of survey effort in Azorean waters between 5th April and 8th May during which 10 cetacean species were encountered; bottlenose dolphin (*Tursiops truncatus)*, blue whale (*Balaenoptera musculus)*, short-beaked common dolphin (*Delphinus delphis)*, fin whale (*Balaenoptera physalus)*, Risso's dolphin (*Grampus griseus)*, sei whale (*Balaenoptera borealis)*, short-finned pilot whale (*Globicephala macrorhynchus)*, Sowerby's beaked whale (*Mesoplodon bidens)*, sperm whale (*Physeter macrocephalus)* and striped dolphin (*Stenella coeruleoalba)*. Common dolphins were the most encountered species and showed a relatively uniform distribution. Other species were seen less regularly and sightings were mostly concentrated to the south of Pico; however, it should be noted that effort was higher in that area. Post-analysis of the acoustic data has resulted in detection of sei whale vocalisations as well as three potential beaked whale acoustic encounters, identified most frequently along ocean floor ridges and between depths of 500 and 2000 m.

1. INTRODUCTION

The International Fund for Animal Welfare (IFAW) has had a long-running interest in the cetaceans of the Azores, primarily through the research work conducted from its research vessel *Song of the Whale* (SOTW). The distribution and behaviour of sperm whales was investigated by the team in 1987 to 1991, 1993 and 1995 using photo-identification and passive acoustic techniques (Leaper *et al*., 1992; Gordon *et al*., 1995; Gillespie & Leaper, 1996; Boisseau *et al*., 1999) whilst the distribution of beaked whales was studied in 2008 (Boisseau *et al*., 2009). The field work conducted in 2012 builds on this previous body of non-invasive research. The objectives of the work were two fold; a) to conduct visual and acoustic research for baleen whales in the waters of the Azores and mid-Atlantic ocean, and b) to investigate the presence of and make further recordings of beaked whales in the study area.

1.1 Baleen whales

Blue whales (*Balaenoptera musculus*), fin whales (*Balaenoptera physalus*), humpback whales (*Megaptera novaeangliae*), Bryde's whales (*Baleanoptera edeni*) and sei whales (*Balaenoptera borealis*) are thought to undertake extensive seasonal migrations within the Atlantic between winter mating and calving grounds and summer feeding grounds – which are mainly in higher latitudes (Clapham *et al*., 1999). During their migration, peaks in abundance occur in the Azores throughout April and May thought to follow a spring bloom of phytoplankton (Visser *et al*., 2011). The Azores is also an occasional stopover point for some individuals from the small population of humpback whales migrating from the Cape Verde breeding ground to Iceland/Norway (Wenzel *et al.* 2009). In addition to more frequent visitors, a North-Atlantic Right whale (*Eubalaena glacialis*) was sighted off the coast of the Azores in 1999, the first since 1888, by biologists from the University of the Azores Department of Oceanography and Fisheries and a biologist from Whale Watch Azores (Silva *et al.,* 2012)

Sei whales are regular visitors to the Azores in spring/early summer during their migration, the routes of which are still poorly understood (Silva *et al.,* 2003; Santos, 2008; Prieto *et al.*, 2010). An early hypothesis by Ingebrigsten (1929) postulated that sei whales spend winter months south of the Iberian peninsula, off northwest Africa migrating north up the mid-Atlantic, off the western continental slope of Europe to their feeding grounds in spring which are in Icelandic, Scottish, Norwegian and Arctic waters. More recently satellite telemetry data, has confirmed movements of tagged sei whales between the Azores and the Labrador Sea (between Canada and Greenland), an area that appears to be an important summering habitat for those whales migrating through the Azorean islands (Olsen *et al.,* 2009; Prieto *et al*., 2010; Prieto *et al*., 2012a). These recent findings suggest more complex migration routes than previously assumed involving not only latitudinal movements but also longitudinal displacements, contradicting with the stock boundaries set by the IWC for sei whales of the North Atlantic (Donovan, 1991).

Large whales are subject to a wide range of anthropogenic impacts. Each of the species of large whale sighted in the Azores suffered some degree of population depletion by whaling in the late 1800s and early 1900s. Since the IWC moratorium on whaling came into effect in 1986, other anthropogenic activities continue to threaten their recovery. Entanglement in fishing gear is a major source of non-natural mortality (Lien, 1994; Perrin *et al*., 1994; Volgenau *et al*., 1995) and ship strikes pose a threat to all species of baleen whale, especially from large, fast commercial vessels such as container ships (Clapham *et al*., 1999). Although most large scale commercial whaling no longer takes place, subsistence and aboriginal whaling takes place on a variety of species in the North Atlantic. In addition, continued catches of minke and fin whales by Iceland and Norway are a cause for concern.

There are a variety of conservation measures in effect for the North Atlantic right whale and humpback whale species in the Northwest Atlantic. However, due to the wide ranging nature of the other species of baleen whales seen in the Azores, and the limited knowledge of the status of many species, conservation plans for these are limited.

Photographic identification studies of baleen whales allow for the on-going investigation of the movements and residency of individuals. It is unclear to which populations or stocks the baleen whales encountered in the Azores belong. Photo-identification images taken of individually distinguishing features including the tail flukes (blue and humpback whale) skin mottling (blue whale), flank chevron (fin whale) and callosity patterns (right whale) allow identification of individuals. Comparison of these images with local photo-identification catalogues and those further afield, for example in Canada, the USA and Iceland, can provide information on whale movements, population structure and stock identity. Improved knowledge of cetacean movements and the areas they pass through has implications for conservation and mitigation of threats. This is particularly important for fin whales, as those visiting the waters of the Azores may be from the same stock that visits Icelandic waters, a region where whaling targeting /removing significant numbers of individuals, has been taking place 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, although Bryde's whale and humpback whales are known to produce calls in frequencies up to 80 Hz (Cummings *et al*., 1986, Edds *et al*., 1993) and 1900 Hz (Thompson *et al*., 1986) respectively. With limited knowledge of sei and Bryde's whale vocalisations in the Atlantic 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 whale are particularly important.

Very few accounts of the acoustic characteristics of sei whale vocalisations exist, with just six published papers describing the species calls (Baumgartner *et al*., 2008). First recordings of sei whale calls were made by Knowlton *et al*. (1991) off Nova Scotia. In this case, calls consisted of phrases with series of 10-20 frequency modulated sweeps lasting approximately 30-40 ms per sweep and restricted to the 1.5-305 Hz band. Vocalisations recorded in the Antarctic Peninsula showed different characteristics and consisted of one and two part tonal calls with average durations of 0.45 s and average frequencies of 433 Hz. They also recorded FM down and up-sweep calls with an average midpoint frequency of 432 Hz and duration of 1.1 s (McDonald *et al*., 2005). Other recordings made in Hawaii showed two types of down-sweep tonal calls: some ranging from 39.1 Hz to 21 Hz and others from 100.3 Hz to 44.6 Hz, both over 1.2 s duration (Rankin and Barlow, 2007). Finally, down-sweep calls were also recorded in New England, with starting frequencies of 82.3 Hz and ending ones at 34 Hz over 1.38 s (Baumgartner *et al*., 2008). The variability in vocalisations found in different areas and seasons could be attributed to geographic separation, population-specific acoustic characteristics and/or distinct call ecological functions (Rankin and Barlow, 2007; Baumgartner *et al*., 2008).

1.2 Beaked whales

The beaked whales, or Ziphiids, are one of the least known families of cetaceans. They are particularly difficult to study, because they are both deep divers and oceanic in distribution. They are also very difficult to detect visually at sea. 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). 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 sounds from sonar may result in the death and injury of beaked whales.

Beaked whales are known to be difficult to spot visually (e.g. Barlow *et al*. 2006), so improved systems for detecting beaked whales for example using passive acoustic techniques have intrinsic value. Where there are data, 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.

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). 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.

A pilot study was carried out in 2008 by IFAW to investigate beaked whale distribution in the north-eastern Atlantic, focused on the Canary Islands, Azores and Madeira. This research provided useful initial data on beaked whales and their vocalisations (Boisseau *et al*., 2009) with potential hotspots of beaked whale presence being identified in the waters south of the main islands.

1.3 Aims

Through a combination of dedicated survey effort and opportunistic sightings via land-based 'vigia' observers and whale-watching vessels, the team aimed to:

- Investigate the presence and offshore distribution of baleen and beaked whales in the spring.
- Acquire high quality recordings of various species for subsequent description and comparison.
- Identify the position and identity of vocalising whales in order to estimate vocalisation rates.
- Contribute to photographic–identification catalogues for the Azores through local collaboration.

2. METHODOLOGY

The research was conducted in the Azorean EEZ from 5th April to 8th May 2012 between 36° and 42°N. Surveys were conducted from the 21m auxiliary-powered cutter-rigged research vessel *Song of the Whale*, under sail, motor or motor/sail between a minimum of 5 knots (to stream hydrophones) and a maximum of 8 knots (to reduce cable strum and keep the arrays at depth). Survey effort was conducted in a quasi-random fashion based largely upon prior sightings, winds favourable to sailing, regions of unusual and varied bathymetry and passage destination.

2.1 Data collection

In daylight hours and in sea states below four, two visual observers with binoculars were positioned on 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 software (IFAW). Environmental and GPS 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 surveys were primarily conducted using 400 m towed broadband stereo hydrophone arrays. Continuous stereo recordings were made at sampling rates of both 8 kHz and 192 kHz via bespoke buffer boxes passing signals to an NI-6251 data acquisition card and an RME Fireface 800 sound card respectively. The 8 kHz recording system also incorporated a Behringer Ultracurve DEQ2496 to introduce a 4 kHz low-pass filter prior to signal digitisation in order to prevent aliasing. The buffer boxes provided variable frequency responses; however, 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 and written to disk as two-channel 16 bit wav files. For a period of time (from the 16th to the 26th of April) an omni-directional and calibrated RESON TC4032 hydrophone was used with a frequency response of ±2.5 dB between 10 Hz and 80 kHz.

The team also explored coastal and offshore habitats around the Azores for other marine mammals. Some research effort was spent on species such as bottlenose and Risso's dolphins and included photo-ID and high-frequency recording to contribute data to collaborative research efforts in the region. The click detection software RainbowClick (IFAW) was run continuously to log odontocete click trains in the audio range (2 to 24 kHz); Whistle detection software (IFAW) was also run to detect FM calls produced by odontocetes.

2.1 Baleen whales

In addition to making recordings with R/V *Song of the Whale*'s towed array, attempts were made to record and localise baleen whale vocalisations using a wide-aperture hydrophone array. When baleen whales were encountered and their movement patterns were predictable, Non-Anchored Underwater Tracking Instrumentation buoys (NAUTI-buoys) were deployed if environmental conditions and daylight hours were conducive. NAUTI-buoys incorporate a hydrophone and a digital recorder suspended below the water surface with a GPS receiver mounted above the waterline to record the track of the buoy (Figure 1). The NAUTI-buoys were deployed in an attempt to make recordings consecutively with towed hydrophone arrays. Ideally, a NAUTI-buoy approximately a kilometre from the towed array could provide a suitably wide aperture for the localisation of whale vocalisations. This allows the subsequent calculation of vocalisation rates, a parameter that is often missing from studies using remote acoustic techniques.

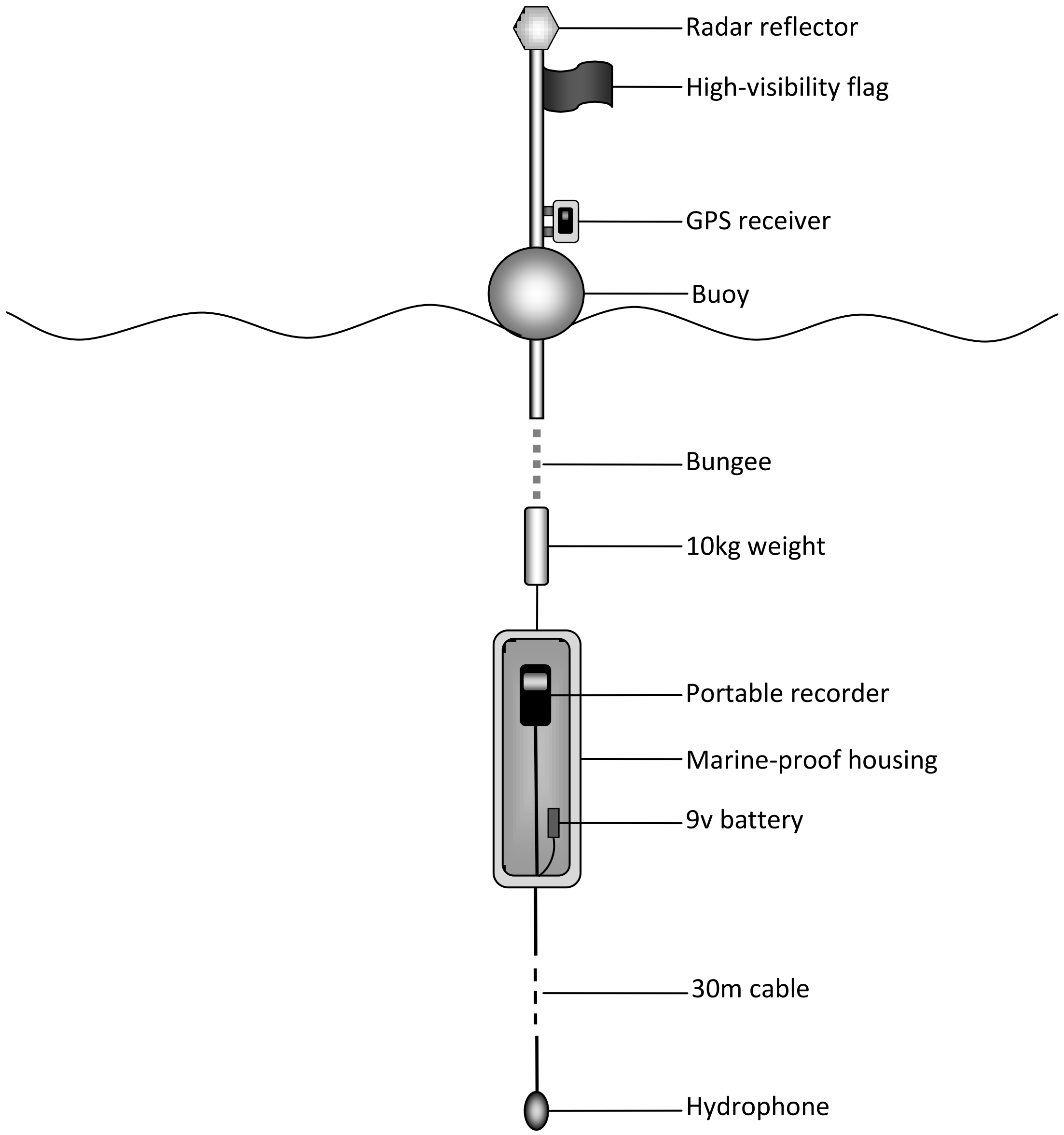


Figure 1. Cross-section schematic of a free-floating NAUTI-buoy. The hydrophone and recorder are suspended below the water surface using a bungee and weight.

When a pair of sei whales was first sighted south of Pico on the 22nd of April 2012, a NAUTI-buoy was deployed at 15:48 for 2 hours and 32 minutes. The R/V *Song of the Whale* drifted in the vicinity of the whales with a calibrated RESON TC4032 hydrophone deployed from the aft of the vessel and a continuous recording was started at 16:18 for a total of 51 minutes (Figure 2).

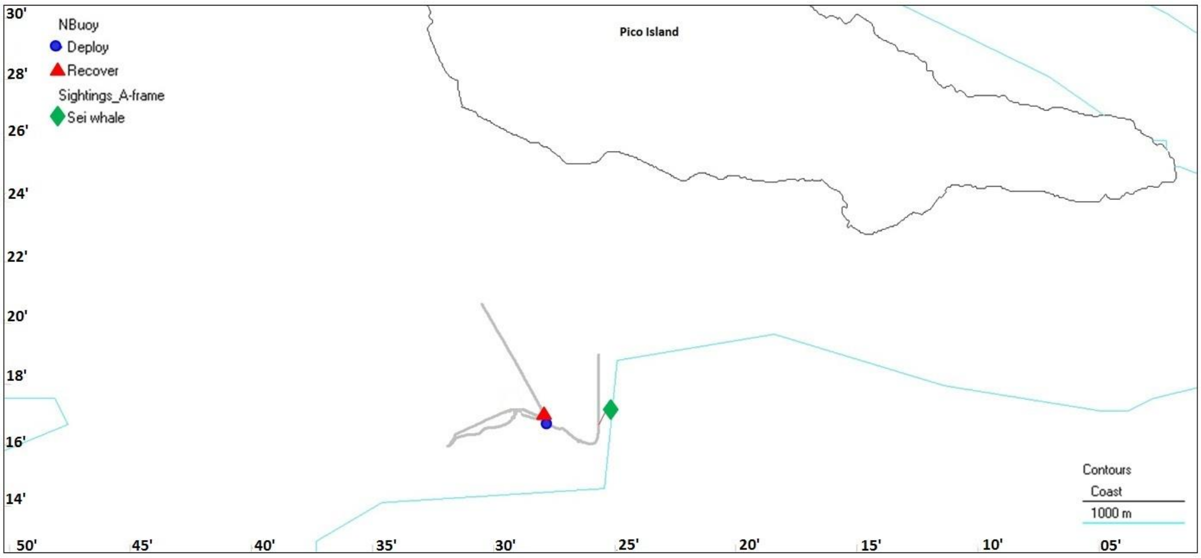


Figure 2. R/V *Song of the Whale* track during the sei whale encounter and NAUTI-buoy deployment on the 22nd of April.

Analysis of the low frequency recordings (with a sample rate of 8 kHz for the towed hydrophone and 48 kHz for the NAUTI-buoys) were 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. Peak frequencies and peak times were measured using Raven Pro64 1.5 software. Sound pressure levels (SPL) for every vocalisation and their respective background noise levels were measured using SpectraPLUS-SC and calculated in 1-Hz bands.

The bearing and distance to individual animals were measured using video range tracking methods to provide an accurate record of the whale's movements in relation to SOTW and the Nauti-buoy. The absolute position of R/V *Song of the Whale* was logged every second from the boat's GPS and allowed the relative positions of other objects such as whales to be back-calculated from ranges and bearings. The position of the NAUTI-buoy was known from the attached GPS system. An observer was situated on the A-frame platform with a monopod which had a pair of 7 x 50 binoculars attached with a small Panasonic HDCSD90 video camera beneath (set with a 3 second pre-record) and a Canon Powershot A495 still camera facing towards the deck. On the first whale sighting of each surfacing event, the observer would press record and aim their binoculars at the animal, making sure that both the animal and the horizon were in video camera's field of view.

In order to gain accurate distances to each surfacing, separate sequential images of each surfacing with the animal and the horizon in the image were extracted post-process. From the observer's eye height on the A-frame and the distance to the horizon, an accurate distance can be calculated to the animal using an automated module in Pamguard.

From images of perpendicular lines on the A-frame deck taken using the still camera each time the whales surfaced, accurate angles to the animal, relative to the boat, were calculated (Figure 3).

(a)

(b)

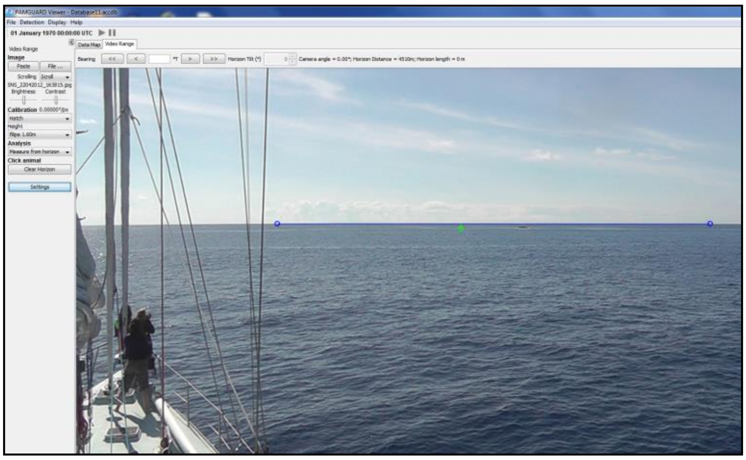


Figure 3. (a) A-frame stripes picture. (b) Pamguard video range software snapshot.

2.1 Beaked whales

As typical 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), it is possible to detect and extract potential beaked whale clicks from background noise using click detection algorithms. Thus, acoustic signals were monitored in real-time during this survey using a click detector module in Pamguard (Passive Acoustic Monitoring Guardianship, www.pamguard.org) whereby sounds with significant energy (>4 dB above background noise) in the 25 to 40 kHz band and waveforms with more than five zero crossings were classified as potential beaked whale clicks (see Gillespie *et al*. 2009 for details). Extra survey effort was spent in those areas previously identified by the *Song of the Whale* team as important for beaked whales (Boisseau *et al*., 2009).

Post-survey, a more thorough analysis was conducted of potential beaked whale clicks using Pamguard software. Clicks were classified as beaked whale clicks if the following characteristics were identified: a significant energy band in the 25 to 40 kHz, a waveform resembling that of published data for other beaked whale species and an upswept narrowband structure revealed in a Wigner plot. Each click was then manually checked by an analyst to remove any false detections and separate the clicks in 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 these parameters. A second analyst independently confirmed these events.

3. RESULTS

A total of 4342 km (414 hours) of research effort was undertaken in Azorean waters over 34 days (Table 1). The majority of this effort was concentrated around the central islands of Pico and Faial, partly for logistical reasons and partly as these areas had been identified as being important for baleen and beaked whales from previous studies and sightings made by the local whale-watch operators.

Table 1. Summary of research effort from 5th April to 8th May 2012.

Effort status	Nautical miles	Kilometres	Time (hh:mm)
Passage	344	636	71:27
Passage + acoustic	548	1015	86:52
Passage + visual	37	68	6:55
Passage + acoustic + visual	201	371	28:57
Track + acoustic	379	701	70:56
Track + visual	304	563	45:08
Track + acoustic + visual	393	728	71:44
Other	139	260	32:04
Total track	2345	4342	414:03

The trackline into and out of the Azorean EEZ coincided with fracture zones of the mid-Atlantic and clusters of seamounts that are thought to be highly productive regions of open oceans (Figure 4).

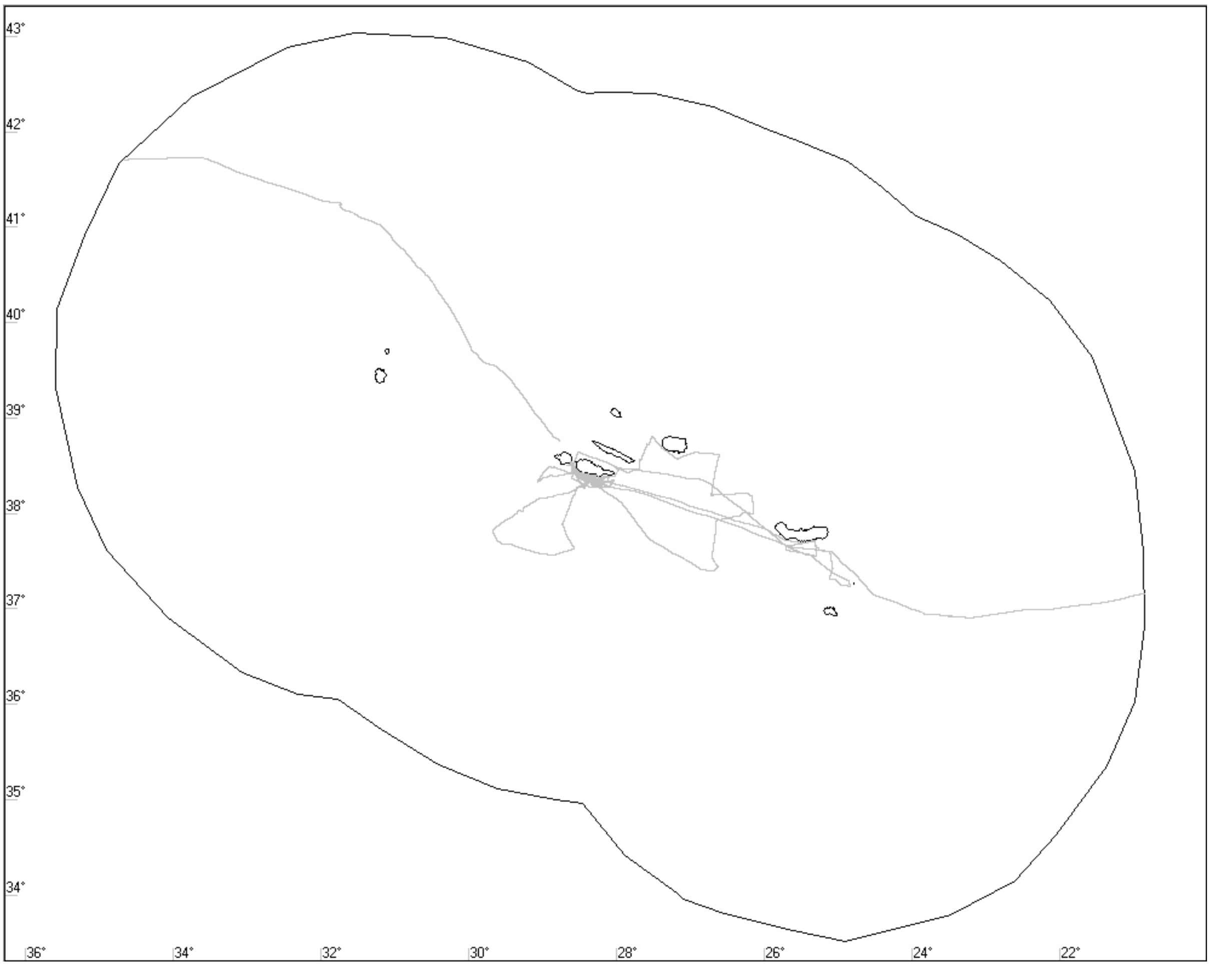


Figure 4. The trackline (in grey) completed by R/V *Song of the Whale* in Azorean waters (the larger ellipse represents the Azores EEZ).

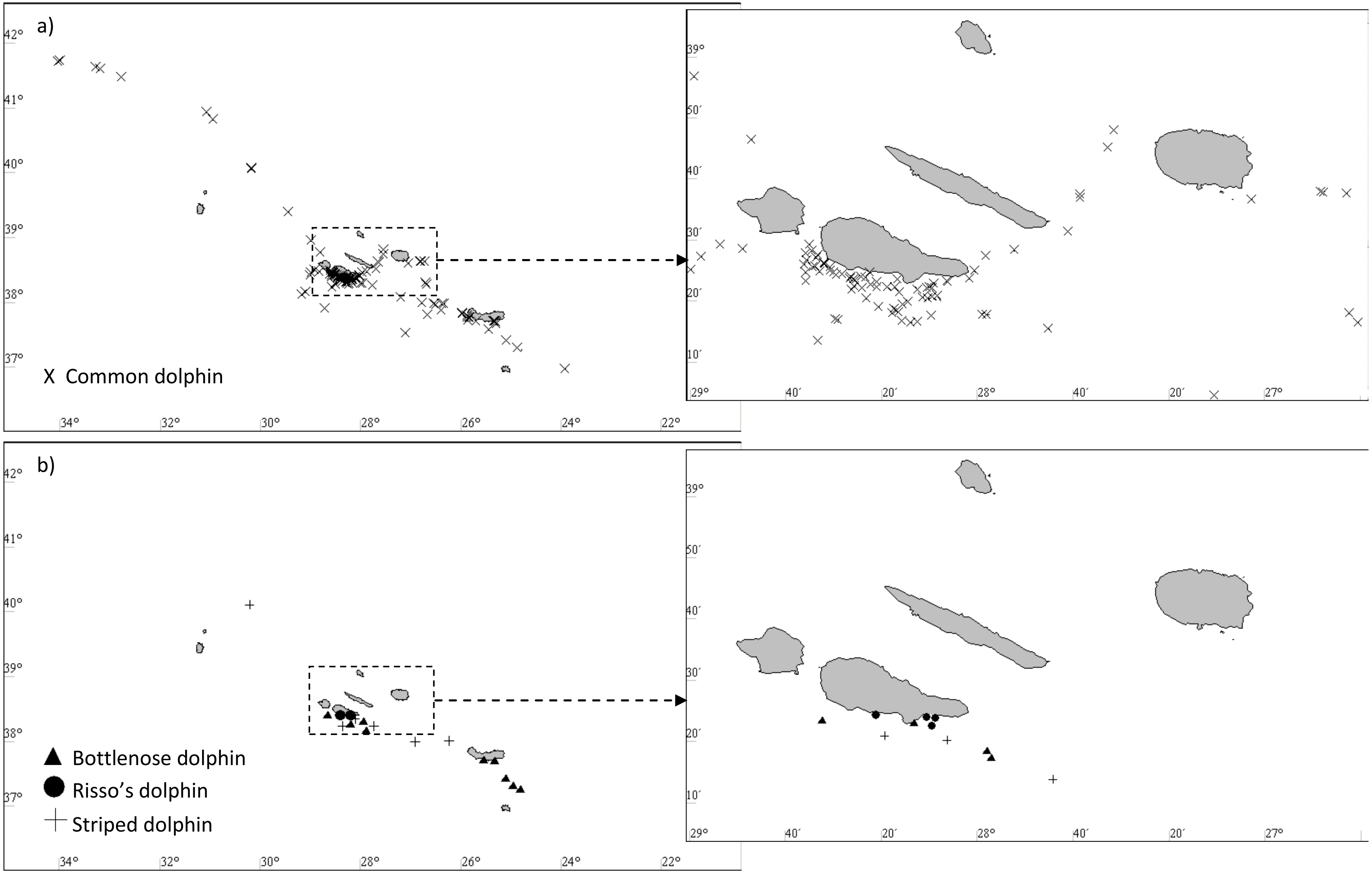
3.1 Sightings

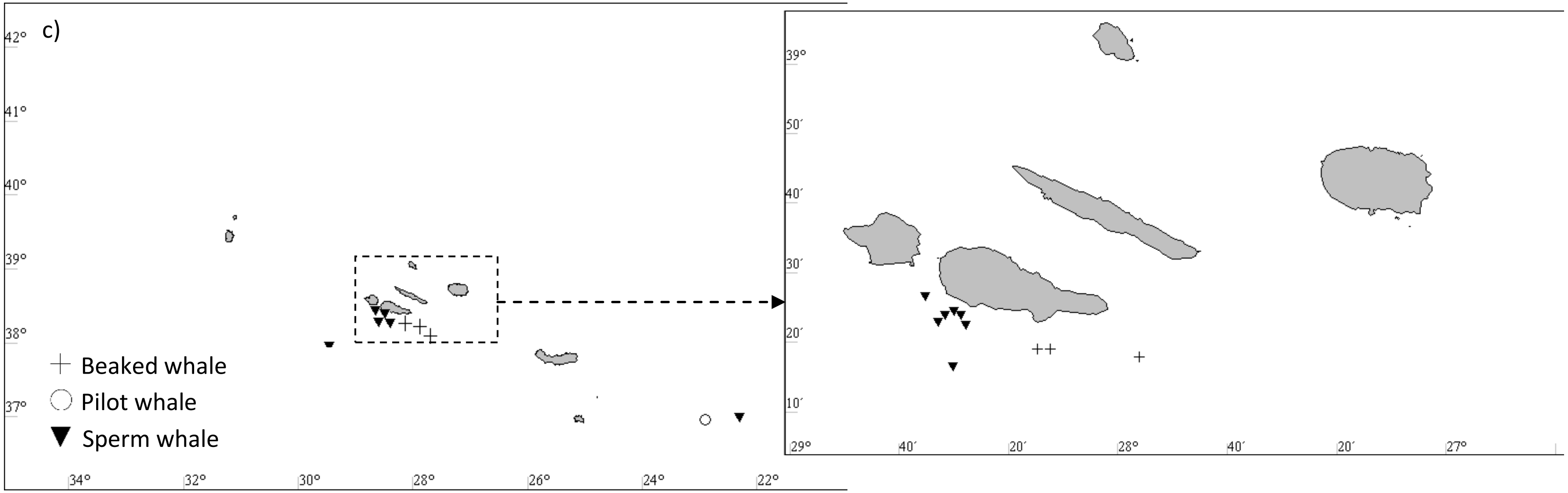
A total of 274 sightings were made of 10 species of cetacean; the species most often encountered was the common dolphin (Table 2). In addition, 14 hard-shelled turtles were observed, 3 sunfish and one unidentified shark.

Table 2. Summary of cetacean encounters in Azorean waters.

Species	Number of encounters	Mean group size	Min. & max. group size
Bottlenose dolphin *Tursiops truncatus*	11	11.9	1 - 50
Blue whale *Balaenoptera musculus*	4	1.0	1 - 1
Short-beaked common dolphin *Delphinus delphis*	130	7.9	1 - 70
Fin whale *Balaenoptera physalus*	3	1.3	1 - 2
Risso’s dolphin *Grampus griseus*	4	6.3	2 - 12
Sei whale *Balaenoptera borealis*	2	1.5	1 - 2
Short-finned pilot whale *Globicephala macrorhynchus*	1	6.0	-
Sowerby’s beaked whale *Mesoplodon bidens*	1	4.0	-
Sperm whale *Physeter macrocephalus*	9	1.9	1 - 2
Striped dolphin *Stenella coeruleoalba*	6	9.2	2 - 30
Unidentified dolphin	74	2.9	1 - 15
Unidentified beaked whale	2	2.0	2 - 2
Unidentified whale	27	1.2	1 - 4

Most of the sightings were clustered to the south of Pico (Figure 5); however, this is in part a reflection of the greater degree of effort in this area. As noted by the local whale-watch operators, this area is typified by frequent encounters with both toothed and baleen whales.


a)
X Common dolphin
b)
Bottlenose dolphin
Risso's dolphin
Striped dolphin


c)
Beaked whale
Pilot whale
Sperm whale
42°
41°
40°
39°
38°
37°
34°
32°
30°
28°
26°
24°
22°
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28°
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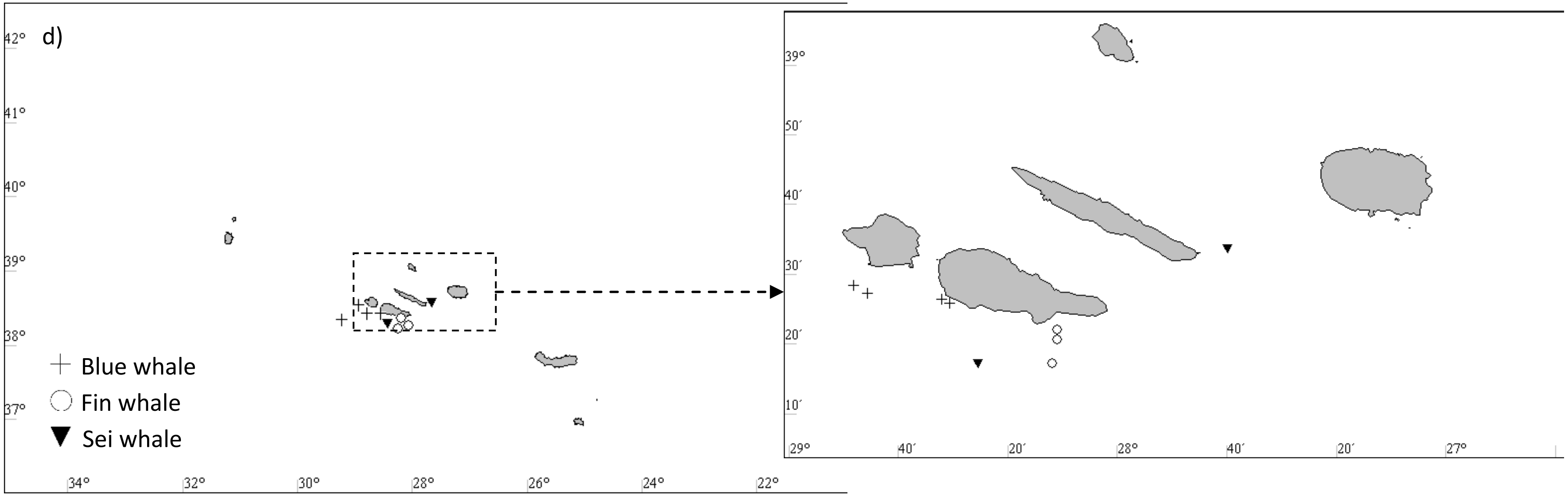
20´
27°


d)
Blue whale
Fin whale
Sei whale
42°
41°
40°
39°
38°
37°
34°
32°
30°
28°
26°
24°
22°
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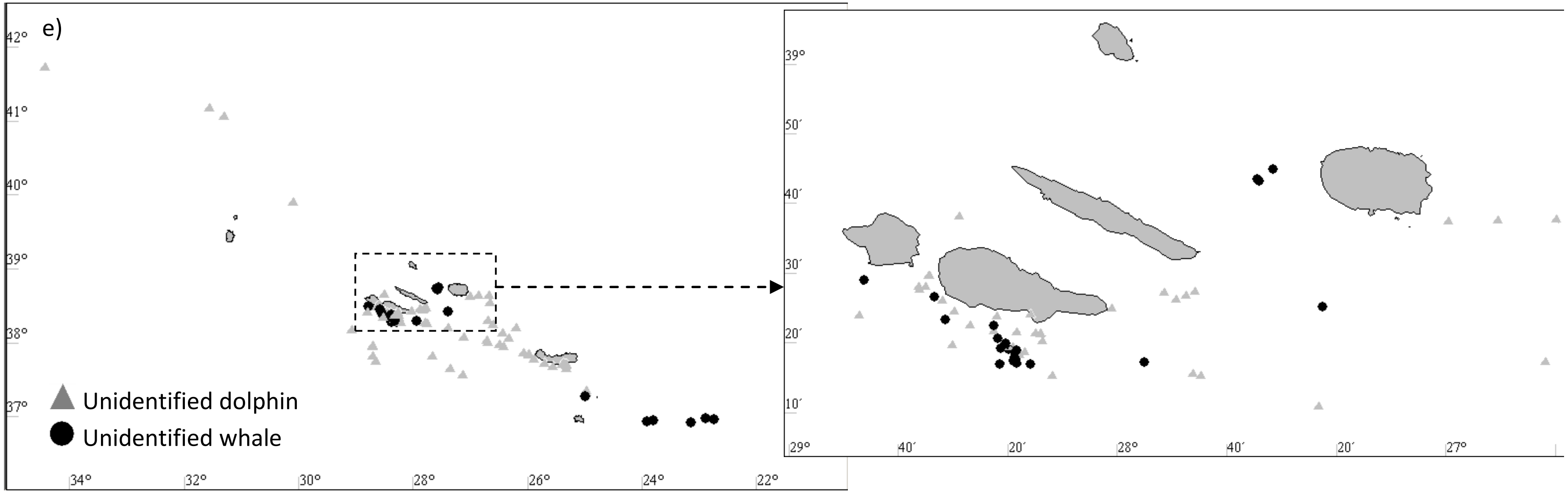


Figure 5. A summary of sightings made from R/V *Song of the Whale* in Azorean waters; a) common dolphins, b) bottlenose, Risso's and striped dolphin, c) beaked, pilot and sperm whale, d) blue, fin and sei whale and e) encounters with unidentified whales and dolphins.

3.2 Acoustic detections

Whenever the water depth and survey speed were appropriate, at least one towed array was deployed from *Song of the Whale*. A member of the team monitored the hydrophone every 15 minutes with headphones and noted the presence of cetacean vocalisations. Dolphin clicks and whistles were heard throughout the study area; sperm whale clicks however were only heard around the islands of Pico and São Miguel and towards the fracture zone located to the north-west of the Azores (Figure 6).

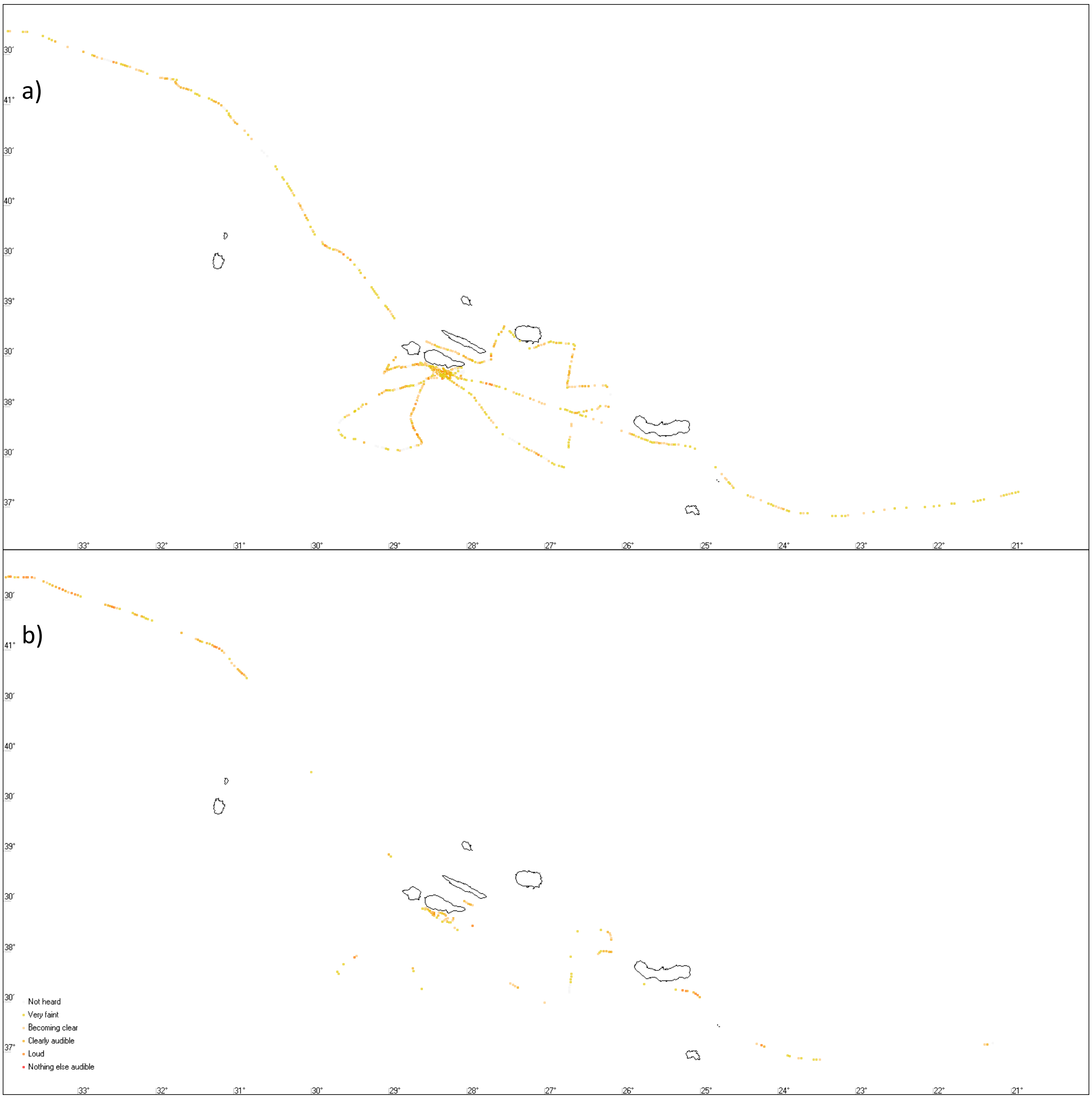


Figure 6. A summary of acoustic detections made from R/V *Song of the Whale* in Azorean waters; a) dolphin clicks and whistles, and b) sperm whale clicks.

3.3 Baleen whales

There were nine encounters with baleen whales during which a stereo hydrophone was used to make continuous recordings. In addition, NAUTI-buoy deployments were made for two of these encounters to the south of Pico in an attempt to localise any vocalisations recorded. The first deployment targeted a pair of fin whales whilst the second was for a pair of sei whales. After analysing low frequency recordings from both the NAUTI-buoys and the towed hydrophone, no vocalisations were detected during the fin whale encounter. However, several calls were recorded in the presence of sei whales. In this case, recordings were obtained from a single NAUTI-buoy and the calibrated hydrophone due to a battery failure in the second NAUTI-buoy.

During the sei whale encounter, calls were detected in both the NAUTI-buoy and the calibrated towed hydrophone. A total of 82 vocalisations were recorded: 53 in the NAUTI-buoy from 2 hours and 32 minutes of recordings and 29 in the towed hydrophone during 51 minutes of recordings. Of these calls, 18 were simultaneously detected in both acoustic devices. (See table 3 for call characteristics). All vocalisations were low frequency down-sweep calls ranging from a mean frequency of 102.5 Hz (SD=13.4 Hz) down to 35.7 Hz (SD=6.9 Hz) over 1.15 seconds (SD=0.32 s) with a peak frequency of 50.9 Hz (SD=11.04 Hz). Only three of the calls occurred in pairs while the rest were identified as individual calls. A call spectrogram and power spectrum of one of the vocalisation events are shown in Figure 7. Further analysis of these data is on-going to confirm that calls were from the observed sei whales, by obtaining the exact localisation of the calls, and ultimately to calculate vocalisation rates.

Table 3. Call characteristics recorded in both the NAUTI-buoy and the RESON calibrated hydrophone.

Call ID	Time	Min. freq. (Hz)	Max. freq. (Hz)	Peak freq. (Hz)	Duration (s)	Source levels (dB rms re 1µPa)
1	16:49:59	45.4	110.7	58.6	1.2	93.3
2	16:50:03	46.7	114.6	58.6	1.2	100.9
3	16:51:12	37.7	108.2	39.1	1.2	106.5
4	16:59:09	35.2	94.1	43	1.1	115.7
5	16:56:30	33.9	86.4	43	1.3	110.1
6	16:56:54	31.3	80	39.1	1.4	92.5
7	16:57:24	27.5	90.2	66.4	1.6	87.6
8	17:00:37	27	92.4	62.5	1.9	116.5
9	17:01:30	33	87.6	50.8	1.5	100.6
10	17:06:37	33.9	92.8	31.2	1.7	109.3
11	17:07:29	33	92.8	54.7	1.7	101.1
12	17:08:12	33	99.9	54.7	1.5	103.5
13	17:10:23	44.4	92	66.4	1.1	104.6
14	17:11:02	36.5	84.9	39.1	1.2	110.2
15	17:12:06	29.4	95.5	66.4	1.7	112.9
16	17:12:38	33	98.1	62.5	1.7	103.5
17	17:13:15	33	94.6	39.1	1.5	104.2
18	17:14:18	35.6	91.1	46.9	1.4	104.9

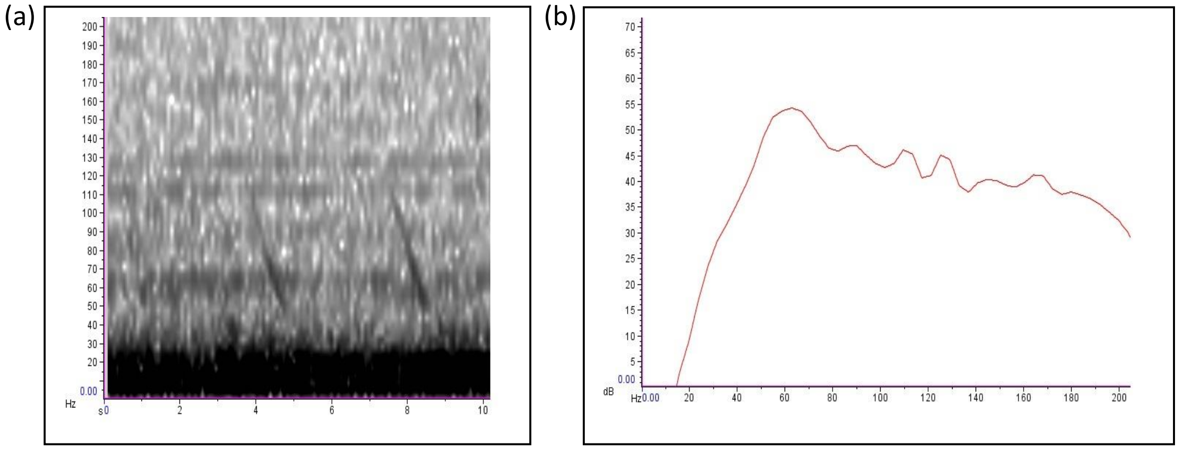


Figure 7. A pair of sei whale calls recorded in the RESON calibrated hydrophone: (a) Spectrogram (b) Power spectrum (30 Hz band pass filter applied to linked spectrogram).

Video tracking of the sei whales encountered during these recordings was undertaken in order to determine their positions in relation to both acoustic devices and confirm calls localisation estimated through acoustic data (analysis is on-going). Sightings positions were calculated using bearings and distances extracted from the video footage (Figure 8). Each boat position plotted has a corresponding whale surfacing event, illustrated using the time link (dotted line).

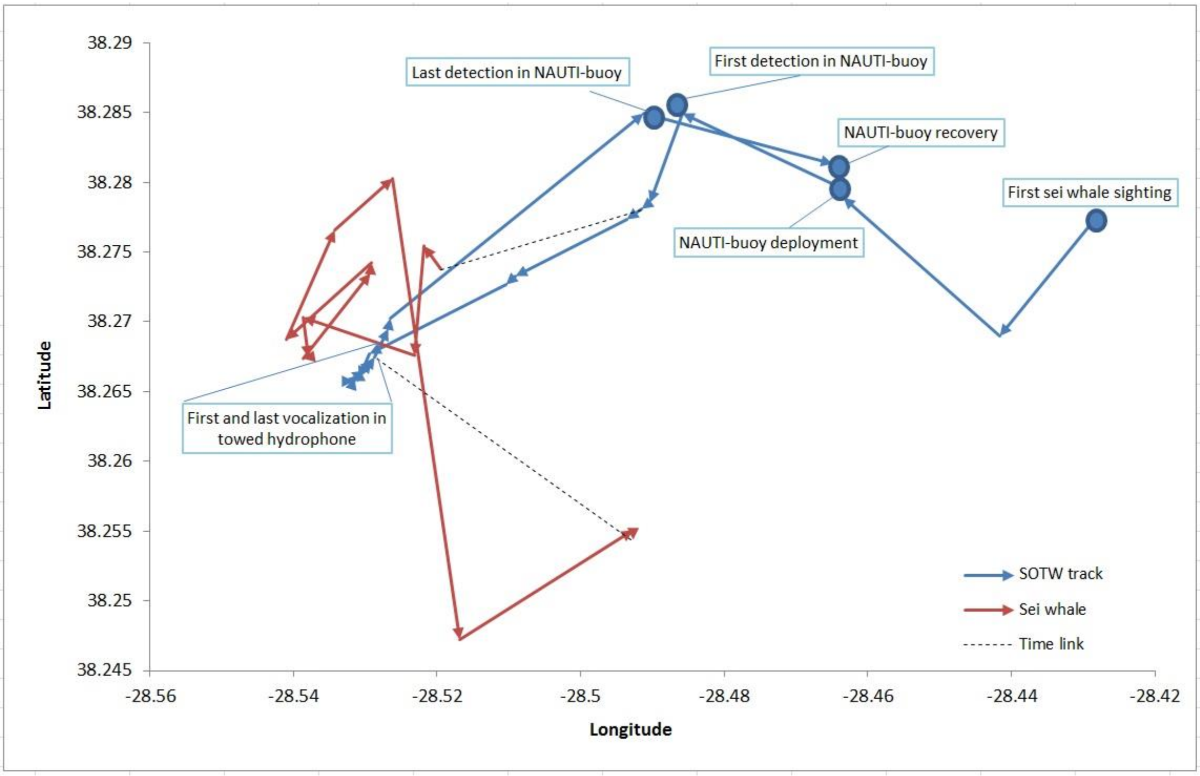
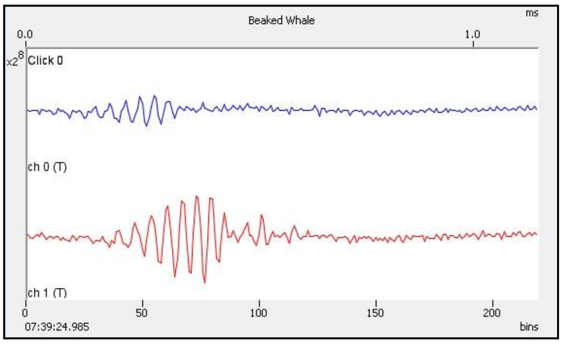


Figure 8. RV *Song of the Whale* track, sei whale positions and NAUTI-buoy deployments during the encounter south of Pico on the 22/04/12.

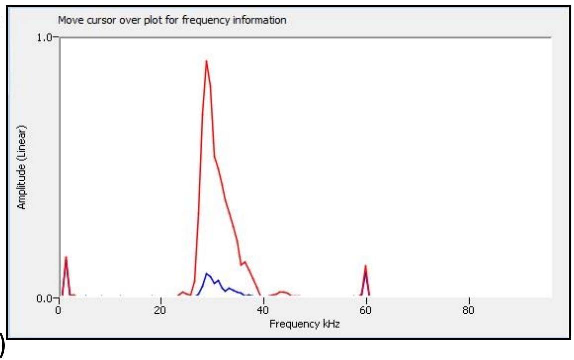
3.4 Beaked whales

During the survey, continuous recordings were made at 192 kHz and a Pamguard module was used to scan this audio stream for potential beaked whale clicks in real-time using a click detection module. Although beaked whale events were periodically noted in the field, a more detailed analysis was completed post-survey. A total of 3 potential beaked whale click events were identified: one definite, one probable and one possible (Table 4). Typical features of the definite beaked whale click event (recorded at 07:39:17 on 30/04/12) are shown in Figure 9: a waveform (a), time-frequency Wigner plot (b) and power spectrum (c). Potential click trains were all detected in waters between 500 and 2000 m deep (Figure 10).

a)



b)



c)

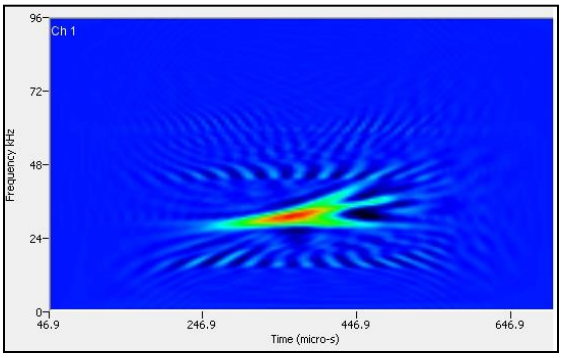


Figure 9. Typical features of a potential beaked whale click (recorded oat 07:39:17 on 30/04/12) as shown in a waveform (a), and power spectrum (b) and time-frequency Wigner plot (c).

Table 4. Potential beaked whale click trains identified during post-survey acoustic analysis.

Date	Time of first click	Time of last click	Confidence	# Clicks
29/04/12	21:55:38	21:56:39	Probable	2
30/04/12	07:39:16	07:39:24	Certain	23
07/05/12	01:06:52	01:09:10	Possible	3

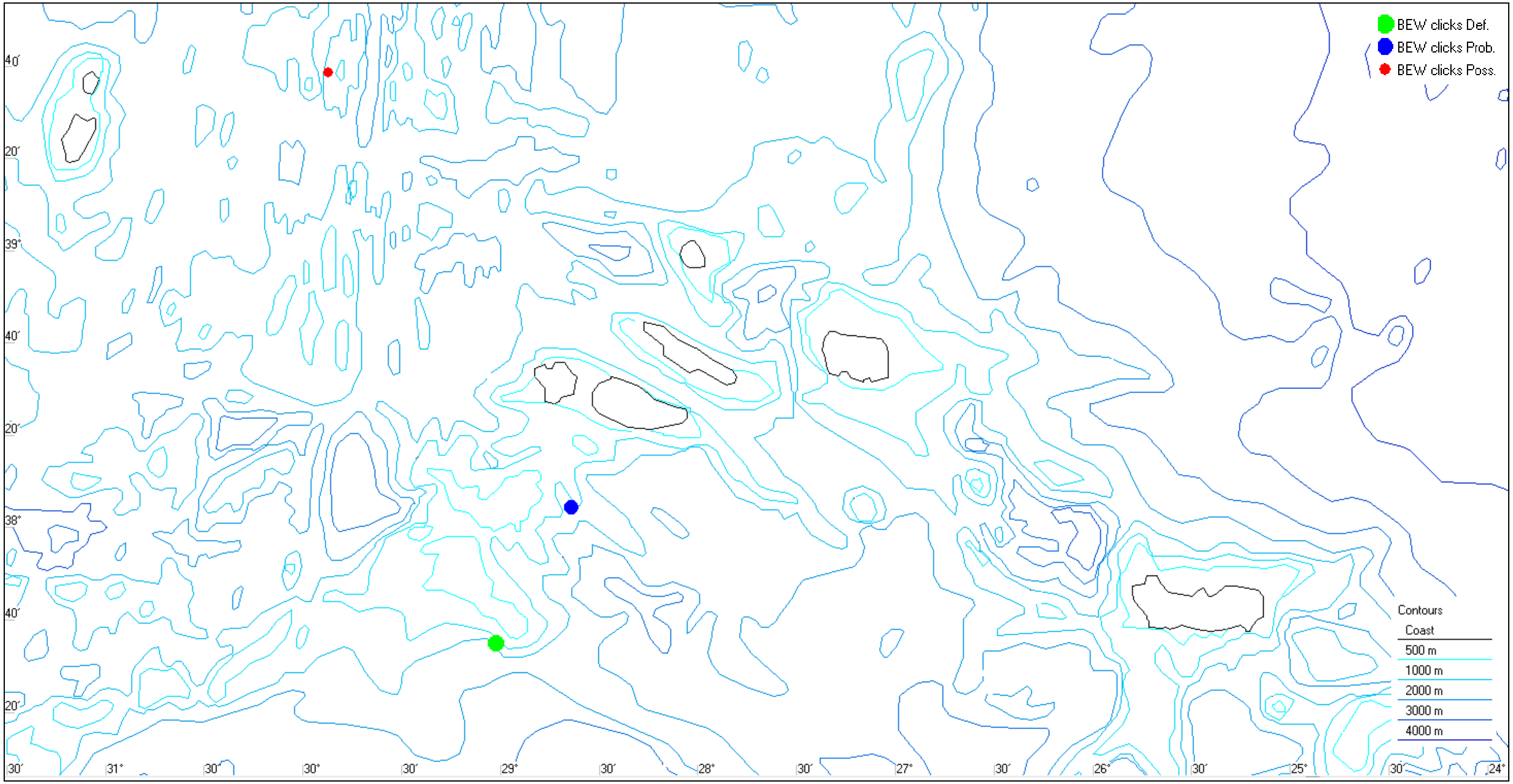


Figure 10. Map showing possible, probable and definite beaked whale detections within Azorean waters.

4. DISCUSSION

The results from the research presented in this document contribute to a growing knowledge of the cetacean fauna of the Azores. A total of 24 species of cetacean have been reported alive in the waters of the Azores, ten of which were encountered in this short study. A high proportion of sightings were reported from the waters to the south of Pico; however research effort was largely focused in this area, in part because of the gracious assistance of the local vigias (land-based lookouts).

Common dolphins were seen regularly throughout the study area. The other dolphin species encountered, however, were mostly seen between the islands of Pico and São Miguel. The Risso's dolphins encountered may be part of a larger group resident to the south of Pico. The photo-ID images from all encounters, including with Risso's dolphins, will be sent to the curators of the relevant catalogues. Although sperm whales were only encountered off Pico, they were often heard around São Miguel and near the fracture zone to the northwest of the Azores. It is likely the upwelling associated with the main islands provides ideal conditions for the cephalopods that are the preferred diet of sperm whales. As such, sperm whales are perhaps less likely to forage in the abyssal regions further from the islands.

4.1 Baleen whales

Despite periodic reports of baleen whales off São Miguel, and some corresponding survey effort in this area, all 36 baleen whale sightings were made around the central islands of Pico and São Jorge. This area seems of particular importance for migrating blue, fin and sei whales during the spring months. It has been postulated that baleen whales track the secondary production generated by the North Atlantic spring bloom and that they might use mid-latitude areas such as the Azores as foraging areas en route towards their summer feeding grounds (Visser *et al*., 2011). It is possible then that these baleen whale sightings represent migrating animals following the mid-Atlantic ridge north to polar waters. However, as the majority of sightings of baleen whales made by local whale-watchers and research groups are to the south of Pico and São Miguel, it would appear there is some degree of site selection on behalf of the individuals seen in the Azores.

Vocalisations recorded during the sei whale encounter are assumed to belong to this species since no other baleen whales were seen in the area during the encounter and call characteristics are very similar to those described in published data (Baumgartner *et al.*, 2008; McDonald *et al*., 2005). Further analysis is on-going in order to localise vocalisations and test this assumption. Despite vocalisation variability described for sei whales in different geographic areas and seasons, calls recorded in the Azores have similar characteristics to those described off both New England by Baumgartner *et al.* (2008) and Hawaii by Rankin and Barlow (2007), see Table 5.

Table 5. Sei whale call characteristics described in published data (extracted from Prieto *et al*., 2012b).

Type of call	Minimum frequency (Hz)	Maximum frequency (Hz)	Average duration (s)	Area & reference
FM down-sweep	34.0	82.3	1.38	New England (Baumgartner *et al*., 2008)
FM up-sweep	1500	3500	0.03	Nova Scotia (Knowlton *et al*., 1991)
FM down-sweep	44.6	100.3	1.2	Hawaii (Rankin and Barlow, 2007)
FM down-sweep	21.0	39.4	1.2	Hawaii (Rankin and Barlow, 2007)
FM down-,up-sweep	200	600	1.1	Antarctic Peninsula (McDonald *et al*., 2005)
Tonal call	100	950	0.45	Antarctic Peninsula (McDonald *et al*., 2005)
Broadband signals	100	600	1.5	Antarctic Peninsula (McDonald *et al*.;, 2005)
FM down-sweep	**35.7**	**102.5**	**1.15**	**Azores (SOTW team, 2012)**

This call similarity between North Atlantic (New England and the Azores) and North Pacific (Hawaii) sei whales could suggest a possible stereotypical call for this species in the Northern Hemisphere, although this is very speculative given the very few recordings available worldwide. It should also be noted that Hawaiian recordings consisted of only two calls of similar features to those of the North Atlantic, in contrast with 105 calls of lower frequencies (Table 5). This fact might suggest a different call repertoire for those whales in New England and the Azores, where only one call type has been recorded so far. At the same time, call similarity between these two North Atlantic areas could be explained by recent findings on sei whale migration routes. Satellite tracking data have shown movements of tagged whales from the Azores to the Labrador Sea, evidencing more complex routes than previously assumed comprising not only latitudinal movements but also longitudinal displacements (Prieto *et al.*, 2012b). Other call types may exist for North Atlantic sei whales, as shown by recordings off Nova Scotia (Knowlton *et al*., 1991), but more data are needed to confirm any of these assumptions.

These findings are of special relevance because they add knowledge to a poorly understood and endangered (IUCN red list under criteria A-1 and CMS-listed in appendix I and II) baleen whale species with very few accounts of their vocalisations described worldwide. Acoustic data from different areas can help understand sei whale distribution and stock identity, two key pieces of information needed for future management and subsequent conservation efforts.

4.2 Beaked whales

Although beaked whales were seen on three separate occasions, the species could only be confirmed as Sowerby's beaked whale for one of these encounters. Most of the beaked whales seen around the Azores are thought to be Sowerby's beaked whales (Espaço Talassa, *pers. comm*). The three beaked whale detections were found along ridges and in depths ranging from 500 to 2000 m. These results are supported by those obtained from a survey made by the R/V *Song of the whale* in the same area in 2008 (Boisseau *et al*., 2009) suggesting that slope waters are important habitats for beaked whales providing favourable foraging conditions.

Acoustic data obtained in this survey contributes to existing information on habitat preference of beaked whales, a data deficient family of cetaceans thought to be vulnerable to increasing anthropogenic noise. Species with specific habitat requirements may be more vulnerable to disturbance of this type and thus added measures for their protection are required. These results also demonstrate that acoustic techniques can be an effective tool for the study of beaked whales, unlike traditional visual study methods (as has previously been demonstrated for sperm whales and harbour porpoises).

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6. REFERENCES

Barlow, J., Ferguson, M., Perrin, W.F., Ballance, L., Gerrodette, T., Joyce, G., MacLeod, C.D., Mullin, K., Palka, D.L. and Waring, G. 2006. Abundance and densities of beaked and bottlenose whales (family Ziphiidae). *Journal of Cetacean Research and Management* **7**(3).

Baumgartner, MF., Van Parijs, SM., Wenzel, FW., Tremblay, CJ., Esch, HC., Ward, AA. 2008. Low frequency vocalizations attributed to sei whales (*Balaenoptera borealis*). *Journal of the Acoustical Society of America* **124**: 1339–1349.

Boisseau, O.J., Prieto, R., Nicholson, D. & Gordon, J. C. D. 1999. An Atlantic cetacean survey using yachtsmen: a pilot study. *Arquipelago* 17: 101-107.

Boisseau, O., Lacey, C., Lewis, T., Thorne, T., Moscrop, A., Gillespie, D. and Aguilar Soto, N. 2009. Mid-Atlantic surveys for beaked whales: The potential for acoustic prediction of critical habitats. *Poster presentation to the European Cetacean Society meeting*, March 09. Istanbul, Turkey.

Clapham, P., Young, S., Brownell Jr., R. 1999. Baleen Whales: Conservation Issues and the Status of the Most Endangered Populations. *Mammal Review* **29**(1): 35-60.

Cummings, W.C.P., Thompson and S.J. Ha. 1986. Sounds from Bryde's, *Balaenoptera edeni*, and finback, *B. physalus*, whales in the Gulf of California. *Fishery Bulletin, U.S*., **84**: 359-380.

Donovan, G.P. 1991. A review of IWC stock boundaries. *Rep. Int. Whal. Comm. (Special Issue)* 13: 39-68

Edds, P., Odell, P.K. and Teshy, B.R. 1993. Calls of a captive juvenile and free-ranging adult-calf pairs of Bryde's whales, *Balaenoptera edeni*. *Marine Mammal Science* **9**: 269-284.

Edds, P.L. 1988. Characteristics of finback *Balaenoptera physalus* vocalizations in the St. Lawrence Estuary. *Bioacoustics* **1**: 131-49

Gillespie, D. & Leaper, R. 1996. Detection of sperm whale (*Physeter macrocephalus*) clicks and discrimination of individual vocalisations. *Eur. Res. Cetaceans*: 87-91.

Gillespie, D., Dunn, C., Gordon, J., Claridge, D. E., Embling, C. and Boyd, I. L. 2009. Field recordings of Gervais' beaked whales *Mesoplodon europaeus* from the Bahamas. *J. Acoust. Soc. Am*. 125(5): 3428-3433.

Gordon, J., Steiner, L. & Martins, H. 1995. Observations of fin whales (*Balaenoptera Physalus* L., 1758) around the Central North Atlantic Islands of the Azores and Maderia. *Arquipelago*: 79-84.

Ingebrigtsen, A. 1929. Whales captured in the North Atlantic and other seas. Rapports et Proces-Verbaux des Reunions. *Conseil International pour l'Exploration de la Mer* **56**: 1–26.

Johnson, M., Madsen., P., Zimmer, W., Aguilar de Soto, N. and Tyack, P. 2004. Beaked whales echolocate on prey. *Proceedings of the Royal Society of London,* **272**(6): 383-6.

Johnson M, Madsen P.T, Zimmer W.M.X, Aguilar Soto N,Tyack P.L 2006 Foraging Blainville's beaked whales (Mesoplodon densirostris) produce distinct click types matched to different phases of echolocation. J. Exp. Biol. 209, 5038–5050. doi:10.1242/jeb.02596.

Kaschner, K. 2007. Air-breathing visitors to seamounts: Marine Mammals. Chapter 12. Pp 230-238 In: Pitcher, T.J., Morato, T. *et al*. (eds). *Seamounts: Ecology, Cons. and Manag.* Fish & Aq. Res. Ser., Blackwell, Oxford, UK.

Knowlton, A., Clark, CW., Kraus, SD. 1991. Sounds Recorded in the Presence of Sei Whales Balaenoptera Borealis. *Abstract Book of The Ninth Biennial Conference on the Biology of Marine Mammals*. Pg: 40. Chicago, Illinois, USA. [abstract only].

Leaper, R., Chappell, O. P. & Gordon, J. 1992. The development of practical techniques for surveying sperm whale populations acoustically. *Rep. Int. Whal. Commn*. 42: 549-559.

Lien, J. 1994. Entanglement of large cetaceans in passive inshore gear in Newfoundland and Labrador (1979–90). *Rep. Int. Whal. Commn., Special Issue*, **15**, 149–157.

McDonald, M.A., Calambokidis, J., Teranishi, A.M. and Hildebrand, J.A. 2001. The acoustic calls of blue whales off California with gender data. *Journal of the Acoustic Society of America* **109**(4): 1728-35.

McDonald, M.A., Hildebrand, J.A., Wiggins, S.M., Thiele, D., Glasgow, D., Moore, S.E. 2005. Sei whale sounds recorded in the Antarctic*. Journal of the Acoustic Society of America* **118**: 3941-3945.

McDonald, M.A., Mesnick, S.L. and Hildebrand, J.A. 2006. Biogeographic characterisation of blue whale song worldwide: using song to identify populations. *Journal of Cetacean Research and Management* **8**(1): 55-65.

Olsen, E, P., Budgell, E., Head, L., Kleivane, L., Nøttestad, R., Prieto, M.A. Silva, H., Skov, G.A., Víkingsson, G., Waring, N., Øien, N. 2009.First Satellite-tracked long distance movement of a sei whale (*Balaenoptera borealis*) in the North Atlantic 2009. *Aquatic Mammals* 35(3): 313-318.

Perrin, W.F., Donovan, G. & Barlow, J., eds. 1994. Gill nets and cetaceans. *Rep. Int. Whal. Commn*, Sp. Issue, 15.

Prieto, R., Silva, MA., Cascão, I., Cruz, MJ., Oliveira, CIB., Waring, G., Gonçalves, J. 2010. *The Importance of Oceanic Fronts in the Labrador Sea to North Atlantic Sei Whales (Balaenoptera borealis). Clues from Satellite Telemetry*. Proceedings from the Arctic Frontiers Conference, Trømso 24–29 January 2010. [abstract only].

Prieto, Rui, Monica A. Silva, Martine Berube, Per J. Palsbøll. 2012a. Migratory destinations and sex composition of sei whales (*Balaenoptera borealis*) transiting through the Azores. SC/64/RMP6, pp. 1-7.

Prieto, R., Janiger, D., Silva, M. A., Waring, G. T. & Gonçalves, J. M. 2012b. The forgotten whale: a bibliometric analysis and literature review of the North Atlantic sei whale *Balaenoptera borealis*. *Mammal Review*. 42, 235–272.

Rankin, S., Barlow, J. 2007. Vocalizations of the sei whale *Balaenoptera borealis* off the Hawaiian Islands. *Bioacoustics* 16: 137–145.

Santos, MBO., 2008. Distribuição e padrão de residência das baleias-de-barbas (Família Balaenopteridae) no Arquipélago dos Açores. BSc thesis, Azores University, Ponta Delgada, Portugal.

Silva, MA., Prieto, R., Magalhães, S., Cabecinhas, R., Cruz, A., Gonçalves, JM., Santos, RS. 2003. Occurrence and distribution of cetaceans in waters around the Azores (Portugal), Summer and Autumn 1999–2000. *Aquatic Mammals* 29: 77–83.

Silva, M.A., L. Steiner, I. Cascão, M. João Cruz, R. Prieto, T. Cole, P.K. Hamilton, and M.F. Baumgartner. 2012. Winter sighting of a known western North Atlantic right whale in the Azores. *Journal of Cetacean Research and Management* 12:65–69.

Thompson, P.O., Cummings, W.C., Samuel, J. Ha. 1986. Sounds, source levels, and associated behaviour of humpback whales, Southeast Alaska*. Journal of the Acoustic Society of America* **80** (3): 735-740.

Thompson, P.O., Findley, L.T., Vidal, O. and Cummings, W.C. 1996. Underwater sounds of blue whales, *Balaenoptera musculus*, in the Gulf of California, Mexico. *Marine Mammal Science* **12**(2): 288-92.

Volgenau, L., Kraus, S.D. & Lien, J. 1995. The impact of entanglements on two sub-stocks of the western North Atlantic humpback whale (*Megaptera novaeangliae*). *Canadian Journal of Zoology*, **73**, 1689–1698.

Visser, F., Hartman, K.L., Pierce, G.J., Valavanis, V.D., Huisman, J. 2011. Timing of migratory baleen whales at the Azores in relation to the North Atlantic spring bloom. *Marine Ecology Progress Series* **440**: 267-279.

Wenzel, F.W., Allen, J., Berrow, S., Hazevoet, C.J., Jann, B., Seton, R.E., Steiner, L., Stevick, P., Lopez Suarez, P., and Whooley, P. 2009. Current knowledge on the distribution and relative abundance of humpback whales (*Megaptera novaeangliae*) off the Cape Verde Islands, Eastern North Atlantic. *Aquatic Mammals* **35**(4): 502-510.

Zimmer, W. M. X., Johnson, M. P., Madsen, P. T. and Tyack, P. L. 2005. Echolocation clicks of free-ranging Cuvier's beaked whales (*Ziphius cavirostris*). *Journal of the Acoustical Society of America* 117(6): 3919-3927.