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Recent occurrence of marine mammals and sea turtles off Angola and first report of right whales since the whaling era

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Abstract

Marine megafauna occurrence was recorded in the deep-sea region bordering the abyssal plain ~400 km north-west of Luanda, Angola. The survey took place during an Environmental Baseline Study (EBS), prior to drilling exploration activities, with the goal of characterizing the habitat and biodiversity of the region. Offshore shipboard surveys were conducted during September 2018 in water depths ranging from 2350–3850 m. We recorded daytime sightings of marine mammals and sea turtles and at night made audio recordings using passive acoustic monitoring (PAM) methods focused on capturing the sounds of vocalizing marine mammals. A variety of species were visually detected, including the humpback whale (*Megaptera novaeangliae*), sperm whale (*Physeter macrocephalus*), common dolphin (*Delphinus* spp.), striped dolphin (*Stenella coeruleoalba*), Atlantic spotted dolphin (*S. frontalis*), and olive ridley turtle (*Lepidochelys olivacea*). Acoustic click bouts similar to those made by several odontocete species, possibly including beaked whales, were recorded within the 25–48 kHz range. The humpback whale was the most frequently sighted species, accounting for 56% of mammal sightings, indicating a potential far offshore migratory habitat in this region. Most notably, right whales (probable *Eubalaena australis*) were visually observed. This is the first confirmed record of right whales in Angolan waters since the early 1900s. As development expands in this offshore region, these data can usefully inform future monitoring and mitigation strategies focused on minimizing impacts to wildlife.

Introduction

This marine megafauna survey was part of an Environmental Baseline Study (EBS) focused on characterizing the benthic and planktonic communities and the biological and physio-chemical characteristics of the sediment and seawater prior to commencement of drilling operations in a deep-water site off Angola. The integration of knowledge about regional biodiversity within oil and gas exploration activities is part of an approach focused on integrated environmental management (Chaineau *et al.*, 2010; Martinez *et al.*, 2019). Few systematic studies of marine megafauna have been conducted in deep waters off Angola. To assess marine megafauna diversity in this planned offshore drilling site, we conducted visual observations and passive acoustic monitoring (PAM) during the EBS shipboard surveys. Our primary objective was to collect visual sightings data and acoustic data containing underwater vocalizations in order to assess the occurrence of marine mammal, sea turtle, seabird, and fish species. The marine mammal and sea turtle data recorded during these surveys are presented here.

Materials and methods

Study area

Angola is on the west coast of Africa in the eastern Tropical Atlantic. The oceanography of this region is influenced by the outflow of the Congo River to the north; the Benguela Current extending northwards along the west coast of southern Africa which brings colder, nutrient-rich water up from the south; and the Angola Current, a fast, narrow band of warm water extending along the Angolan coast from the Gulf of Guinea to the north (Hardman-Mountford & McGlade, 2003). Angola's deep-sea environment is influenced by sedimentary processes. The Congo deep-sea fan, one of the largest fans in the world to be affected by active turbidity currents, extends off northern Angola and southern Gabon, connecting the Congo River Estuary to the Congo Canyon, and thereby facilitating the deposit of sediment into the deep-sea environment (Savoye *et al.*, 2009).

Our study area (Lease Block 48 (B48)) was ~400 km north-west of Luanda, Angola. It consisted of 34 benthic sampling stations with water depths ranging from 2350–3850 m and an average depth of 3155 m (Figure 1). Benthic sampling at these stations was conducted throughout the day and night.

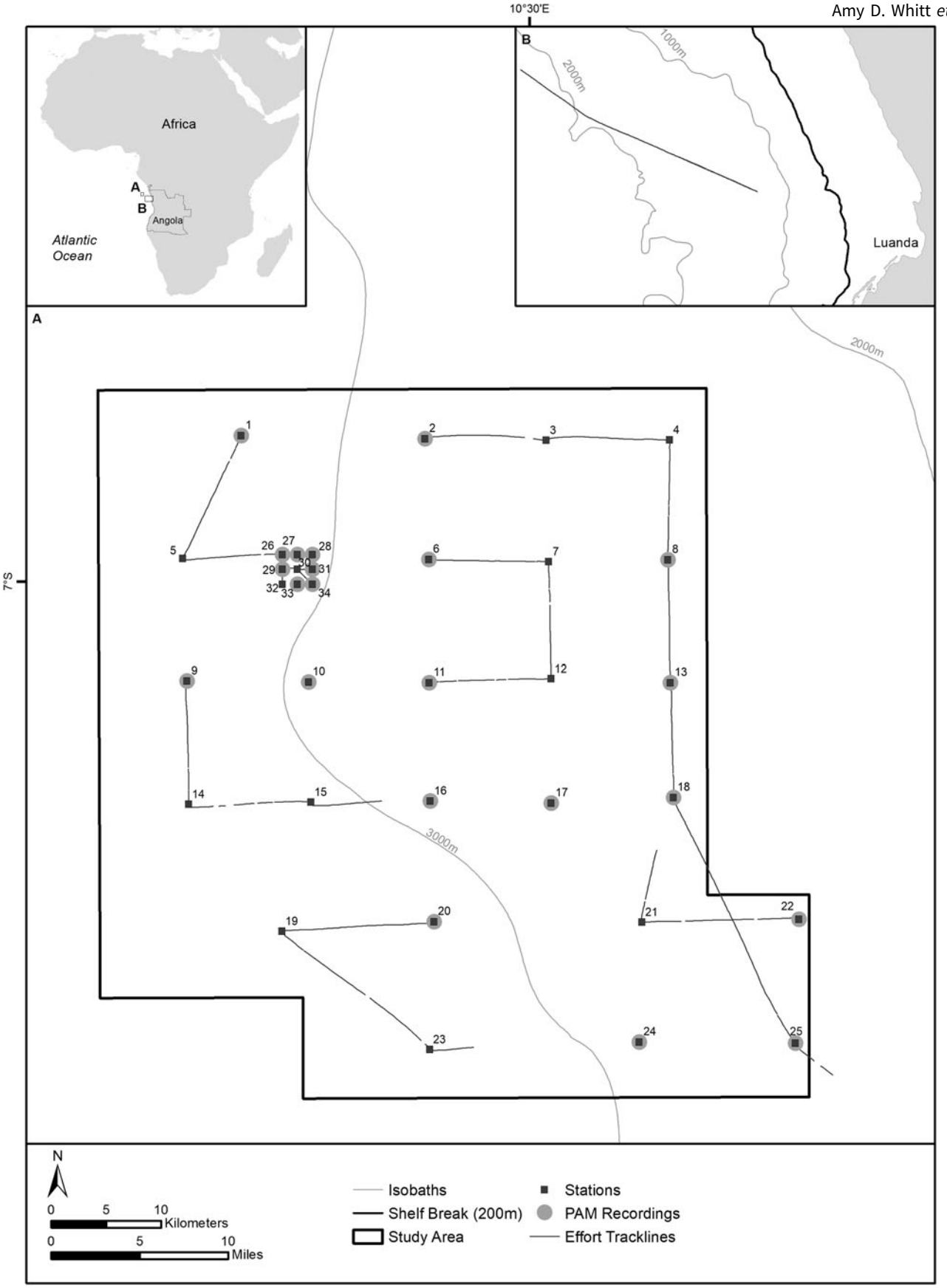

Fig. 1. Study area consisting of 34 benthic sampling stations, visual survey on-effort tracklines, and passive acoustic monitoring locations.

Visual observations

Benthic surveys were conducted in B48 between 6–17 September 2018 onboard the 'Goldblatt Tide', a 70-m anchor handling supply vessel. During these surveys, the vessel was used as a platform for collecting sightings data to determine the occurrence of marine mammal and sea turtle species and vessels in the region. Two trained and experienced marine faunal observers (MFOs) conducted visual surveys during daylight hours in 'passing' mode (i.e. animals were not approached) when the vessel was on station (conducting benthic surveys), transiting between

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stations, and transiting to and from the port in Luanda, Angola. The vessel was relatively stationary during benthic surveys. Average transit speed was 6.7 knots (3.4 m per second). All observations were conducted from the bridge deck (~12.25 m average eye height above the water surface).

For the purposes of this study, 'on effort' is defined as the time when the MFOs were actively scanning for megafauna. MFOs were 'off effort' when it was too dark to detect marine wildlife, when weather conditions prevented detections (i.e. during heavy rain), and during mandatory ship safety meetings and drills. Because the goal of the visual operations was to detect sightings of marine megafauna, the MFOs' effort was not limited to the typical environmental restrictions of systematic line transect surveys. Therefore, the MFOs remained on effort during periods with strong Beaufort Sea States (BSSs) and large swell heights.

MFOs scanned the water and recorded sightings of marine mammals, sea turtles, seabirds, fish, invertebrates, and vessels using handheld binoculars (8 × 42), the naked eye, a DSLR camera with a 100–400 mm telephoto lens, and a laptop computer connected to the ship's Global Positioning System (GPS). During visual observation sessions, one MFO scanned the water's surface for marine wildlife using binoculars and the naked eye, while the other MFO served as the data recorder and assisted in species determinations and photo-documentation of sightings. MFOs scanned 180° in front of the vessel during transit and 360° around the vessel when the vessel was relatively stationary at benthic sampling stations. MFOs rotated through these stations every 60 min to minimize fatigue. During periods of light rain and extremely strong winds/rough seas, the MFOs remained on effort and scanned for wildlife from inside the bridge.

All sightings and environmental conditions data were recorded using WinCruz, a computer program developed specifically for marine wildlife surveys by the National Oceanic and Atmospheric Administration, Southwest Fisheries Science Center. Environmental data, including BSS, wind speed and direction, swell height and direction, weather (e.g. rain, fog, haze), and visibility, were recorded every hour and as conditions changed. The position, course, and speed of the vessel were automatically recorded every 2 min in Wincruz via a connection to the vessel's GPS. A set of data fields were recorded for each marine mammal and sea turtle sighting: geographic position of the vessel (latitude and longitude), initial time of sighting, estimated bearing and distance of sighting from vessel, species identification, number of individuals (group size), behaviour of animals observed, the first cue (e.g. blow or splash) for the sighting, and platform activity during the sighting (e.g. transit, benthic sampling). When feasible, digital photographs were taken to confirm species identification. The water depth of each sighting was determined after the survey using ArcGIS Spatial Analyst software (developed by the ESRI company) and a GEOTIFF bathymetry file from the British Oceanographic Data Centre. The depths of the plotted sightings were assigned the corresponding values of the GEOTIFF.

Passive acoustic monitoring

To complement the visual observations, PAM was used to attempt to capture evidence of the presence of species that may not have been sighted, particularly during the night when visual observations were not possible, and to potentially corroborate species observations through multiple data collection modalities. The PAM equipment was deployed and retrieved during benthic sampling at night when the vessel was relatively stationary. PAM equipment for this study included a C57 hydrophone and a TASCAM DR-100mkIII recorder set to a 96 kilohertz (kHz) sampling rate at a 24-bit resolution so that both low and high frequency marine mammal vocalizations could be recorded. Developed by Cetacean Research™, the C57 hydrophone is an extra rugged version of the popular C55 hydrophone. Its shape allows it to be towed behind a vessel with less flow noise, a useful characteristic given the noise conditions within which the recordings were made. The C57 also utilizes a soft polyurethane encapsulation material intended to optimize underwater acoustic performance.

All acoustic data were analysed after completion of the surveys. Analyses were manually accomplished through the use of Raven audio spectrogram software (Bioacoustics Research Program, Cornell Lab of Ornithology: https://ravensoundsoftware.com/). Each station was analysed separately two times; the full-scale data were viewed first followed by analysis of the 0–500 hertz (Hz) range. Specific analysis methodologies and results are described in detail in the Supplementary Information file.

Results

Survey and acoustic sampling efforts

Over the course of the survey, the MFOs covered ~456 km of on-effort trackline during a total of 132 hours of visual operations. Visual observations were conducted at 27 of the 34 benthic sampling stations and during a large portion of the vessel's transit to Luanda after completion of the survey (Figure 1). Visual observations were not conducted at the other stations because we were at these stations during the night when visual observations were not possible. Over the course of the visual operations, the range of BSS and swell height were 0–5 and 0.3–1.8 m, respectively. For more than 60% of the survey time, the sea state was a BSS 3 with a swell height of ~0.6 m. At night, PAM was conducted at 22 stations during benthic sampling (Figure 1) in locations beyond the shelf break and centred around the 3000-m contour line. A total of 54.95 h of acoustic data were recorded and analysed for marine mammal vocalizations and sounds associated with communication.

Sightings

A total of 41 marine mammal sightings and two sea turtle sightings were recorded during the survey (Table 1, Figure 2). The most frequently sighted species was the humpback whale which accounted for 56% of the total mammal sightings. Thirty-five of the sightings were recorded near and between the benthic sampling stations, while the other eight sightings were recorded in transit between the Study Area and port (Figure 2).

Right whale (probable Eubalaena australis*)*

On 8 September 2018, we sighted right whales in water depths of 2474 m in the south-eastern portion of the Study Area (Table 1, Figure 2). We initially sighted a group of common dolphins (*Delphinus* spp.) exhibiting surface active behaviours (leaping and spinning out of the water) before we noticed a large whale with a well-defined V-shaped blow amidst the dolphins. The callosities on the head were visible when this whale raised part of its head and upper back out of the water as one dolphin leaped near the animal. The large whale was flanked by a second whale, about two-thirds of its size, which exhibited a smaller, less distinct blow. This sighting was concurrent with benthic sampling at Station 21. The vessel then began to transit to another benthic sampling station, moving in the direction opposite to and away from the animals. Although we were too far away to confirm species identification or take photographs (and the vessel could not be redirected due to benthic sampling operations), we assumed that the two whales represented a probable mother–calf/juvenile pair based on the size differences and the fact that the smaller

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Table 1. Summary of marine mammal and sea turtle sightings by species or group

Common name	Scientific name	IUCN status[b]	Total sightings	Group size[a]		Water depth (m)	
				Mean	Range	Mean	Range
Right whale	Probable *Eubalaena australis*	Least Concern	1	2	2	2474	2474
Humpback whale	*Megaptera novaeangliae*	Least Concern	23	2.3	1–8	2776	752–3865
Bryde's/sei whale	*Balaenoptera edeni/B. borealis*	Least Concern/Endangered	1	1	1	857	857
Sperm whale	*Physeter macrocephalus*	Vulnerable	2	9.5	7–12	2474	2474
Atlantic spotted dolphin	*Stenella frontalis*	Least Concern	1	75	75	2198	2198
Striped dolphin	*Stenella coeruleoalba*	Least Concern	1	65	65	2822	2822
Common dolphin	*Delphinus capensis/D. delphis*	Least Concern	1	50	50	2456	2456
Unidentified cetacean	–	–	1	1	1	1790	1790
Unidentified delphinid	–	–	4	36	5–75	2902	2029–3194
Unidentified large whale	–	–	6	3	1–9	2312	752–3194
Olive ridley turtle	*Lepidochelys olivacea*	Vulnerable	1	1	1	2474	2474
Unidentified turtle	–	–	1	1	1	2500	2500

[a]Group size is the estimated number of individuals observed during a sighting; [b]*IUCN Red List of Threatened Species*. Version 2022-1 (www.iucnredlist.org). Downloaded on 25 September 2022.

whale remained next to the larger whale for the entire length of the sighting. We recorded the right whales as probable southern right whales based on the historical occurrence of this species off Angola and the known distribution of North Atlantic right whales (*Eubalaena glacialis*) north of the equator (Reeves, 2001).

*Humpback whale (*Megaptera novaeangliae*)*

The humpback whale was the most frequently sighted marine mammal species during the survey; 23 of the total 41 mammal sightings were humpback whales. We recorded these animals throughout the Study Area in water depths ranging from 752–3865 m (mean 2776 m) at distances of 50–250 km from shore (Table 1, Figure 2). Group sizes ranged from 1–8 individuals (mean 2.3). Although most sightings were too far away to determine the age classes of individuals, one calf was confirmed slow travelling with an adult, and one possible juvenile was observed slow travelling alone; both sightings were in waters ~3503 m deep. Behaviours observed included breaches, tail slaps, pectoral fin slaps, and frequent changes in direction of movement (milling). We obtained fluke photographs of three adult humpbacks slowly travelling south in the north-western part of the Study Area on 12 September 2018. Although we submitted these photos to other researchers for matching to catalogues of humpback whales off Namibia, Gabon, São Tomé and Principe (Gulf of Guinea), and the west coast of South Africa, no matches were made.

Other whales

While in transit to the port in Luanda on 17 September 2018, a Bryde's (*Balaenoptera edeni*) or sei whale (*B. borealis*) surfaced 1000 m off the port side of our vessel and continued travelling near the 857-m isobath (Table 1, Figure 2). Because we did not see the head ridges of the whale, we were not able to positively identify the species and designated the sighting as a Bryde's/sei whale. Due to the low number of sei whale sightings (Weir, 2007*a*, 2011) and the known peak occurrence of Bryde's whales off Angola during austral spring (Weir, 2011), our sighting was probably a Bryde's whale.

On 8 September 2018, we recorded two sightings of sperm whales (*Physeter macrocephalus*) resting at the surface, at a water depth of ~2474 m, in the south-eastern part of the Study Area (Table 1, Figure 2). Group sizes were seven and 12 individuals. One calf was confirmed as a member of one of the sightings (Table 1). Additional calves may have been present, but the whales were too far away to determine the age classes of all individuals. Sperm whales occur year-round offshore of the shelf break off Angola, and large nursery groups are common (e.g. mean group size of 9.2), particularly during January through May (Weir, 2007*a*, 2008).

Delphinids

A group of 75 Atlantic spotted dolphins (*Stenella frontalis*) was seen travelling in ~2198 m of water when the vessel was transiting on 7 September 2018 (Table 1, Figure 2). Calves were observed in this group, and several individuals approached the vessel to bow ride. Our sighting aligns with previous knowledge of this species' association with deep-water habitats off Angola (Weir, 2007*a*, 2008).

A group of 65 striped dolphins (*Stenella coeruleoalba*) was seen at a depth of 2822 m during transit between stations on 16 September 2018 (Table 1, Figure 2). The dolphins exhibited milling behaviour, moving slowly and frequently changing direction. Age classes could not be determined. Large groups of up to 200 striped dolphins have been recorded in deep waters off Angola, and this species may occur here year-round (Weir, 2007*a*).

As mentioned previously, common dolphins (*Delphinus* spp.) were seen travelling and socializing in close association with right whales in the south-eastern part of the Study Area on 8 September 2018 (Table 1, Figure 2). Both short-beaked common dolphins (*Delphinus delphis*) and long-beaked common dolphins (*D. capensis*) occur off Angola (Van Waerebeek *et al.*, 1997). These species can be difficult to differentiate at sea, and there is some uncertainty about their external appearance off Angola (Weir, 2007*a*). Because we were not able to confirm which species was sighted, we recorded the sighting as *Delphinus* spp. The group size was estimated at 50 individuals; the presence of calves could not be determined.

Unidentified cetaceans

Eleven sightings could not be identified to the species or genus levels. We recorded an unidentified cetacean in water depths of ~1790 m during our transit from the port to the Study Area on 7 September 2018 (Table 1, Figure 2). We recorded four unidentified delphinid sightings (2902 m mean water depth): one was

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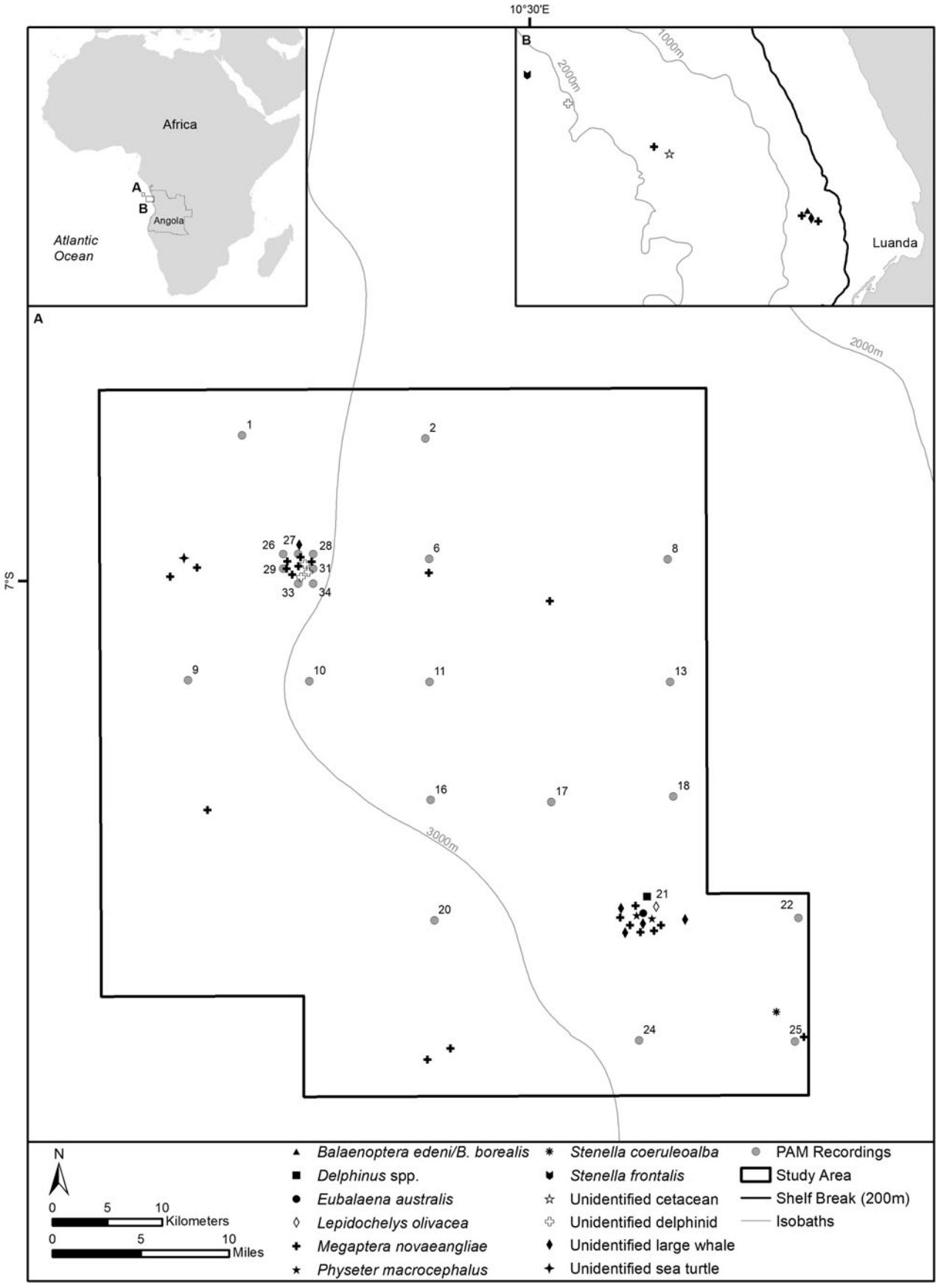

Fig. 2. PAM recording locations and marine mammal and sea turtle sightings recorded during visual observations.

during transit, and the other three were in the north-western part of the Study Area. Group sizes ranged from 5–75 with a mean of 36 individuals (Table 1, Figure 2). Six unidentified large whale sightings were recorded during the survey (2312 m mean water depth). Group sizes ranged from 1–9 with a mean of three individuals (Table 1, Figure 2).

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Sea turtles

One olive ridley turtle (*Lepidochelys olivacea*) was seen resting at the surface in the south-eastern part of the Study Area on 8 September 2018 during benthic sampling at 2474 m (Figure 2). We first sighted the turtle ~5000 m from our vessel; it remained at the surface and moved closer to the vessel (<20 m) as we continued benthic sampling. The benthic sampling team saw an unidentified turtle ~10 m off the stern of the vessel during benthic sampling at night near the centre of the Study Area on 13 September 2018 (Figure 2). The water depth of this sighting was ~2500 m (Table 1).

Passive acoustic monitoring

A full description of the acoustic analysis methods and results is provided in the Supplementary Information file. Overnight acoustic recordings were made only at benthic sampling stations. Since visual sightings were recorded both in the vicinity of those stations and at other locations at various distances from those stations, the potential for ascertaining coordination between visual and acoustic recordings of species could only be approximated (Figure 2).

Although two right whales (one possibly a calf), multiple humpback whales, and a Bryde's/sei whale were sighted, no clearly discernible baleen whale sounds were found within the 10–500 Hz range of active vocalizations made by these species nor were there indications of ~30 second, infrasonic (about 17 Hz) song notes of blue whales which are also known to inhabit the deep waters off Angola. Very faint images of sounds within the 10–500 Hz and above range were observed in spectrograms.

In the full-scale 0–48 kHz analysis, broadband, pulsed sounds were found, and although sperm whales were sighted, these pulsed sounds did not occur within the characteristic 5–25 kHz range of sperm whale codas or echolocation click trains. This frequency range within the data also contains vessel noise, which may have obscured characteristic sperm whale click sequences. Sequences of high frequency pulses were observed, often with upper frequencies that appeared to extend above the 48-kHz upper limit of the data sampling range, and this observation served as an indication that other odontocete sounds were probably present.

High frequency and ultrasonic click sequences were found within the range of 25–48 kHz, including sequences of decreasingly shorter inter-click intervals as well as the extremely rapid click sequences known as 'burst pulses' and 'buzzes' commonly attributed to delphinid species (Griffin *et al.*, 1960; Dawson, 1991; Miller *et al.*, 1995; Dudzinski, 1996; Herzing, 1996; Blomqvist & Amundin, 2004; Lammers *et al.*, 2004; Simard *et al.*, 2008; Martin *et al.*, 2019). These potential odontocete sounds occurred sporadically and were only observed in data collected during a few survey days. For our analysis we selected eight representative click sequences, along with several instances of burst pulses and buzzes, from each of three separate acoustic data collection sessions recorded on 7, 8 and 14 September 2018, as evidence of the presence of characteristic odontocete acoustic activity.

Discussion

Data from this survey provide a deeper understanding of marine megafauna occurrence in this region off western Africa. Results show deep-water (>2000 m) associations of six marine mammal species/groups and one sea turtle species. In addition to general distribution information, our sightings include noteworthy documentation of humpback and right whales far offshore of Angola. Although all of the marine mammal and sea turtle species identified during this survey have been recorded in Angolan waters previously (see Townsend, 1935; Weir, 2007*a*, 2007*b*, 2010*a*, 2011), our probable southern right whale sighting is the first confirmed sighting of this species in Angolan waters since 1913.

The very faint images observed within the 10–500 Hz audio recording range could perhaps be classified as humpback song sequences or possibly as right whale contact calls, both of which would likely be expected based on the characteristic vocal activity of these animals and the large number of humpback whale visual sightings recorded during the study. However, if present, these sounds were not audible, most likely due to masking by louder narrow and broadband mechanical sounds attributable to the vessel's engines and occupying the same frequency range.

Right whales

There are no current or historical records of North Atlantic right whales near Angola. At some point, historically, the eastern North Atlantic population of North Atlantic right whales may have migrated along the coast from northern Europe to the north-west coast of Africa. North Atlantic right whales, including mothers and calves, were distributed throughout coastal waters between Cintra Bay and Cape Barbas (off the coast of Western Sahara) during winter, specifically late November to mid-April (Reeves, 2001). The current distribution and migration patterns of the eastern North Atlantic right whale population are unknown.

Since the early whaling era, North Atlantic right whales have been sighted only extremely rarely in the eastern North Atlantic. A few individuals were sighted as far south as the Bay of Biscay in September 1977 (Aguilar, 1981), near Galicia off north-western Spain in December 1993 (Arcos & Masquera, 1993), off Madeira in February 1967 (calf sighted) (Maul & Sergeant, 1977), off Madeira in January 1959 (a pregnant female captured) (Maul & Sergeant, 1977), off Cape St Vicente on the mainland of Portugal in February 1995 (adult and calf sighted) (Martin & Walker, 1997), and in the Azores in January 2009 (Silva *et al.*, 2012). The southernmost records are from the Canary Islands in 1976 and in January 1999 (Vidal Martin, personal communication, cited in Silva *et al.*, 2012).

Based on the logbooks and journals of United States whaleships from 1785–1913, southern right whale captures were concentrated between 20–40°S (Townsend, 1935). Main whaling grounds were at the Cape of Good Hope in South Africa, Walvis Bay in Namibia, and Tiger Bay (Baia dos Tigres) (~16°S) in southern Angola. During the French whaling period, from 1831–1834, whalers arrived at these whaling grounds in May/June and remained until August/September (Best, 1981). The United States and French whalers depleted these populations and, by the start of modern whaling off the African coast in 1908, right whales were understood to be very rarely encountered. Between 1913 and 1930, no right whales were recorded to have been landed in Namibia, and only one was landed in Angola – reportedly in 1913 near Tombwa in Namibe Province on the shore of Port Alexander (~15°S) in southern Angola (Olsen, 1914; Best & Ross, 1986). Evidence strongly suggests that the 17 right whales reported (in the 1925 Bureau of International Whaling Statistics) to have been landed in Angola in 1925 were actually Bryde's whales (Best, 1990). In 1951, a single right whale female was illegally captured off Cap Lopez in Gabon (1°S) (Budker & Collignon, 1952; Best & Ross, 1986).

In the post-whaling era (after 1975), southern right whales off South Africa have been regularly studied and monitored (see review in Elwen *et al.*, 2011). However, research in other previously known southern right whale grounds in this region has been limited. In Angolan waters, recent cetacean occurrence data have been recorded opportunistically during geophysical

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surveys. For example, between 2004 and 2009, sightings were recorded in oceanic waters off Gabon and Angola (Weir, 2007*a*, 2010*a*, 2010*b*). However, no right whales were observed during these surveys.

The most recent sighting of a right whale in the general vicinity of Angola in the eastern Tropical Atlantic was farther north off Gabon at '1 South and 8 30′ East' on 29 July 1999. This individual was designated as 'likely a southern right whale' (New England Aquarium, unpublished data). Our sighting was at 7°16′S off the Angolan coast just north of the former south Angolan whaling ground of Tiger Bay, which lies at ~16°37′S. Based on current and historical information, it appears that our sighting is the first confirmed right whale sighting in Angolan waters since a whale was landed in southern Angola in 1913.

Aerial surveys flown consistently off southern Namibia in September/October since 1978 have shown a resurgence of southern right whales in the region south of the historical whaling grounds at Walvis Bay, Namibia and Tiger Bay, Angola (Roux *et al*., 2001). The increased sightings in this concentrated, coastal area of Namibia, particularly since 2008, are thought to be due to right whales from the South Africa population perhaps expanding their range northward (Roux *et al*., 2015). Results of recent annual surveys on the South African right whale breeding ground indicate (1) a decline in the number of unaccompanied adults since 2010; (2) extreme fluctuations in the number of cow–calf pairs since 2015; and (3) a continuing decrease in the population increase rate (Brandão *et al*., 2018; Vermeulen *et al*., 2018, 2020). Tour operators in Walvis Bay have seen several right whales every winter during the past 10 years or so. Sightings and survey efforts farther north in Namibia are limited although one sighting of a cow-calf pair was recorded north of Meob Bay at Conception Bay (23°57.75'S) on 19 September 2003 (Roux *et al*., 2015). It is unclear whether Walvis Bay was originally a calving/nursery ground for southern right whales. Calving females have not dominated recent sightings in southern Namibia in September/October, and Roux *et al*. (2015) suggested that Namibian waters may serve as a breeding/mating ground, while South African waters serve as the primary calving/nursery ground for these whales.

Humpback whales

The timing of our humpback whale sightings is consistent with the known occurrence of southern hemisphere humpbacks in this region during the austral winter. Humpback whales in the southern hemisphere migrate between feeding grounds in Antarctic waters during the austral summer and breeding grounds in the tropics during winter. Previous surveys have confirmed Angolan and nearby Gabon waters as humpback breeding grounds (International Whaling Commission (IWC), 1998, 2007; Best *et al*., 1999; Van Waerebeek *et al*., 2001; Weir, 2007*a*; Rosenbaum *et al*., 2009). It is difficult to ascertain the identity of the humpback whales sighted during our study because the population/stocks and boundaries of southern hemisphere humpbacks are not yet well defined. Of the seven breeding stocks of southern hemisphere humpbacks currently recognized by the IWC, Breeding Stock B includes humpback whales that migrate between feeding areas in the Southern Ocean and breeding areas in tropical and subtropical western Africa (IWC, 1998, 2007; Rosenbaum *et al*., 2014). This stock is currently divided into two substocks: B1 ranges from breeding grounds in the Bight of Benin to Angola, and B2 ranges from Angola to South Africa and migrates and occasionally feeds off west South Africa and Namibia (Rosenbaum *et al*., 2009, 2014; Bamy *et al*., 2010; IWC, 2011; Barendse *et al*., 2013; Van Waerebeek *et al*., 2013; Findlay *et al*., 2017; Kershaw *et al*., 2017). The breeding grounds of B2 are currently unknown (Barendse *et al*., 2013; Rosenbaum *et al*., 2017). Both of these substocks occur off Angola with the area of the Walvis Ridge (18°S) serving as a proposed geographic line dividing B1 and B2 (Pomilla & Rosenbaum, 2006; Rosenbaum *et al*., 2009; Collins *et al*., 2010; Carvalho *et al*., 2014). However, the association of specific substocks with distinctly separate geographic locations is understood to be complex (Rosenbaum *et al*., 2009; Collins *et al*., 2010; Carvalho *et al*., 2014).

Our sightings off north-western Angola (~6–7°S) in September overlap with the proposed range of substock B1 and align with peak sightings previously recorded off Angola between June and October (Weir, 2011) which correspond with the known timing of migrations between breeding grounds in the northern Gulf of Guinea and feeding grounds in the Antarctic (Budker & Collignon, 1952; Carvalho *et al*., 2014). Our sightings also suggest that humpback whale migratory habitat off Angola extends far offshore (50–250 km) in deep waters (at least 3865 m).

We observed travelling and surface-active behaviours but did not observe any behaviours that have been used to denote breeding (e.g. singing males, mother–calf–escort groups, competitive groups) (see table 2 in Chou *et al*., 2020). However, we did see one calf with an adult (likely a mother–calf pair), and we could not rule out humpback whale singing which is thought to predominantly occur in breeding regions (Smith *et al*., 2008) and to a lesser extent in feeding areas (Mattila *et al*., 1987) and during migration (Clapham & Mattila, 1990; Cerchio *et al*., 2014). Songs have been recorded in northern Angola from units deployed much closer to shore (15–24 km from shore and 100 m in depth) than our Study Area and primarily from July through October (Cerchio *et al*., 2014), which is consistent with humpback whale occurrence on breeding/wintering grounds in coastal waters over the continental shelf (Rosenbaum & Collins, 2006; Strindberg *et al*., 2011).

Although we did not find conclusive marine mammal vocalizations from the PAM recordings, we cannot confirm that vocalizing marine mammals were not present near the stations where recordings took place due to the amount of vessel noise in the recordings. However, it is not unlikely that humpback whales were vocalizing. At least one previous study reports active singing behaviour just north of our study region (Best *et al*., 1999).

Deep-water sightings

Our study is one of the few to document marine mammals and sea turtles in water depths close to 4000 m off Angola. The depths of our study ranged from 2350–3850 m with an average depth of 3155 m. For instance, previous visual observations for marine mammals off Angola between 2004 and 2009 were conducted primarily on the continental slope (1000–2000 m) with some effort in oceanic waters over 3000 m in depth (Weir, 2011). Maximum depth ranges of our sightings were similar to those recorded by Weir (2011). Of particular interest is the relatively high number of humpback whale sightings which suggests that their migratory habitat includes deep waters (at least 3865 m) off Angola.

Conclusion

We confirmed the presence of six marine mammal species/groups and one sea turtle species in a deep-water site off Angola where few systematic studies of marine megafauna have been previously conducted. Our probable southern right whale sighting is the first confirmed right whale sighting in Angolan waters since 1913 based on current and historical information. This sighting was north of the former whaling grounds of Tiger Bay, Angola and Walvis Bay, Namibia. Future studies are needed to determine if

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the South Africa population is expanding its range northward into Namibian and Angolan waters. Additional studies are recommended (see Supplementary Information file) and needed to gain a better understanding of the occurrence of other cetacean species in this part of the eastern Tropical Atlantic, particularly humpback whales which may be using deep waters offshore Angola as a migratory corridor. This information will help inform environmental planning for offshore development projects.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S0025315422001084

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