Cetacean sightings and acoustic detections in the offshore waters of the Maldives during the northeast monsoon seasons of 2003 and 2004

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ABSTRACT

Despite its central position in the Indian Ocean Sanctuary, little is known about the offshore cetacean fauna of the Maldives. Here we report survey results gathered by the R/V *Odyssey* in the Maldives during the 2003 and 2004 northeast monsoon seasons, and provide data on cetaceans from visual and acoustic observations. The survey was conducted over a period of 72 days and covered 10,915 track line kilometres. The main aim of the survey was to collect biopsy samples from sperm whales (*Physeter macrocephalus)* as part of a global survey of ocean pollutants. Totals of 157 sightings and 1,461 acoustic detections of 16 identified cetacean species were recorded. Risso's dolphin (*Grampus griseus*), pantropical spotted dolphin (*Stenella attenuata*), spinner dolphin (*Stenella longirostris*) and sperm whale were the most commonly sighted species. Sperm whales and pantropical spotted dolphins were particularly abundant in the southern Maldives. The cetacean acoustic detection rate was 2.5 times higher than in the eastern Indian Ocean and Western tropical Pacific, while the non-physeterid sighting rate was 1.7 times higher than the Eastern tropical Pacific and 6.7 times higher than the eastern Indian Ocean based on other research conducted by the R/V *Odyssey* using the same methodology. It is concluded that the Maldives has a diverse and seemingly abundant cetacean community.

KEYWORDS: INDIAN OCEAN; SANCTUARIES; SURVEY-ACOUSTIC; SIGHTING; SPERM WHALE; MALDIVES

INTRODUCTION

The Indian Ocean Sanctuary (IOS) was declared by the International Whaling Commission (IWC) in 1979, and prohibits commercial whaling in the region. It has also had the effect of allowing recovery of exploited populations of great whales within the Indian Ocean and facilitating benign research on populations of cetaceans not subjected to commercial whaling. Relatively few studies have been undertaken to shed light on cetacean communities within the IOS (Ballance and Pitman, 1998; De Boer *et al.*, 2003). Consequently there remains a need for expanding the knowledge of species composition, distribution, abundance and population sizes of cetaceans in the Indian Ocean, to establish baselines for management, conservation measures and mitigation of potential threats.

The Republic of the Maldives lies within the IOS, at the centre of the northern Indian Ocean, but relatively few cetacean studies have been undertaken (reviewed by Anderson *et al*. 2012). Among recent studies, Anderson *et al.* (1999) reviewed information on cetacean strandings. Ballance *et al*. (2001) reported on a cetacean survey around the northeast of the archipelago. Anderson (2005) summarised approximately 2,000 cetacean sightings from the period 1990–2002. These studies demonstrated that Maldivian waters have a rich cetacean fauna, comprising at least 23 different species of the families Balaenopteridae, Delphinidae, Physeteridae and Ziphiidae (Anderson *et al.*, 2012b). Other areas within the Indian Ocean hold equal or greater cetacean diversity, but Maldivian waters are particularly interesting from a cetacean monitoring and conservation perspective because there is no local whaling and the fishing methods employed (mostly pole and line for tunas and handline for reef fishes) result in apparently zero bycatch of cetaceans and negligible catch of their prey (Anderson *et al.*, 2012b; 1999; 1998). Thus, the Maldivian cetacean fauna may, in contrast to many other areas in the Indian Ocean, have suffered little from either deliberate or accidental takes. Nevertheless, in the offshore waters of the Maldives in particular very little is known about the cetacean fauna. Here we report data from the 2003 and 2004 surveys by the R/V *Odyssey*, which spent 72 days in the Exclusive Economic Zone (EEZ) of the Maldives seaward of the atoll slope in search of sperm whales.

The R/V *Odyssey*, research vessel of the Ocean Alliance, launched the Voyage of the *Odyssey* in the spring of 2000. The *Voyage* was a five-year global effort designed to gather the first ever baseline data on levels of contaminants throughout the world's oceans by collecting biopsies from sperm whales (*Physeter macrocephalus*) (Ocean Alliance, 2009). An important area in that study was the tropical Indian Ocean, including Maldivian waters. Since Odyssey's primary research objective involved the collection of biopsies from sperm whales, track lines were biased towards passing underwater features (such as seamounts) that

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increased the chance of finding this species. Thus, the sighting and acoustic data collected do not allow for estimation of absolute densities nor population sizes for species encountered. Nevertheless, the visual and acoustic observations collected in Maldivian waters offer relevant and much needed information on the cetacean community structure and zoogeography in the northern tropical Indian Ocean. Furthermore, the results of this survey provide a contrast to previous surveys in Maldives, which have concentrated on nearshore waters. Here we present sighting and acoustic data from at least 17 different cetacean species and discuss implications for the understanding of cetacean community structure and conservation within the Maldivian region of the IOS.

MATERIALS AND METHODS

Research area and platform

The Republic of the Maldives lies within the IOS, at the centre of the northern Indian Ocean. Comprising more than 1,200 low coral islands, the archipelago stretches north-south from about 7°N to 1°S, and is surrounded by deep oceanic water. The weather is dominated by the monsoons. The northeast monsoon lasts from about December to March (when ocean currents flow mainly to the west) while the stronger southwest monsoon blows from about May to October (when currents flow eastward) (Anderson *et al.*, 2011; Anderson *et al.*, 1999; Longhurst, 1998; Tomczak and Godfrey, 1994). November and April are inter-monsoon months.

Research was conducted aboard the R/V *Odyssey*, a 28m steel ketch, fitted for extended periods of off-shore research on marine mammals. The research in Maldivian waters was conducted in two study periods: the first from 12 January to 17 March 2003, the second from 9 February to 26 March 2004. Research was thus conducted during the annual northeast monsoon season, when winds are generally light and from the NE, and currents generally run from east to west. During each research season, three cruise legs were completed (Table 1). These cruises between them covered the area between about 7°N to 1°S and 71°E to 75°E (Fig. 1). A total of 10,915 track line km were covered (Fig. 1), 1,470 h were spent on acoustic and visual searches, and 70 sperm whale biopsies obtained. Mean sea state was 2.5 ± 0.9 (mean ± SD) (range 0–6) yielding excellent (Beaufort 0–2) sighting and listening conditions 52% of the time, and fair (Beaufort 3–4) observation conditions 47% of the time.

There were some differences in areas surveyed between years. During all three legs in 2003, the R/V *Odyssey* operated offshore, beyond the 2000m isobath, searching for sperm whales. In contrast, in 2004, much time was spent more inshore, searching for beaked whales along the outer atoll slopes. In addition, the only cruise leg to visit the north of Maldives was conducted in 2003. For the purposes of this report, northern Maldives is defined as the area north of 5°N; southern Maldives the area south of 3°N, and central Maldives as the area in between.

Visual survey methodology

A watch was maintained during daylight hours (~0600 to 1900h) from an observation platform located 4.6m above water level, with a maximum sighting distance to the horizon of 7.5km. One or two observers surveyed the area 180° forward of the vessel to the horizon by naked eye and 7x40 binoculars. All marine mammal sightings were recorded in the computerised database *Logger 2000* v. 2.05 (developed by the International Fund for Animal Welfare, IFAW). Sighting data included species identification, position (from GPS), number of animals, behaviour, water depth, bearing and distance to the vessel. In addition, the following data were automatically recorded in the database for each entry: time, vessel course and speed, sea surface temperature (SST) and sea state (SS). Sea surface temperature and weather conditions relating to sighting ability (sea state, swell and meteorological conditions) and navigation data were also entered in the *Logger* database every half hour. Visual effort was suspended during times of heavy rain. Sightings within 2km of the vessel's track were approached to obtain species identification, photographs and to estimate school size.

For all species, animals that were observed to be less than half the length of an accompanying animal were classified as calves. Animals more than half the length of an accompanying adult, but less than full size were classified as immature animals. For sperm whales, mature males were determined by their large size (estimated at greater than 12m). Sexually mature female sperm whales were classified by the presence of callosities on their dorsal fin (Kasuya and Ohsumi, 1966; Whitehead and Gordon, 1986), although this method is not fool-proof.

Acoustic survey methodology

Acoustic detections of marine mammals were made using a 100m long hydrophone array, consisting of two *Benthos* AQ4

Table 1

Summary of survey effort, by cruise leg.

Note: Regions N,C,S = north, centre, south (see text for definitions).

Leg	Dates	Survey effort		Acoustic stations	Region	Inshore/ Offshore	No. sperm whale biopsies
		km	h				
1	12–24/01/2003	1,938	241	325	C, S	Off	7
2	06–28/02/2003	3,567	448	562	N,C,S	Off	16
3	04–13/03/2003	1,636	199	309	C,S	Off	18
4	09–18/02/2004	1,517	200	261	C,S	In and Off	17
5	02–06/03/2004	443	95	217	C	In	0
6	13–26/03/2004	1,814	287	480	C,S	In and Off	12
	Total	10,915	1,470	2,154			70

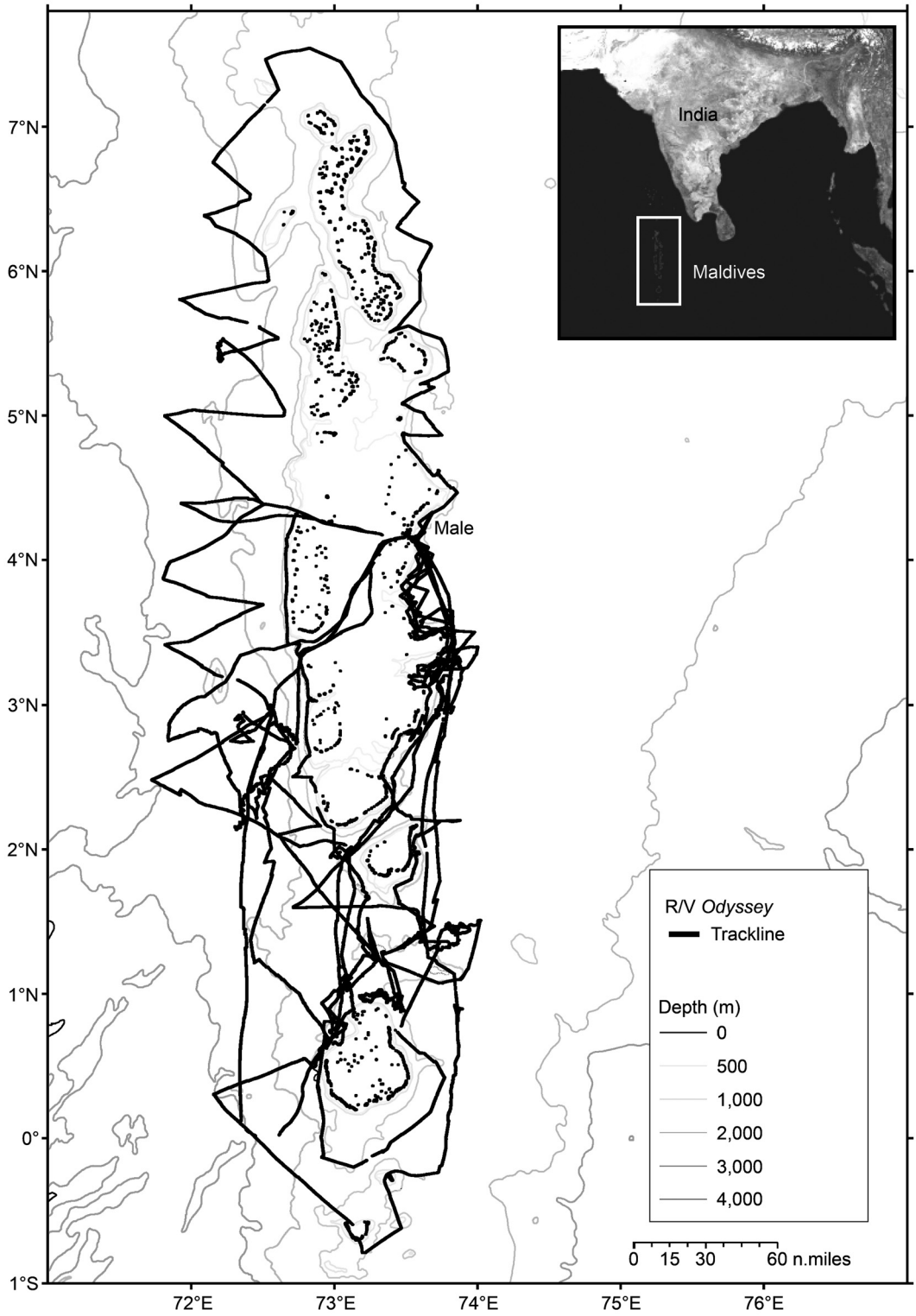

Fig 1. Trackline of R/V *Odyssey.*

hydrophone units with *Benthos* AQ201 pre-amplifiers separated by 2m. Effective listening range was 1–25km depending on weather conditions, vocalising species, and whether the vessel was motoring or sailing. The output signal was connected to headphones, as well as to a pair of stereo speakers located in the pilothouse. Sounds from the array were monitored continuously by the helmsman listening to the speaker set while the vessel was underway. When not actively working with sperm whales, listening stations with headphones were occupied every half hour. An acoustic stop was made on even hours with the engine turned off and the vessel brought to a speed of less than one knot for a minimum of five minutes. During the half hour and odd hour stations, the engine was reduced to idle speed, the autopilot put on standby for a minimum listening period of five minutes. Acoustic contacts with marine mammals were entered in *Logger 2000*. Acoustic detection rates are reported as detections per listening station.

Incoming data from the acoustic array were automatically scanned for sperm whale clicks with different algorithms

depending on background noise levels. Once sperm whales were detected the vessel was manoeuvred to derive the bearing of clicking animals relative to the vessel. Incoming acoustic data from the array were automatically processed in real time by the software *Rainbow Click* v. 1.03 (IFAW). *Rainbow Click* analysed the stereo signal using time of arrival differences between the same clicks on the two channels to estimate a bearing to each click source.

RESULTS

Sightings

A total of 157 cetacean group sightings were made, of at least 17 different species (Table 2). 107 sightings (68%) were identified to species. Locations of all cetacean sightings are shown in Figs 2–3. Numbers of individuals observed, and mean group sizes are listed in Table 3.

For some species there were large differences in the numbers of sightings and of group sizes between years (Tables 2 and 3). For example, for sperm whales there were more sightings in 2003 (n = 14) than in 2004 (n = 5). Nine of the sighting in 2003 consisted of single animals, while no single animals were sighted in 2004. The mean size of the other sperm whale groups was 10.9 animals.

There was a marked increase in the number of spinner and pantropical dolphins sighted between 2003 and 2004. For pantropical spotted dolphins, there were more sightings (n = 13) in 2003 (n = 13) than 2004 (n = 5), but the mean group size was significantly larger (t = 4.7, $p \leq$ = 0.0006) in 2004 (191 ± 131) than in 2003 (24 ± 14). For spinner dolphins, the recorded number of groups was similar in both years (8 in 2003 and 7 in 2004) but the mean group size was significantly larger (t = 2.3, $p \leq$ = 0.04) in 2004 (108 ± 105) than 2003 (15 ± 9).

Table 2

Numbers of cetacean sightings by species during the 2003 and 2004 northeast monsoons.

		Number of sightings		
		2003	2004	Total
Bryde's whale	*Balaenoptera edeni*	4	2	6
Sperm whale	*Physeter macrocephalus*	14	5	19
Dwarf sperm whale	*Kogia sima*	–	1	1
Killer whale	*Orcinus orca*	–	1	1
False killer whale	*Pseudorca crassidens*	2	1	3
Pygmy killer whale	*Feresa attenuata*	–	1	1
Melon-headed whale	*Peponocephala electra*	1	1	2
Short-finned pilot whale	*Globicephala macrorhynchus*	–	1	1
Spinner dolphin	*Stenella longirostris*	8	7	15
Pantropical spotted dolphin	*Stenella attenuata*	13	5	18
Striped dolphin	*Stenella coeruleoalba*	5	3	8
Common bottlenose dolphin	*Tursiops truncatus*	1	4	5
Fraser's dolphin	*Lagenodelphis hosei*	1	1	2
Risso's dolphin	*Grampus griseus*	3	20	23
Cuvier's beaked whale	*Ziphius cavirostris*	–	1	1
Longman's beaked	*Indopacetus pacificus*	1	–	1
Beaked whale	*Mesoplodon* sp.	2	1	3
Unidentified whale		1	6	7
Unidentified dolphin		21	19	40
Total		77	80	157

Acoustics

A total of 2154 acoustic stations were conducted, with cetacean detections recorded during 1461 (68%). Cetacean detections included delphinid species (n = 1175), sperm whale (n = 231), pilot whales (n = 19), killer whale (n = 1) and unassigned (114). Thus, 55% of all listening stations detected the sounds of delphinids. The similarity in tonal and click sounds from a wide range of smaller delphinids did not allow for acoustic species identification, with the exception of dolphin detections which were augmented by visual identification (including Risso's dolphins, n = 18). However, short-finned pilot whales and killer whales could be identified by their distinctive whistles.

All sperm whale groups were first detected acoustically, followed by visual location. No sperm whale groups were detected by only one method. The mean time spent with a group was 14h (±5h) and acoustic and/or visual contact was maintained until effort was terminated upon data set completion; no groups were lost prior to termination of effort.

DISCUSSION

This study recorded 17 species from the Maldives. At the time of these surveys only four other cetacean species had been reported in Maldivian waters (Anderson, 2005; Anderson *et al.*, 1999; Ballance *et al.*, 2001).

Six species were sighted only once each (Table 1): dwarf sperm whale, Cuvier's beaked whale, Longman's beaked whale, killer whale, pygmy killer whale and short-finned pilot whale. The sighting of Longman's beaked whales was previously reported by Anderson *et al.* (2006). The one group of killer whales was seen attacking common bottlenose dolphins off the west side of the Maldives (at 3°03'N 72°49'E) on 24 March 2004. Killer whales and pygmy killer whales are both considered to be uncommon in the Maldives (Anderson, 2005; Ballance *et al.*, 2001). The other four species are not especially rare in the Maldives, indeed short-finned pilot whales and dwarf sperm whales are relatively abundant (Anderson, 2005; Ballance *et al.*, 2001), but they are encountered most commonly over the outer atoll slopes. This survey spent more time in offshore waters than slope waters compared to previous surveys.

More time was spent in near-atoll slope waters in 2004 than in 2003. This may explain inter-annual differences in sightings for some species. Thus, slope-associated species, notably Risso's dolphin, dwarf sperm whale and short-finned pilot whale, but also Cuvier's beaked whale (Anderson, 2005), were sighted only in 2004, but given the low sightability of this species no inferences can be drawn on year to year changes.. In contrast, 'offshore' species such as sperm whale, striped dolphin and spotted dolphin, were sighted more frequently in 2003 than 2004 (Tables 2 and 4). However, there were more individuals of both striped and spotted dolphins recorded in 2004 than 2003, and we note that this division between inshore and offshore does not explain all interannual differences.

The pantropical spotted dolphin was the most common species recorded by number (Table 3). It was also the third most frequently sighted species over both seasons (Table 2). Pantropical spotted dolphins were most frequently

Table 3
Numbers of individuals seen and mean group sizes by species and survey season.

	Number of animals			Mean group size		
	2003	2004	Total	2003	2004	Total
Bryde's whale	4	4	8	1.0	2.0	1.3
Sperm whale	64	54	118	4.6	10.8	6.2
Dwarf sperm whale	0	2	2	–	2	2
Killer whale	0	8	8	–	8	8
False killer whale	40	70	110	20	70	37
Pygmy killer whale	0	10	10		10	10
Melon-headed whale	1	33	34	1	33	17
Short-finned pilot whale	0	15	15		15	15
Spinner dolphin	122	756	878	15	108	59
Pantropical spotted dolphin	288	955	1,243	22	191	69
Striped dolphin	71	127	198	14	42	25
Common bottlenose dolphin	10	107	117	10	27	23
Fraser's dolphin	100	175	275	100	175	138
Risso's dolphin	60	237	297	20	12	13
Cuvier's beaked whale	0	4	4	–	4	4
Longman's beaked	5	0	5	5	–	5
Beaked whale	3	4	7	1.5	4	2.3
Unidentified whale	2	13	15	2	2.2	2.1
Unidentified dolphin	283	226	509	13	12	13
Total	1,053	2,800	3,853			

encountered in the southern Maldives (Figs 2 and 3), and were not recorded at all from the north of Maldives. Ballance *et al*. (2001) considered pantropical spotted dolphins to be uncommon during their survey of northern waters. However, Anderson (2005) reported this species to be common throughout the Maldives, albeit especially so around the southern atolls.

Spinner dolphins have previously been recorded as the most frequently sighted species in the Maldives (Anderson, 2005; Ballance *et al.*, 2001), as well as the most abundant species in the western Indian Ocean (Ballance and Pitman, 1998). During this study, however, spinner dolphins were only the second most numerous and fourth most frequently sighted species (Tables 2 and 3). This might again be explained in part at least by the fact this survey spent much time offshore, since spinner dolphins are frequently atoll-associated (Anderson, 2005).

Sperm whales were the most commonly recorded species in 2003, and the second most commonly recorded species overall. This is consistent with the findings of both Ballance and Pitman (1998), who found sperm whales to be the most frequently sighted cetacean in the western Indian Ocean, and of Anderson *et al.* (1999), who reported the sperm whale to be the most commonly stranded cetacean in the Maldives Furthermore, our survey was designed to maximise the likelihood of finding sperm whales, spending much time offshore and using previous experience of those bathymetric features which provide appropriate habitat for this species. In contrast, surveys of Maldivian inshore waters have recorded relatively low numbers of sperm whales (Anderson, 2005; Ballance *et al.*, 2001).

Nearly all of our sperm whale sightings and acoustic detections occurred in the southern Maldives, between about 0° and 3°N (Figs 2 and 3). This suggests that the mesopelagic prey of sperm whales may be most abundant in this area, at least during the northeast monsoon. The south of the Maldives is under the influence of the equatorial current systems, rather than the seasonal monsoon currents that affect the northern and central atolls. As a result the south of Maldives is known to have a rather different pelagic fauna from the north and centre (Anderson, 2005; Anderson and Saleem, 1994; Anderson *et al.*, 1998).

A similar number of sperm whales were sighted during both years although there were differences in the number of groups sighted. Fourteen groups consisting of 64 sperm whales were sighted in 2003 while five groups consisting of 54 animals were sighted in 2004. However, nine of the 14 groups sighted in 2003 consisted of single animals, while no single animal sightings were recorded in 2004. Although groups of adult males and females, as well as the immature of both sexes were sighted during both years, calves were only sighted in one group in 2004. This group, which was the largest encountered during the study, included two calves and two adult females with callosities on their dorsal fin. Acoustic 'clangs/slow clicks', which are presumed to be made only by mature males (Whitehead, 2003), were recorded while with this group, suggesting that an adult male was within acoustic range of the array even though none was sighted. The two calves recorded represented less than 2% of the sperm whales sighted during this study. The ratio of calves to animals with callosities, which are presumed to be adult females (Kasuya and Ohsumi, 1966; Whitehead and Gordon, 1986), was 1 to 5.5; this is much lower than the 1:2 ratio reported for Sri Lanka (Gordon, 1987). On this basis, only 10% (n = 11) of sperm whales sighted were presumed adult females, which was lower than the average of 33% previously reported for tropical waters (Best, 1979). However, it is likely that there were some adult females without callosities. It is also possible that our working definition of 'calves' as being less than half the length of accompanying animals may have caused us to underestimate their true number. Nevertheless, the data we recorded suggest relatively low numbers of adult females and calves in the Maldives, and may indicate that this area is not a major

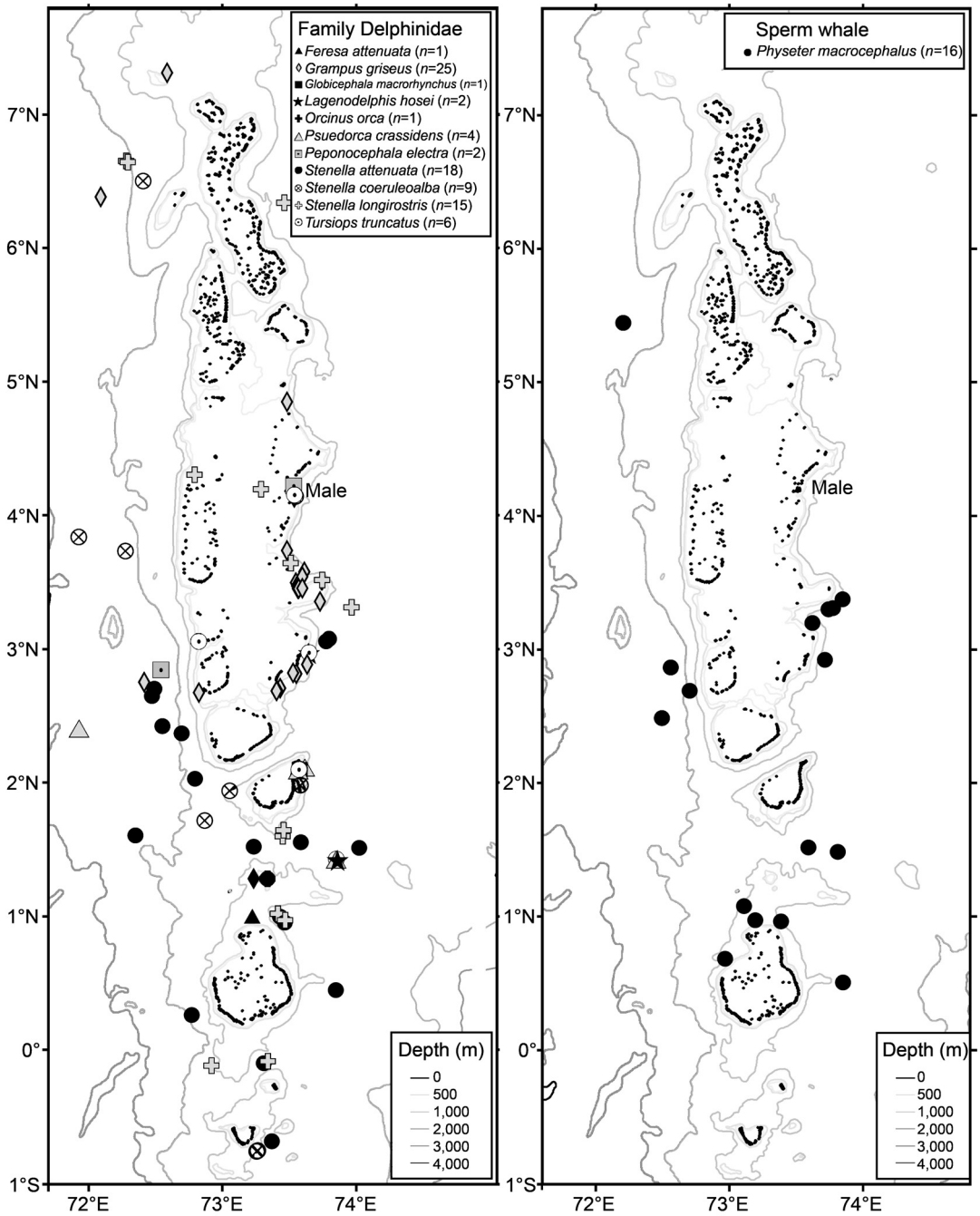

Fig 2. Delphinid and sperm whale sightings.

nursery ground for sperm whales. However, further studies, including surveys at different seasons, and of movements of sperm whale groups within the Indian Ocean, will be needed to understand the social structure of groups and how they change on temporal and geographical scales.

Subadult and adult male sperm whales ($n = 21$) accounted for nearly 19% of all sperm whales recorded. This is much higher than the 3% reported during peak breeding season in Galapagos (Whitehead, 1993) or the 4.2% reported in the West Indies (Whitehead, 1987). Furthermore Gordon (1987) rarely sighted adult males in Sri Lankan waters during the northeast monsoon; the sperm whale population there consisted almost entirely of adult females and immature animals of both sexes, with no animals exceeding 12 m in length (Gordon, 1991). In contrast, Maldivian stranding data show that about 22% of stranded sperm whales were greater than 12m (Anderson *et al.*, 1999) suggesting that they were adult males.

We did not record any blue whales (*Balaenoptera musculus*) although this species had been previously recorded from Maldivian waters during several studies (Anderson, 2005; Anderson *et al.*, 1999; Ballance *et al.*, 2001; Ballance and Pitman, 1998). One reason may be that our hydrophone array was unable to detect blue whale calls due to flow noise, Lloyd mirror effects and a 400Hz high pass filter. In addition, most of our survey effort was in February and March, when blue whales appear to be relatively scarce in the Maldives (Anderson *et al.*, 2012a).

Both acoustic detection rates (defined as detections per listening station) and sightings rates for non-physeterid cetaceans were higher in Maldivian waters then in any other Voyage of the *Odyssey* study area (Ocean Alliance,

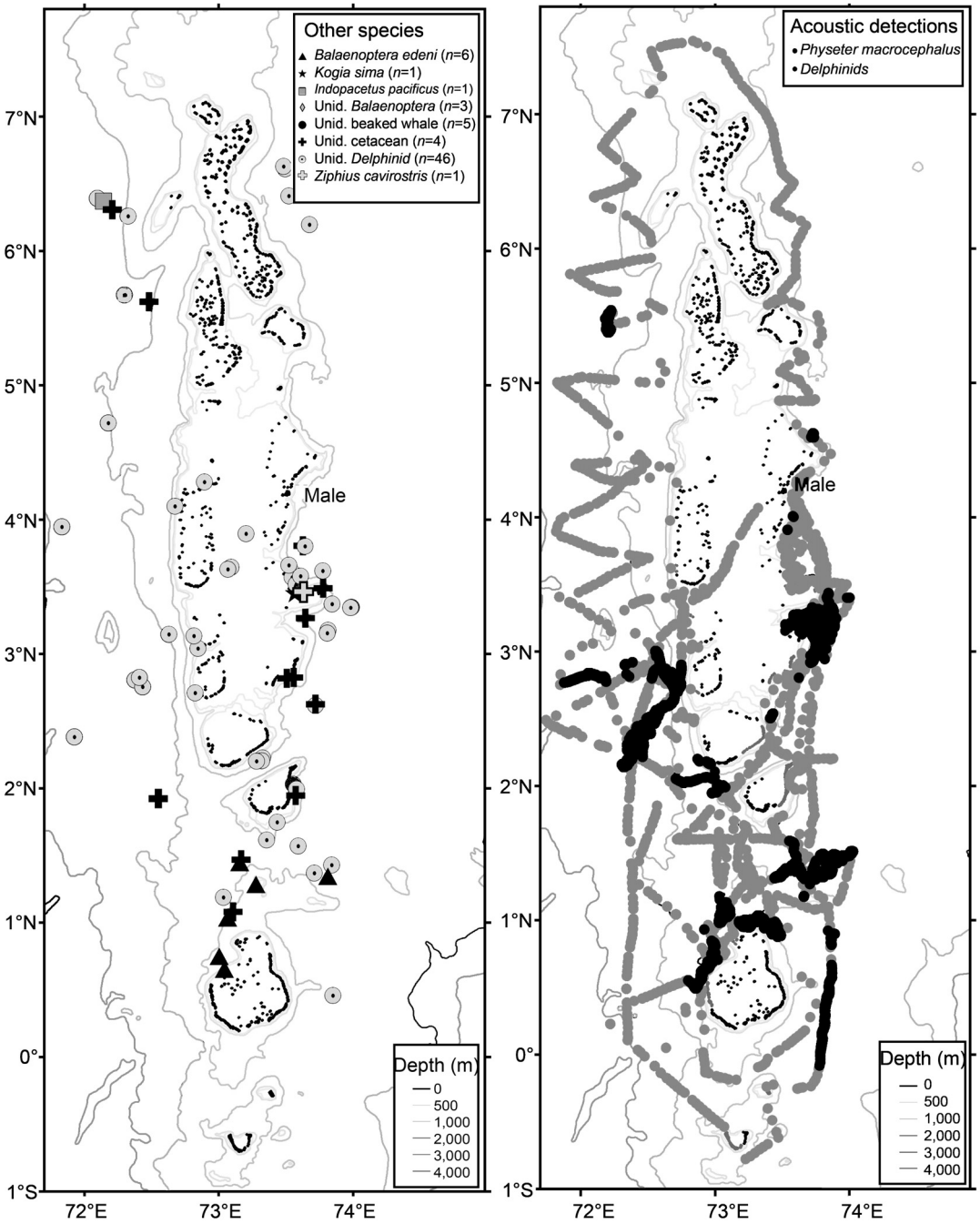

Fig 3. Sightings of other species and acoustic detections of delphinids and sperm whales.

unpublished data). Maldivian cetacean acoustic detection rates were double those for the rest of the western tropical Indian Ocean and over 2.5 times higher than both the eastern Indian Ocean and the Pacific Ocean. Maldivian sighting rates for non-physeterid cetaceans were 1.2 times higher than in the rest of the western Indian Ocean, 6.7 times higher than in the eastern Indian Ocean and 1.7 times higher than in the Western Tropical Pacific.

Differences in sea states and perhaps also seasonal effects in different survey areas will have influenced these regional differences. Nevertheless, the high acoustic and visual detection rates in the Maldives strongly suggest that these waters have a seemingly abundant cetacean fauna in comparison not only to the rest of the Indian Ocean but also to at least some parts of the Western tropical Pacific. One factor contributing to this apparently high cetacean abundance may be the unique geographical setting of the Maldives island chain, which lies north-south across the east-west flow of the monsoon currents. Through upwelling and other processes, this juxtaposition enhances primary productivity, providing increased feeding opportunities for marine predators (Anderson *et al.*, 2011; Longhurst, 1998). In addition, fishing practice and policies within the Maldives result in apparently zero by-catch of cetaceans and very little waste of unwanted fish catch. Tuna fishing is of particular significance, and Maldivians continue to practice a traditional pole and line technique. All forms of pelagic netting (including gill-netting, purse seining and trawling) are banned. Thus, the Maldives represents a rare oceanic area in which fisheries policies are implemented with apparent benefits for cetaceans and the broader oceanic ecosystem.

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