

Cetacean diversity of Mauritius

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ABSTRACT

There is limited information concerning the cetaceans inhabiting the coastal waters of Mauritius. This paper details the sightings of cetaceans encountered during April 2008–September 2014. Boat-based surveys were conducted throughout the year, primarily focusing on spinner and bottlenose dolphin populations that are important for the local dolphin-watching industry. More than 1,246hrs over 749 days of surveys were spent searching for cetaceans. All cetaceans encountered were recorded. During 2013 and 2014, dedicated diversity surveys were conducted and 2443.6km of search effort was covered around the islands. The encounter rate for this period was 0.025 cetacean sightings/km. Over the total study period 13 species were recorded from 1,459 sightings. Species included: humpback whales; spinner dolphins; Indo-Pacific bottlenose dolphins; common bottlenose dolphins; short-finned pilot whales; pantropical spotted dolphins; sperm whales; Blainville's beaked whales; pygmy killer whales; melon-headed dolphins; Risso's dolphins; and Cuvier's beaked whales. In addition, there were strandings of dwarf sperm whales and Cuvier's beaked whales. The most common species encountered were spinner dolphins, Indo-Pacific bottlenose dolphins, humpback whales and sperm whales. As expected, only humpback whales showed any seasonality in monthly encounter rates (Kruskal-Wallis $H = 42.39$, $H_c = 54.25$, $p < 0.001$). The overall Shannon diversity index was 0.58 (95% CI 0.57–0.60) though this ranged between 0.77 in 2009 and 0.25 in 2014. The Shannon index value for the 2013–2014 diversity study was 0.83 (95% CI 0.74–0.91). This study demonstrates the richness of the waters around Mauritius and the importance of the area for beaked whales, migrating humpback whales and resident sperm whales.

KEYWORDS: BEAKED WHALES; CETACEANS; DIVERSITY; MAURITIUS; VISUAL SURVEY; WESTERN INDIAN OCEAN

INTRODUCTION

In 1979, the Indian Ocean became a whale sanctuary established by the International Whaling Commission. The sanctuary led to a review of current knowledge and new studies of cetaceans within the region. These include both coastal and oceanic waters of the Seychelles and Comoros islands, La Reunion Island, Mayotte, Madagascar, Zanzibar and the East coast of Africa (de Boer *et al.*, 2002; Kiszka *et al.*, 2009). However, compared to other oceans, only limited research has been undertaken in this region (Ballance and Pitman, 1998; de Boer *et al.*, 2002). There is a lack of knowledge in the Indian Ocean concerning cetaceans, especially for pelagic species (Elwen *et al.*, 2011). To establish baselines for management, conservation measures and mitigation of potential threats for cetaceans in the region, research needs to be developed/expanded into areas such as species composition, distribution and abundance.

Of over 80 species of cetacean worldwide, at least 32 species have been recorded within the southwest Indian Ocean (Kiszka, 2015). There are very few published records for Mauritius, with only one that focused on species diversity in the waters off the West coast of the island. Corbett (1994) describes the presence of 13 cetacean species in the waters of Mauritius with the spinner dolphin *Stenella longirostris* (inshore) and the sperm whale *Physeter macrocephalus* (offshore) being the most commonly encountered species. Earlier cetacean records from regional voyages mentioned the presence of the Blainville's beaked whale (*Mesoplodon densirostris*) around Mauritius (Michel and van Bree, 1976).

Mauritius relies heavily on the marine environment for its revenue (Daby, 2003) and over the past three decades there

has been considerable growth in both the human population and the tourism industry, particularly along the coast (Daby, 2003; 2006b). This development, in addition to other land-use practices and pollution, has arguably proceeded with little environmental awareness (Ramjeawon and Beedassy, 2004). Subsequently, both its terrestrial and marine biodiversity are threatened. The productivity of the reef habitats has already been negatively affected (Daby, 2006a; 2006b; Sobhee, 2006). Recreational activities such as fishing, snorkelling and diving, along with an increase in leisure boating, have resulted in the degradation or destruction of large areas of reef and lagoon. There is now a need for improved management to mitigate these threats and any further anthropogenic pressures on the ecosystem.

In 2006, in response to these growing concerns and the growth of the dolphin- and whale-watching industry on the southwest coast, the Mauritius Marine Conservation Society (MMCS) began conducting surveys focusing on the number and behaviour of boats involved with dolphin watching. From 2008, these surveys became a formal study with the objectives of determining the dolphin population size and assessing the impacts of dolphin watching on the behaviour of the two species these activities focus on. Concurrently, surveys were also conducted to assess species diversity and collect photo-identification data from the main species encountered. In 2013, in order to contribute to the baseline knowledge on cetacean populations within the waters of Mauritius, a further project was initiated to determine preliminary estimates of diversity of cetaceans around the whole island. Data collected during all surveys from both projects (2008–2014) are presented here to

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provide an overview of the cetacean communities around mainland Mauritius.

METHODS

Mauritius is situated approximately 900km East of Madagascar in the western Indian Ocean (WIO) and is part of the Mascarene archipelago including La Reunion and Rodrigues (Fig. 1). The island is almost entirely surrounded by fringing reef creating 243km² of lagoons (Daby, 2003), which vary in depth from <1m to a maximum of 15–20m (Daby, 2006b). There are a number of smaller islands within 30km of the mainland off the North coast. In this area between the mainland and northern islands, the waters are shallow with a maximum depth of approx. 70m. Around Mauritius, the 1,000m depth contour ranges from approximately 2.8km to 5.6km (1.5 to 3 n.miles) from the coast (Corbett, 1994). Off the West coast the continental shelf drops rapidly while the East coast has a more gradual slope. The western side of the island is sheltered from trade winds that blow from the East and southeast for most of the year (Corbett, 1994). Being subtropical, the sea surface temperature (SST) in the lagoons remains relatively high

throughout the year (22–30°C), while outside the lagoon the SST varies less (Sato *et al.*, 2008).

Data collection and analysis

Between April 2008 and September 2014 boat-based surveys were conducted year-round, two to three times a week, with the assistance of several partners. The majority of the surveys focused on the southwest coast of the island as this was both the launch site for the MMCS research vessel, a 6.4m speed boat with two 60hp engines, and the centre of the dolphin-watching activities. Observation effort concentrated mostly on coastal waters to approximately 100m depth outside the fringing reef. Limited survey effort was also applied in waters >1,000m deep. Survey effort was restricted by sea and weather conditions. Only surveys with an average Beaufort of 3 or less were considered for inclusion in analysis. The objectives of the original study from 2008 until 2012 were predominately to monitor the behaviour and interactions of dolphins with dolphin-watching boats and, secondarily, determine population structure of these groups by conducting photo-identification of individuals. As such, surveys were opportunistic and focused on the groups where dolphin

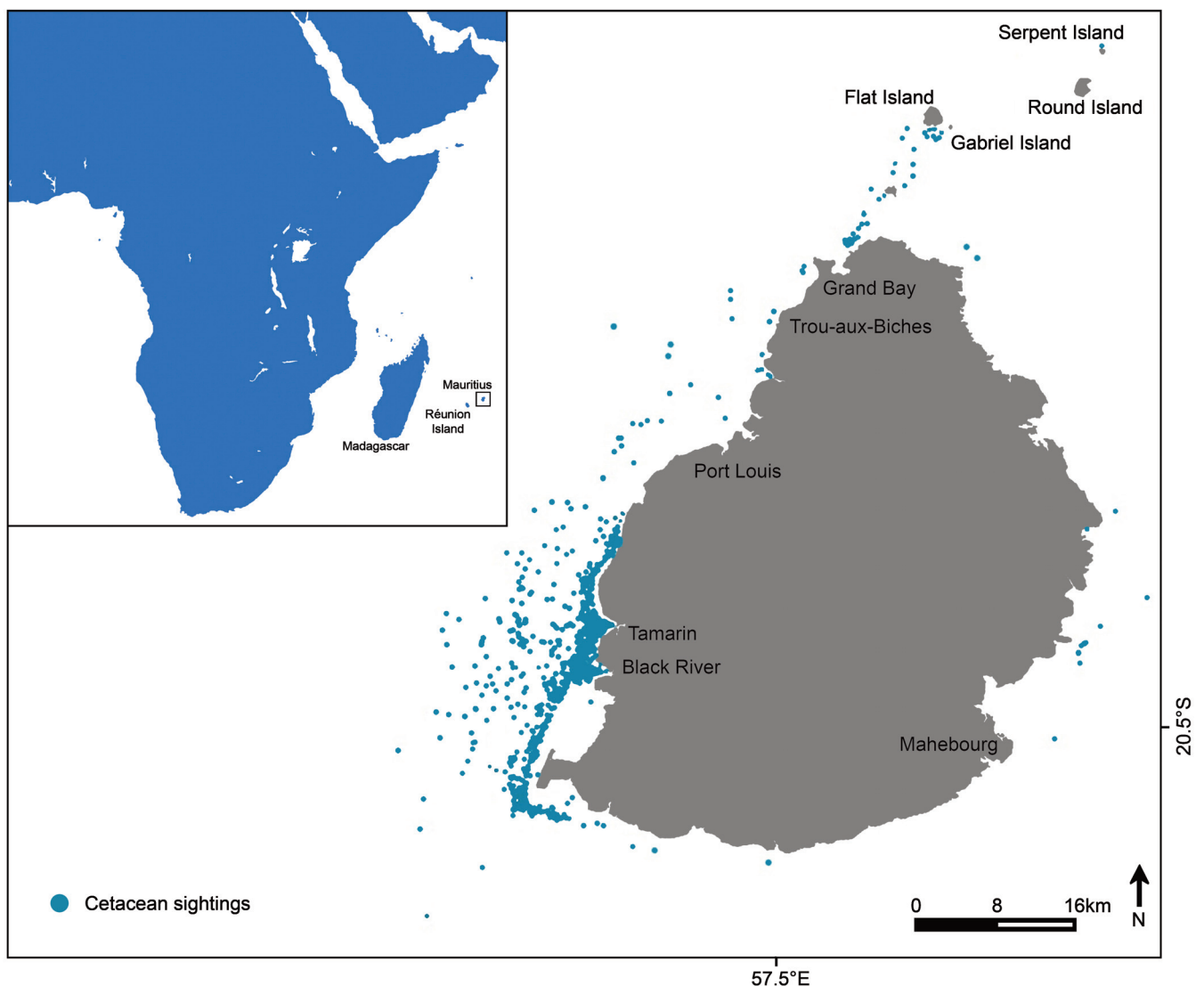


Fig. 1. Position of Mauritius in the Indian Ocean and the distribution of sightings around the island during surveys conducted between April 2008 and September 2014.

watching activities were occurring. These observations were carried out between 0630h and 1400h, which encompassed the period when dolphin-watching boats operated but could also be limited by local sea conditions. A second study investigating cetacean diversity was conducted between June 2013 and May 2014. Attempts were made to cover the coastal waters of the entire island focusing on areas where dolphin watching had the potential to develop. These surveys recorded track length allowing the calculation of encounter rates (sightings/km) which were not possible with the original study due to the time spent focusing on groups with dolphin watchers. To ensure accurate identification, cetacean encounters during diversity surveys were photographed, where possible, for subsequent identification if needed (particularly for beaked whales and the rarely seen delphinids). Photo-identification was also used to determine the extent of movement of known individuals, add new animals to the existing database from the 2008–2012 study and to create new databases for less frequently seen species. Several types of boat were used including speed boats, a 14m catamaran, and pirogues (local fishing boats) equipped with outboard motors. These surveys could run between 0700h and 1600h.

All surveys, regardless of objectives, were undertaken by 2–6 observers searching the sea surface by eye. Species identification, group size estimate, time, and position of the boat (within 100m from the group sighted due to local guidelines and later laws) were recorded and photo-identification was always conducted. Due to the variation in effort between study objectives, the overall results are presented as search effort by time. For each species, the encounter rate was computed for each month and expressed as the number of sightings per hour of search effort. For the six most common species, non-parametric Kruskal-Wallis tests were used to assess significant difference in monthly encounter rates. Encounter rates from the diversity study (2013/14) are additionally and separately presented as sightings by distance (sightings/km). For consistency, only the first 20mins of each encounter were used; the time required for species identification and photo-identification. Identification to species was based on morphology and behaviour. Common bottlenose dolphins (*Tursiops truncatus*) were distinguished from Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) by their larger size, darker colouration and short rostrum. Photo-identification was based on dorsal fin characteristics for dolphin species (as described in Webster *et al.*, 2014; 2015) while fluke shape and notches were used for sperm whales (Arnbom, 1987). Shape and colour patterns on the ventral surface of the fluke were used for individual identification of humpback whales (*Megaptera novaeangliae*) with the nine-category identification system (as described in Katona and Whitehead, 1981).

The Shannon diversity index was used to describe species diversity as: (a) it accounts for both the number of species (species richness) and the evenness with which individuals are distributed among species; and (b) it allowed comparison to be made with other studies in the region. Only groups identified to species level were included in the Shannon diversity calculations. The index was calculated as follows (Begon *et al.*, 1996):

$$H = -\sum P_i \ln P_i$$

where P_i is the ratio of the number of individuals of species i divided by the total number of individuals observed. This calculation was performed with the software PAST (Hammer *et al.*, 2001) which provided 95% confidence intervals.

RESULTS

Survey effort

Between 2008 and 2014, more than 1,246hrs over 749 days were spent searching for cetaceans. On average, this equated to 176hrs/year. Distribution of effort varied around the island due to survey objectives and sea conditions (Fig. 2), with majority of the surveys conducted on the southwest coast where the main launch site and base for the dolphin-watching activities was located. During 2013 and 2014, a more concerted effort was made to survey the North and East coasts as part of the dedicated diversity study. When pooled, the monthly distribution of effort was relatively consistent, though peaked during July (austral winter). Surveys were conducted, on average, for 9.6 days/month (Fig. 3).

Species diversity

In total, 13 species were identified from 1,459 cetacean sightings and almost 37,000 individuals (Table 1). This total included: humpback whales; spinner dolphins; Indo-Pacific bottlenose dolphins; common bottlenose dolphins; short-finned pilot whales (*Globicephala macrorhynchus*); pantropical spotted dolphins (*Stenella attenuata*); sperm whales; Blainville's beaked whales; pygmy killer whales (*Feresa attenuata*); melon-headed dolphins (*Peponocephala electra*); Risso's dolphins (*Grampus griseus*) and Cuvier's beaked whales (*Ziphius cavirostris*). There were 10 sightings recorded as 'unknown cetacean' due to distance and short observation time, and nine sightings of 'beaked whale' that could not be identified to species level. In addition, there were two stranding events during this period. An individual of Cuvier's beaked whale stranded on Flat Island in 2012 and one dwarf sperm whale (*Kogia sima*) stranded on the East coast in 2014.

The most common species encountered were spinner dolphins, Indo-Pacific bottlenose dolphins, humpback whales and sperm whales. Spinner dolphins made up 51.3% of sightings and Indo-Pacific bottlenose 28.2%. Sperm whales and humpback whales comprised 5.5% and 6.9% of sightings respectively. Over the seven years of surveys, Indo-Pacific bottlenose dolphins were sighted every month and spinner dolphins were seen in all except one (January 2014). In addition to these four species, another two, the common bottlenose and pantropical spotted dolphin, were seen every year of the study. Distribution of sightings for these six species are shown in Figs 4 and 5. Beaked whales were also seen each year except during 2014. Sightings of sperm whales, common bottlenose and spotted dolphins varied throughout the year (Fig. 6) but each was encountered in every year. No seasonal trend was observed (Fig. 6) and the monthly encounter rate (sightings/hour) did not vary significantly between months for either bottlenose or spinner dolphins (*T. aduncus*: Kruskal-Wallis test $H = 7.291$, $H_c = 7.291$, $P = 0.7751$, $df = 11$; *S. longirostris*: $H = 3.973$, $H_c = 3.973$, $p = 0.9707$, $df = 11$). As expected, only monthly

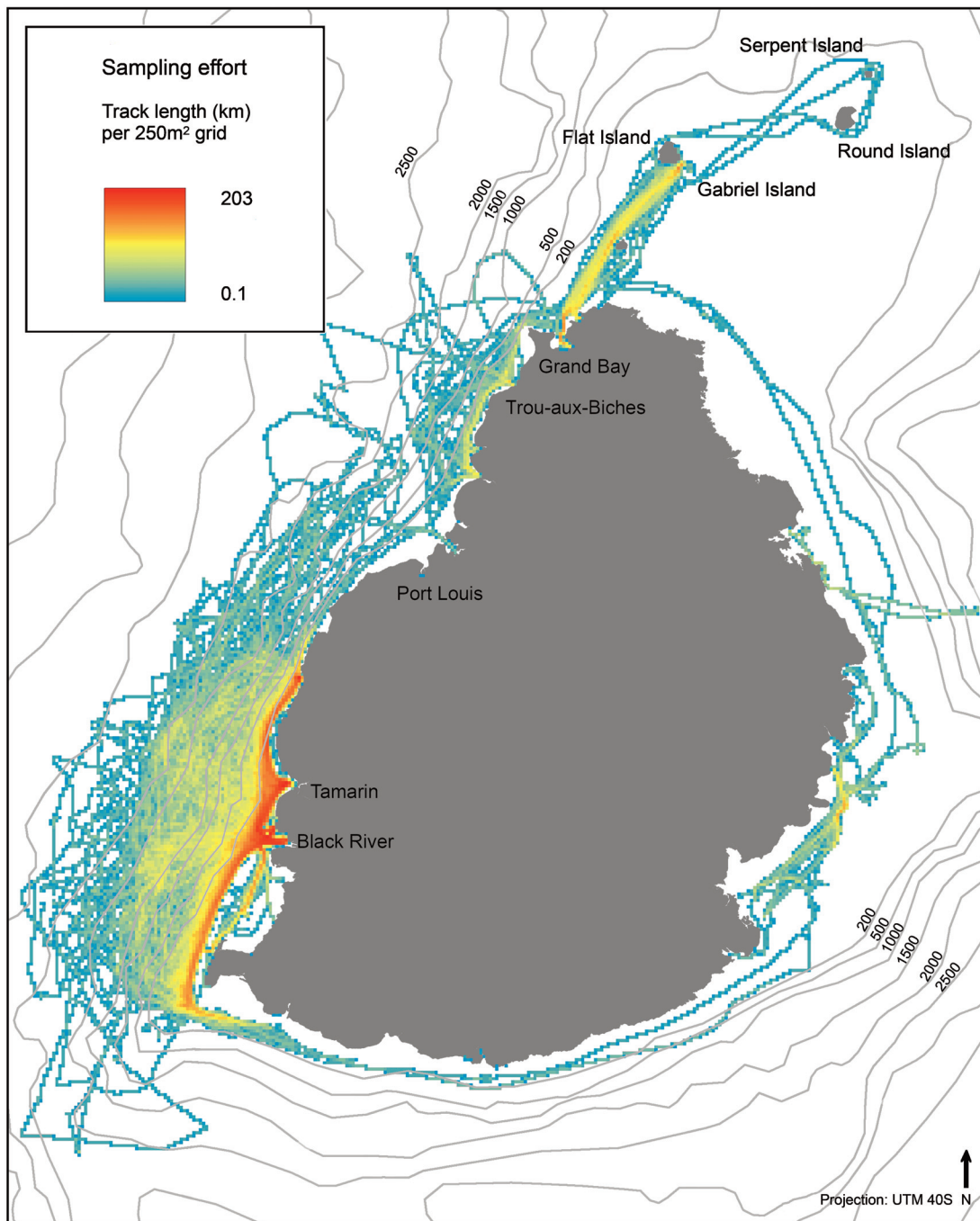


Fig. 2. Distribution of effort around Mauritius between 2008 and 2014.

encounter rates of humpback whales showed any seasonality (Kruskal-Wallis $H = 42.39$, $H_c = 54.25$, $p < 0.001$), peaking during austral winter (Fig. 6).

Short-finned pilot whales were seen on 10 occasions and pygmy killer whales were recorded nine times; both always in offshore waters (Fig. 7). Beaked whale sightings occurred relatively frequently, being recorded 14 times and at least once a year except during 2014. Cuvier's and Blainville's were identified, but for the majority of sightings (75%) it was not possible to identify to species level. Other species that were encountered less often included melon-headed dolphins (1), Risso's dolphins (1) and a dwarf sperm whale (1) stranding (Table 1). Number of encounters, group size and number of animals identified are presented in the species tables (Table 2). Photo-identification catalogues were

developed for those species seen more often including Indo-Pacific bottlenose dolphins, common bottlenose dolphins, spinner dolphins, humpback whales, sperm whales and pygmy killer whales.

The dedicated diversity study of 2013 and 2014 enabled the calculation of cetacean sightings by effort distance. During this period 2,443.6km of search effort were covered around the islands. Sixty cetacean sightings were recorded, giving an encounter rate of 0.025 cetacean sightings/km. However, the number of species observed during this project was less than that collected during the previous years and only included those most frequently observed. Encounter rates for these species ranged from 0.001/km for sperm whales to 0.009/km for Indo-Pacific bottlenose dolphins (Table 2).

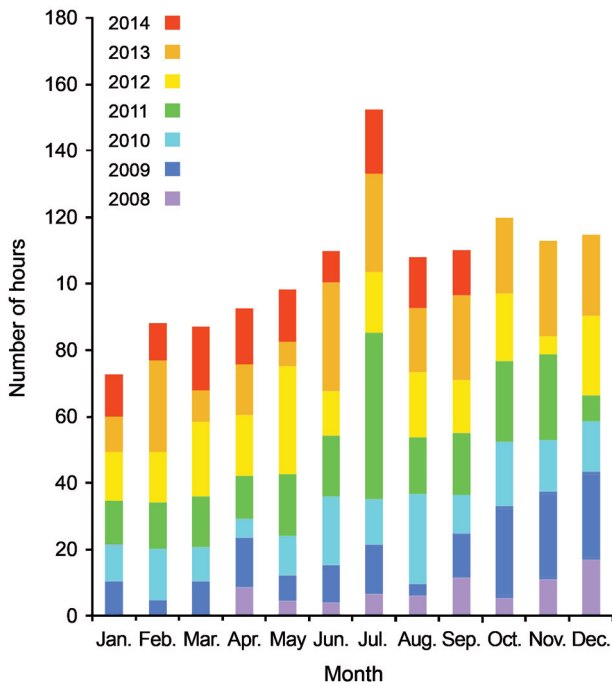


Fig. 3. Monthly distribution of search effort per month per year between 2008 and 2014.

The overall (2008–2014) Shannon diversity index was 0.58 (95% CI 0.57–0.60) though this ranged between 0.77 (95% CI = 0.74–0.80) (2009) to 0.25 (95% CI = 0.22–0.28) (2014). The Shannon index value for the diversity study alone (2013/14) was 0.83 (95% CI 0.74–0.91).

Mixed-species groups were observed on 75 occasions (Fig. 8). Around 16.1% of sightings of Indo-Pacific bottlenose dolphins were associated with at least one other species. The most frequent association was with spinner dolphins, occurring 57 times. Other combinations of cetaceans included humpback whales with Indo-Pacific bottlenose dolphins (n = 2), Indo-Pacific bottlenose with common bottlenose and spinner dolphins (n = 3), the two species of bottlenose dolphins (*T. aduncus*/*T. truncatus* n = 4), spinner dolphins with common bottlenose dolphins (n = 1), sperm whales with pilot whales (n = 1), sperm whales with spotted dolphins

(n = 1) and spinner dolphins with spotted dolphins (n = 5). Pygmy killer whales were never seen in association with another species.

Species accounts

Indo-Pacific bottlenose dolphin

During the diversity project 2013–2014, 42 individuals were identified using photo-identification. From these, 26 were previously known from the West coast of Mauritius and two showed that individuals were moving at least three-quarters of the way around the island between Mahebourg lagoon on the East coast, along the South and West coasts and up to the North coast.

Spinner dolphin

Individuals previously identified from the West coast were not found North of Port Louis or on the East coast. During the diversity study 31 individuals were identified in addition to a minimum of 121 previously identified from the southwest coast.

Common bottlenose dolphin

The number of identified individuals was 56 with 19 animals seen in multiple years although some resightings could be 2–3yrs apart. Resightings occurred a maximum of 12 times, 35.7% more than once and seven animals were seen five times or more. Five individuals were seen up to three times in a single year and one was photographed four times in both 2010 and 2011.

Pygmy killer whale

Photo-identification resulted in the cataloguing of 27 individuals, five of which were re-sighted in multiple years. Only a single animal was identified more than once within a year.

Sperm whale

Fifty-six individual sperm whales were identified over the seven years of data collection. Three of these were identified for the first time during the dedicated diversity study in 2013, all during September. Resighting rates indicate a resident

Table 1
Number of cetacean sightings for each species per year, percentage of total sightings and, in parentheses, estimated total number of individuals.

Species	2008	2009	2010	2011	2012	2013	2014	% of sightings	Total
Spinner dolphin	70	127	142	135	118	89	62	51.3	743 (32,247)
Indo-Pacific bottlenose dolphin	47	64	81	63	56	65	33	28.2	409 (1,831)
Humpback whale	12	32	14	10	6	18	8	6.9	100 (168)
Sperm whale	3	17	26	17	10	5	1	5.5	79 (564)
Pantropical spotted dolphin	2	6	9	12	10	5	1	3.1	45 (1,022)
Common bottlenose dolphin	3	7	11	8	3	6	1	2.7	39 (418)
Short-finned pilot whale	1	2	3	2	2	0	0	0.7	10 (232)
Pygmy killer whale	0	2	1	2	4	0	0	0.6	9 (128)
Blainville’s beaked whale	0	1	0	1	0	0	0	0.1	2 (8)
Risso’s dolphin	0	0	1	0	0	0	0	0.1	1 (15)
Melon-headed dolphin	0	1	0	0	0	0	0	0.1	1 (150)
Cuvier’s beaked whale	0	0	0	0	0	1	0	0.1	1 (1)
Beaked whales	1	0	1	1	2	4	0	0.6	9 (34)
Dwarf sperm whale*	0	0	0	0	0	0	1	0.1	1 (2)
Total	139	259	289	251	211	193	107		1,449 (36,820)

*Stranding.

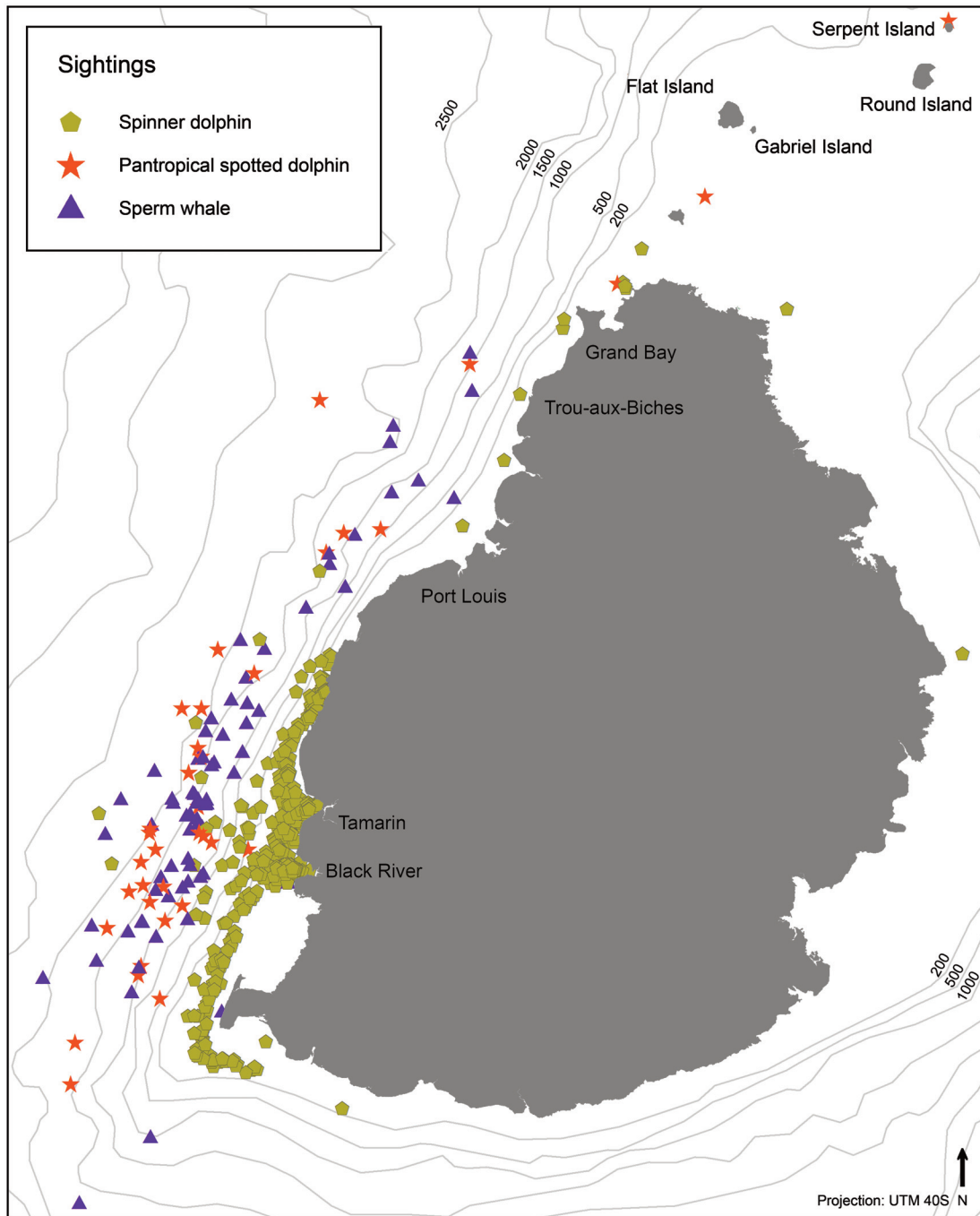


Fig. 4. Distribution of sightings of spinner dolphins, spotted dolphins and sperm whales around the island of Mauritius between April 2008 and September 2014.

population with 46% ($n = 26$) of those identified individuals seen in multiple years.

Humpback whale

Humpback whales were seen between June and December every year of data collection with the highest monthly sighting rate in August (0.278 sightings per hour, range 0.009–0.278 June to December). From 100 sightings of 168 animals, 25 individuals were identified from the fluke. Humpbacks did not appear to fluke often resulting in a low number of individuals catalogued. No animals were re-sighted between years and the number of humpback whale sightings varied greatly between years from six in 2012 to 32 in 2009. Mother/calf pairs made up 42% of sightings and the largest group was composed of four adults.

DISCUSSION

Species diversity

This paper describes the diversity of cetaceans inhabiting the coastal waters around the island of Mauritius. Thirteen cetaceans, including coastal, semi-pelagic and offshore species, were identified in the coastal waters surrounding Mauritius. This total included 1 baleen whale along with 12 toothed whales; all were expected subtropical WIO species. The toothed species included 8 delphinids and 4 others, those being *Physeteridae* (sperm whales), *Kogiidae* (lesser sperm whales) and *Ziphiidae* (beaked whales). During 749 days at sea around Mauritius, 1,459 cetacean sightings were recorded, indicating a high cetacean presence in this area. The most frequently sighted species were spinner and Indo-Pacific bottlenose dolphins, along with sperm and humpback

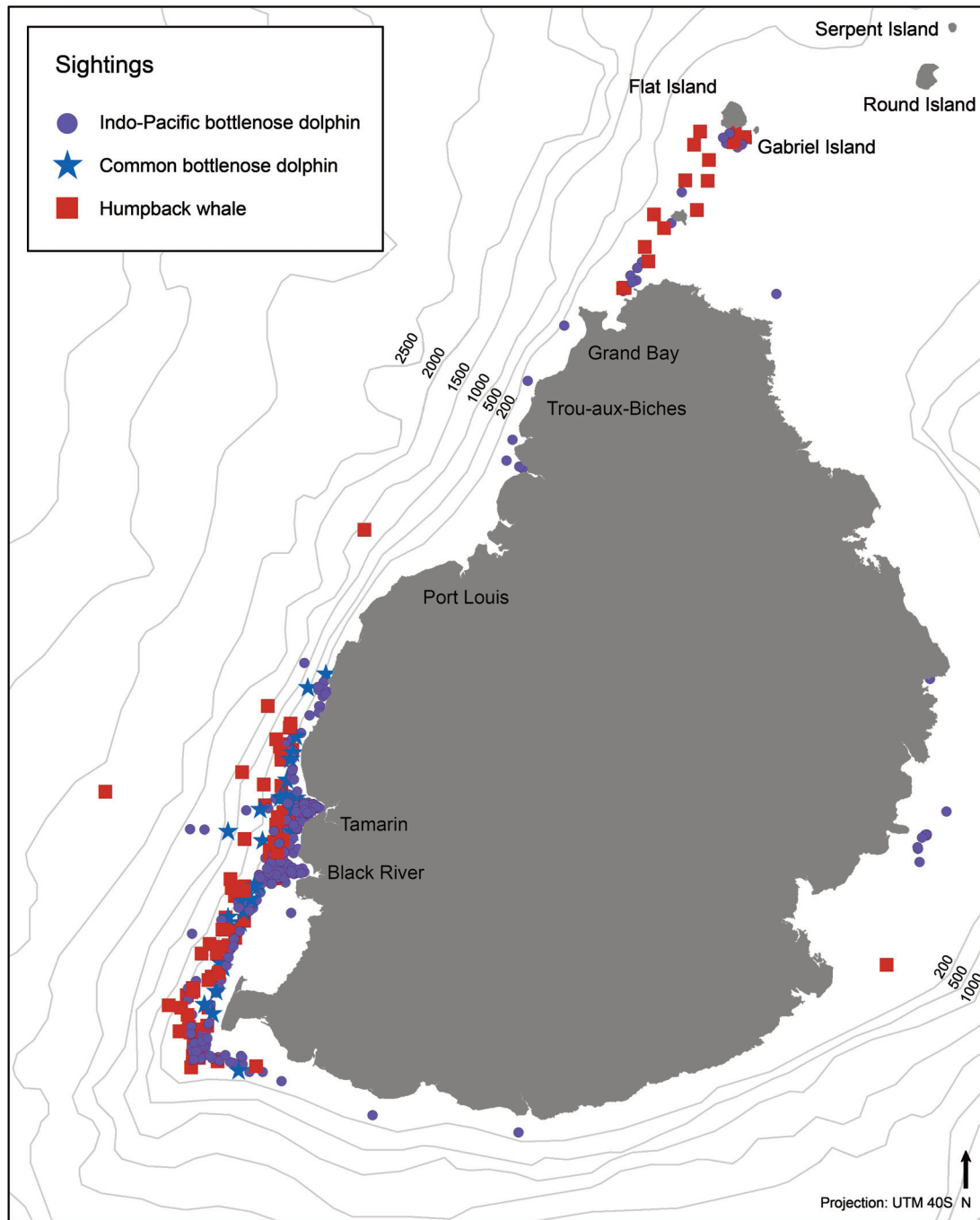


Fig. 5. Distribution of sightings of common dolphins, Indo-Pacific bottlenose dolphins and humpback whales around the island of Mauritius between April 2008 and September 2014.

whales; but the most numerous were spinner dolphins. Moreover, with the exception of humpback whales, the frequency of sightings was relatively stable, without significant variation. The overall Shannon Diversity index was 0.58 while that of the diversity study was 0.83. The former is likely lowered due to the focus on the spinner and bottlenose dolphins during the dolphin-watching project.

Within the WIO, there is considerable similarity in the species observed at the various islands; 12 of the 17 species seen in Mayotte (Kiszka *et al.*, 2007; 2010a) were also seen in Mauritius during this study. Comoros had 10 of the same species (Kiszka *et al.*, 2010b), Reunion 8 of 10 species (Dulau-Drouot *et al.*, 2008), and Maldives 13 common species (Anderson, 2005). The overall Shannon diversity

value is higher for Reunion (0.99, Dulau-Drouot *et al.*, 2008) than Mauritius. Several more species were recorded in Mayotte compared to Mauritius and Mayotte consequently had a Shannon index considerably higher at 1.76 (Kiszka *et al.*, 2010a). In contrast, further afield other oceanic islands which host a similar species richness to Mauritius, had higher Shannon index rates e.g. Suriname, Caribbean 13 species and 1.62 index; Society Islands 12 species and 1.57 index (de Boer, 2015; Gannier, 2000).

Previously, Corbett (1994) used opportunistic platforms to describe the presence of 8 species off the West coast of Mauritius including 2 baleen whales and 6 toothed whales. Seven of these were encountered during this study along with a further six species. Corbett (1994) observed the fin whale

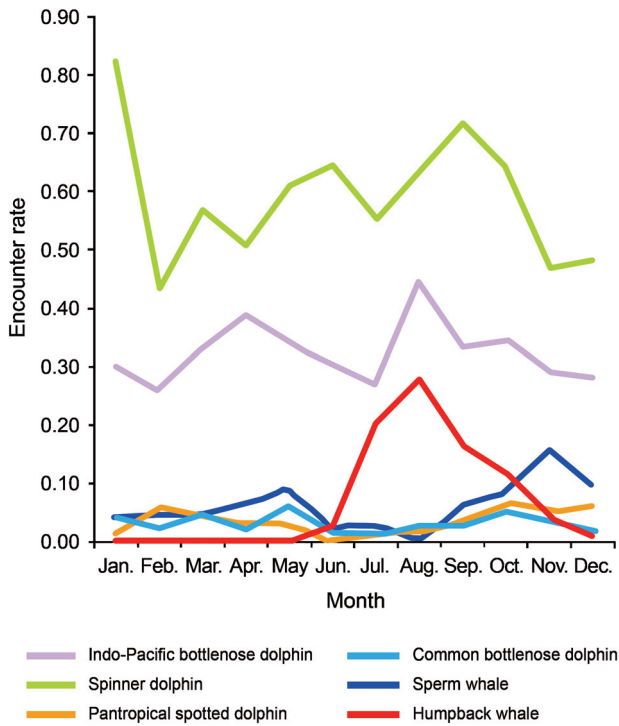


Fig. 6. Pooled monthly encounter rate per hour for the six most frequently encountered species between 2008 and 2014.

(*Balaenoptera physalus*), which was not observed during the seven years of data collection in this study. In addition, Corbett (1994) recorded 'blackfish' but was not able to distinguish between melon-headed whales or pygmy killer whales. Our data confirmed the presence of both species.

Spinner and Indo-Pacific bottlenose dolphins were the most frequently encountered species followed by sperm whales, supporting results reported by Corbett (1994) which indicated that spinner dolphins and sperm whales were abundant and present year round. Off Reunion Island, bottlenose and spinner dolphins were also the most frequently sighted species (Dulau-Drouot *et al.*, 2008). Within the WIO region, the Indo-Pacific bottlenose dolphins are thought to be the most frequently observed coastal delphinids (Kiszka *et al.*, 2009). Corbett used platforms of opportunity, such as deep-sea fishing vessels, which may explain why Indo-Pacific bottlenose dolphins were not encountered, as they are generally restricted to shallow coastal waters (Ross *et al.*, 1987). Our study confirms that both bottlenose dolphin species occur around Mauritius. Photo-identification of the Indo-Pacific bottlenose dolphin confirmed there was considerable movement of some individuals around the island as suggested in Webster *et al.* (2014). The catalogue of identified common bottlenose dolphins also revealed some level of site fidelity for this species. Group size, behaviour and associations with other species are generally consistent with reports from other islands in the WIO (La Réunion: Dulau-Drouot *et al.*, 2008; Mayotte: Kiszka *et al.*, 2007; and Zanzibar: Stensland *et al.*, 2006).

The number of deep-water species detected in Mauritius was higher than that reported for Reunion, particularly for sperm whales, beaked whales and pilot whales. Sperm whales were the third most frequently seen species, with all age groups represented and high resighting rates for identified

animals indicating a resident population. This is consistent with several other studies which found sperm whales to be the most frequently sighted cetacean in the WIO (Ballance and Pitman, 1998) and the most frequently encountered species in the IO Sanctuary (Eyre and Frizell, 2012). This species, along with humpback whales in winter, is the basis for the development of whale watching in Mauritius, giving an indication of its consistent presence. Blainville's is the most widely distributed Mesoplodon species while Cuvier's is the most widely distributed beaked whale (MacLeod *et al.*, 2006). In the Indian Ocean Blainville's have been recorded from sightings and strandings in Reunion (Corbett, 1994; Dulau-Drouot *et al.*, 2008), Seychelles (Besharse, 1971), Mayotte (Kiszka *et al.*, 2007; Kiszka, 2010a) the Maldives (Ballance *et al.*, 2001) and previously in Mauritius (Michel and van Bree, 1976). Within the WIO however, Cuvier's has only been reported from Reunion (Dulau-Drouot, pers. comm.). The detection of these, and possibly other beaked whale species, around Mauritius provides opportunities to add to existing low levels of information regarding this group of whales (MacLeod *et al.*, 2006).

Longhurst (1998) defined three large marine ecosystems within the southwestern Indian Ocean due to differences in oceanography that influence the species found in each area. Laran *et al.* (2012; 2017) found that the models explaining occurrence of small delphinid species were significantly influenced by a number of factors including depth, sea surface temperature, gradient of chlorophyll, along with slope and primary production. Several oceanic delphinids (Risso's dolphin, melon-headed whale, short-finned pilot whale, pygmy killer whale) and an additional sperm whale species (stranded dwarf sperm whale) were encountered during our study. These species are found throughout the WIO (Kiszka *et al.*, 2009; Leatherwood and Donovan, 1991), and tend to be associated with the slope and oceanic waters (Baird *et al.*, 2003; MacLeod and Zuur, 2005). The number of offshore species which are known, or assumed, to feed on squid suggests that the waters around Mauritius are very productive for dwarf sperm whales, Risso's dolphins, short-finned pilot whales, Cuvier's beaked whales and Blainville's beaked whales. Their association with slopes is likely to reflect a concentration of prey in this habitat. Despite the apparent importance of this habitat for some cetaceans, the shelf slope has not been considered in detail in this study due to the limited effort in this area but this should be investigated in the future.

Observation of pygmy killer whales in this study is significant as the species is still considered to be one of the least known of the world's delphinids (Brownell *et al.*, 2009; McSweeney *et al.*, 2009; Ross and Leatherwood, 1994). In all areas that they have been documented, pygmy killer whales have one of the lowest densities of all cetaceans (McSweeney *et al.*, 2009). They have not been observed at sea in Reunion but have been recorded from a single stranding event (Dulau-Drouot *et al.*, 2008), a single sighting in Mayotte (Kiszka, 2010a) and a further sighting recently reported from Mozambique (Allport *et al.*, 2017). McSweeney *et al.* (2009) also observed that in Hawaii this species was associated with islands and showed high site fidelity, in small, long-term associated groups. For

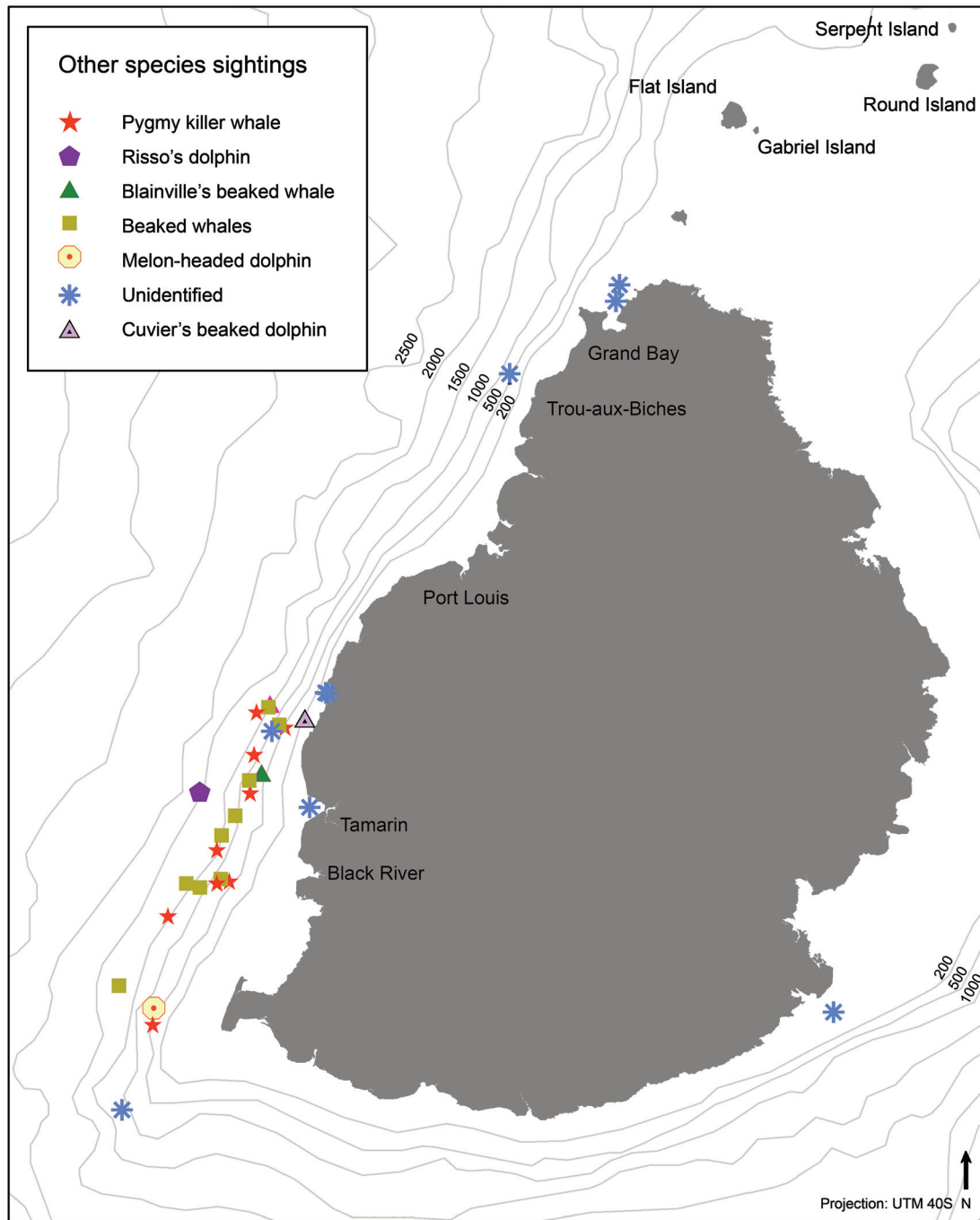


Fig. 7. Distribution of sightings for all other species encountered around the island of Mauritius between April 2008 and September 2014.

Mauritius, the resighting of numerous distinctive animals suggests a similar situation. Further research is required as the records and knowledge of this species in the region are very limited.

The humpback whale was the only baleen whale species recorded around Mauritius during the surveys. The observed seasonality reflects the normal migration pattern of this species as seen in other areas of the WIO. These animals are known as the breeding stock C4 covering the Mascarenes (Jackson *et al.*, 2015) but very little is currently known regarding their movements and numbers. Further research using tracking and photo-identification is needed to allow comparisons between islands and to increase our knowledge of animals using the Mascarene waters.

Mixed-species groups were encountered on 75 occasions. Like Mauritius, Reunion also reported common association between the spinner dolphin and the Indo-Pacific bottlenose dolphin in shallow coastal waters (Dulau-Drouot *et al.*, 2008). Ballance and Pitman (1998) reported that in the pelagic WIO spinner dolphins were frequently associated with pantropical spotted dolphins. This was observed on five occasions during this study. It has been suggested that association in mixed groups may benefit dolphins when foraging or avoiding predators (Stensland *et al.*, 2003). Mixed-species associations may constitute a survival strategy for species present in low numbers and unable to form large groups (e.g. Frantzis and Herzing, 2002; Quérrouil *et al.*, 2008). The benefits of the association depend on the

Table 2

Number of identified individuals, mean group size and encounter rate (groups/hour) of cetacean species sighted during all 2008–2014 surveys, and encounter rate (groups/km) for 2013–2014 diversity study around the island of Mauritius. N, number; SD, standard deviation.

Species	Individuals identified		2008–2014 Group size	2008–2014 Encounter rate/h	2013–2014 Encounter rate/km
<i>Stenella longirostris</i> Spinner dolphin	152	Mean	43.9	0.74	0.006
		N	734	78	15
		SD	24.5	0.50	
		Range	1–200		
<i>Tursiops aduncus</i> Indo-Pacific bottlenose dolphin	42	Mean	4.6	0.41	0.010
		N	396	78	25
		SD	3.2	0.31	
		Range	1–20		
<i>Megaptera novaeangliae</i> Humpback whale	25	Mean	1.7	0.12	0.005
		N	100	78	13
		SD	0.8	0.39	
		Range	1–4		
<i>Physeter macrocephalus</i> Sperm whale	56	Mean	6.7	0.06	0.001
		N	77	78	2
		SD	4.0	0.103	
		Range	1–19		
<i>Stenella attenuata</i> Pantropical spotted dolphin		Mean	29.3	0.03	0.002
		N	35	78	4
		SD	32.4	0.05	
		Range	2–150		
<i>Tursiops truncatus</i> Common bottlenose dolphin	56	Mean	10.7	0.04	0.0004
		N	39	78	1
		SD	17.3	0.07	
		Range	1–100		
<i>Globicephala macrorhynchus</i> Short-finned pilot whale		Mean	23.4	0.008	
		N	10	78	
		SD	20.5	0.02	
		Range	1–50		
<i>Feresa attenuata</i> Pygmy killer whale	27	Mean	14.22	0.006	
		N	9	78	
		SD	14.5	0.019	
		Range	2–50		
<i>Mesoplodon densirostris</i> Blainville's beaked whale		Mean	4	0.002	
		N	2	78	
		SD	2.8	0.011	
		Range	2–6		
<i>Grampus griseus</i> Risso's dolphin		Mean	15	0.0007	
		N	1	78	
		SD		0.006	
		Mean	150	0.0008	
<i>Peponocephala electra</i> Melon-headed dolphin		N	1	78	
		SD		0.007	
		Mean	1	0.0004	
		N	1	78	
Beaked whales		SD		0.0038	
		Mean	3.8	0.010	
		N	9	78	
		SD	1.96	0.037	
<i>Kogia sima</i> (stranding) Dwarf sperm whale		Range	1–6		
		Mean	1		
		N	1		
		N	1		

species involved (Qu erouil *et al.*, 2008). This is another area that could be investigated further relating to the specific conditions in Mauritius.

In the WIO at least 32 cetacean species have been recorded, including 9 baleen whales and 23 toothed cetacean species (Kiszka, 2015). As 45 species have been recorded off the South and East coasts of South Africa it is likely this is an underestimate, especially as the region has limited offshore surveys. Of the delphinids, the Indo-Pacific humpback dolphin, bottlenose dolphin, spinner dolphin, pantropical spotted dolphin and striped dolphin are generally the most frequently encountered (de Boer *et al.*, 2002; De Lestang, 1993). Neither striped (*Stenella coeruleoalba*) nor

humpback dolphins (*Sousa chinensis*) were observed during the current study; however, the waters around Mauritius contain a similar assemblage of dolphin species to the rest of the WIO. Given the considerable sampling effort spent in coastal waters, it is unlikely that the humpback dolphin was missed, furthermore there are no previous records of this species in Mauritius. In contrast, the relatively low amount of effort in waters deeper than 100m could explain the lack of records for striped dolphins. This would also apply to species such as the rough-toothed dolphin (*Steno bredanensis*), Fraser's dolphin (*Lagenodelphis hosei*), false killer whale (*Pseudorca crassidens*) and killer whale (*Orcinus orca*) (de Boer *et al.*, 2002; Dulau-Drouot *et al.*,

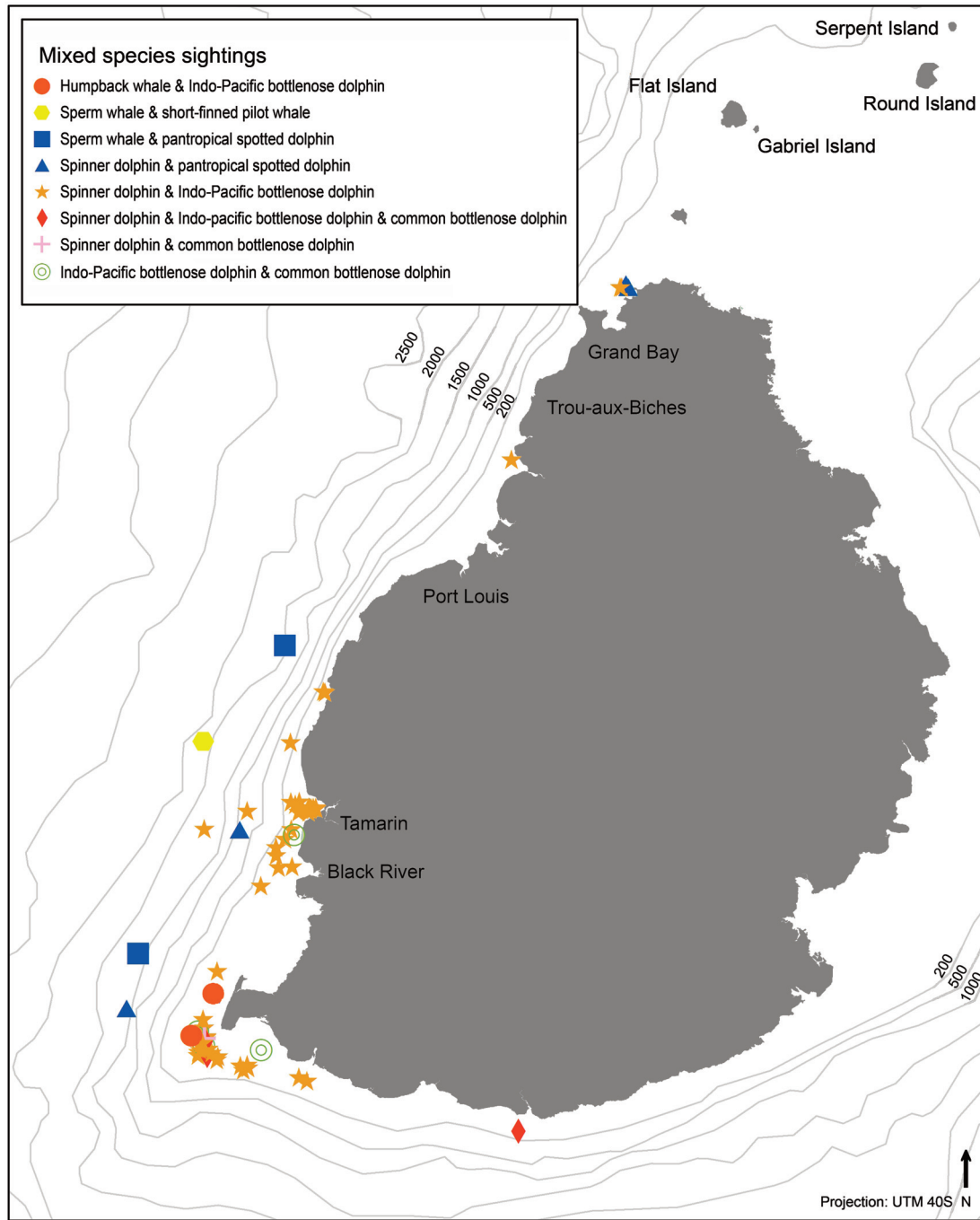


Fig. 8. Distribution of sightings of all mixed species groups encountered around the island of Mauritius between April 2008 and September 2014.

2008; Leatherwood *et al.*, 1991; Peddemors, 1999; Robineau, 1975; Rosenbaum *et al.*, 2001) which have been documented in other areas of the WIO particularly where beaked and sperm whales are also found. Although not seen in these surveys, there have been unconfirmed reports of killer whale sightings off the East and North coasts of Mauritius and a confirmed sighting in April 2018 off the West coast (N. Dubois, pers. comm.). The humpback whale was the only baleen species to be observed. However, there was an unconfirmed sighting of southern right whale (*Eubalaena australis*) in 2014 off the South coast (E. Weaver, pers. comm.). This species has been recorded off Reunion Island (Dulau-Drouot *et al.*, 2008) as well as Madagascar (Rosenbaum *et al.*, 2001) so rare sightings in

Mauritius could be possible. In addition, a previous guide to whales and dolphins in Mauritius indicated that a sei whale (*B. borealis*) had washed ashore on the West coast (Jones and Todd, 1991) and a fin whale was seen during Corbett's surveys (1994). Both of these large baleen whales have been documented in the Indian ocean along with Bryde's whales (*B. edeni*) and minke whales (*B. acutorostrata* and *B. bonaerensis*) (Anderson, 2005; Dulau-Drouot *et al.*, 2008; Kasuya and Wada, 1991; Robineau, 1991).

Comparisons with the present study are difficult as the number of species observed is, in part, a function of the temporal and spatial distribution of effort, which is very different between studies conducted in the region. Some studies used multiple methods of detection such as visual and

acoustic techniques, and others focused on offshore waters (e.g. Clark *et al.*, 2012; De Vos *et al.*, 2012). In oceanic waters, there is generally greater variability in group sizes both within and between species. Delphinids have bigger groups than the largest toothed whales, which causes the diversity index estimate to be lowered as it takes into account the abundance of each species. In the same way, it is possible that the diversity index calculated for Mauritius for the entire study period was influenced by the focus on spinner and bottlenose dolphins as this could inflate the number of individuals, thus lowering the result. The index assumes that all species are represented in a sample and that they are randomly sampled (Ricklefs, 2007). It is therefore likely that the true diversity index value is closer to that of the diversity study than the whole dataset. Continuation of the data collection with more standardised transects, and covering a wider depth range, could make this measurement, along with the species diversity in the area, more accurate.

Management and conservation

The waters of Mauritius support a community of cetaceans which includes coastal, semi-pelagic and oceanic species. The diversity of species, particularly deep-water species, underlines the importance of Mauritius to cetaceans. Our results provide important, descriptive information that is critical for conservation and management efforts. Potential threats posed by interactions with fishing activities, particularly around fish aggregation devices, game-fishing boats and both semi-industrial and industrial longliners, should be considered. The fishing boats could act as platforms to further investigate cetacean species and distribution along with impacts of interactions on the fishing industry. Plans to develop fish farms could also have numerous impacts. Maritime traffic, especially from popular tourism activities such as diving and snorkelling and commercial whale- and dolphin-watching activities, is continuing to grow in the coastal waters of Mauritius, and as such impacts from noise and interactions should be a priority. Feeding ecology of cetaceans in this part of the Indian Ocean is poorly understood, but this information is crucial, particularly for small cetaceans that potentially compete with coastal fisheries (Elwen *et al.*, 2011). Further effort is needed to assess the spatial and temporal interactions between these activities and cetaceans around the island. The introduction of marine protected areas/no-take zones needs to be seriously considered to ensure the continued viability of both the activities and cetaceans.

While research effort has increased in some parts of the Indian Ocean Sanctuary since 2000 (e.g. Feingold and Kerem, 2008; Marsden *et al.*, 2004; Notabartolo di Sciara *et al.*, 2007; 2009; Reijnders, 2001; 2002; Wise *et al.*, 2009) it is clear that long-term, year-round dedicated studies are required to obtain necessary information on abundance, distribution, seasonal patterns and behaviour of cetaceans within the IOS to address potential anthropogenic threats (Eyre and Frizell, 2012). Furthermore, Elwen *et al.* (2011) identified this region (WIO) as needing further research, especially for diversity and abundance of oceanic species. As seen by the results presented here, Mauritius offers considerable scope for cetacean research especially on deep-water species. Species such as beaked whales, which are

often difficult to observe in many parts of the world, are relatively frequently observed off the West coast of Mauritius due to the steep slope close to shore. There could also be long-term monitoring of sperm whale and humpback whale migration and breeding patterns, both on a local and regional level with neighbouring islands.

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REFERENCES

- Allport, G.A., Curtis, C., Simões, T.P. and Rodrigues, M.J. 2017. The first authenticated record of Pygmy Killer Whale (*Feresa attenuata* Gray 1874) in Mozambique; has it been previously overlooked? *Mar. Biodivers. Rec.* 10:17. [Available at: <https://doi.org/10.1186/s41200-017-0119-9>].
- Anderson, R.C. 2005. Observations of cetaceans in the Maldives, 1990–2002. *J. Cetacean Res. Manage.* 7(2):119–36.
- Arbom, T. 1987. Individual identification of sperm whales. *Rep. Int. Whal. Commn* 37:201–04.
- Baird, R.W., McSweeney, D.J., Webster, D.L., Gorgone, A.M. and Ligon, A.D. 2003. Studies of odontocete population structure in Hawaiian waters: results of a survey through the main Hawaiian Islands in May and June 2003. Contract number AB133F-02-CN-0106. NOAA, Western Administrative Support Center, Seattle, Washington, USA. 25pp.
- Ballance, L.T., Anderson, R.C., Pitman, R.L., Stafford, K., Shaan, A., Waheed, Z. and Brownell, R.L., Jr. 2001. Cetacean sightings around the Republic of the Maldives, April 1998. *J. Cetacean Res. Manage.* 3(2):213–18.
- Ballance, L.T. and Pitman, R.L. 1998. Cetaceans of the western tropical Indian Ocean: Distribution, relative abundance, and comparisons with cetacean communities of two other tropical ecosystems. *Mar. Mam. Sci.* 14(3):429–59.
- Begon, M., Harper, J.L. and Townsend, C.R. 1996. *Ecology: Individuals, Populations and Communities*, 3rd Edn. Blackwell Science Ltd, London, UK. x+1049pp.
- Besharse, J.C. 1971. Maturity and sexual dimorphism in the skull, mandible and teeth of the beaked whale, *Mesoplodon densirostris*. *J. Mammal.* 52:297–315.
- Brownell, R.L., Jr., Yao, C.-J., Lee, C.-S., Wang, M.-C., Yang, W.-C. and Chou, L.-S. 2009. Worldwide review of pygmy killer whales, *Feresa attenuata*, mass strandings reveals Taiwan hot spot. Paper SC/61/SM1 presented to the IWC Scientific Committee, June 2009, Madeira, Portugal (unpublished). 20pp. [Paper available from the Office of this Journal].
- Clark, R.A., Johnson, C.M., Johnson, G., Payne, R., Kerr, I., Anderson, R.C., Sattar, S.A., Godard, C.A.J. and Madsen, P.T. 2012. Cetacean sightings and acoustic detections in the offshore waters of the Maldives during the northeast monsoon seasons of 2003 and 2004. *J. Cetacean Res. Manage.* 12(2):227–34.
- Corbett, H.D. 1994. The occurrence of cetaceans off Mauritius and in adjacent waters. *Rep. Int. Whal. Commn.* 44:393–98.
- Daby, D. 2003. Effects of seagrass bed removal for tourism purposes in a Mauritian bay. *Environ. Pollut.* 125(3):313–24.
- Daby, D. 2006a. Coastal pollution and potential biomonitors of metals in Mauritius. *Water Air Soil Pollut.* 174(1–4):63–91.
- Daby, D. 2006b. Current patterns and the distribution of benthic habitats in a coastal lagoon of Mauritius. *Hydrobiologia* 556(1):47–60.
- de Boer, M.N. 2015. Cetaceans observed in Suriname and adjacent waters. *L.A.J.A.M.* 10(1):2–19.
- de Boer, M.N., Baldwin, R., Burton, C.L.K., Eyre, E.L., Jenner, K.C.S., Jenner, M.N.M., Keith, S.G., McCabe, K.A., Parsons, E.C.M., Peddemors, V.M., Rosenbaum, H.C., Rudolph, P. and Simmonds, M.

2002. Cetaceans in the Indian Ocean Sanctuary: A review. Paper SC/54/O5 presented to the IWC Scientific Committee, April 2002, Shimonoseki, Japan (unpublished). 60pp. [Paper available from the Office of this Journal].
- De Lestang, J.N. 1993. Status of marine mammals in the Eastern African region. Report to UNEP, Regional Seas and Studies Series.
- De Vos, A., Clark, R., Johnson, C., Johnson, G., Kerr, I., Payne, R. and Madsen, P.T. 2012. Cetacean sighting and acoustic detections in the offshore waters of Sri Lanka: March–June 2003. *J. Cetacean Res. Manage.* 12(2):185–93.
- Dulau-Drouot, V., Boucaud, V. and Rota, B. 2008. Cetacean diversity off La Reunion island (France). *J. Mar. Biol. Assoc. UK* 88(6):1263–72.
- Elwen, S.H., Findlay, K.P., Kiszka, J. and Weir, C.R. 2011. Cetacean research in the southern African subregion: a review of previous studies and current knowledge. *Afr. J. Mar. Sci* 33(3):469–93.
- Eyre, E.J. and Frizell, J. 2012. A note on observations of cetaceans in the Indian Ocean Sanctuary, Australia to Israel, April 1995. *J. Cetacean Res. Manage.* 12(2):277–85.
- Feingold, D. and Kerem, D. 2008. Cetacean conservation as part of an ecotourism project in the northern Red Sea. Abstract presented to the 22nd Annual Conference of the European Cetacean Society, Egmond aan Zee, The Netherlands, 10–12 March 2008. (Unpublished). [Available from <https://www.europeancetaceansociety.eu/sites/default/files/abstracts.pdf>]
- Frantzis, A. and Herzog, D.L. 2002. Mixed-species associations of striped dolphins (*Stenella coeruleoalba*), short-beaked common dolphins (*Delphinus delphis*), and Risso's dolphins (*Grampus griseus*) in the Gulf of Corinth (Greece, Mediterranean Sea). *Aquat. Mamm.* 28(2):188–97.
- Gannier, A. 2000. Distribution of cetaceans off the Society Islands (French Polynesia) as obtained from dedicated surveys. *Aquat. Mamm.* 26:111–26.
- Hammer, O., Harper, D.A.T. and Ryan, P.D. 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontol. Electron.* 4(1):9pp. [Available at: http://palaeoelectronica.org/2001_1/past/issue1_01.htm].
- Jackson, J.A., Ross-Gillespie, A., Butterworth, D., Findlay, K., Holloway, S., Robbins, J., Rosenbaum, H., Weinrich, M., Baker, C.S. and Zerbin, A. 2015. Southern Hemisphere humpback whale Comprehensive Assessment – a synthesis and summary: 2005–2015. Paper SC/66a/SH03 presented to the IWC Scientific Committee, May 2015, San Diego, CA, USA (unpublished). 38pp. [Paper available from the Office of this Journal].
- Jones, C.G. and Todd D. 1991. *Whales and Dolphins of Mauritius: An Identification Guide*. Mauritius Marine Conservation Society and the Mauritius Wildlife Appeal Fund, Port Louis, Mauritius.
- Kasuya, T. and Wada, S. 1991. Distribution of large cetaceans in the Indian Ocean: data from Japanese sightings records, November–March. pp.139–70. In: S. Leatherwood and G.P. Donovan (eds). *Cetaceans and Cetacean Research in the Indian Ocean Sanctuary*. United Nations Environment Programme Marine Mammal Technical Report No. 3, Nairobi, Kenya. 287pp.
- Katona, S.K. and Whitehead, H.P. 1981. Identifying humpback whales using their natural markings. *Polar. Rec.* 20:439–44.
- Kiszka, J. 2015. Marine mammals: A review of status, distribution and interaction with fisheries in the Southwest Indian Ocean. pp.305–23. In: B.I. Everett and R. van der Elst (eds). *Offshore Fisheries of the Southwest Indian Ocean: Their Status and the Impact on Vulnerable Species*. South African Association for Marine Biological Research and Oceanographic Research Institute, Durban, South Africa. 452pp.
- Kiszka, J., Berggren, P., Rosenbaum, H.C., Cerchio, S., Rowat, D., Drouot-Dulau, V., Razafindrakoto, Y., Vely, M. and Guissamulo, A. 2009. Cetaceans in the southwest Indian Ocean: a review of diversity, distribution and conservation issues. Paper SC/61/O18 presented to the IWC Scientific Committee, June 2009, Madeira, Portugal (unpublished). 13pp. [Paper available from the Office of this Journal].
- Kiszka, J., Ersts, P.J. and Ridoux, V. 2007. Cetacean diversity around the Mozambique Channel island of Mayotte (Comoros Archipelago). *J. Cetacean Res. Manage.* 9(2):105–10.
- Kiszka, J., Ersts, P.J. and Ridoux, V. 2010a. Structure of a toothed cetacean community around a tropical island (Mayotte, Mozambique Channel). *Afr. J. Mar. Sci* 32(3):543–51.
- Kiszka, J., Vely, M. and Breyse, O. 2010b. Preliminary account of cetacean diversity and humpbackwhale (*Megaptera novaeangliae*) group characteristics around the Union of the Comoros (Mozambique Channel). *Mammalia* 74:51–56.
- Laran, S., Authier, M., Van Canneyt, O., Dorémus, G., Watremez, P. and Ridoux, V. 2017. A comprehensive survey of pelagic megafauna: their distribution, densities, and taxonomic richness in the tropical southwest Indian Ocean. *Front. Mar. Sci.* 4:139. [Available at: <https://dx.doi.org/10.3389/fmars.2017.00139>].
- Laran, S., Doremus, G., Mannocci, L., Van Canneyt, O., Watremez, P., Cadinouche, A., Dulau-Drouot, V., Mayer, F.X., Monthy, D., Andrianarivelo, N., Razafindrakoto, Y., Toilibou, A. and Ridoux, V. 2012. Progress of the REMMOA aerial surveys conducted in the French EEZ and adjacent waters: contrasted cetacean habitats in the southwest Indian Ocean. Paper SC/64/E14 presented to the IWC Scientific Committee, June 2012, Panama City (unpublished). 14pp. [Paper available from the Office of this Journal].
- Leatherwood, S. and Donovan, G.P. 1991. *Cetaceans and Cetacean Research in the Indian Ocean Sanctuary*. UNEP Mar. Mamm. Tech. Rep. 3: vii–287. Nairobi, Kenya.
- Leatherwood, S., McDonald, D., Prematunga, W.P., Girton, P., Ilangakoon, A. and McBrearty, D. 1991. Records of the 'Blackfish' (killer, false killer, pilot, pygmy killer and melon-headed whales) in the Indian Ocean, 1772–1986. pp.33–65. In: S. Leatherwood and G.P. Donovan (eds). *Cetaceans and Cetacean Research in the Indian Ocean Sanctuary*. UNEP Marine Mammal Technical Report No. 3, Nairobi, Kenya. 287pp.
- Longhurst, A. 1998. *Ecological Geography of the Sea*. Academic Press, San Diego. 398pp.
- MacLeod, C.D., Perrin, W.F., Pitman, R., Barlow, J., Ballance, L., D'Amico, A., Gerrodette, T., Joyce, G., Mullin, K.D., Palka, D.L. and Waring, G.T. 2006. Known and inferred distributions of beaked whale species (Cetacea: Ziphiidae). *J. Cetacean Res. Manage.* 7(3):271–86.
- MacLeod, C.D. and Zuur, A.F. 2005. Habitat utilisation by Blainville's beaked whales off Great Abaco, Northern Bahamas, in relation to seabed topography. *Mar. Biol.* 174:1–11.
- Marsden, P.T., Kerr, I. and Payne, R. 2004. Echolocation clicks of two free-ranging, oceanic delphinids with different food preferences: false killer whales *Psuedorca crassidens* and Risso's dolphin *Grampus griseus*. *J. Exp. Biol.* 207:1811–23.
- McSweeney, D.J., Baird, R.W., Mahaffy, S.D., Webster, D.L. and Schorr, G.S. 2009. Site fidelity and association patterns of a rare species: Pygmy killer whales (*Feresa attenuata*) in the main Hawaiian Islands. *Mar. Mam. Sci.* 25(3):557–72.
- Michel, C. and van Bree, J.H. 1976. On two strandings of the beaked whale *Mesoplodon densirostris* (de Blainville, 1817) on Mauritius. *Zeitschrift für Säugetierkunde – Mamm. Biol.* 41:194–96.
- Notabartolo di Sciarra, G., Addink, M., Baldwin, R.M., Rudolph, P. and Smeenk, C. 2007. A review of cetaceans from the Red Sea. Poster presented to the 21st Annual Conference of the European Cetacean Society, 23–25 April 2007, San Sebastian, Spain.
- Notabartolo di Sciarra, G., Hanafy, M.H., Fouda, M.M., Afifi, A. and Costa, M. 2009. Spinner dolphin (*Stenella longirostris*) resting habitata in Sanadai Reef (Egypt, Red Sea) protected through tourism management. *J. Mar. Biol. Assoc. UK* 89(1):211–16.
- Peddemors, V.M. 1999. Delphinids of southern Africa: a review of their distribution, status and life history. *J. Cetacean Res. Manage.* 1(2):157–65.
- Quérouil, S., Silva, M.A., Cascão, I., Magalhães, S., Inês Seabra, M., Machete, M.A. and Santos, R.S. 2008. Why Do Dolphins Form Mixed Species Associations in the Azores? *Ethology* 114(12):1183–94.
- Ramjeawon, T. and Beedassy, R. 2004. Evaluation of the EIA system on the Island of Mauritius and development of an environmental monitoring plan framework. *EIA Review* 24(5):537–49.
- Reijnders, P.J.H. 2001. Netherlands. Progress report on cetacean research, May 2000 to May 2001, with statistical data for the calendar year 2000. Paper SC/53/ProgRep Netherlands presented to the IWC Scientific Committee, July 2001, London (unpublished). [Paper available from the Office of this Journal].
- Reijnders, P.J.H. 2002. Netherlands Progress report on cetacean research, May 2001 to May 2002, with statistical data for the calendar year 2001. Paper SC/54/ProgRep Netherlands presented to the IWC Scientific Committee, April 2002, Shimonoseki, Japan (unpublished). [Paper available from the Office of this Journal].
- Ricklefs, R.E. 2007. *The Economy of Nature*. 5th Edn. W.H. Freeman and Company, New York, USA. 620pp.
- Robineau, D. 1975. Echouage d'un *Ziphius cavirostris* Cuvier, 1823 (Cetacea, Hyperoodontidae) dans l'archipel des Comores (Ocean Indien). *Mammalia* 39:513–15. [In French].
- Robineau, D. 1991. Balaenopterid sightings in the western tropical Indian Ocean (Seychelles area), 1982–1986. *UNEP Mar. Mamm. Tech. Rep.* 3. 171–78.
- Rosenbaum, H.C., Razafindrakoto, Y., Vahoavy, J. and Pomilla, C. 2001. A note on recent sightings of southern right whales (*Eubalaena australis*) along the east coast of Madagascar. *J. Cetacean Res. Manage.* (special issue) 2:177–80.
- Ross, G.J.B., Cockcroft, V.G. and Butterworth, D.S. 1987. Offshore distribution of bottlenose dolphins in Natal waters and Algoa Bay, eastern Cape. *South African Journal of Zoology* 22:50–56.
- Ross, G.J.B. and Leatherwood, S. 1994. Pygmy killer whale, *Feresa attenuata* Gray, 1874. pp.387–404. In: S.H. Ridgway and R.J. Harrison (eds). *The First Book of Dolphins*. Academic Press, London and San Diego. 416pp.

- Sato, N., Asahida, T., Terashima, H., Hurbungs, M.D. and Ida, H. 2008. Species composition and dynamics of larval and juvenile fishes in the surf zone of Mauritius. *Environ. Biol. Fishes* 81(2):229–38.
- Sobhee, S.K. 2006. Fisheries biodiversity conservation and sustainable tourism in Mauritius. *Ocean Coast Manag.* 49(7–8):413–20.
- Stensland, E., Angerbjörn, A. and Berggren, P. 2003. Mixed species groups in mammals. *Mammal Rev.* 33(3–4):205–23.
- Stensland, E., Carlén, I., Särnblad, A., Bignert, A. and Berggren, P. 2006. Population size, distribution and behaviour of Indo-Pacific bottlenose (*Tursiops aduncus*) and humpback (*Sousa chinensis*) dolphins off the south coast of Zanzibar. *Mar. Mam. Sci.* 22(3):667–82.
- Webster, I., Cockcroft, V.G. and Cadinouche, A. 2014. Abundance of the Indo-Pacific bottlenose dolphin *Tursiops aduncus* off south-west Mauritius. *Afr. J. Mar. Sci.* 36(3):293–301.
- Webster, I., Cockcroft, V.G. and Cadinouche, A. 2015. Spinner dolphins *Stenella longirostris* off south-west Mauritius: abundance and residency. *Afr. J. Mar. Sci.* 37(1):115–24.
- Wise, J.P., Payne, R., Wise, S.S., Lacerte, C., Wise, J., Gianios, C., Thompson, W.D., Perkins, C., Zheng, T., Zhu, C., Benedict, L. and Kerr, I. 2009. A global assessment of chromium pollution using sperm whales (*Physeter macrocephalus*) as an indicator species. *Chemosphere* 75(11):1461–67.