

The Use of Aldabra and its Protected Waters by Marine Mammals

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Introduction

Marine mammals represent some of the most threatened animal groups on the planet (Temple et al., 2018). They face a multitude of threats mostly attributed to anthropogenic activities that include incidental catch, pollution, direct harvesting and boat traffic (Avila et al., 2018). As a result, many marine mammal species have experienced severe population depletions and extinctions (Pompa et al., 2011) and currently over 25% of marine mammal species are assessed as endangered or threatened (Avila et al., 2018).

Marine Protected Areas (MPAs) are a key management tool to mitigate negative impacts on marine mammals and improve their conservation (Hoyt, 2011). More specifically, large-scale MPAs (i.e. > 150, 000 km²) are essential for the conservation of pelagic species (Laran et al., 2017; Game et al., 2009). In contrast to smaller MPAs, they can encompass entire marine ecosystems and ecological processes, and they are able to protect connecting habitats of many migratory species (Lewis et al., 2017). This is relevant for marine mammals, where protection of their breeding grounds, feeding grounds, and migratory routes are especially important (Pompa et al., 2011).

Several large MPAs have recently been designated in Seychelles, an area of high marine mammal biodiversity with over 28 species recorded (Hermans and Pistorius, 2008; Balance and Pitman, 1998; Eyre, 1995; Robineau, 1991; Racey and Nicole, 1984; Keller et al., 1982). The Seychelles archipelago consists of 115 islands (total land area 455 km²) spread over 1.4 million km² of its territorial waters. The government adopted the Blue Economy concept (Attri and Bohler-Mulleris, 2018), which is founded on and reliant upon healthy oceans. In line with this strategy, a national marine spatial planning process was launched (Lombard et al., 2019), which resulted in the creation of large-scale MPAs around Aldabra (177, 447 km²) and the Alphonse and Fortune Bank (173, 468 km²) in 2019, protecting approximately 26% (350, 915 km²) of Seychelles Exclusive Economic Zone (EEZ).

One particularly important area for marine mammals in Seychelles is Aldabra Atoll. An area of high conservation value, Aldabra, was declared a Special Reserve in 1981 and inscribed as a marine UNESCO World Heritage Site in 1982. Marine mammal observations around Aldabra have occurred opportunistically since the Royal Society of London established the Research Station on the atoll in the early 1970s. Observations between 1973 and 2007 were compiled by Hermans and Pistorius (2008), highlighting the value of Aldabra's waters for marine mammals. Fourteen species were recorded around Aldabra by these authors, representing half of the species documented within Seychelles waters. Furthermore, Aldabra is the only remaining location in Seychelles with a population of dugongs, *Dugong dugon*, which are extirpated elsewhere in the archipelago (Hamylton *et al.*, 2012). Aldabra is on the migration route of calving Southern Ocean humpback whales, *Megaptera novaeangliae* (Cerchio *et al.*, 2016) and hosts large pods of spinner dolphins, *Stenella longirostris*.

The recording of marine mammal observations around Aldabra has continued since 2007 and is aimed at improving insight into marine mammal behaviour, biology and population demographics. To build on the work by Hermans and Pistorius (2008) and underline the potential value of the expanded MPA in the protection of mammals, our study summarises the observational data of marine mammals around Aldabra in the 10-year period (2008–2018) since the previous study (Hermans and Pistorius, 2008). We focused on: (i) interannual and seasonal sighting frequencies; (ii) sightings of juveniles and (iii) the spatial distribution of sightings of the three most abundant marine mammal species seen around Aldabra (dugong, humpback whale and spinner dolphin). With increasing anthropogenic threats to marine mammals worldwide, we highlight the value of Aldabra's protected waters and the significance of its expansion into a large-scale MPA as a regional sanctuary for marine mammals.

Materials and methods

Study site

Aldabra Atoll (9°25'0" S, 46°24'59" E) is a large (34 km × 14 km; land area 155 km²) coral atoll in the south-western Indian Ocean, and is part of the Seychelles archipelago. It is ca. 1100 km from Mahé, the main island of Seychelles and ca. 400 km from Madagascar (Figure 1). The atoll consists of four main islands that protect a shallow interior lagoon (226 km², < 8 m deep) and are surrounded by fringing reefs with steep seaward slopes.

Survey design

Sightings of marine mammals were documented by staff, from shore or boat, at all locations around the atoll. Although a similar approach was followed previously, a protocol was formalised and a dedicated database was created in 2010, to standardise the methods and metadata recorded. Binoculars were used to aid identification of species. For each sighting, information was recorded on (i) the species identified, (ii) the number

of individuals present, (iii) life stage (juvenile or adult), and (iv) location (name of the site and GPS point if available). Behaviours were noted and photographs were taken if a camera was available and the situation allowed. Data were entered into an MS Access database. All sightings assessed here were within the boundary of the previous MPA. Sightings of the three species most commonly encountered, dugong, humpback whale and spinner dolphin, were not consistently documented for the years 2008 and 2009, prior to the formalisation of the monitoring protocol. The analyses therefore cover the 2010–2018 period for those species. Other marine mammals which are rarely observed were documented consistently and the analysis covers the 10-year period 2008–2018.

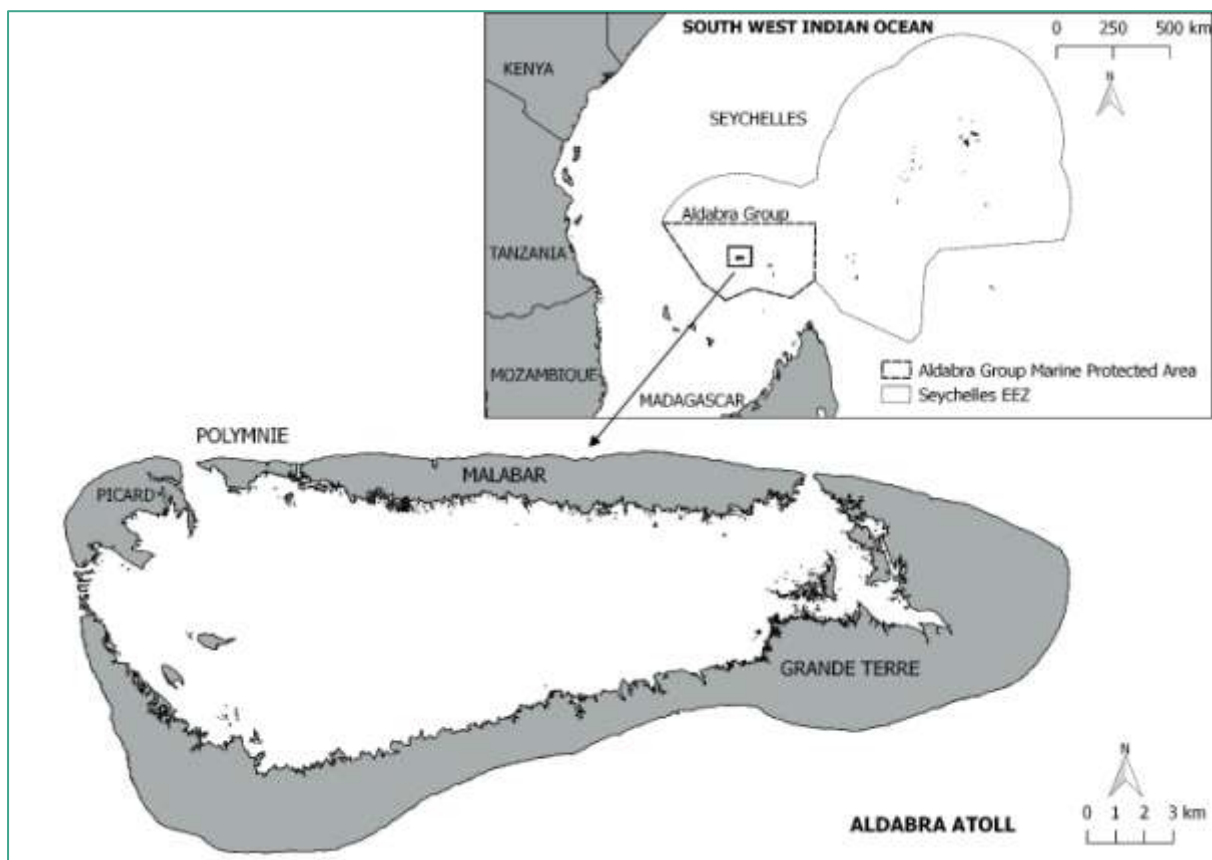


Figure 1. Location of Aldabra Atoll in the south-west Indian Ocean, and the four main islands comprising the atoll

Results

A total of 783 sightings of marine mammals were documented over the years 2008–2018. 764 sightings were of the three focal species recorded between 2010 and 2018 with humpback whales making up 66% of the sightings ($n = 515$), followed by spinner dolphins (26%, $n = 207$) and dugongs (5.4%, $n = 42$) (Table 1). Spinner dolphins were the most abundant group of marine mammals with an average group size of 59.2 and recorded pods ranging up to 500 individuals. Other marine mammal species made up a small proportion of the recorded sightings (2.4%, $n=19$).

Table 1. Sightings and group size characteristics of dugongs, humpback whales and spinner dolphins at Aldabra from 2010 to 2018, and of other marine mammals from 2008 to 2018

Species	Number of sightings	Mean group size	Group size range
Dugong <i>Dugong dugon</i>	42	1.02	1–2
Humpback whale <i>Megaptera novaeangliae</i>	515	1.97	1–15
Spinner dolphin <i>Stenella longirostris</i>	207	59.2	2–500
Other marine mammal species	19	16.2	1–100
Total	783		

Table 2. Sightings and group size characteristics of other marine mammals at Aldabra Atoll (2008–2018)

Species+--	Number of sightings	Mean group size	Group size range
Bottlenose dolphin <i>Tursiops truncatus</i>	5	20.8	2–70
Killer whale <i>Orcinus orca</i>	3	2	1–2
Beaked whale (Ziphiidae)	2	1.5	1–2
Short-finned pilot whale <i>Globicephala macrorhynchus</i>	2	4.5	3–6
Common dolphin <i>Delphinus</i> sp.	2	65	30–100
False killer whale <i>Pseudorca crassidens</i>	2	4.5	3–5
Minke whale <i>Balaenoptera</i> sp.	1	3	-
Sperm whale sp. <i>Kogia</i> sp.	1	6	-
Sperm whale <i>Physeter macrocephalus</i>	1	9	-
Total	19		

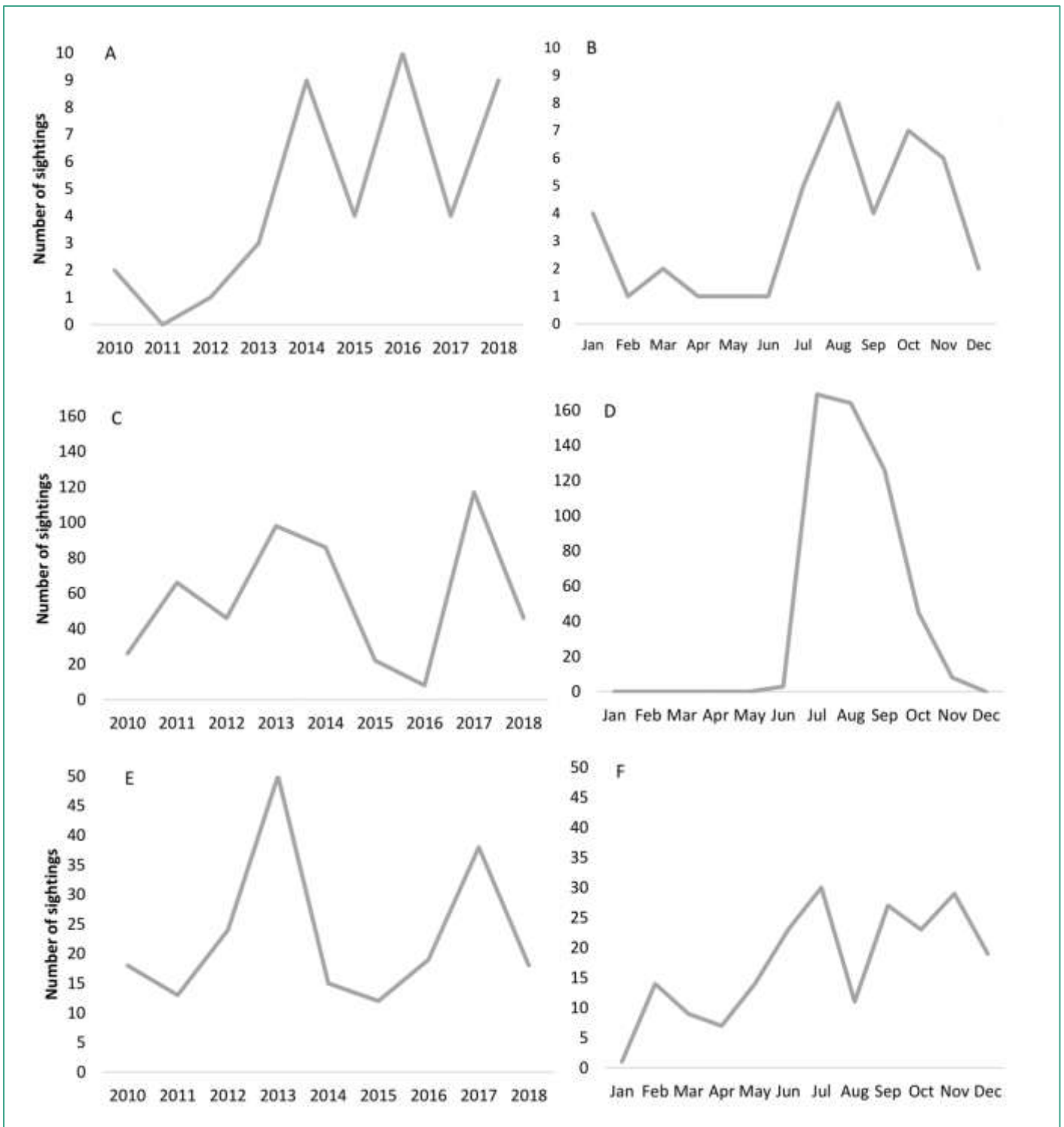


Figure 2. Annual and yearly abundances of marine mammal sightings recorded opportunistically around Aldabra during 2010–2018. (A) Number of sightings of dugong (*Dugong dugon*) per year. Sightings ranged between zero and ten and increased over recent years with a peak in 2016. (B) Number of sightings of dugong per month. Dugongs have been seen throughout the year but most sightings appear to be concentrated in the second half of the calendar year. (C) Number of sightings of humpback whales (*Megaptera novaeangliae*) per year. Sightings were variable over the 8-year period with a peak in 2017. (D) Number of humpback whale sightings per month. Humpback whales were present exclusively between June and November. (E) Number of sightings of spinner dolphins (*Stenella longirostris*) per year. (F) Number of sightings of spinner dolphins per month. Sightings appear to be higher between June and December, compared to the first part of the year.

The life stage of species seen was not always documented. No juveniles were recorded for any dugong sightings, but 73 (14%) and 20 (9.7%) sightings recorded juveniles for humpback whales and spinner dolphins, respectively. A maximum of three juveniles were seen for humpback whales and 50 juveniles were recorded for spinner dolphins during a single sighting.

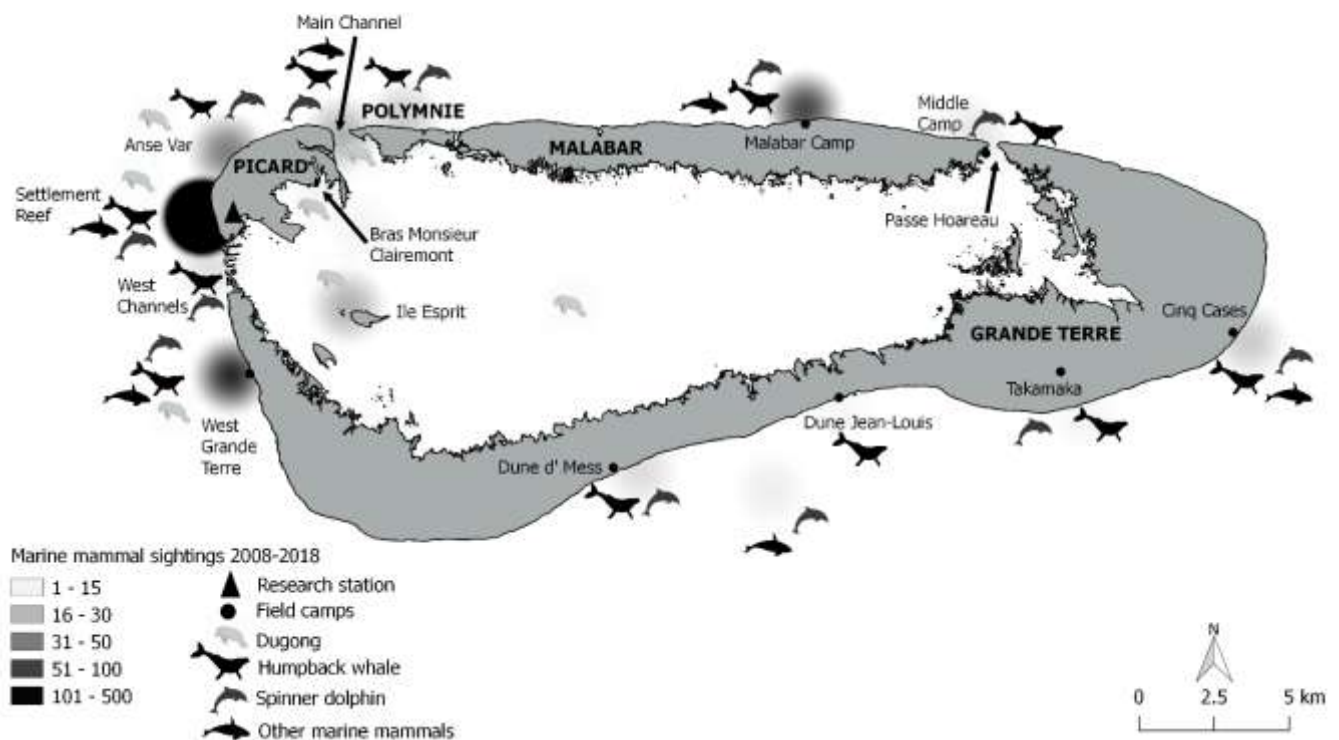


Figure 3. Locations and number of sightings of marine mammals around Aldabra during 2008–2018 (Each icon marks the location of at least one recorded sighting. The data does not account for effort so figure is provided for information only)

Discussion

Composition and abundances of sightings

Our study compiled 10 years of opportunistic observational data on marine mammals at Aldabra. For the three focal species considered, the number of sightings recorded over the 2010–2018 period ($n = 764$) was more than twice that of the previous 34 years (1973–2007, $n = 304$; Hermans and Pistorius, 2008). This increase is potentially partly due to documentation of sightings becoming more regular and standardised from 2010 onwards, when a detailed protocol was written and the monitoring was formalised into the schedule of the Aldabra research station. However, increases in population sizes of these species could also conceivably contribute to the greater number of sightings. For

example, humpback whale populations have been reported to be on the rise in several locations (Stevick et al., 2003; Noad et al., 2018). The composition of species sighted was similar to Hermans and Pistorius's (2008), with humpback whales having the highest number of sightings, followed by spinner dolphins, then dugongs. Our study confirms the continued presence of the three marine mammal species around Aldabra and underlines the importance of the site for these species.

Dugongs

Dugongs are the most endangered marine mammal in the south-west Indian Ocean (Kiszka, 2015). Dugong populations in East Africa are small and fragmented and in most places are rapidly declining due to increasing coastal development, causing environmental degradation and significant loss of seagrass habitat (Hamyton et al., 2012; Muir et al., 2004). Historically common throughout Seychelles' waters, the only remaining population of dugongs in Seychelles occurs at Aldabra (Hermans and Pistorius, 2008). 42 dugong sightings were recorded during the period of 2010–2018 compared to 29 during 1973–2007, and the number sightings has risen notably within our 8-year study period.

It is not yet known whether Aldabra's dugong population is permanent or migratory. Dugongs are known to move as far as 600 km between areas (Marsh et al., 2001), and the presence of dugongs is confirmed at Mayotte (380 km), the Comoros (390 km) and East Africa (430 km) (Hermans and Pistorius, 2008; Muir et al., 2004). Our study indicates that dugongs are present on Aldabra across all months, which may suggest a resident population. However, sightings have been lower between February and June, indicating that perhaps some of the individuals may be vagrant and migrate elsewhere during part of the year (Findlay et al., 2011; Cockcroft et al., 2018).

In addition to the opportunistic sightings, a partial aerial survey of the Aldabra lagoon was conducted in February 2013 using a gyrocopter and helicopter. The survey recorded 14 dugongs, the largest number of dugongs ever counted on Aldabra, and also included two sightings of calves (SIF, unpublished data). Extrapolation of the partial survey suggested a population estimate of 20–25 individuals in the lagoon (SIF, unpublished data). The detection of dugong calves in the aerial survey indicated that Aldabra is a breeding and/or nursery site for the species. Aldabra may therefore be a key area for East African dugongs that contributes towards their protection and could aid their future recovery in other areas in Seychelles. The aerial survey was a targeted search better suited to detect dugongs as well as identify life stages. A newborn dugong calf measures 1.2 m in length at birth (Muir et al., 2004) and without a comparative size reference, the assessment of life stages may be difficult from boat-based observations. This difficulty might explain the lack of juveniles recorded in the opportunistic sightings data.

Aldabra's extensive seagrass beds and shallow lagoon are expected to provide the ideal foraging habitat for dugongs, which are seagrass specialists (Sheppard et al., 2010). As was seen here, previous research indicated a cluster of dugong sightings in the north-west

of Aldabra's lagoon (Hamyton et al., 2012), which the authors explained by the fact that the central western area of the lagoon contained the most suitable dugong habitat but it could also have been due to greater observer effort in this area.

Humpback whales

Globally distributed, humpback whales undertake seasonal long-distance migrations between cold, highly productive foraging areas near the poles and warm, low latitude areas for mating and calving (Rosenbaum et al., 2017). For management purposes, the International Whaling Commission defines, through genetic differences, demographically discrete populations of humpback whales as management units or breeding stocks. Humpback whales from the Southern Ocean visit the south-west Indian Ocean to calve between July and November each year and Aldabra forms part of the C2 breeding sub-region (Fosette et al., 2014). The clear seasonal pattern of humpback sightings off Aldabra closely matches this breeding season. The relatively high counts of sightings, together with regular records of juveniles, indicates the importance of the protected habitat around Aldabra to breeding humpback whales.

The highest annual number of sightings of humpback whales recorded in our study was in 2017 (n = 117). In the same year, the first humpback whale strandings were recorded on Aldabra, when two adults and one juvenile were found stranded inside the lagoon at Passe Hoareau on the north coast. As with most whale strandings the cause of this event remains unknown. It did not appear to be due to direct injury or entanglement as have been implicated in some strandings (Felix et al., 1997; Wiley et al., 1995). The whales were still alive when discovered and the stranding was suspected of being a result of navigational error: after entering the lagoon at high tide, the individuals appear to have become trapped in shallow water as the tide drained from the lagoon.

There was quite a notable drop in humpback whale sightings during 2015–2016. Similar declines in humpback whale encounters were recorded during those years in the northern Pacific and is believed to be linked to the 2015–2016 El Niño event (Cartwright et al., 2019). This climate anomaly and the subsequent changes in oceanic conditions, resulted in reduced productivity and impacted key humpback whale prey resources (Cartwright et al., 2019), causing changes in their migration patterns. The recent 2010–2018 period recorded 515 sightings compared to 215 during 1973–2007. With the continued recovery of whale populations following the industrial whaling era, we expect to see higher numbers of humpback whales around Aldabra, which may increase productivity in the surrounding waters (Roman et al., 2014).

Spinner dolphins

Owing to their large groups, spinner dolphins are the most abundant marine mammal in the waters around Aldabra. The species is frequently observed around Aldabra. As a result of its frequent sighting, spinner dolphin sightings have not been recorded as consistently as other marine mammals and we suspect they remain under documented around Aldabra. Nevertheless, the data show that they are seen throughout the year, in

large numbers, including adults and juveniles, suggesting that the species may be resident and that large groups use Aldabra's waters. Although listed as least-concern by IUCN, and having a pan-tropical marine distribution, island-associated populations of spinner dolphins are often genetically distinct and inhabit small areas (Webster et al., 2015; Braulik and Reeves, 2018); this has yet to be studied for the Aldabra population. The large pods of dolphins seen around Aldabra may substantially influence the reef fish community, both as a predator and as a food source (Silva et al., 2005).

Other marine mammal species

The proportion of other marine mammal species documented during our study period was lower compared to the period assessed by Hermans and Pistorius (2008) (1973–2007, 13%, n = 45; 2008–2018, 2.4%, n = 19). As in the previous study, occasional sightings of bottlenose dolphin, killer whale, short-finned pilot whale, sperm whale, common dolphin and false killer whale were documented. The species of beaked whale recorded in 2009 was not identified but both Blainville's beaked whale *Mesoplodon densirostris* (1973–2007, n = 8) and Curvier's beaked whale *Ziphius cavirostris* (1973–2007, n = 3) have previously been recorded. Our study period included the first records of minke whale (2012, three individuals) and a species from the Kogiidae family (2014, six individuals) around Aldabra. We suspect the species of minke whale was likely the common minke whale, *Balaenoptera acutorosta*, which is common in the south-west Indian Ocean (Kiszka, 2015). *Kogia* sp. is mostly encountered in the northern Seychelles (Laran et al., 2017) but we suspect the species sighted is the dwarf sperm whale (*Kogia sima*) which is common in the region compared to the pygmy sperm whale (*Kogia breviceps*) (Kiszka, 2015). On the other hand, the spotted dolphin, Risso's dolphin and melon-headed whale were not seen in our 10-year study period but were recorded during 1973–2007.

Recommendations

The sightings in this study consist of opportunistic observations by resident staff and visiting researchers and likely represent a small window into the use of Aldabra's waters by marine mammals. Much of the atoll is not observed most of the time. Boat transport is focused around the research station and along set routes to field sites and camps. Moreover, daily monitoring fieldwork on or adjacent to the beach on Picard, together with staff housing there, means that sightings are spatially heavily biased towards an area around the research station. The 1973–2007 period assessed by Hermans and Pistorius (2008) provided a valuable baseline for marine mammal diversity around Aldabra. Our results built on their study in terms of updating results with more recent data but also further investigated inter-annual and seasonal patterns in the number of sightings. Although beyond the scope of this investigation, greater value would be added to these data if a measure of searching effort were included, which might be accomplished if a careful log of man-hours spent on different routes and in different parts of the atoll could

be collated. If this can be incorporated, we recommend the continuation of marine mammal sighting records.

Consistent opportunistic sightings data can provide basic information on distribution and indices of relative abundance which can be used to design aerial surveys but provides no information for population estimates. Although aerial surveys are costly and require optimal sea and weather conditions on Aldabra, they could provide far greater quantitative detail on the spatial distribution and, if repeated often enough, temporal changes in the use of Aldabra's waters by marine mammals. The accessibility of drones and automated image annotation technology make this a realistic monitoring avenue in the near future. Aerial surveys are recommended to strengthen information on the marine mammal populations around Aldabra, particularly for dugongs. Individual-based movement research is also recommended, so that we can start to answer questions about the movement of populations, their migration routes and habitat preferences in Aldabra's waters.

Conclusion

Seychelles has a long history of marine mammal protection. Marine mammals have been strictly protected since 1979 when Seychelles became part of the Indian Ocean Whale sanctuary. The biggest threat to marine mammals in the south-west Indian Ocean region is through by-catch in small scale subsistence fisheries (Temple et al., 2019) but this is uncommon in Seychelles (Kiszka, 2015; Temple et al., 2018). Under the Blue Economy strategy, the Seychelles government recognizes high biodiversity hotspots and is taking steps to safeguard marine ecosystems. The creation of the large-scale MPA around Aldabra in 2019 (177,447 km²) increased its protected area substantially, covering approximately 13% of the Seychelles' EEZ (1.4 million km²). The expanded MPA encompasses a diversity of habitats important to marine mammals and provides protection to both deep-water and slope-associated species, as well as their migratory routes. Steps to strengthen the site's protection may include declaring the Aldabra MPA an important marine mammal area under the IUCN Marine Mammal Protected Areas Task Force. The minimal anthropogenic disturbance of remote waters around Aldabra, together with their increased protection level, provide a wide range of valuable habitats and ecosystems that should benefit regional populations of marine mammals.

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The Seychelles Islands Foundation manages and protects the UNESCO World Heritage Sites of Aldabra Atoll and the Vallée de Mai. Jennifer Appoo is the Science and Projects Coordinator, Cheryl Sanchez is the current Aldabra Science Coordinator, and April J. Burt, Heather Richards, Janske van de Crommenacker and Jock Currie were previous Aldabra Science Coordinators. Frauke Fleischer-Dogley is the CEO of Seychelles Islands Foundation.

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