Spatio-temporal trends in cetacean strandings and response in the south-western Indian Ocean: 2000–2020

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ABSTRACT

The south-western Indian Ocean (SWIO) is a region of global importance for marine mammal biodiversity, but our understanding of most of the species and populations found there is still rudimentary. The Indian Ocean Network for Cetacean Research (IndoCet) was formed in 2014 and is dedicated to the research of all cetacean species across the SWIO. Since 2019, there have been efforts to create a regional network for coordinated response to stranding events as well as training and capacity building in the SWIO region. The present analysis represents a first investigation of stranding data collected by various members and collaborators within the IndoCet network, covering over 14,800km of coastline belonging to nine countries/territories. Between 2000–2020, there were 397 stranding events, representing 1,232 individual animals, 17 genera and 27 species, belonging to six families: four balaenopterids, one balaenid, one physeterid, two kogiids, six ziphiids and 14 delphinids. Seven mass strandings were recorded: two were composed of three to 20 individuals and five composed of > 20 individuals. Spatial analysis of stranding events indicated that local spatio-temporal clusters (excessive number of events in time and geographic space) were present in all countries/territories, except for the Comoros. The only significant cluster was detected on the southwest coast of Mauritius, just west of the village of Souillac. The SWIO region predominantly

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comprises relatively poor countries/territories, but imminent Ocean Economy developments are prevalent throughout the region. This study highlights the importance of establishing baselines upon which any future potential impact from anthropogenic developments in the region can be measured.

KEYWORDS: CONSERVATION; HEALTH; MANAGEMENT; INDIAN OCEAN; STRANDINGS; SPATIO-TEMPORAL VARIATION

INTRODUCTION

The south-western Indian Ocean (SWIO) spans the waters south of the equator from Kenya to the southernmost tip of South Africa (Cape Point), including the island of Madagascar and island archipelagos of the Comoros and Mayotte, the Mascarene Islands (including Reunion, Mauritius and Rodrigues), Seychelles, and the Éparses Islands (Figures 1A–D). The portion of the SWIO analysed in this study covers more than 39% of the latitude of the southern Hemisphere (extending from approximately –36°S at the farthest southern extent of the coast of South Africa, north to approximately –1°S at Kenya's northern border) and comprises almost 15,000km of coastline.

The SWIO contains a high diversity of cetaceans (Findlay *et al*., 1992; Kiszka *et al*., 2007; Dulau-Drouot *et al*., 2008; Pompa *et al*., 2011; Amir *et al*., 2007; 2012; Dulau-Drouot *et al*., 2012; Braulik *et al*., 2017; Laran *et al*., 2017a; 2017b; Webster *et al*., 2020; Mwango'mbe *et al*., 2021; Cerchio *et al*., 2022). At least 29% of globally recognised cetacean species (*n* = 92) inhabit these waters (Committee on Taxonomy, 2022). The conservation status of many species in the SWIO is still poorly understood, but measuring the true consequences of recognised threats is problematic in the absence of reliable information on population status. Previous research efforts which have led to abundance estimates of cetacean populations at a local level have focused on Indo-Pacific bottlenose dolphins (*Tursiops aduncus*), spinner dolphins (*Stenella longirostris*), Indian Ocean humpback dolphins (*Sousa plumbea*),

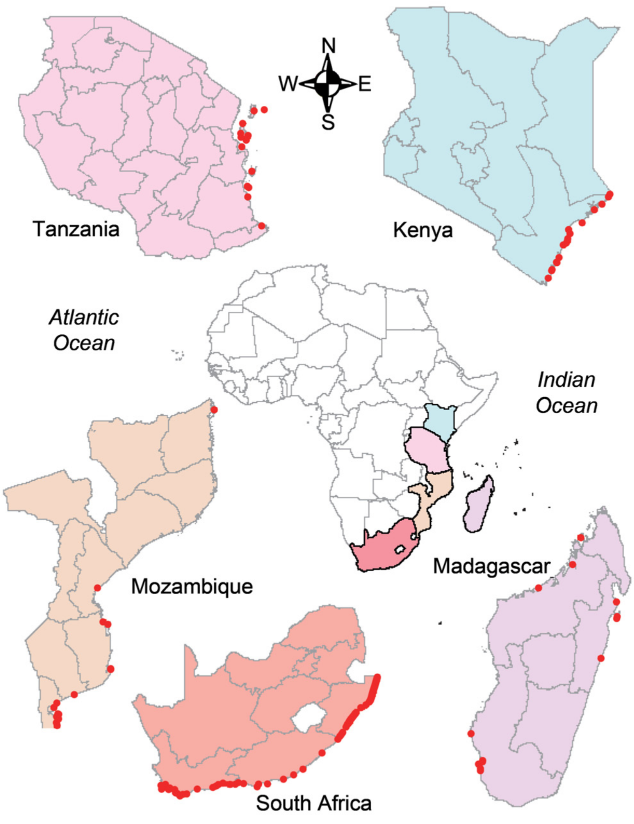

Fig. 1A. South-western Indian Ocean study area showing stranding locations (red dots) for mainland Africa and Madagascar.

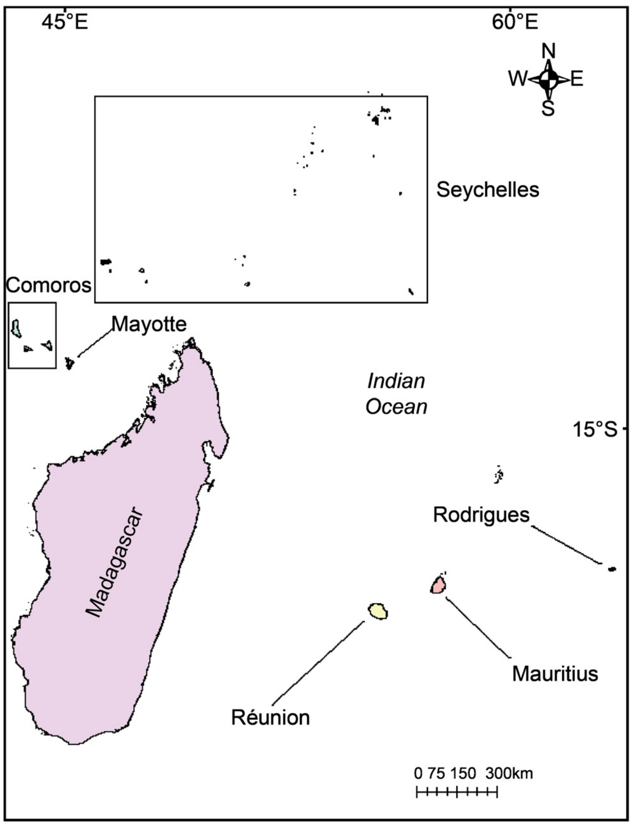

Fig. 1B. South-western Indian Ocean study area showing location of smaller islands in relation to Madagascar.

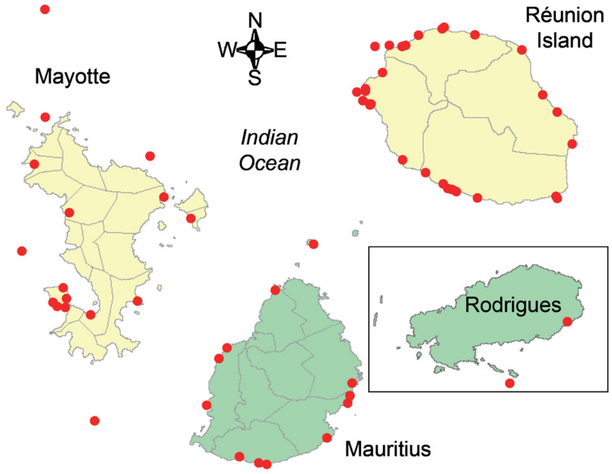

Fig. 1C. South-western Indian Ocean study area showing stranding locations (red dots) for Mauritius (including Rodrigues), Réunion and Mayotte.

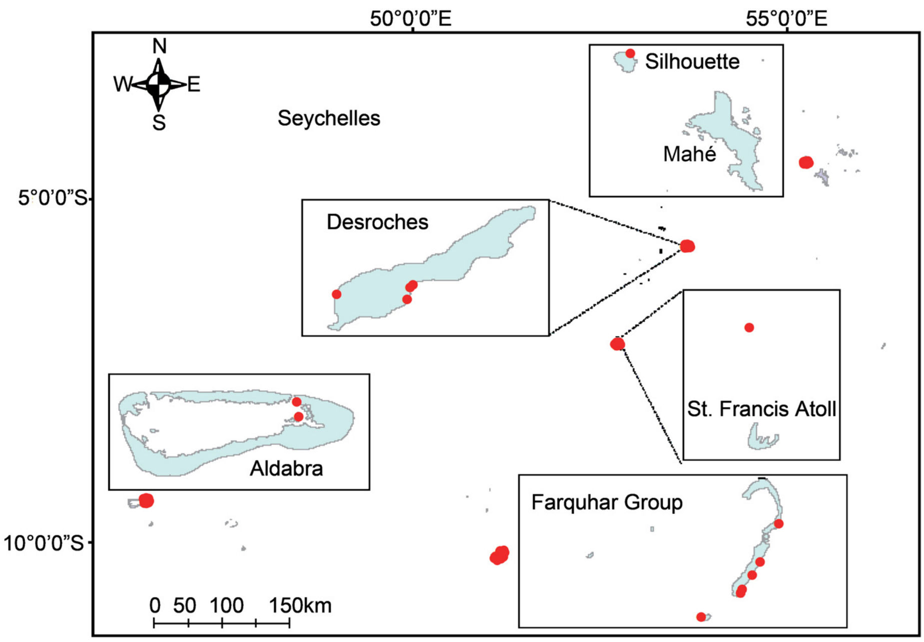

Fig. 1D. South-western Indian Ocean study area showing stranding locations (red dots) for Seychelles.

common bottlenose dolphins (*Tursiops truncatus*), southern right whales (*Eubalaena australis*) and humpback whales (*Megaptera novaeangliae*). The focus on these species is likely due to their accessibility and the relative ease with which individuals can be distinguished using photo-identification (Reisinger and Karczmarski, 2010; Findlay *et al.*, 2011; Pusineri *et al.*, 2014; Webster *et al.*, 2014; 2015; Braulik *et al.*, 2017; Dulau *et al.*, 2017; Estrade and Dulau, 2020; Vargas-Fonseca *et al.*, 2020; Kasuga *et al.*, 2022; Neveceralova *et al.*, 2022).

Strandings inherently provide opportunistic data but can also provide important information on cetacean diversity and occurrence (Ross, 1984; Pyenson, 2011; Groom and Coughran, 2012; Chan *et al.*, 2017). There have been few studies on strandings or unusual mortality events of cetaceans within the region, with many of the stranding records either being anecdotal or unreported. An unusual mortality event is defined by the United States Marine Mammal Protection Act as an unexpected marine mammal stranding event, demanding immediate response, that involves a significant die-off (NOAA Fisheries, 2023). Although response to stranded cetaceans exists at various levels throughout the region, in most parts it is only rudimentary; systematic and trained stranding response protocols are established in only a few countries. At present, several organisations respond to strandings within the SWIO in either a formal or informal manner (see Appendix 1).

A mass-stranding of melon-headed whales (*Peponocephala electra*) at Antsohihy in Madagascar in May/June 2008 presented a highly unusual event involving an oceanic species, which had not been reported in the Loza tidal estuarine system before (Collins *et al*., 2009; Southall *et al*., 2013). It sparked a coordinated international response effort, designed to rescue live animals and collect biological tissue samples for later analysis from dead individuals (Collins *et al*., 2009; Southall *et al*., 2013). It also highlighted the significance of data gaps for cetaceans in Madagascar and the need to build regional capacity for marine mammal stranding response and investigation. It was recognised that adequate and efficient response is often hindered by logistical constraints, which are best overcome by local expertise familiar with the region and terrain (Collins *et al*., 2009; Southall *et al*., 2013). Other recent stranding events in Mauritius (including mass stranding events in 2005 and 2020) (Plön *et al*., 2021a), Sri Lanka (Nov 2020) (de Vos *et al*., 2022) and Mozambique (Feb 2021), have also shown that significant capacity gaps continue to exist in these regions.

The Indian Ocean Network for Cetacean Research (IndoCet) was formed in 2014 and is dedicated to cetacean research across the SWIO (Plön *et al*., 2020). Despite the value of coordinating stranding response within IndoCet and the SWIO region having been recognised after a mass stranding occurred in Madagascar in 2008, a formal stranding coordinator was only appointed in 2019. Concerted efforts were made to improve stranding response at local levels, collection of level-A data (i.e., location, date, species, live/dead) and samples, and improve training opportunities throughout the region. A stranding webpage has been established on the IndoCet website which provides access to additional resources and an online form to report cetacean strandings from the region (IndoCet, 2023). Ongoing efforts are focused on establishing local/regional areas of response and determining the level of capacity and/or training requirements. Remotely supervised necropsies have been completed where local scientists with limited expertise in strandings response conduct necropsies with the support of stranding experts via a VoIP messaging app (Plön *et al*., 2021a).

Importance of data from strandings

There are increasing concerns about the threats posed by anthropogenic activities in the Indian Ocean (Mwango'mbe *et al*., 2021; Plön and Roussouw, 2022). The study of stranded marine mammals can provide valuable insight into the magnitude of these threats and their consequences, including cause of death (Pyenson, 2011; Tomo and Kemper, 2022). The causes of strandings can be qualified and known factors can include fisheries interactions, including bycatch, ship strikes, pollution (both noise and chemical) and pathogens in the region as economic activities intensify in the ocean space (Natoli *et al*., 2007; Kiszka *et al*., 2009a; Miksis-Olds *et al*., 2012; Anderson, 2014; Das *et al*., 2016; Dirtu *et al*., 2016; Peltier *et al*., 2016; de Quirós *et al*., 2018; Anderson *et al*., 2020; Puig-Lozano *et al*., 2020; Schoeman *et al*., 2020; Mwango'mbe *et al*., 2021; Plön and Roussouw, 2022*;* Roussouw *et al.,* 2022). Chemical pollution and pathogens also pose potential risks for coastal human populations (Landrigan *et al*., 2020). As maritime economic activities intensify in the SWIO, we can reasonably assume that marine mammals will be increasingly affected and the number of strandings will increase. This review focuses on strandings information collected in the SWIO region between 2000–2020 and includes information provided by members of the IndoCet network in addition to other collaborators and contributors. The purpose of our study is to present an overview of regional cetacean stranding response efforts and a preliminary analysis of stranding events, which aims to provide a starting point for the assessment of potential impacts from current and planned anthropogenic developments. This work also highlights the importance of further training and capacity building for strandings response in the SWIO and the publication of reports/data where possible.

METHODS

Study area

Cetacean stranding data (see Appendix 2) were collated from published literature and regional contributors and organisations responding to strandings. Collated records are from the South African coastline, the coastlines of Mozambique, Tanzania and Kenya (Figure 1A); the continental island of Madagascar (Figure 1A) and small islands of the SWIO: Mayotte (Figures 1B and C), the Comoros, the Mascarene Islands (Mauritius, Rodrigues and Reunion)) (Figures 1B and C); the Éparses Islands (Glorieuses and Tromelin) (Figure 1B) and Seychelles (Figure 1D).

Data collection, validation and characterisation

Stranding records spanning the period from 1 January 2000 to 31 December 2020 (21 years) were analysed. Cetacean stranding events were defined as involving single individuals or mother/calf pairs, while mass stranding events (MSE) were defined as two or more individuals, excluding mother/calf pairs of the same species, which stranded simultaneously in a defined area and time (Geraci *et al*., 2005). Strandings that occurred on the same day at the same geographic location, or within a maximum of two days, were defined as one event. Data submitted by each contributor included: species, date when stranding was reported (month and year) and location. Records that were retained for analysis included occasions when animals were discovered dead on shore; animals live-stranded and died on shore; animals that live-stranded were subsequently euthanised; animals that live-stranded were successfully refloated; animals were reported floating dead within the country or territory's waters (Geraci *et al*., 2005).

As the stranding records included data recorded from a range of sources with inconsistent methodologies, the data contributors were asked to assign a confidence rating of 'low', 'medium' or 'high' to each record based on species identification, date and location, in accordance with Segawa and Kemper (2015). Where possible, taxonomic uncertainties were resolved by investigating available photographs and/or measurements (e.g., *Kogia* spp., following Ross, 1979). Unconfirmed records were excluded from the analysis. Only records where the location included latitude/longitude, or a location description, were retained for spatial analysis. Where a specific date was not specified, the default was the first day of that month. The record was omitted if the year was missing. Information on age class and sex was not included as these data were not reliably available for the majority of strandings.

Differences in logistical and operational capacity exist between stranding responders, but these differences have not been formally quantified for all organisations contributing to this study (see Appendix 1). Hence, two assumptions were made to enable data comparison (following IJsseldijk *et al*., 2020). The first assumption was that reporting and investigation efforts increased over time, most likely due to increasing awareness of and interest in strandings, technological developments aiding stranding report submission, an increased human presence in remote locations and increased participation by citizens. While carcass drift may be a concern at local level, given the large scale of the present study area, our second assumption was that animals stranded in a specific country or territory had died in these or adjacent waters (IJsseldijk *et al*., 2020).

Descriptive data analysis

Spatial and temporal patterns were investigated for pooled (i.e., all species) cetacean strandings and by country/territory. Due to the study area covering countries/territories from temperate to tropical latitudes, seasonal patterns were described in terms of three-month quarters which relate to monsoon rather than calendar seasons: Dec–Feb, Mar–May, Jun–Aug and Sep–Nov. To test for significant differences in the number of stranding events based on these two independent parameters, three-month quarters and country/territory, we used negative binomial regression to assess for total count of events, at a significance level of $p < 0.05$, using STATA (version 13.0). Negative binomial regression is used to test for associations between independent predictors and a count outcome variable when the count variance is greater than the mean of the count (Lawless, 1987). The results of negative binomial regression are interpreted in a similar fashion to logistic regression with the use of odds ratios with 95% confidence intervals.

Spatial data analysis

Strandings were mapped using ArcGIS Desktop (v10.8.1; ESRI, 2021) and projected for analysis using the WGS 1984 projection. Heat maps calculated using the ArcGIS Density tool (Harris and Gupta, 2006), specifically point density analysis, were used to visualise densities of stranding events. The cell size of the output raster was 0.020, the search radius 0.250 map units, and the area units in square kilometers. We used the Moran's I test, an autocorrelation analysis, to identify spatial autocorrelation at a global scale and characterise the spatial distribution of strandings across the entire SWIO (Carpenter, 2001). Spatial autocorrelation is multi-directional and multi-dimensional, which means it is useful for finding patterns in complicated data sets. The null hypothesis for the Moran's I test was that the spatial distribution of strandings was random. Alternatively, we hypothesised that the spatial distribution of the stranding events was clustered.

To assess local spatio-temporal autocorrelation, stranding event clusters were identified using the space-time permutation model of the scan statistic test implemented in the SaTScan software (SaTScan, Information Management Services, Inc., version 9.6.1). To minimise biases from MSEs, the cluster analyses were run on events. In other words, 'cases' were defined as single stranding events (independent of the number of individuals stranded in the event) that occurred in a single location and were therefore not influenced by the number of individuals in that event. The islands (except Madagascar) were arranged as follows into two separate groups based on geographical location to detect local stranding clusters: 1) Comoros, Glorieuses (Éparses Islands) and Mayotte; 2) La Réunion, Mauritius, Rodrigues and St. Brendan (collectively called the Mascarene Islands), and Tromelin, also one of the Éparses Islands. The model was run using stranding latitude/longitude coordinates and initial stranding dates under the null hypothesis that stranding events were randomly distributed in space and time. The programme counted the number of observed and expected events within a scanning window, moving across space and/or time for each location and variable window size (Kulldorff, 1997). The clusters with the greatest difference between observed and expected events were noted. The maximum size of the temporal window was set to a three-month study period to encompass all four seasons. The maximum spatial extension of clusters was set to a radius of 32.5km (65km diameter), based on the estimated size of the spatial extent of the largest known cetacean stranding event recorded in the SWIO within our dataset: melon-headed whales stranded during the months of May and June 2008 in the Loza Lagoon system in northwest Madagascar (Collins *et al*., 2009; Southall *et al*., 2013). This radius helped ensure the maximum number of stranding events were captured within each scan. The local cluster detection test was computed for each country. For islands that belong to the same country but are geographically distant, such as Réunion and Mayotte which both belong to France, the local cluster test was computed separately.

Distributions of the likelihood ratio and its corresponding *p*-value were obtained using the Monte Carlo simulation by generating 999 replications of the data set under the null hypothesis that stranding events were randomly distributed in time and space at high- and low-rates (Kulldorff and Nagarwalla, 1995). Stranding clusters with a *p*-value < 0.05 were considered statistically significant and temporal similarities within significant clusters were examined.

RESULTS

Stranding events

Over the study period of 2000–2020, 438 stranding events were reported. Of these, 41 were excluded due to insufficient location information, non-cetacean species, such as dugongs (*Dugong dugon*), or because the stranding(s) occurred outside the study period, leaving 397 event records for analysis, representing 1,232 individuals (Table 1). Of the total events, 390 consisted of either one or two animals ($n = 382$ and $n = 8$, respectively); one event involved three individuals, and the remainder ($n = 5$) included ≥ 10 individuals in a single stranding event, with a very large (> 600 individuals) event in Tanzania, and one event in NW Madagascar that involved 100 melon-headed whales (Collins *et al*., 2009; Southall *et al*., 2013). In 2005, one MSE of short-finned pilot whales (*Globicephala macrorhynchus*) in Mauritius reported several individuals stranded, but the exact number was not documented.

Across the entire study region, stranded individuals were reported every month (Figure 2). Mysticetes and odontocetes were evaluated separately. Mysticetes strandings were most frequently reported during Jun–Nov, while odontocetes stranded most during Sep–Nov, followed equally by the other three quarters (Figure 3). In general, similar seasonal patterns held when looking at individual countries/territories, with a few exceptions (Figure 4). The negative binomial regression resulted in the following model to assess differences in stranding numbers by three-month quarters and country/territory: negbinom (#events ~ season + region). This analysis showed significant differences in stranding event numbers between the three-month quarters, most notably comparing March–May to June–August ($\beta = 2.055$; 95% CI = 0.455, 3.665; $p = 0.012$).

Table 1

Cetacean strandings in the south-western Indian Ocean by genus and species, 2000-20.

Species	Events	Individuals
Balaenoptera acutorostrata	2	2
Balaenoptera brydei	15	15
Balaenoptera musculus	1	1
Balaenoptera spp.	1	1
Delphinidae spp.	1	1
Delphinus delphis	9	9
Eubalaena australis	5	5
Feresa attenuata	2	2
Globicephala macrorhynchus	8	7
Globicephala spp.	2	2
Grampus griseus	11	12
Kogia breviceps	9	9
Kogia sima	11	11
Kogia spp.	4	4
Lagenodelphis hosei	3	3
Megaptera novaeangliae	115	115
Mesoplodon densirostris	4	7
Mesoplodon eueu	3	4
Mesoplodon grayi	1	1
Mesoplodon hotaula	1	1
Mesoplodon layardii	1	1
Mesoplodon spp.	1	1
Peponocephala electra	16	234
Physeter macrocephalus	42	42
Pseudorca crassidens	2	2
Sousa plumbea	7	7
Stenella attenuata	17	17
Stenella coeruleoalba	25	25
Stenella longirostris	31	33
Tursiops aduncus	19	31
Tursiops truncatus	22	621
Tursiops spp.	3	3
Ziphius cavirostris	3	3
Total	**397**	**1,232**

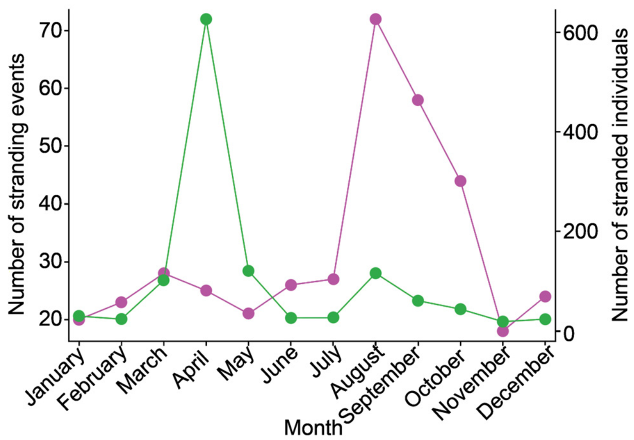

Fig. 2. Monthly number of stranded cetacean events (purple line) and number of stranded individuals (green line) between Jan 2000 and Dec 2020 in the south-western Indian Ocean.

South Africa (total number of stranding events *n* = 180; 45.3%) and Mozambique (total number of events *n* = 44; 11.1%) reported most of the stranding events in the study area, followed by Reunion (*n* = 33; 8.3%) and Madagascar (*n* = 32; 8.1%; Table 1; see Figures 4 and 5). The number of stranded individuals by country/territory was influenced by MSEs. When MSEs (i.e., ≥ 3 individuals) were included, number of stranded individuals was

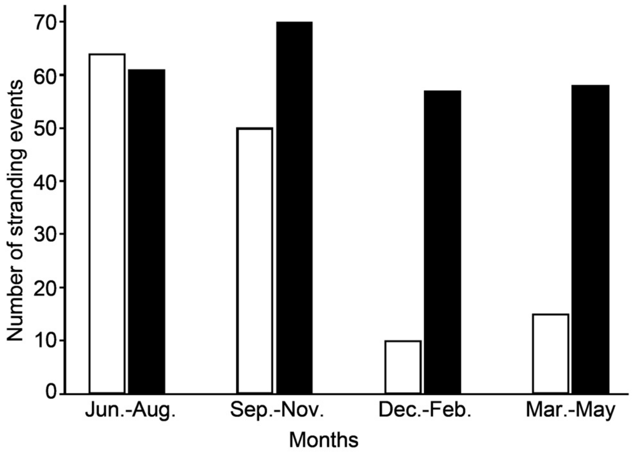

Fig. 3. Number of stranded cetacean events by taxon – mysticete (white bars) and odontocete (black bars) – and three-month quarters, Jan 2000–Dec 2020 in the south-western Indian Ocean.

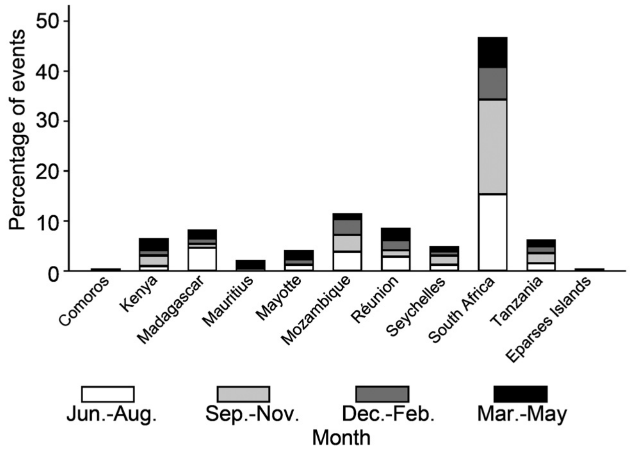

Fig. 4. Percentage of all cetacean stranding events by three-month quarters and country/territory, Jan 2000–Dec 2020, in the south-western Indian Ocean.

highest in Tanzania (*n* = 635; 51.5%) due to their single mass stranding event, plus two smaller events, followed by South Africa (*n* = 180; 14.6%), Mauritius (*n* = 140; 11.4%) and Madagascar (*n* = 131; 10.6%; Appendix 2; Figure 4). Upon removal of these mass stranding events from Madagascar, Mauritius and Tanzania, the ranking of number of stranded individuals by country changed to South Africa (*n* = 180; 46.2%), Mozambique (*n* = 44; 11.3%) and Reunion (*n* = 33; 8.5%). When normalised based on the occurrence of reported stranding events per kilometer of coastline, the highest reported rates occurred in Reunion (0.16/km) and Mayotte (0.09/km). Comoros had the smallest rate with 0.006 strandings reported per km of coastline.

The greatest number of stranding events during the entire study period was observed in 2018 (*n* = 60; 15.1%), followed by 2019 (*n* = 56; 14.1%) and 2020 (*n* = 36; 9.1%; Table 2). Negative binomial regression showed there were no significant differences in the number of stranding events between countries/territories. The reported data did not allow analysis of live versus dead strandings.

Species composition

Reported stranding events represented six cetacean families that included 17 genera and 27 species (see Appendix 2). Mysticetes and odontocetes accounted for 35.3% (*n* = 140) and 64.7% (*n* = 257) of total stranding events, respectively; and for 11.4% (*n* = 141) and 88.6% (*n* = 1,091) of stranded individuals. The majority of mysticete stranding events were Balaenopteridae (*n* = 136; 96.4%) (Figure 6a), followed by Balaenidae (*n* = 5; 3.5%); and for

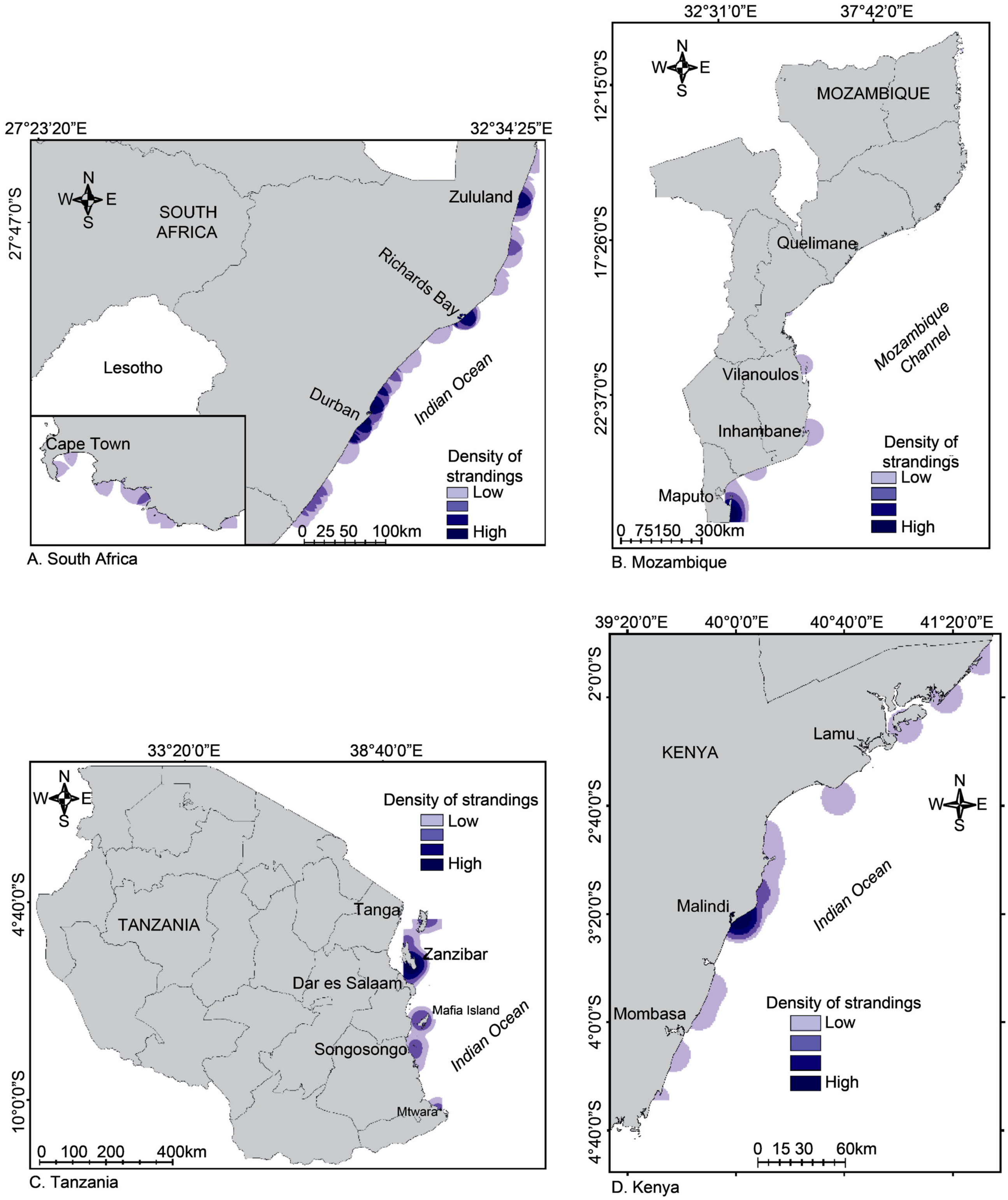

Fig. 5. Density of stranding events as depicted by point density heat maps, 2000–2020, in the south-western Indian Ocean. The cell size of the output raster was 0.020, the search radius 0.250 map units, and the area units in square kilometers.

individuals, 96.5% and 3.5%, respectively (Figure 6b). Out of the total odontocete stranding events, Delphinidae (*n* = 177; 68.9%) were most common, followed by Physeteridae (*n* = 42; 16.3%), Kogiidae (*n* = 24; 9.3%) and Ziphiidae (*n* = 14; 5.4%). Based on the number of total stranded odontocete individuals, members of the Delphinidae family stranded most frequently (*n* = 1,007; 92.3%), followed by Physeteridae (*n* = 42; 3.8%; Figure 6b). The two largest stranding contributions came from Balaenopteridae and Delphinidae, accounting for 78.6% (*n* = 312) of all stranding

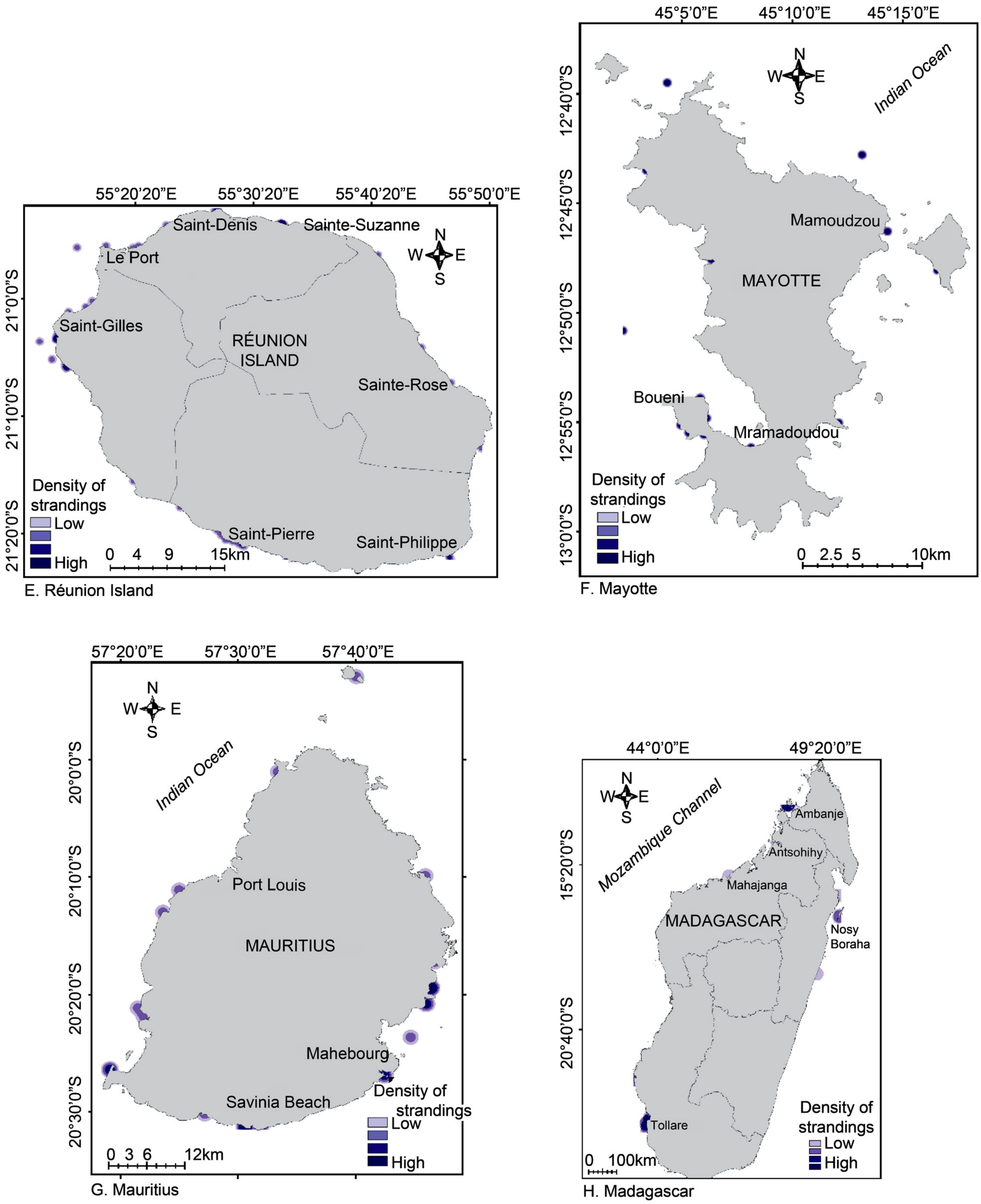

Fig. 5 (continued).

events, and 92.8% (n = 1,143) of all stranded individuals during the study period. Excluding MSEs (n = 6 events; 834 individuals), contributions from these two families to the total number of events and individuals were 78.0% (n = 305) and 77.6% (n = 309).

Out of the 27 species reported, humpback whales and sperm whales stranded most frequently, with 115 and 42 events recorded, respectively, each consisting of only one individual per event (Table 1). Humpback, southern

Table 2

Number (and percent) of all stranding events and all individuals for the south-western Indian Ocean, 2000-20.

Year	Number of events	Percent of events	Number of individuals	Percent of individuals
2000	2	0.5	3	0.2
2001	2	0.5	2	0.2
2002	2	0.5	2	0.2
2003	4	1.0	4	0.3
2004	5	1.3	5	0.4
2005	6	1.5	79	6.4
2006	9	2.3	608	49.4
2007	9	2.3	9	0.7
2008	7	1.8	106	8.6
2009	7	1.8	7	0.6
2010	23	5.8	23	1.9
2011	22	5.5	22	1.8
2012	25	6.3	25	2.0
2013	21	5.3	21	1.7
2014	31	7.8	32	2.6
2015	12	3.0	14	1.1
2016	30	7.6	30	2.4
2017	28	7.1	29	2.4
2018	60	15.1	62	5.0
2019	56	14.1	58	4.7
2020	36	9.1	91	7.4
Total	**397**		**1,232**	

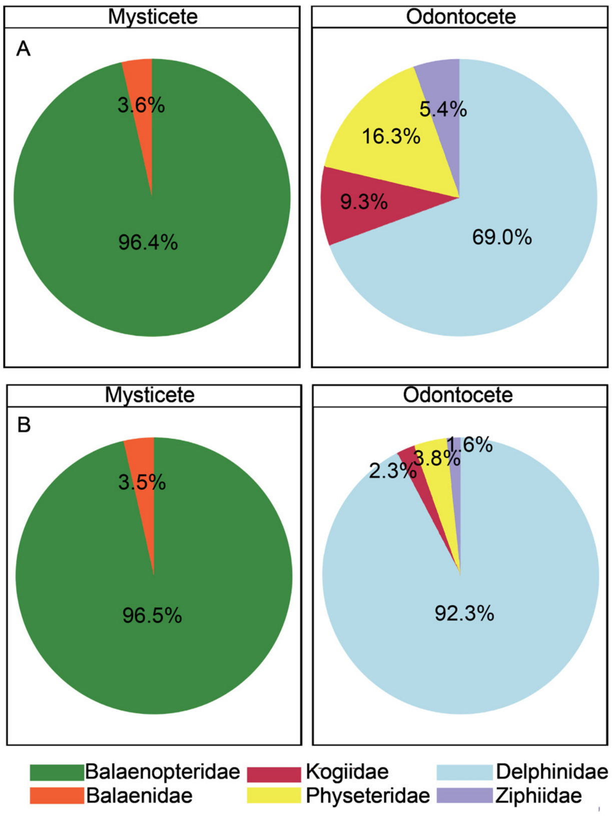

Fig. 6. Percentage of total family-level stranding events (left pair) and individuals (right pair) out of total stranded mysticete and odontocete events and individuals.

right and sperm whales were prominently represented in the records, collectively accounting for almost half of the events (*n* = 162; 40.8%). Of the 115 humpback whale events, 72 (62.6%) were recorded in South Africa and 20 (17.4%) in Madagascar. The species with the fewest number of reported events were the blue whale (*Balaenoptera musculus*), Grays's (*Mesoplodon grayi*), Deraniyagala's (*Mesoplodon hotaula*) and strap-toothed (*Mesoplodon layardii*) beaked whales (*n* = 1 each). Several individual cetaceans were not identified to species level due to advanced decomposition or inability to examine the carcass in sufficient detail: one Delphinidae, two *Globicephala* spp., four *Kogia* spp., one *Mesoplodon* spp., and three *Tursiops* spp.

Distribution of strandings by country/territory and organisation

South Africa, Western Cape province: Mammal Research Institute Whale Unit (MRIUW)

Along the south-western cape of South Africa, the Mammal Research Institute Whale Unit (MRIUW), University of Pretoria, reported 62 cetacean stranding events over the study period. An additional 550 collective records of southern right whale strandings from South Africa (Vermeulen *et al*., 2021) were unfortunately not made available for analysis, except for five submitted by MRIUW. Out of the 62 cetacean stranding events reported by MRIUW, two were not included in the present analysis, because latitude/longitude data were not available, nor identifiable geographical landmarks. The most common stranded species were humpback whales (*n* = 20; 32.3%) and Bryde's whales (*n* = 15; 24.2%). Three whales stranded alive: a humpback whale at Struisbaai (Western Cape) (–34.762062, 20.05531) on 1 September 2019 (euthanised); a southern right whale (*E. australis*) at Pearly Beach on 30 September 2019 (refloated but beached again and died); and a strap-toothed whale (*M. layardii*) at Struisbaai on 24 January 2020 (refloated).

South Africa, KwaZulu-Natal province: Ezemvelo KwaZulu-Natal Wildlife

Along the KwaZulu-Natal coastline, South Africa, Ezemvelo KwaZulu-Natal Wildlife reported 135 strandings. Fifteen were excluded due to missing species identification. One humpback whale stranded at Trafalgar Beach on 29 July 2017 showed signs of entanglement. Four animals that stranded alive were refloated: two humpback whales at Umtentweni on 24 July 2013 and North of Richards Bay on 10 August 2018; one common bottlenose dolphin at Pumula Beach on 2 June 2016; one spinner dolphin at Grannies Pool, Umhlanga, on 30 September 2018. Over a third of the kogiids included in this study stranded in South Africa and represented both species (i.e., *K. sima* and *K. breviceps*; see Table 1 and Appendix 2). Three striped dolphins stranded together on 1 October 2011 between Cape Vidal and Leven Point. A sperm whale and humpback whale stranded on Cassuarina Beach on 28 August 2014. Three short-finned pilot whales stranded together at Red Sands on 26 October 2016. One Risso's dolphin stranded on Estuary Beach on 26 February 2014 was identified as having been struck by a boat. Apart from this last incident, likely causes have not been investigated for any of these strandings.

Mozambique: Dolphin Encountours Research Center (DERC)

In Mozambique, Dolphin Encountours Research Center (DERC), in collaboration with the Natural History Museum in Maputo and Ponta do Ouro Partial Marine Reserve, reported 35 strandings between 2000–20, but four were excluded as non-cetacean species or having occurred outside the study period (see Appendix 2). Five events involved live animals. Three animals were reported to have been harvested for consumption by locals. One Fraser's dolphin (*Lagenodelphis hosei*) that stranded at Ponta do Ouro Partial Marine Reserve on 7 February 2012 was reported to have experienced trauma to the head. Two reports suggest signs of bycatch: a reported puncture to the chest cavity of a Risso's dolphin stranded at Ponta do Ouro Partial Marine Reserve on 13 September 2013; and a wound/cut behind the dorsal fin of an Indo-Pacific bottlenose dolphin stranded at Ponta do Ouro Partial Marine Reserve on 29 March 2019.

Mozambique: Lúrio University

Lúrio University reported two stranding events since 2017, including two beaked whales that stranded together at Tofu Beach at Inhambane Province in April 2019 and have subsequently been identified as Ramari's beaked whale (*M. eueu*) (Carroll *et al*., 2021).

Mozambique: Marine Research Centre, All Out Africa

The Marine Research Centre, All Out Africa, located in Tofo, reported the previous two animals to have been consumed by locals (Reeve-Arnold *et al*., 2020). A third animal (an unknown species of bottlenose dolphin) was also consumed. The Centre reported 11 stranding events in total, two of which were excluded.

Tanzania: Tanzania Whale Network

Along the coastline of Tanzania, individual researchers, alongside collaborators, including the Tanzania Whale Network, have collated information on 27 strandings between 2004–20, three of which were excluded due to the lack of location information (Appendix 2). Eleven Indo-Pacific bottlenose dolphins live stranded on Fanjove Island on 12 January 2019 were reported as refloated and released. An additional live stranding of one spinner dolphin individual at the slipway at Dar es Salaam on 2 June 2014 was refloated and released. A number of stranded individuals were reported as consumed: two Indian Ocean humpback dolphins (7 May 2014 and 23 October 2016, both at Kizimkazi) and one spinner dolphin on 20 February 2015 at Pemba. A further sperm whale (stranded at Kilwa on 14 October 2016) and two humpback whales (stranded at Mtwara on 7 September 2014 and at Songo on 14 August 2019) were also consumed. Two humpback whales stranded at Rufji within days of each other on 4 and 8 April 2011, as did two sperm whales on Chumbe Island, Zanzibar, and Pemba, on 19 and 24 September 2014. An additional 16 strandings from Tanzania for the period 2000–2008 have been previously published (Amir *et al*., 2012; see Table 1). In two separate events in Tanzania, three Indo-Pacific bottlenose dolphins stranded in 2018 and 11 animals of the same species stranded in 2020. In 2006, 600 common bottlenose dolphins stranded in one event in Nungwi, Zanzibar, Tanzania (summarised in Berggren *et al*., 2007).

Kenya: Watamu Marine Association

In Kenya, 29 stranding events were reported, but four were not included in this study due to either the lack of any species identification or because they involved non-cetacean species (Appendix 2). Two spinner dolphins stranded together at Watamu Blue Bay on 22 October 2011. A pygmy sperm whale and a sperm whale stranded within two days of each other on 13 and 15 September 2018 at Blue Lagoon and Waa. Also noteworthy is the stranding of a blue whale at Kiwayu on 12 January 2017, and a Blainville's beaked whale (*Mesoplodon densirostris*) in the Sabaki River on 24 November 2004.

Madagascar: Cetamada and Wildlife Conservation Society (WCS)

In Madagascar, 24 stranding events were reported by Cetamada and Wildlife Conservation Society (WCS), with the earliest observed in 2008 (Appendix 2; Collins *et al*., 2009; Southall *et al*., 2013). Stranding events included humpback whale calves near Mahajanga in December 2009 and on Nosy Antafana in August 2018. One mass-stranding event was reported for melon-headed whales in the SWIO: 75 individuals at the Loza Lagoon system near Antsohihy, northwest Madagascar, in 2008.

Madagascar: Institut Halieutique et des Sciences Marines (IHSM), University of Tuléar

On the south-west coast, the Institut Halieutique et des Sciences Marines (IHSM), University of Tuléar, Madagascar, reported eight strandings since 2014. All were dead and assumed to have died of natural causes.

Mayotte: Parc Naturel de Mayotte

The Parc Naturel Marin de Mayotte reported 27 cetacean strandings that occurred between 2005–20 (Appendix 2). Eleven were excluded from our analysis due to: non-cetacean species (n = 3); lack of geographic coordinate location or local geographic identifying features or landmark information (n = 2); or live sighting of animal at sea (n = 6). The most common reported species was the spinner dolphin (n = 7).

Reunion: GLOBICE

On Reunion, sample collection and, when possible, necropsies are conducted systematically by trained and authorised specialists under the French National Stranding network. The organisation GLOBICE reported 39 strandings. Six were excluded due to being outside the study period or undetermined genus/species (Appendix 2).

Eight stranded animals were alive, two of which were refloated. The most common reported species were the dwarf sperm whale (*K. sima*) and pantropical spotted dolphin (*S. attenuata*). Reunion reported the highest number of dwarf sperm whale strandings (n = 6) in the region, three of which occurred at the same location but in different years. Four stranded sperm whales were reported dead, two of which were drifting and did not wash ashore. Out of the four reported humpback whale strandings, two were live stranded calves. The tympanic bullae were collected for four strandings of delphinids with analysis undertaken for two, but no signs of acoustic trauma were identified which could have contributed to the stranding.

Mauritius: Mauritius Marine Conservation Society

The Mauritius Marine Conservation Society reported 20 cetacean stranding events over the study period in the waters of the Republic of Mauritius, including Mauritius Island, Rodrigues and St. Brandon Shoals (Appendix 2). No likely cause of the strandings or anthropogenic factors have been investigated, but a number of interesting events were reported. First, two strandings of Blainville's beaked whale were reported in 2000 and 2019. For one sperm whale that stranded in 2004 on the eastern coast of Rodrigues, a large fishing float in the throat area was identified as the likely cause of death. In 2005, approximately 75 melon-headed whales stranded in the lagoon (Mahebourg Lagoon) south of Grand Sable (Bois des Amourettes and Bambous Virieux) on the south-east coast of the island. A number of short-finned pilot whales stranded alive and subsequently died at St. Brandon, a shoal located approx. 400km north of Mauritius Island. Though 'many' individual whales were reported stranded, the exact count is unknown. Of the 75 melon-headed whales, 35 died in the lagoon. A second event involved up to 200 animals trapped alive in a lagoon near the same location in 2020, resulting in a mass stranding of 52 melon-headed whales and one common bottlenose dolphin. The remaining live animals were driven back out to sea (Plön *et al*., 2021a). A Cuvier's beaked whale (*Ziphius cavirostris*) stranded off the coast of Rodrigues on Flat Island in 2012.

Mauritius: Marine Megafauna Conservation Organisation (MMCO)

Since 2019, the Marine Megafauna Conservation Organisation (MMCO) in Mauritius also responds to strandings (see Appendix 1). Basic information and samples are collected from stranded animals and members participated in the recovery and necropsies of the mass-stranded melon-headed whales in 2020.

Éparses Islands (including Glorieuse and Tromelin): Terres Australes et Antarctiques Françaises

The French agency Terres Australes et Antarctiques Françaises reported two stranding events on the Éparses Islands since 2008, one of which involved four pygmy killer whales (*Feresa attenuata*) stranded at Grande Glorieuse on 17 May 2016. The likely cause of this mass stranding is unknown and no anthropogenic factors were investigated. The other stranding involved a humpback whale calf at Tromelin.

Seychelles: Island Conservation Society (ICS)

Twenty stranding events in total were reported for the Seychelles, 11 in the Farquhar Group of islands and five from the Amirante Islands.

Seychelles: Seychelles Islands Foundation (SIF)

An additional four stranding events were reported by the Seychelles Islands Foundation (SIF). Two Blainville's beaked whales stranded on the same day (1 February 2015). Four melon-headed whales stranded, three in the Farquhar Group of islands, in addition to three sperm whales, two of which also stranded in this island group. Three humpback whales (two adults and a calf) stranded between 22 and 24 September 2017 on Aldabra. No necropsies were conducted; no anthropogenic factors were investigated.

Spatio-temporal variation

Between 2000–2020, stranding events occurred in multiple locations along the coastlines of each of the countries/territories of the SWIO. There were a few sites that appeared to have higher densities of strandings (Fig. 5A–H). The Global Moran's I index, used to generate a global statistic which provides a single value for the

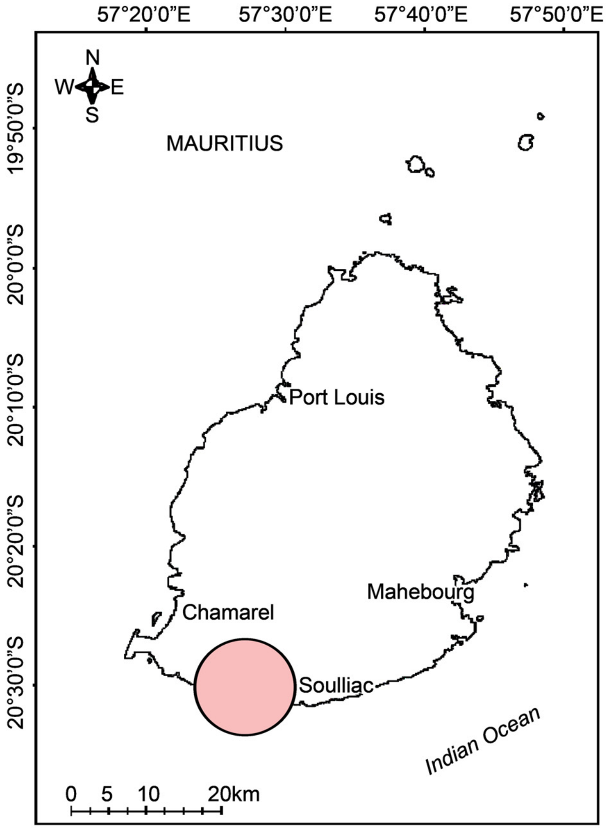

Fig. 7. Location of statistically significant (p < 0.05) cetacean stranding event cluster in Mauritius in the south-western Indian Ocean as described by the permutation space-time analysis.

entire dataset to describe if the stranding events are homogeneously distributed (i.e., not clustered), was not statistically significant ($p = 0.667$). However, given the large expanse of the study area, the Moran's I index was also computed for each country/territory. It was significant for three countries/territories: South Africa ($p < 0.0001$), Mozambique ($p = 0.0007$) and Reunion ($p = 0.0324$), suggesting the spatial distribution of stranding events is more spatially clustered than would be expected if stranding reports were completely random.

Neither the Éparses nor the Seychelles small island groupings had significant stranding clusters upon analysis, but a statistically significant local stranding cluster was identified in Mauritius, located just west of the village of Souillac at the south end of Mauritius (Fig. 7). The cluster area had a 6.3km radius ($p = 0.049$), consisting of four stranding events between Jan–Dec 2000, two involving two animals and two involving two singles.

DISCUSSION

Spatio-temporal patterns

This first stranding analysis for the SWIO presents an important baseline which can be used to measure future impacts from anthropogenic developments in the region as a result of the Ocean Economy. In addition, it has encouraged collaboration between the different countries/territories to contribute towards the overall effort to record and investigate these events. We are aware that a large number of strandings are unreported in the region, so this analysis is a starting point against which future efforts can be measured. While an imperfect dataset, stranding records in the long term may contribute information on changes in cetacean fauna occurrence, density and distribution in the region.

There were several key results from this analysis. First, the finding of significant positive Moran's I correlation coefficients for South Africa, Reunion and Mozambique indicated that, for these three countries, strandings were not independent of each other at the global level, and the underlying reason(s) for the lack of independence is unknown. Second, on a local level, a significant spatio-temporal cluster was detected on the island of Mauritius. Non-significant local clusters were detected in every region/country but are not presented. Some of these might be biologically significant, such as underlying clusters of diseased or ship-struck animals and might warrant further investigation by the respective countries/territories. As more stranding data are collected, spatio-temporal analysis can be repeated in the future to ensure greater precision when detecting 'hotspots' of stranding events that may be of interest and help determine whether they reflect a biologically- or oceanographically-related process (e.g., detection of a warm water event or disease outbreak) or increased reporting effort.

Temporal factors (e.g., breeding season, residency patterns, etc.) and anthropogenic pressures may partially explain the pattern of stranding events reported here (Jackson *et al*., 2015; Webster *et al*., 2020; Dudhat *et al*., 2022; Piwetz *et al*., 2022; Russell *et al*., 2022). The seasonal analysis revealed that strandings occur throughout the year, but the stranding peaks differed between mysticetes and odontocetes. The presence of stranding peaks for mysticetes during the austral winter and spring months (June–Nov) reflects the seasonality of migration, particularly for humpback whales. In contrast, odontocete strandings were greatest in Sep–Nov and almost equally distributed throughout the rest of the year (Figure 3). Compared with stranded mysticetes in other Southern Hemisphere locations, the June–Nov peaks of this study were broader compared to the centered peak around November for Australia (Foord *et al*., 2019), and later in the year than in Chile where peaks occurred in the summer (Jan–Feb) and winter (July). These differences are likely due to latitudinal differences between the study areas (Alvarado-Rybak *et al*., 2020).

It is evident that different levels of expertise exist within the region, both in response to strandings and to investigate the cause of death (including potential anthropogenic factors). While South Africa appears to be a stronghold with long-term systematic data collection already in place, extensive training and capacity building has also been carried out by Observatoire Pelagis, La Rochelle, France, for some of the French Territories, such as Reunion and Mayotte. Significant gaps in resources and expertise in stranding response exist in most other member countries/territories of the IndoCet network. This inequality also leads to difficulties for data comparison due to non-standardised reporting or investigation.

Analyses by species

With 27 species reported, the number of species represented in the stranding record for the SWIO closely mirrors the rich diversity previously reported for the region (Kiszka *et al*., 2009b). The species for which distribution, and, to a lesser degree, density, are most well-known in the SWIO are those most accessible due to their coastal distributions and thus more likely to wash ashore (Heyning and Dahlheim, 1990; Kraus *et al*., 2005; Williams *et al*., 2011). Strandings of humpback whales were reported almost exclusively from June to Dec, coinciding with their presence during calving season (Ersts *et al*., 2011; Dulau-Drouot *et al*., 2012; Van Driessche *et al*., 2020). Southern right whale strandings were exclusively reported in South Africa and thus reflect the documented distribution of the species (Elwen and Best, 2004a, 2004b). Sperm whale strandings occurred in all countries/territories included in this study and closely correspond to previously reported sightings for this species (e.g., Berggren, 2000; Kiszka *et al*., 2006; Dulau *et al*., 2008; Webster *et al*., 2020; Cerchio *et al.*, 2022). All sperm whale strandings were single individuals and occurred in every season.

The volume of stranding records for small- and medium-sized odontocetes was fairly consistent from both opportunistic observations and targeted survey studies. For example, *Stenella* spp. were the most frequently stranded small odontocete species (n = 74 events) and are found throughout the SWIO (Kiszka *et al*., 2006; 2007; Webster *et al*., 2015; Condet and Dulau-Drouot, 2016). *Kogia* spp. were greatly represented in South Africa (Ross, 1979) and Reunion. Records for *Kogia* are not yet published for Reunion but are available through GLOBICE.

Common and Indo-Pacific bottlenose dolphins, known to form resident populations, were the next most common stranded smaller odontocetes, which is consistent with previous studies showing that populations occur close to shore across the region (Pusineri *et al*., 2014; Webster *et al*., 2014; Dulau *et al*., 2017; Pérez-Jorge *et al*., 2015; Estrade and Dulau, 2020). While Indian Ocean humpback dolphins are distributed throughout the SWIO (Findlay *et al*., 1992; Gross *et al*., 2009; Kiszka *et al*., 2010; Elwen *et al*., 2011; Cerchio *et al*., 2015; Plön *et al*., 2015; Mwango'mbe *et al*., 2021; Plön *et al*., 2021b), this was not reflected in the stranding records, as their stranding reports were limited to three countries: Mozambique, South Africa and Tanzania. Strandings of Indian Ocean humpback dolphins were relatively low (n = 7). This may reflect small population size in some regions (e.g., 'Endangered' status), loss of carcasses to scavengers, such as sharks, prevailing currents or other factors (Braulik *et al*., 2017). In the absence of historical data for this species, this result is difficult to interpret.

Implications for management and conservation

Our analysis of spatio-temporal trends of stranding events for the SWIO between 2000–2020 indicates that cetacean stranding reports in the region have steadily increased over the last 10 years, prompting an effort to collate and understand some of the occurrences and patterns related to these events over this wide geographic region. The analysed dataset was built from the cooperative efforts of multiple organisations and agencies that enabled the first comprehensive assessment of cetacean strandings across this region, revealing high cetacean diversity (see Carroll *et al*., 2021). It presents an important baseline to inform future conservation and management efforts. We demonstrate it is possible to combine different datasets (albeit with many caveats) and that further cooperation in the form of communication and data sharing throughout the region will allow level-A data to be made openly available for future combined analysis. This is particularly relevant to detect possible causal connections for regional events that may occur across borders.

As global concerns around anthropogenic impacts on cetaceans continue to increase, the SWIO poses no exception. Our approach is important in view of the planned Ocean Economy developments in the region (Mannocci *et al*., 2013; Ren *et al*., 2016; Findlay, 2018; Mwango'mbe *et al*., 2021; Plön and Roussouw, 2022) which will likely result in an increase of stranding events as Ocean Economy activities increase (Plön *et al.*, 2021a; OECD, 2023). Strandings can provide important information on the biology and health of marine mammals (Williams *et al*., 2011; Rouby *et al*., 2022) and provide baseline data on the species' range, life history parameters (e.g., age, reproductive status, diet) and even the occurrence and prevalence of disease. Given both the importance of stranding records as a valuable source of information regarding the threats to cetacean communities (Pyenson, 2010), and the need to better understand causes of mortality and factors affecting marine animal health (Tucker *et al*., 2018), this approach will help identify population threats and stressors to marine life, especially anthropogenic impacts that can be prevented or mitigated (Peltier *et al*., 2014).

Due to the current need to establish baseline knowledge for many populations in the SWIO, and the lack of response capacity, basic infrastructure and analytical expertise, potential impacts from anthropogenic developments on local cetacean populations may currently go unnoticed. To assess these impacts on a regional scale, the next steps should focus on building capacity through training on health assessments (Lane *et al*., 2014) and standardisation of associated data (see Plön *et al*., 2015). Therefore, the importance of a regional collaborative approach and carrying out detailed necropsies in close collaboration with specialised veterinary pathologists (Lane *et al*., 2014; Roussouw *et al*., 2022) cannot be overstated.

Future efforts should focus on gathering information about anthropogenic impacts on marine mammals from fisheries bycatch, ship strikes, marine debris and other forms of pollution, and aid in detecting unusual mortality events (e.g., Coughran *et al*., 2013). While entanglements were not a specific focus of this study, further data on entanglements in the region, as they relate to beach cast individuals, should be collated to add information on the health status of individual animals and better understand their contribution to cetacean morbidity, mortality and stranding numbers (Amir *et al*., 2012).

As the levels of consumption by local communities may be higher than expected (Ingram *et al*., 2022), and appear to be a common occurrence in Tanzania and Mozambique (Amir *et al*., 2002; Braulik *et al*., 2015; Braulik and Stern, 2019; 2020; Reeve-Arnold *et al*., 2020), as well as an increasing phenomenon on the KwaZulu-Natal coastline, South Africa (Olbers, 2019), the alarmingly high levels of chemical pollutants reported for cetaceans in parts of the region (Dirtu *et al.,* 2016; Gui *et al*., 2016; Aznar-Alemany *et al*., 2019; Plön *et al*., 2023), alongside the global increase in zoonoses over recent years (Tryland, 2018), human consumption of cetaceans in the Indian Ocean region may pose a risk to human health which has been neglected in most discussions. Though bycatch continues to be the number one threat to cetaceans in the Indian Ocean (Anderson *et al*., 2020), sampling even a subset of bycaught animals as representatives of the free-ranging populations in the Indian Ocean may provide a good indication of the health status and thus present information on potential risks to human and cetacean populations alike (Lane *et al*., 2014). As our understanding of marine mammals as indicators of Ocean Health continues to grow (Plön *et al*., 2021b), investigations into the health and cause of death of stranded and/or bycaught marine mammals in this little-known region gain importance, particularly in view of new large-scale anthropogenic Ocean Economy developments in the Indian Ocean.

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Appendix 1

Marine mammal stranding network information for the south-western Indian Ocean.

Region	Responsible stranding network	Stranding data availability	Area of operation	Samples collected/Stranding aspects investigated
Western Cape, South Africa	National Department of Forestry, Fisheries and the Environment (DFFE) operating under The South African Stranding Network	Stranding data is available from 1988 onwards and the effort has been maintained to date. The Mammal Research Institute (MRI) Whale Unit, University of Pretoria, South Africa, has also responded to strandings since its initiation in 1985, but data is available since 1960 (ref. Prof Peter Best).	This network is chiefly informal (not gazetted). DFFE's research unit in Cape Town responds to strandings between Grootbraak River mouth and Olifants River mouth and coordinates data collection efforts and responses in the Northern Cape, where a formal effort is lacking (includes strandings in reserves, diamond mines and private properties).	Dissection training and long-term storage of samples takes place at this facility. Effort within the responding distance includes systematic collection of biological data from comprehensive dissections (smaller cetaceans) and basic sample collections from large cetaceans. Currently no suitable facility exists for large cetacean dissections within the area.
Eastern Cape/KwaZulu-Natal, South Africa	Port Elizabeth Museum (PEM)/Bayworld	The PEM has reported to strandings since the late 1970's (Ross, 1984).	Data and samples have been collected from strandings along the south-eastern coast of South Africa between Mossel Bay in the west and the border to Mozambique in the north.	Since 2010, systematic investigations about the cause of death, including possible anthropogenic factors, have been conducted for the Eastern Cape region following a veterinary-pathology protocol that proposed systematic and standardized investigations for comparative purposes (Plön *et al.*, 2015).
KwaZulu-Natal, South Africa	Ezemvelo KwaZulu-Natal Wildlife	Ezemvelo has participated in stranding responses since 2010.	Ezemvelo is a provincial agency that is mandated to perform biodiversity protection and nature conservation in the province of KwaZulu-Natal.	It has reported 135 strandings over the past 10 years (2010–2020); however, in most cases, the likely causes for the stranding were not investigated, unless obvious physical injuries were observed and reported.
Mozambique	Dolphin Encountours Research Center (DERC) in collaboration with the Natural History Museum Maputo and the Ponta do Ouro Partial Marine Reserve.	DERC has responded to strandings since 1997 and has maintained a data sheet with the stranding records.	DERC collects data and samples between Ponta do Ouro and Santa Maria in Mozambique.	DERC collects samples and provides them to the Natural History Museum in Maputo. Specimens are collected and stored for educational display purposes at the Center in Ponta Do Ouro.
	Lúrio University operates further north.	Lúrio University has reported a few strandings since 2017.	Lurio University (Faculty of Natural Sciences) is a public University that conducts marine research off Vamizi Island and other coastal areas in the Northern part of Mozambique.	The Faculty of Natural Sciences at Lurio University has reported four stranding events between 2017 and 2019; however, no samples were taken for further investigations. The animals reported did not show any visible physical injury.
	All Out Africa Marine Research Centre in collaboration with Eduardo Mondlane University Maputo and the Natural History Museum, Maputo.	All Out Africa Marine Research Centre has reported strandings since 2009.	All Out Africa Marine Research Centre are responding to strandings in the Tofo-Inhambane area and are available for long-distance support regarding strandings across Mozambique.	All Out Africa Marine Research Centre collates stranding reports, attends in person where possible and records data in a standardised way. Where possible photographs, eye-witness reports, samples of skin/blubber/muscle/gut/liver/lung tissue and skeletal remains are collected. Also collects data on the management and outcome of each stranding in relation to opportunistic take as aquatic bushmeat.
Tanzania	Individual researchers, Institute for Marine *Science, Dar es Salaam, and the Tanzania Whale Network.*	Information on animals stranded and bycaught since 2004.		A number of individuals have been reported as consumed by locals, including *Sousa plumbea* and *S. longirostris*. Previous strandings in Tanzania are summarized in Amir et al. (2002, 2012). Amir et al. (2012; Table 1) investigated the cause of strandings, but that data was not available to be included in this analysis. None of the likely causes of the strandings documented for use in this paper are known or have been further investigated and there is no organized stranding response.

Region	Responsible stranding network	Stranding data availability	Area of operation	Samples collected/Stranding aspects investigated
Kenya	Watamu Marine Association	Strandings reported since 2004.	The entire Kenyan coast, from Vanga (bordering Tanzania) on the south to Shakani (bordering Somalia) to the north. In collaboration with Kenya Wildlife Service and Fisheries stations, under a citizen science platform – The Kenya Marine Mammal Network.	Necropsies to further investigate possible causes of strandings have been conducted on four animals stranded since 2018.
Reunion	Globice, coordinator of the stranding network in Reunion, as part of the French Stranding Network.	Strandings reported since 1993.	Globice is the coordinator of the stranding network in Reunion, as part of the French Stranding Network. Data are collected all around the island of Reunion, by trained and authorised staff and veterinary personnel.	Globice reported 35 strandings since 1993. Data and samples are collected based on the protocol of the French stranding Network. Since 2010, Globice systematically performs necropsies for each stranded animal, involving at least a veterinarian to investigate possible causes of stranding/death.
Seychelles (inc. Aldabra Atoll and other islands)	Seychelles Islands Foundation (SIF)	SIF has reported stranding data from Aldabra since 2017.	SIF is a non-profit organisation, established as a public trust by the government of Seychelles in 1979. SIF is responsible for the management and protection of the UNESCO World Heritage Sites of Aldabra Atoll.	SIF reported one stranding event in 2017 from Aldabra. Data from stranding events are recorded in the opportunistic sighting database. Skin and blubber samples have been collected from the event and are pending further analysis. There is currently no facility or in-house capacity for cetacean dissection and subsequent analysis.
	Island Conservation Society (ICS)	ICS reported stranding data since 2009 from the Seychelles (incl. Farquhar, Desroches, Aride, Silhouette and Alphonse islands).	ICS has reported 16 stranding events.	ICS collects standard level A data and information on signs of human interactions.
Mayotte	Parc Naturel Marin de Mayotte, coordinator of the Stranding Network of Mayotte (REMMAT) as part of the French Stranding Network	Information available since 2005.	REMMAT is responsible for the management of strandings in the territorial waters of Mayotte, including its EEZ.	Necropsies are conducted and samples are taken when possible, often at the stranding site. Since 2005, six necropsies have been performed and samples have been taken from 10 animals. REMMAT follows the French RNE necropsy and sampling protocols.
Mauritius (inc. Mauritius, Rodrigues and St. Brandon)	Mauritius Marine Conservation Society (MMCS)	Strandings reported since 1984.	Mauritius, Rodrigues and St. Brandon	Tissue samples and skulls collected where possible.
	Marine Megafauna Conservation Organisation (MMCO)	Information on animals stranded since 2019.	MMCO is an organisation dedicated to the study and conservation of the marine megafauna of Mauritius; it has been assessing dead marine mammals, collecting samples and data and attending necropsies.	MMCO has assessed stranded marine mammals since 2019 and also collected samples and participated in the recovery and necropsies of stranded melon-headed whales in 2020.
Comoros	Oulanga na nyamba Association			
Madagascar	Institut Halieutique et des Sciences Marines (IHSM)	Strandings reported since 2000.	Tuléar, Madagascar	Data collected from fishermen from the Association for the Protection of Whales and Dolphins (FMTF), friends, and NGOs. Data are collected on date, species, site, collector, and threat (e.g., stranding, hunting and bycatch).
	Cetamada	Strandings reported since 2009.	North-east coast of Madagascar.	Data collected by Cetamada's scientific team or reported by Cetamada's local partners. Data collected include: date, location, species, body measurements, photographs, and any relevant information on the stranded animal. Cetamada's scientific team perform necropsies to investigate possible causes of death. Genetic samples are collected when possible.
Eparses Islands (inc. Glorieuses and Tromelin)	Terres Australes et Antarctiques Françaises (TAAF)	Two stranding events reported in 2008 and 2016.	*TAAF* is administrating the Islands of Tromelin, Glorieuses, Juan de Nova and Bassas da India in the SWIO, and the subantarctic islands of Crozet, Kerguelen and St Paul and Amsterdam.	Strandings are reported by members of staff or partners on the islands.

Appendix 2

Cetacean stranding events (individuals) in the south-western Indian Ocean by country/territory and species, 2000–20.

Species	South Africa	Mozambique	Tanzania	Kenya	Madagascar	Mayotte	Réunion	Mauritius	Éparses	Seychelles	Comoros
Balaenoptera acutorostrata	2(2)										
Balaenoptera brydei	15(15)										
Balaenoptera musculus				1(1)							
Balaenoptera spp.					1(1)						
Delphinidae spp.							1(1)				
Delphinus delphis	7(7)	1(1)	1(1)								
Eubalaena australis	5(5)										
Feresa attenuata							1(1)		1(1)		
Globicephala macrorhynchus	2(2)			1(1)			3(3)	1(unknown)		1(1)	
Globicephala spp.		1(1)			1(1)						
Grampus griseus	5(5)	1(1)		1(1)		1(1)				3(4)	
Kogia breviceps	4(4)	1(1)		3(3)	1(1)						
Kogia sima	3(3)	1(1)					6(6)			1(1)	
Kogia spp.	3(3)							1(1)			
Lagenodelphis hosei		3(3)									
Megaptera novaeangliae	72(72)	9(9)	5(5)	2(2)	20(20)	1(1)	4(4)		1(1)		1(1)
Mesoplodon densirostris				1(1)				2(4)		1(2)	
Mesoplodon eueu	1(1)	2(3)									
Mesoplodon grayi	1(1)										
Mesoplodon hotaula										1(1)	
Mesoplodon layardii	1(1)										
Mesoplodon spp.	1(1)										
Peponocephala electra		1(1)		2(2)	1(100)	2(2)	3(3)	2(120)		5(6)	
Physeter macrocephalus	5(5)	1(1)	8(8)	4(4)	7(7)	1(1)	4(4)	7(7)		4(4)	1(1)
Pseudorca crassidens	1(1)							1(1)			
Sousa plumbea	4(4)	1(1)	2(2)								
Stenella attenuata	6(6)	5(5)					6(6)				
Stenella coeruleoalba	16(16)	5(5)		2(2)		1(1)	1(1)				
Stenella longirostris	6(6)	4(4)	3(3)	4(4)	1(1)	7(7)	2(2)	2(3)		2(3)	
Tursiops aduncus	5(5)	7(7)	2(14)	4(4)		1(1)					
Tursiops spp.			1(1)			1(1)	1(1)				
Tursiops truncatus	15(15)	1(1)	1(600)			1(1)		3(3)		1(1)	
Ziphius cavirostris			1(1)				1(1)	1(1)			
TOTAL	**180(180)**	**44(45)**	**24(635)**	**25(25)**	**32(131)**	**16(16)**	**33(33)**	**20(140)**	**2(2)**	**19(23)**	**2(2)**