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8.
MARINE MAMMALS

Table of contents

Previous page: Striped dolphin, rare in the SWIO. Photo by Peter van der Elst.

8. MARINE MAMMALS

A review of status, distribution and interaction with fisheries in the Southwest Indian Ocean

Jeremy Kiszka[1]

Abstract

Information on diversity, spatial and temporal distribution, abundance, population structure of marine mammals in the Southwest Indian Ocean (SWIO) is relatively limited, despite evidence for exposure of these vulnerable species to a variety of threats. This chapter reviews existing information on the status and conservation issues of marine mammals in the SWIO, from 0 to 30°S, from eastern Africa to 60°E. Within the region, a total of 37 marine mammal species have been recorded (authenticated records, including sightings and/or strandings), including 32 cetaceans, 1 sirenian (the dugong *Dugong dugon*) and 4 pinnipeds (30% of global marine mammal biodiversity). Species diversity and distribution have been undertaken in many areas within the region. The existing literature does not provide sufficient information to identify cetacean hotpots in the SWIO, but it seems that oceanic islands and archipelagoes provide quality habitats for a diversity of toothed cetaceans. Among cetaceans, the humpback whale (*Megaptera novaeangliae*) is the most common and widely distributed large whale species during austral winter. The region constitutes a major breeding ground for this species in the southern hemisphere. The amount of knowledge on abundance and distribution of other large cetaceans is far more limited in the SWIO. The dugong is most likely the most endangered marine mammal species in the region. Dugongs have progressively declined in most countries of the region, and the only known viable population is located in the Bazaruto Archipelago, Mozambique. While bycatch is the most important threat to marine mammals, including the dugong, in the SWIO, other threats, including disturbance and noise pollution, have been identified. Overall, marine mammal knowledge has significantly increased over the last decade in the SWIO. However, many gaps remain on the location of hotspots of abundance and on the impact of major threats on their populations, especially through bycatch.

Introduction

Information on diversity, spatial and temporal distribution, abundance, and population structure of marine mammals in the southwest Indian Ocean (SWIO) is relatively limited. However, it has been highlighted that several marine mammal species were exposed to significant anthropogenic impacts, including disturbance, bycatch, and hunting.

This chapter reviews distribution, status, and population structure of marine mammals in this region. It also reviews interactions between these vulnerable species and fisheries, including bycatch, hunting as well as depredation. The geographical area considered in this synthesis includes the EEZ of eastern South Africa (Port Elizabeth as the westernmost limit), Mozambique, Tanzania, Kenya, the Seychelles, Madagascar, the Comoros, the French EEZ (Mayotte, Geyser and Zélée banks, Glorieuses, Juan de Nova, Europa, Bassas da India, Tromelin and La Réunion) and Mauritius. International waters of the region are also considered. The geographical range of the study area extends from 0 to 30°S, from eastern Africa to 60°E.

1. Florida International University, School of Environment, Arts and Society (SEAS), Miami. Email: jkiszka@fiu.edu

Marine mammals in the SWIO: Country overview of status, distribution, abundance and population structure

Cetaceans fall into two principal orders, mysticetes (baleen whales) and odontocetes (toothed whales). Only one species of sirenian occurs in the SWIO, the dugong (*Dugong dugon*). Extra-limital records of pinnipeds have also been recorded on various tropical islands, such as Madagascar (Garrigue & Ross 1996) and the Comoros Archipelago (David *et al.* 1993), for example. However, pinnipeds are not regularly present in the region. The closest area where pinniped colonies are present are located along the south and southwest coasts of South Africa and involve the South African fur seal (*Arctocephalus pusillus*) (Best 2007).

Among baleen whales, there are still several taxonomic uncertainties regarding the status and identity of several species. Nevertheless, there are currently nine species known to occur in the SWIO region. Within the blue whale group, two subspecies co-occur: the Antarctic blue whale (*Balaenoptera musculus intermedia*) and the pygmy blue whale (*B. m. brevicauda*). Concerning the toothed whales, some uncertainties exist regarding the range of several species, especially among beaked whales (Ziphiidae). For example, there are a number of unpublished records of sightings of anti-tropical species, such as True's beaked whale (*Mesoplodon mirus*) around Mayotte (eastern Comoros) (M. Vely, personal communication) and Shepherd's beaked whale (*Tasmacetus shepherdi*) off the Seychelles (G. Doremus, personal communication). Unconfirmed records of ginkgo-toothed beaked whale (*Mesoplodon ginkgodens*) also exist from Mayotte (Kiszka *et al.* 2007a) and eastern Madagascar (Ballance & Pitman 1998).

Within the SWIO area, a total of 37 marine mammal species has been recorded (authenticated records, including sightings and/or strandings), including 32 cetaceans, one sirenian (the dugong) and four pinnipeds (see Annex).

COUNTRY OVERVIEWS

South Africa (eastern region)

Extensive research has been undertaken on southern African marine mammals that commenced with the analysis of whaling data from Durban (Best 2007). A total of 41 species of cetaceans has been recorded in South Africa, 34 of these from the coast of the Indian Ocean. Along the east coast of South Africa, the most common species are the bottlenose dolphin (*Tursiops* spp.), Indian Ocean humpback dolphin (*Sousa plumbea*, Jefferson & Rosenbaum, 2014) and long-beaked common dolphin (*Delphinus capensis*). This latter species is seasonal in the region, being abundant during the winter sardine run, from June to August (between 15,000 and 30,000 individuals; Cockcroft *et al.* 1992). The inshore waters of KwaZulu-Natal also serve as a migration corridor for wintering humpback whales (*Megaptera novaeangliae*). Shore-based surveys of northward migrating humpback whales from Cape Vidal, northern KwaZulu-Natal between 1988 and 1999, suggested a population estimate of 1,700 individuals in 1990 (Findlay *et al.* 1994; Findlay & Best 1996). A further year of survey was conducted in 2002 and an increase of 9.9% per annum has been calculated for the period (Findlay & Best 2006). During the winter months, southern right whales (*Eubalaena australis*) congregate at certain sites to breed and calve, extending from the southwest coast of South Africa to Maputo. Southern right whales use sheltered bays and calm waters around small coastal islands during this season (Best 1990). The most significant wintering zone of this species is located between Port Elizabeth and Cape Town. Right whales arrive in the region's coastal waters in June and then depart by December. Calving peak occurs in August. From 1979 to 1998, the population calving on the south coast of South Africa increased at 7.1% a year. Another whale species that is frequently observed off the Indian Ocean coast of South Africa is the Bryde's whale (*Balaenoptera brydei*), particularly during austral winter, often associated with the migration of sardines (Best 2007).

Along the east coast of South Africa, most delphinid information collected relates to Indo-Pacific bottlenose (*Tursiops aduncus*) and Indian Ocean humpback dolphins

Humpback whale. (Photo: Jeremy Kiszka)

(hereafter humpback dolphins). Around 270 resident humpback dolphins occur in Algoa Bay. However, the total South African population is estimated at about 1,000 individuals (Karczmarski *et al.* 1999). Abundance estimates for *T. aduncus* have been documented for a section of the KwaZulu-Natal coast (Durban to 80km north) in 1984, 1985 and 1989, with 367, 433 and 520 dolphins (95% CI 156-970), respectively (Cockcroft *et al.* 1992). Another survey from the coast of Durban to 100km southwards produced uncorrected counts of 219-249 individuals in 1985 and 98-132 in 1990 (Cockcroft *et al.* 1992). A study of *T. aduncus* abundance in Algoa Bay suggested a population size of 28,482 individuals (95% CI= 16,220–40,744; CV= 0.220; estimate corrected for the proportion of distinctive individuals in the population; Reisinger & Karczmarski, 2010). This is the largest population estimate to date for this species along the South African coast, suggesting that Indo-Pacific bottlenose dolphins inhabiting the Algoa Bay region represent part of a substantially larger population that ranges along a considerable length of the South African coast (Reisinger & Karczmarski 2010).

Mozambique

Limited published information exists on the status and distribution of marine mammals in Mozambique. Mozambican waters are frequented by three species of large whales (humpback whale, minke whale *Balaenoptera acutorostrata* and sperm whale *Physeter macrocephalus*) and ten delphinid species (Rice & Saayman 1987; Findlay *et al.* 1994; Peddemors *et al.* 1997; Jefferson & Karczmarszki 2001). Humpback whales are the most common baleen whale species in Mozambique coastal waters, especially during austral winter. A survey in coastal waters between 14°26'S and 26°S, provided an abundance estimate of 5,811 humpback whales (Findlay *et al.* 1994).

Very little is known on the occurrence and distribution of other cetacean species. The rough-toothed dolphin (*Steno bredanensis*) has been reported from the Zambezi region (Best 1971). The most common cetaceans in Mozambique coastal waters are Indo-Pacific bottlenose dolphins and humpback dolphins, especially in Maputo Bay (105; 95% CI 31-152 humpback dolphins in Maputo; Guissamulo & Cockcroft 2004) and the Bazaruto Archipelago. Around Bazaruto, the abundance estimate of humpback dolphins is 165 (95% CI 118-277; Guissamulo & Cockcroft 2004). In general, individuals of bottlenose and humpback dolphins present an inverse seasonal trend; bottlenose dolphins are more abundant in winter while humpback dolphins are more common during summer.

The largest remaining dugong population in the SWIO region is believed to be in the Bazaruto Archipelago in Mozambique, where aerial surveys conducted between April 2006 and December 2007, estimated 247 animals (Cockcroft *et al.* 2008; Findlay *et al.* 2011). These authors suggest populations are declining and as the only viable population in the region are especially vulnerable. In other coastal areas of Mozambique, dugong appear relatively rare (WWF EAME 2004; Muir & Kiszka 2012).

Tanzania (including Zanzibar)

Eleven species of marine mammals have been recorded in Tanzania, including Zanzibar (Unguja Island). Dolphin species present include Indo-Pacific bottlenose dolphin, humpback dolphin, pantropical spotted dolphin (*Stenella attenuata*), spinner dolphin (*Stenella longirostris*), Risso's dolphin (*Grampus griseus*), rough-toothed dolphin and common bottlenose dolphin (*T. truncatus*) (Amir *et al.* 2002, 2005). Around Zanzibar, the most common species are Indo-Pacific bottlenose, humpback and spinner dolphins (Stensland *et al.* 1998; Amir *et al.* 2002, 2005). The most common large whale species is the humpback whale that migrates to shallow coastal waters every austral winter to breed and calve. Monitoring of Indo-Pacific bottlenose and humpback dolphins has been conducted off the south coast of Zanzibar since 1999. Population estimates range between 136 (124-172, 95% CI) and 179 (167-212, 95% CI) for Indo-Pacific bottlenose dolphin, and between 58 (56-79, 95% CI) and 65 (62-102) for humpback dolphins, in the approximately 26 km² study area (Stensland *et al.* 2006).

The dugong is very rare along the entire coast of Tanzania. However, the most important dugong habitats are associated with the Rufiji Delta east to Mafia Island and south to Kilwa, an area characterized by extensive shallow seagrass beds and sheltered bays and channels (Muir & Kiszka 2012). The exact size and range of the population in Tanzania is unknown, but anecdotal reports and infrequent captures indicate that numbers are very depleted (WWF EAME 2004).

Kenya

Very little is known on the diversity, distribution and occurrence of marine mammals off the coast of Kenya. Information is available from two main reports (Wamukoya *et al.* 1996; WWF EAME 2004). Aerial surveys were conducted in coastal waters of the entire seaboard in November 1994, using both aircraft and helicopters (254 hours of air time). No large whales were recorded, but five dolphin species were positively identified: common dolphin, Indian Ocean humpback dolphin, spinner dolphin, pantropical spotted dolphin and bottlenose dolphin (Wamukoya *et al.* 1996). The bottlenose dolphin species observed was *T. aduncus*, according to the technical supervisor of the survey (V.G. Cockcroft, personal communication). However, the identification of some species is somewhat uncertain. A further research programme has focussed on the residency and abundance of Indo-Pacific bottlenose dolphins in the Kisite-Mpunguti Marine Protected Area (largest MPA in Kenya), off the south coast of Kenya. A closed population model estimated a population size of 119 (95% CI 108-146) in 2006 and 122 (95% CI 110-143) in 2008. Movement patterns suggest this population is resident year-round (Perez *et al.* 2010).

In 2006 near-daily boat-based surveys, during four ten-week periods, of humpback dolphins took place in a 80 km² section of the Kisite Marine Park. Surveys involved 167 survey trips and used photographic identification as a mark–recapture technique. Estimated population size was 104 individuals (95% CI 67-160). Results suggest this to be an important humpback dolphin location and one that sustains dolphin-based tourism (Meyler *et al.* 2012).

Dugongs occurred in large numbers before the 1960s. A large aggregation of around 500 individuals had been seen in the south in 1967 (WWF EAME, 2004). This species declined drastically in the recent decades due to hunting and bycatch in gillnets. In 1994, the aerial survey conducted by Wamukoya *et al.* (1996) of the entire Kenyan coast recorded 10 dugong sightings, notably in the Tana delta area and in the Lamu Archipelago. Currently, dugong are only present in very small numbers, mostly confined to the Tana Delta area, the Lamu Archipelago and Kiunga (WWF EAME 2004; Muir & Kiszka 2012).

Union of the Comoros

A preliminary assessment of cetacean diversity was published in 2010 (Kiszka *et al.* 2010a). Twelve species of cetaceans have been recorded around the Comoros, including humpback whales that migrate to inshore waters for reproduction in winter. Around the Comoros, there is strong evidence that this species is common during austral winter, particularly from July to October (Ersts *et al.* 2011a). The high proportion of mother-calf pairs around the Comoros indicates this area constitutes an important nursing ground for this species (Kiszka *et al.* 2010a). The other most common species are spinner dolphin, pantropical spotted dolphin and melon-headed whale (*Peponocephala electra*). Other species have been observed, such as short-finned pilot whale (*Globicephala macrorhyncus*), Blainville's beaked whale (*Mesoplodon densirostris*) and Longman's beaked whale (*Indopacetus pacificus*) (Anderson *et al.* 2006; Kiszka *et al.* 2010a).

Dugongs still occur in the Comoros, especially in the Mohéli Marine Park, but in small numbers (WWF EAME 2004; Muir & Kiszka 2012). One species of pinniped, the subantarctic fur seal (*Arctocephalus tropicalis*), has been recorded (vagrant individual) on the island of Anjouan (David *et al.* 1993).

Mayotte (including Iris, Zélée and Geyser banks) and French dispersed islands

The diversity and distribution of marine mammals have been assessed around Mayotte (Kiszka *et al.* 2007a, 2007b, 2010b). The variety of available marine habitats around the island, in close proximity to one another, may well explain the high diversity of marine mammals in this area. Many genera of cetaceans are represented around Mayotte, especially delphinids (bulk of cetacean diversity), but also kogiids (dwarf sperm whale, *Kogia sima* and pygmy sperm whale, *K. breviceps*), physeterids (sperm whale), ziphiids (Blainville's beaked whale, Longman's beaked whale, Cuvier's beaked whale (*Ziphius cavirostris*), probably ginkgo-toothed beaked whale) and balaenopterids (humpback and blue whales and probably minke whale (Kiszka *et al.* 2007a; Kiszka 2010; Kiszka *et al.* 2010b). Humpback whales occur during austral winter for breeding. The high proportion of mother-calf pairs suggests that the surrounding waters of Mayotte constitute a nursing ground for this species in the region (Ersts *et al.* 2011a), like around the other Comorian islands (Kiszka *et al.* 2010a). The diversity of dolphins is particularly important around Mayotte, and several species are resident, especially Indo-Pacific bottlenose and humpback dolphins, spinner dolphins, pantropical spotted dolphins and the melon-headed whale.

Other oceanic species also occur, such as Risso's dolphin, short-finned pilot whale, Fraser's dolphin (*Lagenodelphis hosei*), false killer whale (*Pseudorca crassidens*), killer whale (*Orcinus orca*), pygmy killer whale (*Feresa attenuata*) and common bottlenose dolphin (Kiszka *et al.* 2010b). In addition, two other species have been recorded but are considered as very rare in the area: the rough-toothed dolphin and the striped dolphin (*Stenella coeruleoalba*) (Kiszka 2010). Dugong occur in small numbers in the lagoon although this species has declined since the early 80's due to hunting and as bycatch in several fisheries. Probably less than 10 individuals are present throughout the lagoon currently (Kiszka *et al.* 2007b; Pusineri *et al.* 2013).

Preliminary abundance estimates obtained from aerial surveys suggest a total number of 41 Indo-Pacific bottlenose dolphins (95% CI 30-67), 703 spinner dolphins (95% CI 643-1,046) and 375 pantropical spotted dolphins (95% CI 342-557) (Kiszka 2010). Using photo-identification data from 2004 to 2008, estimated annual abundances of bottlenose dolphins ranged from 47 ± 18 to 98 ± 50 individuals, suggesting low population size across its range around the island (estimated population home range is 978 km^2, Pusineri *et al.* 2014). Reef banks off north and north-eastern Mayotte (Iris, Zélée and Geyser banks) have been surveyed in 2002 and 2003, especially to evaluate the density and group composition of wintering humpback whales. The densities of humpback whales ranged from 0.027 to 0.618 whales/nm^2 across three reef banks. Females with calves were the most frequently encountered group type. Encounter rates ranged from 0.98 to 2.36 groups per hour of search effort. These results confirm that the eastern region of the Comoros may be an important area for humpback whales during the late austral winter months (Ersts *et al.* 2011a). Other cetacean species recorded in the shallow waters of these banks, including spinner, spotted dolphins and (only on Iris) Indo-Pacific bottlenose dolphins (Ersts *et al.* 2011a).

Aside from Mayotte, very little is known on the diversity and occurrence of marine mammals around the other French dispersed islands (*îles éparses*) in the Mozambique Channel (Europa, Bassas da India, Juan de Nova, Glorieuses and Tromelin). Dugong are absent around these isolated

False killer whales. (Photo: Jeremy Kiszka)

islands. In 2009, a survey recorded 11 cetacean species in the surrounding waters of these islands (Doremus *et al.* 2009). The spinner dolphin appears the most common species in the inshore waters of Juan de Nova and Glorieuses islands. However, the common bottlenose dolphin was the most frequently encountered species in the offshore waters of Juan de Nova. Around Europa, two species of large whales were recorded: the fin whale (*Balaenoptera physalus*) and the sperm whale (Doremus *et al.* 2009). Strandings have also been reported from the French dispersed islands: a Risso's dolphin and a Cuvier's beaked whale on Juan de Nova, and a dwarf sperm whale on Grande Glorieuse (Doremus *et al.* 2009). The pygmy sperm whale has also been reported from Tromelin Island, off north-eastern Madagascar (Chantrapornsyl *et al.* 1991).

Madagascar

A review of marine mammal diversity indicates the presence of 27 species (Rosenbaum 2003). Some species (especially pinnipeds) are vagrants, such as the crabeater seal (*Lobodon carcinophagus*) and the subantarctic fur seal (*Arctocephalus tropicalis*) (Garrigue & Ross 1996; Rosenbaum, 2003). Baleen whales have been identified, including blue whale, fin whale, pygmy right whale (*Caparea marginata*) and southern right whale. However, the humpback whale appears to be the most abundant species (Rosenbaum 2003). Each year, during the austral winter, a large number of humpback whales aggregate on the known breeding grounds along the southeast coast, especially between Cap Sainte Marie south of Tolagnaro and Antongil Bay (Rosenbaum *et al.* 1997; Ersts & Rosenbaum 2003; Vahoavy 2003) and along the west coast (Cerchio *et al.* 2009; Benbow 2008). Other species recorded include four beaked whale species, pygmy and dwarf sperm whales and at least 10 delphinid species (Rosenbaum 2003).

Indo-Pacific bottlenose and humpback dolphins are the most common species of the 20 odontocetes present and are predominantly distributed along the west and north-east coasts (Cockcroft & Young, 1998; Rosenbaum, 2003; Razafindrakoto *et al.* 2004; Cerchio *et al.* 2009). Between 2004 and 2007, small vessel-based cetacean surveys were undertaken in the southwest region of Madagascar (covering approximately 60 km of coastline; Cerchio *et al.* 2009). Eight dolphin and two baleen whale species were recorded. The encounter rate of humpback whales is high during the breeding season, indicating that the region is an active breeding area (Cerchio *et al.* 2009). Since 2007, new small vessel-based surveys have been done in the northwest, especially in the Nosy Be region. Encounter rates and group size of coastal dolphins (particularly *T. aduncus* and *S. chinensis*) were significantly higher than in the south-western region. Initial interviews with local fishermen highlighted that dolphins were not hunted around Nosy Be, which may explain the higher occurrence of dolphins in the northwest (Cerchio *et al.* 2009).

The dugong is known to occur in Madagascar but its status remains unclear (WWF EAME 2004). However, in late 2009, during a dedicated aerial survey, seven dugong sightings were recorded in the northwest region (Ridoux *et al.* 2010; Muir & Kiszka 2012). The northwest coast of Madagascar is suspected to be an important area for dugong in the SWIO, but more quantitative surveys are needed to assess the distribution and abundance of this species.

Abundance estimates exist for two large whale species migrating off Madagascar: humpback whale and blue whale (presumably *B. m. brevicauda*) (Best *et al.* 2003). The population size of blue whales on the Madagascar Plateau was estimated between 424 (CV=0.42) and 472 (CV=0.48) (Best *et al.* 2003). An estimate of 2,532 (CV=0.27) humpback whales resulted from a yacht-based survey conducted in 1994 off southern Madagascar (Best *et al.* 1996). Johnston & Butterworth (2005) extrapolated this estimate up to 6,172 whales in 2003 using the preliminary increase rate based on the observations conducted from Cape Vidal, in South Africa. A mark-recapture model for Antongil Bay (NE coast) produced an estimate of 1,746 for the period 1996-1999. A subsequent abundance estimate of 8,325 (95% CI 2,323-14,328) humpback whales migrating in this bay was proposed for the periods between 2000 and 2006 (IWC, 2009).

Seychelles

The Seychelles Archipelago, including the Amirantes and Aldabra, was an important whaling ground for American whalers during the 19th Century (Wray & Martin, 1983). Leatherwood *et al.* (1984) reported the presence of sperm whales (including over the Seychelles Bank, east of Bird Island), spinner dolphins and bottlenose dolphins in Seychelles waters. Robineau (1991) recorded Bryde's whales offshore, west of the Seychelles, as well as blue and fin whales. Cetacean sightings and related environmental features were recorded during a NOAA survey (not targeting cetaceans) in 1995 covering a wide area of the western Indian Ocean, including oceanic waters of the Seychelles (Ballance & Pitman 1998). The most common species observed in this area were, in order of occurrence: sperm whales, spinner dolphins, striped dolphins, bottlenose dolphins and pilot whales (unspecified species, but likely short-finned pilot whale). Other species have been observed, including rough-toothed dolphins, dwarf sperm whales, pygmy sperm whales, melon-headed whales, pygmy killer whales and beaked whales (*Mesoplodon* spp). Longman's beaked whales have been recorded on several occasions in the Seychelles (Anderson *et al.* 2006). Off the atoll of Aldabra, opportunistic sightings have been collected for the period 1973-2007 by field workers. A total of 14 species of marine mammals was reported, including humpback whales (during austral winter), spinner dolphins, common bottlenose dolphins, short-finned pilot whales and the dugong. A total of 28 species has been recorded for the entire Seychelles' waters (Hermans & Pistorius 2008).

The dugong occurs in small numbers at Aldabra atoll (WWF EAME 2004). Subsequent changes in dugong numbers at Aldabra remains unknown (Hermans & Pistorius 2008). A recent study indicates that the most suitable dugong habitat is located in the central western area inside the atoll (Hamylton *et al.* 2012).

La Réunion

Ten species of cetaceans have been recorded around La Réunion (Dulau-Drouot *et al.* 2008). Dugong and pinnipeds are not present around the island. A few vagrant pinnipeds, such as the southern elephant seal (*Mirounga leonina*) and the subantarctic fur seal have been observed as strandings (V. Dulau-Drouot, personal communication). The most common species of cetaceans are the Indo-Pacific bottlenose dolphin, the spinner dolphin, the common bottlenose dolphin and the pantropical spotted dolphin (Dulau-Drouot *et al.* 2008). Indo-Pacific bottlenose dolphin show a high degree of site fidelity close to shores, especially on the west coast (Baie de Saint Paul, Saint Leu; Dulau-Drouot *et al.* 2008). Oceanic species are also observed occasionally, especially the melon-headed whale, the short-finned pilot whale and the Fraser's dolphin. Every austral winter, humpback whales aggregate to breed. During 2004-2010, surveys were conducted in the coastal waters of La Réunion, suggesting an increasing occurrence of humpback whales since 2007. In addition, between-year recaptures were reported for 2009-2010, with five individuals re-sighted on consecutive years (Dulau-Drouot *et al.* 2012). The southern right whale (three sightings) and the Bryde's whale (one stranding) have also been recorded around the island but they appear to be very rare (Kiszka *et al.* 2008a).

Mauritius

Early cetacean records mention the presence of the Blainville's beaked whale around Mauritius (Michel & Van Bree 1976). Corbett (1994) provided the most detailed study on the diversity and occurrence of cetaceans off the island. This report documents the presence of 13 cetacean species in the waters of Mauritius. The spinner dolphin (in inshore waters) and the sperm whale (offshore) were the most commonly encountered species. Other species that have been recorded include blue whales, humpback whales during austral winter and fin whales. Odontocete species include the pantropical spotted dolphin, Indo-Pacific bottlenose dolphin, common bottlenose dolphin, short-finned pilot whale, striped dolphin, Risso's dolphin, pygmy killer whale and melon-headed whale (Corbett 1994). Indo-Pacific bottlenose dolphins are also commonly encountered in coastal waters and occur in sympatry with spinner dolphins, particularly off the west coast such as in the Bay of Tamarin (Cadinouche *et al.* 2010). Population estimates of these two species have been produced using mark-recapture analyses. Abundance estimates of spinner and Indo-Pacific bottlenose dolphins are of 432 (95% CI 426-462) and 68 (95% CI 67-80) individuals, respectively (Cadinouche *et al.* 2010). These two species are targeted by an important dolphin watching tourism industry.

MIGRATORY ROUTES AND POPULATION STRUCTURE OF MARINE MAMMALS

Very little is known about the migration routes and population structure of marine mammals in the SWIO except for a limited number of species of large whales, particularly the humpback whale. Some studies have also been conducted on genetic population structure of the Indo-Pacific bottlenose dolphin (Natoli *et al.* 2008; Särnblad *et al.* 2011), Indian Ocean humpback dolphin (Mendez *et al.* 2011) and the spinner dolphin (Ceyrac 2011).

All balaenopterids (except the Bryde's whale) are known to undertake seasonal migrations between their breeding grounds during austral winter and their polar feeding grounds during summer. Humpback whales regularly congregate in nearshore waters and over banks, shoals and offshore reef systems during the breeding season (Dawbin 1966; Balcomb & Nichols 1982; Whitehead & Moore 1982). The IWC (International Whaling Commission) Scientific Committee recognizes seven breeding grounds and migratory corridors (termed as breeding stocks A to G) in the Southern Hemisphere (IWC 2007). In the SWIO, four sub-stocks are currently recognised based largely on distributional evidence and catch histories (Best *et al.* 1998): 1) an East African corridor which is parallel to the South African to Mozambican coasts (termed as C1 by the IWC), 2) Central Mozambique Current corridor to Comoros Archipelago (C2), 3) Madagascar Ridge corridor (C3; Figure 1) and the Mascarene Islands (C4). Analyses of mtDNA population structure and migration rates confirmed the high gene flow within the SWIO region, as well as with wintering grounds in the south-eastern Atlantic. A low gene flow has been found between the south-western and northern Indian Ocean wintering grounds (Rosenbaum *et al.* 2009). Photographic

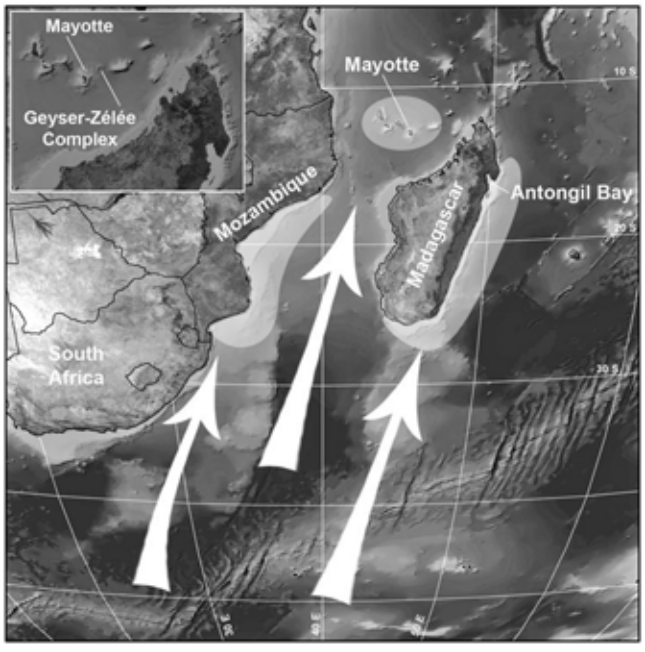

Figure 1: Relationship of sampling sites, migratory routes proposed by Best *et al.* (1998), and the general extent of the current management units recognized by the International Whaling Commission (from Ersts. 2011b).

and genetic evidences also confirmed regular movements of humpback whales within the SWIO region, especially between C2 (Mayotte, in the northern Mozambique Channel) and C3 (Antongil Bay, in north-eastern Madagascar; Ersts *et al.* 2011b). Refinement of humpback whale stock definitions has been a major objective of the IWC during the past decade, as early stock boundaries were shown to be poorly founded with respect to defining biological units.

In 2011 and 2012, 11 satellite transmitters were deployed on wintering humpback whales in the Comoros Archipelago (breeding stock C), including Mohéli and Mayotte (Fossette *et al.* 2014). Eight individuals were successfully tracked for 24.3 ± 12.4 days (range= 8-49 days) and travelled between 146 km and 5804 km in total. Whales either remained at their tagging site for several weeks (n= 3) or dispersed along the west coast (i.e. breeding sub-region C2, n= 4,) or east coast (i.e. breeding sub-region C3, n=1) of Madagascar. Two individuals travelled along relatively straight paths to distant, potential, foraging areas. One whale reached the French subantarctic islands while the other travelled to IWC foraging area III, one of the supposed Antarctic foraging areas for humpback whales of this breeding stock. This is the first time movements of humpback whales from this breeding stock have been described and their potential foraging areas in the Southern Ocean identified. Such dispersal pattern may have important implications for population estimates and for revising the definition of breeding regions established by the International Whaling Commission (Fossette *et al.* 2014).

In the Southern Hemisphere, a genetic (mtDNA) comparison of southern right whales from wintering grounds in Argentina, South Africa, Australia and New Zealand demonstrated differentiation between all wintering grounds (Patenaude *et al.* 2007). Whereas the most significant wintering ground for right whales is located off the south coast of South Africa in the SWIO, updated records provide indications of the existence of other migratory routes. Sightings of right whales were reported further north of the known distribution range; sightings were made off La Réunion, Mauritius and Madagascar. The north-eastern waters of Madagascar may have the northernmost sighting of this species in the western Indian Ocean (Rosenbaum *et al.* 2001). Right whale records in other areas of the SWIO may indicate the existence of former wintering grounds in the region, and that the increasing abundance of right whales may now allow rediscovering their past distribution and migration routes.

Two subspecies of blue whales are currently recognised in the Indian Ocean: the Antarctic blue whale (*B. m. intermedia*) and the pygmy blue whale (*B. m. brevicauda*). Antarctic blue whales are mainly found south of 60°S in summer. Their wintering grounds are not known, but whaling records suggest they may occur (at least young individuals) in the tropical area, such as south of the Mascarenes, off the southeast coast of South Africa or off southern Madagascar. Conversely, pygmy blue whales seem to occur further north in summer (~55°S), and move north to Madagascar and the Seychelles (Amirantes) in winter (Zemski & Sahzinov 1982; Best *et al.* 2003).

The migrations and movements of fin and sei whales are, like for blue whales, quite poorly known, primarily because their movements are oceanic (vs. coastal for humpbacks and rights). In summer, sei whales occur between the subtropical convergence and the Antarctic convergence (40-50°S). Fin whales are found further south during summer, essentially between 50 and 60°S. Both species migrate north to temperate and tropical waters. However, almost nothing is known on the location of their wintering grounds (Best 2007).

Investigation on small cetacean population structure has been undertaken for the three most coastal dolphin species in the SWIO: Indo-Pacific bottlenose dolphin, humpback dolphin and spinner dolphin. In South Africa, two coastal Indo-Pacific bottlenose dolphin populations have been identified along the coast of KwaZulu-Natal, one north and another south of Ifafa (Natoli *et al.* 2008). The low genetic diversity found in these two populations makes them particularly vulnerable to bycatch in the protective shark nets located along the KZN coast. The taxonomic status of *Tursiops* is under revision and genetic analyses have suggested that *T. aduncus* in the western Indian Ocean, (off South Africa and Zanzibar) and in the western Pacific Ocean (off China/Indonesia and Australia) should be classified as separate species (Natoli *et al.* 2008; Särnblad *et al.* 2011). Särnblad *et al.* (2011) suggested that the dolphins found off Zanzibar should be classified as *T. aduncus* alongside the South African animals. Analyses of genetic differentiation showed significant separation between the *T. aduncus* found off northern and southern Zanzibar despite the relatively short distance (approximately 80 km) between these areas (Särnblad *et al.* 2011).

Around Mayotte, the genetic population structure of *T. aduncus* has been assessed using mtDNA and 14 microsatellite markers (Kiszka *et al.* 2012). The analyses revealed no mitochondrial polymorphism and the presence of a single population. Photo-identification and stable isotope analyses (δ13C and δ15N) were also performed to reveal population substructure. Home range analysis revealed the presence of at least two communities of bottlenose dolphins around Mayotte: one occurring in the shallower waters inside the lagoon and a second in the vicinity of a deeper reef bank, situated further offshore in the northern part of the island. It has been suggested that intra-species niche partitioning may be a major driver of habitat segregation within this population (Kiszka *et al.* 2012).

An analysis of population structure and migration patterns of humpback dolphins using mitochondrial DNA data from 94 individuals from the coasts of South Africa, Mozambique, Tanzania and Oman, has been undertaken (Mendez *et al.* 2011). The genetic data were combined with 13 years of remote sensing oceanographic data of variables known to influence cetacean dispersal and population structure. This study showed strong and highly significant genetic distinction between all putative populations, except for those in South Africa and Mozambique (Mendez *et al.* 2011).

A quite similar pattern of fine-scale genetic population structure has also been found in the spinner dolphin in the SWIO, using samples from Zanzibar, Mayotte and La Réunion (Ceyrac 2011). MtDNA control region sequences and microsatellite markers (12 loci) were combined in this study. The main results highlighted a decreasing genetic diversity, from the continental coast of East Africa (Zanzibar) to the oceanic and remote island of La Réunion (Mascarenes).

Relationships with fisheries

Two types of interactions may occur between marine mammals and fisheries: biological interactions and operational interactions. Biological interaction includes trophic competition between these organisms and fisheries, where both marine mammals and fisheries exploit (at least partially) the same resources. Conversely, operational interactions include direct interaction between marine mammals and fisheries; including incidental catches in fishing gears and depredation (when marine mammals take advantage of fisheries by extracting caught fishes and baits). We only describe operational interactions between marine mammals and fisheries, especially bycatch and depredation. As some dedicated marine mammal hunting occurs in the Southwest Indian Ocean, a section is dedicated to describe the extent of this activity in the region, particularly along the west coast of Madagascar.

BYCATCH IN COASTAL FISHERIES

South Africa (KwaZulu-Natal region)

Fisheries in South Africa are highly diversified, including coastal artisanal to oceanic industrial fisheries. Along the east coast of southeast Africa, the major marine mammal bycatch problem has been reported in anti-shark nets in the KwaZulu-Natal region. The affected area stretches from Mzamba to Richards Bay (Cockcroft 1990). Today, nets cover 23 km of coastline out of a total of around 320km, and are managed by the KwaZulu-Natal Sharks Board (www.shark.co.za). Individual nets are 212m long and 6.1m deep, with a 25.5cm bar mesh and are anchored at each end. Main marine mammal bycatch comprises the Indo-Pacific bottlenose dolphin, humpback dolphin and common dolphin (Cockcroft 1990). On average, 76 (range 36-175) dolphins are taken as bycatch every year, of which 46% are common dolphins, 42% are bottlenose dolphins and 8% are humpback dolphins (Peddemors *et al.* 1998; Best 2007). Periodically whales become entangled in anti-shark nets, including minke, humpback and southern right whales (Cockcroft & Krohn 1994). On average 5.6 whales are trapped this way annually (Best *et al.* 2001). However, events of entanglements do not all result in whales' deaths as 75% are released alive from these nets. It should be noted that South Africa is replacing many of the shark nets with baited drumlines, which do not have a problem with marine mammal bycatch. Monitoring of southern right whale mortalities related to a diversity of anthropogenic factors was conducted between 1963 and 1988 off South Africa. Scarring from entanglement that appears as white lines was seen on the peduncle at the base of most of the photographed individuals' flukes (Best *et al.* 2001).

Mozambique

Entanglement in gillnets appears to be the main human-induced cause of dugong mortality along the entire coast and the level of this threat has augmented since the early 1990s as gillnet use has increased (WWF EAME 2004). Interview surveys with fishers have confirmed that humpback dolphins are also caught in the drift gillnet fishery (Guissamulo & Cockcroft 1997). However, the impact of gillnet entanglement on marine mammals is unknown in Mozambique.

Tanzania (including Zanzibar)

Cetaceans have been recorded as bycatch in gillnets at sites around Unguja Island, in the Zanzibar Channel and along the coast of northern Tanzania (Amir *et al.* 2002). The level of dolphin bycatch in the artisanal gillnet fishery has been investigated using a questionnaire-based survey with 101 gillnet vessel operators from 10 villages around Zanzibar (Amir *et al.* 2002). A total of 96 dolphins was reported to have been incidentally caught between 1995 and 1999: 43 Indo-Pacific bottlenose dolphins, 29 spinner dolphins, 5 Indian Ocean humpback dolphins and 19 unidentified dolphins. This study suggests that incidental capture of delphinids in the Zanzibar gillnet fishery may be high enough to negatively impact local populations (Amir *et al.* 2002). The high level of bycatch on the northern side of Zanzibar seems to be related to the high fishing effort in this zone. A study was also conducted to evaluate the magnitude of bycatch in the south-western coast of Zanzibar during 2003 and 2004 (Amir 2010). Data collected by on-board observers indicated high levels of capture compared to the small population size of the humpback and bottlenose dolphins. The annual bycatch rates represented mortality of 9.6% and 6.3% for Indo-Pacific bottlenose and humpback dolphin populations respectively. These rates indicated serious cause of concerns for the population of these two coastal species (Amir 2010).

During questionnaire surveys conducted in April 2007 and February 2008 in Mtwara, where 64 fishers were interviewed, 23% of the fishers had personally caught a dolphin (Indo-Pacific bottlenose, spinner, humpback and Risso's dolphins) in gillnets. However, even respondents who had not personally caught a dolphin still cited gillnets as a major threat. Indo-Pacific bottlenose dolphins were most frequently identified as the species caught, although spinner dolphins were also cited as being caught, particularly in offshore gillnets (Institute of Marine Science, unpublished data). Dolphins have also been recorded as bycatch in Pangani, Temeke, Rufiji and Kilwa (SeaSense, unpublished data).

Dugong bycatch is still frequent in Tanzania; 26 individuals (adults, juveniles and cow-calf pairs) were reported as bycatch from 2000 to 2004 (Muir & Kiszka 2012). These incidental captures mostly occurred in the Rufiji Delta and off Kilwa (WWF EAME 2004). Fishers also report incidental capture of humpback whales in gillnets every year, although these are generally cut free. Dead humpback whales have been found stranded on beaches, still entangled in gillnets (Kiszka *et al.* 2008a).

Kenya

Little is known about any marine mammal bycatch along the coast of Kenya. Incidental catches of dugongs in gillnets and trawls were reported during interview surveys conducted in 14 villages in 2003 (WWF EAME 2004). Cetacean bycatch is currently undocumented, but is expected to occur in areas where gillnets are used (e.g. Bofa, Tenewi Ziwayuu and

Manda regions; Kenya Marine & Fisheries Research Institute, unpublished data). Occasional reports document dolphin bycatch off Kenya, involving Indian Ocean humpback and Indo-Pacific bottlenose dolphins (Kenya Marine & Fisheries Research Institute, personal communication). Although the extent of marine mammal bycatch in Kenya is unknown, it could potentially be considerable due to the extensive use of gillnets (Kiszka *et al.* 2008a).

Union of the Comoros

Cetacean bycatch is considered to be very low around the Comoros. From recent interview surveys, spinner dolphin seems to be the most frequent bycatch species. Bycatch species may also include bottlenose dolphin, humpback dolphin (this species has still not yet been formally recorded around the Comoros; Kiszka *et al.* 2010a) and Risso's dolphin (Poonian *et al.* 2008). Artisanal longline is the primary gear responsible for cetacean bycatch although the extent of cetacean bycatch seems very low, and available information is only based on interview surveys. In addition, these data seem to be biased by species misidentification, as some species that were identified as bycatch that have never been recorded around the Comoros (Poonian *et al.* 2008). In contrast, dugong bycatch has been reported in the Comoros, especially in the marine park of Mohéli, where the species is mainly to be found. The fishing method involved in these catches is gillnetting. No quantitative information exists on the scale of dugong bycatch in the country, even though dugong bycatch occurs regularly (Kiszka *et al.* 2008a).

Mayotte, French dispersed islands

Dugong bycatch and deliberate hunting has been recorded around Mayotte, but has declined in recent decades due to the reduction in numbers of this species (Kiszka *et al.* 2007b; Pusineri *et al.* 2013). Incidental catches in seine nets are likely very rare. During an interview survey in 2007 (n=406), only ten fishers declared that they had caught a cetacean (all were dolphins) and eight of the animals were released alive. Of these ten dolphins, four were caught by net, three by hand line and three by longline (Pusineri & Quillard 2008) and species involved were thought to be Indo-Pacific bottlenose, spinner and spotted dolphin. There is evidence for interactions between Indo-Pacific bottlenose dolphins and the hand line fishery, as well as between short-finned pilot whales (and possibly melon-headed whales) and the pelagic longline fishery. Injuries on the dorsal fin region have been documented in these species, and would likely be due to interactions with these fisheries (Kiszka *et al.* 2008b). Remains of gillnets have also been observed on humpback whales migrating to Mayotte on several occasions although no mortalities have been observed to date (Kiszka *et al.* 2008a). Overall, based on the small numbers reported it is considered that the current bycatch of cetaceans in Mayotte is likely to have a negligible impact on these species. No information on bycatch is available around the French dispersed islands, especially as fishing is restricted to pelagic fisheries, in which marine mammal bycatch appears anecdotal.

Madagascar

Marine mammal bycatch has been reported to occur in commercial, artisanal and traditional fisheries (*Direction des Pêches et des Ressources Halieutiques*, unpublished data), although accurate quantitative data are lacking. Gillnets were reported to incidentally capture dolphins, whales and dugongs off many villages in the north-eastern, south-western, western and north-western coastal zones (Andrianarivelo 2001; Kiszka *et al.* 2008a; Razafindrakoto *et al.* 2004). A project was initiated in 2005 to evaluate the extent of bycatch in artisanal fisheries in the south-western region of Madagascar. A total of 111 interviews was analysed which indicated 56 bycatch events in these villages between 2000 and 2005. Indian Ocean humpback, Indo-Pacific bottlenose, spinner, Fraser's dolphins and humpback whales have been reported as bycatch in gillnets (Andrianarivelo 2001; Razafindrakoto *et al.* 2004). Bottlenose and spinner dolphins represented 48% and 32%, respectively, of the total cetacean bycatch between 2000 and 2005 (Razafindrakoto *et al.* 2008).

Seychelles

No marine mammal catch has been formally recorded as bycatch in coastal fisheries of the Seychelles (Kiszka *et al.* 2008a), although incidental captures may occur in the semi-industrial pelagic longline fishery, where large delphinids (primarily *G. macrorhynchus* and *P. crassidens*) regularly depredate lines (Rabearisoa *et al.* 2010).

La Réunion

There is a minimal incidence of cetacean bycatch reported around La Réunion. Bycatch has been mainly recorded in the gamefish sport-fishery that uses troll-line (Kiszka *et al.* 2008a). Predation in the longline fishery is known to occur with Risso's dolphins (on bait), false killer whales (on catches) and short-finned pilot whales (on both baits and catches), but very few cases of bycatch of this species were reported (J. Bourjea, personal communication). Capture of Indo-Pacific bottlenose dolphin in beach-seine nets is also reported, although this appears to be a rare event. Hook injuries and dorsal fin disfigurements due to fishing lines have been recorded in spinner, Indo-Pacific bottlenose and common bottlenose dolphins; however, no mortalities have been documented to date (Dulau *et al.* 2007).

Mauritius

No cetacean bycatch information has been published for Mauritius (Kiszka *et al.* 2008a).

BYCATCH IN OCEANIC FISHERIES (LONGLINE, PURSE-SEINE)

Two of the major fisheries that occur in the SWIO are purse-seining and longlining. Information on marine mammal bycatch in these oceanic fisheries is very scarce and is mostly anecdotal (IOTC, 2007). Nevertheless, indications are that marine mammal bycatch in this fisheries sector is very low. Since 2007, there has been a reduction in the tuna fleet, for economic and piracy reasons, suggesting a probable further decline in cetacean fisheries interactions. In contrast, the eastern tropical Pacific (ETP), purse-seining caused the decline of several dolphin species, especially spinner dolphin and pantropical spotted dolphin, which still have not recovered (Gerrodette & Forcada 2005). Bycatch in the ETP is due to dolphin-tuna (yellowfin *Thunnus albacares*) associations, whereas these interactions appear rare in the SWIO. However, large whales (*Balaenoptera* spp) do associate with tunas in the western Indian Ocean. A single purse-seine bycatch of a sei whale has been reported by Romanov (2001). According to IOTC (Indian Ocean Tuna Commission), the extent of marine mammal bycatch is insignificant in the oceanic purse seine fisheries (IOTC 2007); although this statement should be confirmed with on-board fisheries observer data before it is fully accepted.

Bycatch records of marine mammals in the pelagic longline fishery have been anecdotally reported. Around the island of Mayotte (NE Mozambique Channel), there is evidence of interaction between oceanic delphinids and the longline fishery, especially short-finned pilot whales, as non-lethal injuries on the dorsal fin have been observed on several individuals (Kiszka *et al.* 2008b). Between 2009 and 2010, an observer programme in the longline fishery around Mayotte recorded only one marine mammal (false killer whale) bycatch in the pelagic longline fishery. The animal was released alive (Kiszka *et al.* 2010c). Another bycatch has been mentioned from the longline fishery off La Réunion, involving a Risso's dolphin (Poisson *et al.* 2001).

Spinner dolphins. (Photo: Jeremy Kiszka)

TARGETED CAPTURE OF MARINE MAMMALS

Regional overview

Direct exploitation of marine mammals occurred in the past (generally prior to the 1990s) in the coastal zones of several countries of the SWIO. Marine mammals were targeted for bait and for direct consumption. The most commonly hunted species was probably the dugong, especially along the east coast of Africa, including Madagascar, Comoros and Mayotte (see for review WWF EAME 2004; Muir & Kiszka 2012). Deliberate hunting of dugong has declined in recent decades due to the reduction in numbers of this species (Kiszka *et al.* 2007b). Now, this species is very rare throughout the region, probably due to the combined effect of direct hunting and bycatch in gillnets (WWF EAME 2004; Muir & Kiszka 2012). Actually, dugong hunting is presently very rare in the region, although two individual dugongs were hunted off the west coast of Madagascar in 2008 (Y. Razafindrakoto, personal communication). When taken as bycatch, animals are indeed consumed as dugong meat is still very appreciated by fishermen, especially in Madagascar. Similarly, dugong are a desired source of meat in parts of Mozambique where targeting around Inhaca Island has been reported (WWF EAME 2004).

Several species of small delphinids were targeted until the mid-1990s off the south coast of Zanzibar, including bottlenose, humpback and spinner dolphins, both for bait (longline) and human consumption. This activity likely reduced the local dolphin populations. However, the hunt was gradually replaced by dolphin-oriented tourism beginning in 1992 (Amir 2010). In the Seychelles, although the national legislation prohibits the capture of cetaceans, it has been estimated that hundreds of dolphin were annually caught by local schooners at the edge of the Seychelles plateau (de Lestang 1993). Several local scientists reported the elusive behaviour of dolphins around the northern islands of the Seychelles, which could be a result of harassment of dolphins by fishers (M. Vely & D. Rowat, personal communication).

Madagascar

Dolphins are opportunistically hunted by fishermen in the coastal waters of Madagascar for local consumption and sale of meat, especially in the south-western region, around Anakao (Andrianarivelo, 2001; Razafindrakoto *et al.* 2004; Cerchio *et al.* 2009). Interviews of fishermen from the village of Anakao suggest that over 6,000 individuals were killed between 1985 and 2000, with 57% of takes occurring after 1995 (Cerchio *et al.* 2009). Species most impacted were spinner, Indo-Pacific bottlenose and humpback dolphins, all having a strong coastal distribution and thus vulnerable to hunting (Andrianarivelo 2001). In 2005, a drive hunt of 100-200 spinner dolphins was reported, supporting the figures reported in the interviews. Interview surveys indicated that while there was some bycatch in coastal fisheries, it was likely much less damaging than the directed hunts reported (Cerchio *et al.* 2009).

DEPREDATION

Depredation is defined as the removal of fish from fishing gear by sharks, cetaceans and other marine predators (e.g. pinnipeds); as opposed to predation, which is the capture of free ranging fish (Gilman *et al.* 2006). The extent of depredation on longline catches throughout the Indo-Pacific has been summarized by Nishida & Shiba (2005) and Nishida (2007). Depredation by predators on pelagic and bottom longlining is a global issue that can have negative impacts both for the species and the fishing industry (Rosa & Secchi 2007). False killer and short-finned pilot whales are the known cetacean species involved in depredation in the tropical waters of the SWIO, while the killer whale is involved in depredation events off South Africa (Petersen & Williams 2007). In addition, Risso's dolphin and common bottlenose dolphins have been identified as responsible for bait depredation (P. Bach, personal communication). Previous observations on depredation related this phenomenon with the specific features of bottom topography such as seamounts, shoals and semi-closed sea areas. Although cetacean depredation is sporadic, its impact can be significant to the landings of the fishing industry. While the magnitude of the depredation remains poorly understood, including any impact on the mammal itself, we summarized the known depredation status in the waters of the SWIO.

South Africa

The main fishing areas targeting swordfish and tuna include the South African EEZ, the southern Atlantic and Indian Oceans. Monitoring of depredation was conducted between 2002 and 2007 for the longline fishing industry; these surveys indicated that killer whales are the principal predator interacting with longline fisheries in this region (Petersen & Williams 2007). These killer whale interactions predominantly occurs on the Agulhas Bank and along the continental shelf toward Port Elizabeth. The study evaluated the loss of 561 fish from 116 longline sets in which killer whales were interacting, 83% of these were swordfish, and 10-20% depredation occurred in the sets deployed (Petersen & Williams 2007). There is also evidence of depredation on the catches made by small-scale commercial line fishers. Garratt (1980) reported localised but intense depredation by bottlenose dolphins on linefish catches in southern KZN, suggesting that local *Tursiops* schools had learned this behaviour and become habituated so as to impact substantially on the livelihood of the fishers at certain sites.

Seychelles

The semi-industrial longline fisheries grew rapidly between the period of 1995 and 2001. However, since 2001, these fisheries have declined as fishermen encountered economic losses due to depredation and, more recently, piracy. Depredation rates of up to 25% were reported annually for yellowfin tuna within Seychelles waters. The main target of this semi-industrial fishing industry is swordfish even though tuna are also exploited in these small commercial fisheries. Cetaceans involved in the depredation are mainly short-finned pilot whales and false killer whales (Romanov *et al.* 2010). The highest depredation rate occurred in areas of the highest swordfish CPUE, suggesting that cetaceans congregate in areas of high swordfish abundance. The proportion of sets with cetacean depredation was about 16% which represented an average 60% of the fish caught. Economic loss was estimated at 340€/1,000 hooks which equates to about 1,000,000€ over the 1995-2006 period (Rabearisoa *et al.* 2007). Recent fishing operations around Mahé plateau show a higher depredation level attributable to cetaceans (20%) and to sharks (51%). GLM analysis demonstrated that deeper set longlines reduce the risk of depredation by sharks, while longer soaking period increases risk of depredation overall (Romanov *et al.* 2010).

La Réunion and Mayotte (France)

Pelagic longlining was first developed after the introduction of this type of fishery in 1990s off Réunion Island (France). The main fishing area includes the south-western and western equatorial waters of the Indian Ocean. The evaluation of depredation was conducted for small-scale commercial fisheries between 1997 and 2000. False killer and short-finned pilot whales were the main identified depredators interacting with longline fisheries during the surveys. An average of 4.3% (80t) of the annual swordfish catch was damaged by cetaceans, representing a rate of catch loss between 3.7% and 5.5% (Poisson *et al.* 2007). Furthermore, the interaction also occasionally damages the fishing gear. Three juveniles of dolphins (species unknown) were incidentally captured and released alive during the surveys conducted between 1997 and 2000. A scientific survey in the framework of *IOSSS-Espadon* was conducted in July 2010 off La Réunion to assess the stock of swordfish. However, depredation by pilot whales was not observed during this survey (Le Couls *et al.* 2010).

Around Mayotte, depredation impact on catches in the local small-scale longline fishery seems only marginally important (3.7% of whole fish production). It involves false killer and short-finned pilot whales, but also common bottlenose and spinner dolphins depredating on baits (Kiszka *et al.* 2010c).

Mitigation measures

BYCATCH

Several mitigation measures have been investigated and some implemented to reduce marine mammal bycatch in the SWIO, especially in South Africa and more recently off the south coast of Zanzibar. Off the coast of KwaZulu-Natal, considerable experimentation has taken place since the 1980s with low cost devices to reduce the cetacean catch in shark nets (Peddemors & Cocroft 1994; Cliff & Dudley 2011). These included acoustic deterrents (pingers) and air filled floats. Results suggested that these devices do attract the dolphins' attention but do not necessarily alert the dolphin to danger or prevent entanglement. Live dolphins that are caught in anti-shark nets are routinely released. During the sardine run, in winter, the nets are lifted to avoid marine mammal mortality as sardine shoals attract a huge number of top predators, including dolphins and large whales (Best 2007). In a further attempt to reduce bycatch, the authorities have introduced drumline fishing systems instead of nets.

In the early 2000s, a survey using independent observers was conducted off the south coast of Zanzibar (Menai Bay) to estimate coastal dolphin bycatch (essentially *T. aduncus* and *S. plumbea*) in drift- and bottom set gillnets (Amir 2010). The project covered 24% of the fishing effort and the estimated total bycatch represented 9.6% and 6.3%, respectively of the estimated Indo-Pacific bottlenose and humpback dolphins resident in the area (Amir 2010). Consequently, these bycatch levels were not considered sustainable. In 2007 and 2008, another project aimed to assess the efficiency of acoustic alarms (Fumunda FMDP-2000 pingers) in reducing dolphin bycatch. Pingers reduced the bycatch of dolphins in both drift- and bottom set gillnets, however the reduction was only significant in the drift gillnets (Amir 2010). New initiatives are currently underway to extend the use of pingers to reduce dolphin bycatch off Zanzibar (P. Berggren, personal communication).

DEPREDATION

A project has been developed to minimise depredation by marine mammals in the pelagic longline fishery (Rabearisoa *et al.* 2009). The goal of this project was to mitigate and reduce depredation caused by cetaceans (mainly false killer and short-finned pilot whales) on longline-caught swordfish and tunas in the SWIO region. The project aims to test the deployment of physical protection of pelagic longline-caught fish using a device called a *spider.* (Rabearisoa *et al.* 2009). It was concluded that the logistical aspects of deploying this device well exceeded the requirement to deploy large numbers of hooks at an industry standard approaching one hook every six seconds. The spider outperformed, logistically and as a depredation mitigation device, the earlier sock-type of physical protection that fully enclosed the hooked fish. However, the spider device did not function well with large fish. Rabearisoa *et al.* (2010) have experimentally extended this work, including the use of visually reflective devices. However, to date this experimental work has only been tested with coastal Indo-Pacific bottlenose dolphins at Saint-Paul Bay, La Réunion, and not yet with species involved in depredation of longline caught fish.

INDIRECT EXPLOITATION: A WAY TO MITIGATE BYCATCH

The global trend for whale watching and dolphin tourism provides compelling incentives to protect marine mammals. In several locations this aspect of ecotourism generates substantial economic benefits. Examples exist from KwaZulu-Natal, southern Mozambique, Mauritius and elsewhere. Concepts of ecotourism and whale watching were specifically developed with the stakeholders of four villages in the Anakao region of south-western Madagascar, as an alternative to hunting and as a viable source of economic support. Fishermen from these villages officially created an association to protect whales and dolphins through the promotion of ecotourism (Y. Razafindrakoto, personal communication).

Summary, gaps, and recommendations

GAPS AND RECOMMENDATIONS

The SWIO supports a high marine mammal diversity relative to the worldwide scale (30% of known marine mammal species). However, very little is known about the actual distribution and abundance of species, except in some coastal locations: KwaZulu-Natal, Maputo Bay, Bazaruto Archipelago, south coast of Zanzibar, Mayotte, La Réunion, for example. Even less information exists on abundance and distribution of cetaceans in oceanic waters in the SWIO. However, extensive aerial surveys conducted by the University of La Rochelle (UMS Pelagis, France) from December 2009 to April 2010 produced 1,274 effort-related sighting records (with at least 18 marine mammal species recorded; Ridoux *et al.* 2010; Mannocci *et al.* 2014). These surveys provided new information on habitat preferences and spatial variations of the abundance of cetaceans in the region, particularly around the Mascarene Islands, Madagascar, the Seychelles and the Comoros (Mannocci *et al.* 2014). Very limited information on the distribution, abundance and critical habitat of some endangered marine mammal species exists in the region, particularly for *T. aduncus*, *S. plumbea* and *D. dugong.* Therefore, based on this retrospective analysis, further aerial surveys should be implemented, especially along the coast of Kenya (northern area), Tanzania (Rufiji Delta, for example) and the north-west coast of Madagascar, where these regionally endangered species potentially occur and are known to be impacted by fisheries activities. This work could provide critical information to define hotspots of abundance and habitat of these vulnerable species, and focus attention to mitigate threats such as bycatch (through MPA implementation, for example).

As bycatch is probably the most significant threat to marine mammals (especially coastal species), it is urgent to better assess the extent (geographical and numerical) of bycatch in the region, especially in artisanal fisheries. However, a

project has been initiated to evaluate the extent of bycatch in multiple gears used in coastal artisanal fisheries (J. Kiszka, unpublished data) and results will be available in due course.

Where the extent of bycatch and marine mammal population boundaries and abundance are well known (Zanzibar, for example), experimental work on mitigation measures should be strongly encouraged (such as acoustic alarm testing).

Except for the recovering humpback whale, almost no information exists on the stock structure of large cetaceans. For several dolphin species (the most coastal and impacted by fisheries), information is now partially available on population structure and boundaries. Available information suggests that coastal cetaceans are best managed at the local scale. However, these population boundaries should be better defined and a regional project on coastal marine mammal population structure and boundaries should be further encouraged, especially using various approaches such as genetic and chemical tracer (stable isotopes, pollutants) analyses.

As depredation is a major issue in the SWIO region, further work to better assess habitat and population characteristics of some deep-water dolphins is critically needed, particularly for *Globicephala macrorhynchus*, *Pseudorca crassidens* and *Grampus griseus*. Future projects should attempt to define hotspots of habitat and abundance of these species in the SWIO, and develop mitigation measures.

VULNERABLE SPECIES AND HOTSPOT DEFINITION

This Retrospective Analysis concludes that marine mammal mortality through fisheries interactions in the SWIO, while not exhaustively studied, is generally low and certainly lower than many other regions of the world. While this is primarily true for offshore regions, there is greater concern for coastal species and fisheries. Through this Retrospective Analysis, it is suggested that three coastal marine mammal species are particularly affected by human activities, including fisheries, and are consequently highly vulnerable:

- *Dugong dugon* (classified as Vulnerable by IUCN, Annex).
- *Sousa plumbea* (still officially classified as Near Threatened under *Sousa chinensis*, but unofficially classified as Vulnerable by IUCN, Annex).
- *Tursiops aduncus* (classified as Data Deficient by IUCN, Annex).

The dugong is probably the most endangered and threatened marine mammal in the SWIO, despite available knowledge on this species, most is empirical and anecdotal (WWF EAME 2004; Muir & Kiszka 2012). Dugongs have progressively declined in most SWIO countries, and the only known viable population is located in the Bazaruto Archipelago, Mozambique (Cockroft *et al.* 2008; Findlay *et al.* 2011). Along the northwest coast of Madagascar, aerial surveys highlighted the existence of a potentially important aggregation of dugong (Ridoux *et al.* 2010), while populations in Mayotte are of uncertain viability (Kiszka *et al.* 2007b; Pusineri *et al.* 2013).

In Zanzibar, Madagascar and South Africa, coastal dolphin bycatch and direct hunting is threatening several species (including those previously cited), and potentially others such as the spinner dolphin. This Retrospective Analysis underlines the fact that these three vulnerable species are patchily distributed in the SWIO region, and that critical attention should be given to the following areas:

- Bazaruto Archipelago (critical area for dugongs in the SWIO, *T. aduncus* and *S. plumbea*).
- Northwest coast of Madagascar (important area for *T. aduncus*, *S. plumbea* and potentially a critical habitat for *D. dugon*, as underlined by a preliminary survey in 2010; Ridoux *et al.* 2010).
- South coast of Zanzibar (critical habitat for both *T. aduncus* and *S. plumbea*, with high bycatch level).

These areas may be considered as hotspots, as they are critical habitat for at least two of the three most vulnerable marine mammal species in the SWIO. It is clear that other areas are also potentially important for these species (for example off Kenya), but need to be further identified in the future, through regional collaboration and the implementation of a regional research project on the status and distribution of the most endangered marine mammals in the SWIO. In the future, a clear priority should be given to the study and management of these three species. For management purposes, stock boundaries should be further investigated (in the frame of this new potential initiative), as management of marine mammal populations is clearly a transboundary issue. Of significance for SWIOFP is the recognition that fisheries development in these sensitive areas needs to be carefully monitored and controlled, and in many cases restricted.

Dugong – probably the most endangered and threatened marine mammal in the SWIO. (Photo: Nils Bertrand)

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Annex:

Marine mammals recorded (authentic) in the Southwest Indian Ocean (multiple sources), their IUCN population trends and status.

	STATUS					***POPULATION TREND***	***IUCN STATUS***
	Common	*Rare*	*Vagrant*	*Resident*	*Migrant*		
CETACEA							
MYSTICETI							
Balaenidae							
Eubalaena australis	x				x	Increasing	Least concern
Neobalaenidae							
Caperea marginata		x			x	Unknown	Data deficient
Balaenopteridae							
Balaenoptera musculus		x			x	Increasing	Endangered
Balaenoptera physalus					x	Unknown	Endangered
Balaenoptera borealis					x	Stable	Least concern
Balaenoptera acutorostrata	x				x	Unknown	Endangered
Balaenoptera bonaerensis					x	Unknown	Data deficient
Balaenoptera brydei				x		Unknown	Data deficient
Megaptera novaeangliae	x				x	Increasing	Least concern
ODONTOCETI							
Physeteridae							
Physeter macrocephalus	x			x		Unknown	Vulnerable
Kogidae							
Kogia breviceps		x		x		Unknown	Data deficient
Kogia sima	x			x		Unknown	Data deficient
Ziphiidae							
Ziphius cavirostris	x			x		Unknown	Least concern
Berardius arnouxii		x		x		Unknown	Data deficient
Indopacetus pacificus		x		x		Unknown	Data deficient
Mesoplodon mirus		x		x		Unknown	Data deficient
Mesoplodon densirostris	x			x		Unknown	Data deficient
Delphinidae							
Steno bredanensis		x		x		Unknown	Least concern
Sousa plumbea	x			x		Assumed to be declining	Vulnerable
Tursiops aduncus	x			x		Unknown	Data deficient
Tursiops truncatus	x			x		Unknown	Least concern
Stenella longirostris	x			x		Unknown	Data deficient
Stenella attenuata	x			x		Unknown	Data deficient
Stenella coeruleoalba		x		x		Unknown	Least concern
Delphinus delphis	x			x		Unknown	Least concern
Lagenodelphis hosei		x		x		Unknown	Least concern
Grampus griseus	x			x		Unknown	Least concern
Globicephala macrorhynchus	x			x		Unknown	Data deficient
Feresa attenuata		x		x		Unknown	Data deficient
Peponocephala electra	x			x		Unknown	Least concern
Pseudorca crassidens	x			x		Unknown	Data deficient
Orcinus orca	x			x		Unknown	Data deficient

PINNIPEDIA (CARNIVORA)							
Otaridae							
Arctocephalus pusillus	x		x			Increasing	Least concern
Arctocephalus tropicalis		x	x			Increasing	Least concern
Phocidae							
Mirounga leonina		x	x			Unknown	Least concern
Lobodon carcinophagus		x	x			Unknown	Least concern
SIRENIA							
Dugongidae							
Dugong dugon	x			x		Declining	Vulnerable