Marine mammal bycatch in the southwest Indian Ocean: review and need for a comprehensive status assessment

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Abstract
Incidental catch in fishing gears is a serious threat to marine megafauna (sea turtles, sharks and marine mammals) at the global scale. It is critical to assess the extent of this threat, both spatially and quantitatively, to ensure its effective management. In the southwest Indian Ocean (from 0 to 25°S, from eastern Africa to 60°E), there is a paucity of information on marine mammal bycatch. Here we review the marine mammal bycatch issue in this region for the following countries: Mozambique, Tanzania (including Zanzibar), Kenya, the Seychelles, the Comoros, Mayotte, Madagascar, Reunion Island and Mauritius. For each country, status of marine mammals, fishing effort, bycatch information and mitigation measures are presented. Quantitative information, especially with respect to number of bycaught animals and impact on local populations, is limited (except for Zanzibar). However, it is clear that several fisheries incidentally catch marine mammals in the region, most notably gillnets catching dugong (*Dugong dugon*) and coastal dolphins (*Tursiops aduncus* and *Sousa chinensis*) in Zanzibar and southwest Madagascar. Mitigation measures are inexistent, particularly efforts to reduce the use of these gears. It is now critical to quantify the extent of bycatch in gillnets and its impact on local marine mammal populations and to implement relevant and effective mitigation measures as necessary.

***Keywords*:** bycatch; *Tursiops aduncus*; *Sousa chinensis*; *Megaptera novaeangliae*, *Dugong dugon*; southwest Indian Ocean; gillnets; longline; handline.

Introduction

One of the most important requirements of the United Nations Convention on the Law of the Sea of 1982, which determines strategies of exploitation of marine living resources (Article 119, b), is to take into account the impact of fisheries on "species associated with, or dependent upon, harvested species with a view to maintaining or restoring populations of such associated or dependent species above levels at which their reproduction may become seriously threatened" (United Nations, 1983). The FAO (Food and Agriculture Organization) Code of Conduct for Responsible Fisheries (CCRF) calls for the catch of non-targeted species to be minimized and promotes the conservation of biodiversity by minimizing fisheries impacts on non-targeted species and the ecosystem in general. Bycatch is defined by the FAO as "part of a fishing unit taken incidentally, in addition to the targeted species towards which fishing effort is directed."

Interactions between marine mammals (cetaceans, pinnipeds and sirenians) and fisheries are widely distributed worldwide and affect numerous species. Interactions between marine mammals and fisheries have occurred for centuries and have been increasing in frequency and intensity during recent decades (DeMaster *et al.*, 2001). It has been estimated that globally 653,365 marine mammals were captured accidentally in fishing gears between 1990 and 1994 (Read *et al.*, 2006). Bycatch is known to occur throughout the southwest Indian Ocean (SWIO) region, both in coastal (Amir *et al.*, 2002) and pelagic ecosystems (Romanov, 2001). However, few studies have been conducted on bycatch in any of the major fisheries including long-line, purse seine, prawn trawl and gillnet fisheries. Information is mostly qualitative and not quantified. Furthermore, few mitigation measures have been implemented in the region.

A dedicated study has been conducted in Zanzibar to determine the level of dolphin mortality in the gillnet fishery (Amir *et al.*, 2002). In Madagascar, interview surveys were conducted to assess the extent of cetacean bycatch in the southwest region (Razafindrakoto *et al.*, 2007). However, no additional investigations have been undertaken to assess the impact of fisheries on the survival of non-targeted species such as cetaceans and the threatened dugong (*Dugong dugon*) (Cockcroft & Krohn; 1994; Romanov, 2001; WWF EAME, 2004). The limited data available, coupled with the fact that most coastal states and territories in the WIO region are presently under-developed with poor infrastructure and limited facilities, creates a major challenge for research and management.

During the Western Indian Ocean Marine Science Association (WIOMSA) Scientific Symposium held in Mauritius in August 2005, a meeting was convened involving 16 participants working on marine mammals and sea turtles in the region. A topic of mutual concern in these taxonomic groups was the issue of fisheries bycatch of these taxonomic groups and ways to mitigate this threat. In view of the limited data available on fishery-related mortality, the group resolved to establish an informal SWIO discussion group and developed a proposal to hold a regional workshop on the problem of bycatch and mitigation measures. Such an event would also be a valuable opportunity for marine mammal and turtle researchers to share ideas and to develop new partnerships and regional projects related to their field, a need clearly identified by dugong researchers in recent years (WWF EAME, 2004). The resulting regional workshop aimed to review the level of threat from fisheries, both coastal and pelagic, in the southwest Indian Ocean, as well as to discuss common issues and data related to bycatch within the region (Kiszka & Muir, 2007). This paper presents an overview of fisheries, marine mammal bycatch and mitigation measures in the southwest

Indian Ocean, based on the data gathered during the workshop and provided by participants (unpublished data) and the available literature (grey and published). Researchers and managers can use the information provided here to prioritize research, management, and mitigation of marine mammal bycatch in the southwest Indian Ocean.

Fisheries and marine mammal bycatch in the southwest Indian Ocean

Union of the Comoros

Marine mammal diversity and status

The status of marine mammals is poorly known in the Union of the Comoros. Fourteen species have been recorded around the three islands (Anjouan, Mohéli and Grande Comore), including migrating humpback whales (*Megaptera novaeangliae*) during austral winter (July-October) and the dugong (WWF EAME, 2004; Kiszka *et al.*, 2006). The most common species around the archipelago are spinner (*Stenella longirostris*), pantropical spotted (*Stenella attenuata*) and Indo-Pacific bottlenose dolphins (*Tursiops aduncus*). Other oceanic species also occur, such a Longman's beaked whale (*Mesoplodon pacificus*) and short-finned pilot whale (*Globicephala macrorhynchus*) (Anderson *et al.*, 2006; Kiszka *et al.*, 2006). The dugong predominantly occurs south of the island of Mohéli (Marine Park; Davis & Poonian, 2007). Sperm whales (*Physeter macrocephalus*) also regularly occur, especially during late austral summer and were caught by American whalers in the vicinity of the Comoros during the 19th Century (Wray & Martin, 1983).

Fisheries

Fishing in the Comoros is entirely artisanal and catches are generally destined for local consumption. However, fishing licences are given to Asian and European longline and purse-seine fishing boats. Coastal fishing gears include beach seines, fish traps, gill nets, lines (including trolling and droplines, Table 1); two types of boat are commonly used: *galawa* (traditional canoe) and *vedette* (motorized boat) (UNEP, 2002). Lines targeting pelagic fish are by far the most common gear used in the Union of the Comoros (Poonian *et al.*, this volume). Shark gillnets of up to 270m long and 2m wide with a mesh size of 30cm have also been reported (*Ministère de l'Agriculture et de la Pêche*, 1995). Fishing activity in the Comoros is seasonal and seasons vary for each island: on Grande Comore, peak production occurs during Kashkazi (November-March) and on Mohéli at the beginning of Kashkazi; seasonality is more complex on Anjouan because of the island's shape: during Kusi (May – August), production peaks on the north-west coast but is poor on the east coast, but the situation is reversed during Kashkazi (Abdoulhalik 1998). The most recent surveys of artisanal fishers in the Comoros reported 3,403 *galawas* and 924 *vedettes* (Abdoulhalik, 1998), and approximately 8,500 fishers (*Union des Comores*, 2005).

Marine mammal bycatch

Cetacean species reported as bycatch in the Union of the Comoros include (from most to least common): spinner dolphin, Indian Ocean bottlenose dolphin, humpback dolphin (*Sousa chinensis*) and Risso's dolphin (*Grampus griseus*) (Table 1). Dolphins caught accidentally are generally released, since they have no value as food; however, some fishers kill them because they perceive them as a threat to fish stocks (mortality of cetaceans caught accidentally estimated at 11% on Grande Comore and 25% on Mohéli; Poonian *et al.*, this volume). Bycatch of dugong has been recorded in gillnets around the island of Mohéli, including inside the Mohéli Marine Park. Dugong captures were most common in the 1970s

and 80s, suggesting that the species has declined significantly in the recent years, as in other areas in eastern Africa (Davis & Poonian, 2007; WWF EAME, 2004).

Mitigation measures
A number of legal restrictions have been put in place, including prohibition of destructive fishing techniques (dynamite, poison) and capture of endangered species, but the enforcement of these restrictions has proved ineffective to date (UNEP, 2002). There has been an official ban on gillnets in Mohéli Marine Park since 2001 (Gabrié, 2003). However, the ban on gillnet fishing in Mohéli Marine Park has been poorly received by local fishing communities; fishers were not provided with viable alternative livelihoods to compensate their loss of income from gillnetting and the ban has proved logistically difficult and costly to enforce in the absence of sustainable funding mechanisms for the Marine Park (Hauzer *et al*, in press).
In addition, informal bans in other areas, enforced by local village associations and fishing syndicates, have been in place in some communities since 1995 (*Ministère de l'Agriculture et de la Pêche*, 1995).

Mayotte (France)
Marine mammal diversity and status
The island of Mayotte is characterized by the presence of a large closed lagoon (around 1,100 km²), and a very steep slope close to the barrier reef. More than twenty species of marine mammals have been recorded around Mayotte, including humpback whales during austral summer, the blue whale (*Balaenoptera musculus*), the dugong, at least 12 species of dolphins (including *S. chinensis, S. longirostris, S. attenuata, Lagenodelphis hosei, T. aduncus, T. truncatus, Peponocephala electra, Feresa attenuata, Pseudorca crassidens, G. griseus, Orcinus orca, G. macrorhynchus*), beaked whales (including *Mesoplodon densirostris*, *M. pacificus* and possibly *Mesoplodon ginkgodens*) and sperm whales (*P. macrocephalus, Kogia sima, Kogia breviceps*) (Kiszka *et al.*, 2007). The most common species are resident throughout the year: the spinner dolphin, the pantropical spotted dolphin, the Indo-Pacific bottlenose dolphin and the melon-headed whale (Kiszka *et al.*, 2007).

Fisheries
The fisheries around Mayotte are artisanal and poorly developed (Table 1). The most important fishery is the hand line, targeting reef fishes, especially predatory demersal species such as groupers and snappers. In 2006, 1,092 small boats (including pirogues and small barks less than 7m long) were censused by the local fishing service (*Direction des Affaires Maritimes de Mayotte*, unpublished data). Other fishing techniques include small seines deployed on barrier and fringing reefs (less than 20 barks). Three long liners are based in Mayotte and fish in the territorial waters, targeting swordfish (*Xiphias gladius*) and tunas, and deploying between 400 and 700 hooks each.

Marine mammal bycatch
Dugong bycatch and deliberate hunting has been recorded around Mayotte, but has declined in recent decades due to the reduction in numbers of dugong (Kiszka *et al.*, 2007a). Incidental catches in seine nets are probably very rare. During a recent interview survey (406 fishers interviewed, 2007), only 10 fishers declared that they had caught a cetacean (dolphins). They were captured both during day and night. Eight of the animals were released alive. Species involved were probably Indo-Pacific bottlenose, spinner and spotted dolphins. Four dolphins were caught by a net, three by a hand line and three by a longline (Pusineri & Quillard, this volume; Table 1). The small numbers reported allow us to conclude that the bycatch of cetaceans can be considered marginal. Evidence of interactions between Indo-Pacific

bottlenose dolphins and short-finned pilot whales, and hand line and longline fisheries, respectively, has been observed around the island of Mayotte (Kiszka *et al*., submitted). Short-finned pilot whales, melon-headed whales and spinner dolphins have been bycaught in the longline fishery, but in very limited numbers (less than 1 every 5 years; F. Fredericci & G. Wunderlee, pers. comm.). Spinner dolphin bycatch is probably linked to bait attraction (squid, saury). Remains of gillnets have also been observed on humpback whales migrating to Mayotte on several occasions. No mortalities have been observed to date.

Mitigation measures
The use of seine nets is controlled (not allowed on seagrasses and live reefs) and the existence of four marine reserves and parks around the island (three of them are located in the eastern part of the lagoon) limits the extent of fisheries. Nets are not allowed in any of the existing marine protected areas, and hand lining is prohibited in one of them. There are no mitigation measures in force for the longline fishery.

Kenya
Marine mammal diversity and status
There is limited information on the status of marine mammals off Kenya. The sperm whale, humpback whale, Bryde's whale (*Balaenoptera edeni*), minke whale (*B. acutorostrata*), killer whale (*Orcinus orca*), melon-headed whale, bottlenose dolphin (*Tursiops* sp.), common dolphin (*Delphinus* sp.), humpback dolphin (*Sousa chinensis*), spinner dolphin, spotted dolphin, Fraser's dolphin, Risso's dolphin and the striped dolphin (*Stenella coeruleoalba*) have been recorded (Wamukoya *et al.*, 1996). Indo-Pacific bottlenose and humpback dolphins seem to be resident in a number of coastal areas. The dugong occurred in large numbers off Kenya before the 1960's and a large group of 500 were seen in the south of the country in 1967. This species declined significantly due to incidental captures in gillnets and hunting. Currently, dugongs still occur, but in small numbers, especially off the Tana delta area, in the Lamu archipelago and in Kiunga (WWF EAME, 2004).

Fisheries
Fishing is an important socio-economic activity for the Kenyan population. Kenya's marine fishery can be classified into two broad categories via artisanal and semi- industrial fishery. Artisanal fishing is confined to the shallow waters along the entire coastline. The artisanal fishery accounts for about 90% of the annual total marine fish landed about 10,000 metric tons. The coastal marine water is a major source of livelihood and employs 9,017 fishers (Frame survey report, 2004) with an estimated over 250,000 persons depending on coastal and marine fish production (UNEP, 1988). The marine catch is estimated to represent approximately 5.0% of the total catch in the country (Fisheries statistical bulletin, 2004). Kenyan fisheries employ a wide range of gears, including gillnets (2006: n=5,916 gears), beach/prawn/reef seines (2006: n=970), prawn trawlers (2006: n=20) and others including long line kooks (2006: n=8,224), monofilament nets, baskets, hand lines, scoop nets and trolling lines. In 2006, 28 landing sites were recorded along the Kenyan coast (Marine Waters Frame Survey 2006 Report, Kenya Marine & Fisheries Research Institute, unpublished data; Table 1).

Marine mammal bycatch
Little is known about marine mammal bycatch along the coast of Kenya. Incidental catches of dugongs have been recorded during interview surveys conducted in 2003 in 14 villages. Gears involved in bycatch were gillnets and trawls (WWF EAME, 2004). Cetacean bycatch is unknown, but they are suspected in many areas where gillnets are used, such as in Bofa,

Tenewi Ziwayuu and Manda areas (Kenya Marine & Fisheries Research Institute, unpublished data). Species bycaught include Indo-pacific humpback and bottlenose dolphins (Table 1). The extent of marine mammal bycatch in Kenya is unknown but possible important due to the extensive use of gillnets.

Mitigation measures
No mitigation measures have been implemented in Kenya to reduce marine mammal bycatch in fishing gears. However, fisher awareness-raising actions have been conducted by various stakeholders.

Madagascar
Marine mammal diversity and status
A review of the diversity and status of marine mammals around Madagascar recorded 27 species (Rosenbaum, 2003). Large cetaceans include the humpback whale, the blue whale, the fin whale (*Balaenoptera physalus*), the southern right whale (*Eubalaena australis*), the pygmy right whale (*Caperea marginata*) and the sperm whale. During austral winters, a large number of humpback whales annually visit the known breeding grounds along the eastern coast, especially between Cap Sainte Marie south of Tolagnaro and Baie d'Antongil and in the south-western region (Rosenbaum *et al.*, 1997; Rosenbaum, 2003; Cerchio *et al.*, 2006). Bottlenose and humpback dolphins are the commonest species of the 20 odontocetes identified in the coastal waters of Madagascar and are mostly distributed along the west and north-east coasts (Cockcroft & Young, 1998; Rosenbaum, 2003; Razafindrakoto *et al.*, 2004). Other species recorded include four beaked whale species, the pygmy and dwarf sperm whales as well as 10 delphinids (Rosenbaum, 2003). The dugong is known to occur in Madagascar but its status remains unclear (WWF EAME, 2004). Two species of pinniped: the crabeater seal, *Lobodon carcinophagus* and the subantarctic fur seal (*Arctocephalus tropicalis*) have been reported stranded on the shores of Madagascar (Rosenbaum, 2003; Garrigue & Ross, 1996).

Fisheries
Fisheries constitute the main source of income for coastal communities and of foreign currencies for Madagascar's economy. Three types of fisheries exist in Madagascar's waters according to the power of the engines used to motorize ships or boats: commercial fishery (>50HP), artisanal fishery (<50HP) and traditional fishery (non-motorized). According to the Fisheries Department, Ministry of Agriculture, Fisheries and Livestock, 80 commercial longline and trawling fishery industries exploiting tunas, swordfish, shark, and shrimps in EEZ of Madagascar were recorded in 2006. The artisanal fishery principally utilize gillnets to target elasmobranches, fishes, gastropods and crustaceans within 12 miles of shore (Table 1). A total of 26 artisanal fishing companies were listed in Madagascar in 2006 (DPRH, unpublished data). Traditional fisheries target a full range of exploitable resources (e.g., elasmobranches, cephalopods, gastropods, echinoderms, turtles, marine mammals) in shallow and pelagic waters within Madagascar's EEZ. A total of 26,000 traditional fishers were recorded by the Fisheries Department in 2006.

Marine mammal bycatch
Marine mammal bycatch has been reported to occur in commercial, artisanal and traditional fisheries in Madagascar (*Direction des Pêches et des Ressources Halieutiques*, unpublished data), however, accurate data are lacking (Table 1). A project was initiated in 2005 to evaluate the extent of bycatch in artisanal fisheries in the south-western region of Madagascar where bycatch of Indo-Pacific humpback, bottlenose, and Fraser's dolphins had been

reported (Andrianarivelo, 2001; Razafindrakoto *et al.*, 2004). Bycatch of humpback whales, Indo-Pacific humpback dolphins, spinner dolphins and bottlenose dolphins through entanglement in gillnets was confirmed by this study. A total of 111 interviews were analyzed and the results showed 56 events of by-catch in the four villages between 2000 and 2005. Three dolphin species and humpback whales were reported incidentally caught in fishing gear targeting sharks. Dolphins were mostly entangled in gillnets; conversely longlines were only reported to incidentally catch humpback whales. Bottlenose and spinner dolphins represented respectively 48.10% and 31.64% of total cetacean by-catch between 2000 and 2005 (Razafindrakoto *et al.*, this volume).

Mitigation measures
Measures to mitigate marine mammal bycatch in any type of fishery have not been implemented in Madagascar. However, the Cetacean Conservation and Research Project of the Wildlife Conservation Society has attempted to involve local communities to implement solutions to reduce threats to marine mammals, in particular hunting and bycatch in artisanal and traditional fisheries. Different suggestions from fishers, e.g. incentive programmes for the release of animals, legislative frameworks and promotion of whale and dolphin watching were discussed during a two day workshop in 2007. A follow-up meeting was held recently to create a local association to protect whales and dolphins in the south-western region of Madagascar (H.C. Rosenbaum, pers. comm.).

Mozambique
Marine mammal diversity and status
Little has been published on the status of marine mammals along the Mozambican coast. Humpback whales are known to occur in coastal waters during austral winter (Findlay *et al.*, 1994). The most common cetacean species in inshore waters are Indo-pacific bottlenose and humpback dolphins, especially in Maputo Bay and the Bazaruto archipelago. In Maputo, humpback dolphin abundance was estimated at 105 individuals (Guissamulo & Cockcroft, 2004). Dugongs occur in Maputo and Inhambane Bays, and the largest population, considered as the single viable population in eastern Africa, in located in the Bazaruto Bay (WWF EAME, 2004). Aerial surveys conducted between 2003 and 2005 in Bazaruto provided an estimate at least 200 individuals (A. Guissamulo, personal communication).

Fisheries
Sixty percent of the Mozambican population is dependant on marine resources. A wide variety of fisheries occur including a significant prawn trawl fishery, hand lining, and gillnetting (for sharks and other large pelagic fishes).

Marine mammal bycatch
Little is known of the extent of marine mammal bycatch off Mozambique. Entanglement in gillnets appears to be a major cause of dugong mortality along the entire coast. The level of this threat has increased since the early 1990s alongside an increase in gillnet use (WWF EAME, 2004). Interview surveys with fishers confirmed that humpback dolphins are also bycaught in the drift gillnet fishery (Guissamulo & Cockcroft, 1997). Gillnets seem to affect small coastal cetaceans, particularly bottlenose and humpback dolphins. A marked decline in coastal dolphin populations was observed in the early 1990's (Cockcroft & Krohn, 1994). Intentional captures also contribute to the decline of humpback dolphins (Guissamulo & Cockcroft, 1997).

Mitigation measures
No mitigation measures have been undertaken in Mozambique to reduce marine mammal bycatch in fishing gears.

Tanzania (including Zanzibar)
Marine mammal diversity and status
At least seven species of dolphin, three species of whales and the dugong have been reported to occur in Tanzania, including Zanzibar (Unguja Islands) where most surveys on the occurrence and distribution of cetaceans have been conducted in the coastal waters. Dolphin species include Indo-Pacific bottlenose dolphins, spinner dolphins, Risso's dolphins, Indo-Pacific humpback dolphins, Pan-tropical spotted dolphins, and common bottlenose dolphins (*T. truncatus*) (Amir *et al*., 2002, 2005). The rough-toothed dolphin has also been reported in Tanzania and Zanzibar (*Steno bredanensis*) (Berggren *et al*., 2001). The most common species are Indo-Pacific bottlenose, spinner and humpback dolphins (Ortland, 1997; Stensland *et al*., 1998; Amir *et al*., 2002, 2005). Dolphins have also been recorded in the Rufiji Delta, Saadani, around Latham Island, Tanga (northern Tanzania) and Mtwara (south Tanzania) (Linden & Lundin, 1995), although without any reference to species. Chande *et al.,* (1994) observed three species of dolphin, *T. truncatus, S. longirostris* and *S. bredanensis,* during a survey conducted along Mtwara, Dar es Salaam, Bagamoyo and Tanga. Sperm whales and humpback whales are the most commonly-recorded whales (Amir & Berggren, 2001). Additional species found in Tanzania waters are pygmy sperm whales and long-finned pilot whale (*Globicephala melas*). The dugong has been recorded as bycatch both on the Tanzanian mainland and Zanzibar, indicating they are present, but in unknown numbers (WWF EAME, 2004).

Fisheries
The marine fisheries in Tanzania are artisanal. Fishing gears used include handlines, gillnets, shark nets, scoop nets, long lines, troll lines, cast nets, ring nets, purse seines, movable traps, fixed fences and spears. The number of fishing vessels recorded in Zanzibar was 7,096 and 7,190 in the Tanzanian mainland (MNRT, 2005; Jiddawi & Khatib, 2007). The most threatening fishing gears are drift set nets for large pelagic fish and bottom set nets for demersal species. Drift nets, targeting large pelagic fish such as kingfish, swordfish, sailfish, skipjack tuna and marlin, are approximately 500–900 m in length with variable mesh sizes from 7–20 cm, while bottom-set nets, targeting sharks and rays, vary in length up to 450 m, with mesh sizes ranging from 20–40 cm. These bottom nets are typically set very close to the shore.

Marine mammal bycatch
Dolphins and whales were recorded as bycaught in gillnets at sites around Unguja Island, in the Zanzibar Channel and along the coast of northern Tanzania. Six species of dolphins were identified from a total of 187 specimens caught in drift- and bottom set gillnets. Most of the specimens (95%) were from drift gillnets. The Indo-Pacific bottlenose dolphin was the most commonly bycaught species (47%) followed by spinner dolphin, Risso's dolphin, Indo-Pacific humpback dolphin, pan-tropical spotted dolphin and common bottlenose dolphin (Berggren *et al*., 2007). During questionnaire surveys conducted in April 2007 and February 2008 in Mtwara, where 64 fishers were interviewed, 15 (23%) of the fishers had personally caught a dolphin (Indo-pacific bottlenose, spinner, humpback and Risso's dolphins) in their 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 (Amir & Jiddawi, unpublished data). Dolphins have been recorded as bycatch in Pangani, Temeke, Rufiji and Kilwa (C. Muir, unpublished data).
Dugong bycatch has been recorded once in 2005 around Zanzibar, and 8 animals have been caught in gillnets in the extensive seagrass beds off the Rufiji Delta between 2004 and 2007 (Amir & Muir, unpublished data). 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 (O.A. Amir, pers. obs.).

Mitigation measures
There are currently no mitigation measures for reduction of bycatch of marine mammals in Tanzania. However, an experiment using acoustic devices (pingers) as a means of reducing incidentally catch of dolphins in gillnet fisheries is currently being conducted in Menai Bay Conservation Area.

Seychelles
Marine mammal diversity and status
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. 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 the Seychelles oceanic waters (Ballance & Pitman, 1998). The most common species observed in this area were, in order of occurrence: sperm whale, spinner dolphin, striped dolphin, bottlenose dolphin and pilot whales (unspecified species, but likely *G. macrorhynchus*). Other species have been observed, including rough-toothed dolphins, dwarf sperm whale, pygmy sperm whale, melon-headed whale, pygmy killer whale and beaked whales (*Mesoplodon* sp.). Longman's beaked whales have been recorded on several occasions (Anderson *et al.*, 2006). Robineau (1991) recorded Bryde's whales offshore, west of the Seychelles, as well as blue and fin whales (species identification still unclear for these two last). The dugong occurs in small numbers (at least 3 individuals) at Aldabra atoll (WWF EAME, 2004).

Fisheries
Various fishing techniques are used in the Seychelles. Among them, the drift longline (8 boats in 2006) targeting swordfish and sharks, handline targeting groupers and snappers, beach seine targeting small pelagic fishes, and traps targeting reef fishes. The use of gillnets (formerly targeting reef sharks) has been recently prohibited in Seychelles territorial waters (Seychelles Fishing Authority, pers. comm.). Seychelles host the major oceanic pure seine fishery of the Indian Ocean. This fishery composed of large boats (up to 100 meters long) operates all year long and only target tuna-like species.

Marine mammal bycatch
No marine mammal bycatch has been recorded in the Seychelles. According to the Indian Ocean Tuna Commission, this problem is not significant in oceanic pure seine fisheries (IOTC, 2007).

Mitigation measures
As bycatch extent is limited around the Seychelles, no mitigation measures are planned.

Reunion Island

Marine mammal diversity and status

Ten species of cetacean have been recorded around Reunion Island; including migrating humpback whales during austral summer (Dulau-Drouot *et al.*, 2008). The most common species are the Indo-Pacific bottlenose dolphin, spinner dolphin, common bottlenose dolphin and pantropical spotted dolphin. Other species, such as the melon-headed whale, the Fraser's dolphin and the short-finned pilot whale, occur but are relatively rare (Dulau-Drouot *et al.*, 2008). Two other species have been recorded by the *Muséum d'Histoire Naturelle* of St Denis: the Bryde's whale (observed stranded once) and the southern right whale, that has been sighted twice (S. Ribes-Beaudemoulin & P. Durville, personal communication).

Fisheries

Two types of fisheries are active around Reunion: the longline (offshore and pelagic) and the hand line fishery (coastal). Longlining is conducted throughout the year by a fleet of around 30 boats; the primary target species are swordfish and tunas. Hand lines target reef fishes, especially groupers and snappers. Around 300 fishing boats have been registered around the island (IFREMER, unpublished data). Game fishing, targeting large pelagic fishes, has a high socio-economical value in Reunion and its extent is currently unknown.

Marine mammal bycatch

There is a minimal amount of bycatch reported around Reunion. Bycatch has been mainly recorded game fishery that uses troll-line (Dulau/Globice personal communication.). Depredation in Réunion longline fishery is known to occur with Risso's dolphins (on bate) and short-finned pilot whales (on catches), but very few case of by-catch of this species over the last 6 years were reported in this fishery (J. Bourjea/IFREMER, personal communication). Two Spinner dolphins were reported entangled in game fishing line, but such a by catch seems to occasionally. 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. No mortalities have been documented (Dulau *et al.*, 2007).

Mitigation measures

As the extent of bycatch is minor around Reunion Island, no mitigation measures are planned.

Mauritius

Marine mammal diversity and status

Very little is known on the diversity and status of marine mammals around Mauritius. Strandings of Blainville's beaked whales have been reported by Michel & van Bree (1976). Corbett (1994), during a year-long study, observed that spinner dolphins and sperm whales were the most common cetacean species around the island. Baleen whales have been recorded also, including blue, humpback, and fin whales. A diversity of odontocetes also occur: pantropical spotted dolphin, bottlenose dolphin (Indo-pacific and common), Risso's dolphin, striped dolphin, melon-headed whale, pygmy killer whale, and Blainville's beaked whale (Corbett, 1994). The spinner dolphin is particularly common in the Bay of Tamarin, where they rest during the day (Mauritius Marine Conservation Society, pers. comm.). The dugong occurred around Mauritius and Rodrigues, and was considered as very abundant in this area in the 17th Century (Haskins & Davis, 2008). This species is now suspected extinct from the Mascarenes.

Fisheries
The following fisheries have been recorded around Mauritius: longline (5 boats) and drift longline (for tunas and swordfish, mainly on FADs, 170 boats), purse seine, handline/traps (artisanal, 3,000 boats) and beach seine (for mullets, 5 boats seasonally) (Kiszka & Muir, 2007). Latest figures are: 183 longliners, 43 purse seiners and 2 midwater trawlers; artisanal fishery (using basket traps, line, harpoon, large nets and gillnets): 2312 fishers and 1852 boats (Ministry of Agro Industry & Fisheries - Fisheries Division 2006).

Marine mammal bycatch
No cetacean bycatch has been recorded around Mauritius.

Mitigation measures
The bycatch issue has been not studied around Mauritius, no mitigation measures are undertaken or planned. Mauritius has a relatively large EEZ, so we suspect substantial bycatch is likely to occur. In addition, there are unknown numbers of illegal vessels that do not report their catches and may be experiencing bycatch.

Discussion and conclusion

Marine mammal bycatch has a highly variable extent within the southwest Indian Ocean region. Along continental coastlines such as in Kenya, Tanzania and Madagascar, gillnets are extensively used to catch sharks and other large fishes. The species most affected through bycatch in this gear are Indo-pacific humpback and bottlenose dolphins, as well as the dugong, which is probably the most endangered large mammal in eastern Africa (WWF EAME, 2004). Where gillnets are not a major fishery, localized and unquantified bycatch still occurs and warrants further investigation. Around oceanic islands, such as in the Mascarene, the Comoros, Mayotte and the Seychelles, marine mammal bycatch has a particularly limited extent. Gillnets are rarely or never deployed around these oceanic islands which may explain the low extent of marine mammal bycatch and may be due to bathymetric characteristics, where the presence of coral reefs and a steep insular slope make effective deployment of large gillnets difficult.

Interactions with the handline fishery occur and cause injuries to inshore dolphins in the lagoon of Mayotte (Kiszka *et al*., submitted). Incidental catches in longline fisheries (targeting swordfish and tuna) is limited to oceanic species in the region, mostly pilot whales. The extent of interactions seems limited. However, these interactions need to be assessed spatially and quantitatively, as such interactions may induce mortalities and demographic impacts on populations. Around Hawaii, false killer whales are genetically and socially isolated around the archipelago. They also seem to regularly interact with the longline fishery. This makes them susceptible to impacts of fisheries (Baird & Gorgone, 2005; Baird *et al.*, in press). Incidental catches in the purse-seine fishery appear rare in the southwest Indian Ocean, as a single baleen whale species has been reported in the Soviet purse-seine fishery (Romanov, 2001). It may be related to the rare occurrence of associations between dolphins and tuna in this region.

Interactions, causing mortalities or injuries, with handlines need to be considered, as they appear to impact regularly small coastal species of delphinids such as around Mayotte and Reunion. Even though data on bycatch within the region remains very poor and heterogeneous, particularly in countries with important artisanal inshore fisheries

(particularly gillnetting), coastal marine mammals are clearly at risk from bycatch along the continental coasts and Madagascar. Surveys to quantify the extent of marine mammal bycatch are urgently needed, and the *Rapid Bycatch Assessment* through interview surveys (see GLOBAL project, Global Bycatch Assessment of Long-lived Species, http://bycatch.env.duke.edu/) provides a useful tool. Other surveys, such as observer programs and coastal marine mammal abundance estimates/demographic studies, are also clearly needed where bycatch is known to occur. This work will help to better understand the level of threat and allow appropriate and effective mitigation measures to be developed in collaboration with local stakeholders.

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Table 1: Marine mammal bycatch matrix for the southwest Indian

Country	Fishery	Tarteted sp.	Fishing effort		Marine mammal bycatch			Data			Data source
			N.	Season	Dugong	Small cet.	Large cet.	Observers	Interviews	Landings	
Comoros	Fish trap	*Reef fishes*	900 gears	Year							
	Gillnet	*Sharks, others*	?	Nov-March	X	X			X		
	Handline	*Reef fishes*	3 300 gears		X	X					Community-Centred Conservation (C3, unpublished data). Poonian *et al.* (this volume).
	Artisanal longline	*Tuna*	?	?							
	Beach seine	*Fry*	?			X					
	Purse seine	*Tuna*	?	?							
	Spear gun	*Reef fishes*	?	?							
Mayotte (FR)	Reef seine	*Reef fishes*	~20 gears			X			X		
	Spear gun	*Reef fishes*	?								Pusineri & Quillard (this volume); Kiszka & Muir (2007); Direction des Affaires Maritimes (unpublished data)
	Handline	*Reef fishes*	1 092 gears			X			X		
	Longline	*Tuna & sword.*	3 gears			X			X		
	Purse seine	*Tuna*	0-3 boats	March-April							
Kenya	Trawling	*Prawns*	20 gears	Year							
	Gillnet	*Sharks*	5 916 gears	Year		X	X		X		
	Handline	*Reef fishes*	6 540 gears	Year							
	Beach seine	*Reef fishes*	970 gears	Year							
	Cast nets	*Various*	812 gears	Year							
	Basket trap	*Various*	5 224 gears	Year							Kenya Marine and Fisheries Research Institute (2006 data, unpublished).
	Monofilament	*Various*	1 050 gears	Year							
	Scoop net	*Various*	764 gears	Year							
	Trammel net	*Various*	23 gears	Year							
	Trolling net	*Various*	640 gears	Year							
	Spear gun	*Octopus*	624 gears	Year							
	Others	*Reef fishes*	9 137 gears	?							

Madagascar	Trawling	*Prawns & Tuna*	?	March-Dec.							
	Longline industrial	*Sharks*	?	Year							
	Longline artisanal	*Sharks*	?	Year	X	X	X		X		Razafindrakoto *et al*. (this volume); Direction de la Pêche et des Ressources Halieutiques (2006 data, unpublished)
	Gillnet industrial	*Shark & others*	?	Year							
	Gillnet artisanal	*Shark & others*	?	Year	X	X	X		X		
	Handline	*Fishes*	?	Year							
	Beach seine	*All resources*	?	Year							
	Spear gun	*Reef fishes*	?	Year							
Tanzania	Trawling	*Prawns*	10 gears	Year							
	Shark net	*Sharks & rays*	8 820 gears	Year	X	X	X		X		
	Gillnet	*Kingfish, grouper*	18 808 gears	Year	X	X			X		
	Longline	*Tuna & sword.*	53 549 gears	Year							
	Handline	*Reef fishes*	14 908 gears	Year							Ministry of Natural Resources & Tourism - Frame Survey. October 2005
	Beach seine	*Reef fishes*	453 gears	Year							
	Basket trap	*Various*	5 907 gears	Year							
	Cast net	*Various*	73 gears	Year							
	Scoop net	*Various*	710 gears	Year							
	Weir	*Various*	14 gears	Year							
	Lift net	*Various*	150 gears	Year							
	Spear gun	*Various*	350 gears	Year							
Zanzibar	Sharknet	*Sharks, others*	1 647 gears	Year	X	X	X	X	X	X	
	Gillnet	*Various*	5 328 gears	Year		X	X	X	X	X	
	Traps	*Various*	10 599 gears	Year							
	Handline	*Reef fishes*	18 865 gears	Year							
	Longline	*Tuna & sword.*	706 gears	Year							
	Beach seine	*Various*	938 gears	Year							Amir *et al*. (2002; 2005) Jiddawi & Khatib (2007)
	Purse seine	*Small pelagics*	215 gears	Year							
	Cast nets	*Various*	1 046 gears	Year							
	Ring nets	*Various*	180 gears	Year							
	Spear gun	*Various*	2 349 gears	Year							
	Scoop nets	*Various*	265 gears	Year							
	Weir	*Various*	13 gears	Year							

Reunion	Semi-industrial longline	*Sword & Tuna*	39 boats	Year		X		X	X	X	
	Beach Seine	*Small pelagics*	27 boats	Year		X			X		Institut Français de recherche pour l'exploitation de la mer (2007 data, unpublished) Bourjea & Evano (2008) Dulau *et al.* (2007)
	Handline	*Reef & pelagics*	183 boats	Year				X	X	X	
	trollline	*Large pelagics*	179 boats	Year		X		X	X	X	
	Spear gun	*Reef & pelag. fish*	?	Year					X		
	Traps	*Crustaceans*	44 boats	Irregular					X	X	
Seychelles	Diving gathering	*Spiny lobsters*	20 boats	Dec-Feb						X	
	Diving gathering	*Seacucumber*	25 boats	Year						X	
	Hook and line longline	*Shark*	6 boats	Year						X	
	Onutboard traps - Active	*Reef Fishes*	2 boats	Year						X	
	Onutboard traps - Static	*Reef Fishes*	41 boats	Year						X	
	Outboard	*Dem. & pelag. fish*	53 boats	Year						X	
	Outboard encircling gillnet	*Mackerels*	14 boats	Year						X	Seychelles Fishing Authority, Technical Report (2007)
	Pirogue encircling gillnet	*Mackerels*	1 boats	Year						X	
	Pirogue handline	*Dem. & pelag. fish*	5 boats	Year						X	
	Pirogue traps - Active	*Demersal fish*	1 boats	Year						X	
	Pirogue traps - Static	*Demersal fish*	7 boats	Year						X	
	Traps whaler - Static	*Reef & dem. Fish*	1 boats	Year						X	
	Semi-industrial longline	*Sword & Tuna*	4 boats	Year						X	
	Indutrial purse seine	*Tuna sp.*	51 boats	Year						X	
Mozambique	Ind. shallow water trawling	*Prawns*	77 boats	Year							
	Ind. deep water trawling	*Gamba*	25 boats	Year							
	Ind. line fishing	*Large pelagics*	27 boats	Year							IDPPE (2004); Guissamulo & Cockcroft (1997)
	Artisanal beach seine	*Reef fishes*	?	Year							
	Artisanal gillnet	*Sharks & rays*	?	Year	X	X	X				
	Artisanal line fishing	*Various fishes*	?	Year							
Mauritius	Basket trap	*Demersal fish*	?	Year							Fishery and Aquaculture Country Profile, Mauritius. FAO (http://www.fao.org/fishery/countrysector/FI-CP_MU/en)
	Hook-and-line	*Demersal and pel.*	?	Year							
	Spear gun	*Demersal fish*	?	Year							
	Gillnet	*Various fishes*	?	Year							
	Semi-industrial longline	*Sword & Tuna*	3 boats	Year							