Bycatch assessment of vulnerable megafauna in coastal artisanal fisheries in the southwest Indian Ocean

Jeremy Kiszka

Final report to:

South West Indian Ocean Fisheries Project (SWIOFP)

May 2012

Content

Executive summary

The incidental catch of marine megafauna, including marine mammals, sea turtles and elasmobranchs, poses one of the main threats to these species at the global scale. These taxa are particularly vulnerable for biological reasons, such as late maturity and low reproduction rates. Artisanal fisheries account for more than 95% of fishers in the world, especially in developing countries where artisanal fisheries are socially and economically most important. Their impact on vulnerable megafauna may thus be significant, either as bycatch or as target in artisanal fisheries. The purpose of this study is to assess bycatch and use of vulnerable megafauna (marine mammals, sea turtles and elasmobranchs) in the SWIO artisanal fisheries using interview surveys. This study focuses on areas where bycatch of vulnerable megafauna has been previously identified, suspected or least known as for the east coast of Africa (Mozambique, Tanzania and Kenya) and Mauritius. This study also provides recommendations for future research, management and mitigation of vulnerable megafauna bycatch in artisanal fisheries of the SWIO region.

A total of 961 interview surveys was conducted in the region, including in Kenya (n=330), Tanzania (n=276), Mozambique (n=296) and Mauritius (n=59). Throughout the region, eight artisanal fisheries types were sampled: mono- and multifilament drift gillnets, bottom-set gillnets, beach seines, purse seines, longlines, lining under FADs (Fish Aggregating Devices) and handlines. These fisheries were considered to be the most likely involved in sea turtle, marine mammal and elasmobranch catches. A particular effort has been devoted to sample gillnet fisheries, previously documented as the major threat to large marine megafauna in the region.

The major finding of this study is the high extent of large marine vertebrate bycatch in artisanal fisheries, especially in drift, bottom-set gillnets and beach seines. At least 59 species were identified as bycatch and by-product species, including five species of sea turtles, eight species of marine mammals and 46 species of elasmobranchs. The Ecological Risk Assessment emphasized that at least 17 species were particularly vulnerable to artisanal fisheries bycatch in the southwest Indian Ocean, including all species of sea turtles (loggerhead, green, hawksbill, olive Ridley and leatherback turtles), 4 species of marine mammals (dugong, Indo-Pacific bottlenose, humpback and spinner dolphins) and 8 species of elasmobranchs. Among elasmobranchs, highest risk was identified for Manta, spotted eagle rays, giant guitarfish and hammerhead sharks (including scalloped and great hammerheads). The risk was particularly enhanced in species with low productivity (low fecundity). Line fisheries (longline and handline) have a low impact on the survival of sea turtles and marine mammals. However, these fisheries have a significant impact on elasmobranchs. As suggested by interview survey data and PSA

plots, there is a difference in the scale and effect of bycatch of vulnerable megafauna among different gear types. Bycatch levels were higher in multifilament than in monofilament drift gillnets, both for cetaceans (small delphinids in particular), sea turtles and elasmobranchs, and involved more species. Sea turtles (especially green, hawksbill, olive Ridley and loggerhead turtles), manta rays, hammerhead sharks and Indo-Pacific bottlenose dolphins were the most common bycatch species, as well as the most impacted by drift gillnets. Bycatch levels were lower for these species in bottom-set gillnets (but they were still high for several species), but affected a greater number of species, especially benthic and demersal species (especially coastal rays and reef sharks). However, the risk associated with bottom-set gillnets was lower for all species (due to lower susceptibility). Concerning one of the most threatened vulnerable species in the region, the dugong, bycatch events were rarely reported, in comparison to previous studies. This may be attributed to the current rarity of this species along the east African coast and a rapid decline since the early 2000s. Beach seines were also noted as highly impacting on sea turtles, especially for the green turtle, as this gear is frequently used very close to shore, over seagrass meadows, known foraging habitats for this species). Other species of sea turtles were also impacted, including hawksbill, olive Ridley and loggerhead turtles and, surprisingly, coastal marine mammals. Bycatch levels were particularly high for inshore Indo-Pacific bottlenose dolphins, especially in Mozambique. The effect of beach seines on more pelagic and oceanic species was low, such as spinner dolphins (rarely observed in inshore waters), Manta rays, great hammerhead sharks and leatherback turtles. Finally, handlines had the lowest impact on vulnerable megafauna, especially due to the low post capture mortality.

Results collected in this study are consistent with previous local studies, undertaken in the southwest Indian Ocean, both in term of species involved and bycatch incidence. However, this is the first in-depth regional study of megafauna bycatch in artisanal fisheries in the southwest Indian Ocean and has clearly highlighted that an important diversity of large and vulnerable marine vertebrates are exposed to artisanal fisheries' bycatch in the SWIO region. It is also clear that net fisheries should be the focus of future management initiatives. A priority should be given to drift gillnet fisheries, posing the greatest threat to marine mammals, sea turtles and large elasmobranchs in the region. Therefore, limiting the use of these nets should be encouraged. These limitations could be either spatial or temporal, and based on scientific information on habitat use of bycatch species. Recently, it has been shown that the establishment of marine protected areas (MPAs) can be effective for a number of taxa, including marine mammals, sharks and probably sea turtles. Initiatives to identify marine protected areas, where gillnets and beach seines may not be used, are strongly encouraged in the SWIO region.

Terms of reference

Jeremy Kiszka (author) was contracted by SWIOFP to undertake a bycatch assessment in coastal artisanal fisheries. This study was conducted under Component 5 of SWIOFP: mainstreaming biodiversity in WIO fisheries. The outputs of the consultancy are as follows:

1. Assess the extent of bycatch of vulnerable marine species (marine mammals, sea turtles and sharks) in coastal artisanal fisheries in the SWIO region. The method to be used should include extrapolation of data derived from interview surveys, a technique that has previously proven to be effective in developing nations, including a literature review.

2. Review the management/mitigations/technical measures and legislations to address bycatch in SWIO and recommend any new initiatives in the artisanal/local/domestic fisheries.

3. Develop map of sensitive/vulnerable areas where impacts of fishing (by gear/species) on bycatch are of concern or of high point of conflict.

4. Work with SWIOFP countries to implement a rapid bycatch impact assessment (coastal fisheries) and provide materials for interviewers, including interview survey details (questionnaire, methodology), simple database to capture the data and species identification sheets (See table 2).

5. Train data recorders to collect interview surveys.

6. Conduct an Ecological Risk Assessment (ERA) on these species and their vulnerability in respect to the targeted species (SWIOFP priority species).

7. Prepare a detailed report with an executive summary and recommendations future actions needed to address the issues or gaps of information for management purposes.

Acknowledgments

The author would like to thank all contributors (field technicians, national coordinators) and colleagues for their contribution, assistance and advice, including Rondolph Payet (SWIOFP), Rudy van der Elst (Oceanographic Research Institute, South Africa), Jérôme Bourjea (IFREMER, France), Francis Marsac (IRD, France), Bernadine Everett (Oceanographic Research Institute, South Africa), Osvaldo Ernesto Chacate (Instituto Nacional do Investigação Pesqueira, Mozambique), Paula Santana (Instituto Nacional do Investigação Pesqueira, Mozambique), Julius Otieno Manyala (MOI University, Department of Fisheries and Aquatic Sciences, Kenya), Boaz Okeyo Orembo (Kenya Marine Fisheries Research Institute, Kenya), Satish Kumar Khadun, Ravi Mohit, Mira Hurbungs (all of the Albion Fisheries Research Center Albion, Mauritius), Bigeyo Kuboja (Tanzanian Fisheries Research Institute, Tanzania), Narriman Jiddawi (Institute of Marine Sciences, Zanzibar), Sergi Pérez Jorge (Global Vision International) and Per Berggren (Newcastle University, UK).

For their technical advices, the author also thanks Alistair Hobday (CSIRO Marine and Atmospheric Research, Hobart, Australia) and Benoit Simon-Bouhet (Université de La Rochelle, France). For funding and managing the project, the author thank the World Bank, the *Fond Français pour l'Environnement Mondial* and the Kenya Marine Fisheries Research Institute. Special thanks are addressed to Rudy van der Elst for his important contribution in revising the early draft of the report.

List of Tables

List of Figures

Introduction

The incidental catch of marine megafauna, including marine mammals, sea turtles and elasmobranchs, poses one of the main threats to these species at the global scale. These taxa are particularly vulnerable especially for biological reasons, such as late maturity and low reproduction rates. A large number of species (both protected and unprotected), are severely threatened due to unmanaged fisheries (Lewison *et al.*, 2004). While the issue of bycatch in fisheries is a major risk factor it has to date primarily been investigated in industrial fisheries, and very little attention has been given to the extent of bycatch in artisanal fisheries. Artisanal fisheries account for more than 95% of fishers in the world, especially in developing countries where artisanal fisheries are socially and economically most important (Pauly, 2006). Their impact on vulnerable megafauna may thus be significant, either as bycatch or as target in artisanal fisheries (Moore *et al.*, 2010).

In the southwest Indian Ocean (SWIO) region, the problem of bycatch in artisanal fisheries is poorly documented despite the fact that 138 out of 254 fisheries identified in the SWIO are artisanal (Everett *et al.*, 2011). Before the early 2000s, most information was anecdotal or unpublished. However, in response to increasing concern about incidental catch of vulnerable megafauna in the region several meetings were organised to address this issue (e.g. FAO, 2006; Kiszka & Muir, 2007). In November 2006, representatives from western Indian Ocean countries attended a workshop to collate available information and assess the potential impact of bycatch on non-targeted marine species in the SWIO, with a focus on marine mammals and sea turtles. It was also acknowledged that while sea turtles, dugongs, cetaceans and sharks are all impacted by fishing activities in the region, it is the dugong which is most severely threatened from gillnetting and habitat disturbance (Kiszka & Muir, 2007). More recently, several local and regional initiatives emerged to assess the extent of bycatch on marine mammals and sea turtles in artisanal fisheries, such as in the Comoros (Poonian *et al.*, 2008), Mayotte (Kiszka *et al.*, 2007; Pusineri & Quillard, 2008); south-western Madagascar (Razafindrakoto *et al.*, 2008) and Zanzibar (Amir *et al.*, 2002; Amir, 2010). These studies highlight that gillnet fisheries (both drift and bottom-set) are the most impacting, especially for marine mammals but also for sea turtles. However, no quantitative information was generated on the extent of vulnerable megafauna bycatch in coastal gillnets and a number of other artisanal fisheries, including handlining, longlining or beach seining. Knowledge on elasmobranch bycatch and exploitation in the SWIO is mostly available for industrial and semi-industrial fisheries, including purse seine, longline and shrimp/prawn trawl fisheries (e.g. Fennessy, 1994; Romanov, 2001, 2008; Huang & Liu, 2010). Information derived from artisanal fisheries is rare, not quantified, and generally focus on sharks as targeted species (Marshall, 1997; Schaeffer, 2004; McVean *et al.*, 2006). Overall, in the SWIO region, information on bycatch of vulnerable megafauna is lacking for many geographical areas. Research efforts have been restricted spatially and focussed on particular fisheries not necessarily representative of those in the broader SWIO.

The flexible and informal nature of most artisanal fisheries (broad range of target species, diversity of gear, occurrence in multiple marine habitats, general absence of seasonality,...) make them very difficult to study, both in term of catch statistics and bycatch. In addition, for most artisanal fisheries (except some gillnet fisheries), observer programs are very difficult to implement, due to logistical constraints such as small boat size. Therefore, in absence of data collected at sea on fishing vessels by observers, researchers have increasingly used social sciences to better understand the interactions between artisanal fisheries and marine ecosystems (Johannes *et al.*, 2000; Close & Hall, 2006), and particularly marine mammals and sea turtles (Van Wearebeek *et al.*, 1997; Amir *et al.*, 2002; WWF EAME, 2004; Pusineri & Quillard, 2008; Moore *et al.*, 2010).

The purpose of this study is to assess bycatch and use of vulnerable megafauna (marine mammals, sea turtles and elasmobranchs) in the SWIO artisanal fisheries using interview surveys. More specifically, this study aims to identify the artisanal fisheries with the highest impacts, geographical areas of higher bycatch rates and the most impacted species of marine mammals, sea turtles and elasmobranchs. It also provides some preliminary information on exploitation of certain vulnerable megafauna, especially elasmobranchs, for which little is known on the extent of their use and exploitation in artisanal fisheries at the SWIO level. This study focuses on areas where bycatch of vulnerable megafauna had been previously identified, suspected or unknown, i.e. the east coast of Africa (Mozambique, Tanzania and Kenya) and the island of Mauritius. This study also provides recommendations for future research, management and mitigation of vulnerable megafauna' bycatch in artisanal fisheries of the SWIO region.

1. Bycatch of vulnerable megafauna in the southwest Indian Ocean: an overview

Vulnerable megafauna in the SWIO may be defined as large species with low fecundity and productivity, slow growth, late age at maturity, large size at birth, high natural survivorship and a long life. Such biological characteristics have serious implications for their sustainability in fisheries, including as bycatch. Such species depend on a stable environment, and generally have limited capacity to sustain and recover from heavy fishing pressure. Here, the species we consider as vulnerable megafauna are marine mammals (cetaceans and the dugong *Dugong dugon*), sea turtles and elasmobranchs (sharks and rays). This section overviews marine mammal, sea turtle and elasmobranch bycatch in the SWIO region. For a more detailed overview of bycatch of these taxa, please refer to the SWIOFP retrospective analysis [Kiszka (2012) for marine mammals, Bourjea (2012) for sea turtles and Kiszka & Van der Elst (2012) for elasmobranchs].

1.1 Marine mammals

Within the SWIO, a total number of 37 marine mammal species have been recorded (authenticated records, including sightings and/or strandings) including 32 cetaceans, 1 sirenian (the dugong) and 4 pinnipeds (Best, 2007; Kiszka, 2012). Marine mammal bycatch in fisheries has been investigated for several years in the region (Table 1.1). Along the east coast of south-east Africa, the main marine mammal bycatch problem has been reported from bather protection anti-shark nets in the KwaZulu-Natal region. The affected area stretches from Mzamba to Richards Bay (Cockcroft, 1990). On average, 76 (range 36-175) dolphins are bycatch every year, of which 46% are common dolphins (*Delphinus delphis*), 42% are bottlenose dolphins (*Tursiops* spp.) and 8% are Indo-Pacific humpback dolphins (*Sousa chinensis*; Peddemors *et al.*, 1998; Best, 2007). 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. Marine mammal bycatch has been investigated in coastal fisheries of the region, especially gillnets, although indications are that marine mammal bycatch in open ocean fisheries is very low (Romanov, 2001, 2008). Bycatch records in the pelagic longline fishery have been anecdotally documented. Large delphinids involved in depredation have been recorded, including false killer whales (*Pseudorca crassidens*) and Risso's dolphins (*Grampus griseus*; Poisson *et al.*, 2001; Kiszka *et al.*, 2010).

Marine mammal bycatch in artisanal fisheries is documented for several countries in the SWIO: around the Comoros and Mayotte (Poonian *et al.*, 2008; Pusineri & Quillard, 2008), in Tanzania (Zanzibar; Amir *et al.*, 2002; Amir, 2010) and the west coast of Madagascar (Razafindrakoto *et al.*, 2008; Table 1.1). Cetaceans have been recorded as bycatch in gillnets at sites around Unguja Island, in the Zanzibar Channel and along the northern coast of Tanzania (Amir *et al.*, 2002). From interview surveys, a total of 96 dolphins were reported to have been incidentally caught between 1995 and 1999: 43 Indo-Pacific bottlenose dolphins (*Tursiops aduncus*), 29 spinner dolphins (*Stenella longirostris*), 5 Indo-Pacific humpback dolphins and 19 unidentified dolphins (Amir *et al.*, 2002). Data collected by on-board observers indicated high levels of capture relative to the small population size of the two coastal species of Indo-Pacific humpback and bottlenose dolphins. The annual bycatch rates represented respectively 9.6% and 6.3% for local Indo-Pacific bottlenose and humpback dolphin populations, respectively, a serious cause of concern for the survival of the two coastal species (Amir, 2010). In more recent 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, personal communication). Dugong bycatch is still frequent in Tanzania; 26 individuals (adults, juveniles and cow-calf pairs) were reported as bycatch from 2000 to 2004. These incidental captures mostly occurred in the Rufiji Delta and off Kilwa (WWF EAME, 2004; Muir & Kiszka, 2012).

In Madagascar, a project was initiated in 2005 to evaluate the extent of bycatch of marine mammals in artisanal fisheries in the south-western region. A total of 111 interviews was analysed which indicated 56 bycatch events in these villages between 2000 and 2005. Indo-Pacific humpback, bottlenose, spinner, Fraser's dolphins and humpback whales were 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).

In other areas, information on bycatch is anecdotal. Interview surveys with fishers in Mozambique have confirmed that humpback dolphins are also caught in the drift gillnet fishery (Guissamulo & Cockcroft, 1997). Although the extent of marine mammal bycatch in Kenya is unknown, it could potentially be considerable due to the extensive local use of gillnets (Kiszka *et al.*, 2008). Around Mayotte, 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.*, 2007). Incidental catches in seine nets are likely very rare. During a recent interview survey in 2007, only ten fishers declared that they had caught a cetacean (only small dolphins; Pusineri & Quillard, 2008). There is a minimal amount of cetacean bycatch reported around other areas in the SWIO, such as the Seychelles, the Union of the Comoros, La Réunion and Mauritius (Kiszka *et al.*, 2008).

Bycatch is the greatest threat to marine mammals in the SWIO (Kiszka & Muir, 2007). Overall, the extent of marine mammal bycatch has only been quantified off Zanzibar (Amir, 2010). Interview surveys conducted in several countries of the region (Comoros, Mozambique, Tanzania) underlined that bycatch occurs in artisanal fisheries, essentially in gillnets (Kiszka *et al.*, 2008). The greatest concern for marine mammal bycatch is gillnets (used in coastal artisanal fisheries), regularly catching coastal marine mammals in the region, including dugongs, dolphins (especially *T. aduncus*, *S. chinensis* and *S. longirostris*) and the humpback whale (*Megaptera novaeangliae*; WWF EAME, 2004; Kiszka *et al.*, 2008; Amir, 2010).

Table 1.1: Overview of marine mammal bycatch information in coastal fisheries in the southwest Indian Ocean

Country	Fishery	Methodology	Bycatch species and characteristics	Reference
South Africa	Anti-shark nets	Net inspections (1978-1996)	76 annual catches (36-175), involving *Delphinus delphis* (46%), *Tursiops spp.* (42%) and *Sousa chinensis* (8%)	Peddemors *et al.* (2008)
	Anti-shark nets	Net inspections (1963-1988)	Occasional catches of large whales: *Balaenoptera acutorostrata* and *Eubalaena australis* (5.6 whales/year)	Best *et al.* (2001)
Mozambique	Gillnets	Interviews (n=84; Inhambane and Cabo Delgado provinces)	Dugong bycatch is regular in the surveyed area, especially in gillnets but few records on beach seines	WWF EAME (2004)
Tanzania mainland	Gillnets	Interviews (n=420 in 57 villages)	Since, about 31 net captures in gillnets, primarily in Rufiji-Kilwa-Mafia and Tanga regions (most significant dugong habitats)	WWF EAME (2004)
Tanzania mainland	Gillnets	Interviews (n=537)	Bycatch incidence rate (porportion of interview respondents reporting annual capture) is low, both for cetaceans (0.03) and dugong (0.03)	Moore *et al.* (2010)
Zanzibar	Gillnets	Interviews with gillnet operators (101), in 10 villages	96 dolphins reported to have been incidentally caught in gillnets (1995-1999), including 43 *T. aduncus*, 29 *S. longirostris*, 5 *S. chinensis* and 19 unid. dolphins	Amir *et al.* (2002)
	Gillnets	Observer program (2003-2004)	Unsustainable bycatch rates in the area: 9.6% for *T. aduncus* and 6.3% for *S. chinensis*	Amir (2010)
Kenya	Gillnets	Interviews (n=222 in 14 villages)	31% claimed said they had seen a dead one either on the beach or trapped / entangled in fishing net	WWF EAME (2004)
Comoros (Grande Comore & Mohéli)	Gillnets	Interviews (n=409)	Dugongs have been reported as bycatch in gillnets off Mohéli. Dolphin bycatch is very rare (*S. longirostris* reported as bycatch)	Poonian *et al.* (2008)
Mayotte (Fr)	All artisanal	Interviews (n=35)	Bycatch in fishing nets is the main threat to dugongs around Mayotte. Only one bycatch event reported from 1999 to 2003	Kiszka *et al.* (2007)
	All artisanal	Interviews (n=406)	9 dugong (gillnets) and 5 dolphins (1 handline and 4 gillnets) catches reported	Pusineri & Quillard (2008)
Madagascar (Anakao region, SW)	Gillnets (sharks)	Interviews (n=111; 4 villages)	56 bycatch events (79 animals) reported between 2000 and 2005: *T. aduncus* (48.1%), *S. longirostris* (31.6%)	Razafindrakoto *et al.* (2008)

1.2 Sea turtles

Five species of sea turtles are known to occur in the SWIO, but green (*Chelonia mydas*), loggerhead (*Caretta caretta*) and hawksbill turtles (*Eretmochelys imbricata*) are the most common and widely distributed in the region. Three fisheries have been identified to significantly catch sea turtles, namely gillnetting, prawn/shrimp trawling and longlining (FAO, 2006; Bourjea *et al.*, 2008; Table 1.2). However, in most countries of the region, the extent and impact of fisheries on sea turtles is poorly known, except for open ocean fisheries of the Seychelles, La Réunion (France) and South Africa. In addition, baseline parameters on sea turtle populations (abundance, reproduction) are only documented from a limited number of locations along the coasts of Madagascar and East Africa, but well documented for islands (Comoros Archipelago, Seychelles Archipelago and French scattered islands).

High mortalities of sea turtles (especially green) in prawn and shrimp trawl fisheries have been documented in the region. In Mozambique, an annual range of 1,932 – 5,436 turtles may be killed in these fisheries in Sofala Bank (Gove *et al.*, 2001). Similar situations may occur elsewhere in the region (Kenya, Madagascar and Tanzania), but recent data are still lacking (Bourjea *et al.*, 2008). Gillnets pose a serious threat for green and hawksbill turtles, especially off Zanzibar (5,329 gillnets recorded in 2008 in Zanzibar and Pemba; Sobo *et al.*, 2008), although no bycatch estimates have been produced. In Kenya, estimated incidental catch rates of turtles in shrimp trawls was estimated to be 100 – 500 turtles/ year when Turtle Excluder Devices (TED) were not in use (Wamukoya *et al*., 1996). In Madagascar, sea turtle mortality in shrimp trawler was very high but, since the introduction of Turtle Excluder Devices (TEDs), mortality has apparently ceased (Rakotonirina *et al.*, 2006). However, artisanal fisheries may have a major impact on sea turtles around Madagascar (especially the green turtle). A recent study showed that the annual turtle catch in the southwestern province of Tulear alone is between 10,000 and 16,000, although this extrapolation should be taken with caution (Humber *et al*., 2011).

In pelagic waters, purse-seining and longlining are known to incidentally catch sea turtles in the SWIO region. However, bycatch rates are relatively low. At La Réunion, less than 0.004 turtles per 1,000 hooks were caught by the pelagic longline fishery from 1990 to 2000 (Poisson & Taquet, 2001). Off Mayotte (2009-2010), on 29 longline sets of 500 hooks, four loggerhead turtles were caught alive (0.28 turtles per 1,000 hooks), and released alive (Kiszka *et al*., 2010). In the purse seine fishery, sea turtle bycatch was estimated based on data collected through French and Spanish observer programs representing a total of 1,958 observed fishing sets monitored between 2005 and 2008. Turtles were only infrequently recorded and almost exclusively made on log-associated tuna school sets (95%). Over the whole period of observations a total of 74 individuals were caught (Amande *et al*., 2008).

In the SWIO region, quantitative information on bycatch levels is still lacking for all fisheries. Bycatch rates should be accompanied by reliable information on sea turtle population abundance, reproductive parameters and spatial dynamics. The lack of information is particularly evident for coastal and artisanal fisheries, also targeting sea turtles in several countries in the region, such as Madagascar (see for review Bourjea *et al.*, 2008).

Table 1.2: Review of sea turtle bycatch information in artisanal fisheries in the southwest Indian Ocean

Country	**Fishery**	**Methodology**	**Bycatch species and characteristics**	**Reference**
South Africa	Anti-shark nets	Net inspections (1981-2008)	Around 40.9 *C. caretta*/y. (SE=2.18) are caught in shark nets. Other most commonly caught species are *C. mydas* (11.9) and *D. coriacea* (5.36)	Bourjea (2012)
Mozambique	Gillnets	?	240-420 sea turtles (3/4 being *C. mydas*) are caught annually in gillnets	Louro *et al.* (2006)
Tanzania mainland	Gillnets	Interviews (n=537)	Bycatch incidence rate (proportion of interview respondents reporting annual capture): from 0.03 to 0.1	Moore *et al.* (2010)
Zanzibar	Gillnets	?	45-60% of gillnet fishing trips catch turtles, accounting for several thousand turtles annually	Bourjea (2012)
Kenya	Gillnets	?	600 turtles are being caught annually and handed over for release in the Watamu area alone	Okemwa *et al.* (2004)
Comoros (Grande Comore & Mohéli)	Gillnets	Interviews (n=409)	Sea turtles are caught in large number around the Comoros, both using gillnets and handlines. Most commonly caught species are *C. mydas* and *E. imbricata*	Poonian *et al.* (2008)
Mayotte (Fr)	All artisanal	Interviews (n=406)	78 fishermen claimed they caught at least one turtle so far in the last year (66 incidental). All animals were kept for consumption. Handlining was the most impacting gear type (especially for *E. imbricata*). Estimated turtle mortality ranged from 111 to 256/y	Pusineri & Quillard (2008)

1.3 Elasmobranchs

At the global scale, 700,000 to 850,000 tons of sharks are caught annually as target species or bycatch, and landings increase roughly at an annual 2% rate (Camhi *et al*., 2009; Lucifora *et al*., 2011). This is however an underestimation (Clarke *et al*., 2006) because of illegal fishing of sharks for their fins. In 2009, 33 countries reported elasmobranch landings from the area 51 (western Indian Ocean), totalling 86 000mt. More than 15 species of sharks (belonging to five families) are regularly taken in the region's fisheries, the most common caught species being blue (*Prionace glauca*) and silky sharks (*Carcharhinus falciformis*; Smale, 2008). However, most of the elasmobranchs landings in the IOTC (Indian Ocean Tuna Commission) region are still not identified to species and are grouped as "sharks". There are still too few observer programmes in the Indian Ocean and SWIO in particular, and little is known on trends in pelagic shark populations of the region, except from data collected in the South African pelagic longline fishery and the KwaZulu-Natal Sharks Board.

In the SWIO, shark carcasses are mostly discarded but fins are collected and retained. Overall, elasmobranchs catches have drastically increased in the western Indian Ocean (FAO fishing area 51), peaking in 1996, partly attributable to higher fishing effort directed at tuna. However, since that peak the reported landings of elasmobranchs has subsided significantly (Smale, 2008). Three main shark families are taken in pelagic fisheries in the SWIO, including Lamnidae, Alopiidae and Carcharhinidae. In the purse seine fishery, for the period 1986 to 1992, the annual bycatch was estimated at 944–2270 t of pelagic oceanic sharks and 53–112 t of *Mobula* and *Manta* (Romanov, 2002). For the period 2003-2009, the quantity of silky shark as the most common bycatch shark species, was estimated from observer data on European vessels in the purse seine fishery associated with floating objects (Amandè *et al.*, 2011). The highest silky shark catch rates were observed in the northern fishing grounds (2°N, 53°E), north of the Seychelles (Amandè *et al.*, 2011). Fishing operations under FADs are characterized by significantly higher silky shark bycatch levels (4.3 sharks in FAD-associated tuna vs. 0.3 sharks in free shoaling tuna; Amandè *et al.*, 2008). In the pelagic longline fishery, in tropical waters of the Indian Ocean, the most common bycatch shark species are *P. glauca*, *C. falciformis*, *A. superciliosus* and *I. oxyrhynchus (*Huang & Liu, 2010). In more temperate waters, such as off South Africa, the blue shark is targeted in the pelagic shark-directed longline fishery and is a common bycatch in the tuna and swordfish directed fisheries. Of the total pelagic shark landings in South Africa, the blue shark comprised 35% of landed mass from 1998 to 2008 (Jolly *et al.*, 2011).

Coastal fisheries, such as the industrial shrimp fishery with shallow inshore and deeper offshore elements, also catch significant amounts of elasmobranchs. From 1989 to 1992, Fennessy (1994) analysed the elasmobranch bycatch of the inshore sector. He estimated that 44,600 elasmobranchs were caught in this fishery during the study period, estimated at 357 tons per year and including 26 species of which seven were endemic. Most of the elasmobranchs taken in Mozambique waters are part of a bycatch with shrimp trawlers catching the most significant amount of elasmobranchs, especially over the continental shelf. However, recently, bycatch reduction devices have been tested in prawn trawl fisheries in Mozambique. Fennessy & Isaksen (2007) showed that 75% of hauls with grids caught fewer large rays than those without grids while hauls using grids caught no large sharks at all.

For artisanal fisheries, data are really limited at the regional level. Sharks are taken both as bycatch and target species in several fisheries. In Tanzania, fishing for elasmobranchs has occurred for centuries with shark fishing, especially in Zanzibar, being mostly seasonal during austral summer. Sharks are important resources for Zanzibar, both as a valuable source of cheap meat when dried, and more importantly as a major source of income provided by the fins (Schaeffer, 2004). Bottom-set gillnets, which particularly target sharks and rays, vary in length up to 450m, with mesh sizes ranging from 20-40cm bar. Longlines are also used to harvest sharks (Barnett, 1997). In Madagascar, there is an active export market along the west coast for shark fins, indicating a considerable social and economic importance. In this Toliara region, results from a total of 1,164 catch records, included at least 13 species of elasmobranch, with an estimated total wet weight of over 23 mt. Hammerhead sharks (*Sphyrna* spp.) representing 29% of sharks caught by number and 24% of the total wet weight (McVean *et al.*, 2006).

Overall, the extent of bycatch and level of exploitation of elasmobranchs in artisanal fisheries of the region are poorly known and documented. A number of species are now classified as endangered (IUCN status), such as the scalloped hammerhead shark (*S. lewini*), that is declining in certain regions such as the southwest coast of Madagascar (McVean *et al.*, 2006). A better understanding of shark fisheries and bycatch in artisanal fisheries is probably a major issue for the survival of certain elasmobranch species/populations in the SWIO region.

2. Artisanal fisheries in the southwest Indian Ocean: an overview

Most information on artisanal fisheries in the SWIO region has been collated by Everett and colleagues, and presented in the annual report of WIOFish database (Everett *et al.*, 2011 and www.wiofish.org). A total of 254 fisheries was recorded by the end of August 2011, with 22 from the Union of Comoros, 33 from Kenya, 19 from Madagascar, 20 from Mauritius, 30 from Mozambique, 41 from the Seychelles, 54 from KwaZulu-Natal, South Africa and 35 from Tanzania. Among them, 138 fisheries are artisanal and 58 are primarily subsistence (Everett *et al.*, 2011). Overall, knowledge on artisanal fisheries is still very limited in the SWIO, especially due to difficulty of estimating the fishing effort (number of fishers, boats and gears), catch and bycatch information. However, some information (especially on fishing effort) has been collected from national fisheries administrations. Here is an overview of artisanal fisheries in the SWIO.

In **Kenya**, 33 fisheries have been recorded in WIOFish. 11 fisheries are artisanal, 9 are artisanal and primarily subsistence and 3 are artisanal and small scale commercial (Everett *et al.*, 2011). Artisanal/subsistence fisheries use a variety of gears, including gillnets, hand lines, beach seines, basket traps, cast, scoop, monofilament, trammel and trolling nets, spear guns and other gears (KMFRI data). Targeted species are highly diversified, including reef and pelagic fish as well as elasmobranchs. Any gear type used can target a variety of species. Kenya's fisheries operate in a multitude of habitats with each fishery type potentially operating in more than one habitat. As would be expected from small-scale fisheries, most operate in inshore habitats (Everett *et al.*, 2011). In artisanal fisheries, gillnets, beach seines and fish traps are more likely to catch marine mammals, sea turtles and elasmobranchs. However, only anecdotal information exists on bycatch of these species (Bourjea *et al.*, 2008; Kiszka *et al.*, 2008).

In **Tanzania**, including Zanzibar, 35 fisheries have been recorded in the WIOFish database. Most (19) fisheries are artisanal, 5 are artisanal/small scale commercial and 3 are artisanal/small scale commercial/subsistence (Everett *et al.*, 2011). Gears used are highly diversified, including gillnets (for sharks, rays, kingfish, groupers), traps and handlines (various fish), longlines (tunas, swordfish), beach seines (various demersal and reef fish) and spear guns (reef fish; Ministry of Livestocks and Fisheries Management (Mainland) & Ministry of Agriculture, Livestocks and Environment (Zanzibar), 2008). The considerable extent of gillnet fisheries in Tanzania is important as it may threaten many non-targeted species, such as marine mammals (Amir *et al.*, 2002; WWF EAME, 2004) and sea turtles (Bourjea *et al.*, 2008). Sharks are also highly exploited using bottom and drift gillnets, especially off Zanzibar (Barnett, 1997; Schaeffer, 2004).

Off the coast of **Mozambique**, 30 fisheries have been recorded in WIOFish. The artisanal/traditional fisheries account for most of these fisheries. Gears used include beach seines (reef fish), gillnets (various fish, elasmobranchs) and line fishing (various fish). Seagrass beds are the most fished habitats in terms of the number of fisheries operating in them followed by coral reef platforms (Everett *et al.*, 2011). Gillnets and beach seines are likely to be the most impacting artisanal fisheries for marine mammals, sea turtles and elasmobranchs off Mozambique.

Along the coast of **KwaZulu-Natal** (KZN), in South Africa, 54 fisheries have been recorded in the WIOFish database. Artisanal fisheries are poorly developed in this region: 3 artisanal and 5 artisanal/subsistence fisheries (Everett *et al.*, 2011). All KZN artisanal fisheries occur either in estuaries, in the inshore waters, and on rocky shores.

Mauritius has 20 fisheries, most of which are artisanal. The most commonly used gears are gillnets (targeting various reef/coastal fish), basket traps, handline and spear guns (all targeting demersal fish). The hand line fishery also extends further offshore, targeting large pelagic fish under FADs. Mauritian fisheries operate in numerous habitats; however, most operate in lagoons, seagrass beds, coral reef platforms and the general inshore areas (Everett *et al.*, 2011). No information exists on vulnerable megafauna bycatch in artisanal fisheries off Mauritius.

Around the **Seychelles**, 41 fisheries have been recorded in the WIOFish database, with half of them being artisanal. These fisheries include diving gathering (sea cucumbers, spiny lobsters), handline and longline (targeting sharks, reef/demersal/pelagic fish), active and static traps (reef fish) and encircling gillnets (mackerels; SFA data). Fisheries around the Seychelles are active in numerous habitats with most operating in the general inshore area, in lagoons, on coral reef platforms and in shallow coastal bays (Everett *et al.*, 2011). Almost nothing is known on vulnerable megafauna bycatch in artisanal fisheries around the Seychelles.

Around **Madagascar**, 19 fisheries have been recorded in the WIOFish database, including 7 artisanal and 3 artisanal/small scale commercial and subsistence fisheries (Everett *et al.*, 2011). In contrast to most countries of the region, marine mammals (essentially in the Anakao region, SW Madagascar;

Razafindrakoto *et al.*, 2008), sea turtles and elasmobranchs are also targeted off Madagascar. The most targeted species are sharks (Carcharhinidae, Sphyrnidae), Serranidae, Lutjanidae, Scombridae and sea turtles. Fisheries in Madagascar use a variety of habitats but the most frequented are the general inshore area and the intertidal zone (Everett *et al.*, 2011). The most extensively used gears are gillnets (mostly targeting sharks and other pelagic fish) and probably have the most significant impact on large vertebrates. They operate in waters from 50 to 200m, are 100m long and have a depth of about 7m.

From the 22 fisheries recorded around the **Union of the Comoros**, 7 are artisanal and/or of subsistence. The Comorian fisheries operate in various habitats and some fisheries operate in more than one type of habitat. Artisanal fisheries operate in the oceanic surface waters, coral reef platforms and the general inshore area (Everett *et al.*, 2011). The most targeted species are demersal (Serranidae, Lutjanidae, Lethrinidae) and pelagic fish (Scombridae). Small nets and surface gillnets are the main gears threatening large vertebrates, especially marine mammals and sea turtles (Poonian *et al.*, 2008; Everett *et al.*, 2011). On Grande Comore, sharks are caught largely as bycatch, while on Anjouan, sharks are more often intentionally targeted (Maoulida *et al.*, 2009).

Fig 2.1: Examples of the most common gears used in artisanal fisheries in the SW Indian Ocean (top left: beach seining; top right: multifilament drift gillnets; bottom left: hook and line; bottom right: monofilament gillnet; Kenya Marine Fisheries Research Institute)

3. Methodology: interview surveys to assess bycatch levels

3.1 Using interview surveys to assess bycatch

In order to spatially and quantitatively estimate fisheries bycatch, two types of information are needed: a measure of fishing effort and a bycatch rate (e.g. number of individuals caught per unit of effort). It is widely accepted that the most accurate method to assess bycatch rates is using independent fisheries observers on board fishing vessels (e.g. Alverson *et al.*, 1994). However, when data collected on fishing vessels is unavailable or impossible to collect, the knowledge of fishermen can be exploited from structured questionnaire surveys (Johannes *et al.*, 2000). Despite limitations of social survey data (data are generally more qualitative than quantitative) this methodology allows assessing the relative importance (spatial and temporal) of fisheries on coastal ecosystems, including large marine vertebrates such as marine mammals, sea turtles and elasmobranchs. Interview surveys have been extensively used to assess the distribution, relative abundance and threats to marine mammals and sea turtles, including in the western Indian Ocean region (Amir *et al.*, 2002; WWF EAME, 2004; Kiszka *et al.*, 2007; Pusineri & Quillard, 2008; Razafindrakoto *et al.*, 2008). These interviews have been rarely used to assess interactions between elasmobranchs and fisheries, except in the Comoros, Mayotte and northern Madagascar, where some investigations have provided some information on shark bycatch, exploitation and use (Maoulida *et al.*, 2009; Whitty *et al.*, 2010).

Rapid bycatch assessment (RBA), which forms the basis of this study, consists of in-person questionnaire surveys that were conducted in Mozambique, Tanzania (Zanzibar and Pemba), Kenya and Mauritius. A single questionnaire form was used, based on the methodology described by Moore *et al.* (2010). The questionnaire included mostly closed questions, allowing collecting quantified and factual information (Gomm, 2004; White *et al.*, 2005). Each questionnaire was completed in-person with fishermen at landing sites (Fig. 1.1; Appendix 1). Questions included fishers' practices, gear use, boat type, targeted species, and bycatch of marine mammals, sea turtles and elasmobranchs (species, seasonality, number caught during the last year and use of caught animals by fishermen). Prior to each survey a statement explaining the purpose of the study and assuring confidence was made by the interviewer. Illustrations cards and identification guides were used to ensure proper bycatch species identification.
A questionnaire was generally completed in 20-30 minutes. Port or landing site description was also completed (not with interviews) to record the number and types of boats, gear types used and general

description of the area. A unique questionnaire form has been designed with national coordinators during a workshop held at Albion Fisheries Research Center, in Mauritius (May 2011). For each country, a national coordinator was designated. He/she led training activities, supervised interviewers and collated data to fill in the national database (Excel table). National coordinators were permanent citizens/residents of the study countries and were experienced working with fishing communities and bycatch issues (except for 50 interviews conducted by a UK-based NGO, Global Vision International). Interviewers were staff members of local fisheries institutes or national environmental agencies (Kenya Marine Fisheries Research Institute, Institute of Marine Sciences Zanzibar, Instituto Nacional do Investigação Pesqueira in Mozambique, Tanzanian Fisheries Research Institute, MOI University, Department of Fisheries and Aquatic Sciences in Kenya, Albion Fisheries Research Center in Mauritius). Training of the interviewers included explaining the purpose of the study, survey protocol and design.

Fig. 3.1: Illustration of RBA surveys conducted in Mauritius (training session, May 2011)

3.2 *Sampling design and data analyses*

Interview surveys were undertaken where bycatch was likely to occur or had been documented (without any quantified information), both for sea turtles and marine mammals (Bourjea *et al.*, 2008; Kiszka *et al.*, 2008). The general attempt was to quantify marine mammal, sea turtle and elasmobranch bycatch and exploitation/use for artisanal fisheries in each of the sampled countries. Several fisheries were targeted, including gillnet (bottom-set and drift), beach seine, purse seine, lining under FADs (Fish Aggregating Devices) longline and handline fisheries. A particular effort was given to gillnet fisheries known to catch large marine vertebrates in the coastal waters of the SWIO region (Amir *et al.*, 2002; WWF EAME, 2004; Bourjea *et al.*, 2008; Kiszka *et al.*, 2007, 2008; Razafindrakoto *et al.*, 2008).

For each country (Mauritius, Kenya, Tanzania and Mozambique), description of gear used, fishing practices, fishermen's experience and age characteristics were provided. Sampling effort (expressed as a number of interviews conducted) was also described for each fishery and region/province sampled (especially for Mozambique and Tanzania). Based on fishermen's declarations, a description of fishing effort was made, taking into consideration months fished for each interviewed fisherman. This information was particularly useful to assess temporal (seasonal/monthly) variations for relative fishing effort for each fishery, as well as seasonal/monthly rates of bycatch occurrence. Bycatch composition was assessed for each main taxonomical group (sea turtles, marine mammals, rays and sharks) and each fishery/gear, especially in term of species composition (species identified by fishermen) and numbers (number of individual per taxonomical group caught during the last year). When sharks and rays were essentially targeted, a brief description of the fishery was made. For each main fishery (main gear used[1]), a description of targeted species (based on fishermen declarations[2]) and bycatch characteristics was made. Bycatch incidence was also calculated for each fishery. This simple calculation takes into account number of individuals caught during the last year per boat and main taxonomical group. The value corresponds to an average number of individuals per taxonomical group caught during the last year (2010-2011) for each fishery. It is calculated as follows:

$$BI = (N_{mean/last\ year} / N_{fisher})$$

[1] Monofilament and multifilament drift nets were treated separately.
[2] Except for Mozambique, where data on targeted species were provided by Instituto Nacional do Investigação Pesqueira.

Where BI is bycatch incidence (or average number of individuals/taxonomical group per boat), $N_{mean/last\ year}$ is the average number of sea turtles, marine mammals, rays and sharks caught during the last year for each boat and N_{fisher} is the number of interviewed fishermen (declaring a number of caught individuals from 0 to ∞[3]). This measure was used to build maps on the relative importance of each fishery for each taxonomical group. Finally, use of bycatch species (how bycatch species were utilized by fishermen) and fishermen's perception of megafauna' population and bycatch trends (fishermen's perceptions on the abundance of populations and bycatch occurrence) were described. This information was important to document decline of the main taxonomical groups for each surveyed country.

3.3 Ecological Risk Assessment (ERA)

The Ecological Risk Assessment for the Effects of Fishing (ERAEF, hereafter ERA) framework involves a hierarchical approach that moves from a comprehensive but largely qualitative analysis of risk, through a more focused and semi-quantitative approach, to a highly focused and fully quantitative "model-based" approach (Hobday *et al.*, 2007, 2011 ; Fig. 3.2). Three levels of ERA have been identified: Level 1 analysis (Scale Intensity Consequence Analysis, SICA) is designed to identify hazards to species and systems using qualitative data and expert opinion; Level 2 (Productivity-Susceptibility Analysis, PSA) is based on the biological characteristics of species caught in the fishery concerned (Productivity), and the degree of interaction between that fishery and those species (Susceptibility). The Level 2 methodology considered to be the most appropriate and robust for fisheries ERA is termed Productivity-Susceptibility Analysis (PSA) (Hobday *et al*., 2011). Five general ecological components are evaluated: a- target species; b- by-product and bycatch species, c- threatened, endangered and protected species (TEP), d- habitats and e- ecological communities (Hobday *et al.*, 2011).

Such analyses allow the targeting of more detailed monitoring, research, and caution to be applied in managing effects of fishing, where information is incomplete or uncertain. This ERA method examines the likely consequences of removals through accidental fishing mortality on populations (their susceptibility to population effects of fishing) and recognizes that the differing fecundity and life-history attributes of populations (their productivity) play a role in determining likely population responses.

[3] For a number of fishermen, caught numbers of individuals/taxonomical group were not provided. These were discarded from the analysis.

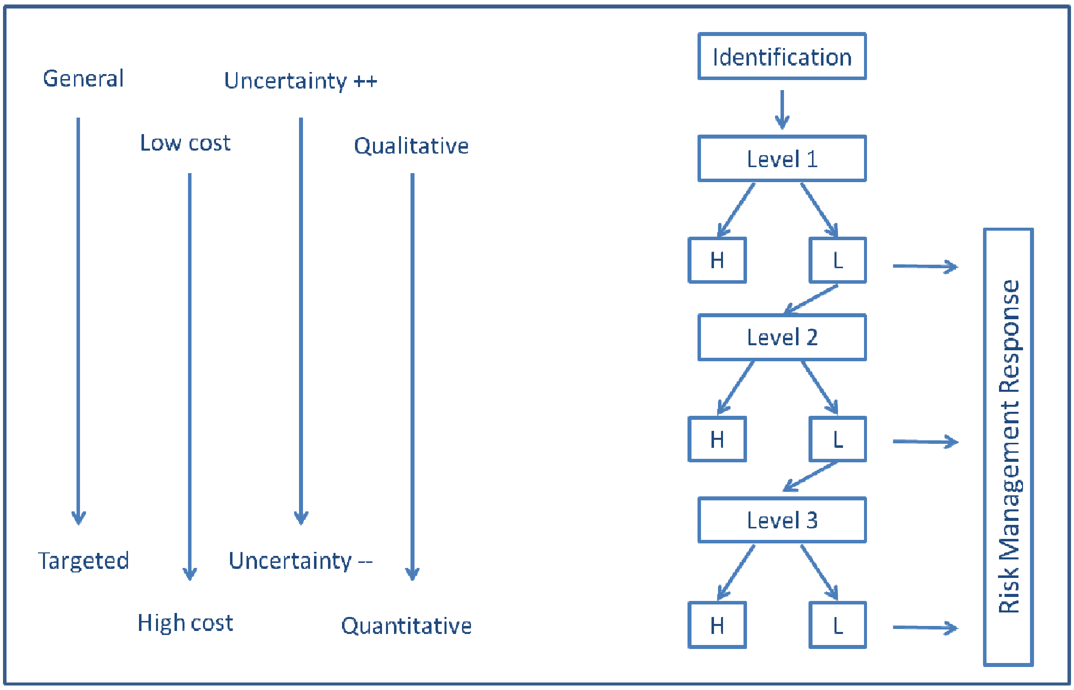

Fig. 3.2: ERAEF framework showing focus of analysis for each level (1 to 3; H: high risk, L: low risk). At leach level a risk management response is an alternative to proceeding to the next level (Marsac, 2011)

Level 1 (SICA) relies on expert judgment involving the stakeholders, and focus on the ecological component. An exposure-risk assessment approach is used at Level 1, and is only applied to the "worst case" unit. It involved scoring each fishing activity (hazard) for impact on the core objective for the component (Hobday *et al.*, 2011). The score and intensity of the activity are scored and the consequence score is selected from a component-specific set of scoring guidelines, e.g. from negligible (score 1) to extreme (score 6; Hobday *et al.*, 2007).

Level 2 (PSA) documents, for each species, its resilience and exposure to gears/fisheries. This approach is particularly suitable in data-paucity situations (including interview survey data). Each species is evaluated according to its life history characteristics (average age at maturity, maximum age, fecundity, maximum size, size at maturity, reproductive strategy, habitat characteristics and feeding strategies, i.e. productivity *P*) and exposure to gears/fisheries (overlap of species range with fishery, encounterability, post capture mortality and selectivity of the gear, Susceptibility *S* (Hobday *et al.*, 2011). A score is attributed for each element. There are several methods to calculate a global score for a given species, and the result is reported graphically (Fig. 3.3). A risk score is the Euclidian distance from the origin, which allows a single risk ranking. Risk values are mostly determined by biological characteristics of the species (*P*), while the relative fishery interactions are measured through the susceptibility attributes (impact of the fishery on the species). The *x*-axis score derives from attributes that influence the productivity of a unit, or its ability to recover after impact from fishing, while the *y*-axis score derives from attributes that influence the susceptibility of the unit to impacts from fishing. Combination of productivity and susceptibility determines the relative risk to a unit, i.e. units with high susceptibility and low productivity are at higher risk, and units with low susceptibility and high productivity are at lower risk (Fig. 3.3).

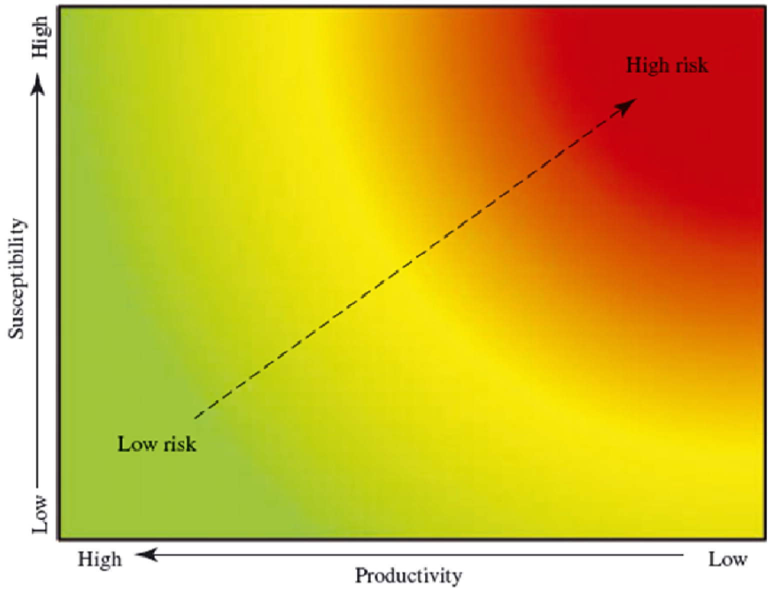

Fig. 3.3: Productivity-susceptibility analysis (PSA) plot used in semi-quantitative ecological risk assessments (from Gallagher *et al.*, 2012)

Based on interview survey data conducted in Mauritius, Kenya, Tanzania and Mozambique and the available literature for Madagascar and the Comoros (but only for gillnet fisheries), a PSA was conducted based on scoring methods provided by Hobday *et al.* (2011) and adapted for species of our interest. First, Level 1 analysis (SICA) was undertaken to identify most impacting fisheries and species that are particularly involved in bycatch events. Fishery selection was based on the extent of survey effort conducted, its geographical/numerical extent (at the regional level) and overall bycatch levels of sea turtles, marine mammals and elasmobranchs. Selected species for the PSA (Level 2) was based on species IUCN status, regional range and occurrence as bycatch species. PSA scoring methods followed methodology described in Hobday *et al.* (2011) for productivity *P*. Productivity and susceptibility attributes are scored as 1 (low), 2 (medium) or 3 (high), and missing attributes are scored as a 3. A total of nine criteria were used to calculate *P*, including age at maturity, size at maturity, maximum age, fecundity, reproductive strategy, range (global and regional distributions), global population size, habitat characteristics and diet. The arithmetical mean of all criteria constituted *P.* Susceptibility (*S*) was calculated for each selected fishery and was based on bycatch incidence (N individuals/taxonomical group during the last year). However, as bycatch incidence was calculated for each main taxonomical group, species composition (proportion) was used to estimate a specific bycatch incidence for the species included in the PSA. In our case, *S* was calculated as the arithmetic mean of scores of five criteria, including mean regional bycatch incidence (mean of bycatch incidence for each surveyed country), commercial value, gear selectivity, habitat overlap between gear and bycatch species and post capture survival. Curved lines (thresholds) have been added graphically (at 2.5 and 3 scores), dividing the PSA plot into thirds, representing low, medium and high risk, and group units of similar risk levels (Hobday *et al.*, 2011).

4. Results

4.1 Sampling effort

A total of 961 interview surveys was conducted in the region, including in Kenya (n=330), Tanzania (n=276), Mozambique (n=296) and Mauritius (n=59; Fig. 4.1). Originally, the west coast of Madagascar was included in the sampling but, for a number of reasons, surveys were not undertaken there. However, interview surveys had already been conducted in this region (Razafindrakoto *et al.*, 2004), as well as in the Comoros and Mayotte (Poonian *et al.*, 2008; Pusineri & Quillard, 2008). Surveys were not conducted in South Africa (KwaZulu-Natal province) and the Seychelles as bycatch of vulnerable megafauna appears minimal in artisanal fisheries of these countries.

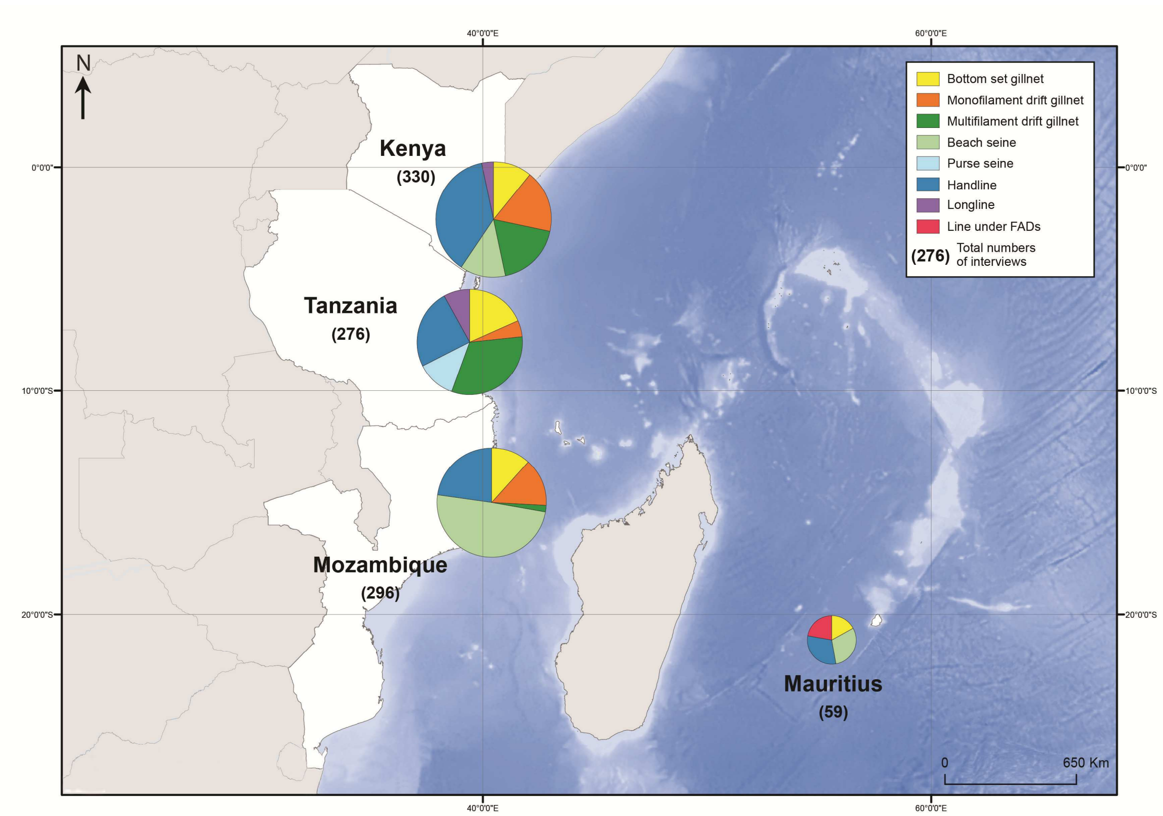

Fig. 4.1: Number of interview surveys conducted in each sampled countries (N = 961)

Throughout the region, eight artisanal fisheries were sampled (Fig. 4.1). These fisheries were the most likely involved in capture of sea turtles, marine mammals and elasmobranchs. A particular effort was devoted to sample gillnet fisheries, previously documented as the major threat to large marine megafauna in the region (Bourjea *et al.*, 2008; Kiszka *et al.*, 2008). Some geographical variations of gear used were observed. Around Mauritius, lining under fixed FADs is possible due to the proximity of deep oceanic waters (narrowness of shelf). Conversely, along the east coast of Africa, beach seining and gillnetting is intense due to the presence of a wide continental shelf and availability of coastal marine habitats. In the study, results are presented for each sampled country separately.

4.2 Mauritius

Questionnaire surveys were conducted from March 2011 to April 2012. A total number of 59 interviews was conducted around Mauritius from the four most important artisanal fisheries, including line fishing around FADs (n=13), bottom gillnetting (n=10), handlining (n=18) and beach seining (n=18, Fig. 4.2). Interviews were undertaken in various locations, and under varying circumstances, including returning from fishing trip, at fisher's house or when repairing nets on the beach. All interviewees were males, only 12% of fishermen participated in previous scientific surveys on fishing practises or on sharks. Age of interviewed fishermen averaged at 48 (SD=10; Range=29-81). Their mean fishing experience was 26 years (SD=9; Range=6-48). For more than 99% of interviewed fishermen, fishing was their primary activity.

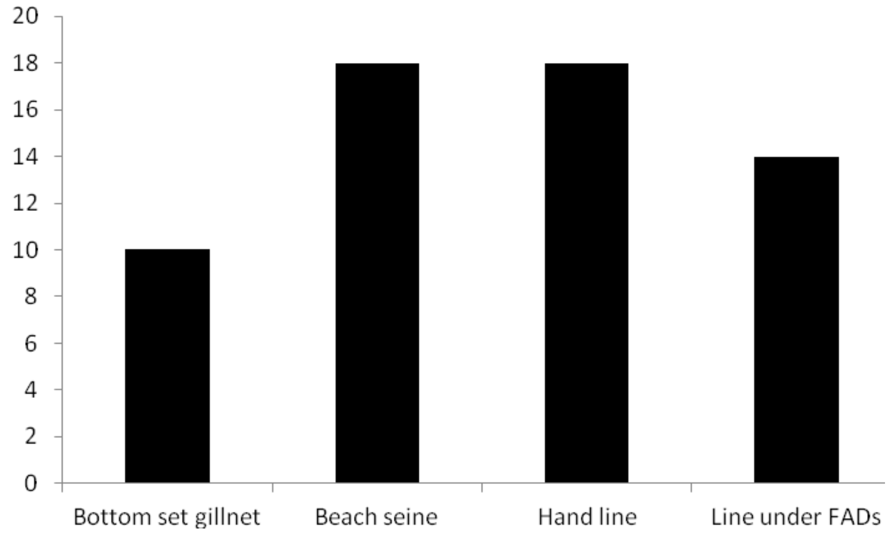

Fig. 4.2: Number of RBA interviews for the main artisanal fisheries around Mauritius

Gear characteristics and fishing effort

Four main gear types are reflected in the surveys of artisanal fisheries around Mauritius. Beach seines are all 500m long with a mesh size of 9cm. Bottom-set gillnets are 250m long with a mesh size of 11cm. For longlines/hook and line around FADs, hook number varies between 1 and 8. Handlines in coastal areas only use 1 hook. For beach seines, motorized pirogues are used (fiberglass, 50% or wood, 50%, mostly 7m long). For bottom-set gillnets, 7m wooden pirogues are predominantly used as is the case for the coastal handline fishery. Number of days spent at sea per week are between 4 and 5 (modal range) for the beach seine fishery, from 2 to 7 days for the bottom-set gillnet fishery (modal range=4-5 days), from 2 to 7 days for the line fishery under FADs (modal range=4-5 days) and 4-7 days (modal range=6-7 days) for the coastal handline fishery.

Only 20% of fishermen declared they were fishing on a year round basis. Overall, fishing effort was relatively stable throughout the year, with higher effort from March to September (Fig. 4.3). Fishing effort for beach seine and bottom-set gillnet fisheries was only concentrated between March and September. Fishing under FADs (for pelagic fish) and handlining (targeting coastal fish) occurred year-round.

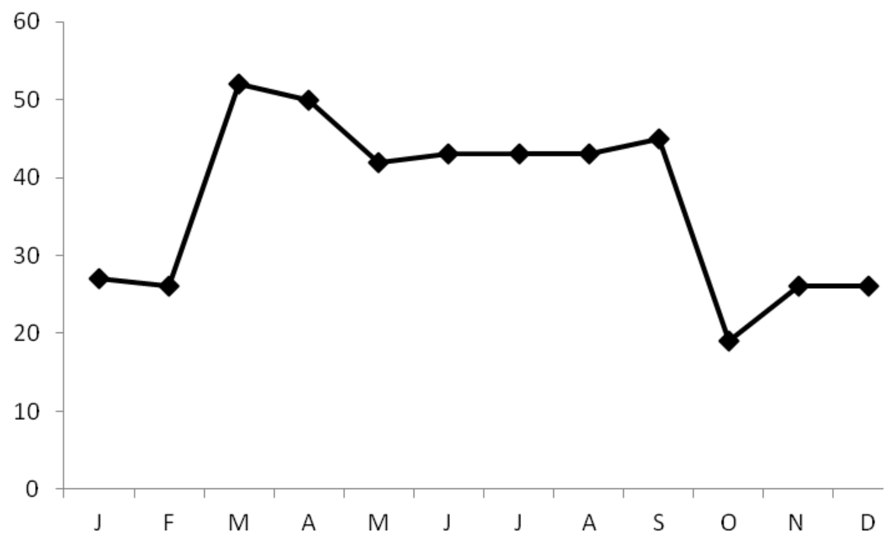

Fig. 4.3: Fishing effort (per month) by interviewed fishermen around Mauritius for all artisanal fisheries (unit is the number of fishermen who declared fishing for each month)

Overall bycatch composition

Overall, 16 species were mentioned as bycatch, including two species of sea turtles (*E. imbricata* and *C. mydas*), and 15 species of elasmobranchs (Fig. 4.4). Names for each bycatch species for each country is presented in Appendix 2 (English, Latin names and IUCN Red List Status). Four species of rays were identified as bycatch; including *A. narinari*, *T. meyeni*, *R. djiddensis* and *Manta* spp (2 species co-occur in the western Indian Ocean region, i.e. *M. alfreidi* and *M. birostris*). Eleven shark species were identified by fishermen as bycatch species, including *Sphyrna* spp. (most likely *S. lewini*), *T. obesus*, *I. oxyrhinchus* and *C. longimanus*.

Bycatch composition was variable among fisheries (Fig. 4.4). Beach seine was probably the most impacting gear, especially for the two species of sea turtles, two species of rays (*A. narinari* and *T. meyeni*) and two species of sharks (*Sphyrna* spp and *T. obesus*). Similar bycatch species were recorded for the bottom-set gillnet fishery. Line fishing under FADs essentially involved pelagic sharks as bycatch species, while the inshore handline fishery involved a variety of coastal species (at least 11 species, Fig. 4.4). No cetacean bycatch in any fishery was reported. For 94% of cases, fishermen were very confident with species identification (except for bycatch rays in the line fishery under FADs).

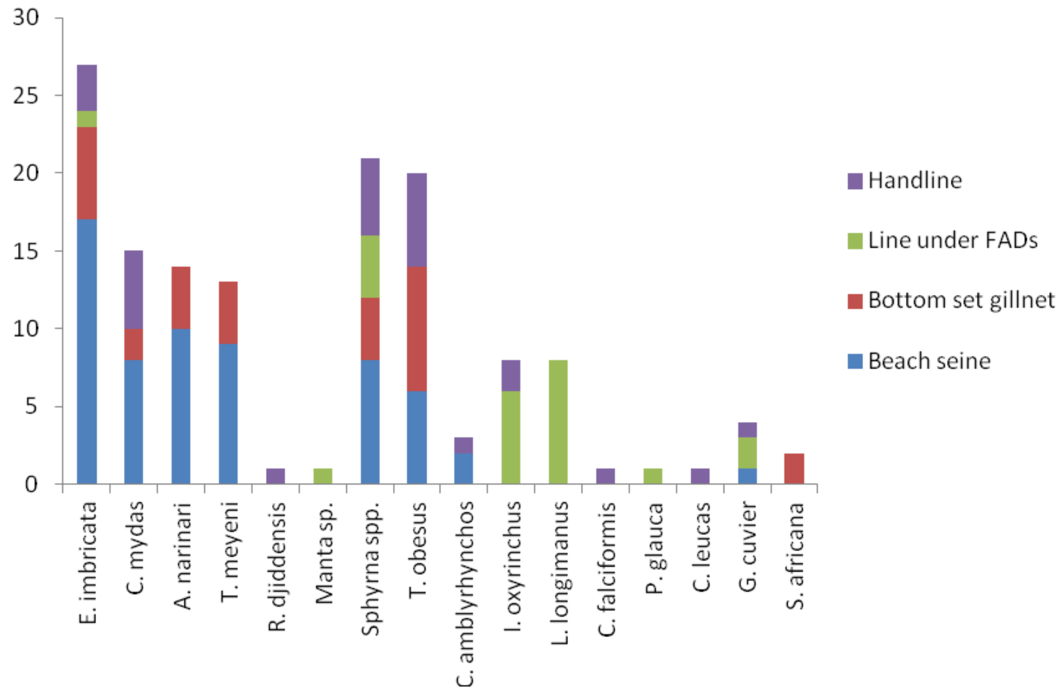

Fig. 4.4: Occurrence of bycatch species of sea turtles and elasmobranchs in all artisanal fisheries around Mauritius (unit is the number of time species were mentioned as bycatch by fishermen)

Beach seine bycatch

The beach seine fishery targets a variety of coastal fish species, essentially lethrinidae, scaridae, siganidae, mugilidae and sparidae. A list of all identified targeted species (for all surveyed countries) is provided in Appendix 3. A bycatch of sea turtles was declared by 94% (17/18) of respondents in the beach seine fishery. *E. imbricata* was the most common bycatch species (100% of bycatch sea turtles), followed by *C. mydas* (47%; 8 cases as the second most frequently bycatch species). No other sea turtle species were reported as bycatch in the beach seine fishery. Three ranges of annual catch levels (catches in the last year, prior to the survey) were proposed to fishermen (1-3; 4-10; 11-20 turtle(s)/year). 40% declared they caught 1-3 individuals in the last year, 40% 4-10 turtles and 20% 11-20 turtles.

Bycatch of rays was declared by 94% (17/18) of respondents. Two species of rays were identified as bycatch in the beach seine fishery, including *A. narinari* (53% of declared catches) and *T. meyeni* (47%). For rays, four ranges of annual catch levels were proposed to fishermen (1-10; 11-20; 21-50 and >50). 82% declared 1-10 ray catches in the last year, 6% 11-20 and 12% 11-20.

Shark bycatch was declared by 94% of respondents. Four species of sharks were mentioned as bycatch in beach seines, namely *Sphyrna spp*. (47%), *T. obesus* (35%), *C. amblyrhynchos* (12%) and *G. cuvier* (6%). Four ranges of annual shark catch levels were proposed to fishermen (1-10; 11-20; 21-50 and >50): 76% caught 1-10 sharks and 12% 11-20 individuals. The other fishermen could not provide a number of shark catches in the last year.

No particular monthly bycatch peaks were detected during the beach seine fishing period (March-September; Fig. 4.5).

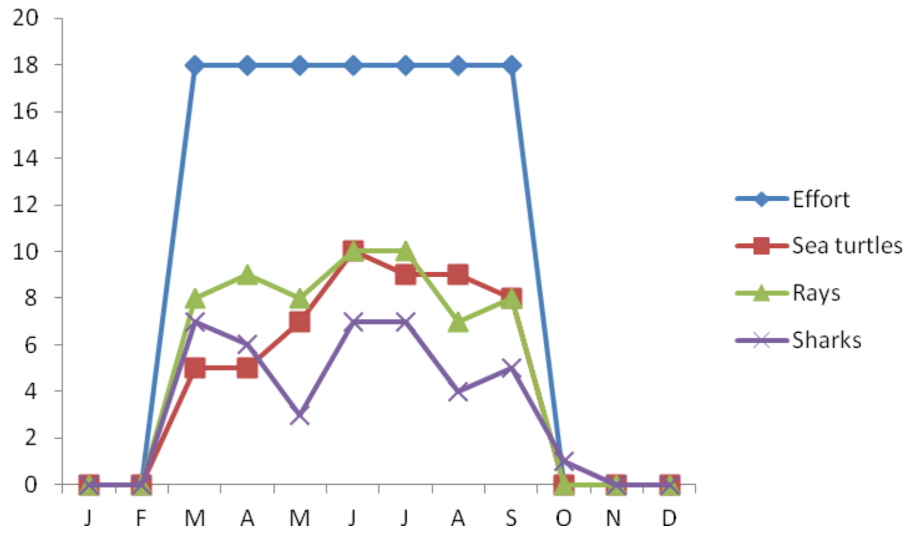

Fig. 4.5: Fishing effort (per month) and declared main bycatch taxonomic groups by interviewed fishermen around Mauritius for the beach seine fishery (unit is the number of fishermen who declared fishing and bycatch events for each month)

Bottom-set gillnet bycatch

A diversity of fish species are targeted by the bottom-set gillnet fishery around Mauritius. These species include members of the lethrinidae, scaridae, siganidae, mugilidae, sparidae and carangidae. Bycatch of sea turtles was declared by 100% (n=10) of respondents. In order of occurrence, *E. imbricata* was the most commonly bycatch species (75%), followed by *C. mydas*. Some 60% of fishermen declared they had caught 1-3 individuals and 20% 4-10 individuals. 20% of respondents could not provide a number of bycatch sea turtles in the last year of fishing.

Bycatch of rays was declared by 80% of respondents. Two species of rays were identified by fishermen: *A. narinari* (50% of declared catches) and *T. meyeni* (50%). A total of 60% of fishermen declared 1-10 ray catches in the last year in bottom-set gillnets.

Bycatch of sharks was also declared by 80% of respondents. 100% of fishermen declared 1-10 shark catches in the last year. Three species of sharks were mentioned as bycatch species in bottom-set gillnets, notably *T. obesus* (60%), *Sphyrna* spp. (30%) and *S. africana* (10%). No obvious bycatch peak was detected for any of the taxa under consideration during the fishing period (March-September; Fig. 4.6).

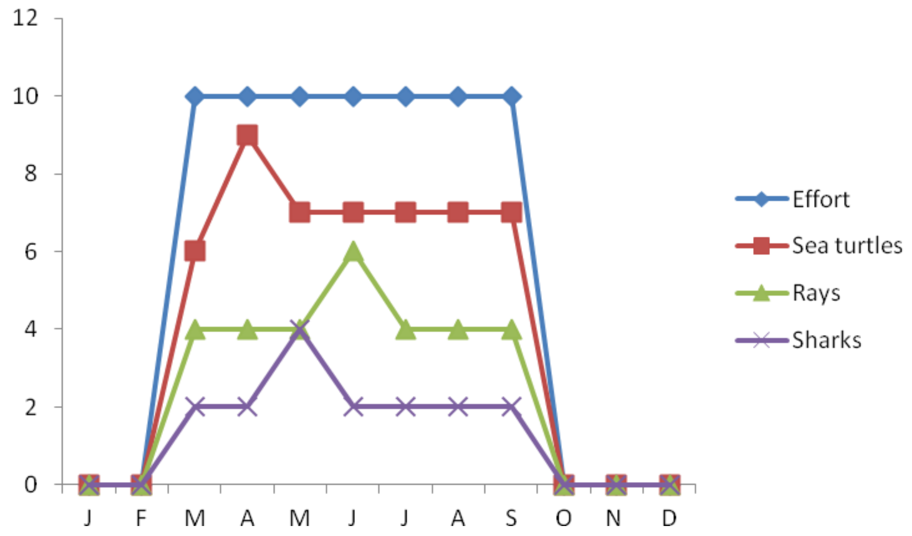

Fig. 4.6: Fishing effort (per month) and declared main bycatch taxonomic groups by interviewed fishermen around Mauritius for the bottom-set gillnet fishery (unit is the number of fishermen who declared fishing and bycatch events for each month)

Line under FADs bycatch

Around Mauritius, fishermen use longline or hook and line when fishing under FADs. Targeted species are essentially pelagic fish, mainly scombridae (especially tunas) and coryphaenidae.

Bycatch of sea turtles was declared by 8% of respondents. The only species involved seems to be *E. imbricata*. According to the fisherman, sea turtle bycatch is very rare (around one catch every year). Bycatch of rays have been declared by 23% of respondents. Two species of rays were identified by fishermen: *T. meyeni* (but species identification is uncertain) and *Manta* spp. For two fishermen, 1-10 stingrays have been caught in the last year in the line fishery under FADs. For one fisherman, 11-20 *Manta* sp. were caught in the last year. Pelagic sharks are the mostly commonly bycatch species in this fishery, especially *C. longimanus* (36%), *I. oxyrhinchus* (27%), *Sphyrna* spp (18%) and *G. cuvier* (9%). For all respondents, shark bycatch number in the last year varied between 1 and 10 individuals.

Sample size was relatively limited for this fishery, but effort seems to be distributed all year round, with a higher fishing pressure during the rainy season (Fig. 4.7).

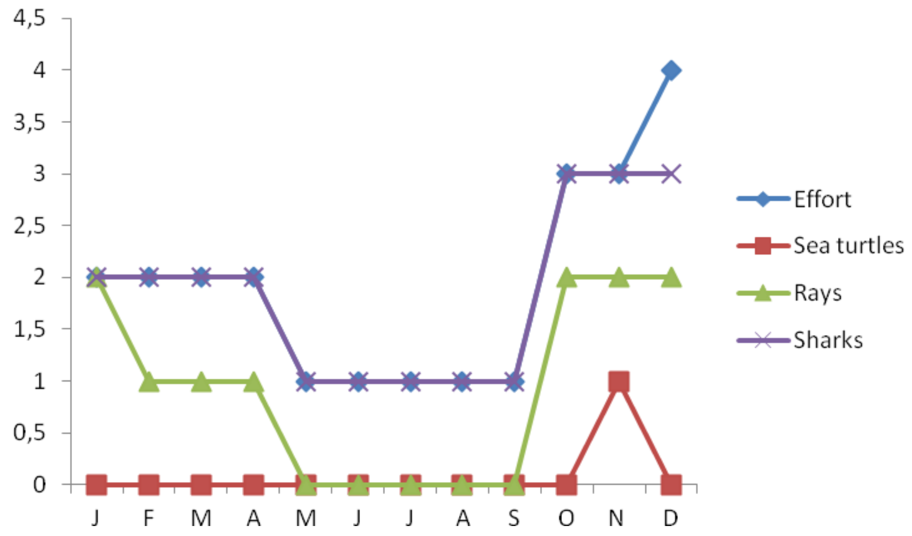

Fig. 4.7: Fishing effort (per month) and declared main bycatch taxonomic groups by interviewed fishermen around Mauritius for the line fishery under FADs (unit is the number of fishermen who declared fishing and bycatch events for each month)

Handline bycatch

Handlining (using a single hook and line) occurs in coastal/lagoonal waters around Mauritius. This fishery targets a diversity of coastal species belonging to the lethrinidae, serranidae, lutjanidae, acanthuridae and carangidae.

Bycatch of sea turtles in this fisher was declared by 44% of respondents. The two most common sea turtle species around Mauritius are implicated in this bycatch, i.e. *C. mydas* (50%) and *E. imbricata* (30%). Some 20% of fishermen could not identify sea turtles to the species level. For all respondents, 1-3 sea turtles were caught in the last year in the handline fishery.

Bycatch of rays was also declared by 44% of respondents. However, only one species could be identified (*R. djiddensis*), but this only accounted for 5% of catches. Like for sea turtles, 1-3 rays were caught in the last year in the handline fishery. In contrast, shark bycatch is much more common in the coastal handline fishery, with 83% of respondents having declared shark as bycatch. At least nine species were declared as regularly caught in this fishery (Fig. 4.4), including *T. obesus* (29%), *Sphyrna* spp (25%), *I. oxyrhinchus* (10%) and *G. cuvier* (5%).

In all 87% of fishermen could provide a number of shark catches in the last year with 92% claiming they caught between 1 and 10 sharks, while a single fisherman declared catching 11-20 sharks in the last year. The handline fishery effort is higher outside the trade wind season. No significant temporal variations of bycatch o were detected (Fig. 4.8).

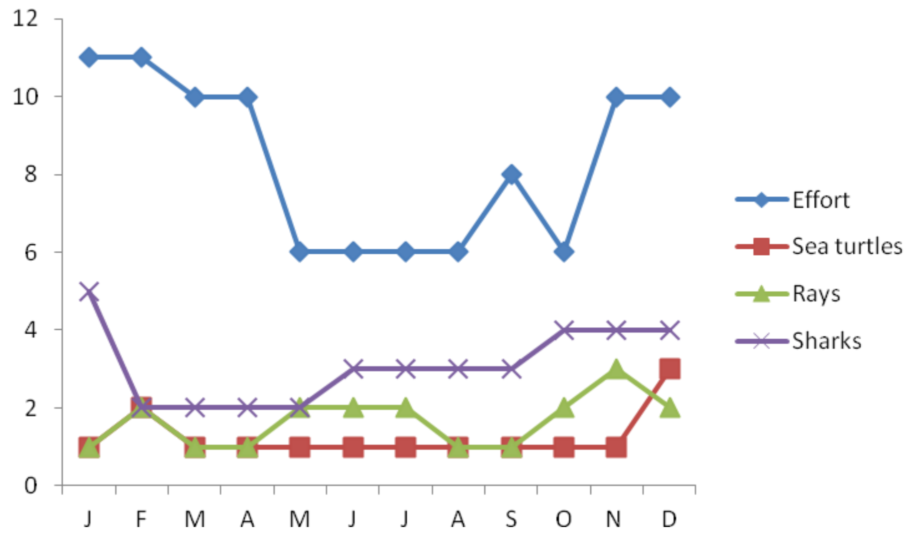

Fig. 4.8: Fishing effort (per month) and declared main bycatch taxonomic groups by interviewed fishermen around Mauritius for the handline fishery (unit is the number of fishermen who declared fishing and bycatch events for each month)

Bycatch incidence

Bycatch incidence (bycatch/last year/boat) was calculated for each fishery and each taxonomic group (sea turtles, rays, sharks). It has also been extrapolated at the fishery level (based on boat counts, as such information was available for Mauritius), for the year prior to the survey (2010-2011). All values are presented in table 4.1.

Table 4.1: Mean annual number of bycatch sea turtles, rays and sharks per boat around Mauritius and extrapolated bycatch numbers per year per fishery.

	N/boat/last year			Extrapolated N/last year		
	Sea turtles	Rays	Sharks	Sea turtles	Rays	Sharks
Beach seine	6.74	9.62	6.83	283.08	404.04	286.86
Bottom-set gillnets	3.38	5.5	5.5	15.52	22	22
Line under FADs	0.17	2.04	4.58	30.94	371.28	833.56
Handline	0.44	2.14	4.53	241	1177	2491.5

Results of bycatch rates per boat per year suggest net fisheries have the highest impacts for both sea turtles and elasmobranchs with beach seines the highest. Line fisheries have low bycatch rates for sea turtles, and appear to have a modest impact on sharks, and even less so for rays. However, when extrapolated to the full fishery level, it appears that elasmobranch and sea turtle bycatch incidence may be significant for the handline fishery, mainly as effort around Mauritius is significantly higher than in any artisanal net fishery.

Use of bycatch species

When a sea turtle was taken as bycatch, 69% of fishermen confirmed releasing the animal alive, 5% discarded the animal (dead), 19% used the turtle for food and 3% for medicinal purposes. Concerning rays, 75% of bycatch animals were generally used for meat while 25% of rays were released/discarded (no distinction could be made). 81% of sharks were killed when caught, and were used for meat by fishermen and/or sold on local markets. Only 5% of fishermen sold fins and discarded shark bodies.

Perceptions of bycatch incidence and population trends

Nearly 55% of fishermen declared that they considered sea turtle bycatch to be decreasing around Mauritius in contrast to only5% who there to be an increasing trend. Concerning rays, 52% of fishermen declared a decline of ray abundance as bycatch while a similar decreasing abundance was perceived by fishermen for sharks (57%). For cetaceans, while zero bycatch events were reported, 65% of fishermen claimed they were either similarly or more common in the waters around Mauritius.

4.3 Kenya

In Kenya, 330 questionnaire surveys were undertaken from November 2011 to March 2012. The bulk of interviews were conducted in March 2012 along the whole coast, in the four main districts, including Kwale (n=157 interviews), Kilifi (n=89), Lamu (n=93) and Malindi (n=117). Sampled fisheries were those likely to catch sea turtles (n=330), marine mammals and elasmobranchs, i.e. bottom-set gillnets (n=36), handlines (n=122), longlines (n=11), monofilament drift gillnets (n=58), multifilament drift gillnets (n=60) and beach seines (n=43; Fig. 4.9). A total of 15 fishing communities were sampled along the coast of Kenya. Interviews were conducted under varying circumstances, including repairing fishing gears/boats, at landing sites, or when coming back/going to fishing. Along the south coast, interviews were also conducted at the office of Global Vision International (GVI) or at fish markets. All interviewees were male. At least 31% of interviewees had been already involved in questionnaire surveys in the past, including the frame survey for sea turtles, marine mammals, sharks and fishing practices. Age of interviewed fishermen averaged at 40.3 (SD=13.4; Range=16-90). Their mean fishing experience was 19.8 years (SD=11.4; Range=1-63). For only 0.03% of interviewed fishermen, fishing was not their primary activity.

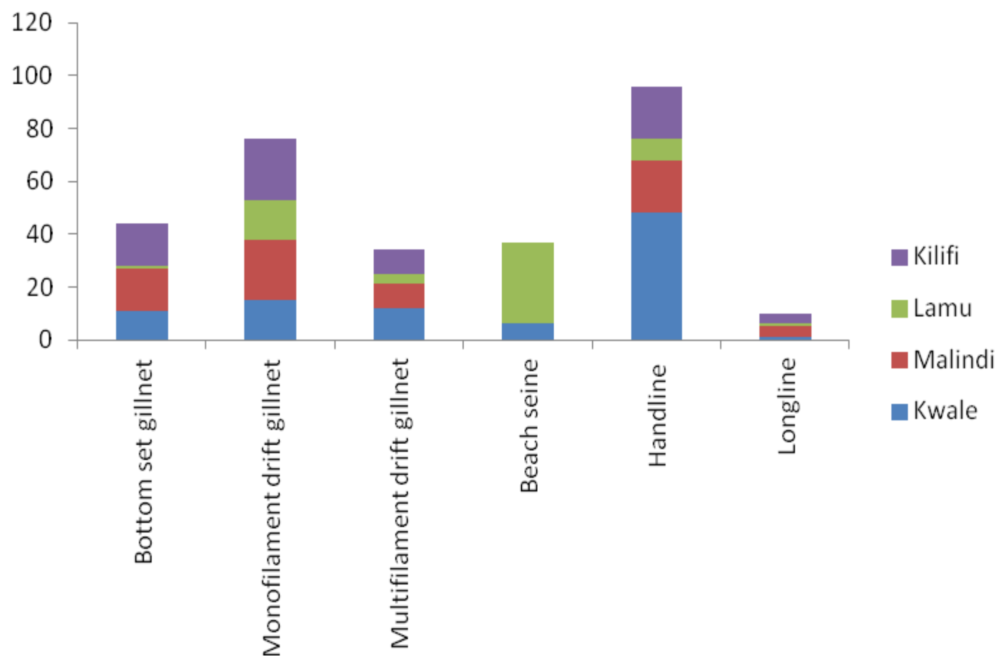

Fig. 4.9: Number of RBA interviews for the main artisanal fisheries along the coast of Kenya for the four main districts (Kwale, Malindi, Lamu and Kilifi)

Artisanal fisheries were not surveyed randomly across the four districts (Kwale, Malindi, Lamu and Kilifi; Fig. 4.9) because a higher effort was dedicated to sample handline and gillnet fisheries. In this analysis, we focus on bycatch taken in gillnet (mono-, multifilament and bottom-set), longline and handline fisheries.

Gear characteristics and fishing effort

Gear characteristics were highly variable, for each gear type. Net, mesh and hook sizes were significantly different among fishermen and were not linked to geographic locality. Some general basic features of gears have been recorded. Bottom-set gillnets have a mean length of 267m (SD=160; range=25-600). Mesh size was also highly variable, ranging from 1.5 to 4.5cm (mean=4.8; SD=2). Beach seine length (mean=89m; SD=115; range=10-400) and mesh size (mean=2cm; SD=0.5; range=0.5-4.5) were also highly variable among fishermen. Multifilament drift gillnets had a mean length of 383m (SD=394; Range=15-1500) and mesh size varied from 1.5 to 8cm (mean=5.4; SD=1.2). Monofilament drift gillnet characteristics were similarly variable along the whole coast, ranging from 8 to 1300m in length (mean=468; SD=310) and from 2 to 6cm in mesh size (mean=2.9; SD=0.8).

A wide range of hook numbers was also used in line fisheries, from 2 to 300 hooks for longlines and from 2 to 20 for handlines.

Number of days spent at sea per week was between 2 and 7 (modal range=6-7 days, i.e. 55% of interviewed fishermen) for the beach seine fishery, from 2 to 7 days for the bottom-set gillnet fishery (modal range=6-7 days), from 4 to 7 days for trap fisheries (modal range=6-7 days), from 3 to 7 days for both monofilament and multifilament drift gillnet fisheries (modal range=6-7 days), from 4 to 7 days for the longline fishery (modal range=6-7 days) and 4-7 days (modal range=6-7 days) for the handline fishery.

Based on fishermen declarations on the months during which they fish, fishing effort is similar between gear types (Fig. 4.10). This is particularly the case for longline, trap and beach seine fisheries. For handline and drift net fisheries, fishermen seem to increase fishing effort from January to April. For all fisheries, lowest effort is observed during the trade wind season, i.e. from June to August (Fig. 4.10). This phenomenon is linked to better sea conditions, especially between October and March (rainy season).

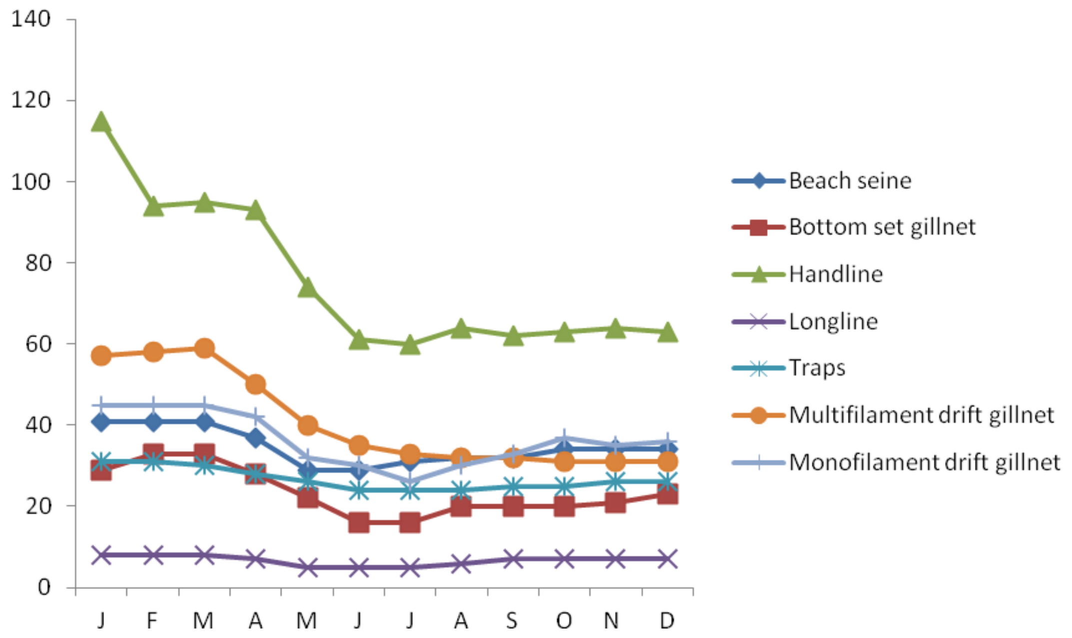

Fig. 4.10: Fishing effort (per month) by interviewed fishermen along the coast of Kenya for all gear types of artisanal fisheries (unit is the number of fishermen who declared fishing for each month)

<u>Overall bycatch composition</u>

A total of 31 species were mentioned as bycatch during surveys along the coast of Kenya, including all five species of sea turtles (*C. mydas*, *E. imbricata*, *C. caretta*, *L. olivacea* and *D. coriacea*; Fig. 4.11), seven species of marine mammals (*S. chinensis*, *T. aduncus*, *D. delphis*, *M. novaeangliae*, *S. longirostris*, *S. attenuata* and *D. dugon*; Fig. 4.11) and 19 species of elasmobranchs (Fig. 4.12).

Concerning sea turtles, *C. mydas* was, by far, the most commonly bycatch species in all fisheries (57% of reported bycatch species), especially in net fisheries. The two other most commonly bycatch sea turtle species were *E. imbricata* (19%) and *C. caretta* (17%). Marine mammals were rarely reported as bycatch, with most bycatch events reported from the multifilament drift gillnet fishery (Fig. 4.11). For both sea turtles and marine mammals, no bycatch events were reported in trap fisheries.

Elasmobranchs were mostly considered as bycatch species. Among rays, the most common bycatch species were *A. narinari* (30%), *T. lymma* (28%), *Manta* sp (21%) and *R. djiddensis* (14%). Among sharks, *C. melanopterus* was by far the mostly commonly bycatch species (44%), followed by *G. cuvier* (19%), *Sphyrna* spp (most likely *S. lewini*; 18%) and *T. obesus* (16%). On several occasions, *S. mokarran* had been distinguished from *Sphyrna spp* and recorded as bycatch (1%). Elasmobranchs were caught in all fisheries; with a higher reported occurrence in beach seine, handline and multifilament drift gillnet fisheries (Fig. 4.12).

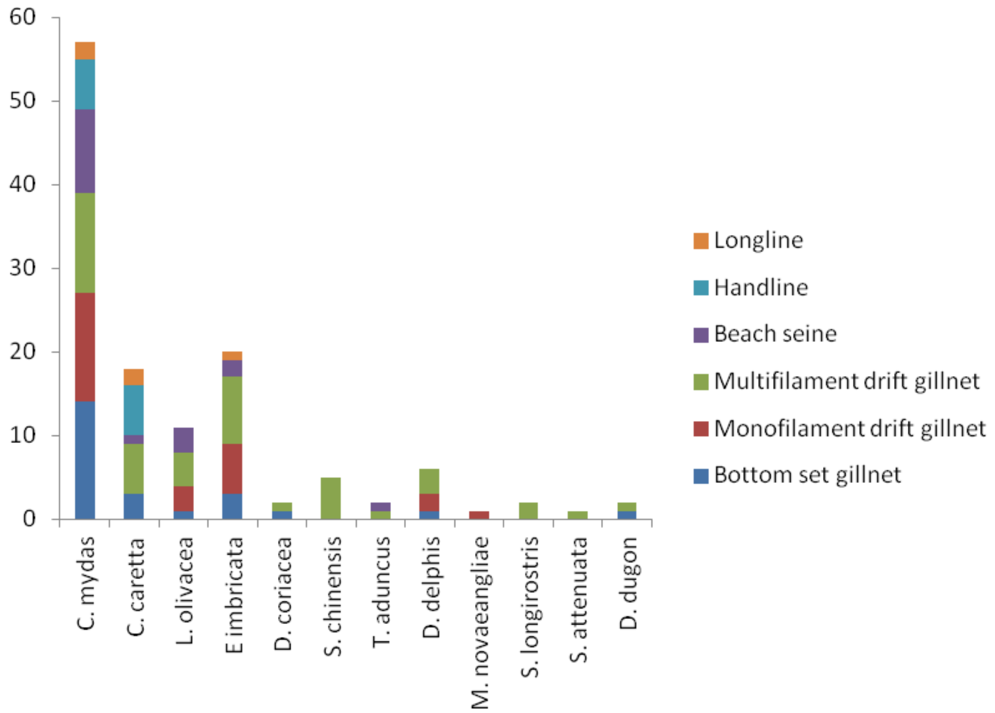

Fig. 4.11: Occurrence of bycatch species of sea turtles and marine mammals in all artisanal fisheries' types along the coast of Kenya (unit is the number of times species were mentioned by fishermen as bycatch)

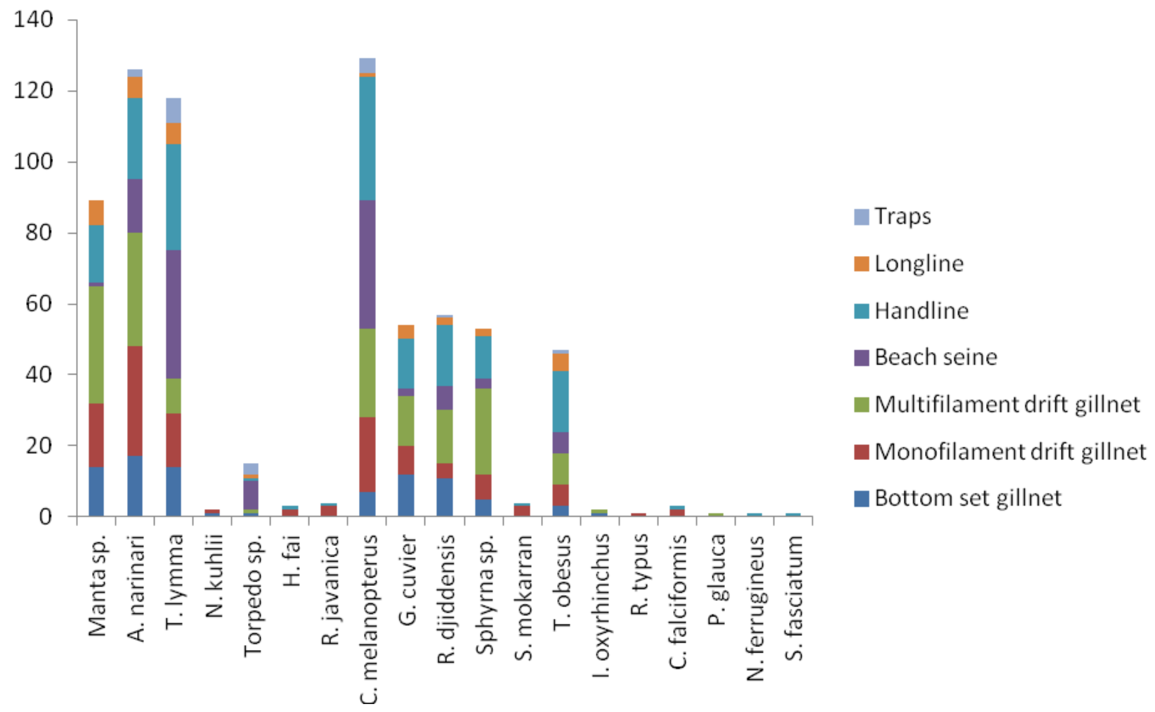

Fig. 4.12: Occurrence of bycatch species of elasmobranchs in all artisanal fisheries types along the coast of Kenya (unit is the number of times species were mentioned by fishermen as bycatch)

Shark fishery

Sharks were targeted species for only 20 fishermen (4% of all interviewees). They constitute secondary targets for only 1% of interviewed fishermen. Fishermen primarily use multifilament drift gillnets to catch sharks (60%), monofilament drift gillnets (15%), bottom-set gillnets (10%), longlines (10%) and handlines (5%). For all fishermen, sharks are sold whole (body and fins).

Drift gillnet fisheries

Drift gillnet fisheries use two types of nets along the coast of Kenya: monofilament and multifilament nets. These fisheries target a variety of species, including scombridae (30%), sharks and their relatives (carcharhinidae, rhinobatidae, sphyrnidae; 13% of interviewed fishermen), istiophoridae (especially *I. platypterus*; 9%), siganidae (8%) and other demersal species (e.g. lethrinidae, lutjanidae, mugilidae). This fishery is basically multi-specific, but preferentially targets pelagic fish. Bycatch information was treated separately for monofilament and multifilament drift gillnets.

In monofilament drift gillnets, sea turtle bycatch was reported by 33% of fishermen. In multifilament drift gillnets, this proportion was lower, with 28% of fishermen having declared they had previously caught a sea turtle in their nets. Five species (all species recorded in Kenya) of sea turtles were caught in monofilament drift gillnets while three species were identified by fishermen in multifilament drift gillnets (*C. mydas*, *E. imbricata* and *L. olivacea*). In monofilament drift gillnets, numbers of sea turtles caught in the last year was reported to be between 1 and 10 (Modal range=1-3). In multifilament drift gillnets, this range was more important (1 to > 20; modal range=1-3). Marine mammal bycatch was only declared by 3% of fishermen using monofilament drift gillnets. *D. delphis* was the only species mentioned as bycatch (3-5 individuals in the last year). This proportion reached 15% in fishermen using multifilament drift gillnets; with the most commonly species involved (in order of occurrence) are *S. chinensis*, *S. longirostris*, *T. aduncus*, *D. dugon*, *S. attenuata* and *D. delphis.* Number of marine mammals bycatch in the last year varied from 1 to 10 individuals (Modal range=1-2).

In monofilament drift gillnets, ray and shark bycatch was declared by 59% and 65% of fishermen, respectively. In the multifilament drift gillnet fishery, ray and shark bycatch reached 75% and 88% of interviewed fishermen, respectively. The most frequently caught species were (for both gears), in order of occurrence, *A. narinari*, *Manta* sp. and *C. melanopterus*. No clear seasonality of bycatch events was found in bycatch (but most bycatch events were recorded during the rainy season); both for monofilament and multifilament drift gillnet fisheries (Fig. 4.13 & 4.14).

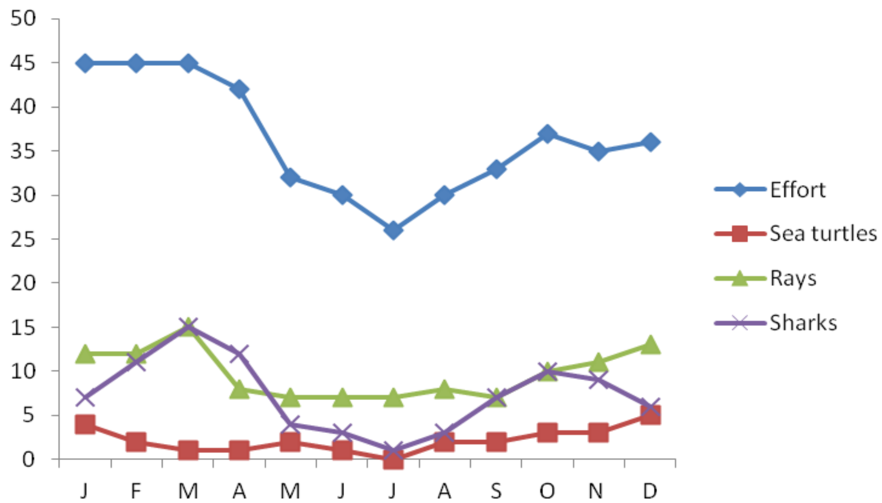

Fig. 4.13: Fishing effort (per month) and declared main bycatch taxonomic groups by interviewed fishermen along the coast of Kenya for the monofilament drift gillnet fishery (unit is the number of fishermen who declared fishing and bycatch events for each month)

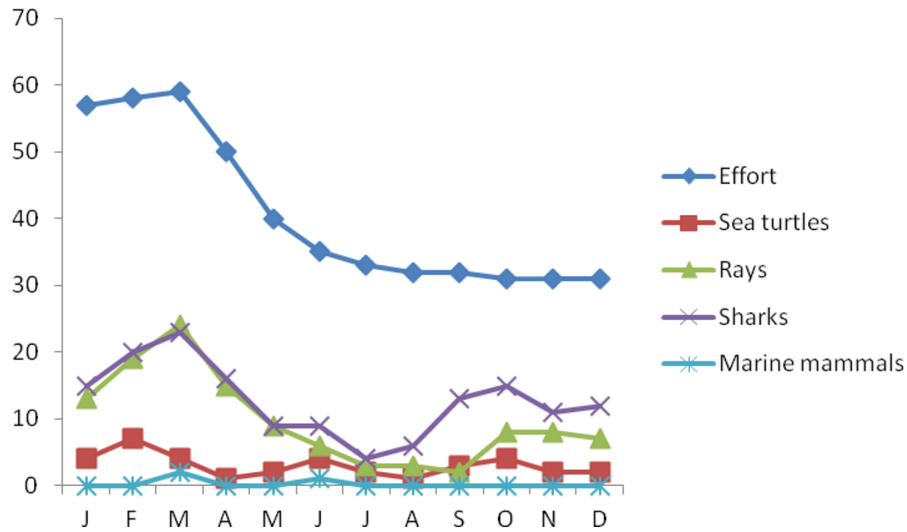

Fig. 4.14: Fishing effort (per month) and declared main bycatch taxonomic groups by interviewed fishermen along the coast of Kenya for the multifilament drift gillnet fishery (unit is the number of fishermen who declared fishing and bycatch events for each month)

Bottom-set gillnet bycatch

A diversity of fish species are targeted by the bottom-set gillnet fishery along the coast of Kenya. These species (primary targets) include various demersal coastal/reef fishes (47%, siganidae, mugilidae, lutjanidae and serranidae), pelagic fish (24%, istiophoridae, scombridae) and sharks and rays (18%). Bycatch of sea turtles was declared by 44% of respondents. *C. mydas* was the most commonly bycatch species (80% of reports). The other species involved in bycatch were *E. imbricata*, *C. caretta*, *L. olivacea* and *D. coriacea*. More than 60% of fishermen declared they had caught 1-3 individuals in the last year, less than 20% 4-10 individuals and 20% 11-20 individuals. In contrast, marine mammal bycatch involving *D. dugon* was declared only once by a fisherman.

Bycatch of rays was declared by 76% of respondents. Six species were identified by fishermen: *A. narinari* (31% of declared catches), *T. lymma* (24%), *Manta* spp (24%) and *R. djiddensis* (19%). The electric ray *Torpedo* sp. (1%) and *N. khulii* (1%) were rarely reported. Some 58% of fishermen declared 1-10 individuals as bycatch in the last year in bottom-set gillnets, 19% 11-20 individuals and 15% more than 21 individuals. Bycatch of sharks in bottom-set gillnets was declared by 68% of respondents. Five species of sharks were mentioned as bycatch species in bottom-set gillnets, including *G. cuvier* (44%), *C.*

melanopterus (25%), *Sphyrna* spp (18%), *T. obesus* (10%) and *I. oxyrhinchus* (3%). 76% of fishermen declared 1-10 shark individuals caught in the last year.

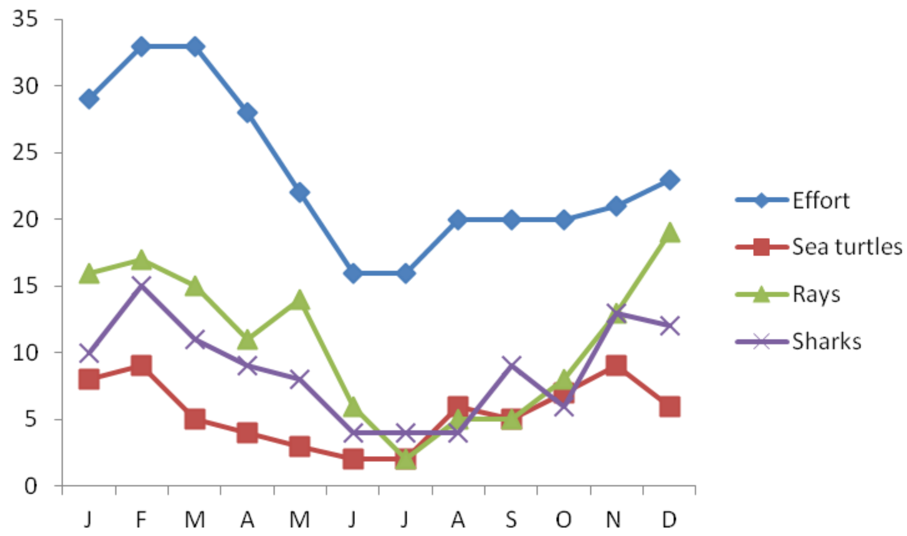

Fig. 4.15: Fishing effort (per month) and declared bycatch species by interviewed fishermen along the coast of Kenya for the bottom-set gillnet fishery (unit is the number of fishermen who declared fishing and bycatch events for each month)

Monthly occurrence of bycatch was highly correlated with reported fishing effort. Lower bycatch rates were reported during austral winter, when fishing effort is lower (Fig. 4.15).

Beach seine bycatch

The beach seine fishery essentially targets coastal fish species, including lethrinidae, siganidae and scaridae. Bycatch of sea turtles was declared by 50% of interviewees. The green turtle *C. mydas* was the most commonly bycatch species (53% of sea turtles bycatch events). The other species included *E. imbricata*, *C. caretta* and *L. olivacea.* Among fishermen who declared sea turtle bycatch, only 48% could provide number of bycatch sea turtles in the last year (Modal range=1-3 individuals).

Only 2% of fishermen reported marine mammal bycatch (*T. aduncus*; 1-2 individuals in the last year).

Bycatch of rays was declared by 40% of respondents. The most frequently caught species were, in order of occurrence, *T. lymma* (54%), *A. narinari* (22%) and *Torpedo* sp (12%). Other species recorded were *R.*

djiddensis and *Manta* spp. Some 94% of fishermen declared they caught 1-10 individual rays in the last year and 6% between 11 and 20.

Shark bycatch was reported by 62% of fishermen. Four species were identified, in order of occurrence: *C. melanopterus* (77%), *T. obesus* (13%), *Sphyrna* spp (6%) and *G. cuvier* (4%). Some 69% of fishermen confirmed they caught 21-50 individual in the last year.

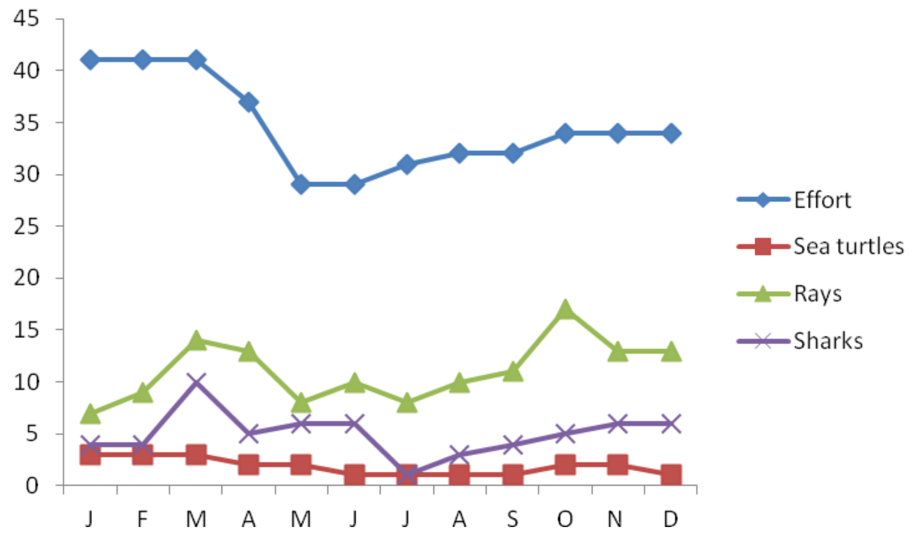

Fig. 4.16: Fishing effort (per month) and declared bycatch species by interviewed fishermen along the coast of Kenya for the beach seine fishery (unit is the number of fishermen who declared fishing and bycatch events for each month)

Overall, monthly bycatch occurrence follows fishing effort, but elasmobranch bycatch events were more commonly reported in March and October (only for rays; Fig. 4.16).

<u>Longline and handline bycatch</u>

Only 10 interviews were undertaken for longlines. Fishermen declared targeted species were both demersal predatory fish species (50%; especially lutjanidae, lobotidae), elasmobranchs (30%) and pelagic fish (20%). A total of 30% of fishermen declared they had already caught sea turtles as bycatch and three species were identified (*E. imbricata*, *C. caretta* and *C. mydas*). Sea turtle bycatch was considered as rare by most fishermen (no accurate estimates provided). No marine mammal bycatch was reported. Conversely, ray bycatch was declared by all fishermen (for those not specifically targeting elasmobranchs). Four species were identified by fishermen, namely *A. narinari*, *Manta* spp (the two most commonly caught species), *T. lymma* and *Torpedo* sp.

Concerning those fishermen not targeting sharks, 71% declared sharks were a regular bycatch species. Four species were identified: *G. cuvier* (most commonly reported species), *Sphyrna* spp, *C. melanopterus* and *T. obesus.* Some 60% of fishermen reported 1-10 sharks caught in the last year.

Handline fishermen were mostly targeting demersal fish species (66%), including lethrinidae, lutjanidae, siganidae and serranidae. However, 20% of fishermen declared they were primarily targeting pelagic fish (scombridae, istiophoridae and sphyraenidae).

Sea turtle bycatch was reported by only 13% of interviewed fishermen. The most commonly reported species were, in order of occurrence, *C. mydas* (53%), *C. caretta* (21%), *E. imbricata* (13%) and *L. olivacea* (13%). An estimated 73% of these fishermen caught 1-3 sea turtles during the last year and 18% caught between 11 and 20 individuals during the same period. Only one case of dolphin bycatch event has been reported by a handline fisherman, involving *D. delphis.*

Ray bycatch was reported by 51% of handline fishermen. Seven species were recorded, in order of occurrence: *T. lymma* (34%), *A. narinari* (26%), *R. djiddensis* (19%) and *Manta* spp (18%). The other species, more rarely reported, were *Torpedo* sp., *H. fai* and *R. javanica.* Similarly to rays, shark bycatch was reported by 52% of handline fishermen and involved eight species. The most commonly caught species were *C. melanopterus* (43%), *T. obesus* (21%), *G. cuvier* (17%) and *Sphyrna* spp (15%). Other species recorded were *S. mokarran*, *C. falciformis*, *N. ferrugineus* and *S. fasciatum.*

Bycatch events have been reported throughout the year, both for sea turtles and elasmobranchs (Fig. 4.17).

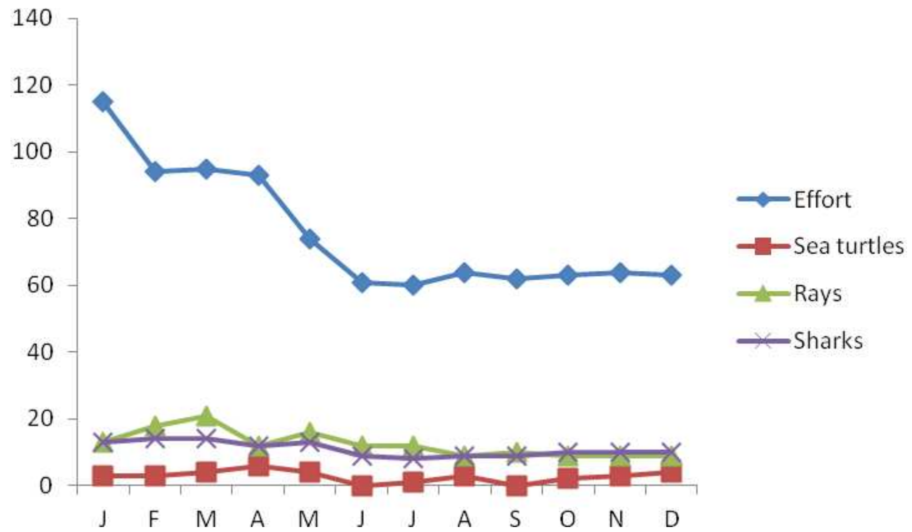

Fig. 4.17: Fishing effort (per month) and declared bycatch species by interviewed fishermen along the coast of Kenya for the handline fishery (unit is the number of fishermen who declared fishing and bycatch events for each month)

Bycatch incidence

Bycatch incidence (bycatch/last year/boat) was calculated for each fishery and each taxonomic group (sea turtles, elasmobranchs and marine mammals). All values are presented in table 4.2.

Table 4.2: Mean number of bycatch sea turtles, marine mammals and elasmobranchs in the last year per boat along the coast of Kenya

	N/boat/last year			
	Sea turtles	Rays	Sharks	Mammals
Monofilament. drift gillnets	0.286	8.73	13.69	0.082
Multifilament drift gillnets	1.37	10.725	14.37	0.283
Bottom-set gillnets	2.51	9.74	7.62	0.029
Beach seine	1.33	5.48	21.29	0.036
Longline	1.1	17.45	15.75	0
Handline	0.374	4.34	9.39	0.017

Results of bycatch rates per boat for the last year suggest net fisheries capture the highest number of marine mammals, sea turtles and elasmobranchs. For sea turtles, it appears that bottom-set gillnets, multifilament drift gillnets and beach seine have the highest bycatch rates. Marine mammal bycatch was higher in multifilament drift gillnets, but was low for most fisheries. Elasmobranch bycatch rates were relatively high, especially for longlines, beach seines (for sharks only) and gillnets.

Use of bycatch species

When a sea turtle was bycatch, 69% of interviewed fishermen declared they generally released the animal alive, 15% eat the meat, 10% discard the turtle dead and 6% sell the meat. Marine mammals were systematically discarded or released alive, except when the dugong was the bycatch species (the meat was consumed and/or sold). Rays were, even for large species (*Manta* sp), all consumed/sold on local markets. For shark bycatch, 97% of caught individuals were sold whole on local markets (fins and meat). Sharks were rarely finned with carcase discarded (3%).

Perceptions of bycatch incidence and population trends

Perceptions of population trends of sea turtles, elasmobranchs and marine mammals were provided by most of interviewed fishermen. According to them, there is a decline of elasmobranchs and marine mammals in Kenyan waters. Conversely, sea turtles are considered to be more numerous by artisanal fishermen (Fig. 4.18).

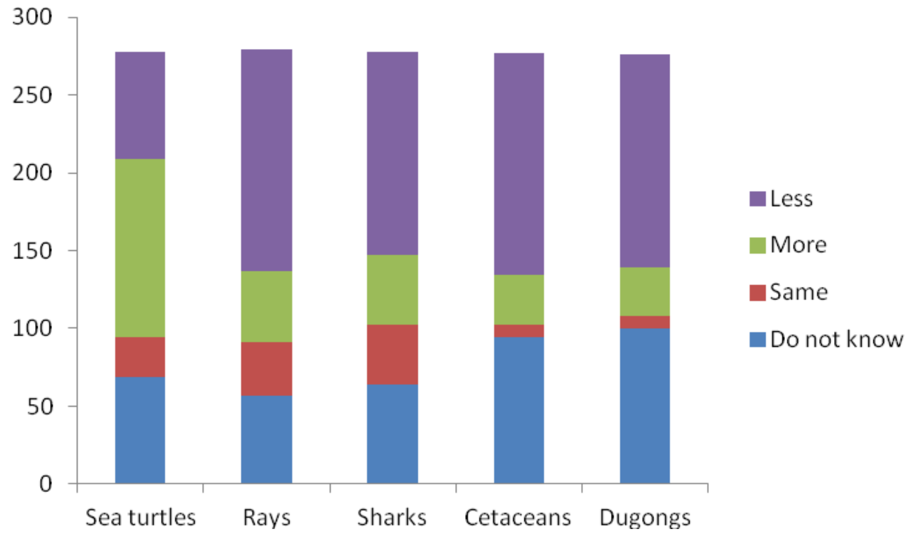

Fig. 4.18: Perception of population trends of sea turtles, elasmobranchs and marine mammals by artisanal fishermen in Kenya

Quite similarly (except for sea turtles), most fishermen declared that bycatch of sea turtles, elasmobranchs and marine mammals were decreasing in artisanal fisheries of Kenya (Fig. 4.19). This trend is particularly accentuated for the dugong, now considered rare in Kenyan coastal waters.

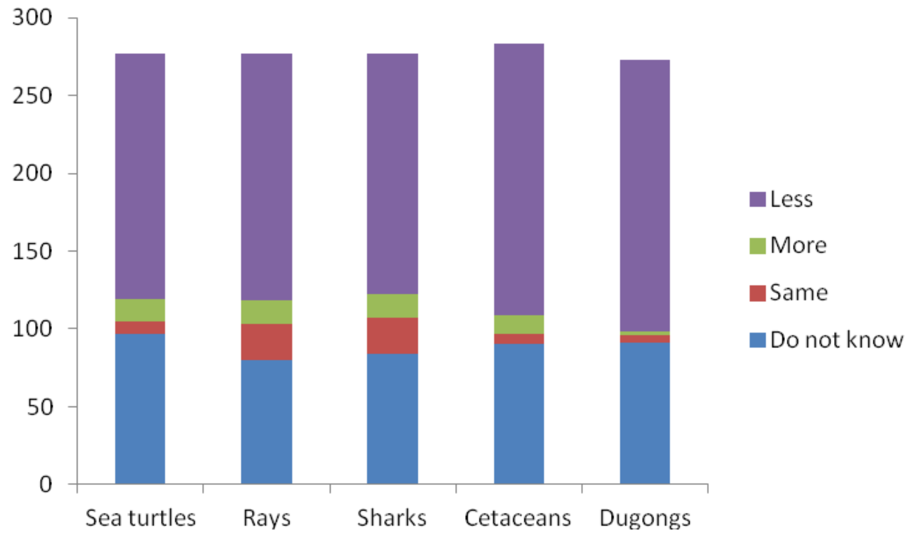

Fig. 4.19: Perception of bycatch trends of sea turtles, elasmobranchs and marine mammals by artisanal fishermen in Kenya

4.4 Tanzania

In Tanzania, questionnaire surveys were undertaken on Zanzibar and Pemba islands in February 2012. A total of 226 interviews were completed in Zanzibar and 90 in Pemba in 12 communities. For 84%, interviews were conducted at landing sites, essentially when fishermen were repairing their gears, returning from fishing, going out at sea or when resting. Almost all interviewees were males, except two females fishing with mosquito nets. Age of interviewed fishermen averaged at 39.2 (SD=13.3; Range=15-90), and was very similar to those in Kenya. Their mean fishing experience was 20.5 years (SD=12.5; Range=1-75). For 47% of interviewed fishermen, fishing was their only activity, and for all of them, fishing was their primary professional activity. Some 19% of interviewees had previously been involved in questionnaire surveys, including on fish and fisheries, sea turtles, marine mammals and sharks. Analyses of bycatch were only conducted on fisheries most likely considered to catch sea turtles, marine mammals and elasmobranchs, i.e. purse seines (n=33), bottom-set gillnets (n=51), handlines (n=67), longlines (n=22), monofilament drift gillnets (n=14) and multifilament drift gillnets (n=89; Fig. 4.20).

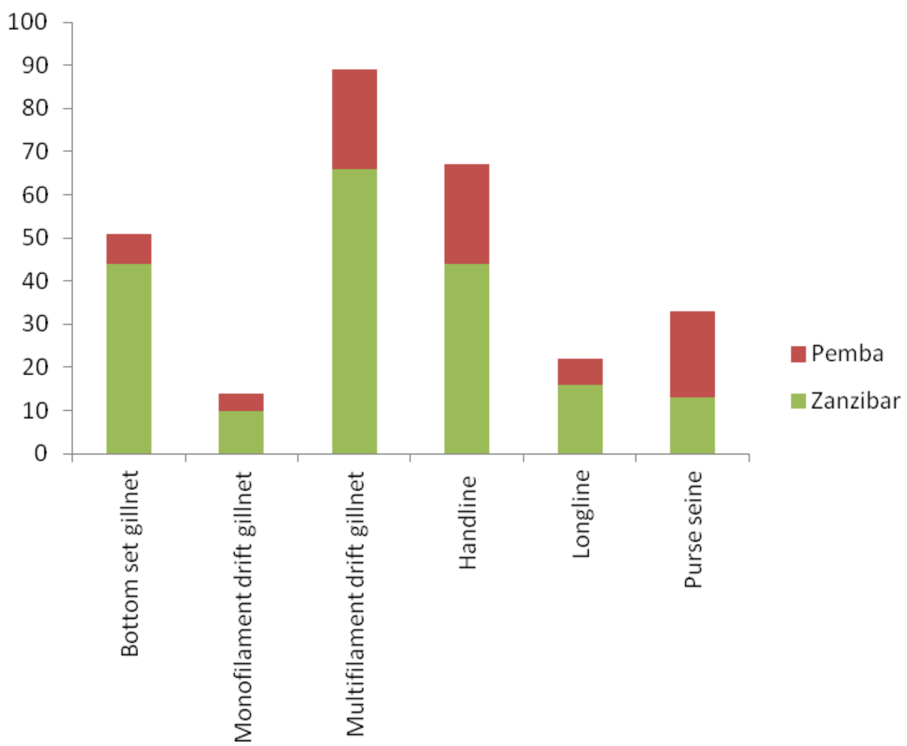

Fig. 4.20: Number of RBA interviews for the main artisanal fisheries in Zanzibar and Pemba islands

Sampling at the two islands was not random and was inherent to fishermen availability. A higher effort was devoted to sample gillnet fisheries (particularly multifilament and bottom-set).

Gear characteristics and fishing effort

During surveys, some basic information on fishing gears was collected. Bottom-set gillnets have a mean length of 307m (SD=264; range=14-900). Mesh size was highly variable, ranging from 4 to 22.9cm (mean=13.6; SD=4). Multifilament drift gillnets have a mean length of 443m (SD=361; Range=30-1600) and mesh size varied from 3 to 17.8cm (mean=12.3; SD=4). Monofilament drift gillnet range from 20 to 900m in length (mean=229; SD=289) and from 5 to 15.2cm in mesh size (mean=10; SD=4). Overall, gillnet mesh size is larger than in Kenya, suggesting that larger fish species are more targeted around Zanzibar and Pemba. Purse seines consist in small meshed nets (mean=5.2cm; SD=3.7), ranging from 30 to 1500m long (mean=211; SD=275).

Hook number used in line fisheries was highly variable, from 6 to 500 hooks for longlines (Mean=169; SD=144) and from 1 to 150 for handlines (mode=1; mean=7; SD=24). Number of days spent at sea per week was between 3 and 7 (mode=5) for the purse seine fishery, from 4 to 7 days for the bottom-set gillnet fishery (mode=6), from 4 to 7 days for the monofilament drift gillnet fishery (mode=6), from 3 to 7 days for multifilament drift gillnet fishery (mode=6),from 2 to 7 days for the longline fishery (mode=6) and 2-7 days (mode=6) for the handline fishery. Based on fishermen declarations on the months during which they fish, fishing effort was relatively stable throughout the year off Zanzibar and Pemba (Fig. 4.21).

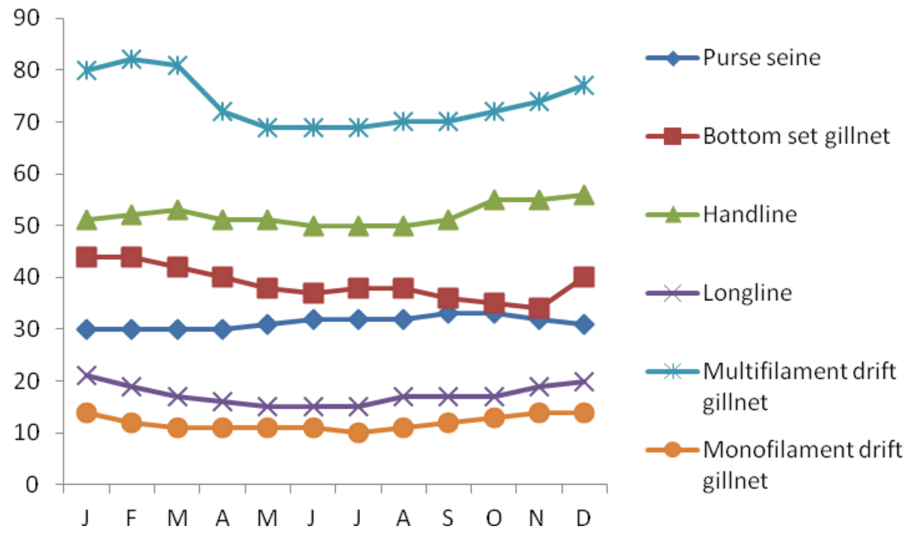

Fig. 4.21: Fishing effort (per month) by interviewed fishermen off Zanzibar and Pemba islands for all artisanal fisheries gear types (unit is the number of fishermen who declared fishing for each month)

<u>Overall bycatch composition</u>

At least 31 species were mentioned as bycatch during surveys off Zanzibar and Pemba islands, including all five species of sea turtles (*C. caretta*, *E. imbricata*, *L. olivacea*, *D. coriacea*, *C. mydas*; Fig. 4.22), at least five species of marine mammals (*T. aduncus*, *S. longirostris*, *G. griseus*, *S. chinensis* and at least one species of large whale, *Balaenoptera* sp; Fig. 4.22) and at least 21 species of elasmobranchs (Fig. 4.23). *C. caretta* was the most commonly bycatch species in all fisheries (51% of reported bycatch species), especially in multifilament drift gillnet but also in the bottom-set gillnet fishery. The two other most commonly reported bycatch sea turtle species were *E. imbricata* (21%) and *L. olivacea* (11%). Marine mammals were frequently reported as bycatch, but the bulk of bycatch events were reported in multifilament drift gillnet and bottom-set gillnet fisheries (Fig. 4.22). The most frequent bycatch species were *T. aduncus* (67%) and *S. longirostris* (19%).

Elasmobranchs were mostly considered as by-product species although 27% of fishermen had, among their targeted catch some species of sharks and/or rays. The most common bycatch rays were *Manta* spp (58%), *T. meyeni* (35%), *T. lymma* (22%) and *A. narinari* (17%). It is interesting to note that sawfish (rare and currently critically endangered) bycatch was reported in several coastal artisanal fisheries, including longline, handline and purse seine fisheries. Among sharks, the most frequently caught species was *Sphyrna* spp (43%), followed by *I. oxyrhinchus* (15%), *T. obesus* (11%) and *C. melanopterus* (8%). Elasmobranchs were caught in all fisheries; with a higher reported occurrence in multifilament drift gillnet, bottom-set gillnet and handline fisheries (Fig. 4.23).

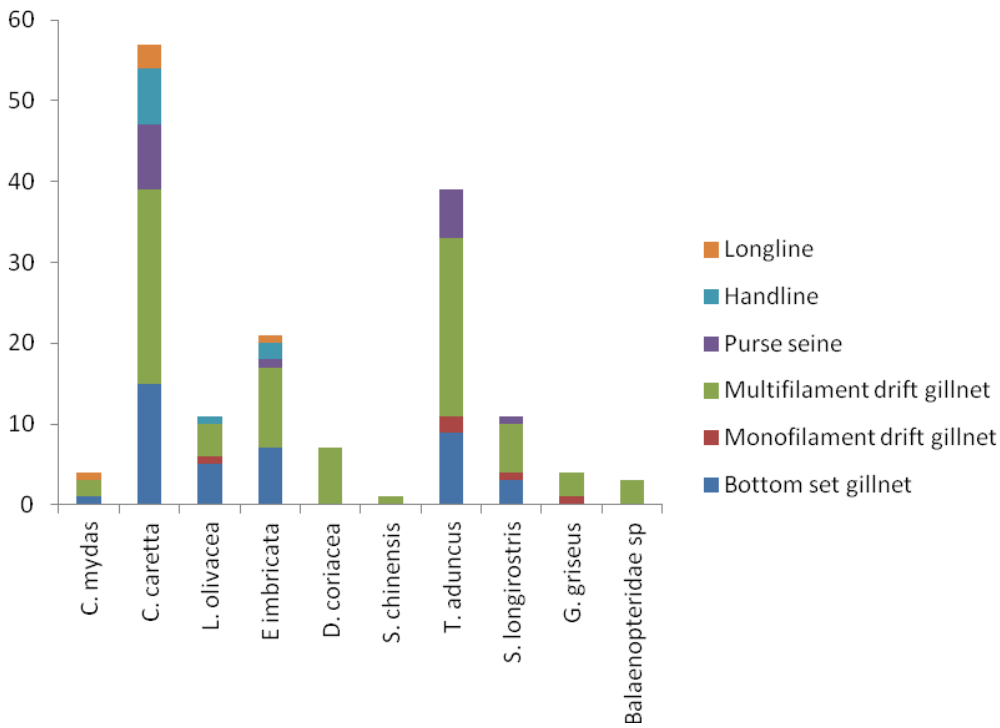

Fig. 4.22: Occurrence of bycatch events of sea turtles and marine mammals in all artisanal fisheries off Zanzibar and Pemba (unit is the number of times species were mentioned by fishermen as bycatch)

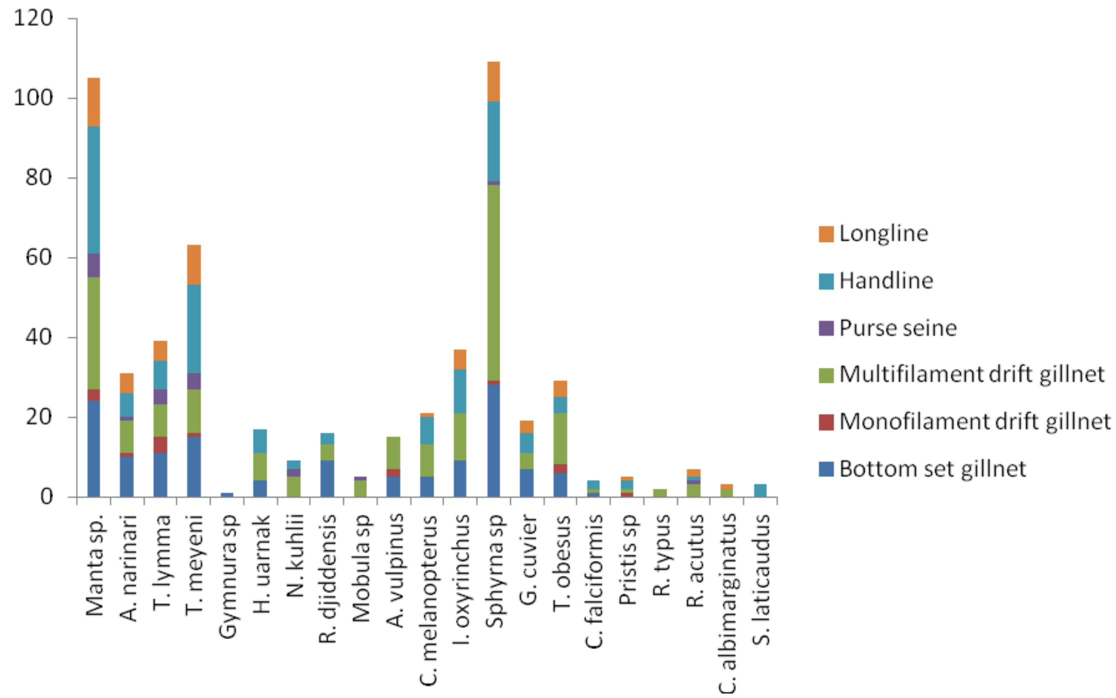

Fig. 4.23: Occurrence of bycatch events of elasmobranch species in all artisanal fisheries off Zanzibar and Pemba (unit is the number of times species were mentioned by fishermen as bycatch)

Shark fishery

As previously reported, 27% of fishermen target (at least partially) sharks and rays off Zanzibar and Pemba. Fishermen use multifilament drift gillnets to catch sharks (38%), bottom-set gillnets (28%), handlines (22%) as well as longlines (5%) and monofilament drift gillnets (2%). Among interviewed fishermen, only 11% were exclusively targeting elasmobranchs.

Drift gillnet fisheries

Drift gillnet fisheries use two types of nets off Zanzibar and Pemba: monofilament and multifilament nets. These fisheries generally target a diversity of species with a preference for pelagic fish. During surveys, fishermen almost never declared targeting one family of species. In both fisheries, the preferred species belonged to the carangidae, lethrinidae, scombridae, sphyraenidae, lutjanidae, istiophoridae and siganidae. As previously reported, elasmobranchs (especially carcharhinidae, rhinobatidae, sphyrnidae) were more frequently targeted in the multifilament drift gillnet fishery. In monofilament drift gillnets, sea turtle bycatch events were declared by only 7% of fishermen. In multifilament drift gillnets, this proportion was significantly higher, with 38% of fishermen having declared they had previously caught a sea turtle in their nets. Only one species of sea turtle was declared as bycatch in the monofilament drift gillnets (*L. olivacea*), while five species were recorded in multifilament drift gillnets: most commonly *C. caretta*, *E. imbricata* and *L. olivacea*. In monofilament drift gillnets, numbers of sea turtles caught in the last year was between 1 and 3. In multifilament drift gillnets, only 6% of fishermen declared they did not catch any sea turtle in the last year, while 24% declared 1-3 sea turtles as bycatch in the last year.

Marine mammal bycatch events were declared by 43% of fishermen using monofilament drift gillnets. Three species were identified; *T. aduncus* (50%, 1-5 individuals in the last year), *G. griseus* and *S. longirostris* (1-2 individuals in the last year). In multifilament drift gillnets, 37% of fishermen declared cetacean bycatch events involving five species. *T. aduncus* was, by far, the most commonly bycatch species (63% of fishermen had caught this species). Between 1 and 2 individuals were caught in the last year for the 37% of fishermen that declared cetacean bycatch events, 3-5 for 20% of them and more than 10 individuals for 10% of them. Among surveyed areas in the SW Indian Ocean, the scale of cetacean bycatch is the highest off Zanzibar and Pemba, attributable to the multifilament drift gillnet fisheries

In multifilament drift gillnets, ray and shark catches were declared by 51% and 81% of fishermen respectively while in the monofilament drift gillnet fishery, ray and shark bycatch reached only 36% and 29% of interviewed fishermen, respectively. In drift gillnets, most frequently caught species included, in order of occurrence, *Manta* spp, *Sphyrna* spp and a diversity of stingrays (Fig. 4.23). No clear seasonality of bycatch events was found, although most bycatch events were recorded during the rainy season types of drift gillnet fisheries; particularly apparent for sharks (Fig. 4.24).

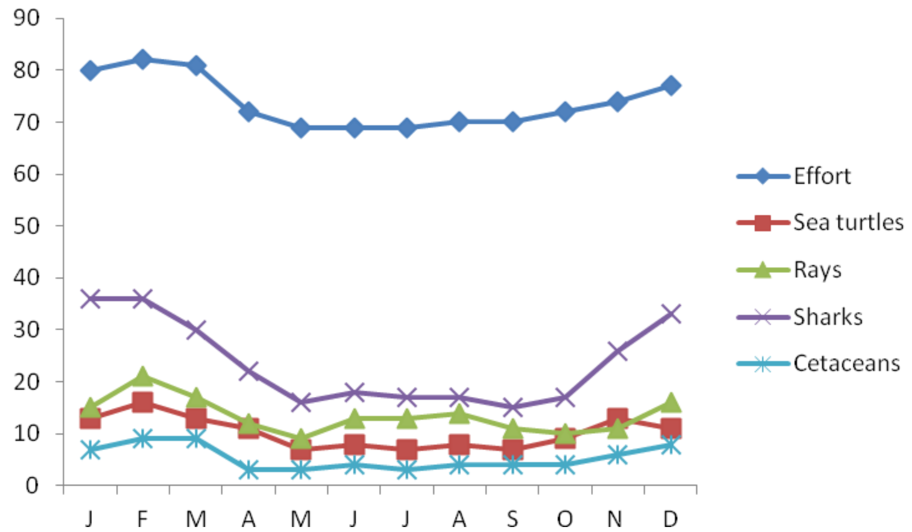

Fig. 4.24: Fishing effort (per month) and declared main bycatch events for taxonomic groups by interviewed fishermen off Zanzibar and Pemba for drift gillnet fisheries (unit is the number of fishermen who declared fishing and bycatch events for each month)

Bottom-set gillnet bycatch

Overall, bottom-set gillnet fishermen off Zanzibar and Pemba target a diversity of species, including demersal (lutjanidae, serranidae, lethrinidae, siganidae) and pelagic fish (scrombridae, istiophoridae, carangidae). As previously reported, 28% of interviewed fishermen target, at least partially, sharks and other elasmobranchs. A bycatch of sea turtle events was declared by 39% of respondents. In order of occurrence, *C. caretta* (65%), *E. imbricata* (10%) and *D. olivacea* (8%) were the most commonly bycatch turtle species. *C. mydas* was also captured, but on rare occasions. Some 75% of fishermen declared they caught 1-3 sea turtles in the year prior to the interview, 10% claimed 4-10 individuals and 5% at least 20 individuals.

According to fishermen, two species of marine mammal (delphinidae) were bycatch in bottom-set gillnets, including *T. aduncus* (87% of identified species) and *S. longirostris* (13%). Number of catches in the last year was 1-2 individuals (71%) and more than five individuals (12%). For some fishermen, the number of bycatch events in the last year was not provided as they could not recall.

Bycatch of rays was declared by 76% of respondents. Eight species were identified by fishermen: *Manta* spp (32% of declared events), *T. meyeni* (21%), *T. lymma* (15%), and *A. narinari* (14%) as well as *R. djiddensis*, *H. uarnak*, *Pristis* sp and *Gymnura* sp. For 46% of fishermen, 1-10 rays were bycatch in the last year in bottom-set gillnets, 21% between 11 and 50 individuals and for 8% of them, more than 50 individuals.

Shark bycatch events in bottom-set gillnets was declared by 80% of respondents with at least seven species reported: *Sphyrna* spp (46%), *I. oxyrhinchus* (15%), *G. cuvier* (11%) and *T. obesus* (9%) as well as occasionally, *C. melanopterus*, *A. vulpinus* and *C. falciformis*. Notably these were both coastal/reef associated and pelagic/oceanic species of which 66% of fishermen declared 1-10 shark individuals caught in the last year, 12% between 11 and 20 individuals and for only 7% of them, more than 20 individuals. Sharks, were used/sold whole by fishermen. Monthly occurrence of bycatch was highly correlated with reported fishing effort. However, for elasmobranchs, seasonality was more accentuated with highest reported occurrence of bycatch between December and March (Fig. 4.25).

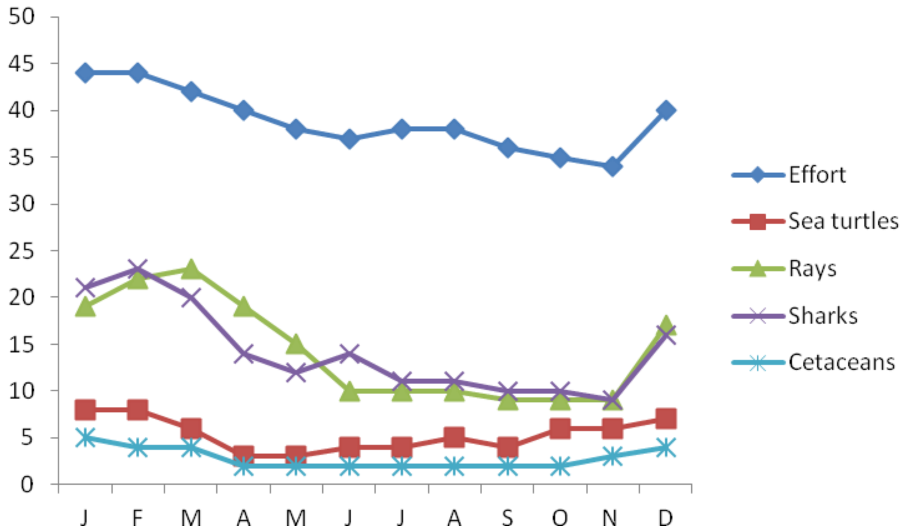

Fig. 4.25: Fishing effort (per month) and declared bycatch events by interviewed fishermen off Zanzibar and Pemba for the bottom-set gillnet fishery (unit is the number of fishermen who declared fishing and bycatch events for each month)

Purse seine bycatch

The purse seine fishery primarily targets small schooling fish species, such as sardines, Indian mackerel (clupeidae, scombridae), other epipelagic fishes (such as hemiramphidae), but also a number of other pelagic (carangidae) and to a lesser extent demersal species (lethrinidae).

Bycatch of sea turtles was declared by 24% of interviewees with *C. caretta* the predominant species mentioned with *E. imbricata* cited only once as a secondary species that is rarely caught. Some 87% of fishermen declared they caught 1-3 individuals in the last year and 13% at least 20 individuals. Marine mammal bycatch was reported as relatively rare by purse seine fishermen (8% of interviewees). Two species were reported as bycatch: *T. aduncus* (86%) and *S. longirostris* (14%). For all fishermen, number of bycatch individuals in the last year was between 1 and 2.

Elasmobranchs were never directly a target species in the purse seine fishery, although as a bycatch some species were marketed and used whole for meat and fins when caught. Ray bycatch was declared by 36% of respondents. At least six species of rays were identified by purse seine fishermen: *Manta* spp (33%), *T. lymma* (21%) and *T. meyeni* (22%) with less common *Mobula* spp, *A. narinari* and *N. khulii*. For 50% of fishermen involved in ray bycatch events, 50% caught 1-10 individuals in the last year, while 9% of fishermen caught 11-20 individuals and 7% caught more than 20 individuals. Shark bycatch was considered as rare in the purse seine fishery and reported by only 3% of fishermen. Only one species was identified: *R. acutus.* No significant seasonal variations of bycatch events were evident (Fig. 4.26) although slightly higher bycatch events were reported during the rainy season.

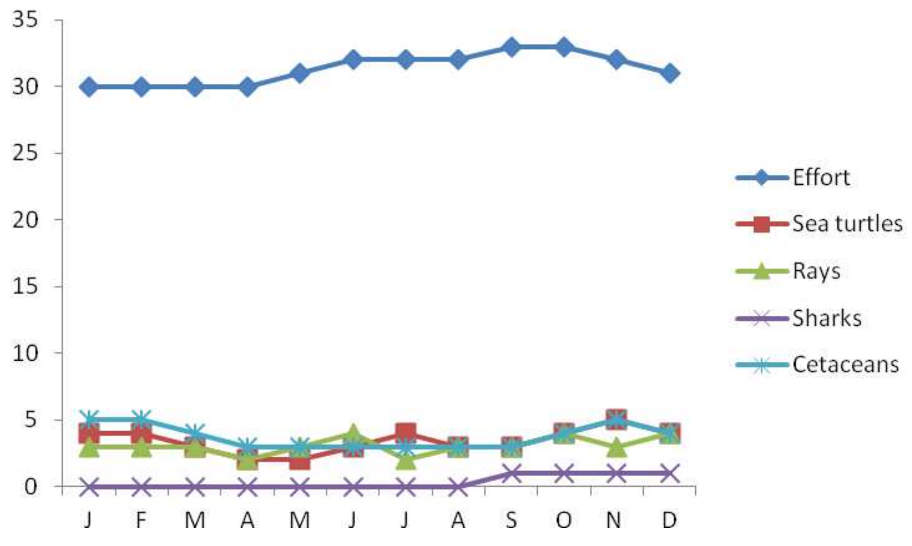

Fig. 4.26: Fishing effort (per month) and declared bycatch species by interviewed fishermen off Zanzibar and Pemba for the purse seine fishery (unit is the number of fishermen who declared fishing and bycatch events for each month)

Longline bycatch

As for most artisanal fisheries off Zanzibar and Pemba islands, longline fishermen target a diversity of fish species. From the interview data, it was observed that sharks were rarely targeted in the longline fishery (5% as targeted species, among other fish families). Targeted fish families include both demersal and pelagic predatory species, including scrombridae, lethrinidae, istiophoridae, serranidae and lutjanidae.

Some 27% of fishermen reported sea turtles as a bycatch species and three species were identified (*C. caretta, E. imbricata* and *C. mydas*). The survey indicated that 60% of fishermen declared they caught 1-3 individuals in the last year, 17% 11-20 individuals and 15% declared no sea turtle catch in the last year, but regular catches since they first started their longline fishing activity. No marine mammal bycatch events were reported.

Ray bycatch was reported by 82% of interviewed fishermen. Four species were identified by fishermen: *Manta* spp (38%), *T. meyeni* (31%), *T. lymma* (16%) and *A. narinari* (15%). Concerning sharks, bycatch was reported by 73% of longline fishermen with eight species reported: *Sphyrna* spp (27% of most frequently cited caught species), *I. oxyrhinchus* (13%) and a diversity of occasional/rare species: *T. obesus*, *G. cuvier*, *R. acutus*, *C. melanopterus*, *C. albimarginatus* and *Pristis* sp. For 77% of fishermen, 1-10 individual sharks were caught in the last year, while 21% of them caught between 11 and 50 sharks during the same period.

No clear seasonal variations of bycatch events could be detected. However, for sea turtles and sharks, higher occurrence of catch events was reported during early winter (June-July), when fishing effort was lower (Fig. 4.27).

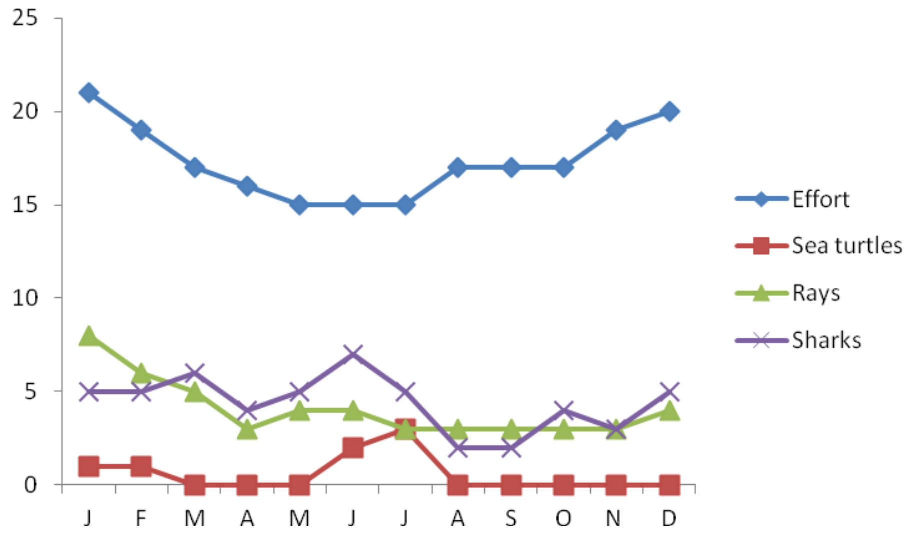

Fig. 4.27: Fishing effort (per month) and declared bycatch species by interviewed fishermen off Zanzibar and Pemba for the longline fishery (unit is the number of fishermen who declared fishing and bycatch events for each month of the year)

Handline bycatch

Handline fishermen were targeting a diversity of fish, including demersal species from the lethrinidae, serranidae, lutjanidae and siganidae. However, pelagic fish were exclusively targeted by 30% of interviewed handline fishermen, including scombridae and istiophoridae). Sharks and rays were also frequently cited as target species (22%) but never exclusively the only targeted group. Sea turtle was reported by only 13% of interviewed fishermen, as it was in Kenya. The most commonly reported species were, in order of occurrence, *C. caretta* (70%), *E. imbricata* (20%) and *L. olivacea* (10%). For 70% of fishermen involved in sea turtle bycatch the catch amounted to 1-3 individuals during the last year while 10% caught between 4 and 10 specimens. In the case of 10% of fishermen they could not provide a number of bycatch sea turtles in the last year. No marine mammal bycatch event was reported.

Ray bycatch was been reported by 66% of handline fishermen. Seven species were identified as bycatch, in order of occurrence: *Manta* spp (43%), *T. meyeni* (30%) and at a relatively similar proportion (8%), *T. lymma*, *A. narinari* and *H. uarnak.* Least common were *R. djiddensis* (3%) and *N. khulii* (less than 2%).

Shark bycatch was reported by 54% of handline fishermen and involved nine species. *Sphyrna* spp were most commonly reported (36%), followed by *I. oxyrhinchus* (20%) and *C. melanopterus* (13%). The other species were less common such as *G. cuvier*, *T. obesus*, *Pristis* spp, *C. falciformis*, *R. acutus* and *S.*

laticaudus. There were no obvious seasonal variations of reported bycatch events with slightly higher incidence during summer; Fig. 4.28).

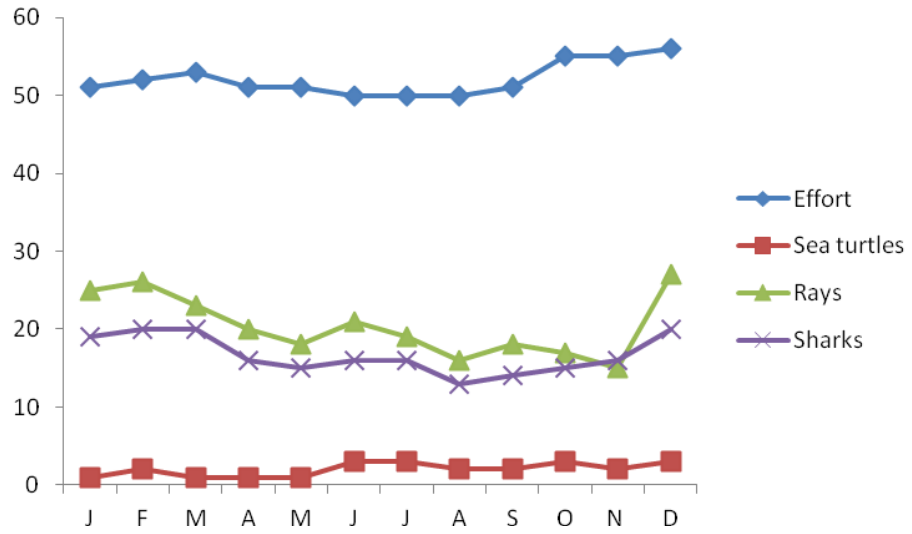

Fig. 4.28: Fishing effort (per month) and declared bycatch events for selected species by interviewed fishermen off Zanzibar and Pemba for the handline fishery (unit is the number of fishermen who declared fishing and bycatch events for each month)

Bycatch incidence

Bycatch incidence (bycatch/last year/boat) was calculated for each fishery and each taxonomic group (sea turtles, rays, sharks, marine mammals; Table 4.3). Results suggest that bycatch incidence is significantly higher in multifilament drift and bottom-set gillnets. Surprisingly, bycatch incidence of monofilament drift gillnets is lower, especially for sea turtles, sharks and cetaceans. Overall, line fisheries do not have a direct impact on marine mammals, but the effect on elasmobranchs (especially rays) is high. Conversely, the purse seine fishery seems to have a very limited extent for sharks.

Table 4.3: Mean number of bycatch sea turtles, marine mammals and elasmobranchs in the last year per boat off Zanzibar and Pemba

	N/boat/last year			
	Sea turtles	Rays	Sharks	Cetaceans
Monofilament drift gillnets	0.143	4.036	1.179	0.51
Multifilament drift gillnets	0.949	4.831	5.64	1.11
Bottom-set gillnets	1.275	9.62	6.39	0.755
Purse seine	0.75	2.82	0	0.303
Longline	0.59	15.272	7.045	0
Handline	0.313	8.746	4.276	0

Use of bycatch species

Once a sea turtle was taken as bycatch, 53% of interviewed fishermen declared they generally release the animal alive. A further 42% either ate the meat or sold it and only 4% discarded the dead turtle. Captured cetaceans were released alive in 37% of cases but a significant proportion was used for personal consumption and some even sold (34%). More than 20% of fishermen discarded dead bycatch animals (generally dolphins) and some of them also contributed to scientific programmes by providing carcasses to local authorities and scientists (4%). Rays, even for large species like *Manta* spp, were all consumed and/or sold on local markets (98%). For a small number of fishermen (n=3), rays were released alive. For bycatch of sharks, 99% of the catch was sold whole on local markets, inclusive of fins and flesh. Sharks were rarely finned with the body discarded (1%).

Perceptions of bycatch incidence and population trends

According to fishermen in Zanzibar and Pemba, there has been a significant decline of elasmobranchs and sea turtles in the areas where they fish (Fig. 4.29). This decline is less apparent for cetaceans, notably dolphins. Concerning dugongs, most of fishermen were unaware of their presence and local status off Zanzibar and Pemba; although a high proportion of fishermen did not provide a trend of their captures (Fig. 10). However, for fishermen that did provide details most of them (76%) think that there had been there a decline of this species in the region. Similarly, most fishermen declared bycatch of sea turtles and elasmobranchs to be on the decrease in artisanal fisheries of Zanzibar and Pemba (Fig. 4.30). A similar trend is also apparent for marine mammals, but less significant as most fishermen were unaware of their past and present status.

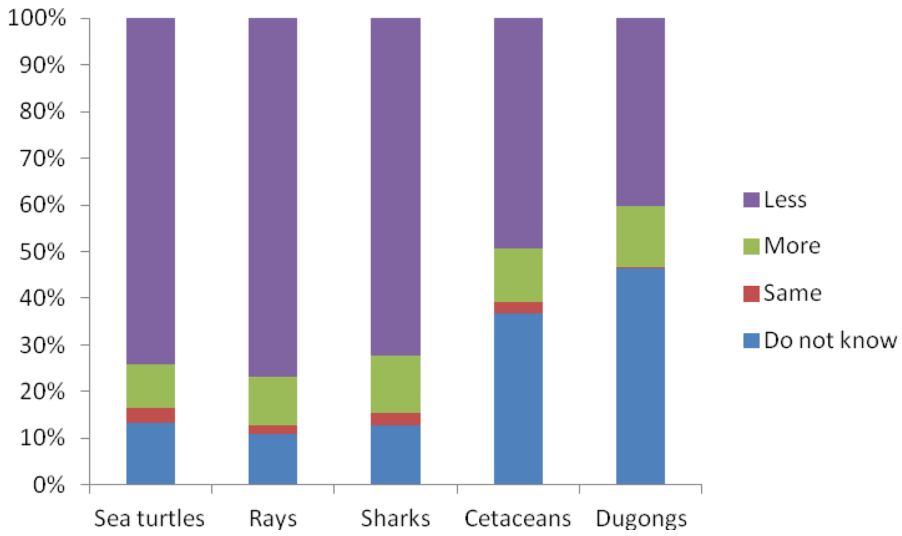

Fig. 4.29: Perception of population trends of sea turtles, elasmobranchs and marine mammals by artisanal fishermen in Zanzibar and Pemba

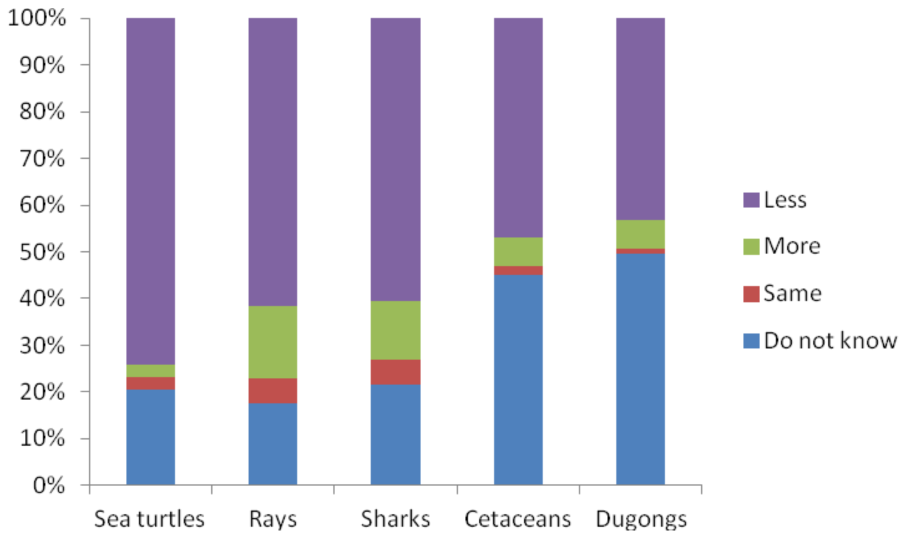

Fig. 4.30: Perception of bycatch trends of sea turtles, elasmobranchs and marine mammals by artisanal fishermen in Zanzibar and Pemba

4.5 Mozambique

A total of 296 questionnaire surveys were undertaken in Mozambique in the ten communities of Angoche, Inhaca, Inhambane, Inhassoro, Macaneta, Machangulo, Maputo, Marracuene, Matutuine and Vilankulo, belonging to the four provinces of Nampula, Inhambane, Gaza and Maputo. Most interviews were performed at landing sites (58%), at fisher's home (37%) and more rarely at fisheries centres (3%) or at markets (2%). Most of interviewees were male (96%), with a number of women interviewed essentially involved with beach seining. The age of interviewees averaged 38 (SD=12.3; Range=17-85). Their mean fishing experience was 18.2 years (SD=10.9; Range=1-50). For 94% of interviewees, fishing was their primary activity and for 64% of them, it was their only activity. Some 19% of interviewees had already been involved in questionnaire surveys in the past, including on fishing and sea turtles. Analyses of bycatch were only conducted on fisheries that were most likely to catch sea turtles, marine mammals and elasmobranchs, i.e. beach seines (n=146), bottom-set gillnets (n=35), handlines (n=67), monofilament drift gillnets (n=42) and multifilament drift gillnets (n=6; Fig. 4.31).

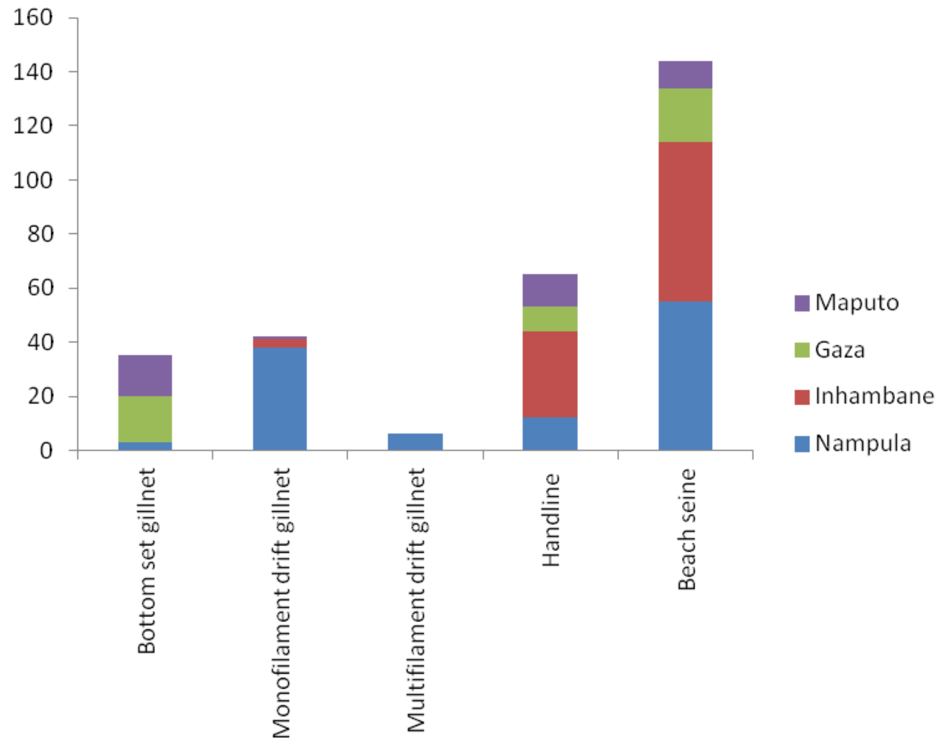

Fig. 4.31: Number of RBA interviews for the main artisanal fisheries in Mozambique

Most of sampling effort was concentrated on beach seine and handline fisheries in the four provinces sampled. Drift gillnet fisheries were primarily sampled in northern Mozambique (Nampula) while bottom-set gillnets were mostly sampled in the south (Fig. 4.31).

Gear characteristics and fishing effort

Along the coast of Mozambique, beach seines have a mean length of 232m (SD=91; range=9-480). Mean mesh size was 4.53cm (SD=1.46). Bottom-set gillnets have a mean length of 348m (SD=263; Range=30-900) with highly variable mesh size, ranging from 5.1 to 11.4cm (mean=7.5; SD=2.4). Monofilament drift gillnet range from 50 to 650m in length (mean=489; SD=170), but are mostly 600m (modal size), and from 1.3 to 5.1cm in mesh size (mean=3.6; SD=1.3). Limited data was collected on multifilament drift gillnets, but their mean length was 302m (SD=146; Range=230-600), with mesh size varying from 2.3 to 3.8cm (mean=3.3; SD=7.7). Handline fishermen were mostly using a single hook and line.

Number of days spent at sea was relatively variable among fishermen, but not between fisheries. Indeed, 38% of artisanal fishermen declared fishing every day of the week. About 54% of them declared fishing between 4 and 6 days in the week, while less than 6% claimed to be fishing only 1-3 days per week. Based on fishermen declarations as to the months during which they fish, fishing effort appeared relatively stable throughout the year off Mozambique (Fig. 4.32).

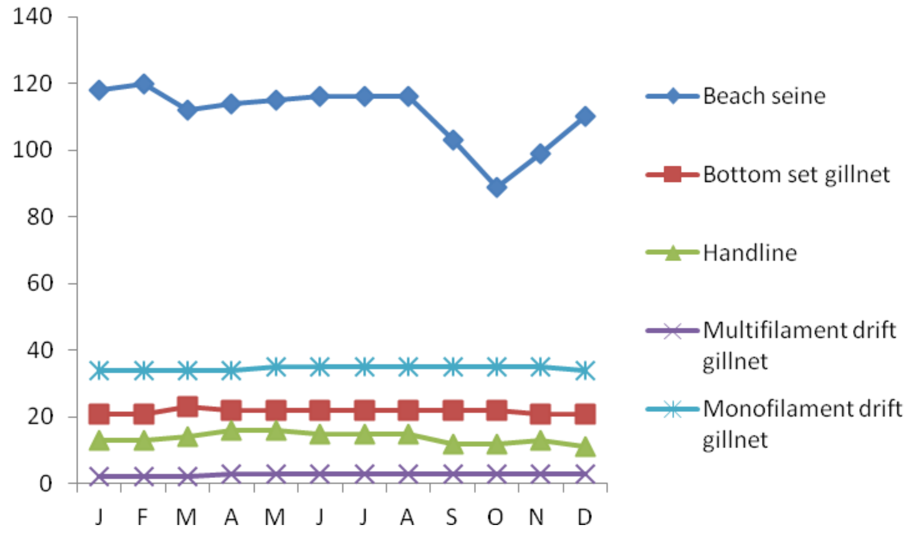

Fig. 4.32: Fishing effort (per month) by interviewed fishermen off Mozambique for all artisanal fisheries (unit is the number of fishermen who declared fishing for each month of the year)

Target species

The main gears used are: beach seines, gillnets (including drift and bottom-set gillnets), handlines (hook and line) and longlines. The catch from those gears currently constitutes more than 95% of the total catch of the artisanal fisheries and about 82% of the catch comes from the beach seines and gillnets. In general, the species that contribute most to the total catch of the fleet and are of economic importance are: *Hilsa kelee*, *Sillago sihama*, *Thryssa vitrirostris*, *Otolithes ruber*, *Mugil cephalus*, *Siganus sutor*, *Pomadasys kaakan* and *Lethrinus* spp. The *Lethrinus* spp. complex includes five different species: *L. harak*, *L. lentjan*, *L. nebulosus*, *L. rubrioperculatus and L. variegates*, all caught by the hook and line fisheries. Overall, artisanal fisheries in Mozambique are multi-species.

Overall bycatch composition

At least 41 species of bycatch were mentioned by Mozambique artisanal fishers during the surveys, including all five species of sea turtle: *C. caretta*, *E. imbricata*, *L. olivacea*, *D. coriacea* and *C. mydas* (Fig. 4.33), three species of marine mammal: *T. aduncus*, *S. longirostris* and *S. chinensis* (Fig. 4.33) and at least 33 species of elasmobranchs (Fig. 4.34).

Among sea turtles, *C. caretta* was the most common bycatch species in all fisheries (41% of reported bycatch species), especially in the beach seine fishery. The two other most common bycatch species were *L. olivacea* (22%), *E. imbricata* (20%), *C. mydas* (16%) and *D. coriacea* (1%). Marine mammals were rarely reported as bycatch and the only bycatch events were reported from the beach seine fishery, being *T. aduncus* (67%), *S. longirostris* (22%) and *S. chinensis* (11%). Surprisingly, no bycatch events were recorded in gillnet fisheries (Fig. 4.33).

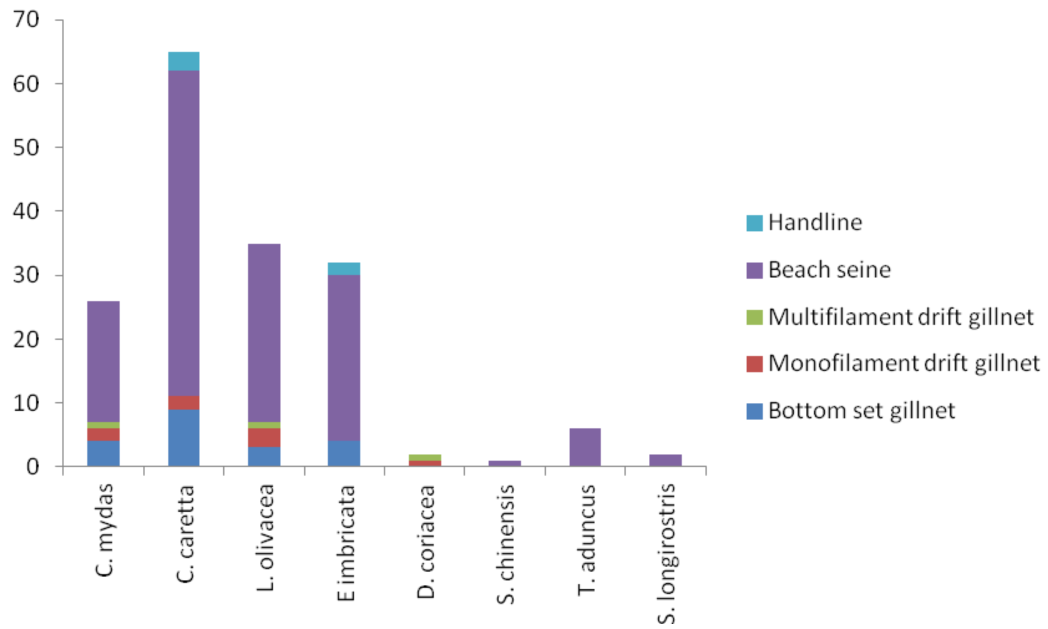

Fig. 4.33: Occurrence of bycatch events by species of sea turtles and marine mammals in all artisanal fisheries off Mozambique (unit is the number of times species were mentioned by fishermen as bycatch)

Elasmobranch diversity as bycatch species was the highest in the sampled region. A total of at least 41 species was recorded, including 15 ray and 18 shark species respectively (Fig. 4.34 & 4.35). As many as 99% of fishermen declared that elasmobranchs were not their primary target. Among rays, the most common bycatch species were *H. uarnak* (25%), *H. fai* (20%), *P. bovinus* (13%) and *A. narinari* (10%). A number of less common species were also mentioned as bycatch (see Fig. 4.34), including *Manta* spp and *Pristis* spp. Among sharks, the most frequently caught species was, by far, *Sphyrna* spp (44%). Three other species were identified by fishermen: *S. lewini*, *S. mokarran* and *S. zygaena*. However, as species discrimination may be erroneous for a number of cases, all hammerhead sharks were pooled together as *Sphyrna* spp. A range of other less common species were reported including a number of species that were not recorded in other countries of the study, such as *Carcharodon carcharias*.

Shark fishery

No more that 1% of interviewed fishermen declared they were targeting elasmobranchs, predominantly using handline and multifilament drift gillnets. It appears that the shark fishery mostly operates with offshore longlines along the coast of Mozambique.

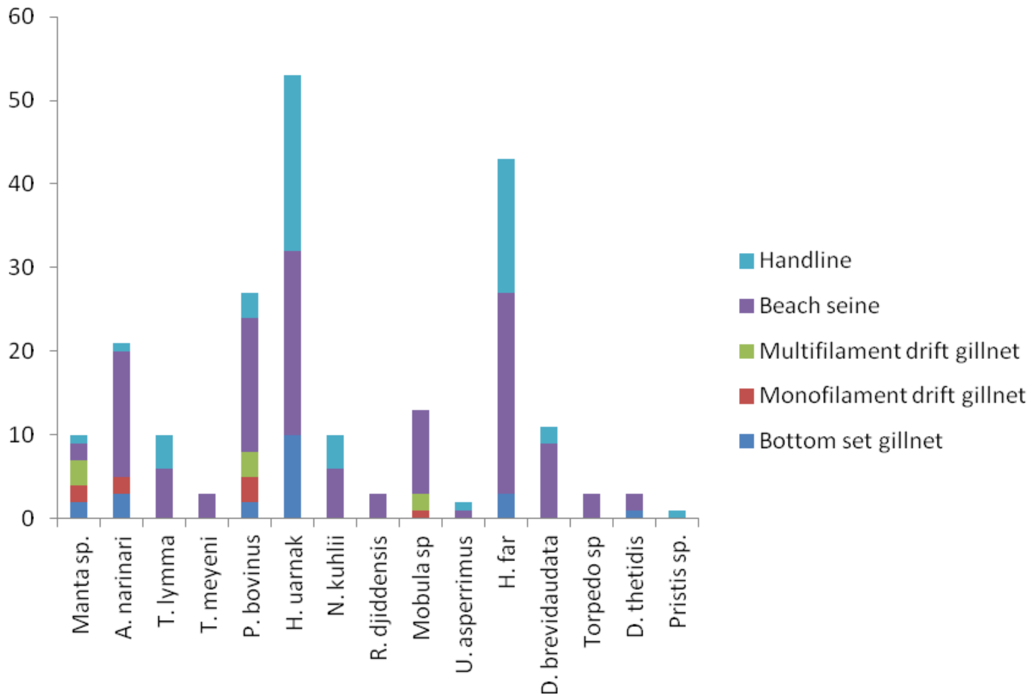

Fig. 4.34: Occurrence of bycatch species of rays in all artisanal fisheries off Mozambique (unit is the number of times species were mentioned by fishermen as bycatch event)

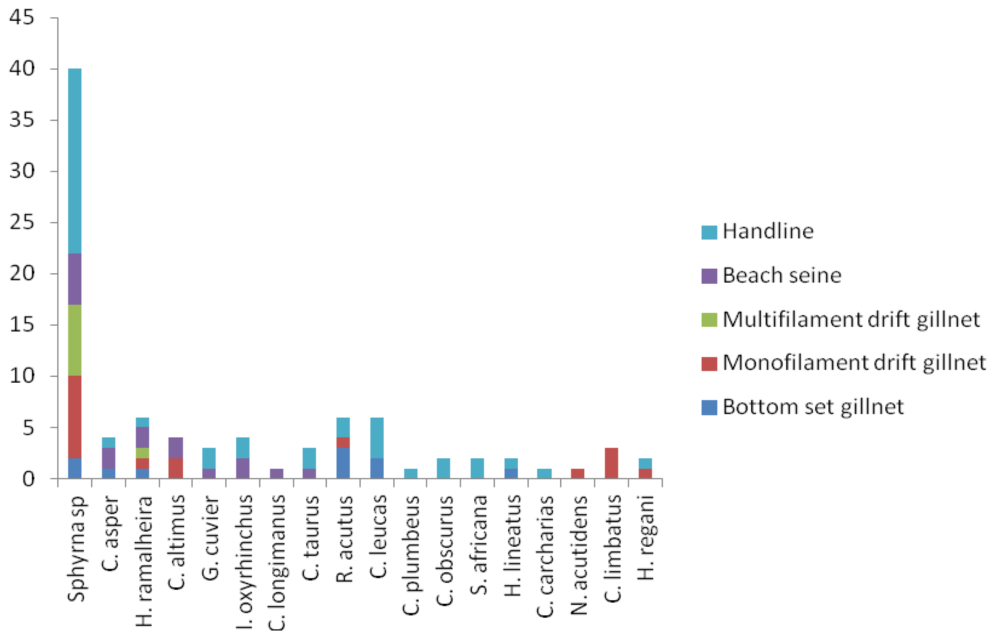

Fig. 4.35: Occurrence of bycatch species of sharks in all artisanal fisheries off Mozambique (unit is the number of times species were mentioned by fishermen as bycatch)

Drift gillnet fisheries

During the questionnaire surveys in Mozambique, monofilament drift gillnets were far more intensely sampled than multifilament nets (reflecting uses), so that accordingly data from both gears have been combined. Sea turtle bycatch was declared by only 8% of interviewed fishermen – the same proportion as in the monofilament drift gillnet fishery off Zanzibar/Pemba). Four species were identified by fishermen as bycatch species: *L. olivacea*, *C. caretta*, *C. mydas* and *L. coriacea.* Numbers of sea turtles caught in the last year was between 4 and 5 for all fishermen. No marine mammal bycatch was reported from drift gillnets. Ray and shark catches were declared by 19% and 31% of fishermen respectively with 11 species identified. Most frequently reported shark species was *Sphyrna* spp. (29%), while *Manta* sp, *P. bovinus* and *Mobula* spp were the most frequently reported rays (Fig. 4 and 5). According to some fishermen, there was a seasonality of bycatch events for both groups of elasmobranchs, although this was based on rather few bycatch reports. It was particularly apparent at the end of the rainy season (Fig. 4.36).

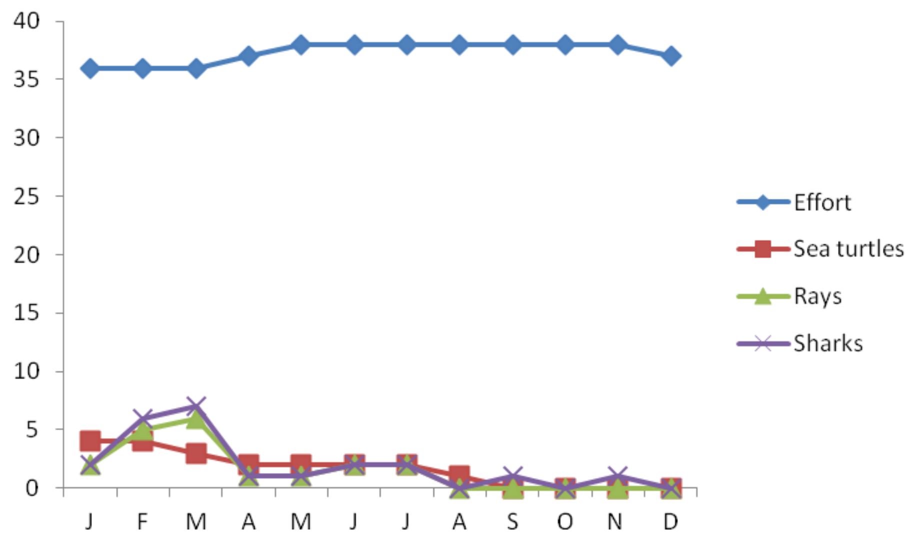

Fig. 4.36: Fishing effort (per month) and declared main bycatch taxonomic groups by interviewed fishermen off Mozambique for drift gillnet fisheries (unit is the number of fishermen who declared fishing and bycatch events for each month)

Bottom-set gillnet bycatch

A bycatch of sea turtles was declared by 34% of respondents. Four species were involved: *C. caretta* (45%), *C. mydas* (20%), *E. imbricata* (20%) and *D. olivacea* (15%). More than 83% of fishermen declared they caught 1-3 individuals in the year prior to the interview, whereas 4-10 individuals were caught by 17% of fishers. No marine mammal bycatch was reported. Bycatch of rays was declared by 60% of respondents. Six species were identified by fishermen. *H. uarnak* (48% of declared catches) and less common *A. narinari* (15%), *H. fai* (14%), *P. bovinus* (9%), *Manta* spp (9%) and *D. thetidis* (5%). For 91% of fishermen, 1-10 rays were taken as bycatch in the last year in bottom-set gillnets while only 9% of them caught more than 10 individuals during the same period.

Bycatch of sharks in bottom-set gillnets was declared by 34% of respondents. At least seven species of sharks were mentioned as bycatch species in bottom-set gillnets, including *R. acutus* (30%), *Sphyrna* spp (20%), *C. leucas* (20%), *H. lineatus* (10%), *H. ramalheira* (10%) and *C. asper* (10%). For 24% of fishermen, 1-10 sharks were taken as bycatch in the last year in bottom-set gillnets while only 9% of them caught more than 10 individuals during the same period. The rest of the fishermen could not provide a number of sharks caught during their last year of fishing. No significant variations of the monthly occurrence of bycatch were detected. However, shark bycatch events were least common in July and August (Fig. 4.37).

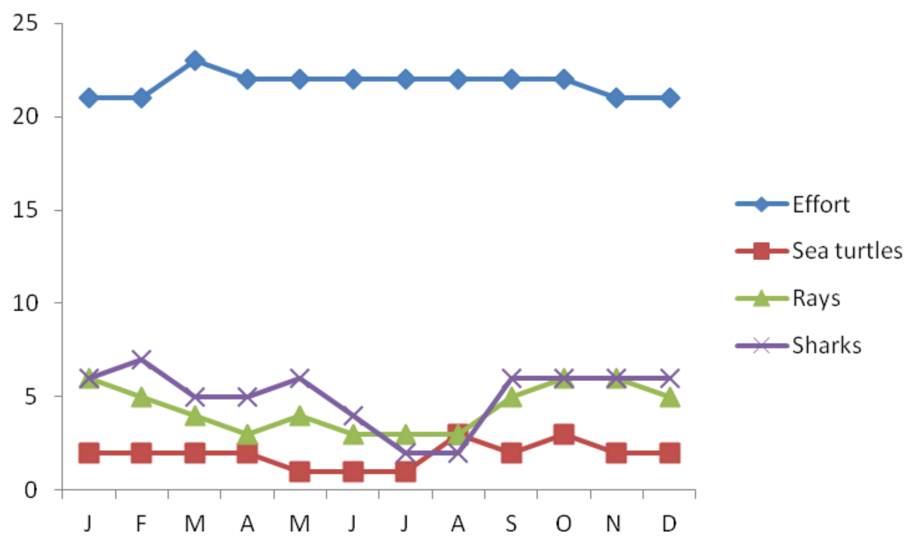

Fig. 4.37: Fishing effort (per month) and declared bycatch species by interviewed fishermen off Mozambique for the bottom-set gillnet fishery (unit is the number of fishermen who declared fishing and bycatch events for each month)

Beach seine bycatch

Bycatch of sea turtles was declared by 44% of interviewed fishermen. *C. caretta* was the most commonly reported species (38%), followed by *L. olivacea* (21%), *E. imbricata* (20%) and *C. mydas* (14%). For 53% of fishermen, between 1 and 3 sea turtles were caught in the last year in their nets, 17% caught 4-10 individuals and 6% of them caught more than 20 individuals during the same period. The remaining fishermen could not specify any number of bycatch sea turtles in their last year of fishing. While 87% of fishermen declared they caught 1-3 individuals in the last year, 13% reported at least 20 specimens.

Marine mammal bycatch was reported to be rare by beach seine fishermen (7% of interviewees). Three species were reported as bycatch: *T. aduncus* (67%), *S. longirostris* (22%) and *S. chinensis* (11%). For 78% of fishermen, the number of bycatch individuals in the last year was between 1 and 3. For 11% of fishermen, between 6 and 10 individuals were caught in the last year of fishing and for the other 11%, more than 10 individuals were caught.

Ray bycatch was declared by 49% of respondents. At least 14 species were recorded as bycatch, with the most commonly bycatch species being *H. fai* (20%), *H. uarnak* (18%), *P. bovinus* (13%) and *A. narinari* (12%). For 50% of fishermen involved in ray bycatch events, 62% caught 1-10 individuals in the last year, while 25% of fishermen caught more than 10 individuals. The remaining fishermen could not provide a number of bycatch rays in the last year. Shark bycatch was considered as rare in the beach seine fishery (reported by only 10% of fishermen). A total of eight species was recorded during surveys, but none of them were particularly frequent except for *Sphyrna* spp, at 31%. Other species that were recorded as bycatch species include *C. asper*, *H. ramalheira*, *C. altimus*, *I. oxyrhinchus*, *G. cuvier*, *C. longimanus* and *C. taurus.* For 53% of fishermen, the number of bycatch individuals in the last year was less than 10 specimens, while 26% of them declared having caught more than 10 individuals in their nets. No seasonal variations of bycatch events were significant (Fig. 4.38).

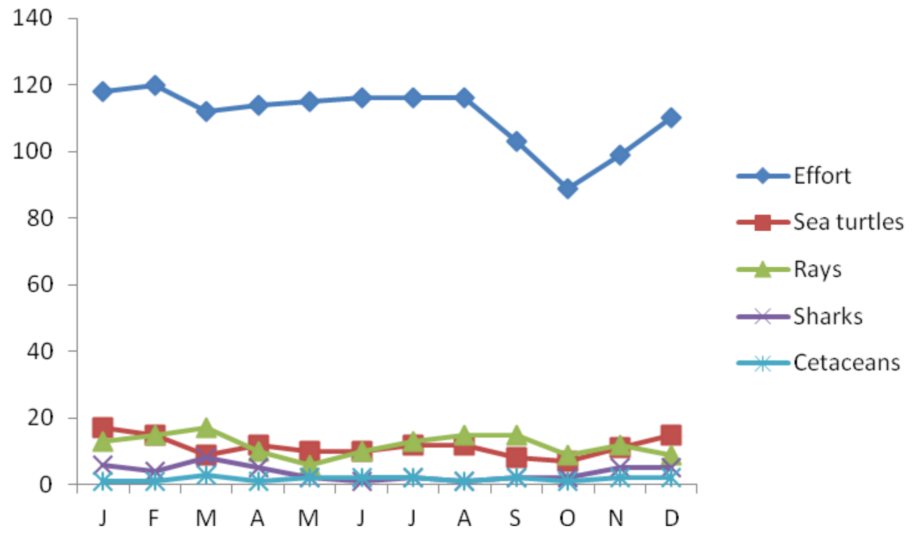

Fig. 4.38: Fishing effort (per month) and declared bycatch species by interviewed fishermen off Mozambique for the beach seine fishery (unit is the number of fishermen who declared fishing and bycatch events for each month of the year)

Handline bycatch

Sea turtle bycatch was reported by 4% of interviewed handline fishermen who identified three species: *C. caretta* (50%), *C. mydas* (25%) and *E. imbricata* (25%). The number of sea turtles caught in the last year was only provided by 33% of fishermen involved (1-3 individuals). Dolphin bycatch was also reported by only 4% of handline fishermen, but no details on species caught and number of individuals could be provided.

In contrast, the elasmobranch bycatch was far more common in this fishery. Ray bycatch was reported by 55% of handline fishermen with at least ten species identified, including two dominant species: *H. uarnak* (39%) and *H. fai* (30%). All the other species were rarely reported as a regularly bycatch, e.g. *Torpedo* sp, *Manta* spp, *T. lymma* and *Pristis* sp. For 86% of fishermen, number of rays caught in the last year was less than 10 individuals, while 3% of them declared having caught more than 10 specimens in their nets. Shark bycatch was reported by 40% of handline fishermen and involved fourteen species. *Sphyrna* spp were far more cited (45%) than any others which included *C. leucas* (10%), *I. oxyrhinchus*, *G. cuvier*, *C. taurus*, *S. Africana*, *C. obscurus* and *R. acutus* (all at 5%). For the first time in RBA surveys, *C. carcharias* was recorded as bycatch species by a fisherman. For 78% of fishermen, only less than 5 sharks were caught during the last year; for 11% of them, 5-10 individuals were caught while for only 7% of them, more than 10 individuals were caught.

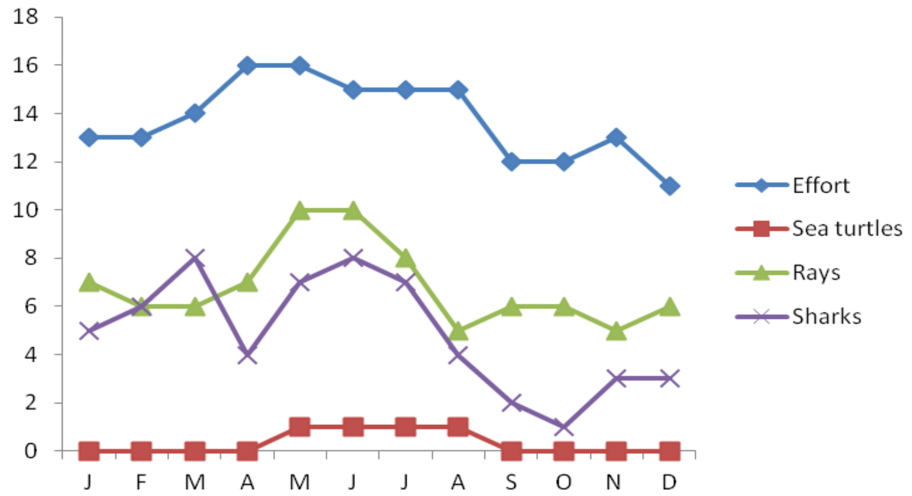

Fig. 4.39: Fishing effort (per month) and declared bycatch species by interviewed fishermen off Mozambique for the handline fishery (unit is the number of fishermen who declared fishing and bycatch events for each month of the year)

For elasmobranchs, seasonality of catch events was highly correlated with fishing effort. Despite very few bycatch records of sea turtles, these all occurred during winter months (Fig. 4.39).

<u>Bycatch incidence</u>

Bycatch incidence (bycatch/last year/boat) was calculated for each fishery and each taxonomic group (sea turtles, rays, sharks, marine mammals; Table 4.4). For sea turtles, the extent of bycatch in beach seines is relatively important, especially in comparison to gillnets. Generally the bycatch of marine mammals in artisanal fisheries of Mozambique is low, moreover as no dugong were reported at all. However, the beach seine fisheries are an exception where cetacean bycatch proved surprisingly frequent. As for other countries surveyed, highest catch rates were recorded for elasmobranchs and especially rays. The highest impact gears seem to be handlines, beach seines and bottom-set gillnets. However, reported numbers of caught individuals were relatively low for all fisheries in comparison to other countries.

Table 4.4: Mean number of bycatch sea turtles, cetaceans and elasmobranchs in the last year per boat off Mozambique

	N/boat/last year			
	Sea turtles	Rays	Sharks	Cetaceans
Drift gillnets	0.33	0.552	1	0
Bottom-set gillnets	0.743	2.7	2.14	0.071
Beach seines	1.56	2.49	0.418	0.199
Handlines	0.09	3.87	1.567	0

Use of bycatch species

Once a sea turtle was caught, 92% of interviewed fishermen declared they generally released the animal alive. The remaining fishermen declared eating the animal. Captured dolphins were mostly released alive (82%) while some declared keeping dead animals to use for medicinal purposes or food. Concerning rays, 98% of fishermen declared eating and/or selling the animals in its whole state. A similar trend was observed for sharks that were primarily for their meat (94%), either by the fishermen themselves or sold on local markets. Only 4% of fishermen declared selling only the fins to fin collectors.

Perceptions of bycatch incidence and population trends

Overall, fishermen in Mozambique did not have a clear feeling on population trends of marine mammals and rays (Fig. 4.40). Surprisingly, when a trend was provided, they generally considered an increase of marine mammal populations (cetaceans: 47% of increase vs. 40% decrease; dugong: 46% of increase vs. 40% decrease). Concerning sea turtles, it was difficult to extract a trend (decrease: n=107 fishermen; increase: n=106). Conversely, most fishermen were convinced by a decrease of shark populations in Mozambican coastal waters (42%). The majority of fishermen could not provide a trend for rays (Fig. 4.40). Concerning temporal trends in bycatch occurrence (Fig. 4.41), most fishermen could not provide a trend, except for sharks. A majority of fishermen declared that shark catches were on the decrease along the coastal waters of Mozambique (42%).

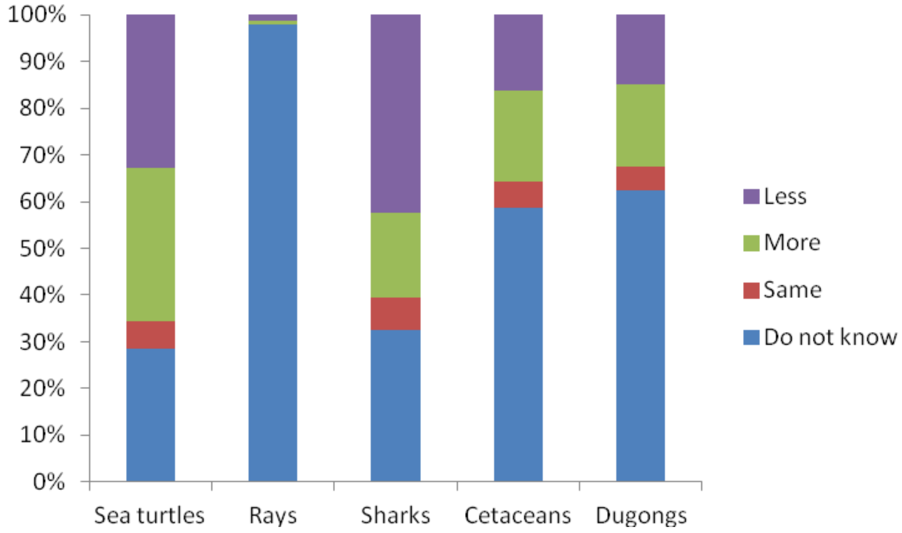

Fig. 4.40: Perception of population trends of sea turtles, elasmobranchs and marine mammals by artisanal fishermen in Mozambique

Trend of catch occurrence was not detected for rays. Sea turtle bycatch was mostly considered as decreasing off Mozambique (47%). For marine mammals, when a trend was provided, most fishermen declared bycatch events to be declining (Fig. 4.41).

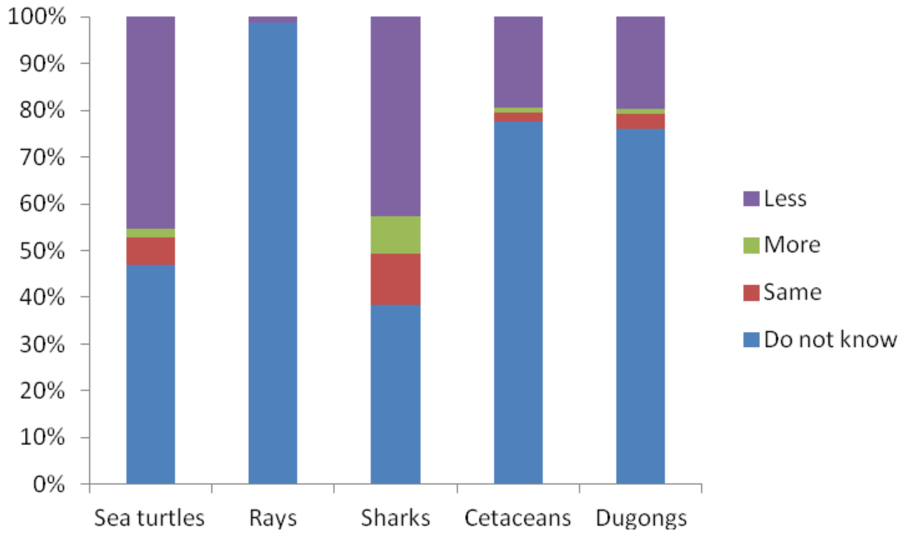

Fig. 4.41: Perception of bycatch trends of sea turtles, elasmobranchs and marine mammals by artisanal fishermen in Mozambique

4.6 Spatial variations

Throughout the region, spatial variations on bycatch patterns could be highlighted for each main taxonomic group (Fig. 4.42 to 4.45). These variations both reflect spatial variations of fishing practices as well as present day occurrence and abundance of vulnerable bycatch species. In order to represent spatial variations of bycatch of vulnerable species, bycatch incidence was used represented by the mean number of individuals/boat in the last year. For cetaceans, it appears that drift and bottom-set gillnets have the most significant impact. Multifilament drift gillnets are characterized by the highest bycatch rates. However, it has also been highlighted that bycatch incidence of cetaceans in beach seines was significant and represented the bulk of bycatch events in Mozambique. Line fisheries have a minor impact on cetaceans in the region, except for longlines in Zanzibar (Fig. 4.42).

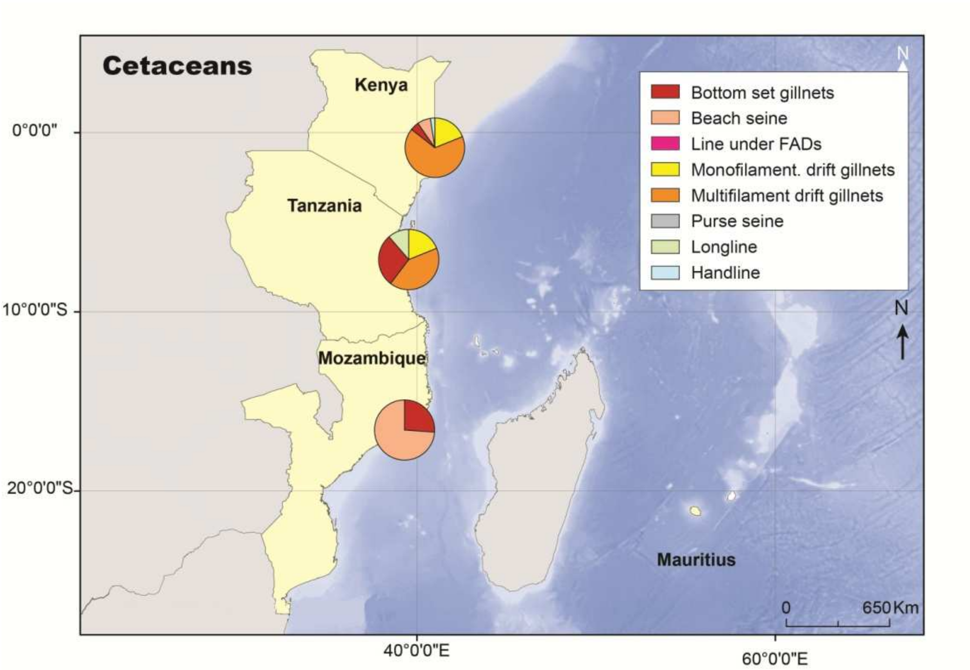

Fig. 4.42: Spatial variations of cetacean bycatch incidence

Sea turtles (Fig. 4.43) were impacted by a diversity of gears in the region, especially in Kenya and Tanzania. The extent of sea turtle bycatch in drift gillnet fisheries was more significant in Kenya and Tanzania. Line fisheries, particularly longlines, were also responsible for relatively high bycatch levels, especially in Kenya and Tanzania. However, as for cetaceans, bycatch incidence was highest in bottom-set gillnets and beach seines (Fig. 4.43).

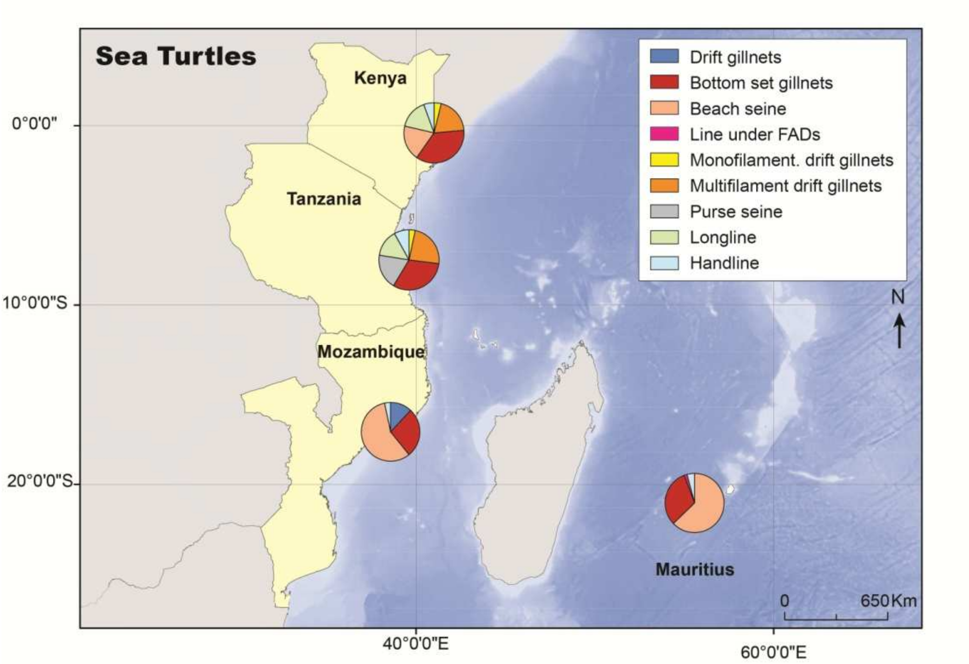

Fig. 4.43: Spatial variations of sea turtle bycatch incidence

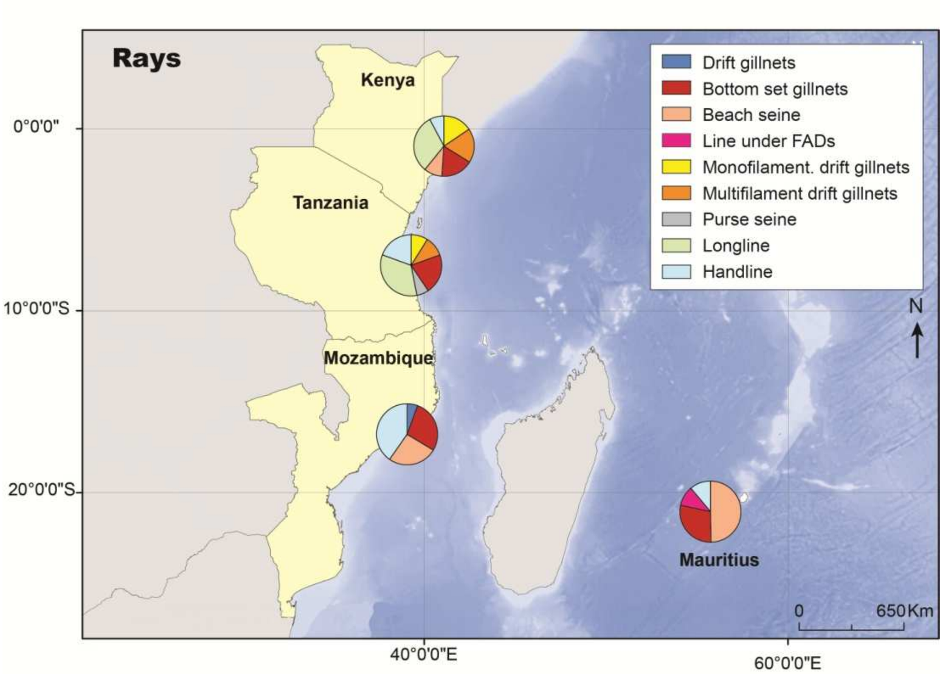

Fig. 4.44: Spatial variations of ray bycatch incidence

Ray bycatch incidence (Fig. 4.44) was more randomly distributed among fisheries, but was also highly variable among countries. In Mauritius, as for sea turtles, bottom-set gillnets and beach seines had the highest impact on rays. Along the east coast of Africa, line and net fisheries have relatively equal proportions of bycatch incidence (Fig. 4.44).

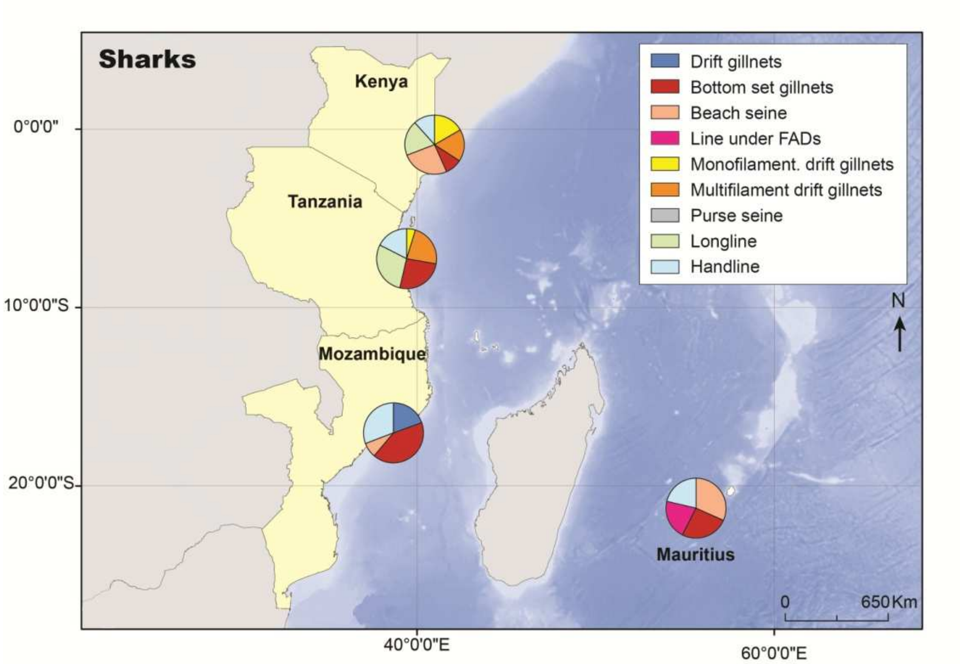

Fig. 4.45: Spatial variations of shark bycatch incidence

As for rays, there were spatial variations of the incidence of artisanal fisheries on sharks (Fig. 4.45). In Mauritius, sharks were equally impacted by line (handlining and lining under FADs) and net fisheries, notably bottom-set gillnets and beach seines. Along the east coast of Africa, the situation was variable, probably related to fishing practices and/or the survey effort distribution, as net fisheries seemed to have the highest shark catch rates. The exception was Tanzania, where longline fishermen were significantly more intensely sampled.

4.7 Ecological Risk Assessment

Level 1 (SICA) of the ERA identified five gears/fisheries to be included in the PSA: multifilament drift gillnets, monofilament drift gillnets, bottom-set gillnets, beach seines and handlines. The other fisheries provided few replicates (limited amount of data), or were geographically restricted (purse seines, longlines and lines under FADs). During the RBA surveys, a total of 59 species was identified by fishermen as bycatch/by-product species, including all five species of sea turtle, eight species of marine mammal and 46 species of elasmobranchs (Appendix 2). However, only 17 species were selected for the Productivity-Susceptibility Analysis as the other species were inadequately recorded at the regional level. As previously mentioned, selected species for the PSA was also based on species' IUCN status and their occurrence as bycatch species or incidence. All species of sea turtles, the most common marine mammal species and the most commonly caught elasmobranchs were included in the analysis (Table 4.5).

Table 4.5: Selected species for the Productivity-Susceptibility Analysis

	English name (abbreviation)	Latin name
Sea turtles		
	Green turtle (GNT)	*Chelonia mydas*
	Hawksbill turtle (HKS)	*Eretmochelys imbricata*
	Loggerhead turtle (LOG)	*Caretta caretta*
	Leatherback turtle (LET)	*Dermochelys coriacea*
	Olive Ridley turtle (OLI)	*Lepidochelys olivacea*
Marine Mammals		
	Dugong (DUG)	*Dugong dugon*
	Indo-Pacific bottlenose dolphin (BOT)	*Tursiops aduncus*
	Indo-Pacific humpback dolphin (HUM)	*Sousa chinensis*
	Spinner dolphin (SPI)	*Stenella longirostris*
Elasmobranchs		
	Manta ray (MAN)	*Manta spp.*
	Spotted eagle ray (NAR)	*Aetobatus narinari*
	Giant guitarfish (GIT)	*Rhynchobatus djiddensis*
	Black-spotted stingray (BLS)	*Taeniurops meyeni*
	Honeycomb stingray (HON)	*Himantura uarnak*
	Scalloped hammerhead shark (SHH)	*Sphyrna lewini*
	Great hammerhead shark (GHH)	*Sphyrna mokarran*
	Whitetip reef shark (WTR)	*Triaenodon obesus*

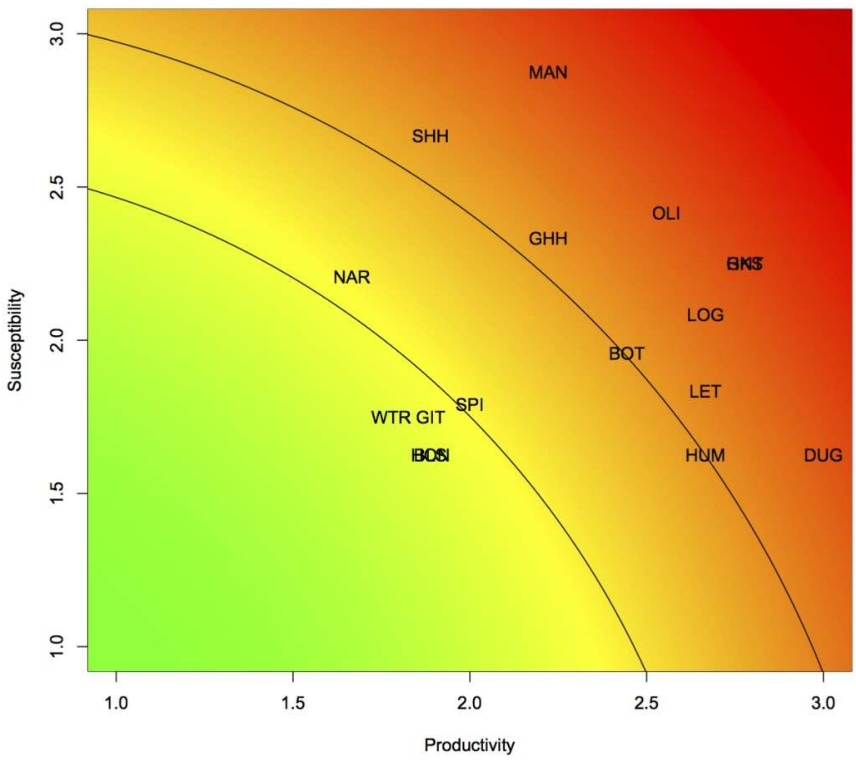

Fig. 4.46: PSA output for monofilament drift gillnets

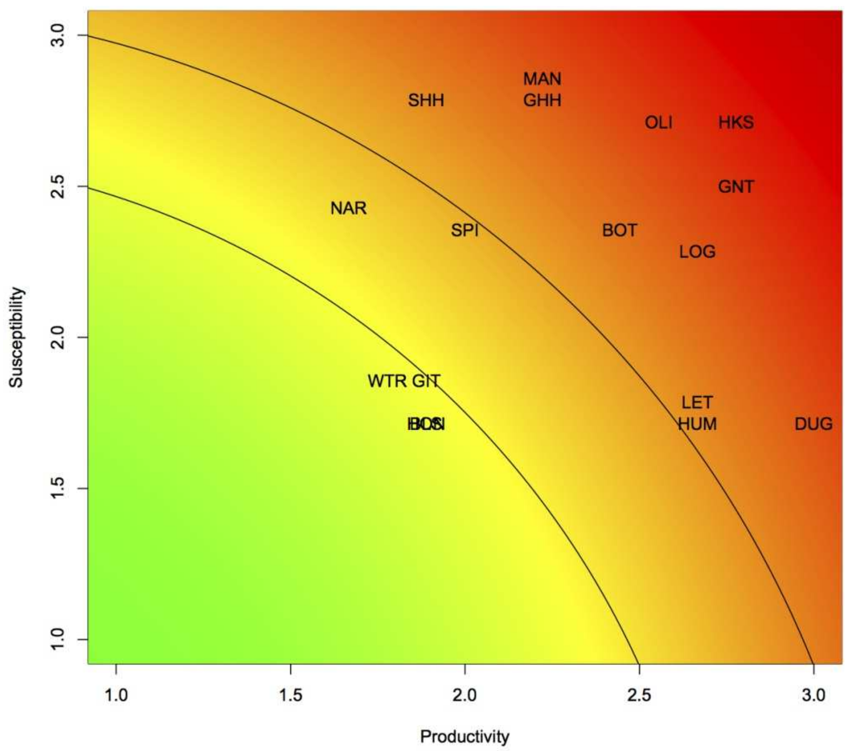

Fig. 4.47: PSA output for multifilament drift gillnets

Outputs for monofilament and multifilament drift gillnets are presented in Fig. 4.46 and 4.47, respectively. Patterns are relatively similar among the two gears, but higher risk is encountered for all species of sea turtles (especially for multifilament drift gillnets), coastal marine mammals (especially *Tursiops aduncus*), as well as three large elasmobranchs (*Manta* spp, *S. lewini* and *S. mokarran*). Two species (*Stenella longirostris* and *Aetobatus narinari*) face a medium level risk. Benthic and coastal/demersal species of elasmobranchs face a low level risk in drift gillnet fisheries.

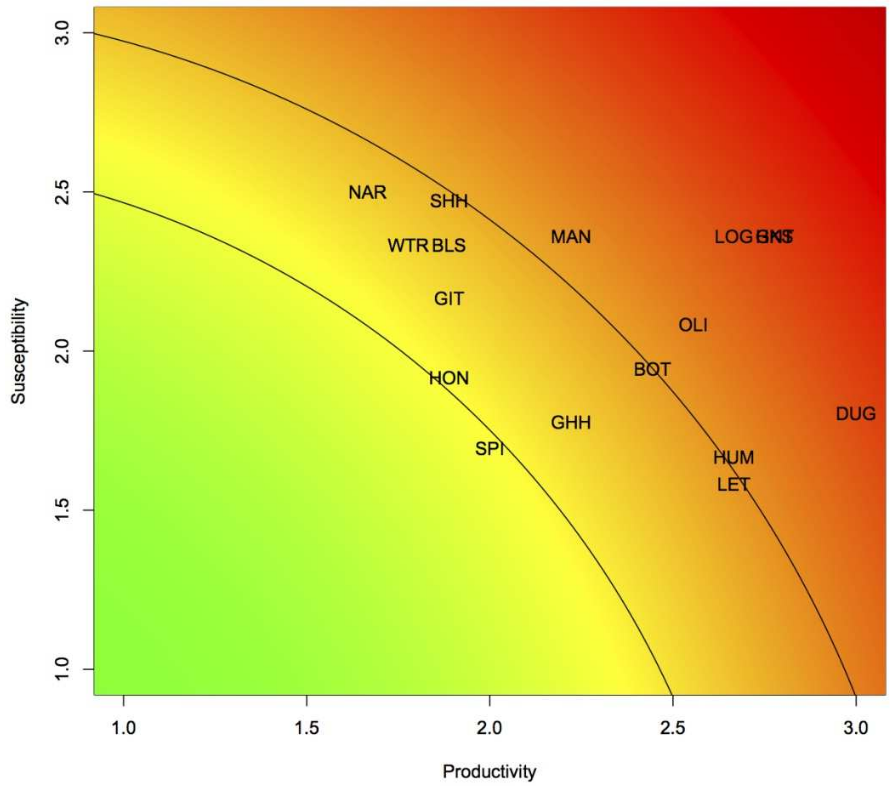

Fig. 4.47: PSA output for bottom-set gillnets

The situation for bottom-set gillnets is significantly different to that of drift gillnets (Fig. 4.47). Benthic and coastal/demersal elasmobranchs (including most rays) face a medium risk, while pelagic/oceanic species are less impacted by bottom-set gillnets. Higher risk is encountered by most of the sea turtle species (except *D. coriacea*), *Manta* spp, *Tursiops aduncus* and *Dugong dugon*. *Stenella longirostris* faces a low level of risk, primarily due to its preferential oceanic foraging habitat.

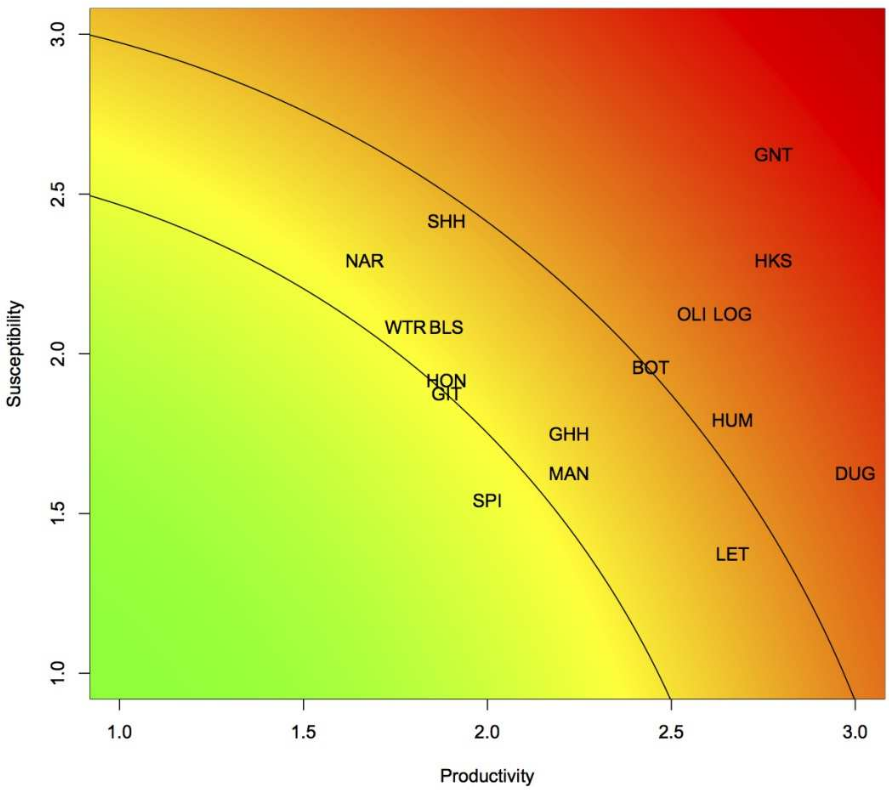

Fig. 4.48: PSA output for beach seines

In beach seines, higher risk is encountered by *Chelonia mydas* and the other sea turtles except *D. coriacea* (Fig. 4.48). Coastal marine mammals are also at risk in beach seines. Risk is medium for all elasmobranch species, while oceanic dolphins (*Stenella longirostris*) face a low level of risk in this fishery.

From handlines (Fig. 4.49), *Chelonia mydas* and *Eretmochelys imbricata* face higher risk. *Sphyrna lewini* is situated in the medium risk category. Overall, risk faced by vulnerable megafauna from handline fisheries is relatively low at the regional level.

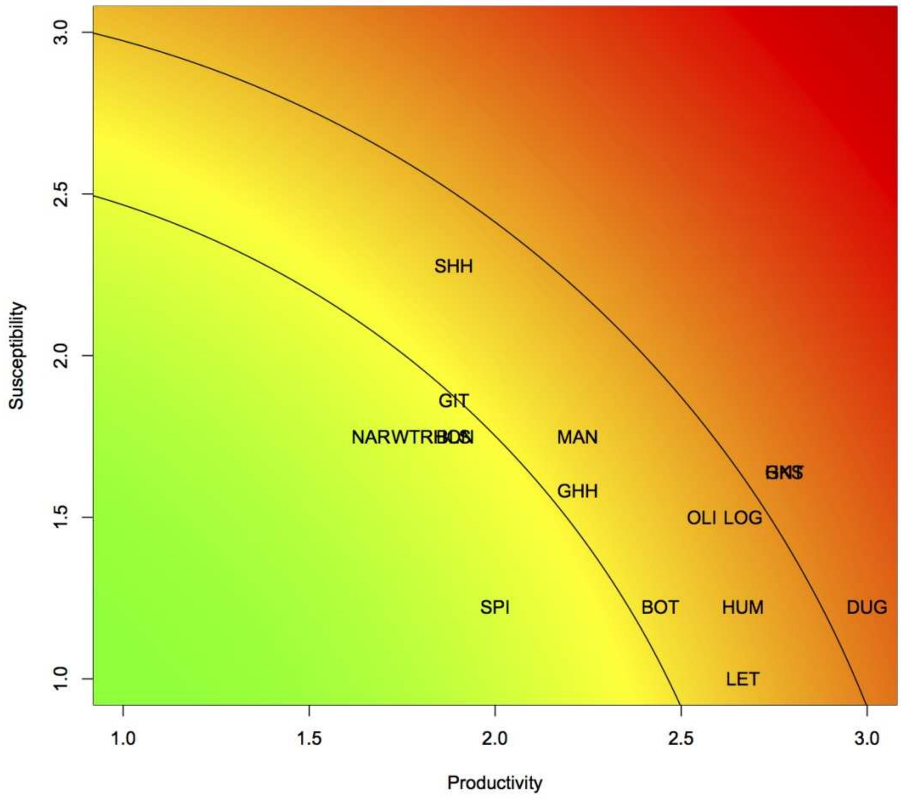

Fig. 4.49: PSA output for handlines

Table 4.5 overviews risks levels for all species and all fisheries.

Table 4.5: Risk levels for sea turtles, marine mammals and elasmobranchs based on PSA scores (red: high risk; orange: medium risk; green: low risk)

	Mono-filament drift gillnets	**Multi-filament drift gillnets**	**Bottom set gillnets**	**Beach seines**	**Handlines**
Sea turtles					
Chelonia mydas	☒ (red)	☒ (red)	☒ (red)	☒ (red)	☒ (red)
Eretmochelys imbricata	☒ (red)	☒ (red)	☒ (red)	☒ (red)	☒ (red)
Caretta caretta	☒ (red)	☒ (red)	☒ (red)	☒ (red)	☒ (orange)
Dermochelys coriacea	☒ (red)	☒ (red)	☒ (orange)	☒ (orange)	☒ (green)
Lepidochelys olivacea	☒ (red)	☒ (red)	☒ (red)	☒ (red)	☒ (orange)
Marine mammals					
Dugong dugon	☒ (red)	☒ (red)	☒ (red)	☒ (orange)	☒ (green)
Tursiops aduncus	☒ (red)	☒ (red)	☒ (red)	☒ (red)	☒ (green)
Sousa chinensis	☒ (red)	☒ (red)	☒ (red)	☒ (red)	☒ (green)
Stenella longirostris	☒ (orange)	☒ (orange)	☒ (green)	☒ (green)	☒ (green)
Elasmobranchs					
Manta spp.	☒ (red)	☒ (red)	☒ (red)	☒ (orange)	☒ (orange)
Aetobatus narinari	☒ (orange)	☒ (orange)	☒ (orange)	☒ (orange)	☒ (green)
Rhynchobatus djiddensis	☒ (green)	☒ (green)	☒ (orange)	☒ (orange)	☒ (green)
Taeniurops meyeni	☒ (green)	☒ (green)	☒ (orange)	☒ (orange)	☒ (green)
Himantura uarnak	☒ (green)	☒ (green)	☒ (orange)	☒ (orange)	☒ (green)
Sphyrna lewini	☒ (red)	☒ (red)	☒ (orange)	☒ (orange)	☒ (orange)
Sphyrna mokarran	☒ (red)	☒ (red)	☒ (orange)	☒ (orange)	☒ (orange)
Triaenodon obesus	☒ (green)	☒ (green)	☒ (orange)	☒ (orange)	☒ (green)

5. Management of bycatch in artisanal fisheries of the southwest Indian Ocean

5.1 Overview of bycatch mitigation measures

Very little attention has been given to bycatch mitigation in artisanal fisheries, including gillnet fisheries, where most vulnerable megafauna bycatch occurs. In contrast, various successful initiatives have been undertaken to reduce bycatch, especially of sea turtles and elasmobranchs, in other coastal fisheries, such as in prawn trawl fisheries of the region (Fennessy *et al.*, 2008). In Kenya, the use of TEDs (Turtle Excluder Devices) was legislated in 2003. In 2008, a draft discussion paper aimed at developing a prawn fishery management plan was circulated to stakeholders. This plan includes gear modification, reduced fishing effort and zonation of the fishing grounds in order to minimise bycatch. No concrete mitigation measures were implemented in Tanzania, while in Mozambique; legislation has required the compulsory use of TEDs since 2005. A number of experiments to test various BRD (Bycatch Reduction Devices) were been conducted collaboratively with South Africa. Currently, there are additional initiatives to investigate prawn trawl gear technology including TEDs (Fennessy *et al.*, 2008). In South Africa, the use of NordmØre grids provided good results, with a reduction by 60% of elasmobranch bycatch. Other legislated measures reducing bycatch have also been implemented, including a minimum mesh size limit (50mm), an inshore trawling distance limit of 0.5nm, and the prohibition of the sale of certain bycatch species (Fennessy *et al.*, 2008). In Madagascar, a number of mitigation measures have been implemented to reduce bycatch in prawn trawl fisheries, including mesh size restrictions, trawl gear size limits, closed seasons and areas, partial prohibition of nocturnal trawling, limited number of permits and zonation of effort. The compulsory use of TEDs was legislated in 2003 and enforced in 2005 (Fennessy *et al.*, 2008).

In artisanal fisheries, the only significant mitigation measure in the region to reduce bycatch in drift- and bottom-set gillnets in the use of pingers to reduce dolphin bycatch off Zanzibar (Amir, 2010). Based on the results of an observer programme conducted in 2003-2004 on the drift- and bottom-set gillnet fishery off the south coast of Zanzibar, 9.6% of the estimated number (136, 95% CI 124-172) of Indo-Pacific bottlenose dolphins and 6.3% of the estimated number (63, 95% CI 57-95) of humpback dolphins are taken as bycatch annually in this area. These levels of bycatch are considered unsustainable (Amir, 2010). In 2007 and 2008, a second observer programme was conducted in the same area to investigate the effectiveness of acoustic alarms (Fumunda FMDP-2000 pingers) in reducing the bycatch of dolphins in the drift- and bottom-set gillnets. The observed effort in the drift gillnets was 257 control sets without pingers (21% of the total recorded effort) and 251 sets with pingers (20% of the total recorded effort). Six dolphins were taken as bycatch during this pinger experiment: one Indo-Pacific bottlenose dolphin in a net with pingers and four Indo-Pacific bottlenose dolphins plus one spinner dolphin in the control nets without pingers. In the bottom-set gillnet fishery, the observed fishing effort was 236 sets without pingers (28% of the total recorded effort) and 224 sets with pingers (27% of the total recorded effort). In this fishery one humpback dolphin was taken as bycatch in the control nets and no dolphins were recorded from nets equipped with pingers. Clearly, the pingers reduced the bycatch of dolphins in both drift- and bottom-set gillnets, although the reduction was only significant in the drift gillnets. Importantly, there was no significant difference in the catch of all target fish species combined between control and pinger sets. In the short term, pingers thus seem to provide an effective strategy for mitigation small cetacean bycatch. A new project, starting in 2012 and funded by SWIOFP, will pursue this initiative.

5.2 Legislation

Little or no legislation exists in the region that is specifically designed to address the reduction of bycatch in artisanal fisheries. However, indirectly some national regulations contribute to minimizing bycatch. For example, in Mauritius, the use of drift gillnets that could potentially impact marine mammals, sea turtles and several large pelagic elasmobranchs, is prohibited. Large nets, such as beach seines, are prohibited from October to February, and cannot be used at night (from 18:00 to 6:00). Conversely, bottom-set gillnets cannot be used during the day. In addition, installation of FADs is strictly controlled and a person shall only place a FAD if authorized by the Permanent Secretary (Fisheries and Marine Resources Act, 2007). In the Seychelles, the use of nets is regulated through licensing (Fisheries Act, enacted in 1986). Shark fishing using nets has been prohibited since 1998, which potentially greatly reduces megafauna' bycatch in artisanal fishing gears. The Fisheries Act N°7 of 2010 prohibits the use of beach seines in Zanzibar. In Madagascar, there are no specific regulations, especially related to gillnet fisheries that significantly impact large vertebrates (e.g. Razafindrakoto *et al.*, 2008). In Kenya (Fisheries Management and Development Bill 2011), there is a limitation of fishing effort, as only one net may be used at the same time. In addition, monofilament drift gillnets are prohibited, although many fishermen still use them, as suggested by the present study.

FAO is committed to assisting Member States, particularly developing countries, in the efficient implementation of the Code of Conduct for Responsible Fisheries (CCRF) and will report to the United Nations community on the progress achieved and further action required. The CCRF is voluntary, but certain parts of it are based on relevant rules of international law, including those reflected in the United Nations Convention on the Law of the Sea of 10 December 1982. States should ensure that only fishing operations allowed by them are conducted within waters under their jurisdiction and that these operations are carried out in a responsible manner. In addition, statistical data, updated at regular intervals, on all fishing operations allowed by them. In term of gear selectivity and bycatch of non-targeted species (including marine mammals, sea turtles and elasmobranchs), States should require that fishing gear, methods and practices are sufficiently selective so as to minimize waste, discards, catch of non-target species, both fish and non-fish species, and impacts on associated or dependent species and that the intent of related regulations is not circumvented by technical devices.

6. Discussion and conclusions

Major findings

This study investigated the extent of marine mammal, sea turtle and elasmobranch bycatch and their use in several countries of the southwest Indian Ocean. It is based on nearly 1000 interviews with artisanal fishers undertaken Kenya, Tanzania, Mozambique and Mauritius, where very little was known about the megafauna bycatch in artisanal fisheries. The extent of this interview survey effort is currently one of the most comprehensive ever conducted at the global scale and the most significant in the Indian Ocean. This is also the first ever study of marine mammal, sea turtle and elasmobranch bycatch and utilization in artisanal fisheries of Kenya, Mozambique and Mauritius. The major finding of this study reveal the high extent of large marine vertebrate bycatch in artisanal fisheries, especially in drift, bottom-set gillnets and beach seines. At least 59 species were identified as bycatch and by-product species, including five species of sea turtles, eight species of marine mammals and 46 species of elasmobranchs. The Ecological Risk Assessment emphasized that at least 17 species were particularly vulnerable to artisanal fisheries bycatch in the southwest Indian Ocean, including all species of sea turtles (loggerhead, green, hawksbill, olive Ridley and leatherback turtles), four species of marine mammals (dugong, Indo-Pacific bottlenose, humpback and spinner dolphins) and eight species of elasmobranchs. Among elasmobranchs, highest risk was identified for Manta, spotted eagle rays, giant guitarfish and hammerhead sharks (including scalloped and great hammerheads). The risk was particularly enhanced in species with low productivity (low fecundity). Line fisheries (longline and handline) were seen to have a low impact on the survival of sea turtles and marine mammals. However, these fisheries have a significant impact on elasmobranchs. This was particularly evident for the artisanal longline fishery off Zanzibar, but this statement is only based on a relatively limited sample size and hence the exclusion of this fishery/gear from the PSA. Therefore, a future regional survey effort would be critical to characterize the extent of vulnerable megafauna bycatch in artisanal longline fisheries.

As suggested by interview survey data and PSA plots, there is a difference in the extent and effect of bycatch of vulnerable megafauna among gears. Bycatch levels were higher in multifilament than in monofilament drift gillnets, notably for cetaceans (small delphinids in particular), sea turtles and elasmobranchs, and involved more species. Sea turtles (especially green, hawksbill, olive Ridley and loggerhead turtles), manta rays, hammerhead sharks and Indo-Pacific bottlenose dolphins were the most common bycatch species, as well as the most impacted by drift gillnets due to their low productivity. However, bycatch levels were lower for these species in bottom-set gillnets. In the case of several other species the catches were high in these nets, especially and demersal species such as rays and reef sharks. However, the risk associated with bottom-set gillnets was lower for all species due to lower levels of susceptibility. One of the most threatened vulnerable species in the region, the dugong, was rarely reported as a bycatch event; in comparison to previous studies that reported higher mortality rates (see WWF EAME 2004, for regional review). This may be attributed to the current rarity of this species along the east African coast and its rapid decline since the early 2000s. The ongoing regional assessment of the status of dugongs in the western Indian Ocean, coordinated by CMS secretariat (Convention on Migratory Species), should complement information collected in this study.

Beach seines were noted for high impact on sea turtles, especially the green turtle, as this gear is frequently used very close to shore, over seagrass meadows which are the primary foraging habitat for this species. Other species of sea turtles were also impacted, including hawksbill, olive Ridley and loggerheads. Surprisingly, coastal marine mammals were also taken, especially Indo-Pacific bottlenose dolphins in Mozambique. The effect of beach seines on more pelagic and oceanic species was low, such as spinner dolphins, Manta rays, great hammerhead sharks and leatherback turtles, all of which are in any case not commonly observed in inshore waters. Finally, handlines had the lowest impact on vulnerable megafauna, especially due to the low post-capture mortality.

The adverse effects of gillnets, including drift and bottom-set gillnets, have already been highlighted in previous studies in the southwest Indian Ocean, such as off Zanzibar (Amir *et al.*, 2002), along the southwest coast of Madagascar (Razafindrakoto *et al.*, 2008), around Mayotte and the Comoros (Kiszka *et al.*, 2007; Poonian *et al.*, 2008; Pusineri & Quillard, 2008) and in the region for particularly vulnerable species, such as the dugong (WWF EAME, 2004; Muir & Kiszka, 2012). In 1999, in 10 villages around Zanzibar, a questionnaire survey of 101 gillnet vessel operators was made (Amir *et al.*, 2002). A total of 96 dolphins were reported to have been incidentally caught between 1995 and 1999; 43 Indo-Pacific bottlenose dolphins, 29 spinner dolphins, 5 Indo- Pacific humpback dolphins and 19 unidentified dolphins (Amir *et al.*, 2002). In addition, 0.46 dolphins was the extrapolated bycatch rate per vessel. The results of the present study are consistent with this earlier study in the area, both in term of species involved and bycatch incidence. Indeed, bycatch incidence (or bycatch rate per vessel) was 0.51 for monofilament drift gillnets. However, this study reports that multifilament drift gillnets have a higher incidence than monofilament, both for dolphins (1.11) but also for sea turtles and elasmobranchs.

This study also highlighted new result on sea turtle bycatch in gillnets. High bycatch levels observed for loggerhead turtles in Mozambique and northern Tanzania is likely to be linked to the presence of major feeding grounds for this species off these countries. In addition, even if leatherback turtle bycatch was relatively uncommon in drift gillnets, it should be seriously taken into account as this species is severely in decline in the southwest Indian Ocean region.

Data limitations

In this study, we used data from a large number of interviews in comparison to most other studies conducted (e.g. Moore *et al.*, 2010). Therefore, sample size is not a significant issue, especially for net fisheries. However, as longline bycatch is potentially a serious threat to a number of sea turtle and elasmobranch species, a larger sample would be needed in a future assessment, both at the local (Zanzibar and Pemba) and regional scale (SW Indian Ocean). Further confidence of the sampling approach can be seen from the consistency of results compared with empirical local knowledge and published information from the region (Amir *et al.*, 2002; Kiszka & Muir, 2007; Bourjea *et al.*, 2008; Kiszka *et al.*, 2008; Amir, 2010). However, for species that are difficult to identify, particularly elasmobranchs, such as stingrays, a number of shark species as well as sea turtles, this analysis could have some limitations. However, bycatch incidence was calculated for main taxonomic groups and the most vulnerable species, especially those included in the PSA analysis, were the most easily identifiable species. Concerning bycatch incidence, it was based on fishermen's declarations, which were sometimes quite approximate because of recall bias. Therefore, the values presented in this study should be taken into account with care, especially to extrapolate them at the country level. Nevertheless, these calculations are probably the most accurate that could be produced for artisanal fisheries, recognizing that observer programmes are almost impossible to implement. A possible exception might be programmes implemented on the larger boats, such as longliners and large gillnet boats, as was previously conducted in Zanzibar (Amir, 2010).

Spatial and seasonal patterns of bycatch

Spatial and temporal patterns of bycatch were essentially correlated with fishing effort. Seasonal variations of bycatch occurrence were almost not detectable in the four countries investigated. This may be due to combining of all species for each main taxonomic group to calculate monthly bycatch incidence, as sample size was generally too small to assess seasonal variations of bycatch occurrence for a given single species. Spatial variations of bycatch incidence were likely due to higher beach seine fishing effort. That is why it is critical to take into account fishing effort for all countries to assess spatial and seasonal trends of bycatch. Therefore, future steps could include assessing these spatial and temporal variations with improved quality fishing effort data.

Trends of populations and bycatch occurrence

At the regional level, artisanal fishermen declared sharks and rays to be declining as catches were on the decrease. A similar decline was also reported for dugongs, especially in Kenya where they were abundant in the past (WWF EAME, 2004). Decline of cetaceans, particularly dolphins, was also reported by Tanzanian fishermen from Zanzibar and Pemba, where bycatch levels were also the highest in the SWIO region. Conversely, in Mozambique and Kenya, fishermen declared that sea turtles were on the increase. While it is difficult to take these witnesses as real population trends, it is interesting to see that they are correlated to previous studies, highlighting the decline of dugongs and elasmobranchs at the regional level (see for review WWF EAME, 2004; Kiszka & van der Elst, 2012). Concerning the decline of cetaceans in Zanzibar and Pemba islands reported by local fishermen, it may be related to high bycatch levels in drift and bottom-set gillnets (Amir *et al.*, 2002; Amir, 2010; Kiszka, this study). Based on the results of an observer programme conducted in 2003-2004 on the drift- and bottom-set gillnet fisheries off the south coast of Zanzibar, 9.6% of the estimated number (136, 95% CI 124-172) of Indo-Pacific bottlenose dolphins and 6.3% of the estimated number (63, 95% CI 57-95) of humpback dolphins are taken as bycatch annually in this area (Amir, 2010). These levels of bycatch are considered unsustainable, which supports the trends declared by fishermen.

Use of bycatch megafauna

There were considerable geographic variations of the use and fate of the bycatch of sea turtles and marine mammals in the SWIO region. However, throughout the area, sharks and rays were considered as by-product species and used for meat and, more rarely, for fins. Finning was almost never an exclusive activity and seems to be confined to larger longline vessels, operating in oceanic waters. Marine mammals and sea turtles were not commonly used for food in the region, except in Zanzibar and Pemba, where bycatch animals were frequently consumed by fishermen or sold. When still alive, marine mammals and sea turtles were generally released. Overall, marine mammal and sea turtle consumption may be underestimated, as fishermen may fear reprimanding as killing and consuming these species is prohibited in all countries of the region.

Main conclusions and recommendations

This study, conducted at a regional level, clearly highlighted that an important diversity of large and vulnerable marine vertebrates were exposed to artisanal fisheries bycatch in the SWIO region. This is the first in-depth study of megafauna' bycatch in artisanal fisheries in the southwest Indian Ocean. It is clear that net fisheries should be the focus of future management initiatives. A priority should be given to drift gillnet fisheries, posing the greatest threat to marine mammals, sea turtles and large elasmobranchs in the region. It has also been emphasized that certain gears were illegally used in the region, such as in Kenya, where monofilament drift gillnets are used. In this case, governments should be encouraged to implement their regulations. Mitigation measures, such as the use of pingers to reduce dolphin mortalities, are probably not suitable for artisanal fisheries due to their prohibitive cost. In addition, these deterrent devices are not suitable for other vulnerable species, such as sea turtles and elasmobranchs. Therefore, limiting the use of these nets should be encouraged. These limitations could be either spatial or temporal, and based on scientific information on habitat use of bycatch species. Recently, it has been shown that the establishment of marine protected areas (MPAs) can be effective for a number of taxa, including marine mammals, sharks and probably sea turtles (e.g. Gormley *et al.*, 2012), especially to manage interactions between these species and gillnet fisheries. However, a significant regional effort should be undertaken to identify areas of special interest for marine mammals, sea turtles and elasmobranchs. Existing information on population abundance, structure and habitat preferences should be used (see SWIOFP retrospective analysis, especially Bourjea, 2012, Kiszka, 2012 and Kiszka & van der Elst, 2012), but more in-depth studies of critical habitats, movements and population structure of the most vulnerable species (identified in this study) should be carried out in the future, in order to provide scientific bases of management and conservation of these species. That includes the definition of critical habitats, where the use of drift and bottom-set gillnets could not be used (e.g. major seagrass beds, i.e. critical habitats for dugongs and green turtles; aggregation areas for manta rays, core home range for coastal dolphins, etc.). Such a regional project could greatly contribute to manage interactions between artisanal net fisheries. However, more information on patterns of bycatch is needed. It is clear that interview surveys, and particularly those used in the present study, should be carried out in the future and extended to other fisheries/gears, such as artisanal longlines but also bottom-set and drift gillnets, in areas where effort was lower (e.g. Mozambique). New and simple information should be also included in the interviews, including soak time and periods, that have a critical impact on bycatch incidence. This question could be simply added to the existing interview form, and would potentially provide new important information on patterns of bycatch. In addition, in order to produce more robust bycatch rates, number of bycatch individuals for each main taxonomic group should be asked for the last year of fishing, as well as during the last five years, as some differences are clearly expected.

Overall, a list of recommendations for future research and management initiatives can be listed:

- Conduct a specific and robust RBA on drift gillnet fisheries temporarily and spatially well designed in order to assess the real impact of this fishery on SWIO megafauna
- Continue RBA surveys in the southwest Indian Ocean, including in non-surveyed countries, to assess bycatch in artisanal fisheries, and include new questions (soak time and periods; number of bycatch individuals during the last year and before). This could be carried out with local/national fisheries organizations, conducting regularly interview surveys in their countries
- Extend RBA surveys to artisanal longline fisheries, such as in Zanzibar and elsewhere along the east African coast, especially to better assess the extent of vulnerable megafauna bycatch
- Produce, for each country of the region, the most accurate data on artisanal fishing effort. The bycatch incidence rates produced in this study could then be used to extrapolate bycatch numbers, for each fishery and species, at the local and regional levels.

- Compare interview survey data with observer programme data, such as those collected in Zanzibar to assess the extent of dolphin bycatch in drift and bottom-set gillnet fisheries. Comparing bycatch rates between the two data sources would assess the reliability of interview survey data
- Identify and map major habitats of the most vulnerable species identified in this study (cf. PSA) at the regional level and further investigate population structure and connectivity in order to spatially define management units and potential areas for conservations (MPAs). A regional project should be implemented and led by a consortium of scientists and fisheries managers
- Where possible, encourage training of fishermen to develop ecotourism activities, especially to increase the socio-economic value of marine mammals, sea turtles and elasmobranchs in the SWIO region

7. Literature cited

Alverson, D., Freeberg, M., Murawski, S., Pope, J. 1994. A global assessment of fisheries bycatch and discards. FAO Technical Paper N°339. Food and Agriculture Organization (FAO), Rome Italy.

Amandè, M.J., Ariz, J., Chassot, E., Chavance, P., Delgado De Molina, A., Gaertner, D., Murua, H., Pianet, R., Ruiz, J. 2008. Bycatch and discards of the European purse seine tuna fishery in the Indian Ocean. Estimation and characteristics for the 2003-2007 period. IOTC-2008-WPEB-12.

Amandè, M.J., Bez, N., Konan, N., Murua, H., Delgado De Molina, A., Chavance, P., Dagorn, L. 2011. Areas of high bycatch of silky sharks (*Carcharhinus falciformis*) in the western Indian Ocean purse seine fishery. IOTC–2011–WPEB07–29. 10p.

Amir, O.A. 2010. Biology, ecology and anthropogenic threats of Indo-Pacific bottlenose dolphins in east Africa. PhD Thesis: Stockholm University, Sweden.

Amir, O.A., Berggren, P., Jiddawi, N.S. 2002. The incidental catch of dolphins in gillnet fisheries in Zanzibar, Tanzania. *Western Indian Ocean Journal of Marine Science*, 1(2): 155-162.

Andrianarivelo, N. 2001. Inventaire et essai d'évaluation de la pêche aux dauphins d'Anakao, région du sud-ouest de Madagascar. Mémoire de DEA Institut Halieutiques et des Sciences Marines, Université de Toliara. 61p.

Best, P.B. 2007. Whales & Dolphins of the Southern African Subregion. Cape Town: Cambridge University Press.

Best, P. B., Brandão, A., Butterworth, D. 2001. Demographic parameters of the southern right whales off South Africa. *Journal of Cetacean Research and Management* (Special issue), 2: 161-169.

Bourjea, J. 2012. Sea turtles. *In*: R. van der Elst (Ed.). *Mainstreaming biodiversity in fisheries management: a retrospective analysis of existing data on vulnerable organisms in the southwest Indian Ocean*. Prepared for the South West Indian Ocean Fisheries Project (SWIOFP).

Bourjea, J., Nel, R., Jiddawi, N.S., Koonjul, M.S., Bianchi, G. 2008. Sea turtle bycatch in the West Indian Ocean: review, recommendations and research priorities. *Western Indian Ocean Journal of Marine Science*, 7(2): 137-150.

Camhi, M.D., Valenti, S.V., Fordham, S.V., Fowler, S.L., Gibson, C. 2009. *The Conservation Status of Pelagic Sharks and Rays: Report of the IUCN Shark Specialist Group Pelagic Shark Red List Workshop*. IUCN Species Survival Commission Shark Specialist Group. Newbury, UK. 78p.

Clarke, S.C., McAllistair, M.K., Milner-Gulland, E.J., Kirkwood, G.P., Michielsens, C.G.J., Agnew, D.J., Pikitch, E.K., Nakano, H., Shivji, M.S. 2006. Global estimates of shark catches using trade records from commercial markets. *Ecology Letters*, 9: 1115-1126.

Close, C.H., Hall, G.B. 2006. A GIS-based protocol for the collection and use of local knowledge in fisheries management planning. *Journal of Environmental Management*, 78: 341-352.

Cockcroft, V.G. 1990. Dolphin catches in the Natal shark nets, 1980-1988. *South African Journal of Wildlife Research*, 20(2): 44-51.

Everett, B.I., van der Elst, R.P., Santana-Afonso, P., Jiddawi, N., Assan, C., Robinson, J., Fondo, E., Khadun, S., Boinali, K., Ramanantsoa, M., Andriamaharo, T. 2011. WIOFish database: A catalogue of small-scale fisheries of the western Indian Ocean: Annual Report, September 2011. 168p.

Gomm, R. 2004. *Survey research methodology: a critical introduction*. Palgrave Macmillan, New York.

Guissamulo, A., Cockcroft, V.G. 1997. Dolphin and dugong occurrence and distribution and fisheries interactions in Maputo and Bazaruto bays, Mozambique. Paper SC/49/SM24 presented to the Scientific Committee of the International Whaling Commission.

Huang, H.-W., Liu, K.-M. 2010. Bycatch and discards by Taiwanese large-scale tuna longline fleets in the Indian Ocean. *Fisheries Research*, 106: 261-270.

Jolly, K.A., da Silva, C., Jarre, A., Atwood, C.G. 2011. Spatial and temporal patterns in blue shark (*Prionace glauca*) catch in South African longline fisheries. IOTC-2011-WPEB07-32. 36p.

FAO, 2006. Report of the workshop on assessing the relative importance of sea turtle mortality due to fisheries. Zanzibar, United Republic of Tanzania, 25-28 April 2006. Meeting report n°1 GCP/INT/919/JPN. 17p.

Fennessy, S.T. 1994. Incidental capture of elasmobranchs by commercial prawn trawlers on the Tugela Bank, Natal South Africa. *South African Journal of Marine Science*, 14: 278-296.

Fennessy, S.T., Isaksen, B. 2007. Can bycatch reduction devices be successfully implemented in prawn trawlers in the western Indian Ocean? *African Journal of Marine Science*, 29(3): 453-463.

Gallagher, A.J., Kyne, P.M., Hammerschlag, N. 2011. Ecological risk assessment and its application to elasmobranch conservation and management. *Journal of Fish Biology*. doi:10.1111/j.1095-8649.2012.03235.x. Available online at wileyonlinelibrary.com

Gormley, A.M., Slooten, E., Dawson, S., Barker, R.J., Rayment, W., du Fresne, S., Bräger, S. 2012. First evidence that marine protected areas can work for marine mammals. *Journal of Applied Ecology*, 49: 474-480.

Gove, D., Pacules, H., Gonçalves, M. 2001. The impact of Sofala Bank (Central Mozambique) shallow water shrimp fishery on marine turtles and effect of introducing TED (Turtle Excluder Device) on shrimp fishery. WWF report. 24p.

Hobday, A.J., Smith, A.D.M., Webb, H., Daley, R., Wayte, S.E., Bulman, C., Dowdney, J., Williams, A., Sporcic, M., Dambacher, J.M., Fuller, M., Walker, T.I. 2007. risk assessment for the effects of fishing: methodology. Report R04/1072 for the Australian Fisheries Management Authority, Canberra, July 2007.

Hobday, A.J., Smith, A.D.M., Stobutzki, I.C., Bulman, C., Daley, R., Dambacher, J.M., Deng, R.A., Dowdney, J., Fuller, M., Furlani, D., Griffiths, S.P., Johnson, D., Kenyon, R., Knuckey, I.A., Ling, S.D., Pitcher, R., Sainsbury, K.J., Sporcic, M., Smith, T., Turnbull, C., Walker, T.I., Wayte, S.E., Webb, H., Williams, A., Wise, B.S., Zhou, S. 2011. Ecological risk assessment for the effects of fishing. *Fisheries Research*, 108: 373-384.

Humber, F., Godley, B.J., Ramahery, V., Broderick, A.C. 2011. Using community members to assess artisanal fisheries: the marine turtle fishery in Madagascar. *Animal conservation*, 2010: 1-11.

Johannes, R.E., Freeman, M.M.R., Hamilton, R.J. 2000. Ignore fisher's knowledge and miss the boat. *Fish and Fisheries*, 1: 257-271.

Kiszka, J. 2012. Marine mammals. *In*: R. van der Elst (Ed.). *Mainstreaming biodiversity in fisheries management: a retrospective analysis of existing data on vulnerable organisms in the southwest Indian Ocean*. Prepared for the South West Indian Ocean Fisheries Project (SWIOFP).

Kiszka, J., van der Elst, R. 2012. Elasmobranchs. *In*: R. van der Elst (Ed.). *Mainstreaming biodiversity in fisheries management: a retrospective analysis of existing data on vulnerable organisms in the southwest Indian Ocean*. Prepared for the South West Indian Ocean Fisheries Project (SWIOFP).

Kiszka, J., Muir, C. 2007. Incidental catches of non-targeted marine species in the Western Indian Ocean: problems and mitigation measures. Workshop proceedings. 13-15th November 2006, Mayotte, France. Western Indian Ocean Marine Science Association (WIOMSA). 111p.

Kiszka, J., Muir, C., Jamon, A. 2007. Status of a marginal dugong (*Dugong dugon*) population in the lagoon of Mayotte (Mozambique Channel), in the western Indian Ocean. *Western Indian Ocean Journal of Marine Science*, 6(1): 111-116.

Kiszka, J., Muir, C., Poonian, C., Cox, T.M., Amir, O.A., Bourjea, J., Razafindrakoto, Y., Wambiji, N., Bristol, N. 2008. Marine Mammal Bycatch in the Southwest Indian Ocean: Review and Need for a Comprehensive Status Assessment. *Western Indian Ocean Journal of Marine Science*, 7(2): 119-136.

Kiszka, J., Bein, A., Bach, P., Jamon, A., Layssac, K., Labart, S., Wickel, J. 2010. Catch and bycatch in the pelagic longline fishery around Mayotte (NE Mozambique Channel), July 2009-September 2010. Report to the Working Party on Ecosystems and Bycatch, Indian Ocean Tuna Commission. 6p.

Lewison, R.L., Crowder, L.B., Read, A.J., Freeman, S.A. 2004. Understanding impacts of fisheries bycatch on marine megafauna. *Trends in Ecology and Evolution*, 19: 598-604.

Louro, C.M.M, Pereira, M.A.M., Costa, A. 2006. The conservation status of marine turtles in Mozambique. Report submitted to MICOA, Maputo. 45p.

Lucifora, L.O., Garcìa, V.B., Worm, B. 2011. Global diversity hotpots and conservation priorities for sharks. *PloS One*, 6(5): e19356. doi:10.1371/ journal.pone.0019356

Maoulida, K., Hauzer, M., Poonian, C., Kiszka, J. 2009. Artisanal shark fisheries of the Comoros: status and threats. 6th Scientific Symposium of the Western Indian Ocean Marine Science Association, La Reunion, France, 24-29 August 2009.

Marsac, F. 2011. *Approche écosystémique des pêches thonières tropicales*. Habilitation à Diriger des Recherches. Université de Montpellier 2 « Sciences et Techniques ». 145p.

Marshall, N.T. 1997. Trade in sharks and shark products in Kenyan waters. In: *Elasmobranch biodiversity, Conservation and Management* (eds. S.L. Fowler, T.M. Reed and F.A. Dipper). Proceedings of the International Seminar and Workshop, Sabah, Malaysia, July 1997. Occasional paper of the Species Survival Commission, N°25, pp. 31-38.

McVean, A.R., Walker, S.C.J., Fanning, E. 2006. The traditional shark fisheries of southwest Madagascar: a study in the Toliara region. *Fisheries Research*, 82: 280-289.

Muir, C.E., Kiszka, J. 2012. Eastern African dugongs. In: E. Hines, J. Reynolds, L. Aragones, T. Mignucci, & M. Marmontel (Eds.). *Sirenian Conservation: Issues and Strategies in Developing Countries.* University Press of Florida, USA.

Moore, J.E., Cox, T.M., Lewison, R.L., Read, A.J., Bjorkland, R., McDonald, S.L., Crowder, L.B., Aruna, E., Ayissi, I., Espeut, P., Johnson-Hicks, C., Pilcher, N., Poonian, C.N.S., Solarin, B., Kiszka, J. 2010. An interview-based approach to assess marine mammal and sea turtle captures in artisanal fisheries. *Biological Conservation*, 143: 795-805.

Okemwa, G.M., Nzuki, S., Mueni, E.M. 2004. The status and conservation of sea turtles in Kenya. *Marine Turtle Newsletter*, 105: 1-6.

Pauly, D. 2006. Major trends in small-scale fisheries, with emphasis on developing countries, and some implications for the social sciences. *Maritime Studies*, 4: 7-22.

Peddemors, V.M., Cockcroft, V.G., Best, P.B. 1998. Exploitation of small cetaceans off South Africa: 1978-1996. Paper SC/49/SM34 submitted to the Scientific Committee of the International Whaling Commission.

Poisson, F., Taquet, M. 2001. L'espadon: de la recherché à l'exploitation durable – Programme Palangre Réunionais. Rapport final, 248 p.

Poisson, F., Marjolet, C., Mété, K., Vanpouille, M. 2001. Evaluation du phénomène de déprédation dû aux mammifères marins. Pp. : 231-247. *In* : F. Poisson & M. Taquet (Eds.). *L'espadon : de la recherche à l'exploitation durable.* Programme Palangre Réunionais. Rapport Final, Novembre 2001.

Poonian, C.N.S., Hauzer, M.D., Ben Allaoui, A., Cox, T.M., Moore, J.E., Read, A.J., Lewison, R.L., Crowder, L.B. 2008. Rapid assessment of sea turtle and marine mammal bycatch in the Union of the Comoros. *Western Indian Ocean Journal of Marine Science*, 7(2): 207-216.

Pusineri C, Quillard M. 2008. Bycatch and direct captures of protected megafauna by the artisanal coastal fishery of Mayotte. *Western Indian Ocean Journal of Marine Science*, 7(2): 195-206.

Rakotonirina, B.P., Andriamiseza, O., Rakotomavo, H. 2006. Madagascar report. Document prepared for the "Workshop on assessing the relative importance of sea turtle mortality due to fisheries", orgasised by FAO and the Directorate of Fisheries, Zanzibar, Tanzania. Zanzibar 25-28 April 2006, 11p.

Razafindrakoto, Y., Andrianarivelo, N., Rosenbaum H.C. 2004. Sightings, catches and other records of Indo-Pacific Humpback dolphins in the coastal waters of Madagascar. *Aquatic Mammals*, 30(1): 103-110.

Razafindrakoto, Y., Andrianarivelo, N., Salvatore C., Rasoamananto I., Rosenbaum H.C. 2008. Preliminary assessment of cetacean incidental mortality in artisanal fisheries in Anakao, southwestern region of Madagascar. *Western Indian Ocean Journal of Marine Science* 7(2): 175-184.

Romanov, E. 2001. Bycatch in the tuna purse-seine fishery in the western Indian Ocean. *Fishery Bulletin*, 100: 90-105.

Romanov, E. 2008. Bycatch and discards in the Soviet purse seine tuna fisheries on FAD-associated schools in the north equatorial area of the western Indian Ocean. *Western Indian Ocean Journal of Marine Science*, 7(2): 163-174.

Schaeffer, D. 2004. Assessment of the Artisanal Shark Fishery and Local Shark Fin Trade on Unguja Island, Zanzibar. *ISP Collection.* Paper 536.

Smale, M.J. 2008. Pelagic shark fisheries in the Indian Ocean. In: *Sharks of the Open Ocean: Biology, Fisheries and Conservation* (eds. M.D. Camhi, E.K. Pikitch and E.A. Babcock). Blackwell Publishing, Oxford, UK.

Sobo, F., Jaddawi, N.S., Mwakosya, C., Khatib, H., Dadu, A. 2008. Marine Fisheries Frame Survey Results for 2007. Report of the Ministry of Livestock and Fisheries Development (mainland) and Ministry of Agriculture, Livestock and Environment (Zanzibar). 32p.

Van Waerebeek, K., Van Bressem, M.-F., Félix, F., Alfaro-Shigueto, G., Garcìa-Godos, A., Chàves-Lisambart, L., Ontòn, K., Montes, D., Bello, R. 1997. Mortality of dolphins and porpoises in coastal fisheries off Peru and southern Equator. *Biological Conservation*, 81: 43-49.

Wamukoya, G.M., Mirangi, J.M., Ottichillo, W.K., 1996. Report on the marine aerial survey of the marine mammals, turtles, sharks and rays. *Kenya Wildlife Service Technical Report Series N°1.* 22p.

White, P.C.L., Jennings, N.V., Renwick, A.R., Barker, N.H.L. 2005. Questionnaires in ecology: a review of past use and recommendations for best practise. *Journal of Applied Ecology*, 42: 421-430.

Whitty, T.S., Davis, P., Poonian, C., Leandre, I. 2010. Rapid assessment of marine megafauna capture, fishing effort, and socioeconomic and cultural drivers of artisanal fisheries in northern Madagascar. Proceedings of the World Small Scale Fisheries Congress, Bangkok, Thailand, 18-22 October 2010.

WWF Eastern African Marine Ecoregion (EAME), 2004. Towards a Western Indian Ocean Dugong Conservation Strategy: The Status of Dugongs in the Western Indian Ocean Region and Priority Conservation Actions. Dar es Salaam, Tanzania. 68p.

Appendix 1: Questionnaire used for the rapid bycatch assessment

FOR INTERVIEWER ONLY

Interview #: __________

Date:__________

Time of day: ____________

Interviewer name:__________

Location Information:

State:__________

Village:_____________

Community:__________

Landing Site (within the community):__________

Interview location: At landing site At fisher's house Other: _______________

Interview circumstance: Fisher going out to sea Fisher returning from fishing trip Other: __________

Gender of interviewee: Male Female

Is a translator or intermediate person being used to help conduct this interview? Y N

FOR FISHER

Opening Statement:

My name is __________. I work on a project conducted by _______________________. This organization conducts research and management about fishing and the ocean. The goal of this project is simply to learn more about coastal fisheries and their relationships with marine mammals and sea turtles, because there is increasing interest about these species.

Your participation is voluntary and confidential. We will not record your name or any personal contact information or share your individual answers with anyone outside of the research team. Your honest answers will not have any consequences for you; this is strictly for academic research. Our research could, however, be used to help improve the marine environment and sustainability of the fishery in the long term. For example, it could lead to the development of educational or conservation programs in certain areas. You do not have to answer any questions that you do not want to, and you can choose to end this interview at any time. The full interview will take about 15 - 30 minutes. We realize that you are very busy and we greatly appreciate your willingness to take time with us.

Background questions:

Have you previously participated in research related to (circle):

sharks? fishing? marine mammals? sea turtles? none of these

If yes, describe: ____

How old are you?__________

For how many years has fishing been your occupation?__________

Is fishing your primary occupation? Yes No

Is fishing your only occupation? Yes No
(If No): What are your other occupations? ____________________
During which months did you fish out of the last 12? _______________

Do you own your own fishing boat? Yes No
Do you lead the fishing trips or are you a crew member on trips that someone else leads?
Circle one: I lead the trips I am a crew member; someone else is in charge

1- Boat description

1-1 What type of boat do you have or fish on?
1-2 How long (in meters) is your boat or the boat you fish on?__________
1-3 Is the boat motorized? Yes No
1-4 What is the horsepower of the motor? __________

Fishing and Catch questions:
Answer these questions to describe your individual experience, not that of your community.

2- Gear 1: fishing and catch questions

2-1 What type of fishing gear do you use most often over the course of one year? (use illustrations)
Circle ONE:
Bottom set gill nets. Length ___________ Mesh size ____________
Mono-filament Drift gill nets. Length __________ Mesh size ____________
Multi-filament Drift gill nets. Length __________ Mesh size ____________
Longline (many hooks) Hook size:_________ Number hooks _____________
Hook and line (1 or few hooks)
Purse seine or surround seine. Mesh size ____________ Net length _____________
Beach seine. Mesh size ____________ Net length _____________
Towed nets
Traps
Other (describe): __________

2-2 How many fishermen, including yourself, are on the boat to fish with this gear? __________

2-3 During which months of the year do you use this gear? __________________

2-4 How many days per week do you fish with this gear, during these months?
1 2-3 4-5 6-7

2-5 What are you trying to catch when you fish with this gear? ___________________

2-6 Have you ever caught sea turtles using this fishing gear? Yes No Can't recall

If yes:

Which sea turtle species have you caught with this gear (use illustrations), and how certain are you of this? List species in order from most commonly to least commonly caught.
__________________ very sure fairly sure not sure
__________________ very sure fairly sure not sure

___________________ very sure fairly sure not sure
___________________ very sure fairly sure not sure
___________________ very sure fairly sure not sure

During which months of the year have you caught sea turtles with this gear?
First species____________________
Second species___________________
Third species____________________

How many total sea turtles did you catch in the last year, with this gear?
circle one: 0 1 - 3 4 - 10 11 - 20 >20 don't know

In what water depth or how far from shore were you fishing when you caught them?
____

2-7 Have you ever caught marine mammals when you use this fishing gear? Yes No Can't recall

If yes:

Which species have you caught with this gear (use illustrations), and how certain are you of this? List species in order from most commonly to least commonly caught.

___________________ very sure fairly sure not sure
___________________ very sure fairly sure not sure
___________________ very sure fairly sure not sure
___________________ very sure fairly sure not sure
___________________ very sure fairly sure not sure

During which months of the year have you caught marine mammals with this gear?
First species____________________
Second species___________________
Third species____________________

How many total marine mammals did you catch in the last year, with this gear?
circle one: 0 1 - 2 3 - 5 6 - 10 >10 don't know

In what water depth or how far from shore were you fishing when you caught them?
____

2-8 Have you ever caught rays when you use this fishing gear? Yes No Can't recall

If yes:

Which species have you caught with this gear (use illustrations), and how certain are you of this? List species in order from most commonly to least commonly caught.

___________________ very sure fairly sure not sure
___________________ very sure fairly sure not sure
___________________ very sure fairly sure not sure
___________________ very sure fairly sure not sure

___________________ very sure fairly sure not sure

During which months of the year have you caught rays with this gear?
First species____________________
Second species___________________
Third species____________________

How many total rays did you catch in the last year, with this gear?
circle one: 0 1 - 10 11 - 20 21 - 50 >50 don't know

In what water depth or how far from shore were you fishing when you caught them?
____

2-9 Have you ever caught sharks when you use this fishing gear? Yes No Can't recall

If yes:
Which species have you caught with this gear (use illustrations), and how certain are you of this? List species in order from most commonly to least commonly caught.
___________________ very sure fairly sure not sure
___________________ very sure fairly sure not sure
___________________ very sure fairly sure not sure
___________________ very sure fairly sure not sure
___________________ very sure fairly sure not sure

During which months of the year have you caught sharks with this gear?
First species____________________
Second species___________________
Third species____________________

How many total sharks did you catch in the last year, with this gear?
circle one: 0 1 - 10 11 - 20 21 - 50 >50 don't know

In what water depth or how far from shore were you fishing when you caught them?
____

3- Other gears: fishing and catch questions

3-1 What other fishing gears do you use over the course of one year? (use illustrations)
Circle ALL THAT APPLY:
Bottom-set gill nets. Length ____________ Mesh size _____________
Mono-filament Drift gill nets. Length ___________ Mesh size _____________
Multi-filament Drift gill nets. Length ___________ Mesh size _____________
Longline (many hooks) Hook size:__________ Number hooks ______________
Hook and line (1 or few hooks)
Purse seine or surround seine. Mesh size _____________ Net length ______________
Beach seine. Mesh size _____________ Net length ______________
Towed nets
Traps
Other (describe): ___________

3-2 Have you ever caught sea turtles in any of these other gears? Yes No Can't recall

If yes:

In which of these gears have you caught sea turtles? (list all that apply): _________________
In which one of these other gears have you caught the most sea turtles?__________

Which sea turtle species have you caught in these gears (use illustrations), and how certain are you of this? List species in order from most commonly to least commonly caught.

__________________	very sure	fairly sure	not sure
__________________	very sure	fairly sure	not sure
__________________	very sure	fairly sure	not sure
__________________	very sure	fairly sure	not sure
__________________	very sure	fairly sure	not sure

How many total sea turtles did you catch in the last year, in these gears?

circle one: 0 1 - 3 4 - 10 11 - 20 >20 don't knolw

3-3 Have you ever caught marine mammals in any of these other gears? Yes No Can't recall

If yes:

In which of these gears have you caught them (list all that apply): _________________
In which one of these other gears have you caught the most marine mammals?______________

Which marine mammal species have you caught in these gears (use illustrations), and how certain are you of this? List species in order from most commonly to least commonly caught.

__________________	very sure	fairly sure	not sure
__________________	very sure	fairly sure	not sure
__________________	very sure	fairly sure	not sure
__________________	very sure	fairly sure	not sure
__________________	very sure	fairly sure	not sure

How many total marine mammals did you catch in the last year, in these gears?

circle one for cetaceans: 0 1 - 2 3 - 5 6 - 10 >10 don't know

circle one for dugong 0 1 - 2 3 - 5 6 - 10 >10 don't know

3-4 Have you ever caught sharks/rays in any of these other gears? Yes No Can't recall

If yes:

In which of these gears have you caught them (list all that apply): _________________
In which one of these other gears have you caught the most marine mammals?______________

Which dolphin species have you caught in these gears (use illustrations), and how certain are you of this? List species in order from most commonly to least commonly caught.

__________________	very sure	fairly sure	not sure
__________________	very sure	fairly sure	not sure

___________________ very sure fairly sure not sure
___________________ very sure fairly sure not sure
___________________ very sure fairly sure not sure

How many total sharks/rays did you catch <u>in the last year</u>, in these gears?
circle one: 0 1 - 2 3 - 5 6 - 10 >10 don't know

3-5 What did you do with the sea turtles you caught in the last 12 months?
Eat Release alive Discard dead Other: __________
Sell meat Sell whole Sell shell
Why?____________________________

3-6 What did you do with the marine mammals you caught in the last 12 months?
Eat Sell Release alive Discard dead Other: __________
Why?____________________________

3-7 What did you do with the rays you caught in the last 12 months?
Eat Release alive Discard dead Other: __________
Sell the whole body
Why?____________________________

3-8 What did you do with the sharks you caught in the last 12 months?
Eat Release alive Discard dead Other: __________
Sell only fins Sell the whole body
Why?____________________________

3-9 Do sea turtles damage your fishing gear? Yes No
If yes, which types of gear do they damage? ______________________

3-10 Do dolphins/whales damage your fishing gear? Yes No
If yes, which types of gear do they damage? ______________________

3-11 Do sharks damage your fishing gear? Yes No
If yes, which types of gear do they damage? ______________________

3-12 Do dolphins negatively affect your fishing in any other way? Yes No
If yes, describe how: _______________________________________

4- Historical questions

4-1 Compared to when you started fishing:
are there more, fewer, or the same amount of turtles in the areas you fish? or do you not know?
are accidental sea turtle captures in fishing gear higher, lower, the same, or do you not know?
is intentional sea turtle capture more or less common, or the same, or do you not know?

4-2 Compared to when you started fishing:
are there more, fewer, or the same amount of sharks/rays in the areas you fish? you don't know?
are accidental rays/sharks captures in fishing gear higher, lower, the same, or do you not know?
is intentional rays/sharks capture more or less common, or the same, or do you not know?

4-3 Compared to when you started fishing:

- are there more / fewer / the same number of cetaceans or dugongs in the areas you fish?
- are accidental cetacean/dugong captures in fishing gear higher, lower, the same?
- is intentional cetacean capture more common, less common, the same, or do you not know?

FOR INTERVIEWER ONLY

How open and honest did the fisherman seem about answering bycatch questions?

Very open/honest	Somewhat open/honest	Not honest

How interested and engaged did the fisherman seem with the interview?

Very interested	Moderately interested	Bothered/ Not interested

How certain did the fisherman seem about answers to numerical questions?

Very sure	Reasonably sure	Unsure

Appendix 2: List of species identified as bycatch in coastal artisanal fisheries in surveyed countries

English and Latin names of sea turtles, marine mammals and elasmobranchs cited as bycatch species in artisanal fisheries in the southwest Indian Ocean.

English name	**Latin name**	**IUCN red list status**
Sea turtles		
Green turtle	*Chelonia mydas*	Endangered
Hawksbill turtle	*Eretmochelys imbricata*	Critically Endangered
Loggerhead turtle	*Caretta caretta*	Endangered
Leatherback turtle	*Dermochelys coriacea*	Critically Endangered
Olive Ridley turtle	*Lepidochelys olivacea*	Vulnerable
Marine mammals		
Dugong	*Dugong dugon*	Vulnerable
Indo-Pacific bottlenose dolphin	*Tursiops aduncus*	Data Deficient
Indo-Pacific humpback dolphin	*Sousa chinensis*	Near Threatened
Spinner dolphin	*Stenella longirostris*	Data Deficient
Pantropical spotted dolphin	*Stenella attenuata*	Least Concern
Risso's dolphin	*Grampus griseus*	Least Concern
Common dolphin	*Delphinus delphis*	Least Concern
Humpback whale	*Megaptera novaeangliae*	Least Concern
Elasmobranchs		
Giant Manta ray	*Manta birostris*	Vulnerable
Reef Manta ray	*Manta alfreidi*	Vulnerable
Spotted eagle ray	*Aetobatus narinari*	Near Threatened
Bluespotted ribbontail stingray	*Taeniura lymma*	Near Threatened
Bluespotted stingray	*Neotrygon kuhlii*	Data Deficient
Pink whipray	*Himantura fai*	Least Concern
Javanese cownose ray	*Rhinoptera javanica*	Vulnerable
Giant guitarfish	*Rhynchobatus djiddensis*	Vulnerable
Black-spotted stingray	*Taeniurops meyeni*	Vulnerable
Bullray	*Pteromylaeus bovinus*	Data Deficient
Honeycomb stingray	*Himantura uarnak*	Vulnerable
Porcupine ray	*Urogymnus asperrimus*	Vulnerable
Short tail stingray	*Dasyatis brevicaudata*	Least Concern
Thorntail stingray	*Dasyatis thetidis*	Data Deficient
Sawfish	Pristis spp.	Critically Endangered
Torpedo rays	*Torpedo* spp.	
Devil rays	*Mobula* spp.	
Scalloped hammerhead shark	*Sphyrna lewini*	Endangered

Smooth hammerhead shark	*Sphyrna zygaena*	Vulnerable
Great hammerhead shark	*Sphyrna mokarran*	Endangered
Blacktip reef shark	*Carcharhinus melanopterus*	Near Threatened
Silvertip shark	*Carcharhinus albimarginatus*	Near Threatened
Bignose shark	*Carcharhinus altimus*	Data Deficient
Gray reef shark	*Carcharhinus amblyrhynchos*	Near Threatened
Silky shark	*Carcharhinus falciformis*	Near Threatened
Bull shark	*Carcharhinus leucas*	Near Threatened
Blacktip shark	*Carcharhinus limbatus*	Near Threatened
Oceanic whitetip shark	*Carcharhinus longimanus*	Vulnerable
Dusky shark	*Carcharhinus obscurus*	Vulnerable
Sandbar shark	*Carcharhinus plumbeus*	Vulnerable
Tiger shark	*Galeocerdo cuvier*	Near Threatened
Shortfin mako shark	*Isurus oxyrhinchus*	Vulnerable
Sand tiger shark	*Carcharias taurus*	Vulnerable
White-eyed shark	*Rhizoprionodon acutus*	Least Concern
African angel shark	*Squatina africana*	Data Deficient
Banded catshark	*Halaelurus lineatus*	Data Deficient
Izak catshark	*Holohalaelurus regani*	Least Concern
Sharptooth lemon shark	*Negaprion acutidens*	Vulnerable
Whitetip reef shark	*Triaenodon obesus*	Vulnerable
Tawny nurse shark	*Nebrius ferrugineus*	Vulnerable
Blue shark	*Prionace glauca*	Near Threatened
Leopard shark	*Stegostoma fasciatum*	Vulnerable
Spadenose shark	*Scoliodon laticaudus*	Near Threatened
Common thresher shark	*Alopias vulpinus*	Vulnerable
Whale shark	*Rhincodon typus*	Vulnerable
Great white shark	*Carcharodon carcharias*	Vulnerable

Appendix 3: List of targeted species identified during RBA interview surveys

Targeted species	English names	Latin names
	Emperor breams	*Lethrinidae* spp.
	Perrot fishes	*Scaridae* spp.
	Rabbit fishes	*Siganidae* spp.
	Sea breams	*Sparidae* spp.
	Groupers	*Serranidae* spp.
	Snappers	*Lutjanidae* spp.
	Surgeon fishes	*Acanthuridae* spp.
	Jacks	*Carangidae* spp.
	Halfbeak fishes	*Hemiramphidae* spp.
	Sailfish	*Istiophorus platypterus*
	Dolphin fish (mahi-mahi)	*Coryphaena hippurus*
	Yellowfin tuna	*Thunnus albacares*
	Bigeye tuna	*Thunnus obesus*
	Skipjack tuna	*Katsuwonus pelamis*
	Narrow-barred Spanish mackerel	*Scomberomorus commerson*
	Swordfish	*Xiphias gladius*
	Southern African pilchard	*Sardinops sagax*
	Kelee shad	*Hilsa kelee*
	Northern whiting	*Sillago sihama*
	Orangemouth anchovy	*Thryssa vitrirostris*
	Tigertooth croaker	*Otolithes ruber*
	Flathead mullet	*Mugil cephalus*
	Shoemaker spinefoot	*Siganus sutor*
	Barred javelin	*Pomadasys kaakan*
	Thumbprint emperor	*Lethrinus harak*
	Pink ear emperor	*Lethrinus lentjan*
	Spangeled emperor	*Lethrinus nebulosus*
	Spotcheek emperor	*Lethrinus rubrioperculatus*
	Slender emperor	*Lethrinus variegates*