Cetacean bycatch in the western Indian Ocean: a review of available information on coastal gillnet, tuna purse seine and pelagic longline fisheries

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Abstract
Bycatch is the most significant and immediate threat to cetacean populations at the global scale. Here we review available information on cetacean bycatch in industrial and small-scale (mostly artisanal) fisheries in the western Indian Ocean (WIO). In coastal waters of the WIO region, the impact of bycatch has not been quantified in small-scale fisheries, except in bottom-set gillnets and driftnets targeting large pelagic fish (including tuna) off Zanzibar. Based on bycatch data from observer programs and estimated abundance of coastal dolphins, the bycatch off the south coast of Zanzibar was found to be unsustainable. Elsewhere in the region, other species are also bycaught, including coastal, oceanic and migratory species such as humpback whales (*Megaptera novaeangliae*), mostly in bottom-set and drift gillnets. In open-ocean fisheries, bycatch in pelagic longlines has been recorded but seems to be rare. Species affected are mostly medium-sized delphinids (*Globicephala macrorhynchus*, *Grampus griseus*, *Pseudorca crassidens*) involved in depredation (on either bait or catch). Areas of high co-occurrence of cetaceans and purse seine fisheries have been identified, particularly east of the Seychelles (December to March) and in the Mozambique Channel (April and May). However, few cetacean deaths have been reported. The presence of observers could affect purse seining practices, and therefore affect data reliability. Overall, cetacean bycatch is very poorly documented in the region and more systematic assessment is critical, particularly for those fisheries that use gear known to entangle or entrap cetaceans; gillnets are of greatest concern.

Introduction

The incidental catch (bycatch) of marine megafauna, including marine mammals, sea turtles and elasmobranchs, is one of the main threats to these taxa worldwide (e.g. Lewison *et al.* 2004, Read *et al.* 2006, Temple *et al.* 2017). They are particularly vulnerable due to their late sexual maturity and subsequent low reproductive rates. Additionally, many marine mammal populations are small and demographically isolated, and therefore even relatively small numbers of annual bycatch may be sufficient to cause long-term (and potentially terminal) population declines (e.g. Moore 2015). To date, bycatch has been assessed in only a few locations and documented anecdotally elsewhere in the western Indian Ocean (WIO) region (e.g. Kiszka *et al.* 2009, 2010a; Amir 2010; Anderson 2014; Escalle *et al.* 2015). For the

purpose of this review, the WIO is defined as the area located between of 10°N and 40°S, and west of 70°E.

In coastal fisheries of the WIO region (including those targeting tuna and tuna-like species), the presently available data on bycatch and landings are generally anecdotal, of poor quality and resolution, and heavily biased towards easily identifiable species. Consequently, it is impossible to assess the current scale of marine megafauna bycatch in the WIO, or the status of affected populations. However, the available information provides some indications of overexploitation in several areas (Temple *et al*. 2017). A dedicated study of coastal fisheries in Zanzibar (Tanzania) has highlighted the unsustainability of dolphin bycatch, particularly for Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) and Indian Ocean humpback dolphins (*Sousa plumbea*) in gillnets (Amir *et al.* 2002; Amir 2010). There is clearly an urgent need for the proper documentation, monitoring and assessment at the regional level of small-scale fisheries and affected megafauna in order to inform evidence-based fisheries management, without which any management plan is incomplete (Kiszka *et al.* 2009, Temple *et al*. 2017).

For open-ocean fisheries (pelagic longlines and purse seines), the available information is also very limited; one study of tuna purse seine fisheries concluded that cetacean mortality is not especially high (Escalle *et al.* 2015). However, these results are contestable since there is increasing evidence that a number of cetacean species (particularly *Stenella* spp. and *Balaenoptera* spp.) associate with tuna across the Indian Ocean (Anderson 2014). Work to assess bycatch in similar fisheries in the eastern tropical Pacific has demonstrated unsustainable catches (Gerrodette 2002). Subsequent management actions have helped to reduce dolphin bycatch, but populations in this area are not yet showing clear signs of recovery (Gerrodette and Forcada 2005, Wade *et al.* 2007, Cramer *et al.* 2008).

Cetacean entanglement in the WIO is a justified and urgent concern. Here we provide an updated review of existing information on cetacean bycatch in coastal gillnet, tuna purse seine and pelagic longline fisheries in the region.

Bycatch in open-ocean industrial fisheries

Pelagic longlines

In the WIO, killer whales (*Orcinus orca*) are involved in depredation in the pelagic longline fishery targeting tuna (*Thunnus* spp.), swordfish (*Xiphias gladius*) and sharks off South Africa, especially on the Agulhas Bank and the along the continental shelf toward Port Elizabeth (Petersen and Williams 2007). Peterson and Williams (2007) estimated the loss of 561 fish from 116 longline sets with which killer whales were interacting; 83% of these were swordfish and depredation rates were 10-20% in the depredated sets.

In the western tropical Indian Ocean, false killer whales (*Pseudorca crassidens*), short-finned pilot whales (*Globicephala macrorhynchus*) and Risso's dolphins (*Grampus griseus*) are the cetacean species known to be involved in depredation of either catch or bait in pelagic longline fisheries (Poisson *et al*. 2001, Rabearisoa *et al*. 2012, Kiszka 2015). In the semi-industrial pelagic longline fishery of the Seychelles from 1995 to 2006, the proportion of sets with cetacean depredation was about 16% which represented an average 60% of the fish caught (Rabearisoa *et al*. 2007). Around the island of La Réunion (Mascarene archipelago), from 1997 to 2000, an average of 4.3% (80t) of the annual swordfish catch was damaged by

cetaceans, representing a rate of catch loss between 3.7% and 5.5% as well as gear damages (Poisson *et al*. 2007). Previous observations on depredation related this phenomenon to the specific features of seabed topography, including seamounts, shoals and enclosed sea areas (Rosa and Secchi 2007). In WIO, the highest depredation rates occur in areas of the highest swordfish CPUE (Catch-Per-Unit-of-Effort), suggesting that cetaceans may also make use of areas where there is high fishing effort. Although cetacean depredation is sporadic, its impact is high in terms of the fish catches. For instance, in the Seychelles, from 1995 to 2005, the economic loss due to depredation was estimated at 340 €/1000 hooks which equates to about 1,000,000 € (Rabearisoa *et al*. 2007). The magnitude of the depredation is poorly understood; furthermore, data needed to determine whether there are population-level effects from injury and mortality induced by entanglement are lacking (Rosa and Secchi 2007, Kiszka *et al*. 2009).

Pelagic longline fisheries are known to capture cetaceans. In the US pelagic longline fisheries operating in the central North Pacific, the bycatch of false killer whales exceeds allowable levels under the Marine Mammal Protection Act (e.g. Gilman *et al.* 2007, Forney *et al.* 2011). There are anecdotal reports of cetacean bycatch in WIO pelagic longline fisheries. Around the island of Mayotte (NE Mozambique Channel), non-lethal injuries observed on the dorsal fins of several oceanic short-finned pilot whales provide evidence that interactions with the longline fishery occur (Kiszka *et al.* 2008). Between 2009 and 2010, an observer program recorded only one cetacean capture - a false killer whale - in the Mayotte longline fishery; the animal was released alive (Kiszka *et al.* 2010a). A Risso's dolphin was reported as bycatch in the longline fishery off La Réunion (Poisson *et al.* 2001). Around the Seychelles, incidental captures may occur in the semi-industrial pelagic longline fishery, where large delphinids (primarily pilot whales and false killer whales) have a major impact through depredation of catches (Romanov *et al.* 2009, Rabearisoa *et al.* 2012). Overall, there is a critical need to understand the spatial and temporal patterns of cetacean bycatch and depredation in pelagic longline fisheries in the Indian Ocean.

Purse seines

In the tropical open ocean, operators of tuna purse seiners use several cetacean species (small delphinids, baleen whales) to detect tuna schools (Gerrodette 2002). This frequently leads to the targeted encirclement of the cetaceans by the seine, which can lead to bycatch (Gerrodette 2002, Gerrodette and Forcada, 2005). The first accounts of interaction between purse seine fisheries and cetaceans in the WIO came from Robineau (1991) and Romanov (2002). Between 1986 and 1992, observer data were collected aboard Soviet purse seiners (a total of 494 sets; Romanov 2002), mostly around the Seychelles and to a lesser extent in the Mozambique Channel. A total of 45 sets were on whales, possibly sei *Balaenoptera borealis* and fin whales *B. physalus* (but other species have apparently also been identified, including blue *B. musculus*, Bryde's *B.* cf. *brydei* and minke whales *B. acutorostrata*; Romanov 2002). Skipjack, yellowfin, and bigeye tuna dominated in whale-associated schools. The whales often remained in the net until the end of pursing and then escaped from the purse seine by either diving under the purse line, ramming through the net wall, or sinking the corkline. A single incident of death involving a sei whale was reported (Romanov 2002).

Escalle and colleagues (2015) provided a detailed analysis of the interactions between French and Spanish purse-seine fisheries in the tropical Atlantic and Indian Oceans using captain's logbooks (1980–2011) and reports from on-board scientific observers (1995–2011). In the WIO, distribution maps of sightings per unit of effort highlight two main areas of relatively high co-occurrence of dolphins and seine fisheries: 1) east of the Seychelles (December–

March) and 2) the Mozambique Channel (April–May). The percentage of cetacean-associated fishing sets was ~ 3% whereas 0.6% of sets involved the encirclement of cetaceans; no cetacean mortality was reported. The high apparent survival rates of cetaceans near, or directly involved in, fishing sets suggest that purse seine operations have little impact on cetacean populations in the region. However, a number of unverified factors could explain the lack of reports of cetacean mortality in the WIO, including changes of fishing practices in the presence of observers or the failure of captains to report mortality events in their logbooks when an observer is not present. Several species of baleen whales and small delphinids (*Stenella attenuata* and *S. longirostris*) have been observed in association with tuna schools (particularly yellowfin tuna *Thunnus albacares*; Anderson 2014) across the WIO and could therefore be captured in purse seines. However, the prevalence of these associations remains unknown and the impact of purse seining on cetacean populations in the region needs to be further investigated.

Bycatch in coastal small-scale fisheries (including anti-shark nets)

East coast of South Africa
Most reports of cetacean bycatch are from anti-shark nets set to protect human swimmers in the KwaZulu-Natal region. Captured cetaceans consist mainly of Indo-Pacific bottlenose and common dolphins (*Delphinus delphis*), although Indian Ocean humpback dolphins are also caught (Cockcroft 1990; Atkins *et al.* 2013). The affected area stretches from Mzamba to Richards Bay (Cockcroft 1990). From 1980 to 2009, a total of 203 Indo-Pacific humpback dolphins were reported to have died in shark nets, with most catches recorded in Richards Bay (Atkins *et al.* 2013). On average, 76 (range 36-175) dolphins were taken as bycatch every year (mean), of which 46% were common dolphins, 42% were bottlenose dolphins and 8% were humpback dolphins (Peddemors *et al.* 1998; Best 2007). Periodically, whales also become entangled in anti-shark nets, including common minke (*Balaenoptera acutorostrata*), humpback and southern right whales (*Eubalaena australis*) (Cockcroft & Krohn 1994). On average, 5.6 whales were caught in this way annually between 1963 and 1998 (Best *et al.* 2001). However, entanglements do not always result in death as 75% of whales are released alive. It should be noted that South Africa is replacing many of the anti-shark nets with baited drumlines, which are not associated with marine mammal bycatch. Monitoring of southern right whale mortality related to a variety of anthropogenic factors was conducted in South Africa between 1963 and 1988. Entanglement scars (appearing as white lines) were observed on the peduncle at the base of the flukes of most photographed individuals, indicating that bycatch likely poses a major threat to the species in this region (Best *et al.* 2001).

Mozambique
Interview surveys with fishermen have confirmed that humpback dolphins are caught in the drift gillnet fisheries in Mozambique coastal waters (Guissamulo and Cockcroft 1997). However, no recent studies have been conducted, and the scale and population consequences of gillnet entanglement in Mozambique are unknown.

Tanzania (including Zanzibar)
Cetaceans have been recorded as bycatch in gillnets at sites around Unguja (Zanzibar) and Pemba Islands, in the Zanzibar Channel, and along the entire coast of Tanzania (Amir *et al.* 2002, Braulik *et al.* 2017). A total of 573 interviews were conducted with fishermen from all coastal provinces on the Tanzania mainland as well as the islands of Pemba and Unguja. In total, 17.4% of gillnetters reported that they had caught dolphins in the last calendar year and,

based on this, an estimated national bycatch rate of 0.17 dolphins per gillnet boat per year was calculated. The highest reported bycatch rate was in the Pemba Channel, with 0.24 dolphins per gillnet boat per year, almost five times higher than the lowest reported rates in Dar es Salaam and Mafia/Rufiji, which were 0.05 and 0.04 dolphins per boat per year, respectively. In general, the bycatch rate on the islands of Pemba and Unguja, collectively 0.24 dolphins per gillnet boat per year, was two and half times greater than from the mainland Tanzania coast (0.10 dolphins per gillnet boat per year; Braulik *et al.* 2017).

The level of dolphin bycatch in artisanal bottom-set and drift gillnet fisheries was investigated using a questionnaire-based survey administered to 101 gillnet vessel operators from 10 villages around Zanzibar (Amir *et al.* 2002). A total of 96 dolphins was reported to have been incidentally caught between 1995 and 1999: 43 Indo-Pacific bottlenose dolphins, 29 spinner dolphins *Stenella longirostris*, 5 Indian Ocean humpback dolphins and 19 unidentified dolphins. This study suggested that the incidental mortality of delphinids in Zanzibar gillnet fisheries was high enough to cause declines in local populations (Amir *et al.* 2002). The high level of bycatch on the northern side of Zanzibar seems to be related to the scale of driftnet fishing effort in this zone.

A study was also conducted to evaluate the magnitude of bycatch in Menai Bay off the south-western coast of Zanzibar during 2003/2004 (Amir 2010). Data collected by on-board observers indicated high bycatch rates relative to the small local population sizes of humpback and bottlenose dolphins. The annual bycatch rates represented mortality of 9.6% and 6.3% for Indo-Pacific bottlenose and humpback dolphin populations respectively. These rates raised serious concern about the populations of these two species (Amir 2010). The recorded bycatch rates in Menai Bay were confirmed during a trial in 2007/2008 testing the effectiveness of acoustic alarms (pingers) to reduce bycatch in the gillnets (Amir 2010).

Kenya

Cetacean bycatch is currently undocumented along the Kenya coast and gillnets are prohibited in many places. However, bycatch is expected to occur in areas where gillnets are used (e.g. Bofa, Tenewi Ziwayuu and Manda regions; Kenya Marine & Fisheries Research Institute, unpublished data). There are anecdotal reports of dolphin bycatch off Kenya, involving Indian Ocean humpback and Indo-Pacific bottlenose dolphins (N. Wambiji, personal communication). Although the extent of marine mammal bycatch in Kenya is unknown, it is likely to occur due to the extensive use of gillnets (Kiszka *et al.* 2009).

Union of the Comoros

The frequency of cetacean bycatch around the Comoros is considered to be low. Artisanal longlining is the primary gear responsible, and recent interview surveys suggest that spinner dolphins are the most frequently captured species. Other species that are bycaught may include bottlenose and Risso's dolphins (Poonian *et al.* 2008). These data may be inaccurate given uncertain species identification, as some species identified as bycatch have never been recorded during boat surveys around the Comoros (Kiszka *et al.* 2010b).

Mayotte (France)

During an interview survey in 2007 (n=406), only ten fishermen declared that they had caught a cetacean (all were dolphins). Gears involved were gillnets, hand lines and longlines (Pusineri and Quillard 2008). The species involved were thought to be Indo-Pacific bottlenose, spinner and pantropical spotted dolphins. There is evidence for interactions between Indo-Pacific bottlenose dolphins and the hand-line fishery, as well as between short-

finned pilot whales (and possibly melon-headed whales *Peponocephala electra*) and the pelagic longline fishery. Injuries on the dorsal fin region have been documented in these species, and would likely be due to interactions with these fisheries (Kiszka *et al.* 2008). Gillnet gear has also been observed on migrating humpback whales in Mayotte on at least two occasions although no deaths have been observed to date (Kiszka *et al.* 2009). Overall, based on the small numbers reported, it is assumed that bycatch in Mayotte currently has a low impact on these cetacean populations.

Madagascar
Gillnets reportedly capture dolphins, whales and dugongs (*Dugong dugon*) off many villages along the north-eastern, south-western, western and north-western coasts of Madagascar (Andrianarivelo 2001; Kiszka *et al.* 2009; Razafindrakoto *et al.* 2004; Cerchio *et al*. 2015; Kiszka 2015). A project initiated in 2005 to evaluate the extent of bycatch in artisanal fisheries in the south-western region involved a total of 111 interviews with fishermen, resulting in reports of 56 bycatch events between 2000 and 2005 (Razafindrakoto *et al.* 2004). Indian Ocean humpback, Indo-Pacific bottlenose, spinner, and Fraser's dolphins *Lagenodelphis hosei* and humpback whales have been reported as bycatch in gillnets in Madagascar (Andrianarivelo 2001; Razafindrakoto *et al.* 2004). Bottlenose and spinner dolphins represented 48% and 32%, respectively, of the total reported cetacean bycatch between 2000 and 2005 (Razafindrakoto *et al.* 2008). Coastal dolphin surveys conducted in the southwest (Anakao) revealed low encounter rates and mean group sizes, and markedly declining trends in both from 1999 to 2013. Conversely, in the northwest (Nosy Be and Nosy Iranja), encounter rates were higher, as were mean group sizes, suggesting a greater impact of dolphin hunting and bycatch in the southwest (Cerchio *et al.* 2015).

Seychelles
No marine mammal catches have been officially recorded as bycatch in coastal fisheries of the Seychelles (Kiszka *et al.* 2009).

La Réunion
There is a minimal incidence of cetacean bycatch reported around La Réunion. Bycatch has been recorded mainly in the gamefish sport-fishery that uses troll-lines (Kiszka *et al.* 2009). Depredation in the longline fishery is known to occur, involving Risso's dolphins (on bait), false killer whales (on catch), and short-finned pilot whales (on both bait and catch), but very few cases of bycatch of these species have been reported (Kiszka 2015). Captures of Indo-Pacific bottlenose dolphins in beach-seine nets have been reported, although this appears to be rare. Hook injuries and dorsal fin disfigurements due to fishing lines have been recorded for spinner, Indo-Pacific bottlenose, and common bottlenose dolphins; however, no deaths have been documented to date (Globice Réunion, personal communication).

Mauritius
No cetacean bycatch information has been published for Mauritius, but bycatch might be rare (Kiszka *et al.* 2009; Kiszka 2015).

Ongoing initiatives to assess and mitigate bycatch

Coastal gillnet fisheries
In the early 2000s, a survey using independent observers was conducted off the south coast of Zanzibar (Menai Bay) to estimate coastal dolphin bycatch (principally *T. aduncus* and *S.*

plumbea) in drift and bottom-set gillnets (Amir 2010). The project covered 24% of the fishing effort and the estimated total bycatch represented 9.6% and 6.3%, respectively, of the estimated local Indo-Pacific bottlenose and Indian Ocean humpback dolphin populations (Amir 2010). These bycatch levels were considered unsustainable. In 2007 and 2008, another project aimed to assess the effectiveness of acoustic alarms (Fumunda FMDP-2000 pingers) in reducing dolphin bycatch. Pingers reduced the bycatch of dolphins in both drift and bottom-set gillnets. However, the reduction was only significant in the drift gillnets (Amir 2010).

In 2015, the BYCAM project, funded by the Western Indian Ocean Marine Science Association (WIOMSA), was initiated in several countries of the East Africa region, including Madagascar, Mozambique, Tanzania (Zanzibar), and Kenya. The aim of this project is to assess bycatch and develop methods for mitigation of non-target megafauna bycatch (retained or discarded) in artisanal, small-scale commercial and semi-industrial fisheries in the WIO. The project focuses on three types of fisheries with known bycatch: prawn trawls, coastal longlines, and gillnets (drift and bottom-set). Several approaches are being used to assess the magnitude of bycatch, including observer programs (drift gillnet boats in Zanzibar, prawn trawlers in Kenya), landing-site data collection (Madagascar, Zanzibar and Kenya) and interview surveys (Mozambique, Madagascar, Zanzibar and Kenya). In addition, field-testing of new low-cost mitigation devices has been initiated in Zanzibar and Kenya, particularly to reduce dolphin bycatch in drift and bottom-set gillnets. Results of the experiments will be available in 2018.

Open-ocean tuna fisheries
Pelagic longline and purse seine fisheries have been monitored for several decades in the Indian Ocean, but relatively limited data have been collected on their interactions with cetaceans (but see Escalle *et al*. 2015). No dedicated program to mitigate interactions is known.

Conclusions

There is a clear need for greater inter-governmental and inter-organizational collaboration to accurately assess and address cetacean bycatch in Indian Ocean fisheries, including offshore tuna gillnet fisheries that are not addressed in this report (but see Anderson 2014). The gillnet bycatch may have had, and may continue to have, a major impact on cetacean populations in the Indian Ocean (Anderson 2014). Current protections for cetaceans in the Indian Ocean are patchy at best. The International Whaling Commission (IWC) established the Indian Ocean Sanctuary in 1979 to protect whales from whaling. The sanctuary still exists, but currently does nothing to mitigate fisheries bycatch, a significant modern threat to all cetaceans. The Indian Ocean Tuna Commission (IOTC) has established a Working Party on Ecosystems and Bycatch (WPEB) but this group's work to date has focused primarily on sharks, sea turtles, seabirds, and non-targeted large pelagic fish despite clear concerns about cetacean bycatch. While the IWC is limited in its ability to influence fishing practices, a bycatch mitigation initiative is ongoing and includes plans to collaborate with other intergovernmental organizations. Among the recommendations of the IWC Scientific Committee at its 2017 annual meeting were the following (IWC 2017):

- Designate bycatch in the Western, Central and Northern Indian Ocean as a priority topic for a future annual meeting, either in 2018 in Slovenia or in 2019 in Kenya, part

of the affected region. Through this, the IWC should encourage member states and scientists to increase research and data collection efforts to assess and monitor fisheries bycatch of cetaceans in the region, in both industrial (open-ocean) and small-scale (more coastal) fisheries.

- Support the IOTC to encourage and help member states more effectively implement the UN and IOTC resolutions banning large-scale, high-seas drift-net fishing (nets greater than 2.5 km in length).
- Support the IOTC and other regional bodies in efforts to implement cetacean bycatch data collection and reporting protocols.

Given the limited data, improvements in bycatch data collection, particularly in pelagic longline, tuna drift gillnet (likely the most significant tuna-related issue), and purse-seine fisheries in the Indian Ocean are greatly needed. The IOTC's planned production and distribution of identification cards to improve species identification onboard vessels should have a positive effect on data collection and reporting. Efforts to achieve a better understanding of the drivers of tuna-cetacean associations are also strongly recommended, particularly so that it will be possible to predict the spatial and temporal dynamics of these associations.

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