Cetaceans in the tuna drift gillnet fishery off Pakistan (Arabian Sea): can we reduce bycatch at low cost with no impact on targeted species catch rates?

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Abstract
Bycatch is the most significant threat to cetacean populations worldwide. Therefore, assessing and identifying bycatch mitigation measures is critical for cetacean conservation and management. Here we provide the first assessment of cetacean bycatch in tuna drift-gillnet fisheries in the Arabian Sea. Using a network of trained captains (four 15-20 m vessels), targeted-catch (tunas) and bycatch data were collected systematically from 2013 to 2017. Over the study period, a total of 3,874 drift-gillnet sets was monitored. Two fishing methods using multifilament gillnets were used: surface and subsurface gillnets. Surface gillnets were deployed at the surface, whereas subsurface gillnets were deployed at 2 m below the surface; net height varied from 10 to 14 m). A total of 203 cetacean captures were recorded (0.04% of all catch). A total of seven species of cetaceans was recorded as bycatch, including spinner dolphin (*Stenella longirostris*), common bottlenose dolphin (*Tursiops truncatus*), common dolphin (*Delphinus delphis*), striped dolphin (*Stenella coeruleoalba*), pantropical spotted dolphin (*Stenella attenuata*), Risso's dolphin (*Grampus griseus*), dwarf sperm whale (*Kogia sima*) and an unidentified baleen whale (*Balaenoptera* spp., probably *Balaenoptera edeni*). Catch per unit of effort (CPUE) were calculated for both targeted species and cetaceans, and were also compared between the two fishing methods used. Overall, tuna CPUE in surface and subsurface gillnets were not significantly different, whereas cetacean bycatch was significantly higher in surface gillnets. Cetacean bycatch has become a major issue in the northern Indian Ocean because drift-gillnet fisheries are expanding in the region. Although this study should be improved in its spatial extent and use of other monitoring methods (e.g., electronic monitoring systems), the conclusions reached here are sufficient to recommend subsurface gillnet deployments as a precautionary solution.

Introduction

Marine megafauna bycatch, including marine mammals, sea turtles, seabirds and elasmobranchs, is one of the main threats to these taxa worldwide (e.g., Lewison *et al.* 2004, Read *et al.* 2006). These taxa are particularly vulnerable due to their late maturity and low reproductive rates. Additionally, many marine mammal populations are small and demographically isolated, and therefore even small numbers of bycatch annually may be sufficient to cause long-term, potentially terminal, population declines. The magnitude of cetacean bycatch in the Indian Ocean region is poorly known, and limited research has been conducted so far in small-scale coastal (but see Kiszka *et al*. 2009, Temple *et al*. 2018) and industrial open-ocean fisheries (e.g., Anderson 2014, Escalle *et al.* 2015). Some bycatch is known to occur in most fisheries, and it is likely the leading cause of the decline of some populations of coastal cetaceans (e.g., Kiszka 2015, Cerchio *et al.* 2015). Tuna fisheries, both industrial and small-scale, are of major socioeconomic importance throughout the Indian Ocean. Industrial tuna fisheries are dominated by purse-seines and pelagic longlines, whereas artisanal tuna fisheries involve the use of handlines, poles-and-lines, and gillnets. Over the last two decades, there has been an increasing number of studies suggesting that cetacean bycatch rates are low in industrial tuna fisheries in the Indian Ocean, particularly in purse-seine and pelagic longline fisheries (Poisson *et al.* 2001, Romanov 2002, Huang and Liu 2010, Sabarros *et al.* 2013, Escalle *et al.* 2015, Kiszka 2015 for a review). Conversely, gillnet fisheries are known to have a high impact on cetacean populations throughout their range (e.g., Lewison *et al.* 2004, Reeves *et al*. 2013). In the Indian Ocean, gillnet fisheries (primarily bottom set and drift gillnets) are known to have a significant impact on coastal marine mammals (e.g., Kiszka *et al.* 2019, Kiszka 2015, Moazzam and Nawaz 2014, Temple *et al.* 2018). Off Zanzibar (Tanzania), the rate of incidental dolphin capture is unsustainable for Indo-Pacific bottlenose (*Tursiops aduncus*) and Indian Ocean humpback (*Sousa plumbea*) dolphins (Amir 2010).

There is currently an urgent need for proper documentation, monitoring and assessment at the regional level of gillnet fisheries and affected megafauna in order to inform evidence-based fisheries management (Kiszka *et al.* 2009, Temple *et al*. 2018). The number of gillnet fishing boats has been increasing for several years in the Indian Ocean (Aranda 2017), likely due to the low cost of operating gillnets compared to other gear types. Since gillnets are likely to have a major impact on marine megafauna such as cetaceans, it is critical to implement monitoring of targeted captures and bycatch in these fisheries. In this context, beginning in 2013, WWF-Pakistan implemented a monitoring program on 4 tuna drift-gillnet boats off the coast of Pakistan, and trained five of their captains to collect data. During monitoring, possible mitigation methods to reduce air-breathing species bycatch (primarily sea turtles and cetaceans) were discussed. A possible solution was discussed with fishermen based on empirical observations of bycatch. Since bycatch of these species were observed mostly in the upper section of the net, fishermen suggested setting the net 2 meters deeper. Sets at the surface (surface deployments) and those set deeper (subsurface deployments) were monitored throughout the study period.

This report presents information on cetacean bycatch composition and rates in tuna drift drift-gillnet fisheries in Pakistan, and assesses the effectiveness of subsurface deployment as a possible solution to mitigate cetacean bycatch in tuna drift gillnet fisheries.

Materials and methods

Tuna drift-gillnet fishery in Pakistan

Off Pakistan, tuna are caught mainly by using pelagic drift gillnets made of multifilament nylon. It is estimated that more than 500 fishing boats are exclusively engaged in tuna fishing. Most of these vessels operate from Karachi harbor; others operate on the west coast from Gwadar. In this study we sampled four 15-20 m wooden vessels (five captains) operating from Karachi harbor. Net lengths on the sampled vessels ranged from 4000 to 7000 m. Such nets are normally placed at the surface, 10 – 14 m deep, and have a stretched mesh size of 13 to 17 cm. The net is usually set in early morning, hauling starts after 12 hours, and it takes about 2-3 hours on average to haul the net. Sampled vessels operate mostly in the north-eastern Arabian Sea. Fishing operations were confined to the continental shelf off the Indus canyon and along the Balochistan coast (Fig. 1).

Data collection

Training the five captains was critical to the success of the study. Species identification guides of the Indian Ocean Tuna Commission were prepared in the local language (Urdu) by WWF-Pakistan. The captains were trained to document any capture (targeted, non-targeted, including fish, marine reptiles, marine mammals, invertebrates, etc.). During each trip, they recorded fishing hours, position of gillnet sets, the length of net deployed and fishing method (either surface or subsurface net deployment). Gillnet sets had an average duration of 12 hours. The captains were provided digital cameras (to confirm species identification), global position system (GPS) devices and data recording templates based on Indian Ocean Tuna Commission (IOTC) requirements.

Data analysis

Captures per unit of effort (CPUE), in numbers per kilometers of net fished, were calculated and compared between taxa and fishing methods using the following formula:

$$\text{CPUE} = \frac{\text{Number of captures}}{\text{net length (km)* number of sets}}$$

A Pearson's chi-squared test was used to compare captures between surface and subsurface deployments. In addition, a zero-inflated negative binomial regression was used to investigate the effects of fishing method, year, season and captain on CPUE.

Results

Fishing effort

From 2013 to 2017, a total of 3,874 drift-gillnet sets were monitored. Sets were distributed throughout the Pakistani, Iranian and Indian EEZs, as well as in international waters (Fig. 1). Sets were distributed over continental shelf, slope and deep oceanic waters.

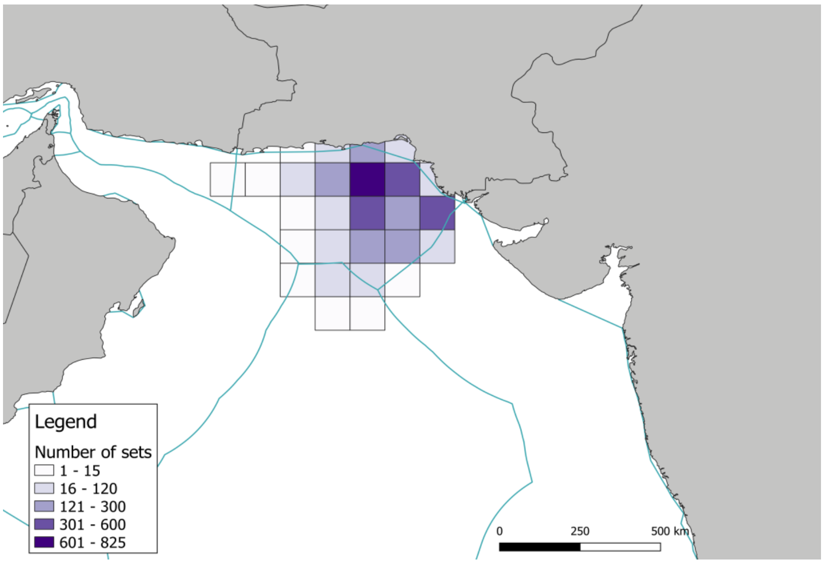

Fig. 1: Tuna drift gillnet fishing effort (number of sets per 1° cell) off Pakistan from 2013 to 2017.

Species composition

Over the course of the monitoring, cetacean species identification was based on photographs collected by boat captains (Fig. 2). A total of 203 cetaceans were captured, but only 45 individuals could be identified at the species level and one at the family level (Fig 3).

Fig. 2: Photographs collected by boat captains for species identification purposes: a- juvenile common bottlenose dolphin (*Tursiops truncatus*), b- spinner dolphins (*Stenella longirostris*), c- common dolphin (*Delphinus delphis*) and d- Risso's dolphin (*Grampus griseus*).

Overall, identified species were, in order of occurrence, spinner dolphin (*Stenella longirostris,* 67%), common bottlenose dolphin (*Tursiops truncatus*, 11%), common dolphin (*Delphinus delphis*, 8%), Risso's dolphin (*Grampus griseus*, 5%), pantropical spotted dolphin (*Stenella attenuata*, 3%), dwarf sperm whale (*Kogia sima*, 3%) and an unidentified baleen whale (*Balaenoptera* spp., probably *Balaenoptera edeni*, 3%). Another species, the striped dolphin (*Stenella coeruleoalba*), was also identified based on anecdotal reports but no data were collected on the species.

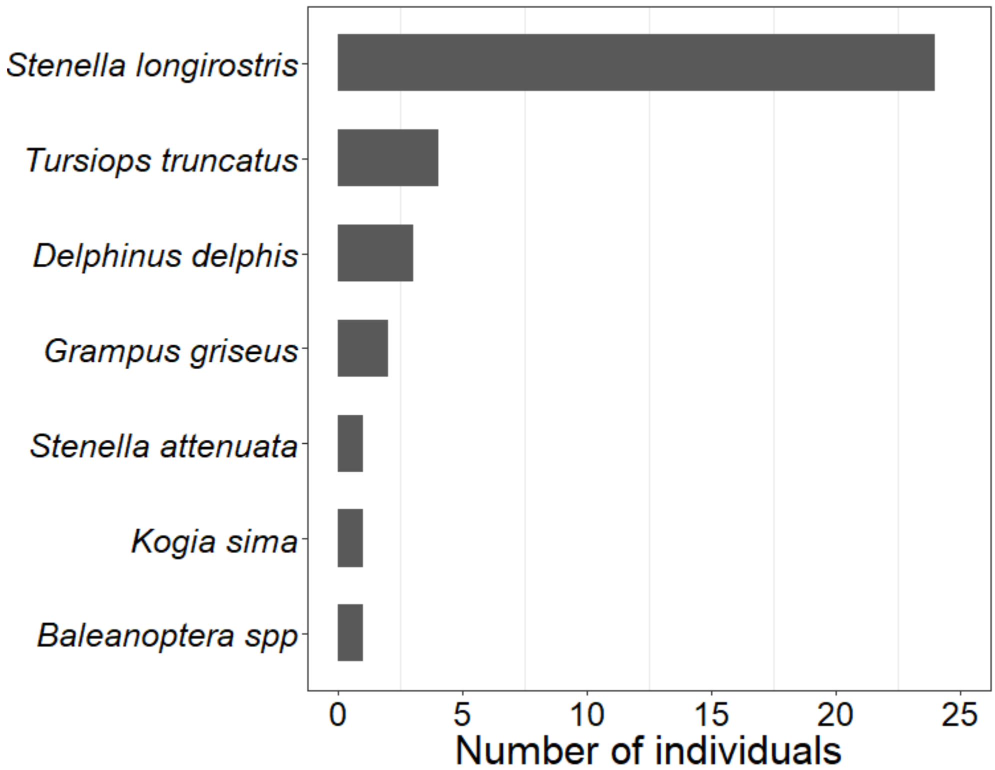

Fig. 3: Species of cetaceans incidentally captured in tuna drift gillnets off Pakistan from 2013 to 2017.

Influence of fishing method on CPUEs

Tuna accounted for 60.3% of the total catch (number of individuals), while cetaceans made up just 0.04%. Tuna CPUE in surface and subsurface gillnets was not significantly different ($\chi^2 = 3.423$, df = 1, $p > 0.05$; Fig. 3a), whereas cetacean bycatch was significantly higher in surface than in subsurface gillnets ($\chi^2 = 69.18$, df = 1, $p < 0.001$; Fig. 3b).

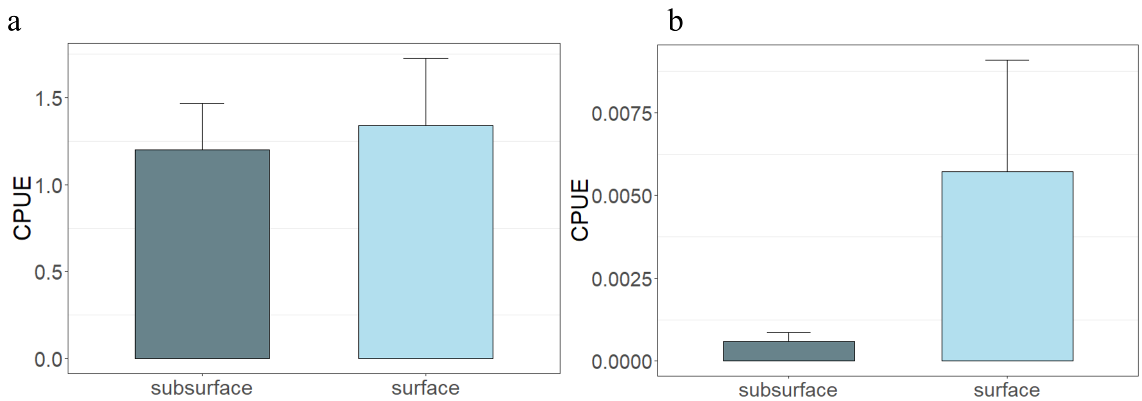

Fig. 3: Tuna (a) and cetacean (b) CPUE in subsurface and surface drift gillnets.

Discussion

This study provides the first assessment of cetacean bycatch in a tuna drift-gillnet fishery in the Arabian Sea. A number of species were bycaught, particularly small delphinids, but also other toothed cetaceans as well as baleen whales. Further analyses are underway to extrapolate the number of cetaceans captured in tuna drift-gillnet fisheries to the fleet level in Pakistan. However, without information on the abundance of cetaceans in the waters of Pakistan, no assessment of the impact of gillnet bycatch in terms of sustainability is possible.

The major result of this study is an indication that slight changes in fishing practices can reduce the rate of incidental captures of cetaceans, without having a significant effect on catch rates of targeted species. The subsurface deployment of drift gillnets significantly reduced cetacean bycatch rates off the coast of Pakistan. Underlying factors will be investigated in the future. A precautionary approach would be to encourage fishermen to deploy gillnets at least 2 meters deeper in order to reduce cetacean bycatch. The monitoring of tuna drift gillnet bycatch was expanded in 2018, and 75 boats (at least 15% of the fleet) are now being monitored. Using electronic monitoring should improve species identification and data quality more generally. Dedicated surveys to obtain estimates of cetacean abundance are being considered, which should make it possible to assess the impacts of bycatch on cetacean populations in this region.

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