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Spatially-explicit risk assessment of interactions between marine megafauna and Indian Ocean tuna fisheries

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Abstract:	Bycatch is likely the most significant direct threatening process marine megafauna face at the global scale. However, the magnitude and spatial patterns of marine megafauna bycatch are still poorly understood, especially in regions where monitoring has been very limited and where fisheries are expanding. The Indian Ocean, for example, is a globally important region for tuna fisheries and has limited bycatch data. Anecdotal and scattered information indicates high bycatch could be a major issue. Here, we develop a risk assessment framework designed for

	data-poor contexts to present the first spatially explicit estimates of bycatch risk of sea turtles, elasmobranchs and cetaceans in Indian Ocean tuna fisheries. Our assessment of the three major tuna fishing gears (purse seines, longlines, driftnets) highlights a potential opportunity for multi-taxa benefits by concentrating management efforts in particular coastal regions. The vast majority of coastal waters in the northern Indian Ocean, including countries that have had minimal engagement with regional management bodies (e.g., Myanmar, Bangladesh) stand out as a region with potentially high mortality. In addition to species known to occur in tuna gears, we find high expected mortality from multiple gear types for many poorly known elasmobranchs that do not fall under any existing conservation and management measures. Our results show that existing bycatch mitigation measures, which focus on safe-release practices, are unlikely to be effective in reducing the substantial cumulative fishing impacts on threatened and data-poor species. Preventative solutions that reduce interactions with non-target species are crucial for alleviating risks to megafauna from fisheries.

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2. Relative risk of megafauna bycatch in Indian Ocean tuna fisheries
3. Spatially-explicit risk assessment of sea turtles, cetaceans, and elasmobranchs in Indian Ocean tuna fisheries

Running Title: Indian Ocean megafauna bycatch risk

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ABSTRACT:

Bycatch is likely the most significant direct threatening process marine megafauna face at the global scale. However, the magnitude and spatial patterns of marine megafauna bycatch are still poorly understood, especially in regions where monitoring has been very limited and where fisheries are expanding. The Indian Ocean, for example, is a globally important region for tuna fisheries and has limited bycatch data. Anecdotal and scattered information indicates high bycatch could be a major issue. Here, we develop a risk assessment framework designed for data-poor contexts to present the first spatially explicit estimates of bycatch risk of sea turtles, elasmobranchs and cetaceans in Indian Ocean tuna fisheries. Our assessment of the three major tuna fishing gears (purse seines, longlines, driftnets) highlights a potential opportunity for multi-taxa benefits by concentrating management efforts in particular coastal regions. The vast majority of coastal waters in the northern Indian Ocean, including countries that have had minimal engagement with regional management bodies (e.g., Myanmar, Bangladesh) stand out as a region with potentially high mortality. In addition to species known to occur in tuna gears, we find high expected mortality from multiple gear types for many poorly known elasmobranchs that do not fall under any existing conservation and management measures. Our results show that existing bycatch mitigation measures, which focus on safe-release practices, are unlikely to be effective in reducing the substantial cumulative fishing impacts on threatened and data-poor species. Preventative solutions that reduce interactions with non-target species are crucial for alleviating risks to megafauna from fisheries.

Table of Contents

Main text

1. Introduction

Fishing, either targeted or incidental, is the primary threat directly driving population declines and extinction risk for many species of cetaceans, sea turtles, seabirds, and elasmobranchs (Brownell et al., 2019; M. J. Costello et al., 2010; Lewison, Crowder, Read, & Freeman, 2004; Ripple et al., 2019). The risk that fishing poses varies across species, locations, and gear types, but gillnets are associated with high mortality per unit of fishing effort for megafauna globally (Lewison et al., 2004; Read, Drinker, & Northridge, 2006; Reeves, McClellan, & Werner, 2013). Gillnets are a broad category of relatively cheap and simple to operate gear that can be anchored or drifting and are increasingly common in the coastal and continental shelf waters in developing countries (Northridge, Coram, Kingston, & Crawford, 2017). Gillnets are the primary cause of extinction of the baiji (*Lipotes vexilifer*) and the possible extinction of the vaquita (*Phocoena sinus*), and the most significant and increasing threat to a diversity of endangered marine mammals, sea turtles, elasmobranchs, and seabirds (Brownell et al., 2019; Jabado et al., 2018; Lewison et al., 2014; Reeves et al., 2013).

Tuna fisheries are some of the world's most valuable fisheries, with an annual landed value of US$12.2 billion, which comes mostly from industrial purse seine and longline sectors (Rogers et al., 2016). Tuna from the Indian Ocean account for 20% of the global commercial tuna catch (WWF, 2020). The Indian Ocean is unique amongst the world's tuna fisheries because of the large gillnet sectors, especially the expansion of large pelagic gillnets ("driftnets") in addition to more traditional inshore nets (Temple et al., 2018). Gillnets contribute greater catch volumes of tuna than the industrial purse seine and longline sectors in the Indian Ocean, which is atypical compared to the rest of the world's tuna fishing regions (Aranda, 2017). Gillnet vessels target a wide range of species in addition to the 16 tuna and tuna-like species that fall under the mandate of the Indian Ocean Tuna Commission (IOTC), including many elasmobranchs (Jabado et al., 2018). Countries are required to report information about some fishing gears to the IOTC but not about where gillnet fisheries operate or how many vessels are involved (Roberson, Kiszka, & Watson, 2019).

Recently, gillnets (and driftnets in particular) have emerged as a primary concern for marine biodiversity in the region, with one report estimating that 100,000 marine mammals were caught annually in Indian Ocean tuna fisheries between 2004 and 2006 (Anderson et al., 2020). However, there is limited information available about fishing impacts on large marine vertebrates from this region (Anderson et al., 2020; Clarke et al., 2014; Garcia & Herrera, 2018; Lewison et al., 2014), and the many loopholes in the existing regulatory framework result in severely incomplete catch monitoring of these species (WWF, 2020). Limited bycatch data is an issue across all ocean regions, including in many wealthy countries, especially for unselective fishing gears that catch many species (e.g., small or medium-mesh gillnets) and for species that are rarely encountered or difficult to identify (Clarke et al., 2014; Lewison et al., 2014). This problem is amplified in the Indian Ocean, where a comparative study of ecosystem-based management approaches—including bycatch management—rated the IOTC as the worst performing Regional Fisheries Management Organization (RFMO) for tropical tuna (Juan-Jordá, Murua, Arrizabalaga, Dulvy, & Restrepo, 2018). The IOTC faces considerable challenges in managing 31 contracting Parties in addition to massive distant water fleets from Europe and Asia, and compared to the other four tuna RFMOs, it has the most recently developed fisheries, countries with the lowest average per capita GDP, high economic dependency on tuna fisheries, the smallest vessels, and the most vessels (Pons, Melnychuk, & Hilborn, 2018; Sinan & Bailey, 2020).

Previous research shows that fishing—both incidental and targeted—is a primary direct threat to marine megafauna in the Indian Ocean, including sea turtles (Bourjea, Nel, Jiddawi, Koonjul, & Bianchi, 2008; Wallace et al., 2013; Williams et al., 2018), cetaceans (Böhm et al., 2013; Elwen, Findlay, Kiszka, & Weir, 2011), and elasmobranchs (Davidson & Dulvy, 2017; Dulvy et al., 2014; Jabado et al., 2018). Available data suggest that sea turtles are vulnerable to capture in all three tuna gears but have lower mortality in purse seines compared to longlines and gillnets (Williams et al., 2018). Cetaceans are considered to be at greatest risk from drift gillnets, especially small and medium-sized delphinids such as bottlenose dolphins (*Tursiops truncatus*), short-beaked common dolphins (*Delphinus delphis*), and *Stenella* spp. Toothed whales—particularly Risso's dolphin (*Grampus griseus*), false killer whales (*Pseudorca crassidens*), and short-finned pilot whales (*Globicephala macrorhynchus*), depredate longlines but the interactions are less lethal than entanglement in other gears (Clarke et al., 2014; Garcia & Herrera, 2018; Huang & Liu, 2010; Murua et al., 2018; Wallace et al., 2010). Oceanic and pelagic elasmobranchs are the most commonly reported bycatch in all three tuna gears (by numbers of individuals). The most commonly reported species are silky sharks (*Carcharhinus falciformis*) in all three gears; blue sharks (*Prionace glauca*) and oceanic whitetip sharks (*Carcharhinus longimanus*) in both longlines and purse seines; shortfin makos (*Isurus oxyrinchus*) in purse seines and driftnets; pelagic stingrays (*Pteroplatytrygon violacea*) in driftnets and longlines; hammerheads (*Sphyrna* spp) and crocodile sharks (*Pseudocarcharias kamoharai*) in longlines; and whale sharks (*Rhincodon typus*) and pelagic batoids (e.g. Myliobatidae, Mobulidae) in driftnets (Clavareau et al., 2020; Escalle et al., 2015; Garcia & Herrera, 2018; Moazzam, 2012; Murua et al., 2018). Overall, purse seine fleets reportedly have the lowest bycatch rates per unit of fishing effort (especially for cetaceans), lower mortality for sea turtles and cetaceans, and fewer species that are caught in large numbers compared to driftnets and longlines

(Clavareau et al., 2020). However, all the available literature for the Indian Ocean notes the lack of quality data for megafauna bycatch relative to other regions (for all gear types), and there are many contradictory reports. For example, no shortfin makos were reported by purse seines fleets in the IOTC data (Garcia & Herrera, 2018), compared to substantial shortfin mako catch reported in a study of the Spanish purse seine fleet operating in the Indian Ocean (Clavareau et al., 2020).

Evaluating the risk that fishing poses to marine biodiversity requires accurate information about both the threat and the impacted species. Data limited approaches offer a range of options, such as Ecological Risk Assessment (ERA) methods, which have been used extensively to estimate risk in these data-poor contexts, often by incorporating expert knowledge with available quantitative or empirical data (Georgeson et al., 2020; Hobday et al., 2007; Zhou et al., 2013; Zhou, Hobday, Dichmont, & Smith, 2016). Productivity susceptibility analyses—a type of ERA that compares life history characteristics and susceptibility to fisheries catch— have been widely used to estimate potential impact from fisheries for data-poor species (Arrizabalaga et al., 2011; Moore et al., 2013; Murua et al., 2018). Many ERA methods are based wholly or partially on categorical scores (e.g. low, medium, or high overlap with fishing), which is useful in cases with missing or highly uncertain information. However, methods that use categorical scoring may not have sound mathematical principles, leading to many haphazard applications of ERAs and potentially misleading or mathematically flawed results (Baillargeon, Tlusty, Dougherty, & Rhyne, 2020; Hordyk & Carruthers, 2018).

Of the many species reportedly caught in tuna fisheries and in large-scale fisheries more broadly, relatively few are actively monitored and managed by fisheries agencies (C. Costello et al., 2012; Ricard, Minto, Jensen, & Baum, 2012). Species often interact with multiple gears in one area or across their range, and these cumulative impacts are difficult to detect and monitor (Riskas, Fuentes, & Hamann, 2016). Bycatch rates vary across regions due to different environmental conditions, species abundances, and fishing effort dynamics, even for the same species and fishing gear, which means trends from one ocean or region may not be representative of another area (Clarke et al., 2014; Lewison et al., 2014). In general, multi-taxa or multi-gear studies of bycatch species are rare or lack a spatial component, and this gap is particularly glaring for the Indian Ocean (Lewison et al., 2014).

Our goal in this study was three-fold: 1) To estimate the magnitude and location of fishing effort, including driftnets; 2) to quantify the spatially explicit risk to megafauna species across the three major tuna fishing gears; and, 3) to analyse the conservation status of species at risk from fishing. We develop an adaptation of a semi-quantitative ERA method (described in (Hobday et al., 2007; Hobday et al., 2011) that uses ranked probabilities instead of categorical scores to improve estimates of risk and uncertainty.

We apply this method to a data-poor context that is typical of many fisheries and bycatch species, and present the first spatially explicit estimate of risk of mortality across multiple gears and taxa in the Indian Ocean. These results can serve as a baseline to guide regional management organizations such as the IOTC, national governing bodies, and NGOs to better prioritize how and where to invest limited resources in reducing fishing impacts on threatened species.

2. Materials and Methods

2.1 Species distributions and conservation status

We used species distribution maps from AquaMaps (Kaschner et al., 2016, August), which models species-specific envelopes of environmental preference based on occurrence records from published databases and include variables such as temperature, depth, and salinity (Ready et al., 2010). The model estimates a probability of occurrence for each species in each 0.5° grid cell. We first selected all probabilities of occurrence for 405 species (348 elasmobranchs, 51 cetaceans, and six sea turtle species) that the AquaMaps models predict to occur in the upper 400 m depth column within IOTC Area of Competence (hereafter "IOTC Area"), which covers the Indian Ocean (including the Persian Gulf and the Red Sea) to 45° and 55° South in the western and eastern Indian Ocean, respectively**.** Approximately two-fifths of the maps in this subset have been reviewed by experts. We used version 2020-2 of the Red List to assess species' conservation statuses as a fishery-independent indication of species of concern (IUCN, 2020).

2.3 Fishing effort

Reporting of catch and effort is not consistent across the tuna sectors in the Indian Ocean. Countries with fleets targeting tuna are required to report their catch to the IOTC at a maximum spatial aggregation of 1°x1° grid cells for purse seines and 5°x5° cells for longlines (IOTC, 2020). There are fewer requirements for gillnets because they are usually classified as artisanal gears; where gillnet catch or effort are reported, the data may refer to irregular areas (e.g. per port of unloading) (IOTC, 2020). For a standard index of fishing effort across the three gear types, we used a global and spatially explicit model of fishing effort that reports effort in terms of engine power and fishing days (kWdays per year) for each 0.5° grid cell (Rousseau, 2020; Rousseau, Watson, Blanchard, & Fulton, 2019), and we selected all grid cells within the IOTC Area **(**Supplementary Info 1: Fishing effort).

Compared to longline and purse seine gears, there is considerable variability in the characteristics and configuration of gillnets and what species are targeted. A variety of gillnets are used in the Indian Ocean and the country reports rarely include specific information about their gillnet fleets, such as the number of vessels that use gillnets, whether they are bottom-set or drifting, and mesh sizes used. Most fleets using driftnets to target tuna and tuna-like species in the Indian Ocean have a stretched mesh size of 13-17cm (Shahid, Khan, Nawaz, Dimmlich, & Kiszka, 2015). However, these nets can be used to target a variety of other species in addition to tunas, including demersal sharks and rays, Spanish mackerels (Scombridae), catfish (*Arius* spp.), and seabreams (Sparidae), and can be used interchangeably as bottom set gillnets and driftnets depending on the season and target species (Khan, 2017; Shahid, Khan, Nawaz, Abdul Razzaq, & Ayub, 2016). Vessels also frequently use multiple gears in combination, such as drift gillnets with snoods attached along the lead line or nets hung between pelagic longlines, which further complicates estimates of fishing effort (Henderson, McIlwain, Al-Oufi, & Al-Sheili, 2007; Jabado & Spaet, 2017; Winter et al., 2020; Yulianto et al., 2018). The catch data reported to the IOTC does not distinguish between larger, offshore driftnets primarily targeting tuna and smaller inshore drift or set gillnets. To overcome associated challenges of estimating gill and driftnet fishing effort and to focus on boats more likely using driftnets, we first removed all unpowered vessels and vessels in power categories 1 and 2, leaving only vessels >25 kW (approximately 35 HP). Second, we conducted a literature review and removed gillnet effort from countries with no reported drift gillnet fleets operating in the Indian Ocean (Supplementary Table 1). Finally, we corrected for spatial skewness by adjusting outlier cells and scaled the fishing effort from 0-1 (Supplementary Info 1: Fishing effort). The resulting value represents a relative probability that fishing occurs in each grid cell.

2.4 Risk Assessment

To compare risks to species across the three tuna fishing gears, we used a semi-quantitative ecological risk assessment (ERA) that incorporates expert judgment where empirical data are not available (Hobday et al., 2007; Hobday et al., 2011). This method is designed to assess risk when information is missing or highly uncertain, such as the Indian Ocean where there is limited information for both species (e.g. distribution, abundance, habitat preferences) and fishing (e.g. intensity and location). We adapted this method to use ranked probabilities instead of discrete scales (e.g. low, medium, high or 1, 2, 3), which is the typical approach used in earlier iterations of the method.

This ERA method expresses risk in terms of a relative probability of capture and a range of possible outcomes for an individual animal based on species and gear attributes (the per capita vulnerability). It is essentially the first half of a Productivity Susceptibility Analysis (PSA), which estimates a threat's potential impact on a species or population. A PSA incorporates information about the species' productivity (factors that influence the intrinsic rate of increase, such as reproductive rate, lifespan, and biomass) as well as its susceptibility to fisheries mortality (likelihood of encountering and entangling in fishing gear) to estimate the damage that fishing could cause to a species or population (Hobday et al., 2007). The biological information needed for the productivity component of the PSA is not available for most species in our focus subset; therefore, we limit this analysis to the estimated mortality in fishing gears (the susceptibility component).

The model estimates the per-capita risk of capture, injury or mortality in a fishing gear by generating a function where; “availability” (A) is the horizontal overlap of the species and the fishing gear, “encounterability” (E) represents the vertical overlap of the animal and the gear in the water column, and “selectivity” (S) is the specificity of the gear to capture an animal of a certain size, shape, swimming style, and foraging behaviour, and lethality is the potential outcome if the animal is entangled. The first three parameters are probabilities and the product is the relative probability of capture. The lethality is estimated as an interval indicating the range of outcomes if the animal were captured (or, "how bad is it?"). The final score can be interpreted as “expected mortality” and has an upper and lower bound:

$$Expected\ mortality_{(i,\,min)} = A\ x\ E\ x\ S\ x\ lethality_{(lower\ bound)}$$
$$Expected\ mortality_{(i,\,max)} = A\ x\ E\ x\ S\ x\ lethality_{(upper\ bound)}$$

where i = an individual animal, A = availability, E = encounterability, and S = selectivity.

To calculate availability, we converted the fishing effort and species’ distribution maps to raster files, then multiplied the probability of occurrence for each species and the scaled fishing effort value in each grid cell using the Raster Calculator Tool in ArcMap 10.8. The resulting values are proxies for density of animals and fishing gear (assuming more fishing gear in high effort cells and more animals present in a cell with a high probability of occurrence). In this per-capita framing of risk, the availability represents the probability that an individual animal and fishing gear are both present in that cell.

$$Availability_{(cell)} = P(species\ occurs) * P(fishing\ occurs)$$

This calculation of availability does not account for temporal variability (e.g. diurnal vertical migrations, time of day of fishing operations), seasonal variability (e.g. annual migrations, shifting fishing effort around the monsoon season), or ontogenetic shifts of species (e.g. sea turtles and many elasmobranchs have juvenile phases with distinct life histories). These assumptions lead to overestimations of risk where the actual overlap between fishing and animals is lower than predicted, and underestimations of risk where overlap is greater than predicted because seasonal or diurnal densities coincide.

To estimate encounterability (vertical overlap), we conservatively assumed all gears are deployed from the surface to 20 m for drift gillnets (Aranda, 2017), 280m for purse seines (Romanov, 2002), and 400 m for longlines (Song et al., 2009). For species' depth ranges, we used depth ranges from the AquaMaps model and adjusted depths for 46 species (38 cetaceans, two sharks, and six sea turtle species) based on available empirical information (Supplementary Info 2: Species information). We then calculated the overlapping depth range for each species and gear types, assuming that both species and fishing gears were evenly distributed throughout the overlapping range and that the overlap was the same across all cells. This assumption leads to underestimates of catchability for species and gears that more often concentrate in the same shallow portion of their depth ranges, and overestimates the catchability for species that spend more time at depths beyond the range where most of the fishing effort is concentrated (for example, many demersal-associated elasmobranchs are less likely to encounter tuna gears than the depth overlaps suggest).

$$Encounterability_{(species,\, gear)} = \frac{overlapping\ depth\ range}{species\ depth\ range}$$

Less empirical information is available for the third parameter of gear selectivity because relatively few studies have quantified the likelihood of entanglement in fishing gears independent of species abundance and fishing effort. We compiled a database of the 405 species and used information from additional sources (i.e. peer reviewed publications and grey literature) to group species according to life history traits that lead to a similar propensity for entanglement and mortality in fishing gear. We considered a variety of factors including body size and shape, adult habitat use and occupancy in the water column, foraging ecology, and attraction to Fish Aggregating Devices (FADs) (Table 1, Supplementary Table 5**).** Elasmobranch species that occupy a variety of habitats and depths are grouped into 'generalist' categories (e.g. tiger shark, *Galeocerdo cuvier*, 'pelagic elasmobranchs'). We conservatively assumed that all purse seines are fishing around FADs, which has become the dominant (although not universal) practice in Indian Ocean tuna fisheries (Davies, Mees, & Milner-Gulland, 2014). Purse seine sets on FADs have bycatch levels approximately three times those on free-swimming sets, in addition to capturing more species (Davies et al., 2014; Lezama-Ochoa et al., 2015). We then ranked the species groups (allowing ties) by the likelihood of entanglement in each gear type, if encountered, allowing species to receive individual selectivity ranks. For example, humpback whales (*Megaptera novaeangliae*) are more often recorded entangled in gillnets compared to other baleen whales, and thus were ranked higher for that gear (Johnson et al., 2005). We then randomly generated probabilities for each rank using an order-preserving Monte Carlo process in R and allowing ties.

The probability of capture is the likelihood of the event occurring. The second component of the estimate of risk is the severity of the outcome, if the event occurs. We assume the interaction is lethal unless the animal is able to escape, as there is insufficient information about compliance with safe release practices in the Indian Ocean (Zollett & Swimmer, 2019). Releasing entangled animals is usually ineffective for gillnets because they are static and typically deployed overnight, so air-breathing species or elasmobranchs that need to swim to breathe are likely to drown (Zollett & Swimmer, 2019). Pelagic longlines allow hooked animals to move but are usually set at depth and can also have long set times (usually more than 12 hours and sometimes more than 24 hours) (W. Chen, Song, Li, Xu, & Li, 2012; Clarke et al., 2014) and survival rates are highly variable for individuals that are successfully released (Carruthers, Schneider, & Neilson, 2009). Compared to longlines and gillnets, survival rates of species released from tuna purse seines are expected to be higher for sea turtles and cetaceans, although studies are lacking (Escalle et al., 2015; Hamilton & Baker, 2019; Zollett & Swimmer, 2019). Studies suggest much lower post-release survival rates for pelagic elasmobranchs caught in purse seines (Eddy, Brill, & Bernal, 2016).

Once entangled, the severity of the outcome depends on physical characteristics of the animal, reflecting its ability to escape. We assigned an interval for the lethality of the outcome to each group based on available empirical information for species within that group (Table 2), allowing out-of-group intervals for species where available empirical data suggest they differ from their species group in terms of the lethality of entanglement. For example, blue whales are large enough to break through drift gillnets more easily than other baleen whales. We assumed that all longline fleets use monofilament leaders, which are easier for larger species to break compared to wire leaders (Gilman, 2011). However, vessels that are targeting (or sub-targeting) sharks will likely use wire leaders and there is no comprehensive information about targeting dynamics across the wide variety of longline fleets operating in the region (Ardill, Itano, & Gillett, 2013). Following the ERA principle of precautionary scoring, we assigned the more conservative lethality interval where empirical data were lacking (Hobday et al., 2007).

From the three probabilities calculated above, we calculated the probability of capture and expected mortality intervals for each species and gear type in each grid cell:

$$Catchability_{(cell)} = Availability_{(cell)} * Encounterability * Selectivity$$

$$Expected\ mortality_{(min)} = Catchability_{(cell)} * Outcome_{(lower\ bound)}$$

$$Expected\ mortality_{(max)} = Catchability_{(cell)} * Outcome_{(upper\ bound)}$$

We then calculated the mean catchability and expected mortality intervals for each species across all cells where it occurred within the IOTC area and the percent overlap of each species and gear (a rough indicator of exposure to fishing, at least in the horizontal dimension).

3. Results

3.1 Species catchability and conservation status

Of the 405 species included in this study, 367 (91%) were catchable in at least one of the three gears examined. The species ranking highest for mean catchability across the three gears are all shallow shelf elasmobranchs, pelagic generalist elasmobranchs, or shallow inshore dolphins and porpoises, with three sea turtle species also scoring in the top 25 species (Figure 1**,** Table 3). The three species with the highest cumulative catchability scores are the slender weasel shark (*Paragaleus randalli*), Human's whaler shark (*Carcharhinus humani*), and Grey sharpnose shark (*Rhizoprionodon oligolinx*) (Table 3). In general, the species with the highest cumulative catchability scores have wide ranges and inhabit offshore pelagic regions, such as *Alopias* spp*., P. violacea, Sphyrna* spp*., C. longimanus,* and *C. falciformis.*

Many of the species with the highest cumulative catchability scores are listed as threatened by the IUCN or have an unknown conservation status (Figure 1**,** Table 3). Overall, more than a quarter (27%) of the catchable species are threatened, with 5% (17) Critically Endangered, 8% (30) Endangered, and 14% (52) Vulnerable. The groups containing fewer species have the highest proportions of threatened species, with seven out of nine (78%) filter feeder elasmobranchs, five out of six (83%) sea turtles, six out of seven (86%) oceanic elasmobranchs, and four out of seven (57%) inshore dolphins and porpoises listed as threatened. Over half (51%) of the catchable species are not threatened (Least Concern or Near Threatened), although one-fifth (21%) are listed as Data Deficient or have not been assessed by the IUCN. Oceanic toothed whales (e.g. *Mesoplodon* spp., *Kogia* spp.) have the highest proportion of Data Deficient species (60%), followed by 36% of deep shelf pelagic elasmobranchs (e.g. *Oxynotus bruniensis, Cirrhigaleus asper*) and 25% of demersal generalist elasmobranchs (e.g. *Squatina* spp*., Raja miraletus*) (Supplementary Table 2). Most sea turtles and cetaceans are listed on CMS or CITES (or both), but most elasmobranchs are not, especially poorly known species and species that are widely targeted by fisheries.

Many species with medium to high mean catchability scores have large ranges that overlap closely with fishing effort, and thus have high cumulative risk across the IOTC Area. For example, *Caretta caretta* has high cumulative catchability in driftnets, *I. oxyrinchus* and *P. glauca* in longlines, *Mobula birostris* and *Stenella longirostris* in purse seines, and *C. longimanus, C. falciformis, P. kamoharai, Alopias* spp.*, Sphyrna* spp. and *P. violacea* in both longlines and purse seines (Supplementary Figures 1-3). Many species with low mean and low cumulative catchability probabilities (e.g. baleen whales) still have a large proportion of their range overlapping horizontally with fishing gears (based on presence-absence of species and fishing), especially with longlines and purse seines (Figure 2). A proportionally large horizontal overlap of a species and gear does not necessarily mean the species is likely to be caught, but does indicate species-gear interactions that could be important over the extent of the species range in the IOTC Area, even if the mean catchability per cell is relatively low.

Overall, the potential for cumulative impacts from multiple tuna gears on species is high. Two-fifths (41%) of the 367 catchable species are catchable in all three gears, 36% are catchable in two of the three gears, and 23% are only catchable in longlines (mostly deep shelf elasmobranchs). The high cumulative expected mortality scores are driven by driftnets, which have high catchability probabilities and lethality outcomes compared to longlines and purse seines, although all gears were conservatively rated as "lethal" for most species (Figure 2 and 3**).** In fact, most of the lethality intervals are not visible in Figure 2 because the species-gear combinations with the highest expected mortality scores were all scored as lethal (except for *M. mobular*). The interactions where species are more likely to escape (potentially lethal, sublethal, or no damage) are primarily cetaceans, sea turtles, and larger elasmobranchs in longlines and purse seines (Supplementary Figure 9). Although less lethal potential outcomes are obviously better for the animal, these interactions also have the widest margin of uncertainty about the level of damage inflicted on the individual, as it is difficult to measure the impacts of fishing interactions on animals that escape.

3.2 Comparison to available bycatch reports

The estimation of expected mortality for individual species is not directly comparable to reported bycatch in Indian Ocean tuna fisheries because available data rarely account for fishing effort (catches are given in total volume or number of individuals, not per unit of fishing), and abundance and density are not known for most non-target species. Therefore, this measure of risk cannot be translated into a total catch estimate for each species. As a rough validation of our results, we compare the ranked probability scores to available bycatch reports and find general agreement at the level of the species group (e.g. sea turtles, pelagic filter feeding elasmobranchs) and for species with high cumulative probabilities of capture

(Supplementary Figure 1, Supplementary Figure 2, Supplementary Figure 3). However, catchability scores were unexpectedly high for many demersal elasmobranchs (e.g. electric rays, guitarfish) in all three gear types. This is a function of the species ranges extending into shelf areas where the gear's possible depth range would extend to the seafloor. In reality, these species are unlikely to encounter pelagic fishing gears because they remain near the sea floor while the gear would be deployed in the pelagic zone.

3.3 Risk across gear types

We selected motorized fishing effort in 2015 in the IOTC Area and found 22 countries fishing with driftnets, 26 countries fishing with purse seines, and 39 countries fishing with pelagic longlines. Longlines have a large footprint and the largest depth range (0-400m and sometimes deeper), although most fishing effort occurs shallower than 300m as deeper sets are only for albacore and bigeye tuna (*Thunnus alalunga* and *T. obesus*) in some fishing grounds (I. C. Chen, Lee, & Tzeng, 2005; Song et al., 2009). Across the IOTC area, longlines are predicted to encounter the most species (n=367), followed by purse seines (n=269) and drift gillnets (n=178) (Figure 3). In general, purse seines and longlines pose the greatest risk to elasmobranchs (pelagic generalists, shallow shelf, and inshore species) and proportionally more small cetaceans are ranked high for driftnets, although driftnets are high-risk for many elasmobranchs as well (Figure 2, Supplementary Table 3). All three gears pose a high risk to sea turtles. Compared to longlines and purse seines, driftnets have fewer high-risk cells and lower cumulative catchability values (Figure 4).

The cumulative threat from the tuna sectors is concentrated in a relatively small proportion of the IOTC area, mostly in coastal regions (Figure 4). Western Indonesia stands out as a high-risk area across all three gears, and there is substantial overlap between fishing and bycatch species in parts of the Red and Arabian Seas as well. Driftnet catchability is high along most of the coastal areas, including regions that have lower cumulative risk from purse seines and longlines (Madagascar, Tanzania, Kenya, Iran, Pakistan, eastern India, Bangladesh, Myanmar, and north-western Australia). Compared to driftnets, high-risk longline and purse seine areas are more dispersed in offshore areas. High purse seine catchability overlaps with driftnets around Sri Lanka, the western coast of India, and in parts of the Arabian Sea. High risk areas in the Southwest Indian Ocean around Seychelles, Mauritius, and Reunion are driven primarily by purse seines.

There is moderate overlap of the highest risk cells in the IOTC Area across fishing gears and species groups (Figure 5). For example, sea turtles have high catchability in driftnets, and most of those high-risk cells also have high catchability for sea turtles in longlines and purse seines. Inshore dolphins and porpoises are most at risk from driftnets, but there is substantial overlap between those high-risk cells and the high-risk cells for other gears and species groups (e.g. sea turtles in all gears and the high-risk elasmobranch groups in longlines and purse seines). Overall, the pattern of high-risk cells is most similar between purse seines and longlines for all elasmobranch groups, except for deep elasmobranchs which are only predicted to encounter longlines.

4. Discussion

High-risk species

The aim of this analysis is to quantify the risk of capture for megafauna species in tuna fishing gears, and the severity of that outcome. We use an ERA method that expresses risk in terms of vulnerability of an individual animal, which can then be summed across the population or geographic areas. The method is not designed to estimate the total number of animals caught in fishing gears, although these point estimates are important communication tools for management and conservation purposes (Anderson et al., 2020; Read et al., 2006).

Our results show that cetacean, sea turtle, and elasmobranch species face substantial cumulative risks from tuna fishing sectors in the Indian Ocean, with driftnets driving the highest catchability scores for individual species. Many species with the greatest expected mortality across their range are listed as threatened on the IUCN Red List and have few protections (Jabado et al., 2018; Pacoureau et al., 2021). We found high risk of capture and mortality for known risk groups such as small cetaceans in driftnets (Anderson et al., 2020; Brownell et al., 2019; Reeves et al., 2013), mesopelagic sharks and rays in longlines and purse seines (Amande et al., 2012; Garcia & Herrera, 2018; Murua et al., 2018), and sea turtles in all three gears (Ardill et al., 2013; Lewison et al., 2014; Ortiz et al., 2016; Varghese & Somvanshi, 2010; Wallace et al., 2013). Additionally, we found that many poorly known or monitored elasmobranchs are at high risk from one or more gears (e.g., smalleye stingray, *Megatrygon microps*, and sicklefin weasel shark, *Hemigaleus microstoma*). Most of these species are rarely (if ever) specifically listed in available catch reports from the Indian Ocean.

The high-risk species that are not mentioned in reports (e.g., many species in the genus *Carcharhinus*) are either rarely caught (perhaps because they are not abundant), or the catch is not being recorded or only recorded in very aggregated groups (e.g., "pelagic sharks"). The latter is likely the case for many of the high risk pelagic and semi-pelagic elasmobranchs, which can be difficult to identify even for trained observers (Roman-Verdesoto & Orozco-Zoller, 2005; Smart et al., 2016). In contrast, the high-risk benthic or demersal elasmobranchs are probably not often caught in tuna gears. These high scores are driven by the assumptions of the encounterability parameter, which assumes uniform distribution throughout the depth range and results in a high probability of encountering gear if the species' depth range overlaps closely with the depth of the fishing gear. Future analyses could refine this parameter by estimating the distribution of species and fishing effort throughout the depth range, at least by life-history group (e.g. sea turtles, benthic elasmobranchs, deep-diving whales), and could also incorporate estimates of the distribution of fishing effort in the water column. The encounterability parameter could be further improved by area-specific depth ranges, which would give a probability of encounter per cell instead of a uniform value, in the same way that availability is calculated.

Gear-specific dynamics

Overall, we likely overestimate the mortality from fishing effort managed by the IOTC. One reason is that cumulative expected mortality in purse seines is likely lower than our results indicate. We assume that all purse seiner sets on Fish Aggregating Devices (FADs). Although we likely overestimate expected mortality in purse seines for some species (e.g., *S. longirostris, Neophocaena phocaenoides, Eretmochelys imbricata*), known bycatch rates in purse seines set on FADs do not account for the additional mortality from ghost fishing, where pelagic sharks and sea turtles in particular can get entangled in the net hanging below the raft (Davies et al., 2014). We also assume that no bycatch mitigation tactics are in place for any gears, even for species with little market value (such as small deep-sea skates and rays). Since some Indian Ocean purse seiners do use safe release practices, which are reasonably effective for cetaceans and turtles, we likely overestimate risk to these taxa from this gear type (Amande et al., 2012; Bourjea et al., 2008; Clavareau et al., 2020; Escalle et al., 2015).

Importantly, we expect that a large portion of the driftnet effort is not aimed at species managed by the IOTC. Although we make some rough adjustments to the effort model in an attempt to subset drift gillnets targeting tuna and tuna-like species, many of these boats are targeting species outside of the IOTC mandate, including small pelagic fish such as anchovies, sardinellas, hilsa shad, and other herrings, especially around estuaries (FAO, 2014; Sekadende et al., 2020). There is also a sizable bottom-set gillnet sector that uses slightly larger mesh nets to target sharks and rays, particularly in the North Indian Ocean (the Arabian Sea, Bay of Bengal, and western coast of Indonesia) (Henderson et al., 2007; Jabado, Al Ghais, Hamza, & Henderson, 2015). The relatively high expected mortality off northwestern Australia is a result of large demersal gillnets targeting sharks and nearshore gillnets targeting barramundi (*Lates calcarifer)* (Gaughan & Santoro, 2020).

For many megafauna species, catch rates in inshore bottom-set gillnets are likely different from offshore pelagic gillnets (Gillett, 2011). Standardized gillnet sub-categories—even if they were broad—would greatly improve our knowledge and understanding of this important sector. The IOTC is working to improve reporting but this will require substantial investment in helping member countries to inventory their fleets and monitor catch, especially for countries with very limited management capacity such as Somalia or Yemen (Sinan & Bailey, 2020). Improving monitoring and management of the essentially unregulated gillnet sector (including both set and driftnets) should be a priority to reduce megafauna bycatch in this region. In addition to the high risk of mortality for a variety of species, gillnets are a major source of mortality in marine debris globally and are likely contributing to a growing issue of unmonitored FADs in the Indian Ocean (Davies et al., 2014; Good, June, Etnier, & Broadhurst, 2010).

Reducing bycatch mortality in tuna gears

Improving our understanding of the dynamics of the diverse fishing sectors in the Indian Ocean is a crucial first step in directing conservation resources and designing interventions to mitigate bycatch and protect threatened species (Teh, Teh, Hines, Junchompoo, & Lewison, 2015). In general, there are two main strategies for reducing mortality in fishing gears: reducing entanglement and reducing post-release mortality (Carruthers et al., 2009; Senko, White, Heppell, & Gerber, 2014). Techniques that reduce encounters and entanglement include time-area closures (e.g. marine protected areas or closed areas for certain seasons or gears), modifications to the gear itself (e.g. attaching acoustic pingers to nets or changing bait, hooks, leaders, or mesh size and materials), or changing how the gear is deployed (e.g. setting gillnets lower in the water column, prohibiting purse seine sets on cetaceans, or restricting use of FADs) (Gilman, 2011; Northridge et al., 2017; Senko et al., 2014). The second broad strategy is to improve survivability after entanglement—usually by implementing safe release practices—although tactical measures such as shortening the time the gear is deployed can also reduce mortality (Carruthers et al., 2009; Zollett & Swimmer, 2019). Some strategies are widely effective in mitigating bycatch of a variety of species—such as restricting FADs or switching from wire to mono leaders—although target catch rates may be affected (Gilman, 2011). Other strategies are more variable depending on the context and species, and in some cases may reduce one type of bycatch but increase catch rates of another species (Gilman, Chaloupka, Swimmer, & Piovano, 2016).

The IOTC has fewer bycatch monitoring and mitigation requirements compared to the other tuna RFMOs, and it is the only one that does not implement spatial closures or gear restrictions (Boerder, Schiller, & Worm, 2019). There are relatively few MPAs in the Indian Ocean, and none located in international waters. The increased piracy around Somalia initially functioned as a de facto MPA, but evidence suggests that the governance void has over time resulted in increased illegal fishing in that area (Glaser, Roberts, & Hurlburt, 2019). There is a global ban on setting driftnets longer than 2.5km in the High Seas and some scattered management measures within the IOTC Area (e.g., prohibiting purse seines from intentionally encircling whale sharks or marine mammals) (Garcia & Herrera, 2018). However, reports indicate high rates of noncompliance across all types of fishing regulations (e.g., gear and area restrictions) within most EEZs and on the High Seas (Jabado & Spaet, 2017; WWF, 2020). The only bycatch mitigation techniques that the IOTC mandates are prohibiting purse seine sets on cetaceans and whale sharks, some regulation of FADs, and some requirements for safe release practices. However, lack of a common definition for FADs limits their effective management, and the IOTC has fewer safe release requirements than the other tropical tuna RFMOs (Swimmer, Zollett, & Gutierrez, 2020; Zollett & Swimmer, 2019).

While safe release practices are an important component of the bycatch mitigation portfolio and can move species from a lethal to a potentially lethal or sublethal outcome, they can still have significant effects on the animal's fitness (Adams, Fetterplace, Davis, Taylor, & Knott, 2018; Wilson, Raby, Burnett, Hinch, & Cooke, 2014). Furthermore, safe release is only relevant to certain species and gears. Our results show high cumulative catchability and expected lethality for many sea turtles, cetaceans and elasmobranchs, with driftnets driving the very high scores. Most species entangled in gillnets are dead by the time they are landed, so safe release practices will not mitigate the impacts of this sector. Studies show that gillnets are also difficult to effectively modify (Brownell et al., 2019; Senko et al., 2014), although there are potential modifications that have not been rigorously tested across different areas and megafauna species (e.g., type and color of net filament, type of floatline, weight of lead line, net hanging ratio) (Northridge et al., 2017). There has been some success using acoustic pingers to reduce gillnet bycatch of beaked whales and some small cetaceans (e.g., harbor porpoise *Phocoena phocoena*), although they are relatively expensive to purchase and maintain (Carretta, Barlow, & Enriquez, 2008; Hamilton & Baker, 2019). Thus, the most promising effort control-based solutions are likely to be tactical changes in how the gear is deployed (e.g. setting slightly below the surface) and restricting their use at certain high-risk times or areas (Hamilton & Baker, 2019; Hembree & Harwood, 1987).

We find that the cumulative risk of capture is concentrated in a relatively small proportion of the IOTC Area near the coasts, which suggests that targeted interventions in specific geographic areas could have important benefits for a range of species. Species with high expected mortality and overlap with fisheries proportional to their range and species with high cumulative catchability should be conservation priorities, especially species that are known to be threatened or declining. We found high catchability probabilities in purse seines and longlines for many elasmobranchs, which are likely overestimated for demersal and benthic species. However, it is possible that some of these species are catchable in tuna gears because the Indian Ocean has biodiverse seamounts that are relatively shallow, and many elasmobranchs make diurnal migrations through wide ranges of the water column, making them simultaneously epipelagic, mesopelagic and bathypelagic (Heard, Rogers, Bruce, Humphries, & Huveneers, 2018; Sims et al., 2006; Speed, Field, Meekan, & Bradshaw, 2010; WWF, 2020). An additional concern for many species in our analysis (including demersal elasmobranchs) is additional impacts from shrimp trawlers that are managed at national levels by the coastal or flag states (Oliver, Braccini, Newman, & Harvey, 2015). The limited conservation and management measures under the IOTC mandate only cover incidental catches of a relatively short list of non-target species, which is especially concerning for elasmobranchs as fishing patterns shift and demand from Asian markets grows (Jabado & Spaet, 2017; WWF, 2020). Better catch monitoring—especially in the essentially unmonitored gillnet sectors—will be critical for management of fishing pressure on all bycatch species, particularly for the most vulnerable species for which populations are naturally small (e.g., small cetaceans), or severally depleted by high bycatch levels.

The current regulatory framework in the Indian Ocean—which includes the IOTC mandate—has substantial limitations and loopholes that allow fishing impacts on marine megafauna to continue at unsustainable levels (WWF, 2020). The IOTC alone does not have the capacity to close these loopholes; effective bycatch management in the Indian Ocean will require coordinated efforts from all of the region's RFMOs, as well as Regional Fisheries Bodies, national governments and agencies (e.g. the US Marine Mammal Commission), non-governmental organizations, other international agencies (e.g. the International Whaling Commission), and the seafood industry itself. We find that cumulative risks are concentrated in coastal areas within Exclusive Economic Zones, which highlights the importance of the coastal States in managing fishing in their waters. Given the severely limited governance capacity of many Indian Ocean countries, improving national fisheries management institutions will require substantial assistance from wealthier governments and regional organizations (Sinan & Bailey, 2020). Although voluntary, international commitments such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the Convention on Migratory Species (CMS) also provide opportunities to strengthen regulations around data collection and management measures for sea turtles, cetaceans, and elasmobranchs. Currently, the CMS and CITES provide some protections to sea turtles and cetaceans but few high-risk elasmobranchs are protected by these agreements. Better catch documentation would help identify species that merit consideration of CITES or CMS listings, including the many IUCN listed Data Deficient cetaceans and elasmobranchs that our results suggest are potentially caught in tuna fisheries.

Despite the challenges of improving catch documentation, emerging technologies such as electronic monitoring systems are becoming increasingly feasible (Suuronen & Gilman, 2020). There are promising solutions aimed at reducing bycatch that are advancing beyond gear modifications to make fishing more selective for target species; for example, integrating satellite and other data sources to build dynamic management tools and bycatch warning systems (Hazen et al., 2018; Howell et al., 2015). Given the challenging management context in the Indian Ocean and the diversity of fishers and fishing fleets, bycatch mitigation tactics will likely be intractable without early and consistent engagement with fishers and local management bodies (Gladics et al., 2017; Karnad & St. Martin, 2020; McCluney, Anderson, & Anderson, 2019). While baseline information on species biology and catch should remain a priority for management agencies in the Indian Ocean, there is an urgent need to implement bycatch reduction strategies, as threatened species could be declining too rapidly to wait for complete documentation of the problem before taking actions.

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Data Availability Statement

Two databases were used in this study: a publicly available database of marine species distributions (AquaMaps) and a database of global non-industrial fishing effort, which is available upon request from the authors. The code and data required to reproduce the figures and results in this paper will be made freely available as RMarkdown and csv files on a publicly accessible GitHub repository.

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Tables

Table 1: Fifteen species groups for ranking gear selectivity and assigning lethality intervals, based off habitat use, physical characteristics, and known interactions with fisheries

Taxonomic Group	Subgroup name	Description
Cetaceans	Baleen whales	Coastal and oceanic baleen whales
Cetaceans	Large oceanic dolphins	Large oceanic dolphins (beyond continental shelf)
Cetaceans	Oceanic toothed whales	Beaked and toothed whales (including all sperm whales) with oceanic distr
Cetaceans	Inshore dolphins & porpoises	Nearshore species primarily in shallow (<50m) depths
Cetaceans	Small oceanic & coastal dolphins	Small or medium sized dolphins found in oceanic or coastal areas primarily
Elasmobranchs	Deep sea elasmobranchs	Benthic or demersal species anywhere along the continental shelf and uppe depth, or deep sea pelagic species >400m depth (species primarily outside t tuna gears)
Elasmobranchs	Deep shelf pelagic elasmobranchs	Pelagic species anywhere along the continental shelf and upper slope >200
Elasmobranchs	Demersal generalist elasmobranchs	Primarily feeds or lives on the bottom, occupies range of depths & range of
Elasmobranchs	Inshore elasmobranchs	Shallow (<100m depth), common in coastal areas (continent & island)
Elasmobranchs	Oceanic elasmobranchs	Pelagic species found in open ocean (beyond continental shelf)
Elasmobranchs	Filter feeder elasmobranchs	Filter feeders that primarily feed or live in the pelagic zone, occupy a range of habitats
Elasmobranchs	Pelagic generalist elasmobranchs	Primarily feeds or lives in the pelagic zone, occupies range of depths & ran
Elasmobranchs	Reef elasmobranchs	Known to occupy temperate and tropical reef habitat a majority of the time
Elasmobranchs	Shallow shelf elasmobranchs	Anywhere along the continental shelf <200m depth
Sea turtles	Sea turtles	Six species of sea turtles (including *Dermochelys coriacea*)

Table 2: Intervals and descriptions of possible outcomes (lethality) if an animal is entangled in gear

Category	Interval	Description
No damage	[0,0]	Species escapes without injury that decreases fitness
Sublethal	[0,1)	Species will most likely escape, potentially unharmed, or will suffer minor to serious injuries
Potentially lethal	(0,1]	Species may escape with minor to serious injuries, or could be landed or die during entanglement
Lethal	[1,1]	Species is a target or like-target species and will likely be landed or die during entanglement

Table 3: Conservation status information and cumulative catchability scores for the 25 species with the highest catchability score (cumulative catchability across all gear types). Catchability sum = sum of all catchability scores across all gears and cells. Mean = mean score across all gear types and cells. CR = Critically Endangered, EN = Endangered, VU = Vulnerable, NT = Near Threatened, LC = Least Concern, DD = Data Deficient, Elasmos = elasmobranchs

Species	Species group	Catchability		Red List	Appendix	
		Mean	Sum		CMS	CITES
Paragaleus randalli	Shallow shelf elasmos	0.556	132	NT	--	--
Carcharhinus humani	Pelagic generalist elasmos	0.42	47	DD	--	--
Rhizoprionodon oligolinx	Shallow shelf elasmos	0.359	265	LC	--	--
Carcharhinus galapagensis	Pelagic generalist elasmos	0.314	64	LC	--	--
Carcharhinus sealei	Shallow shelf elasmos.	0.273	184	NT	--	--
Glaucostegus halavi	Shallow shelf elasmos	0.263	195	CR	--	II
Mobula mobular	Filter feeder elasmos	0.245	265	EN	--	--
Chaenogaleus macrostoma	Shallow shelf elasmos	0.24	121	VU	--	--
Neophocaena phocaenoides	Inshore dolphins & porpoises	0.24	80	VU	II	I
Eretmochelys imbricata	Sea turtles	0.239	300	CR	I/II	I
Sousa chinensis	Inshore dolphins & porpoises	0.233	185	VU	II	I
Carcharhinus brevipinna	Shallow shelf elasmos.	0.222	202	NT	--	--
Lepidochelys olivacea	Sea turtles	0.221	176	VU	I/II	I
Chelonia mydas	Sea turtles	0.221	275	EN	I/II	I
Orcaella brevirostris	Inshore dolphins & porpoises	0.211	43	EN	I/II	I
Carcharhinus sorrah	Shallow shelf elasmos.	0.207	180	NT	--	--
Brevitrygon imbricata	Shallow shelf elasmos.	0.202	169	DD	--	--
Rhynchobatus djiddensis	Shallow shelf elasmos.	0.201	71	CR	--	II
Aetomylaeus maculatus	Inshore elasmos.	0.196	108	EN	--	--
Megatrygon microps	Inshore elasmos.	0.188	141	DD	--	--
Himantura undulata	Shallow shelf elasmos.	0.183	82	VU	--	--
Carcharhinus plumbeus	Pelagic generalist elasmos.	0.182	231	VU	--	--
Carcharhinus dussumieri	Shallow shelf elasmos.	0.181	27	EN	--	--
Torpedo panthera	Demersal generalist elasmos.	0.177	42	DD	--	--
Aptychotrema vincentiana	Shallow shelf elasmos.	0.175	39	LC	--	--

Figure Legends

Figure 1: Mean catchability probabilities summed across the three gear types for species in 15 species groups, ordered first by taxonomic group (purple for cetaceans, green for sea turtles, blue for elasmobranchs) then by sub-group (See Table 1 for full species group names). Color shows threat group (Threatened = Critically Endangered, Endangered, Vulnerable, Not Threatened = Near Threatened, Least Concern, Unknown = Data Deficient or Not Assessed.

Figure 2: Mean expected mortality across the study region and percent range overlap with driftnets, longlines, and purse seines for species listed as Threatened, Not threatened, and Unknown on the IUCN Red List. The 25 species with the highest mean catchability scores overall are labelled.

Figure 3: Lethality intervals for species catchable in driftnets, purse seines, and longlines, ordered by their cumulative catchability score for the three gears (highest scores on right). For each gear type, empty bars are species that are not catchable, taller bars show species appearing in IOTC reports, and inset horizontal bar shows the number and proportion of species in each lethality interval.

Figure 4: Sum of catchability scores for all species in each grid cell for driftnets, purse seines, and longlines.

Figure 5: Sum of catchability scores for all species occurring in each cell for gillnets, longlines and purse seines, separated into species groups. Green is for sea turtles, purple is cetaceans, and blue is elasmobranchs ("elasmos"). Cells are ordered by ascending cumulative catchability across all species and gears (meaning each cell's location on the x-axis is unique and comparable across all plots). The 2,037 cells in the top 10% of catchability values (for all three gears combined) are shown.

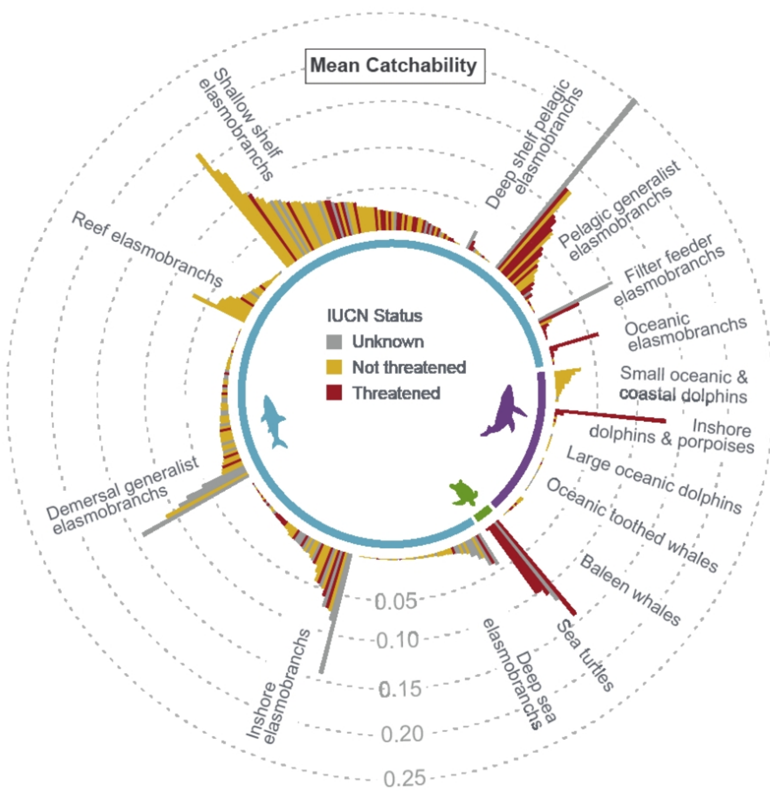


Figure 1: Mean catchability probabilities summed across the three gear types for species in 15 species groups, ordered first by taxonomic group (purple for cetaceans, green for sea turtles, blue for elasmobranchs) then by sub-group (See Table 1 for full species group names). Color shows threat group (Threatened = Critically Endangered, Endangered, Vulnerable, Not Threatened = Near Threatened, Least Concern, Unknown = Data Deficient or Not Assessed.

250x263mm (118 x 118 DPI)

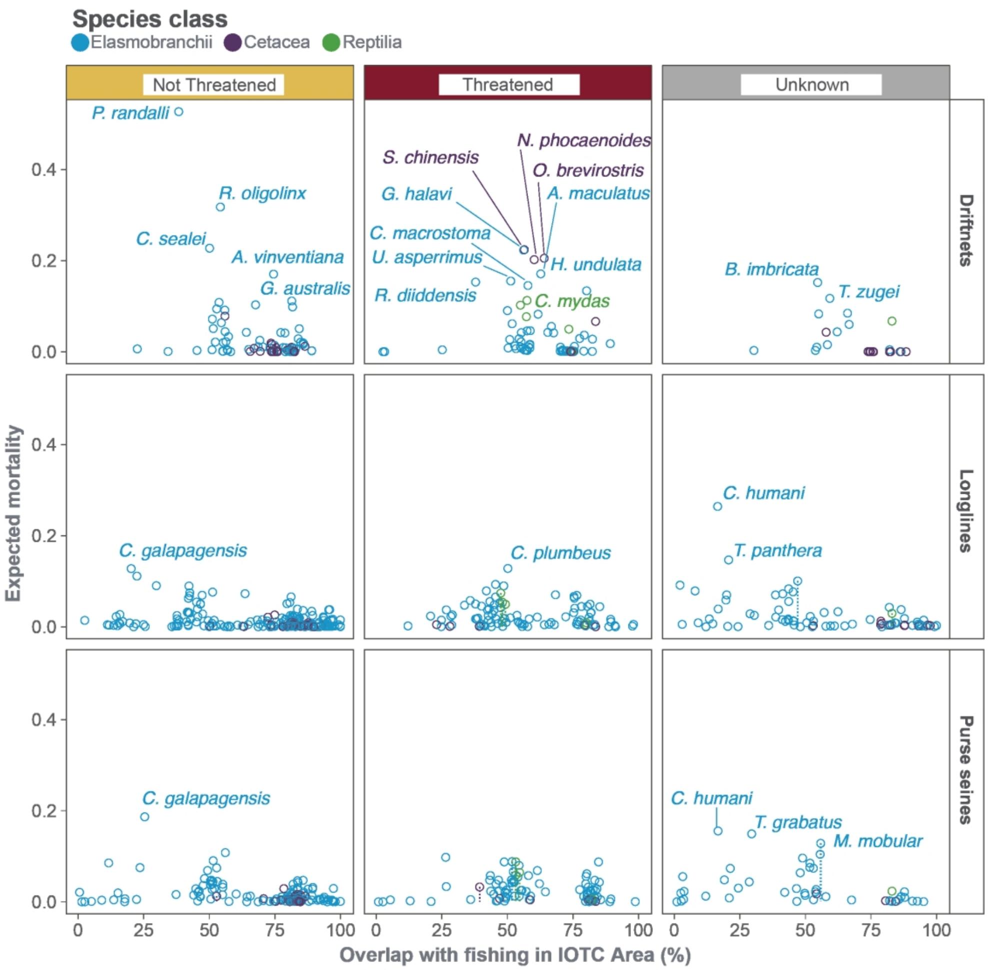


Figure 2: Mean expected mortality across the study region and percent range overlap with driftnets, longlines, and purse seines for species listed as Threatened, Not threatened, and Unknown on the IUCN Red List. The 25 species with the highest mean catchability scores overall are labelled.

529x529mm (118 x 118 DPI)

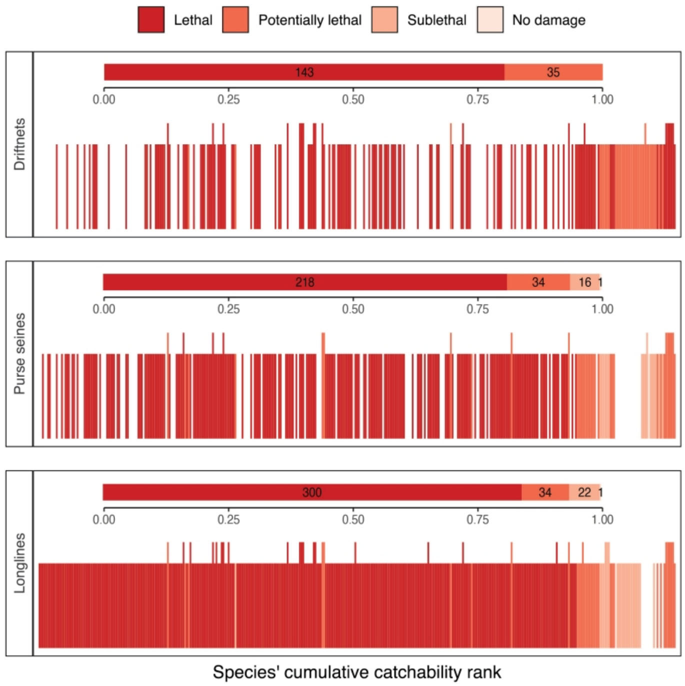


Figure 3: Lethality intervals for species catchable in driftnets, purse seines, and longlines, ordered by their cumulative catchability score for the three gears (highest scores on right). For each gear type, empty bars are species that are not catchable, taller bars show species appearing in IOTC reports, and inset horizontal bar shows the number and proportion of species in each lethality interval.

706x531mm (118 x 118 DPI)

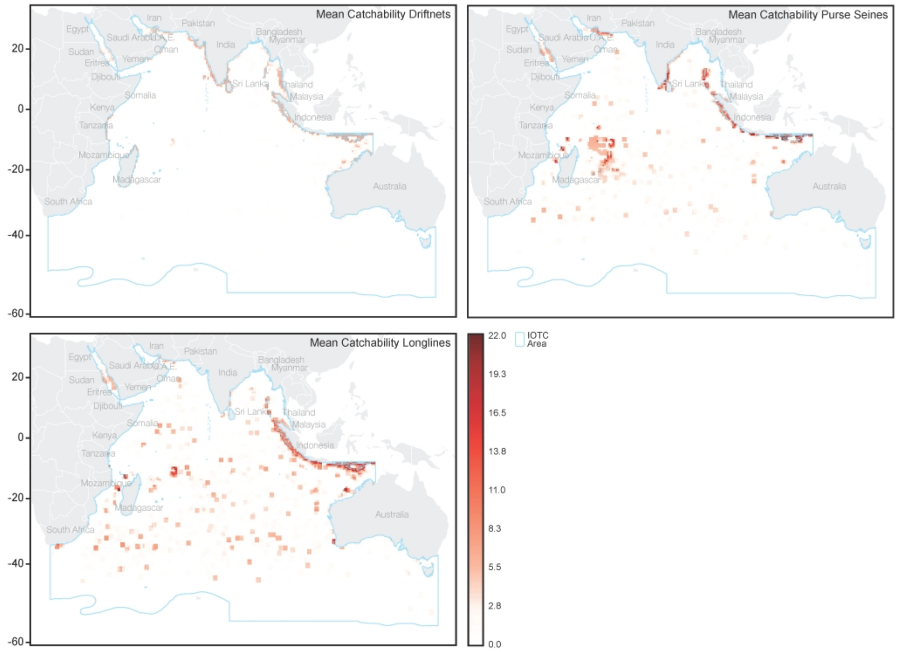


Figure 4: Sum of catchability scores for all species in each grid cell for driftnets, purse seines, and longlines.

548x710mm (236 x 236 DPI)

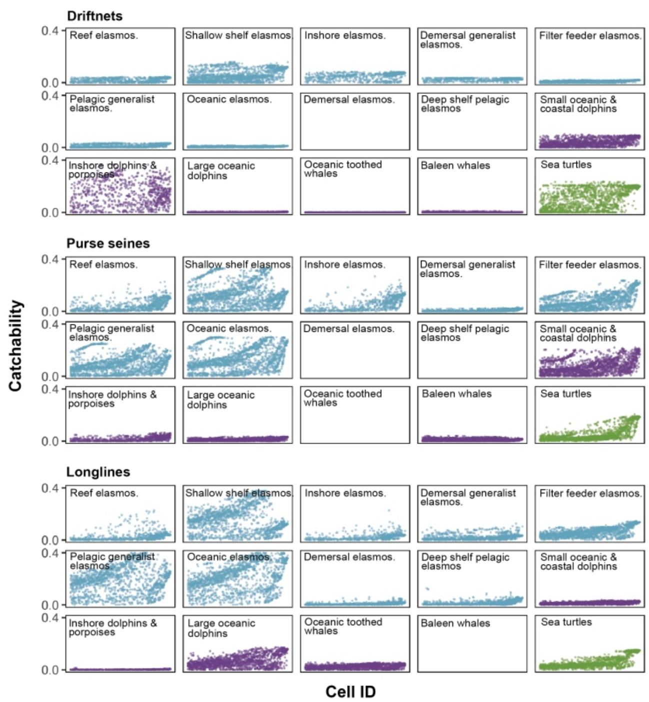


Figure 5: Sum of catchability scores for all species occurring in each cell for gillnets, longlines and purse seines, separated into species groups. Green is for sea turtles, purple is cetaceans, and blue is elasmobranchs ("elasmos"). Cells are ordered by ascending cumulative catchability across all species and gears (meaning each cell's location on the x-axis is unique and comparable across all plots). The 2,037 cells in the top 10% of catchability values (for all three gears combined) are shown.

710x548mm (118 x 118 DPI)

Supplementary Information

Supplementary Info 1: Fishing effort

The model of fishing effort uses data from FAO and country-specific reports to divide each country's effort into ten power classes based on gross tonnage, length overall, and engine power and associate effort with a corresponding catch (Rousseau, 2020; Rousseau et al., 2019). The effort was mapped in 0.5 degree cells using a ratio to the total catch, and limiting the distance from the coast that boats of certain size classes could operate (e.g. limiting artisanal boats to the EEZ of the country and unmotorised boats to 12nm from the coast) (Rousseau, 2020). Incompatibilities between effort and catch were resolved by comparing broader families of gears (e.g., lines instead of longlines, bottom nets instead of bottom trawls, etc.). For countries where there was no information on the link between tonnage, length, and engine power, characteristics are assumed to be similar to neighbouring countries. This approach fills missing data with information from neighbouring countries, which improves upon earlier approaches where missing data were replaced with global averages derived from the larger industrial fleets (Rousseau et al., 2019). This approach can generate errors for countries with missing information that are anomalous to their neighbours. We removed South Africa's large gillnet effort in the P4 and P5 power categories (50-200 kW). South Africa does not have a fleet targeting tuna and tuna-likes with gillnets in the IOTC area (Parker et al., 2018), and this error likely arises because of the characteristics of neighbouring countries that do have substantial gillnet effort in the low and medium power classes.

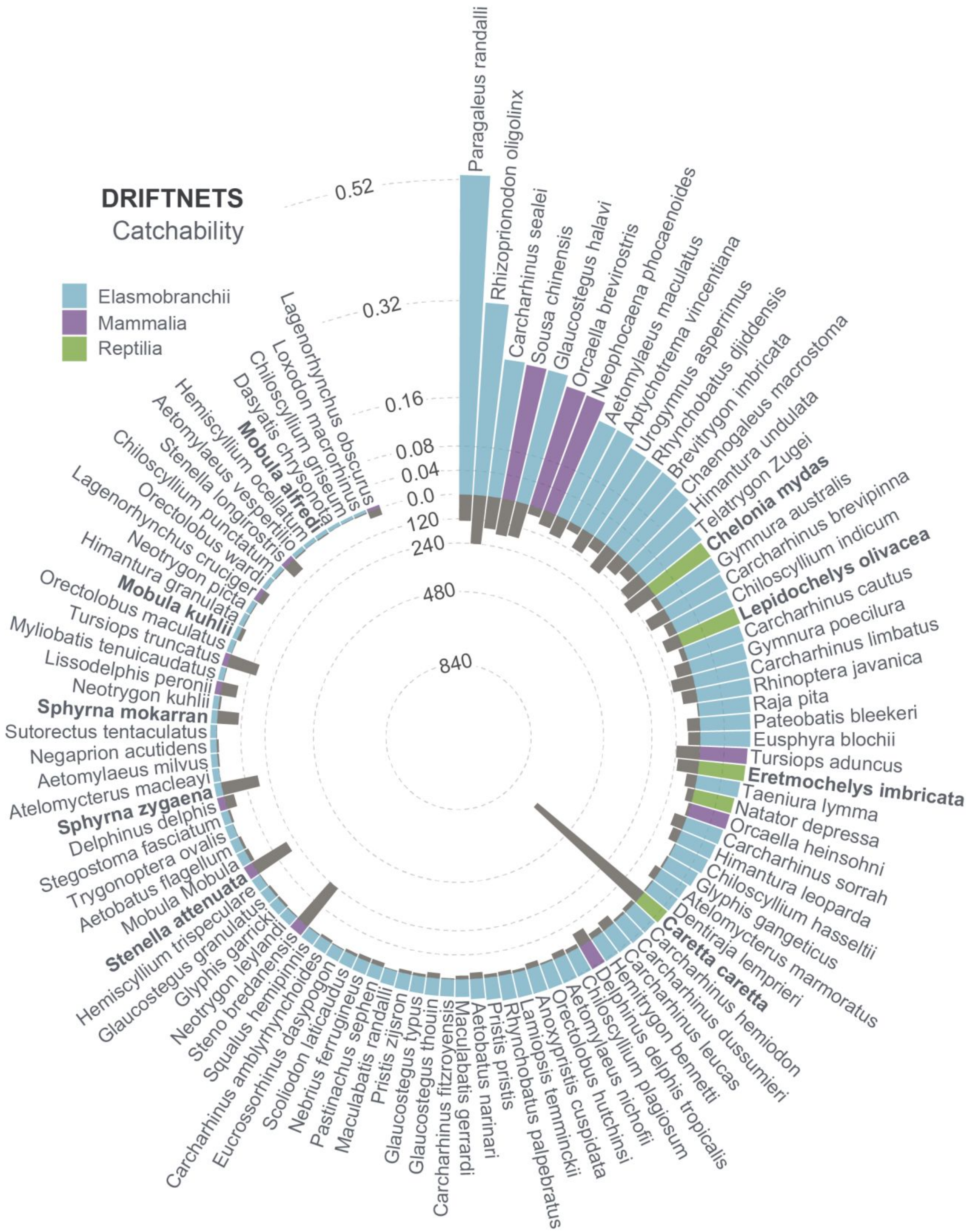
We also conducted a review of the peer-reviewed and grey literature, including IOTC reports for each country, to identify which countries have a gillnet sector targeting tuna or tuna-likes in the Indian Ocean. For countries where there is no available information about whether their gillnets are small inshore bottom set nets versus larger drift nets, we errored on the conservative side and included effort from these countries in the final analysis. The model maps effort to particular grid cells. Where information on catch is missing, effort is attributed to grid cells based on the characteristics of that country's fleet, including assumptions about major ports and the distance that vessels in different power classes can travel from the coast.

Despite these assumptions, the lack of spatial information in the catch data (especially for gillnets) results in extremely skewed effort in a small number of cells typically clustered near ports along certain coasts. Assuming that effort from one fishing country and gear type will not vary dramatically between neighbouring cells, we first smoothed the predicted fishing effort across each country and gear type using a custom smoothing method in R based on functions in the GDAL library. Next, we made separate rasters for each country and fishing gear, then smoothed the fishing effort values by first summing each cell's value with its 8 neighbouring cells, then dividing the sum by the sea surface area within the 9 cells. The rasters from all countries were summed to obtain a global raster for each gear type. Next, we examined the spread of fishing effort and adjusted outlier values based on quantile thresholds for each gear type. For gillnets, we replaced values greater than the 90th percentile with a value one greater than that percentile (replacing all the very high values with one number). For purse seine and longline effort, which is less skewed, we replaced the values above the 95th percentile value. Finally, we scaled the effort from 0 to 1 across all gear types, to get a relative probability that fishing occurs for each gear type in each cell. The resulting effort remains heavily skewed, but we assume the skewness derives from real patterns in fishing effort. For example, smaller gillnet vessels are clustered near certain ports and population centres, and in some areas are known to concentrate near Fish Aggregating Devices.

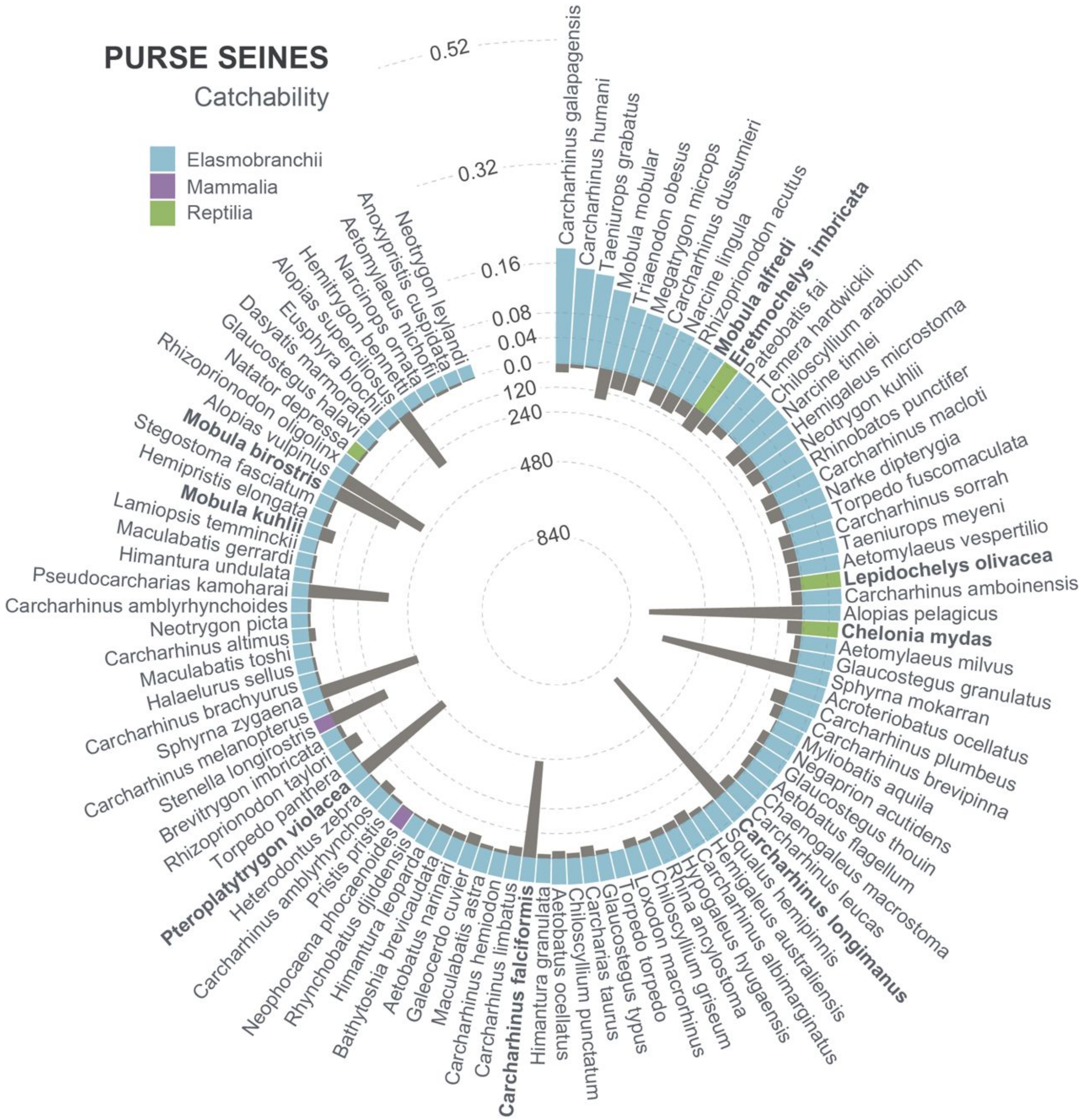
Supplementary Info 2: Species information

The AquaMaps model gives four depth limits (minimum, preferred minimum, maximum, and preferred maximum). For air-breathing species (sea turtles and marine mammals), we used the minimum depth (0m) and maximum preferred depth. For the majority of the air-breathing species, the maximum preferred depth predicted by AquaMaps extends beyond the deepest published dive records. For these 43 sea turtles and cetaceans we used information from IUCN, OBIS, and WoRMS to adjust the depth maxima. Where depth information was not available for a species (e.g., many beaked whales), we adjusted the maximum depth to the genus or family average. For elasmobranchs, we selected the minimum preferred depth and the maximum depth because overall, these limits corresponded best to information from published global databases (Froese & Pauly, 2019; OBIS, 2020; WoRMS Editorial Board, n.d.). Modelled depth limits aligned better with empirical data for elasmobranchs compared to air-breathing taxa, and we only adjusted depths for two requiem shark species (silky shark, *Carcharhinus falciformis* and Human's whaler shark, *C. humani,* Carcharhinidae).

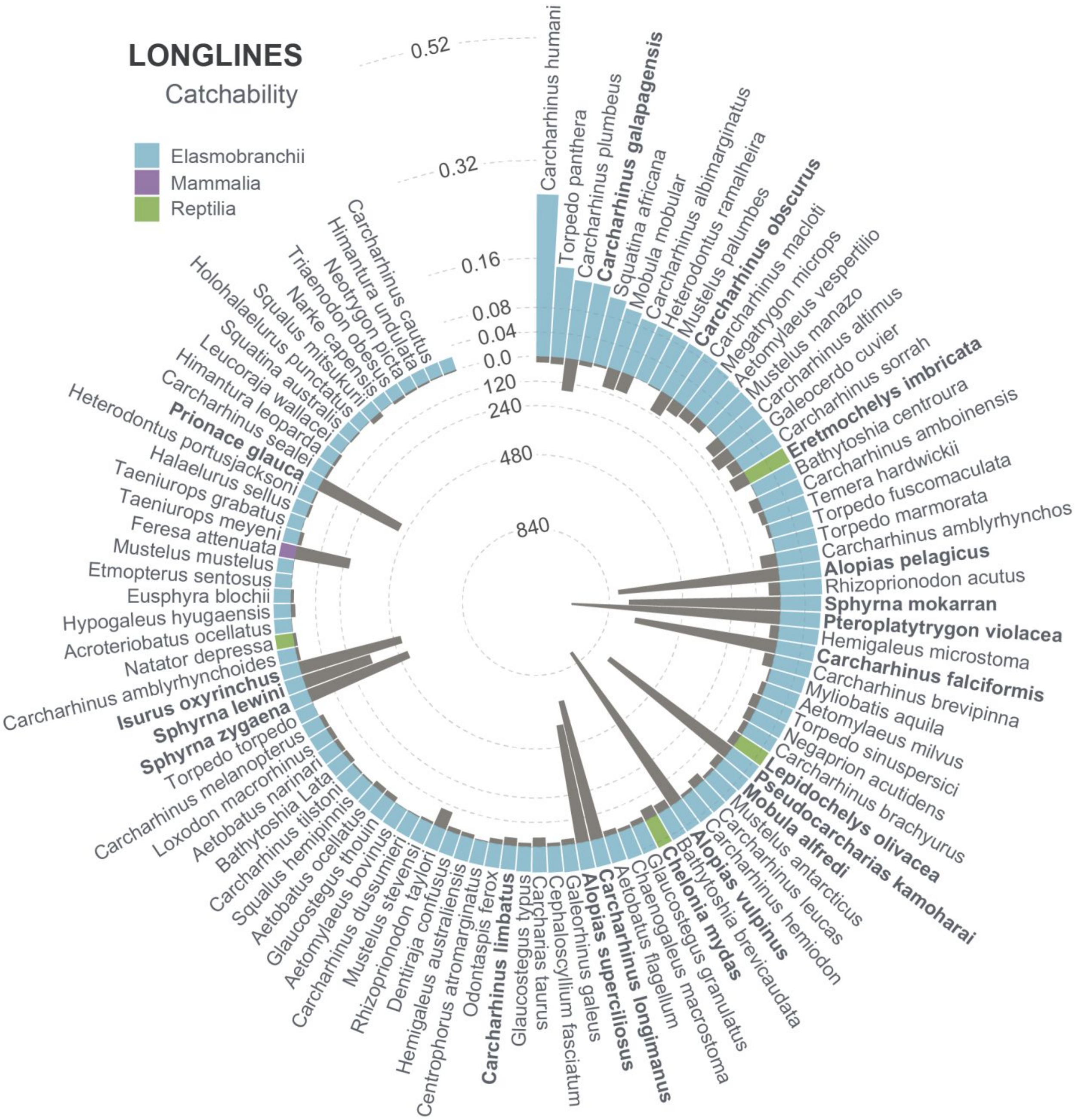
Supplementary Figures



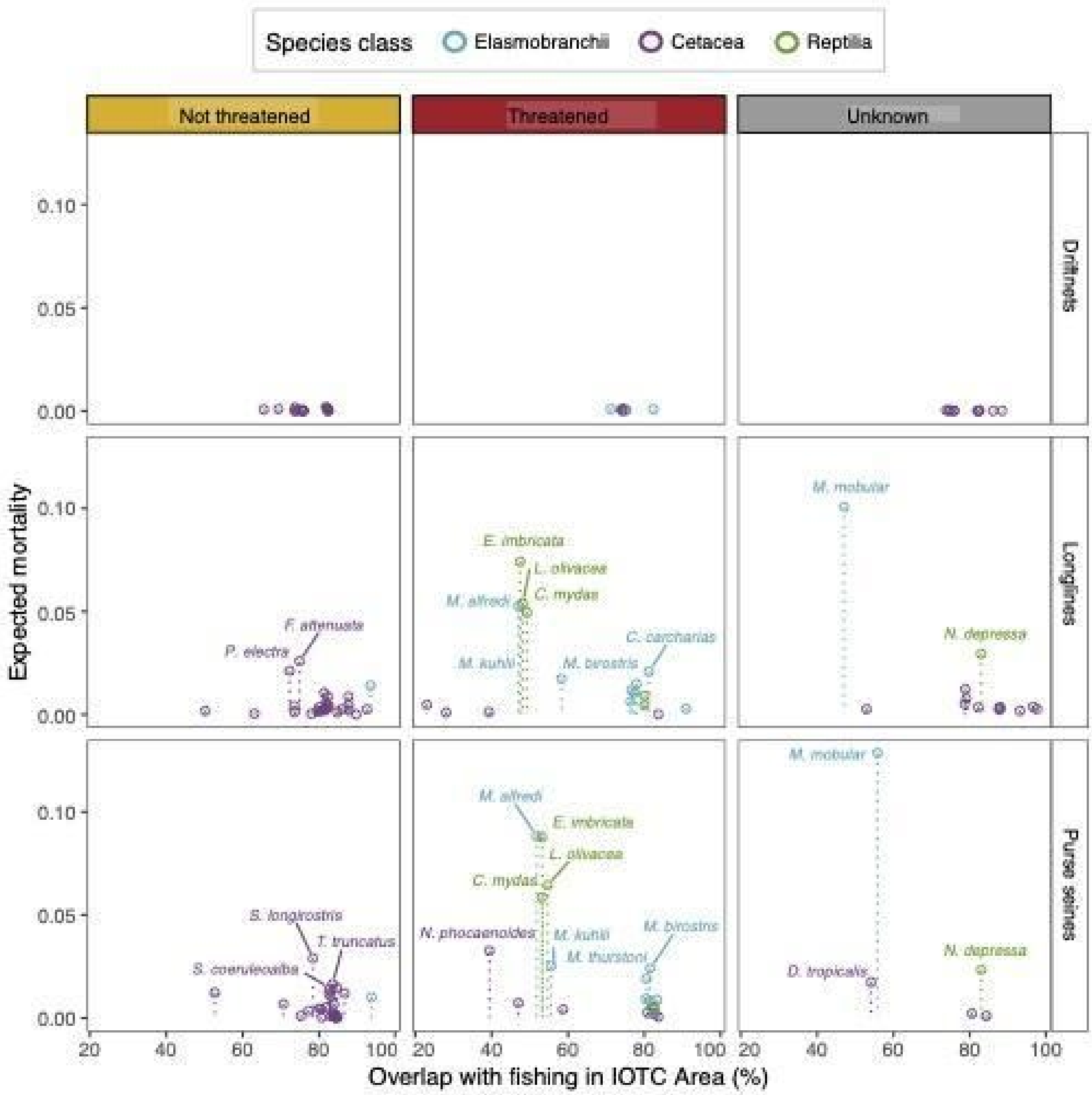
Supplementary Figure 1: Mean (outer ring) and cumulative (inner ring) catchability scores for driftnets. Species are ordered clockwise by descending mean catchability score and the top 100 species are shown. Bars are colored by taxonomic group (elasmobranchs, cetaceans, and sea turtles). Species names are in bold if that species is listed in catch records for that gear type in the Indian Ocean (peer reviewed literature or IOTC reports).



Supplementary Figure 2: Mean (outer ring) and cumulative (inner ring) catchability scores for purse seines. Species are ordered clockwise by descending mean catchability score and the top 100 species are shown. Bars are colored by taxonomic group (elasmobranchs, cetaceans, and sea turtles). Species names are in bold if that species is listed in catch records for that gear type in the Indian Ocean (peer reviewed literature or IOTC reports).



Supplementary Figure 3: Mean (outer ring) and cumulative (inner ring) catchability scores for longlines. Species are ordered clockwise by descending mean catchability score and the top 100 species are shown. Bars are colored by taxonomic group (elasmobranchs, cetaceans, and sea turtles).. Species names are in bold if that species is listed in catch records for that gear type in the Indian Ocean (peer reviewed literature or IOTC reports).



Supplementary Figure 4: Mean expected mortality across all cells and percent range overlap with drift gillnets, longlines, and purse seines for the 67 species that were not in the "lethal" category for at least one of the three gears. Species are grouped by conservation status (Threatened = Critically Endangered, Endangered, Vulnerable, Not threatened = Least Concern or Near Threatened, Unknown= Data Deficient or Not Assessed). Species with the 25 highest mean catchability scores overall are labeled

Supplementary Tables

Supplementary Table 1: Fishing countries known to use gillnets targeting tuna or tuna-like species in the Indian Ocean

Country	Reference
Australia	Hobsbawn, P.I., Patterson, H.M. and Williams, A.J. (2018) Australian National Report To the Scientific Committee of the Indian Ocean Tuna Commission for 2018.
Bahrain	FAO (2012) Bahrain Skiffs gillnets small pelagics and Spanish mackerel fishery - Gulf Bahraini waters (1-20/40m). Available at: http://firms.fao.org/firms/fishery/670/en#VesseltypeOverview.
Bangladesh	Barua, S., Akter, M.R. and Roy, B. (2018) Bangladesh National Report to the Scientific Committee of the Indian Ocean Tuna Commission, 2018.
Brunei Darussalam	No specific reference for tuna gillnets in the IOTC Area
China	Zhu, J., Wu, F. and Yang, X. (2018) China National Report to the Scientific Committee of the Indian Ocean Tuna Commission, 2018.
Eritrea	Anderson, R., Herrera, M., Ilangakoon, A., Koya, K., Moazzam, M., Mustika, P. and Sutaria, D. (2020) Cetacean bycatch in Indian Ocean tuna gillnet fisheries. *Endangered Species Research* **41**, 39–53.
India	Ramalingam, L., Tiburtius, A., Siva, A., Das, A., Sanadi, R.B. and Kumar Tailor, R.B. (2015) India’s National Report to the Scientific Committee of the Indian Ocean Tuna Commission 2015.
Indonesia	Ruchimat, T., Fahmi, Z., Setyadji, B. and Yunanda, T. (2018) Indonesia National Report to the Scientific Committee of the Indian Ocean Tuna Commission, 2018.
Iran	IOTC (2018) I.R.Iran National Report For IOTC-2018-SC21-R10 The 21nd Scientific Committee of the IOTC, 2018.
Kenya	Ndegwa, S. and Okemwa, G. (2017) Kenya National Report to the Scientific Committee of the Indian Ocean Tuna Commission, 2017.
Kuwait	Ye, Y., Al-Husaini, M. and Al-Baz, A. (2001) Use of generalized linear models to analyze catch rates having zero values: The Kuwait driftnet fishery. *Fisheries Research* **53**, 151–168.
Madagascar	Ye, Y., Al-Husaini, M. and Al-Baz, A. (2001) Use of generalized linear models to analyze catch rates having zero values: The Kuwait driftnet fishery. *Fisheries Research* **53**, 151–168.
Malaysia	Samsudin, B., Sallehudin, J., Tengku Balkis, T.. and Nor Azlin, M. (2018) Malaysia National Report to the Scientific Committee of the Indian Ocean Tuna Commission, 2018.
Mauritius	Poonian, C.N.S. (2015) A first assessment of elasmobranch catch in Mauritian artisanal fisheries using interview surveys. *Phelsuma* **23**, 19–29.
Mozambique	Anderson, R., Herrera, M., Ilangakoon, A., Koya, K., Moazzam, M., Mustika, P. and Sutaria, D. (2020) Cetacean bycatch in Indian Ocean tuna gillnet fisheries. *Endangered Species Research* **41**, 39–53.

Myanmar	Alessi, M. De (2017) Fishery Performance Indicators and Coastal Fisheries Management in Southern Rakhine.
Oman	Al-Zaabi, I.A.A. (2015) Sultanate of Oman National Report to the Scientific Committee of the Indian Ocean Tuna Commission, 2015.
Pakistan	Khan, M.W. (2017) Pakistan's National Report to the Scientific Committee of the Indian Ocean Tuna Commission, 2017: IOTC-2017-SC20-NR20 Rev_1.
Qatar	Grandcourt, E.M. (2013) A review of the fisheries, biology, status and management of the narrow-barred Spanish mackerel (Scomberomorus commerson) in the Gulf Cooperation Council countries (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates).
Saudi Arabia	Abdulqader, E.A.A., Miller, J., Al-Mansi, A., Al-Abdulkader, K., Fita, N., Al-Nadhiri, H. and Rabaoui, L. (2017) Turtles and other marine megafauna bycatch in artisanal fisheries in the Saudi waters of the Arabian Gulf. *Fisheries Research* **196**, 75–84.
Somalia	Breuil, C. and Grima, D. (2014) Country Review Smartfish Programme Somalia. Ebene, Mauritius.
Sri Lanka	Aranda, M. (2017) Description of tuna gillnet capacity and bycatch in the IOTC Convention Area.
Tanzania	Amir, O.A. and Hamid, Z.A. (2016) Tanzania National Report to the Scientific Committee of the Indian Ocean Tuna Commission, 2016. 1–9.
Thailand	Anderson, R., Herrera, M., Ilangakoon, A., Koya, K., Moazzam, M., Mustika, P. and Sutaria, D. (2020) Cetacean bycatch in Indian Ocean tuna gillnet fisheries. *Endangered Species Research* **41**, 39–53.
Timor-Leste	Anderson, R., Herrera, M., Ilangakoon, A., Koya, K., Moazzam, M., Mustika, P. and Sutaria, D. (2020) Cetacean bycatch in Indian Ocean tuna gillnet fisheries. *Endangered Species Research* **41**, 39–53.
UAE	Anderson, R., Herrera, M., Ilangakoon, A., Koya, K., Moazzam, M., Mustika, P. and Sutaria, D. (2020) Cetacean bycatch in Indian Ocean tuna gillnet fisheries. *Endangered Species Research* **41**, 39–53.
Viet Nam	No specific reference for tuna gillnets in the IOTC Area

Supplementary Table 2:

Tax group	Subgroup	Count species	Percent of species listed			
			CITES	CMS	Threatened	Unknown
Cetaceans	Baleen whales	10	90.0	80.0	30.0	10.0
Cetaceans	Large oceanic dolphins	7	100.0	42.9	0.0	14.3
Cetaceans	Oceanic toothed whales	15	100.0	13.3	6.7	60.0
Cetaceans	Inshore dolphins & porpoises	7	100.0	100.0	57.1	0.0
Cetaceans	Small oceanic & coastal dolphins	12	91.7	66.7	0.0	8.3
Elasmobranchs	Demersal generalist elasmobranchs	61	0.0	0.0	14.8	29.5
Elasmobranchs	Deep sea elasmobranchs	50	0.0	0.0	8.0	28.0
Elasmobranchs	Deep shelf pelagic elasmobranchs	11	0.0	9.1	27.3	36.4
Elasmobranchs	Inshore elasmobranchs	50	6.0	6.0	36.0	28.0
Elasmobranchs	Oceanic elasmobranchs	7	85.7	85.7	85.7	0.0
Elasmobranchs	Filter feeder elasmobranchs	9	55.6	55.6	77.8	11.1
Elasmobranchs	Pelagic generalist elasmobranchs	24	12.5	25.0	54.2	8.3
Elasmobranchs	Reef elasmobranchs	25	4.0	0.0	8.0	8.0
Elasmobranchs	Shallow shelf elasmobranchs	73	12.3	4.1	32.9	13.7
Sea turtles	Sea turtles	6	83.3	83.3	83.3	16.7

Supplementary Table 3: Taxonomic information for 367 species scoring as catchable in at least one gear type, with selectivity rank and lethality interval for the three gear types (GND=driftnets, PST=purse seines, LLT=longlines). Pot lethal=potentially lethal. Min and max depths are from the AquaMaps model except for 46 species with adjusted depths.

AquaMaps ID	Tax group	Sub group	Name	New name	Selectivity rank			Lethality interval			Depth (m)	
					GND	PST	LLT	GND	PST	LLT	Min	Max
ITS-Mam-180524	Cetaceans	BW	*Balaenoptera acutorostrata*	No	9	9	--	Pot.lethal	Sublethal	No damage	0	2000
ITS-Mam-612592	Cetaceans	BW	*Balaenoptera bonaerensis*	No	9	9	--	Pot.lethal	Sublethal	No damage	0	100
ITS-Mam-180526	Cetaceans	BW	*Balaenoptera borealis*	No	9	9	--	Pot.lethal	Sublethal	No damage	0	300
ITS-Mam-612597	Cetaceans	BW	*Balaenoptera brydei*	No	9	9	--	Pot.lethal	Sublethal	No damage	0	2000
ITS-Mam-180525	Cetaceans	BW	*Balaenoptera edeni*	No	9	9	--	Pot.lethal	Sublethal	No damage	0	2000
ITS-Mam-180528	Cetaceans	BW	*Balaenoptera musculus*	No	9	9	--	Pot.lethal	No damage	No damage	0	250
ITS-Mam-180527	Cetaceans	BW	*Balaenoptera physalus*	No	9	9	--	Pot.lethal	Sublethal	No damage	0	250
ITS-Mam-180535	Cetaceans	BW	*Caperea marginata*	No	9	9	--	Pot.lethal	Sublethal	No damage	0	100
ITS-Mam-552771	Cetaceans	BW	*Eubalaena australis*	No	8	9	--	Pot.lethal	Sublethal	No damage	0	175
ITS-Mam-180530	Cetaceans	BW	*Megaptera novaeangliae*	No	8	9	--	Pot.lethal	Sublethal	No damage	0	200
ITS-Mam-180461	Cetaceans	LOD	*Feresa attenuata*	No	7	9	9	Pot.lethal	Sublethal	Sublethal	0	400
ITS-Mam-180466	Cetaceans	LOD	*Globicephala macrorhynchus*	No	7	9	9	Pot.lethal	Sublethal	Sublethal	0	800
ITS-Mam-552461	Cetaceans	LOD	*Globicephala melas*	No	7	9	9	Pot.lethal	Sublethal	Sublethal	0	400
ITS-Mam-180457	Cetaceans	LOD	*Grampus griseus*	No	7	9	9	Pot.lethal	Sublethal	Sublethal	0	1000
ITS-Mam-180469	Cetaceans	LOD	*Orcinus orca*	No	7	9	9	Pot.lethal	Sublethal	Sublethal	0	500
ITS-Mam-180459	Cetaceans	LOD	*Peponocephala electra*	No	7	9	9	Pot.lethal	Sublethal	Sublethal	0	500
ITS-Mam-180463	Cetaceans	LOD	*Pseudorca crassidens*	No	7	9	9	Pot.lethal	Sublethal	Sublethal	0	2000
ITS-Mam-180495	Cetaceans	OTW	*Berardius arnuxii*	No	8	--	11	Pot.lethal	Sublethal	Sublethal	0	1000
ITS-Mam-180505	Cetaceans	OTW	*Hyperoodon planifrons*	No	8	--	11	Pot.lethal	Sublethal	Sublethal	0	2000
ITS-Mam-180502	Cetaceans	OTW	*Indopacetus pacificus*	No	8	--	11	Pot.lethal	Sublethal	Sublethal	0	1500
ITS-Mam-180491	Cetaceans	OTW	*Kogia breviceps*	No	8	--	11	Pot.lethal	Sublethal	Sublethal	0	400
ITS-Mam-180492	Cetaceans	OTW	*Kogia sima*	No	8	--	11	Pot.lethal	Sublethal	Sublethal	0	2000
ITS-Mam-180513	Cetaceans	OTW	*Mesoplodon bowdoini*	No	8	--	11	Pot.lethal	Sublethal	Sublethal	0	2000
ITS-Mam-180517	Cetaceans	OTW	*Mesoplodon densirostris*	No	8	--	11	Pot.lethal	Sublethal	Sublethal	0	2000
ITS-Mam-180510	Cetaceans	OTW	*Mesoplodon ginkgodens*	No	8	--	11	Pot.lethal	Sublethal	Sublethal	0	2000
ITS-Mam-180511	Cetaceans	OTW	*Mesoplodon grayi*	No	8	--	11	Pot.lethal	Sublethal	Sublethal	0	2000
ITS-Mam-180507	Cetaceans	OTW	*Mesoplodon hectori*	No	8	--	11	Pot.lethal	Sublethal	Sublethal	0	2500
ITS-Mam-180516	Cetaceans	OTW	*Mesoplodon layardii*	No	8	--	11	Pot.lethal	Sublethal	Sublethal	0	1000

ITS-Mam-180508	Cetaceans	OTW	*Mesoplodon mirus*	No	8	--	11	Pot.lethal	Sublethal	Sublethal	0	2000
ITS-Mam-180488	Cetaceans	OTW	*Physeter macrocephalus*	No	9	--	11	Pot.lethal	No damage	No damage	0	2500
ITS-Mam-180500	Cetaceans	OTW	*Tasmacetus shepherdi*	No	8	--	11	Pot.lethal	Sublethal	Sublethal	0	1000
ITS-Mam-180498	Cetaceans	OTW	*Ziphius cavirostris*	No	8	--	11	Pot.lethal	Sublethal	Sublethal	0	3000
ITS-Mam-180451	Cetaceans	IDP	*Cephalorhynchus heavisidii*	No	3	8	12	Lethal	Pot.lethal	Pot.lethal	0	50
ITS-Mam-180478	Cetaceans	IDP	*Neophocaena phocaenoides*	No	3	8	12	Lethal	Pot.lethal	Pot.lethal	0	50
ITS-Mam-180471	Cetaceans	IDP	*Orcaella brevirostris*	No	3	8	12	Lethal	Pot.lethal	Pot.lethal	0	10
ITS-Mam-771132	Cetaceans	IDP	*Orcaella heinsohni*	No	3	8	12	Lethal	Pot.lethal	Pot.lethal	0	10
ITS-Mam-180475	Cetaceans	IDP	*Phocoena dioptrica*	No	3	8	12	Lethal	Pot.lethal	Pot.lethal	0	2000
ITS-Mam-180419	Cetaceans	IDP	*Sousa chinensis*	No	3	8	12	Lethal	Pot.lethal	Pot.lethal	0	25
ITS-Mam-612596	Cetaceans	IDP	*Tursiops aduncus*	No	3	8	12	Lethal	Pot.lethal	Pot.lethal	0	50
ITS-Mam-180449	Cetaceans	SOCD	*Cephalorhynchus commersonii*	No	2	8	12	Lethal	Pot.lethal	Pot.lethal	0	50
ITS-Mam-180438	Cetaceans	SOCD	*Delphinus delphis*	No	2	8	12	Lethal	Pot.lethal	Pot.lethal	0	200
ITS-Mam-555654	Cetaceans	SOCD	*Delphinus delphis tropicalis*	No	2	8	12	Lethal	Pot.lethal	Pot.lethal	0	100
ITS-Mam-180440	Cetaceans	SOCD	*Lagenodelphis hosei*	No	2	8	12	Lethal	Pot.lethal	Pot.lethal	0	600
ITS-Mam-180447	Cetaceans	SOCD	*Lagenorhynchus cruciger*	No	2	8	12	Lethal	Pot.lethal	Pot.lethal	0	200
ITS-Mam-180445	Cetaceans	SOCD	*Lagenorhynchus obscurus*	No	2	8	12	Lethal	Pot.lethal	Pot.lethal	0	200
ITS-Mam-180455	Cetaceans	SOCD	*Lissodelphis peronii*	No	2	8	12	Lethal	Pot.lethal	Pot.lethal	0	200
ITS-Mam-180430	Cetaceans	SOCD	*Stenella attenuata*	No	2	8	12	Lethal	Pot.lethal	Pot.lethal	0	100
ITS-Mam-180434	Cetaceans	SOCD	*Stenella coeruleoalba*	No	2	8	12	Lethal	Pot.lethal	Pot.lethal	0	700
ITS-Mam-180429	Cetaceans	SOCD	*Stenella longirostris*	No	2	8	12	Lethal	Pot.lethal	Pot.lethal	0	250
ITS-Mam-180417	Cetaceans	SOCD	*Steno bredanensis*	No	2	8	12	Lethal	Pot.lethal	Pot.lethal	0	100
ITS-Mam-180426	Cetaceans	SOCD	*Tursiops truncatus*	No	2	8	12	Lethal	Pot.lethal	Pot.lethal	0	200
Fis-170784	Elasmobranchs	DGE	*Aetomylaeus bovinus*	No	6	9	5	Lethal	Lethal	Lethal	25	150
Fis-140641	Elasmobranchs	DGE	*Asymbolus occiduus*	No	6	9	12	Lethal	Lethal	Lethal	132	400
Fis-140692	Elasmobranchs	DGE	*Asymbolus rubiginosus*	No	6	9	12	Lethal	Lethal	Lethal	86	540
Fis-25886	Elasmobranchs	DGE	*Brachaelurus waddi*	No	6	9	12	Lethal	Lethal	Lethal	15	140
Fis-161440	Elasmobranchs	DGE	*Cephaloscyllium albipinnum*	No	6	9	8	Lethal	Lethal	Lethal	176	554
Fis-161438	Elasmobranchs	DGE	*Cephaloscyllium speccum*	No	6	9	8	Lethal	Lethal	Lethal	184	455
Fis-23084	Elasmobranchs	DGE	*Cephaloscyllium sufflans*	No	6	9	8	Lethal	Lethal	Lethal	107	600
Fis-160851	Elasmobranchs	DGE	*Dentiraja cerva*	Yes	6	9	12	Lethal	Lethal	Lethal	73	470
Fis-161213	Elasmobranchs	DGE	*Dentiraja falloarga*	Yes	6	9	12	Lethal	Lethal	Lethal	81	256
Fis-131829	Elasmobranchs	DGE	*Dipturus pullopunctatus*	No	6	9	12	Lethal	Lethal	Lethal	97	457
Fis-23113	Elasmobranchs	DGE	*Echinorhinus brucus*	No	4	9	12	Lethal	Lethal	Lethal	350	900

Fis-29406	Elasmobranchs	DGE	*Halaelurus boesemani*	No	6	9	12	Lethal	Lethal	Lethal	60	250
Fis-29409	Elasmobranchs	DGE	*Halaelurus lineatus*	No	6	9	12	Lethal	Lethal	Lethal	32	290
Fis-23144	Elasmobranchs	DGE	*Halaelurus natalensis*	No	6	9	12	Lethal	Lethal	Lethal	18	172
Fis-161473	Elasmobranchs	DGE	*Hemitrygon parvonigra*	Yes	6	9	6	Lethal	Lethal	Lethal	130	183
Fis-23149	Elasmobranchs	DGE	*Heptranchias perlo*	No	6	9	7	Lethal	Lethal	Lethal	180	1000
Fis-23153	Elasmobranchs	DGE	*Heterodontus portusjacksoni*	No	6	9	7	Lethal	Lethal	Lethal	31	275
Fis-23155	Elasmobranchs	DGE	*Heterodontus ramalheira*	No	6	9	7	Lethal	Lethal	Lethal	100	275
Fis-33775	Elasmobranchs	DGE	*Heteronarce garmani*	No	6	9	12	Lethal	Lethal	Lethal	101	329
Fis-23157	Elasmobranchs	DGE	*Hexanchus griseus*	No	6	9	6	Lethal	Lethal	Lethal	180	2500
Fis-29416	Elasmobranchs	DGE	*Hexanchus nakamurai*	No	6	9	12	Lethal	Lethal	Lethal	90	600
Fis-132550	Elasmobranchs	DGE	*Leucoraja wallacei*	No	6	9	8	Lethal	Lethal	Lethal	114	450
Fis-31600	Elasmobranchs	DGE	*Mustelus manazo*	No	6	9	4	Lethal	Lethal	Lethal	41	360
Fis-58409	Elasmobranchs	DGE	*Narcine rierai*	No	6	9	12	Lethal	Lethal	Lethal	173	214
Fis-54855	Elasmobranchs	DGE	*Narcinops tasmaniensis*	Yes	6	9	12	Lethal	Lethal	Lethal	82	640
Fis-25888	Elasmobranchs	DGE	*Nebrius ferrugineus*	No	6	9	12	Lethal	Lethal	Lethal	5	70
Fis-58285	Elasmobranchs	DGE	*Neoraja stehmanni*	No	6	9	12	Lethal	Lethal	Lethal	382	1025
Fis-161493	Elasmobranchs	DGE	*Neotrygon annotata*	No	6	9	12	Lethal	Lethal	Lethal	15	62
Fis-24153	Elasmobranchs	DGE	*Notorynchus cepedianus*	No	6	9	12	Lethal	Lethal	Lethal	68	570
Fis-131815	Elasmobranchs	DGE	*Okamejei powelli*	No	6	9	12	Lethal	Lethal	Lethal	135	244
Fis-23202	Elasmobranchs	DGE	*Orectolobus ornatus*	No	6	9	12	Lethal	Lethal	Lethal	10	100
Fis-31583	Elasmobranchs	DGE	*Parascyllium ferrugineum*	No	6	9	12	Lethal	Lethal	Lethal	20	150
Fis-25895	Elasmobranchs	DGE	*Parascyllium variolatum*	No	6	9	12	Lethal	Lethal	Lethal	20	180
Fis-21801	Elasmobranchs	DGE	*Pastinachus sephen*	No	6	9	12	Lethal	Lethal	Lethal	6	60
Fis-35265	Elasmobranchs	DGE	*Pateobatis jenkinsii*	Yes	6	9	12	Lethal	Lethal	Lethal	34	50
Fis-54800	Elasmobranchs	DGE	*Pavoraja nitida*	No	6	9	12	Lethal	Lethal	Lethal	71	390
Fis-29481	Elasmobranchs	DGE	*Pliotrema warreni*	No	6	9	12	Lethal	Lethal	Lethal	60	430
Fis-23220	Elasmobranchs	DGE	*Poroderma africanum*	No	6	9	12	Lethal	Lethal	Lethal	10	100
Fis-23221	Elasmobranchs	DGE	*Poroderma pantherinum*	No	6	9	12	Lethal	Lethal	Lethal	28	256
Fis-23223	Elasmobranchs	DGE	*Pristiophorus cirratus*	No	6	9	12	Lethal	Lethal	Lethal	37	310
Fis-29485	Elasmobranchs	DGE	*Pristiophorus nudipinnis*	No	6	9	12	Lethal	Lethal	Lethal	50	165
Fis-31187	Elasmobranchs	DGE	*Raja miraletus*	No	6	9	12	Lethal	Lethal	Lethal	50	462
Fis-131805	Elasmobranchs	DGE	*Rajella caudaspinosa*	No	6	9	12	Lethal	Lethal	Lethal	357	718
Fis-33777	Elasmobranchs	DGE	*Rhinobatos holcorhynchus*	No	6	9	12	Lethal	Lethal	Lethal	94	253
Fis-32609	Elasmobranchs	DGE	*Rhinobatos schlegelii*	No	6	9	12	Lethal	Lethal	Lethal	66	200

Fis-131821	Elasmobranchs	DGE	*Rostroraja alba*	No	6	9	12	Lethal	Lethal	Lethal	50	600
Fis-23252	Elasmobranchs	DGE	*Scyliorhinus capensis*	No	6	9	12	Lethal	Lethal	Lethal	81	495
Fis-23253	Elasmobranchs	DGE	*Scyliorhinus garmani*	No	6	9	12	Lethal	Lethal	Lethal	116	800
Fis-160854	Elasmobranchs	DGE	*Spiniraja whitleyi*	Yes	6	9	12	Lethal	Lethal	Lethal	21	170
Fis-29539	Elasmobranchs	DGE	*Squatina africana*	No	6	9	6	Lethal	Lethal	Lethal	60	494
Fis-29540	Elasmobranchs	DGE	*Squatina australis*	No	6	9	6	Lethal	Lethal	Lethal	41	256
Fis-160862	Elasmobranchs	DGE	*Squatina pseudocellata*	No	6	9	6	Lethal	Lethal	Lethal	167	312
Fis-29547	Elasmobranchs	DGE	*Squatina tergocellata*	No	6	9	6	Lethal	Lethal	Lethal	250	400
Fis-31247	Elasmobranchs	DGE	*Torpedo marmorata*	No	6	9	7	Lethal	Lethal	Lethal	44	370
Fis-61240	Elasmobranchs	DGE	*Torpedo panthera*	No	6	9	7	Lethal	Lethal	Lethal	41	350
Fis-32610	Elasmobranchs	DGE	*Torpedo sinuspersici*	No	6	9	7	Lethal	Lethal	Lethal	22	200
Fis-53171	Elasmobranchs	DGE	*Urolophus cruciatus*	No	6	9	7	Lethal	Lethal	Lethal	18	160
Fis-54647	Elasmobranchs	DGE	*Urolophus expansus*	No	6	9	7	Lethal	Lethal	Lethal	200	420
Fis-34717	Elasmobranchs	DGE	*Urolophus flavomosaicus*	No	6	9	7	Lethal	Lethal	Lethal	86	300
Fis-47425	Elasmobranchs	DGE	*Urolophus viridis*	No	6	9	7	Lethal	Lethal	Lethal	80	200
Fis-61410	Elasmobranchs	DGE	*Urolophus westraliensis*	No	6	9	7	Lethal	Lethal	Lethal	76	210
Fis-131852	Elasmobranchs	DSE	*Amblyraja hyperborea*	No	--	--	12	Lethal	Lethal	Lethal	300	2500
Fis-140639	Elasmobranchs	DSE	*Asymbolus parvus*	No	--	--	12	Lethal	Lethal	Lethal	170	260
Fis-32598	Elasmobranchs	DSE	*Bathytoshia Lata*	Yes	--	--	7	Lethal	Lethal	Lethal	51	440
Fis-154010	Elasmobranchs	DSE	*Bythaelurus hispidus*	No	--	--	12	Lethal	Lethal	Lethal	222	403
Fis-154012	Elasmobranchs	DSE	*Bythaelurus lutarius*	No	--	--	12	Lethal	Lethal	Lethal	388	766
Fis-131127	Elasmobranchs	DSE	*Centrophorus atromarginatus*	No	--	--	7	Lethal	Lethal	Lethal	213	450
Fis-29321	Elasmobranchs	DSE	*Centrophorus moluccensis*	No	--	--	7	Lethal	Lethal	Lethal	210	823
Fis-23077	Elasmobranchs	DSE	*Centrophorus uyato*	No	--	--	7	Lethal	Lethal	Lethal	200	1400
Fis-23074	Elasmobranchs	DSE	*Centroscymnus crepidater*	No	--	--	7	Lethal	Lethal	Lethal	394	1500
Fis-29332	Elasmobranchs	DSE	*Cephaloscyllium fasciatum*	No	--	--	8	Lethal	Lethal	Lethal	232	450
Fis-161448	Elasmobranchs	DSE	*Cephaloscyllium hiscosellum*	No	--	--	8	Lethal	Lethal	Lethal	307	420
Fis-29338	Elasmobranchs	DSE	*Chlamydoselachus anguineus*	No	--	--	12	Lethal	Lethal	Lethal	120	1570
Fis-131465	Elasmobranchs	DSE	*Cruriraja andamanica*	No	--	--	12	Lethal	Lethal	Lethal	300	511
Fis-164699	Elasmobranchs	DSE	*Cruriraja hulleyi*	No	--	--	12	Lethal	Lethal	Lethal	200	545
Fis-27678	Elasmobranchs	DSE	*Cruriraja parcomaculata*	No	--	--	12	Lethal	Lethal	Lethal	205	620
Fis-23101	Elasmobranchs	DSE	*Dalatias licha*	No	--	--	12	Lethal	Lethal	Lethal	200	1800
Fis-161159	Elasmobranchs	DSE	*Dentiraja healdi*	Yes	--	--	12	Lethal	Lethal	Lethal	327	520
Fis-161218	Elasmobranchs	DSE	*Dentiraja oculata*	Yes	--	--	12	Lethal	Lethal	Lethal	220	389

Fis-132518	Elasmobranchs	DSE	*Dipturus campbelli*	No	--	--	12	Lethal	Lethal	Lethal	167	403
Fis-131844	Elasmobranchs	DSE	*Dipturus stenorhynchus*	No	--	--	12	Lethal	Lethal	Lethal	313	761
Fis-31585	Elasmobranchs	DSE	*Eridacnis radcliffei*	No	--	--	12	Lethal	Lethal	Lethal	156	766
Fis-25897	Elasmobranchs	DSE	*Eridacnis sinuans*	No	--	--	12	Lethal	Lethal	Lethal	214	480
Fis-58162	Elasmobranchs	DSE	*Etmopterus bigelowi*	No	--	--	8	Lethal	Lethal	Lethal	267	1000
Fis-166044	Elasmobranchs	DSE	*Etmopterus sculptus*	No	--	--	8	Lethal	Lethal	Lethal	320	900
Fis-29385	Elasmobranchs	DSE	*Etmopterus sentosus*	No	--	--	8	Lethal	Lethal	Lethal	234	500
Fis-23127	Elasmobranchs	DSE	*Euprotomicrus bispinatus*	No	--	--	12	Lethal	Lethal	Lethal	241	1800
Fis-6652	Elasmobranchs	DSE	*Figaro boardmani*	No	--	--	12	Lethal	Lethal	Lethal	213	823
Fis-125906	Elasmobranchs	DSE	*Galeus gracilis*	No	--	--	12	Lethal	Lethal	Lethal	309	470
Fis-30995	Elasmobranchs	DSE	*Hexatrygon bickelli*	No	--	--	12	Lethal	Lethal	Lethal	362	1120
Fis-31589	Elasmobranchs	DSE	*Iago garricki*	No	5	--	12	Lethal	Lethal	Lethal	275	475
Fis-25903	Elasmobranchs	DSE	*Iago omanensis*	No	5	--	12	Lethal	Lethal	Lethal	394	2195
Fis-161235	Elasmobranchs	DSE	*Irolita westraliensis*	No	--	--	12	Lethal	Lethal	Lethal	148	209
Fis-161233	Elasmobranchs	DSE	*Leucoraja pristispina*	No	--	--	8	Lethal	Lethal	Lethal	236	504
Fis-31578	Elasmobranchs	DSE	*Mitsukurina owstoni*	No	--	--	12	Lethal	Lethal	Lethal	270	1300
Fis-149485	Elasmobranchs	DSE	*Narcinops lasti*	Yes	--	--	12	Lethal	Lethal	Lethal	196	350
Fis-23198	Elasmobranchs	DSE	*Odontaspis ferox*	No	--	--	6	Lethal	Lethal	Lethal	72	530
Fis-161225	Elasmobranchs	DSE	*Okamejei arafurensis*	No	--	--	12	Lethal	Lethal	Lethal	191	298
Fis-132528	Elasmobranchs	DSE	*Okamejei heemstrai*	No	--	--	12	Lethal	Lethal	Lethal	286	500
Fis-161228	Elasmobranchs	DSE	*Okamejei leptoura*	No	--	--	12	Lethal	Lethal	Lethal	265	735
Fis-144985	Elasmobranchs	DSE	*Parascyllium sparsimaculatum*	No	--	--	12	Lethal	Lethal	Lethal	208	245
Fis-54790	Elasmobranchs	DSE	*Pavoraja alleni*	No	--	--	12	Lethal	Lethal	Lethal	320	458
Fis-161638	Elasmobranchs	DSE	*Pavoraja arenaria*	No	--	--	12	Lethal	Lethal	Lethal	300	712
Fis-26519	Elasmobranchs	DSE	*Plesiobatis daviesi*	No	--	--	12	Lethal	Lethal	Lethal	275	780
Fis-165849	Elasmobranchs	DSE	*Pristiophorus nancyae*	No	--	--	12	Lethal	Lethal	Lethal	318	570
Fis-132559	Elasmobranchs	DSE	*Rajella barnardi*	No	--	--	12	Lethal	Lethal	Lethal	372	1700
Fis-160879	Elasmobranchs	DSE	*Sinobatis bulbicauda*	No	--	--	12	Lethal	Lethal	Lethal	273	1125
Fis-29531	Elasmobranchs	DSE	*Squaliolus laticaudus*	No	--	--	7	Lethal	Lethal	Lethal	326	1200
Fis-160439	Elasmobranchs	DSE	*Squalus edmundsi*	No	--	--	7	Lethal	Lethal	Lethal	300	850
Fis-160378	Elasmobranchs	DSE	*Squalus montalbani*	No	--	--	7	Lethal	Lethal	Lethal	383	1370
Fis-160444	Elasmobranchs	DSE	*Squalus nasutus*	No	--	--	7	Lethal	Lethal	Lethal	300	850
Fis-23075	Elasmobranchs	DSPE	*Centrophorus granulosus*	No	1--	--	7	Lethal	Lethal	Lethal	200	1200
Fis-29319	Elasmobranchs	DSPE	*Centrophorus harrissoni*	No	1--	--	7	Lethal	Lethal	Lethal	314	790

Fis-23278	Elasmobranchs	DSPE	*Cirrhigaleus asper*	No	1--	--	7	Lethal	Lethal	Lethal	253	650
Fis-29380	Elasmobranchs	DSPE	*Etmopterus gracilispinis*	No	1--	--	7	Lethal	Lethal	Lethal	187	1000
Fis-23124	Elasmobranchs	DSPE	*Etmopterus spinax*	No	1--	--	7	Lethal	Lethal	Lethal	200	2490
Fis-23204	Elasmobranchs	DSPE	*Oxynotus bruniensis*	No	1--	--	7	Lethal	Lethal	Lethal	350	1070
Fis-61614	Elasmobranchs	DSPE	*Scymnodalatias albicauda*	No	1--	--	7	Lethal	Lethal	Lethal	191	510
Fis-23260	Elasmobranchs	DSPE	*Somniosus rostratus*	No	1--	--	7	Lethal	Lethal	Lethal	345	1330
Fis-29532	Elasmobranchs	DSPE	*Squalus acanthias*	No	1--	--	7	Lethal	Lethal	Lethal	50	1460
Fis-159586	Elasmobranchs	DSPE	*Squalus crassispinus*	No	1--	--	7	Lethal	Lethal	Lethal	194	262
Fis-29536	Elasmobranchs	DSPE	*Squalus mitsukurii*	No	1--	--	7	Lethal	Lethal	Lethal	48	600
Fis-31408	Elasmobranchs	IE	*Acroteriobatus annulatus*	Yes	6	8	12	Lethal	Lethal	Lethal	7	73
Fis-32608	Elasmobranchs	IE	*Acroteriobatus blochii*	Yes	5	8	12	Lethal	Lethal	Lethal	3	30
Fis-27240	Elasmobranchs	IE	*Aetobatus flagellum*	No	5	7	5	Lethal	Lethal	Lethal	9	80
Fis-28560	Elasmobranchs	IE	*Aetomylaeus maculatus*	No	5	7	5	Lethal	Lethal	Lethal	2	18
Fis-28561	Elasmobranchs	IE	*Aetomylaeus milvus*	No	5	7	5	Lethal	Lethal	Lethal	10	100
Fis-26906	Elasmobranchs	IE	*Anoxypristis cuspidata*	No	6	8	12	Lethal	Lethal	Lethal	4	40
Fis-131407	Elasmobranchs	IE	*Atelomycterus fasciatus*	No	6	8	12	Lethal	Lethal	Lethal	37	122
Fis-29298	Elasmobranchs	IE	*Atelomycterus macleayi*	No	6	8	12	Lethal	Lethal	Lethal	0	4
Fis-26085	Elasmobranchs	IE	*Bathytoshia brevicaudata*	Yes	5	8	7	Lethal	Lethal	Lethal	0	476
Fis-23993	Elasmobranchs	IE	*Bathytoshia centroura*	Yes	5	8	7	Lethal	Lethal	Lethal	15	270
Fis-23055	Elasmobranchs	IE	*Carcharhinus fitzroyensis*	No	6	8	4	Lethal	Lethal	Lethal	4	40
Fis-23082	Elasmobranchs	IE	*Cephaloscyllium laticeps*	No	6	8	8	Lethal	Lethal	Lethal	25	220
Fis-58398	Elasmobranchs	IE	*Dasyatis chrysonota*	No	4	8	7	Lethal	Lethal	Lethal	11	100
Fis-33107	Elasmobranchs	IE	*Dasyatis marmorata*	No	4	8	7	Lethal	Lethal	Lethal	17	65
Fis-60598	Elasmobranchs	IE	*Fontitrygon margaritella*	Yes	6	8	12	Lethal	Lethal	Lethal	6	50
Fis-23138	Elasmobranchs	IE	*Glyphis gangeticus*	No	6	8	12	Lethal	Lethal	Lethal	3	20
Fis-161453	Elasmobranchs	IE	*Glyphis garricki*	No	6	8	12	Lethal	Lethal	Lethal	1	11
Fis-24044	Elasmobranchs	IE	*Gymnura altavela*	No	6	8	12	Lethal	Lethal	Lethal	15	100
Fis-24046	Elasmobranchs	IE	*Gymnura micrura*	No	6	8	12	Lethal	Lethal	Lethal	6	55
Fis-15849	Elasmobranchs	IE	*Gymnura natalensis*	No	6	8	12	Lethal	Lethal	Lethal	28	100
Fis-26932	Elasmobranchs	IE	*Gymnura poecilura*	No	6	8	12	Lethal	Lethal	Lethal	3	25
Fis-28559	Elasmobranchs	IE	*Gymnura zonura*	No	6	8	12	Lethal	Lethal	Lethal	29	37
Fis-154456	Elasmobranchs	IE	*Hemitrygon bennetti*	Yes	6	8	7	Lethal	Lethal	Lethal	5	40
Fis-28555	Elasmobranchs	IE	*Himantura granulata*	No	6	8	12	Lethal	Lethal	Lethal	9	85
Fis-148497	Elasmobranchs	IE	*Lamiopsis temminckii*	No	6	8	12	Lethal	Lethal	Lethal	5	50

Fis-161488	Elasmobranchs	IE	*Maculabatis astra*	Yes	6	8	12	Lethal	Lethal	Lethal	16	141
Fis-47488	Elasmobranchs	IE	*Maculabatis gerrardi*	Yes	6	8	12	Lethal	Lethal	Lethal	6	50
Fis-166946	Elasmobranchs	IE	*Maculabatis randalli*	Yes	6	8	12	Lethal	Lethal	Lethal	5	40
Fis-47495	Elasmobranchs	IE	*Maculabatis toshi*	Yes	6	8	12	Lethal	Lethal	Lethal	23	140
Fis-47352	Elasmobranchs	IE	*Megatrygon microps*	Yes	5	8	7	Lethal	Lethal	Lethal	22	200
Fis-25062	Elasmobranchs	IE	*Myliobatis aquila*	No	5	8	5	Lethal	Lethal	Lethal	35	300
Fis-47427	Elasmobranchs	IE	*Narcine lingula*	No	6	8	12	Lethal	Lethal	Lethal	22	200
Fis-26903	Elasmobranchs	IE	*Narcine timlei*	No	6	8	12	Lethal	Lethal	Lethal	22	200
Fis-28947	Elasmobranchs	IE	*Narke dipterygia*	No	6	8	12	Lethal	Lethal	Lethal	39	200
Fis-28785	Elasmobranchs	IE	*Pateobatis bleekeri*	Yes	6	8	12	Lethal	Lethal	Lethal	3	30
Fis-35264	Elasmobranchs	IE	*Pateobatis fai*	Yes	6	8	12	Lethal	Lethal	Lethal	22	200
Fis-27224	Elasmobranchs	IE	*Pristis pristis*	No	6	8	12	Lethal	Lethal	Lethal	5	50
Fis-32599	Elasmobranchs	IE	*Pristis zijsron*	No	6	8	12	Lethal	Lethal	Lethal	0	5
Fis-22814	Elasmobranchs	IE	*Pseudobatus percellens*	Yes	6	8	12	Lethal	Lethal	Lethal	11	110
Fis-64122	Elasmobranchs	IE	*Raja pita*	No	6	8	12	Lethal	Lethal	Lethal	1	15
Fis-57444	Elasmobranchs	IE	*Rhinobatos punctifer*	No	6	8	12	Lethal	Lethal	Lethal	16	150
Fis-29505	Elasmobranchs	IE	*Scoliodon laticaudus*	No	6	8	12	Lethal	Lethal	Lethal	10	13
Fis-27236	Elasmobranchs	IE	*Taeniurops grabatus*	Yes	6	8	12	Lethal	Lethal	Lethal	42	300
Fis-166734	Elasmobranchs	IE	*Taeniurops meyeni*	No	6	8	12	Lethal	Lethal	Lethal	20	500
Fis-32811	Elasmobranchs	IE	*Temera hardwickii*	No	6	8	7	Lethal	Lethal	Lethal	39	200
Fis-31223	Elasmobranchs	IE	*Torpedo fuscomaculata*	No	6	8	7	Lethal	Lethal	Lethal	51	439
Fis-25905	Elasmobranchs	IE	*Triakis megalopterus*	No	6	8	12	Lethal	Lethal	Lethal	6	50
Fis-161466	Elasmobranchs	IE	*Trygonoptera imitata*	No	6	8	12	Lethal	Lethal	Lethal	13	120
Fis-61250	Elasmobranchs	IE	*Trygonoptera ovalis*	No	6	8	12	Lethal	Lethal	Lethal	8	43
Fis-6035	Elasmobranchs	IE	*Urogymnus asperrimus*	No	5	8	12	Lethal	Lethal	Lethal	3	20
Fis-31568	Elasmobranchs	OE	*Alopias pelagicus*	No	5	4	1	Lethal	Lethal	Lethal	0	300
Fis-23898	Elasmobranchs	OE	*Alopias superciliosus*	No	5	4	1	Lethal	Lethal	Lethal	0	730
Fis-23899	Elasmobranchs	OE	*Alopias vulpinus*	No	5	4	1	Lethal	Lethal	Lethal	0	650
Fis-23061	Elasmobranchs	OE	*Carcharhinus longimanus*	No	5	2	1	Lethal	Lethal	Lethal	0	230
Fis-58485	Elasmobranchs	OE	*Isurus oxyrinchus*	No	5	4	1	Lethal	Lethal	Lethal	100	750
Fis-29423	Elasmobranchs	OE	*Isurus paucus*	No	5	4	1	Lethal	Lethal	Lethal	234	1752
Fis-25899	Elasmobranchs	OE	*Pseudocarcharias kamoharai*	No	5	4	1	Lethal	Lethal	Lethal	0	590
Fis-22747	Elasmobranchs	FFE	*Cetorhinus maximus*	No	4	5	7	Pot.lethal	Pot.lethal	Pot.lethal	0	2000
Fis-31577	Elasmobranchs	FFE	*Megachasma pelagios*	No	4	5	1--	Pot.lethal	Pot.lethal	Pot.lethal	120	600

Fis-163295	Elasmobranchs	FFE	*Mobula alfredi*	Yes	4	5	6	Lethal	Pot.lethal	Pot.lethal	13	120
Fis-24098	Elasmobranchs	FFE	*Mobula birostris*	Yes	4	5	6	Lethal	Pot.lethal	Pot.lethal	12	120
Fis-61508	Elasmobranchs	FFE	*Mobula kuhlii*	No	4	5	6	Lethal	Pot.lethal	Pot.lethal	10	100
Fis-21798	Elasmobranchs	FFE	*Mobula Mobula*	Yes	4	5	6	Lethal	Pot.lethal	Pot.lethal	0	300
Fis-35514	Elasmobranchs	FFE	*Mobula tarapacana*	No	4	5	6	Lethal	Pot.lethal	Pot.lethal	0	1896
Fis-24127	Elasmobranchs	FFE	*Mobula thurstoni*	No	4	5	6	Lethal	Pot.lethal	Pot.lethal	10	100
Fis-30583	Elasmobranchs	FFE	*Rhincodon typus*	No	4	5	1--	Pot.lethal	Pot.lethal	Pot.lethal	0	1928
Fis-23322	Elasmobranchs	PGE	*Aetobatus narinari*	No	5	6	5	Lethal	Lethal	Lethal	1	80
Fis-28563	Elasmobranchs	PGE	*Aetobatus ocellatus*	No	5	6	5	Lethal	Lethal	Lethal	20	100
Fis-28562	Elasmobranchs	PGE	*Aetomylaeus vespertilio*	No	5	6	2	Lethal	Lethal	Lethal	11	110
Fis-23044	Elasmobranchs	PGE	*Carcharhinus albimarginatus*	No	5	6	4	Lethal	Lethal	Lethal	20	800
Fis-23054	Elasmobranchs	PGE	*Carcharhinus falciformis*	No	5	1	1	Lethal	Lethal	Lethal	0	500
Fis-23056	Elasmobranchs	PGE	*Carcharhinus galapagensis*	No	5	6	2	Lethal	Lethal	Lethal	30	286
Fis-23057	Elasmobranchs	PGE	*Carcharhinus hemiodon*	No	5	6	2	Lethal	Lethal	Lethal	6	50
Fis-169677	Elasmobranchs	PGE	*Carcharhinus humani*	No	5	6	2	Lethal	Lethal	Lethal	22.5	408
Fis-23064	Elasmobranchs	PGE	*Carcharhinus obscurus*	No	5	6	2	Lethal	Lethal	Lethal	200	400
Fis-23066	Elasmobranchs	PGE	*Carcharhinus plumbeus*	No	5	6	2	Lethal	Lethal	Lethal	20	500
Fis-23071	Elasmobranchs	PGE	*Carcharodon carcharias*	No	6	6	2	Pot.lethal	Pot.lethal	Sublethal	0	1200
Fis-29367	Elasmobranchs	PGE	*Echinorhinus cookei*	No	5	6	2	Lethal	Lethal	Lethal	70	1100
Fis-23129	Elasmobranchs	PGE	*Galeocerdo cuvier*	No	5	6	2	Lethal	Lethal	Lethal	0	800
Fis-25233	Elasmobranchs	PGE	*Galeorhinus galeus*	No	5	6	2	Lethal	Lethal	Lethal	2	1100
Fis-22768	Elasmobranchs	PGE	*Lamna nasus*	No	5	6	2	Lethal	Lethal	Lethal	87	715
Fis-25412	Elasmobranchs	PGE	*Mustelus mustelus*	No	5	6	4	Lethal	Lethal	Lethal	5	624
Fis-31594	Elasmobranchs	PGE	*Mustelus palumbes*	No	5	6	4	Lethal	Lethal	Lethal	52	443
Fis-161402	Elasmobranchs	PGE	*Mustelus stevensi*	No	5	6	4	Lethal	Lethal	Lethal	152	402
Fis-32960	Elasmobranchs	PGE	*Myliobatis tenuicaudatus*	Yes	5	6	5	Lethal	Lethal	Lethal	9	85
Fis-23193	Elasmobranchs	PGE	*Negaprion acutidens*	No	5	6	2	Lethal	Lethal	Lethal	9	92
Fis-23222	Elasmobranchs	PGE	*Prionace glauca*	No	5	6	1	Lethal	Lethal	Lethal	1	1000
Fis-20033	Elasmobranchs	PGE	*Pteroplatytrygon violacea*	No	5	6	2	Lethal	Lethal	Lethal	1	381
Fis-32611	Elasmobranchs	PGE	*Rhinoptera javanica*	No	5	6	2	Lethal	Lethal	Lethal	3	30
Fis-23280	Elasmobranchs	PGE	*Squalus megalops*	No	5	6	2	Lethal	Lethal	Lethal	118	750
Fis-23028	Elasmobranchs	RE	*Asymbolus analis*	No	8	8	12	Lethal	Lethal	Lethal	10	180
Fis-140634	Elasmobranchs	RE	*Asymbolus submaculatus*	No	8	8	12	Lethal	Lethal	Lethal	48	200
Fis-23029	Elasmobranchs	RE	*Asymbolus vincenti*	No	8	8	12	Lethal	Lethal	Lethal	102	650

Fis-24448	Elasmobranchs	RE	*Atelomycterus marmoratus*	No	8	8	12	Lethal	Lethal	Lethal	5	25
Fis-23046	Elasmobranchs	RE	*Carcharhinus amblyrhynchoides*	No	8	8	4	Lethal	Lethal	Lethal	5	50
Fis-23047	Elasmobranchs	RE	*Carcharhinus amblyrhynchos*	No	8	8	4	Lethal	Lethal	Lethal	0	1000
Fis-23063	Elasmobranchs	RE	*Carcharhinus melanopterus*	No	8	8	4	Lethal	Lethal	Lethal	25	75
Fis-31571	Elasmobranchs	RE	*Chiloscyllium arabicum*	No	8	8	12	Lethal	Lethal	Lethal	13	100
Fis-30780	Elasmobranchs	RE	*Chiloscyllium griseum*	No	8	8	12	Lethal	Lethal	Lethal	12	80
Fis-132130	Elasmobranchs	RE	*Chiloscyllium hasseltii*	No	8	8	12	Lethal	Lethal	Lethal	1	12
Fis-25892	Elasmobranchs	RE	*Chiloscyllium indicum*	No	8	8	12	Lethal	Lethal	Lethal	2	20
Fis-25470	Elasmobranchs	RE	*Chiloscyllium plagiosum*	No	8	8	12	Lethal	Lethal	Lethal	7	25
Fis-31573	Elasmobranchs	RE	*Chiloscyllium punctatum*	No	8	8	12	Lethal	Lethal	Lethal	8	85
Fis-23126	Elasmobranchs	RE	*Eucrossorhinus dasypogon*	No	8	8	12	Lethal	Lethal	Lethal	5	40
Fis-25894	Elasmobranchs	RE	*Hemiscyllium ocellatum*	No	8	8	12	Lethal	Lethal	Lethal	5	50
Fis-31576	Elasmobranchs	RE	*Hemiscyllium trispeculare*	No	8	8	12	Lethal	Lethal	Lethal	5	50
Fis-23156	Elasmobranchs	RE	*Heterodontus zebra*	No	8	8	12	Lethal	Lethal	Lethal	66	200
Fis-161494	Elasmobranchs	RE	*Neotrygon kuhlii*	No	4	8	12	Lethal	Lethal	Lethal	9	170
Fis-23201	Elasmobranchs	RE	*Orectolobus maculatus*	No	8	8	12	Lethal	Lethal	Lethal	0	110
Fis-29459	Elasmobranchs	RE	*Orectolobus wardi*	No	8	8	12	Lethal	Lethal	Lethal	1	3
Fis-32975	Elasmobranchs	RE	*Rhina ancylostoma*	No	8	8	12	Lethal	Lethal	Lethal	12	90
Fis-8339	Elasmobranchs	RE	*Stegostoma fasciatum*	No	8	8	7	Lethal	Lethal	Lethal	5	63
Fis-23292	Elasmobranchs	RE	*Sutorectus tentaculatus*	No	8	8	12	Lethal	Lethal	Lethal	5	50
Fis-25603	Elasmobranchs	RE	*Taeniura lymma*	No	8	8	12	Lethal	Lethal	Lethal	3	20
Fis-23311	Elasmobranchs	RE	*Triaenodon obesus*	No	8	8	12	Lethal	Lethal	Lethal	8	330
Fis-47714	Elasmobranchs	SSE	*Acroteriobatus ocellatus*	Yes	1	8	7	Lethal	Lethal	Lethal	73	185
Fis-27676	Elasmobranchs	SSE	*Aetomylaeus nichofii*	No	1	7	5	Lethal	Lethal	Lethal	8	70
Fis-54720	Elasmobranchs	SSE	*Aptychotrema vincentiana*	No	1	8	7	Lethal	Lethal	Lethal	4	32
Fis-28787	Elasmobranchs	SSE	*Brevitrygon imbricata*	Yes	1	8	7	Lethal	Lethal	Lethal	6	50
Fis-23045	Elasmobranchs	SSE	*Carcharhinus altimus*	No	1	8	4	Lethal	Lethal	Lethal	80	810
Fis-23048	Elasmobranchs	SSE	*Carcharhinus amboinensis*	No	1	8	4	Lethal	Lethal	Lethal	16	150
Fis-23050	Elasmobranchs	SSE	*Carcharhinus brachyurus*	No	1	8	4	Lethal	Lethal	Lethal	41	360
Fis-23051	Elasmobranchs	SSE	*Carcharhinus brevipinna*	No	1	8	2	Lethal	Lethal	Lethal	0	100
Fis-23052	Elasmobranchs	SSE	*Carcharhinus cautus*	No	1	8	4	Lethal	Lethal	Lethal	6	50
Fis-23053	Elasmobranchs	SSE	*Carcharhinus dussumieri*	No	1	8	4	Lethal	Lethal	Lethal	10	100
Fis-23059	Elasmobranchs	SSE	*Carcharhinus leucas*	No	1	8	4	Lethal	Lethal	Lethal	1	152

Fis-23060	Elasmobranchs	SSE	*Carcharhinus limbatus*	No	1	8	4	Lethal	Lethal	Lethal	0	100
Fis-23062	Elasmobranchs	SSE	*Carcharhinus macloti*	No	1	8	4	Lethal	Lethal	Lethal	19	170
Fis-23068	Elasmobranchs	SSE	*Carcharhinus sealei*	No	1	8	4	Lethal	Lethal	Lethal	4	40
Fis-23070	Elasmobranchs	SSE	*Carcharhinus sorrah*	No	1	8	4	Lethal	Lethal	Lethal	1	140
Fis-47835	Elasmobranchs	SSE	*Carcharhinus tilstoni*	No	1	8	4	Lethal	Lethal	Lethal	16	150
Fis-29388	Elasmobranchs	SSE	*Carcharias taurus*	No	1	8	5	Lethal	Lethal	Lethal	15	191
Fis-25889	Elasmobranchs	SSE	*Chaenogaleus macrostoma*	No	1	8	5	Lethal	Lethal	Lethal	6	59
Fis-161209	Elasmobranchs	SSE	*Dentiraja confusus*	Yes	1	8	7	Lethal	Lethal	Lethal	18	390
Fis-164471	Elasmobranchs	SSE	*Dentiraja lemprieri*	No	1	8	7	Lethal	Lethal	Lethal	0	170
Fis-160925	Elasmobranchs	SSE	*Electrolux addisoni*	No	1	8	7	Lethal	Lethal	Lethal	9	35
Fis-23128	Elasmobranchs	SSE	*Eusphyra blochii*	No	1	8	3	Lethal	Lethal	Lethal	9	50
Fis-25900	Elasmobranchs	SSE	*Furgaleus macki*	No	1	8	7	Lethal	Lethal	Lethal	27	220
Fis-159583	Elasmobranchs	SSE	*Glaucostegus granulatus*	No	1	8	7	Lethal	Lethal	Lethal	12	119
Fis-159582	Elasmobranchs	SSE	*Glaucostegus halavi*	No	1	8	7	Lethal	Lethal	Lethal	4	40
Fis-28552	Elasmobranchs	SSE	*Glaucostegus thouin*	Yes	1	8	7	Lethal	Lethal	Lethal	11	100
Fis-159584	Elasmobranchs	SSE	*Glaucostegus typus*	No	1	8	7	Lethal	Lethal	Lethal	10	100
Fis-47368	Elasmobranchs	SSE	*Gymnura australis*	No	1	8	7	Lethal	Lethal	Lethal	5	50
Fis-160267	Elasmobranchs	SSE	*Halaelurus sellus*	No	1	8	7	Lethal	Lethal	Lethal	72	164
Fis-23146	Elasmobranchs	SSE	*Haploblepharus edwardsii*	No	1	8	7	Lethal	Lethal	Lethal	40	130
Fis-29411	Elasmobranchs	SSE	*Haploblepharus fuscus*	No	1	8	7	Lethal	Lethal	Lethal	7	25
Fis-156398	Elasmobranchs	SSE	*Hemigaleus australiensis*	No	1	8	7	Lethal	Lethal	Lethal	29	170
Fis-31570	Elasmobranchs	SSE	*Hemigaleus microstoma*	No	1	8	7	Lethal	Lethal	Lethal	30	200
Fis-48194	Elasmobranchs	SSE	*Hemipristis elongata*	No	1	8	7	Lethal	Lethal	Lethal	14	130
Fis-161480	Elasmobranchs	SSE	*Himantura leoparda*	No	1	8	7	Lethal	Lethal	Lethal	8	70
Fis-26148	Elasmobranchs	SSE	*Himantura uarnak*	No	1	8	7	Lethal	Lethal	Lethal	23	50
Fis-28553	Elasmobranchs	SSE	*Himantura undulata*	No	1	8	7	Lethal	Lethal	Lethal	6	50
Fis-160938	Elasmobranchs	SSE	*Holohalaelurus favus*	No	1	8	7	Lethal	Lethal	Lethal	299	1000
Fis-23158	Elasmobranchs	SSE	*Holohalaelurus punctatus*	No	1	8	7	Lethal	Lethal	Lethal	244	440
Fis-23159	Elasmobranchs	SSE	*Holohalaelurus regani*	No	1	8	7	Lethal	Lethal	Lethal	150	1075
Fis-139820	Elasmobranchs	SSE	*Hypnos monopterygius*	No	1	8	7	Lethal	Lethal	Lethal	26	240
Fis-25902	Elasmobranchs	SSE	*Hypogaleus hyugaensis*	No	1	8	7	Lethal	Lethal	Lethal	60	230
Fis-54787	Elasmobranchs	SSE	*Irolita waitii*	No	1	8	7	Lethal	Lethal	Lethal	66	200
Fis-29421	Elasmobranchs	SSE	*Isistius plutodus*	No	1	8	7	Lethal	Lethal	Lethal	75	200
Fis-29436	Elasmobranchs	SSE	*Loxodon macrorhinus*	No	1	8	7	Lethal	Lethal	Lethal	16	100

Fis-31602	Elasmobranchs	SSE	*Mustelus antarcticus*	No	1	8	4	Lethal	Lethal	Lethal	40	350
Fis-160464	Elasmobranchs	SSE	*Mustelus ravidus*	No	1	8	4	Lethal	Lethal	Lethal	127	300
Fis-161457	Elasmobranchs	SSE	*Narcinops ornata*	Yes	1	8	7	Lethal	Lethal	Lethal	56	132
Fis-54860	Elasmobranchs	SSE	*Narcinops westraliensis*	Yes	1	8	7	Lethal	Lethal	Lethal	16	70
Fis-58273	Elasmobranchs	SSE	*Narke capensis*	No	1	8	7	Lethal	Lethal	Lethal	37	183
Fis-161495	Elasmobranchs	SSE	*Neotrygon leylandi*	No	1	8	7	Lethal	Lethal	Lethal	12	80
Fis-161491	Elasmobranchs	SSE	*Neotrygon picta*	No	1	8	7	Lethal	Lethal	Lethal	14	96
Fis-160886	Elasmobranchs	SSE	*Orectolobus floridus*	No	1	8	7	Lethal	Lethal	Lethal	46	85
Fis-159132	Elasmobranchs	SSE	*Orectolobus hutchinsi*	No	1	8	7	Lethal	Lethal	Lethal	0	106
Fis-160887	Elasmobranchs	SSE	*Orectolobus parvimaculatus*	No	1	8	7	Lethal	Lethal	Lethal	22	135
Fis-25414	Elasmobranchs	SSE	*Paragaleus pectoralis*	No	1	8	7	Lethal	Lethal	Lethal	30	100
Fis-140161	Elasmobranchs	SSE	*Paragaleus randalli*	No	1	8	7	Lethal	Lethal	Lethal	2	18
Fis-159136	Elasmobranchs	SSE	*Rhinobatos sainsburyi*	No	1	8	7	Lethal	Lethal	Lethal	80	200
Fis-23239	Elasmobranchs	SSE	*Rhizoprionodon acutus*	No	1	8	7	Lethal	Lethal	Lethal	22	200
Fis-29500	Elasmobranchs	SSE	*Rhizoprionodon oligolinx*	No	1	8	7	Lethal	Lethal	Lethal	3	36
Fis-23243	Elasmobranchs	SSE	*Rhizoprionodon taylori*	No	1	8	7	Lethal	Lethal	Lethal	34	300
Fis-25664	Elasmobranchs	SSE	*Rhynchobatus djiddensis*	No	1	8	7	Lethal	Lethal	Lethal	6	50
Fis-161456	Elasmobranchs	SSE	*Rhynchobatus palpebratus*	No	1	8	7	Lethal	Lethal	Lethal	10	61
Fis-23273	Elasmobranchs	SSE	*Sphyrna lewini*	No	1	7	3	Lethal	Lethal	Lethal	0	1000
Fis-23274	Elasmobranchs	SSE	*Sphyrna mokarran*	No	1	7	3	Lethal	Lethal	Lethal	1	300
Fis-23277	Elasmobranchs	SSE	*Sphyrna zygaena*	No	1	7	3	Lethal	Lethal	Lethal	0	200
Fis-160691	Elasmobranchs	SSE	*Squalus hemipinnis*	No	1	8	7	Lethal	Lethal	Lethal	11	100
Fis-26902	Elasmobranchs	SSE	*Telatrygon Zugei*	Yes	1	8	7	Lethal	Lethal	Lethal	6	50
Fis-24377	Elasmobranchs	SSE	*Torpedo torpedo*	No	1	8	7	Lethal	Lethal	Lethal	48	400
Fis-161470	Elasmobranchs	SSE	*Trygonoptera galba*	No	1	8	7	Lethal	Lethal	Lethal	111	210
Fis-47420	Elasmobranchs	SSE	*Urolophus bucculentus*	No	1	8	7	Lethal	Lethal	Lethal	113	230
Fis-61406	Elasmobranchs	SSE	*Urolophus orarius*	No	1	8	7	Lethal	Lethal	Lethal	23	50
Fis-54691	Elasmobranchs	SSE	*Urolophus paucimaculatus*	No	1	8	7	Lethal	Lethal	Lethal	20	150
Rep-2666	Sea turtles	ST	*Caretta caretta*	No	1	3	3	Lethal	Pot.lethal	Pot.lethal	0	40
Rep-2941	Sea turtles	ST	*Chelonia mydas*	No	1	3	3	Lethal	Pot.lethal	Pot.lethal	0	95
Rep-4381	Sea turtles	ST	*Dermochelys coriacea*	No	1	3	3	Lethal	Pot.lethal	Pot.lethal	0	2000
Rep-5181	Sea turtles	ST	*Eretmochelys imbricata*	No	1	3	3	Lethal	Pot.lethal	Pot.lethal	0	140
Rep-6936	Sea turtles	ST	*Lepidochelys olivacea*	No	1	3	3	Lethal	Pot.lethal	Pot.lethal	0	95
Rep-8732	Sea turtles	ST	*Natator depressa*	No	1	3	3	Lethal	Pot.lethal	Pot.lethal	0	95