IN SUPPORT OF THE IOTC ECOSYSTEM REPORT CARD: INDICATORS FOR NON-RETAINED SHARKS AND RAYS

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Summary

In this working paper, we address the ecosystem component consisted of “non-retained sharks and rays” to support the development of an ecosystem report card in the IOTC region. This group includes sharks and ray species that are not retained due to retention bans or due to their low or no commercial value. The interaction between these non-retained species and IOTC fisheries needs to be monitored because, in most cases, stock assessments have not yet been conducted due to lack of data and their status remain unknown or poorly known. The conceptual objective of this work is to reduce the interactions and mortality induced by IOTC fisheries to levels that would be sustainable for these species. The operational objective is to determine whether the number of interactions and total mortality is not jeopardizing the reproductive capacity of the species. To do so, we propose a list of candidate indicators to be calculated for key species and fishing gears. Two examples of indicator trends derived from purse seine data are presented and briefly discussed. Future steps include making an inventory of available data sources by species, updating the list of priority species by gear type, exploring indicators for species for which data is available and defining periodicity for the indicator assessments. The work presented here is still in progress and requires the collaboration of multiple experts with experience on the multiple gears operating in the IOTC convention area. We invite the IOTC community to contribute towards the development of this ecosystem component to support the IOTC ecosystem report card.

Introduction

With the objective of supporting the implementation of an Ecosystem-based fisheries management (EBFM) in the IOTC region, the WPEB is developing an indicator-based ecosystem report card. In this working paper we address the "non-retained sharks and rays" ecosystem component, and specifically, we develop the following elements towards the implementation of EBFM for this component:

1. We illustrate the importance of "non-retained sharks and rays" for the application of EAFM-and describe briefly the potential risks of not monitoring it. We also make a proposal of a conceptual and an operational objective which can be used to measure progress towards management of this component;
2. We propose candidate indicators to be calculated for key species and fishing gears relevant to monitor this ecosystem component;
3. We discuss the main issues when monitoring this ecosystem component;
4. We present several indicators, describe their trends and briefly discuss their relevance and limitation towards monitoring this ecosystem component; and
5. We draft a work plan to guide our future work.

1. The "non-retained sharks and rays" ecosystem component and possible objectives to manage this component

Sharks are not part of the 16 species directly under the IOTC mandate, yet sharks are frequently caught in association with fisheries targeting IOTC species, and stock assessment are carried out for some of the shark species. In 2012 and 2013, the IOTC Secretariat identified those "most commonly caught" sharks and ray species, which make an important part of the bycatch in IOTC fisheries (Table 1) (IOTC Secretariat, 2014).

Currently, IOTC CPCs are requested to report fishery statistics for the "the most common shark species" by gear specified in Resolution 15/01 (shark and ray species or species groups shaded in grey in Table 1) at the same level of detail as for the 16 species directly under IOTC mandate. Some of the shark species in Table 1 can be retained for their commercial value, while others are mostly discarded, either due to their null or low commercial value or due to no retention measures in place. Furthermore, of these 21 shark and ray species, the IOTC considers seven species of sharks as priority species for which executive summaries are developed. These are the blue shark, oceanic whitetip, scalloped hammerhead, shortfin mako, silky shark, and bigeye and pelagic threshers. It is worth noting that blue and mako sharks can be considered as target species in some fisheries and, thus, they are not considered as part of the “non-retained sharks and rays” ecosystem component shown in this paper.

In IOTC, the shark species with current retention bans in place are all threshers (family Alopiidae) and the oceanic whitetip (Res. 12-09 and Res. 13-06). A resolution prohibiting purse seine setting on whale sharks and calling for its safe release in case of encirclement is also in place (Res. 13-05). However, there are other pelagic sharks and rays that are caught in IOTC fisheries and, despite the lack on non-retention measures, are still mostly discarded due to low or no commercial value (Amandè et al., 2012; Capietto et al., 2014; Cortés et al., 2018; Huang and Liu, 2010; Worm et al., 2013). Some of those species have retention bans in other oceans and/or are listed under Appendix II of the Convention on International Trade in Endangered Species (CITES) (Tolotti et al., 2015). Moreover, these shark species are mainly bycatch, contrary to blue shark and shortfin mako, and, thus, considered to be part of the “non-retained” shark and rays component.

As such, the list for the "non-retained sharks and rays" for consideration in this indicator are: oceanic whitetip shark (*Carcharhinus longimanus*), bigeye thresher (*Alopias superciliosus*), pelagic thresher (*A. pelagicus*), common thresher (*A. vulpinus*), whale shark (*Rhincodon typus*), silky shark (*C. falciformis*), scalloped hammerhead (*Sphyrna lewini*), smooth hammerhead (*S. zygaena*), great hammerhead (*S. mokarran*), porbeagle (*Lamna nasus*), manta and devil rays (*Manta spp.* and *Mobula spp.*).

It is important to monitor the interaction of IOTC fisheries with those non-retained species, as, in most cases, stock assessments have not yet been conducted due to lack of data and their status remain unknown or poorly known. Ecological Risk Assessments were carried out to infer the susceptibility and risk of these species to various IOTC gears (Murua et al., 2018, 2012), which is the basis for providing their current management advice. A preliminary stock assessment for the silky shark was carried out in 2018 that put the basis for future stock assessment of data poor shark species (Ortiz de Urbina et al., 2018). Those species are also generally characterized by low productivity values (Cailliet et al., 2005; Cortés, 2000; Dulvy et al., 2008; Musick et al., 2000), making them more vulnerable to over-fishing. Without proper monitoring, assessment and management, the abundance of these non-retained shark and ray species might decline to critical levels.

In order to progress towards addressing the “non-retained shark and rays” ecosystem component within the IOTC ecosystem report card, we propose the following conceptual and operational objectives:

- **Conceptual objective:** "To reduce the number of fishing interactions and mortality induced by IOTC fisheries to levels that would be sustainable for these species".

- **Operational objective:** "Determine whether the number of interactions and total mortality is not jeopardizing the reproductive capacity of the species".

2. Candidate indicators for key species

In the open ocean, where most tuna fisheries operate, fishery-dependent data are mainly obtained from fishery logbooks. However, the historically low economic value of shark products compared to the target species has resulted in fewer incentives for research and monitoring (Barker and Schluessel, 2005), and the reporting of bycatch has only become mandatory in recent years. That is why, when it comes to non-retained species, fisheries observer programs are often the most reliable, if not the only, source of data to support indicator development. Nonetheless, it is worth noting that observer programs are relatively new and that observer coverage varies greatly across gears and fleets.

Taking into account these data restrictions, simple indicators, such as catch rates and size indicators, based on observer programs should be prioritized. Where data allows it, the possibility of more robust indicators such as estimation of biomass and fishing mortality rates derived from fishery stock assessments should be investigated. Ideally, the ecological report card for this ecosystem component should include either the most commonly captured and/or most susceptible species by fishing gear. In any case, when looking at the indicators, it is important to bear in mind that fishing gears often do not operate in the same areas and sometimes the impact of a particular gear on particular species might differ spatially within the IOTC convention area. Some species might also be impacted by multiple gears and therefore the cumulative pressures across all gears needs to be accounted for. A non-exhaustive list of potential indicators is provided in Table 2.

Due to the lack of reliable stock assessments, the population status of most species within the non-retained sharks and rays group is unknown, rendering the task of selecting priority species more difficult. As an alternative, results from ecological risk assessments (ERA) could be used, as these assessments provide relative measures of vulnerabilities of each species to the different fisheries. In 2012 the Scientific Committee conducted preliminary ERAs for shark species (Murua et al., 2012). These ERAs, determined by a susceptibility and productivity analysis, ranked the relative vulnerability of 16 sharks to longline and purse fisheries in the IOTC area. This assessment identified the most vulnerable shark species to longline and purse seine fisheries, which has been used to provide research priorities for shark management to the Commission. Oceanic whitetip shark was ranked as the most vulnerable to purse seine fishery, followed by silky shark and shortfin mako, while shortfin mako, bigeye thresher and pelagic thresher were ranked as the most vulnerable to longline gear (Murua et al., 2012).

In 2018 an updated ERA was conducted, including longline, purse seine and gillnet data (Murua et al., 2018). Overall, shortfin mako, silky shark, porbeagle and bigeye thresher were classified as the most vulnerable species to longliners, while crocodile shark, pelagic thresher and longfin mako where the most vulnerable to purse seiners. For the gillnet fleets, the most vulnerable species were crocodile shark, smooth hammerhead, pelagic thresher, silky shark and scalloped hammerhead. In this 2018 assessment, oceanic whitetip and silky shark were ranked in much lower vulnerability levels in the purse seine fishery because it was considered that after implementation of safe release best practices the post-release mortality would be lower. Nonetheless, it is important to take into account that, even if half of the released sharks might survive, the total mortality is still quite high as many sharks are already dead by the time they reach the deck. According to electronic tagging studies conducted in the Pacific, Atlantic and Indian oceans, the total mortality of silky sharks caught by purse seiners is around 80% (Eddy et al., 2016; Hutchinson et al., 2015; Poisson et al., 2014). Based on the 2012 and 2018 assessments, a list of priority species for the ecosystem component of non-retained sharks and rays is given in Table 3.

3. The main issues in the non-retained sharks and rays group

As mentioned above, the historical lack of monitoring and resulting paucity of data has hampered the conduction of population assessments for most species of this group (Barker and Schluessel, 2005; Oliver et al., 2015). Even if CPCs are now required to provide fishery statistics for some of these species, the issue remains because historical data that would be needed to establish baseline numbers of the indicator(s) cannot be estimated. Historical information (or some proxies) of the indicator should ideally be available to understand its trend. In the exercise of the ecosystem report card, the objective is to examine the general trends of the indicators and to evaluate its variations over time (e.g. the direction in which the trend is pointing).

Having said that, it should be emphasized that indicator trends of catch rates and size-based trends or others (Table 2) cannot replace population estimates, as an upward trend does not necessarily mean that the population of the species is in a healthy state. When needed and possible, estimation of population trends derived from stocks assessments would be the preferred option. In the absence of baseline population estimates from stock assessments, assumptions about stock status will remain questionable. Therefore, the direction in which the indicator trend is pointing will only infer on whether the species local abundance is improving or declining. In practice, the indicator trends will determine if the amount of fishery interactions and resulting mortality is not jeopardizing the reproductive capacity of the species (operational objective described in section 1).

Although in some cases data deficiency will still prevent the development of indicators for some of the species comprised in non-retained sharks and rays group, periodical data revisions will identify data availabilities for updating/estimating new indicators for particular species.

4. Indicators trends

In this section, examples of indicator trends by species are provided. For each key species, the results are preceded by a brief description of the available dataset and followed by some comments regarding the potential and limitations of the indicator. Some indicators are very preliminary and are presented with the objective of starting discussions to move towards more robust indicators.

Purse seine fishery: The European fleet (French and Spanish) covers a large area of the western Indian Ocean, roughly limited by the latitudes of 15°N and 25°S and by the longitudes of 40°E and 75°E (Figure 1). The data used for the following indicators come from observer programs conducted under European Data Collection Framework (EU/DCF) and under programs funded by the industry (i.e. *Observateurs Communs Uniques et Permanents* – OCUP and Best practices Monitoring Program). A single database stores the information from all observer programs and is managed by Ob7[1], AZTI and IEO[2]. From 2015 to 2018, a total of 19522 fishing sets were observed, although no sets were observed in 2010 due to the piracy issues in the area.

Oceanic whitetip shark (*C. longimanus*; OCS)**:** A simple occurrence indicator, based on the proportion of positive sets, was calculated. On average, the oceanic whitetip shark was present in 5% of the sets conducted on floating objects (FOBs), while its presence in free-swimming tuna school (FSC) sets averaged 2%. The occurrence trend derived from FOB sets varied along the years, with a decline from 0.11 in 2005 to 0.01 in 2009 and an overall slight rise until 2018 to 0.06 (Figure 2, top panel). The

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[1] Observatoire des Ecosystèmes Pélagiques Tropicaux exploités

[2] Instituto Español de Oceanografía

exception was a peak in 2011, which must be considered with caution since it is derived from a low sample size (63 sets). The trend derived from FSC sets did not vary as much, remaining below 0.03 for most of the time series (Figure 2, bottom panel). Interestingly, a large peak, equally derived from few fishing sets (75), was also observed in 2011.

OCS trend summary: Although observer coverage varied along the time series, the indicator shows that oceanic whitetip sharks appear to be more frequently caught in recent years in FAD sets while it remained at more constant level for FSC sets.

OCS trend remarks: This is a preliminary indicator and, therefore, results must be interpreted with caution. The main issue is that the sample size is not evenly distributed along the years of the time series, as observer coverage varied (Figure 2). However, the use of techniques such as bootstrap resampling can, to some extent, minimize this problem (Efron and Tibshirani, 1994). In this type of analysis, the impact of sampling variability could be evaluated and confidence intervals are provided. Furthermore, the European purse seine fishery operates in a large area of the western Indian Ocean, which comprises the core of oceanic whitetip tropical distribution (Bonfil et al., 2008). In addition to that, observer coverage has greatly improved in the Indian Ocean, reaching 31% on the past year (Bach and Sabarros, 2019), and will likely continue to improve; which can support the development of more robust indicators. This exercise has already started (Tolotti et al., 2016) and is now updated at this 2019 WPEB meeting with this paper. There are also plans to continue updating these indicators as better information becomes available. It is also worth noting that oceanic whitetip sharks are more frequently caught under FOBs. It is well known that purse seiners have been increasingly deploying man-made floating objects, also called fish aggregating devices (FADs), as a fishing strategy and its increase has been substantial since the mid 2000's (Hall and Roman, 2013). Increased FAD densities might affect the catchability of the species and generate bias in the indicator trend. In this sense, being able to quantify the number of FADs is key. FAD densities still remain uncertain although efforts have been directed to address this issue (Dagorn et al., 2013; Maufroy et al., 2015).

Silky shark (*C. falciformis*; FAL): Using a new modeling approach, abundance indices based on the associative behavior of silky sharks with floating objects were estimated (Diallo et al., 2018). Here, we briefly summarize the indicator trend and highlight the main points of the work. A detailed description of the methodology and obtained results is given on document IOTC-2019-WPEB15-23. The input data consisted of histograms depicting the proportion of catch events on FOB sets, starting from sets with zero silky sharks up to sets with 20 sharks. A temporal window of three months was defined as follows: December-January-February (Q1), March-April-May (Q2), June-July-August (Q3) and September-October-November (Q4). In the Seychelles area, the temporal units spanned from Q1 2007 to Q3 2018. Due to the fishery seasonality in the Mozambique Channel area, the temporal units were mostly represented by Q2 and spanned from 2007 to 2018. An example of temporal unit with its respective catch events histogram is shown in Figure 3. To account for sample size variability, the temporal units with more than 100 fishing sets were down-sampled using bootstrap. For both areas, the abundance indices fluctuated along the years, but an overall upward trend was observed (Figures 4 and 5). In the Seychelles area, the abundance index increased by a factor of 3 and in the Mozambique Channel the increase reached a factor of 15.

<u>FAL trend summary:</u> The upward trends indicate that the local abundance has increased in both Seychelles and Mozambique Channel areas. However, it is not possible to infer on the significance of these increases as the relationship between the abundance index and the actual population size is unknown.

<u>FAL trend remarks:</u> The results are a first attempt to derive an abundance index for the silky shark based in its associative behavior with FOBs and should be regarded as preliminary. The model depends on the probability of a shark to associate with a FOB as well as on the probability of the shark to leave the FOB and these probabilities depend on FOB density and social behavior, respectively (Sempo et al., 2013). FOB density is in fact incorporated as variable in the model, which is an advantage as the increasing number of FOBs deployed by the industry (Fonteneau et al., 2013) might affect the catchability of the species. However, since actual FOB densities are not yet available, a simple FOB-density index based on random encounters was used. To assure more robust model estimates, accurate FOB densities are required. The probabilities of arrival and departure could be obtained from electronic experiments measuring residence and absence times of silky sharks in an array of FOBs. But, for the moment, the electronic tagging data recorded for silky sharks can only provide estimates of residence times (Filmalter et al., 2015). Field experiments can also shed a light into the associative behavior of the species. Studies using photography and video analysis, as well as acoustic telemetry, have described intraspecific interactions and movements of a range of species (Capello et al., 2011; Filmalter et al., 2015; Mourier et al., 2012; Robert et al., 2013). Further field experiments could give a finer understanding of the mechanisms underlying silky shark's associative behavior, and also allow for a finer estimation of the model parameters.

5. Future steps

Below we summarize some future steps planned to advance work towards monitoring the “non-retained sharks and rays”, which we plan to update annually at future WPEB meetings. This is work in progress that requires the collaboration of multiple experts with experience on the multiple gears operating in the IOTC convention area and the diversity of shark species caught. We invite the IOTC community to contribute towards the development of the “non-retained sharks and rays” component to support the IOTC ecosystem report card. If interested, contact the corresponding authors to find out how you can contribute to this initiative.

Future steps:

- Make an inventory of available data sources by species;
- Update data table with priority species by gear type to guide indicator development;
- Explore indicators for species for which data is available, even if they are not listed as a priority on Table 3;
- Examine the usefulness of the observer data to estimate size based indicators for sharks;
- Determine what indicators/species have the largest potential to be periodically assessed; and
- Define periodicity for the indicator assessments.

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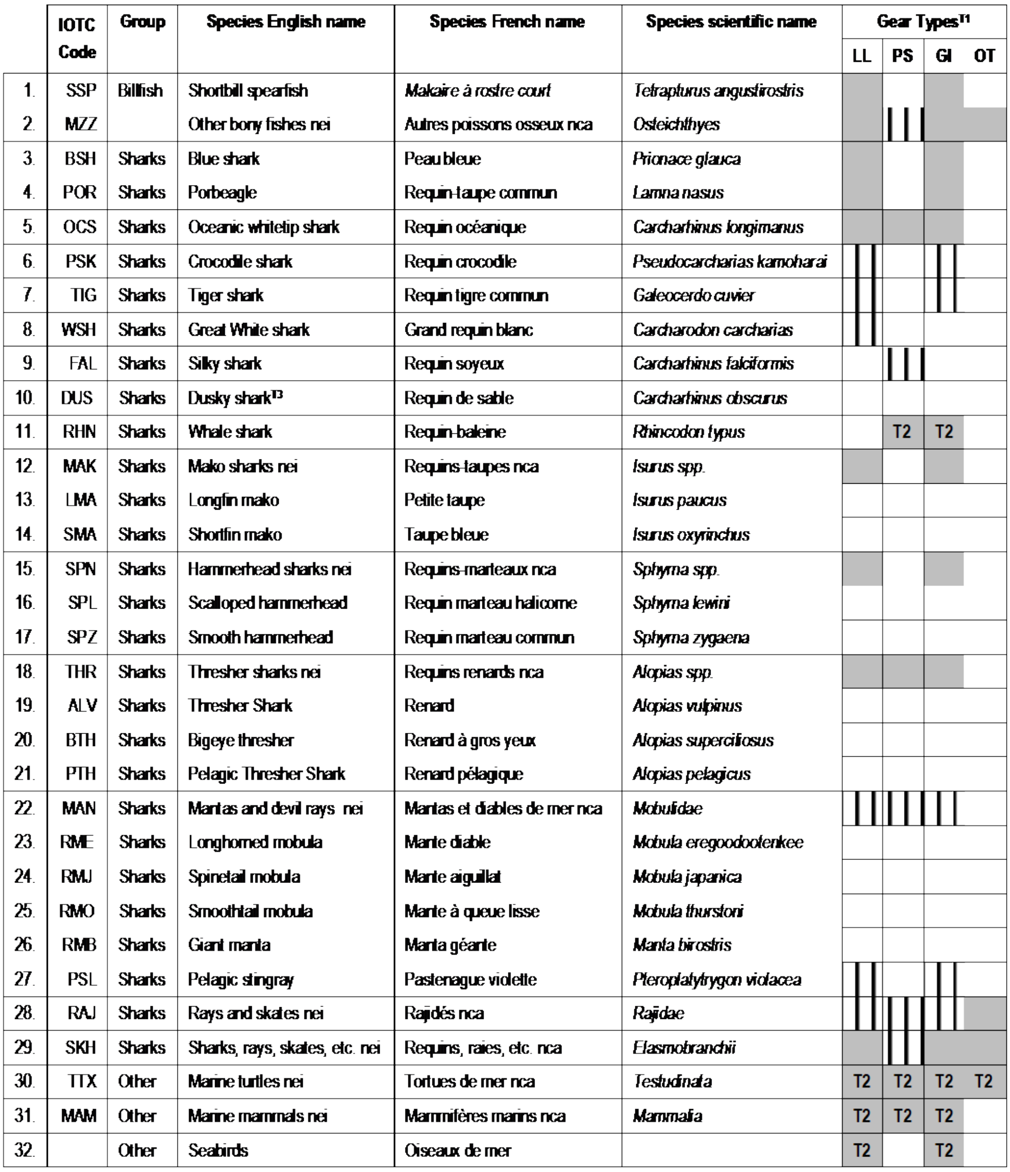
Table 1. Species not included in the IOTC mandate that make an important bycatch contribution in IOTC fisheries. It mostly includes oceanic sharks commonly caught incidentally in IOTC fisheries. Cells shaded in grey refer to individual species or species groups for which reporting of fisheries statistics is obligatory, using the same standards as those used for IOTC species; vertical bar cells refer to individual species or species groups for which reporting of fisheries statistics is voluntary; white cells refer to individual species or species groups for which reporting of fisheries statistics is encouraged (IOTC Secretariat, 2014).



	IOTC Code	Group	Species English name	Species French name	Species scientific name	Gear Types[T1]			
						LL	PS	GI	OT
1.	SSP	Billfish	Shortbill spearfish	*Makaire à rostre court*	*Tetrapturus angustirostris*	▒		▒	
2.	MZZ		Other bony fishes nei	Autres poissons osseux nca	*Osteichthyes*	▒	▥	▒	▒
3.	BSH	Sharks	Blue shark	Peau bleue	*Prionace glauca*	▒		▒	
4.	POR	Sharks	Porbeagle	Requin-taupe commun	*Lamna nasus*	▒		▒	
5.	OCS	Sharks	Oceanic whitetip shark	Requin océanique	*Carcharhinus longimanus*	▒	▒	▒	
6.	PSK	Sharks	Crocodile shark	Requin crocodile	*Pseudocarcharias kamoharai*	▥		▥	
7.	TIG	Sharks	Tiger shark	Requin tigre commun	*Galeocerdo cuvier*	▥		▥	
8.	WSH	Sharks	Great White shark	Grand requin blanc	*Carcharodon carcharias*	▥			
9.	FAL	Sharks	Silky shark	Requin soyeux	*Carcharhinus falciformis*		▥		
10.	DUS	Sharks	Dusky shark[T3]	Requin de sable	*Carcharhinus obscurus*				
11.	RHN	Sharks	Whale shark	Requin-baleine	*Rhincodon typus*		▒ T2	▒ T2	
12.	MAK	Sharks	Mako sharks nei	Requins-taupes nca	*Isurus spp.*	▒		▒	
13.	LMA	Sharks	Longfin mako	Petite taupe	*Isurus paucus*				
14.	SMA	Sharks	Shortfin mako	Taupe bleue	*Isurus oxyrinchus*				
15.	SPN	Sharks	Hammerhead sharks nei	Requins-marteaux nca	*Sphyrna spp.*	▒		▒	
16.	SPL	Sharks	Scalloped hammerhead	Requin marteau halicorne	*Sphyrna lewini*				
17.	SPZ	Sharks	Smooth hammerhead	Requin marteau commun	*Sphyrna zygaena*				
18.	THR	Sharks	Thresher sharks nei	Requins renards nca	*Alopias spp.*	▒	▒	▒	
19.	ALV	Sharks	Thresher Shark	Renard	*Alopias vulpinus*				
20.	BTH	Sharks	Bigeye thresher	Renard à gros yeux	*Alopias superciliosus*				
21.	PTH	Sharks	Pelagic Thresher Shark	Renard pélagique	*Alopias pelagicus*				
22.	MAN	Sharks	Mantas and devil rays nei	Mantas et diables de mer nca	*Mobulidae*	▥	▥	▥	
23.	RME	Sharks	Longhorned mobula	Mante diable	*Mobula eregoodootenkee*				
24.	RMJ	Sharks	Spinetail mobula	Mante aiguillat	*Mobula japanica*				
25.	RMO	Sharks	Smoothtail mobula	Mante à queue lisse	*Mobula thurstoni*				
26.	RMB	Sharks	Giant manta	Manta géante	*Manta birostris*				
27.	PSL	Sharks	Pelagic stingray	Pastenague violette	*Pteroplatytrygon violacea*	▥		▥	
28.	RAJ	Sharks	Rays and skates nei	Rajidés nca	*Rajidae*	▥	▥	▥	▒
29.	SKH	Sharks	Sharks, rays, skates, etc. nei	Requins, raies, etc. nca	*Elasmobranchii*	▒	▥	▒	▒
30.	TTX	Other	Marine turtles nei	Tortues de mer nca	*Testudinata*	▒ T2	▒ T2	▒ T2	▒ T2
31.	MAM	Other	Marine mammals nei	Mammifères marins nca	*Mammalia*	▒ T2	▒ T2	▒ T2	
32.		Other	Seabirds	Oiseaux de mer		▒ T2		▒ T2	

T1 Longline (LL), purse seine (PS), gillnet (GI); and other gears (OT), including pole-and-line, handline and trolling.

T2 Incidental catches shall be reported as the total number of specimens caught

T3 Dusky sharks are not included in the list of species agreed to by the Commission; however, some longline fleets report high catches of dusky sharks and therefore they have been included in the table

Table 2. List of possible indicators

Indicator type	Potential data sources
Catch rates	Logbooks and observer programs from major fisheries
Size-based indicators	Observer programs
Biomass estimates	Fishery stock assessments
Post-release mortality	Electronic tagging programs
Bycatch fate	Observer programs
Distributional range and habitat maps	Logbooks and observer programs from major fisheries

Table 3. Focus species by gears type to guide indicator development, based on the results of Ecological Risk Assessments conducted in 2012 and 2018 (Murua et al., 2018, 2012).

Gear type	Focus or priority species
Longliners	**ERA 2012:** Bigeye and pelagic thresher, silky shark, oceanic whitetip, smooth hammerhead **ERA 2018:** Silky shark, porbeagle, bigeye thresher, great hammerhead, oceanic whitetip
Gillnets	**ERA 2018:** Crocodile shark, smooth hammerhead, pelagic thresher, silky shark, scalloped hammerhead
Purse seiners	**ERA 2012:** Silky shark and oceanic whitetip **ERA 2018:** Crocodile shark, pelagic thresher, silky shark, common thresher, great hammerhead

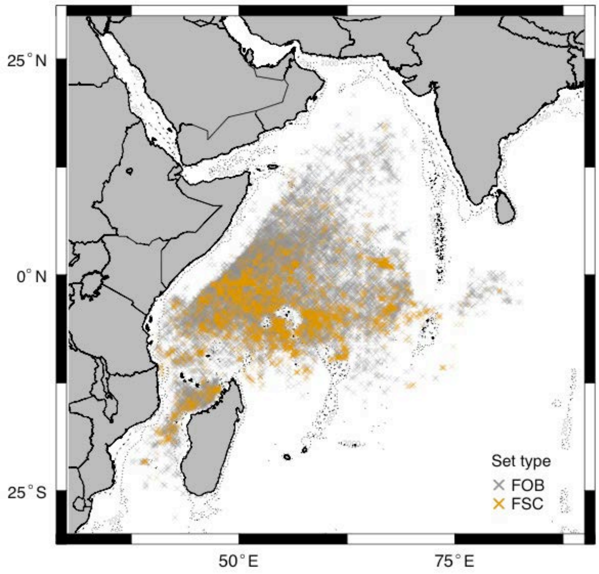


Figure 1. Location of fishing sets conducted by the European purse seine fleet in the Indian Ocean between 2005 and 2018. FOB= sets on floating objects, FSC= sets on free-swimming schools.

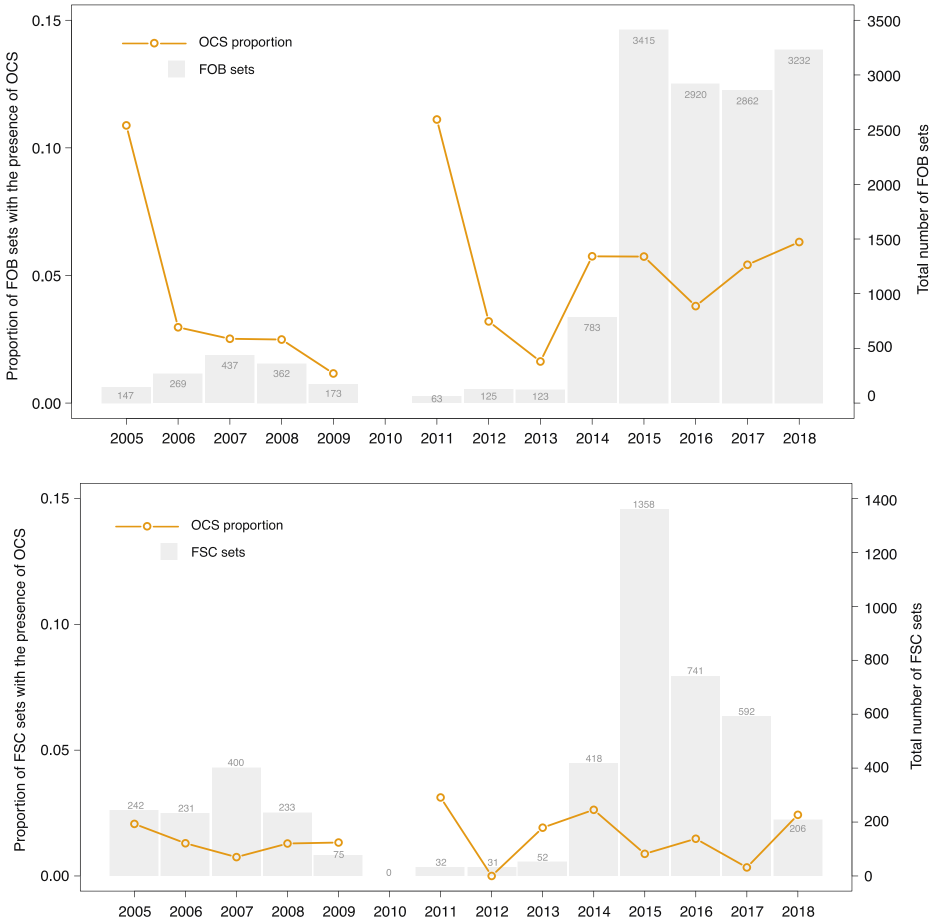


Figure 2. Occurrence of oceanic whitetip shark (OCS) in observed sets from the European purse seine fleet in the Indian Ocean. Top panel shows the proportion of FOB sets with the presence of OCS. Bottom panel shows the proportion of FSC sets with the presence of OCS. FOB= sets on floating objects, FSC= sets on free-swimming schools.

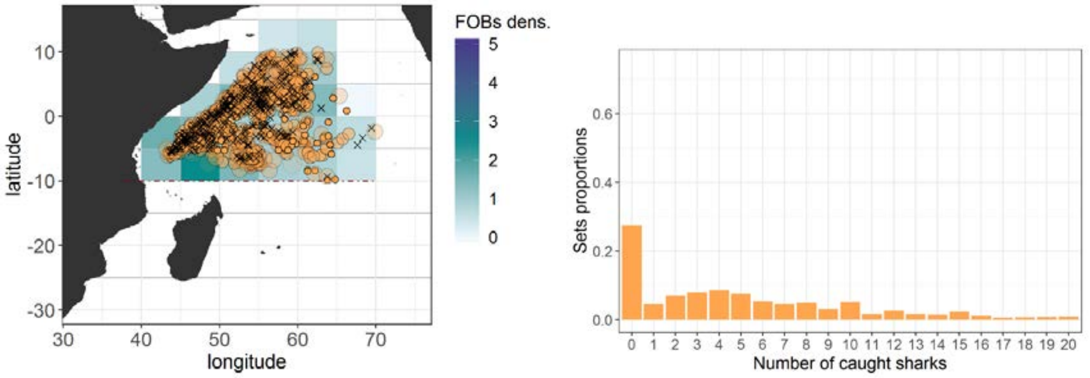


Figure 3. Example of temporal unit. Left panel shows the spatial distribution of sets in the Seychelles area during the Set-Oct-Nov quarter (Q4) of 2017. Right panel shows the corresponding catch events histogram.

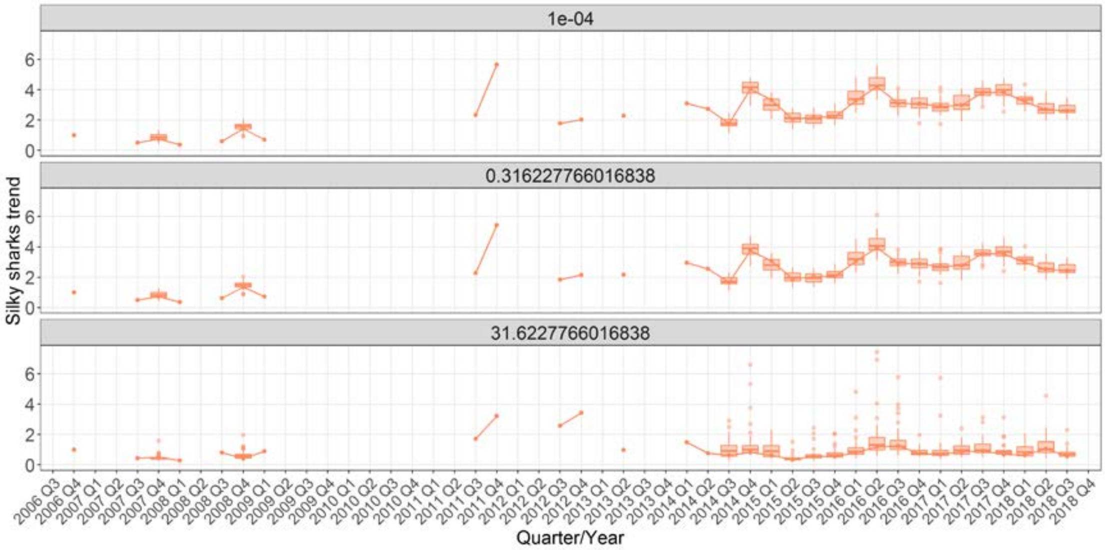


Figure 4. Silky shark abundance trend for the Seychelles area based on three different values of γ'. Solid points represent the index values derived from observed distributions and boxplots represent index values derived from the bootstrapped samples.

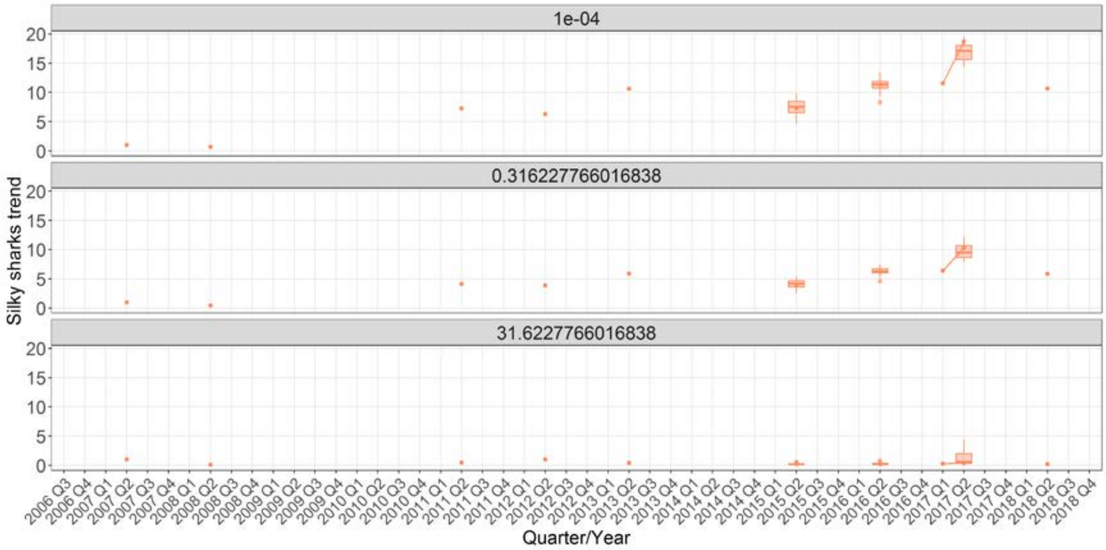


Figure 5. Silky shark abundance trend for the Mozambique Channel area based on three different values of γ'. Solid points represent the index values derived from observed distributions and boxplots represent index values derived from the bootstrapped samples.