Carcharhinus falciformis - a massive bycatch in the industrial purse seine industry but systematically underreported and deprived of any protection in the Indian Ocean

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Abstract

Carcharhinus falciformis is known to be the most significant bycatch species in purse sein tuna fisheries especially when setting on drifting FADs, the increasingly applied practice by large tuna fleets in the Indian Ocean. However, the magnitude of impact of this practice on the Indian Ocean stock of silky sharks continues to be considered as very low whilst longlining and gillnetting are quoted to be the main contributors to the overall annual catch of silky sharks at IOTC (Garcia and Herrera, 2018).
However, considering the poor compliance with reporting requirements for sharks in line with Resolution 17/05 huge doubts remain on both, the overall fishery related mortality of this IUCN listed vulnerable species and in particular the contribution of discards from purse seine fleets to this overall mortality. By combining data reported by CPCs to the IOTC Secretariat with fishery specific data disclosed by fisheries as part of their MSC certification the cumulative impact of purse seine fisheries on silky sharks in the Indian Ocean can be assessed more adequately.
This paper presents a first, preliminary assessment and results in a quite different estimate about the magnitude of impact this fishing practice has on silky sharks, contradicting the assumption of the negligible impact of purse seining on silky shark mortality. With close to 1,000 tonnes of cumulated annual discards or more than 50,000 animals reported by the 28 vessels of the three currently MSC certified fleets alone, the total annual dimension of discards from large purse seine vessels in the Indian Ocean may easily be two to three times higher than these numbers without even considering any retained bycatch or discards by the large number of small purse seine vessels operated for example by the Indonesian fleet. The extent of discards of possibly 2,000 tonnes or more and the resulting total silky shark mortality is therefore at least ten times higher than previously assumed, while industry continues to claim that purse seine fleets are only responsible for a very small percentage of 1.3% (Garcia & Herrera 2018) of the total fishing induced mortality of silky sharks in the Indian Ocean.
In conclusion this bycatch level should no longer be ignored especially in view of the large overall percentage of tuna caught by large purse seiners setting on dFADs in the Indian Ocean. The situation certainly requires both, substantially improved and enforced reporting requirements for bycatch and discards and the improved granularity by providing these reports at the level of the individual vessel, as well as the introduction of more effective bycatch avoidance measures. While bycatch mitigation measures reducing on board mortality and increasing post release survival certainly remain important and should be further improved, these alone should not be considered as sufficient to address the overall problem. Especially in view of the widespread lack or inadequate application of existing technical measures and best practices by most fleets and the high vulnerability of juvenile silky sharks, making up for the majority of the bycatch, effective bycatch avoidance and fully transparent reporting of all interactions at vessel level must be made a priority.

Introduction

Sharks are in a crisis and scientists around the world are warning that we are at risk of losing more than 30% of all known shark and ray species within the next decades. Overexploitation by industrial fishing over the last 50 years is cited as the main cause for this unprecedented loss of marine biodiversity. (IPBES 2019). The Red List of Threatened Species of the International Union for Conservation of Nature (IUCN 2021/3) lists 167 out of 537 evaluated shark species as „threatened“ and out of these 35 species are already considered to be “critically endangered”. This demonstrates the dramatic acceleration at which elasmobranchs have become threatened over the last decade, when 23.4% of species identified as data deficient in 2014 were categorised as threatened in 2021 (Dulvy et al. 2021). This is an increase of almost 10%, from 23.9% threatened elasmobranch species in 2014 to 33% in 2021. While this overall trend affects almost all chondrichthyans the increase has found to be most dramatic for pelagic species. Pacoureau et al. (2021) alarm that populations of pelagic sharks and rays have decreased by 71% over the last 50 years due to overfishing and that half of all pelagic shark species are now categorised as “critically endangered” or “endangered”. Benthic sharks are also under severe pressure with 20% of the world’s coral reefs having been depleted of their shark populations (MacNeil et al. 2020), but pelagic sharks are specifically vulnerable to overfishing due to their biologic vulnerability with late sexual maturity and low fecundity, and the high overlap of their habitats and

migration pathways with industrial fisheries. Being either a common bycatch in industrial teleost fisheries or directly targeted for their fins, many once abundant pelagic sharks have globally suffered from dramatic declines but still lack effective protection in the four big tuna RFMOs, including IOTC. RFMOs have not implemented harvest control rules and science-based rebuilding plans for sharks, while most of these stocks are recognised either as overfished or highly uncertain. To date only ICCAT has committed to the sustainable management of its shark stocks (ICCAT 2019), but the implementation of this new objective is still pending. Without an ecosystem based sustainable management and effective bycatch avoidance measures already depleted stocks of pelagic shark will continue to decrease or even collapse completely and once overfished these stocks may take decades to recover if ever, as projected for the overfished stock of Northern Atlantic *Isurus oxyrinchus* at ICCAT (ICCAT SCRS 2019). Despite warnings from scientists and civil society since 2017 that this stock is overfished and needs rebuilding, overfishing has continued at least until 2021, when the Commission finally adopted a temporary retention ban and committed to limit total fishing induced mortality in the North to levels that will allow this stock to rebuild by 2070 with a probability of 60-70%. (ICCAT Rec 21/09). However, it took the Commission more than five years to adopt this measure, despite clear scientific advice and although the species has been listed by CITES on App II in 2019, acknowledging its endangered status and its overexploitation due to the high value of both, its fins and its meat, in the international trade.
No measures are in place in the South Atlantic, in the Pacific, or in the Indian Ocean to reduce the mortality of this highly vulnerable species and to prevent those stocks following a similar trajectory as in the North Atlantic.

Longlines and gillnets/driftnets are known to present the biggest risk of bycatch of pelagic sharks and those gears are also used in mixed species and targeted shark fisheries. However, also other fishing gear such as purse seines take their toll on depleted stocks of pelagic sharks.
All RFMOs but especially the big tuna RFMOs do play a major role for the survival of these species and should therefore urgently commit to the sustainable management **(**Pacoureau et al. 2021) of sharks by establishing precautious harvest control rules, including a high probability for the rebuilding of overfished stocks. Especially in the absence of sufficient data a precautionary approach is needed. The active management of all shark stocks even if taken "only as a bycatch" and substantially increased research efforts to avoid bycatch in the first place, to reduce on board mortality, to decrease unobserved mortality from ghost gear, and to increase post release survival rates via best handling practices and the use of technical measures are called for by many marine conservation organisations (ISSF 2019, NGOTF 2021, Sharkproject 2021, WWF 2022).
While the need for improved shark management and bycatch mitigation measures are widely acknowledged there are still many misperceptions on the extent of the impact of certain gear types on the mortality of a species and the future of a specific stock. Often the total amount of bycatch and fishery induced mortality of a species by a specific gear are substantially underestimated, especially when the overall catch quantity is large and does represent the majority of total catch in a region. The absence of fishery specific data for validation of the accuracy of estimates derived from aggregated data and the widespread non reporting or underreporting of discards considerably hinder evaluation of the overall impact of a specific gear or fishery.
Furthermore, independent monitoring at sea is generally much too low and if existing then coverage is often not representative for all fleets and fishing efforts in a region. At an observer coverage at sea of 5% or less and actual observer coverage in fisheries often being not representative of total fishing efforts as observers are placed on a few, selected vessels of the fleet, the accuracy and trueness of bycatch data and especially shark bycatch data may be severely biased. For example, only 651 sets out of a total of 4590 purse seine sets of the Spanish fleet in the Indian Ocean in 2021, i.e., 14% of all its sets targeting tropical tunas (IOTC-2021-SC24-NR06_Annex2_EU_Spain) were directly observed and all the observed sets came from only 5 vessels for a fleet comprising 15 large vessels altogether.
Having to use these data for stock assessments of pelagic sharks then often fails to provide robust outcomes e.g. for shortfin mako when the Working Group on Ecosystems and Bycatch concluded in 2020 that no management recommendation based on these stock assessment results could be made "*inter alia due to lack of data credibility of nominal catch*" (IOTC–2020–WPEB16–R[E]). Therefore, adoption of effective conservation measures is often lacking, and the effectiveness of the few existing measures can't be evaluated (Sharkproject IOTC 2022).

Compliance with reporting requirements for sharks at IOTC continues to be extremely poor with only 44% of all CPCs having submitted mandatory shark statistics to the Commission in 2021 (data reported for 2020) in line with Resolution 17/05, only 30% of the catch and effort data for sharks and only 15% of the size frequency data for sharks were reported. Even reporting of nominal catches of sharks was only 52% and EU remained among those Contracting Parties with repeated compliance issues for shark data reporting (IOTC-2022-CoC19-03 [E]). The Working Party on Ecosystems and Bycatch has also criticised that errors in the reported shark catches are significant as estimates are based on retention numbers instead of the total catch.
Therefore, high discards will without doubt lead to substantial underreporting of total impacts and underestimation of total fishing induced mortality in general and mortality of certain species by a specific gear in particular.

Background
A classic example for such an underestimated gear is purse seine fishing on drifting fish aggregation devices (dFADs), which aggregate tuna beneath artificial rafts to reduce the efforts needed when searching for free swimming schools in the open ocean. These rafts are equipped with buoys transmitting their location and even the size of biomass aggregated below them and are then visited by the purse seine vessels to harvest the biomass beneath them. As tuna fishing with purse seine nets on "unassociated" or "free" sets is associated with lower bycatch levels this fishing practice has been certified as sustainable by the Marine Stewardship Council (MSC), while setting on dFADs has not received MSC certification until 2018. Since most fisheries certified for fishing on free sets at the same time also set on dFADs as part of their fishing operation, often even by the same vessels and on the same trips, public criticism had mounted about this "compartmentalisation" of fisheries and MSC finally changed its requirements requesting that all fishing practices of a fishery on the same stock with the same gear will have to be assessed and certified together. (Blue Marine Foundation, 2020) However, instead of providing an incentive for fisheries to focus on free sets only, the end of compartmentalisation has resulted in most "Units of Certification" having aspired and received MSC certification for all of their purse seine fishing operations, with Echebastar having been the first fishery to receive MSC certification for dFADs and free sets in 2018.
With increasing numbers of purse seine sets now being made on dFAD global criticism against this practice being considered as sustainable has also increased (Blue Marine Foundation 2021, IPNLF 2021), highlighting the massive negative impacts of dFADs on vulnerable ecosystems and ETP species. Drifting FADs increase unobserved mortality through unreported "ghost fishing", when animals die unnoticed and unreported after having become entangled in the materials used for the construction of dFADs.
Also, high bycatch of juvenile yellowfin tuna in dFADs is a growing concern, since yellowfin is overfished and in need of stock rebuilding (IOTC WGFAD 2021) in the Indian Ocean. Proposals for a transition to a responsible dFAD management and harmonised requirements for the construction of dFADs are still under discussion at all RFMOs. In 2013 Filmalter et al. had estimated that 80,000 of these floats may be drifting around in the Indian Ocean alone, yet all RFMOs still struggle today to implement science-based limits on the allowed number of dFADs. At the same time the number of dFADs being deployed and floating around in our oceans continue to increase.

Specific improvements as requested in the position statements of NGOs (NGOTF 2021, Sharkproject 2021, WWF 2021, IPNLF 2021, Blue Marine Foundation 2021) demonstrate the extent of improvements needed and include inter alia:

- Banning the use of all netting and meshed materials in the construction of FADs to ensure these are lifetime non entangling and do not contribute to unobserved mortality from ghost fishing
- Using only biodegradable materials in dFAD construction to reduce marine litter caused by non-biodegradable materials (plastics) when dFADs are lost or abandoned at sea.
- Limiting numbers of deployed dFAD and requiring near real time monitoring of all dFADs while in the water
- Establishing lifetime management and retrieval policies
- Defining spatial and time closures for dFADs applying scientific advice

- Implementing avoidance and release practices for bycatch species by continued research and application of technical measures and the use of best practice handling practices to reduce mortality of these species
- Defining total mortality limits and establishing bycatch reduction targets for purse seiners for all impacted species

Also, IOTC Res 19/02 **(**2019) defines requirements for the transition to completely non entangling dFAD constructions mandatory since January 2022, while real life on the water still looks differently as many fisheries have continued to deploy so called “lesser entangling FADs” (ISSF 2019) with rolled up sausages of netting that may however unravel over time. Similar as in the Western Central Pacific where many entangling dFADs are reported by Escalle et al. in 2021 to be still drifting around, the same most probably also applies to the IOTC area as fisheries have failed removing entangling or lesser entangling FADs from the water.

Methodology

This study investigates the silky shark bycatch taken by purse seiners in the Indian Ocean by using a combined approach to enable better estimates of the cumulative impact on silky shark mortality resulting from this gear. The hypothesis postulated is, that the magnitude of this cumulative impact is grossly underestimated, and that the uncertainty on stock status is the root cause for the absence of effective conservation measures for vulnerable silky sharks.

Therefore, information is extracted from published reports and other publicly available data on the IOTC website for a time series from 2014 to 2020, the time over which the massive shift has occurred in the industrial purse seine tuna fishing industry, shifting from sets on free schools to sets on dFADs.

This information was combined with fishery specific data sets obtained from the MSC certification reports of purse seine fleets in the Indian Ocean, all of them fishing almost entirely on dFADs. The data sets were used to validate the published bycatch and discards of CPCs and to derive information on the total mortality in purse seining including specific differences between fisheries.

Unfortunately, such data fleet specific data is not publicly available for all fisheries and vessels outside of MSC certifications. Therefore, the derived findings should be seen as an indicator for the minimum impact rather than as a quantitative assessment. Furthermore, silky shark bycatch also applies to small purse seine vessels as operated e.g., by Indonesia. Although these vessels are much smaller (between 25 and 40 m) and impacts are thus not comparable to those of the big industrial purse seine fleets of the EU and the Seychelles, operating vessels of 80 to 100 meters and more. However, it should be noted that due to the big number of small vessels with e.g., Indonesia operating more than 100 of those small, industrial purse seine vessels at IOTC ,(IOTC–2021–SC24–NR09) this impact shouldn’t be ignored either. Another shortcoming of fishery specific data set from MSC reports is that these data sets are generally not available for the same time periods for all assessed fisheries. The assessors and fisheries are free to choose which data from consecutive years they want to submit, and this may often not be the most recent three years. Reporting quality also differs quite significantly between fisheries even in MSC assessments as both, the level of independent monitoring at sea and the extent of data and details reported, varies substantially between fisheries.

However, when combining data reported by IOTC with fishery specific data disclosed as part of MSC certifications, to assess the magnitude of the cumulative impact of purse seine fisheries on silky sharks in the Indian Ocean a surprising outcome was found for the first preliminary analysis reported in this paper. Additional data analysis and evaluation of metadata is planned in the future when more fishery specific data becomes available, either from other MSC certifications or if fisheries agree to voluntarily share fishery specific information about their silky shark bycatch, e.g., the number of silky sharks caught per set, the weight of the animals caught, and observer reports of total discards.

Observed & Unobserved Mortality of Silky Sharks in the Indian Ocean due to drifting FADs

Today more than 40% of global tuna catches are done on dFADs and an increasing number of purse seine fleets concentrated their fishing efforts on dFADs, including MSC certified fisheries. In 2013 Filmalter et al estimated that about 7,500 dFADs are deployed in the Indian Ocean per year by the EU fleets alone.

Based on a field study with observed entanglement of silky sharks in dFADs that then died and fell out within two days, he estimated the extent of cryptic mortality for dFADs to be very high. An estimated

480,000 - 960,000 silky sharks per year might become entangled adding to unobserved mortality in the Indian Ocean alone (Filmalter et al. 2013) and that this number may exceed the estimated observed bycatch by a factor of 5 to 10.

However, also this “observed” mortality of silky shark bycatch in purse seine fishing is substantial as this species makes up for 90% of the elasmobranch bycatch caught in tropical tuna purse-seine fisheries (Poisson et al. 2014).

In addition, bycatch rates in the Indian Ocean have found to be substantially higher than in other oceans such as the Atlantic Ocean. The proportion of dFAD sets having at least one elasmobranch caught was significantly higher (39.3% and 67.8% in the Atlantic and Indian oceans, respectively) than for free school sets (17.5% and 12.8%) in both oceans (Clavareau et al. 2020). There also appears to be much less seasonal difference in the Indian Ocean than in the Atlantic Ocean, while the size distribution analysis of *Carcharhinus falciformis* clearly indicated that a high proportion of juveniles was captured in both oceans. (Clavareau et al. 2020)

Adding to both, unobserved mortality from entanglement and the incidence of juvenile bycatch, the discussion of dFADs being an ecological trap should also be considered. Sharks become trapped within arrays of drifting FADs due to the anthropogenic alteration to the natural habitat for prolonged periods of time, thereby potentially modifying the movements and negatively impacting the biology of the sharks (Marsac et al. 2000). Bonnin et al. showed in 2020 that silky sharks spend only approximately 30% of their time away from dFADs, thereby conforming the high spatial overlap of the species with dFADs and the risk of juveniles being captured as they move with the draft.

Filmalter et al. 2013 estimated that as an overall result the chances of survival for silky sharks in the Indian Ocean are only 29% up to the age of one year, dropping to 9% for survival up to two years, and that only a mere 3% will survive up to the age of three years.

This dramatic mortality rate is further supported by a high on-board mortality for bycaught silky sharks and the very low chances of post release survival, even if animals are released alive, resulting in a total mortality of 85% for all brailed sharks (Poisson et al 2014). Similar mortality rates are also reported by Hutchinson et al. 2015 who report a total mortality rate of 84.2% for the bycatch of mostly juvenile sharks, while Eddy et al. 2016 estimate the combined mortality rates of at-vessel and post-release mortalities to add up to 80% to 95%.

For comparison, hooking mortality on tropical longlines is reported to be approximately 56% (Coelho et al. 2016).

Silky Shark Bycatch in dFAD Purse Seining is grossly Underreported, Underestimated and Under-evaluated by Tuna RFMOs

Drifting FADs are associated with substantial bycatch rates of *Carcharhinus longimanus* and *Carcharhinus falcifomis* in all oceans, as both species are specifically vulnerable to this fishing practice due to their tendency to aggregate below floating objects and staying associated with those objects over prolonged periods of time as juveniles. While it is well documented that especially silky sharks make up the single biggest bycatch of non-tuna species in dFAD fisheries and that mortality rates for these bycaught animals are high (Murura et al. 2021, Eddy et al. 2016, Hutchinson et al. 2015, Poisson et al. 2014), the extent of the overall impact of purse seining with dFADs on this vulnerable shark species is grossly underestimated or completely ignored. The critically endangered *Carcharhinus longimanus* is affected in the same way but accounts for much lower numbers of dFAD bycatch as its abundance has already plunged dramatically after decades of overfishing, which was mostly driven by the lucrative fin trade.

In all big tuna RFMOs discussions mostly focus only on improved bycatch mitigation measures, i.e., voluntary commitments by purse seiners to discard bycaught silky sharks and improved handling procedures on board to reduce the mortality of discards. The existence of economic incentives from shark fins continues to be ignored although silky sharks are the second most widely caught shark species (Oliver et al. 2015) and are one of the three species, most commonly found in the global fin trade in Hong Kong, (Clarke. S. Magnusson. J.E et al 2006, Clarke M.S, McAllister. M et al. 2006).

Especially in the absence of a ‘Fins Naturally Attached’ policy for all sharks (IOTC Res 17/05) existing anti-finning regulations are subject to widespread non-compliance and prosecution of offenses remains difficult in lack of undisputable proof of an infringement having happened when loose fins are discovered on board (Ziegler et al. 2021).

Furthermore, compliance with reporting requirements for discarded bycatch and shark data continues to be extremely low at IOTC and technical solutions to reduce elapsed time until sharks are released from the vessel, are not widely implemented although existing. Only few crews take reasonable efforts to minimise release time of bycatch and to date very few vessels have installed technical measures such as separate conveyer belts or release ramps for bycatch. Onandia et al. 2021 demonstrated a substantial reduction of on-board mortality and improved post release survival of released sharks when vessels were equipped with such technical improvements and had experienced crews. Nevertheless, it is important to recognise that even this is still a very high overall mortality affecting almost exclusively juvenile animals, which have not yet been able to reproduce.
In the Indian Ocean (Hall et al. 2012) size at birth is estimated to be 65-81 cm TL (total fork length), with males mature at 242 cm TL and females at 263 cm TL. Animals therefore gain sexual maturity at approximately 13 years (208 cm TL) males and 15 years (216 cm TL) females. At 2-18 pups per litter every 2-3 years the species has a low fecundity, which increases somewhat with increasing size of the females.

The stock status of silky sharks in the Indian ocean has been highly uncertain for many years. Simeon et al. warned in 2018 that increased abundance indices between 2015 and 2016 in the Eastern Indian Ocean may not be a good sign after all and there is no stock status determination available at IOTC (IOTC–2021–SC24–R[E]). However, fisheries report decreased sightings of this once abundant species and there is a high risk of stocks having decreased by more than 50% in the past 20 years (Anderson et al. 2009). In 2017 the International Union for the Conservation of Nature classified silky sharks globally as "vulnerable" with the trend "abundance decreasing" as a "result of weighted global population trend estimated a 47-54% decline over three generations" (IUCN 2021). This is a case study example for the record worsening of the conservation status of a species from "least concern" in 2000 to "near threatened" in 2009 or within roughly one generation length of this species which is 15 years (IUCN 2021). Silky shark is also listed on Annex I of Highly Migratory Species of the UN Convention on the Law of the Sea, on the Convention of Migratory Species App II (2014), the Memorandum of Understanding of Migratory Sharks (2016) and since 2017 also on App II of CITES. Since then, all international trade must demonstrate to be supplied from sustainably harvested stocks in a non-detriment finding (NDF) which has to be issued by the exporting nation and in the European Union also by the importing member state in case of introduction from the High Seas. Together with *Carcharhinus longimanus* silky shark ranked first in the IOTC's Ecological Risk Assessment for purse seine gear in 2012 (Murua et al. 2012) but in the 2018 revision (Murua et al. 2018) it was downgraded to 5th rank assuming a decreased post capture mortality of 0.560 instead of 0.990, following the implementation of best handling practices. However, no quantitative study results confirm mortality rates have really reduced throughout all fleets at IOTC.
In recognition of the global threats to silky sharks some RFMOs have prohibited the retention of silky sharks or their body parts, e.g., ICCAT in 2011 and WCPFC in 2016. IATTC has limited the total permissible bycatch for longlining fleets to 20% of the total catch (IATTC Res C-21-06) and requires the release of all silky sharks caught in purse seine fisheries. IOTC however has not yet implemented any measures at all, let alone defined a Total Allowable Catch for this shark species, while noting that F_{MSY} and B_{MSY} are unknown. However, modeling performed by Coelho et al. in 2019 concluded that the stock has most probably been experiencing overfishing since 1994 and therefore the authors advised to limit total mortality to a maximum of 6400 mt per year following a precautionary approach in view of the high uncertainty.

Reported landing of silky sharks at IOTC was 1,314 mt in 2020 and an average of 1,833 mt has been reported since 2016 while total mortality is assumed to be largely underestimated as silky sharks are often not reported at species level with an average of 30,277 mt of sharks reported as "not elsewhere included (nei) sharks" (IOTC–2021–SC24–R[E]) to the Secretariat and compliance with shark data reporting continues to be extremely poor (IOTC-2022-CoC19-03 [E]). This is also apparent from the unexpected decrease of silky shark landings since 2016 while sharks continue to be landed in large numbers and skipjack tuna catches, a fishery most associated with shark catches, have increased as shown in **Table 1** and **Figure 1.**

Year	YFT	BET	SKJ	ALB	SWO	FAL
2014	403,554.14	93,034.80	423,900.20	38,343.58	27,268.48	3,100.42
2015	400,257.26	96,333.25	400,498.17	35,571.14	31,346.05	3,268.02
2016	424,988.25	86,822.01	469,967.54	35,704.31	30,739.67	2,215.27
2017	418,961.36	90,896.56	505,173.98	38,942.75	32,929.14	1,812.47
2018	439,919.42	94,743.84	608,906.44	41,604.70	31,017.76	1,817.54
2019	447,971.72	80,374.60	590,129.87	39,616.25	33,461.16	2,124.38
2020	427,539.05	90,470.70	546,908.73	41,051.06	27,068.51	1,335.16
Total 2014 - 2020	**2,963,191.20**	**632,675.76**	**3,545,484.92**	**270,833.79**	**213,830.76**	**15,673.27**

Table 1: *IOTC database assessed in August 2022 selecting IOTC-DATASETS-2022-05-17-NC-sharks 2014 to 2020 for all gear and all fleets showing total tonnage of annual catch for major tuna species and reported landings of silky sharks in the same time periods*

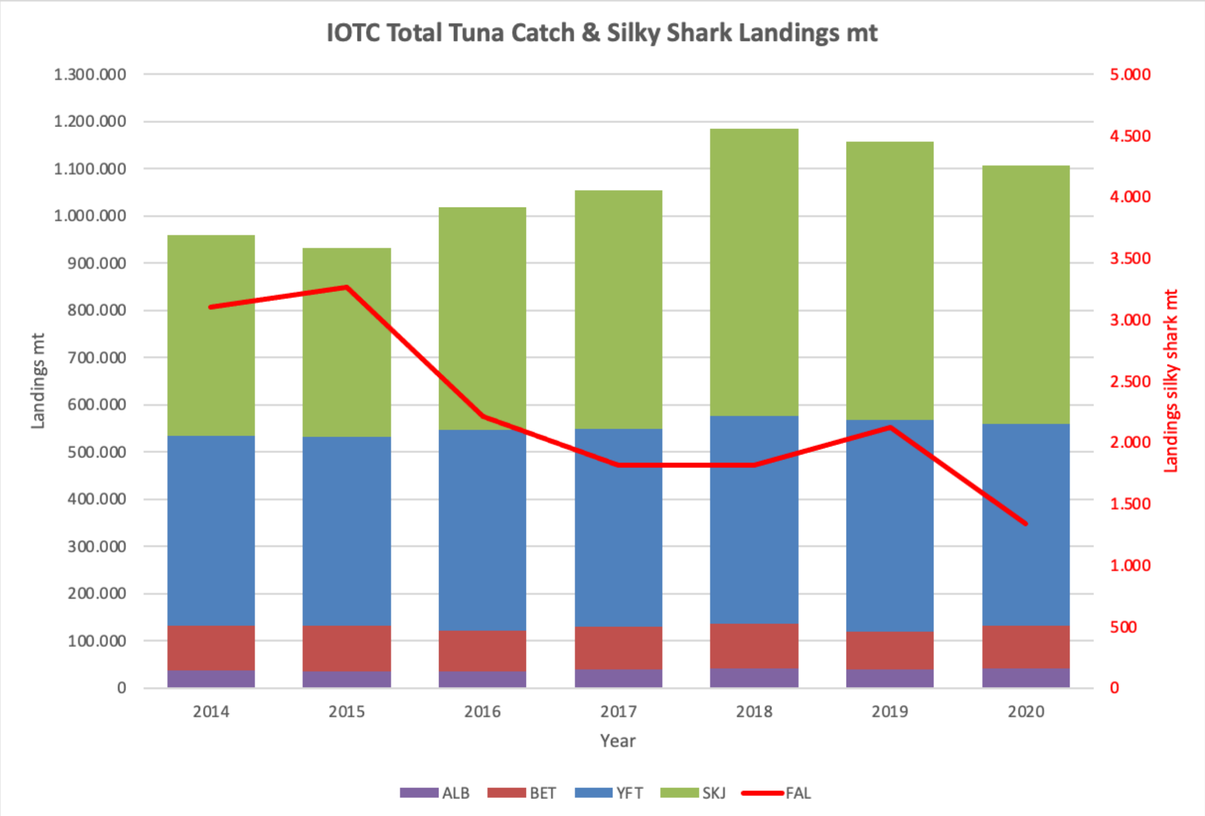

Figure 1: *IOTC database assessed August 2022 IOTC-DATASETS-2022-05-17-NC-sharks 2014 to 2020 all gear and all fleets with total tonnage of annual catch for major tuna species and reported landings of silky sharks over the same time period*

Gear specific landing reports from purse seiners are even lower, do not correlate with overall shark landings, and may thus be totally unrealistic as shown in **Table 2** and **Figure 2** below with a total of less than 10 tonnes reported over the last five years, despite an increasing percentage of all catch of tropical tuna in the Indian Ocean in these years having been caught by purse seiners and small purse seiners. While a voluntary non retention of silky sharks in some purse seine fleets might explain a decrease the actual up and down of reported landings appears to be arbitrary and the extremely low numbers reported overall don’t support such an assumption.

Year	YFT	BET	SKJ	ALB	FAL
2014	139,520,09	26,197,79	168,612,27	646,51	

Year	YFT	BET	SKJ	ALB	FAL
2015	147,924,90	31,380,35	169,967,46	645,31	
2016	154,152,47	27,738,35	226,012,01	538,41	
2017	150,456,54	35,583,74	251,329,63	543,17	1.02
2018	143,895,99	51,282,34	336,553,14	392,32	5.20
2019	148,884,76	32,368,88	344,065,00	492,67	2.12
2020	122,165,60	32,380,88	269,885,75	647,43	
Total for 2014-2020	**1,007,000,35**	**236,932,34**	**1,766,425,25**	**3,905,82**	**8.35**

Table 2: *Table landings in mt for 2015 to 2020 reported in IOTC data base for purse seiners and small purse seiners and associated reporting of silky shark bycatch in these operations from of all reporting parties. 2022 IOTC-DATASETS-2022-05-17-NC-sharks 2014 to 2020*

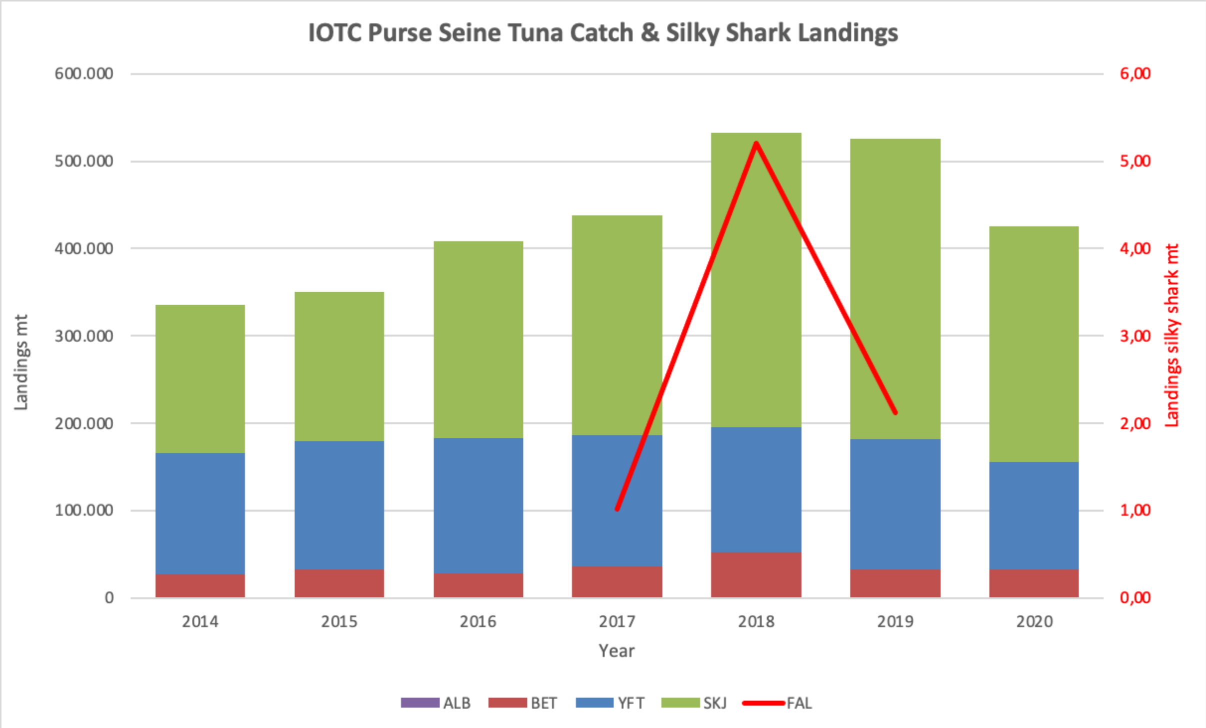

Figure 2: *Landings in mt for 2015 to 2020 reported in IOTC data base for purse seiners and small purse seiners and landings of silky shark bycatch in these operations from of all reporting parties. 2022 IOTC-DATASETS-2022-05-17-NC-sharks 2014 to 2020*

At only 30% of CPCs having complied with reporting requirements for catch & effort for sharks in 2021 when reporting 2020 data (IOTC-2022-CoC19-03 [E]), reporting of discards (dead discards or live release) could be expected to be even less and indeed most CPCs did not fully report discards or did not report discarded sharks at all in their annual national reports or elsewhere, let alone at a gear specific level. And even major tuna fishing nations at IOTC like Spain and Seychelles failed to report the discards of silky sharks from their purse seine fleets for 2020, while at the same time Spain reported 574.3 t of silky shark landings/transshipment for its purse seine fleet in its 2021 national report (IOTC-2021-SC24-NR06_Annex2_EU_Spain).
France and Italy on the other hand reported discards of silky sharks for their fleets between 2016 and 2020. As shown in **Table 3** also Mauritius reported some discards although there the report isn't clear whether this number applies to the purse seine fleet specifically or was cumulated for all gear and no discards were reported for other years.
Extrapolating the reported French and Italian discards from observed sets to the total catch numbers of animals increase by a factor of two to four as observer coverage reported by France for its purse seiners was 25 – 49% for this time period, thereby adding up to 10,000 – 20,000 animals per year.

Estimating similar bycatch levels for the 13 large size Seychelles purse seine vessels of 80 to 101 meters with a catch of skipjack tuna of 60,000 to 80,000 metric tons per year over the period 2016 - 2020 (**Table 3**), which was two to three times the tuna catch of France and Italy, at least twice as many discards as for the French plus Italian fleets or 20,000 to 40,000 animals per year might have been expected. The Seychelles' fleet is after the Spanish fleet the second largest industrial purse seine fleet operating at IOTC, many of its vessels belong to Spanish fishing companies and nine vessels owned by Spanish companies are even part of MSC certified fleets.

For the 15 large seize Spanish vessels of 84 - 116 meters and their even higher catch exceeding 100,000 tonnes of skipjack during the peaks in 2018 and 2019 (**Table 3**) even higher discards in the range of 30,000 to 60,000 animals per year or three times the discards of France and Italy would have been expected.

Therefore, combined discards accumulating to 60,000 - 120,000 animals might be expected per year from these five fleets alone (Spain, France, Italy, Mauritius, and Seychelles). This estimation does however not even account for the bycaught silky sharks in the purse seine fleets of Iran, Korea, or Japan, which have either retained or discarded silky sharks without reporting, let alone those unreported silky sharks caught by the large armada of purse seine vessels in Indonesia's industrial purse seine fleet. These small purse seine vessels also accounted for an average of 44,624 mt of skipjack tuna catch between 2016 and 2020, although each of the 103 vessels is only 30 to 40 meters (IOTC–2021–SC24–NR09). And while no discarded or retained silky shark numbers are available from any of these other fleets the overall impact from purse seine fishing on silky shark mortality in the Indian Ocean should be estimated to be substantially higher than commonly assumed, and even more so when keeping the low observer coverage in most CPC fleets and the poor reporting compliance in mind.

Purse Seine Fleets of CPCs	**2020**	**2019**	**2018**	**2017**	**2016**
Number of silky sharks discarded					
France: 12 (10 in 2020) vessels (observed sets only)	4,589	6,752	8,907	7,546	4,250
France: # scaled to total catch (based on % observed sets)	18,356 (25)	15,345 (44)	18,951 (47)	15,400 (49)	9,444 (45)
Italy: 1 vessel, 100% observed	1,047	681	1,178	752	452
Mauritius*: 2 (3 in 2019 & 2020) vessels	982	n/a	n/a	n/a	n/a
Total	**24,974**	**16,026**	**20,129**	**16,152**	**9,896**
Landings of skipjack tuna in mt					
France	30,569	35,733	49,001	22,231	30,698
Italy	1,893	2,670	4,624	2,052	1,392
Mauritius	9,210	12,742	9,283	8,503	3,788
Indonesia	65,787	63,034	35,885	55,614	28,828
Seychelles	75,486	72,917	81,451	69,994	60,991
Spain	85,153	119,138	132,986	84,432	75,264

Table 3*: Number of silky sharks discarded by purse seiners between 2016 and 2020 compared to the reported skipjack catch of the fleets; discards of silky sharks were reported by France (IOTC-2021-SC24-NR06_Annex1_Rev1), Italy (IOTC-2021-SC24-NR06_Annex4) and possibly Mauritius (IOTC-2021-SC24-NR17), but not by Seychelles (IOTC-2021-SC24-NR22_Rev1), Spain (IOTC-2021-SC24-NR06_Annex2), or Indonesia (IOTC–2021–SC24–NR09)*

** report does not specify whether discards come from purse seine fleet or longline fleet*

MSC Certification of Purse seine Fisheries in the IOTC for Skipjack Tuna Ignoring the Cumulative Impact of Silky Shark Bycatch from dFADs

Also, during sustainability assessments by the Marine Stewardship Council this magnitude of discards and the associated mortality is grossly neglected when assessing the impact of dFADs fishing operations on silky shark stocks, as perceived by industrial purse seine fleets aspiring certification for their dFAD operations or their combined fishing operations with free sets and dFADs. As only bycatch data for the fleet under assessment is evaluated for its contribution to the overall estimated mortality of silky sharks in the Indian Ocean, the cumulated mortality from all certified purse seine fleets in combination with the other purse seiners operating in the area is consistently ignored. To date three fisheries have been assessed and certified by the MSC and the conformity assessment bodies (CABs) always concluded that the fishery does not negatively impact the stock or potentially hinder the recovery of the stock as purse seining operations by the UoC account for less than 2% of the total fishing induced mortality in the Indian Ocean (MSC AGAC objection 2022). Therefore, all assessed fisheries to date have been scored by the respective CABs to meet the criteria for P2 (bycatch and ecosystem impact) of the MSC's Fisheries Standard and therefore obtained certification without having to introduce further bycatch avoidance measures or measures to reduce on board and post release mortality. (MSC certification reports for Echebastar, AGAC & CFTO). To date the following fleets have obtained MSC certification for as of 2020/2021at total of 28 vessels.

Fleet	Vessel Name	Flag State	No of vessels in Fleet as of 2020/2021	References @MSC org
Echebastar Indian Ocean Skipjack Tuna Purse Seine Fishery MSC certified in 2018	Elai Alai	Spain	6 vessels	https://fisheries.msc.org/en/fisheries/echebastar-indian-ocean-purse-seine-skipjack-tuna/@@assessments
	Aterpe Alai	Spain		
	Alakrana	Spain		
	Izaro	Seychelles		
	Jai Alai	Seychelles		
	Euskadi Alai	Seychelles		
AGAC four oceans Integral Purse Seine Tropical Tuna Fishery (Indian Ocean) MSC certified in 2021	Albacan	Spain	14 vessels	https://fisheries.msc.org/en/fisheries/cfto-indian-ocean-purse-seine-skipjack-fishery/@@assessments
	Albatun Dos	Spain		
	Albacora Uno	Spain		
	Draco	Seychelles		
	Galerna II	Seychelles		
	Galerna III	Seychelles		
	Intertuna Tres	Seychelles		
	Txori Zuri	Spain		
	Itsas Txori	Spain		
	Txori Gorri	Spain		
	Txori Argi	Spain		
	Txori Toki	Seychelles		
	Txori Aundi	Seychelles		
	Albacora Cuatro	Spain		
Indian Ocean Purse Seine Skipjack fishery Compagnie Française du Thon Océanique S.A.S. (CFTO) MSC certified in 2021	Axel Vad	France	8 vessels	https://fisheries.msc.org/en/fisheries/agac-four-oceans-integral-purse-seine-tropical-tuna-fishery/@@assessments?assessments=
	Cap Saint Vincent	France		
	Cap Sainte Marie	France		
	Glenan	France		
	Talenduic	France		
	Drennec	France		
	Trevignon	France		
	Torre Italia	Italy		

***Table 4**: MSC certified fisheries with vessels authorised in the UoC and at IOTC*

While bycatch and discards have been reported during MSC assessment by all three fleets, only Echebastar has reported silky shark bycatch as both, the number of individual animals and the tonnage of bycatch per type of set and for all years on its website, updating information as it became available (Echebastar). The other two fleets provided the bycatch of silky sharks only as tonnes and cumulated over both types of sets.

Therefore, the Echebastar data sets from 2014 to 2021 were used to calculate an average weight of bycaught silky sharks for dFADs, ranging between 10 and 25 kg as demonstrated in **Table 5**. This shows that over all analysed years the bycatch in dFADs was predominantly juvenile animals, as sexually mature sharks would have had much higher body weights. This is also consistent with sizes reported by Hutchinson et al. 2015 and relates to a bycatch of mostly juvenile animals with less than 200 centimetres of total fork length. Filmalter et.al (2013) also postulated, that the majority of animals caught will be less than three years of age.

To obtain also the number of individuals for the other two fleets an average of 19 kg was applied to convert the reported tonnages. This average weight per animal had been calculated from the bycatch data of Echebastar over a time series of eight consecutive years including all years reported by the other two fleets.

Fishery	Gear	Year	Mean weight of silky sharks
Echebastar Indian Ocean Skipjack Tuna Purse Seine Fishery	PS FAD	2014	9.85
	PS FAD	2015	23.51
	PS FAD	2016	20.79
	PS FAD	2017	17.75
	PS FAD	2018	18.98
	PS FAD	2019	19.41
	PS FAD	2020	24.48
	PS FAD	2021	16.84
	Mean weight per animal in kg		**19**

Table 5: *Mean weight per silky shark caught as bycatch derived from numbers and tonnage of discards from Echebastar between 2014 and 2021*

Table 6 and **Table 7** summarise all publicly available data from the three certified fisheries including the annual bycatch rates of silky sharks in tonnes and number of individual animals for each fleet. Bycatch ratios were also calculated as percentage of the total catch of each fishery and of its landings of skipjack tuna, as all three fisheries share the same stock of skipjack tuna as the Unit of Certification (UoC).

While the three fleets differ significantly in size and total catch as well as in their operations having different levels of observer coverage and reporting standards for bycatch and discards implemented, all of them report similar bycatch rates of silky sharks in relation to the total catch, fluctuating mostly between 0.2 and 0.4% of the total catch. This may appear to be low at first sight, but it is important to consider the total accumulated impact of this percentage in numbers of individuals with several thousand or ten thousands of animals caught by various fleets without adequate reporting and these numbers don't even include any unobserved mortality resulting from entanglement in dFADs that are still using netting or rolled up netting and other meshed materials that unravel over time and then become entangling again.

It should also be noted that the reported bycatch level for Echebastar is based on human observer coverage of more than 50% of all dFAD sets since 2017, which was maintained even in 2020 and 2021 despite the pandemic, while AGAC and CFTO had coverage levels of less than 50% and less than 30% respectively, with no additional data provided since 2018.

When calculating bycatch rates based on the Unit of Certification which is skipjack tuna (SKJ), accounting only for 30 to 60% of the total catch (

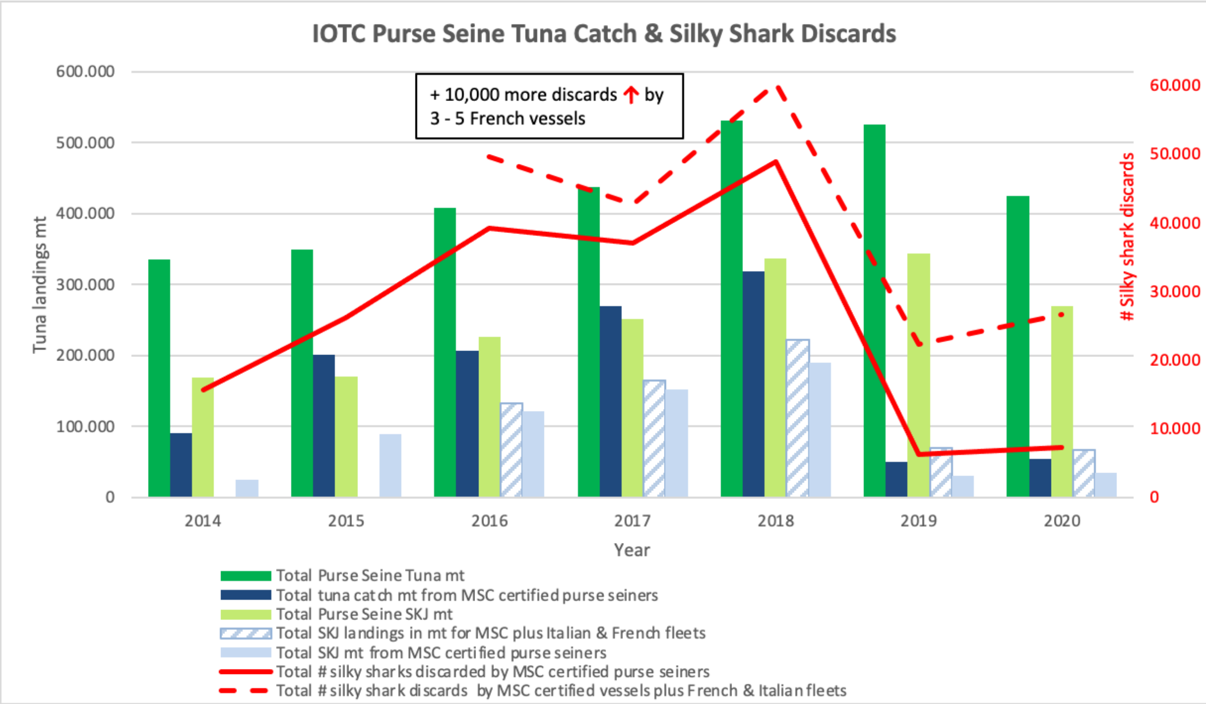

Figure 4), then bycatch levels increase substantially and vary significantly more between years and fisheries. As yellowfin tuna is overfished in the Indian Ocean this part of the catch is excluded from the certification, while the fisheries continue to catch yellowfin tuna (YFT) at a substantial percentage but varying quite substantially between years and fleets. Depending on the batch composition, which varies significantly between fleets and years for the same fleet the silky shark bycatch related to 0.2 to 1% w/w of the certified SKJ catch for Echebastar, 0.4 to 0.6% w/w for AGAC and 0.3 to 1.8% w/w for CFTO. Percentage of bycatch based on SKJ increases as the percentage of the UoC SKJ of the overall catch decreases.
Observer coverage fluctuates between years for all fisheries but shows an extreme spread between the three certified fisheries, from only 5% up to 89% of all sets having been observed. Higher observer coverage is expected to also improve the accuracy and precision of bycatch reports and therefore the highest certainty about the overall bycatch levels and extent of discarded animals can be derived from the provided Echebastar data, justifying the use of this data as the best estimate for missing data from other fleets like the mean weight of bycaught silky sharks and the number of silky sharks per set.
Total number of sets made on dFADs was only provided by Echebastar while the percentage of dFADs of all sets were also provided by CFTO, but not by AGAC. From the provided percentage of dFADs in **Table 7** it is obvious that since 2014 the contribution of dFADs in purse seine fishing has increased dramatically from about 60% in 2014 to well above 90% by 2018 and close to 100% by 2020, in parallel to increasing total tuna catches.
Theoretically three to six silky sharks were caught in each of the approximately 1,500 sets on dFADs made by the five to six vessels of the Echebastar fleet each year since 2015. While silky sharks are also caught in free sets and the weight percentage suggested this rate to be not very different to the bycatch in dFADs the correlation between the number of sets per type and the number of sharks caught per set type shows the substantial difference between both bycatch rates. Between 0.1 and 0.3 animals per set were caught in free sets while 3.1 to 6.4 sharks were caught in dFADs. Similarly, a much higher bycatch rate for dFADs was also reported by Clavareau et al. 2020 for the Indian Ocean but could unfortunately only be confirmed for the Echebastar fleet for this review as the number of sets per set type and set type specific bycatch numbers were not available from the other fleets.

Figure 3 shows the accumulated purse seine tuna catch of the three MSC certified fleets and the respective discards of silky sharks in number of individuals demonstrating the increase of silky shark bycatch between 2015 and 2018 with a peak of almost 50,000 animals reported in 2018. Data for all three fleets are available for 2015 to 2018 while only data from one fleet were available for 2019 and 2020, and data from two fleets for 2014.

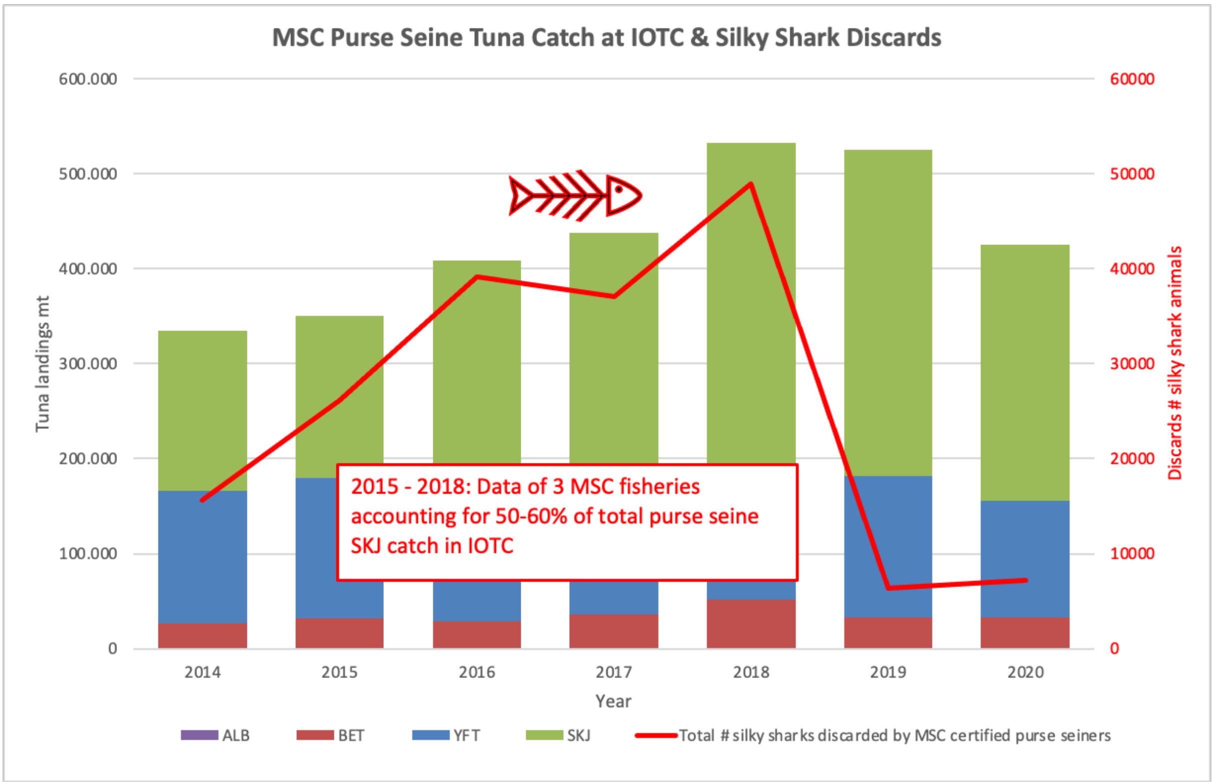

Figure 3: *Landings of tuna from purse seiners in IOTC in mt and number of discarded silky sharks (IOTC data and MSC data added where possible without overlap) on second y-axis*
*MSC Silky shark discards for 2019 & 2020 are only available from 1 fleet (Echebastar) and for 2014 from 2 fleets (Echebastar & CFTO)

It should also be noted that those numbers are derived from reported tonnage or numbers of individuals discarded in observed sets and have then be extrapolated by the CABs or fishery to the total catch level for reporting during MSC certification, while observer coverage has been quite different between those three fleets over the years as shown in **Table 6**.

Table 7 calculates an average of 4.4 silky sharks caught per set in dFADs between 2014 and 2021based on the total discards and the number of sets on dFADs. However, it should be highlighted that individual vessels or individual sets do exceed this average and that sets often have substantially higher numbers of silky sharks per set as also observed by Hutchinson et al in 2015 with 20 and more sharks per set. This could also be verified for 2016 data from Echebastar by analysing the observed sets for each of the five vessels for their silky shark bycatch in numbers per set showing bycatch data of to 75 sharks in a single set and also a considerable number of 71 sets out of the total of 404 observed sets on dFADs with 10 or more silky sharks per set, while 17 sets had even 20 or more sharks per set (unpublished information received during the objection against the MSC certification of the fishery in 2017). The biggest number of sets with 10 or more sharks was observed for the biggest vessel of the fleet clearly demonstrating thereby the importance of bycatch evaluation at a vessel and set level in order to identify high risk areas of silky shark bycatch and to investigate avoidance measures based on spatial and temporal bycatch frequencies as well as testing the effectiveness of such measures after implementation.
In 2021each of Echebastar's six vessels landed between 8,000 and 13,000 tonnes of tuna (Echebastar) but silky shark bycatch was only reported at fleet level with 76.08 tonnes of discards respectively 4,519 animals. While this was a low rate of 0.22% in relation to the SKJ catch for 2021 the average weight of silky sharks caught by the fleet was only 16.8 kg and thus certainly below the average of the last eight years (**Table 5** & **Table 6**). Here an investigation at set level could greatly help to understand potential causes for this below average mean weight of animals, e.g., whether sets have been made in a nursery area and therefore catching high numbers of very juvenile animals.

Fishery	Total Landings mt	Gear	Year	Total Catch UoC mt	Observed catch (% of sets)	Silky shark estimated total catch mt	Silky shark estimated total catch (# animals)	% (w/w) bycatch from UoC	% (w/w) bycatch from total landings
Echebastar	**34,547**	PS FAD	2014	8,726	29	18	1,827	0.21	0.05
		PS Free	2014	1,055	29	1	73	0.09	
	35,521	PS FAD	2015	13,294	53	138	5,870	1.04	0.39
		PS Free	2015	135	53	2	80	1.48	
	40,911	PS FAD	2016	19,333	34	149	7,168	0.77	0.37
		PS Free	2016	470	34	3	53	0.64	
	46,075	PS FAD	2017	27,308	86	86.5	4,874	0.32	0.19
		PS Free	2017		62	1.04	62		
	52,729	PS FAD	2018	33,866	87	166.4	8,769	0.49	0.32
		PS Free	2018		90	0.2	4		
	49,483	PS FAD	2019	30,682	79	121.1	6,238	0.40	0.25
		PS Free	2019		78	1.8	77		
	53,432	PS FAD	2020	33,867	52	177.0	7,233	0.52	0.33
		PS Free	2020		35	0.2	3		
	59.412	PS FAD	2021	33,814	58	76.1	4,519	0.22	0.13
		PS Free	2021	325	36	0	0	n/a	
AGAC	**126,811**	PS FAD	2015	51,842	45	257	13,526	0.50	0.20
	155,649	PS FAD	2016	81,127	23	485	25,526	0.60	0.31
	177,331	PS FAD	2017	102,585	21	543	28,579	0.53	0.31
	203,861	PS FAD	2018	134,578	31	598	31,474	0.44	0.29
CFTO	**56,024**	PS FAD	2014	14,735	5.2	261	13,737	1.77	0.47
	39,313	PS FAD	2015	23,331	8.73	127	6,684	0.54	0.32
	39,249	PS FAD	2016	19,896	7.93	122	6,421	0.61	0.31
	46,247	PS FAD	2017	22,658	16.33	67	3,526	0.30	0.14
	62,618	PS FAD	2018	21,223	15.04	165	8,684	0.78	0.26

Table 6: *Catch data and discards of silky sharks reported for applicable observer coverage levels as indicated for at least three consecutive years from MSC certified purse sein fisheries catching skipjack tuna as the Unit of Assessment in the Indian Ocean by free sets and dFADs*

Fishery	Year	Observed % of sets	Silky shark estimated total catch mt	Silky shark estimated catch # animals	% (w/w) bycatch of silky sharks for UoC	% (w/w) bycatch of silky sharks for total	Discards and discard status (dead/alive) % or number	No of sets	No of vessels in UoC	% of sets dFAD	Bycatch animals per set
Echebastar	2014	29	18	1,827	0.21	0.05	53% discarded alive	567	4	64	3.2
	2014	29	1	73	0.09		20% discarded alive	237	4		0.3
	2015	53	138	5,870	1.04	0.39	52% discarded alive	1158	6	81	5.1
	2015	53	2	80	1.48		70% discarded alive	235	6		0.3
	2016	34	149	7,168	0.77	0.37	68% discarded alive	1510	5	90	4.7
	2016	34	3	53	0.64		100% discarded alive	190	5		0.3
	2017	86	86.5	4,874	0.32	0.19	2782 sharks discarded alive	1250	5	89	3.9
	2017	62	1.04	62			53% discarded alive	213	5		0.3
	2018	87	166.4	8,769	0.49	0.32	5298 sharks discarded alive	1369	5	98	6.4
	2018	90	0.19	4			100% discarded alive	29	5		0.1
	2019	79	121.1	6,238	0.40	0.25	79% discarded alive	1384	6	90	4.5
	2019	78	1.77	77			100% discarded alive	147	6		0.5
	2020	52	177.03	7,233	0.52	0.33	59% discarded alive	1608	6	97	4.5
	2020	35	0.24	3			100% discarded alive	43	6		0.1
	2021	58	76.08	4,519	0.22	0.13	47% discarded alive	1467	6	97	3.1
	2021	36	0	0	n/a		n/a	162	6		0
AGAC	2015	45	257	13,526	0.50	0.20	38.1% of 52.104 animals reported to be discarded alive between 2015 and 2018	n/a	14	n/a	n/a
	2016	23	485	25,526	0.60	0.31		n/a	14	n/a	n/a
	2017	21	543	28,579	0.53	0.31		n/a	14	n/a	n/a
	2018	31	598	31,474	0.44	0.29		n/a	14	n/a	n/a
CFTO	2014	5.2	261	13,737	1.77	0.47	observer only on board of 1 vessel; 52% discarded alive between 2014 and 2018	n/a	8	65	n/a
	2015	8.73	127	6,684	0.54	0.32		n/a	8	60	n/a
	2016	7.93	122	6,421	0.61	0.31		n/a	8	74	n/a
	2017	16.33	67	3,526	0.30	0.14		n/a	8	76	n/a
	2018	15.04	165	8,684	0.78	0.26		n/a	8	93	n/a

Table 7: *Catch data and bycatch levels of silky sharks reported for at least three consecutive years from MSC certified purse sein fisheries catching skipjack tuna as the Unit of Assessment in the Indian Ocean by free sets and dFADs*

Table 8 tabulates the reported discard estimates for all three MSC certified fleets combined, clearly demonstrating that the 296 tonnes of silky shark bycatch estimated for purse seiners for 2015 – 2016 by Garcia & Herrera (2018) underestimated the real extent at least by a factor of two to three in 2016. Adding up to almost 1,000 tonnes in 2018 for all 28 MSC certified vessels this bycatch level is more than three times higher than estimated translating into 40,000 – 50,000 silky sharks for 2016 – 2018, as combinied discards from all three fleets.
It should however also be kept in mind that even for the peak period between 2016 to 2018, with data from all three certified fisheries being available, the total SKJ catch of these 28 vessels and therefore also the reported silky sharks account only for 50-60% of the total purse seine catch in the IOTC as shown in Fehler! Verweisquelle konnte nicht gefunden werden. and

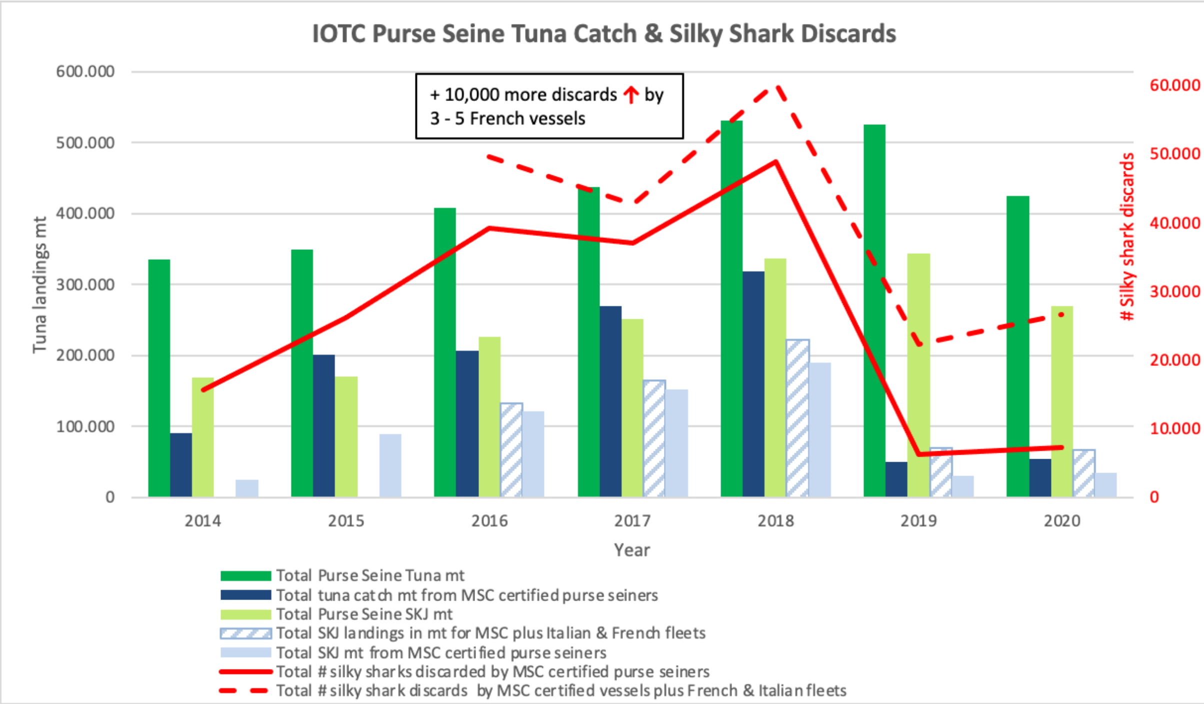

Figure 4. The Figure also demonstrates that the number of silky sharks taken, clearly correlates with increasing SKJ catches at IOTC.
Therefore, the total bycatch from purse seiners in the IOTC might be expected to be at least twice as high although these discards may not have been reported to IOTC.

Year	2020	2019	2018	2017	2016
Total skipjack catch in mt being **MSC certified** from purse seiners in Indian Ocean	**33,867	**30,682	**189,667**	**152,551**	**120,826**
Total silky shark discards estimated in mt for all **MSC certified purse seiners** for 2016-2018 and for Echebastar vessels for 2019 & 2020	**177.27	**122.87	**929.59**	**697.54**	**759**
Total silky shark discards in # for all **MSC certified purse seiners** for 2016-2018 and for Echebastar vessels for 2019 & 2020	**7,236	**6,315	***48,931**	***37,041**	***39,168**
Total skipjack catch in mt # estimated for 1 Italian vessel & 12 French (10 in 2020) vessels in addition to those discards reported in MSC report for CFTO fleet already	66,329 ***	69,085 ***	222,069 ***	165,367 ***	133,020 ***

Year	2020	2019	2018	2017	2016
Total silky shark discards in # estimated for 1 Italian vessel & 12 French (10 in 2020) vessels in addition to those discards reported in MSC report for CFTO fleet already	19,403 ***	16,026 ***	11,445 ****	12,626 ****	3,475 ****
Total silky shark discards in # for MSC certified purse seiners <u>**combined with**</u> # animals discarded by <u>**all**</u> Italian & French vessels	**26,639**	**22,341**	**60,376**	**49,667**	**42,644**

Table 8: *Cumulated silky shark bycatch reported per year by MSC certified purse seine fleets and converted to number of animals for fleets other than Echebastar compared to discards from Italian plus French fleets and adding both sources to obtain total estimates*

* for the years 2016 to 2018 discarded animals have either been directly reported or can be converted via standardized body weights from reports for all three MSC certified fleets

** for the years 2019 and 2020 only data from Echebastar (6 vessels) are publicly available from MSC certifications

*** for the years 2019 & 2020 total discards by Italy and France were projected from national reports to the total catch based on observer coverage for the French purse seine fleet.

**** for the years 2016 to 2018 total discards were projected from national reports to the total catch of Italy and France but corrected for reported discards for the MSC certified CFTO fleet, which were subtracted, thereby reflecting combined discards from the MSC fleets plus the additional (3 – 5) non MSC certified vessels of the French fleet.

Silky shark is named as the fourth most important shark species (García and Herrera 2018) in the Indian Ocean tuna fisheries accounting for 23,000 tonnes being caught per year, or 10% of the total shark catches. Based on their analysis with data from multiple fishery sources and the IOTC database they had estimated that gillnets and longliners are the main contributors to the catch of silky sharks with 57% and 42% respectively, while purse seining is said to only account for 1.3% of the total. This 1.3% of 23,000 tonnes of silky sharks would however translate into only 299 tonnes for the total Indian Ocean per year or when using the weight of 19 kg, as suggested in this paper, to convert silky shark tonnage from purse seine catch into number of animals, to approximately 15,800 animals per year.
As summarised in **Table 8** and Fehler! Verweisquelle konnte nicht gefunden werden. **already** these estimates are already contradicted by the reported bycatch tonnes and number of discarded animals from MSC certified fleets alone, exceeding this estimate by a factor of more than four in 2018.

However, not only these 28 vessels but all silky shark bycatch by the 50 - 60 large industrial purse seiner of 60 meters and more operating in the Indian Ocean and the 100 smaller purse seiners of 30 - 40 meters from Indonesia's industrial purse seine fleet also need to be considered.
Therefore, **Table 8** extrapolates discards beyond MSC fleets by including further discards as available from the national reports submitted to IOTC in 2021 with data for 2016 to 2020, combining all discards for

- MSC certified vessels (MSC reports)
- 12 (10 for 2020) French vessels (French national report, 7 of these vessels are part of CFTO)
- 1 Italian vessel (Italian national report, the vessel is part of CFTO)

These 33 vessels accounted together for 222,069 mt of SKJ and 60,376 silky sharks in 2018 and for 165,367 mt of SKJ and 49,667 silky sharks in 2017, thereby adding roughly another 10,000 sharks from the five additional French purse seiners (3 in 2020) and increasing the total percentage of SKJ caught to 60 - 66% of the total purse seine SKJ in the IOTC as shown in **Figure 4**.
This however still does not account for the catches by the other four large Spanish vessels, and the four large Seychelles vessels, that are not part of a MSC certified fishery. These # of discards also not account for all other fleets which might add another 50,000 – 100,000 animals as discussed earlier for **Table 3**, bringing the <u>total easily to more than 100,000 animals or more than 2,000 tonnes, respectively</u>. And in view of the low reporting compliance and the varying observer coverage levels even for MSC certified fleets, there is a high probability that discards from purse seiners are indeed <u>10 times higher than estimated by Garcia & Herrera (2018) and as high as the reported landings of silky shark and thus contributing to a much bigger percentage to the total fishing induced mortality in the Indian Ocean</u>.

As neither Spain nor Seychelles have provided any information on silky shark discards estimates beyond MSC data are also needed for the four additional large Spanish vessels and four large additional Seychelles vessel all of which are not part of the MSC certified fleets but also catch tuna at IOTC.
In addition, the fleets of Iran, Korea, Japan, and Indonesia also should be considered when reviewing the total impact from industrial purse seiners in the Indian Ocean.

Combining both, the MSC reported bycatch and number of discards and the discards from national reports whenever available, and then using these data to extrapolate silky shark bycatch also for other vessels from similar fleets may at this point be the best way to generate overall estimates of silky shark mortality in the industrial purse seine fleets, although real discards at fleet level or even vessel level would be the best source to evaluate all cumulative impacts.
However, in the absence of such fleet specific data from CPCs the MSC certification scheme may provide a good interim proxy as demonstrated here to bridge missing CPC data via extrapolation from similar MSC fleets.
Therefore, a doubling of the reported numbers from the three MSC certified fleets should easily be assumed as being realistic and bringing total numbers of discards up to more than 100,000 silky sharks. And even this may be only a temporary result as discards possibly will increase further, as more and more vessels transition to setting almost exclusively on dFADs and more and more dFADs continue being deployed. This appears also quite realistic when considering that the Spanish fleet alone did 4,577 sets in 2019 in and 4.590 sets in 2020 and that based on the results from Echebastar an average of 4.4 silky **(Table 7)** sharks are caught in each set or at least 20,000 animals overall.

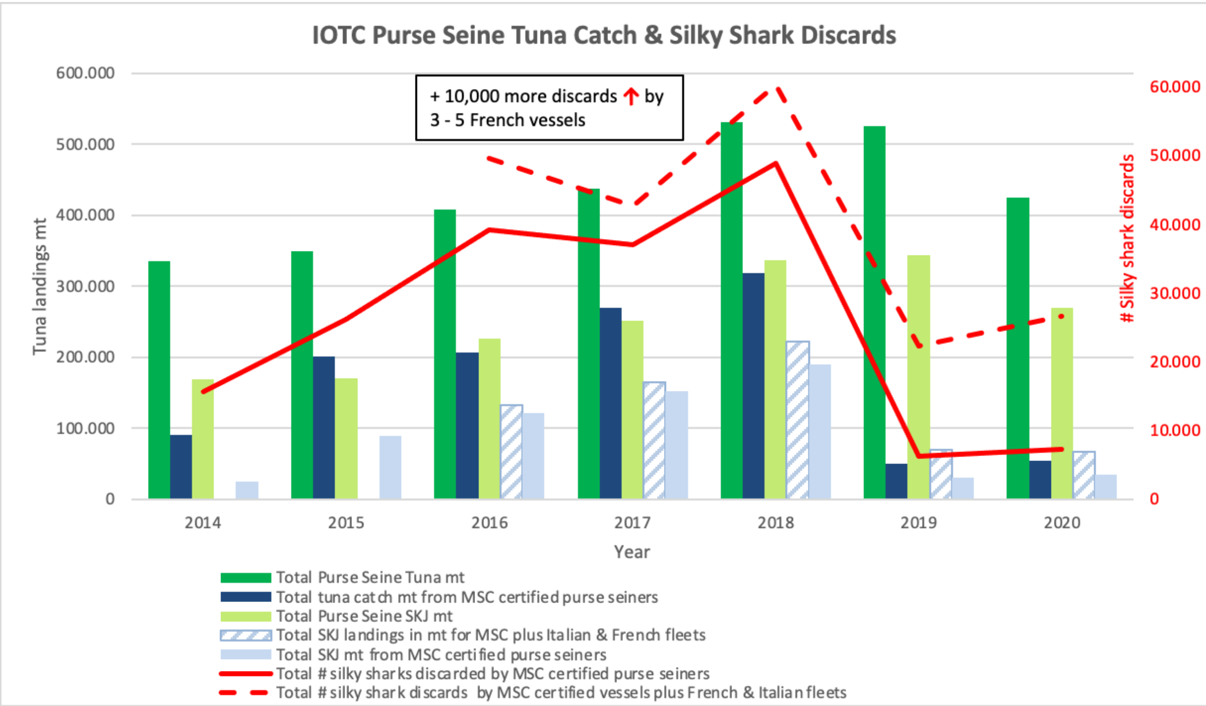

***Figure 4**: Landings of Skipjack tuna in mt in correlation to total purse sein tuna catch at IOTC, MSC certified purse seine catches and MSC plus Italian & French fleet SKJ landings; number of discarded silky sharks from CPC fleets and MSC certified fleets combined on second y-axis*
* 2014, 2019 & 2020 MSC data only available from Echebastar fleet
** 2015 MSC data only available from Echebastar and CFTO fleets

While it is at this point unknown whether the majority of animals are discarded or retained with no reports available from the three biggest purse seine fleets (based on their annual catch of tropical tuna) Spain, Seychelles, and Indonesia, but even those that are discarded alive should be assumed to be subject to very high post release mortality. Lower levels of on-board mortality require specifically equipped vessels with experienced crew on board, which is certainly not the case for the majority of even the European flagged vessels. A much higher on-board mortality with lower live release ratios has been seen for both, AGAC and CFTO, during MSC certification with 40% and 50% of the silky sharks released alive (**Table 7**). While Echebastar has shown overall lower on-board mortality rates, even these had varied between 50% and 80% for dFADs over the reference period between 2014 and 2021 as shown in **Table 7**. In this context it should be noted that the promising study results by Onandia et al. 2021 only relate to those vessels of the fleet equipped with the additional conveyor belts, which applies to date only to the three newer vessels of the fleet.

Conclusions and Recommendations

The perception that purse seine fisheries have little to no impact on threatened species like silky sharks is wrong and fails to address the magnitude of these fisheries catching about 400,000 to 500,000 tonnes of tuna (skipjack and yellowfin from ***Figure 2***) or almost half of the total annual catch of tuna in the Indian Ocean. At such a scale even a nominally low bycatch rate of 0.3 – 1% as documented for the three MSC certified purse seine fisheries should no longer be considered being negligible, especially when impacting such a low fecundity species as silky sharks and a stock that has most certainly already experienced overfishing for more than a decade. At an uncertain stock status even a bycatch rate of 0.5% of the total catch, translating into 100,000 to 150,000 individuals caught every year, substantially contributes to threatening the survival of this stock and must therefore no longer be ignored, even more so when almost the complete bycatch is made up by juveniles, that have not yet reproduced.

The bycatch of silky sharks in purse seine fleets therefore requires urgent mitigations beyond best handling practices for bycatch, as most sharks will die even if discarded alive. As discards are underreported, effective avoidance strategies are essential to reduce the probability of catching the animals in the first place. Onandia et al. (2021) reported a lower at vessel mortality of 40% and increased post release survival rates of 43% for vessels equipped with double conveyor belts as state-of-the-art bycatch release aids and specifically trained crews. Therefore, such technology should be mandatory for all newly build vessels while existing industrial vessels should at least be refitted with additional release ramps.

reporting of bycatch and discards must no longer be treated as a “petty crime” without further consequences. Full data representative of all fishing induced mortality are essential to better inform scientific advice.

But even then, post release survival strongly depends on characteristics such as size and vitality of the animals emphasizing the need to investigate specific migration patterns in the Indian Ocean to avoid the bycatch of juvenile silky sharks and to develop and test opportunities to identify the presence of sharks below dFADs prior to setting on them, e.g., via echosounders and/or cameras.

Filmalter et. al. suggested 2021 that time or spatial closures might be most effective to reduce silky shark bycatch as static spatial conservation and/or management initiatives will most likely not be effective for protecting and conserving silky sharks in the Western Indian Ocean due to their broad movement patterns. Dynamic spatial management initiatives were proposed as a better alternative but require considerably more information on habitat preferences of silky sharks in this region. Such studies should be initiated as a priority. Furthermore, they proposed regulations limiting fishing efforts on dFADs as the most direct measure to reduce the impacts of the purse seine fishery on this species.

Obviously, all entangling and partially entangling dFADs must be removed from the water and only lifetime non-entangling, biodegradable dFADs should be allowed to be deployed. This should be strictly enforced with defined penalties for non-compliance.

At less than 50% compliance with reporting of catch data and mandatory statistical data (Res. 15/02 and Res. 17/05) all estimates of the fishing impact on bycatch species remain completely inadequate and with only 15% compliance for length frequency data reporting and catch effort data for sharks, stock assessments and projections are jeopardised, resulting in an unknown stock status for most shark species. While mechanisms exist for encouraging CPCs to comply with their recording and reporting obligations

(Resolution 18/07), these need to be further implemented by the Commission. Non-In IOTC–2021–SC24–R[E] the Scientific Committee advised management regarding silky sharks, that "despite the absence of stock assessment information, the Commission should consider taking a cautious approach by implementing some management actions for silky sharks." However, to date no measures have been implemented and more data still don't exist.
"**No data means no certainty and without certainty no management measures get implemented"** (Sharkproject, IOTC 2022)! This "vicious circle" therefore results in ongoing overfishing of already depleted sharks and other bycatch of threatened species at IOTC, while most of these stocks will take decades to recover if ever.
Therefore,

- Compliance with mandatory reporting requirements needs to be increased substantially and there need to be **clear consequences communicated and enforced in case of repeated non-compliance**
- To estimate the true overall **fishery induced mortality reporting of discarded sharks by all fleets at vessel level** in compliance with Res. 15/01 Annex II 2.4 needs to be improved substantially and the **list of sharks and fishing gear obliged to be reported this way needs to be extended**.
- Requirements for reporting of **catches and discards** of all sharks at a species level and for all gear types need to be mandatory **for all fisheries and no longer exempt artisanal fleets**, which to date are exempted as small vessels remain exempt from reporting requirements of Res 17/05.
- Artisanal fisheries should have access to simplified reporting methods and receive assistance with reporting, but it is important to recognise that these vessels impact the abundance of sharks in the Indian Ocean and these impacts must no longer be ignored

While a precautious approach is certainly needed more needs to be done on the water to reduce shark mortality and no fleet, vessel, or gear should be exempt from having to implement improvements to reduce the overall number of individuals impacted by each gear.
In view of the dramatic findings of this review showing the cumulative extent of discards by the purse seine fishing fleets and the widespread not reporting of discards, calling for improved reporting alone is no longer enough. Effective measures are needed to avoid the bycatch of silky sharks in dFADs and to limit overall mortality of silky sharks in the Indian Ocean and reporting must be facilitated generally by making all fishery related data publicly available with full transparency of all bycatch and ecosystem impacts of a fishery has - down to the vessel level.

Acknowledgement
It is very difficult to extract relevant information on silky shark bycatch and discards in purse seining fisheries from both, the IOTC database and MSC reports. Therefore, multiple sources and estimations had to be combined to account for missing details and data sets. While publicly accessible in electronical format the IOTC database lacks fishery specific disaggregation of the data and has almost no bycatch and discard information on sharks due to the poor compliance of CPCs with their reporting obligations. The MSC reports provide fishery specific data sets and thereby allow for much better informed and differentiated assessment of impacts. However, the provided data/report formats are not consistent for different CABs and different fleets. It is also difficult to extract information and search these pdf reports, which are unfortunately mostly not updated over the duration of the certification period unless there has been a specific condition set for the fishery to provide bycatch and discard data as part of the annual surveillance reports.
Therefore, I would like to thank the Echebastar fishery for their regular updates of catch efforts provided on their website and for their approach to provide bycatch data in a consistent format for all years, including important details such as the number of individuals and the tonnage per set type. This helps to improve accessibility and analysis of multiple data sets and improves transparency about fishing operations. I certainly wished other fisheries would do the same. While I have not reached out to the fleet to obtain additional information for this paper so far, I would certainly appreciate access to more detailed data for future analysis. Details such as animals per individual set and spatial / time resolution about when and where sets are done will allow correlation with the extent and composition of bycatch and inform future avoidance strategies.

We believe that public access to all fishery related data on data about bycatch and ecosystem impacts as well as full transparency about all fishing operations is essential to improve the sustainability of fishing and to facilitate improvements at both, the individual fishery level and at RFMO level.

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