Assessing the impact of drifting FADs on silky shark mortality in the Indian Ocean

Iris Ziegler, Sharkproject International, Zürich

Introduction

Today more than 40% of global tuna catches occur around drifting fish aggregating devices (dFADs), and an increasing number of purse seine fleets concentrate their fishing efforts on dFADs, including MSC certified fisheries. The silky shark (*Carcharhinus falciformis*) is known to be the most significant ETP species bycatch in purse seine tuna fisheries when setting nets around dFADs. The use of dFADs also increases unobserved mortality through unreported "ghost fishing". This is when animals die unnoticed and unreported after having become entangled in the materials used for the construction of dFADs. In 2020, Bonnin *et al.* showed that silky sharks spend only around 30% of their time away from dFADs, thereby confirming the high spatial overlap of the species with dFADs and the risk of juveniles being captured.

The high levels of juvenile silky sharks caught as part of purse seine fishing on dFADs are of growing concern, as is the high bycatch of juvenile yellowfin tuna stock (IOTC WGFAD, 2021). Proposals for a transition to harmonized requirements for the construction of lifetime non entangling and biodegradable dFADs in combination with responsible dFAD management regulations are still under discussion at all RFMOs. Back in 2013 Filmalter et al. estimated that 80,000 dFADs were 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 continues to increase. Based on a field study investigating entanglement of silky sharks in dFADs that then died and fell out within two days, scientists 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 and add to unobserved mortality in the Indian Ocean alone (Filmalter *et al.* 2013). This number may exceed the estimated observed bycatch by a factor of 5 to 10, but the "observed" mortality of silky shark bycatch in purse seine fishing is also substantial as this species makes up 90% of the elasmobranch bycatch caught in tropical tuna purse-seine fisheries (Poisson *et al*. 2014). In the Indian Ocean, due to the high abundance of FADs, Filmalter *et al.* 2013 estimated that silky sharks only have a 29% chance of surviving to age 1, a 9% chance of survival to 2 years, and only 3% chance of reaching age of 3 years. Both, overall bycatch rates and a higher percentage of bycatch in dFADS compared to free sets, have also been reported for the Indian Ocean when compared to Atlantic Ocean, with high proportions of juvenile silky sharks being impacted across both oceans (Clavareau *et al.* 2020).

Discussion

Specific improvements to dFAD management have been requested by many concerned groups for years (NGOTF 2021, Sharkproject 2021, WWF 2021, IPNLF 2021, Blue Marine Foundation 2021) which demonstrates the extent of improvements needed. Suggested improvements that would reduce impacts upon silky sharks include:

- Prohibit 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 dFADs 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 applying technical measures, as well as the use of best practice handling practices, to reduce mortality of these species
- Defining total mortality limits and establishing bycatch reduction targets on all impacted species for purse seiners

Also, IOTC Res 19/02 (2019) defines requirements for completely non-entangling dFADs constructions as being mandatory from January 2022. Unfortunately, life on the water still looks different as many fisheries continue to deploy, so called, "lesser entangling FADs" (ISSF, 2019) with rolled up sausages of netting that unravel over time and become entangling. Similarly, in the Western Central Pacific, many entangling dFAD designs were reported by Escalle *et al*. in 2021 to be still drifting around. Despite the WCPFC requirement of low entangling dFAD design since January 2020, about 65–90% of dFADs, depending on the year considered, have at least some nets used as appendages as well as on the rafts. Less than 13% of observed dFADs had no nets at all (Escalle, 2020). Fisheries in the IOTC area also seem to have failed to remove entangling or lesser entangling FADs from the water, and likely continue to deploy them. Meanwhile the IOTC Compliance Committee was presented with clear evidence of regional non-compliance with such regulations earlier this year (IOTC, 2022).

Sharkproject (Ziegler, 2022) analyzed available data from the three fleets that have so far obtained MSC certification for skipjack in the Indian Ocean, to better understand the impacts that purse seine fleets and their drifting FADs are having upon silky sharks.

- Echebastar Indian Ocean Skipjack Tuna Purse Seine Fishery MSC certified in 2018
- AGAC four oceans Integral Purse Seine Tropical Tuna Fishery (Indian Ocean) MSC certified in 2021
- Indian Ocean Purse Seine Skipjack fishery Compagnie Française du Thon Océanique S.A.S. (CFTO) MSC certified in 2021

Only the Echebastar fleet had human observer coverage of more than 50% on all dFAD sets since 2017, which was maintained also in 2020 and 2021 despite the pandemic, while AGAC and CFTO had coverage levels of less than 50% and less than 30% (MSC reports), respectively, with no additional data provided since 2018. The difference in observer coverage to supply important data is a concern that needs to be resolved as a matter of urgency. In addition, out of 80,000 dFAD trajectories (56,263 tracking buoys) in the Indian and Atlantic oceans from 2012 to 2018, more than 40% of dFAD trajectories ultimately drifted away from fishing grounds and become abandoned, lost or discarded fishing gear (ALDFG) (Imzelen *et al.* 2022) demonstrating the high risk derived from lost dFADs when sausages of rolled up netting may unravel over time. Altogether silky sharks are directly exposed to three sources of fishing induced mortality from purse fishing on dFADs:

1. Entanglement (unobserved mortality)
2. On board mortality of bycatch (observed mortality)
3. Post release mortality of bycatch released alive (unobserved mortality)

There is a high total mortality rate of 84.2% for sharks landed during typical purse seine fishery operations (pre-set and encircled sharks excluded) (Hutchinson *et al*. 2015). Between 2011 and 2012, at-vessel mortality rate ranged in another study from 15% to 70%, and total mortality rate 80% to 95%. (Eddy *et al*. 2016). Lower at vessel mortality (40%) and higher overall shark survivorship was reported when technical measures like double conveyor belts are in place (Onandia *et al.* 2021) but overall mortality was still high.

Reported discards by MSC certified fleets alone exceed previous assumptions from Garcia & Herrera (2018) by a factor of two to three for the period 2014 - 2016 and by a factor of three to four in 2018. Around 1,000 tonnes, or close to 50,000 silky sharks, were reported (MSC reports) being caught as bycatch by MSC fleets alone in 2018 (Table 1).

Year	2021*	2020*	2019*	2018	2017	2016	2015**	2014**
Total catch in mt MSC certified purse seine catch	59,412	53,432	49,483	319,208	269,653	206,971	201,645	90,571
Total skipjack in mt MSC certified purse seine catch	**34,139**	**33,867**	**30,682**	**189,667**	**152,551**	**120,826**	**88,602**	**24,516**
Total silky shark mt in MSC certified purse seine = 28 vessels	76.08	177.27	122.87	**929.59**	**697.54**	**759**	**524**	280
Total # silky shark in MSC certified purse seine = 28 vessels	4,519	7,236	6,315	**48,931**	**37,041**	**39,168**	**26,161**	15,637
Total # silky shark in purse seine fleet: 28 MSC vessels + national reports from Italy (1 vessel) & France (12/10 vessels)		26,639	22,341	**60,376**	49,667	42,644		

Table 1: Silky shark discards by purse seine fleets in mt and # animals from MSC certified purse seine fleets between 2014 and 2021 in correlation to the catch of MSC certified skipjack in mt;
Discards reported by purse seine fleets to IOTC between 2016 and 2020 were raised to total catch and corrected for discards already reported by OFTC's MSC certified vessels
All discard weights were transformed to number of animals using a harmonized average weight of 19 kg as derived from Echebastar discards which had provided both, weight and numbers for all years;
** MSC data only from Echebastar fleet available*
*** MSC data only from Echebastar and CFTO fleets available*

When combining these discards with data reported by the French and Italian fleets to the IOTC for 2016 to 2020 in the national reports (IOTC-2021-SC24) at least 60,000 silky sharks were discarded in 2018 by MSC fleets and the Italian plus French fleets (Table 1). However, discard data are only publicly available for about 65% of all skipjack tuna caught by industrial purse seiners in the Indian Ocean, as the other purse seine fleets had not reported silky shark discards as part of the national reports.
Increasing bycatch levels of silky sharks coincide with increasing purse seine catches of tropical tuna seen over the period from 2014 to 2018 and the increasing transition to dFAD sets.
In 2016 the French CFTO fleet had used dFADs for 74% of its settings but by 2018 had increased this to 93%, while the Spanish Echebastar fleet had already performed 90% of its sets on dFADs in 2016 and had increased to 93% dFADs bei 2021 (**Ziegler, 2022**)
As discards from other major purse seine fleets (including Spain, Seychelles, Korea, Japan, Iran, Mauritius, and Indonesia among others) are not publicly available the total extent of silky shark bycatch is still widely underestimated, and at least 100,000 animals, most of them being juveniles should be anticipated ending up as bycatch and dying in the purse seine fisheries every year. Although best handling practices and technical on-board facilities to accelerate release have shown (Onandia et al. 2021) to be effective in lowering on board and post release mortality the overall impact of this fishing practice on juvenile silky sharks remains high especially as technical measures are not yet widely implemented on board of vessels.
Additional discards reported as part of the 1DI Form to the IOTC were obtained from the Secretariat at the end of September 2022 for the period between 2016 and 2021 and additional information on discards is shown in Table 2.

	2021	2020	2019	2018	2017	2016
EU Spain	Not reported	19,815.84	Not reported	*524.68	Not reported	Not reported
EU France	6,428.053	8,145.684	12,153.58	23,346.47	Not reported	Not reported
Seychelles	Not reported	Not reported	Not reported	14,224	Not reported	Not reported
Mauritius	1,383.526	1,165	4,351.684	Not reported	Not reported	78
Korea	Not reported	Not reported	Not reported	Not reported	58	Not reported
Total reported	**7,812**	**29,127**	**16,505**	**38,095**	**58**	**78**

Table 2: Discards reported as part of 1DI forms by the CPCs to IOTC and provided by IOTC secretariat in September 2022 for the time period between 2016 and 2021; if discards of silky sharks were provided in weight those were transformed into number of animals for consistency using the same transformation weight of 19 kg as used otherwise in this paper.

** Spain reported for 2018 number of silky sharks in the form but this might in reality be mt as otherwise completely unplausible*

All available data that could be incorporated from the provided reports are shown in Figure 1, but unfortunately, the majority of these data could not be added to update overall discard estimates in Table 1, as data from Spain and Seychelles were not provided for all of the years and no data at all seem to be publicly available on discards / retained silky sharks from Japan, Korea, and the Indonesian fleet of more than 100 small purse seiners.

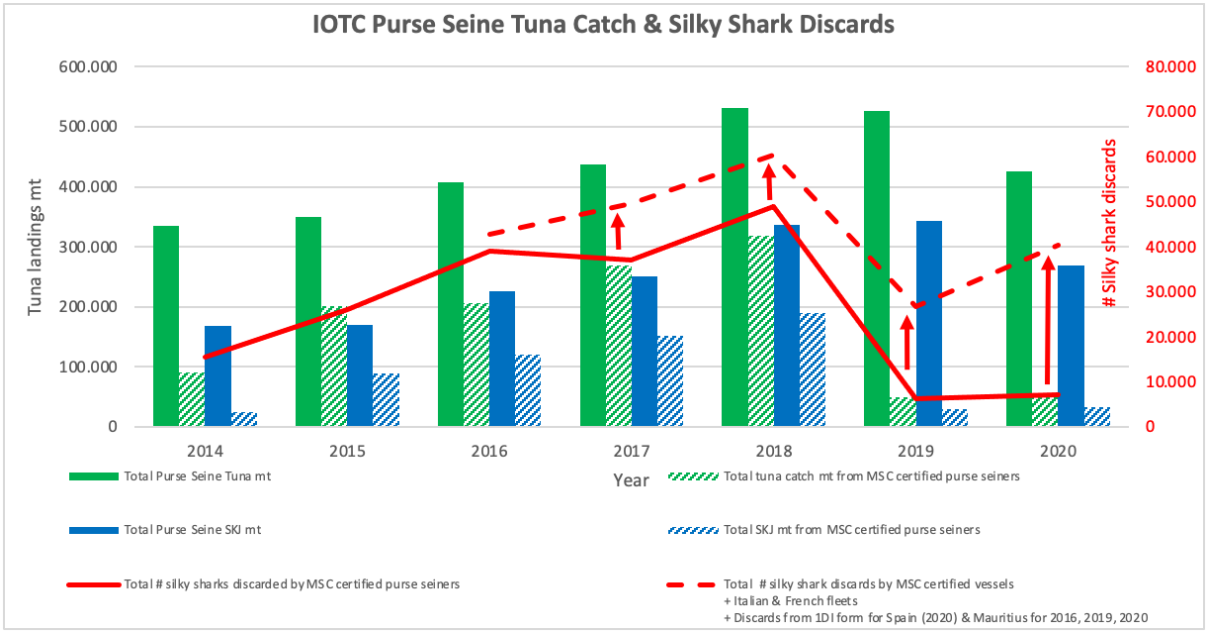

Figure 1: Comparison of overall tuna / skipjack catches and catches from MSC certified purse seine fleets in the IOTC area with reported bycatch/discards of silky sharks from all available data sources (MSC reports, national reports, 1DI Forms); note that data are not available for all years from all fleets at this time

This lack of consistent reporting of discards over the years as well as the lack of specification whether sets were performed as free school sets or sets on dFADs makes it difficult to gain an overview on the full extent of silky shark bycatch in purse seine fishing and prevents revising the communicated low impact hypothesis on silky sharks that is still widely referred to.
There is however, a clear trend that bycatch of silky sharks has increased with the increasing number of sets being made on dFADs and when set types are specified e.g. French fleet in 1DI forms or Echebastar it is clear that bycatch in tonnage is 10 - 100 times higher for dFAD sets as compared to free sets. Table 3 compares observer data on interactions with silky sharks for observed sets for the year 2016 for Spain, Seychelles, and France and for the Echebastar fishery for which both, break down on set type and vessel level is available for this year (unpublished data provided by Echebastar during stakeholder consultation in 2017 during MSC certification).

2016	Spain 14 vessels	Seychelles 13 vessels	France 12 vessels	Echebastar dFAD sets	Echebastar free sets	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5
total # sets	n/a	n/a	n/a	1,510	190	327	354	394	289	336
Observed # sets	545	1783	1152	518	65	167	89	83	149	95
Observer coverage %		45.87	45	34	34	51	25	21	52	28
# Silky sharks discarded or retained	2,399	4,414	2,875	2,459	18	737	416	348	616	339
Sets with at least 1 silky shark	386	803	521	399	5	105	59	58	118	59

2016	Spain 14 vessels	Seychelles 13 vessels	France 12 vessels	Echebastar dFAD sets	Echebastar free sets	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5
Interaction with silky sharks % of sets	70.8	45.0	45.2	77.0	7.7	62.9	66.3	69.9	79.2	62.1
Sets with 10 or more silky sharks	71	114	64	71	0	22	13	10	9	8
% sets with ≥10 silky sharks	18.4	14.2	12.3	17.8	0	21.0	22.0	17.2	7.6	13.6
# Silky sharks retained	139	12	0	6	0					
# Silky sharks discarded alive	933	2319	905	1447	18	193	394	135	484	241
% of live discards	**39**	**53**	**31**	**59**	**100**	**26**	**95**	**39**	**79**	**71**
Max # of silky sharks per set	60	49	46	75	6	30	29	40	75	24
Average # silky sharks per set	**4.4**	**2.5**	**2.5**	**4.7**	**0.3**	**4.4**	**4.7**	**4.2**	**4.1**	**3.6**

Table 2: Comparison of silky shark interaction in 2016 for different fleets, set types and vessels based on observer data from observed sets

The data summarized in Table 4 for the Spanish, French, and Seychelles fleet from observed sets in 2016 shows an average of 2.5 to 4.7 silky sharks bycaught in purse seine fleets in each observed set, when the majority of sets is made on dFADs, while being only 0.3 sharks per set for free sets as shown for the Echebastar fleet of five vessels for the same year. Korea and Mauritius had observed 71 and 65 sets respectively in 2016 but not reported interactions.

The number of silky sharks bycaught obviously varies depending on the number of dFAD sets made but also depending on the fleet and the individual vessel. The same also applies to the number of sets with more than ten silky sharks caught in an individual set, that varied greatly between 7% and 22% for individual vessels. Between 45% and 80% of all sets observed in 2016 for these fleets had at least one silky shark as bycatch demonstrating again the impact of the percentage of sets being made on dFADs with the French fleet having had a lower percentage of dFADs and reporting lower interactions at this time than the Spanish or Seychelles fleets. Maximum number of sharks observed per set also vary between fleets and vessels depending on where sets have been made and in one case 486 silky sharks were reported for a set of the Seychelles fleet in 2017. In total 66 sets were found in the observer database having had 30 or more silky sharks as bycatch in a single set for the period of 2014 to 2018 (IOTC, 2020).

However, the most obvious difference visible only at vessel level is that the percentage of sharks released alive varies greatly between vessels for the same fleet between 22% and 95% on dFAD sets alone. This clearly shows the importance of vessel specific data when trying to evaluate the effectiveness of best handling practices on board and/or the availability of on-board technical systems for bycatch release. To evaluate the probability of survival for these released sharks however also the stage at which it has been detected during the brailing process and the condition of the sharks at the time of release are important as reported by Onandia et. al in 2021 as only sharks released prior to the first brail (i.e. those who were removed from the net) had a probability of survival of more than 80%.

Conclusion

While it is well documented that 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 and too often ignored. The critically endangered *Carcharhinus longimanus,* the oceanic whitetip shark, 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.

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 to reduce on-board mortality and increase 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. A significant reduction of dFADs on the water and a reduction of sets made on these dFADs might be the most effective short-term measure to reduce silky shark mortality.

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 and a requirement to remove all partially entangling or entangling dFADs from the water when encountered.

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. Furthermore, with only 15% compliance for length frequency data reporting and catch effort data for sharks, stock assessments and projections are jeopardized which results 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.

Acknowledgement

Thanks to the IOTC Secretariat for providing additional data from 1DI discard forms and the Regional Observer Database summarising available information on interactions of purse seine fleets with silky sharks and discards which have been used to update the analysis provided earlier as part of paper IOTC-2022-WPEB18-29_rev1. This information has been extremely helpful to have.

References

Blue Marine Foundation; FISH AGGREGATING DEVICES (FADs) IN RESPONSIBLE TUNA FISHERIES; August 2021
https://www.bluemarinefoundation.com/wp-content/uploads/2021/10/FADs-in-Responsible-Tuna-Fisheries.pdf

Bonnin C. Dagorn, L, et al. Can drifting objects drive the movements of a vulnerable pelagic shark? *Aquatic Conserv: Mar Freshw Ecosyst*. 2021; 31: 74– 82. https://doi.org/10.1002/aqc.3420

Clavareau, Lyndsay & Sabarros, Philippe & Escalle, Lauriane & Bach, Pascal & Abascal, Francisco & Lopez, Jon & Murua, Hilario & Alayón, Pedro J. & Ramos, Maria & Ruiz, Jon & Mérigot, Bastien. (2020). Elasmobranch bycatch distributions and mortality: Insights from the European tropical tuna purse-seine fishery. Global Ecology and Conservation. 24. e01211. 10.1016/j.gecco.2020.e01211.

Eddy. F. Brill. R. Bernal. D. 2016. Rates of at-vessel mortality and post-release survival of pelagic sharks captured with tuna purse seines around drifting fish aggregating devices (FADs) in the equatorial eastern Pacific Ocean. *Fish. Res.* 174: 109–117.

Escalle, L., Muller, B., Hare, S., Hamer, P., Pilling, G., and PNA Office 2020. Report on Analysis of the 2016/2020 PNA FAD tracking programme. WCPFC-SC16-2020/MI-IP-15

Filmalter. J.D. Capello. M Deneubourg. J.L. Cowley. P.D. and Dagorn. L. 2013. Looking behind the curtain: quantifying massive shark mortality in fish aggregating devices. *Frontiers in Ecology and the Environment* 11(6): 291-296.

Filmalter, J. D., Bauer, R. K., Forget, F., Cowley, P. D., and Dagorn, L. Movement behaviour and fishery interaction of silky sharks (Carcharhinus falciformis) in the tropical tuna purse seine fishery in the Western Indian Ocean ICES Journal of Marine Science; 2021 https://doi.org/10.1093/icesjms/fsab119

Garcia A. and Herrera M. 2018. Assessing the Contribution of purse seine fisheries to overall levels of bycatch in the Indian Ocean. IOTC-2018-WPDCS14-26_Rev1

Hutchinson. M. Itano. D. Muir. J. Leroy. B. Holland. K. 2015. Post-release survival of juvenile silky sharks captured in tropical tuna purse seine fishery. Marine Ecology Progress Series. 521: 143-154.

Imzilen, T., Lett, C., Chassot, E. et al. Recovery at sea of abandoned, lost or discarded drifting fish aggregating devices. Nat Sustain 5, 593–602 (2022). https://doi.org/10.1038/s41893-022-00883-y

IOTC. Systematic non-compliance of drifting fish aggregating devices with resolution 19/02 'procedures on a fish aggregating devices (FADS) management plan. *IOTC*. 2022. https://iotc.org/documents/systematic-non-compliance-drifting-fish-aggregating-devices-dfads-resolution-1902-

IOTC-2021-SC24 NR06_Annex1; National report 2021 from France
IOTC-2021-SC24 NR06_Annex4; National report 2021 from Italy
IOTC-2021-SC24 NR06_Annex2; National report 2021 from Spain
IOTC-2021-SC24 NR22_rev1; National report 2021 from Seychelles

IOTC-2020-WPEB16-DATA12_Interactions; ROS database 2020
Summary of data currently within the ROS Regional Database for 2007 to 2019; version 2.2

Murua. H. R. Cohelo. M.N. Santos. H. Arrizabalaga. K. Yokawa. E. Romanov. J.F. Zhu. Z.G. Kim. P. Bach. P. Chavance. A. Delgado de Molina and J. Ruiz. 2012. Preliminary Ecological Risk Assessment (ERA) for shark species caught in fisheries managed by the Indian Ocean Tuna Commission (IOTC). IOTC–2012–SC15–INF10 Rev_1.

Marine Stewardship Council PCR Echebastar.
- Public Certification Report November 2018 for Echebastar; Bycatch composition: p 42ff; Table 22ff
- MSC 1st surveillance report February 2020 for Echebastar; Bycatch composition: p 23ff; Table 4.2.5ff
- MSC 2nd surveillance report 25/08/2021 for Echebastar; Bycatch composition: p 28ff; Table 4.2.7.3ff

all reports are available at
https://fisheries.msc.org/en/fisheries/echebastar-indian-ocean-purse-seine-skipjack-tuna/@@assessments

Marine Stewardship Council FDR CFTO. Final Determination Report CFTO Indian Ocean Purse Seine Skipjack fishery Compagnie Française du Thon Océanique S.A.S. (CFTO), May 2021 at
https://fisheries.msc.org/en/fisheries/cfto-indian-ocean-purse-seine-skipjack-fishery/@@assessments
Bycatch composition: p51 / Table 15

Marine Stewardship Council FDR AGAC. Final Determination Report AGAC four oceans Integral Purse Seine Tropical Tuna Fishery – Indian Ocean, October 2021at https://fisheries.msc.org/en/fisheries/agac-four-oceans-integral-purse-seine-tropical-tuna-fishery/@@assessments?assessments=
Bycatch composition: p134; Table 34

NGOTF Aligned Guidance for Well-Managed FAD Fisheries; *NGO Tuna Forum* IOTC-2021-WGFAD02-INF17

Onandia Inigo, Maitane Grande, José Maria Galaz, Jon Uranga, Nerea Lezama-Ochoa, Jefferson Murua, Jon Ruiz, Igor Arregui, Hilario Murua, Josu Santiago.
New assessment on accidentally captured silky shark post-release survival in the Indian Ocean tuna purse seine fishery. IOTC-2021-WPEB17(DP)-13_Rev1

Sharkproject Position paper on required improvements in industrial fisheries and fishing gear. 2021 including minimum improvements required for purse seine fishing when using drifting fish aggregating devices (dFADs) at transition to an ecosystem based fishery management

WWF Position for the Special Session of the Indian Ocean Tuna
Commission 24th Session; *WWF 2021*;
https://wwfint.awsassets.panda.org/downloads/wwf_position_iotc_ss4_final.pdf

Ziegler I. Carcharhinus falciformis - a massive bycatch in the industrial purse seine industry but systematically underreported and deprived of any protection in the Indian Ocean; IOTC-2022-WPEB18-29_rev1