New assessment on accidentally captured silky shark post-release survival in the Indian Ocean tuna purse seine fishery.

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A tagging experiment for Carcharhinus falciformis post-release survival assessment was conducted in a trip on-board the tuna purse seiner Jai Alai from Echebastar company in the Indian Ocean. Twenty-eight sharks were tagged with 24 SPATs and 4 MiniPATs and blood samples were collected in 45 sharks for lactate concentration measurement to be used as an indicator of shark survival. A vitality index based on state and behavior at release was also assigned to all the sharks caught accidentally. The overall predicted survival of silky shark in this trip was estimated to be 43%, both using survival rate by vitality index derived from tagged sharks and survival rate predicted using lactate concentration threshold. Shark survivorship decreased as the fishing operation advanced and vitality index declined. This information is essential to ensure the conservation of this vulnerable species and for a proper management of the fishery.

KEYWORDS: Silky shark, C. falciformis, post-release survival, FADs, purse seiner, tropical tuna

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1. Introduction

Silky shark (*Carcharhinus falciformis*) is a circumglobally distributed, tropical and subtropical species (Rabehagasoa, et al. 2012). It is a pelagic and highly migratory shark distributed from continental slopes to open oceans (IOTC, 2019), from surface waters down to at least 500 m depth (Compagno, 1984). Adults and sub-adults are found in deep waters just off continental and insular shelves but also are common in open-ocean waters (Clarke et al., 2015). Juvenile smaller specimens are typically found in coastal waters (IOTC, 2019). Although there have been long-distance movements recorded in large silky shark individuals, most of the tagging studies describe more limited movements (Clarke et al., 2015) or aggregation behaviours around drifting Fishing Aggregating Devices (FADs) used in the tropical tuna purse-seine fishery (Filmalter et al., 2011; Filmalter et al., 2015). High fidelity of adults associated with seamounts, and juveniles with floating objects were also described (Ebert et al., 2016). In the Indian Ocean, the population structure of silky sharks is unknown, but a single stock may be assumed (Coelho et al., 2019). However, recent genetic studies on mitochondrial DNA suggested that despite its large population size, silky sharks in the Indo-Pacific region seem to be separated on relatively small spatial scales, showing certain genetic differentiation between sampled regions (Clarke et al., 2015).

Due to the increasing fishing pressure, silky shark abundance, as is the case for other pelagic sharks, has been markedly decreased during the last half century (Pacoureau et al., 2020). This species is listed as vulnerable by the IUCN Red List of Endangered Species[4]. In the Indian Ocean, previous Ecological Risk Assessments (ERAs) identified silky sharks among the species with higher vulnerability risk for longlines and purse seines (Murua et al., 2012; 2018). A preliminary data poor stock assessment was carried out in 2018 (Ortiz de Urbina et al., 2018), using a time-series of reconstructed catches, but the results of the assessment were extremely uncertain and, hence, the population status of silky sharks in the Indian Ocean is considered uncertain (IOTC, 2020). This species is the fourth most important shark species in the Indian Ocean tuna fisheries (23,000 tonnes caught yearly, 10% of the overall shark catches) (Garcia and Herrera, 2018). Gillnet and longline are the main contributors to silky shark catch (57% and 42%, respectively) while the purse seine fishery is responsible for 1.3% (Garcia and Herrera, 2018). Due to their aggregating behaviour around FADs and the overlap of the juvenile silky shark habitat with tropical tuna purse seine fishery, silky sharks are common in FAD sets and the most important bycatch shark species for tropical tuna purse seiners (Gilman 2011, Garcia and Herrera, 2018; Hutchinson et al., 2019, Ruiz et al., 2018).

Management and mitigation measures in IOTC require that fisheries fully utilise shark catches on those fisheries targeting sharks and prohibit shark finning (IOTC Resolution 17/05). As such, shark should be landed with fins attached in fisheries landing fresh sharks and fins should not exceed 5% of the weight of sharks on-board in those landed frozen (IOTC, Res. 17/05). For sharks incidentally caught, they should be released and care should be taken to increase the survival rate (Res. 17/05; Res. 19/05, IOTC). As such, and to reduce shark mortality, EU and Seychellois purse seiner vessels have adopted for sharks that accidentally arrive on board best handling and safe release practices (Poisson et al., 2014; Grande et al., 2019; Maufroy et al., 2020; Zolett and Swimmer, 2019), and for this some vessels have adapted the upper deck or lower deck by installing specific release devices for fauna (i.e., hoppers, bycatch release conveyor belt). Post release survival studies in purse seiners showed that shark mortality highly depends on which landing stage is handled and released (e.g., entangled in the net, 1st brail, posterior

[4] https://www.iucnredlist.org/ja/species/39370/117721799

brails) and the state of the specimen at release (Poisson et al. 2014b, Hutchinson et al., 2015, Filmalter et al., 2015b, Eddy et al., 2016). Overall it is estimated that the application of best practices for handling and release could contribute to 20% of bycaught sharks survival (Filmalter et al., 2015b) (Table 1). If combined with other mitigation measures, both active and passive measures (i.e., the use of non-entangling FADs, implementing fishing strategies to avoid bycatch such as avoiding sets on small schools; release sharks from the net), shark mortality could be reduced by 60-65% (Restrepo et al., 2016, 2019).

Due to the high cost of satellite archival POP-UP tags (e.g., 2,000-4,000 USD per tag), experiments on post release survival rates are scarce and often based on very small sample sizes of specimens. To increase the sample size other physiological indicators (e.g., blood lactate levels), in combination with tagging experiments, were also used and resulted to be a good predictor of shark stress and survival (Myers et al., 2004; Hutchinson et al., 2015). This document aims to further investigate the post-release survivorship of silky shark in the Indian Ocean when released using best handling and release practices in tuna purse seiners, using POP-UP tagging combined with blood lactate concentration and a vitality index based on state and behaviour at release. This study has been supported by the Echebastar fishing company.

Table 1. Post release mortality on shark species released from tropical tuna purse seiners in the Atlantic Ocean (AO), Indian Ocean (IO), Western and Central Pacific Ocean (WCPO) and Eastern Pacific Ocean (EPO)

Reference	Ocean	n satellite tags and species	fishing operation stage	Post-release mortality	Overall mortality rate
Poisson et al., 2014	IO	31 FAL	entangled in the net	18%	81%
			brailing	48%	
Hutchinson et al., 2015*	WCPO	28 FAL	pre-set	0%	84%
			entangled in the net	31.3%	
			First brail	83.3%	
			posterior brails	93.3%	
Eddy et al., 2016	EPO	13 FAL and 3 SPN	brailing	62%	80% - 95%.
Sancristobal et al., 2017	AO	11 FAL	Swiming in the net (pre-sack)	0%	-

*Biochemical indicators were measured in 87 silky sharks (17 were also tagged with archival satellite tags).

2. Material and Methods

2.1. Field work

This study was carried out during a trip on board the Seychelles flagged purse seine vessel Jai Alai (Echebastar fishing company) in the Indian Ocean. The trip lasted from the 22nd of October to the 23rd of November 2020. The survey area comprises the waters north of Seychelles up to 9ºN latitude and between longitudes 57ºE and 63ºE in the Western Indian Ocean (Fig. 1).

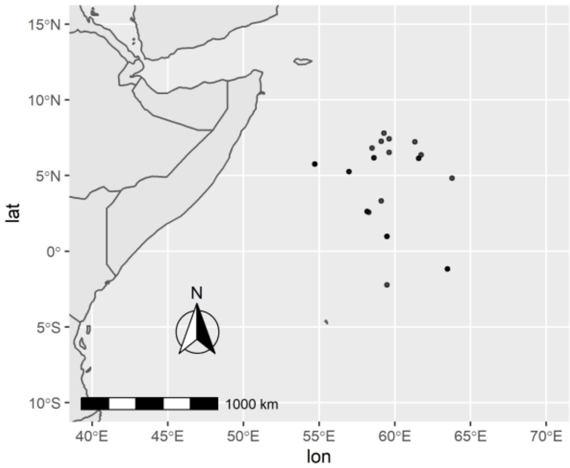

Fig 1. Positions of sets in which Silky sharks (*C. Falciformis*) were tagged (n =28) with SPAT or MiniPATs and blood sampled (n=45)

In each interaction with *C. falciformis*, the following variables were recorded:

- sex (female, male, indeterminate or unknown),
- length (cm),
- number of the brail in which the specimen was taken on board (1st, 2nd, 3rd brail and subsequent),
- position in the brail (up, medium, bottom),
- time when brailed on board and released,
- mode of release: (i) using the brailer, (ii) using light equipment such as stretcher, fabric, *sarria* or cargo net, (iii) using specific equipment such as a hopper or lateral doors, (iv) manually from deck, (v) after disentangling from hauling net;;
- vitality index, —i.e., status of the animal at release based on the states proposed by Heuter and Manire (1994):
    - (i) excellent (very active and energetic, strong signs of life on deck and when returned to water);
    - (ii) good (active and energetic, moderated signs of life on deck and when returned to water);
    - (iii) correct (tired and sluggish, limited signs of life, moderate revival time required when returned to water, slow or atypical swimming away);
    - (iv) poor (exhausted, no signs of life, bleeding from gills, jaw or cloaca, long revival time required when returned to water, limited or no swimming observed upon release);
    - (v) very poor or death: moribund, no signs of life, excess bleeding from gills, jaw or cloaca, unable to revive upon return to water, no swimming movement, sinks.
- behavior after release (swim vigorously, swim slowly near the surface, sinks with little movement).

Also, in each interaction, the observer recorded if the handling and release practices applied followed the guidelines defined in the Code of Good Practices (Grande et al., 2019).

A total of 28 sharks were tagged with POP-UP satellite archival tags, 24 SPAT[5] and 4 MiniPATs[6] (Wildlife Computers, Inc.) during two different stages: *i)* when releasing the shark on the upper deck or *ii)* when releasing the shark using the bycatch release conveyor belt installed in the lower deck. The tags were attached with a 10 cm long monofilament tether protected with alimentary silicon tube. A small titanium dart was used in 17 individuals and a Domeier anchor in the other 11 individuals. A 2 cm incision was done with a scalpel in the dorsal fin base (tether, anchor and scalpel were smeared with Betadine Antiseptic Cream (5% povidone iodine).

To evaluate the content of lactate, blood samples were taken from the caudal peduncle of silky sharks and measured "in situ" using a lactate meter[7] (Lactate plus). Lactate concentration was measured in situ in 45 individuals (23 of them tagged).

2.2. Tag programing

SPATs tags were programmed for 60 day deployments and set by default to record maximum and minimum daily depth and temperature, and at ten-minute time-series depth data for the end of the deployment (i.e. last 4 days). MiniPATs tags were programmed for 180 day release. If depth exceeded 1,700 m or remained constant for more than 3 days PSATs were also programmed to be released. Daily data recorded with MiniPATs correspond to the temperature and depth, and change in light-level for each UTC day light intensity data every 600 seconds.

2.3. Post-release survival analysis

For each tagged shark a fate was given (dead or alive) based on the depth records transmitted by the SPATs or MiniPATs and the time elapsed from tagging to detachment date. Sharks were considered to survive the fishing operation if tags showed they remained alive ≥15 days.

In tagged specimens', difference in survival rate depending on vitality index categories were assessed by Chi-square test. This analysis includes 4 individuals that were not finally tagged due to their poor condition but were considered as dead. The percentage of survivorship by vitality index category was applied to predict survivorships for all sharks bycaught in the trip.

Moreover, for silky sharks tagged and blood sampled Wilcoxon rank sum test was used to evaluate differences in lactate between survivors and dead sharks. This analysis also included 4 dead individuals blood sampled but not tagged. A logistic regression model was done to relate survivorship (based on tagging) and lactate concentration estimated from blood samples. This logistic regression model and maximum likelihood estimation were used to predict the probability of survival for sharks with blood analysis taken but were not tagged (using as a survival threshold the 50% of probability of the survivorship curve) (Hutchinson et al., 2015). The fitted values were then used to predict survival rates by fishing operation stage and applied to predict survivorship for all the sharks captured during the fishing trip (Hutchinson et al., 2015).

[5] *https://wildlifecomputers.com/our-tags/pop-up-satellite-tags-fish/spat/*
[6] *https://wildlifecomputers.com/our-tags/pop-up-satellite-tags-fish/minipat/*
[7] *https://www.laktate.com/producto/lactate-plus/*

3. Results

3.1. Shark bycaught and released

A total of 278 silky sharks (*C. falciformis*) were incidentally caught during 41 FAD set operations. Sharks were handled and released applying best practices (Grande et al., 2019): 15% (n=41) were entangled in the net when hauling (i.e., sharks entangled in the purse seine net during 'haul back' and removed by the fishermen as the net emerged from the water which were lifted on board before sacking up and brailing) and 85% were brailed and released; from which 63 were caught in the first (23%), 78 in the second (28%) and 96 in the third or subsequent brails (34%). Silky shark at vessel mortality was of 40% (n=109). Vitality index was obtained for all the silky sharks caught (Table 2).

Table 2. Number of sharks released by status and fishing operation stage from which were released (i.e., entangled in the net or brailed).

Release stage	Very Poor	Poor	Correct	Good	Excellent	TOTAL
Entangled	0	2	8	15	16	41
1st brail	12	12	27	12	0	63
2nd brail	31	26	17	4	0	78
3er brail or later	66	21	9	0	0	96
TOTAL	109	61	61	31	16	278

Twenty-eight sharks (101-188 cm TL) were tagged with satellite tags (4 MiniPATs and 24 SPATs) (Fig.1): 5 in excellent, 3 in good, 13 in correct, 6 in poor and 1 in very poor condition. All were released upon the first 4 minutes after being detected on board. 7 sharks (25% of tagged sharks) showed immediate mortality within the first 24 hours after release (depth of more than 1,700 m or constant depth for at least three days) attributed to post-release mortality events. One of the tags popped off prematurely after 9 days at sea with no apparent clear reason (i.e., due to the pin broken or tag detach) but was considered as a death event based on the last horizontal and vertical behavior. Twenty tags remained attached for more than 15 days, which was considered to represent surviving sharks (71.4%). All the tags attached have reported transmission.

3.2. Post-release survival based on the vitality index

The percentage of tagged sharks that survived according to the vitality index was 100% for those released in excellent or good conditions (n=5 and n=3, respectively), 69.23% (9 out of 13) for sharks in correct condition, 50% (3 out of 6) in poor condition and 0% for very poor or dead (0 out of 1) condition. Significant differences were detected in survivorship among vitality index categories (p-value = 1e-04 < 0.01). Combining the survival rates obtained from tagged individuals with the vitality scores determined by the observer, we predicted an overall survival rate of silky sharks accidentally captured for this trip of 43.17% (Table. 3).

Table 3. Number of sharks by fishing stage and vitality index category. The predicted survival (%) is given for each category.

	Dead (0)	Poor (1)	Fair (2)	Good (3)	Excellent (4)	Total	Survivors	Pred. survival (%)
Tangled	0	2	8	15	16	41	38	92.68
1st_brail	12	12	27	12	0	63	37	58.73
2nd_brail	31	26	17	4	0	78	29	37.18
3rd_brail	66	21	9	0	0	96	17	17.71
(all)	109	61	61	31	16	278	120	43.17
Pred. survival (%)	0	50	69.23	100	100			
Survivors	0	30	42	31	16			

3.3. Post-release survival based in lactate levels

Significant differences in lactate concentrations were found (Wilcoxon rank sum, n = 27, p-value = 0.02) between tagged and blood sampled sharks that survived the fishing operation (n=15) and dead sharks (n=12, 8 tagged and 4 considered death with only blood samples but not tagging). Analyzing survival rates by lactate level intervals obtained from tagged individuals, we calculated the survival probability curve shown in Figure 2. We assume a survival threshold at 8.16 mmol/L, concentration at which the probability of survival was estimated as p=0.5 from the survivorship curve (i.e., if [lactate] < 8.16 mmol/L then is considered "survivor" otherwise "non-survivor"). Based on this survival threshold, the percentage of survival was estimated by fishing operation stage and applied to all sharks in the trip. The overall shark survival estimated is of 43.8% (Table 4).

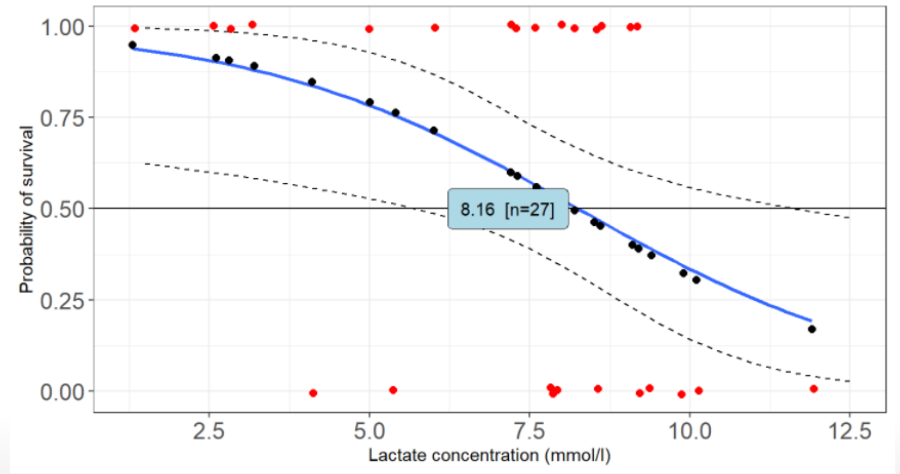

Fig 2. Logistic regression model for the estimated proportion of survival *C. falciformis* at lactate concentration (LC) intervals. Red points are the observations of shark with blood samples that were released and survived or died. Black points represent the predicted proportion of survival sharks. The solid blue line is the logistic regression curve (i.e., P = EXP(3.46 + (-0.4238*LC)·(1 + EXP(3.46 + -0.4238* LC))−1, p=0.0145, n = 27).

Table 4. Predicted survival by fishing operation stage.

	Lactate<8.16	N measured	Pred. survival (%)	Total	Survivors
Tangled	12	15	80.00	42	34
1st_brail	8	14	57.14	62	35
2nd_brail	3	8	37.50	78	29
3rd_brail	2	8	25.00	96	24
(all)	25	45	43.88	278	122

4. Conclusions and Recommendations

Post-release survival rate of sharks released from purse seiners, in which best handling and release practices are implemented, is estimated by satellite POP-UP archival tagging and lactate blood levels. When the percentage of survivorship by vitality index stage was applied to predict survivorship for all sharks, a 43.17% survivorship was estimated for sharks bycaught and released during the trip. When lactate level thershold was estimated for survivorship and used to predict survival rates, we obtained a 43.88% of overall survival. As observed in previous works on tuna purse seiners, the post-release mortality is at its lowest when sharks are in good shape and when they are swimming in the net. Mortality starts to increase from the moment the sac is formed and with the number of brails which concomitantly decreases the vitality index observed. In this study the at vessel mortality observed (40%) was lower and overall shark survivorship higher than the ratios estimated in previous works. The difference could rely on the fishing operation itself and the time elapsed from the catch to release (which can be influenced for example by set size, brail size or environmental conditions) or shark biological characteristics (e.g. size, age). In addition the experience gained by the crew over time since the application of best releasing practices several years ago and the adaptation of the deck by the instalation of the bycatch release conveyor belt could have a positive influence to reduce the at vessel mortality.

These findings suggest that if best handling and release practices are applied and fauna handling/release devices are incorporated on board, a significant increase in post-release survival of sharks could be obtained on tuna purse seiners.

To further explore the influence of different factors affecting shark post-release survival, such as improved onboard handling methods, new release devices and mitigation approaches that minimize shark mortality, more research efforts should be conducted using satellite survivorship tag experiments.

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References:

Clarke, C. R., Karl, S. A., Horn, R. L., Bernard, A. M., Lea, J. S., Hazin, F. H., & Shivji, M. S. 2015. Global mitochondrial DNA phylogeography and population structure of the silky shark, Carcharhinus falciformis. Marine Biology, 162(5), 945-955.

Coelho, R., Apostolaki, P., Bach, P., Brunel, T. P. A., Davies, T., Diez, G., Ellis J., Escalle L., Lopez J., Merino G., Mitchell R., Macias D., Murua H., Overzee H., Poos J.J., H. Richardson, D. Rosa, S. Sánchez, C. Santos, B. Séret, J. O. Urbina Walker, N. (2019). ***Improving scientific advice for the conservation and management of oceanic sharks and rays: Final report - Study***. Brussels: European Commission. https://doi.org/10.2826/229340

Compagno, L.J.V. 1984. FAO Species Catalogue. Vol. 4. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Part 2 - Carcharhiniformes. FAO Fish. Synop., 125(4/2): 251-655. Rome, FAO.

Ebert DA, Fowler SL, Compagno LJ 2016. Sharks of the world: a fully illustrated guide. Wild Nature Press. pp.

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.

Filmalter, J., Cowley, P., Forget, F., and Dagorn, L. (2015). Fine-scale 3-dimensional movement behaviour of silky sharks Carcharhinus falciformis associated with fish aggregating devices (FADs). Marine Ecology Progress Series 539, 207-223.

Filmalter, J.D., Dagorn, L., Cowley, P.D., and Taquet, M. (2011). First descriptions of the behavior of silky sharks, Carcharhinus falciformis, around drifting fish aggregating devices in the Indian Ocean. Bulletin of Marine Science 87(3), 325-337.

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

Gilman, E.L. 2011. Bycatch governance and best practice mitigation technologyin global tuna fisheries. Mar. Pol.35: 590–609. doi:10.1016/j.marpol.2011.01.021

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.

Hutchinson, H., Daniel M. Coffey, Kim Holland, David Itano, Bruno Leroy, Suzanne Kohin, Russell Vetter, Ashley J. Williams, Johanna Wren (2019) Movements and habitat use of juvenile silky sharks in the Pacific Ocean inform conservation strategies, Fisheries Research 210: 131–142, https://doi.org/10.1016/j.fishres.2018.10.016

Maufroy A , Gamon, A. , Vernet A-L , and Goujon M, 2020. 8 years of best practices onboard french and associated flags tropical tuna purse seiners: an overview in the atlantic and indian oceans. IOTC-2020-WPEB16-11

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.

Murua H, Santiago, J, Coelho, R, Zudaire I, Neves C, Rosa D, Semba Y, Geng Z, Bach P, Arrizabalaga, H., Baez JC, Ramos ML, Zhu JF and Ruiz J. (2018). Updated Ecological Risk Assessment (ERA) for shark species caught in fisheries managed by the Indian Ocean Tuna Commission (IOTC). IOTC–2018–SC21–14_Rev_1.

Ortiz de Urbina, J., T. Brunel, R. Coelho, G. Merino, D. Rosa, C. Santos, H. Murua, P. Bach, S. Saber, D. Macias. 2018. A Preliminary Stock Assessment for the Silky Shark in the Indian Ocean Using a Data-Limited Approach. IOTC-2018-WPEB14-33

Pacoureau N, Cassandra L. Rigby, Peter M. Kyne, Richard B. Sherley , Henning Winker, John K. Carlson, Sonja V. Fordham, Rodrigo Barreto, Daniel Fernando, Malcolm P. Francis, Rima W. Jabado, Katelyn B. Herman, Kwang-Ming Liu, Andrea D. Marshall, Riley A. Pollom, Evgeny V. Romanov, Colin A. Simpfendorfer, Jamie S. Yin, Holly K. Kindsvater & Nicholas K. Dulvy, 2020. Half a century of global decline in oceanic sharks and rays. Nature | Vol 589.

Poisson. F., Filmalter. J.D., Vernet. A.L., Dagorn. L. 2014b. Mortality rate of silky sharks (*Carcharhinus falciformis*) caught in the tropical tuna purse seine fishery in the Indian Ocean. Canadian Journal of Fisheries and Aquatic Sciences 71: 795–798.

Rabehagasoa N, Lorrain A, Bach P, Potier M, Jaquemet S, Richard P, Ménard F 2012. Isotopic niches of the blue shark Prionace glauca and the silky shark Carcharhinus falciformis in the southwestern Indian Ocean. Endangered Species Research 17: 83-92.

Restrepo, V., L. Dagorn and G Moreno. 2016. Mitigation of Silky Shark Bycatch in Tropical Tuna Purse Seine Fisheries. ISSF Technical Report 2016-17. International Seafood Sustainability Foundation, Washington, D.C., USA.

Restrepo, V., H. Koehler, G. Moreno and H. Murua (2019). Recommended Best Practices for FAD management in Tropical Tuna Purse Seine Fisheries. ISSF Technical Report 2019-11. International Seafood Sustainability Foundation, Washington, D.C., USA

Ruiz Gondra, J., Abascal, F.J., Bach P., Baéz, J.C., Cauqil, P., Krug, I., Lucas, J., Murua, H., Ramos Alonso, M.L., Sabarros, P.S., 2018. By-catch of the European purse seine tuna fishery in the Indian Ocean for the period 2008–2017. WD-IOTC-2018-WPEB14-15.

Sancristobal I, Martinez U, Boyra G, Muir JA, Moreno G, Restrepo V. ISSF bycatch reduction research cruise on the F/V Mar de Sergio in 2016. Collect Vol Sci Pap ICCAT. 2017;73(9):3152-62

Zollett E., Swimmer Y., 2019. Safe handling practices to increase post-capture survival of cetaceans, sea turtles, seabirds, sharks, and billfish in tuna Fisheries. Endang Species Res. Vol. 38: 115–125.