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Trialing shark bycatch release devices on board purse seiners in the Pacific Ocean to enhance shark survival

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Abstract

Shark bycatch mortality is one of the primary impacts of tuna fisheries, posing a threat to the sustainability of vulnerable elasmobranch populations. This study evaluated the effectiveness of updated best handling and release practices, along with a custom-designed shark release ramp, in improving post-release survival of sharks onboard a U.S. purse seine vessel in the Pacific Ocean. A total of 134 sharks, primarily silky sharks (*Carcharhinus falciformis,* n=122) and oceanic whitetip sharks (*Carcharhinus longimanus,* n=11), were incidentally captured and released, with 98.5% released using the ramp system. Post-release condition was assessed using a vitality index, blood lactate concentration, and satellite pop-up tagging. While 47% of sharks exhibited poor or moribund condition at release, indicating 47% at haul-back mortality, tagging data indicated survival in at least two of three tagged individuals, with another showing likely survival. The findings demonstrate the potential of combining best practices with effective bycatch release devices to significantly improve shark post-release survival, supporting shark conservation efforts in purse seine fisheries. A ramp system with a hopper improved operational efficiency, enhanced crew safety, increased shark survival and represents a cost-effective mitigation measure. However, the small number of tagged sharks highlights the need for expanded tagging to validate and generalize these results.

Introduction

Bycatch mortality is one of the principal impacts of fisheries on marine ecosystems, particularly for endangered, threatened and protected (ETP) species showing marked population declines in recent years. Due to their life histories traits such as slow growth, late maturation, and low fecundity resulting in low reproductive potential, marine megafauna such as sea turtles, sharks or mobulid rays are among the most vulnerable groups to anthropogenic effects with low resilience to fishing activity (Dulvy et al., 2021; Juan-Jorda et al., 2022).

Tunas support some of the largest and most valuable artisanal and industrial fisheries worldwide (FAO, 2022; ISSF, 2025). The global catch of albacore, bigeye, bluefin, skipjack, and yellowfin, the major commercial oceanic tunas, in 2023 was 5.2 million tonnes. Among the major commercial tunas, the tropical tuna fisheries account for 95% of the catches in weight and tropical tuna purse seine fisheries catch 66 % of the total catch of tunas, approximately 38% associated, 25 % unassociated, and 3% dolphin set) (ISSF, 2025). Although tuna populations are in general managed sustainably, their fisheries also have impact on non-target species that are unintentionally caught (Dagorn et al., 2013). Shark and rays and sea-turtles are among those incidentally caught species (Juan-Jorda et al., 2022; Bourjea et al., 2014; Croll et al., 2016), which need to be monitored, impacts mitigated, and populations assessed and managed for their long-term conservation (Gilman et al., 2023).

Considering the decline of their populations (Pacoureau et al., 2021, Juan-Jorda et al., 2022), several shark, and all Mobula ray species have been recently added to the Convention on International Trade in Endangered Species (CITES) Appendix II (CITES, 2022). Moreover, Oceanic whitetip shark (*Carcharhinus longimanus*), scalloped hammerhead shark (*Sphyrna lewini*), the giant manta ray (*Manta birostris*) are listed as threatened (some endangered depending on the region) under the U.S. Endangered Species Act (ESA), for which initiatives to reduce the interaction and mortality for their protection and conservation should be developed and promoted for U.S. fleets.

For some of the megafauna bycatch species of purse seiners there are already well-defined protocols that are effective at releasing alive most of the animals such as methods employed to release dolphins (e.g., backdown maneuver, use of divers, etc. specified by Agreement on the International Dolphin Conservation Program (AIDCP) protocols; Hall and Roman, 2013) or whale sharks (e.g., release over the net's corkline, Escalle et al., 2016). For sea turtles, research has shown that most turtles survive if they are released promptly and following best practices (Hall and Roman, 2013; Bourjea et al., 2014; Zollet and Swimmer, 2019).

However, for elasmobranch species best handling and release protocols were developed over 10 years ago (Poisson et al., 2012) and have not been updated until recently (Hutchinson et al., 2024; Murua et al., 2024). In the past, onboard handling practices have resulted in high levels of post-release mortality for this group (Hall and Roman, 2013). For elasmobranchs, tagging studies showed an overall estimate of 15-20% survival for encircled sharks brought onboard, when good practices (Poisson et al., 2012) were applied to release them (Poisson et al. 2014, Eddy et al. 2016, Hutchinson et al. 2015, Restrepo et al. 2017). This can be increased to around 45% if updated handling and safe release best practices are applied and efficient bycatch release devices (BRDs) are employed (Onandia et al., 2021; Grande et al., 2022). The survival rate in these studies corresponded to the combination of two factors: (i) 30-60% of the sharks arriving on the deck were alive, and (ii) 50-70% of these live sharks released from the deck could survive if they were released promptly following best practices. Therefore, the use of new (BRDs) as well as best practices on handling and safe release are required so that the currently poor elasmobranch survival rates on purse seine vessels can substantially improve.

The present paper aims to investigate the post-release survivorship (PRS) of sharks in tuna purse seiners operating in the Pacific Ocean when released using most updated best handling and release practices for sharks (i.e., hopper with a shark release ramp). The methodology combines the use of pop-up satellite archival tags (PSATs), blood lactate sampling and a vitality index based on the condition of sharks at release. This study was conducted under the NOAA Bycatch Reduction Engineering Program (BREP) to increase awareness and use of BRDs and best practices for safe-handling and release, as well as to enhance the post-release survivorship of sensitive, vulnerable species caught by U.S. purse seine vessels. The study had the following specific objectives, which will be presented throughout the paper:

1. A research trip onboard a purse seine vessel to survey the application of best practices and BRDs to quantify the increase in post-release survivorship of vulnerable fauna, using PSATs;
2. Skipper Workshops to ensure continuous training of fishing vessels' crews on the use of the latest BRDs and safe-handling and release practices; and
3. Develop and update safe-handling and release Best Practices for vulnerable fauna bycaught in tropical tuna purse seine fisheries.

Material and Methods

Bycatch Release Devices

The release ramp was manufactured in Manta, Ecuador, using marine-grade aluminum to minimize weight. Prior to its construction, *in situ* measurements were taken on the working deck of the Cape Ferrat fishing vessel (Figure 1A) to tailor the ramp's shape and dimensions. The design connected the stern-side edge of the hopper, located on the port side, to a door on the starboard side that opened to the sea.

The ramp measured 8.6 meters in length, 0.55 meters in width, and reached a maximum height of 1.0 meter near the hopper (Figure 1B). Side walls at the base stood 0.3 meters high and had multiple welded handles to facilitate installation and removal. To enable compact storage when not in use, the ramp was built in two detachable sections, which could be stored inside the hopper tray.

When the ramp was installed, it was not permanently affixed to the hopper. A 0.45-meter gap was intentionally left between them, allowing a crew member to be positioned in this space to assist with bycatch release. A 5 cm hole was installed at the top of the ramp for connecting a water hose, enabling the ramp's surface to be kept wet to ease the sliding of animals during release (Figure 1C).

Despite its length, the ramp was designed with a steep enough incline to allow sharks and other bycatch to slide efficiently into the water via the final part of the ramp (Figure 1D). The ramp was not a permanent fixture and could be quickly installed and removed during each fishing set, with minimal installation effort required.

Figure 1.- (A) Cape Ferrat (Cape Fisheries) purse seine; (B) Cape Ferrat's hopper and bycatch release ramp; (C) First section of the release ramp with a connected water hose and showing the 0.45-meter gap between the hopper and the ramp that allows a crew member to be positioned in this space to assist with bycatch release; (D).

Field research aboard Cape Ferrat

A fishing trip was conducted aboard the Cape Ferrat purse seine vessel operating in the Western Pacific Ocean, from 28 December 2024 to 30 January 28 **2025 (Figure 2). The** study took place in the high seas during a regular fishing trip. During the fishing trip, a total of 17 sets were performed, all sets were associated to Fish Aggregating Devices (FADs).

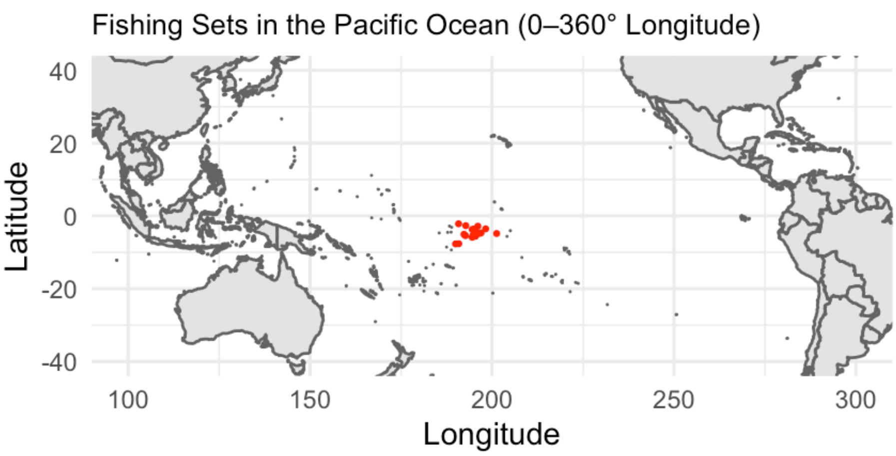

Figure 2.- Geographic positions of sets in which incidental catch of sharks occurred.

Data collection

During each set with shark interactions, the following data were recorded:

- species
- sex (categorized as female, male, indeterminate, or unknown),
- total length (TL) in cm,
- brail number in which the specimen was brought on-board (e.g., 1st, 2nd, 3rd brail, etc.),
- position in the brail (top, middle, bottom),
- time when the shark was brought on board (time of brailing) and release,
- mode of release, classified as: (i) via brailer, (ii) using light equipment such as stretcher, fabric, sarria or cargo net, (iii) manual release from the deck, (iv) after disentanglement from the hauling net, or (v) via the ramp attached to the hopper.
- vitality index or the condition at release, following the criteria of Heuter and Manire (1994):
    - (i) excellent - very active and energetic, strong signs of life on deck and when release to the water;
    - (ii) good - active and energetic, moderate signs of life on deck and when release to the 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, 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, no revival upon release to water, no swimming movement, sinks.
- behavior after release, noted as: vigorous swimming, slow swimming near the surface, or sinking with minimal movement.

Additionally, in each interaction, the observer recorded whether the handling and release practices applied followed the guidelines defined by RFMOs (e.g., IATTC Res. C-24-05 and WCPFC CMM-24-05).

Blood Sampling and Lactate Measurement

To assess physiological stress, blood samples were collected from the caudal peduncle of 27 individuals (including the tagged sharks): 21 silky sharks (*Carcharhinus falciformis*), 5 oceanic whitetip sharks, and 1 hammerhead shark (*Sphyrna sp.*). Samples were taken onboard, and lactate concentrations were measured *in situ* using a portable lactate meter[1] (Lactate Plus, Nova Biomedical).

Tag programming and tagging

Satellite pop-up archival transmitting tags, both survivorship (sPAT) and miniPATs (Wildlife Computers, Inc.), were programmed for detachment 60 days post-deployment for sPATs and 180 days for the miniPAT. sPATs were programmed to record maximum and minimum daily depths and temperatures as well as depth at 10-minute intervals during the final four days of deployment.

[1] *https://www.laktate.com/producto/lactate-plus/*

sPAT and miniPAT release was also triggered if a tag exceeded 1,400-1,700 meters or remained at a constant depth for more than three consecutive days.

Three sharks were equiped with sPATs, and one individual was tagged using a miniPAT. In all cases, tags were attached using a 10 cm monofilament tether encased in an alimentary-grade silicone tubing. A Domeier-style anchor was used for tag attachment to sharks. To ensure proper insertion of the tag, a 2 cm incision was made at the base of the dorsal fin using a sterilized scalpel. All tagging equipment (tether, anchor, and scalpel) was treated with 5% povidone-iodine (Betadine Antiseptic Cream) to minimize the risk of infection.

Post-Release Survival Assessment

Post-release survival was inferred from depth telemetry data transmitted by the sPATs and miniPAT and the time elapsed from tagging to detachment. Sharks were classified as survivors if their movement data indicated normal diel vertical migration and active horizontal displacement for at least 10 consecutive days post-release, following criteria established by Hutchinson et al. (2015). Mortality was inferred when tags reported depth anomalies (e.g., constant depth over several days or extreme depth breaches) prior to premature detachment.

Results

Sharks Bycaught and Release

A total of 134 sharks were incidentally captured during the trip: 122 silky sharks, 11 oceanic white-tip sharks and one hammerhead. The total length of silky sharks ranged from 68 cm to 218 cm (mean ± SD, 143±43.9 cm) (Figure 3). For oceanic white tip sharks, the range was 149-199 cm (mean ± SD, 174±14.9 cm), while the single hammerhead shark measured 227 cm.

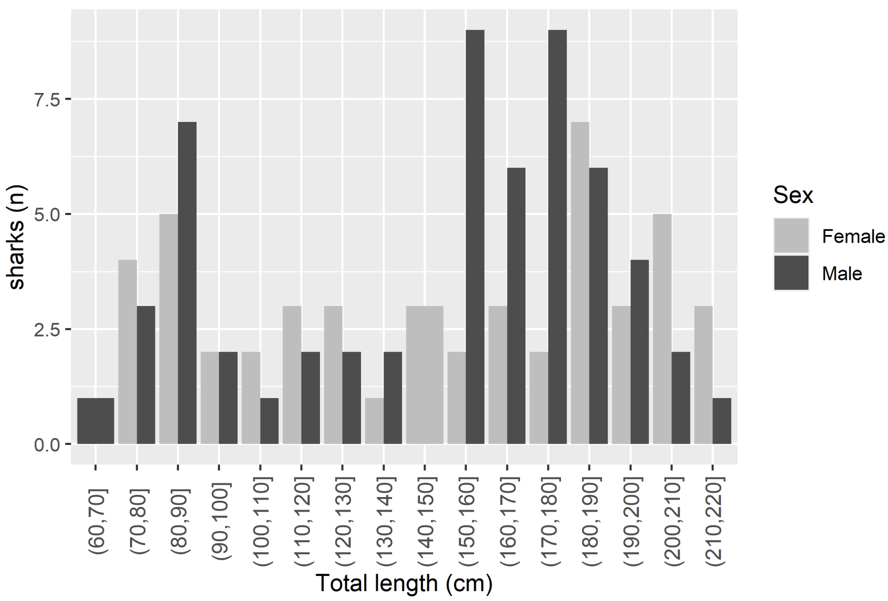

Figure 3.- Size distribution of silky sharks (*C. falciformis*) incidentally captured during the trip.

Most sharks (n=132 or 98.5%) were released from the upper deck using the hopper with the release ramp. Only two individuals (1.5%) were released manually without the ramp. In general, the release time did not exceed 2 minutes (Figure 4).

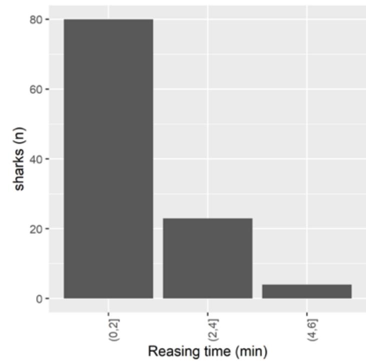

Figure 4.- Releasing time of incidentally caught sharks

A vitality index was recorded for 132 of the 134 bycaught sharks: 120 silky sharks, 11 oceanic white tip sharks, and one hammerhead (Table 1). At-vessel mortality, defined as either observed mortality or a shark with a "poor" or "very poor" vitality index, was estimated at 47% (n=62) (Table 1). The "poor" category was considered as "mortality"; however, in some cases individuals may survive depending on their condition at release and lactate level. Therefore, our at-vessel mortality estimate is conservative. For silky sharks, the rate was slightly higher at 49% (59 individuals out of 120), while oceanic white tip sharks had a lower rate of 27% (3 out of 11 individuals).

Table 1.- Number of sharks (total, silky sharks and oceanic white-tip sharks) released by vitality index and brail number in which the specimen was brought on-board.

ALL SHARKS					
# Brail/Vitality Index	**Excelent**	**Good**	**Correct**	**Poor/Very Poor**	**Total**
1	4	3	2		9
2		3	4	4	11
3	2	1		3	6
=>4	4	20	27	55	106
Total	**10**	**27**	**33**	**62**	**132**
%	**8%**	**20%**	**25%**	**47%**	**100%**

SILKY SHARK					
# Brail/Vitality Index	**Excelent**	**Good**	**Correct**	**Poor/Very Poor**	**Total**
1	4	3	2		9
2		3	4	4	11
3	2	1		3	6
=>4	3	16	23	52	94
Total	**9**	**23**	**29**	**59**	**120**
%	**8%**	**19%**	**24%**	**49%**	**100%**

OCEANIC WHITE-TIP SHARK					
# Brail/Vitality Index	**Excelent**	**Good**	**Correct**	**Poor/Very Poor**	**Total**
1					0
2					0
3					0
=>4	1	4	3	3	11
Total	**1**	**4**	**3**	**3**	**11**
%	**9%**	**36%**	**27%**	**27%**	**100%**

Blood lactate levels were measured in 27 individuals: 21 silky sharks, 5 oceanic white tip sharks, and one hammerhead. Mean lactate concentration levels by species are summarized in Table 2.

Species	# Individuals	Min	Max	Mean (± S.D)
FAL	21	3.6	13.7	7.61±2.51
OCS	5	4.3	8.8	6.38±2.03
SPL	1			8.5

For silky sharks, blood lactate levels differed significantly among vitality index categories (p-value<0.05; Kruskal-Wallis non-parametric test) (Figure 5), being highest in moribund individuals.

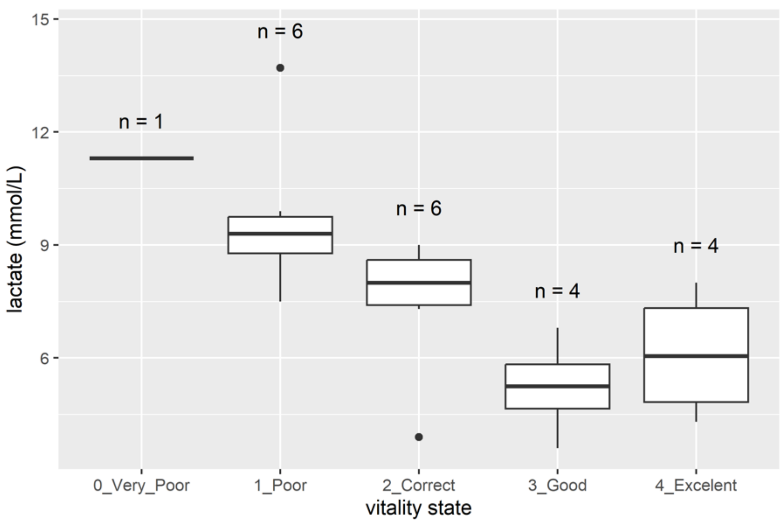

Figure 5.- Lactate levels by vitality index in silky sharks

Tagged sharks

Four sharks were tagged during the trip: three silky sharks with sPATs and one oceanic white-tip shark with a miniPAT (Table 3). One deployed tag (miniPAT) was programmed for a 180-day detachment and it is expected to detach on August 9, 2025. The remaining three detached prematurely (tag detachments were programmed for 60 days). Despite early detachments, two sharks (IDs 262504 and 262512) showed normal vertical movement patterns and were confirmed to have survived for at least ten days (32 and 11 days). A third shark, although tracked for only 7 days, displayed consistent and normal diel vertical behaviour (Curnick et al., 2020), low lactate levels, and a good vitality state at release; suggesting likely survival and was considered as alive.

Table 3.- Summary of tagged sharks

#	Tagging Date	TT	Tag Id	Species	Length (cm)	Sex	Release Date	Days	Release Reason
1	08/01/25	262504	23P2586	FAL	174	Female	09/02/25	32	premature
2	11/01/25	228817	21P1402	OCS	161	Male	-	-	-
3	14/01/25	262511	23P2601	FAL	187	Male	21/01/25	7	premature
4	15/01/25	262512	23P2602	FAL	158	Female	26/01/25	11	premature

Vertical movements during the four days prior to tag detachment are shown in Figure 6. The sharks exhibited predominantly shallow depth distributions, typically remaining above 150 m and spending considerable time at depths of approximately 50 m or shallower. These shallow depth preferences were observed both during the day and at night. Occasional deep dives were also recorded. This behaviour is consistent with previous studies conducted with silky sharks in the western Indian Ocean (Curnick et al., 2020, Filmalter et al., 2021; Grande et al., 2022).

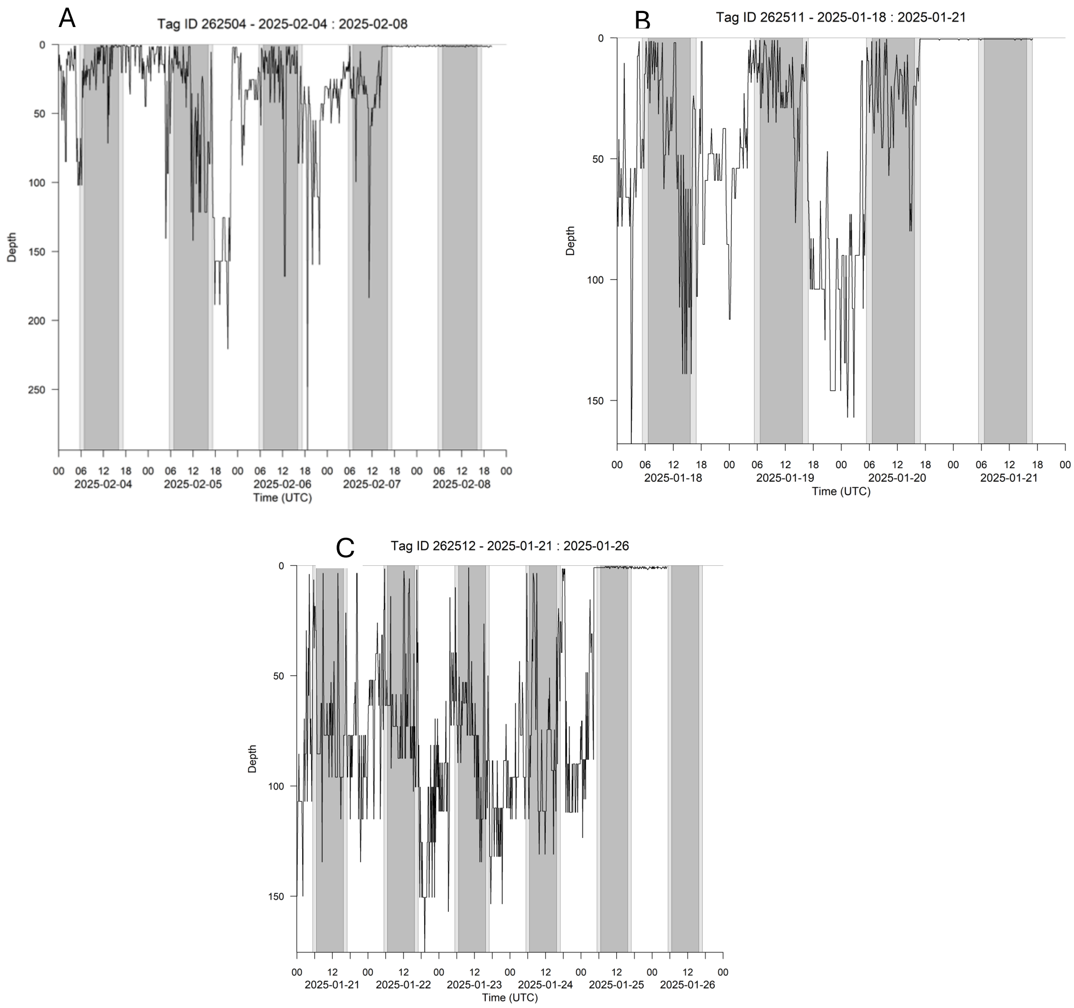

Figure 6.- Diel vertical movement of silky sharks during the last 4 days before tag detachment: (A) Individual 1 (Tag Id 262504) tag release after 32 days, (B) Individual 3 (Tag Id 262511) tag release after 7 days, (C) Individual 1 (Tag Id 262511) tag release after 11 days.

Skipper and Train-the-Trainer Workshops

Skipper workshops and a train-the-trainer session were held in Pago Pago, American Samoa, home base of the U.S. tuna purse seine fleet. These workshops engaged captains and crew in best practices for bycatch reduction, including the application and use of BRDs and sustainable fishing techniques. The workshops were strategically scheduled during port calls when vessels were unloading, ensuring crew availability and high participation.

Between March 14 and 21, 2024, project scientists delivered several onboard workshops, covering a range of key topics, including juvenile tuna bycatch mitigation, best handling and release practices for ETP species, and recent developments in non-entangling and biodegradable FADs. Particular emphasis was places on the use and potential implementation of BRDs in the U.S. fleet (Figure 7).

Figure 7.- Training session onboard a US purse seiner, where the project team discusses recent advances in bycatch release device technology with the vessel's captain and navigator (©ISSF/Gala Moreno).

During the eight-day mission, the project team visited four U.S. purse seine vessels docked in Pago Pago, collectively representing a significant segment of the fleet. The following summarizes vessel-specific and fishers feedback:

- Discussion focused on BRDs, particularly hoppers with ramps designed for the safe release of elasmobranch.
- Fishers expressed interest in adopting the ramp system with a hopper, as current practices involve the use of stretchers or manual release. The crew favored integrating ramps with hoppers for safer shark releases compared to current manual or stretcher-based release methods.

- Manual lever mechanisms for hopper doors, featured in demonstration videos, also garnered interest.
- One vessel confirmed that its onboard hopper had not yet been installed, but a similar unit was available onshore and would be used on the following trip. The crew confirmed plans to use a ramp-equipped hopper, signaling active engagement with BRD solutions.
- All vessels have a mobulid sorting grid onboard to enable the safe release of large individuals.

Additionally, a tailored training session was provided to a National Marine Fisheries Service (NMFS)/NOAA American Samoa field office staff member based in Pago Pago to ensure continue outreach and in-port crew instructions for those unable to attend the in-person workshops. The session covered topics such as: (i) status of tropical tuna stocks in the Pacific, (ii) best practices for FAD management, (iii) mitigation and safe release of vulnerable species, (iv) operational use of BRDs, (v) and biodegradable FADs.

Discussion

This study provides valuable insights into the application of updated BRDs and best handling practices designed to enhance the post-release survivorship of sharks incidentally caught in tropical tuna purse seine fisheries. The integration of a custom-built release ramp with a hopper, combined with established safe-handling protocols, substantially improved operational practices aboard the Cape Ferrat vessel. The ramp enabled rapid and safe releases, with 98.5% of sharks released using this method and release times generally under two minutes. This minimizes air exposure and handling stress, two critical factors influencing elasmobranch survival (Stewart et al., 2024) while also reducing handling effort and risk for crew members. Notably, both the onboard observer and fishers reported that the ramp did not interfere with other deck operations (e.g., brailing), and fish loading times remained unaffected. Moreover, the ramp was not permanently installed and could be deployed and removed quickly during each fishing set, requiring minimal effort and causing no disruption to routine fishing operations. The cost of the ramp, which varies between USD 2,000 and USD 7,000 depending on vessel size and deck configuration, is considered affordable for most purse seine fleets. Thus, given the operational benefits, crew safety issues, and potential for substantial reductions in shark (and other groups) bycatch mortality, the ramp represents a cost-benefit mitigation measure. When combined with proper handling techniques and consistent BRD use, this approach not only improves crew safety during the release of hazardous species but also enhances the post-release survival (PRS) of vulnerable taxa. Such improvements contribute to reducing the ecological footprint of U.S. tuna purse seine vessels and other fleets operating in the Pacific Ocean.

At-vessel mortality estimates (47%) are similar to those obtained by Onandia et al. (2021) and Grande et al. (2022) and lower than the research conducted by Poisson et al. (2014), Eddy et al. (2016), and Hutchinson et al. (2015), which observed a higher mortality at haul-back. Post-release survivorship, as inferred from PSAT data and physiological stress indicators, offers encouraging evidence that the proper use of BRDs and best practices can increase survival rates. Of the four tagged sharks, three yielded data consistent with short-term survival, and two were confirmed to survive at least after 10 days post-release. Despite one premature tag detachment occurred before the 10-day threshold, the combination of normal vertical movements, low lactate levels, and favourable vitality scores supports the inference of likely survival for this individual as well.

Vitality indices and lactate levels provided additional evidence of the potential benefits of rapid, low-stress release methods. Silky sharks exhibited a significant relationship between lactate concentration and vitality, suggesting that immediate and proper release reduces elasmobranch physiological stress (Grande et al., 2022). These indicators are crucial in the context of quick release protocols as they can improve our confidence in survivorship estimates.

The demonstrated improvements in shark survivorship are essential to the broader objective of enhancing the sustainability of shark populations. Sharks, characterized by slow growth, late maturity, and low fecundity, are particularly vulnerable to overexploitation and incidental capture (Juan-Jordá et al., 2022). Reducing post-release mortality is thus a critical step toward mitigating fishery impacts and promoting the recovery and resilience of depleted populations. Moreover, evaluating survival rates of vulnerable released fauna in purse seine fisheries will help guide management decisions, as simply banning retention onboard will not be an effective strategy in the case of purse seine vessels where a high proportion of individuals do not survive after release under current practices (Tolotti *et al.*, 2015). However, given the post-release mortality rates observed at haulback, it is also important to prioritize shark bycatch mitigation measures within a hierarchical framework, as proposed by Gilman et al. (2023). This approach includes implementing avoidance strategies prior to net setting, as well as mitigation measures before sharks are brought aboard, such as releasing individuals while still in the net, to more effectively reduce bycatch mortality (Restrepo et al., 2019).

Moreover, the training initiatives, including the skipper and train-the-trainer workshops, represent an effective strategy for scaling best practices across fleets. Building knowledge and operational familiarity with BRDs favours voluntary uptake and ensures more consistent and widespread application, which is key for meaningful reductions in bycatch mortality at the fishery-wide level.

Since 2009, ISSF has organized and hosted more than 135 Skippers Workshops at major ports on five continents (Murua et al., 2023; 2025). ISSF Skippers Workshops bring together tuna fishers and marine scientists to share ideas, information and co-develop tools and best practices to reduce fishery impacts, including bycatch reduction, and improve tuna fisheries sustainability. The goal of these Skipper Workshops is to develop and present to tuna fleets the state of the art in responsible fishing operations and bycatch mitigation (e.g., use of the most efficient BRDs). These efforts have yielded novel improved sustainable fishing practices in all oceans; for example, the adoption and widespread use of non-entangling fish aggregating devices (NEFADs) and the development and adoption of best practices for the safe handling and release of vulnerable bycatch using BRDs.

Fishers' continuous training promotes the application of the most advanced responsible fishing practices onboard tropical tuna. More importantly, the frank dialogue established and the mutual trust developed with scientists through the history of the Skipper Workshops, increases the buy-in of fishers and their willingness to use newly co-developed mitigation tools. We hope that face to face Skipper Workshop will continue to be a channel to present the results of this research and foster the implementation of hoppers with ramps to release sharks safely.

However, several limitations temper the strength of our conclusions. Most notably, the limited number of tagged sharks (n=4), and the premature detachment of three of those tags, constrain the statistical power and generalizability of our PRS estimates. While physiological and behavioural indicator data collected support our survivorship inference, the low tagging sample size limits our ability to account for set-specific stressors and differences in vitality index related to the brail number where the shark was onboard, or long-term mortality due to sublethal effects. Future work should prioritize scaling up tagging efforts across multiple vessels and fishing conditions to refine survival estimates with greater precision and confidence.

Additionally, although release practices were closely monitored during this study, the effectiveness of BRDs under broader operational conditions, across different vessels, crews, and environmental contexts, remains to be fully evaluated. Ongoing efforts to train crews and monitor compliance are critical to ensure that the observed improvements in shark quick release and survival are maintained over time and extended across fleets.

In conclusion, our results indicate that incorporating effective fauna handling and release devices on tuna purse seine vessels, such as shark ramps with a hopper, can lead to an increase in shark post-release survival. Thus, this study underscores the potential of updated release techniques and training programs to enhance shark PRS in tuna purse seine fisheries. Such improvements are essential for reducing fishery-induced mortality and supporting the long-term sustainability of vulnerable shark populations. However, further research with expanded sample sizes and longer-term monitoring is needed to strengthen the evidence base and guide policy and operational decisions across the tropical tuna fishing sector

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