AT-SEA TESTS OF RELEASING SHARKS FROM THE NET OF A TUNA PURSE SEINER IN THE ATLANTIC OCEAN

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SUMMARY

A research cruise in support of the International Seafood Sustainability Foundation (ISSF) bycatch reduction project was conducted on the tuna purse seine vessel PACIFIC STAR, during June-July 2018 in the eastern tropical Atlantic Ocean. During a 4-week period a group of three scientists joined the fishing trip with the following primary objectives: (1) Estimate post-release survival of sharks (from the net); (2) Test the feasibility of crew members releasing sharks from the net. Additionally, two other objectives were pursued opportunistically: (3) Estimate post-release survival of whale sharks (from the net); and, (4) Estimate post-release survival of rays (from deck). Preliminary results of these studies are presented.

RÉSUMÉ

Une campagne de recherche, en appui au projet de réduction des prises accessoires de International Seafood Sustainability Foundation (ISSF) a été réalisée à bord du thonier senneur PACIFIC STAR en juin et juillet 2018 dans l'océan Atlantique tropical oriental. Pendant quatre semaines, trois scientifiques ont participé à la sortie de pêche dans le but de remplir les objectifs principaux suivants : (1) estimer la survie suivant la remise à l'eau des requins (du filet) et (2) déterminer s'il est faisable que les membres de l'équipage remettent les requins à l'eau depuis le filet. De plus, deux autres objectifs ont été poursuivis de manière opportuniste : (3) estimer la survie suivant la remise à l'eau des requins-baleines (depuis le filet) et (4) estimer la survie suivant la remise à l'eau des raies (depuis le pont). Les résultats préliminaires de ces études sont présentés.

RESUMEN

Se realizó un crucero de investigación en apoyo del proyecto de reducción de la captura fortuita de la International Seafood Sustainability Foundation (ISSF) a bordo del cerquero atunero PACIFIC STAR, durante junio-julio de 2018 en el océano Atlántico tropical oriental. Durante 4 semanas un grupo de tres científicos se unió a la marea de pesca con los siguientes objetivos principales: (1) estimar la supervivencia posterior a la liberación (de la red) de los tiburones, (2) probar la viabilidad de que los miembros de la tripulación liberen a los tiburones de la red. Además, se perseguían, de forma oportunista, otros dos objetivos: (3) estimar la supervivencia posterior a la liberación (de la red) de los tiburones ballena y (4) estimar la supervivencia posterior a la liberación (de la cubierta) de las rayas. Se presentan los resultados preliminares de estos estudios.

KEYWORDS

Purse Seine, Bycatch, FAD, Silky Shark, Rays, Whale Shark, Tuna, Bycatch mitigation

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1. Introduction

The International Seafood Sustainability Foundation (ISSF) supports science-based initiatives for the long-term conservation and sustainable use of global tuna stocks. Bycatch reduction and improved targeting in large-scale tuna fisheries is a primary focus area implemented by the ISSF Bycatch Steering Committee. In order to define and test technical solutions to bycatch reduction, ISSF conducts at-sea research cruises to investigate potential mitigation measures centered on tropical tuna purse seine fisheries operating with floating objects. Seventeen research cruises have been conducted in the Western Indian Ocean, Eastern Pacific, Western and Central Pacific and Atlantic Oceans since 2011 (Restrepo *et al.*, 2018), mainly looking at ways to reduce catches of bigeye tuna and oceanic sharks.

This report summarizes the activities of the fourth ISSF bycatch reduction research cruise in the Atlantic Ocean onboard the purse seine vessel PACIFIC STAR (Curaçao flag).

2. Cruise description and objectives

2.1 Vessel and personnel

The F/V PACIFIC STAR is a 107 m tuna purse seiner built in Spain in 1990 with 3,500 m^3 of fish hold volume. The cruise took place in the Eastern Atlantic Ocean, departing from Abidjan, Cote d'Ivoire on 25 June 2018, and ending on July 21, 2018 in Sao Tome for a crew swap. Research was conducted by ISSF-supported scientists Melanie Hutchinson, Alfredo Borie and Alexander Salgado (who also served as the observer) with technical support provided by the vessel captain and crew. A total of 40 sets were made in the EEZ of Gabon where the vessel was licensed to fish (**Figure 1**).

2.2 Cruise objectives

The research cruise had the following objectives, the last two being pursued if the opportunity arose:

1. Estimate post-release survival of sharks (from the net): To estimate the survival rate (using satellite tags) of juvenile silky sharks caught inside the net (with handlines) then released outside the net.

2. Test the feasibility of crew members releasing sharks from the net: To test the feasibility of the above method being utilized by the crew to remove sharks from the net.

3. Estimate post-release survival of whale sharks (from the net): Assess survival of whale sharks released from the net.

4. Estimate post-release survival of rays (from deck): Assess survival of mobulid rays released from the deck.

3. Materials and methods

3.1 Estimate post-release survival of sharks (from the net)

Previous ISSF research cruises have shown that sharks could be efficiently fished by handline from the purse seine net before being brailed onboard (Hutchinson *et al.*, 2012; Sancristobal *et al.*, 2016). The research in this study built upon the lessons learned in 2012 and 2016.

Scientists and crew worked to build a stretcher that could be attached to the side of a small work boat, so that when a shark was captured it could be leadered into the stretcher, where the animal could be safely restrained to facilitate tagging and release without having to bring the shark onboard a small boat. The stretcher (**Figure 2**) was made out of two PVC pipes forming a V, heavy metal chain to sink the opening and two layers of small mesh FAD netting. The apex of the V was attached to the rail of the small boat and the other two ends formed handles that could be opened to bring the animal in and closed to restrain the animal against the vessel. The stretcher was light and maneuverable and kept the animal in the water, facilitating safe handling on a small boat where maneuverability is limited while allowing the animal to ventilate.

During the cruise, the scientists had access to the vessel's 5 m 'panguita' boat that was normally used to assess species composition and density under FADs. During FAD sets, the FAD was typically pulled out of the water as soon as the net had been pursed. The scientists were then able to board the panguita shortly thereafter to begin fishing for sharks. During free school sets, the scientists were able to board the vessel as soon as the net was closed and the jet boats had been recovered. This maximized the amount of time for fishing inside the net until it was too small to maneuver the panguita (35-50 minutes).

Sharks were captured using handlines composed of small 11/0 and 14/0 galvanized circle hooks with depressed barbs, 0.5 meters of braided wire leader to 20 m of nylon line. Hooks were baited with skipjack or small scombrids. Hooked animals were leadered into the stretcher and restrained in the water while they were measured and tagged. Captured sharks were tagged with satellite linked pop-off archival tags (miniPAT; Wildlife Computers Inc.) programmed for 180-day deployment periods. Sharks were released with the hook to simulate the condition of release by commercial fishers.

3.2 Test the feasibility of crew members releasing sharks from the net

The scientific protocol for this test was to have only one scientist onboard the panguita, with 2 crew members doing the shark fishing. The scientist would count the number of sharks caught and released outside the net, and document any difficulties encountered by the crew during the operation, but also measure the time needed to catch and release a shark. Once a shark was caught, it would not be tagged so as not to slow down the fishing operation.

3.3 Estimate post-release survival of whale sharks (from the net)

PAT tags were to be used opportunistically, if any whale sharks were encircled during a set, in order to estimate their survival after the release maneuver used by the vessel. The freeboard on this vessel was too high to tag anything from the deck of the purse seiner so tagging was done from the panguita. As soon as the whale sharks were observed, the panguita was deployed and tags were attached from the small boat with a tagging pole fabricated from a ¾" diameter pipe found onboard the purse seiner.

3.4 Estimate post-release survival of rays (from deck)

PAT tags were to be used opportunistically, if any rays from the family Mobulidae were captured incidentally, in order to estimate their survival after release to assess the efficacy of the recommended best practices (Poisson *et al.*, 2012; ISSF 2016).

4. Results and conclusions

4.1 Estimate post-release survival of sharks (from the net)

This method was tested on nine occasions, during all FAD sets (n=3) and during six free-school sets. Sharks were only captured on FAD sets and it was only juvenile silky sharks (*Carcharhinus falciformis*) that bit the hooks (bait was taken by a hammerhead on one occasion, but it was not hooked).

The first FAD set was set number 11, where three sharks were removed from the net in 48 minutes of fishing (two entangled hammerheads and one juvenile silky shark [FAL]). The FAL was hooked, tagged and released outside the net in excellent condition (see **Table 1** for tagging details). There were 25 additional sharks landed via normal fishing operations (entangled or brail) during this set; 22 adult scalloped hammerheads (*Sphyrna lewini*), two adult smooth hammerheads (*S. zyganea*) and one juvenile FAL. The next FAD set was set number 15. During 35 minutes fishing, scientists captured two juvenile FAL, one was a neonate and had swallowed the hook so it was not tagged, but it was released outside the net in fair condition. The other FAL was tagged and released outside the net in excellent condition. Three sub-adult FAL and one entangled adult unidentified hammerhead were landed during normal fishing operations. Set number 16 was the third and final FAD set during this cruise. In 36 minutes fishing in the net, scientists captured four juvenile FAL. One was a neonate and too small for a PAT so it was tagged with an identification tag and released outside the net in excellent condition. The other three were all measured, tagged with PATs and then released outside the net in excellent condition. There were two additional juvenile FAL in this set, one was entangled on the outside of the net and self-released, the other FAL was released from the sack because it was opened to release unmarketable species (null set).

Sets 2, 12, 18-21, and 27 were all free-school sets where scientists also fished for sharks. There were sharks of several species encircled in all of these sets except 12 and 18. During each of these sets, scientists fished from the earliest possible opportunity to enter the net until it was closed. Fresh bait was used, alternating bait types and chumming the water heavily throughout the entire operation but never had a bite from any of the larger sharks. During several of these sets the larger sharks were landed with whole skipjack in their mouths. Many of the larger sharks expelled their gut contents on deck and they were full of small engraulid baitfish, suggesting that this method may not work for larger sharks that are actively feeding at this aggregation location.

All of the tags deployed on FAL reported before the programmed 180-day pop-off date (53-118 days), due to tag attachment failures. Most studies that have assessed post release fate of silky sharks captured in purse seine fisheries have shown that mortalities due to the fishing interaction will occur immediately or within a 10-day window of release (Poisson *et al.* 2014; Hutchinson *et al.* 2015; Eddy *et al.* 2016). Therefore, it is assumed that all of the animals captured with handlines, while the net was still open and the sharks were free swimming, tagged and then released outside the net, survived the fishing interaction (**Table 1**, **Figure 3**).

4.2 Test the feasibility of crew members releasing sharks from the net

There was no opportunity to conduct this activity. There were several complicating factors. The primary issue was that the vessel set on FADs in only 3 of 40 sets. The 37 free-school sets almost always contained large adult sharks which were not biting as they were very successfully foraging within the tuna schools and on bait fish that had aggregated at this upwelling location. Additionally, handling these large sharks would have been very dangerous for crew members without considerable experience hooking and handling large, very active sharks.

4.3 Estimate post-release survival of whale sharks (from the net)

Three whale sharks were captured during two different sets (33 and 38), both of which were on free-swimming tuna schools. On both sets the animals were not seen until the end of the net haul back when the crew was sacking up. The first whale shark (RHN17P0687), in set 33, was over 10 m in total length, and its sex was not determined. It was tagged with a PAT and then immediately released from the sack by dropping the corks and rolling the net out from under the shark (**Figure 4**). Most of the target tuna catch was retained during this operation with minimal losses as the whale shark was being released. Brailing commenced after the shark was released. On set 38, two female whale sharks, both over 10 meters total length, were encircled. Only one of these sharks was tagged with a PAT (RHN17P0683). The second shark was not tagged because the anchor configuration of the two remaining tags (Domeier anchors) could not be adapted to fit onto the tagging pole at that moment. Both animals were released in good condition immediately after tagging, from the sack via the same method described above. This set was a null set but it is unclear if it was because the school was missed or if it was because the net had to be pulled all the way up and out from under the sharks, to roll them both out of the net. It was noted by the observer and the crew that on both sets where whale sharks were captured, conditions had been ideal for the safe release of all of these animals because they were all facing towards the bow. On occasions where the animal is facing the stern, it is much more difficult to get them out of the net because the stern portion of the sack cannot be dropped as easily.

Both of the tagged animals survived the interaction. RHN17P0687 survived to 81 days when the tag initiated release because the animal had reached the critical depth of the tag at 1,400 meters. RHN17P0683 survived to 103 days before it too reached the critical depth threshold of 1,400 m and the tag came off (**Figure 5**). The dive data from RHN17P0683 indicates that the animal may have exceeded the depth threshold of the tag during a deep dive as opposed to it reaching this depth due to mortality and sinking through the water column. The last 5 days of depth data from RHN17P0687 did not transmit and we cannot conclusively rule out mortality for this animal. Whale sharks are known to conduct deep foraging dives beyond 1000 m in every ocean (e.g. Rowat and Gore 2007; Berumen *et al.* 2014). Thus, the tags may have initiated release during normal diving activities as opposed to mortalities.

4.4 Estimate post-release survival of rays (from deck)

Chilean devil rays, *Mobula tarapacana* (RMT) were captured in sets 30, 32 and 34, all of which were on free swimming tuna schools. On set 30, the target school was missed so the sack, containing eight to ten RMT, was opened to release the rays. All appeared to be in good condition and swam out of the net. On set 32, three RMT were captured. One female ray (RMT17P0533) came up entangled in the net while the other two were landed in the later brails (12 and 15 of 15 brails). The animal landed in brail 12 was a mature male (RMT17P0618) and the other landed in brail 15 was a female (RMT17P0534). All three were tagged with PATs and released by the crew

using the recommended best handling practices. This method requires the crew to maneuver the animal from the brail onto a large piece of net that can be picked up with a crane and lifted over the deck to release the animal back into the water (**Figure 6**).

Eight RMT were captured in set number 34. All of these animals were landed via brailing and released using the aforementioned best practices. The first animal that was tagged was an adult male (RMT17P0540), landed in the first brail and released in good condition. Two RMT were landed in the second brail, one of these was a female and was tagged (RMT16P0060). The other was an adult male and was not tagged, they were released together and in good condition. The third brail contained another mature male that was also tagged and released in fair condition (RMT17P0694). Brails 4, 5 and 6 contained four additional adult RMT that were released alive using the recommended practices but were not tagged.

Five of the six tags initiated release because the animals had exceeded the tag's critical depth threshold of 1,400 meters. Typically, this would be indicative of mortality, or an animal sinking through the water column. All of the mortalities occurred between two and 11 days post-release with one tag that was shed early due to an attachment failure on day 65 (RMT17P0694). Interestingly, this animal was released in fair condition and was the only one that survived the interaction. All of the movement paths for these animals are illustrated in **Figure 7**. The maximum likelihood locations for RMT17P0694 closely mirrors that of whale shark RHN17P0683.

5. Discussion and conclusions

This was the third ISSF bycatch research cruise conducted in the Atlantic Ocean onboard a tropical tuna purse seine vessel. Experiments at-sea to test three out of the four cruise objectives were successfully conducted.

The first objective that was achieved was releasing sharks from the net. It is well known that shark survival in purse seine fisheries is very low once they are brailed on board. With good practices for handling and releasing sharks that come up entangled in the net, survival can be increased, up to about 35% (Hutchinson *et al.*, 2015). ISSF has been researching ways in which sharks could be released before they are brailed onboard, which could have an even greater impact on survival. One possible approach that has been tested is to install an escape panel in the net (e.g. Itano *et al.*, 2012). Several ISSF research cruises have shown mixed potential for success that depend on factors like the size of the net, the way the skipper sets, and oceanographic variables. And, vessel owners usually react quite negatively to what they see as "making a hole in the net". In this PACIFIC STAR cruise, scientists tested a much simpler method: Fishing the sharks from inside the net and releasing them outside the net, which had already been tested in the 2012 Western Central Pacific Ocean cruise on the F/V CAPE FINISTERRE and the 2016 Atlantic Ocean cruise on board the F/V MAR DE SERGIO (Hutchinson *et al*., 2012, Sancristóbal *et al.*, 2016). Results show that this is relatively easy to do in good weather conditions and 100% of those sharks released survived. This adds to the evidence that sharks survive if they are removed from the net while it is still open enough for them to swim. The challenge of finding an effective means of removing them from the net remains (e.g. non-dependent on optimal weather conditions). On the other hand, catching sharks in the net during free-school sets proved impossible during this cruise and a different solution may be necessary.

The second objective also consisted on fishing sharks from the net, only in a more realistic scenario, where two crew members would be in charge of fishing and no sharks would be tagged. Unfortunately, there was no opportunity during the cruise to conduct this activity and hence, the objective was not achieved.

Tropical tuna species are known to associate with large, slow moving animals, such as whale sharks (*Rhyncodon typus*). The problem is that whale sharks are typically not visible prior to purse seine setting and subsequently become encircled together with the tuna (Restrepo *et al.*, 2017). Recent studies of post-release survival have suggested that whale sharks released from the purse seine gear using best practices have a high rate of survival (Escalle *et al.* 2016 and Escalle *et al.* 2017). The third objective of the PACIFIC STAR cruise was to tag whale sharks opportunistically in order to improve knowledge on whale shark survival after release. The objective was achieved given both whale sharks tagged and released using best practices during the cruise survived.

Manta and devil rays are known to concentrate in oceanic areas with high productivity and are incidentally captured by tropical purse seiners when targeting tuna on FADs and free-swimming schools (Restrepo *et al.*, 2017). The fourth objective of the cruise was to estimate survival rates of rays that could not be released from the net and were brailed onboard. Six Chilean devil rays were tagged and released from the deck using best practices. Unfortunately, 5 of 6 tagged devil rays died within 11 days after release. It appears as if releasing these animals from the deck using best practices may reduce mortality to a small percentage of mobulids that are brought on board the vessel,

but the physiological impacts of the interaction cause delayed mortality in a larger proportion (see also Francis and Jones, 2016, who found similar results tagging *M. japanica*). These data suggest that alternative mitigation actions, such as avoiding hot spots or releasing them from the sack or while the net is still open, may be more effective for reducing mortality of mobulid rays.

While not part of the cruise's objectives, scientists reached additional conclusions from the cruise. For instance, it was observed that while sharks tend to be a more common bycatch in FAD sets than in free school sets, during this cruise sharks were caught in 31 of 37 free school sets, sometimes in large numbers (up to 9 sharks per ton of tuna, which is a high bycatch ratio; a more common ratio is ~0.1). The observer on the vessel noted that this is not uncommon for this area and time of the year. It would be useful to analyze observer records in order to identify shark "hot spots" in the eastern Atlantic Ocean. In addition, all whale sharks and mobulid rays caught during the cruise were caught on free-swimming schools.

It was also noted that Gabon in July appears to be an important area for feeding and may support several breeding populations of coastal and pelagic teleosts, sharks, rays, turtles and marine mammals. A recent analysis of the diversity patterns and environmental characteristics of the bycatch assemblages in the tropical tuna purse seine fishery in the eastern Atlantic Ocean found that the bycatch assemblages showed preferences for specific oceanographic characteristics such as the equatorial and seasonal coastal upwelling systems, the Cape Lopez front system and the Guinea dome (Lezama-Ochoa *et al.* 2018). Thus, integration of temporal oceanographic parameters into future bycatch mitigation techniques is the next step in improving the sustainability of this fishery. Avoidance of elasmobranch interactions and additional controls (e.g., avoiding hot spots, setting catch or effort limits) may be the best conservation strategies for this region, particularly during upwelling seasons. A better understanding of habitat requirements for biological imperatives and times and areas of aggregations of bycatch species is required.

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Table 1. Tag deployment data. All of the tags that were not mortalities were 'floaters' because they came off the animals before the pre-programmed pop-off date due to attachment failures. We consider them to be 'survivors' because a mortality due to the fishing interaction would have occurred within 10 days. Silky shark 17P0691 was actually eaten by a thermo-regulating non-air breather – (probably a mako). But because it survived beyond 10 days we are considering it to have survived the fishing interaction. The whale shark tags came off because the animals had both exceeded the depth threshold of the tag. But this could have been due to normal dive activity and because they survived > 80 days we can conclude that they survived the fishing interaction.

Date	***Set***	***Species***	***Sex***	***TL/DW***	***Tag serial***	***Released from***	***Release Condition***	***Fate***	***Deployment period (days)***
3-Jul-18	11	*Carcharhinus falciformis*	F	105 cm	17P0460	Fished from net	Excellent	Survivor	57
6-Jul-18	15	*Carcharhinus falciformis*	F	120 cm	17P0691	Fished from net	Excellent	Survivor	98
7-Jul-18	16	*Carcharhinus falciformis*	F	110 cm	17P0690	Fished from net	Excellent	Survivor	118
7-Jul-18	16	*Carcharhinus falciformis*	M	159 cm	17P0692	Fished from net	Excellent	Survivor	53
7-Jul-18	16	*Carcharhinus falciformis*	M	106 cm	17P0696	Fished from net	Excellent	Survivor	85
15-Jul-18	32	*Mobula tarapacana*	F	275 cm	17P0533	Entangled	Fair	Mortality	2
15-Jul-18	32	*Mobula tarapacana*	F	299 cm	17P0534	Brail	Good	Mortality	3
15-Jul-18	32	*Mobula tarapacana*	M	265 cm	17P0618	Brail	Fair	Mortality	3
15-Jul-18	33	*Rhincodon typus*	U	> 10 m	17P0687	Sack	Good	Survivor	81
16-Jul-18	34	*Mobula tarapacana*	F	269 cm	16P0060	Brail	Good	Mortality	4
16-Jul-18	34	*Mobula tarapacana*	M	290 cm	17P0540	Brail	Good	Mortality	11
16-Jul-18	34	*Mobula tarapacana*	M	300 cm	17P0694	Brail	Fair	Survivor	65
17-Jul-18	38	*Rhincodon typus*	U	> 10 m	17P0683	Sack	Good	Survivor	103

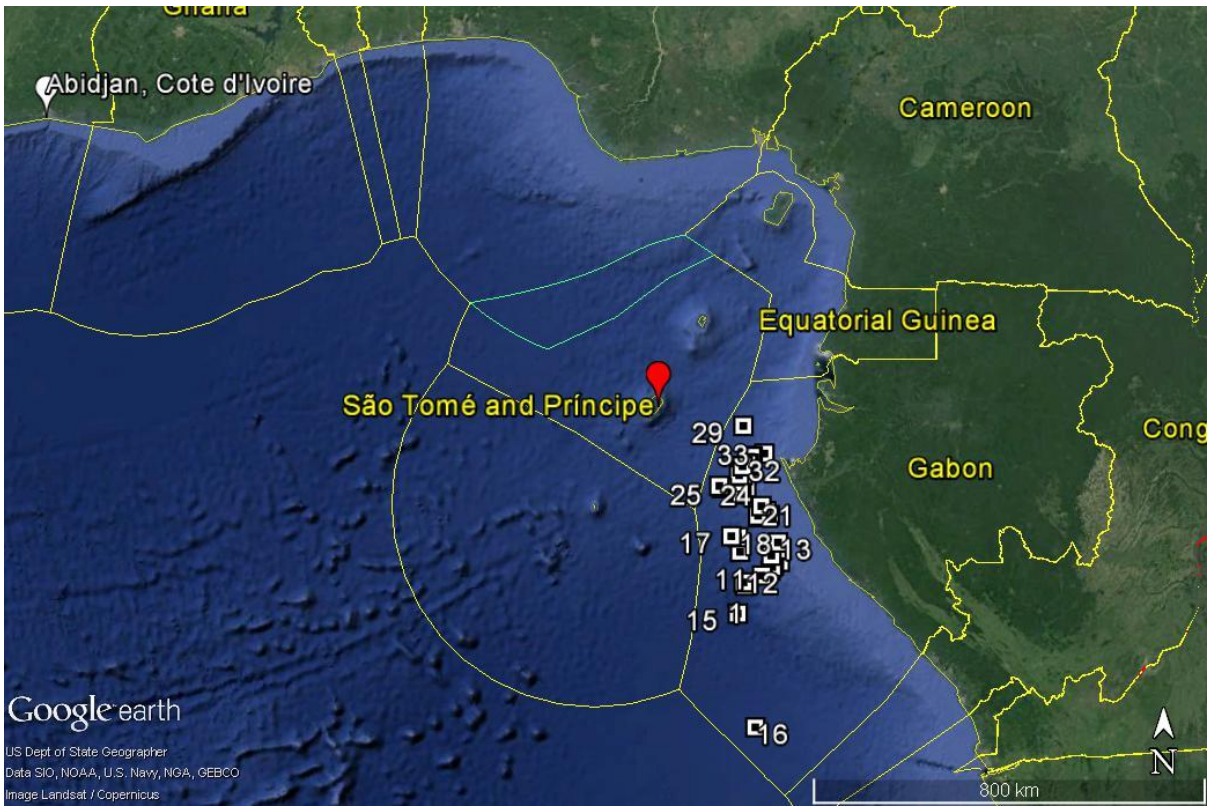

Figure 1. F/V PACIFIC STAR cruise set locations. Departure port was Abidjan Côte d'Ivoire and the cruise ended in Sao Tomé.

Figure 2. Stretcher configuration prior to adding the netting (left) and use at sea (right).

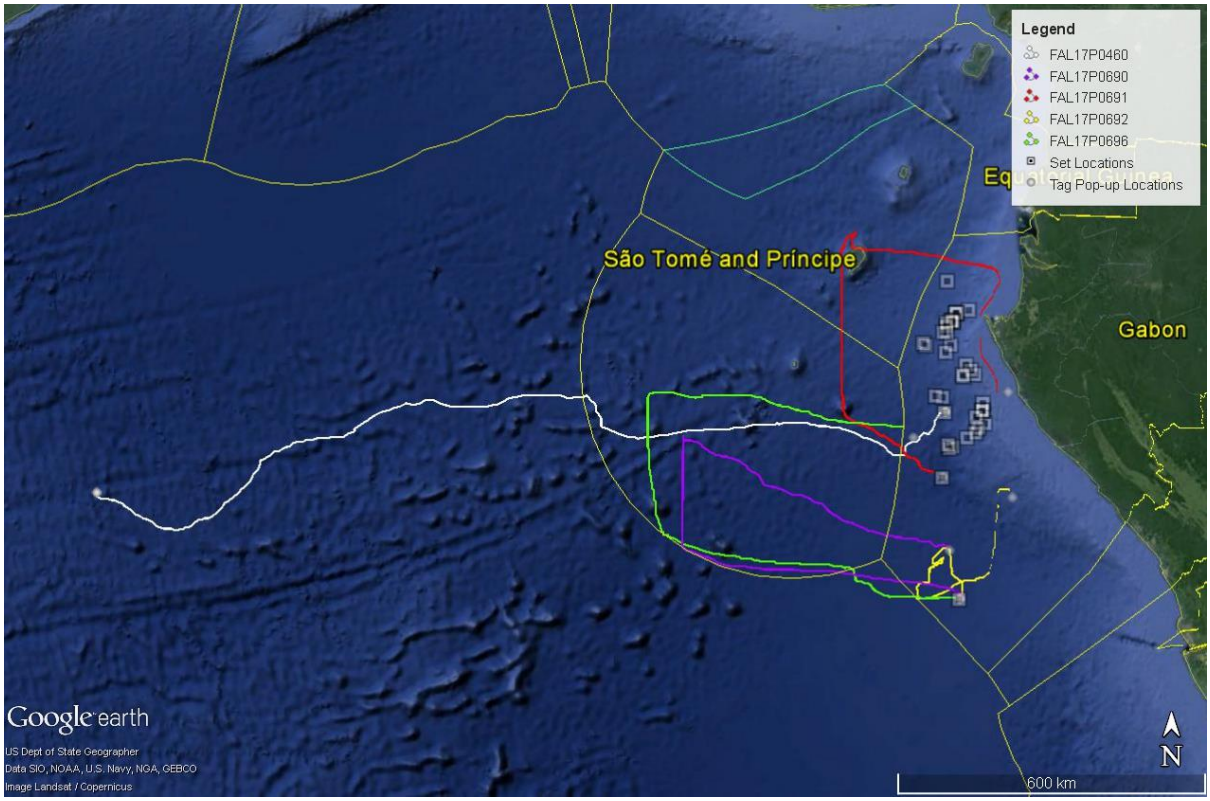

Figure 3. Movement paths of all five silky sharks post release.

Figure 4. Whale shark release from the net.

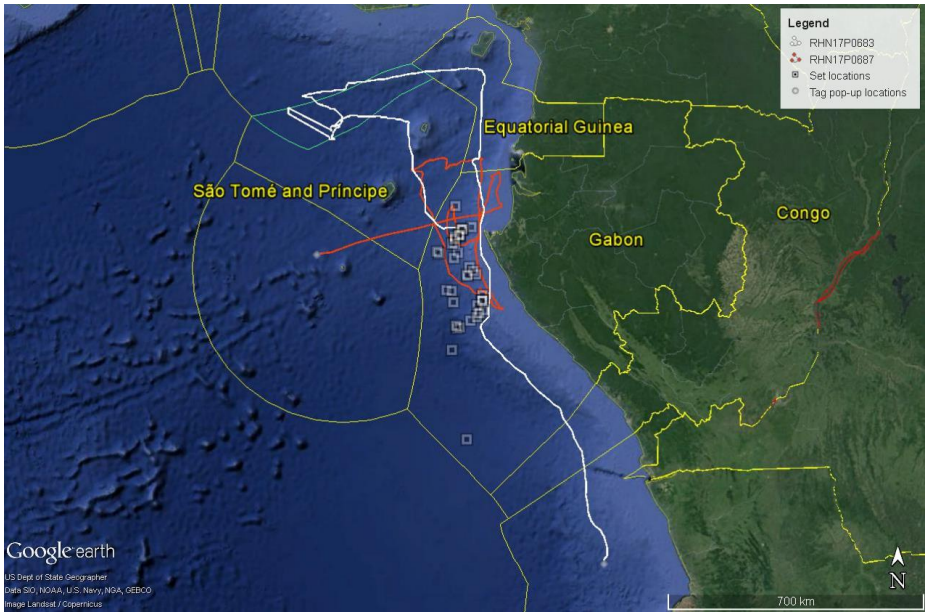

Figure 5. Movement paths from two whale sharks tagged during this cruise.

Figure 6. Safe release of two *Mobula tarapacana* from the deck. On the left the line that was used to manoeuvre the animals is shown. On the right the animal is shown on the netting used to lift it and return it to sea.

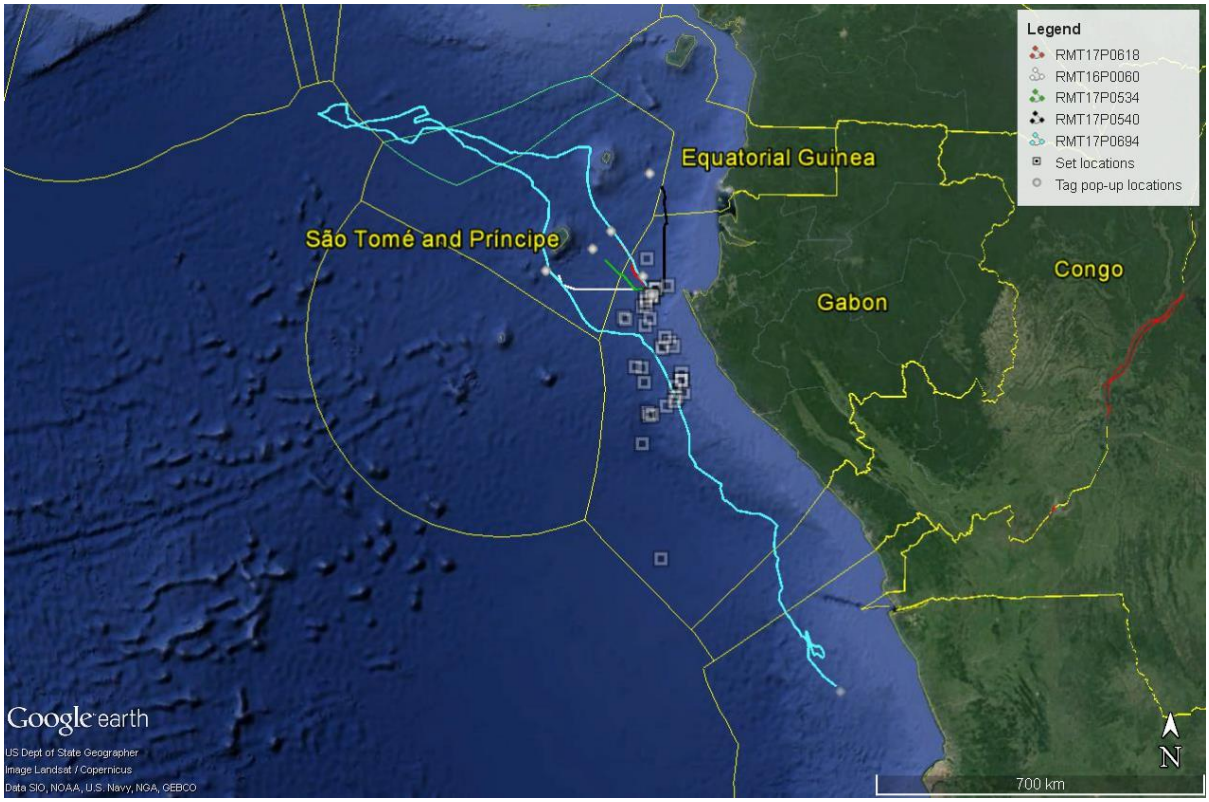

Figure 7. Maximum likelihood locations from the 65-day movement track of the *Mobula tarapacana* that survived the fishing interaction.