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A SUMMARY OF BYCATCH ISSUES AND ISSF Mitigation Activities To Date in Purse Seine Fisheries, with Emphasis on FADs

Photo: Fabien Forget

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Abstract

This document summarizes the main bycatch issues in tropical purse seine fisheries, with emphasis on FAD sets (including natural log sets, since the available data does not always allow for a separation of the two). These issues and known mitigation measures are presented separately by species groups. A summary of ISSF activities related to bycatch is given. This document updates an earlier version published in 2014 with more recent data.

November 2017

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Executive Summary

There are 23 stocks of the major commercial tuna species (albacore, bigeye, skipjack, yellowfin and 3 bluefin tuna species) worldwide, supporting an annual catch of about 4.7 million tons. About 64% of this catch is made by purse seine vessels that target the three main tropical tuna species: Bigeye, Skipjack and Yellowfin (ISSF, 2017). Of the total tropical tuna catch by the purse seine fishery, sets on floating objects, including FADs, account for more than half total global landings.

This document summarizes the main bycatch issues in tropical purse seine fisheries, with emphasis on FAD sets (including natural log sets, since the available data does not always allow for a separation of the two). These issues and known mitigation measures are presented separately by species groups: sharks, whale sharks, rays, finfish, sea turtles, billfish and juvenile bigeye and yellowfin tuna.

In terms of vulnerable or endangered species caught as bycatch in purse seine fisheries (e.g. sharks, turtles); the main issue is the mortality of captured individuals and other types of indirect mortality resulting from interaction with fishing gear (e.g. FAD entanglement). Bycatch species with low conservation concern can be utilized (e.g. some finfish species); in this case, the principal issues are wastage and potential loss of data when these fish are discarded and unreported.

Bycatch mitigation options for endangered, threatened or protected (ETP) species range from implementation of time-area closures to live release from the deck or applying modifications to the fishing gear (e.g. FAD design). For bycatch species that can be utilized, the main measure to avoid waste and data loss are full retention policies and market innovation, essentially making them non-target retained catch which is a positive outcome.

Planned activities by ISSF include both the continuation of research in these areas, and the dissemination of the results encountered so far. RFMOs have adopted several conservation measures to tackle bycatch issues in purse seine fisheries. These measures are also presented here by species groups.

ISSF has dedicated considerable effort to better understand what the main issues of concern are in these fisheries, by using scientific information (primarily from scientific observer programs) to quantify relative impacts. At the same time, ISSF has (a) conducted at-sea research to identify and critically test potential mitigation measures, (b) conducted workshops with purse seine skippers to share with them mitigation techniques and to seek their input about other potential mitigation measures, and (c) advocated for RFMOs to adopt mandatory data-collection and mitigation measures. A summary of these is given in the Section describing Related ISSF activities.

Key Findings:

1. Purse seine fisheries, both on free-swimming schools and on FADs present bycatch issues
2. Bycatch mitigation methods exist (several of which have been tested during ISSF research activities) and can be implemented
3. RFMOs have already adopted several conservation measures in this regard
4. ISSF will continue bycatch mitigation research and dissemination of results

Introduction

There are 23 stocks of the major commercial tuna species (albacore, bigeye, skipjack, yellowfin and 3 bluefin tuna species) worldwide, supporting an annual catch of about 4.7 million tons. About 64% of this catch is made by purse seine vessels that target the three tropical tuna species: Bigeye, Skipjack and Yellowfin (ISSF, 2017).

Purse seine vessels operate in different ways depending on the fleet, the area, the season and several other factors. Typically, the main fishing modes include fishing around floating objects (FADs and natural floating objects), free-swimming schools of tuna or fishing tuna associated with other fauna. These fishing modes are the main "set types" that include free-swimming schools (FS), floating object aggregations (including FADs - Fish Aggregating Devices - as well as natural floating objects), and tuna-dolphin associations (this is only common in the eastern Pacific Ocean). There are also other, but less frequent, set types such as on dead whales and on live whale sharks and manta rays which are usually classified as floating object sets.

Of the total tropical tuna catch by the purse seine fishery, sets on floating objects, including FADs, account for more than half of total global landings. Several fleets have increased their use of FADs to catch tuna, especially skipjack (40% of the global skipjack catch) which is the main species used for canning. Scott and Lopez (2014) estimate that 65% of all the purse seine sets made globally are on floating objects, either drifting or anchored. Drifting FADs can be quite sophisticated, equipped with buoys that can be located remotely and transmit via satellite estimates of the fish biomass aggregated underneath. This makes them particularly efficient in terms of searching for tuna. In addition, purse seine sets on floating objects rarely miss the tuna aggregations, compared to sets on free-swimming schools (Fonteneau *et al.*, 2013; Lopez *et al.*, 2014.)

All fishing methods have some level of environmental impact, which is often measured in terms of fishing mortality of non-target species (bycatch[1]) that may be retained or discarded at sea as well as target species that may be discarded at sea for a variety of reasons, i.e. too small, damaged, exceeds capacity or replaced with higher value species (high grading). In the tropical tuna purse seine fishery, sets on floating objects have a higher rate of bycatch than sets on free-swimming schools (Fonteneau *et al.*, 2000, Dagorn *et al*. 2013) The fast growth in usage of artificial FADs since the mid-1990s has prompted a number of organizations to be concerned about the impact of FAD sets on non-tuna species, calling into question the environmental sustainability of this fishing method.

Since its inception in 2009, ISSF has dedicated considerable effort to better understand what the main issues of concern are in these fisheries, by using scientific information (primarily from scientific observer programs) to quantify relative impacts. At the same time, ISSF has (a) conducted at-sea research to investigate potential mitigation measures, (b) conducted workshops with purse seine skippers to share with them mitigation techniques and to seek their input about other potential mitigation measures, and (c) advocated for RFMOs to adopt mandatory data-collection and mitigation measures. A summary of these is given in the Section describing Related ISSF activities.

This document summarizes the main bycatch issues in tropical purse seine fisheries, with emphasis on FAD sets (and also sets on natural floating objects). These issues and known mitigation practices are presented separately by species groups, and mitigation practices are categorized according to their efficiency as either efficient (✓), not efficient (✗) or unknown (?).

Finally, a summary of ISSF activities related to bycatch is given.

[1] Different people use the term "bycatch" to mean different things, generally referring to whether or not the catch is retained or whether or not it was caught intentionally. Very generally speaking, bycatch is the catch of anything that is not the reason for which the skipper is fishing.

Issues and activities by species group

1.Sharks

The main shark species caught by tropical tuna purse seine fisheries are the silky shark (*Carcharhinus falciformis*), representing 90% of the shark catch, followed by the oceanic whitetip shark (*C. longimanus*) (Gillman 2011). Most stocks of silky sharks have not been assessed. According to the IUCN, the global status of silky sharks is Near Threatened, and the status of oceanic whitetip is vulnerable. Both species of pelagic sharks are also captured by a multitude of fishing gears including the pelagic longline fishery and some gillnet fisheries, which are responsible for high mortality of sharks, although scientific data documenting this are poor. Considering the importance of silky sharks in the purse seine catch, we mainly focus the description of the fishing impacts on this species.

In the Indian Ocean, recent estimates (Murua *et al.* 2013) have suggested that the total annual catch of silky sharks may reach close to 32,000 tons (caution should be used when considering this value, as it is largely based on extrapolations). Nonetheless, using this estimate and data from scientific observer programs in the purse seine fishery (from Dagorn *et al.* 2013), it is estimated that the contribution of purse seine fishing activities using floating objects represents approximately 4% of the total silky shark catch per year in this Ocean. The primary contribution of silky shark catch in this ocean comes from the gillnet fisheries (Murua *et al.* 2013).

In the Atlantic Ocean, total silky shark catch is estimated to be much lower than in the Indian Ocean, up to 455 tons annually (Murua *et al*. 2013). Purse seine sets represent about 38% of the reported silky shark catch, about 39 tons per year (based on reported ICCAT Task 1 statistics, 2010-2015 average). This compares to about 56% of the catch for longline fisheries using the same data. However, these estimates are highly uncertain because many purse seine and longline fishing countries do not report any silky shark catch, or do so inconsistently over time.

Estimates reported by Gilman (2011) indicate that the catch of silky sharks by purse seiners in the Pacific is about ten times lower than the catch by longliners. In the WCPO, data from Rice *et al.* (2013) show that the majority of silky shark catches correspond to longline fishing fleets (both targeted and non-targeted), while there are also significant impacts on the stock derived from purse seine fisheries. It is estimated that around 90% of silky shark catches in purse seine fishing activities occur during sets on floating object. In the EPO, according to Aires-da-Silva *et al.* (2013), silky shark catches in longline fisheries reach up to 14,000 tons (2008-2010 average), while purse seine catches for the same period are estimated to reach about 650 tons, (less than 5% of the total). Contribution from different purse seine fishing modes are estimated to be 70% from floating object-associated sets and 15% from both sets on free-swimming schools and dolphin-associated sets (IATTC 2013, IATTC 2014).

Despite being incidentally captured by the purse seine fishery, the catch of pelagic sharks in the fishery can be substantial and any efforts to reduce that mortality can contribute towards conservation of this sensitive species group. Three main issues related to purse seine fisheries have been identified.

1.1. ISSUES OF CONCERN

Observed catch

The shark bycatch-to-tuna catch ratio in purse seine fisheries is relatively small, on average, less than 0.5% in weight (**Figure 1**). However, given the global magnitude of catch of the purse seine fishery, a reduction of mortality incurred by this fishery can contribute towards global conservation efforts. The main species caught by the purse seine fishery is the silky shark (90% of caught sharks) and the oceanic whitetip shark and thus most conservation efforts have been directed towards these species. Although environmental NGOs often focus most of the attention on FAD fishing, it is noteworthy that in some regions (e.g. Atlantic Ocean, Western Pacific Ocean), the magnitude of shark bycatch ratios for free-swimming school sets and FAD sets are comparable. In contrast, shark bycatch in the Indian Ocean purse seine fishery is mainly from FAD associated sets (Figure 1).

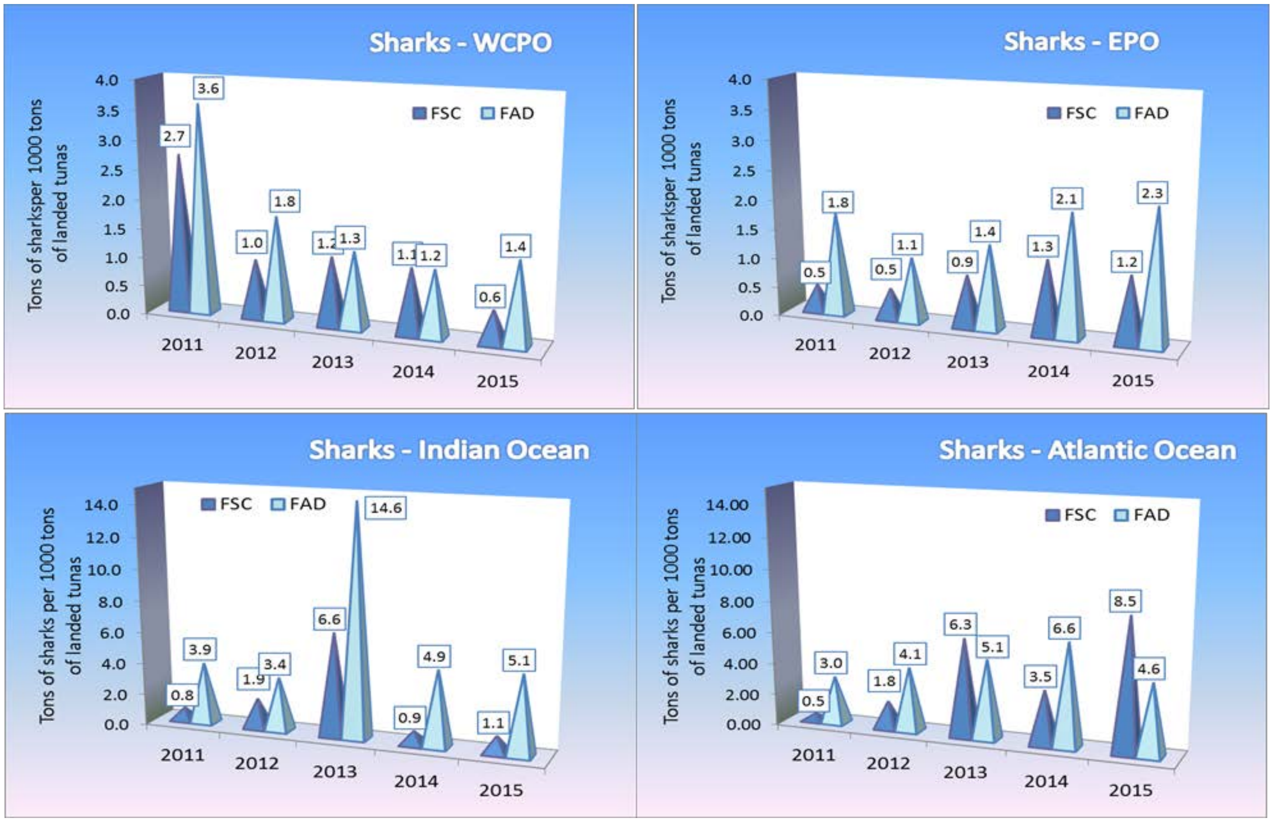

Figure 1: Tons of sharks caught by purse seiners per 1000 tons of landed tunas. Data from observer programs (SPC, IATTC, IRD, IEO-AZTI). FSC: free-swimming school sets. FAD: FAD and log sets

Unobserved mortality due to entanglement

Sharks can become entangled in the underwater netting added to drifting FADs by some fleets (Figure 2). This mortality was first considered to be negligible as there had been few observations of entangled sharks. However, observing entangled animals from the deck (by crews or observers) is nearly impossible. Such observations are only possible with remote cameras or divers making direct observations (underwater visual census) or when the entire FAD is lifted out of the water to observe the underwater structure. Moreover, it turns out that the sharks do not remain entangled for long (around one day) before dropping out of the net or being consumed. However, an assessment made in the Western Indian Ocean (based in part on observations obtained during ISSF at-sea research cruises in 2010-2012) showed that 0.5-1 million small silky sharks might die every year in this ocean due to entanglement in FAD netting (Filmalter *et al.*, 2013). The magnitude of this issue is not known in other oceans. Furthermore, not all fleets use the same type of FAD structure and netting; it is likely that netting with smaller mesh sizes will entangle fewer sharks.

Figure 2: Silky sharks entangled in the underwater netting of a FAD with large mesh size netting (i.e., of high entanglement risk).

Waste and poor data through finning

Some fisheries carry out "shark finning", which is the practice of cutting the fins off and discarding the carcass at sea. This practice is not only wasteful, but it also reduces the accuracy of catch statistics (amounts, species identifications) that scientists need in order to accurately assess all impacts of fishing on these shark populations. The use of fins to identify the different shark species and extrapolate shark biomass killed in fishing operations is approximate. Moreover, because fins can be very valuable, such practices could represent an incentive for fishers to increase bycatch of sharks (e.g. not releasing live sharks).

1.2. MITIGATION PRACTICES

Reducing observed shark mortality

	Approach	Description	References
✓	**Live release**	The EU MADE project, the ORTHONGEL-IRD bycatch mitigation project and the ISSF Bycatch project already found that following best practices onboard purse seine vessels to release live sharks from the deck can reduce the fishery induced mortality of silky sharks by 15-20%.	Poisson *et al.* 2014b Hutchinson *et al.* 2012 Filmalter et al. 2015 Good practices are described in Poisson *et al.* (2012 and 2014) and included in the ISSF Skippers' Guidebooks (Purse seine skipper's guidebook
✓	**Avoid setting on small schools**	By avoiding setting on small schools of tuna (e.g. < 10 tons), fishers could significantly reduce their catches of silky sharks by 20% to 40%, depending on the oceans.	Dagorn *et al.* 2012. Information on this mitigation measure is included in the ISSF Skippers Guidebook.
✓	**Release sharks from the net**	Fishing sharks from the net was tested in an ISSF research cruise in 2016 and preliminary results indicate that it could be a	Sancristobal *et al*. 2016.

		relatively simple and low-risk (to the catch and PS vessel's net) way of removing sharks from the net once they are encircled. Further testing and refinement of this method will continue on future ISSF research cruises	
✔	**Shift some effort to free-swimming schools**	In most regions, sharks are more commonly found in natural log and FAD sets than they are on free swimming schools. For a given amount of fishing effort, shifting to more free-swimming school sets will reduce the overall catch of sharks. For example, a 20% effort shift towards sets on free schools could decrease mortality by 16% in the western and central Pacific Ocean.	Peatman, T. and G. Pilling. 2016
✘	**Set time**	Fish don't always stay close to FADs as they sometimes make short excursions (lasting a few hours) away from FADs, and then return to the FADs. Through the simultaneous electronic tagging of tunas and sharks at FADs, we determined the periods during the 24-hour cycle when each species is usually present at the FAD, and when they are usually making an excursion. Unfortunately, at least in the Indian and Atlantic Oceans, ISSF research has shown that silky sharks and tunas exhibit very similar temporal patterns: they all make excursions away from FADs at similar times (usually during nighttime). Adjusting the fishing time in order to reduce catches of sharks while maintaining good catches of tunas therefore does not appear to be an effective solution, at least in the Indian and Atlantic Oceans.	Forget *et al*. 2013, Itano *et al*. 2016.

Altogether, the four actions above in combination can increase silky shark survival in purse seine fisheries by about 60%, and they would also increase the survival of other shark species (Restrepo *et al*., 2016b).

Reducing entanglement in FADs

	Approach	Description	References
✓	**FAD design**	The solution to entanglement is simple: Fishers should use non-entangling materials in the submerged and floating structures of FADs. In order to eliminate entanglement, this simply consists of completely avoiding the use of meshed materials when building FADs. Entanglement can also be substantially reduced by tightly wrapping the submerged nets with ropes, resulting in a tight cylinder ("sausage" or "chorizo"). It is noteworthy that the use of non-entangling FADs is likely to have avoided the mortality of between half a million and a million of small silky sharks in the Indian Ocean only. IATTC, ICCAT and IOTC have adopted measures for purse seine fleets to start using FAD designs that minimize entanglement (IATTC 17-02; ICCAT 16-01; IOTC 15/08).	Information on non-entangling FAD design is included in the ISSF Skippers Guidebook and the ISSF Guide For Non-Entangling FADs.

Reducing waste and improving data

	Approach	Description	References
✓	**Prohibiting finning**	Fishers should abandon the practice of finning. If fishers retain the sharks (where it is not prohibited by national or international legislation), they should retain both the fins and the carcass. Fishers should ensure that the information (discarded/retained) is recorded in the logbooks. This record-keeping can be greatly improved by the deployment of on-board observers. All tuna RFMOs have measures in place to prohibit shark finning by requiring that the landings of sharks conform to a ratio of fins to carcass weight. But this type of measure is ineffective because the actual ratios of fins to carcass can vary considerably depending on species and handling practices, and the ratios assumed by RFMOs can thus be quite inaccurate. ISSF advocates for RFMOs to prohibit shark finning and adopt measures requiring sharks be landed with fins naturally attached, unless their retention is prohibited, in which case they must be discarded. ISSF has also adopted a market-based resolution to prohibit shark finning by purse seine vessels (Conservation Measure 3.1).	ISSF Conservation measure 3.1

1.3. PLANNED ACTIVITIES

The ISSF Bycatch mitigation project will continue the tests to release sharks from the net, in order to confirm the efficiency and practicality of such a practice. ISSF also plans to test other ideas such as attracting sharks away from the FAD or options for time-area closures.

The ISSF Bycatch mitigation project is currently focusing on communicating the bycatch mitigation measures that have been tested during ISSF research activities to skippers worldwide. The two main tools used are approaching skippers directly at the Skipper Workshops organized by ISSF and the Skipper and Observer Guidebooks published by ISSF.

1.4. RFMO MEASURES IN PLACE

IATTC

General. Resolution 04-05 requires the release of non-target species caught in purse seine fisheries.
Sharks. Resolution C-16-04 discourages shark retention and establishes a limit in the amount of shark fins that can be landed, relative to the total weight of shark bodies that must be retained. This ratio of fin-to-body-weight acts as a disincentive to target sharks because the shark carcasses occupy hold space on the vessel and have little market value. The Resolution also mandates reporting of shark catches to IATTC. Resolution C-11-10 prohibits the retention of oceanic whitetip sharks and requires the release of specimens that are alive when caught. Resolution C-17-02 calls for a transition to non-entangling FADs in purse seine fisheries. C-16-05 calls for a workplan for completing full stock assessments of silky and hammerhead sharks, and requires catch data collection for those species. C-16-06 defines other shark conservation measures with an emphasis on silky shark.

ICCAT

General. Recommendation 16-01 requires a transition to non-entangling FADs.
Sharks. Recommendation 04-10 established a limit on the ratio of fin weight to total shark weight that can be retained onboard a fishing vessel, and encouraged the release of live sharks in fisheries that do not target sharks. Recommendation 07-06 limits mortality on porbeagle and North Atlantic shortfin mako. Recommendation 14-06 aims to improve data collection and reporting for shortfin mako. Recommendation 16-12 establishes limits on catches, aims to improve data collection and encourages scientific research on blue sharks. Recommendation 15-06 prompts CPCs to promptly release unharmed and to ensure the collection of Task I and Task II data for porbeagle sharks. Recommendations 09-07, 10-07, 10-08 and 11-08 prohibit the retention on board of bigeye thresher, oceanic white tip, several species of hammerhead sharks, and silky sharks. All of these measures have a reporting requirement associated with them (Recommendation 12-05 requires all parties in 2013 to report on their compliance with Recs. 04-10, 07-06, 09-07, 10-08, 10-07, 11-08, and11-15). Recommendation 10-06

prohibits the retention of shortfin mako onboard vessels flagged to countries that do not report catches for this species. Recommendation 16-13 prompts CPCs to submit details of their implementation of and compliance with shark conservation and management measures.

IOTC

Sharks. The IOTC has adopted measures that address shark conservation concerns. Resolution 17/05 established that CPCs shall take the necessary measures to require that their fishermen fully utilize their entire catches of sharks, with the exception of species prohibited by the IOTC. Resolution 12/09 prohibits the retention on board of all species of thresher sharks, a group that is thought to be particularly vulnerable due to its low productivity. In addition, Resolution 12/09 requires data reporting to IOTC, especially for fisheries targeting sharks. Resolution 13/06 prohibits the retention of oceanic whitetip sharks. Resolution 17/08 calls for a transition to non-entangling FADs in purse seine fisheries starting in 2014.

WCPFC

Sharks. CMM-2010-07 requires reporting of shark catches and discards by gear type and species. The measure also established a limit on the ratio of shark fins to total shark weight that can be retained onboard fishing vessels, and encourages the release of live sharks. CMM-2011-04 prohibits the retention on board of oceanic white tip sharks and CMM-13-08 does the same for silky sharks. For longline fisheries that target tunas and billfishes, CMM-2014-05 requires Members to either not use wire trace as branch lines or not use shark lines; for fisheries targeting sharks, it requires a management plan to limit shark catches. WCPFC initiated a research plan aimed at improving statistics and observer coverage on sharks and conducting assessments for key shark species (Clarke and Harley, 2010).

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2. Whale Sharks

Tropical tuna species are known to associate with large, slow moving animals, such as whale sharks (*Rhyncodon typus*). The association can form a true aggregation to the whale shark, as if it were a large, slow moving log or FAD, and other finfish bycatch species typical of floating object associations may be present (Hampton and Bailey, 1993; Bailey *et al.*, 1996). For this reason, sets where whale sharks are found are usually classified as "associated" or "floating object" (FAD) sets, even though a floating object or a FAD is almost never actually present. However, whale sharks also congregate in areas of high productivity to feed where tuna are also found feeding and fished by purse seine gear. The problem is that whale sharks are typically not visible prior to setting and subsequently become encircled together with the tuna. The incidental encircling of whale sharks has been documented in the tropical tuna purse seine fisheries of the Indian, east Atlantic, Eastern Pacific and Western and Central Pacific Oceans. Typically only one animal is involved per interaction but multiple animals may be encircled, particularly at feeding aggregations (SPC-OFP 2011). ISSF is working to promote best practices to avoid whale sharks and to utilize best practices for the release of whale sharks in good condition that become accidentally encircled during fishing operations while also recognizing crew safety issues.

2.1. ISSUES OF CONCERN

Whale shark interaction rates with tuna purse seine gear are very low. The WCPFC observer database recorded whale shark encounters in 155 of 88,084 observed sets (2008-2012 average) for a set encounter rate of 0.94% (Harley *et al*. 2013). The encounter rate according to the observer program in the Atlantic Ocean was about 1.5% of all sets with a very low apparent mortality rate (Capietto *et al*. 2014, Escalle *et al*. 2016) Although interaction rates are low, any level of fishing mortality is of concern due to their life history and ecological significance. Whale sharks are characterized by slow growth, delayed maturity, extended lifespan with a low reproductive potential (Compagno 1984). Furthermore, this species is listed as vulnerable by the IUCN (IUCN 2013), is listed under CITES and there is concern that whale shark populations are declining worldwide.

Whale shark interactions with purse seine gear result from both setting on tuna schools found in association with whale sharks and accidental encirclement when the sharks and tuna co-occur. It has been noted that whale shark-associated sets are likely to be under-reported in vessel logsheet data or misreported as to set type (SPC-OPF 2011). One explanation has to do with the fact that the animals are often not visible at the start of the set which is then logged as an unassociated set. The main concern is that when encircled, the slow-moving animals are not able to evade capture or capable of freeing themselves without considerable interaction from the crew.

Release techniques employed by purse seine crews vary widely. Methods that remove sharks from the water or vertically lift the sharks by the tail fin can inflict serious injury and are strongly discouraged by management bodies. Studies examining observer and logbook data report very low encounter rates overall and good condition at release with apparent high survival rates (Capietto *et al.* 2014). However, post–release survival needs to be scientifically verified with pop-up satellite tags and tested across a variety of release methods in all oceans to develop best practices for release techniques proven to maximize post-release condition. Recent studies of this type have suggested that whale sharks released from purse seine gear using best practices have a high rate of survival, but further studies are needed (Escalle *et al*. 2016 and Escalle *et al*. 2017b).

2.2. MITIGATION PRACTICES

	Approach	Description	References
✓	**Avoidance**	Avoidance of whale sharks during fishing operations is a simple mitigation concept but often impossible to achieve if the animals are not visible prior to encirclement, which is often the case.	

		Three RFMOs (IOTC, IATTC, WCPFC) currently have management measures that prohibit the intentional setting of purse seine gear around a whale shark if the animal is detected prior to setting (IATTC Res C-16-01; IOTC Res 13/05; WCPFC CMM 2012-04). In the event that a whale shark is encircled for any reason, the vessel master is required to ensure that all reasonable steps are taken to ensure its safe release and report the incident as required by the relevant authority.	
✗	**Time/area closures**	The presence of whale sharks in each fishery appears to vary by area and season, with the exception of the Atlantic Ocean, where the interactions with whale sharks occur in a restricted spatial and temporal window (i.e. Gabon upwelling). Overall, encounter rates are so low and variable between years that time/area closures have not been considered an effective mitigation tool. Instead, RFMOs have moved toward developing best practices for the safe release of whale sharks and mandating their use while also recognizing the safety of the crew.	Capietto *et al.* 2014
✓	**Release from the net**	Best practice guidelines for release of whale sharks from the net provide a set of options to apply depending on several factors, including the environmental conditions and sea state; the size/weight of the catch, the size and orientation of the whale shark (facing to bow or stern); and the brailing style employed (with or without skiff). Best practices developed for the release of whale sharks generally propose a list of do's and don'ts considering issues of crew safety and minimizing impact to the shark. In some cases, cutting the lacing between the corkline and net or the net itself may be the safest way to release a whale shark if conditions are favorable. Passively rolling the shark out of the sack or bunt end of the net is generally accepted to be a highly desirable, low-impact method of releasing whale sharks that is relatively safe for the crew. However, these release methods require retrieving the net and drying of the bunt end to facilitate release	See a list of handling *do's* and *don'ts* in ISSF Purse Seine Skippers' Guidebook. See Escalle *et al*. 2016 for detailed descriptions of whale shark release methods.

2.3. PLANNED ACTIVITIES

The ISSF Bycatch Mitigation Project supports the opportunistic satellite tagging of whale sharks during ISSF funded or sponsored research cruises. However, the rarity of whale shark encounters in the fishery will limit observations. Although rare, when interactions occur ISSF promotes the adoption of best practices techniques for the safe release of whale sharks from purse nets as outlined in Poisson *et al.* (2012). Relevant section of this and similar publications have been duplicated and incorporated into outreach and training materials and venues, such as the ISSF Skippers' Guidebook to Sustainable Purse Seine Fishing Practices and at ISSF Skippers' Workshops.

2.4. RFMO MEASURES IN PLACE

IATTC
General. Resolution 04-05 requires the release of non-target species caught in purse seine fisheries.
Whale sharks. Resolution C-16-01 prohibits deliberate setting on whale sharks.

ICCAT
None.

IOTC

Whale sharks. Resolution 13/05 prohibits intentional purse seine setting on tunas associated with whale sharks.

WCPFC

Whale sharks. CMM-2012-04 prohibits deliberate purse seine sets around whale sharks and requires reporting of interactions. From December 2015 the Commission endorses the whale shark handling guidelines from its Technical and Compliance.

3. Rays

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. The giant manta ray (*Manta birostris*) and spinetail devil ray (*Mobula japanica*) are often cited as uncommon bycatch to purse seine fisheries, but several species of Mobulid rays may interact with purse seine gear, i.e. *Mobula tarapacana*, *M. munkiana*, *M. thurstoni* (Scott and Hall 2014).

Rays are rarely captured in tuna purse seine gear, generally less than 0.1% by weight and therefore considerably less than shark catch (Figure 3). In contrast to other non-target species that interact with purse seine gear, rays are mostly taken in free-swimming school sets in all oceans.

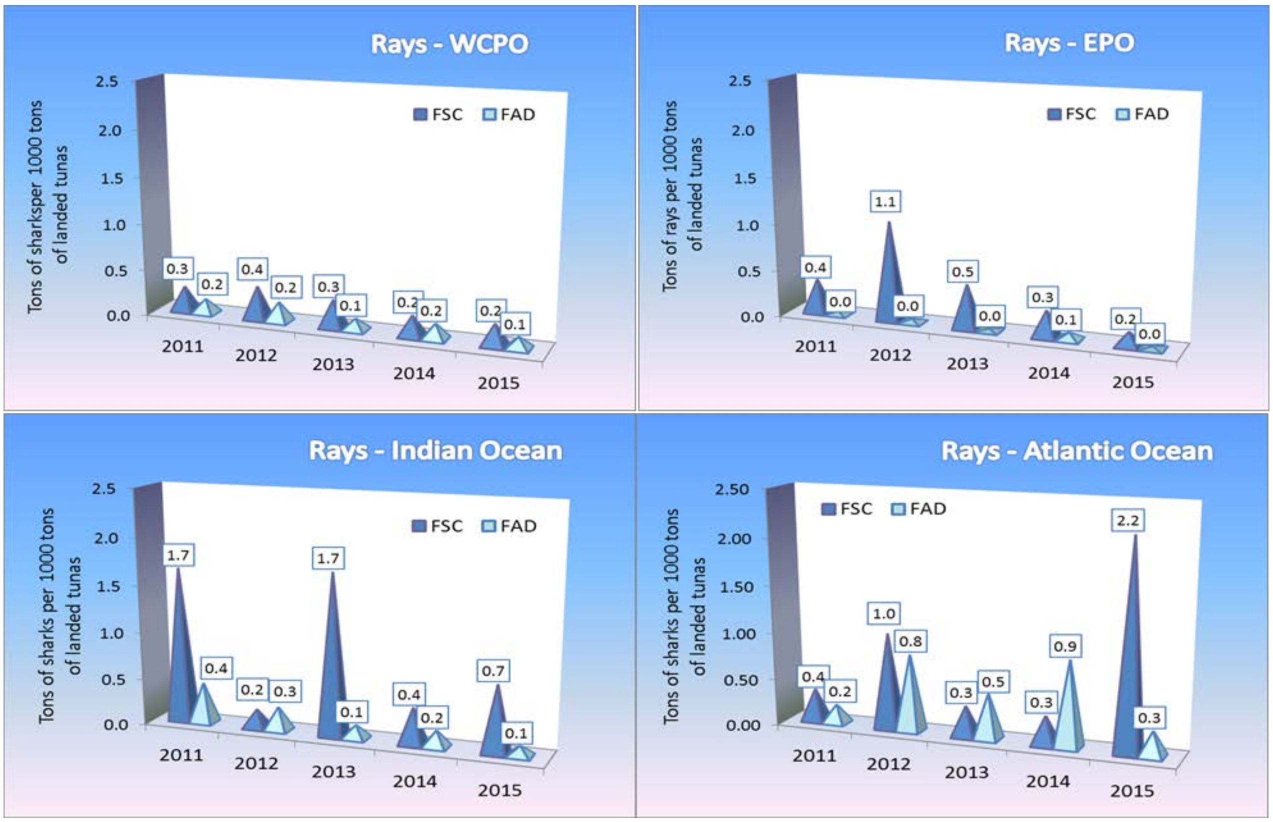

Figure 3. Tons of rays caught by purse seiners per 1000 tons of landed tunas. Data from observer programs (SPC, IATTC, IRD, IEO-AZTI). FSC: free-swimming school sets. FAD: FAD and log sets

3.1. ISSUES OF CONCERN

Mobulid ray species have slow population growth rates and have been listed by the IUCN as Near Threatened, Vulnerable or Data Deficient (IUCN 2013). Manta rays are known to be targeted by some artisanal fisheries in several locations worldwide for fins, leather products, meat and gill rakers which are used for medicinal purposes and fetch a high market value. Such artisanal fisheries are often poorly monitored and consequently, rarely managed. Large manta and devil rays are also incidentally captured through entanglement in longlines, gillnets, drift and pound net gear.

The giant manta can reach 9 m in width and exceed 1,000 kg in weight. Releasing such large animals from purse seiners can be extremely difficult and pose a safety hazard to the crew.

3.2. MITIGATION PRACTICES

	Approach	Description	References
✓	**Release from the net or deck**	Minimizing fishery impacts to manta and devil ray population mirrors efforts to conserve whale sharks through the development and promotion of best practices techniques for safe release. However, in the case of rays, release from the deck is also seen as a viable alternative to releasing from the net, especially for smaller individuals. Most of the recommended best practices for release outline procedures that minimize injury risks for the animals while ensuring the safety of the crew. It is recommended to avoid the use of hooks, wires or tightening slings; lifting or dragging by the gill slits or cephalic lobes. Rays that are scooped onboard the vessel should be returned to the sea as quickly as possible, either by carefully lifting by the side of the wings, using a ramp to an opening on the side of the vessel or lowering to the water using a large-mesh net or canvas cargo net. Purpose-built release nets should be ready in the event that large rays are taken. Direct release of large rays from the brailer is another option. It should be noted that post-release survival of released manta and devil rays has not yet been investigated. Studies using pop-up satellite tags to verify post-release survival should be conducted to better determine the potential impacts of these interactions in the fishery.	Poison *et al.* 2012, ISSF Skippers' Guidebooks

3.3. PLANNED ACTIVITIES

Specific activities to mitigate manta and devil ray bycatch and impact are not currently planned. However, best practices for the safe release of rays will be tested and evaluated if large rays are accidentally captured during ISSF research cruises. ISSF will continue to develop and promote safe release techniques through the work of the ISSF Bycatch Mitigation Project and dissemination of outreach and training materials and at ISSF Skippers Workshops.

3.4. RFMO MEASURES IN PLACE

IATTC
General. Resolution 04-05 requires the release of non-target species caught in purse seine fisheries.
Rays. Resolution C-15-04 requires CPCs to prohibit retaining onboard, transshipping, landing, storing, selling, or offering for sale any part or whole carcass of Mobulid rays and to release all Mobulid rays alive wherever possible.

ICCAT
None.

IOTC
None.

WCPFC
Rays. From December 2015 the Commission endorses the rays handling guidelines from its Technical and Compliance committee.

4. Finfish

In addition to the target tropical tuna species (skipjack, yellowfin and bigeye tuna), several fish species are also caught by purse seiners, primarily when fishing on FADs. The main finfish species are other small tuna species such as kawakawa (*Euthynnus affinis*), frigate tuna (*Auxis thazard*), bullet tuna (*Auxis rochei*), or non-tuna species like mahi-mahi (*Coryphaena hippurus*, Figure 4), oceanic triggerfish (*Canthidermis maculata*, Figure 4), rainbow runner (*Elagatis bipinnulata*) and wahoo (*Acanthocybium solandri*). Globally, these species are the major finfish bycatch species of the tropical purse seine fishery.

Figure 4: Mahi-mahi (left) and oceanic triggerfish (right), two of the main bycatch species of the tropical tuna purse seine fishery.

The catch of finfish bycatch come mainly from sets on both anchored and drifting FADs as well as logs in the WCPO (Figure 5a) and from drifting FADs and logs in the Indian, Atlantic and Eastern Pacific Oceans (Figures 5b-d). Catches of small non-target tuna species (kawakawa, frigate tuna, etc.) can be significant in both free-swimming school and FAD sets in some areas, particularly in highly productive areas (e.g. coastal waters). The catch of the small tunas and finfish bycatch is relatively higher in the Atlantic Ocean (Gulf of Guinea) fishery when compared to other oceans (Figure 5c) on FADs. However, those species are targeted and marketed in the Atlantic Ocean fishery, (associated to the "faux-poisson" market, which is a local market based on these fish, see (Romagny *et al.*, 2000; Chavance *et al.* 2014; Amandé *et al*., 2016a, 2016b), which may contribute to such high landings. It is noteworthy that several finfish species are often targeted by tropical purse seine fisheries in the Philippines, Indonesia and Vietnam.

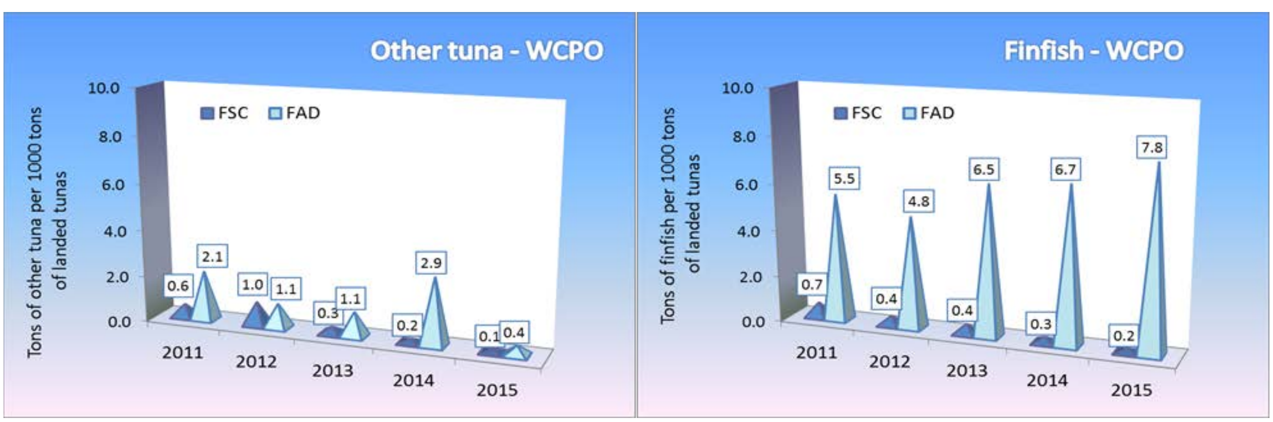

Figure 5a: Tons of other tunas (L) and finfish (R) per 1000 tons of landed tunas in the WCPO

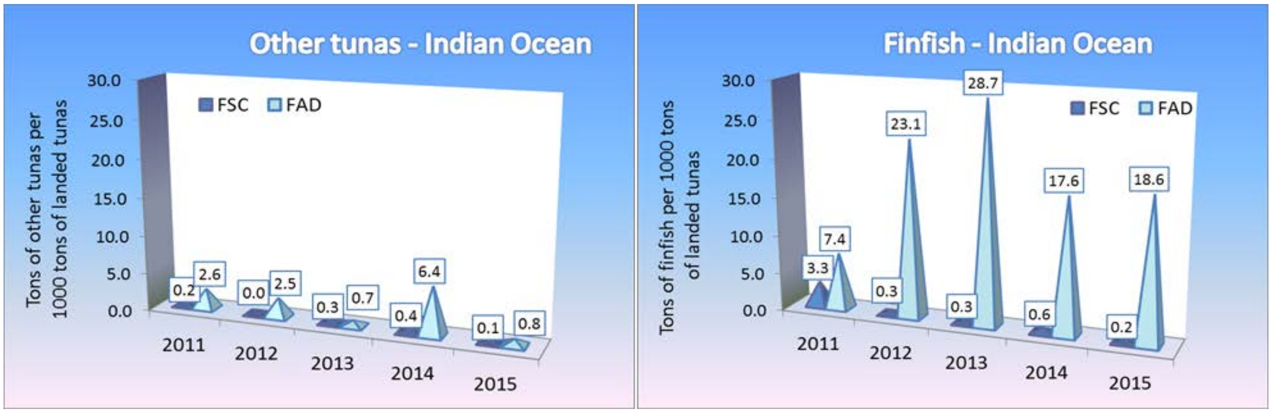

Figure 5b. Tons of other tunas (L) and finfish (R) per 1000 tons of landed tunas in the IO

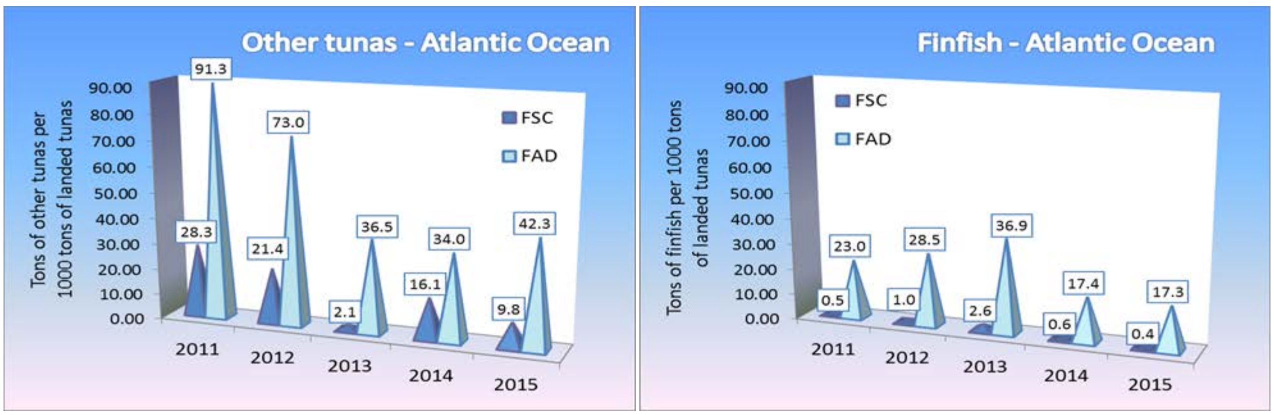

Figure 5c: Tons of other tunas (L) and finfish (R) per 1000 tons of landed tunas in the AO

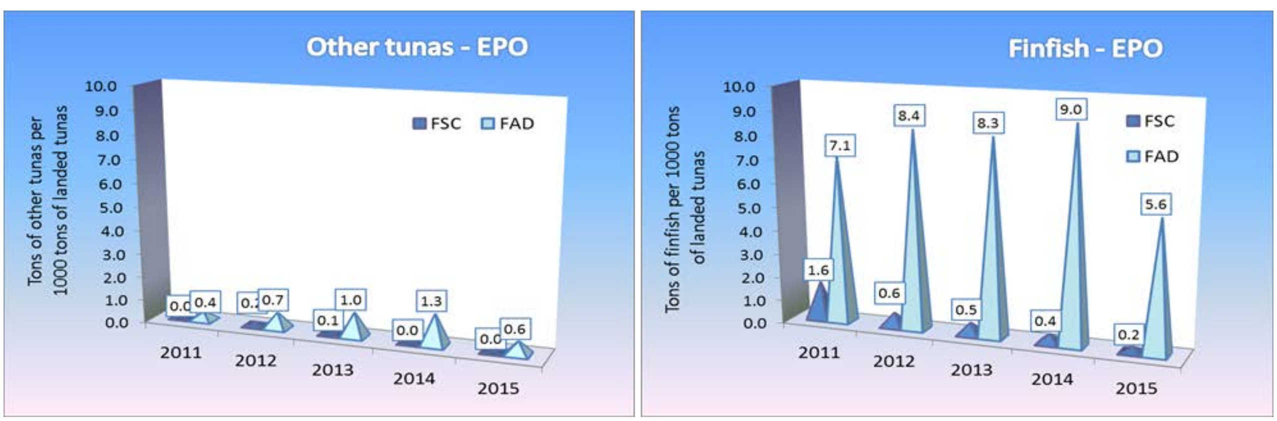

Figure 5d: Tons of other tunas (L) and finfish (R) per 1000 tons of landed tunas in the EPO

4.1. ISSUES OF CONCERN

Tuna RFMOs regularly assess and manage target tuna stocks as well as billfishes and some species of sharks. With some exceptions, no stock assessment is available for the other fish species caught in tuna fisheries. Because of this, key biological parameters of some of these species are unknown. Nevertheless, most of these species are believed to be fast-growing and have early sexual maturity and high fecundity (but note the comments below about biological parameters), which make them more resilient to overfishing than other species.

Waste

A large portion (75% to 95%) of the catch of non-target tunas in purse seine sets on floating objects corresponds to minor tuna species and other bony fishes. In some cases, these are utilized to a minor extent, e.g. to be eaten by the crew. In other cases, such as in the Atlantic purse seine fishery (Abidjan, Ivory Coast), local markets have developed to commercialize these fish (Romagny *et al*., 2000; Chavance *et al.* 2014; Amandé *et al*., 2016a, 2016b) and this explains why the catch ratio relative to target tunas is so high in the Atlantic (**Figure 5c**). But, in most cases, minor tunas and other finfish end up being discarded at sea, which is a wasteful practice that undermines the FAO Code of Conduct for Responsible Fisheries (FAO, 1995). Food security is an important issue in aligning ecosystem health with societal needs (GPO, 2013). However, creating new markets to utilize these fish is not a simple task (Lewis, 2016). Options have to be evaluated for different locations. For example, the landing of 20 tons of minor tunas by a purse seiner in a small island could create intense market competition and conflicts with artisanal and subsistence fishers.

Very selective fisheries versus balanced harvesting

A debate currently exists in the scientific community between proponents of highly-selective fisheries (by species and size, which has been a paradigm in the past) and those of fisheries that would exploit many species and size ranges, proportionally to their productivity, in order to respect the structure of the ecosystem. Garcia *et al.* (2012) consider that balanced fishing across a range of species, stocks, and sizes could mitigate adverse effects, help maintain the structure of the ecosystem and address food security better than increased selectivity. While MSY is a target for fisheries catching a single species, the management of fisheries that catch many species is challenging, as every species does not have the same productivity or vulnerability to fisheries which results in different levels of impact from fishing pressure.

4.2. MITIGATION PRACTICES

	Approach	Description	References
✓	**Technical solution to reduce overall bycatch of purse seiners**	By avoiding setting on small schools of tuna (e.g. < 10 tons), fishers could significantly reduce their impacts on non-target species. While the total catch from these sets (< 10 tons) appears minor (approximately 3%–10% depending on the ocean), they contribute to a large portion of the total bycatch (e.g., non-target species; 23%–43%). Higher ratios were observed in the Atlantic Ocean, which is likely a result of the existence of a local market for bycatch (called “faux-poisson”) that could represent an incentive for fishers to set more often on FADs that have little or no target tuna (hence, in these cases it is unreasonable to consider these species as "bycatch", since they are being targeted).	Dagorn *et al.* 2012 Romagny *et al.* 2000 ISSF Skippers Guidebook
✓	**Retention and utilization**	Three RFMOs already require mandatory retention of target tuna species caught by purse seining in order to reduce discards and improve utilization as well as data collection. This action is aimed at modifying fisher behavior to avoid setting on floating objects with a high percentage of small tuna. Retaining bycatch of other resilient species onboard can be a solution to avoid wasting resources that are caught, and can increase food security in some regions. It is also an indirect solution to reduce the amount of bycatch, as fishers prefer to fill their wells with valuable target species. This measure can also	Amandé *et al*. 2016a, 2016b

		improve sampling of bycatch species in port, providing very useful information on biological parameters as well as better estimates of bycatch amounts. However, crews must be trained to retain dead bycatch and release live animals as this practice can increase, if badly used, the mortality of some bycatch species that could be released alive from the deck. Vessels must also be equipped with conservation and storage facilities to preserve the bycatch species in marketable condition. The retention practice could also create new markets, which, in some cases, could increase the demand in those species, or affect existing local markets. For these reasons, full retention measures need to be studied carefully before they are implemented.	

4.3. PLANNED ACTIVITIES

The ISSF Bycatch project is collecting data and supporting research on the biology and FAD behavior of major bycatch species (e.g. oceanic triggerfish, rainbow runner) that are poorly known. Analyses to-date of the daily FAD-associative behavior of oceanic triggerfish and rainbow runner in contrast to target tuna species, show that it could be possible to reduce the catch of these species by adapting the time of day when sets are made. This is because the peak times of presence at FADs of these species and those for tunas appear, at least in some oceanic regions, to differ. However, more tests are needed in different ocean regions and research is ongoing.

ISSF is also conducting pilot studies in major landing and transshipment ports throughout the world to better understand how the catch of finfish could be better utilized for food security (Lewis, 2016).

4.4. RFMO MEASURES IN PLACE

IATTC
General. Resolution 04-05 requires the release of non-target species caught in purse seine fisheries.

ICCAT
None.

IOTC
Resolution 17/04 requires that purse seine vessels retain and land, to the extent practicable: Other tunas, rainbow runner, dolphinfish, triggerfish, billfish, wahoo, and barracuda, except fish considered unfit for human consumption.

WCPFC
None.

5. Sea turtles

Marine turtles have life histories that make them highly vulnerable to fishing. They are also protected by many national and international treaties and regulations. Several turtle species can be found around floating objects depending on area, the most common being the Olive Ridley turtle (*Lepidochelys olivacea*). Sea turtles are caught in very small numbers (from a few tens up to a couple of hundreds of individuals per year in every ocean) by purse seiners and most of them (> 90%) are released alive relatively easily. The mortality of turtles due to being captured by the seine can be considered negligible (Amande *et al.*, 2010, Gilman 2011, Dagorn *et al.* 2013, Hall & Roman 2013). Nevertheless, while their catches in purse seine fisheries are insignificant compared to other fishing methods, any efforts to avoid fishing mortality will aid in their conservation.

5.1. ISSUES OF CONCERN

Unobserved mortality due to entanglement

Turtles can get entangled in the nets covering the bamboo rafts that form traditional FADs. While turtles can get trapped in the submerged netting, they can also entangle when they climb on the floating structure. No estimate of such mortality has been obtained so far, although it is likely to be extremely low compared to mortality from other fishing gears.

5.2. MITIGATION PRACTICES

Reducing entanglement in FAD structures

	Approach	Description	References
✓	**FAD design**	To avoid the entanglement of turtles in FAD netting, the solution is simple. Fishers should use non-entangling FADs. To reduce entanglement of turtles on the FAD itself, the surface structure should not be covered or only covered with non-meshed material. If the surface structure is covered, log-shaped (i.e. cylindrical) or spherical floats naturally deter turtles from climbing onto the device, and should be used in preference to flat rafts. IOTC, IATTC and ICCAT have adopted measures for the fleets to start changing towards FAD designs that minimize entanglement.	ISSF Guide For Non-Entangling FADs ISSF Skippers Guidebook
✔	**Release from the net or deck**	Releasing turtles alive from the deck is already a well-established practice in industrial purse seine fisheries. The majority of these turtles survive.	Poisson *et al*. 2012 Hall and Roman. 2013 ISSF Skippers Guidebook

5.3. PLANNED ACTIVITIES

ISSF plans to continue to document turtle entanglement in FADs during its bycatch mitigation research cruises.

5.4. RFMO MEASURES IN PLACE

IATTC

General. Resolution 04-05 requires the release of non-target species caught in purse seine fisheries.

Sea Turtles. Resolution C-07-03 requires fishermen to release sea turtles entangled in FADs or caught in longlines and to avoid encircling them with purse seine nets. The resolution also calls for research to mitigate sea turtle bycatch, especially with gear modifications. Resolution C-16-01 calls for a transition to non-entangling FADs in purse seine fisheries.

ICCAT

General. Recommendation 16-01 requires a transition to non-entangling FADs.

Sea Turtles. Recommendations 10-09 and 13-11 set up reporting requirements for sea turtle interactions and mandates its scientific committee to assess, by 2014, the impact of tuna fisheries on sea turtle populations. The measure has specific requirements for longline operators to be trained on appropriate handling and release of live turtles so as to maximize their survival.

IOTC

Sea Turtles. Resolution 12/04 (which supersedes various prior measures) requires IOTC members to mitigate sea turtle mortality and to provide data on turtle bycatch to the SC. The measure has specific requirements for longline and purse seine operators to facilitate the appropriate handling and release of live turtles. Resolution 17/08 calls for a transition to non-entangling FADs in purse seine fisheries starting in 2014.

WCPFC

Sea Turtles. CMM 2008-03 instructs WCPFC members to implement the FAO (2009) guidelines for reducing sea turtle mortality, and requires longline operators to use line cutters and de-hookers to handle and promptly release sea turtles caught or entangled. The measure also requires purse seine operators to avoid setting on turtles if possible and to disentangle/release them when caught alive.

6. Billfish

Billfish are also caught by purse seiners in addition to the tropical tuna species. Among species caught are Black marlin (*Istiompax indica*), Blue marlin (*Makaira nigricans,* Figure 6), Striped marlin (*Kajikia audax*), White Marlin (*Kajikia albida*), Swordfish (*Xiphias gladius*) and Sailfish (*Istiophorus albicans, Istiophorus platypterus*).

Total catch of billfish by tropical tuna purse seine fisheries worldwide is negligible in comparison to catches by longline fleets, which capture billfish both as target species and as bycatch (Justel-Rubio and Restrepo 2015). For this reason, bycatch of billfish in purse seine fisheries is not an issue of priority.

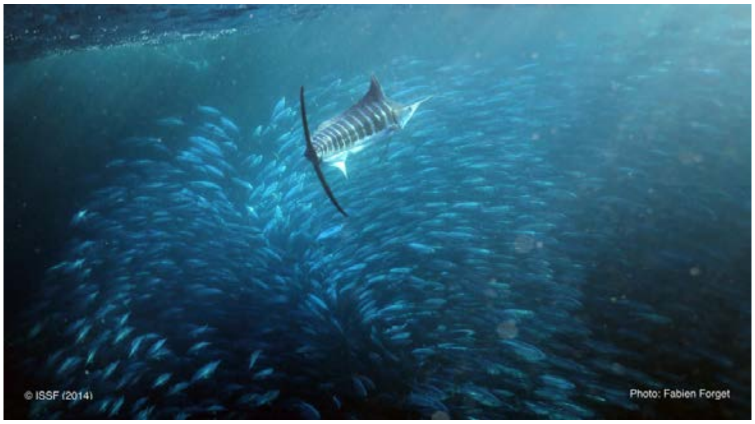

Figure 6. Blue marlin in a skipjack tuna school.

Billfish are more often caught as bycatch in purse seine fisheries in the Atlantic Ocean, while encounters are significantly lower in other regions like the Indian Ocean. Billfish are predominantly caught in sets associated with floating objects, although in some regions (e.g. WCPO) catches in both associated and free-school sets are similar, with annual ratios sometimes being higher in unassociated sets (Figure 7).

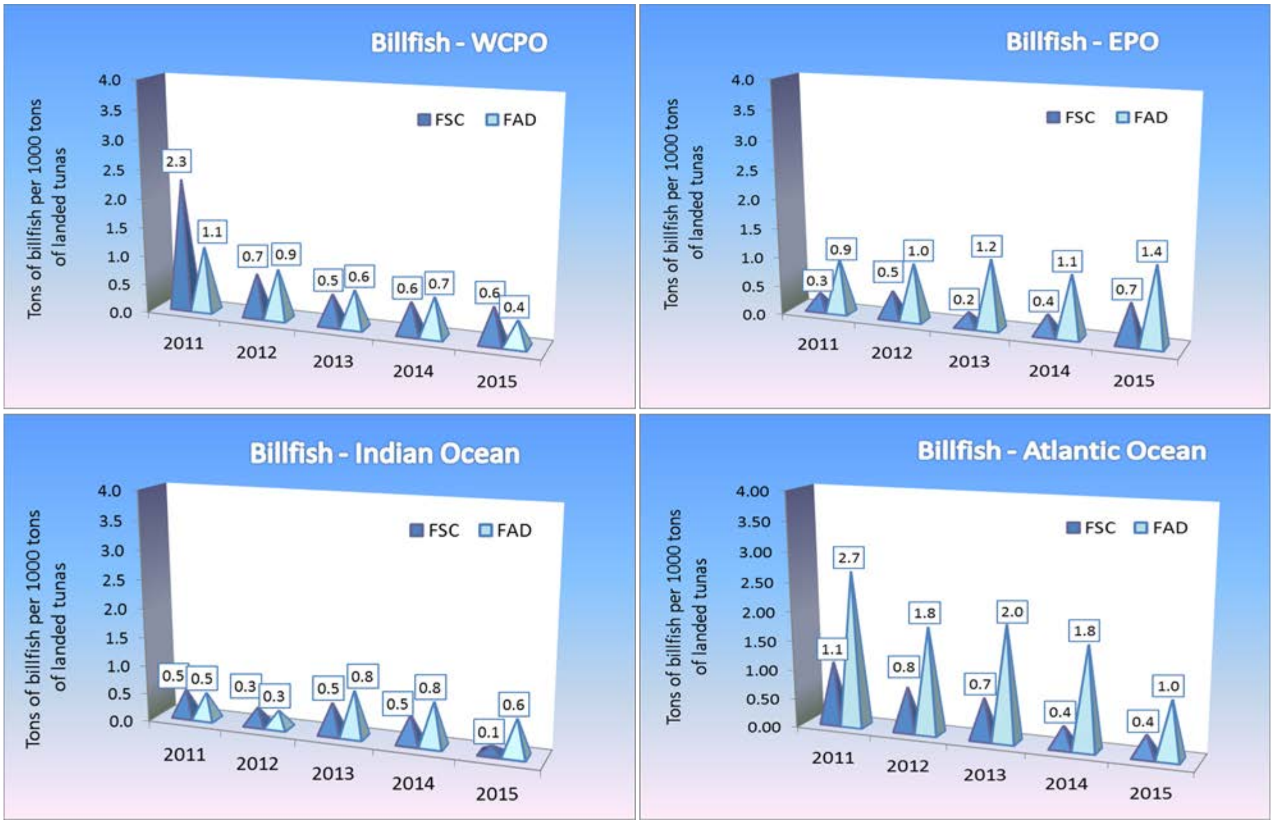

Figure 7. Tons of billfish caught by purse seiners per 1000 tons of landed tunas. Data from observer programs (SPC, IATTC, IRD, IEO-AZTI). FSC: free-swimming school sets. FAD: FAD and log sets

6.1. ISSUES OF CONCERN

Observed catch

Billfish are a common bycatch of purse seine fisheries targeting tuna. RFMOs have conducted stock assessments for some billfish species, however, these assessments have not been performed for all stocks. One of the problems RFMOs face when trying to assess the status of billfish species is that commercial catches have frequently been reported in aggregated form for more than one billfish species, increasing uncertainty in historical single species catch statistics and stock assessments (Justel-Rubio and Restrepo 2015).

6.2. MITIGATION PRACTICES

	Approach	Description	References
?	**Time/area closures**	Implementation of time-area closures that avoid bycatch hotspots could potentially decrease billfish mortality in purse seine fisheries. However, currently no FAD moratorium exists that was developed to avoid billfish bycatch.	Escalle *et al*. 2017a
✓	**Limitation on catches**	Three RFMOs already established catch limits for some billfish species: ICCAT adopted a rebuilding plan with catch limits by country for blue and white marlin, IOTC members are required to make any possible effort to reduce the level of catches of striped marlin, black marlin and blue marlin and the WCPFC set a cap on	

		the catch of striped marlin. All three RFMOs have also conservation measures in place for swordfish stocks.	
✓	**Retention and utilization**	Mandatory retention of billfish caught as bycatch (except in cases where retention is prohibited) would result in a decrease of discards with the consequent reduction in waste of resources. In addition, it would improve data collection, providing very useful information on biological parameters as well as better estimates of bycatch amounts.	

6.3. RFMO MEASURES IN PLACE

<u>IATTC</u>
General. Resolution 04-05 requires the release of non-target species caught in purse seine fisheries.

<u>ICCAT</u>
Billfish. Longliners and other fisheries also take Atlantic blue and white marlin as bycatch, both of which are thought to be overfished. ICCAT adopted Recommendation 06-09, later superseded by 15-05, a rebuilding plan with catch limits by country.

<u>IOTC</u>
Billfish. Resolution 15/05 requires IOTC members to make any possible effort to reduce the level of catches of striped marlin, black marlin and blue marlin in 2016. The baseline of the reduction of catches shall be the average catches for the period between 2009 and 2014. It also requires the release of specimens of those species if brought alive on board.

<u>WCPFC</u>
Billfish. Striped marlin are also caught as bycatch in longline fisheries; this species is of more concern because it has been declining in abundance. The WCPFC adopted CMM 2010-01 which sets a cap on the catch of striped marlin for each member relative to historical levels.

7. Juvenile bigeye and yellowfin tuna

While not really bycatch species in tuna fisheries, we include small bigeye and yellowfin tuna in this report because of concerns that large numbers of small bigeye and yellowfin are caught in association with FAD sets, and how this contributes to overfishing of some bigeye and yellowfin stocks.

Bigeye and yellowfin tuna are caught by many tuna fisheries and gear types. Large mature individuals are targeted by longline fisheries while smaller fish (typically juveniles) are caught by purse seine, pole-and-line and handline fisheries. Of the three tropical tuna species, bigeye has slower growth rates, higher longevity and higher age at maturity, which makes this species more vulnerable to fishing pressure. In the last decade, the FAD-based fisheries targeting skipjack tuna have intensified and, consequently, they also yield higher catches of small bigeye and yellowfin. Globally, the catch composition on floating objects contain 10% bigeye, while global catches from free-swimming school sets contain 2% bigeye (Restrepo *et al*., 2017).

7.1. ISSUES OF CONCERN

The public debate about bigeye conservation is at times confusing because two different elements are mixed: The catch of juveniles (immature fish) and the catch of undesirably small fish.

Juvenile bigeye and yellowfin

Practically all fishing gears catch juvenile tunas (immature individuals), but some catch more than others.

Bigeye tuna attains sexual maturity around a size of 119 cm and yellowfin at around 97 cm (although actual estimates of size at maturity vary by region and by study). A high percentage of the bigeye and yellowfin tuna catch in purse seine sets on FADs corresponds to juvenile individuals, similarly to pole and line catches in all ocean regions. Juvenile bigeye and yellowfin are also caught in purse seine sets on free-swimming schools and in longline fisheries, but in a lower proportion (Restrepo *et al*. 2017).

There are two potential impacts from catching juvenile tunas: Overfishing and loss in potential yield.

Many people believe that catching juveniles automatically leads to overfishing. But this is not necessarily the case. A stock can be overfished by catching too many juveniles, too many adults or too many of both. In a way, catching adults impacts the reproductive potential of the stock in the short term while catching juveniles impacts reproduction at some time in the future.

Catching fish of different sizes leads to changes in potential yield. From a theoretical point of view, there is an optimum size at which the maximum sustainable yield (MSY) would be highest if all the fish were caught at that size, depending on the life history of the species (growth, maturity, natural mortality and spawner-recruit relationship). This optimum can never be achieved exactly because it is not possible to design a fishing gear that will catch all the tuna at the same size. But, there are fisheries whose size selectivity will be close to this optimum size and, if those fisheries are the main source of fishing for the stock, then MSY will be close to the theoretical optimum. In contrast, if the main source of fishing is from fisheries that catch fish of sizes away from the optimum (either too small or too large), then MSY will be less than the optimum (Restrepo *et al*. 2017). In order to address this situation, it is necessary that RFMOs establish management objectives for tropical tuna stocks in which the targets and limits for each gear type are clearly articulated. This is largely an allocation exercise, and not a technical one. A study of the management of tuna and billfish stocks by RFMOs found that implementing and enforcing total allowable catches (TACs) had the strongest positive influence on rebuilding overfished stocks (Pons *et al*., 2017). Similarly, at a Global Science Symposium on FADs, a large number of experts suggested setting catch limits specifically for juvenile tunas caught by purse seine operations, particularly of overfished stocks (Hampton *et al.*, 2017).

7.2. MITIGATION PRACTICES

The three main tropical tuna species, skipjack, bigeye and yellowfin typically co-occur at FADs. Thus, one of the challenges that purse seine fleets working with FADs are facing worldwide is being able to capture skipjack, the main tropical tuna species targeted and in healthy condition worldwide, while avoiding bigeye and yellowfin, in those areas where there is a need for the conservation of these tuna species. Finding a technical solution for selective fishing at FADs combined with incentives to avoid undesired catches could be the mean to minimize bigeye and yellowfin catches.

	Approach	Description	References
?	**Shift some effort to free-swimming schools or reduce number of FAD sets**	Small yellowfin and bigeye are caught in greater proportion on floating object sets than in free-swimming school sets. Thus, for a given number of sets, shifting to a greater proportion of school sets would result in lower catches of small bigeye and yellowfin. Note, however, that this is not so easy to implement. For example, effort targeted at FADs that is prohibited during a season or in an area could redistribute to other areas and seasons. Also, in some cases, a shift towards more school sets could put more pressure on larger yellowfin which are targeted in free-swimming schools.	
✓	**Setting catch limits by gear and enforcing them**	RFMOs could set TACs for the different fisheries that target yellowfin and bigeye tunas, ensuring they are respected. This would require the setting of clear management objectives for the stocks. A study of the management of tuna and billfish stocks by RFMOs found that implementing and enforcing total allowable catches (TACs) had the strongest positive influence on rebuilding overfished stocks (Pons et al., 2017).	Pons *et al*., 2017; Hampton *et al*.; 2017
?	**Technical measures to reduce catch combined with (dis) incentives**	The significant difference and difficulty between reducing catches of small bigeye and yellowfin tuna and other species of concern in purse seine fisheries (e.g. sharks) is that bigeye and yellowfin tuna are targeted and regularly marketed by the fishery, like skipjack tuna. From a fishers' perspective, catching a school of small bigeye or yellowfin tuna yields profits, on a similar level as a school of skipjack tuna. The priority is therefore to find technical solutions in which the catches of bigeye and/ or yellowfin could be reduced for those stocks that are being overfished, and to create disincentives or incentives to force or motivate fishers to implement these techniques, such as adjusting the relative prices of small bigeye, small yellowfin and skipjack tuna.	
?	**Selective fishing using acoustics**	The fact that the 3 main tropical tuna species are found together at FADs makes it difficult for fishers to avoid certain species that may be subject to a quota (bigeye, yellowfin) while they continue catching skipjack tuna, for which stocks are considered to be in good condition. One of the technical tools under research to be used for selective fishing at FADs is the acoustic discrimination of tuna species.	Moreno *et al*. 2017a, 2017b

		Acoustics are widely used in tuna fishing in every fleet, the possibility of knowing the species composition at FADs would allow fishers to avoid those areas or FADs where the presence of undesired species is high while approaching those FADs with higher proportions of skipjack tuna. ISSF is working on the acoustic signature of the 3 main tropical tuna species, which were unknown, as well as on their acoustic response to different frequencies which would be the means for tropical tuna species discrimination.	
?	**Time/area closures**	Time/area closures can be an effective way to reduce the catch of a species in certain situations. ICCAT (Rec. 16-01), WCPFC (CMM 2016-01) and IATTC (Res. C-17-01) have adopted time/area closures to reduce the catch of small bigeye tuna by purse seine fisheries, but the efficacy of these is still not obvious. The movement, dispersion and mixing of bigeye tuna can be quite extensive and therefore the benefits of a closure can easily erode if the fish eventually move to be caught outside the area. For tropical tunas, spatial closures probably need to be very large in order to reduce fishing mortality substantially at the stock level.	Schaefer *et al.* 2015 Anon. 2012 Kaplan *et al.* 2014
✗	**Set time and net depth**	Acoustic telemetry has been used as part of ISSF research activities to characterize the associative pattern and vertical distribution of the three tropical tuna species as well as the major bycatch species in order to estimate the species-specific vulnerability to the purse seine fishing gear on a 24-hour scale in the Indian Ocean. Juvenile bigeye tuna was found to have similar diel associative pattern to that of yellowfin and skipjack tuna and therefore a change of set time does not appear to be an appropriate solution to reduce the capture of bigeye tuna at FADs. Juvenile bigeye tuna generally occurred deeper than the other two tuna species, however, this observed difference in vertical distribution when associated to FADs is not sufficient to envisage modifying the depth of purse seine nets as a technical measure to reduce the catch of juvenile bigeye tuna. Significant shallowing of the purse seine net would also make them inefficient for capturing school fish in some oceans with deep thermocline.	Forget *et al*. 2015

7.3. PLANNED ACTIVITIES

The ISSF bycatch mitigation research project is studying technical methods to reduce catches of small bigeye tuna by purse seiners, with a focus on FAD sets. This research includes:

- Research on methods that can help fishers assess the amount of small bigeye tuna around a FAD, prior to setting, through:
    - The assessment of the amount of small bigeye tuna around FADs using the acoustic equipment onboard purse seiners as well as the echo-sounders that are equipping the buoys to track FADs. This involves (i) knowing the acoustic signature and frequency response of the 3 tuna species, so that a mask (i.e. post processing filter) is created to provide the biomass proportion of the different tuna species at FADs, (ii) Comparing the result of the mask with catches for different environmental scenarios, (iii) implementing this new knowledge on species discrimination mask in the acoustic tools used by fishers, working in collaboration with buoy manufacturers and echo-sounder and sonar manufacturers.

As a result, this research would allow fishers to determine whether one FAD has a larger biomass ratio of bigeye:skipjack than another one, and visit FADs in a way that minimizes this ratio in the catch.

- Investigation of the effect of different depths of materials suspended beneath FADs on the amount of small bigeye tuna aggregated. This could potentially be utilized to regulate the construction of FADs in a way that reduces bigeye aggregations.
- Research to assess the potential of competing stimuli to segregate tuna species. Activities consist of improving our knowledge on the schooling behavior of bigeye, yellowfin and skipjack tuna, the sensory abilities of the different species, and their behavioral responses to different stimuli. This could potentially be used during fishing operations to separate bigeye from the FAD that the vessel will set on. For instance, underwater surveys have demonstrated that bigeye do separate at times from other species inside the net, and tend to be deeper. However, this separation is in the order of tens of meters, so it is necessary to manipulate the behavior in order to enhance this segregation. Research on sensory physiology of three tuna species is necessary, before further investigation on tunas in a net (Restrepo, 2016).

In addition, ISSF has strongly advocated for the mandatory provision of data on FADs (design, quantities, usage) to the RFMO science bodies. Reporting is now required by IATTC (C-16-01), ICCAT (Rec. 16-01) and IOTC (Res. 15/08). With this information, RFMOs will be able to make science-based decisions to manage FAD fisheries, e.g., limiting the number of FADs per vessel or the number of FAD sets in a way that controls fishing. To date, ICCAT and IOTC have adopted a limitation of 500 and 350 active FAD buoys per vessel, respectively.

7.4. RFMO MEASURES IN PLACE

IATTC
Resolutions C-17-01 and C-17-02 include a time-area fishing closure for purse seine vessels greater than 182 tons carrying capacity; a full retention requirement for all purse seine vessels regarding bigeye, skipjack and yellowfin tunas; and a limit on the number of active FADs that each purse seiner can have.

ICCAT
Recommendation 16-01 calls for a two-month prohibition of fishing on floating objects in an area off West Africa and for a limit on the number of active FADs per purse seine vessel.

IOTC
Resolution 17/04 establishes a ban on discards of bigeye, skipjack and yellowfin tuna by purse seine vessels. Resolution 17/08 includes a limit in the number of buoys active at sea and acquired annually by each fishing vessel.

WCPFC
CMM 2016-01 calls for a 3-month closure (July through September) of fishing on FADs, a limitation on the number of vessel days and a full-retention requirement for all purse seine vessels regarding bigeye, skipjack and yellowfin tunas.

Related ISSF activities

Skipper workshops

Since 2009, ISSF has been conducting workshops that join scientists, fishers and other key stakeholders from the principal tropical tuna fleets of the world (See: ISSF Technical Report 2014-06 and 2017-03). The goal is to collectively find ways to reduce bycatch and the catch of small, undesired tuna in FAD fisheries by developing more selective fishing practices and adopting technology that improves targeting of desirable catch. Sustainable management measures resulting from a participatory approach are more likely to be relevant and readily adopted by fishery members. Skippers possess extensive knowledge on tuna behavior and vessel fishing technology, which is required to understand the effects of fishing practices on bycatch and the environment and can lead to developing practical solutions to reduce bycatch. Lopez *et al.* (2014) represents an example of how information provided by skippers during these workshops can be used to assess changes in fishing efficiency by a fleet, by documenting when different technologies and practices where introduced over time.

RFMO Advocacy (FAD data, non-entangling FAD design, observer coverage, strengthened bycatch data collection and shark conservation measures, EMS, Side events)

ISSF engages in strategic outreach and advocacy to tuna RFMOs and governments using a variety of tools. ISSF urges the adoption of measures for biological reference points and harvest control rules, closed vessel registries and the management of fishing capacity, strengthened compliance and transparency, bycatch mitigation and shark conservation and management, electronic skippers' logbooks and observer reporting and the improvement of data reporting in poorly monitored fisheries. Specifically for purse seine vessels, ISSF advocates for requiring FAD data collection and management and the use of non-entangling FAD designs, 100% observer coverage (either human or electronic), and full retention of tunas. Regarding longline vessels, ISSF urges tuna RFMOs to increase the level of observer coverage (or the use of electronic monitoring technology when human observers are not feasible) and strengthened transshipment regulation. ISSF also hosts side events during tuna RFMO annual commission meetings to provide the current science on issues like mitigating ecosystem impacts of FADs and the movement and behavior of bigeye, and provides support for RFMO workshops, such as on stock assessment methods, capacity, rights-based management and management strategy evaluation.

Research cruises and other bycatch mitigation activities

Seventeen at-sea bycatch mitigation research activities have been conducted under the framework of the ISSF Bycatch project since 2011: 3 in the WCPO, 2 in the IO, 5 in the EPO, 4 in the central Pacific and 3 in the Atlantic Ocean (Restrepo *et al*., 2016). Nine of them were research cruises onboard purse seiners (flagged to USA, Ecuador, Spain, France, Ghana and Panama), two were on a longline vessel modified to troll and handline gear, one on a multipurpose vessel with longline gear and two on non-fishing vessels. Other activities include tests of shallow versus normal FADs which are conducted in collaboration with 11 purse seiners from Ecuador, the testing of biodegradable twines for FAD construction at the University of Hawaii and in the Maldives (with the Marine Research Center) and acoustic research in an off-shore cage in Achotines, Panama. Objectives of each research activity are defined by the ISSF Bycatch Committee, and all address the general aim of finding solutions to mitigate bycatch by purse seiners. These cruises and research offer a unique opportunity to collect basic information on the behavior of tunas and bycatch species, on fishing practices by different fleets, and of course to test new solutions, often using actual commercial fishing vessels. It is noteworthy that observation activities such as underwater characterizations of fish aggregations at FADs by divers and behavior of sharks observed from electronic tags, two activities that can be considered as fundamental and not practical science, led to one of the most practical results of the project: the urgency to move to non-entangling FADs. Testing hypothetical solutions is, however, one of the main goals of the cruises. Being able to work onboard purse seiners, observing current practices of fishermen, allows scientists to test the potential of some ideas. It is then as important to conclude that one hypothesis is not valid as to obtain positive results.

Research collaborations

The vision of the project is clearly to discover, develop and disseminate methods that will decrease the ecological impacts of purse seine fishing. Following this vision, the ISSF Bycatch project has been working in collaboration with other projects that have the same aim. Until 2012 (when the other project concluded), a strong synergy was developed with the EU FP7 funded project MADE (Mitigating adverse ecological impacts of open ocean fisheries), in particular during two scientific cruises conducted in the Indian Ocean in 2011 and 2012. The progress on non-entangling FADs (extent of the issue in the Indian Ocean and practical solutions) was clearly possible thanks to a collaboration between these two projects and the ORTHONGEL-IRD Bycatch project. Other collaborations were formed during the Eastern and Central Pacific cruises, where ISSF Bycatch Project objectives were supported tagging cruises and personnel from the SPC – Oceanic Fisheries Programme, the WCPFC and the IATTC. Recently, ISSF has also collaborated with IATTC on the testing of shallow versus normal depth FADs and on acoustic research towards increased selectivity conducted at the IATTC tuna research station at Achotines, Panama.

Because the ISSF Bycatch Project is global, it clearly has a role of facilitator between national and international initiatives. It also provides an excellent opportunity, in particular through the skippers' workshops, to develop solutions and disseminate results and good practices to many fleets in the world. ISSF is also a partner in the Global Environmental Facility's Areas Beyond National Jurisdiction (ABNJ) Common Oceans tuna project which is supporting bycatch mitigation research.

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