ISSF INTERNATIONAL SEAFOOD SUSTAINABILITY FOUNDATION

ISSF Technical Report 2017-04

QUESTIONS AND ANSWERS ABOUT FADS AND BYCATCH

Photo: ISSF

Víctor Restrepo, Laurent Dagorn and Ana Justel-Rubio / **August 2017, Version 2.0**

Suggested citation:
Restrepo, V., Dagorn, L. and Justel-Rubio, A. 2017. Questions and Answers about FADs and Bycatch (Version 2). ISSF Technical Report 2017-04. International Seafood Sustainability Foundation, Washington, D.C., USA

Topic Categories: FADs, Bycatch, Purse seine

Abstract

This work presents answers to key questions about Fish Aggregating Devices, or FADs — inanimate objects used to aggregate tunas. The authors compare the catch composition of target tuna species in FAD and Free-Swimming School purse seine sets, consider the bycatch of non-target species (including from a conservation viewpoint), discuss fishing in relation to juvenile tunas, and address other issues. This document updates an earlier version (Dagorn and Restrepo, 2011) with more recent data and findings.

August 2017

The research reported in this Technical Report was funded by the International Seafood Sustainability Foundation (ISSF). The report and its results, professional opinions, and conclusions are solely the work of the author(s).

ISSF is a global coalition of scientists, the tuna industry and World Wildlife Fund (WWF) — the world's leading conservation organization — promoting science-based initiatives for the long-term conservation and sustainable use of tuna stocks, reducing bycatch and promoting ecosystem health. ISSF receives financial support from charitable foundations and industry sources.

To learn more, visit **iss-foundation.org**.

Table of Contents

Executive Summary **4**

FADs Q&A **6**

1.What are FADs? 6

2.What is the difference between a FAD and a “Floating Object”? 6

3.What is “bycatch”? 7

4.What is the catch composition of target tuna species in FAD and free-swimming school purse seine fisheries? 7

5.How does the catch of tropical tuna species in FAD and free-swimming school purse seine fisheries compare to other fishing gears? 12

6.What is the magnitude of non-target species caught in FAD and free-swimming school purse seine fisheries? 13

7.What are the non-target species caught in FAD sets? 14

8.Which FAD-caught bycatch species are of concern from a conservation viewpoint? 15

9. Are undesired catches discarded? Are all discards dead? 16

10.How does the bycatch of non-target species in purse seine fisheries compare to other major global fisheries? 17

11.Do sets on FADs and other methods catch juvenile tunas? What are their impacts? 18

12.Can bycatch from FAD fishing be reduced? 21

13. What are "eco-FADs"? 22

14.Can FAD use in purse seine fisheries be sustainable? 23

Bibliography **24**

Executive Summary

Tropical tunas (skipjack, yellowfin and bigeye) are caught by a variety of fishing gears, including by purse seining. Purse seiners use two main modes of fishing, usually within the same fishing trip: Setting on FADs (fish aggregation devices) and setting on free-swimming schools (FS) of tuna. A third fishing mode, setting on tuna-dolphin associations, also takes place but is only common in the eastern Pacific. FAD use has been increasing steadily since the 1980s-1990s, and many FADs are now equipped with sophisticated electronics that make them very efficient. Today, 40% of the catch of skipjack, the most abundant tuna species, is made with FADs.

There are many questions about the use of FADs and their impacts. This paper updates a 2011 ISSF publication with the most recent data and findings. Some of the main conclusions provided here are as follows:

- FAD target catches consist of skipjack tuna (from 58% to 78% depending on ocean region) as well as yellowfin and bigeye tuna. Combining all Oceans, the catches in FAD sets are 72% SKJ, 18% YFT, and 10% BET. Sets on free-swimming schools (FS) are often mono-specific (but not always). Skipjack and yellowfin tuna represent the main catch on FS. There is more variability by ocean region in FS sets than in FAD sets (for example, the catch of skipjack varies between 13% and 78% in FS sets). Combining all Oceans, the catches in FS sets are 71% SKJ, 27% YFT, and 2% BET.
- There are several types of associated sets depending on the characteristics of the object the school of tuna is associated with. These types include: natural logs, drifting FADs, anchored FADs, associations with marine mammals and associations with whale sharks.
- Tropical tunas are not only caught by purse seining on FADs and FS. In the Eastern Pacific Ocean, large amounts of yellowfin are also caught by purse seine sets on tuna-dolphin associations. Longliners catch large amounts of bigeye in all oceans, and pole-and-line fishing catches primarily skipjack but also about 10% bigeye and yellowfin. Gillnet and handline fisheries are also important in the Indian Ocean, where they target mainly yellowfin.
- The average percentage of the total catch that corresponds to non-target species in FS sets is 0.3% versus 1% in FAD schools in the Western Pacific Ocean, 0.3% versus 1.1% in the Eastern Pacific Ocean, 0.5% versus 2.8% in the Indian Ocean, 1.9% versus 7.7% in the Atlantic Ocean. The main difference in the Atlantic Ocean comes from the high catches of other tuna species (e.g., little tunny, bullet tuna), which are targeted and retained opportunistically.
- In terms of weight, the species groups that make up most of the non-target species bycatch in FAD set purse seining are: tunas other than SKJ, BET and YFT (e.g., little tunny, bullet tuna,

Key Findings:

1. **Combining all Oceans, the catches in FAD sets are 72% SKJ, 18% YFT, and 10% BET, and catches in free-swimming school sets are 71% SKJ, 27% YFT, and 2% BET.**
2. **Different fishing gears have different relative impacts on non-target species caught in tuna fisheries.**
3. **Reductions in bycatch rates can be achieved by a combination of (a) technological changes in gear and equipment, (b) deployment and retrieval changes, (c) skipper training, and (d) management regulations.**

kawakawa); other bony fishes (e.g. mahi-mahi, triggerfish, rainbow runners); billfishes; and sharks and rays. Other tunas and bony fishes make up between 74% and 92%, respectively, of these non-target species bycatches.

- Some FAD-caught species can be a concern from a conservation point of view, although their catches in purse seine fisheries tend to be small compared to other fisheries. These include (a) some billfish stocks, which are thought to be overfished (e.g., Atlantic marlins); (b) some sea turtles and sharks, which may get entangled in traditional FADs that use open netting with large mesh size for the floating and/or hanging structures; and (c) some shark species, primarily silky shark and oceanic whitetip shark, which are encircled and caught together with the tunas. Tuna RFMO conservation measures as well as best practices to mitigate bycatch exist in most cases.
- Different fishing gears have different relative impacts on non-target species caught in tuna fisheries. While some non-target species are a common bycatch for some fishing methods, other gears may have a much lower impact on them.
- Practically all tuna fishing gears catch juveniles (immature individuals).
  A high percentage of the BET and YFT catch in purse seine sets on FADs correspond to juvenile individuals, similar to pole-and-line catches in all ocean regions.
  There are two potential impacts from catching juvenile tunas: Overfishing and loss in potential yield. A stock can be overfished by catching too many juveniles, too many adults or too many of both. Catching fish of different sizes leads to changes in potential yield. The question of what is the right mix of gears that catch small vs. large fish, juveniles vs. adults, is not a scientific one. It is a largely political management decision, which is difficult to tackle because different countries tend to have mainly fisheries of one gear type or the other.
- Reductions in bycatch rates can be achieved by a combination of (a) technological changes in gear and equipment, (b) FAD deployment and retrieval changes, (c) skipper training, and (d) management regulations.
- Tropical tuna purse seine fisheries can and should be managed such that all of their operations are sustainable. This includes managing their impacts on the target tuna stocks and on associated bycatch species, as well as a robust management system. All tuna RFMOs are making progress towards better management of FAD use. This includes non-entangling FADs (IOTC and ICCAT), limits on the number of active FADs per vessel (IOTC and ICCAT), time/area prohibitions on FAD sets (ICCAT and WCPFC), and catch limits by set type (IATTC). Still, more needs to be done, in particular to set scientifically-based limits that are commensurate with the productivity of the tuna stocks.

FADs Q&A

1.What are FADs?

The term FAD stands for "fish aggregating device." This term is supposed to strictly refer to man-made floating objects (a surface structure, usually bamboo rafts, with underwater materials, traditionally old nets hanging underneath or more recently ropes or other non-entangling materials) deployed by fishers, although it is sometimes used to refer to any floating object, including natural ones such as logs, vegetal debris, etc. These floating objects attract and aggregate fish, including schools of tropical tunas (skipjack, yellowfin and bigeye). After discovering that tunas aggregate around natural floating objects, tuna fishers started to fabricate and deploy bamboo rafts. Fishing on floating objects has existed for a long time, but the practice of using artificial FADs really took off in the 1990s and has become more and more important. Some FADs are anchored to the ocean bottom and are used in semi-industrial fisheries (western Pacific and some areas of the Indian Ocean) or artisanal fisheries (small islands in all oceans).

Fishers have learned that setting their nets on FADs is very efficient; they tend to catch more tons of tunas more quickly during a trip than if they were looking for free-swimming tuna schools (FS). FADs allow them to find tunas more easily and faster. Sets on FADs are almost always successful, while FS sets have only a 50% chance of success (schools often escape from the net-setting maneuver); also, the tonnage per set is higher in FAD sets relative to FS sets (Fonteneau *et al*., 2000).

Fishers commonly equip drifting FADs with satellite buoys so they can be tracked remotely. Some are satellite sonar buoys that estimate the amount of fish under a FAD, which helps fishers decide the most efficient strategy for when and where to go to maximize their catch during a trip. Ongoing research tries to develop methods to discriminate species, so that fishers will obtain remotely not only an estimate of the total fish biomass under a FAD, but also the relative proportion of each tuna species and their sizes, as well as of non-tuna species. In some oceans (e.g. Indian and Atlantic Oceans), purse seiners use supply vessels to maintain their FAD network (deploying or visiting them). In other regions, the use of supply vessels is forbidden (e.g., Eastern Pacific Ocean) or limited (Indian Ocean).

2.What is the difference between a FAD and a "Floating Object"?

A floating object (FOB) is any object that floats at the surface of the ocean; it could be either natural (e.g. a log or a dead whale), natural but altered by fishers, or artificial (man-made). The following broad categories of floating objects are defined (adapted from Gaertner et. al. 2016):

FAD (fish aggregating device): A man-made FOB specifically designed to encourage fish aggregation at the device.

> **DFAD (Drifting FAD)**: A DFAD typically has a floating structure (such as a bamboo or metal raft with buoyancy provided by corks, etc.) and a submerged structure (made of old netting, canvass, ropes, etc.).
>
> **AFAD (Anchored FAD)**: AFADs usually consist of a very large buoy, or a set of many small buoys, anchored to the bottom with a chain and a rope. AFADs are called "**payaos**" in some regions.

LOG: A natural (branches, carcasses, etc.) or artificial (wreckage, nets, washing machines, etc.) log.

> **FALOG (Artificial log resulting from human fishing activity)**: These artificial logs are usually abandoned or lost materials related to fishing activity (nets, wreck, ropes, vessels that act as FADs, etc.).
>
> **HALOG (Artificial log resulting from human non-fishing activity)**: Other artificial logs (e.g., a washing machine, oil tank, etc.)

ANLOG (Natural log of animal origin): A natural log such as a whale carcass.

VNLOG (Natural log of plant origin): A natural log such as a branch, trunk, palm leaf, etc.

WHALE SHARK: In some regions, sets on whale sharks are seen as being similar to FAD sets, whereas in other regions they are seen as more similar to free-swimming school (FS) sets.

Some people use the term "FAD" for any floating object as long as it is used to catch tunas. With few exceptions (e.g., in the western Pacific), fishery statistics do not distinguish between purse seine sets made on natural objects and artificial objects. Most statistics differentiate between FS sets (or "unassociated" sets) and sets on floating objects (or "associated" sets). In the eastern Pacific fishing statistics, sets on tuna-dolphin associations are also distinguished. In recent years, following resolutions adopted by some t-RFMOs, some countries have developed national FAD Management Plans that require linking FAD activities to a wider range of FAD categories (e.g. using the categories above) which will potentially lead to more detailed t-RFMO statistics and improved FAD management.

In this document, we use the term "FAD" because that is more commonly used by a non-technical audience. However, it would be more accurate to use the term "floating object."

3.What is “bycatch”?

There is no universally-agreed definition of the term “bycatch.” Different people use "bycatch" to mean different things. And some people use the term to mean different things in different contexts. Very generally speaking, bycatch is the catch of any species that is not the main reason for which the skipper is fishing, whether it is retained or discarded.

In the case of tropical tuna fisheries, any species that is not the target species (skipjack, yellowfin, bigeye tuna) is bycatch. However, some tuna catches are discarded at sea (because of their small size, for instance) and some people consider dead discards of tuna as bycatch.

The inclusion (or not) of discards of target species in estimates of bycatch is the main reason for differences in numbers when people compare percentage of bycatch in a fishery.

It is important to always define how the term is being used in a given context. Otherwise, people who cite a bycatch of x% of the catch of the target species in this fishery and a bycatch of y% in that fishery too often end up mixing apples and oranges, because each study may be using the term "bycatch" to mean a different thing.

4.What is the catch composition of target tuna species in FAD and free-swimming school purse seine fisheries?

Tropical tuna purse seine fisheries take three main species — Skipjack (SKJ), yellowfin (YFT) and bigeye (BET) — and occasionally albacore (ALB). FAD sets (including those using both artificial and natural objects) and free-swimming school (FS) sets perform differently in different Ocean regions, depending on variables such as the relative abundance of the different species and their availability to the fishing gear. **Table 1** shows total catches of tropical tuna by species, ocean and fishing gear (Object associated purse seine sets, sets on free-swimming schools and other gears) for 2011-2015.

Table 1. Total catches of tropical tuna species (tons) in all oceans in purse seine fisheries (object associated and free-swimming school sets) and other fisheries (2011-2015).

Atlantic Ocean											
Object Assoc.				**Free-Swimming School**				**All Other Gears**			
Year	YFT	SKJ	BET	Year	YFT	SKJ	BET	Year	YFT	SKJ	BET
2011	18059	136211	24549	2011	52184	12342	4957	2011	32396	74947	53448
2012	17403	158903	20999	2012	56795	11354	6589	2012	30315	82934	48345
2013	15068	163458	24101	2013	53026	20644	4527	2013	29175	71628	44580
2014	20968	166289	22489	2014	50812	9912	6612	2014	25213	54973	48938
2015	26997	169786	24056	2015	57433	14070	3492	2015	24480	45356	52029
Indian Ocean											
Object Assoc.				**Free-Swimming School**				**All Other Gears**			
Year	YFT	SKJ	BET	Year	YFT	SKJ	BET	Year	YFT	SKJ	BET
2011	80404	158166	20242	2011	38224	11870	8520	2011	210195	213089	63950
2012	67628	115635	13385	2012	68603	5725	10300	2012	263987	217357	96733
2013	105535	159375	28325	2013	36958	8368	5963	2013	262300	266548	76530
2014	89870	157283	18979	2014	49516	8021	6706	2014	268704	256104	65149
2015	92859	156850	21497	2015	55178	8000	8779	2015	258920	229098	62395
Eastern Pacific Ocean											
Object Assoc.				**Free-Swimming School**				**All Other Gears**			
Year	YFT	SKJ	BET	Year	YFT	SKJ	BET	Year	YFT	SKJ	BET
2011	42189	170986	55589	2011	29823	100677	921	2011	9454	2260	32318
2012	37527	177239	65040	2012	26774	86856	980	2012	14840	3793	36193
2013	35089	194372	48337	2013	25666	79916	1150	2013	13406	3230	36303
2014	45476	199488	59803	2014	20288	57654	647	2014	12023	1470	35273
2015	43152	205976	61277	2015	41130	117653	1950	2015	863	478	38246
Dolphin Assoc.											
Year	YFT	SKJ	BET								
2011	134839	4372	2								
2012	133716	2120	0								
2013	157432	4272	0								
2014	168209	4436	3								
2015	160901	5651	2								
Western and Central Pacific Ocean											
Object Assoc.				**Free-Swimming School**				**All Other Gears**			
Year	YFT	SKJ	BET	Year	YFT	SKJ	BET	Year	YFT	SKJ	BET
2011	156669	683687	68161	2011	146813	496723	3232	2011	218814	361041	80489
2012	146157	693599	55756	2012	236407	724799	8198	2012	225709	359692	90719
2013	168456	685515	63000	2013	184951	812020	8601	2013	206915	364363	71687
2014	139074	738729	56755	2014	218843	916344	10218	2014	237665	367827	87352
2015	111095	615410	37597	2015	191020	804113	11193	2015	271343	408698	80112

In general, FAD target catches comprise not only skipjack tuna (from 58% to 78% depending on ocean region - see **Figure 1**) but also yellowfin and bigeye tuna. Combining all Oceans, the catches by species in FAD sets are 72% SKJ, 18% YFT, and 10% BET.

Sets on free-swimming schools are often mono-specific (but not always). Skipjack and yellowfin tuna represent the main catch on free-swimming schools. There is more variability by ocean region in FS sets than in FAD sets (**Figure 2**). For example, the catch of skipjack varies by ocean between 13% and 78% in FS sets. Combining all Oceans, the catches in FS sets are 71% SKJ, 27% YFT, and 2% BET.

When these are compared to catch compositions described in Dagorn and Restrepo (2011), which used an earlier dataset (2000-2009), the biggest shift is found on the catch composition of sets on free-swimming schools in the Eastern

Pacific Ocean, which used to be 56% skipjack and 43% yellowfin tuna, and are now constituted predominantly by skipjack tuna (75%).

Sets on FADs in the Atlantic Ocean have also experienced an increase in skipjack tuna catches (from 69% to 79%). In contrast, catches on both FAD and FS sets in the Indian Ocean have seen their skipjack tuna component decrease in favor of yellowfin tuna.

When looking at changes to the global percentages, there are only slight differences in FAD set composition; in the FS sets, there is a noticeable decrease of yellowfin tuna catches that has translated into an increase in skipjack catches (from 63% to 71%).

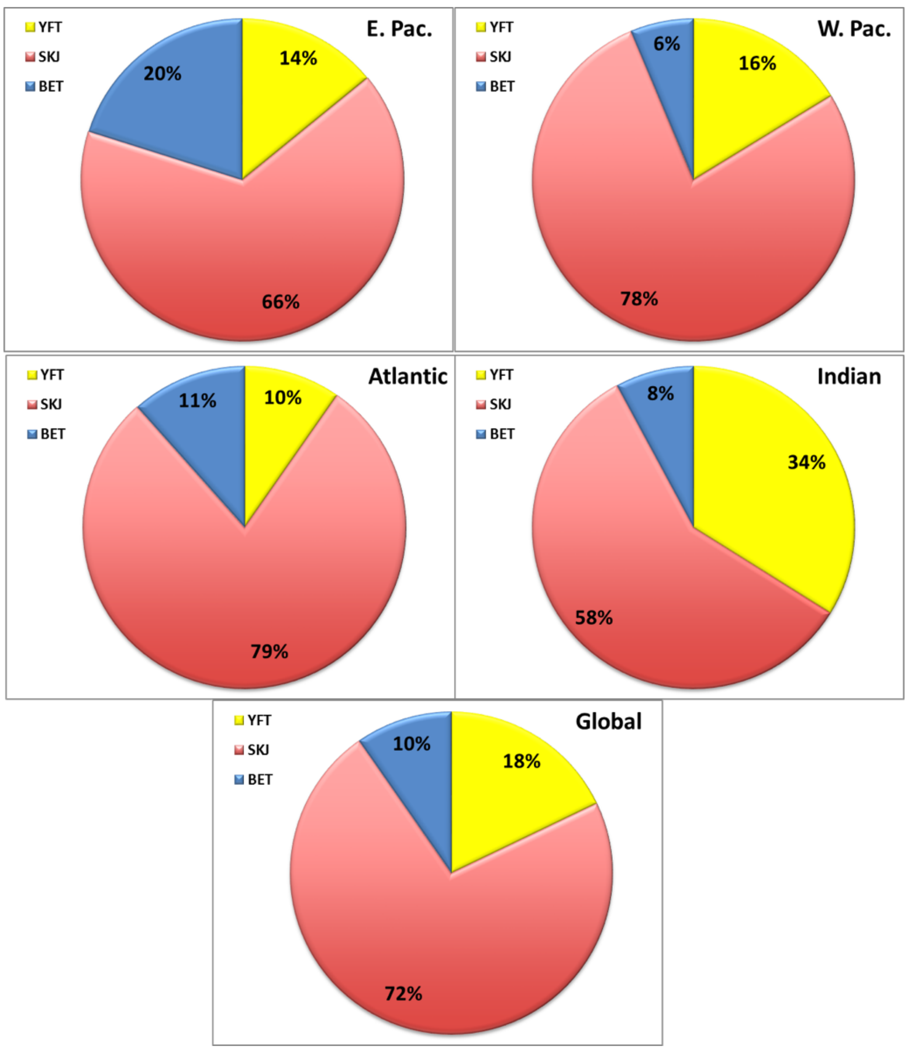

Figure 1. Composition of tropical tuna species in FAD sets, by Ocean region. Data are from the tuna RFMOs for the period 2011-2015.

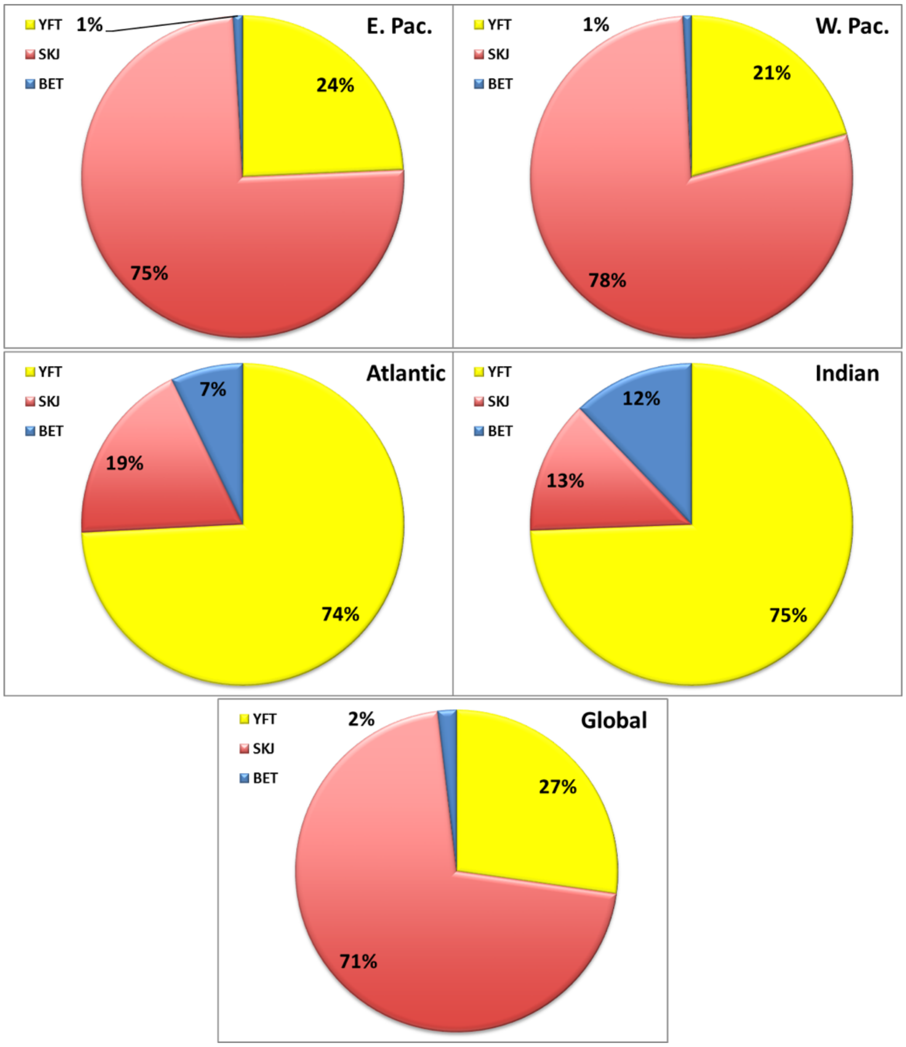

Figure 2. Composition of tropical tuna species in free‐swimming school sets, by Ocean region. Data are from the tuna RFMOs for the period 2011-2015.

There are several types of associated sets depending on the characteristics of the object the school of tuna is associated with (see Q2). These types include: natural logs (NLOGs), drifting FADs (DFADs), anchored FADs (AFADs), associations with marine mammals and associations with whale sharks. **Figure 3** represents the percentages of catches of BET, SKJ and YFT in the Western and Central Pacific Ocean for each type of associated sets and for sets on free-swimming schools.

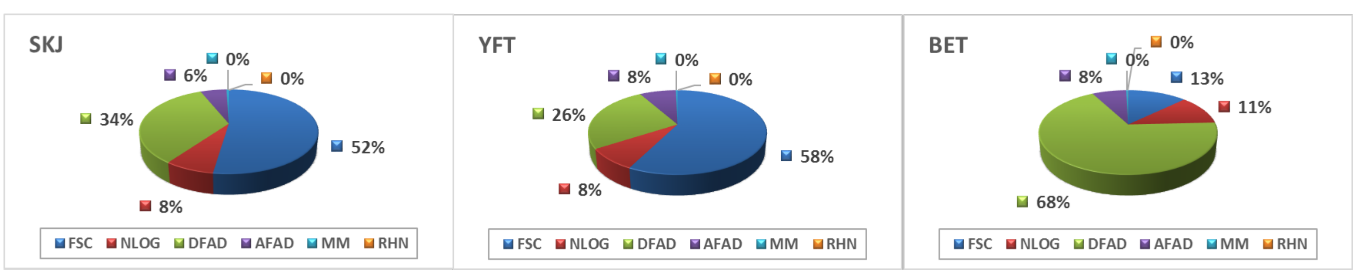

Figure 3. Composition of tropical tuna species in free-swimming school and different types of associated sets in the Western and Central Pacific Ocean (WCPFC Convention Area minus overlap with IATTC Convention Area). Data are from the SPC for the period 2011-2015 (Peter Williams, pers. comm). FSC = free-swimming school, NLOG = natural log, DFAD = drifting FAD, AFAD = anchored FAD, MM = association with marine mammal, RHN = association with whale shark.

As an illustration of the frequency of different set types, Figure 4 shows the number of different purse seine set types in the Eastern Pacific Ocean for the period 1979-2016.

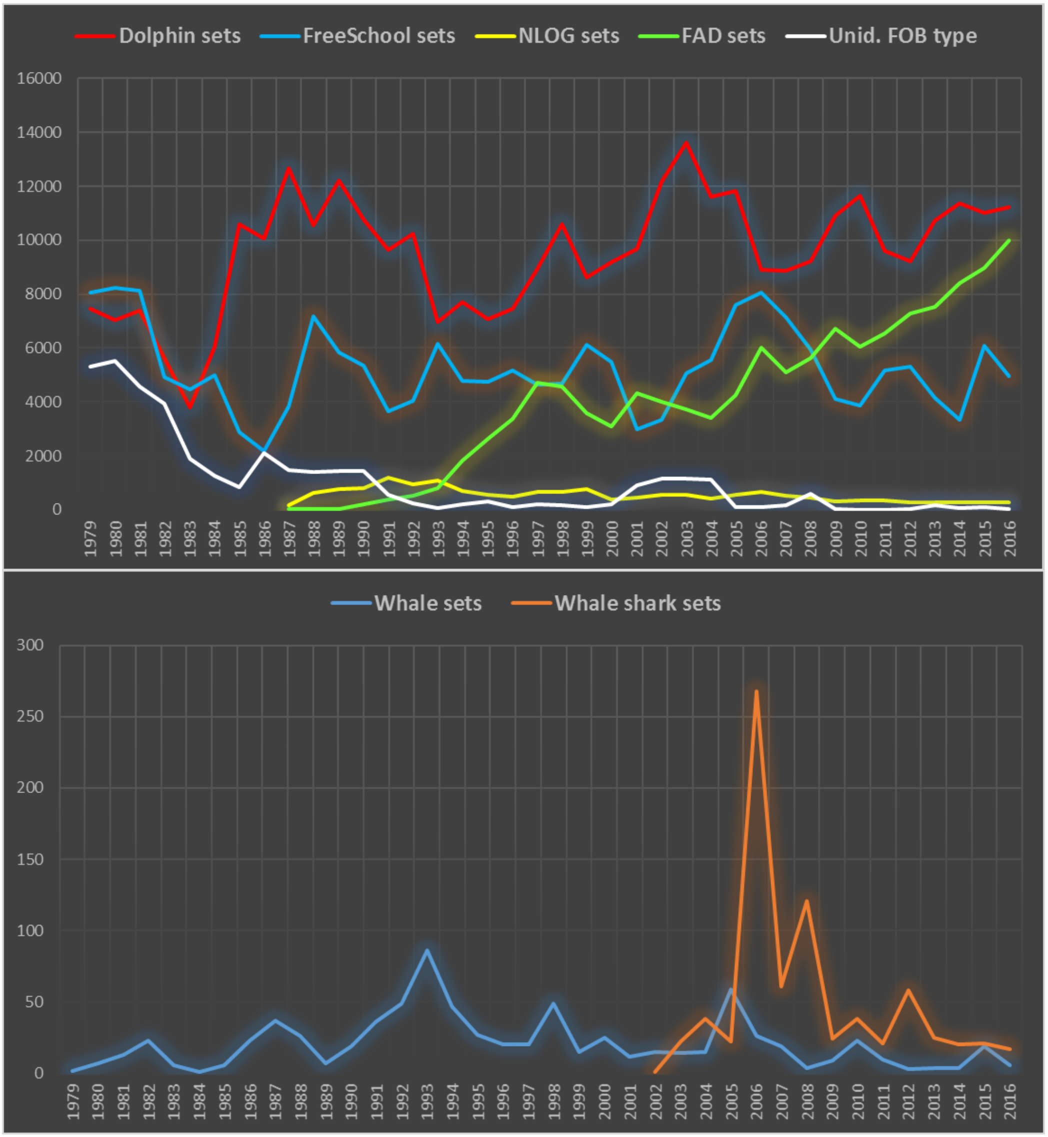

Figure 4. Number of sets by type in the Eastern Pacific Ocean (1979-2016). Top: Dolphin, free-swimming school, natural log (NLOG), FAD sets and sets on unidentified floating objects (Unid. FOB type). Bottom: whale and whale shark sets. Data taken from the IATTC observer database and logbooks for class 6 purse seine vessels (carrying capacity greater than 363 metric tons (M. Hall, pers. comm.). Whale shark sets include all sets with a whale shark involved, both intentional and unintentional sets.

5.How does the catch of tropical tuna species in FAD and free-swimming school purse seine fisheries compare to other fishing gears?

Tropical tunas are not only caught by purse seining on FADs and free-swimming schools (FS). In the EPO, large amounts of yellowfin are also caught by purse seine sets on tuna-dolphin associations. Longliners catch large amounts of bigeye in all oceans, and pole-and-line fishing catches primarily skipjack but also about 10% bigeye and yellowfin. Gillnet and handline fisheries are also important in the Indian Ocean, where they target mainly yellowfin.

The catch of skipjack by gear type is variable depending on ocean region. FADs account for 38% to 67% of skipjack catches (**Figure 5**). Combining all Oceans, the catches of skipjack are 43% by FAD sets, 32% by FS sets, and 25% by a variety of other gears.

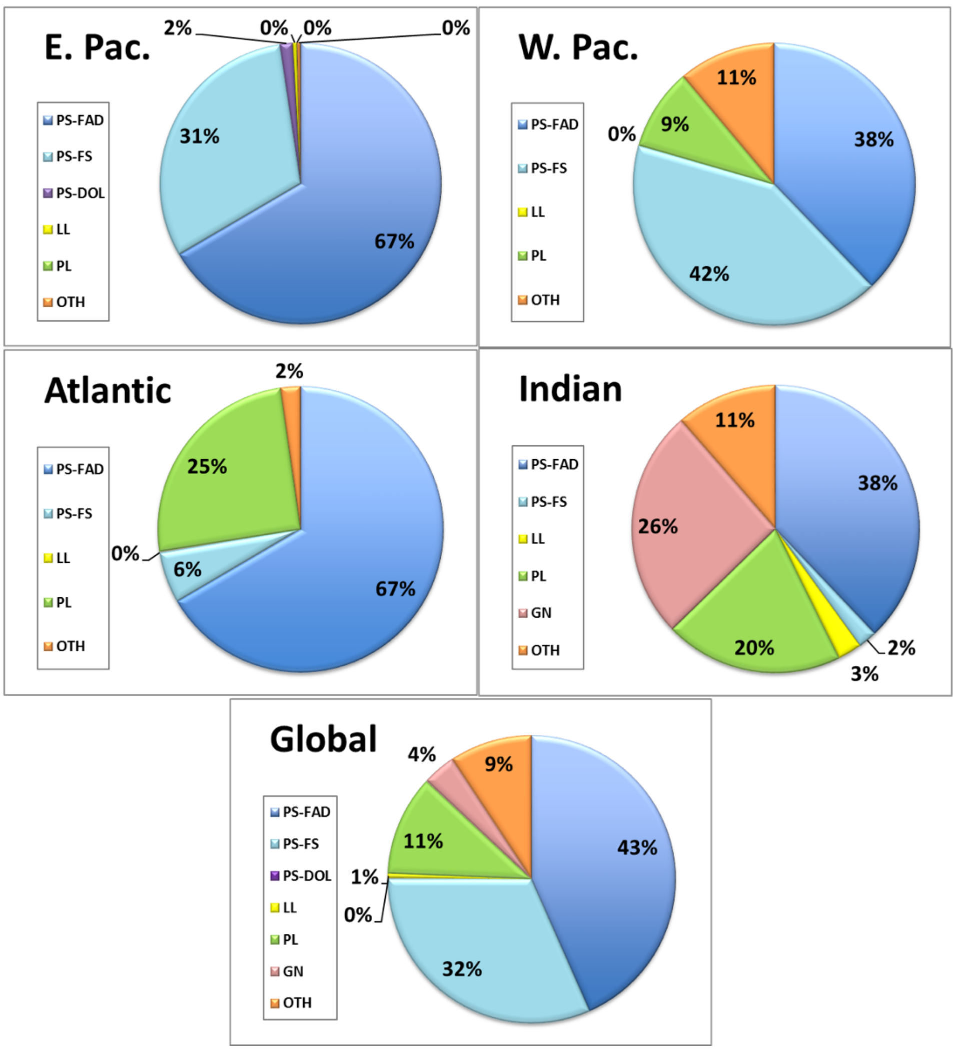

Figure 5. Catch of skipjack tuna by gear type (Purse seine FAD, Purse seine Free-Swimming School, Purse seine Dolphin, Longline, Pole and Line, Gillnet and Other gears), by Ocean region. Data are from the tuna RFMOs for the period 2011-2015.

The catch of the three tropical species together by gear type is also variable depending on ocean region. FADs account for 29% to 48% of the catches of skipjack, yellowfin and bigeye combined (**Figure 6**). Combining all Oceans, the catches of tropical tunas are 37% by FAD sets, 27% by FS sets, and 36% by a variety of other gears.

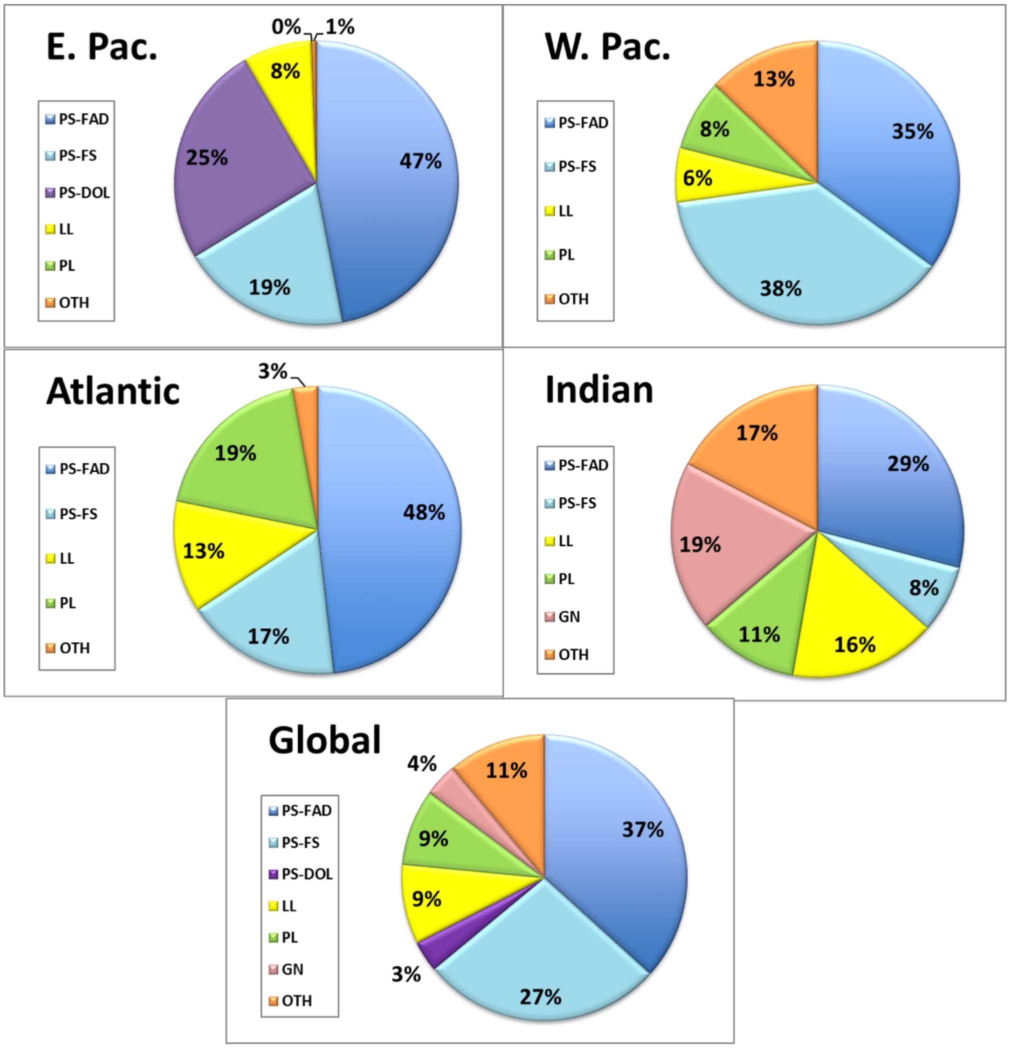

Figure 6. Catch of skipjack, yellowfin and bigeye tunas combined, by gear type (Purse seine FAD, Purse seine Free-swimming School, Purse seine Dolphin, Longline, Pole and Line, Gillnet and Other gears), by Ocean region. Data are from the tuna RFMOs for the period 2011-2015.

6.What is the magnitude of non-target species caught in FAD and free-swimming school purse seine fisheries?

Both FAD and free-swimming school (FS) fishing practices result in bycatch of non-target species. Data collected by independent scientific observers onboard purse seiners indicate that FAD sets usually have a higher catch of non-target species (**Figure 7**). In three Ocean regions, the catch of non-target species in FAD sets is 3 to 4.5 times higher than it is on FS sets. In the Indian Ocean, this ratio goes up to 6 times higher.

Average percentage of the total catch that corresponds to non-target species in FS sets is 0.3% versus 1% in FAD schools in the Western Pacific Ocean, 0.3% versus 1.1% in the Eastern Pacific Ocean, 0.5% versus 2.8% in the Indian Ocean, and 1.9% versus 7.7% in the Atlantic Ocean. The main difference in the Atlantic Ocean comes from the high catches of other tuna species (e.g., little tunny, bullet tuna; Amandé *et al*., 2010, 2016a, 2016b). These figures correspond to catches expressed as weight (not numbers of individuals).

The accuracy of these data depends on the coverage of the observer programs in each ocean. Coverage is 100% on large purse seine vessels only in the Pacific Ocean as required by IATTC and WCPFC. RFMO-mandated observer coverage is less than 10% in the Atlantic and Indian Oceans. However, some Atlantic and Indian Ocean fleets have 100% observer coverage, in order to meet voluntary commitments or to comply with ISSF Conservation Measure 4.3.

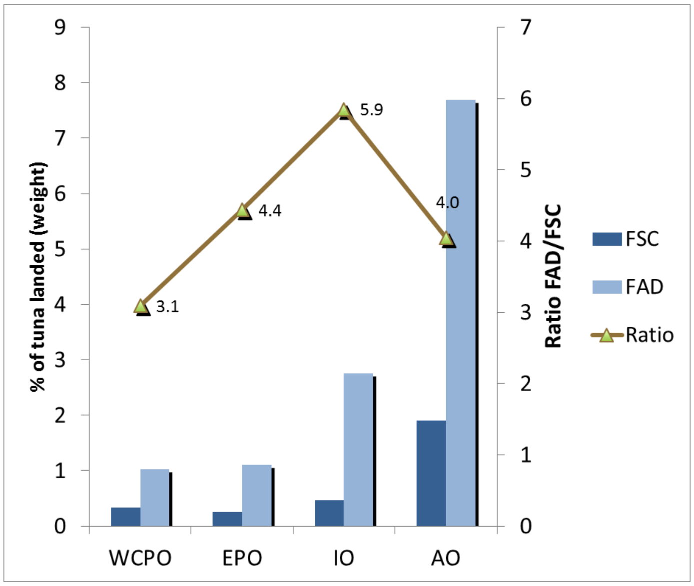

Figure 7. Amount of non-target species bycatch as a percentage of total catch (target and non-target species), with information on the ratio of bycatch between FAD and FS sets (average 2011-2015). Data sources: WCPO: 2011-2015 observer data by P. Williams (SPC, pers. comm.). EPO: 2011-2015 observer data by M. Hall (IATTC, pers. comm.). IO: 2011-2015 French PS observer data by L. Dagorn (IRD, pers. comm). AO: 2011-2015 French PS observer data by L. Dagorn (IRD, pers. comm) and Spanish PS observer data by H. Murua (AZTI, pers. Comm).

7.What are the non-target species caught in FAD sets?

Different categories of non-target bycatch for tuna fisheries are:

- tunas other than SKJ, BET and YFT (e.g., little tunny, bullet tuna, kawakawa)
- other bony fishes (e.g., mahi-mahi, triggerfish, rainbow runners)
- billfishes
- sharks and rays
- marine mammals
- sea turtles
- sea birds

In terms of weight, the first four categories — tunas other than SKJ, BET, and YFT as well as other bony fishes, billfishes, sharks and rays — make up most of the non-target species bycatch in FAD set purse seining globally (**Figure 8**). Other tunas and bony fishes make up between 74% and 92% of these non-target species catches. Minor tuna species make a considerable proportion of the non-target catch in the Atlantic Ocean, where they are often utilized. Sharks and rays make up between 0.17% and 0.62% of these catches, which is very small compared to other fishing gears. Note that mobulid rays are more commonly caught on free-swimming school sets than they are in FAD sets.

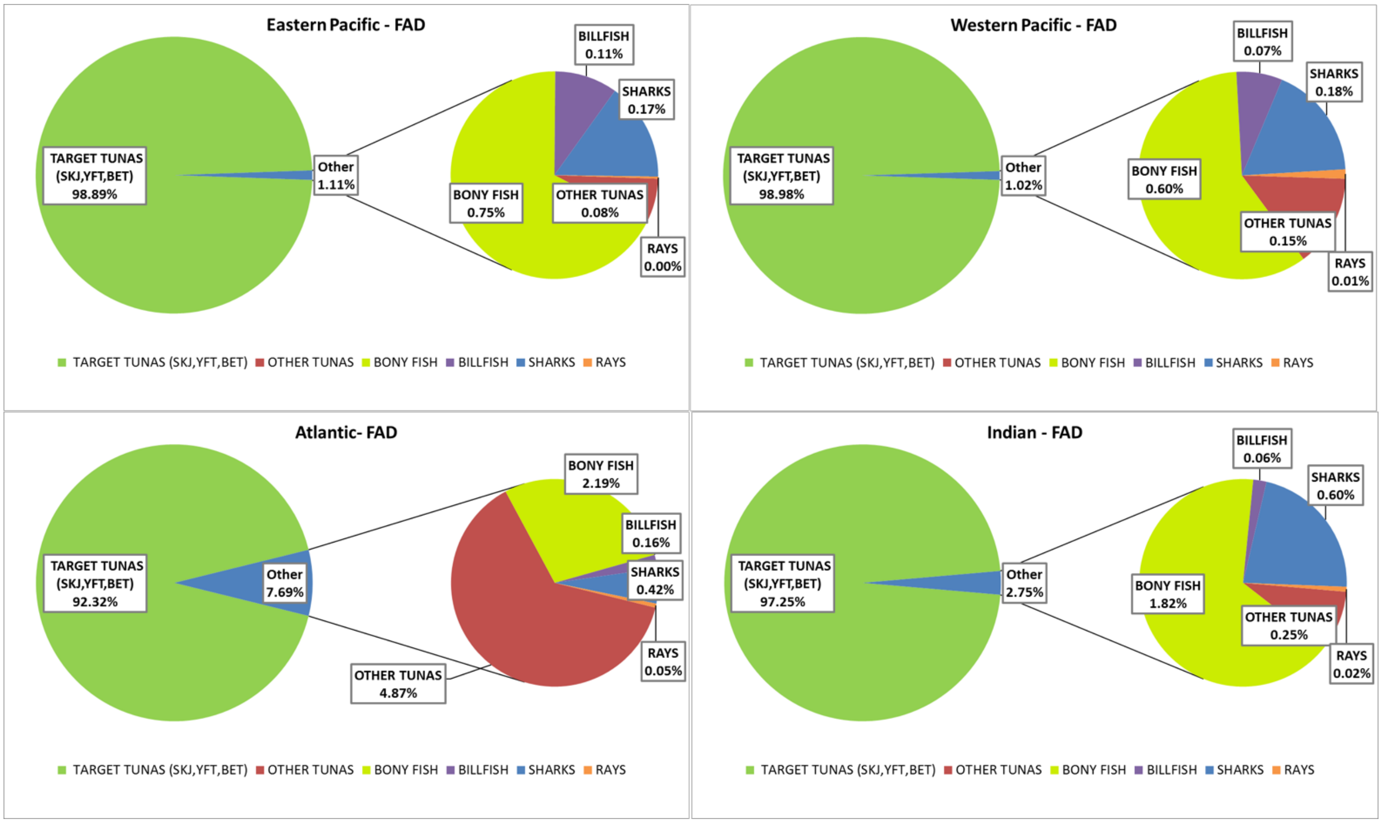

Figure 8. Composition of non-target species bycatch in FAD fisheries, by Ocean region. Data sources: WCPO: 2011-2015 observer data by P. Williams (SPC, pers. comm.). EPO: 2011-2015 observer data by M. Hall (IATTC, pers. comm.). IO: 2011-2015 French PS observer data by L. Dagorn (IRD, pers. comm). AO: 2011-2015 French PS observer data by L. Dagorn (IRD, pers. comm) and Spanish PS observer data by H. Murua (AZTI, pers. Comm).

8.Which FAD-caught bycatch species are of concern from a conservation viewpoint?

Other fishes. In purse seine fisheries, most of the non-target species bycatch (around 80%) is represented by other (minor) tuna species and bony fishes (see Question 7, above). These species are generally considered fast growing, and highly fertile with high natural mortality rates, which makes them resilient to exploitation. Therefore, the main concern with these species is that they are not utilized if discarded (Amandè *et al*. 2016a, 2016b).

Sea birds. Sea bird bycatch is not a concern in purse seine fisheries (Gilman, 2011).

Marine mammals. Catches of marine mammals on FADs are rare but can occur (SPC/OFP 2010b, Anderson 2014).

Billfishes. Some billfishes are of concern because they are thought to be overfished (e.g. Atlantic marlins). Catches of billfishes are relatively small in purse seine fisheries, however, compared to in other gears such as longlining (Justel-Rubio and Restrepo, 2015).

Turtles. Sea turtles are caught in small numbers by purse seiners and can be released alive relatively easily. However, traditional FADs that use open netting with large mesh size for the floating and/or hanging structures can result in ghost fishing of turtles through entanglement.

Noting that turtles are rated by IUCN from Vulnerable (Olive Ridley and Loggerhead) to Endangered (Green) to Critically Endangered (Hawksbill), there have been efforts to develop mitigation measures. For instance, ISSF collaborating scientists have created guidelines for the design of non-entangling FADs (ISSF 2015). ICCAT, IOTC and IATTC now require that fleets deploy non-entangling FADs.

Sharks. FAD fisheries catch sharks, primarily silky and oceanic whitetip sharks. These are also caught in other tuna fisheries (e.g., estimates reported by Gilman, 2011, indicate that the total catch of silky sharks by purse seiners in the Pacific is about ten times lower than the catch by longliners). IUCN lists the silky shark as Near Threatened, and lists the oceanic white tip shark as Vulnerable or Critically Endangered depending on the oceans. These species usually have a slow growth, low fertility, and low natural mortality rates, which make them sensitive to overexploitation. For that reason, the four tuna RFMOs responsible for managing tropical tuna fisheries have adopted conservation measures that specifically prohibit the retention of oceanic whitetip sharks and silky sharks by purse seine vessels (except for the IOTC on silky sharks; however, Resolution 05/05 established a limit on the ratio of fin weight to total shark weight that can be retained onboard fishing vessels). Some fisheries use FADs whose submerged structure is made up of old nets that can entangle sharks and other fauna. Filmalter *et al*. (2013) estimated that the magnitude of shark mortality due to this type of "ghost fishing" could have been very high in the Indian Ocean at the beginning of this decade. Since then, many fleets introduced non-entangling FADs (see ISSF 2015) voluntarily, and the IOTC, ICCAT and IATTC require that newly-deployed FADs be non-entangling, thus reducing or eliminating this problem.

9. Are undesired catches discarded? Are all discards dead?

Undesired catches consist of very small and/or damaged tunas, as well as some non-target species. WCPFC, IOTC and IATTC have adopted mandatory measures for the full retention of yellowfin, skipjack and bigeye unless the fish are unfit for human consumption. In the Atlantic Ocean, catches of very small tunas as well as non-tuna species are frequently kept and sold in local markets in western Africa (as fish called "*faux poisson*"), playing an important role in food security in this region. *Faux poisson* landings have been estimated in recent years by ICCAT (see Chavance *et al*. 2010, Amandè *et al*. 2016). Information from other regions is sparse (Lewis, 2016).

Traditionally, while a small portion of non-target bony fish is kept and used for consumption onboard (e.g. dolphinfish), non-tuna species are often discarded at sea (except in some places, see Lewis 2016). In recent years, many fleets are keeping their catches of non-target species onboard and landing them as "byproducts" that have an important commercial value. For instance, this is the case for dolphinfish ("dorado" or "mahi-mahi") in the EPO, whose discards have decreased from 55% in 2001 to 18% in 2016 (**Figure 9**).

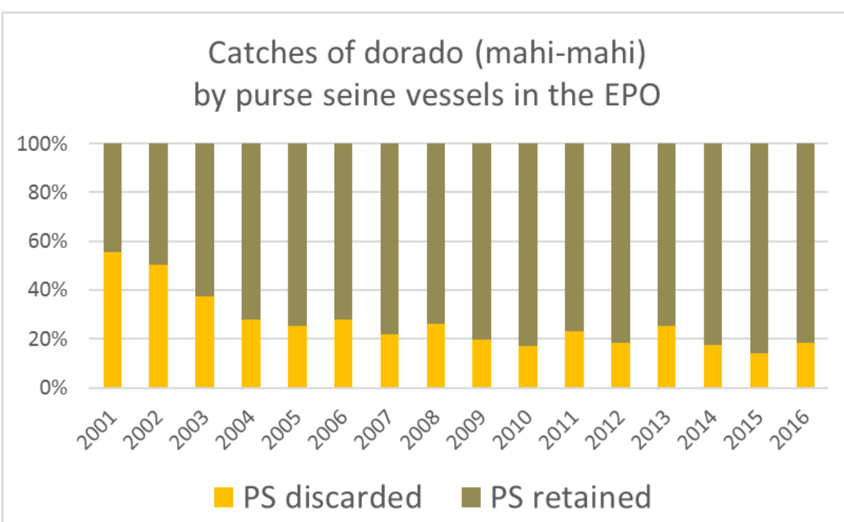

Figure 9. Estimated retained catches and discards by purse seine vessels of more than 363 t carrying capacity of dorado in the Eastern Pacific Ocean. Source: IATTC 2017a.

Most sea turtles and some sharks are expected to be alive when caught in purse seine operations. Tagging has shown that 50% of the live sharks released from the deck can survive if they are released promptly following best practices (Poisson *et al*. 2014). Combined with the percentage of sharks arriving live or dead on the deck, this leads to an overall estimate of 15-20% survival for all sharks that are encircled and brought onboard, if good practices are put in place (Poisson *et al.* 2014, Eddy *et al*. 2015, Hutchinson *et al*. 2015, Restrepo *et al*. 2016).

Research has shown that most turtles survive if they are released promptly and following best practices (Poisson *et al*.2014.) For example, in the EPO purse seine fishery, which caught over 675,000 tons of tuna in 2016, only six turtles were observed dead (IATTC 2017b).

10.How does the bycatch of non-target species in purse seine fisheries compare to other major global fisheries?

Bycatch occurs in almost all fisheries, not only in tuna fisheries. The table below from Kelleher (2005) illustrates the rates of discards in different fisheries globally. They range widely, from less than a tenth of a percent to over 60%. These percentages represent only discards (which Kelleher defined as "bycatch"), so they are not comparable to the percentages shown in previous questions above, which represent bycatch over total catch, whether retained or discarded.

Fishery	Landings	Discards[1]	Weighted average discard rate *(%)*	Range of discard rates *(%)*
Shrimp trawl	1 126 267	1 865 064	62.3	0-96
Demersal finfish trawl	16 050 978	1 704 107	9.6	0.5-83
Tuna and HMS longline	1 403 591	560 481	28.5	0-40
Midwater (pelagic) trawl	4 133 203	147 126	3.4	0-56
Tuna purse seine	2 673 378	144 152	5.1	0.4-10
Multigear and multispecies	6 023 146	85 436	1.4	n.a.
Mobile trap/pot	240 551	72 472	23.2	0-61
Dredge	165 660	65 373	28.3	9-60
Small pelagics purse seine	3 882 885	48 852	1.2	0-27
Demersal longline	581 560	47 257	7.5	0.5-57
Gillnet (surface/bottom/trammel)[2]	3 350 299	29 004	0.5	0-66
Handline	155 211	3 149	2.0	0-7
Tuna pole and line	818 505	3 121	0.4	0-1
Hand collection	1 134 432	1 671	0.1	0-1
Squid jig	960 432	1 601	0.1	0-1

Justel-Rubio and Restrepo (2015) compared the relative fishery impacts on non-target species caught in various tuna fisheries. While some non-target species are a common bycatch for some fishing methods, other gears may have a much lower impact on them (**Figure 10**).

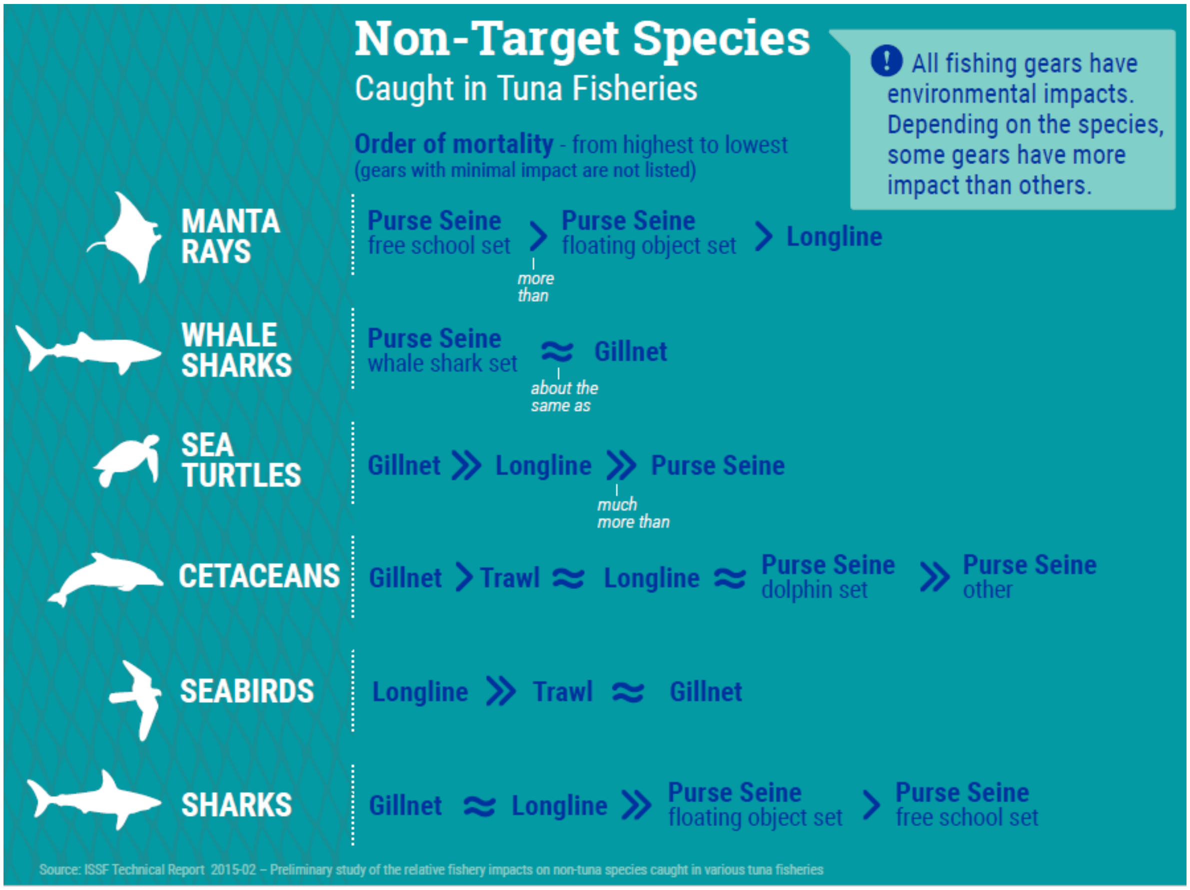

Figure 10. Relative impact of tuna fishing methods on non-target species in tuna fisheries.

11.Do sets on FADs and other methods catch juvenile tunas? What are their impacts?

Yes. However, practically all tuna fishing gears catch juveniles (immature individuals). But some catch more than others.

Figure 11 shows the percentage of the catch that constitutes juvenile individuals of bigeye (BET), yellowfin (YFT) and skipjack (SKJ) caught using four different fishing methods (purse seine on FAD sets; purse seine on free-swimming schools (FS) of tuna; pole and line; and longline) in the eastern Pacific, western and central Pacific, Atlantic and Indian Oceans.

BET become sexually mature around a size of 119 cm, YFT matures at near 97 cm and SKJ at near 43 cm (actual estimates of size at maturity vary by region and by study, but these sizes should suffice as an approximation to illustrate the catches of juveniles for these three species). Most of the catch of bigeye and yellowfin in FAD sets consists of juvenile individuals.

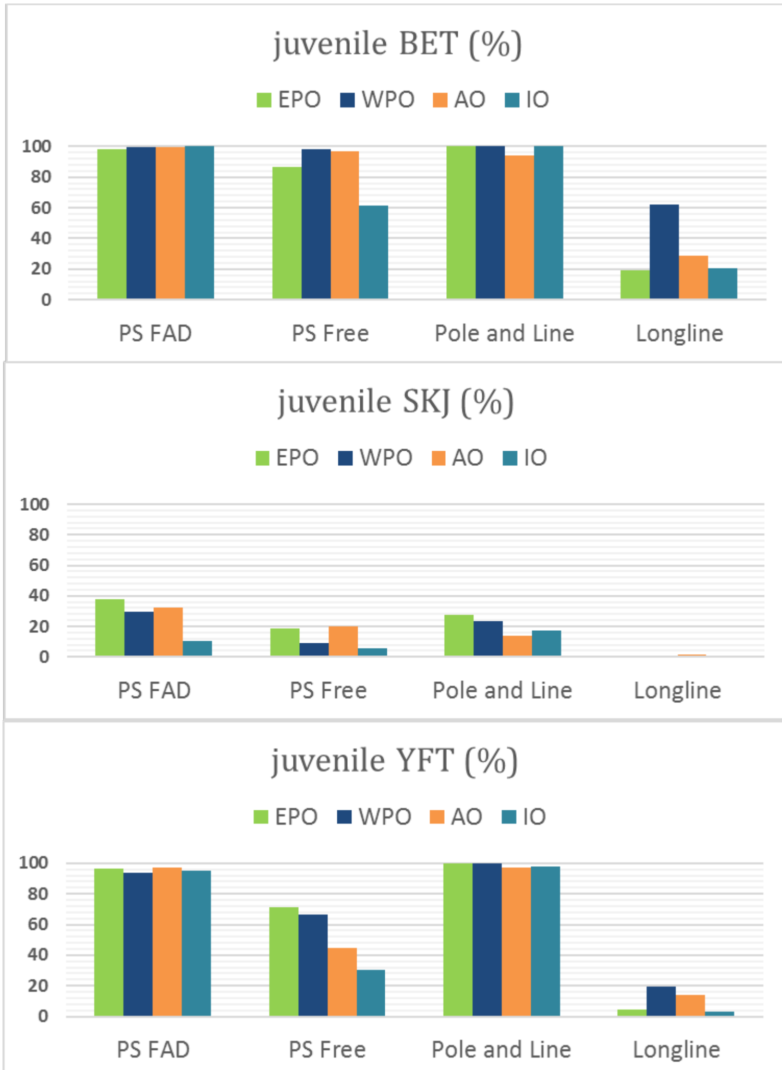

Figure 11. Percentage of the catch constituted by juvenile individuals of bigeye (BET), yellowfin (YFT) and skipjack (SKJ) caught in purse seine FAD sets, purse seine FS sets, pole and line, and longline fisheries in different Ocean regions. Data are from IATTC (EPO), SPC (WCPO), ICCAT (AO) and IOTC (IO); years are the most recent 5-year period available from the latest stock assessment or from the corresponding RFMO database.

A high percentage of the BET and YFT catch in purse seine sets on FADs corresponds to juvenile individuals, similarly to pole and line catches in all ocean regions. Juvenile BET and YFT are also caught in purse seine sets on free-swimming schools and in longline fisheries, but in a lower proportion. Juvenile SKJ are overall less common in purse seine and pole-and-line catches, and are very scarce in longline catches.

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.

These impacts can be measured in the assessments of the stocks. For example, **Figure 12** shows how the "spawning potential" of the WCPO bigeye stock has been impacted by various fishery types over the years (from McKechnie *et al.*, 2017). Longline fisheries (in green in the figure), which catch largely adults, have been impacting the spawning potential since they started in the 1950s. The purse seine-associated (FAD) fisheries (in dark blue in the figure), which catch mostly juveniles, had an increasing impact on spawning potential since they began in the 1990s until recently. Today, both purse seine-associated and longline fisheries have a similar impact on the spawning potential of this bigeye stock.

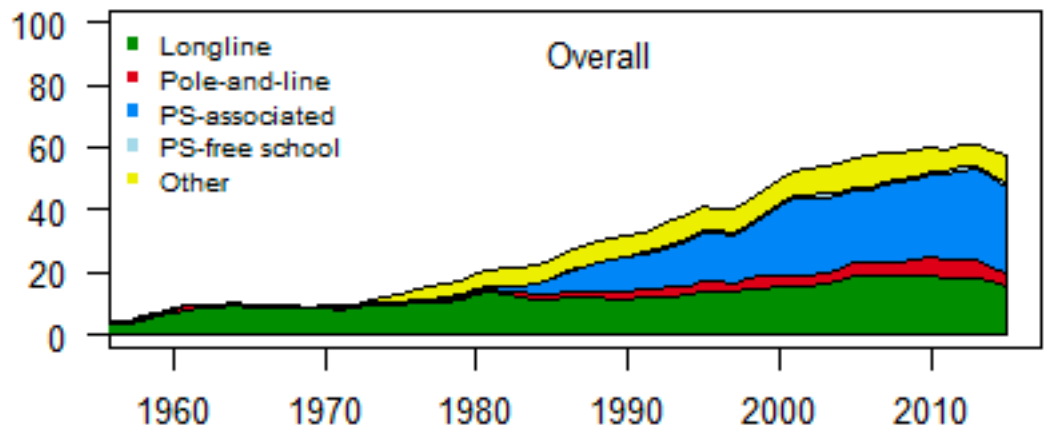

Figure 12. Estimates of reduction in spawning potential due to fishing for the WCPO bigeye stock attributed to various fishery groups.

Catching fish of different sizes leads to changes in **potential yield**. From a theoretical point of view, there is an optimum size at which 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. This is illustrated in **Figure 13** for the WCPO bigeye stock (from McKechnie *et al*. 2017). In this case, when most of the fishing was from longlining (until about 1970), MSY was over 300,000 tons. As fishing increased in the Indonesian and Vietnamese small-fish fisheries and the Indonesian-Philippines ex-EEZ purse seine fishery (the "Other" fisheries shown in yellow in the figure), MSY decreased substantially, to around 150,000-200,000 tons. Starting in the early 1980s, as industrial purse seine fisheries were introduced, MSY has fluctuated around 150,000 tons.

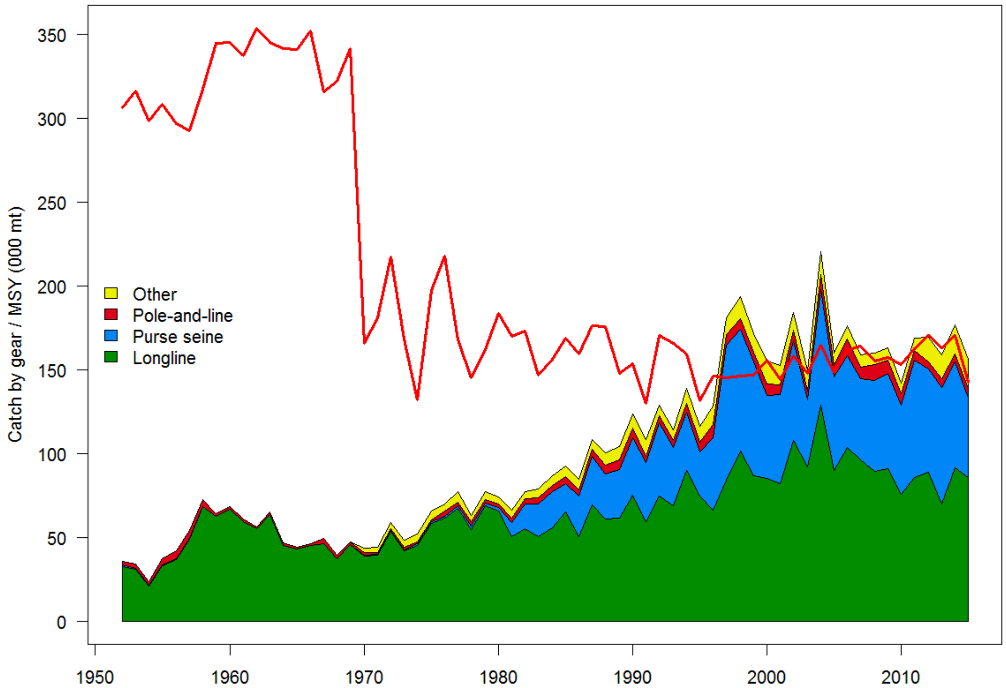

Figure 13. History of the annual estimates of MSY (red line) compared with annual catch split into three fishery sectors.

The question of what is the right mix of gears that catch small vs. large fish, juveniles vs. adults, is not a scientific one. It is largely a political management decision, which is difficult to tackle because different countries tend to have fisheries of one type or the other. Some people consider juvenile bigeye to be bycatch. But, in our minds, this is neither correct nor useful. Bigeye makes up 10% of the catch in purse seine-associated sets, which is not insignificant. These catches are retained, sold, canned and consumed. And the catches from other fisheries that catch juveniles, such as those from Indonesia, Vietnam and Philippines, are also commercialized and constitute an important component of food security. Thus, rather than seeing small bigeye as bycatch, we see it as a targeted catch that needs to be actively managed, along with the catches from all other fishing gears.

12.Can bycatch from FAD fishing be reduced?

We are convinced that it can. As Hall *et al*. (2000) show, reductions in bycatch rates can be achieved by a combination of (a) technological changes in gear and equipment, (b) deployment and retrieval changes, (c) skipper training, and (d) management regulations. For example, Restrepo *et al.* (2016b) outline four actions that, in combination, can increase silky shark survival in purse seine fisheries by 62%.

ISSF launched in 2009 an ambitious research program to address (a) and (b), focusing on reducing the catch of small bigeye tuna, as well as turtle and shark bycatches. Restrepo *et al.* (2016) presents all research and progress achieved to date. ISSF has carried out numerous training workshops (c) in 20 different countries, including Ecuador, Ghana, Panama, Samoa, Seychelles, Indonesia, USA, France and Spain, and is planning to continue doing so as one of its priority efforts (Murua *et al*. 2017). See **Figure 14**. And, ISSF's potential to advocate policy changes in RFMOs (d) should be fully utilized so that more complete data are reported on bycatch, and known mitigation techniques are adopted as mandatory requirements.

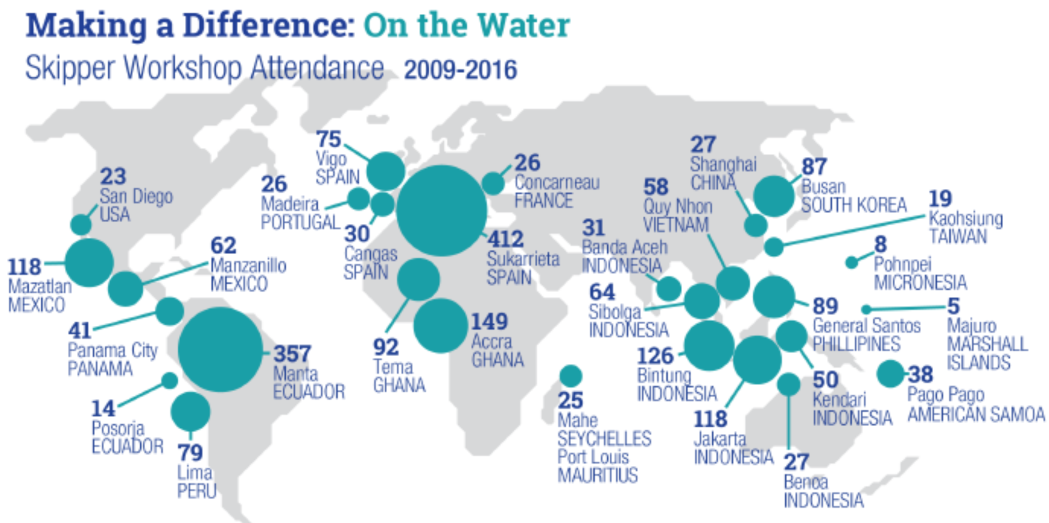

Figure 14. Location and attendance to ISSF skipper workshops (2009-2016).

Significant pressure is being exerted by some environmental NGOs to call attention to bycatch issues in FAD fisheries. This can be a driver for improvement in these very efficient fisheries that harvest a very large quantity of tunas for human consumption. We note, however, that FAD fisheries are not the only tuna fisheries with bycatch issues (in fact, some of the bycatch issues in FAD fisheries are very minor compared to those of other fisheries; see Justel-Rubio and Restrepo, 2015). Therefore, the bycatch of species of concern (especially some sharks and turtles) needs to be tackled for all major fishing gears. The first step towards this is to improve bycatch data collection and reporting to the RFMOs.

13. What are "eco-FADs"?

Some people use the term “eco-FAD,” but there is no official definition for one. Instead, it is best to talk about elements that mitigate the ecosystem impacts of FADs. This requires thinking about three main elements: Ghost fishing, marine debris, and modification of tuna habitat.

Ghost fishing, primarily of sharks, can occur when the submerged structure is made of open panels of nets that have a mesh size large enough to entangle fauna. This was demonstrated by Filmalter *et al.* (2013) in the Indian Ocean. Fortunately, FADs can be constructed to be non-entangling (partially or completely) and still attract tunas. The ISSF (2015) Guidelines explain how.

Marine debris can be of concern when FADs are constructed with materials that degrade very slowly, such as PVC pipes for the rafts or old nylon nets for the submerged structure. In addition, lost or abandoned FADs can drift and beach in sensitive areas such as coral reefs. Research efforts are being made to develop biodegradable FADs. ISSF is involved in a series of initiatives to help develop FADs that use organic materials as much as possible and are therefore biodegradable, but that also last long enough to be useful to fishers (about 8-12 months). Examples of these efforts are given in Moreno *et al.* (2017) and Restrepo (2016), and preliminary results are very promising. Lost FADs are more of a matter for management. Tuna RFMOs need to clearly define FAD ownership rules and responsibilities. For instance, fleets could be required to recover a certain percentage of their FADs each year or at the end of a season, as the IATTC now requires.

There has been a long debate about whether FADs modify the habitat of tunas and change their behavior (e.g., migratory routes, etc.). This is called the "ecological trap" hypothesis. It is likely that natural floating objects always occurred in the habitats occupied by tunas. Such objects are primarily tree trunks or branches that were washed down rivers into the ocean. Human activities (logging, coastal development, shipping, etc.) also increased the number of floating objects encountered by tunas, in some cases before modern purse-seine tuna fishing began (Caddy and Majkowski 1996). There are also environmental changes that affect the production and movement of floating objects (floods, El Niño events, tsunamis), so the ecosystem has always been dynamic. In recent years, however, the large and continuous increase in the number of drifting FADs used by fishers raises the question of this practice's impact on the tropical tuna habitat.

A modified habitat can be detrimental to animal populations, but not always. Hypothetically, if FADs were deployed in the ocean but never fished, would they provide benefits to populations of tunas and other species, or would they modify migratory routes and biology in ways that are negative for the populations? Such effects are extremely difficult to research. There are as many indirect studies that support a negative effect as there are studies that do not (Anon., 2014; MRAG 2017). Whether FADs could actually make some tuna stocks more productive, in a way similar to what artificial reefs do for some fish species, is also very difficult to test. No firm conclusions can be drawn from any existing study, which is exacerbated by the fact that the reporting of FAD deployments to RFMOs only started recently.

In any case, it seems important that the number of FADs in the oceans be managed, to mitigate potential ecological effects as well as to control fishing effort and consequently catches of tunas and bycatches. There are yet no scientific methods to help determine what would be an "optimum" FAD density. Nevertheless, three RFMOs (IATTC, ICCAT and IOTC) have established FAD limits per vessel. These limits can then be adapted if needed, as the RFMOs collect more accurate data on FAD deployments and densities.

14.Can FAD use in purse seine fisheries be sustainable?

Yes, it can. Tropical tuna purse seine fisheries can and should be managed so that all of their operations are sustainable. This includes managing their impacts on both target tuna stocks and associated bycatch species, as well as having a robust management system. Hampton *et al*. (2017) discuss the elements that would make FAD use well managed in the context of the overall purse seine fishery.

All tuna RFMOs are making progress towards better management of FAD use. This includes non-entangling FADs (IOTC, ICCAT and IATTC), limits on the number of active FADs per vessel (IOTC, ICCAT and IATTC), time/area prohibitions on FAD sets (ICCAT and WCPFC), and catch limits by set type (IATTC). Still, more needs to be done, in particular to set scientifically-based limits that are commensurate with the productivity of the tuna stocks.

In addition, mitigation of habitat impacts due to marine debris (lost FADs) is needed. In this sense, research efforts are being made to develop biodegradable FADs. ISSF is involved in a series of initiatives with this aim: (i) Biodegradable rope tests at anchored FADs in Hawaii, (ii) Biodegradable rope tests in Maldives both "at sea" and after beaching occurs, (iii) An ISSF workshop in 2016 on the use of biodegradable FADs with scientists and fishing masters, and (iv) test of biodegradable FADs in real fishing conditions in the Maldives. For further information, see Moreno *et al*. (2017) and Restrepo (2016).

Bibliography

Anderson, R. C. (2014) Cetaceans and Tuna Fisheries in the Western and Central Indian Ocean. IPNLF Technical Report 2, International Pole and Line Foundation, London. 133 pages.

Amandè, M.J., Ariz, J., Chassot, E., Delgado de Molina, A., Gaertner, D., Murua, H., Pianet, R., Ruiz, J. and Chavance. P. (2010) Bycatch of the European purse seine tuna fishery in the Atlantic Ocean for the 2003–2007 period. Aquat. Living Resour. 23: 353–362

Amandè, M.J., Dewals, P., N'Cho, A.J., Pascual, P., Cauquil, P. Irie, B.Y., Floch, L. and Bach P. (2016) Retaining bycatch to avoid wastage of fishery resources: how important is bycatch landed by purse-seiners in Abidjan. ICCAT Document SCRS/2016/017

Amandè M. J., N'Cho A.J., Kouakou N. D., N'Cho C.M., Koffi K.F., Kouadio A.N.C., Dewals P., and Restrepo V. (2016) Utilization and trade of faux poisson landed in Abidjan. ICCAT Document SCRS/2016/158

Anonymous. (2011) Report of the 2011 ISSF Stock Assessment Workshop. ISSF Technical Report 2011-02. International Seafood Sustainability Foundation, McLean, VA, USA.

Anonymous. (2014) Report of the ISSF workshop on FADs as ecological traps. ISSF Technical Report 2014-03. International Seafood Sustainability Foundation, Washington, D.C., USA.

Caddy, J. and J. Majkowski. 1996. Tuna and trees: a reflection on a long-term perspective for tuna fishing around floating logs. Fisheries Research 25(3-4): 369-376.

Chavance, P., Amon-Kothias, J.B., Dewals, P., Pianet, R., Amandè, M.J., Delgado de Molina, A. and Djoh, A. (2010) Statistics on tuna surface fishery's bycatch landed in Abidjan, Cote d'Ivoire, for the 1982-2009 period. Document ICCAT SCRS-2010-140 submitted at the 2010 SCRS meeting.

Cury, P.M., Fromentin, J.-M., Figuet,, S. and Bonhommeau, S. (2014) Resolving Hjort's Dilemma: How Is recruitment related to spawning stock biomass in marine fish? Oceanography 27(4):42–47, http://dx.doi.org/10.5670/oceanog.2014.85

Dagorn, L. and Restrepo, V. (2011) Questions and answers about FADs and bycatch. ISSF Technical Report 2011-03. International Seafood Sustainability Foundation, McLean, Virginia, USA.

Eddy, C., Brill, R. and Bernal, D. (2015) Rates of at-vessel mortality and post-release survival of pelagic sharks captured with tuna purse seines around drifting fish aggregating devices (FADs) in the equatorial eastern Pacific Ocean. Fisheries Research 174 (2016) 109–117

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

Fonteneau A., Pallares P., Pianet R. (2000) A worldwide review of purse seine fisheries on FADs. In: J.Y. Le Gal, P. Cayre P., and M. Taquet, editors: Peche thoniere et dispositifs de concentration de poissons. Actes Colloques-IFREMER 28:15–35.

Gaertner, D., Ariz, J., Bez, N., Clermidy, S., Moreno, G., Murua, H. and Soto, M. (2016) Results achieved within the framework of the EU research project: Catch, Effort, and eCOsystem impacts of FAD-fishing (CECOFAD). ICCAT document SCRS/2016/030.

Gillett, R. (2011) Replacing purse seining with pole-and-line fishing in the central and Western Pacific: Some aspects of the baitfish requirements. Marine Policy 35: 148-154.

Gilman, E. (2011) Bycatch governance and best practice mitigation technology in global tuna fisheries. Marine Policy 35: 590-

Hall, M.A., Alverson, D.L. and Metuzals, K.J. (2000) By-Catch: Problems and Solutions. Marine Pollution Bulletin 41: 204-219.

Hampton, J., Leape, G., Nickson, A., Restrepo, V., Santiago, J., Agnew, D., Amandè, J., Banks, R., Brownjohn, M., Chassot, E., Clarke, R.Davies, T., Die, D., Gaertner, D., Galland, G., Gershman, D., Goujon, M., Hall, M., Herrera, M., Holland, K., Itano, D., Kawamoto, T., Kumasi, B., Maufroy, A., Moreno, G., Murua, H., Murua, J., Pilling, G., Schaefer, K., Phillips, J.S., Taquet, M. (2017) What does well-managed FAD use look like within a tropical purse seine fishery? Presented at Joint t-RFMO FAD Working Group meeting (Doc. No. j-FAD_35/2017)

Hutchinson, M., Itano, D., Muir, J., LeRoy, B. and Holland, K. (2015) Post-release survival of juvenile silky sharks captured in a tropical tuna purse seine fishery. Marine Ecology Progress Series. doi: 10.3354/meps11073

IATTC. (2010) Tunas and billfishes in the eastern Pacific Ocean in 2009. Document IATTC 81-05 (distributed at the 2010 meeting of the IATTC).

IATTC (2017a) The fishery for tunas and billfishes in the Eastern Pacific Ocean in 2016. Document SAC-08-03a

IATTC. (2017b) Ecosystem considerations. Document SAC-08-07a.

ISSF. (2015) Guide for non-entangling FADs. http://iss-foundation.org/knowledge-tools/guides-best-practices/non-entangling-fads/download-info/issf-guide-for-non-entangling-fads/

Justel-Rubio, A., Restrepo, V. (2015) Preliminary study of the relative fishery impacts on non-tuna species caught in tuna fisheries. ISSF Technical Report 2015-02. International Seafood Sustainability Foundation, Washington, D.C., USA.

Justel-Rubio, A. and Restrepo, V. (2017) Computing a global bycatch rate of non-target species in tropical tuna purse seine fisheries. ISSF Technical Report 2017-01. International Seafood Sustainability Foundation, Washington, D.C., USA.

Kelleher, K. (2005) Discards in the world's marine fisheries. An update. FAO Fisheries Technical Paper. No. 470. Rome, FAO. 2005. 131p.

Lewis, A. (2016) Implementation of pilot projects to explore the market viability of full retention of non-tuna species in purse seine fisheries: Phase 2 Report. ISSF Technical Report 2016-16. International Seafood Sustainability Foundation, Washington, D.C., USA.

McKechnie, S., G. Pilling and J. Hampton. (2017) Stock assessment of bigeye tuna in the western and central Pacific Ocean. WCPFC-SC13-2017/SA-WP-05 (Rev. 1).

MRAG. (2017). An analysis of the uses, impacts and benefits of fish aggregating devices (FADs) in the global tuna industry. A report produced for WWF-UK by MRAG Ltd. London, UK. pp. 51.

Moreno, G., Restrepo, V., Dagorn, L., Hall, M., Murua, J., Sancristobal, I., Grande, M., Le Couls, S. and Santiago, J. (2016) Workshop on the use of Biodegradable Fish Aggregating Devices (FADs). ISSF Technical Report 2016-18A. International Seafood Sustainability Foundation, Washington, D.C., USA.

Moreno, G., Jauharee, R., Muir, J., Schaefer, K., Adam, S., Holland, K., Dagorn, L. and Restrepo, V. (2017) FAD structure evolution: from biodegradable FADs to biodegradable FADs. Presented at Joint t-RFMO FAD Working Group meeting (Doc. No. j-FAD_08/2017)

Murua, J., Moreno, G., Itano, D., Hall, M., Dagorn, L. and Restrepo, V. (2017) ISSF Skippers' workshops round 6. ISSF Technical Report 2017-03. International Seafood Sustainability Foundation, Washington, D.C., USA

Olson, R.J. (2010) Effects of the tuna fisheries on the ecosystem of the eastern Pacific Ocean. Document SAC-01-15 (distributed at the 2010 meeting of the Scientific Advisory Committee of the IATTC).

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

Restrepo, V., Dagorn, L., Moreno, G., Forget, F., Schaefer, K., Sancristobal, I., Muir, J. and Itano, D. (2016) Compendium of ISSF At-Sea Bycatch Mitigation Research Activities as of 12/2016. ISSF Technical Report 2016-13A. International Seafood Sustainability Foundation, McLean, Virginia, USA.

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

SPC/OFP. (2010a) Non-Target Species Interactions with the Tuna Fisheries of the Western and Central Pacific Ocean. Document WCPFC-SC6-2010/EB-IP-8 (distributed at the 2010 meeting of the Scientific Committee of the WCPFC).

SPC/OFP. (2010b) Summary information on whale shark and cetacean interactions in the tropical WCPFC purse seine fishery. Document WCPFC7-2010-IP/01 distributed at the 2010 meeting of the WCPFC.

INTERNATIONAL SEAFOOD SUSTAINABILITY FOUNDATION

www.iss-foundation.org

1440 G Street NW
Washington D.C. 20005
United States

Phone: + 1 703 226 8101
E-mail: info@iss-foundation.org