ISSF Skipper Workshops:

Collaboration between scientists and fishing industry to mitigate bycatch in tuna FAD fisheries

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SUMMARY

Since 2009, ISSF has been conducting workshops that join scientists, fishers and other key stakeholders from the principal tropical tuna fleets of the world. The goal is to find ways to reduce bycatch and the catch of small undesired tuna in Fish Aggregating Device (FAD) fisheries by developing more selective fishing practices and adopting technology that improves targeting of desirable catch. The workshop concept is based on the premise that 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 can be used to understand the effects of fishing practices on non-target species and the environment and can lead to developing practical solutions to bycatch mitigation. This document describes the collaborative dialogue process and the results obtained during a series of workshops conducted between scientists and fishermen from 2009 – 2013.

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BACKGROUND

Bycatch mortality is one of the most significant negative impacts a fishery can have on marine ecosystems (Davies et al., 2009). The accidental catch of non-targeted species is a general feature across all fishing gear types because marine species tend to co-occur in space and time. Selectively harvesting targeted species and sizes from unwanted catch during the fishing operation, while they are still viable and in the marine environment is a difficult task. Fisheries scientists and technologists have worked for decades in the development of selective or mitigating gear such as tori lines, circle hooks, turtle excluders, or sorting grids to reduce bycatch (see review by Gilman, 2011). Despite some important advances in technology, most current fishing gears do not completely isolate target from incidental catch. At present, complete species separation is only possible when the catch arrives on deck, but by this time many animals are moribund or dead.

Since the early 1990s an important increase in tuna catches has been associated with a greater use of artificial floating objects, i.e. Fish Aggregating Devices (FADs), both drifting (DFAD) and anchored (AFAD) (Fonteneau et al, 2013). Today tropical tuna purse seine fishing is one of the most important fisheries worldwide both by captured volume and total value (Miyake et al., 2010). Bycatch generated per ton of target species in purse seine FAD fishing is low relative to other fishing gears (e.g. gillnet, trawling) (Alverson, 1994; Kelleher, 2005), however, there is still room for improvement. Tuna purse seining has generally three fishing modes depending on set type. Tuna can be found either moving in (a) schools (unassociated), (b) aggregated under floating objects, or (c) in association with dolphins (Hall and Roman, 2013). School sets of tuna are among the most selective ways of fishing with almost no bycatch (range = 0.26 % (WCPO) – 2.84% (ATL) non-target species catch relative to target catch; Restrepo, 2011). Sets on tunas aggregating with slow moving floating natural objects (logs) or artificial objects (DFADs), have higher bycatch levels (range = 1.74 % (WCPO) – 8.93 % (ATL) non-target species catch relative to target catch; Restrepo, 2011) as other species (e.g. sharks, bony fish, etc.) also tend to gather around these same floating objects (Taquet et al., 2007). The third type, sets on tuna associated with dolphins, which occurs in localized regions of the Eastern Pacific

Ocean, was a great problem prior to the 1990s. Large herds of dolphins caught in the net with the tuna were drowning, sometimes hundreds of individuals per set. This situation has been resolved since, thanks to the development and implementation of effective bycatch reduction measures including the backdown procedure, net modifications like the small-mesh Medina panel, and ongoing skipper training programs incorporated into cooperative programs like the Inter-American Tropical Tuna Commission (IATTC) coordinated Agreement on the International Dolphin Conservation Program (AIDCP). With the introduction of these mitigating actions, bycatch is now very low (0.17 (EPO) non-target species catch relative to target catch; Restrepo, 2011) and dolphin populations in the region have been generally stable or slowly rebuilding after a period of decline (Hall, 1998; Restrepo, 2012). This bycatch reduction success story was a result of a pioneering collaboration between tuna scientists from the IATTC and purse seine skippers gathering through workshops during the 1990s to develop operational and technological solutions (Hall, 1996; Hall et al., 2001).

The benefit of joining scientists and fishers to design bycatch reducing practices is clear. Understanding fishers' behavior is crucial to achieve successful fisheries management measures (Hilborn, 2007). Often scientists' and fishers' knowledge overlaps (e.g. fish behavior, ecosystem changes, fleet strategies) and comparison between both can help to support or disprove each other's theories. Broadly speaking, in other areas of knowledge either scientists (e.g. fish physiology, stock assessments) or fishers (e.g. fishing practices, fishing technology use) may have an edge due to the nature of their work. This specialized knowledge is sometimes referred to as fishers' ecological knowledge (FEK) or local ecological knowledge (LEK) (Moreno et al., 2007). In pelagic fisheries skipper collaboration is especially important as scientists usually have fewer opportunities to conduct research at sea, especially in commercial purse seiners, due to the high costs of operating industrial scale fishing vessels in distant open waters.

In 2009 the International Seafood Sustainability Foundation (ISSF) began their Bycatch Project, aimed at developing and implementing improved bycatch mitigation measures in tropical tuna fisheries. For this purpose ISSF created their Bycatch Steering

Committee (BSC) formed by expert tuna fishery scientists working in all tropical tuna regions where drifting FADs are commonly used (Western and Central Pacific, Eastern Pacific, Western Indian and Equatorial Atlantic Oceans). The BSC generated a list of most promising research ideas to develop selective technologies and practices to use before, during and after the purse seine fishing operation on FADs to prevent undesirable catches (Anonymous, 2010). Research focusing on ecologically sensitive species such as sharks and sea turtles was prioritized. Also measures to reduce catches of undersized tunas (i.e. bigeye tuna and yellowfin tuna) are studied, although the situation can be different in each ocean depending on the status of these tuna stocks. For instance, in the Pacific, it is necessary to reduce captures of small bigeye tuna while in the Indian and Atlantic Oceans, catches of small bigeye are not an issue at present. There will still be a portion of the tunas which end up being discarded (i.e. too small to be sold) and this part of the catch is something all fishers would like to avoid. Some of the mitigation ideas for different kinds of species where tested at sea by scientists during research cruises in ISSF chartered vessels (including purse seiners) or opportunistically during commercial fishing trips. Five major research trips have been conducted in the Indian and Pacific Oceans, and more are being planned for 2014 and possibly into the future.

In November 2009 ISSF organized a meeting in Sukarrieta (Spain) joining an international panel of FAD tuna scientists and purse seine fishers to discuss ways to improve bycatch mitigation (Anonymous, 2010). This was the seed for a series of bycatch reduction participatory workshops with captains and crew from the principal fleets in the world, colloquially referred to as “Skipper Workshops”. The objective of this collaborative effort with fishers is to obtain their expert feedback to improve BSC scientists’ proposed bycatch reduction research and key is also the provision of new ideas by skippers that scientists can then test. In addition, the Skipper Workshops provide a direct platform to showcase fishers the latest best practices and technological developments in bycatch mitigation. The final objective is for fleets to adopt these mitigation measures in their day to day fishing operations where they will have the most impact.

The following sections describe in more detail the format, contents and contributions to bycatch reduction so far achieved by the ISSF Skipper Workshops.

WORKSHOP LOCATIONS AND ATTENDANCE

The objective of ISSF to mitigate bycatch impacts and improve the sustainability in tuna fisheries is global in nature. Therefore there has been a strong emphasis on coordinating workshops with fleets operating in all oceans, seeking the maximum representation possible from international fleets. Skipper Workshops have been conducted in Asia (e.g. Indonesia, Philippines, Korea, Taiwan), Oceania (e.g. American Samoa, Federated States of Micronesia, Marshall Islands), Americas (e.g. Ecuador, Peru, Panama), Europe (e.g. Spain), and Africa/Indian Ocean (e.g. Seychelles, Mauritius, Ghana). Often skippers from different fleets may participate in workshops at certain port locations. Participants from the majority of key fleets in tuna purse seining have participated including Filipino, Indonesian, Ecuadorian, French, North American, Chinese, Spanish, Taiwanese, Korean, Ghanaian, or Panamanian skippers. Several key locations have been revisited annually since the beginning of the project (Table 1). This constancy in the interaction with skippers and other stakeholders is important as feedback information is greatly improved when participants get to know and trust the scientists involved.

ROUND	LOCATION	DATE	PRINCIPAL FLAGS PRESENT	SKIPPERS	CREW	SHIP-OWNERS	FLEET MANAGERS	FLEET REPS.	GOV. REPS.	NATIONAL SCIENTISTS
0	SUKARRIETA (SPAIN)	Nov-2009	Spain, USA, France	15	1	1	1	6	1	0
1	MANTA (ECUADOR)	Sept-2010	Ecuador	56	18	1	0	1	0	0
1	PANAMA CITY (PANAMA)	Sept-2010	Panama	6	6	1	0	0	3	6
1	ACCRA (GHANA)	Nov-2010	Ghana	2	0	0	2	21	6	1
1	SUKARRIETA (SPAIN)	Dec-2010	Spain, Ecuador, Panama, Venezuela, El Salvador, Kiribati, Seychelles, Madgascar, Cote d'Ivore, Guatemala, Vanuatu	32	0	0	0	6	0	5
1	MAHE (SEYCHELLES) / PORT LOUIS (MAURITIUS)	Feb-2011	France	11	5	0	0	1	0	0
1	PAGO PAGO (AMERICAN SAMOA)	Mar-2011	USA	2	0	2	1	4	3	2
1	MAJURO (MARSHALL ISLANDS)	Jul-2011	USA, China, Taiwan	2	1	0	0	1	1	0
1	POHNPEI (MICRONESIA)	Jul-2011	USA, Solomon Islands, Federated States of Micronesia	3	1	0	0	4	0	0
2	ACCRA (GHANA)	Mar-2012	Ghana	2	0	0	2	18	6	0
2	MAHE (SEYCHELLES)	May-2012	France	5	2	0	0	1	0	0
2	PAGO PAGO (AMERICAN SAMOA)	Jul-2012	USA, Ecuador	3	2	0	0	3	0	2
2	GENERAL SANTOS (PHILIPPINES)	Aug-2012	Philippines	26	4	0	1	3	0	21
2	BINTUNG (INDONESIA)	Sept-2012	Indonesia	20	0	0	0	0	25	3
2	JAKARTA (INDONESIA)	Sept-2012	Indonesia	13	1	0	0	0	10	3
2	MANTA (ECUADOR)	Sept-2012	Ecuador, Spain, Panama	17	4	4	0	1	0	1
2	SUKARRIETA (SPAIN)	Dec-2012	Spain, Ecuador, Panama, Venezuela, El Salvador, Kiribati, Seychelles, Madgascar, Cote d'Ivore, Guatemala, Vanuatu	87	3	2	2	9	0	6
3	ACCRA (GHANA)	May-2013	Ghana	13	0	2	1	18	7	0

3	LIMA (PERU)	Aug-2013	Peru	0	0	2	2	16	2	15
3	MANTA (ECUADOR)	Aug-2013	Ecuador	37	5	0	3	4	1	0
3	PANAMA CITY (PANAMA)	Aug-2013	Panama	2	0	2	1	7	0	7
3	SUKARRIETA (SPAIN)	Nov-2013	Spain, Ecuador, Panama, Venezuela, El Salvador, Kiribati, Seychelles, Madgascar, Cote d'Ivore, Guatemala, Vanuatu	44	6	2	2	5	0	0
4	BUSAN (SOUTH KOREA)	Feb-2014	Korea	8	9	0	1	10	3	12
4	KAOSHIUNG (TAIWAN)	Feb-2014	Taiwan	1	0	0	6	12	0	0
TOTAL				**407**	**68**	**19**	**25**	**151**	**68**	**84**

Table 1 – Skipper workshop location and participation by stakeholder profession.

Throughout the three rounds of workshops conducted to date, the bulk of the participants have been skippers (fishing masters or captains) totaling more than 400 participants. This is a significant number considering that the global fleet of large scale industrial purse seiners is made up of around 700 vessels.

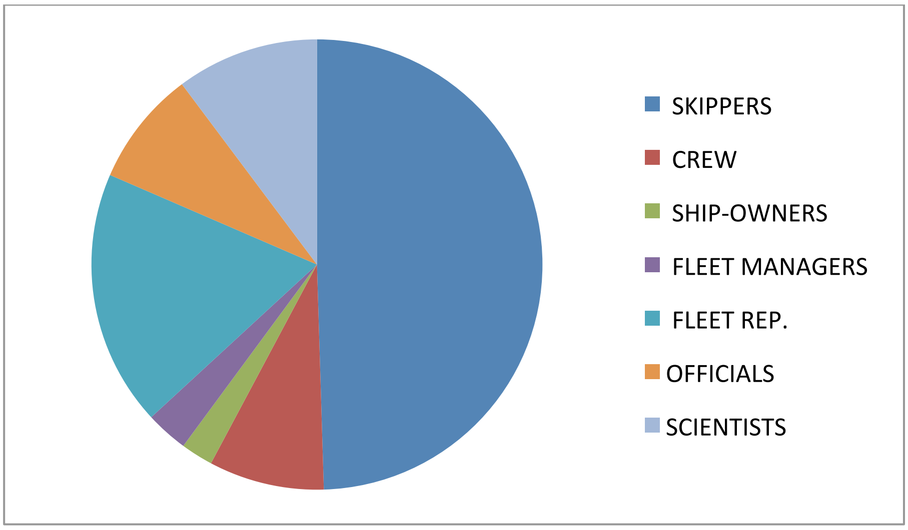

Figure 1 – Skipper workshop participant composition

In addition to skippers, other crew members like deck officers, deck bosses and chief engineers have attended. Other key stakeholders like vessel owners and fleet managers are sometimes present. Their participation is important because owners and managers of the companies have the capacity to provide fishers with means to adopt mitigation measures (e.g. provision of materials for

-entangling biodegradable FADs) and empower their application. In some workshops, fisheries officials or managers (from tuna RMFOs, government, etc.) and also national scientists have participated to learn more about bycatch issues and the latest best mitigation practices.

Often ISSF scientists conducting the workshops visit tuna vessels at their unloading ports to examine the equipment utilized on board (i.e. sonars, echo-sounders, bird radars, helicopters, workboats, etc.), and learn about the different types of boats used by each fleet. Skipper workshops could take two forms: collective workshops with more than tens of participants, or one-to-one interviews (or with two skippers).

SKIPPER WORKSHOP CONTENTS AND CONTRIBUTIONS

Each workshop lasts approximately 3 to 6 hours and covers a range of subject areas on bycatch and bycatch mitigation. Since 2009, the materials presented have developed because the Bycatch Project is continuously generating new findings from the latest scientific research. For instance, during the first year of workshops, fishers were presented with the ideas that scientists wanted to test at sea with the main objective to gain feedback from fishers on these ideas, as well as new ideas from them. In following rounds, the workshops have been updated with results scientists have obtained during those research cruises. If feedback on how to improve future research is an ongoing objective of the workshops, the following grounds were an opportunity to show what experimental measures worked in order to promote good practices that could contribute to reduce bycatch. In addition, for each workshop, specific information/themes relevant to those particular fleets or regions are incorporated. Workshop presentations and logistical preparations are coordinated by a permanent team of scientists to ensure homogeneity of workshop contents and results across different locations.

In general terms the workshops have been following an agenda divided into three parts:

1) **Introduction**: The concepts of what bycatch is and why it is important to pro-actively work to reduce bycatch levels are addressed. The significance and relevant information on bycatch in FAD fisheries is explained, including which species groups are involved (and which are more ecologically vulnerable, due to life history characteristics, such as sharks). This part is not repeated when the participants already attended a workshop previously. Also, present bycatch regulations that are currently discussed at RFMOs (e.g. full bycatch retention, non-entangling DFADs, etc.) are presented. In addition, other initiatives which promote sustainability and transparency in tuna fisheries, such as the Marine Stewardship Council (MSC) eco-certification and the ISSF ProActive Vessel Register (PVR), are discussed with fishers.

2) **Bycatch mitigation research:** This section of the workshop is the most extensive and detailed, as participants are introduced to the latest bycatch study results and best practices identified by ISSF research and that of other national and international scientific efforts. Future ISSF experiments and project proposals to be conducted in the next year are discussed with skippers. Research projects to investigate bycatch mitigation options are presented by species categories (e.g. sharks, turtles, small tuna) to show what can be done for each group. Solutions discussed can be implemented at different stages during the fishing operation (i.e. remotely[1], before setting a FAD[2], after setting[3], after hauling[4]). The role of fishers in developing solutions to the utilization of retained individuals is also discussed.

   The following lists gather research activities presented at workshops during the different workshop rounds (see Table 2), considering for instance that some activities were presented in early rounds and were not covered in subsequent rounds after negative results from trials at sea, or that some were not present during the first workshops but appeared in the following rounds after new ideas from scientists and/or fishers:

A. SHARKS

1. Non-entangling FAD solutions (underwater structure)[1]: Prevent sharks entangling with the FAD's sub-surface netting, used to increase their attractiveness and modify drift speed, by construction with non-entangling materials like ropes, and promoting the use of biodegradable materials.
2. Characterization of shark behavior at FADs[1,2]: Investigate if there is some time period during the day when sharks move away from the FAD while tunas are present, to adapt fishing time[2].
3. Attraction of sharks away from the FAD[2]: Before the set by using a speedboat to slowly tow an attractant, such as bait, to move sharks away from the FAD.
4. Shark release through windows in the net[3]: Introduce a window in the net that can be opened during the set to let sharks and other bycatch escape.
5. Best liberation practices on deck[4]: Find best and safest techniques to release sharks in the best condition possible when arriving on deck, supported by post-release survival data.
6. Best practices and survival of whale sharks and manta rays[4]: Show best procedures and equipment required to release live whale sharks and manta rays and verify release condition and survivorship.

B. SEA TURTLES

1. Non-entangling FAD solutions (surface structure) [1]: Avoid turtle entanglement by avoiding use of loose netting on the FAD's raft, using no netting or canvas/tarpaulin instead or by construction of FADs with minimal surface area on which turtles can climb to rest
2. Best liberation practices from the net and on deck[3,4]: Show best ways to handle turtles to maximize survival during removal from net or release from the deck.

C. SMALL TUNA

1. Acoustic selectivity of echo-sounder buoys[1]: Develop acoustic discrimination using echo-sounder equipped GPS buoys to know remotely if FADs have a large amount of small bigeye and yellowfin tuna or bycatch and avoid unwanted sets with high bycatch ratios.
2. Characterization of tuna behavior at FADs[1,2]: Investigate if there is some time period during the day when small bigeye tuna are away from the FAD while skipjack tuna are present, to adapt fishing time[2].
3. Pre-estimation at the FAD (vessel sonar and sounder, or cameras)[2]: Improve the ability of skippers to estimate the species and sizes under a FAD prior to setting with their onboard acoustics (or cameras) to avoid sets with undesirably small tuna or bycatch.
4. Sets on skipjack away from the FAD[2]: Try to capture skipjack away from the FAD when they abandon it daily after dawn to preventing catch of the remaining bycatch species still associated with the FAD.
5. Schooling behavior of tuna in the net[3]: Study the specific schooling behavior of tuna in the net in order to investigate solutions to segregate species in the net through the exploitation of specific reactions to particular stimuli, and then release unwanted species (e.g. small bigeye tuna) through windows in the net.

D. BONY FISH BYCATCH

1. Avoidance of small sets (< 10 tons) [1,2]: Show that small sets produce as much bycatch as large sets but contribute very little to the catch of target tuna.
2. Characterization of bony fish bycatch species behavior at FADs[1,2]: Investigate if there is some time period during the day when bony fish bycatch are away from the FAD while tunas are present, to adapt fishing time.
3. Removal from net and deck[3,4]: Show information on fish escapes with large mesh sizes and procedures and tools which aid live release of non-target fish, such as hoppers or double conveyor belts.
4. Double FADs: Seed two FADs linked together and separate them before the set towing away one FAD and observe if bycatch (i.e. sharks and non-tuna fish) divide between both FADs.

5. Utilization[4]: Examine the potential utilization of some FAD bycatch species for food which are highly productive (e.g. mahi-mahi, rainbow runner, wahoo).

Some particular details of the research are sometimes highlighted, e.g. results on the behavior of fish at FADs or in the net from tagging or diving, in order to contrast scientific knowledge from researchers with empirical knowledge from fishers on particular points. In addition, possible effects of FADs on the biology and ecology of tunas are also discussed for skipper feedback.

Table 2 - Summary of feedback and novel ideas on bycatch mitigation by species groups provided by participants during the Skipper Workshops.

SHARKS	
1.Non-entangling DFADs	• The most common type of non-entangling FAD is one with a tarpaulin covered raft and underwater appendage made of netting tied in sausages (either one large central one, or four smaller in each corner of the raft). Strictly speaking non-entangling FADs should have no netting, and fewer skippers are using only rope material for FAD tails at present. This kind of tied-netting design was initially envisaged by scientists as an intermediate step towards non-entangling FADs that greatly reduces entanglement, with a low incidence of ghost fishing reported only if the bundles become untied. • Large scale utilization of tied-netting “reduced entanglement” FADs is being implemented by some European purse seine fleets (e.g. French, Spanish) with many vessels using 100% FADs of this kind. • Present designs of non-entangling FADs work better in the Pacific and Indian Oceans, where FADs use sorter tails as fishers want to track surface oceanographic currents. • In the Atlantic fishers use longer tails (60 m or more) with netting opened as a sail because superficial currents drift too fast and fishers want to “anchor” the FADs to the slower, deeper, currents. The sausage type design does not slow down the FAD

	enough, making it drift at high speeds. Also in colder waters (i.e. Gabon, Angola) biofouling by barnacles makes the FADs too heavy and they sink. Some fishers use rope going from the raft surface to 10-20 m depth (i.e. no netting in the first 20 m, where most entanglement occurs) and below they hang netting of small size mesh. • Accounting for camouflage or low visibility of the FAD is an important element in the design of the structure as many FADs get intercepted and stolen by other vessels, especially in the Indian Ocean. A raft with no dark cover might be too visible. • Fleets relying mainly on anchored FADs do not have a problem with entanglement as these do not use netting in their construction. • The use of biodegradable materials in the non-entangling FADs is still slow. Biodegradable materials currently used are the bamboo raft, and some companies are using biodegradable agricultural tarpaulin to cover the raft. However, this canvas only lasts a few months before breaking apart. The major problem skippers have is that they have not identified yet suitable biodegradable materials that are durable and cheap. The fleets are asking scientists to find the right materials and fishers will then try them at sea. • In some ports, especially in the Atlantic (e.g. Abidjan) and the Seychelles, FADs are constructed on land. Control of good standards and practices in FAD construction and materials used might be easier at port than monitoring at sea.
2.Shark behavior at FADs	• Some fishers think sharks appear and abandon the FADs at similar times of the day as tunas. Other fishers are not sure as with their acoustic equipment they cannot know if sharks are present or not at the FAD.
3.Move away from FAD	• Skippers believe trying to get sharks out of the net either following the towed FAD or some attractor like bait/light should be done far away from the purse seine vessel if possible as its noise and shadow can scare them.
4. Net modification (windows)	• Some fishers show concern for net windows or escape panels as it could risk target species escaping too. • Some skippers, including those collaborating in research cruises, have contributed feedback on escape window location and design.

5.Shark release practices	• Several fleets have been provided with guides for best release practices available and are taking steps to implement them. However, loading the tuna quickly to ensure fish quality remains the principal task. In smaller sets there is more time to deal with bycatch. • Equipment for fast and safe shark release is lacking. Few vessels have aiding tools such as double conveyor belts or hoppers and these are somewhat inefficient. Release aiding equipment should be simple to use and not be bulky as most purse seiners have little spare space on the top deck. • Many skippers think that the number of sharks arriving on board per set is very low (i.e. 1 or 2 sharks). The ISSF research WCPO cruise showed that skippers might underestimate the number of sharks arriving on deck as often it is difficult to see them in the brail as many are small.
6.Manta ray and whale shark release practices	• Skippers think most whale sharks accidentally caught in the net are released alive and well, following the procedure of lowering the corkline to let them pass over it. Whales on the other hand behave differently usually liberating themselves by pushing and making a rip through the net. Scientific tagging data would be welcome to assess post-release effects. • Sets with some kinds of manta rays (free swimming school sets) or whale sharks might be limited in time and space to areas of high productivity with coastline or seamounts. Further investigation is required to identify these hot spots. Sets near coastal areas or seamounts can result in captures of large numbers of individuals. • Novel ways of liberating sharks and manta rays have been described in previous reports (e.g. "cable" system utilized in some Ecuadorian vessels to lift and liberate manta rays).
TURTLES	
1. Non-entangling FADs	• Few turtles become entangled in the FADs and when they are found fishers liberate them without much difficulty, most alive (observer RMFO data supports this; Hall and Roman, 2013). • Different fleets have tried using tightly stretched small mesh netting on the raft to avoid turtle entanglement. Others cover the raft with biodegradable tarpaulin. However, when the tarpaulin breaks down it exposes the netting underneath. • Many fishers are reluctant to use bare bamboo rafts (without netting or tarpaulin)

	because without a dark cover the raft is more visible and also it produces less shadow to attract fish. In addition, the net around the raft holds the structure together (bamboo canes, floats, etc.) when the FAD starts to deteriorate. • Models of "submerged" FADs without rafts, which would prevent turtle entanglement, have been used previously by some fishers (Appendix I).
2. Turtle release practices	• When a turtle gets entangled in the vessel's net, rather than deploying a speedboat to liberate the turtle which keeps diving deeper in the net when it sees the speedboat approaching, skippers think that stopping the net rolling when the turtle is at deck level is more efficient and also safer for the crew.
SMALL TUNA	
1.Acoustic selectivity of buoys with echo-sounder	• The use of echo-sounder buoys has been growing exponentially in the last five years. Their technology is improving and becoming more reliable, thus giving fishers crucial information on which FADs do or do not have fish. However, species discrimination using echo-sounder buoy information with present technology is extremely difficult. The fishers welcome any effort from scientists to improve acoustic discrimination between target and non-target species/sizes as it would save them long costly trips (spending over 15000 l/day of fuel) to areas with undesirable small fish. • Skippers believe that in some zones the echo-sounder buoys work better than others. Variability can come from different sources (e.g. water temperature, salinity, rough weather, etc.). • Skippers check the echo-sounder buoy information several times a day, follow the evolution of the FAD (i.e. how the aggregation of fish is increasing or not), and make their own adjustments to tonnage estimation based on their experience. They also try to guess how much fish are bycatch species, which can be found mostly in the top 20 m below the surface.
2.Tuna behavior at FADs	• There are important differences in tuna behavior between oceans. Whereas in the Atlantic tuna schools are smaller and several sets can be made throughout the day, in the Western Pacific FAD sets are usually done once a day just before dawn. Even within oceans, like in the Western Indian Ocean the behavior of tuna in the northern areas is different (e.g. maximum aggregation at the FADs happens latter in the morning) than in southern zones. • Many skippers consider that the behavior of tuna is different when it is in a zone of

	very high FAD densities. In some oceans there is a tendency to increase the size of FADs because some skippers think that in this way they can attract more tuna and out compete smaller FADs. The amount of natural floating objects relative to FADs is nowadays very small (< 10%) and often skippers do not even inspect them, as they rarely attract tuna anymore. • Fishers have reported rare events they have been observing in their oceans in the last few years, such as unusually large amounts of bycatch in sets in the Atlantic (e.g. sets with 30 tons of triggerfish), or lower captures of skipjack but more small yellow fin in the north Indian Ocean. • Oceanographic conditions determine where tuna are found. Fishers believed that more important that the structure of a FAD is which trajectory it follows tracking productive zones. Large tuna tend to aggregate in colder water masses. Large changes is tuna distribution occur during El Niño-La Niña years in the Pacific. In normal years some areas near islands which tend to generate pockets of recirculating waters are very productive. Other environmental factors, such as lunar phases, are also very influential. • In cold waters the amount of bycatch species per FAD is lower, producing a “cleaner” catch, and tuna sizes tend to be larger. • Some Indian Ocean fishers think that many FADs drifting eastward, which are not retrieved by PS, may be diverting a large amount of tuna out of the Western Indian Ocean. Similar comments have been made by Eastern Pacific fishers thinking that FADs drifting towards the west may carry the tuna to the Central and Western Pacific. • Because in the Indian Ocean there are large areas protected from fishing (i.e. Chagos is an MPA, Somalia is not fished due to piracy, other coastal nations require fishing licenses that some companies do not have), some skippers think that this acts as a large enough buffer to maintain the populations of tuna despite strong improvements in fishing efficiency.
3.Pre-estimation at the FAD	• There are notable differences in the acoustic equipment (i.e. sonars, echo-sounders) used onboard by different fleets. While some vessels might only have old sonars, others will have long range sonars, plus several lateral and vertical echo-sounders with multi-beam frequencies. This is important when prioritizing technological improvements, like better acoustic selectivity, that can benefit the greatest number of fleets possible.

	• At present even those skippers using the best acoustics find it difficult to pre-estimate the schools of tuna (i.e. which sizes and species are present) under a FAD before the set. • Fishers give importance to recent sets in the area. If they have had small tuna in the previous set, they will be more cautious and check more carefully. • Close pre-estimation with the vessels' echo-sounder is only done if the sonar shows a small amount of fish and they are in doubt whether to make a set or not. If the sonar indicates a threshold school size normally fishers will make the set without further inspection.
4.Catch of skipjack away from the FAD	• This idea received poor acceptance as fishers thought skipjack would not always leave the FAD all together in one school and there would be a higher probability of skunk sets if the tuna was not aggregated under the FAD.
5. Behavior of tuna in the net	• Some skippers pointed out that with the vessel's lateral echo sounder they could observe that tuna separate by species and sizes in the net while there is space, during the first stages of the fishing maneuver. • Fishers point out that when there are billfishes inside the net, tuna behavior is much more unpredictable and erratic.
BONY FISH AND OTHERS	
1.Avoid small sets	• The fishing strategy and behavior and size of tuna schools in each ocean determine very much which is the lower threshold a skipper considers is required to make a set. In the Western Pacific as there is usually only one FAD set per day the threshold is higher (i.e. 15-20 tons). In the Atlantic (except for some zones like Piccolo or Mauritania) where tuna schools tend to be small and several sets per day are normal, fishers will consider setting on schools of 10-15 tons. • There are also seasons during which fishing is slow (e.g. monsoons), and skippers will be less selective settling for lower sized sets. • Fishers agree that the tons of bycatch fish species are similar between FADs and not related to the tons of tuna present.
2.Bony fish bycatch behavior at	• Very few times they find tuna with no other bony fishes at FADs. • After a set fishers are interested in keeping as many non-target fish alive associated

FADs	with the FAD as they can, because they think these species are responsible for attracting tuna. If all bycatch fish species are removed the FAD "maturation" process will be slower. There are generally differences in the amount of bycatch species found in each ocean. For example, in the Atlantic FADs might have more bycatch aggregated compared to the Western Pacific. Even within oceans depending on water temperature or plankton concentration bycatch fish abundance can vary.
3.Removal from net and deck	• Part of the smaller species (i.e. decapterus, trigger fish) gets out of the net before brailing, either through the gap in the oertza or the net mesh. There is a trend in some fleets to use wider sized mesh (300 mm) in the center of the net, which could facilitate escape of small fish. • Some vessels have modifications onboard to facilitate non-target fish liberation like double conveyor belts (some French vessels) or hoppers on deck (many vessels in the Pacific).
4. Double FADs	• Skippers have experience in joining floating objects (i.e. two nearby FADs) but not separating them. Some indicate that when they join two FADs with a small amount of tuna in each to get a greater capture, sometimes the schools from the two individual FADs will not mix or join together, they will remain spatially separated.
5.Utilization	• Utilization of non-target, highly productive species characteristically associated with FADs such as mahi-mahi, rainbow runner, wahoo or triggerfish are being considered by scientists and managers as long as the stocks of these species are not impacted. Other bycatch species with a lower reproductive rate and declining populations (e.g. sharks, turtles) should not be utilized. • Part of the non-target species are usually consumed on board by the crew (e.g. mahi-mahi, wahoo) and in some oceans like the Eastern Atlantic local markets exist at ports to sell small tuna and other bycatch species (called "faux poisson"; Chavance et al., 2011). • While in the Western Pacific generally there is little utilization of bycatch yet, in some ports of the Eastern Pacific like Manta, new factories specializing in processing and commercializing fish products derived from purse seiner bycatch species (e.g. mahi-mahi, wahoo, billfishes, etc.) have recently emerged. This valorization of bycatch might extend to other regions if a wider market for these products develops.

E. FISHING INFORMATION

In the latest round of workshops, information related to fishing efficiency and catch-per-unit-effort (CPUE) has been also introduced (see Table 3), as learning first hand from each fleet about the latest developments in what tools they prioritize to fish (e.g. echo-sounder buoys, supply vessels, oceanographic fishing services, bird radars) and which strategies they use (e.g. sharing of DFADs, numbers of DFADs used, changes in fishing effort) are key in understanding their impact on the fishery.

Table 3. Fishing information provided by skippers on fishing capacity, technology and general fleet trends gathered through the questionnaires and also during workshop conversations with the skippers.

FISHING INFORMATION

- There is disagreement between skippers on whether having very large purse seiners with a supply vessel is more economically profitable for a company than having medium size, fuel-efficient, purse seiners with no supply vessels. While in the Pacific supply vessels are prohibited, the recent tendency in fleets of the Atlantic and Indian Ocean is to build more of these vessels. Supply vessels in charge of building, seeding and monitoring FADS are particularly important in companies using an intensive FAD fishing strategy.

- Several skippers, especially in the Indian Ocean, showed concern with the strong increase in the last five years of the number of FADs being used. Some fleets like the French have started self-restricting their number of FADs.

- Most skippers earn a salary proportional to the market value of the catch of their vessel, but some are paid on the tonnage, not on the value per catch composition. Some companies pay only half price to their skippers for small individuals (e.g. < 1.5 kg) or even no money at all (e.g. the French). This may serve as an incentive to avoid catching small sized tunas, when combined with a full retention requirement, as is the case in several RMFOs.

- Although a minority, there are still reports of IUU vessels operating in tropical tuna fisheries. RMFOs and other bodies (including ISSF) are improving their databases to identify and expose these illegal boats.

- Due to a call for vessel capacity limitation by 2015 many new purse seiners have been and are being constructed in the last two years prior to this deadline. Many of these new vessels are being flagged under coastal nations which had little or no fleet before. This has resulted in an increase of the purse seiners operating in some oceans.

- Purse seine companies, even those in the same fleet, can show differences in their fishing strategy (i.e. amount of buoys, use of supply vessels, sharing of FADs between vessels, fishing directed by the fleet manager or the skippers). Being aware of these differences is important to help understand better the impact of each one.

  There are several fleets which typically use a strategy of strong investment in fishing technology (sonars, sounders, bird radars, echo-sounder buoys, supply vessels, larger vessels, etc.). For this heavy investment to pay off skippers much catch larger amounts of fish and this is one reason why the number of FADs has escalated in some fleets. Some fleets which have traditionally concentrated great part of their effort on other fishing modes (i.e. free school sets, dolphin sets) are increasing their use of FADs.
- The introduction of GPS buoys expanded fishing grounds outwards from the continental shelf. Now, with the use of echo-sounder buoys telling fishers which FADs have fish, fishers are expanding their fishing zones or going to areas at times of the year they would have not thought of before.

- Modern fleets are moving towards 100% echo-sounder buoy use (e.g. EU fleets), while fleets with fewer economic means are still using few buoys of this kind, although their proportion is also increasing.

  There is a strong technological “arms race” between sonic equipment brands to develop the best product. There are clear differences in the quality and reliability of echo-sounder buoy brands, and the skill of fishers to read the instruments is likely to be improving too.
- Fishers in the Pacific give more importance to echo-sounder buoy information than those in the Atlantic and Indian Oceans. One factor being the long distances and travel days skippers can save checking FADs in the much larger Pacific Ocean.

- In the Pacific all large purse seiners have 100% observer coverage. In the Atlantic and Indian Ocean historically there has been a very low coverage (5-10% trips), but there is a tendency to increase observers either voluntarily (e.g. for eco-certification purposes) or by mandate (e.g. during RMFO FAD closures). Electronic observers are starting to be used in some vessels.

- Many FAD restrictions and bycatch regulations may start to come directly from national governments from which they purchase fishing licenses, even earlier than through RMFOs which are more complex and slower to pass enforcing laws.

3) <u>Questionnaires</u>: In the last part of the workshop skippers are asked to fill in an anonymous multiple choice questionnaire which covers a range of important topics. In total there are between 40-50 questions (Appendix II), which offer all skippers the chance to share their knowledge.

This exercise gives every fisher a chance to contribute their knowledge on several topics, as sometimes skippers are reluctant to talk about certain issues in front of their peers (e.g. confidential issues such as FAD numbers, fishing strategy). To facilitate the task, questionnaires are usually given in the native language of the fishers and most questions are in a multiple choice format with a section to add comments if desired. Fishers can select several options in a question if they feel it is appropriate and they are asked to provide truthful information, having the option of not answering questions they might consider too sensitive.

The questionnaire starts by asking details on the position and experience at sea of the participant and then follows a series of sections by themes including:

(1) FAD structure and tuna attraction

(2) Fishing efficiency and CPUE

(3) FAD composition pre-estimation

(4) Use of FADs by tuna

(5) Buoys with echo-sounder

(6) Tuna sustainability measures and economic incentives

One of the advantages of the questionnaires is that it allows comparison within and between both fleets and oceans. The questionnaires not only highlight the differences between fleets but also within fleets as companies vary in the resources and fishing strategies used (i.e. types of FADs, acoustic equipment, use of supply vessels). The information provided also helps to characterize the similarities and differences between oceans (i.e. oceanographic variables, tuna behavioral traits) that strongly influence fishing practices and bycatch composition.

A very important role of the questionnaire is its ability to document highly detailed technical information, trends and changes in technology and fishing practices of these key fleets. This kind of first-hand information that is updated regularly is often scarce and of great value for scientists to understand efficiency and impacts of the fleets as it happens. For example, the rapid increase in the number of echo-sounder buoys is clearly observed by comparing their proportion utilized by fishers from the same fleet in the last three years. Whereas modern fleets like the Spanish in 2010 had less than 25% of all buoys with echo-sounders, by 2013 the majority of vessels carry over 75% sounder buoys (Lopez et al., In press). This increase in echo-sounder buoys is also starting to be observed in other fleets worldwide, although at different rates depending on the economic capacity of each fleet to invest in these expensive buoys. These buoys have a direct impact on catch-per-unit-effort (CPUE) because they can reduce the proportion of "skunk sets" (sets without capture) and increase the average catch per set by providing more information to the skippers on the biomass available in different FADs. Obtaining direct information from various fleets on fishing practices that influence bycatch rates and fishing efficiency is an important outcome from the Skipper Workshops.

Note that the principal materials covered in the Skipper Workshops are also available in a shortened online format of a Skippers Guidebook (http://iss-foundation.org/resources/downloads/?did=392) for those fishers wishing to learn more about bycatch but are unable to attend the meetings in person. Skippers attending the workshops or successfully completing the Guidebook test receive status of being trained in bycatch education should their vessels join the ISSF ProActive Vessel Register (http://iss-foundation.org/pvr/).

ACTIVITY ACCEPTANCE LEVEL BY FLEET

In the workshops the acceptance level by each fleet for the proposed bycatch mitigation measure are recorded. It is important to acknowledge that the differences in fishing technology and practices between some purse seine fleets, even those working in the same ocean, can be significant. These acute differences in capacity and technology strongly influence the acceptance level of some activities. For instance, measures like improved selectivity of small tuna and bycatch species by the remote discrimination of echo-sounder buoys is favored by fleets with stronger economic means capable of investing in expensive state-of-the-art buoys. Note though that acceptance level by each fleet for some activities is not fixed and can change from year to year for example with the move to different fishing strategies (e.g. adoption of new technologies like instrumented buoys).

Depending on particular fleets, some fishing practices are not applicable to them. For example, fleets working with drifting FADs, which utilize netting in their construction, are interested in finding non-entangling designs that prevent bycatch of sharks or turtles. Meanwhile, fleets working on anchored FADs that do not have netting give more priority to other bycatch measures.

From the beginning of the workshops acceptance level of the research activities has provided a good indicator of which measures were more likely to succeed and be adopted more readily by the fleets. For example, activities to improve survival of non-target species through the use of better release techniques and instruments from the deck were widely accepted from the start by most fleets. Three years later many vessels employ best release methods and carry onboard best practice guidelines, like that published by the project MADE (Poisson et al., 2012; http://www.made-project.eu), for crew to follow.

Another measure that has received wide approval is the move from traditional DFADs to non-entangling DFADs which minimize ghost fishing. Designing functional DFADs that maintain certain features desired by fishers (i.e. endurance, low visibility, provision of shadow for fish, tracking of underwater currents, etc.) is not a simple matter. However, we have observed a strong commitment by some fleets to move towards 100 per cent non-entangling FADs. With RMFOs and organizations like ISSF also favoring the use of non-entangling FADs (e.g. Resolution C-13-04-FADs by IATTC; Resolution 13/08 by IOTC; Recommendation 13-01 by ICCAT; ISSF 2012) it is likely this more benign kind of FAD will become the norm in the coming years.

There have been other activities which skippers thought had lower potential. This is the case for example of the idea proposed by some scientists who wanted to try to catch the skipjack schools away from the FAD when they abandon the floating object after sunrise. Skippers argued that the capture of skipjack using this method would be almost impossible as the fish would not leave the FAD at once in one school, but gradually in several groups and often at depths away from the surface, making detection difficult. Also, capturing a school in movement is much more difficult than capturing a school associated with a FAD, as the proportion of skunk sets in both types of sets show (Hall and Roman, 2013). Tagging data during research cruises proved fishers were right and this bycatch mitigation measure has now been abandoned.

CONCLUSIONS

All fisheries should strive to minimize their impact on the oceans' ecosystems. The ISSF Skipper Workshops provide an on-going foundation for the improved long term sustainability of the tropical tuna fisheries worldwide based on the collaboration between fishers and scientists in the Atlantic, Pacific and Indian Oceans. The workshops have highlighted the great diversity of practices and equipment utilized by the international fleets exploiting this resource, helping identify bycatch reducing measures which suit each region best.

Despite skippers being arguably the most important participants in the fishery (i.e. their daily actions directly impact the fishery), they are usually left out of the decision making process on how to improve fishery sustainability. Fishers in many cases are seen as the cause of the problem rather than a critical part of the solution. At present for example there is strong lobbying by certain environmental NGOs against the use of FADs, which portrays tuna FAD fishers in a negative light. This approach historically, has made fishers to some extent reject scientists, NGOs and managers. However, when fishers have been given the chance to participate in finding solutions to fishery problems their contributions have been substantial (see Hall et al., 2007). In this project fishers' know-how or FEK has directly contributed to improve ISSF scientific research campaigns in each ocean. The ultimate goal is to improve our ability to mitigate bycatch by utilizing the accumulated knowledge and expertise of fishers. Achieving this goal will also have direct benefits for skippers and the fishing industry by reducing negative publicity, avoiding potential unwanted or poorly conceived regulations and helping maintain a healthy pelagic ecosystem.

In addition, the most effective bycatch mitigation measures will only be as good as the degree to which they are effectively applied on the sea, within the active fishery where it counts. Understanding which initiatives have greater acceptance by the fleets and why is crucial to designing practical solutions can facilitate adoption of these measures.

Currently there is a battery of research activities being tested to reduce bycatch in FAD fisheries. Long-term fundamental research on the biology and physiology of pelagic species lies at the basis of these activities and should always remain a long term foundation for developing the best possible management advice. Having said this, the priority and degree of utilization of particular bycatch mitigation measures is dynamic and may change over time, area or fleet. Below is a summary of today's most promising bycatch research options and where they are at in relation to their application according to skippers' feedback.

DEVELOPMENTS IN NON-ENTANGLING FADS

Recent work from the Indian Ocean suggests that shark mortality caused by entanglement in the netting of drifting FADs is more significant than previously thought, possibly surpassing the fishing mortality that occurs during the purse seine fishing operation in some oceans (Filmater et al, 2013). The rate of FAD entanglement in other oceans is presently unknown and could be very different from that of the

Indian Ocean. For example, FAD entanglement in the eastern Pacific appears to be levels of magnitude lower according to entanglement incidents recorded by observers based on many thousands of FADs recovered by the boats for redeployment (approx. 10,000 per year) that allow observers an easy count. Differences in shark densities between oceans or FAD construction designs by each fleet are likely to affect shark entanglement rates and merit further research. The principal shark species which shows strong FAD-aggregating behavior and highest fishing mortality is the silky shark (*Carcharhinus falciformis*) and their populations are being heavily impacted by different fisheries (e.g. industrial longline, artisanal longline, purse seine, etc.). Thus, there is a strong urgency to move away from traditional FADs and adopt non-entangling FADs designs.

Due to the heavy reliance on FADs as fishing gear to catch tuna, finding a non-entangling FAD that maintains the required characteristics of normal FADs (e.g. attract fish, durability, drift speed, shadow generation, floatation, low visibility) is necessary if they are to be adopted voluntarily. Major oceanographic differences, especially between the Atlantic and the other oceans, affecting the drift of FADs have been emphasized by fishers. There is not a single non-entangling FAD model that can fit all oceans and tuna RMFO's should consider this input when preparing regulatory guidelines on this subject. In 2013, fishers report that several companies from the Spanish and French fleets have started utilizing successfully FADs that significantly reduce entanglement (primarily tying the FAD's netting into sausage-type bundles, or using ropes) at a large scale in the Indian and Pacific Oceans. According to some skippers these prototypes have not worked well in the Atlantic, due to strong currents in this ocean making FADs drift too fast and also heavy biofouling sinking them. Some Atlantic-based fishers are trying alternative designs with longer FAD appendages and the results of current prototypes they are testing should be reported back to scientists in following workshops. The workshops help fishers learn from what other fleets are doing and hopefully encourage them to follow these steps. For example several Ghanaian skippers are starting to experiment with non-entangling FADs since last year's workshop, and in the near future it is probable that other important fleets will do the same.

Scientists are recommending that ideal non-entangling FADs should not use any netting in their construction and be made of biodegradable materials to prevent potential ghost fishing, grounding damage to reefs and long term littering. Some skippers are using biodegradable elements (e.g. agricultural tarpaulin on the raft) but they have not found yet the ideal biodegradable materials that last long enough without quickly degrading. Skippers are under pressure from ship-owners to achieve catch targets and an unproductive campaign experimenting with alternative FADs could cost them their jobs. Therefore, fishers are asking scientists to test and find the right biodegradable materials to use (i.e. sisal, jute, or others).

ACOUSTIC SELECTIVITY

Another bycatch mitigation strategy showing high acceptance, especially among fishers with modern instrumentation onboard (i.e. echo-sounder buoys, sounders, sonars), is acoustic selectivity through better discrimination of species and sizes before making a set. Technological developments in acoustic discernment are complex due to the array of species under FADs including target (e.g. skipjack, bigeye, yellow fin) and bycatch species. However, the potential to prevent the capture of unwanted small sized tuna or bycatch before the set is very appealing. Remote discrimination with the echo-sounder buoys to avoid costly long trips to areas of small fish would be very welcome by fishers.

Nevertheless, there is still much work to do, as skippers across oceans have reported difficulties in discriminating species and sizes under a FAD before the set with current equipment. The workshops have helped characterize how and when fishers use acoustics to pre-estimate fish schools under the FADs. For example, scientists are learning how fishers interpret remote data from the echo-sounder buoys (i.e. times they consult the buoys, adjustments they make to the information received depending on zone or water characteristics, etc.) to decide if a FAD is worth visiting. Also, it is important to learn if fishers regularly try to pre-estimate species composition before a set or it is only done in certain occasions (i.e. only in FADs with few tons). This information on fishing practices is necessary to learn if fishers would make full use of possible advances in acoustic instrumentation.

RELEASE FROM THE NET

While non-entangling FADs and acoustic selectivity pre-estimation are bycatch reduction measures applied before the set, once a set has been made on a FAD other methods can be used to liberate unwanted species caught in the net. One idea tested without success was trying to slowly tow the FAD out of the net through the stern Oertza gap hoping that sharks and other bycatch would follow it outside. Skippers were skeptical as they rarely see sharks get close to the vessel, possibly due to the noise and shadow it generates. It was also noted that the FADs are towed out of the net at high speed in order to raise the sub-surface structure to avoid tangling which greatly discourages the associated sharks and bycatch from exiting the net with the FAD.

Following the idea of a French skipper, and after critical observations by divers certifying the separation of sharks and bycatch from tuna inside the net, scientists have been experimenting with escape windows for sharks in the net. A novel window was constructed with the help from a company's crew (Trimarine Ltd.) and tested during ISSF research cruises in the Pacific. Following these experiments, skippers at workshops have contributed feedback on window location and design, and indicated that these windows can be fabricated *in situ* on board the vessel while at sea without the need to offload the net in port to effect the modifications. Scientists are currently working on determining the best stimuli to encourage sharks to move out through the window.

BEST HANDLING PRACTICES

Scientists through ISSF campaigns and other projects (e.g. MADE; www.made-project.eu) have been assessing the survival of bycatch species liberated after arriving on deck (Poisson et al., in press). Findings show that survival of these species is generally very low, with individuals arriving at the beginning of brailing process being the least damaged. During the workshops fishers are instructed on the best techniques available on liberation to maximize survival. Most of these practices are covered in the guide produced by MADE (Poisson et al., 2012) and disseminated by ISSF. Since the start of the workshops many fleets report having adopted some of these methods and carry the guidelines on board for crew reference. Note that even with the best available protocols shark mortality is still very high (approx. 80% of encircled animals), but without these methods shark survival would be close to zero.

During the workshops scientists learn from fishers about the structure and equipment of their vessels (i.e. available deck space, use of sorting hoppers, double conveyor belts) and the ways in which they liberate different species (i.e. whale sharks, turtles, mantas, etc.). The objective is to identify the easiest, fastest and safest liberation methods for each kind of animal to encourage application of these guidelines by fleets.

FUTURE WORK

The ISSF Skipper Workshops are presently embarked in their fourth year (2014), continuing to promote the joint work of scientists and fishers to reduce bycatch and tuna targeting by improving practical, technical solutions. The workshops will build and strengthen the relationships already established with previously visited fleets and aims to expand to cover new locations (e.g. China, Papua New Guinea, etc.).

In 2014 there are plans for three ISSF research cruises to be conducted. Skippers' input before the trips will help to fine tune the relevant protocols for bycatch reduction studies in each ocean and for different fleets. Newly obtained research findings will then be shared with the industry for utilization by their fleets. Meanwhile, skippers will also be updating scientists on their latest efforts (e.g. non-entangling FADs) and any changes in fishing practices. This communication loop between key FAD fishing experts and scientists ensures a more balanced, transparent and effective approach to achieve the goal of bycatch reduction.

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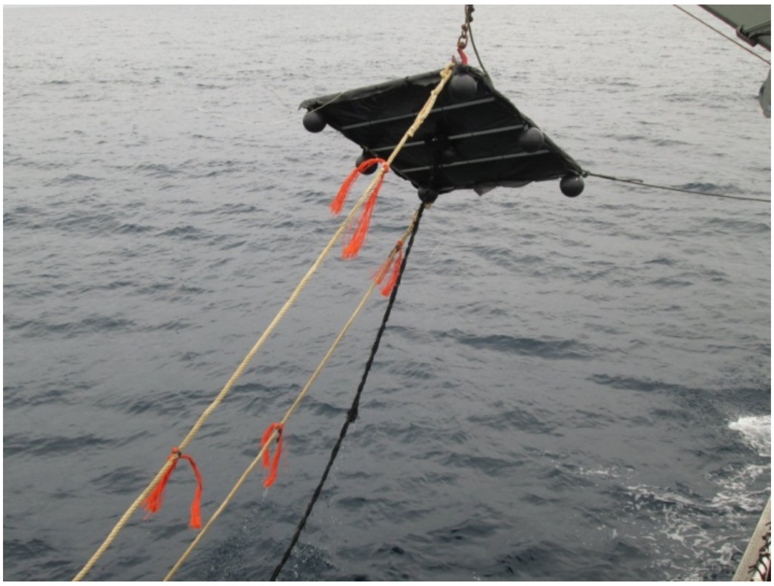
Appendix I – Selection of images illustrating the Skipper Workshops

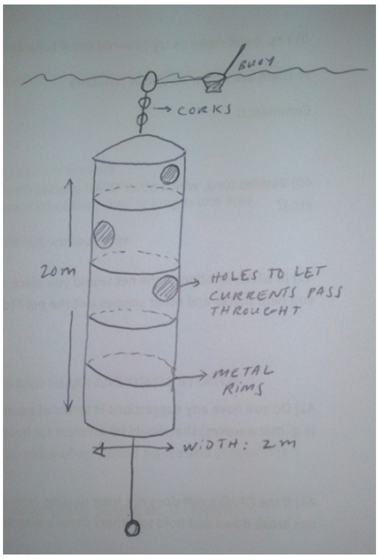
(a) Fishers during a workshop in Sukarrieta for the Spanish fleet, with skippers working in the Indian, Atlantic and Pacific Oceans.

(b) Skipper providing feedback on anchored FADs during a workshop in Bitung (Indonesia).

(c) Scientist conducting an onboard workshop with a skipper at the port of Majuro (Marshall Islands).



(d) Example of non-entangling FAD used in the Indian Ocean by the Spanish fleet, with a raft covered by a biodegradable tarpaulin and a tail made of rope and sausage-tied netting. Photo courtesy of Pevasa.



(e) Skipper's diagram of a non-entangling FAD used in the Pacific, with no raft and a cylindrical underwater structure made of tarpaulin held by rims and with holes to let ocean currents make it drift.

(f) Selection of meal products from a processing plant in Ecuador utilizing bycatch fish species found in FADs (e.g. mahi-mahi, wahoo, swordfish, etc.).

Appendix II – Example of workshop questionnaire

ISSF SKIPPERS WORKSHOPS ANONYMOUS QUESTIONNAIRE

This questionnaire is completely anonymous and the questions are aimed at understanding better how each fleet works and what bycatch measures could work better. If there is a question you are unsure off or do not want to answer you can leave a blank. We do encourage you to write comments to explain better your answers.

WORKSHOP LOCATION AND DATE:

____

JOB AND EXPERIENCE DETAILS

Job title: ___________________

Company: __________________

Ocean or area in which you currently work: _____________

Years of experience in current Ocean: _____YEARS

Other oceans or areas in which you have worked: _________

Total years of purse seine experience: _____YEARS

PLEASE MARK SELECTED OPTIONS AND WRITE ANY COMMENTS. The abbreviation **DFADs (drifting fish aggregation devices)** will be used hereafter to refer to man-made free drifting artificial structures used to attract tuna.

SECTION 1 – DFAD STRUCTURE & TUNA ATTRACTION

1) Do you think that the depth of the submerged part of the DFAD (i.e. length of material hanging down) is critical to attract more tuna?

a) No, the capacity to attract tuna is not related to the depth of the submerged structure

b) Yes, DFADs of greater depth attract more tuna than a DFAD with shallower netting

c) Yes, DFADs with a deeper net attract better bycatch finfish that then help attract tuna

d) Others, specify

Comments:

2) Do you consider that a DFAD needs to create shadow to work better?

a) Yes, because the shadow attracts the bycatch finfish (triggerfish, mahi-mahi, etc.)

b) Yes, because tuna like DFADs with more shadow

c) No, the size of the shadow is not important in a DFAD

d) No, but netting on the raft is necessary to conceal the DFAD from other vessels

e) Others/specify

Comments:

3) Please indicate from 1 to 6 (1 being most important) the functions a DFAD's tail or submerged netting plays?

a) Slow down and control the drift speed of a DFAD

b) Cast shadow to attract bycatch finfish species

c) Helps the floating object track oceanic currents, instead of drift with the superficial wind

d) Accumulate bio-fouling on the net that attracts fish

e) Attractors on the net (palm leaves, sac stripes, etc.) make a DFAD more visible to tuna

f) Others/specify

Comments:

4) What is the depth (in metres) reached by the hanging net in the DFADs that you use (1 fathom = 1.8 m)?

a) 0-19 m

b) 20-39 m

c) 40-59 m

d) 60-79 m

e) 80-99 m

f) > 100 m

Comments:

5) Has your opinion on the depth required for the underwater structure of a DFAD changed over time? Explain.

a) Yes. Why?

b) No

c) Others/specify

Comments:

6) Do you use different DFAD types (different depth, materials, etc.) in different areas of your ocean? Explain why

a) Yes

b) No

c) Others/specify

Comments:

7) Is there an “optimum” speed at which a DFAD must drift to attract bycatch species and tuna?

a) Yes, there is (specify speed in knots)

b) The slower the drift the better

c) The drifting zone is the important thing, more than the speed

d) Constant direction of drift is better than a drift that goes in several directions (makes turns)

Comments:

8) The quantity of small tuna (e.g. individuals less than 2 kg) aggregated around a DFAD depends on: (choose the two most important options, mark from 1 to 7 in order or importance)

a) Time a DFAD has been drifting at sea

b) The structure of the DFAD

c) The direction followed by the DFAD

d) The geographical area where the DFAD is

e) Time of the year

f) Time of the set

g) Others/specify

Comments:

9) Of the floating objects you find in the ocean, what percentages are natural and man-made DFADs?

a) 20% max are natural

b) 20-50% are natural

c) 50%-50%

d) More natural than DFADs

Comments:

10) Has the proportion between natural objects and DFADs changed over time?

a) Yes, there proportion of natural objects was higher before (i.e. 90s). Explain.

b) No, the proportion has been more or less the same always

c) Others/specify

Comments:

11) Have you used “alternative” DFADs without nets or other turtle/shark entangling materials (e.g. palm leaves, ropes, etc.)? What were the results compared to “traditional” net built DFADs?

a) Yes. Explain

b) No

c) Others/specify

Comments:

SECTION 2 – FISHING EFFICIENCY AND CPUE

12) How many days on average does it take to fill up your boat?

Number of days =

Comments:

13) How many trips (i.e. filling up the boat) do you do per year?

Number of trips per year =

Comments:

14) In general, has the length of the trips (i.e. filling the vessel) changed over the years?

a) Yes, now they are shorter

b) Yes, now they are longer

c) No

d) Others/specify

Comments:

15) Rank in order of importance (1 most important and 8 least) the tools or information you use to go to one area or another to find tuna. If you don't use some of these options please cross them.

a) Echo-sounder buoy tuna estimates
b) Communication with other skippers (e.g. satellite telephone, secrephone, etc.)
c) Oceanographic prediction (e.g. CATSAT, GEOEYE, etc.)
d) Supply vessel information
e) Your previous experiences with catches in an area or season
f) Oceanographic conditions (i.e. calm weather forecast)
g) Location where you have more DFADs drifting
h) Others/specify

Comments:

16) Once you are in the target area, what tools help you most in finding tuna in this shorter distance range? Rank in order of importance (1 most important and 9 least). If you don't use some of this equipment please cross it.

a) Bird radar
b) Sonar
c) Vessel echo-sounder
d) Helicopter
e) Binoculars

f) Echo-sounder buoys
g) GPS buoys
h) Sightings of other vessels
i) Others/specify

Comments:

17) On average how many DFADs of your own do you have available to choose to fish on during one trip?

a) 0-20 DFADs

b) 20-50 DFADs

c) 50-100 DFADs

d) 100-200 DFADs

e) 200-300 DFADs

f) 300-400 DFADs

g) > 400 DFADs

Comments:

18) Do you share your DFADs with other vessels from your company?

a) Yes, we all share our DFADs between us

b) Yes, only a few at the end of the trip or if they are too far away

c) Yes, only when the ship owner/fleet manager asks to

d) No

e) Others/specify

Comments:

19) How many DFADs do you deploy on average during a trip?

a) 0-20 DFADs

b) 20-40 DFADs

c) 40-60 DFADs

d) 60-80 DFADs

e) 80-100 DFADs

f) >100 DFADs

Comments:

20) What percentage of the sets made during an average trip on DFADs are made on DFADs which were deployed by another vessel which you found?

a) 0-20 %

b) 20-40 %

c) 40-60%

d) 60-80 %

e) 80-100 %

Comments:

21) What percentage of the sets are made during an average trip on natural objects (i.e. logs) compared to DFADs?

a) 0% natural -100% DFADs

b) 20% natural - 80 % DFADs

b) 40% natural - 60 % DFADs

c) 60% natural - 40 % DFADs

d) 80% natural - 20 % DFADs

e) 100 % natural – 0% DFADs

Comments:

SECTION 3 – DFAD COMPOSITION PRE-ESTIMATION

22) Before setting on a DFAD, do you check first which species and sizes are present?

a) Always

b) Only sometimes

c) Never

c) I only check the quantity (tons), not the species/sizes present

d) Others/specify

Comments:

23) Do you only get close to the DFAD to pre-estimate when there is a small amount of fish and you are unsure whether to make a set or not? Select several if necessary.

a) Yes, because if the sonar detects enough tuna I will set anyway (How many tons is enough (i.e. 5 t, 10 t, 15 t, 20 t?)
b) Yes, because the information the echo-sounder will give me is not too valuable
c) Yes, because I don't want the fish in the DFAD to escape
d) No, I always get close to the DFAD to check sizes and species
e) It depends/Others/specify

Comments:

24) Which methods do you use to pre-estimate the species and size composition of the fish in a FAD? Mark several if necessary.

a) Visually
b) With the PS echo-sounder
c) With the buoy echo-sounder
d) With the working vessel echo-sounder
e) With the sonar
f) Others/specify

Comments:

25) Do you usually get right how many species are present and which is the most abundant?

a) Yes

b) Most times

c) Few times

d) No

e) Others (specify)

Comments:

26) How often are your pre-estimations of the tons for the species and sizes present in a DFAD before the set close (i.e. within 20% error difference) to the actual catch you obtain (e.g. in 70% of the sets the tons for each species caught in a set where close, less than 20% different, to what you had thought)? Fill in.

Size composition pre-estimation=

Species composition pre-estimation=

Comments:

27) What are you able to distinguish using the purse seiner's **echo-sounder**? (Please select more than one if appropriate)

a) Non-target fish species (trigger fish, dolphin fish, etc) from tuna

b) Bigeye (BET) from the rest of tuna (skipjack (SKJ) and yellow fin (YFT))

c) Skipjack (SKJ) from the rest of tuna

d) Skipjack (SKJ) from non-target fish species

e) Small tuna (less than 2 kg) from larger tuna

f) I can't distinguish

Comments:

28) And with the **sonar**? (Please select more than one if appropriate)

a) Non-target fish species (trigger fish, dolphin fish, etc) from tuna

b) Bigeye (BET) from the rest of tuna (skipjack (SKJ) and yellow fin (YFT))

c) Skipjack (SKJ) from the rest of tuna

d) Skipjack (SKJ) from non-target fish species

e) Small tuna (less than 2 kg) from larger tuna

f) I can't distinguish

Comments:

29) Under what conditions is it more difficult to distinguish between species and sizes? (mark more than one if necessary).

a) In large schools

b) When the schools are compact, very close together

c) Under certain oceanographic conditions like bad weather, etc. (Please explain)

d) Others (specify)

Comments:

SECTION 4 – USE OF DFADs BY TUNA

30) When tuna (SKJ, YFT, BET) abandon a FAD, do you think it happens quickly or it does it happen gradually, little by little?

a) They disappear suddenly

b) They disappear very slowly

c) It depends on the species (specify)

d) I don't know

Comments:

31) Have you noticed if the behaviour of tuna (e.g. more active, more movements between DFADs) is different in areas with many DFADs and those with fewer DFADs?

a) Tuna behaviour is always the same

b) Tuna behaviour depends on the number of DFADs in an area

c) It depends (please explain how)

Comments:

32) Are catches per set (tons) lower when there are many floating objects (logs, DFADs, etc.) close to each other?

a) Yes

b) No

c) Other (specify)

33) Do you work with buoys with echo-sounder?

a) Yes

b) No (Why?)

Comments:

PLEASE FILL IN SECTION 5 **ONLY** IF YOU HAVE **WORKED WITH BUOYS WITH ECHO-SOUNDER**; OTHERWISE GO DIRECTLY TO SECTION 6

SECTION 5 - BUOYS WITH ECHO-SOUNDER

34) In which year did you start to use buoys with echo-sounder more regularly (i.e. 2009)?

Write year:

Comments:

35) Please select the brands of buoys with echo-sounder that you are currently using and what percent (e.g. Zunibal 50%, Nautical 50%, Satlink, 0%, Others 0%):

a) Zunibal

b) Satlink

c) Nautical

d) Thalos

e) Ryokusheisa

f) Others/specify

Comments:

36) Why do you use these brands?

a) Ship owner's decision

b) I think it is the best brand (quality of information, reliability, etc.)

c) Price

d) Specific features (explain)

e) Others/specify

Comments:

37) What percentage of all the buoys that you use have echo-sounders?

a) Less than 25% have echo-sounders

b) 25-50% have echo-sounders

c) 50-75% have echo-sounders

d) 75-100% have echo-sounders

Comments:

38) Which strategy do you use to seed your buoys with echo-sounder?

a) All buoys have echo sounder

b) One of every x with echo sounder, the rest without (x =)

c) Beginning, middle and end of seeding I put a buoy with echo sounder

d) Depends on the fishing zone

e) Other (explain)

Comments:

39) Please write for each brand of buoy with echo-sounder that you use the tonnage estimation reliability (1 to 10). If there are brands you have not used, please leave blank:

Zunibal =

Nautical =

Satlink =

Thalos =

Ryokusheisa =

Others (specify brand) =

Comments:

40) Has the reliability of the echo sounder buoys (i.e. the estimation of tons) improved in the last few years?

a) Yes, it is much better

b) Yes, but only marginally

c) No, it is the same

d) Others/specify

Comments:

41) When using buoys with echo-sounder, how important are they in making fishing decisions?

a) Not important

b) Very little

c) Very important

d) Most important tool

Comments:

42) When you check the echo-sounder from a DFAD buoy, what do you use as a guide - the tonnage estimation or the image sent?

a) The image (colours, shape, intensity)

b) Estimated tonnage

c) Both

d) Neither

Comments:

43) Are you able to distinguish the type of fish present around a DFAD using the buoy echo-sounder (specify brand)? Select several if necessary.

a) Non-target fish species (wahoo, trigger fish, etc.)

b) Small sized tuna (i.e. under 2 kg)

c) Medium sized tuna (i.e. 2-10 kg)

d) Large sized tuna (i.e. >10 kg)

e) I can´t distinguish, I only obtain total tonnage estimations

f) Others/specify

Comments:

44) Has the introduction of echo sounder buoys changed your fishing strategy? If "yes" in what ways has it changed your fishing operation? (Mark more than one if appropriate).

a) Reduced the search time needed to find a DFAD that is holding fish

b) Move more frequently between ocean areas

c) Pattern of fishing more flexible, less reliant on traditional seasons and areas

d) More selective, making catches on the best DFAD available, increasing average catch

e) Has not changed the way you fish (why?)

f) Others/specify

Comments:

SECTION 6 – TUNA SUSTAINABILITY MEASURES AND ECONOMIC INCENTIVES

45) What would be the best option to reduce the catch of very small bigeye and yellowfin (< 5 kg)?

a) Change vessel's net depth (or other characteristics – mesh size, weight, etc. Please explain

b) Mesh size of vessel's net

c) DFAD underwater tail depth

d) Location and/or season avoidance

e) Market disincentives (i.e. no payment)

f) Sorting grids

g) Others/specify

Comments:

46) Which bycatch sorting/release equipment do you use (if any) on board during fishing operations?

a) Double conveyor belt

b) Hopper on top deck

c) Liberation (release) ramp

d) Crew member dedicated to manual releasing bycatch on deck

e) Cargo net or other netting to move and release large live animals (i.e. mantas, sharks)

f) Others/specify

Comments:

47) Do you think full retention regulations will reduce the overall levels of non-target catch that is set on by the fishery?

a) No (Why?)

b) Yes, it will make us try to avoid small tuna and bycatch

c) There are better solutions (Which?)

Comments:

48) Do you get paid the same for all species and sizes of tuna? What are the differences in price?

a) Yes, I get paid the same for all tuna

b) No, I get paid less for small BET than for SKJ or YFT

c) No, I get paid less for small tuna (i.e. SKJ under 2 kg)

d) Other wage differences (explain)

Comments:

49) Do you think not getting paid for small tuna (i.e. under 2 kg) or for small BET would make fishers more selective?

a) Yes, it would make fishers look more carefully what is under the DFAD with the acoustics

b) Yes, it would prevent trips to zones with lots of small tuna

c) No, because the quantities of small tuna per trip are quite small anyway

d) No, for other reasons (explain)

Comments:

50) Besides target tuna species (BET;YFT;SKJ;ALB), which other DFAD species do you retain for sale (e.g. mahi-mahi, wahoo, marlin, other non-commercial tuna species, etc.)?

Species:

Comments:

51) Do you know how they are used?

a) Local market

b) Fish meal

c) Processed and exported

d) Consumed onboard

e) Others (explain)

Comments: