SCRS/2016/054 Collect. Vol. Sci. Pap. ICCAT, 73(3): 958-973 (2017)

PROGRESS ON THE ADOPTION OF NON-ENTANGLING DRIFTING FISH AGGREGATING DEVICES IN TUNA PURSE SEINE FLEETS

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SUMMARY

Up to recently drifting fish aggregation device (DFAD) designs usually had a structure built with a floating component covered with net and an underwater appendage with open net panels. Unintentional mortality though entanglement in DFADs has been observed mainly for oceanic silky sharks (Carcharhinus falciformis), and to a lower degree turtles. In recent years, scientists and fishers from key tuna purse seiner fleets have been collaborating to design DFADs minimizing entanglement. In addition, all except one tuna regional marine fisheries organization (RMFO) have guidelines for non-entangling (NE) DFADs. This paper describes the adoption of entanglement-reducing DFADs by several key fleets through skipper workshops sponsored by ISSF. At present, progress with DFADs that prevent entanglement appears to be highest in the Indian and Atlantic Ocean, medium in the Eastern Pacific and lowest in the Western and Central Pacific. The acceptance degree of NE FADs by fishers and ship-owners has been gradually increasing since 2010 and especially after learning how some fleets (e.g. European Union) have moved almost entirely to 100% NE FADs without adverse effects on their catches of tuna.

RÉSUMÉ

*Jusqu' à une époque récente, les dispositifs dérivants de concentration du poisson (DCP dérivants), de par leur conception, possédaient une structure construite avec un élément flottant couvert d'un filet et d'un appendice submergé avec des panneaux de filet ouvert. On a observé une mortalité accidentelle par emmêlement dans les DCP dérivants affectant principalement les requins soyeux (*Carcharhinus falciformis*) et dans une moindre mesure les tortues. Au cours de ces dernières années, les scientifiques et les pêcheurs originaires des principales flottilles thonières de senneurs ont collaboré pour concevoir des DCP dérivants qui minimiseraient l'emmêlement. En outre, toutes les organisations régionales de gestion de la pêche de thonidés (ORGP thonières), sauf une, possèdent des directives concernant les DCP dérivants non emmêlants. Le présent document décrit l'adoption, par plusieurs importantes flottilles, de DCP dérivants réduisant l'emmêlement par le biais d'ateliers parrainés par l'ISSF. À l'heure actuelle, les progrès accomplis avec les DCP dérivants qui évitent l'emmêlement semblent être plus importants dans les océans Indien et Atlantique, moyens dans le Pacifique Est et faibles dans le Pacifique Ouest et central. Depuis 2010, les pêcheurs et les armateurs acceptent peu à peu d'utiliser davantage les DCP non emmêlants et ce, depuis qu'ils ont appris que certaines flottilles (p.ex. l'Union européenne) emploient désormais à presque 100% des DCP non emmêlants sans que ce changement n'ait eu de répercussions néfastes sur leurs prises de thonidés.*

RESUMEN

Hasta hace poco, los diseños de los dispositivos de concentración de peces a la deriva (DCPd) tenían por lo general una estructura constituida por un componente flotante cubierto por una red y un apéndice submarino con paneles de red abierta. Se ha observado mortalidad no intencionada por enmalle en DCP-D principalmente del tiburón jaquetón (Carcharhinus falciformis) y, en menor medida, de tortugas. En años recientes, los científicos y pescadores de las principales flotas atuneras de cerco han colaborado para diseñar DCPd que minimicen el enmalle. Además, todas las organizaciones regionales de ordenación pesquera de túnidos (OROPt), excepto una, cuentan con directrices respecto a los DCPd no enmallantes (NE). Este

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documento describe el cambio a DCPd que reducen el enmalle por parte de varias flotas clave gracias a la celebración de talleres para patrones, patrocinados por ISSF. Actualmente, los progresos con DCP-D que impiden el enmalle parecen ser más elevados en el océano Índico y Atlántico, medios en el Pacífico oriental y bajos en el Pacífico central y occidental. El grado de aceptación de los DCP no enmallantes por parte de los pescadores y los armadores ha ido aumentando gradualmente desde 2010, especialmente después de observar cómo algunas flotas (por ejemplo, la de la Unión Europea) han cambiado casi por completo a utilizar el 100% de DCP no enmallantes sin efectos negativos en sus capturas de atún.

KEYWORDS

Gear selectivity, fishing nets, purse seining, tuna fisheries, by-catch

Introduction

Tropical tunas show a strong associative behavior towards floating objects in the sea (Castro et al., 2002). Taking advantage of this tuna behavior fishers of purse seine fleets began to build artificial floating objects referred to as fish aggregating devices (FADs) to increase catch opportunities (Fonteneau et al., 2013). FADs can be either static (anchored FADS; AFADs) or mobile, equipped with a buoy or radio transmitter for remote location (drifting FADS; DFADs). Due to the efficiency of FAD fishing the numbers of DFADs have increased at a very fast rate (Hall and Roman, 2013). Scott and Lopez (2014) estimate about 12,700 AFADs and 97,000 DFADS used annually in tuna fisheries. As a consequence nowadays the largest portion of tuna catches worldwide derives from FAD sets (Miyake et al., 2010; ISSF, 2015). However, FADs do not only attract tuna but also certain species of sharks, turtles and bony fish.

The design, size, and structure of DFADS can vary markedly between oceans and fleets but a common trait is the use of a floating structure (e.g. bamboo raft, purse seine corks, PVC pipes, etc.) usually wrapped in net material from which open panels of netting hang in the water column underneath ranging from 10 to 120 meter depths. The net on top is used to hold together the bamboo canes and corks that form the rafts, increase shadow provided by the structure and to make it less visible to other vessels. The submerged netting provides shade and a micro-habitat for small fish that remain very close to the DFAD structure. For most fishing companies, worn-out purse seine nets have been the principal choice of DFAD material because it is free to them and available in large quantities. One undesirable impact of DFADs with this kind of wide mesh netting (e.g. 200-300 mm stretched mesh) is the unintentional entanglement of sharks and turtles aggregating near them. This form of ghost fishing has been observed across oceans.

When turtles are found entangled, it has been mainly observed near or on top of the DFADs' surface netting. The numbers of turtles entangled is believed to be low and according to fishers and scientists the animals are usually released alive when encountered. For example Clermont et al. (2012) report a combined 80% live release of turtles that have been either found in the purse seine or entangled in a DFAD. Considering the very low encounter of turtles associated with DFADs in tuna purse seine nets (less than 250 turtles per ocean per year, **Table 1**) which is several orders or magnitude lower than other gears such as longline or gillnetting, it is likely that turtle DFAD entanglement figures are possibly low as well. Nevertheless, lost DFADs that have abandoned fishing areas or are not monitored by fishers due to buoy failure can continue to drift in the ocean and "ghost" fish. The extent of the cryptic entanglement of turtles or other animals in these lost DFADs has not been quantified but it is thought to be low.

Few shark species show aggregative behavior around floating objects. Sharks aggregating near DFADs are almost exclusively juvenile silky sharks (*Cacharhinus falciformis*), followed in second place by oceanic white tip sharks (*Cacharhinus longimanus*), both making about 90% of all sharks captured in this fishery (Amandè et al., 2008). Shark entanglement is more difficult to evaluate than for turtles because it often happens out of sight in the net panels hanging under the surface. Bycaugt shark individuals are difficult to spot unless entanglement happens near the surface or if the DFAD is lifted out of the water for repairs, which is not a very common practice. Because many of these shark entanglement events were often undetectable to the eye, many captains and skippers thought that his was more a problem of bad image to DFAD fishing (e.g. anti-DFAD campaigns) that one really impacting shark populations. Chanrachkij and Loog-on (2003) examined visually (i.e. with no tagging) 20 DFADs for shark entanglement in the Indian Ocean and found that 40 per cent of them had an individual entangled. However, the only work to-date attempting to quantify shark entanglement mortality using divers checking DFADs coupled with shark electronic tagging showed that shark entanglement mortality in the Indian Ocean could be five to ten times higher than bycatch caused by active fishing of purse seiners (Filmalter et al., 2013). The tagging information was critical in discovering that entangled sharks once dead did not last many days in the DFAD's net, rapidly detaching and falling down. Therefore visual inspection of DFADs by captains or observers can only account for sharks that have been recently entangled, but would miss out on shark entanglement events which happened days to weeks before that. Purse seine fishers consulted since in different fleets and oceans agreed that sometimes they see sharks entangled in DFADs, although the range they report goes from 1% up to 25% of DFADs with a shark.

Since the mid-2000s scientists and fishers had been testing prototypes of DFADs constructed to minimize entanglement while still retaining desired traits of traditional DFADs such as ability to aggregate tuna, low price of materials and durability in the water (Delgado de Molina et al. 2005, 2007; Franco et al., 2012). These initial non entangling (NE) DFADs were tested in very small numbers and results to establish their ability to aggregate tuna while reducing entanglement were not conclusive. This uncertainty prevented the early adoption of NE DFADs by the commercial purse seine vessels as ensuring target tuna catches is a necessary condition for the acceptance of alternative DFADs. Fishers are practical people and when something is efficient for fishing, like their traditional DFADs had, it is difficult for them to change and are usually reluctant to search for new gears. However, in 2010 the French fleet in the Indian Ocean conducted a series of trials with a much larger sample size, approximately 1000 units, of anti-entangling DFADs which had been designed collaboratively between fishers and scientists. These trials proved tuna catches remained similar between traditional and non-entangling (NE) DFADs in this ocean while minimizing shark and turtle entanglement (Goujon et al., 2012). Lower risk entanglement improvements included using small meshed (< 70 mm) tightly strapped net on the raft to reduce chances of turtles entangling, and underwater netting tied into bundles or "sausages" to eliminate open large mesh net surfaces. Only in very limited instances (0.004 percent of NE DFADs tested) did sharks appear entangled due to the rope tying the net into bundles having loosened to leave segments of the netting open. These positive results encouraged French purse seine companies to adopt the lesser entangling DFADs. In 2012, the ISSF Bycatch Mitigation Steering Committee released a guide setting a series of recommendations for NE FADs encouraging fishers to reach their preferred NE designs, recognizing that different FADs could work better for different oceans or fleets (the guide was updated in 2015, see below). Changing from entangling FADs to NE FADs needs some time to take place as often new designs and materials need to be tested and in most cases DFADs cannot be replaced all at once. For this reason in the first version of the ISSF guide the use of FADs with no netting was encouraged, but small mesh netting and tied up netting were also allowed during the transition period between traditional DFADs to no-net DFADs. Also in 2012, the Spanish tuna purse seine fleet and associated vessels signed a voluntary Code of Good Practices that established the move from entangling to NE DFADs over the following two years. This change came about because all Spanish ship-owners approved the change in the same period of time and fishers felt less pressure if NE FADs failed to aggregate tuna as the rest of the fleet were operating under the same circumstances. After some adjustments in DFAD designs nowadays Spanish vessels which operate in the Indian, Pacific and Atlantic Ocean have moved to NE DFADs and tuna catches have been maintained (Goñi et al., 2015).

Three t-RMFOs (IOTC, ICCAT, IATTC) have introduced NE FAD recommendations in their measures from 2013 onwards (**Table 2**). Since then, voluntary adoption of NE FADs has been spreading to fleets and companies in different oceans. This document illustrates the use of traditional and NE FADs in some of the principal purse seine tuna fisheries of the world as of early 2016 based on information provided by fishers and scientists working in collaborative bycatch workshops.

METHODS

Since 2010, ISSF has been conducting bycatch reduction workshops with fishers of tuna purse seine fleets in which the subject of FAD entanglement is an important part (ISSF Skippers Workshops, Murua et al. 2014). In the past, skipper knowledge, sometimes referred to as Fishing Ecological Knowledge (FEK), has provided useful insight into various aspects of tuna purse seine fisheries (e.g. Moreno et al. 2007a,b; Lopez et al., 2015). During the ISSF workshops fishing masters and captains attending fill in a questionnaire covering various bycatch issues including the kind of FADs they utilize. During the 2014-2015 workshops, 66 questionnaires were collected in Manta (Ecuador), 7 in Lima (Peru), 20 in Concarneau (France), 32 in Sukarrieta (Spain), 6 in Tema (Ghana), 5 in Busan (Korea), 5 in Pango Pango (American Samoa) and 1 in Kaoshiung (Taiwan). Completion of these questionnaires on FADs is voluntary and skippers have the option of leaving questions blank rather than provide false information.

The question options under which skippers could categorize their FADs were based on the revised 2015 ISSF guideline for NE FAD (Appendix I; http://iss-foundation.org/knowledge-tools/guides-best-practices/non-entangling-fads/download-info/issf-guide-for-non-entangling-fads/) which includes 3 classes according to entanglement risk and an additional one for NE FADs built with biodegradable materials. The entanglement categories are the following:

1) Highest entanglement risk FADs (HER FADs): constructed with any netting materials, including old purse seine netting, used to cover rafts or suspended beneath in open panels. These DFADs are known to cause entanglements with turtles and sharks.
2) Lower entanglement risk FADs (LER FADs): only small mesh netting used (e.g. < 2.5 inch (7 cm) stretched mesh). Rafts are tightly wrapped with small mesh netting, with no loose netting hanging from it. The underwater structure is tightly tied into bundles (sausages). A single panel can be used instead of bundles, but the panel must be weighted to keep it taut. The panel should consist of either netting with a stretched mesh of 2.5 inches (7 cm) or less, or a solid sheet (e.g. canvas or nylon). Despite using netting, these design elements reduce the risk of entanglement events.
3) Non-entangling FADS (NE FADs): no netting is used in their construction. The raft is not covered or covered with black shade cloth or canvas. The subsurface structure is made with ropes, canvas or nylon sheets, or other non-entangling materials. These FADs are expected to have minimum risk of causing entanglement.

Some of the information on FAD types provided by skippers can be supported by specific programs of some fleets such as the Code of Good Practices Verification System that collects observer information on the types of DFADs the Spanish fleet uses in the Atlantic, Indian and Pacific Oceans (Goñi et al., 2015), or the French fleet FADs monitored by French scientists (IRD). Observer programs from the RMFOs are also starting to record FAD aspects such as structure, design and types of materials used in each FAD, which can indicate the likelihood of entanglement. However, for the largest part, obtaining observer records on FAD entanglement information from various RMFOs is difficult as this data is not publicly available. This report also includes information on FAD designs from other fleets for which questionnaires were not collected but with which ISSF scientists have interacted and learnt firsthand about the FADs utilized by skippers (e.g. Indonesia, Mexico). This information is descriptive rather than quantitative.

During the Skippers Workshops, different bycatch mitigation options are discussed with fishers and, based on their positive or negative comments towards these activities, an average acceptance level is recorded. High acceptance level indicates that fishers in general liked the idea presented and consider it is feasible to implement, whereas low acceptance levels are for options which are not favored. From lower to higher acceptance the categories are: low, mid-low, mid, mid-high, and high. The acceptance levels presented are based on results from the latest workshops conducted between 2014 and 2015. Note that acceptance level is a useful indicator of the opinion of the fishers and key stakeholders of a fleet present at a workshop, but not necessarily represents the views of all members of a fleet.

Adoption of Entanglement-Reducing FAD Designs by Ocean

Western Indian Ocean

Most purse seine vessels in the Indian Ocean are from the Spanish and French fleets (and associated vessels under other flags like Seychelles or Mauritius but which have European skippers and use the same kind of DFADs). These vessels are more than 50 in total. It was in the Indian Ocean that the first large scale experiments with LER and NE DFADs were conducted with the French fleet, and where the first Spanish companies started using anti-entanglement DFADs in their fishing trips. The predominant DFAD category used by Spanish and French skippers nowadays is the LER FAD (**Table 4**) consisting of small mesh netting tightly fitted on top of the raft, sometimes covered with black canvas, and netting tied into sausages in the underwater structure (see photos Appendix II). The depth of the DFADs is mostly 50 meters or less, which is shallower than in the Atlantic Ocean. About 20% of consulted Spanish and French skippers report the use of NE FADs with no netting being used for the underwater appendage and canvas on the raft. Instead of tied mesh, these fishers use rope under the raft. There are a few other fleets with fewer boats that use DFADs in this region, namely Korea and Iran. The DFADs that they use are thought to be in the HER category. Trials are being prepared for 2016 with biodegradable and NE FADs by Korean scientist in this ocean (Kim Zheung; pers. comm.) as part of the FAD Management Plan required by the IOTC.

Eastern Atlantic Ocean

In the Atlantic, the majority of purse seiners also belong to the EU fleets (an associated vessels under different coastal nation flags). Over 90% of consulted Spanish and French fishers operating in this area utilize LER DFADs with small mesh net panels used in the long underwater appendages of these DFADs. Initial trials in 2013 with DFADs having the underwater structure made of netting tied into sausages or using rope were unsatisfactory. These DFADs appeared to drift too fast and attract less tuna than DFADs which included some kind of open net panel in the subsurface appendage (see examples in Appendix II). Due to the predominant strong westward current moving DFADs out of the fishing area towards the American continent, fishers prefer floating objects with deeper appendages (e.g. 50-100 m) and open net panels that act as anchors slowing down drift. The predominant LER FAD currently includes an initial section of sausage tied net in the first 5-20 m, depth where most shark entanglement is thought to happen, and below small mesh netting (< 70 mm stretched mesh) panels are used to better control rapid drift of DFADs.

Another fleet also operating in the Atlantic is Ghana, with around 18 vessels. According to questionnaires (n=6) and talk with fleet managers, about half the fleet is using LER FADs. Several models being utilized by members of the Ghanaian fleet (TTV Ltd., the largest Ghanaian purse seine company at the time of this study) were presented at the first meeting of the ICCAT Working Group on FADs in May 2015 showing designs with small mesh and tied up netting. The Ghanaian fleet is also known to have been using traditionally mesh green mesh trawler net panels in their DFADs for the underwater structure (photo 6.a. Appendix I). These nets are thought to be of lower entangling risk as the mesh does not hang loosely but remains rigid and shark entanglement is not observed according to fishers, but there are no scientific observations on these DFADs to corroborate this.

Eastern Pacific

There are several fleets operating in the Eastern Pacific region with Ecuador being the most important both by vessel number, over 87 medium to large purse seiners (Justel-Rubio and Restrepo, 2015), and high use of DFADs. Since 2013, the use of LER and NE DFADs appears to have been increasing in this fleet. For example, Spanish-owned companies with Ecuadorian flag (e.g. Albacora, Ugavi, Garavilla, Calvo) are subscribed to the Code of Good Practices in which the use of HER FADs is forbidden. Some of the most important Ecuadorian companies also, such as Nirsa, with 11 vessels, have moved in the last year to building an important proportion of their DFADs with small mesh and sausages.

There are some other fleets in the EPO such as that of Panama, El Salvador, Peru, Mexico or USA which use FADs. Fleets such as the Peruvian and Mexican have only recently, around 2014, started to use DFADs and it is thought that the number per vessel is still relatively low (e.g. < 50 DFADs). At the time of consultation, many of the skippers of these fleets were not aware about the concept of NE FADs, but fishers were open to the idea of moving towards this kind of DFAD. In fact, some of the elements of their DFADs such as the use of small mesh netting from recycling Medina mesh panels (for the Mexicans) or anchoveta nets (for Peru) would make these FADs fall in the LER category.

Western and Central Pacific

In the Western Pacific, in addition to the use of DFADs, there are several fleets particularly the Indonesian, Filipino and Papua Nueva Guinean which take most of their tuna from AFADS. These FADs are static, with a floating structure that is anchored to the seafloor by a long rope or chain with a heavy weight at the bottom. There are different models of AFADs with bamboo, plastic, or metallic foam filled cylinders as floats for example; but one trait AFADs share is that they are all NE as netting is not used in their construction. Accidental entanglement events in AFADs are not known off.

Regarding DFADs, these are much more abundant than AFADs both in numbers and fleets that use them (e.g. Korean, Chinese, Filipino, Taiwanese, USA and Pacific island nation flags like Kiribati, Vanuatu, etc.). The principal type of DFADs utilized in this ocean is made of a bamboo raft covered with old purse seine large mesh netting and a complex submerged appendage with long panels of wide open mesh and tied colored strips thought to attract fish. Different Asian fleets appear to have adopted this kind of DFAD which tends to also be quite deep (e.g. > 50 m). To our knowledge from recent workshops held in the region, including Philippines, Korea, Indonesia, Micronesia, Marshall Islands, or American Samoa, no skippers in this region were using LER or NE DFADs yet. At present, the WCPFC remains the only tuna RMFO which has not passed recommendations for the use of NE FADs.

Discussion

Adoption Process

Since 2010 with the first large-scale trials to test anti-entanglement DFADs in the Indian Ocean with the French fleet, the adoption of better DFAD designs to reduce ghost fishing of sharks and turtles has advanced rapidly in many tropical tuna fleets. An element that has facilitated faster voluntary adoption has been the joint collaboration of ship-owners, skippers, and scientists to solve the FAD entanglement issue. Rather than proposing a fixed NE FAD design, scientists provided industry with a series of guidelines and left skippers themselves to design and choose their preferred models. This is important, on one hand because skippers have their own FAD type preferences to fish and, on the other, because they have the technical knowledge to make efficient non-entangling FADs. For decades, captains have relied on traditional net-built DFADs to attract tuna, so moving to new materials and designs that might not yield the same catch results and put their jobs at risk was initially a concern. The European purse seine fleets showed from the initial workshops in 2010 a high level of acceptance for NE FADs and were the first to use them at a commercial scale in their fisheries (**Table 3**). During the Spanish and French fleets' move away from HER DFADs, there has been a process of trial and error and some DFAD designs such as ropes or netting tied in sausages appears to work better in the Indian or Eastern Pacific compared to the Atlantic. After an initial period of widespread experimentation, the number of LER and NE FAD types appears to have settled into a few designs per ocean that fishers consider work best. The repeated annual interaction with key fleets to discuss anti-entanglement FAD improvements and other bycatch issues, such as the ISSF Skippers' Workshops, in which more than 1500 fishers and stakeholders have participated, has proven a valuable approach. For example, not all fleets appeared initially open to the move to NE FADs. There process of change is gaining momentum in most oceans as fishing companies observe how other companies have successfully moved to NE FADs without adversely impacting their target tuna catches. Support from ship-owners to provide the adequate materials (e.g. canvas, ropes, and small mesh net) to fishers and allowing a period of adaptation until the best designs are found is critical. Note that the acceptance level recorded during ISSF workshops is just a qualitative indicator obtained from fishers and key stakeholders (e.g. ship-owners, fleet managers, fisheries managers, local scientists) attending, and may not necessarily represent the views of all captains and companies in a fleet. In fleets for which the workshops have covered a high proportion of their fishers and ship-owners (e.g. Spain, Ecuador, Mexico) there is more certainty that the acceptance levels obtained are highly representative of the fleet.

RMFO NE FAD Regulation

At present, the process of adoption of LER and NE DFADs has been voluntary. Despite the fact that these kinds of DFADs can be in some instances more expensive than traditional old purse seine netting ones, many fishing companies have still decided to invest in these more sustainable DFAD models. The fact that three tuna RMFOs (IOTC, ICCAT, and IATTC) have adopted recommendations for NE FADs provides an incentive to their respective fleets to move in the right direction. For example, the IOTC in resolution 13/08, point 6 and 7, states that members must provide FAD Management Plans that minimize bycatch, including NE FADs, which should gradually be applied. For 2016, the IOTC Scientific Committee will analyze the data and consider phasing out FAD designs that do not prevent the entanglement of sharks. Perhaps unsurprisingly, the ocean with the lowest degree of NE FAD adoption, the WCPO, is the only remaining RMFO (WCPFC) that at present has no recommendations on FAD entanglement reduction. Nonetheless, this situation could rapidly change. For example the EU fleets have shifted from HER to LER and NE DFADs in a very short period of time, under 2 years. The use of NE FADs in commercial fishing is a relatively new concept and some fleets are just starting to learn about it. A high proportion of consulted captains and stakeholders from fleets that at present are not using anti-entanglement FADs (e.g. Korea, Philippines, USA) showed mid to high acceptance of the idea of moving to less entangling FAD types when consulted. The process of acceptance of new ideas for fishing gear is a gradual one. Not all important fleets were convinced about NE FADs when initially consulted in 2010 (e.g. Ecuador, Panama, and Ghana). When first approached with the idea of alternative DFADs, fishers in these fleets were less open, but as they have learned from the experiences from other fleets or encountered NE FADs from other companies in the water, gradually have come to see lower entanglement FADs as a positive viable option.

Future NE FAD Perspectives

One issue that remains to be clarified is whether LER DFADs are comparable in terms of shark and turtle entanglement to NE DFADs. At present, the number of DFADs that do not use any netting (NE FADs) is still very low compared to LER DFADs. Only when the small mesh netting starts to degrade making larger holes or the sausage tied netting becomes undone and the mesh opens up, it can occasionally entangle shark individuals. Accidental entanglement in LER DFADs has been observed, but in very few instances only when experimental use of these FADs started in 2010. Also, DFADs nowadays are being built mostly on land at ports like Abidjan, Seychelles, or Manta by specialized personnel. This standardizes construction of LER DFADs and permits easier quality controls by ship-owners. It is up to scientists and RMFOs to establish if LER DFADs are good enough to minimize entanglement rates or the industry should move all the way to use NE DFADs with zero netting.

Observer data on entanglement rate with each kind of DFAD and detailed studies with electronic tags on sharks in FADs to monitor "unseen" entanglement events can shed light on this issue. ISSF is conducting research onboard purse seiners diving at DFADs and tagging sharks at DFADs to assess entanglement at LER DFADs. New work comparing shark entanglement prior to anti-entanglement DFADs (e.g. Filmalter et al., 2013) and now when LER DFADs are being widely used in the Indian Ocean would also show a clear picture on whether these DFADs are significantly preventing entanglement events.

Finally, given the wide acceptance by fishers from many fleets, including those in the WCPO, of anti-entanglement FAD designs to reduce unwanted mortality of sharks and turtles, and the successful transition of some of the largest FAD-fishing tuna fleets to LER and NE FADs, it could be expected that in a not so distant future HER FADs will be phased out of all oceans.

Acknowledgements

We are grateful to all the fishers, ship-owners, fleet managers and crew from the 17 different fleets which have participated in the ISSF Skipper Workshops and contributed with their knowledge and experience to the questionnaires. Many thanks are due to tuna fisheries scientists Mr. Dave Itano, Dr. Martin Hall, and Dr. Laurent Dagorn, who have regularly presented workshops and interacted with the skippers.

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Table 1. Estimates of numbers of sea turtles and sharks mortality per ocean by purse seiners (PS), long liners (LL), and FAD entanglement. Sources: Hall and Roman, 2013; Anon, 2001; Lawson, 2011: Clermont et al., 2012; Filmalter et al., 2013; Bourjea et al., 2014; Amandè et al., 2008.

Ocean	*Sea Turtles*			*Sharks*		
	Capture PS net	*DFAD entanglement*	*Capture LL*	*Capture PS net*	*DFAD shark entanglement*	*Capture LL*
WCPO	0.10	-	30-75	93.5	-	11,999
EPO	0.08	0.09		37.4	-	
ATL	0.22	-	200-150	14.0	-	10,967
IO	0.25	-	6	82.0	480-960	667

Table 2. Tuna RMFO management resolutions covering the use of NE FADs (as of 2015).

RFMO	**DOCUMENT**	**WEB LINK**
IATTC	C-15-03	http://www.iattc.org/PDFFiles2/Resolutions/C-15-03-Amendment-C-13-04-FADs.pdf
IOTC	15/08	http://www.iotc.org/cmm/resolution-1308-procedures-fish-aggregating-devices-fads-management-plan-including-more-detailed
ICCAT	Rec. 15-01	http://iccat.int/Documents/Recs/compendiopdf-e/2015-01-e.pdf
WCPFC		-

Table 3. Evolution in the acceptance level of fishers for the use of FADs that minimize entanglement by different tuna fleets in ISSF Skipper Workshops between 2010 and 2015. Estimated number of large purse seiners (> 335 m^3 fish holding volume) by fleet and level of use of FADs.

FLEET	OCEAN	LARGE PS	FAD USE	ACCEPTANCE LEVEL				
				2010-11	2011-12	2012-13	2013-14	2014-15
ECUADOR	EPO	86	HIGH	LOW	MID	MID-HIGH	MID-HIGH	MID-HIGH
MEXICO	EPO	41	LOW	-	-	-	-	HIGH
PERU	EPO	8	LOW	-	-	MID	-	MID-HIGH
PANAMA	EPO	17	MID	MID	-	MID-HIGH	-	-
USA	EPO, WCPO	31	MID	HIGH	HIGH	-	MID-HIGH	MID-HIGH
INDONESIA	WCPO	20	HIGH	-	-	-	HIGH	HIGH
KOREA	WCPO, IO	32	HIGH	-	-	-	HIGH	MID
PHILIPPINES	WCPO	73	HIGH	-	MID-HIGH	-	MID-HIGH	MID-HIGH
TAIWAN	WCPO	54	MID	-	-	-	MID-HIGH	-
FRANCE	IO, ATL	20	MID	HIGH	HIGH	-	-	MID-HIGH
SPAIN	IO, ATL, EPO	32	HIGH	MID-HIGH	HIGH	HIGH	HIGH	HIGH
GHANA	ATL	17	HIGH	LOW	LOW-MID	MID	MID	MID-HIGH

Table 4. Use of DFAD type by fleet according to entanglement characteristics. Source: ISSF Skippers' Workshop fishing master and captain questionnaires. Highest Entanglement Risk (HER); Lower Entanglement Risk (LER); Non-entanglement (NE).

FLEET	HER DFAD (%)	LER DFAD (%)	NE DFAD (%)
Ecuador	27	70	3
Peru	0	100	0
France	0	73	27
Spain	3	74	23
Ghana	55	45	0
USA	100	0	0
Korea	100	0	0
Taiwan	100	0	0

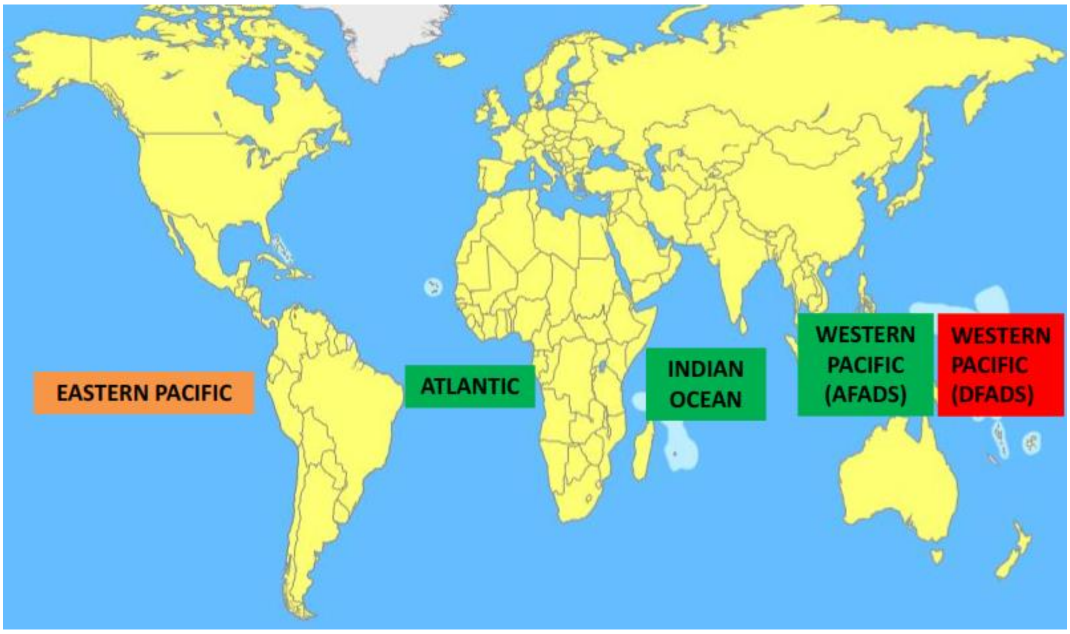
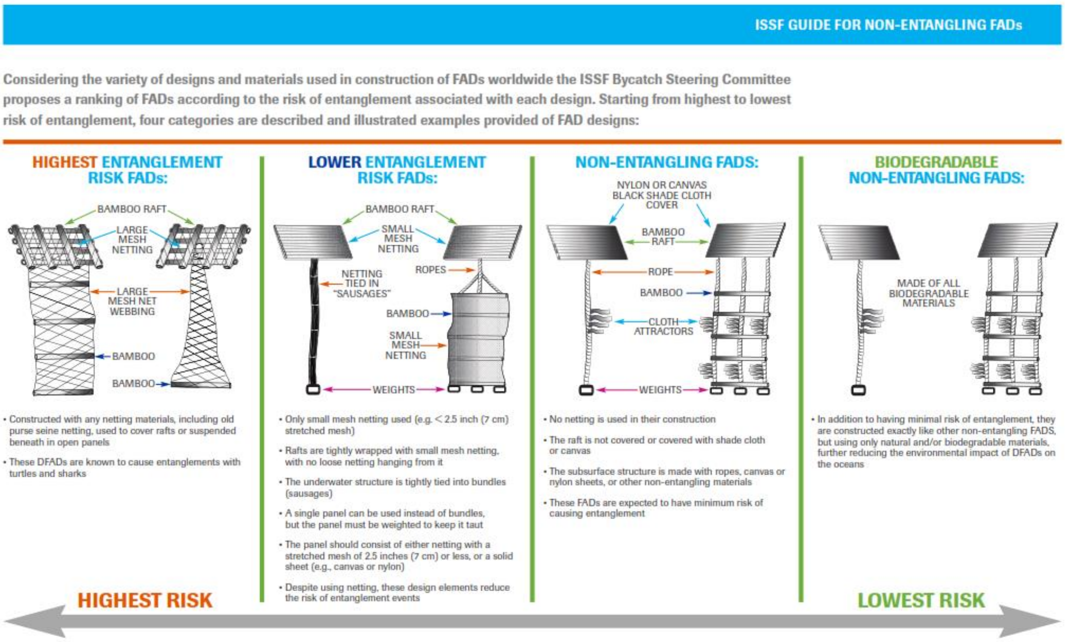


Figure 1. Map of degree of adoption of modified FADs to reduce entanglement (NE and LER types) by ocean. Green: High degree of adoption; Orange: Mid degree; Red: Low degree.

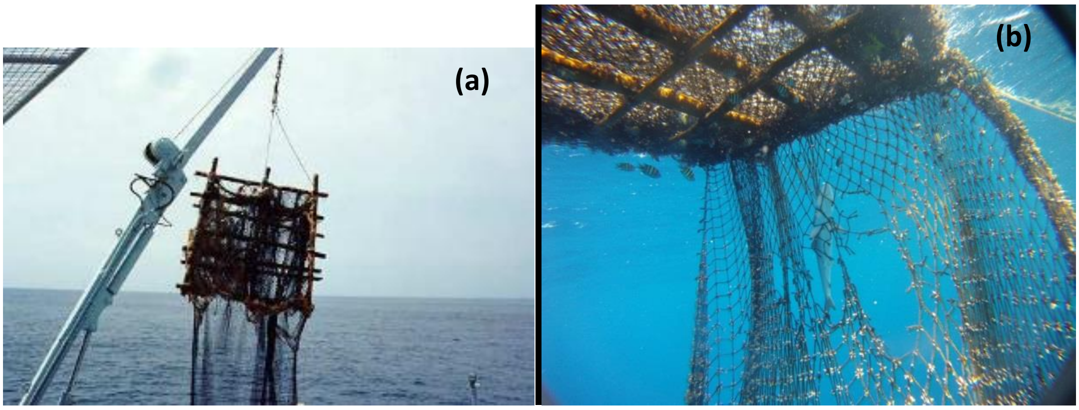
Appendix 1

FAD ENTANGLEMENT CATEGORIES (from ISSF Guidelines)

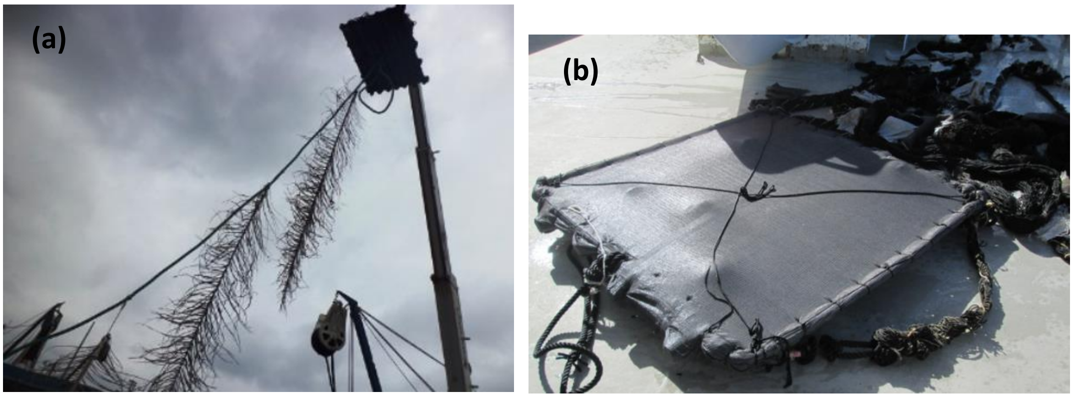


Appendix 2

Examples of DFADs Used by Various Tuna Purse Seine Fleets



1. **Example of (a) traditional HER DFAD with loosely tied purse seine net which used to be used by EU fleets in the Indian Ocean prior to 2013, (b) shark entangled in the net of a HER DFAD.**



2. **Spanish fleet examples of (a) NE FAD with tail made of rope and palm leave attractors used in the Indian Ocean, and (b) canvas covered raft to prevent turtle entanglement. Photos courtesy of ANABAC and OPAGAC.**

3. **French fleet (a) LER DFADs used in the Indian Ocean with "sausage" tied netting and (b) detail of tying net into sausage bundles. Photos courtesy of Orthongel.**

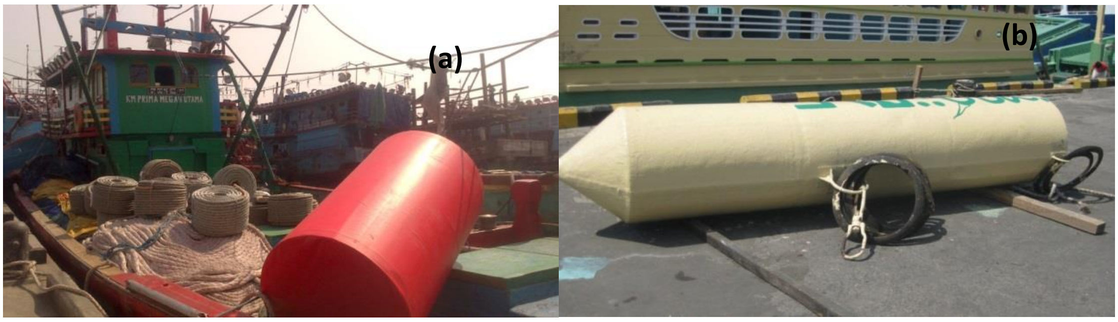
4. Spanish LER DFADs used in the Atlantic combining "sausage" tied netting in the first 15 m of the tail appendage and open small mesh netting underneath. (a) DFADs being built at port of Abidjan (Ivory Coast) and (b) condition of DFAD's small mesh net panels after several months at sea. Photos courtesy of Opagac

5. Example of LER FAD used in Ecuador (a) with small mesh netting tightly fitted on the raft and sausage tied netting in the tail and (b) construction operation of LER FADs on land in Manta. Photos courtesy of Nirsa and Ugavi.

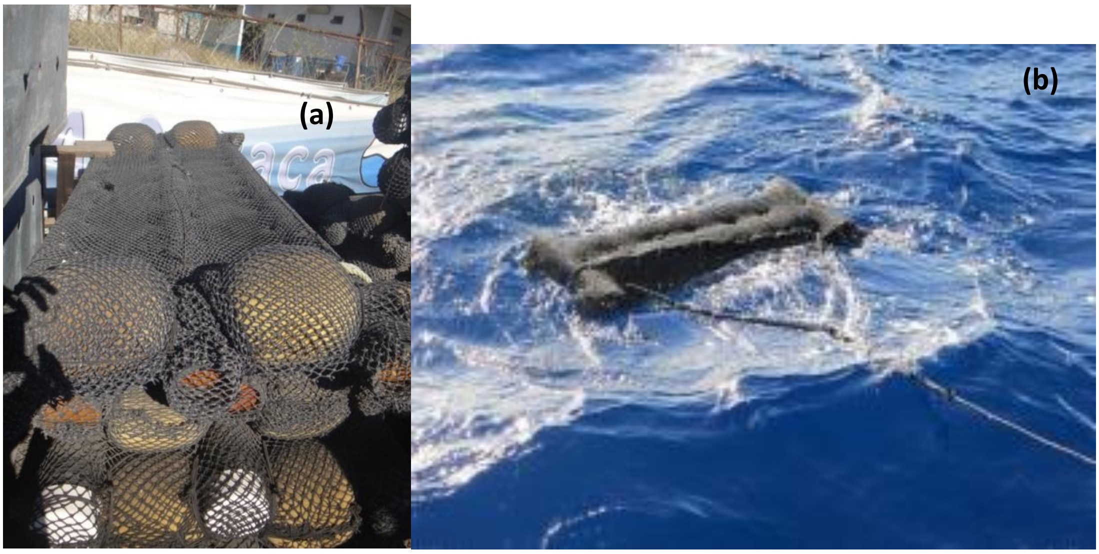
(a)

6. **Example of DFADs used by the Ghanaian fleet in the Atlantic, with (a) green trawler netting in the underwater appendage, and (b) a LER DFAD with no netting on the raft and netting tied into sausages in the tail.**

7. **(a,b) Traditional HER DFAD often used by Asiatic fleets in the WCPO with long panels of old purse seine mesh and green trawl mesh, with multiple color strips as attractors.**



8. **Examples of NE AFADs from Indonesia, (a) foam filled plastic raft and rope use for anchorage, (b) glass fiber cylindrical raft with anchorage points for rope attachment.**



9. **Examples of LER rafts with narrow rafts built with corks wrapped in small sized mesh used by some companies of the (a) Mexican and (b) USA fleet.**