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THE USE OF FADS IN TUNA FISHERIES

NOTE

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DIRECTORATE GENERAL FOR INTERNAL POLICIES

POLICY DEPARTMENT B: STRUCTURAL AND COHESION POLICIES

FISHERIES

THE USE OF FADS IN TUNA FISHERIES

NOTE

This document was requested by the European Parliament's Committee on Fisheries.

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DIRECTORATE GENERAL FOR INTERNAL POLICIES

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Abstract

An analysis of the use of FADs in the tuna fisheries and a summary of available information on the likely influence of FADs on the ability of a fishing vessel to catch fish, is presented. Making use of the information held in tuna RFMO data bases, the extent to which FAD use in tropical tuna fisheries continues to expand and the effect of FAD use on targeted tunas and other accompanying species is provided.

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LIST OF ABBREVIATIONS

BET	bigeye tuna (*Thunnus obesus*)
CMM	Conservation Management Measure
CPC	Contracting Parties and Cooperating Non Members of the Commission
CPUE	catch per unit of effort
EPO	Eastern Pacific Ocean
EEZ	exclusive economic zone
FAD	fish aggregating device
aFAD	anchored fish aggregating device
dFAD	drifting fish aggregating device
FHV	fish hold volume
F_{MSY}	Fishing Maximum Sustainable Yield
GPS	global positioning system
IATTC	Inter-American Tropical Tuna Commission
ICCAT	International Commission for the Conservation of Atlantic Tunas
IOTC	Indian Ocean Tuna Commission
ISSF	International Seafood Sustainability Foundation
LOA	Length over all
MADE	Mitigating ADverse Ecological impacts of open ocean fisheries
MSY	Maximum Sustainable Yield
PNG	Papua New Guinea
RFMO	regional fisheries management organization
SKJ	skipjack (*Katsuwonus pelamis*)
SLA	sea level anomaly
SPC	Secretariat of the Pacific Community
SST	sea surface temperature
tRFMO	tuna regional fisheries management organization

VMS	vessel monitoring system
WCPFC	Western and Central Pacific Fisheries Commission
WPO	Western Pacific Ocean
YFT	yellowfin tuna (*Thunnus albacares*)

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EXECUTIVE SUMMARY

Background

Floating objects have been used for centuries to enhance fishers' capacity to catch fish. Over the past half century, fishers have intentionally placed or modified floating objects, both natural and man-made, into the sea to attract fish with increasing frequency. Fish Aggregating Devices (FADs) now support thousands of fishing vessels all over the world. Two general categories of FADs are used, industrial and artisanal, which serve different user groups in somewhat different ways and the scale of operations and objectives are different. Industrial-scale FADs are anchored or drifting objects that are put in the ocean to attract fish. Tuna and other fish gather around FADs, which makes it easier to find and catch them, and so increases a fisher's capacity to catch fish. While FADs attract species of interest to the tuna fleets, they also draw in non-targeted marine life, such as sharks and other bony fish. Developing methods to mitigate the impact of FAD fishing on non-targeted, by-catch, is an active research area.

Since the early 1990s, the use of FADs for tuna fishing has widely and rapidly expanded, especially for the purse seine fleet targeting tropical tunas: skipjack (*Katsuonus pelamis),* yellowfin *(Thunnus albacares),* and bigeye tuna *(Thunnus obesus).* A number of factors contribute to a vessel's increased ability to catch fish, especially those related to FAD fishing. Purse seine fishing in general, and especially in FAD fishing, has experienced a large number of innovations that have made fishing more effective over time. The application of tracking buoys are likely the most significant technological development that has occurred within the last 20-30 years for increasing the efficiency of FAD fishing for tuna.

AIM

The aim of this briefing note is to analyze the use of FADs in the tuna fisheries and summarize available information on the likely influence of FADs on fishing capacity, which in this case is defined as the ability of a fishing vessel to catch fish, and fishing effort. This study also aims to inform to what extent FAD use continues to expand, for which tuna species they are intended, and the effect of FAD use on targeted tunas and other accompanying species. For this purpose the study considers historical development of FAD fishing for tropical tuna species, an identification of likely methods by which FAD fishing may have increased a vessel's ability to catch tuna, an examination of catch and effort indicators recorded in tuna Regional Fishery Management Organization's (tRFMO) data bases, a brief consideration of the status of tuna stocks targeted using FAD fishing and the implications of FAD fishing on those stocks, and an assessment of the rules governing the use of FADs in the tRFMO and their impact on effort control.

KEY FINDINGS

On a global scale, catches of tropical tunas across the world's oceans have grown to ~4.5 million tons (t). Of this, 60% was made by purse seine, and nearly 65% of purse seine catch was made by fishing on floating objects. Most of the growth in tropical purse seine catch is due to increasing skipjack catch, which was at ~2.8 million t in 2012. Since the early 1990s, purse seine catches of tropical tunas increased by nearly 60% which reflected an increase of about 33% in free school catches but nearly an 82% increase in catches made on floating objects.

Globally since the 1990s, purse seine fishing effort has also grown at an average pace of about 2%/year. During this time, the growth in floating object purse seine effort (sets) increased by 70%, compared to about 20% for free-school purse seine fishing effort.

Across the oceans, floating object purse seine fishing is now about 50% more productive (in t per set) than free-school fishing for the three tropical tunas in combination and about twice as effective for skipjack. For yellowfin, however, the relative efficiency of floating object fishing is about the same as for free schools, although the size of yellowfin caught on objects is much smaller than for free schools. On the other hand, the relative efficiency of bigeye caught on floating objects is about 10 times that for free-school fishing and the fish taken are also typically much smaller (around 50 cm fork length (FL) for FAD fishing and >100 cm FL for free school fishing). Ocean-specific patterns show variation from all of the global patterns noted, as the global patterns are dominated by the western Pacific statistics.

The global fleet of large-scale purse seiners making use of FADs is not well documented for lack of an adequate monitoring system. Although the tRFMOs maintain lists of vessels authorized to fish in their respective management areas, the number authorized typically is in excess of the number of vessels actually fishing. None-the-less, an estimate of the global fleet in 2013 based on these lists and specific knowledge of the European and Associated flag fleet is somewhat above 700 vessels, most of which are authorized to fish in the Pacific. FAD management plans, which woud permit monitoring FAD deployment and useage patterns, are not yet in place across the tRFMOs. As such we estimate, largely on extrapolation, that the current level of FAD deployments per year could be on the order of 91,000.

There are 13 stocks of tropical tunas around the world. Of these, all except yellowfin in the Atlantic and in the eastern Pacific were found to be at healthy biomass levels in the most recent stock assessments. In terms of exploitation level, all of the skipjack stocks were experiencing a low fishing mortality rate, and although some of the yellowfin and bigeye stocks were experiencing fishing mortality levels in excess of F_{MSY} (the rate of fishing producing maximum sustainable yield), most were being adequately managed to bring the exploitation to levels at or below F_{MSY}. The bigeye stock in the western Pacific, however, was experiencing high exploitation and management measures in place were judged insufficient to reduce the exploitation rate to or below F_{MSY}.

Overall, 93% of the recent tropical tuna catch, mostly skipjack, came from healthy stocks and a high proportion of that catch came from fisheries using FADs. There is no strong evidence that the use of FADs necessarily leads to overfishing of the tunas although harvesting large amounts of certain small tunas (*e.g.* bigeye or yellowfin) can reduce Maximum Sustainable Yields and contributes to the overall condition of these stocks, which are also harvested by other fisheries having impact (*e.g.* longline fishery).

While the tropical tuna stocks impacted by FAD (and other) fishing are mostly in healthy condition, further increases in fishing pressure could well change that picture. Unabated, the continued growth of FAD fishing for tropical tunas at the pace witnessed over the past few years would increase overal fishing pressure on these stocks. While all skipjack stocks are in healthy condition and could sustainably support some degree of increased fishing pressure (although skipjack in the western Pacific, Atlantic, and other areas may now be close to fully exploited), further increase in fishing pressure on bigeye and yellowfin stocks should be avoided.

All sources of fishing mortality reduce spawning biomass, either immediately or at some time in the future. A stock can be overfished by taking too many immature or too many mature fish, or both. All sources of fishing mortality need to be monitored and managed.

By-catch in purse seine FAD fishing is higher than in purse seine fishing on free schools of tuna for many but not all species, but the overall level of by-catch is lower than observed for some other tuna fisheries, such as longlining or drift netting. Research is ongoing on development of further mitigation actions to reduce impacts of FAD fishing on by-catch species, including sharks, turtles, small bigeye and yellowfin, much of it in collaboration with the fishing industry. A number of Best Practices have been identified for use in purse seine fishing on FADs and these have been communicated to a broad range of vessel owners and skippers through workshops conducted across the globe. A broad acceptance and application of these practices should reduce the impact of FAD fishing on by-catch species and tRFMOs have established some Conservation and Management Measures (CMM) to mitigate by-catch in purse seine FAD fisheries.

1. Introduction

KEY FINDINGS

- Fishing on floating objects has been employed for hundreds of years to enhance fisher's ability to catch fish.
- There are many thousands of FADs in the oceans, and their use has been accelerating, especially by purse seine vessels targeting tropical tunas.
- Concern exists about the impact of this expansion on targeted stocks and on by-catch species which generally occurs more frequently in purse seine fishing on FADs than when purse seine fishing without them.

Different fishing techniques have been used for millennia by fishers harvesting tuna: pole and line, purse seines, traps, long lines, handline, *etc.* These techniques typically were first used in coastal areas and then applied offshore in open ocean waters in the search for more productive fishing. During explorations for more productive fishing grounds, fishers noticed in some regions, that schools of tunas (and other species) could be found, associated with objects floating at or near the ocean surface (even dolphin schools, whales or whale sharks (Hall and Roman, 2013)). It is widely recognized that floating objects attract different species of marine life such as pelagic sharks, turtles and/or a large variety of bony fishes (Castro et al., 2002). Although the precise reasons why tunas and other marine animals aggregate around floating structures are still elusive, fishers have been taking advantage of this associative behavior for many years to enhance their ability to catch fish.

Fish aggregating devices (FADs) are anchored (aFADs) or drifting (dFADs) objects (both natural and man-made) that are intentionally put in the ocean to aggregate fish. Tuna and other fish gather around FADs, which makes it easier to find and catch them, and so increases a fisher's (and the fleet's) capacity to catch fish. Over time, fishers evolved a myriad of designs for FADs. These designs and techniques for relocating and judging the amount of fish associated with FADs keep evolving and, through trial and error, result in further improvements in fishers' capacity to catch fish. While FADs attract species of interest to the tuna fleets, they also aggregate non-targeted marine life, such as sharks and other bony fish.

There are many thousands of FADs in the oceans, and their use has been accelerating. Industrial FAD fishing is now commonly used by purse seiners and pole and line vessels to target skipjack (*Katsuwonus pelamis*) although other associated tunas including juvenile yellowfin (*Thunnus albacares*), and bigeye (*Thunnus obesus*) tunas are frequently caught under FADs with skipjack fished with purse seine. Small juvenile bigeye and yellowfin may represent a substantial proportion of purse seine catch on FADs in the world's oceans. For some stocks of tropical tunas that have been subject to overfishing, there is management interest in reducing these high levels of catch in order to reduce fishing pressure and increase MSY (maximum sustainable yield). Additionally, because floating objects not only attract species of interest to the tuna fleets, concern has been raised regarding purse seine fishing with FADs due to the potential impacts on these by-catch species and tropical pelagic ecosystems.

By-catch of the tropical tuna purse seine dFAD fishery is currently estimated at around 4-5% of total catch by weight (1-2% in free school sets), which are lower rates than those than estimated for some other tuna fisheries such as longline (*i.e.* global averages of 7.5%)(Gerrodette et al., 2012). However, the total amount of by-catch and discards for purse seine dFAD fishery is large and has been estimated at 100,000 t annually (Fonteneau et al., 2013). Large-scale deployment of dFADs is hypothesized to potentially modify the pelagic habitat and consequently, the spatial-temporal distribution of fish aggregations, and which might then have direct implications for changing species behaviour (Hallier and Gaertner, 2008; Marsac et al., 2001), although this 'ecological trap' hypothesis remains unverified (Dagorn et al., 2012). These issues have led to ongoing FAD investigation, monitoring and/or managing programs.

The intent of this Briefing Note is to analyze of the use of FADs in the tuna fisheries and summarize available information on the likely influence of FADs on fishing capacity, which in this case is defined as the ability of a fishing vessel to catch fish, and fishing effort. This study also wants to understand to what extent FAD use continues to expand, for which tuna species they are intended, and the effect of FAD use on targeted tunas and other accompanying by-catch species. For this purpose the study considers historical development of FAD fishing for tropical tuna species, an identification of likely methods by which FAD fishing may have increased a vessel's ability to catch tuna, an examination of catch and effort indicators recorded in tRFMO data bases, a brief consideration of the status of tuna stocks targeted using FAD fishing and the implications of FAD fishing on those stocks, and an assessment of the rules governing the use of FADs in the tRFMO as well as their impact on effort control. Finally, recommendations for improvement are offered.

2. Analysis of the Use of FADs in Tuna Fisheries

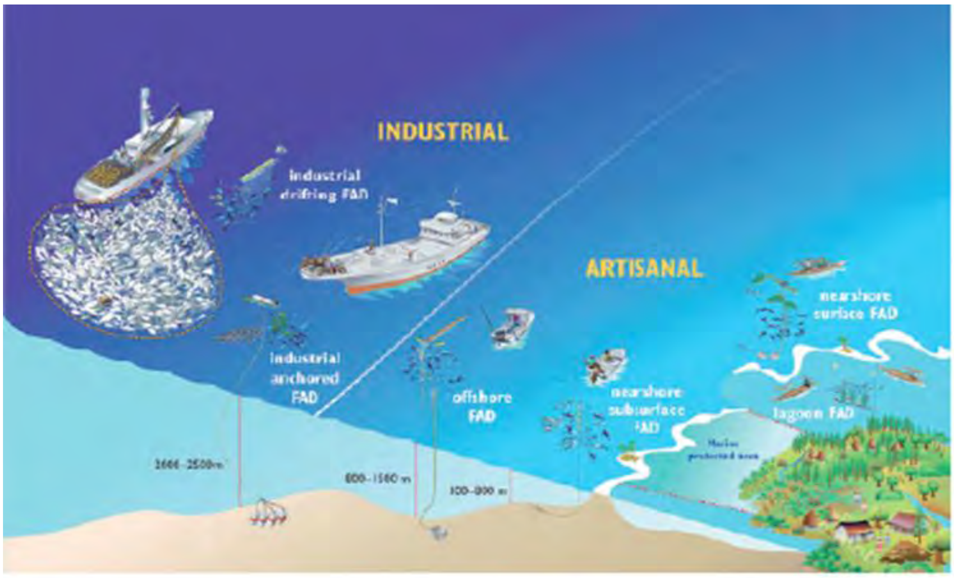
2.1. Development of FAD Fishing for Tropical Tunas

KEY FINDINGS

- aFADs and dFADs support thousands of fishing vessels all over the world.
- Purse seiners use industrial dFADs in support of high catch level harvesting of large schools of tropical tuna.
- The heavy use of dFADs since the 1990s is mostly responsibe for substantially growing the world-wide catches of skipjack.
- Industrial aFADs are used extensively in countries like Indonesia, Papua New Guinea (PNG), the Philippines, Thailand, Federated States of Micronesia and the Solomon Islands where tropical tunas are also targeted.

Currently, both aFADs and dFADs support thousands of fishing vessels all over the world. The Secretariat of the Pacific Community (SPC, PolicyBrief19_FADs.pdf) identifies two general categories of FADs used, industrial and artisanal, which serve different user groups in somewhat different ways for which the scale of operations and objectives are different. The selectivity (size and/or species) of fish caught, including pelagic sharks and other endangered, threatened or protected species, is influenced by the type of gear used for fishing. Industrial FADs are either drifting or anchored and are utilized mainly by purse seine and pole and line fleets in support of high catch level harvesting of large schools of tuna. Artisanal FADs are anchored to the bottom in offshore, near-shore (at the surface and subsurface) and in lagoon environments in support of subsistence, artisanal and recreational fishers. The artisanal FADs are typically set by government fisheries agencies in order to improve food security and small-scale domestic fisheries development, which can include sport fishery tourism. A graphic (Figure 1) developed by the SPC is useful to envision the range of FADs employed by various groups.

Figure 1. A depiction of some types of FADs used by fishers (SPC Policy Brief 19/2012, PolicyBrief)



Source: http://www.spc.int/DigitalLibrary/Doc/FAME/Brochures/Anon_12_PolicyBrief19_FADs.pdf

A symposium held in Tahiti in 2011[1] provided information on the current status of aFAD programs from more than 28 nations. In general, aFADs are mainly placed in coastal zones, typically placed at depths up to 2500m in order to attract tunas and other species and are frequently used to provide enhanced opportunity for artisanal and semi-industrial fishers. Many aFAD programs are designed as a small-scale fishery management approach to relieve the frequently heavy fishing pressure being experienced by more coastal species by transferring effort toward pelagic species, including tunas. These programs are thought to provide many positive benefits for local fisheries (Beverly et al., 2012).

The use of dFADs, in particular, has increased greatly in recent years and are now widely used in large numbers in the tropical and sub-tropical zones of the world's oceans. Fonteneau et al. (2013) provided a description of the use of dFADs in purse seine fisheries since the early 1990s and attribute the heavy use of dFADs as substantially growing the world-wide catches of skipjack. As previously mentioned, in addition to skipjack, two other tropical tunas are commonly caught when purse seine fishing on dFADs, notably yellowfin and bigeye tuna, which are also targeted by longline and other competing fisheries, including purse seine fishing on free swimming, or unassociated, tuna schools. In contrast to the small sizes of yellowfin and bigeye tuna caught by purse seiners fishing with dFADs (~ 45-50 cm fork length (FL); ~2 kg. (Fonteneau et al., 2013)), the sizes of bigeye and yellowfin tuna taken in the other fisheries for these species are much larger (e.g. ~130 cm FL for bigeye tuna caught by longling and purse seine fishing on free schools (schools unassociated with floating objects), (Fonteneau et al., 2013)). Increasing catches of small yellowfin and bigeye tunas tends to reduce the long-term maximum sustainable catch levels (in biomass) of these species since the biomass gained through growth is not attained in the catches of small fish.

2.1.1. Anchored FADs (aFADs)

The use of aFADs is wide-spread and occurs in all the world's oceans, but they are not necessarily used for targeting tunas (Figure 2). Most of the Southern Asia and Western Pacific countries, many countries in the Caribbean, and some Indian Ocean and Mediterranean locations are known to have made use of these devices at one time or another, and the majority maintain ongoing aFAD programs. Anchored FAD use was first documented in the Mediterranean and were first introduced into the Pacific from the Philippines, via Hawaii, in the late 1970s with a high rate of success: in 1984 more than 600 aFADs were deployed in the region (Désurmont and Chapman, 2000). Since then, the focus on aFAD use has centered on modifying the traditional Filipino payao structure (Figure 3) and optimizing the mooring system, in order to efficiently adapt them to high-energy ocean environments typical of the Pacific (Anderson and Gates, 1996).

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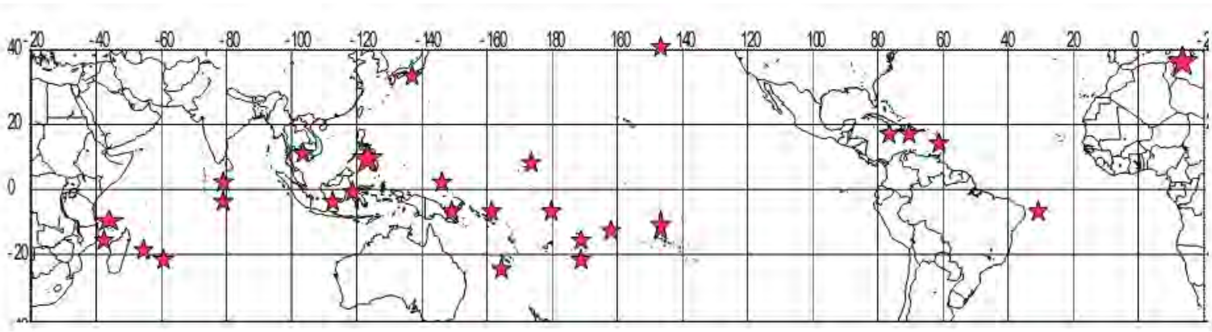
[1] Second International Symposium on: Tuna Fisheries and Fish Aggregating Devices, 28 Nov - 2 Dec, 2011, Tahiti, French Polynesia (http://wwz.ifremer.fr/institut_eng/The-Institute/News/Archives/2011/DCP-Tahiti-2011)

Figure 2. AFADs deployment sites all over the world (from Fonteneau (2011)).

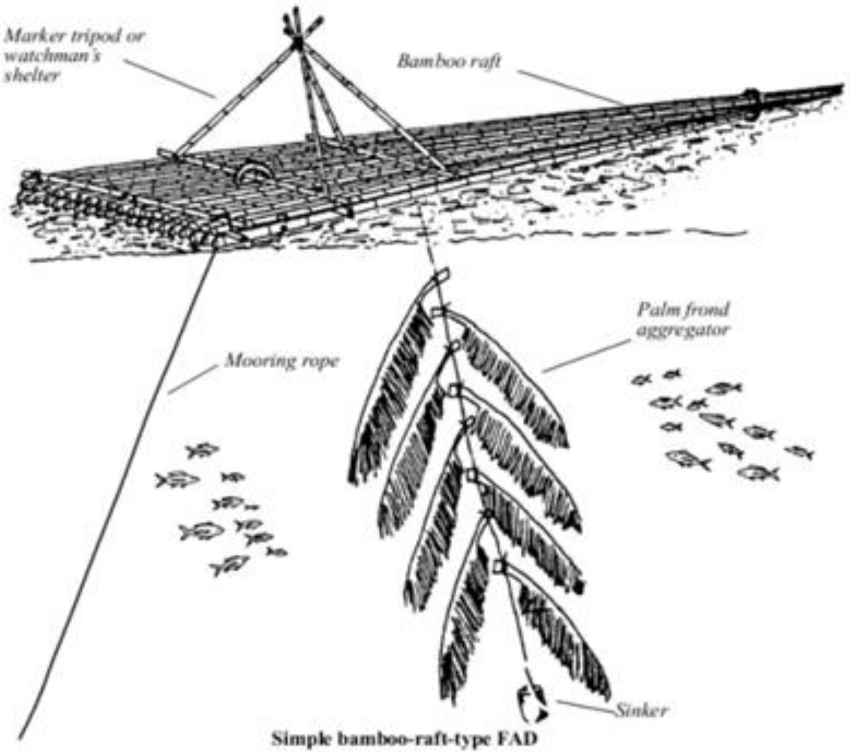


Source: Fonteneau, A., 2011. *An overview of world FAD fisheries by purse seiners, their impact on tuna stocks and their management*. Second international symposium on: Tuna Fisheries and Fish Aggregating Devices. TAHITI, Polynésie française. 28 novembre - 2 décembre 2011.

Modern aFADs, with a raft typically made from steel, aluminum and fiberglass, may be anchored in waters up to 2,500 m deep and be equipped with radar reflectors and solar-powered lights (Anderson and Gates, 1996) and are usually fished using several techniques, such as trolling, pole and line fishing, trapping (for small pelagics), vertical long-lining, drop-stone handlining, ring netting (for bait fish), but rarely by purse-seining.

In the industrial sector, private interests fund, deploy and monitor their own aFADs, while in small-scale fisheries, aFADs are almost exclusively maintained and deployed by the public sector and overseas funding agencies (Désurmont and Chapman, 2000). Industrial aFADs are used extensively in countries like Indonesia, Papua New Guinea (PNG), the Philippines, Thailand, Federated States of Micronesia and the Solomon Islands.

Figure 3. Simple bamboo-raft-type aFAD (from Anderson, 1996)

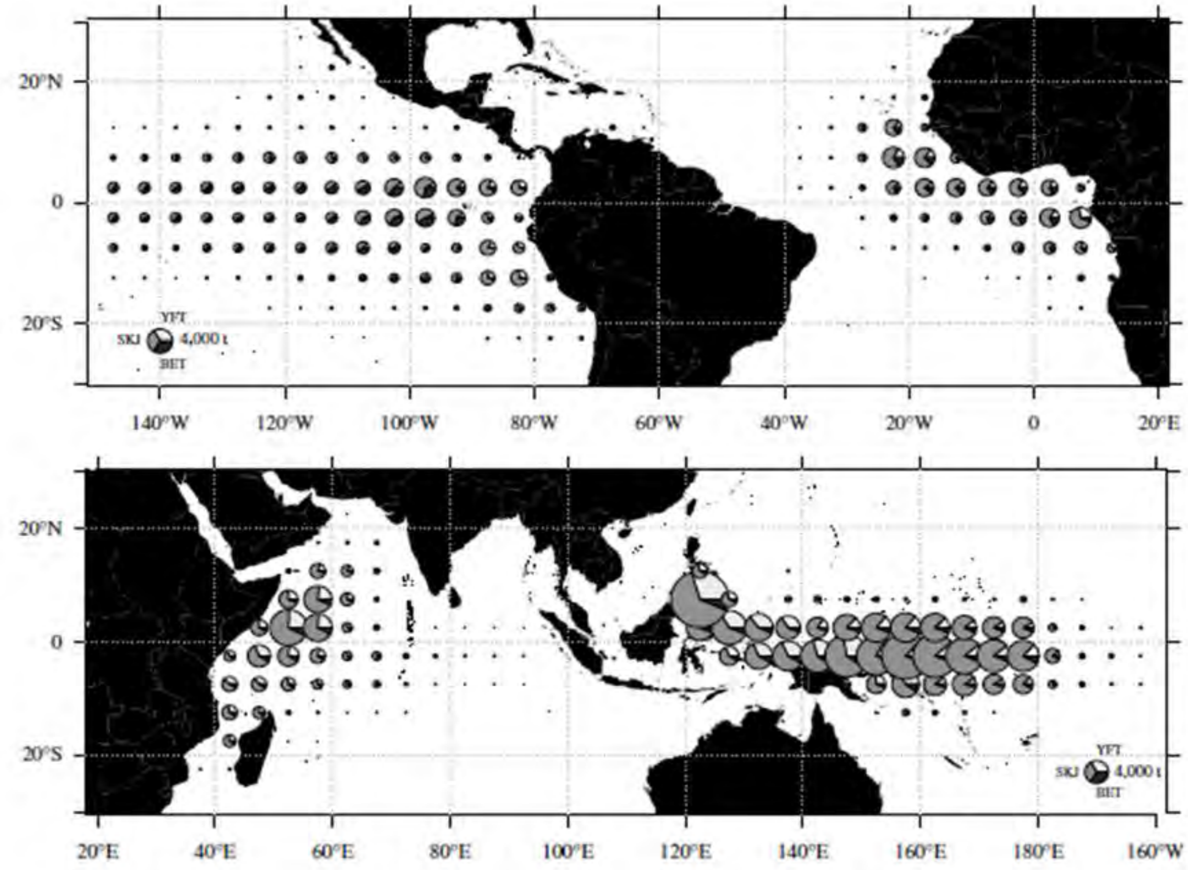


Source: Anderson, J., Gates, P. D., 1996. *South Pacific Commission fish aggregating device (FAD). Volume I: Planning FAD programmes.* . Noumea, New Caledonia: South Pacific Commission, 7: 46.

2.1.2. Drifting FADs (dFADs)

The use of dFADs by purse seine fleets has widely and rapidly expanded (Fonteneau et al., 2013), who gave a global view of the geographical range and scale of dFAD catches (Figure 4). As Itano (2004) stated, many fleets or vessels based their fishing strategy on setting on their own or other vessels' dFADs. Those objects are deployed and left to drift freely with the currents with the intention of being exclusively used by the boat or fleet that set them afloat. However, many vessels take advantage of setting on dFADs deployed by others, when they are opportunistically encountered. Some vessels also experiment with retrieving dFADs and re-deploying them at different locations where better signs of tuna are present (*i.e.* jumping tuna, tuna schools forming 'breezers' on the surface, baitfish concentrations, *etc.*), or tethering several natural drift logs together to form a larger floating mass (Itano, 2004). Interviewed skippers said that the area of deployment and drift are more important to FAD biomass aggregation than structural design (J. Lopez, pers. obs). However, there is agreement that structure hanging down from the FAD is important to allow the FAD to drift with the current to productive areas. The depth reached by the structure (generally netting) ranges from 15 to 80-100 meters, and is ocean-specific (15-20m in the Indian Ocean, 80-100m in the Atlantic Ocean, and around 30m in the Eastern Pacific Ocean (EPO)).

Figure 4. Recent fishing zones of FAD fisheries: average catches by species (for all gears) during the period 2000-2009 (upper figure Eastern Pacific and Atlantic Ocean, lower figure Indian Ocean and Western Pacific). Figure courtesy of A. Fonteneau (pers. comm., Fonteneau et.al. 2013)



Source: Fonteneau, A., Chassot, E., Bodin, N., 2013. *Global spatio-temporal patterns in tropical tuna purse seine fisheries on drifting fish aggregating devices (DFADs): Taking a historical perspective to inform current challenges*. Aquatic Living Resources, 26: 37-48.

Apparently, and as Hall (2011) has demonstrated for the fleet operating in the EPO, the depth reached by the net hanging down has evolved with time, and is now significantly deeper than at the beginning of the fishery. The design of the FAD can vary between fleets but they all employ similar elements for their construction: bamboo rafts, purse seine net, chain or a weight, *etc.* For the typical European fleet design, bamboo rafts are simple and light in construction but held together with net twine and generally have added purse seine corks to increase strength and flotation (Itano et al. (2004), Figure 5).

Figure 5. Picture of a typical EU dFAD raft in the Mozambique Channel

Source: J. Lopez (© EU Project MADE/AZTI/J. Lopez)

Sub-surface aggregators such as coconut fronds and other materials are also usually attached to the lower part of the raft (Itano, 2004). Rafts are attached with an instrumented buoy (GPS buoy, echo-sounder buoy, *etc.*) to allow accurate geo-location in time and space. These rafts are usually constructed aboard the fishing or the support vessel, but also on land. Some European vessels are already buying land-produced rafts (in Abidjan or the Seychelles) to increase the productivity and certain fleets are now setting non-entangling and biodegradable 'ecoFADs', which do not use net material underneath structures to reduce the risk of entanglement of sharks and turtles in the FAD and reduce other potential environmental impacts.

Many factors have direct implications for dFAD seeding strategies of a purse seine vessel, which in turn have direct influence on the number of dFADs deployed for the year by each vessel. As previously suggested, location is one of the most important factors. Some fleets have very seasonal catch patterns. Fishers seed dFADs in locations, characterized by specific oceanographic features, with the intention of finding them in productive areas after a certain period of time (usually 3 to 5 weeks, (Hall, 2011; Moreno et al., 2007)). These spatio-temporal considerations are important in determining the number of dFADs that vessels will deploy during a fishing trip. In addition, a purse seine vessel's seeding strategy is also primarily affected by the number of other vessels' dFADs that are encountered during fishing, the potential poaching rate of an area, the likely quantity of free schools available in the fishing zone, the particular economic situation of the fleet owner and/or the number of dFADs deployed by vessels of the same company, which sometimes share fishing strategy and dFADs.

2.2. Identification of the Likely Methods by which FAD Fishing has increased a Vessel's Ability to Catch Fish

KEY FINDINGS

- Many changes in fishing technology and operations have occurred, each potentially affecting fishing power of tropical purse seiners; 23 elements have been identified to contribute to gains in purse seine fishing efficiency.
- Tracking buoys are likely the most significant technological development that has occurred within the last 20-30 years for increasing the efficiency of dFAD tuna fishing. It is likely that since the introduction of the sonar (for free school fishing), no other single technological improvement has had an equal magnitude of impact on improving the efficiency of purse seine fishing.
- All of the technology changes noted operate at the individual vessel level to increase fleet capacity, undermining attempts to manage capacity through vessel numbers. Obviously, addition of vessels to the fleet also increases capacity and should not be overlooked as a source of increasing fishing pressure.

A number of factors contribute to a vessel's increased ability to catch fish, especially those related to FAD fishing. Effort creep represents the gain in capacity through innovation and, in many cases, it is difficult to quantify the specific impacts of technological innovation, skipper skill, or factors from among a range that can improve a vessel's capacity to catch fish. In 2012, a scientific workshop[2] that examined the current use of purse seine catch and effort noted that globally, since 1980, many changes in fishing technology and operations have occurred, each potentially affecting fishing power of tropical purse seiners. Table 1 (Anonymous, 2012) identifies 23 elements the workshop considered important, some of them not directly related to the use of FADs, in this respect and also characterizes the geographical scale of the influence of each factor, the approximate year when the change was first introduced, the relative cost of the factor, the likely magnitude of the factor's effect on fishing efficiency and the potential annual rate of change in each factor after its introduction.

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[2] Anonymous. 2012. Report of the 2012 ISSF Stock Assessment Workshop: Understanding Purse Seine CPUE. ISSF Technical Report 2012-10. International Seafood Sustainability Foundation, Washington, D.C., USA. http://iss-foundation.org/wp-content/uploads/downloads/2012/09/ISSF-2012-10-CPUE-WS-report1.pdf

Table 1. Initial, partial list of 23 factors that have changed historically in purse seine fisheries and their likely importance in affecting fishing power (from Anonymous (2012)).

Factor	Scale	Year	Cost	Impact	Annual increase
Use of FADs *	Global	1990	Low	Major	Steep
Use of support vessels *	Global**	1992	High	Major	Steep
Faster unloadings	Global	1980	Low	Significant	Slow
Use of computers	Global	1990	Low	Significant	Slow
Technological improvement of FADs *	Global	1990	Low	Major	Steep
Improved GPS positioning of vessels	Global	1994	Low	Marginal	Stable
Improved fishing memory of fisheries	Global	1990	Low	Marginal	Stable
Increased freezing capacity	Global	1990	Moderate	Significant	Slow
Increasing vessel size and capacity	Global	1980	High	Significant	Slow
Ageing of fleets	Global	1980		Marginal	Slow
Use of satellite imagery	Localized	1997	Low	Significant	Slow
Bird radars	Localized	1985	Low	Major	Slow
Helicopters	Localized	1980	High	Significant	Stable
Improved Sonar/long range	Localized	2002	Low	Significant	Stable
Higher, improved crow nests	Localized	1985	Moderate	Marginal	Slow
Improved navigation radars	Localized	1995	Low	Significant	Stable
Real-time private radio communication	Localized		Low	Significant	Stable
Improved echo sounders *	Set-specific	1990	Low	Significant	Stable
Deeper and faster nets	Set-specific	1985	High	Significant	Slow
Canon vs opening rings	Set-specific	1985	Low	Marginal	Stable
Larger skimming nets and mast	Set-specific	1987	Moderate	Marginal	Stable
Underwater current meters	Set-specific	1991	Low	Marginal	Slow
Monitoring of net fishing depth	Set-specific	1990	Low	Marginal	Slow

* Factor directly related to FADs. ** But note that support vessels are now prohibited in some RFMO areas.

One of the major difficulties encountered when estimating change in tuna purse seine vessels' ability to catch fish is to correlate technological change with effective fishing effort. Fine-scale and detailed operational data on the application of each of these factors is generally lacking, at the regional level, which is an obstacle for scientists addressing this issue. Major technical and technological advances have been identified as principal causes of fishing efficiency increase, such us the use of helicopters, bird radars, sonar, supply vessels, echo-sounder buoys, or hydraulic gear, which increase the fish detection capacity of the vessel or contribute to reduce the duration of the fishing related activities. As noted, detailed information on the time of introduction and intensity of use of these elements on the tuna purse seine fleet is still scarce. In stock assessment evaluations for the Atlantic and Indian Oceans, an annual average 3% increase of the effective fishing effort for the purse seine fishery has been assumed, based on Gascuel *et al*. (1993) and Fonteneau et al. (1999). This result also coincides with the value suggested by Moron (2004) for the Spanish purse seine fleet fishing in the Indian Ocean. However, as implied in Table 1, a smooth change over time, such as implied by an annual effective rate of change of 3% is unlikely. Rather, these changes are more likely more abrupt and variable between years.

Prior to the widespread use of dFADs (1980-1995), most modifications to purse seine technology were driven by the desire to improve the success rate for free school fishing and to be able to load and store the large catches that are possible on unassociated schools (Itano, 1998). Technological developments over the last 20 years have focused on increasing the number of productive sets possible during a fishing trip and enhancing the catch rate on dFADs. A number of the factors identified are commented upon below.

2.2.1. Net Size and Design

Net dimensions have direct implications on fishing efficiency, making the design ocean-specific due to the different water characteristics in each region (turbidity, density, thermocline depth, *etc*.). The shallow nets commonly used in the Atlantic Ocean (around 220 m depth, (Gaertner and Sacchi, 2000; Santana et al., 2002)) need to be completely remade for use in the Indian Ocean (275 m depth, (Santana et al., 2002)), and in a more evident way for the Pacific Ocean (>300 m depth, (Farman, 1987; Gillett, 1986; Itano, 1998; Itano, 1991)). The most popular net type is the knotted one, being almost the totality of the fleets, with the exception of Japanese, using it (Itano, 2003). Roller rings have also been adopted by most fleets, which allow reducing friction significantly and faster pursing speeds.

2.2.2. Hydraulic Gear

The hydraulic power systems of purse seiners operating in the Pacific were considerably modified during the mid-1980s to provide sufficient power to the power blocks and rail rollers required to purse and haul the larger nets. This improvement contributes to decrease the time needed for a set and increase the capacity of hauling larger free schools sets.

2.2.3. Catch Loading/Unloading and On-Board Refrigeration

The ability to load and refrigerate large catches has been the most significant development in fishing power to occur in the 1990s (Itano, 1998). Proof of that is the wide use of the European style of fish brailing, which is capable of loading approximately 8 to 10 tons per individual lifting. Vessels have also adopted refrigerated brine circulation systems to efficiently cool and freeze the catch as quickly as possible in a tropical environment. The unloading process on modern purse seiners has also been revolutionized by "floating" the wells. This process involves pumping brine into the wells to float tuna up to the surface allowing much faster port unloading thus gaining time for fishing activities (Itano, 2003).

2.2.4. Electronics

The Japanese fleet is credited as being the first to include marine electronics (depth sounders, sonar, bird radar, *etc.*) into their fishing operations (Itano, 1998). However, there have been few relevant developments in electronic devices within the past twenty years, with the exception of the use of satellite imagery and tracking buoys. The majority of these devices were initially introduced to improve purse seine catches on free schools. Tracking buoys, on the other hand, were specifically introduced to increase productivity of dFAD fishing. The broad use of marine electronics has now evolved for both free school and dFAD fishing based on experience gained through their use at sea when looking for free schools and opportunistically encountering floating objects.

2.2.4.1. Bird radar (S- Band) and navigational radar (X-Band)

The presence of bird flocks in the open ocean is usually a sign of baitfish and surface concentrations of tuna or the proximity of floating objects. Bird radar (S-Band) is capable of detecting seabirds at distances of 15 nautical miles, even under unfavorable weather conditions. Bird radar is now adapted for detection of small ships, buoys and floating objects. Most modern tuna purse seine vessels have adopted bird radar as a basic component of their searching/fishing strategy and in many cases have substituted bird radar for helicopter searching (Itano, 2003).

Since the late 1990s, navigational radars (X-Band) have been equipped with tracking software (Itano, 2003). This improvement allows fishers to use their navigational radar as a fishing tool, by simultaneously tracking the position and direction of tuna schools and competitor vessels, which is especially useful when moving in an area of free school fish.

2.2.4.2. Doppler current meter

The majority of modern tuna purse seine vessels are equipped with current meters to monitor surface and sub-surface currents prior to and during fishing operations (Itano, 2002). This device provides continuous information on the speed and direction of the water column at different depths, aiding fishers in deciding the best time and place to set the net, especially for free school sets in order to reduce the number of unsuccessful (null) sets.

2.2.4.3. Sonar

The use of the sonar is mostly focused on free schools sets as well. However, this device is also necessary when setting on floating objects in the Pacific Ocean, where FADs are usually fished in pre-dawn darkness (Harley et al., 2009). Modern tuna purse seiners have two or more sonar units installed on the bridge, which are usually operating at low and high frequencies and different ranges to assist in tuna school detection. Sonars are continuously displayed during the whole searching operation to opportunistically find surface or subsurface tuna aggregations. According to Itano (2003), EU purse seine captains claim that these sonar units have been responsible for increases in vessel productivity of 10% to 20% when fishing on free schools.

2.2.4.4. Oceanographic Map Service

Although remote sensing maps arrived later for vessels operating in the Atlantic and Indian Oceans than for Pacific Ocean vessels, their use today is wide-spread and the vast majority of modern purse seine vessels subscribe to oceanographic information service providers on board to assist in locating best areas for fishing. This technology incorporates information in near real time about sea surface temperatures (SST), currents, chlorophyll, sea level anomaly (SLA) and other useful parameters to their fishing operations, especially for the identification of potential free school locations. In fact, the commercial companies that provide satellite imagery to purse seines have also consulting services assessed by fisheries experts. Fishers also take advantage of this tool to categorize and detect potential dFAD deployment and retrieval areas.

2.2.4.5. Depth sounders

The latest generation of scientific sounders are increasingly being used on modern purse seine vessels to gather information on and enhance fishers’ ability to discriminate species, school size or the depth distribution of target tunas found in association with dFADs. These units can operate up to four frequencies and display simultaneously and accurately fish schools or individuals. With experience, school size, species and the average size of fish in a school can be assessed with a high degree of accuracy, permitting avoiding setting on FADs that contain high quantities of by-catch or small tuna. In interviews conducted with Spanish skippers operating in all the three ocean regions, more than the 80% of fishers claimed that they are now able to effectively distinguish fish species and sizes at dFAD thanks to the color, shape and depth of the acoustic signal (J. Lopez, *pers. obs.*).

2.2.4.6. Buoys

Tracking buoys are likely the most significant technological development that has occurred within the last 20-30 years for increasing the efficiency of dFAD tuna fishing. It is likely that since the introduction of the sonar (for free school fishing), no other single technological improvement has had an equal magnitude of impact on improving the efficiency of purse seine fishing. Because they are of particular interest for our study, instrumented buoys (Figure 6) are discussed in more detail below.

Figure 6. A pool of the three main instrumented buoys manufacturers (Satlink, Marine Instruments and Zunibal) in Port Victoria, Seychelles.

Source: J. Lopez (© EU Project MADE/AZTI/J.Lopez)

Buoys are retrieved by any fishing vessel that found them at sea and left in the port when unloading fish to allow buoy owners recovery them during their next visit. This buoy exchange could also occur at sea when vessels are fishing in the same area (©MADE/AZTI/J.Lopez).

2.2.5. Communication and Navigation Aids

Email and satellite phones have allowed easy, secure and economical communication between vessels and their management. Boat-to-land and boat-to-boat links are now much faster and more efficient, which promotes information sharing and increases vessels' fishing response to productive free school or dFAD areas.

2.2.6. Support vessels

Another significant development utilized by the Spanish fleet is the incorporation of dFAD support vessels (Figure 7) into their fishing strategy (Itano, 2004). These vessels work in conjunction with one or a group of large purse seine vessels to improve overall efficiency. The support vessels collaborate in all tasks related to dFAD fishing, such as dFAD deployment, monitoring of aggregations, retrieving dFADs when they drift off too far from the area of interest, *etc*. In addition, these auxiliary ships also look for and evaluate other vessels' dFADs and safeguard aggregations of tuna on their own dFADs from theft by other vessels (Arrizabalaga et al., 2001). Although the contribution of support vessels to purse seine vessel efficiency has not been analyzed in detail, it is widely recognized to be high and, in the case of IATTC (Inter-American Tropical Tuna Commission), the use of support vessels has been banned because of this.

Figure 7. A Spanish support vessel in Port Victoria, Seychelles in 2011. These ships are significantly smaller than regular purse seines (±30 meters) and aid fishing vessels in dFAD related activities

Source: J. Lopez (© EU Project MADE/AZTI/J.Lopez)

2.2.7. Instrumented Bouys

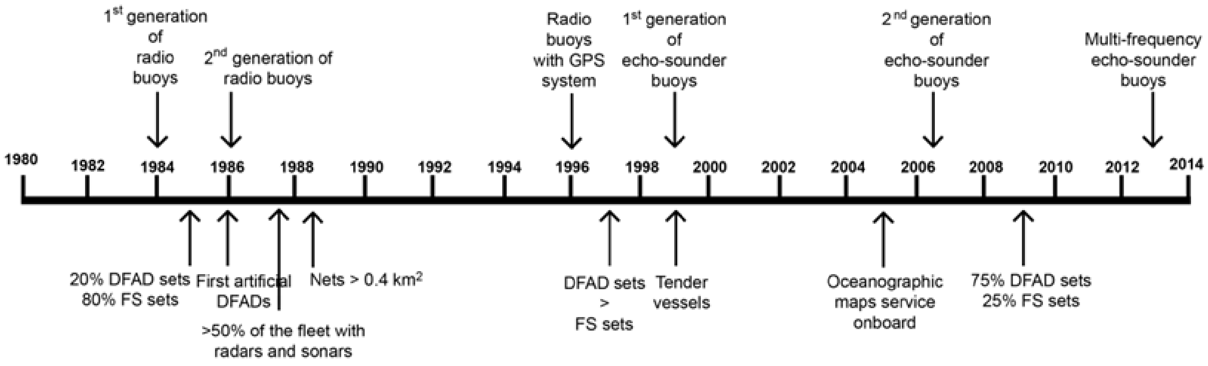
The development of highly efficient purse seining on dFADs would not likely have been possible without rapid improvement in marine electronics and buoy technology that has occurred over the 30 years. Table 2 and Figure 8 summarize the most important technological events and evolution of the buoys used for dFAD tracking by the purse seine fleet, globally and for the specific case of the Indian Ocean for which more detailed information is available.

Table 2. Different type of instrumented buoys and their time of introduction as well as their main detection and battery characteristics.

Type	Year	Signal detection/transmission system	Detection range (nmi)	Battery	Notes
Radio buoys	mid 80s	Constant transmission Radio Detection Finder (RDF)	100	Battery	Detected by foreign RDFs and radars
Select call radio buoys	late 80s	RDF (no constant transmission)	200	Battery	Detected by foreign RDFs and radars
Radio GPS buoys	mid 90s	RDF (no constant transmission) + GPS position	700-900	Battery	Contribute to the first expansion of FAD fishing grounds (Moron 2001)
GPS tracking buoys	late 90s	GPS position (continuous emiting)	1000	Battery	First info on battery and SST
Echo-sounder buoys	2000s	Inmarsat satelllite conexión + light when approaches	virtually unlimited	Battery	First echo-sounder readings
2nd gen. Echo-sounder buoys	mid 00s	Satellite connection	virtually unlimited	Solar panels	Fist info on current speed and direction
3rd gen. Echo-sounder buoys	2012	Satellite connection	virtually unlimited	Solar panels	Multifrequency transducers

Similar patterns might have occurred, although with some lag (technology needs time to be trialed and settled in the fishery), in other oceans due to a high degree of interaction between fleets and fishing companies sharing information. The most notable changes in the buoy technology have occurred in the area of detection (increasing in the range and signal privacy), battery life, and remote sensing of tuna abundance under dFADs. Today, tracking buoys are equipped with echo-sounders, providing fishers with remotely sensed estimates of the biomass associated with instrumented dFADs. The information on the size of the aggregation and accurate distance to the dFAD facilitates discrimination of the most favorable dFADs and permits careful planning fishing trips to reduce unproductive search for tuna schools to fish.

Figure 8. Timeline of the most important events on instrumented buoys and some of the most significant technological developments and fishery events for the Indian Ocean.



Source: J Lopez

Incorporation of GPS technology into the drifting radio buoys in the late 1990s revolutionized purse seine fishing on dFADs and this technology was quickly adopted by all modern purse seine fleets. Moron et al. (2001) noted that GPS buoys significantly contributed to an expansion of the Indian Ocean dFAD fishing grounds since purse seiners started to visit and retrieve buoys that had drifted out of traditional fishing areas, thus expanding productive fishing grounds. Skippers interviewed during International Seafood Sustainability Foundation (ISSF) workshops held in the main tuna fishing ports all over the world confirmed this observation (J. Lopez, *pers. obs.*). Fishing zone expansion seems more evident since the introduction and the regular use of echo-sounder buoys in this fishery around the mid-2000s. Since then, the number of sets on floating objects and the number of $1^{o}x1^{o}$ squares prospected and exploited by the Spanish fleet has almost doubled in both the Atlantic Ocean (Delgado de Molina et al., 2012b) and Indian Ocean (Delgado de Molina et al., 2012a). Early models of echo-sounder buoys provided fishers with crude biomass estimates and no information on species composition. However, with better technology and experience, echo-sounder buoys (in combination with other sources of information, such as other fishers' communications and support vessel reports) have become very helpful in optimizing "search time" between two successful dFAD sets.

Artetxe and Mosqueira (2003) examined catch parameters for dFADs marked by different types of buoys and concluded that the success rate and percent of larger sets appeared to be significantly higher on dFADs equipped with echo-sounder buoys. Even though the price of echo-sounder buoys is generally 50-60% higher than similar buoys without the sounder, the percentage of the buoys containing echo-sounders on dFADS has considerably increased since 2010 for the Spanish fleet (J. Lopez, pers. obs.), which underscores the technological advantage they provide. Analogous patterns are expected to occur in other fleets following similar fishing strategies in a way similar to the way other innovations demonstrated to improve fishing efficiency have been widely adopted.

Baske et al. (2012) gathered information on market share, recent production and increased demand for satellite-tracked buoys from the five major suppliers of this technology and estimated an output of 47,500−70,000 buoys per year, which represents a high proportion of the estimated annual deployment of dFADs. The European and associated vessel fleet and a high proportion of other fleets fishing on dFADs use instrumented buoys for the monitoring and control of their dFADs, suggesting a rapid incorporation of this technology into the global fleet. Most likely, the technology involved with instrumented buoys will continue to improve and will likely further increase the efficiency of vessels, undermining attempts to limit capacity by limiting vessels. All of the above elements that increase capacity are on a per-vessel basis. Obviously adding vessels to the fleet also increases the overall capacity of the fleet. Currently there exists substantial scope for increasing the number of vessels actively fishing through fleet development plans that have been registered at tRFMOs, particularly in the Western Central Pacific and Indian Oceans.

3. Catch and Effort Indicators Recorded in tRFMO Data Bases

KEY FINDINGS

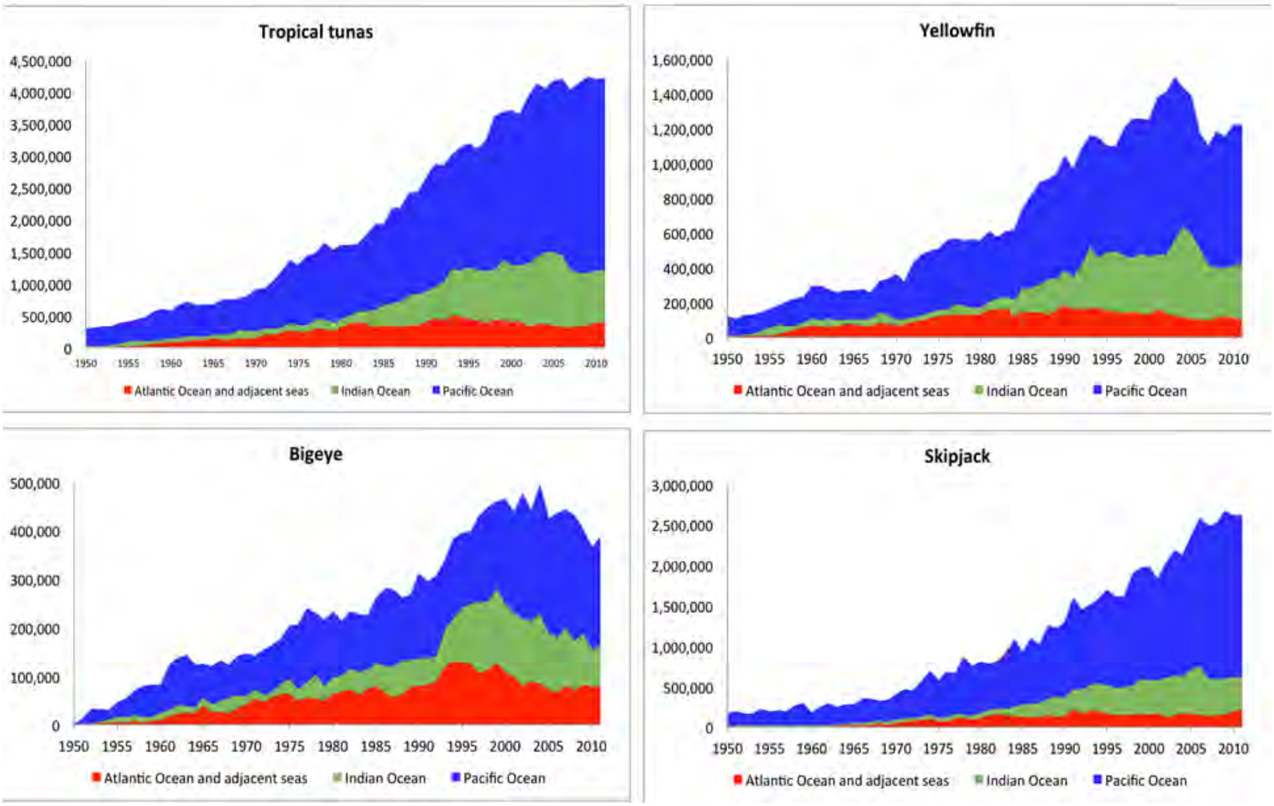
- Catches of tropical tunas across the world's oceans have grown to ~4.5 million tons (t) in 2012. Of this, 60% was recorded by purse seine, and nearly 65% of purse seine catch was made by fishing on floating objects. Most of the growth in tropical purse seine catch is due to increasing skipjack catch, which was at 2.8 million t per year in 2012.
- Since the early 1990s, purse seine catches of tropical tunas increased by nearly 60% which reflected an increase of about 33% in free school catches but nearly an 82% increase in catches made on floating objects.
- Globally since the 1990s, purse seine fishing effort has also grown at an average pace of about 2%/year. During this time, the growth in floating object purse seine effort (sets) increased by 70%, compared to about 20% for free-school purse seine fishing effort.
- Floating object purse seine fishing is about 50% more productive (in t per set) than free-school fishing for the three tropical tunas in combination and about twice as effective for skipjack. For yellowfin, however the relative efficiency of floating object fishing is about the same as for free schools, although the size of yellowfin caught on objects is much smaller than for free schools. On the other hand, the relative efficiency of bigeye is about 10 times that for free-school fishing and the fish taken are typically much smaller (~50 cm FL for fish caught on FADs and >100 cm FL for free school fish).
- An estimate of the large-scale global purse seine fleet in 2013 is uncertain but is somewhat above 700 vessels.
- FAD management plans which woud permit monitoring FAD deployment and useage patterns are not yet in place across the tRFMOs., however, we estimate that the current level of FAD deployments per year could be on the order of 91,000.

Up to date purse seine catch, effort and vessel information was obtained from various sources, including the tRFMOs (see Annex). For this analysis, purse seine catch and effort was categorized as either free school (unassociated) catch and sets or object-oriented (including FADs, natural logs, and other objects, except dolphins) catch and sets. That is because most of the tRFMO fishery statistics do not distinguish between purse seine sets made on natural objects and on introduced artificial objects, although differentiation between free-school sets and sets on floating objects are maintained. In the eastern Pacific fishing statistics, sets on tuna-dolphin associations are also distinguished in the available data.

3.1.1. Catch Indicators

Overall, catches of tropical tunas across the world's oceans have grown to ~4.5million t per year in 2012. Much of this growth is attributed to increasing skipjack catch, which had grown to 2.8 million t per year in 2012 (Figure 9). Pacific Ocean catches of tropical tunas dominate the global production with about 75% of the global catch coming from this region.

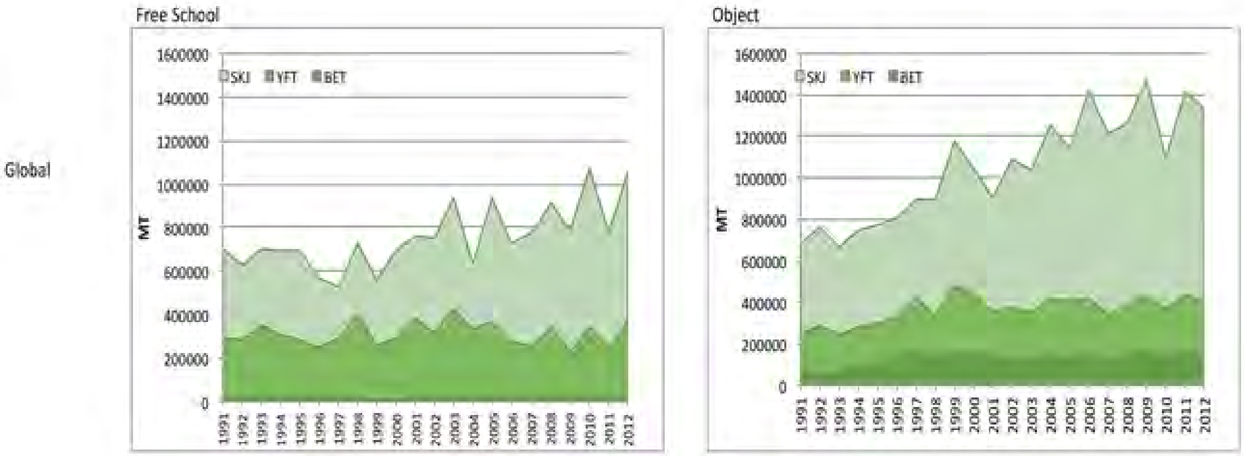
Figure 9. There has been global growth in the catches of tropical tunas across the three oceans by all gears.



Source: GPS and JL based on tRFMO data

Flucuation in catches in the past decade for Bigeye and Yellowfin, which are taken in longline, purse seine and pole and line fisheries are evident, while continued global growth in skipjack catches which are made primarily by purse seine and pole and line fisheries is noted.

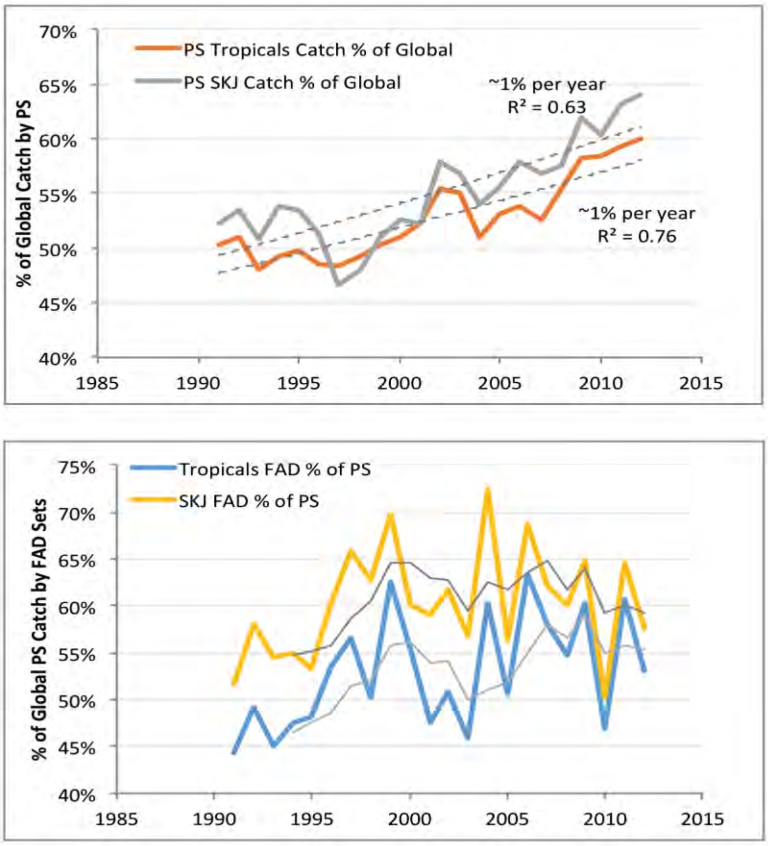
Figure 10. Time tendency in global purse seine catches of tropical tunas by species and set type.



Source: GPS and JL based on tRFMO data

Of the ~4.5 million t recorded for 2012, 60% was recorded by purse seine, of which nearly 65% was made by object-oriented sets. The global proportion statistics for skipjack are slightly higher, but lower for yellowfin and bigeye, for which substantial catches by longline and other gears are made. Between the periods from 1991 through 1995 and 2008 through 2012, purse seine catches of tropical tunas increased by nearly 60% (Figure 10), which reflected an increase of about 33% in free school catches and a nearly 82% increase in object-oriented (including FAD) purse seine catch. The level of change between these periods varies with species and type of purse seine fishing mode. These changes over time could have resulted from increased effort, increased stock abundance, and/or increased capacity to catch fish. Of these, increased abundance seems least likely.

Figure 11. Tendency over time in the proportion of tropical tuna and skipjack catches made by purse seine fishing compared to the global catch of tropical tunas and skipjack by all gears, which indicates an average annual increase in proportion of the total of about 1% per year (upper plate). Lower plate: Temporal pattern in proportion of FAD catches of tropical tuna combined and of skipjack compared to global purse seine catches of these species. A 4-year running average pattern is also indicated which shows growth from the earliest part of the time series.



Source: GPS and JL based on tRFMO data

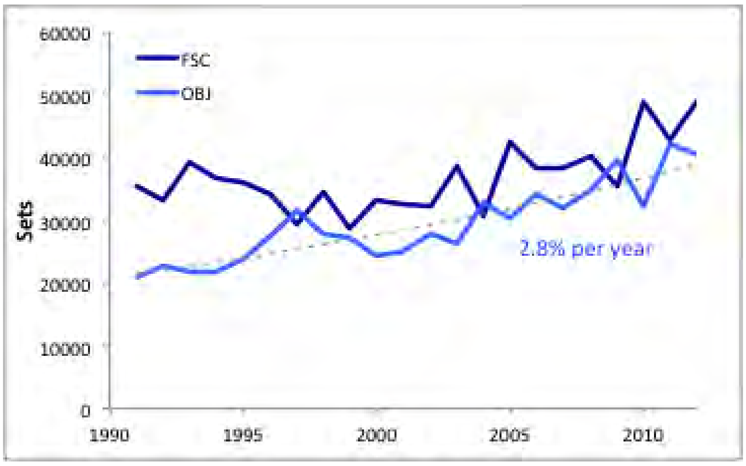
Since the early 1990s, the proportional representation of purse seine tropical tuna catch relative to global catch across all gears has also increased (at about a 1% per year), but the proportional representation of object-oriented catch of tropical tunas shows a more variable tendency with the most recent proportions generally higher than those of the early 1990s (Figure 11). These tendencies in catch proportions can be explained by increasing effort, increasing capacity for catch, and/or decreasing catch by other gear types, but the underlying reasons for the interannual variability is not known to the authors. While the global patterns provide information, they tend to mask different ocean region patterns. In general, the global patterns largely reflect the Pacific, and the western Pacific in particular, since the dominant catches of tropical species come from that region. Several differences in catch patterns emerge comparing the ocean region specific patterns (Annex Tables 1 and 2). The pattern of continual growth in skipjack catch is largely the result of catches from the western Pacific, which as noted earlier, are dominant in a global production sense.

While there has been a decline in free school catches and increase in object-oriented catches in the Atlantic and Indian Oceans in recent years (2008-2012)(Annex Tables 1 and 2), the Pacific, and especially the western Pacific, has shown growth in both free school and in object-oriented catches of tropical tunas in the same period. Patterns in catch in and of themselves do not directly address the issue of increasing vessel capacity to catch fish. A consideration of catch and effort indicators is required to more fully address the issue.

3.1.2. Effort Indicators

Due to the shift in the fishing strategy from free school to FAD sets, search time (i.e. the time devoted to the searching of tuna concentrations and the metric traditionally used to reflect nominal effort), is no longer useful for this fishery (Fonteneau et al., 2013). In this study, alternative effort indicators (i.e. number of sets) have been considered then in detriment of search time. Globally, since the early 1990s, there has been general growth in purse seine effort measures recorded in the tRFMO data sets. On average, the number of fishing sets recorded for free school and object-oriented sets has grown at about 2.8% per year (Figure 12). Since the mid 1990's, the global growth in recorded free school purse seine sets has kept pace with object-oriented sets. While the number of recorded free school and object-oriented sets has grown over time, by about40% between the 1991-1995 and 2008-2012 periods, the number of free school sets only increased by about 20% in that time compared to a 70% increase in object-oriented sets.

Figure 12. Global time trend of growth in purse seine effort by set type.



Source: GPS and JL based on tRFMO data

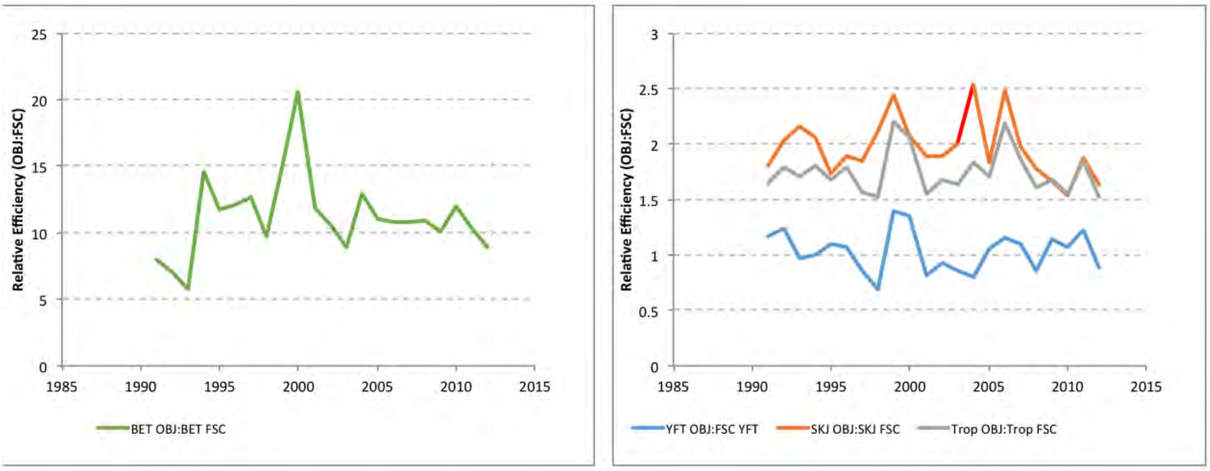
As noted for the catch indicators, the global pattern tends to mask ocean region differences in this metric as well. While the global pattern shows growth in both object-oriented and free school sets, that global pattern and rate of growth is not the same in all ocean areas. The Atlantic showed a pattern of decline from 1991-2006, with a strong reversal in trend since then (Annex Tables 1 and 2). In contrast, the western Pacific showed a pattern of higher rate of growth in free school sets than object-oriented sets over the same time period, but like the Indian Ocean, also with an approximately 2.6% annual growth rate in object-oriented sets. A more rapid rate of increase in object-oriented sets (at about 5.5% per year) was recorded for the eastern Pacific. Other than in the western Pacific, there has been a general reduction in free school sets recorded compared to the earliest part of the time series examined (Annex Tables 1 and 2).

The overall increase in purse seine effort (40% between the 1991-1995 and 2008-2012 periods) can at least partially explain the overall increase in purse seine catch of tropical species (of 60% over the same period) and also admits the possibility of an overall increase in the capacity to catch fish. An evaluation of the relative efficiencies of free school and object-oriented purse seine sets can provide additional information to consider.

3.1.3. Relative Efficiency

Comparison of catch rate (t per set) between free school and object-oriented purse seine fishing sets can give insight into the potential for change in overall fleet capacity to catch fish. A global comparison of the relative efficiencies (t per set) by species is provided in Figure 13. In this comparison, there is little difference, on average, between free school catch (t) per set and object-oriented catch per set for yellowfin tuna, although if the comparison were to be made on numbers of fish per set, the difference would be quite large (on average, purse seine free school caught yellowfin weigh about 20 times more than individual yellowfin taken in object-oriented sets). For the other species, object-oriented sets are at least 1.5 times more effective than free school sets in terms of catch (t) per set and for bigeye, the relative efficiency is on average about 10 times more effective than free school sets recorded in the tRFMO data sets. In fact, as Fonteneau et al. (2013) stated for the period 2001–2010, dFAD fishing represented 90% of the purse seine catches of bigeye, highlighting the power of this fishing tool for harvesting bigeye compared to free school fishing targeting bigeye, which is much less common than for yellowfin.

Figure 13. A global comparison of the relative efficiency of object-oriented sets and free school oriented sets over time (in t/set). Values above 1 indicate that catch per set in object-oriented sets is higher (more efficient) than free school sets, thus leading to increased capacity to catch fish.



Source: GPS and JL based on tRFMO data

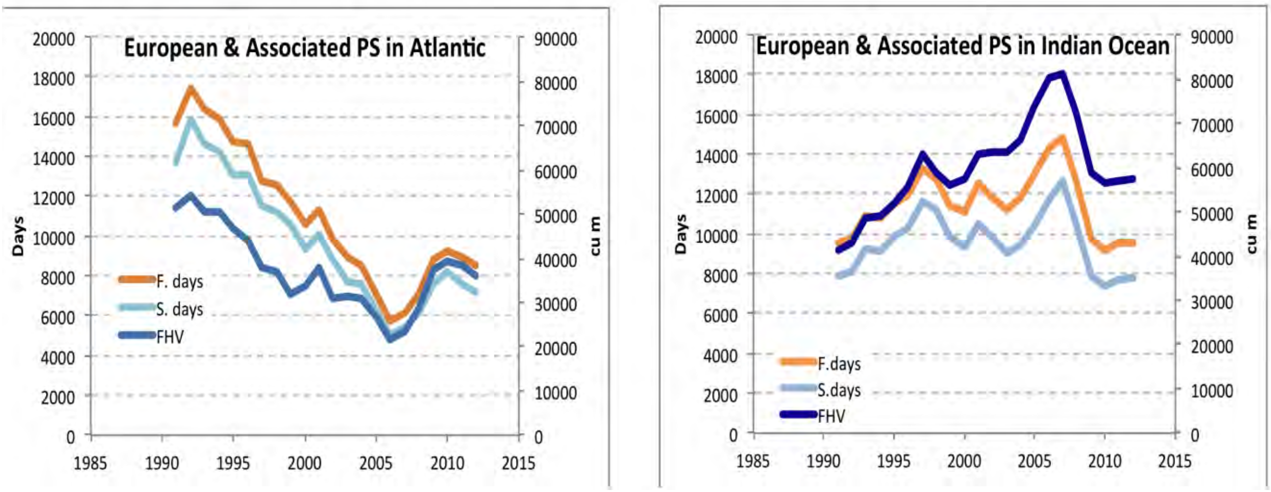
According to Fonteneau et al. (2013), the average catch per successful set is often higher for dFAD-associated sets than free school sets. For instance, between 2000 and 2010, average annual catch values of 32 t set^{-1} and 27t set^{-1} were observed for European purse-seine fisheries in the Atlantic on dFAD-associated and free schools, respectively. Similarly, these values were observed at 40 t set $^{-1}$ and 25 t set $^{-1}$, respectively, in the Eastern Pacific for the same period (Martin Hall, pers. comm.). However, this pattern has not been observed in the Indian Ocean (Floch et al., 2012).

As with the other indicators, the global pattern masks ocean region specific differences. For yellowfin in the Atlantic and Indian Oceans, object-oriented sets are less effective than free school sets (in t/set), while in the western Pacific, object-oriented sets appear generally more effective than free school sets. For bigeye in the Atlantic and Indian Oceans, it appears the relative efficiencies of object-oriented compared to free school sets have declined over time and in the case of the Indian Ocean, the relative efficiency may now be about the same as free school sets. In contrast, Pacific bigeye object-oriented relative efficiencies are higher than the global average (more than 10 times in the western Pacific and on the order of 60 times as effective in the eastern Pacific) than free school sets in those ocean areas. In the case of skipack, there appears to be an increasing tendency in object-oriented relative efficiencies in all but the eastern Pacific, where the trend appears to be a decline in object-oriented sets compared to free school sets, although the most recent relative efficiencies in the EPO remain about 1.5 times that of free school sets.

3.1.4. Detailed Catch-Effort Indicators from a Subseet of the Global Fleet

Detailed catch and effort indicators are available from the European and associated purse seine fleet operating in the Atlantic and Indian Oceans in recent documents produced for tRFMO scientific committees (e.g. (Delgado de Molina et al., 2013; Chassot et al., 2013). These documents provide a view of the evolution of the active fleet performance statistics in a finer scale way than what is publically available in other tRFMOs. In the Atlantic and Indian Oceans, this fleet dominates the purse seine catch (and effort) and represents vessels flying EU and non-EU flags, and so the patterns found also reflect those based on the global statistics noted in the previous sections for those Oceans. Figure 14 provides a view of the time trajectory of this fleet active in the Atlantic and Indian Oceans.

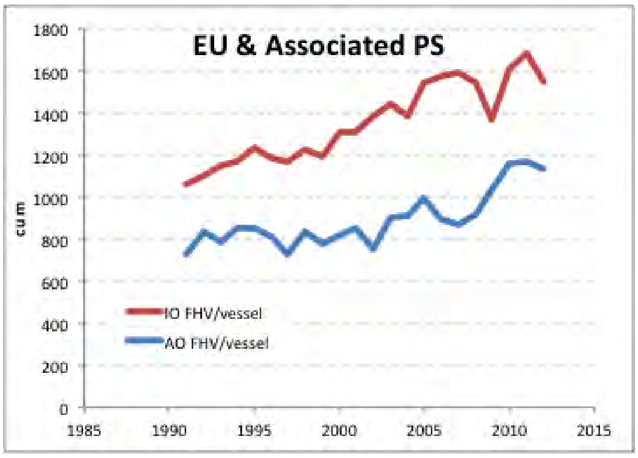
Figure 14. Effort indicators for the European and Associated fleets operating in the Atlantic and Indian Oceans (F.days, fishing days; S.days, search days; FHV, estimated fish hold volume (in m^3). Data as reported in (Delgado de Molina et al., 2013) and Chassot et al. (2013).



Source: GPS and JL based on data in Delgado de Molina et.al (2013) and Chassot et al (2013)

It is evident that there was a reduction in the Atlantic fleet capacity and participation level between 1991 and the mid 2000's whereas there was an increase in the Indian Ocean. During this period, a number of vessels and newly constructed vessels began fishing in the Indian Ocean. The vessel size characteristics for the Indian Ocean generally showed larger (and newer) vessels participating in the fishery. On average, the vessels in the Indian Ocean fleet were more than 30% larger (in estimated fish hold volume (FHV), Figure 15). In both oceans, however, there has been a tendency for increase in the average estimated fish hold volume of vessels in the fleets, which is likely an indicative of overall increase in vessels' capacity to catch and carry fish. The Atlantic increasing trend in per vessel fish hold volume appears to have initiated in the mid 2000s after a period of stability of close to 800m^3 to a level close to 1200m^3 in 2012, whereas the Indian Ocean tendency has been a more continuous increase over the same time period from about 1000m^3 in 1991 to nearly 1500m^3 in 2012. Today, newly constructed modern purse seines can hold 2500-3000m^3 (Itano, 2002).

Figure 15. Trend over time for increasing estimated average fish hold volume (m^3) by vessel in the Indian and Atlantic Ocean EU and Associated purse seine fleets.

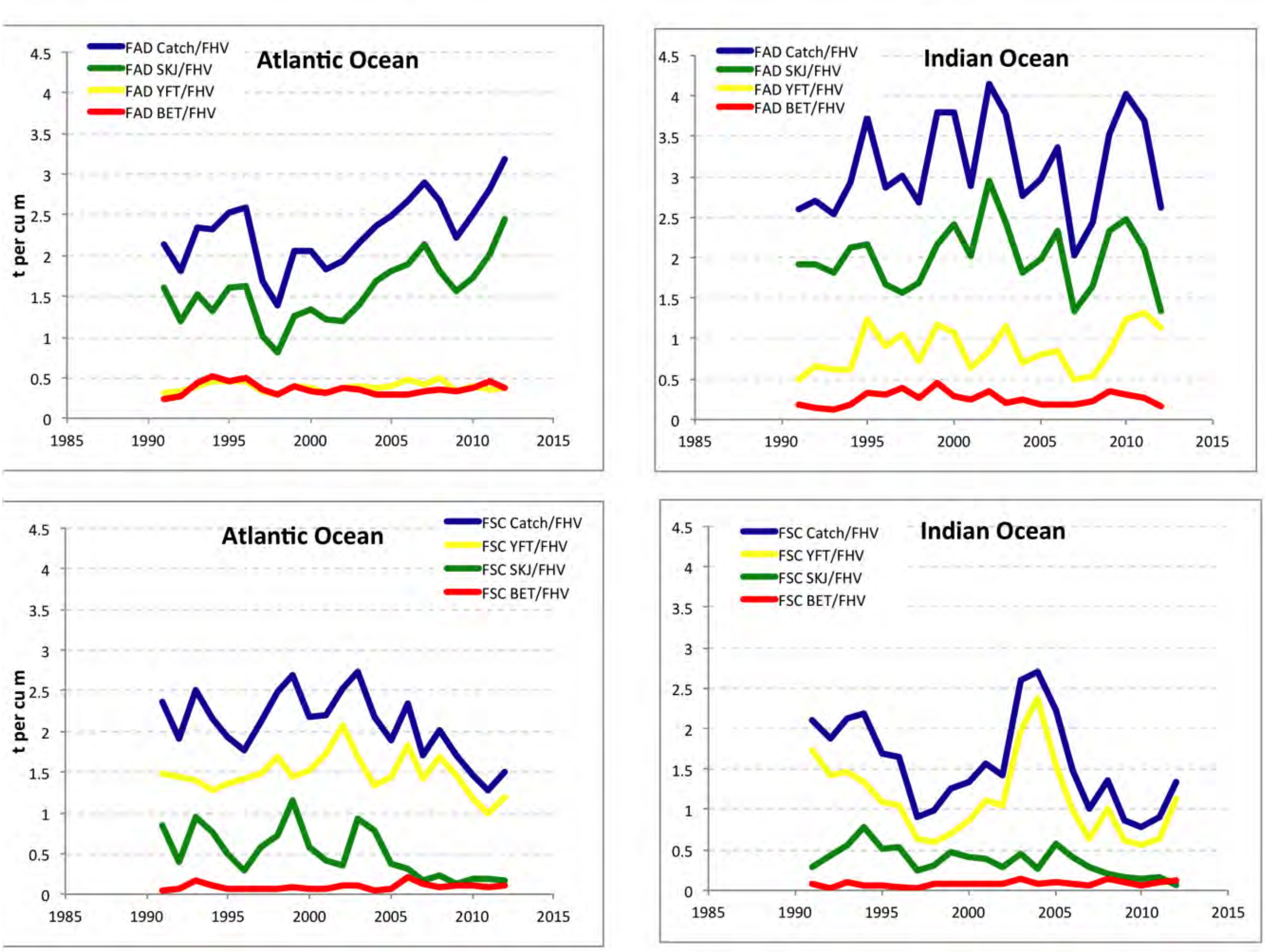


Source: GPS and JL based on data in Delgado de Molina et.al (2013) and Chassot et al (2013)

In the Atlantic Ocean, increasing FAD catch per fish hold volume for the EU and Associated fleet positively correlates for skipjack but not other tropical species, to some degree, with the increase in per vessel average fish hold volume and negatively correlates with free school catch per fish hold volume which may reflect replacement of older, less efficient vessels with newer ones in the Atlantic fleet. This positive correlation is not evident in the Indian Ocean (Figure 16) which typically has had newer and more technologically advanced vessels comprising the fleet.

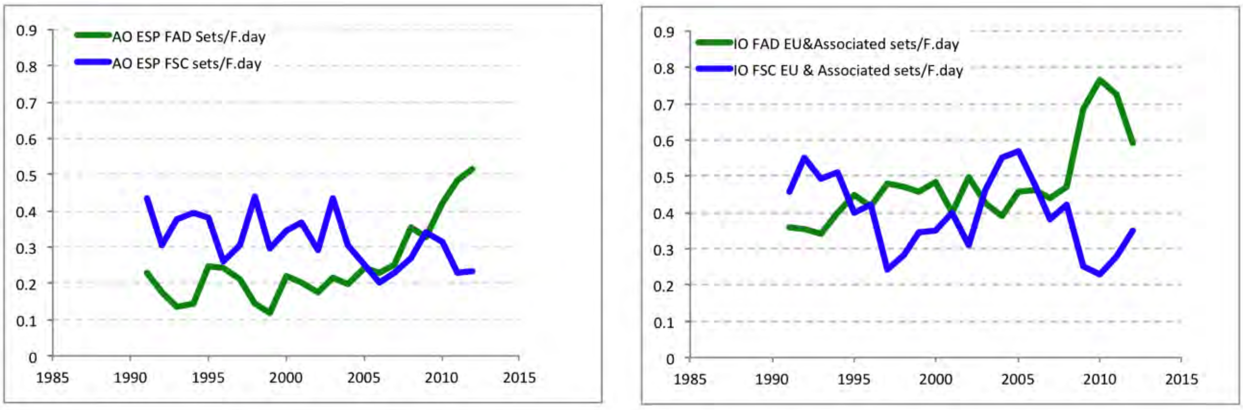
Although there is not a clear pattern of increase in FAD catch per fish hold volume with increasing average fish hold volume, there appears to be a consistent pattern in terms of an increase in the number of FAD sets per fishing day and a decrease in the number of free school sets per day recorded in both oceans for this fleet (Figure 17) which is also consistent with increasing the ability of a vessel to catch fish. Although top speed is not especially relevant for purse seines, larger vessels are faster than small ones, reaching a maximum speed of 19 knots, which allow larger ships to decrease the time between two successful FAD sets and increase their efficacy when setting on free schools.

Figure 16. FAD (upper row) catch per fish hold volume for the Atlantic (left column) and Indian (right column) Oceans for the EU and Associated fleets since 1991. Free school catch rates are in the bottom row.



Source: GPS and JL based on data in Delgado de Molina et.al (2013) and Chassot et al (2013)

Figure 17. Time trend in FAD and Free School Sets per fishing day for the Spanish Atlantic purse seine fleet (left panel) and the European and Associated Indian Ocean purse seine fleet (right panel). In both cases, recent increases in the frequency of FAD sets per fishing day are evident which is a pattern consistent with increasing efficiency for catching fish via FAD fishing in these fleets.



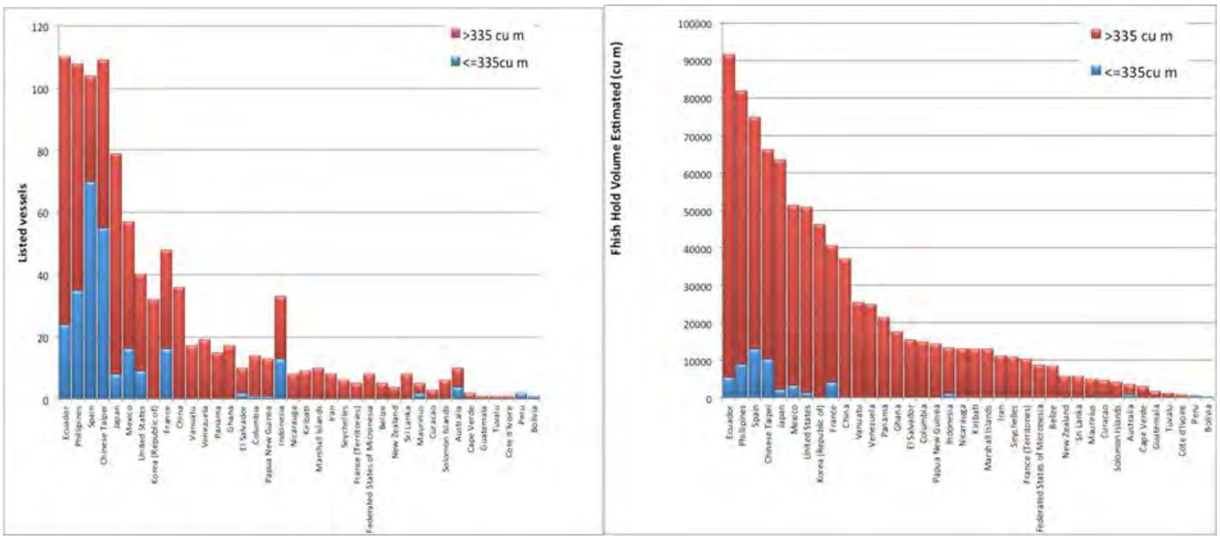
Source: GPS and JL based on data in Delgado de Molina et.al (2013) and Chassot et al (2013)

3.1.5. Fleet indicators

Restrepo and Forrestal (2012) provided a snapshot of the global large-scale tropical tuna purse seine fleet (≥335m^3 fish hold volume), based on examination of tRFMO and other vessel lists for 2011. An updated snapshot was conducted making use of the most recent tRFMO vessel lists (as of November 2013) for this analysis. Results of this updated analysis are similar to that of Restrepo and Forrestal (2012), although the number of large scale purse seine vessels identified is somewhat larger and somewhat differently distributed amongst flag States than previously estimated. This is not too suprising, given the dynamic nature of the large scale purse seine fleet and the potential for growth in the fleet through development plans proposed to the different tRFMOs. It is noteworthy that the number of registered vessels can be higher than those actively fishing and in numerous occasions, the same vessels are simultaneously registered in different ocean regions.

Figure 18 provides a view of the estimated fish hold volume (m^3) and number of unique purse seine vessels (duplicate registrations removed, to the degree possible) by flag of registry and by estimated fish hold volume. The estimated fish hold volume is approximately 970,000 m^3, from 977 vessels, of which 26% (254) are <335m^3, but representing less than 7% (67,900 m^3) of the estimated fish hold volume. As a system of unique vessel identifiers (such as an IMO number) is not yet available, it is generally not possible to track, over time, the distribution and number of vessels involved in the global tropical purse seine fishery because of the dynamics of the fleet, including change of vessel names, ownership, flag of registration, and ocean region(s) of registration.

Figure 18. Left plate: Estimated fish hold volume for purse seine vessels globally authorized to capture tropical tunas. Large scale tuna vessels (those with fish hold volumes of at least 335 m^3) dominate this global fishing capacity measure. Right plate: Estimated global number of purse seiners authorized by tRFMOs to capture tropical tunas characterized as large ($\geq$335 m^3) or small (<335m^3) fish hold volume vessels.

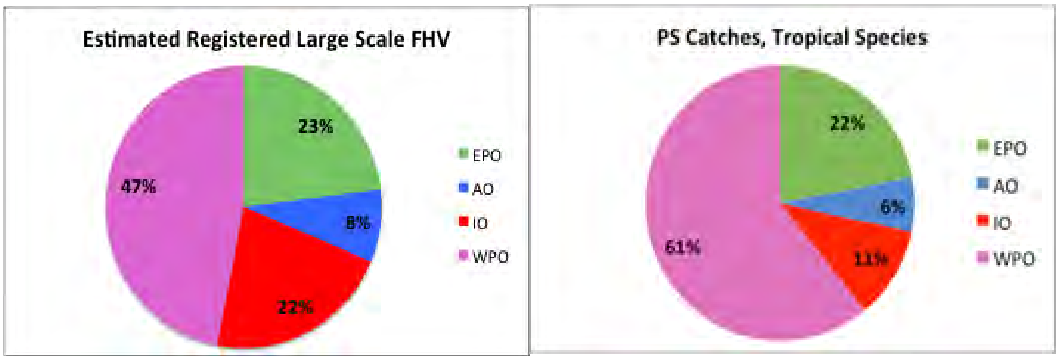


Source: GPS and JL based on vessel lists held by tRFMOs and FFA

Given the nature of the various authorized vessel lists, it is quite evident that the authorized capacity for fishing is well in excess of the actual, active fishing capacity. This feature alone offers potential for considerable growth in overall fleet effort. For example, Moreno and Herrera (2013) compiled the available information from the IOTC (Indian Ocean Tuna Commission) on active fishing vessels targeting tuna and tuna-like species in the Indian Ocean. For 2012, they estimated that the active purse seine fleet in the Indian Ocean focusing on tropical tunas was on the order of 68 vessels (63 of which were large-scale (>24m LOA)). This is in contrast to 178 large ($\geq$335 m^3) purse seine vessels registered as authorized to fish under the IOTC scheme. Similar outcomes can be found for the other RFMO authorized lists because individual vessels can be authorized to fish in more than one tRFMO and not all vessels authorized to fish actually do so. Thus, while elaboration of the numbers and fish hold volume of purse seine vessels authorized to fish for tropical tunas through the authorized lists can be accomplished, such an accounting likely exceeds by a significant degree, the active fishing capacity used to produce the global catch levels reported. None-the-less, these approaches can be used to estimate the potential effort for FAD fishing, should the authorized vessels adopt the patterns used by the most active FAD fishing vessels for which more detailed information exists.

The distribution of tRFMO authorized, estimated fish hold volume (m^3) and number of large scale ($\geq$335 m^3) purse seine vessels by ocean region and catch is shown in Figure 19. Nearly half of the global registered large scale purse seine fish hold volume is registered in the Western Pacific, followed by the Eastern Pacific, Indian Ocean, and Atlantic. Similarly, more than half of the purse seine tropical tuna catches occur in the Western Pacific Ocean, followed by the Eastern Pacific, Indian, and Atlantic Oceans.

Figure 19. A view of the proportional distribution of large-scale purse seine fish hold volume by ocean region and purse seine proportional catch of tropical tunas by region.



Source: GPS and JL based on vessel lists held by tRFMOs and FFA

3.2. How Many FADs are in the Oceans?

KEY FINDINGS

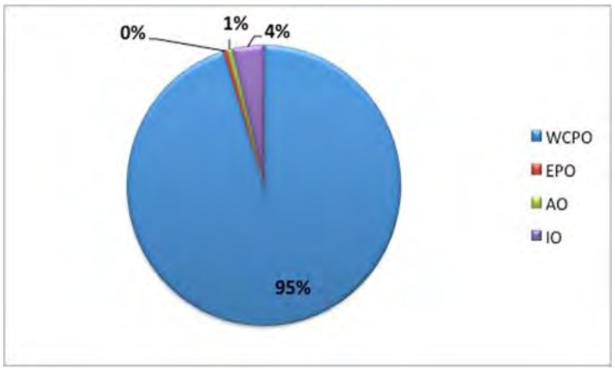
- There is not yet an adequate monitoring system in place to keep track of global FAD deployments and utilization patterns.
- Nearly 13,000 aFADs support around 8,000 vessels that harvest tuna and tuna-like species, among others. The ratio of aFADs per vessel is 1.6, which is 100 fold lower than the ratio of dFADs per vessel using dFADs.
- A provisional estimate of ~91,000 annual dFAD deployments per year is largely made based on extrapolation from the lists of vessels authorized to fish in the tRFMO management areas
- Almost 60% of the potential global dFAD deployments occur in the western central Pacific, followed by the eastern Pacific Ocean (24%) and at a lower level in the Atlantic and Indian Oceans (around 10% each). These proportions correspond well with the recorded number of purse seine sets in the tRFMO data sets for 2012, of which 50% were recorded for the western central Pacific, 25% for the eastern Pacific, 13% for the Indian Ocean and 10% for the Atlantic.

As adequate monitoring programs for the global use of FADs are not yet available, estimates of the global scale of FAD useage patterns and deployments for targeting tropical tunas need to be based on extrapolation from literature reports, market information from FAD component manufacturers, and expert knowledge. As the tRFMOs are moving toward implementation of FAD management plans that should permit more accurate accounting of the introduction and use of FADs by fishers targeting tropical tunas, the future prospects for accounting for FAD effects should improve if these are properly implemented.

3.2.1. Anchored FADs

We estimate the global abundance of aFADS to exceed 73,000, based on literature and personal communications with experts on the topic. Most of these (about 60,000) are moored in the Mediterranean Sea and are not used for targeting tuna but most frequently to attract dolphinfish (*Coryphaena spp*. (Morales-Nin et al., 2000)). Other aFADS are mostly deployed in the EEZs of coastal countries in tropical and subtropical areas. Table 3 summarizes the number of aFADs that are thought to be recently in use by each country as well as an estimate of the number of vessels fishing those aFADs and for which species. The table indicates nearly 13,000 aFADs supporting around 8,000 vessels that harvest tuna and tuna-like species, among others. By these data, the ratio of aFADs per vessel (which is likely an overestimate since a full accounting of vessels visiting aFADs is not possible) is 1.6. This ratio is more than 2 orders of magnitude (100 fold) less than the ratio recently estimated for industrial dFADs per vessel (198 dFADs/vessel, Baske et al. (2012)). Almost the 95% of the aFADs documented in Table 3 are deployed in the western central Pacific Ocean, while the Indian Ocean accounts for about 4% and the eastern Pacific and Atlantic Oceans (excluding the Mediterranean) represent less than 1% (Figure 20).

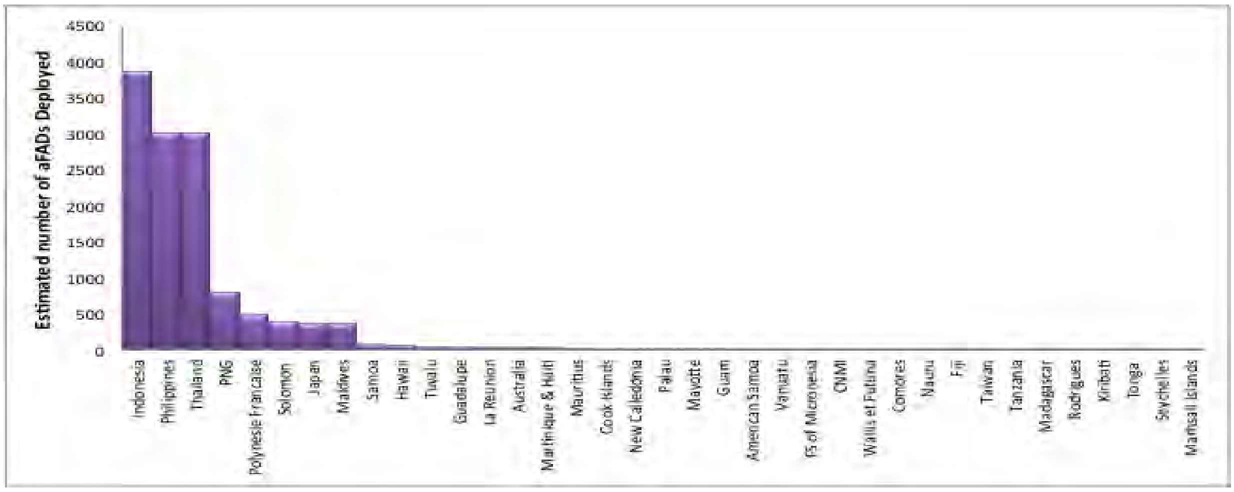
Figure 20. Proportional distribution of the estimated number of aFADs used for tuna and tuna-like species.



Source: J Lopez based on literature search and consultations with experts

The use of aFADs in West Africa is not well documented and for this report, we assume their use for tuna targeting to be negligible. There may be potential for their application for artisanal fisheries in the region, which do harvest tuna and tuna-like species, by adapting and testing the East Africa aFAD design (Richmond and Mohamed, 2006). Four South Asian and Western Pacific countries account for about 85% of the aFADs total shown in Table 3. Indonesia, the Philippines, and Thailand each make use of around 3,000 industrial aFADs and Papua New Guinea accounts for around 800 aFADs (Figure 21, Table 3). These industrial aFADs are typically used for targeting tuna by pole and line or purse seining. In contrast, artisanal aFADs usually support near shore and coastal fisheries and catch tuna and other finfish species, such as wahoo, rainbow runner, triggerfish, bigeye scad, mackerel or other species.

Figure 21. Estimated number of aFADs used by country in support of fishing tuna and other species.



Source: J Lopez based on literature search and consultations with experts

Table 3. Estimated number of aFADs currently in use by country, as well as the number of vessels supported by them and the species for which they are intended to. Sources of information indicated.

Region/Country	*Number of AFADs*	*Number of vessels*	*Target species*	*Reference*
Melanesia				
Fiji	6	-	-	(William Sokomi, pers. comm.)
New Calledonia	21	-	Tuna and tuna like species	(Ducrocq, 2011)
Papua New Guinea	800	85	Large and medium pelagics	(Itano et al., 2004; Kumoru, 2002)
Solomon	377	23	Medium pelagics	(Luda, 2011)
Vanuatu	11	-	Tuna and tuna like species	(William Sokomi, pers. comm.)
Micronesia				
FS of Micronesia	10	30	Tuna species	(William Sokomi, pers. comm.)
Guam	15	-	Large and medium pelagics	(Bass, 2011)
Kiribati	4	-		(William Sokomi, pers. comm.)
Marhsall Islands	3	20	Large and medium pelagics	(Candice pers.comm)
Palau	18	-	Large and medium pelagics	(William Sokomi, pers. comm.)
Nauru	7	120	Medium pelagics	(Templeton and Blanc, 2008)
CNMI	10	198	Tuna and tuna like species	(Beverly, 2001)
Polynesia				
American Samoa	14	-	Tuna and tuna like species	(William Sokomi, pers. comm.)
Cook Islands	23	400	Tuna and tuna like species	(William Sokomi, pers. comm.)
Polynesie Francaise	480	900	Tuna and tuna like species	(Mainui, 2011)
Samoa	70	-	Small and medium pelagics	(Tauaefa, 2011)
Tonga	4	25	Tuna and tuna like species	(Mailau, pers.comm.)
Tuvalu	44	-	Tuna and tuna like species	(Samuelu, 2011)
Wallis et Futuna	9	70	Tuna and tuna like species	(Mugneret, 2011)
North-Pacific				

Hawaii	60	-	Large and medium pelagics	(Warren Cortez, pers.comm.)
Japan	370	1000	Tunas (Mostly YFT)	(Kakuma, 2000)
South-east Asia				
Australia	33	-	Dolphinfish	(Spooner, 2011)
Philippines	3000	-	Medium pelagics	(Anderson and Gates, 1996)
Taiwan	6	-	-	(Kakuma, 2000)
Thailand	3000	-	Small pelagics	(Noranarttragoon, 2011)
Indonesia	3858	866	Tuna and tuna like species	(Natsir, 2011)
Indian Ocean				
Seychelles	4	-	Tuna and tuna like species	(Gervain, 2011b)
Mayotte	16	-	Tuna and tuna like species	(Gervain, 2011b)
La Reunion	34	900	Large pelagics	(Conand and Tessier, 1996; Guyomard et al., 2011)
Comores	9	1000	Tuna and tuna like species	(Cayré et al., 1990)
Mauritius	27	-	Large and medium pelagics	(Panray, 2011)
Maldives	363	1422	Tuna and tuna like species	(Shainee, 2011)
Tanzania	6	192	Large and medium pelagics	(Richmond and Mohamed, 2006)
Madagascar	6	-	Tuna and tuna like species	(Venkatasami, 1990)
Rodrigues	6	-	Tuna and tuna like species	(Venkatasami, 1990)
Mediterranean Sea				
Mediterranean (Spain, Malta, Sicily, Tunisia)	60000	2300	Dolphinfish	(Morales-Nin, 2011)
Caribbean				
Guadalupe	40	300	Large and medium pelagics	(Gervain, 2011a)
Martinique & Haiti	33	300	Large and medium pelagics	(Gervain, 2011b)

3.2.2. Drifting FADs

Drifiting FAD use has grown considerably since the 1990s. For instance, observed dFAD deployments increased by more than 25 percent since 2006 in the eastern Pacific alone (Hall, 2011). The number of dFADs populating the ocean as well as most of the details concerning their use remains largely unknown, except for certain fleets. To improve the situation, the IOTC, ICCAT (International Commission for the Conservation of Atlantic Tunas), and IATTC have instituted FAD monitoring and reporting schemes which aim to permit estimating the regional numbers and usage patterns of FADs. WCPFC (Western Central Pacific Fishery Commission) is considering FAD monitoring strategies, but a sufficient monitoring strategy for that region has not yet been adopted by the members.

Table 4 provides an estimate of the potential number of dFADs annually deployed for each fleet based on current knowledge of dFAD deployment patterns. These estimates are based on literature (when available), expert knowledge of the active vessels in certain fleets, and in some cases, extrapolations considering the number of purse seiners authorized to operate in an area (see section 2.3). Some vessels flying flags of Panama, Ecuador, El Salvador or Seychelles are managed by Spanish fishing companies and operate like Spanish flagged vessels. This also occurs with some French fishing companies, which manage vessels flagged to French territories. In cases like these, where the fishing strategy is similar between same company vessels they are considered to fish in the Spanish or French style. The most recent t-RFMO authorized vessel records were used to extract the most updated list of large scale purse seiners by flag (*i.e.* large scale purse seine is that with a fish hold volume larger than 335 m^3 (Restrepo and Forrestal, 2012)). This list was revised, updated and corrected to the degree possible using authors' expertise on current spatial distribution of active purse seine vessels. When no published references for annual FAD deployments were available, the number assumed was 100 (in case of the developing economies) or 180 (for the developed economies). Various authors indicated that Spanish, Japanese or US vessels deploy about 25-30 dFADs on each fishing trip (or 150-180 deployments/year) (Artetxe and Mosqueira, 2003; Itano et al., 2004; Hall, 2011) while Baske et al. (2012) estimated an average of 198 deployments per year for each purse. The assumed deployment rate for developing economies equates to less than 10 per vessel per month. This is in line with the FAD deployment plan of the Federated States of Micronesia, in which each vessel is allowed to deploy no more than 100 dFADs per year, and with reported deployment rates for Papua New Guinean (PNG) and Ghanaian vessels, at around 90 dFADs per year (Itano et al., 2004; ICCAT, 2011).

Table 4. Estimated potential number of dFADs deployed annually by fleet/country as well as the number of large scale (>335 m3 of fish holding volume) authorized to operating on them.

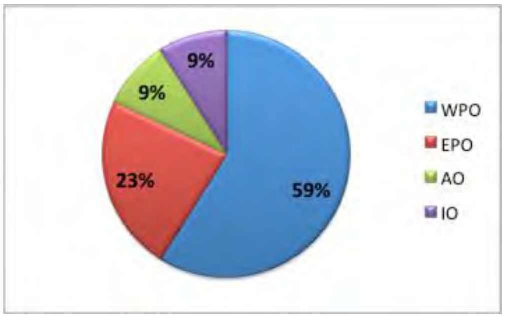
Flag	Annual Potential Number of DFADs	Number of large scale vessels
Japan	12780	71
Ecuador	9000	86
Philippines	7300	73
China	6480	36
United States	5580	31
Korea	5760	32
Spain	5760	32
Chinese Taipei	5400	54
Mexico	4100	41

France	3600	20
Micronesia*	3000	30
Indonesia	2000	20
Venezuela	1900	19
Panama	1820	15
Vanuatu	1700	17
Ghana **	1500	17
Colombia	1300	13
Seychelles	1260	7
El Salvador	1120	8
Marshall Islands	1000	10
PNG***	1000	12
Kiribati	980	9
France (Territories)	900	5
Iran	800	8
Nicaragua	800	8
Sri Lanka	800	8
Australia	600	6
Solomon Islands	600	6
Curacao	540	3
Belize	500	5
New Zealand	400	4
Cape Verde	360	2
Maurutius	300	3
Guatemala	180	1
Cote d'ivore	100	1
Tuvalu	100	1

* Micronesia FAD plan, 2009; ** ICCAT 2011 annual report; *** Itano, 2004

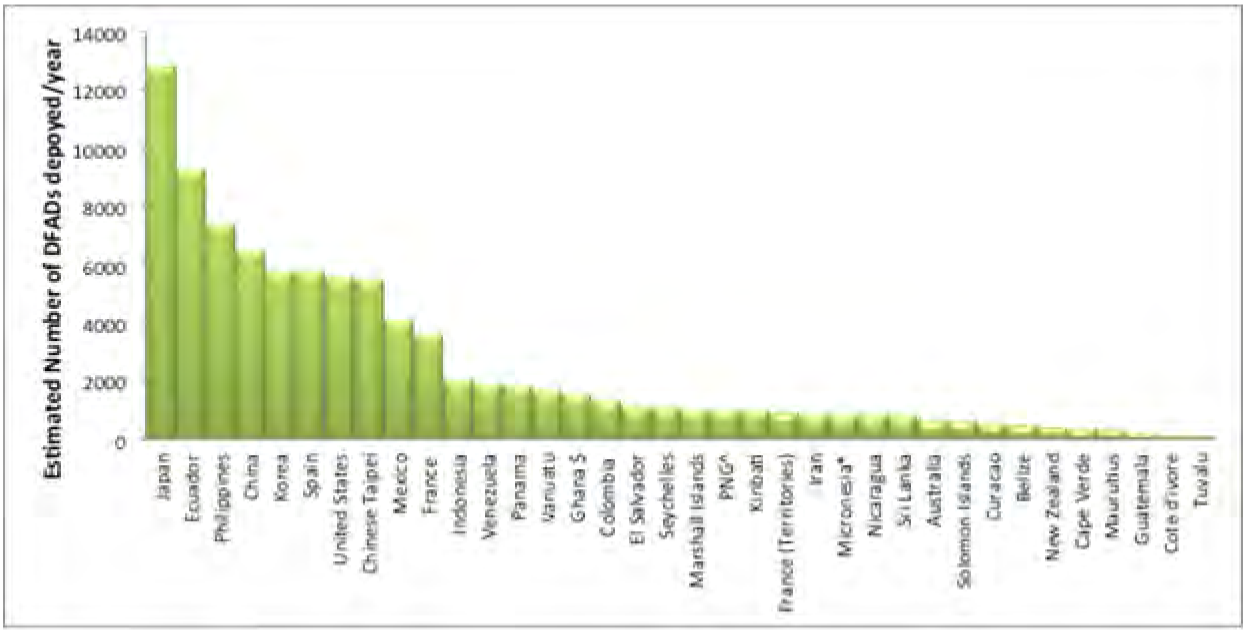
Based on these estimates and considering the distribution of vessels registered in each tRFMO, almost 60% of the potential global dFAD deployments could occur in the western central Pacific, followed by the eastern Pacific Ocean (~20-25%) and at a lower level in the Atlantic and Indian Oceans (around 10% each) (Figure 22). These proportions correspond well with the recorded number of purse seine sets recorded in the tRFMO data sets for 2012, of which 50% were recorded for the western central Pacific, 25% for the eastern Pacific, 13% for the Indian Ocean and 10% for the Atlantic (see section 2.3.2).

Figure 22. Estimated proportions of dFADs potentially deployed every year in each ocean region from our estimates.



Source: GPS and J Lopez based on literature search, tRFMO vessel lists and consultations with experts

Figure 23. Estimated potential number of dFADs deployed annually by fleet/country



Source: GPS and J Lopez based on literature search, tRFMO vessel lists and consultations with experts

This distribution is explained by the higher number of large-scale vessels authorized to operate in the Pacific (around 600) in relation to the Atlantic and Indian Oceans and the differences in the amount of FAD fishing effort recorded in the three Oceans. Our estimates indicate that relatively few vessels and countries (Figure 23) could be responsible for more than 80% of the potential global dFADs deployed annually. The total number of deployments estimated in this study is ~91,000, but in the absence of adequate monitoring systems, the estimate is largely based on extrapolation from authorized vessel lists, which leads to inaccuracy for several reasons. This estimate is on the order of 2.3 times the recorded number of object-oriented purse seine sets recorded in the tRFMO data bases (section 2.3.2), which implies a relatively high turnover (loss, removal, reintroduction, *etc.*) of dFADs. Our estimate falls in the range well with that suggested by (Baske *et al.*, 2012) of between 50,000 and 105,000 dFADs deployed in 2011. It must be noted, however, that annual deployment estimates do not imply that the number of dFADs in the ocean increases by this value every year or that there are that number of dFADs in the ocean at any one time. Many of the dFADs are retrieved, lost, abandoned, re-deployed and/or recycled by fishers during their fishing trips. In fact, as Hall (2011) stated, 85-95% of the FADs deployed in the eastern Pacific from 2006-2009 were also removed from the sea with the aim of reusing them. The absence of comprehensive, global monitoring of FAD deployment and usage patterns prevents a full and accurate accounting of FAD abundance and usage patterns.

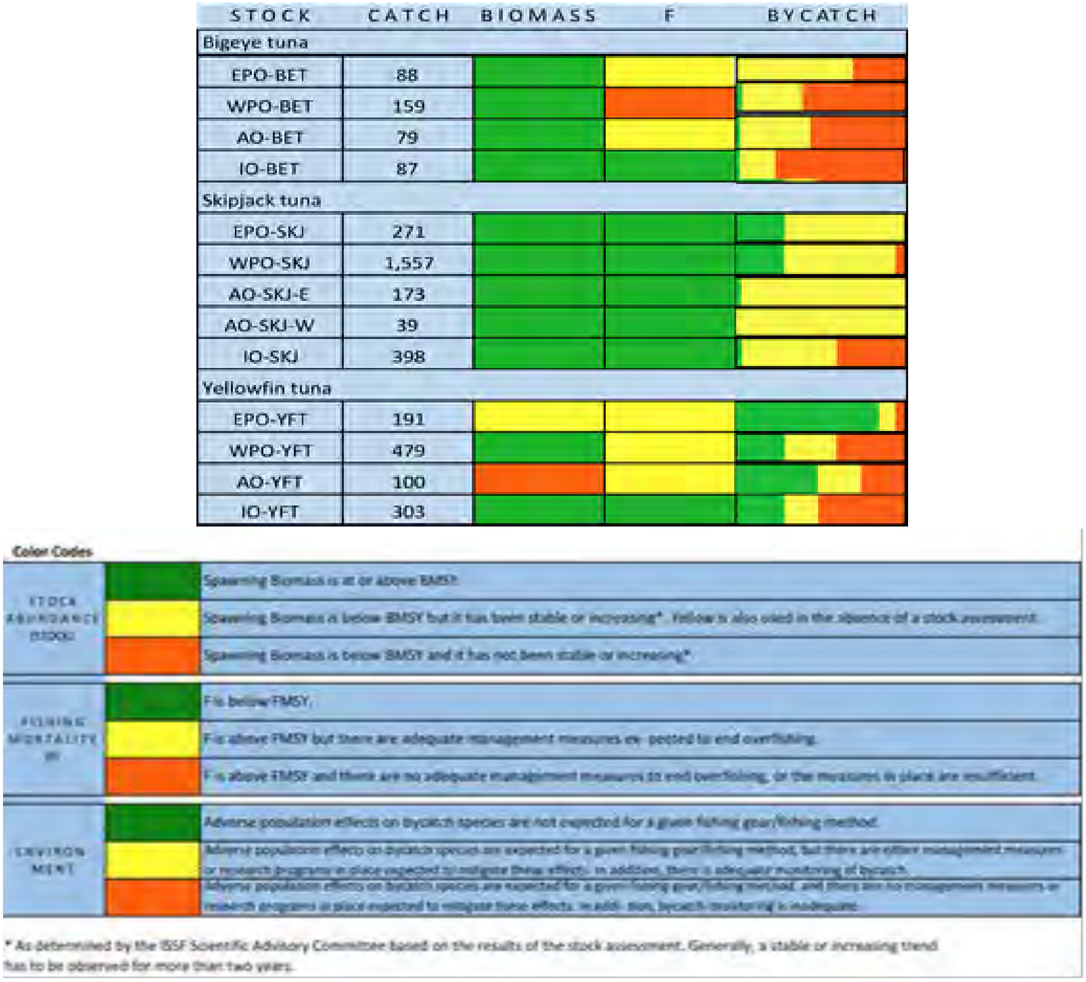
4. Status of Tuna Stocks Targeted Using FAD Fishing

KEY FINDINGS

- There are 13 stocks of tropical tunas around the world. Of these, all except yellowfin in the Atlantic and in the eastern Pacific were found to be at healthy biomass levels in the most recent stock assessments.
- In terms of exploitation level, all of the skipjack stocks were experiencing a low fishing mortality rate, and although some of the yellowfin and bigeye stocks were experiencing fishing mortality levels in excess of F_{MSY}, most were being adequately managed to bring the exploitation levels to levels at or below F_{MSY}.
- The bigeye stock in the western Pacific, however, was experiencing high exploitation and management measures in place were judged insufficient to reduce that rate to or below F_{MSY}
- 93% of the recent tropical tuna catch came from healthy stocks and a high proportion of that came from fisheries using FADs, mostly due to skipjack.
- The use of FADs does not necessarily lead to overfishing (high exploitation) of tropical tunas although harvesting large amounts of certain small tunas (e.g. bigeye or yellowfin) can reduce long-term potential MSY.
- While the tropical tuna stocks impacted by FAD (and other) fishing are mostly in healthy condition, further increases in fishing pressure could well change that picture. Unabated, the continued growth of FAD fishing for tropical tunas at the pace witnessed over the past few years would increase overal fishing pressure on these stocks unless compensated by reductions in other fisheries affecting these stocks.
- All sources of fishing mortality reduce spawning biomass, either immediately or at some time in the future. A stock can be overfished by taking too many immature or too many mature fish, or both. All sources of fishing mortality need to be monitored and managed.
- FAD fishing can cause adverse population effects on by-catch species, but in the world’s oceans there are either management measures or research programs in place expected to mitigate these effects and in addition, there is adequate monitoring of by-catch.
- Best Practices have been identified for use in purse seine fishing on FADs and these have been communicated to a broad range of vessel owners and skippers through workshops conducted across the globe to accelerate their uptake by the global fleet.
- Research conducted in collaboration with fishers is continuing to develop further techniques in order to mitigate adverse effects on by-catch species and the environment.

A convenient document which summarizes the current state of knowledge of status and management of the world’s tropical tuna stocks is provided by ISSF (2013), available at iss-foundation.org and last updated in August 2013. There are 13 stocks of the major commercial tropical tuna species worldwide (4 bigeye, 5 skipjack, and 4 yellowfin stocks). The document, which is updated 2 times per year in consultation with scientists actively involved in tRFMO stock assessments, summarizes the results of the most recent scientific assessments of these stocks, as well as the current management measures adopted by the RFMOs. It also ranks the status of the stocks and stock management using three factors: (i) stock abundance, relative to that expected to produce Maximum Sustainable Yield (MSY), (ii) the level of fishing mortality relative to that which could maintain the stock at the level expected to produce MSY, and (iii) the degree of bycatch made by the fisheries harvesting the stock. Figure 24 summarizes the current knowledge of status of these stocks from the ISSF (2013) report.

Figure 24. Ranking of the global tropical tuna stocks by the ISSF Scientific Advisory Committee based on stock assessment information available in August 2013. Catch is in 1000 t units for a recent 3-year period, Biomass is the stock abundance relative to MSY levels, F is the exploitation rate relative to FMSY and Bycatch is explained in the text.



STOCK	CATCH	BIOMASS	F	BYCATCH
Bigeye tuna				
EPO-BET	88	🟩	🟨	🟨🟧
WPO-BET	159	🟩	🟧	🟨🟧
AO-BET	79	🟩	🟨	🟨🟧
IO-BET	87	🟩	🟩	🟨🟧
Skipjack tuna				
EPO-SKJ	271	🟩	🟩	🟩🟨
WPO-SKJ	1,557	🟩	🟩	🟩🟨🟧
AO-SKJ-E	173	🟩	🟩	🟨
AO-SKJ-W	39	🟩	🟩	🟨
IO-SKJ	398	🟩	🟩	🟨🟧
Yellowfin tuna				
EPO-YFT	191	🟨	🟨	🟩🟨🟧
WPO-YFT	479	🟩	🟨	🟩🟨🟧
AO-YFT	100	🟧	🟨	🟩🟨🟧
IO-YFT	303	🟩	🟩	🟩🟨🟧

Color Codes

STOCK ABUNDANCE (SSB)	🟩	Spawning Biomass is at or above BMSY.
	🟨	Spawning Biomass is below BMSY but it has been stable or increasing*. Yellow is also used in the absence of a stock assessment.
	🟧	Spawning Biomass is below BMSY and it has not been stable or increasing*.
FISHING MORTALITY (F)	🟩	F is below FMSY.
	🟨	F is above FMSY but there are adequate management measures ex- pected to end overfishing.
	🟧	F is above FMSY and there are no adequate management measures to end overfishing, or the measures in place are insufficient.
ENVIRONMENT	🟩	Adverse population effects on bycatch species are not expected for a given fishing gear/fishing method.
	🟨	Adverse population effects on bycatch species are expected for a given fishing gear/fishing method, but there are either management measures or research programs in place expected to mitigate these effects. In addition, there is adequate monitoring of bycatch.
	🟧	Adverse population effects on bycatch species are expected for a given fishing gear/fishing method, and there are no management measures or research programs in place expected to mitigate these effects. In addi- tion, bycatch monitoring is inadequate.

* As determined by the ISSF Scientific Advisory Committee based on the results of the stock assessment. Generally, a stable or increasing trend has to be observed for more than two years.

Source: ISSF, 2013. *ISSF Tuna Stock Status Update, 2013(2): Status of the world fisheries for tuna.* ISSF Technical Report 2013-04A. International Seafood Sustainability Foundation, Washington, D.C., USA.

As noted, over the past 5 years (2008-2012), the average catch of these 13 tropical tuna stocks was about 4.1 million tons globally. Skipjack dominated the global catch of the tropical stocks in that period, representing 61% of the total, followed by yellowfin at 29% and bigeye tuna at 10%. Of these stocks, all except yellowfin in the Atlantic and in the eastern Pacific were assessed to be at healthy levels in the most recent stock assessments reflected in the report. In terms of exploitation level (fishing mortality rate), all of the skipjack stocks were experiencing a low fishing mortality rate, and although some of the yellowfin and bigeye stocks were experiencing fishing mortality rates in excess of F_{MSY} (Fishing MSY), most were being adequately managed to bring the exploitation levels to levels at or below F_{MSY}. The bigeye stock in the western Pacific, however, was experiencing high exploitation and management measures in place were judged insufficient to reduce the exploitation rate to or below F_{MSY}.

Considering total catch, 93% of the recent tropical tuna catch came from healthy stocks and a high proportion of that came from fisheries using FADs. This is due to the fact that skipjack stocks contribute more than one half of the global catch of tropical tunas, and they are all in a healthy situation.

4.1. Conservation and Management Measures Intended to Rebuild and/or Maintain Stocks at Healthy Levels

In the western Pacific, the main binding conservation management measure (CMM) for tropical tunas and bigeye in particular, established by WCPFC is CMM 2012-01 which is intended to reduce fishing mortality on bigeye to levels at or below F_{MSY} by the end of 2017. The management measure applies multiple approaches in attempting to reduce the bigeye exploitation rate including flag-specific catch limits for the longline fleets, time-area closure to FAD fishing, limits on FAD sets, limits on numbers of vessel days for fishing the high seas, development of FAD management plans for the fleets utilizing them, etc. Additionally, the measure requires full-retention of tunas caught by purse seiners operating in the sub-tropical zone of the western Pacific and 100% regional observer coverage for purse seiners fishing on both the high seas and the subtropical zone of the western Pacific. However, the CMM has not yet resulted in achieving its intended goal and concern over continuing high levels of fishing pressure on the stock led the Commission to work toward improving the effectiveness of its management measures. At the 2013 meeting, the WCPFC adjusted limits on the use of FAD sets, as well as on fishing days on the High Seas. Based on the most recent assessment of yellowfin tuna, it was considered that the CMM is achieving its objective of limiting overall fishing mortality on western Pacific yellowfin to sustainable levels. For skipjack, the assessment indicated that if recent fishing patterns continue, catch and catch rates are likely to decline. In this scenario, the scientific committee recommended that the WCPFC consider developing limits on fishing for skipjack to limit the declines in catch rate associated with further declines in biomass. To date, the WCPFC has yet to agree to a FAD management plan that would permit adequate monitoring of dFAD deployments and utilization patterns.

In the eastern Pacific Ocean, the main CMM established by the IATTC for bigeye, yellowfin, and skipjack is Resolution C-13-01, which includes an annual fishing closure (of 62 days) for purse seine vessels greater than 182 tons carrying capacity (~224 m^3 fish hold volume) and a seasonal closure of the purse seine fishery in an area west of the Galapagos Islands for one month, where catch rates of small bigeye are high. A requirement for full retention of purse seine catches of bigeye, skipjack and yellowfin tunas, and bigeye catch limits for the main longline fishing nations have also been included in the CMM. For eastern Pacific bigeye tuna, the CMM appears to have kept recent fishing mortality at a sustainable level. It was noted, however, that increasing the exploitation level would not likely result in significantly increased sustainable catch, but would significantly reduce spawning biomass. The potential for such an increase exists since there is concern about excess capacity of the purse seine fleet in the eastern Pacific Ocean. For yellowfin, the CMM has not been sufficient to maintain spawning biomass at healthy levels, due to recent exploitation rates above $F_{MSY,}$ although the exploitation level in the most recent year of the stock assessment indicates overfishing is no longer occuring. For skipjack, on the other hand, the CMM appears sufficient to maintain the stock at a healthy level as the assessment indicates that while exploitation rates may be near the MSY level, there is no indication of a credible risk to the stock from overfishing. It should be noted that full use of the purse seine overcapacity in the eastern Pacific could change this diagnosis. The IATTC (Inter American Tropical Tuna Commission) has implemented a FAD management measure that should permit adequate monitoring of dFAD deployments and utilization patterns.

In the Atlantic Ocean, the main CMM agreed by ICCAT is Recommendation 11-01, which for the period 2012-2015, establishes a Total Allowable Catch (TAC) of 85,000 t for bigeye tuna with an allocation scheme for members of ICCAT, including penalty for overharvest. It also established an overall TAC of 110,000 t for yellowfin, but without country-specific allocations. The CMM also includes a country-specific capacity limit for the number of longline and purse seine vessels over 20 m in length, establishes a record of vessels actively fishing for bigeye and yellowfin, implements a two-month prohibition of fishing on floating objects in an area off West Africa, with 100% observer coverage during this time/area closure; and a requires submission of FAD management plans by countries with purse seine and baitboat (pole and line) fisheries. It is notable that while a TAC of 85,000 t for bigeye is specified, the permissible catch under the CMM exceeds that level by a noticeable amount due to catch allowance made for CPCs (Contracting Parties and Cooperating Non Members of the Commission) not included in the allocation scheme agreed. At its 2013 meeting, ICCAT agreed to require members to report specific data elements for FAD management that will permit adequate monitoring of dFAD deployment and utilization patterns.

For the Indian Ocean, the CMM established by the IOTC for tropical tunas is Resolution 12/13, which affects vessels greater than 24 m as well as smaller vessels fishing on the high seas. This CMM calls for a one-month closure for purse seiners and longliners (in different months) in an area of size 10°x20°. The effect of the closure on the status of IO tuna stocks cannot be evaluated yet, but preliminary analyses based on historical catches indicate its effect is likely to be very small. Resolution 13/11 also bans discards by purse seine vessels. Recent estimates of stock status for the tropical tunas indicate a reduction in catch and in exploitation rate. However, none of the three stocks are now experiencing overfishing and/or are considered to be overfished. The main reason for this was the impact of piracy along the Somali coast, which resulted in a substantial reduction in purse seine and longline fishing effort in the area. That effort was displaced to other areas in the Indian Ocean and to other Oceans, with corresponding impacts on other stocks. In 2012, the IOTC agreed to require members to report specific data elements for FAD management that will permit adequate monitoring of dFAD and aFAD deployment and utilization patterns.

4.2. Environmental Dimension Ratings for the Tuna Stocks Targeted by FAD Fishing

The third dimension used in the ISSF ranking scheme relates to bycatch impacts by the primary gears used in the capture of the stocks. As indicated in Figure 28, a green ranking is used when adverse population effects on bycatch species are not expected for a given fishing gear/fishing method. A yellow ranking is used when adverse population effects on bycatch species are expected for a given fishing gear/fishing method, but there are either management measures or research programs in place expected to mitigate these effects. An additional condition for a yellow ranking, is having adequate monitoring of bycatch. An orange ranking is used when adverse population effects on bycatch species are expected for a given fishing gear/fishing method, and there are no management measures or research programs in place expected to mitigate these effects or if bycatch monitoring is inadequate.

Regarding FAD fishing, ISSF’s Scientific Advisory Committee characterizes purse seine FAD fishing to cause adverse population effects on bycatch species, but in the world’s oceans there are either management measures or research programs in place expected to mitigate these effects and in addition, there is adequate monitoring of bycatch.

ISSF's (2013) Scientific Advisory Committee indicates that purse seining on FADs (aFADs, dFADs and natural logs) generally has bycatch rates of non-target species that are higher than those of free school sets. In terms of tonnage, available estimates place the bycatch species at about 2% of the targeted tuna catch in global purse seine FAD fishing, , although there is variability by ocean region and can range to 8% in the Atlantic (Amandè et al., 2010). While sea turtles are known to be among the bycatch in FAD fisheries, the number of turtles that die in purse seine fishing operations is much smaller that in other gears, such as longline and since it is relatively easy to release turtles when caught alive, this is the main mitigation measure used by RFMOs. Purse seine FAD fishing operations catch several species of sharks, some of which (e.g. oceanic white tip, *Carcharhinus longimanus* and silky sharks, *Carcharhinus falciformis*) appear to have been declining in abundance in recent years. Entanglement and unobserved mortality can be a significant problem, especially if FAD designs use underwater netting materials with large mesh sizes. Use of non-entangling FAD designs ('Eco-FADs') can effectively mitigate mortality due to entanglement. Mortality of other sensitive species like seabirds in FAD operations is almost nonexistent. FAD fishing does result in large catches of other finfish such as dolphinfish ("mahi-mahi"), but it appears that these catches do not adversely impact the abundance of these species which are very productive and resilient to fishing. The main problem with these bycatches is one of utilization (waste), since the majority of these are discarded at sea so that the fish holding tanks can be reserved for the more valuable tunas. Requiring full retention of this bycatch component can mitigate this issue to a large degree and several tRFMOs have instituted such requirements for purse seine fishing.

In the western Pacific, 38% of the bigeye, 36% of yellowfin and 56% of skipjack catch is made by purse seining on floating objects (including FADs). Several bycatch mitigation measures are in place (turtles, sharks) and there is 100% observer coverage on part of the purse seine fleet. In the eastern Pacific, 63% of the skipjack catch, 16% of the yellowfin catch and 69% of the bigeye catch is made by purse seine fishing on floating objects (including dFADs). There is 100% observer coverage on large purse seiners to monitor these catches and there are several mitigation measures in place regarding incidental catches of sensitive species (e.g. sharks, turtles, and non-target species in general). In the Atlantic, 35% of the bigeye, 13% of yellowfin and nearly 80% of the skipjack catch is made by purse seining on floating objects (including FADs). Several bycatch mitigation measures are in place (turtles, sharks) and there are observer requirements for monitoring purse seine fishing (although not a 100% requirement yet). And in the Indian Ocean, 20% of the bigeye, 17% of yellowfin and 31% of the skipjack catch is made by purse seining on floating objects (including FADs). Several bycatch mitigation measures are in place for the IOTC fisheries (turtles, sharks) and there are observer requirements for monitoring purse seine fishing (although not a 100% requirement yet).

Ongoing research is being conducted on development of further mitigation actions to reduce impacts of FAD fishing on bycatch species, including small bigeye and yellowfin. Notably, the European project MADE (Mitigating Adverse Ecological impacts of open ocean fisheries; www.made-project.eu) and the cooperative research sponsored by ISSF, is focused on reducing the amount of by-catch produced by purse seines and longliners targeting tunas and large pelagics and evaluating mitigation measures to reduce potential negative impacts of these fisheries on pelagic ecosystems. Based on this work, and that of others, a number of Best Practices have been identified for use in purse seine fishing on FADs and these have been communicated to a broad range of vessel owners and skippers through workshops conducted across the globe.

5. RECOMMENDATIONS

Recommendation 1. Unabated, the continued growth of FAD fishing for tropical tunas at the pace witnessed over the past few years would increase overal fishing pressure on these stocks. While all skipjack stocks are in healthy condition and could sustainably support some degree of increased fishing pressure (although skipjack in the western Pacific, the Atlantic and other areas may now be close to fully exploited), further increase in fishing pressure on bigeye and yellowfin stocks by further increase in FAD fishing without compensatory reductions in other fisheries should be avoided.

Recommendation 2. Owing to the lack of an adequate monitoring system in place for global FAD deployments and utilization patterns, such a system should be implemented and harmonized through the tRFMOs. It is noteworthy that the recently agreed FAD management plans for the Atlantic (ICCAT Recommendation, 13-01), Indian Ocean (IOTC Resolution 13-08) and eastern Pacific (IATTC Resoution C-13-04) follow the basic structure for FAD data collection for Spanish fleet tropical purse seiners and provide a good basis for a global monitoring system for FADs. But to date, an adequate monitoring system in the western Pacific has not been agreed. High priority should be placed on attaining such through the WCPFC where the highest usage of FADs for tuna fishing occurs followed by a detailed analysis of operational level information to fully evaluate impacts of FAD fishing on tunas, by-catch species, and the environment.

Recommendation 3. The utility of tRFMO authorized vessel lists to monitor overall utilized fleet capacity is hindered by an apparently large degree of unutilized authority to fish in these lists. Furthermore, there is no unified methodology to monitor individual vessels through time, since no unique vessel identification system is in place for these lists. As such, a unified system of unique vessel identification which would allow tracking of vessel performance (at the operational level) through time needs to be implemented across the tRFMOs.

Recommendation 4. Bycatch-species impacts of FAD fishing should be minimized through application of and adherence to «Best Practices» such as those already identified through collaborative research between scientists and fishers. While a number of these Best Practices have been identified largely through research funded by the EU, further improvements are needed to reduce potential negative impact and assure greater adherence to Best Practices by the fleets. Implementing systems of incentivizing such positive behavior, including full utilization of catch or the use of sharks and turtles friendly non-entangling FADs, by the participating fleet vessels should be considered and collaborative research making use of fine-scale data collected by vessels and instrumented bouys on FADs should be strongly encouraged.

Recommendation 5. It is necessary to monitor by-catch and verify the application of such Best Practices through data collection systems, such as on-board observations (i.e. human, electronic, or both). By-catch, by nature, is relatively rare compared to the targeted catch, and generally requires higher levels of monitoring to result in precise estimates of by-catch rates for estimating overall impacts. Frequently, on-board observation systems which sample a small proportion of the overall effort are insufficient to provide precise (or even accurate) estimates of by-catch of some sensitive species. Requirements for 100% observation coverage for purse seine FAD fishing should be considered to overcome this shortcoming.

Recommendation 6. Fine-scale and detailed operational data on the application of factors influencing effort creep is generally lacking at the regional level, which is an obstacle for scientists addressing the issue and its undermining effect on attempts to manage capacity. Efforts should be made to assure that detailed, operational level data are available through the tRFMOs for monitoring effort creep and its impact on growing fleet capacity. Data provided through vessel VMS (Vessel Monitoring System) (Bez et al., 2011) as well as scientific access to instrumented bouy data, with a suitable delay to ensure confidentiality, should be provided.

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ANNEX

Annex Table 1: Sum of # of Purse Seine Sets Recorded by Set Type in each tRFMO. DOL=Dolphin sets; FSC= Free school sets; OBJ=Object-oriented sets.

	IATTC	IATTC	IATTC	IATTC Total	ICCAT	ICCAT	ICCAT Total	IOTC	IOTC	IOTC Total	WCPFC	WCPFC	WCPFC Total	Global	Global	Global Total
Year	DOL	FSC	OBJ		FSC	OBJ		FSC	OBJ		FSC	OBJ		FSC	OBJ	
1991	9661	7183	2984	19828	6833	3272	10105	4387	3419	7806	17097	11296	28392	35500	20971	66131
1992	10424	8089	2631	21144	5434	3058	8492	5349	3444	8793	14440	13675	28114	33312	22808	66543
1993	6987	12006	2556	21549	6243	3159	9402	5357	3701	9058	15801	12530	28331	39407	21946	68340
1994	7809	10275	3438	21522	5676	3314	8990	5503	4313	9816	15482	10875	26356	36936	21940	66684
1995	7185	10902	4226	22313	5180	4068	9248	4635	5164	9799	15349	10404	25752	36066	23862	67112
1996	7486	10925	5195	23606	4714	3742	8456	5045	5006	10051	13605	13587	27192	34289	27530	69305
1997	9020	10014	7309	26343	4099	2593	6692	3250	6348	9598	12144	15601	27745	29507	31851	70378
1998	10645	10307	6663	27615	5134	2395	7529	3624	6040	9664	15493	12845	28338	34558	27943	73146
1999	8648	11771	5113	25532	4273	1947	6220	3948	5238	9186	8718	15083	23800	28710	27381	64738
2000	9235	10969	4221	24425	4138	2246	6384	3876	5353	9229	14318	12447	26765	33301	24267	66803
2001	9876	7046	6501	23423	4313	2305	6618	4972	5017	9989	16196	11121	27318	32527	24944	67348
2002	12290	8380	6638	27308	3496	1913	5409	3684	5918	9602	16881	13467	30347	32441	27936	72666
2003	13760	12405	6163	32328	4403	2111	6514	5210	4792	10002	16829	13196	30025	38847	26262	78869
2004	11783	10665	5601	28049	2871	2182	5053	6507	4616	11123	10816	20704	31520	30859	33103	75745
2005	12173	13925	5631	31729	2512	2001	4513	7358	5923	13281	18591	16769	35360	42386	30324	84883
2006	8923	14632	8020	31575	1888	1725	3613	6802	6630	13432	15098	17940	33038	38420	34315	81658
2007	8871	12056	7241	28168	1744	2012	3756	5662	6538	12200	18845	16201	35046	38307	31992	79170
2008	9246	10981	8474	28701	2484	2574	5058	5284	5954	11238	21683	17974	39656	40432	34976	84653
2009	10910	7417	8898	27225	3280	3162	6442	2467	6690	9157	22468	21035	43502	35632	39785	86326
2010	11645	6138	8187	25970	3252	4129	7381	2100	7029	9129	37394	13021	50414	48884	32366	92894
2011	9604	8020	9450	27074	2710	4413	7123	2676	6935	9611	29401	21370	50772	42807	42168	94580
2012	9220	8250	10563	28033	2803	4225	7028	3342	5653	8995	34574	20227	54801	48969	40668	98857

Annex Table 2: Reported PS Catch (t) of species indicated by tRFMO and set type

	IATTC									WCPFC					
	DOL			FSC			OBJ			FSC			OBJ		
Year	BET	YFT	SKJ	BET	YFT	SKJ	BET	YFT	SKJ	BET	YFT	SKJ	BET	YFT	SKJ
1991	0	155283	1332	2123	50473	21848	2747	25501	39048	3671	83029	335222	30920	132419	236440
1992	0	165647	1262	5131	47464	33876	2048	15010	49145	3407	83884	269805	39370	167503	276708
1993	51	110893	587	3465	88985	30234	6141	19614	53009	3500	100955	259952	28798	110378	211102
1994	1	125000	1105	933	62019	17876	33965	21389	51145	3655	107876	301786	29631	103137	250720
1995	1	132561	2546	3445	61509	44449	41875	21364	80052	3991	90847	322506	24400	92908	213345
1996	57	138295	1760	2878	72210	32576	58376	28102	69637	4333	43982	239567	32816	108833	258355
1997	0	152052	8149	1568	62571	28505	62704	30255	116802	6404	119598	173472	62805	149371	227371
1998	6	154200	4992	2204	72990	25304	41919	26769	110335	6808	217080	252579	58551	135833	312304
1999	5	143128	1705	1823	95451	78224	49330	43341	181636	1453	67586	158231	59411	210944	355868
2000	15	146533	540	2301	64208	83384	92966	42522	121723	1475	117033	276782	37898	159367	303110
2001	6	238629	1802	764	78107	19000	59748	67200	122363	5623	153922	323242	40713	109523	257669
2002	2	301099	3180	1518	73130	33573	55901	38057	116793	6283	95647	375447	53414	134299	370802
2003	1	265512	13332	1755	87460	79422	51296	30307	181214	3497	143095	368915	33384	123252	305163
2004	3	177460	10730	1463	66757	69882	64005	28340	117212	2226	55236	194002	58835	186807	541070
2005	2	166211	12127	1636	75764	117593	66257	26126	133509	5300	125700	392387	44216	170364	412902
2006	0	91978	4787	1702	40340	100388	82136	34313	191093	3411	100060	312676	46412	154729	585620
2007	7	97032	3277	1254	43365	82732	62189	29619	122286	3659	111344	417327	37634	141208	588558
2008	5	122105	8382	1168	28133	130947	73855	34819	157274	2726	174157	418332	47754	150013	546054
2009	1	178436	2719	910	22200	70737	75888	36136	157067	4093	98232	475211	53782	174689	687623
2010	4	168984	1627	581	43912	31849	57167	38113	113716	8166	204463	678241	42127	108362	414727
2011	2	131485	4443	932	29081	102305	56256	41127	173653	4121	131904	412614	64107	152731	611286
2012	0	124306	2242	968	28003	87666	67630	37529	181207	7012	212509	590554	54810	140150	589294

Annex Table2 (continued): Reported PS Catch (t) of species indicated by tRFMO and set type

	ICCAT						IOTC					
	FSC			OBJ			FSC			OBJ		
Year	BET	YFT	SKJ	BET	YFT	SKJ	BET	YFT	SKJ	BET	YFT	SKJ
1991	1730	75987	39065	11957	15577	80819	3744	72023	11553	7785	20330	79392
1992	3176	77835	17616	14378	17904	64160	1142	61182	18821	5852	27970	82686
1993	7197	69066	38454	21853	19404	75561	5258	70669	27357	5469	29831	88113
1994	3755	62661	28987	25911	23044	65750	3031	66199	38102	9043	30043	104900
1995	2467	62390	19501	19167	19260	68641	3337	56817	27024	17298	64433	111808
1996	3118	62083	12510	17476	17282	58964	2515	58688	30193	16732	50022	92611
1997	2304	55834	21275	11895	11079	35269	1622	40325	15238	24896	66665	98073
1998	2238	62405	26605	10382	10844	29805	4732	35116	18617	15519	42994	99425
1999	2899	45888	36874	12380	12132	38779	4150	39672	26871	25385	65776	121612
2000	2536	51305	19439	11162	12879	45038	4244	49317	23122	16798	62128	139023
2001	2836	65154	15250	11784	11660	45397	4790	69831	24427	15141	40064	126767
2002	3148	64046	10722	11230	11776	36634	4701	67095	18269	21989	53970	187619
2003	3349	53779	28845	11063	12860	43877	9389	126304	29053	13185	72833	154242
2004	1792	41303	24594	9101	11952	52293	5299	157642	17541	16902	47120	120195
2005	1862	38504	10181	7824	10820	48329	8025	113898	42234	13984	59498	145979
2006	4451	39869	6666	6499	10352	41039	5852	80411	32908	14350	68380	188082
2007	3197	33261	3814	7598	9922	50363	5566	52365	23647	15581	40774	108675
2008	2268	48320	6598	10336	14256	51671	9610	73360	14779	16972	39377	119219
2009	4124	56529	4775	12773	12237	58360	5349	35980	9379	21116	48720	137402
2010	4144	46182	7830	14974	15906	68180	3722	31641	8601	17805	70259	139456
2011	3609	36628	6995	17550	13099	76151	6351	35932	9030	15088	75582	120319
2012	4209	43298	6287	13352	13239	88635	7351	65501	3798	9552	64570	76718

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