The use of echo-sounder buoys in purse seine fleets fishing with DFADs in the eastern Pacific Ocean

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Summary

Tuna purse seine fishers utilizing Drifting Fish Aggregating Devices (DFADs) are increasingly incorporating echo-sounder buoys in their fishing strategy. Echo-sounder buoys attached to DFADs provide an estimate of fish biomass beneath each of these floating objects, causing a rapid change in fishing strategy with DFADs in recent years. Likewise, echo-sounder buoy technology is evolving very fast. Few studies have characterized these changes that are critical to better assess the change in fishing efficiency over time. The present study provides information on the degree of use, strategy and state of the art of echo-sounder buoys used by eastern Pacific Ocean (EPO) fleets using DFADs. A questionnaire was designed to gather this information from fishers, during ISSF Skipper´s Workshops held in South America, in 2015. Some key findings were that the majority of fishers in fleets using DFAD incorporated this technology between 2008-2010 and nowadays more than half of the fishers are working with 75-100% of their DFADs equipped with echo-sounder buoys. Although up to 5 different buoy brands are used, only 2 are predominant. The vast majority (90%) of fishers believed that echo-sounder buoys are very important or the most important tool when choosing which fishing zone to visit next. However, according to fishers, the reliability of the biomass estimates by the different echo-sounder buoys ranged from an average of 5 to a maximum of 6.8, (in a scale from 0 to 10) indicating that there is still room for improvement in biomass estimation. Most of fishers (60%) were not able to discriminate any species using echo-sounder buoys. Findings on the use of echo-sounder buoys are discussed in relation to the monitoring and management of DFADs.

Keywords: FAD, echo-sounder buoy, acoustic discrimination, purse seine, fishing effort

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Introduction

Tuna purse seiners fishing with Drifting Fish Aggregating Devices (DFADs) are amongst the most technologically developed fleets in the world (Itano 2003; Moreno et al., 2007). Fishers deploy DFADs at sea with satellite-linked buoys to track their trajectories and monitor their drift towards productive areas, where DFADs potentially can aggregate tunas. Prior to echo-sounder buoys, a DFAD would only be visited after the object had drifted at sea during a minimum amount of time and following an appropriate trajectory necessary to aggregate enough tunas (e.g. "soaking" time in the EPO used to be 30-40 days; Hall and Roman, 2013). Nowadays fishers are working with echo-sounder fitted buoys, providing them remotely with real-time estimates of biomass under DFADs. Thus, instead of relying just on their experience to visit a given DFAD after an adequate soaking time, now they have an approximate idea of the presence and quantity of fish at their DFADs from the moment it is deployed at sea. This technological development is causing rapid and important changes in DFAD fishing strategy and efficiency (Lopez et al., 2014). It also hinders a proper definition of the effective fishing effort and thus introduces biases and uncertainties into the CPUE-biomass relationship (Fonteneau et al., 1999).

The aim of this technical paper is to provide information on the degree of use, strategy and state of the art of echo-sounder buoys technology in the eastern Pacific Ocean (EPO) fleets working with DFADs. For that purpose, we gathered 61 questionnaires from fishers participating in workshops organized by the International Seafood Sustainability Foundation (ISSF) in South America in 2015.

Finally, we discuss some of the findings in relation to the potential use of echo-sounder buoys (i) as tools to conduct selective fishing by discriminating species remotely, so that areas of high presence of undesired sizes and species at FADs can be avoided using the appropriate management tools, and (ii) to gather data for scientists to monitor the species at DFADs.

Methodology

Since 2010, ISSF has been conducting by-catch reduction workshops with fishers of tuna purse seine fleets worldwide (Murua et al., 2014). The benefits of working with fishers to find solutions for bycatch and learn about the fishery have been well described by different studies (Hall et al., 2000; Johannes et al., 2000; Mackinson 2001; Moreno et al., 2007). During the ISSF workshops, fishing masters and captains discuss together with scientist by-catch concerns and fill in a questionnaire covering various by-catch issues, including the technology involved in fishing, new ideas to avoid by-catch, the use of acoustics (echo-sounder, sonars and buoys with echo-sounders) and the kind of FADs they utilize. During South American workshops in 2015, 61 questionnaires were collected from skippers. The results presented here are from 2015 questionnaires, to reflect current use of echo-sounder buoys in the EPO. In order to account for the evolution of the number of echo-sounder buoys used over time, 27 questionnaires from the ISSF skippers' workshop in 2013 were also utilized. Completion of these

questionnaires on DFADs is voluntary and skippers have the option of leaving questions blank if they consider that information is sensitive. The total number of responses to each question did not always equal the total number of fisher interviews because some fishers did not answer all questions, or because some fishers provided multiple answers to multiple-choices questions.

Results

Participation

Participation in responding questionnaires was high, with 66 skippers attending the workshop and 61 of them filling in the questionnaire. Most of the questionnaires belonged to skippers (fishing masters and captains, 80%) but also deck bosses (11%), officials (2%), fleet managers (2%), chief engineers (2%) and deck crew (3%). One of the important things when trying to solve by-catch issues is having the experience not only of the fishing masters and captains in the bridge but also the view of fishers that are working on the deck and can anticipate difficulties and solutions related to specific by-catch mitigation measures. Thus, our survey was rich in the sense of having a holistic view by fishers with different positions and tasks in the purse seine vessel.

Most of the interviewees (85%) had worked only in the EPO and had an average of 15.3 years (SD=9.4 years) of fishing experience in the tropical tuna fishery. The accumulated time spent at sea working with DFADs, which was calculated by summing all interviewed fishers´ years at sea, yielding 1,072 man-years of practical experience at sea and working with DFADs. The majority of interviewed fishers (90%) had been active in the fishery since the beginning of echo-sounder buoy use, allowing them to account for the effect of the introduction and expansion of echo-sounder buoys over time in the fishing strategy with DFADs (Fig.1).

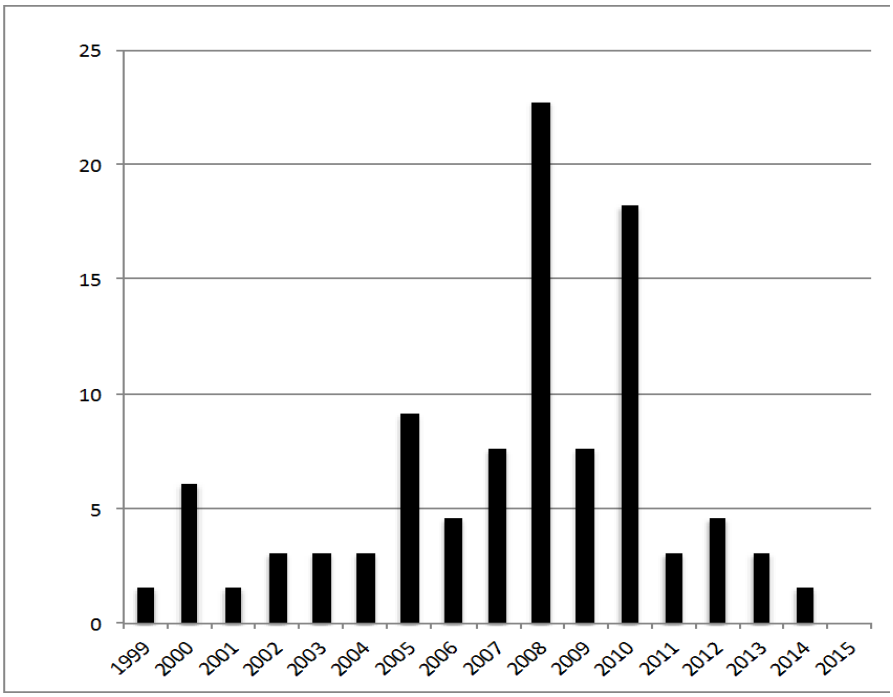

Fig 1. Year in which different skippers interviewed started to work with echo-sounder buoys in the EPO. Bars are in percentages of the skippers that introduced these buoys in a given year

Use of echo-sounder buoys

Detailed answers from fishers to the questions related to the use of echo-sounder buoys are presented in Table 1. According to the responses, by 2015, more than half of vessels (55%) were using 75-100% of their buoys equipped with echo-sounders and a large majority (83%) was using more than half of their buoys with echo-sounders. This amount has increased rapidly, as shown by previous interviews conducted in 2013, where 56% of the fishers were using a smaller amount of echo-sounder buoys, between 25 to 50 % of their buoys were equipped with echo-sounders. Almost 50% of skippers consulted, adopted this technology for the first time between 2008 and 2010 (Fig 1).

Table 1. Fishers' answers to questions about the use of echo-sounder buoys.

Question	Response	% (*)	
Percentage of buoys with echo-sounder		2015	2013[$]
	0-25%	8 (5)	11 (3)
	25-50%	9 (6)	56 (15)
	50-75%	28 (18)	15 (4)
	75-100%	55 (36)	19 (5)
Brands used	Brand A	48[§]	
	Brand B	42	
	Brand C	18	
	Brand D	6	
	Brand E	1	
Use of one or multiple brands	Just one brand	47 (27)	
	More than one	53 (30)	
Chosen brands to work only with them	Brand A	44 (12)	
	Brand B	52 (14)	
	Brand C	4 (1)	
	Brand D	0 (0)	
	Brand E	0 (0)	
Choice Reason	Ship-owner´s decision	77 (51)	
	Best brand	20 (13)	
	Price	2 (1)	
	Others	2 (1)	

(*) Number of observations in parenthesis
[$] Interview conducted in 2013 to 27 skippers
[§] Number of skippers using the brand

Among the 5 brands available nowadays in the market, 2 brands showed a similar high degree of use. Brands A and B were utilized by 48 % and 42 % of fishers consulted

respectively, followed by Brand C used by 18 % of fishers. The other 2 brands, D and E, were used by few fishers, 6 % and 1 % of fishers respectively. Around half (53%) of fishers were using multiple brands, while the other half (47%) were using just one brand. For those fishers using just one brand, half of them (52%) were electing brand B (52%) as their single brand and the other half was using only brand A (44%). Only one fisher was using brand C as his single buoy brand. Half of fishers (51%) were utilizing the buoy brands that the ship-owner had decided to buy, while others (20%) reported they were using the brand they considered best according to their own criteria. The price of the different echo-sounder buoys did not appear to be a significant variable for fishers when choosing the brand.

Strategy fishing with echo-sounder buoys

Responses related to the strategy of fishers utilizing echo-sounder buoys are detailed in Table 2. The vast majority (90%) of fishers believed that echo-sounder buoys are very important or the most important tool when selecting fishing zones.

Related to the effect of the use of echo-sounder buoys on fishing strategy, 29% of fishers reported that echo-sounder buoys reduce searching time for tuna. A similar amount of fishers (25%) also found that they navigate more between different areas due to the information provided by the echo-sounder, and 24% found that now they can schedule the DFADs that they will visit later based on the information from the echo-sounder buoys. Another important fishing strategy change due to having information on the biomass beneath each DFAD is that fishing has become less seasonal. Before echo-sounder buoys, fishers kept to specific areas for fishing depending on the time of the year but now due to the information of the echo-sounders fishing has become more flexible. Few fishers (6%) believed that fishing strategy has remained the same after the introduction of echo-sounder buoys.

Fishers were also asked about DFAD seeding strategy, to see if using echo-sounder buoys had changed this activity. More than half of the fishers (56%) were deploying all their DFADs equipped with echo-sounder buoys by 2015. From those fishers that did not have 100% of their buoys equipped with echo-sounder, the majority were seeding by alternating buoys equipped with and without echo-sounders. Other fishers (10%) responded that seeding strategy depends on the area they are fishing, while few fishers (5%) reported that they seed DFADs equipped with echo-sounder buoys at the beginning, middle and end of seeding operation.

Finally, the majority of fishers (42%) share DFADs with other vessels just towards the end of the trip, when they leave at sea productive DFADs without the possibility to set on them (e.g. during a FAD closure or when they go to port for repairs). Another important amount of fishers (36%), shared all the DFADs with vessels from the same company. Some (19%) shared DFADs when ship-owners asked specifically for those DFADs to be made available to another vessel, and 3% said they never share FADs.

Table 2. Fishers' answers to questions about their fishing strategy with echo-sounder buoys

Question	**Response**	% (*)
Importance to choose fishing zone	None	3 (2)
	Low	8 (5)
	High	62 (40)
	Most important tool	28 (18)
Effect of the use of echo-sounder buoys	Reduced searching time	29 (15)
	More movemens between areas	25 (13)
	Less seasonality for fishing	16 (8)
	Selection of productive FADs	24 (12)
	Has not changed	6 (3)
Seeding strategy	All FADs with echo-sounder	56 (35)
	Alternating with and without echo-sounder	30 (19)
	Echo-sounder buoys at beginning, middle and end of seeding operation	5 (3)
	Depending on the area	10 (6)
Sharing FAD´s	We share all FADs in the company	36 (23)
	Only some at the end of the trip	42 (27)
	Only when requested by the ship-owner	19 (12)
	We don´t share	3 (2)

(*) Number of observations in parenthesis

State of the art of echo-sounder buoys

In order to understand the evolution and current state of technology of the echo-sounder buoys, we asked fishers about the reliability of these buoys when assessing biomass beneath the FAD (i.e., accuracy of the biomass estimated by the buoy in relation to the actual catch from that DFAD) (Table 3). Fishers had to provide a number between 0 and 10, with 0 representing no reliability and 10 maximum reliability. The reliability was similar for 3 of the brands used (A, C and E), which were assigned an average score of 6.8, 6.4 and 6 for reliability respectively. Based on the questionnaire answers brands B and D were considered less reliable, with 5 and 5.5 mean reliability, respectively.

Table 3. Fisher´s answer to acoustic biomass estimates reliability

Question	Response	Mean (*)	SD[§]
Mean reliability of echo- sounder buoys (0-10)[$]	Brand A	6.8 (10)	1.6
	Brand B	5 (43)	2.5
	Brand C	6.4 (35)	1.7
	Brand D	5.5 (4)	0.6
	Brand E	6.0 (1)	–

[$] 0-10 scale: being 0 the minimum and 10 the maximum reliability

(*) Number of observations in parenthesis

[§]SD: Standard deviation

When asking fishers if echo-sounder buoy biomass estimate reliability had improved in recent years, most fishers (63%) positively identified significant improvements in all brands, another 30% of fishers believed that improvements had been limited, and few thought that they had not improved in recent years (Table 4).

Echo-sounder buoys provide echograms or an image of targeted aggregation with a color scale that depends on the strength of the echoes received. Also, depending on the brand, an estimate of the biomass in tons beneath the DFAD is available (brand C) or a number with the intensity of the signal (brands A and B). We asked fishers which was the information used by them to make fishing decisions. The majority of fishers (52%) did not pay attention to estimates of biomass (in tons or intensity of signal), but they do use the echogram (the image of the aggregation with the color scale). Few fishers (11%) believed that biomass estimation by itself provided reliable information about the aggregation. However, a combination of both, image and biomass estimation, was chosen by 33% of fishers as useful to make decisions (Table 4).

Regarding the capability of fishers to distinguish different groups of species under the DFADs (i.e., by-catch from tuna), and/or sizes of species using information from echo-sounder buoys, the majority of fishers (60%) stated that they were unable to do so using acoustic data provided by the buoy. However, 25 % of fishers answered they could discriminate by-catch from tuna. Finally, few were able to discriminate tunas, responding they were able to distinguish big tuna (8%), small tuna (2% of fishers) and medium sized tuna (2%) (Table 4).

Table 4. Fishers' answers to questions about echo-sounder buoys state of technology

Question	Response	% (*)
Have echo-sounder buoys improved?	A lot better	63 (40)
	Limited improvements	31 (20)
	The same	6 (4)
Used information	Echo-sounder image	52 (33)
	Estimates of tones	11 (7)
	Both	33 (21)
	None	3 (2)
Capacity to distinguish different fish using echo-sounder buoy info	By-catch	25 (16)
	Small tuna	2 (1)
	Medium tuna	2 (1)
	Big tuna	8 (5)
	Don´t distinguish	60 (39)
	Others	5 (3)

(*) Number of observations in parenthesis

Discussion

The results of this study based on fishers´ knowledge undoubtedly indicate that the introduction of echo-sounder buoys in the EPO represents a milestone in the use of technology used to fish tunas with DFADs. Most fishers agreed that buoys with echo-sounders are very important or the most important tool to choose the fishing zone, which is reflected in the fast adoption of this technology and the increasing percentage of numbers of buoys equipped with echo-sounders despite their higher market price. In this section we will discuss some of the findings on the use, strategy and state of technology of echo-sounder buoys by the EPO DFAD fishing fleets in relation to the monitoring and management of DFADs.

Use of echo-sounder buoys

Almost all of the skippers interviewed adopted this technology on a regular basis between 2008 and 2010. However, there were some skippers (8%) that started using echo-sounder buoys much earlier, around 1999-2000. At that time, the first generation of echo-sounder buoys was launched by one of the brands (Fig. 2). However, the performance of the early echo-sounder buoys was poor (e.g. inaccurate biomass estimates) and fishers rapidly rejected this emerging technology which had not advanced enough yet to provide dependable information. This situation prevented fishers from using buoys with echo-sounder during the following years (early 2000s). Meanwhile, buoy manufacturers continued working to improve the performance of the echo-sounders fitted in the buoys and also new brands emerged. By 2006-2007, a

second generation of echo-sounder buoys appeared in the market with much improved performance characteristics (Fig. 2). The fleet in the EPO started using this second generation of echo-sounder buoys with their DFADs on a regular basis one or two years later in 2008-2010.

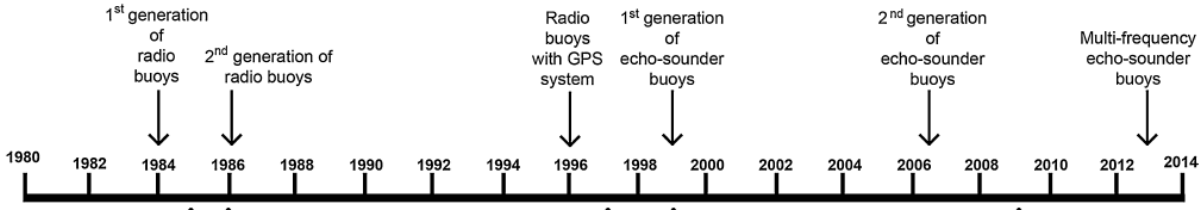

Fig 2. Time-line of the most important events occurred in the developement of buoys technology (from Lopez et al. 2014)

Adoption of new fishing technologies requires an initial testing time to evaluate their reliability and gain acceptance. The time frame of echo-sounder buoy adoption by the EPO DFAD fleets approximately matches the time-line of development and improvement in echo-sounder buoys technology. However, there is a time-lag between the introduction time of a new technology and the time at which improvements in fishing efficiency caused by that particular technology can be observed. In the case of echo-sounder buoys, factors affecting this delay are related to the skippers´ learning process to correctly understand acoustic echograms and develop fishing tactics to use this information effectively. Fishers require time to learn to interpret the acoustic information as there are a number of physical and biological factors affecting biomass estimation readings (e.g. water temperature, species depth distributions, plankton density, etc.). Skippers also needed to devise the most appropriate sampling strategy with the echo-sounders (i.e., time of day at which biomass estimation should be requested), as especially at the beginning, access to echo-sounder data transmitted via satellite to the vessel was limited and costs per reading requested were high. Nowadays, most brands provide a flat-rate contract which allows for biomass estimation data every hour.

There are 2 main brands used by the EPO DFAD using fleets, namely brands A and B. In terms of measuring fishing effort, as well as for interpretation of biomass estimates to be used for scientific purposes, it is very important to monitor the brands and models used by the fleet in fishing trips. Each manufacturer´s specifications (echo-sounder frequency, sampling strategy, data post-processing, etc.) differ significantly from one brand to another, thus providing different estimates and echograms for the same aggregation. This means that biomass measurements between different brands are not directly comparable. The buoy model and brand used in fishing operations could be easily monitored by observers or by interviewing fishers, as done in this study. Half the fishers consulted were using one brand only, while approximately the other half was using multiple brands at the same time. In other fleets, like in the European fleet working with DFADs, the evolution has been from one initially operating with a single brand, towards working with multiple brands (Lopez et al., 2014). This change of strategy towards using multiple brands in the European fleet is likely related to an economic strategy, whereby ship-owners promote competition and innovation amongst the manufacturers and reduce echo-sounder buoy prices by preventing monopolization.

In relation to this, half the fishers in the EPO answered that brand selection was driven by ship-owner choice (51%). While in general each skipper tends to have a preferred brand (e.g. based on criteria such as ease of use of the software, performance of the echo-sounder), it seems that the brand purchase decision is taken by the ship-owner and might be related to the price of the buoys. Although in the questionnaire, few fishers (2%) selected *price* as one of the main reasons for choosing a given buoy, we believe the price is implicit in the *ship-owners´ decision* answer. In fact, one of the brands that is not used as much as the two EPO dominant brands (brands A and B), is considered to be the best one in terms of echo-sounder by many fishers, however, its higher market price possibly prevents ship-owners buying this brand in larger quantities.

Strategy using echo-sounder buoys

Most fishers (90%) agreed that buoys with echo-sounders are very important or the most important tool to choose the fishing zone. Before the use of echo-sounder buoys, DFADs were visited either based on information reported by other vessels in the area (e.g. communication between a network of collaborating fishers) or by relying on historical catches (e.g. season-area monthly trends).

Nowadays fishers use directly echo-sounder buoys to decide the best route towards productive DFADs. Having remote biomass estimates of fish at DFADs allows more efficient decisions on navigation routes, reducing economic costs by decreasing fuel consumption and minimizing search time for tunas. This results in more time focused on the activity of catching fish, or what is the same, greater fishing efficiency. Echo-sounder buoy information should be especially helpful to EPO DFAD fleets given the large oceanic area covered by these vessels. As stated by Branch et al. 2006, "*unfortunately, CPUE is the most likely of all data inputs to be influenced by fleet dynamics and fishermen behavior, including increases in fishing power, information sharing, switching between target species, and many other factors"*. The increasing role echo-sounder buoys play in today´s tuna fisheries should be taken into account when assessing changes in effective fishing effort.

Another effect of having multiple real-time remote estimates of biomass in different areas of the ocean is the fact that fishers can move towards areas they would not have visited without having the information from the echo-sounder buoys. If for example a purse seiner has access to one or two hundred active DFADs at any given time, in different zones, it provides the fishers with better chances of hitting hot spots that might arise temporarily. Fishers highlighted the capability gained by the echo-sounder buoy to identify good areas with abundant tuna. Similar studies conducted with the European fleet clearly elucidated that the use of echo-sounder buoys has widened the fishing area, as fishers can navigate further to a given DFAD if they know that the DFAD is worth visiting, thanks to the remote information provided by the buoy on the presence of fish (Lopez et al., 2014). Previously, fishers would not risk travelling to a remote region due to the uncertainty about not knowing if the DFADs had aggregated enough tuna to make the trip worthwhile.

Fishers were also consulted about DFAD deployment (or “seeding”) strategy using echo-sounder buoys. Usually fishers deploy networks of DFADs that have the potential

to drift together towards productive areas that fishers will later visit to catch tunas. From our results it appeared that seeding strategy remains the same, in terms of numbers of buoys in each group of DFADs seeded. The strategy followed by fishers that have less than 100% of buoys fitted with echo-sounders is to alternate buoys with and without echo-sounder. Fishers believe that if a given buoy belonging to a "seeding group" provides remote information on the presence of fish, it is likely that DFADs nearby have also aggregated fish beneath them. So they use the echo-sounder buoys as indicators of the presence of tuna in an area. However, the trend in the fleet is towards using 100 % of buoys with echo-sounders and this might be due to the fact that DFADs, even within the same seeding group, can drift apart hundreds of miles and fishers therefore prefer to have information for each DFAD.

Finally, another tendency observed through the ISSF skippers' workshops in most purse seine fleets worldwide is that vessels from the same company are starting to share DFADs, working as a team to improve fishing efficiency for the company as a whole. This is probably driven by the complexity of monitoring, protecting, and fishing on a growing number of DFADs. In the case of EPO fleets using DFADs, a high proportion of fishers (42%) shared DFADs just at the end of the trip while others (36%) shared all the DFADs with vessels from the same company. It is important to start monitoring the rate of DFAD sharing as this strategy is thought to considerably improve DFAD fishing efficiency. Nowadays a vessel with 200 DFADs, sharing them with another vessel with the same amount, would imply monitoring at sea 400 DFADs which clearly increase the chances of finding tuna for the two vessels combined. For example, this allows whichever vessel is closer to the productive DFADs to reach them faster, combining efforts to exploit more rapidly a region with many productive DFADs, or utilization of DFADs from other vessel which might be at port due to repairs or the FAD closure. Traditionally, this sharing strategy had not been adopted mainly due to the high competition within and between companies, arising among other things, from the form of payment based on tons caught by each individual vessel. Currently, ship-owners are recognizing the benefits for the company from increased cost-effectiveness and better catches when sharing DFADs between vessels, and have started requesting their skippers to share DFADs. Some ship-owners pay their fishers the average catch of all the vessels of the company, to incentivize collaboration between them. The fact that nowadays ship-owners and/or fleet managers can monitor in real-time (from their office in land) all the buoy information from of the company´s DFADs has facilitated this strategy.

State of technology of echo-sounder buoys

Technology associated with echo-sounder buoys is evolving very fast. Since the first prototypes about 15 years ago, manufacturers have greatly improved acoustic capabilities by changing the frequency used, beam angles, sampling rate and other factors that allow having better estimates of biomass. Fishers interviewed agreed with the fact that significant improvements have been made in recent years. From the fishers´ point of view, current reliability of acoustic measures are best for brand A and C, with a relatively high reliability rate of 6.8 and 6.4 respectively (from 0 to 10), followed by brand E (6) and finally having brands B and D rated with poorer performances of 5 and 5.5, respectively. The buoy from brand D belongs to a manufacturer that has entered the market recently and the poorer rate may be due to the fact that their product has not

been perfected yet. In contrast, brand B is one of the most established echo-sounder buoy manufacturers in many EPO fleets. Despite being one of the most used brands, its echo-sounder buoys were rated as having the lowest reliability score. The high utilization might be due to the fact that there are other features of the buoy that make it attractive including its good autonomy, accurate position, power of the light used to locate the DFAD, or a low incidence of technical failures, which makes it a robust and reliable buoy in other sense. Also the lower market price could be a factor that makes this buoy one of the most used. During 2016 buoy manufacturers will be launching a new generation of buoys, most of them using multiple frequencies in a single buoy, which anticipates better estimates of biomass by species in the near future. This is a challenge that needs to be met from the fishers´ point of view, as average biomass estimate reliability did not surpass 6.8 out of 10, showing that there is still room for improvement in all buoy brands.

Perhaps due to the fact that biomass estimates are not robust enough yet, fishers rely more on the echogram (an image of the aggregation by using a color scale) rather than on the biomass or intensity value estimated by the manufacturer. Fishers have learned by trial and error to calibrate the echograms by comparing the echogram provided by the buoy with their real catches after setting on the DFAD. This experience gives them an idea of the amount of fish that can be expected from a given echogram. In conversations with fishers, it appeared that for them the most relevant information from echo-sounder buoys was the daily changes observable in the echogram images reflecting the evolution of a fish aggregation under a DFAD over time. Nowadays most buoys allow having an echogram every hour. Rather than being interested in an isolated maximum biomass reading for one day or at a given time (which might arise from an erroneous measurement) fishers are interested in buoys that clearly show how the aggregation is increasing over several days or weeks, which is more likely to represent a "solid" aggregation worth visiting. This strategy has resulted from the experience gained in recent years, many times having navigated for hundreds of miles towards DFADs that were not productive, driven by a false acoustic measurement.

Finally, the capability of discriminating species or a group of species or sizes using echograms provided by echo-sounder buoys was null for 60% of the interviewees. However some fishers (25%) were able to discriminate by-catch species from tuna species. Although some manufacturers state that their buoy model has the ability to distinguish sizes or species of tunas, scientific research using these buoys have proved that at present there is no echo-sounder buoy with the capacity to discriminate between them adequately (Lopez et al., 2016).

One of the current challenges associated to autonomous acoustic tools is remote species discrimination. This is particularly difficult around DFADs, because multiple species of different sizes are aggregated and often occupying similar depth layers. Lopez et al. (2016) have published a behavioral based model to improve biomass estimates of fishers´ echo-sounder buoys. This model could be applied in different oceans, taking into account individual species behavior at DFADs in each region. However, it cannot be used to discriminate the species at DFADs. Potentially, remote species discrimination would allow avoiding areas with high occurrence of undesired species and/or sizes at DFADs, thus promoting selective fishing. Recent research by ISSF is devoted to tuna species discrimination at DFADs by (i) using multiple frequencies simultaneously to study tuna species´ response to low and high frequencies which is

different for each tropical tuna species (e.g. skipjack, yellowfin and bigeye tuna), and by (ii) providing target strength (TS) values (a value needed to convert acoustic back-scatter into biomass) for each tropical tuna species.

Ongoing research on tuna species discrimination and TS values, together with the inclusion of two frequencies in new generations of echo-sounder buoys shows promise for species discrimination capability using fisher´s echo-sounder buoys in the near future. As stated by Maunder et al (2006), "*in the EPO purse-seine fishery on FADs, bigeye tuna are exploited at a rate that exceeds MSY, while skipjack tuna are exploited at a rate well below MSY. Only a change in fishing technology might rectify this problem*". The capability of echo-sounder buoys to discriminate species together with appropriate management tools could provide the means to exploit DFADs selectively to achieve objectives such as catching fewer undersized individuals, to catch less bigeye, etc.

The potential to use data from fishers' echo-sounder buoys for scientific purposes has been revealed recently by scientists working with DFADs in different research projects[3] (Moreno et al., 2016). The amount of data that these devices could provide to scientists can hardly be obtained by any scientific program alone, as tens of thousands of drifting buoys per ocean are active at all times. The spatial coverage of DFADs in tropical waters together with the sampling rate of each buoy, that can provide biomass estimates beneath DFADs every hour, potentially make echo-sounder buoy fitted DFADs unique scientific platforms to observe species community dynamics in the pelagic ecosystem. Some research programs have started exploring echo-sounder derived data to get fishery-independent indices of tuna abundance (Capello et al. 2013; Gaertner et al., 2014; Santiago et al., 2014). There is a need to gather data not only for tunas but also for other species associated to DFADs (e.g. sharks, manta rays, dolphin fish, trigger fish, etc.), as biological and fisheries data are severely limited for most of these non-target stocks living in the open ocean (Anonymous 2014). DFADs if properly managed could provide this data at the spatial and temporal scales required to understand key processes involved in DFAD´s aggregations and pelagic ecosystem in general.

Conclusion

ISSF Skipper workshops and the questionnaires completed by purse seine fleets operating in the EPO represent a valuable source of information on the use of echo-sounder buoys in the eastern Pacific Ocean. This information highlights the relevance of echo-sounder buoys in the increase of fishing efficiency over time. There is a need to monitor the evolution and performance of these tools in order to better manage the tuna stocks in DFAD fisheries. Recent studies have shown the potential of echo-sounder buoys to promote selective fishing and to be used as scientific platforms that provide independent indices of abundance for tropical tunas.

Acknowlegements

First of all we would like to thank the members of the EPO tuna purse seine fleets working with DFADs, ship-owners and fishers who shared their knowledge with us and

[3] MADE and CECOFAD European projects

collaborated with the questionnaires. We also sincerely thank Martin Hall from the IATTC for taking part in the ISSF/IATTC Skipper Workshops in South America.

References

Anonymous, 2014. IATTC Scientific and advisory committee fifth meeting. 12-16 May. La Jolla. California.

Branch, T. A., R. Hilborn, et al., 2006. Fleet dynamics and fishermen behavior: lessons for fisheries managers. Can. J. Fish. Aquat. Sci. 63(7), 1647-1668.

Capello, M., Deneubourg J.L., Robert, M., Holland, K., Schaefer,K., Dagorn L., 2013. A new fisheries independent method to estimate abundances of tropical tunas. IOTC. Tech. Rep. 2013- WPTT15-12.

Fonteneau, A., Gaertner, D., Nordstrom, V., 1999. An overview of problems in the catch per unit of effort and abundance relationship for the tropical purse seine fisheries. Col. Vol. Sci. Pap.,ICCAT, 49(3), 258-278.

Gaertner, D., Ariz, J., Bez, N., Clermidy, S., Moreno, G., Murua, H., Soto, M. 2014. Catch, Effort, and eCOsystem impacts of FAD-fishing (CECOFAD). SCRS/2014/165

Hall, M., Alverson, D., Metuzals, K. 2000. By-catch:Problems and solutions. Marine Pollution Bulletin 41, 204-219. http://dx.doi.org/10.1016/S0025-326X(00)00111-9.

Hall, M., and Roman, M. 2013. Bycatch and non-tuna catch in the tropical tuna purse seine fisheries of the world. FAO Fisheries and Aquaculture Technical Paper No. 568. p. 249.

Itano, D., 2003. Documentation and classification of fishing gear and technology on board tuna purse seine vessels. 16th meeting of the Standing Committe on Tuna and Billfish. Working Paper SCTB16–FTWG-3.

Johannes, R., Freeman, M., Hamilton, R., 2000. Ignore fishers' knowledge and miss the boat. Fish Fish. 1, 257–271.

Lopez, J., Moreno, G., Sancristobal, I., and Murua, J., 2014. Evolution and current state of the technology of echo-sounder buoys used by Spanish tropical tuna purse seiners in the Atlantic, Indian and Pacific Oceans. Fisheries Research, 155: 127-137.

Lopez, J., Moreno, G., Boyra, G., Dagorn, L. 2016. A model based on data from echosounder buoys to estimate biomass of fish species associated with fish aggregating devices. Fish. Bull.114:166-178.doi:10.7755/FB.114.2.4

Maunder, M.N., Sibert, J., Fonteneau, A., Hampton, J., Kleiber, P., and Harley S. J. 2006. Interpreting catch per unit effort data to assess the status of individual stocks and communities. ICES Journal of Marine Science, 63: 1373e1385 (2006) doi:10.1016/j.icesjms.2006.05.008

Mackinson, S., 2001. Integrating local and scientific knowledge: an example in fisheries science. Environ. Manage. 27, 533–545.

Moreno, G., Dagorn, L., Sancho, G., Itano, D., 2007a. Fish behaviour from fishers knowledge: the case study of tropical tuna around drifting fish aggregating devices (DFADs).Can. J. Fish. Aquat. Sci. 64, 1517–1528.

Moreno, G., Dagorn, L., Capello, M., Lopez, J., Filmater, J., Forget, F., Sancristobal, I., Holland, K. (2016). Fish Aggregating Devices (FADs) as scientific platforms. Fisheries Research 178, 122-129. http://dx.doi.org/10.1016/j.fishres.2015.09.

Murua, J., Moreno, G., Hall, M., Itano, D., Dagorn, L., and Restrepo, V., 2014. ISSF

Skipper Workshops: Collaboration between scientists and fishing industry to mitigate bycatch in tuna FAD fisheries. ISSF Technical Report 2014-06, International Seafood Sustainability Foundation, Washington, D.C., USA.

Santiago, J., Lopez, J., Moreno, G., Murua, H., Quincoces, I., Soto,M. 2014. Towards a Tropical Tuna Buoy-derived Abundance Index (TT-BAI). SCRS/2015/90