Western and Central Pacific Fisheries Commission

3rd MEETING OF THE FAD MANAGEMENT OPTIONS INTERSESSIONAL WORKING GROUP

Majuro, Republic of the Marshall Islands
3 October 2018

Chair Report of the 1st Joint Tuna RFMO FAD Working Group Meeting

(19-21 April 2017, Madrid, Spain)

FADMO-IWG3-IP-06
15 June 2018

CHAIR REPORT OF THE 1ST JOINT TUNA RFMO FAD WORKING GROUP MEETING

(*19-21 April 2017, Madrid, Spain*)

1 Opening and meeting arrangements

The meeting Chair, Mr. Stefaan Depypere (Chair of the Kobe process), opened the meeting by welcoming all the participants to the first joint Tuna RFMO FAD Working Group (the Group) meeting and stated his hope that it would be the beginning of a process of coordination and cooperation between the t-RFMOs. He noted that the last meeting of the Kobe process Steering Committee had identified the benefits of coordinating the work of t-RFMOs on FAD related issues and the need to hold a Joint t-RFMOs FADs working group. The Chair then thanked the ICCAT Secretariat for coordinating the preparation of the meeting in cooperation with IATTC and IOTC Secretariats. He also thanked all the Chairs and Keynote speakers for their availability and contribution to the meeting, as well as the European Union and FAO (via the Common Oceans ABNJ Tuna Project) for providing financial support for this initiative.

The high level of participation in the meeting was noted, which showed the interest that all stakeholders have in this topic. The Chair stated that "*fish aggregating devices (FADs) have been used as a fishing technique for centuries, and are now extensively used in purse seine fisheries for tropical tuna. However recent exponential increases in their numbers and technological developments, and the possible adverse impact these trends might have on the fish stock dynamics and also on the oceanic ecosystem, have put FADs in the spotlight. While the use of FADs does not automatically lead to overfishing of tropical tunas, there is a risk that the continued growth of their use in tuna fisheries at the current pace could increase overall fishing pressure on tuna stocks (and in particular juveniles) unless framed by adequate management measures. In addition, FAD associated fishing has impacts on by-catch species and when lost and dismantled by currents and tide effects, man-made FADs may also have consequent impact on the environment, due to the non-biodegradable material they are made of or due to damages they may cause to vulnerable coastal habitats, such as coral reefs*".

The Chair concluded by stating that "*to date, although management plans have been adopted in several t-RFMOs allowing for a better monitoring and data collection on FADs associated fisheries, there is still lack of sufficient information and data on FADs. It is important to improve collection of data and their harmonisation and comparability across all t-RFMOs so to have a solid scientific base for the adoption of meaningful management measures. For a proper and successful management, the involvement of all stakeholders is needed: scientists, industry and managers. This meeting has brought together all the different actors involved. The different sessions of this meeting will look at the different aspects surrounding the use and management of FADs and the array of presentations on the different topics, will hopefully stimulate a lively debate. The Chair stated his wishes that by the end of this meeting a better understanding of all issues surrounding the use FADs will be reached, and a set of concrete actions and priorities which will form a blueprint for future work for all tuna RFMOs will be formed*".

The Chair handed the floor to the ICCAT Executive Secretary (Mr. Driss Meski), who provided logistical information regarding the meeting. He further extended his welcome to the participants to the first meeting of the Joint t-RFMO FAD Working Group and thanked the EU and FAO/ABNJ for the provision of financial support. Mr. Meski then welcomed the Contracting parties from the three tuna RFMOs present at the meeting. In total, 35 Contracting Parties, namely Belize, Colombia, Costa Rica, Côte D'Ivoire, Ecuador, El Salvador, European Union, Gabon, Ghana, Guatemala, Equatorial Guinea, Honduras, Indonesia, Islamic Republic of Iran, Japan, Kenya, Liberia, Mauritius, Mexico, Mozambique, Nicaragua, Nigeria, Pakistan, Peru, Republic of Maldives, Sao Tomé y Principe, Senegal, Somalia, Sri Lanka, Sultanate of Oman, Thailand, Tunisia, U.K. (O.T.), United States and Venezuela. Also in attendance were 8 non-governmental organisations and entities, namely Greenpeace, IPNLF (The International Pole & Line Foundation), ISSF (International Seafood Sustainability Foundation), MSC (Marine Stewardship Council), PEW Charitable Trusts, SFP (Sustainable Fisheries Partnership), TRI MARINE, and WWF (World Wildlife Fund). The list of participants is provided as **Appendix 1**.

2 Adoption of Agenda and assignment of rapporteurs

The Agenda was adopted without changes (documents **j-FAD-01** and **j-FAD-02A** attached as **Appendix 2**). It was, however, clarified that all participants would have an opportunity to comment on the recommendations drafted by Sessions Chairs and t-RFMOs FAD WG Chairs during the meeting held on Thursday night (Point 9). **Appendix 3** lists the documents made available to the meeting participants. The latter are appended at the end of this report.

The following representatives served as rapporteurs for the various sections of the report:

Items 1 to 3 and 9 to 11 – ICCAT Secretariat
Item 4 – ABNJ/FAO
Item 5 – ICCAT/SCRS Chairs
Item 6 – IOTC Secretariat
Item 7 – IOTC Secretariat
Item 8 – ORTHONGEL/OPAGAC

3 Review of the state of play and progress on tuna (anchored and drifting) FAD fisheries in all three t-RFMOs

Three presentations were provided, by each of the three t-RFMO FAD Working Group Chairs. Each of the presentations provided an updated summary of technical findings and management and conservation measures adopted by each Commission. These are attached as documents **j-FAD-36**, **j-FAD-29** and **j-FAD-40**. The following additional paper was also addressed: **j-FAD-32**.

Following the presentations, it was noted that a common observation between the three t-RFMOs, was the low level of participation at FAD related meetings by Contracting Parties. ICCAT clarified that although this was noted, the majority of the major FAD fishing nations did in fact participate, however, participation by other nations that have a stake in tropical tuna fisheries (which do not fish on FADs) was low. In IATTC it was noted that although participation in the physical FAD meeting was low, significant work had been carried out prior to those meetings, electronically. It was also stated, however, that electronic meetings are useful for facilitating and continuing the work of FAD working groups, but firm commitment to advance work inter-sessionally is required in order make this platform effective. The challenge of providing simultaneous translation in all official languages using an electronic platform was also highlighted and it was agreed that translation should occur, even though it may increase the costs of this platform.

The t-RFMOs clarified that they do have several management and conservation measures in place regarding FADs that complement each other, although only a few were discussed during their presentations. It was commented that it may be beneficial to standardise and harmonise FAD data collection and monitoring in order to improve management across the tropical oceans. It was suggested that with time, participation in FAD working groups and in discussions on FAD issues, will likely increase as momentum regarding these important issues is gained.

4 Assessment of the use of FADs in tuna fisheries in all three t-RFMO Convention areas and impact of FAD fishing on the tropical tuna stocks

Dr Josu Santiago, Chair of the session, introduced the theme, the three keynote speakers (**j-FAD-28**, **j-FAD-05** and **j-FAD-04**) and the three additional presentations (regarding documents **j-FAD-17**, **j-FAD-22** and **j-FAD-25**) that were provided.

The Group noted that the use of FADs has been steadily increasing since 1990 and that today around 50% of the global purse seine tropical tuna catches are made on FADs, half of these catches coming from the Western Pacific Ocean. In particular for skipjack and bigeye, FAD catches are always higher than free school catches. It was also noted the developments in FAD technology including FAD design, but also the increasing use of satellite tracking buoys equipped with echosounder.

The Group acknowledged that the main issues related to FAD fishing include: the high catches of juveniles yellowfin and bigeye tuna; bycatch of protected, endangered and threatened species, e.g. turtles, sharks, etc.; potential changes in the ecosystems, marine pollution; as well as environmental damage.

The Group noted that the absence of data should not be an impediment for t-RFMOs to take decisions regarding FAD management and recognized that FAD related data needed to be made accessible to Scientific Committees of the t-RFMOs under certain confidentiality rules. It also acknowledged that knowing the total number of FADs used and the total number of active FADs would be a starting point, and that FAD data might not be needed in real time, and could be provided with a delay, which could already solve some of the confidentiality issues.

5 Review and assessment of developments in FAD related technology and in the mitigation of its impact

Ms. Amanda Nickson, the session Chair, acknowledged that there was some overlap between this session and session 4, which treated many similar issues but related to target species, and session 8 on FAD management. A keynote (based on documents **j-FAD-28**, **j-FAD-05** and **j-FAD-04**) and four additional presentations (regarding documents **j-FAD-09**, **j-FAD-30**, **j-FAD-37** and **j-FAD-38**) were provided. The following additional papers were also addressed: **j-FAD-06, j-FAD-07, j-FAD-08, j-FAD-12, j-FAD-23** and **j-FAD-34.**

During the presentations, the following key points were raised by speakers and fruitful discussions took place:

General observations relevant to most mitigation measures

- When properly designed and implemented, "Best Practices" on safe release of vulnerable species and the adoption of non-entangling FADs can be followed by a majority of the fleet and be effective in mitigating negative effects of FADs (e.g. EU Spanish and French fleets).

- Periodic review of the implementation of "Best Practices" can lead to an increase in the proportion of the fleet that adopts and uses these practices.

Target tunas

- The vertical separation of skipjack and bigeye/yellowfin tuna around the FAD is not conducive to such fish being separated through manipulation of net depth.

- Acoustic discrimination of fish close to FADs may help fishermen, in the future, to avoid schools with a high proportion of small bigeye and yellowfin individuals. For this technology to be taken up by industry it may be necessary to use regulatory measures or market incentives.

- Data from buoys are a rich and unparalleled source for estimates of biomass (currently for all species combined) at ocean scale. For this to happen scientists need access to information on acoustic biomass estimates by the buoys, respecting appropriate confidentiality requirements.

Sharks

- Should ideally be released prior to being taken out of the water in order to maximize survival.

- Use of non-entangling FADs will reduce incidental catches of sharks.

- Guidelines for the safe handling and release of sharks are useful, but they must consider crew safety.

Sea turtles

- Non-entangling FADs reduce the bycatch of sea turtles.

- Current guidelines for safe handling of sea turtles are effective instruments to obtain high levels of survival for animals that interact with FADs and purse seine.

Fish bycatch

- Many teleost species that are not tunas are caught by purse seines fishing around FADs. It is recommended to encourage the elimination of discards of these species and their landing and use. This has to be promoted in a way that does not encourage fishers to focus on fishing such resources.

- There is evidence that the amount of fish biomass (non tuna) around a FAD is relatively constant, unlike the catch of tropical tunas which is highly variable. Therefore a reduction of the proportion of sets on FADs which are associated with low tuna biomass will reduce the discard of other teleost fishes.

Habitat

- Research on FADs built with biodegradable materials has been done in controlled environments. Final conclusions on the effectiveness of such designs should be confirmed across t-RFMOs through large-scale field tests.

- There is technology under development that will allow for FADs to be equipped with independent navigation capabilities to reduce their movement away from the prime fishing areas and their beaching in sensitive areas.

Fleet behavior

- Some actions are more costly than others. Mitigation measures will not address all issues related to FADs and they have to be considered in the light of other conservation measures.

During the discussion following the presentations, it was noted that:

- As long as the effort on FADs increases the gains obtained from mitigation efforts will be less impactful.

- That there are areas of the ocean which constitute hotspots for interactions with vulnerable species and this warrants further investigation as even safe release practices do not lead to 100% survival. The need for real-time data to help avoid conflict between FADs and other ocean use activities (e.g. Oil exploration) was raised.

- There is currently no scientific determination on the maximum number of FADs that should be allowed to be deployed. Although in principle reducing the number of FADs used should reduce some of its negative impacts there are other factors that may determine the relative benefit of a limitation based on only the numbers of deployed FADs.

6 Review of data requirements needs and data collection systems of relevant information on tuna FAD fishing

Mr. Ahmed Al Mazroui (IOTC Chair), the session Chair, welcomed the participants and presented the keynote speaker (Mr. Miguel Herrera, document **j-FAD-41**) and the following six additional presentations (regarding documents **j-FAD-10**, **j-FAD-11**, **j-FAD-13, j-FAD-14, j-FAD-26** and **j-FAD-31**) that were provided. The following additional paper was also addressed: **j-FAD-27.**

Three key questions related to FAD data collection requirements were identified as being common to all t-RFMOs, namely:

- Which data can be collected?
- Where do t-RFMOs stand with respect to data collection requirements?
- Are currently collected FAD data adequate enough for management purposes?

All identified information requirements should apply to both anchored and drifting FADs, and shall include FAD design data – as the design has a direct impact on the aggregation capacity of FADs themselves – as well as details about tracking devices and equipment. FAD GPS positions and the presence of echo-sounders providing biomass estimations were also highlighted as key information, together with the availability of buoy unique identifiers that are expected by the majority of the t-RFMOs, although at different level of details.

The second core component of the expected information related to FAD activity data, should include all available information about: FAD deployment time and locations, clear records of any FAD encounter, and eventually the set results in terms of catch and bycatch – should the encounter be followed by a positive set. An important question that emerged is related to the property of a FAD, which is strictly linked to the attempts of explaining what happens to a FAD during its lifecycle (ownership can change very frequently and, unless proper identification is available, it is very difficult for data owners to keep track of all occurring changes). Some recently developed FAD logbook formats, are tackling the latter issue by formalizing the report of ownership changes in a structured way.

FAD data based on the identified information sets above could lead to the production of fishery independent indicators such as the position of FADs over time and – for those FADs equipped with echo-sounders – the readings and consequent estimation of biomass. For this last information to be of practical use, though, it would be necessary to also record the type of device (including its model and specifications) as different types of device might have different attracting effect on the shoals.

The Table below summarizes the current status of FAD data collection for four t-RFMOs (IATTC, ICCAT, IOTC and WCPFC), analysing the details about data collection requirements, original data providers and data repositories as they currently stand for the considered t-RFMOs.

t-RFMO	ICCAT			IOTC			IATTC			WCPFC		
FAD data	Required	Source	Repository	Required	Source	Repository	Required	Source	Repository	Required	Source	Repository
# Buoy purchased	Manag. Meas.	Prov.	Sec	No	Prov.	Prov.	No	Prov.	Prov.	No	Prov.	Prov.
FAD Desig/Activities	Data req.	Ind.	FSt	Data req.	Ind.	FSt	Data req.	Ind./Obs.	Sec	Data req.	Obs.	Sec
Buoy density	Manag. Meas.	Prov.	FSt	Data req.	Prov.	Sec	No	Prov.	Prov.	No	Prov.	Prov.
Echo-sounder reading	No	Prov.	Prov.	No	Prov.	Prov.	No	Prov.	Prov.	No	Prov.	Prov.

Data Req. - The RFMO has adopted specific data collection and reporting requirements, which may include reporting of data to the RFMO in raw or aggregated form.
FSt - The raw data are kept by the administration of the flag State; the RFMO Secretariat may receive data in aggregated form.
Manag. Meas. - Data have to be collected by the flag State to validate compliance with management measures adopted by the RFMO.
Sec - The RFMO Secretariat keeps the data in raw form (as collected).
Ind. - Data are collected by the fishing industry.
Obs. - Data are collected by scientific observers (regional programme).
Prov. - Data are collected / kept by the service provider.

When evaluating whether current FAD data collection requirements are adequate for management purposes, it was suggested to consider across all t-RFMOs, the following six different key areas:

- FAD management plans (requested at flag-State level);
- Marking and identification of FADs;
- FAD logbooks (including detailed FAD activities);
- FAD density / capacity (complemented by echo-sounder data);
- Bycatch mitigation measures;
- Environmental impacts of FADs (loss and beaching events - that for the time being are a topic explicitly addressed by IOTC and ICCAT only).

To ensure that all information collected and managed for these six areas is adequate for management purposes, a common agreement about terminology and modelling of FAD-related concepts should be found across all stakeholders. It was noted that only the WCPFC has formally defined the concept of what a FAD set is. Scientists have proposed a different definition, though, and reconstructing and identifying catches made on FAD sets is apparently not always possible when considering the nature of collected FAD data as currently available for each t-RFMO. As of today, only the IOTC and ICCAT have been splitting catches in their associated/un-associated components and, overall, very few anchored-FAD catches are reported.

Data collection is in most cases a task performed by the industry or by observers on board. However, no shared validation system is currently in place, although electronic observer systems have proven to be a reliable and effective solution to different validation and verification needs. Nevertheless, a more formal analysis and further considerations have to be made to clearly define the extent and goals of all data collection and validation systems. Once detailed logbook and observer-sourced information become available, it will be possible to provide estimates on retained bycatch and discards - today, this information while actively collected, is not yet ready to provide reasonable and accurate estimates.

The Group noted the concern raised as regards to the following question: Are flag States and t-RFMO Secretariats in a position to manage all the information ideally to be collected and gathered? Although no clear answer could be provided at this stage, it became clear that further work needs to be done, and that all these aspects should be further discussed at future Group meetings.

7 Review of current research plans on tuna FAD fisheries related issues

This session, chaired by Dr David Die (Chair of the ICCAT SCRS), focused on the plans each t-RFMO has for future research. The session follows presentations and discussions from previous sessions regarding past and ongoing research activities conducted in relation to FADs and how these have impacted our understanding of FAD management. The session aimed to discuss the benefits that might be gained from coordinating research activities related to FADs across the t-RFMOs and to further improve the advice that scientists are able to provide Commissioners with. Accordingly, three presentations were provided as regards each t-RFMO by each of the Scientific Committees' Chairs (see **j-FAD-42, j-FAD-43** and **j-FAD-44**).

Representatives of ICCAT, the IOTC and the IATTC summarized on-going research and science plans related to FADs. Only ICCAT has a strategic science plan, while IOTC is in the process of preparing one. None of the t-RFMOs have specific research plans for FADs but all recognized the fact that such research is connected to core aspects of their research on data, tropical tuna stocks as well as bycatch and ecosystem aspects. Whereas in ICCAT and the IOTC much of this research is conducted by national scientists supported by their respective Secretariats, namely within various scientific working groups (e.g. focusing on tropical tunas, ecosystems and bycatch). Whereas in the IATTC it is the scientific staff of the Secretariat that conducts much of it, with the support of national scientists.

Presenters acknowledged the existence of research collaborations which cover more than one of the t-RFMO areas, and the fact that many research projects related to FADs are funded through similar funding sources. The skippers' workshops organized each year in the different regions have allowed a fluid communication of problems and solutions, for the different aspects of the FAD fisheries among the regions, bringing up to date the fishers and listening to their suggestions and initiatives.

The three t-RFMOs are conducting research related to FADs on a range of topics including some common research priorities and other that may vary by region in view of the differences in some status of stocks or of bycatch populations. Among those, the following were highlighted:

- Standardization and harmonization of the FAD terminology and definitions as well as data collection requirements.

- Understanding the impacts of FAD fishing in the different regions (within each RFMO Convention area) and time periods, and building that regional knowledge into the management decision-making.

- Development of independent indices of abundance for tropical tunas using acoustic signals from buoys.

- Standardization of CPUE from purse seine fleets including FAD fishery characteristics information (support vessel, FAD density, etc.), when available.

- Testing biodegradable materials and improving FAD design to reduce the entanglement of marine turtles and sharks and to minimize the impact on ecosystems.

- Incorporate the FAD trajectories and catch history as a major tool to understand and manage the fisheries.

- Large scale tagging programs for the purposes of estimation of population parameters (e.g. Atlantic Ocean Tropical Tuna Tagging Programme), migrations and movements of target and non-target species that may be affected by FAD drift.

A number of scientific organizations, in collaboration with NGOs and the fishing industry, are currently conducting global research on FADs across more than one ocean. The ABNJ Common Oceans Tuna Project has provided some support for technical activities related to this research.

8 Consideration of possible common (and/or additional) actions related to FAD management and recovery

The session was chaired by the meeting Chair (Mr. Stefaan Depypere) and focused on possible common (and/or additional) actions related to FAD management and recovery. Seven presentations were provided (regarding documents **j-FAD-15**, **j-FAD-16**, **j-FAD-18, j-FAD-19, j-FAD-20, j-FAD-24** and **j-FAD-35**).

The presentations covered a wide range of issues related to FAD fisheries management and recovery issues, including examples of volunteer implemented measures, such as the:

- Need for clear definitions (e.g. FAD, FAD set and FAD type);
- Need for clear management objectives (define stock target levels) and management options within a more comprehensive framework related to the general management of tropical tunas (i.e. catch limits, juveniles and adults; number of FADs by boat, area and/or at the ocean level; etc.);
- Enhancement of the use of biodegradable FADs, include the recovery of FADs in FAD management plans (e.g. through "FAD Watch" programs or by using support vessels to recover FADs before they are lost) or using self-propelled FADs;
- Implementation of best handling practices based on training;
- Provision and collection of data (e.g. echosounder buoy data; implementation of Electronic Monitoring Systems and onboard Observer program);
- Recovery schemes for lost FADs and FAD beaching (including the need for a clear definition to distinguish pollution from destruction of habitat due to FAD loss).

9 Sessions Chairs and t-RFMOs FAD WG Chairs meeting

The sessions Chairs and t-RFMOs FAD WG Chairs met to review the major aspects discussed during the different sessions. Based on those, a list of key areas for future action for the joint t-RFMO FAD WG was drafted for consideration under agenda item 10.

10 Key areas for future action for the joint t-RFMO FAD WG

The Chair presented a list of key areas for future action for the joint t-RFMO FAD WG, which were discussed by the Group and are presented below.

List of key areas for future action for the joint t-RFMO FAD WG

KEY AREAS	SPECIFIC ACTIONS	KOBE	RFMO	CPC
GENERAL ISSUES	Legal aspects:			
	– Definition of a FAD	X	X	
	– Definition of ownership and responsibilities	X	X	
	Definitions and common indicators:			
	– Identify available sources for common definitions	X		
	– Harmonize definitions related to science and management of FADs: FAD set (associated vs non- associated), non-entangling, biodegradable, active buoy, type of operation at FADs etc. Prioritization should be given to those definitions with direct management implications and the science needed to guide that management	X	X	
	– Need to develop harmonized FAD fishery indicators (e.g. number of FADs, FAD sets, ratio of FAD-associated sets to unassociated sets, numbers of vessels deploying FADs and supply vessels etc.) to estimate the contribution of FADs to the overall effective fishing effort and capacity in tropical tuna fisheries across ocean regions	X	X	
	Enhanced cooperation:			
	– Collaboration between industry and scientists for the improvement of the collection of data, scientific research and to develop effective mitigation techniques			X
	– Coordination and collaboration on research plans on FADs across t-RFMOs	X	X	
	– Creation of a small technical working group of experts under the KOBE umbrella, with a focus on research and other technical aspects	X	X	
	Elaboration and implementation of appropriate management frameworks:			
	– Define clear management objectives	X	X	
	– Review existing FADs management plans and explore potential for harmonization across t-RFMOs	X	X	
	– Assess the effectiveness of various management options for FADs within the framework of general tropical tuna fisheries management (e.g. overall fishing capacity)		X	
	– Address monitoring (e.g. 100% observer and VMS coverage) and compliance issues		X	X

	– Consider adaptive, precautionary, management with respect to emerging issues with FADs, taking into account the best available science		X	X
DATA GAPS AND NEEDS	Data:			
	– Identify data gaps and needs		X	
	– Optimize and harmonize the collection of data and develop common minimum standards and formats	X	X	X
	– Improve data collection in FAD fisheries in general		X	X
	– Establish comprehensive systems to accurately quantify numbers of FADs and active buoys	X	X	
	– Need for development of robust FAD marking and tracking systems	X	X	
	– Establish wide-scale collection of individual FAD deployment, tracking, and set-history data		X	X
	– Collect new types of data on the operational and technical fleets´ characteristics, including on supply vessels		X	X
	– Facilitate access by scientists to acoustic records of the echo-sounder buoys as a potential source of fishery independent indices		X	X
	– Develop appropriate framework of confidentiality	X	X	X
	– Ensure/facilitate access to data for scientists and managers		X	X
MITIGATION	– Mitigate the impact of FADs, consider establishing limits on the number of FADs deployed, and consider feasibility and cost-effectiveness of FAD recovery practices	X	X	X
	– Evaluate economic incentives and disincentives in all FAD management measures.	X	X	X
	Target species:			
	– Identification of hotspots for juvenile BET and YFT		X	
	– Evaluate benefits of gear modifications: net changes, FADs designs, etc.	X	X	X
	– Encourage further research on pre-set echo-sounder discrimination of species, and size, at a FAD	X	X	X
	– Consider the regional effectiveness of time-area closures, including adaptive closures, and catch and/or FADs sets limits and allow this to inform future management		X	
	Non-target species:			
	– Improve information on the impacts of FAD fisheries on vulnerable elasmobranch and turtle species	X	X	

	– Identification of hot spots for vulnerable species		X	
	– Implement best practices for handling and safe release of by-catch species as appropriate			X
	– Introduction of non-entangling FADs designs			X
	– Outreach and training of operators		X	X
	– Promote full utilization of low value bony fish by-catch, as appropriate, and reduction of discards			X
	Habitat:			
	– Mapping and recognition of sensitive areas using available information and identification of post-beaching impacts to inform mitigation initiatives		X	
	– Tracking positions and trajectories of FADs		X	X
	– Develop innovative FAD designs to mitigate the habitat impact of FAD fisheries such as prevention of FADs sinking and beaching, recovery at sea, “smart FADs”, biodegradable designs…		X	X
	– Assess the effect of establishing limits on numbers of FADs deployed as well as on areas or periods of deployment		X	X
	– Promote involvement of coastal communities in implementing actions or management measures		X	X
	– Consider anchored and drifting FADs in the overall analysis of impacts		X	X

It was the general opinion that the process conducted during the current meeting was extremely productive and it was recommended that a technical working group on FADs should be created under the KOBE process to continue the work initiated during the 1st joint t-RFMO FAD meeting.

11 Adoption of the report and closure

The Chair informed the participants that he would prepare a report of the meet – the Meeting Chair’s report, which would be posted on the meeting ownCloud documents folder and on the tuna.org webpage, sent to all t-RFMOs and to the Kobe Steering Committee.

The Chair thanked the ICCAT Secretariat for organizing the meeting, and the European Union Commission and the Common Oceans ABNJ Tuna Project for funding the meeting and providing financial assistance to participants from developing countries attending the meeting, respectively. He also thanked the participants, particularly those providing documents and presentations, as well as the session Chairs and the interpreters, which deeply contributed to the success of the meeting.

The ICCAT Executive Secretary also highlighted the high level of participation in the meeting and the spirit of cooperation of all participants. He also thanked the funders, the staff of the three Secretariats and the interpreters, for their hard work which deeply contributed for a successful meeting.

The meeting was adjourned.

Appendix 1

List of participants/Liste des participants/Lista de participantes

1st Joint T-RFMO Fad Working Group Meeting (Madrid, Spain, 19 – 21 April 2017)
1re Réunion du groupe de travail conjoint des ORGP Thonières Sur Les DCP (Madrid, Espagne, 19 – 21 avril 2017)
1ª Reunión del grupo de trabajo conjunto sobre DCP de las OROP-T (Madrid, España, 19 – 21 de abril de 2017)

CHAIRMAN/PRÉSIDENT/PRESIDENTE

Depypere, Stefaan
Director International Affairs and Markets, European Commission, DG Maritime Affairs and Fisheries, Rue Joseph II, Building J-99, office 03/10, B-1049 Brussels, Belgium
Tel: + 322 298 99 07 13, Fax: +322 297 95 40, E-Mail: stefaan.depypere@ec.europa.eu

DELEGATIONS FROM MEMBERS AND CPCs/DÉLÉGATIONS DES MEMBRES ET DES CPC/ DELEGACIONES DE LOS MIEMBROS Y DE LAS CPC

BELIZE/BELICE

Pinkard, Delice
Senior High Seas Fisheries Officer, Belize High Seas Fisheries Unit, Ministry of Finance, Government of Belize, Suite 204 Marina Towers, Newtown Barracks
Tel: +1 501 22 34918, Fax: +1 501 22 35087, E-Mail: fishingadmin@immarbe.com; sr.fishofficer@bhsfu.gov.bz

Hohagen Peschiera, Augusto Carlos
Tel: +34 605 724 334; +51 99810 3968, E-Mail: ahohagen@me.com

Alsina Lagos, Hugo Andrés
Campomarino Group
Tel: +507 6211 4381, E-Mail: halsina@campomarino.ws

COLOMBIA/COLOMBIE

Jaramilllo Gómez, Alejandro
Asesor, Coordinación de Asuntos Económicos, Dirección de Asuntos Económicos Sociales y Ambientales, Ministerio de Relaciones Exteriores, Calle 10 No. 5 – 51 Palacio de San Carlos, Bogotá
Tel: +57 (1) 381 4000, Ext: 1831; +57 318 349 6938, E-Mail: alejandro.jaramillo@cancilleria.gov.co

Ortiz Astudillo, Andrés Felipe
Fisheries and Aquaculture Scientist, Fisheries and Aquaculture Research Office, National Authority for Aquaculture and Fisheries – AUNAP, Calle 40ª No. 13 - 09 Edificio UGI Piso 15, Bogota D.C.
Tel: +571 377 0500 Ext. 1016; +57 317 615 8559, E-Mail: andres.ortiz@aunap.gov.co

COSTA RICA

Carvajal Rodríguez, José Miguel
Instituto Costarricense de Pesca y Acuicultura (INCOPESCA), 200 metros este de las escuelas Mora y Cañas, El Cocal, Puntarenas; Tel: +506 872 80000; +506 263 00600, E-Mail: jcarvajal@incopesca.go.cr

Otarola Fallas, Álvaro
Instituto Costarricense de Pesca y Acuicultura (INCOPESCA), 200 metros este de la Escuela Mora y Cañas, El Cocal, Puntarenas; Tel: +506 883 50671; +506 263 00600 Ext. 788, E-Mail: aotarola@incopesca.go.cr

CÔTE D'IVOIRE

Shep, Helguilè
Directeur de l'Aquaculture et des Pêches, Ministère des Ressources Animales et Halieutiques, Rue des Pêcheurs; B.P. V-19, Abidjan
Tel: +225 21 35 61 69 / 21 35 04 09, Mob:+225 07 61 92 21, E-Mail: shelguile@yahoo.fr; shep.helguile@aviso.ci

Amandè, Monin Justin
Chercheur Halieute, Centre de Recherches Océanologiques de Côte d'Ivoire, Département Ressources Aquatiques Vivantes - DRAV29 Rue des Pêcheurs, BP V 18, Abidjan 01
Tel: +225 05 927 927, Fax: +225 21 351 155, E-Mail: monin.amande@yahoo.fr; monin.amande@cro-ci.org

Hema, Cathérine
Coordonnatrice Adjointe de Projet de Développement Durable des Ressources Halieutiques
Tel: +225 49 924 593, E-Mail: hemacathy@yahoo.fr

ECUADOR

Alcivar Rosado, Victor Ezequiel
Puerto Pesquero Artesanal de San Mateo, Manta - Manabi
Tel: +593 999 561 669, E-Mail: victor.alcivar@pesca.gob.ec

Benincasa Azúa, Luigi Antonio
Asociación de Atuneros del Ecuador (ATUNEC), Autoridad Portuaria de Manta Muelle Marginal #1, 1305186 Manta
Tel: +593 5 262 6269, Fax: +593 5 262 6467, E-Mail: luigibenincasa@gmail.com; info@atunec.com.ec

Moran Velasquez, Guillermo Alejandro
Ciudad del Mar 08-21, Manta; Tel: +593 984 81516, E-Mail: gamv6731@gmail.com

EL SALVADOR

Osorio Gómez, Juan José
Ministerio de Agricultura y Ganadería, Dirección General de Pesca y Acuicultura (CENDEPESCA), Final 1º Av. Norte y Av. Manuel Gallardo, Santa Tecla, La Libertad
Tel: +503 2210 1921, Fax: +503 2534 9885, E-Mail: juan.osorio@mag.gob.sv

Álvarez Colmenarejo, Oscar Gustavo
Gerente de operaciones, Calvopesca & Gestra Corporation, Via de los Poblados 1, 5ª Planta. Edificio A/B, 28042 Madrid, España; Tel: +34 91 782 33 00; +34 91 745 7964, Fax: +34 91 782 33 12, E-Mail: oscar-gustavo.alvarez@calvo.es

Barahona Hernández, Diana Elizabeth
Dirección General de Pesca y Acuicultura (CENDEPESCA), Ministerio de Agricultura y Ganadería, Final 1ª Av. Norte y Av. Manuel Gallardo y 13 Calle Poniente, Santa Tecla, La Libertad
Tel: +503 2210 1913, E-Mail: diana.barahona@mag.gob.sv; dianaebh@gmail.com

Barquín, Belén
Calvopesca El Salavador SA, Via de los Pobaldos 1 - 6ª Planta, Madrid, Spain
Tel: +34 618 975 958, E-Mail: belen.barquin@calvo.es

De Paz Martínez, Celina Margarita
Técnico de Investigación pesquera, Dirección General de Desarrollo de la Pesca y la Acuicultura (CENDEPESCA), Final 1ª Av. Norte, 13 calle Poniente y Av. Manuel Gallardo, Santa Tecla
Tel: +503 2210 1913, E-Mail: celina.depaz@mag.gob.sv; celinam.dpaz@gmail.com

Ubis Lupion, Macarena
Calvopesca El Salvador, S.A., Via de Poblados, 1 - 5ª Planta, 28042 Madrid, Spain
Tel: +34 617 068 486, E-Mail: macarena.ubis@calvo.es

EUROPEAN UNION/UNION EUROPÉENNE/UNIÓN EUROPEA

Martini, Angela
International Relations Officer, European Commission, Directorate-General for Maritime Affairs and Fisheries Unit B2, Regional Fisheries Management Organisations J99/03/37, B-1049 Brussels, Belgium
Tel: +32 2 299 42 53, E-Mail: angela.martini@ec.europa.eu

Ansell, Neil
European Fisheries Control Agency, Avenida García Barbón 4, 36201 Vigo, Spain
Tel: +34 986 120 658, E-Mail: neil.ansell@efca.europa.eu

Báez Barrionuevo, José Carlos
Instituto Español de Oceanografía, Centro Oceanográfico de Canarias, Dársena Pesquera Santa Cruz de Tenerife, Spain
Tel: +34 669 498 227, E-Mail: josecarlos.baez@ca.ieo.es

Beloso Gonzalez, Jose Luis
SATLINK, S.L., Avenida de la Industria, 53, 28108 Alcobendas, Madrid, Spain
Tel: +34 91 327 21 31, Fax: +34 91 327 21 69, E-Mail: jlb@satlink.es

Calvo Burón, Daniel
Polígono Lamiarán Aranburu s/n, 48360 Vizkaya Mundaka, Spain
Tel: +34 946 179 000, Fax: +34 946 187 161, E-Mail: daniel.calvo@isabel.net

Capela, Pedro
APASA, Casi de Santa Cruz, Horta, Portugal
E-Mail: apasa_op@hotmail.com

Capello, Manuela
IRD, Institut de Recherche pour le Développement UMR MARBEC - Station Ifremer de Sète, Av Jean Monnet CS 30171, 34203 Sète, France
Tel: +33 499 57 3257, Fax: +33 499 57 3295, E-Mail: manuela.capello@ird.fr

Carré, Pierre-Alain
Compagnie Francaise du Thon Oceanique, 9 Rue du Professeur Legendre, 29186 Concarneau, Cedex, France
Tel: +33 682 234 171, Fax: +33 298 60 52 59, E-Mail: pierrealain.carre@cfto.fr

Centenera Ulecia, Rafael
Subdirector General de Acuerdos y Organizaciones Regionales de Pesca, Dirección General de Recursos Pesqueros y Acuicultura, Ministerio de Agricultura, Alimentación y Medio Ambiente, C/ Velázquez, 144 2ª Planta, 28006 Madrid, Spain
Tel: +34 91 347 6048/679434613, Fax: +34 91 347 6049, E-Mail: rcentene@magrama.es; orgmulpm@magrama.es

Consuegra Alcalde, Elena
Policy officer, Ministerio de Agricultura, Alimentación y Medio Ambiente - MAGRAMA, Unit of Agreements and RFMOs, Secretary General for Fisheries, Spain, C/ Velázquez, 144, 2ª Planta, 28006 Madrid, Spain
Tel: +34 91 347 60 66, Fax: 91 347 60 42, E-Mail: econsuegra@magrama.es

Daniel, Patrick
Commission européenne - DG MARE, J-99 02/17, 1000 Brussels, Belgium
Tel: +32 229 554 58, E-Mail: patrick.daniel@ec.europa.eu

De la Cal, Javier
SATLINK, S.L., Avenida de la Industria, 53, 28108 Alcobendas, Madrid, Spain
Tel: +34 91 327 21 31, Fax: +34 91 327 21 69, E-Mail: jdc@satlink.es

De la Figuera Morales, Ramón
Jefe de Sección en la subdirección General de Acuerdos y Organizaciones Regionales de Pesca, Secretaría General de Pesca, Ministerio de Agricultura, Alimentación y Medio Ambiente, C/ Velázquez, 144, 28006 Madrid, Spain
Tel: +34 91 347 6041, Fax: +34 91 347 6049, E-Mail: rdelafiguera@magrama.es

Fonteneau, Alain
9, Bd Porée, 35400 Saint Malo, France
Tel: +33 2 23 52 59 80, E-Mail: alain.fonteneau@ird.fr

Gaertner, Daniel
IRD-UMR MARBEC, CRH, CS 30171, Av. Jean Monnet, 34203 Sète Cedex, France
Tel: +33 4 99 57 32 31, Fax: +33 4 99 57 32 95, E-Mail: daniel.gaertner@ird.fr

Goujon, Michel
ORTHONGEL, 5 Rue des Sardiniers, 29900 Concarneau, France
Tel: +33 2 9897 1957, Fax: +33 2 9850 8032, E-Mail: mgoujon@orthongel.fr

Herrera Armas, Miguel Angel
OPAGAC, C/ Ayala 54, 2A, 28001 Madrid, Spain
Tel: 91 431 48 57, Fax: 91 576 12 22, E-Mail: miguel.herrera@opagac.org

Laurent-Monpetit, Christiane
Chargée de Mission Pêche au Ministère des Outre-mer, Délégation Générale à l'Outre-mer, Département des politiques agricoles, rurales et maritimes, 27 Rue Oudinot, 75358 Paris SP07, France
Tel: +331 53692466, Fax: +33 1 53692038, E-Mail: christiane.laurent-monpetit@outre-mer.gouv.fr

Le Couls, Sarah
ORTHONGEL, 11 bis rue des Sardiniers, 29900 Concarneau, France
Tel: +0 607 662 143, E-Mail: sarah.lecouls@cfto.fr

Legorburu, Gonzalo
Avd. Ribera de Axpe 50, Edificio Udondo 3º - 2, 48950 Erandio Bizkaia, Spain
Tel: +34 944 361 710, E-Mail: glm@digitalobserver.org

Lizcano Palomares, Antonio
Subdirector Adjunto de la Subdirección General de Acuerdos y Organizaciones Regionales de Pesca, Ministerio de Agricultura, Alimentación y Medio Ambiente, Secretaría General de Pesca, C/ Velázquez, 144 2ª Planta, 28006 Madrid, Spain
Tel: +34 91 347 6047, Fax: 91 347 60 42, E-Mail: alizcano@magrama.es

Lopes, Luís
Av. Brasilia, 1449-030 Lisbon, Portugal
Tel: +351 213035720, Fax: +351 213035922, E-Mail: llopes@dgrm.mam.gov.pt

Lopez, Jon
AZTI-Tecnalia, Herrera kaia z/g, 20110 Pasaia, Gipuzkoa, Spain
Tel: +34 634 209 738, Fax: +34 94 657 25 55, E-Mail: jlopez@azti.es

Marsac, Francis
IRD, Avenue Jean Monnet, 34023 Sète, France
Tel: +33 787 044 744, E-Mail: Francis.Marsac@ird.fr

Mattlet, Anne-France
Direction des pêches maritimes et de l'aquaculture, Ministère de l'environnement, de l'énergie et de la mer, Tour Séquoïa, 1 Place Carpeaux, 92800 Punteaux, France
Tel: +33 076 313 4235, E-Mail: anne-france.mattlet@developpement-durable.gouv.fr

Maufroy, Alexandra
IRD, 5 rue des sardiniers, 29900 Concarneau, France
Tel: +33 2 98 97 19 57, Fax: +33 2 98 50 80 32, E-Mail: alexandra.maufroy@ird.fr; amaufroy@orthongel.fr

Moniz, Isadora
ANABAC, Txibitxiaga24, Entreplanta, 48370 Bermeo, Spain
Tel: +34 94 688 28 06, Fax: +34 94 688 50 17, E-Mail: isadora@anabac.org

Morón Ayala, Julio
Organización de Productores Asociados de Grandes Atuneros Congeladores - OPAGAC, C/ Ayala, 54 - 2ºA, 28001 Madrid, Spain
Tel: +34 91 575 89 59, Fax: +34 91 576 1222, E-Mail: julio.moron@opagac.org

Muniategi Bilbao, Anertz
ANABAC-OPTUC, Txibitxiaga, 24 - Entreplanta Apartado 49, 48370 Bermeo - Bizkaia, Spain
Tel: +34 94 688 28 06, Fax: +34 94 688 50 17, E-Mail: anertz@anabac.org; anabac@anabac.org

Murua, Hilario
AZTI - Tecnalia /Itsas Ikerketa Saila, Herrera Kaia Portualde z/g, 20110 Pasaia Gipuzkoa, Spain
Tel: +34 667 174 433, E-Mail: hmurua@azti.es

Nader, Gelare
Dutch National Ministry of Economic Affairs, Agriculture and Innovation, Ministry of Economic Affairs, Directorate-General Agro, Department of Sustainable Fisheries, Prins Clauslaan 8, POB 20401, 2500 EK The Hague, The Netherlands
Tel: + 316 388 25305, E-Mail: g.nader@minez.nl

Oñorbe Esparraguera, Manuel
C/ Velázquez, 144, Madrid, Spain
Tel: +34 91 347 36 31, E-Mail: monorbe@magrama.es

Peyronnet, Arnaud
Directorate-General, European Commission _ DG MARE D2, Conservation and Control in the Mediterranean and the Black Sea, Rue Joseph II – 99, 06/56, B-1049 Brussels, Belgium
Tel: +32 2 2991 342, E-Mail: arnaud.peyronnet@ec.europa.eu

Rita, Gualberto
Associaçao de Produtores de Atum e Similares deos Açores, Rua da Trincheira, 1, 9675-161 Ribeira Quente - Azores, Portugal; Tel: +351 962 524 244, E-Mail: gualberto.rita@sapo.pt; federacaopescasacores@sapo.pt

Rodrigues, Luis
Diretor Regional das Pescas, Rua Cónsul Dabney - Colónia Alema, Horta - Azores, Portugal
Tel: +351 292 202 400, Fax: +351 292 293 166, E-Mail: luis.m.rodrigues@azores.gov.pt

Rodríguez, Alexandre
Executive Secretary, LDAC, C/ Del Doctor Fleming 7, 2º derecha, 28036 Madrid, Spain
Tel: +34 91 432 36 23, Fax: +34 91 432 36 24, E-Mail: alexandre.rodriguez@ldac.eu

Santiago Burrutxaga, Josu
Head of Tuna Research Area, AZTI-Tecnalia, Txatxarramendi z/g, 48395 Sukarrieta (Bizkaia) País Vasco, Spain
Tel: +34 94 6574000 (Ext. 497); 664303631, Fax: +34 94 6572555, E-Mail: jsantiago@azti.es; flarrauri@azti.es

Uriarte, Iñaki
Anabac - Asociación Nacional de Armadores de Buques Atuneros Congeladores, Txibitxiaga 24 - Entreplanta Apartado 49, 48370 Bermeo Bizkaia, Spain
Tel: +34 94 688 28 06; +34 607 048 570, Fax: +34 94 688 50 17, E-Mail: iñakiuriarte@pevasa.es; iuriarte@pevasa.es; anabac@anabac.org

Urrutia, Xabier
ANABAC - Asociación Nacional de Armadores de Buques Atuneros Congeladores, Txibitxiaga, 24 – Entreplanta, Apartado 49, 48370 Bermeo Bizkaia, Spain
Tel: +34 94 688 0450, Fax: +34 94 688 4533, E-Mail: xabierurrutia@pevasa.es; anabac@anabac.org

Varsamos, Stamatis
European Commission, DG MARE, Rue de la Loi, 200 - J99, 03/69, Brussels, Belgium
Tel: +32 229 89465, E-Mail: stamatios.varsamos@ec.europa.eu

Velasco Maganto, Faustino
SATLINK, S.L., Avenida de la Industria, 53, 28108 Alcobendas, Madrid, Spain
Tel: +34 91 327 21 31, Fax: +34 91 327 21 69, E-Mail: fvm@satlink.es

GABON/GABÓN

Schummer Gnandji, Micheline
Directeur Général des Pêches et de l'Aquaculture du Gabon, Immeuble des Eaux et Forêts, Boulevard Triomphal Omar BONGO, BP 9498 Libreville; Tel: +241 0 661 0033, E-Mail: schmiche@yahoo.fr; dgpechegabon@netcourrier.com

Angueko, Davy
Chargé d'Etudes du Directeur Général des Pêches, Direction Générale des Pêche et de l'Aquaculture, BP 9498, Libreville
Tel: +241 0653 4886, E-Mail: davyangueko@yahoo.fr

Mba-Asseko, Georges H.
Directeur Général, Agence Nationale des Pêches et de l'Aquaculture (ANPA), BP. 9498, Libreville
Tel: +241 07020129, E-Mail: mbasseko@yahoo.com; gmbaasseko@anpagabon.org; gmbasseko@yahoo.com

GHANA

Coussey, Pierre Charles Edward
Economic Advisor, Ministry of Fisheries, Marine Technology Consultant, Panofi Company LTD, P.O. Box TT 581, Tema
Tel: +233 24442 5390, Fax: +233 303 206101, E-Mail: pierccou@yahoo.com

Acquah, Philip Kobla
Embassy of Ghana, Ministry of Foreign Affairs & Regional Integration Accra, C/ Capitan Haya 38-3, 28020 Madrid, Spain
Tel: +34 685 320 296, Fax: E-Mail: philipkobla@hotmail.com; consul@ghanaembassyspain.com

Farmer, John Augustus
President, Ghana Tuna Association, Managing Director Agnes Park Fisheries, Agnes Park Fisheries, P.O. Box CO 1828, Tema
Tel: +233 202 113230, Fax: +233 303 301 820, E-Mail: Johnebus63@gmail.com

GUATEMALA

Marín Arriola, Carlos Francisco
Director de la Dirección de Normatividad de la Pesca y Acuicultura, DIPESCA, Ministerio de Agricultura, Ganadería y Alimentación, Km 22 Carretera al Pacífico, Ed. La Cieba, 3er nivel, Bárcenas, Villanueva
Tel: +502 6640 9334, E-Mail: cfmarin1058@gmail.com; dipescaguatemala@gmail.com; visardespacho@gmail.com

HONDURAS

Cabrera Quesada, Blas Norberto
Asesor en Pesca y Acuicultura, Secretaria de Estado en los Despachos de Agricultura y Ganadería de la República de Honduras, Secretaría de Agricultura y Ganadería, Avenida La FAO, Colonia Loma Linda, Contiguo a INJUPEMP, Boulevard Miraflores, Tegucigalpa, M.D.
Tel: +504 3366 0881, E-Mail: BlasCabreraQ@hotmail.com

Chavarría Valverde, Bernal Alberto
Dirección General de Pesca y Acuicultura, Secretaría de Agricultura y Ganadería Boulevard Centroamérica, Avenida la FAO, Tegucigalpa
Tel: +506 229 08808, Fax: +506 2232 4651, E-Mail: bchavarria@lsg-cr.com

Mena Villegas, Oscar
Secretaría de Agricultura y Ganadería, Colonia Loma Linda, Avenida la Fao, Boulevard Centroamérica, Tegucigalpa
Tel: +626 163 760, E-Mail: omena@bcelaw.com

INDONESIA

Widodo, Anung
Center for Fisheries Research
E-Mail: anungwd@yahoo.co.id

ISLAMIC REPUBLIC OF IRAN/RÉPUBLIQUE ISLAMIQUE D'IRAN/REPÚBLICA ISLÁMICA DEL IRÁN

Mirzale, Mehrdad
Sistan and Baluchestan Province for Fishing Affairs
Tel: +98 903 692 7243, E-Mail: mirzaee.mehrdad@yahoo.com

Moradi, Gholamali
Pffshore Fishing Affairs of Iran Fisheries Organization
E-Mail: moradi54ali@gmail.com

JAPAN/JAPON/JAPÓN

Tominaga, Haruo
Assistant Director, International Affairs Division, Resources Management Department, Fisheries Agency, Ministry of Agriculture, Forestry and Fisheries, 1-2-1 Kasumigaseki, Chiyoda-ku, Tokyo 100-8907
Tel: +81 3 3502 8460, Fax: +81 3 3504 2649, E-Mail: haruo_tominaga170@maff.go.jp

Ishida, Yukimasa
Senior Research Scientist, National Research Institute of Far Seas Fisheries, Fisheries Research and Education Agency, 5-7-1 Orido, Shimizu Ward, Shizuoka City, Shizuoka Prefecture, 424-8633
Tel: +81 54 336 6000, Fax: +81 54 335 9642, E-Mail: ishiday@fra.affrc.go.jp

Nishida, Hiroshi
Tuna and Skipjack Resources Division, National Research Institute of Far Seas Fisheries, Fisheries Research and Education Agency, 5-7-1 Orido, Shimizu, Shizuoka 424 8633
Tel: +81 54 336 6000, Fax: +81 54 335 9642, E-Mail: hnishi@affrc.go.jp

Oshima, Tatsuki
Head, Pelagic Fish Research Group, Marine Fisheries Research and Development Center (JAMARC), Fisheries Research and Education Agency, Queen's Tower B 15F, 2-3-3 Minatomirai, Yokohama
Tel: +81 45 227 2737, Fax: +81 45 227 2705, E-Mail: oshima@jamarc.go.jp

LIBERIA/LIBÉRIA

Boeh, William Y.
Coordinator, Ministry of Agriculture (MOA), Bureau of National Fisheries (BNF), P.O. Box 10-90100, 1000 Monrovia 10;
Tel: +231 888198006, E-Mail: w.y.boeh@liberiafisheries.net; williamboeh92@gmail.com

Togba, Glasgow B.
Director, Division of Marine Fisheries, Bureau of National Fisheries, Ministry of Agriculture, P.O. Box 10-9010, 1000 Monrovia 10;
Tel: +231 888 835 144; +231 777 098 224, E-Mail: glasgowtogba@yahoo.com; gbtogba@liberiafisheries.net

MAURITIUS/MAURICE/MAURICIO

Bauljeewon, Subhas
Seafood Hub, C/O Ministry of Ocean Economy, Marine Resources, Fisheries and Shipping, (Fisheries Division)
Tel: +230 206 2823, Fax: +230 20602809, E-Mail: sbauljeewon@gmail.com

Bibi Swaleha, Gungadeen
Assistant Permanent Secretary, Ministry of Ocean Economy, Marine Ressources, Fisheries and Shipping, 4th Floor, LICI Building, Port Louis
Tel: +230 579 71804, Fax: +230 211 2451, E-Mail: sgungadeen@govmu.org; gswaleha@gmail.com

MEXICO/MÉXIQUE/MÉXICO

López Fleischer, Luis Armando
Consejería de la SAGARPA, Embajada de México en Washington D.C., 1911 Pennsylvania Ave. NW, Washington, D.C. 20006, United States
Tel: +202 255 71 75 012, E-Mail: lfleischer21@hotmail.com; lfleischer.sagarpausa@verizon.net

Dreyfus León, Michel Jules
INAPESCA, CRIP – Ensenada Carretera Tijuana - Ensenada Km 97.5
Tel: +646 116 7084, E-Mail: dreyfus@cicese.mx

Ramos Sánchez, Mariana
Directora, Alianza del Pacífico por el Atún Sustentable, Insurgentes Sur 1647, Piso 1, Benito Juárez, 03900
Tel: +52 55 8000-8157, E-Mail: ramoss.mariana@gmail.com

MOZAMBIQUE

Halafo, Jose Sebastiao
Ministry of Sea, Inland Waters and Fisheries
Tel: +258 824 033 950, E-Mail: jhalafo@yahoo.com

Naene, Galhardo Havier
Ministry of Sea, Inland Waters and Fisheries
E-Mail: gnaene@gmail.com

NICARAGUA

Norori, Tania
INPESCA, Km 3.5 Carretera Norte, Managua
Tel: +505 22 442401, E-Mail: tnorori@inpesca.gob.ni

Guevara Quintana, Julio Cesar
Comisionado CIAT - Biólogo, ALEMSA, Rotonda el Periodista 3c. Norte 50vrs. Este, Managua
Tel: +505 2278 0319; +505 8396 7742, E-Mail: juliocgq@hotmail.com; alemsanic@hotmail.com

NIGERIA

Mu'Azu, Mohammed
Director of Fisheries, Federal Ministry of Agriculture and Rural Development, Department of Fisheries, Area 11, Abuja Garki
Tel: +234 803 373 5943, E-Mail: modmazu@yahoo.com

PAKISTAN/PAKISTÁN

Chandna, Asad Rafi
Ministry of Ports and Shipping
E-Mail: fdcofpakistan@gmail.com

PERU/PÉROU/PERÚ

Cárdenas de Pellón, Gladys
Bióloga, Instituto del Mar del Perú, Esquina Gamarra y General Valle s/n, Chucuito Callao
Tel: +511 997 455 291, Fax: +511 208 8660, E-Mail: gcardenas@imarpe.gob.pe; gcardenas7@hotmail.com

Pellon Farfan, Jose Carlos
Tecnólogo Pesquero; Tel: +993 246 646, E-Mail: josepellon5@hotmail.com

Ríos Bravo de Rueda, Omar
Dirección de Políticas y Ordenamiento, Dirección General de Políticas y Análisis Regulatorio en Pesca y Acuicultura, Viceministerio de Pesca y Acuicultura - Ministerio de la Producción
Tel: +511 616 2222 Anexo 4111, E-Mail: orios@produce.gob.pe

REPUBLIC OF MALDIVES/RÉPUBLIQUE DES MALDIVES/REPÚBLICA DE MALDIVAS

Adam, Mohamed Shiham
Director General, Ministry of Fisheries & Agriculture, Marine Research Centre H. White Waves, Moonlight Higun, 20025 Malé
Tel: +960 779 2687, Fax: +960 332 2509, E-Mail: msadam@mrc.gov.mv

Ziyad, Adam
Ministry of Fisheries & Agriculture, Velaanage 7th floor, Ameer Ahmed Magu, 20096 Malé
Tel: +960 332 2625, Fax: +960 332 6558, E-Mail: adam.ziyad@fishagri.gov.mv

S. TOMÉ E PRÍNCIPE/SANTO TOMÉ Y PRÍNCIPE

Pessoa Lima, Joao Gomes
Directeur Génerale des Pêches, Ministério das Finanças Comercio e Economia Azul, Direction Générale des Pêches, Largo das Alfandegas, C.P. 59
Tel: +239 222 2828, E-Mail: dirpesca1@cstome.net; jpessoa61@hotmail.com

Goret Gomes Cravid, Mirian
Biologiste Marin du Departement de la Recherche
Tel: +2399850091, E-Mail: miriangomescravid@gmail.com

SENEGAL/SÉNÉGAL

Sow, Fambaye Ngom
Chercheur Biologiste des Pêches, Centre de Recherches Océanographiques de Dakar Thiaroye, CRODT/ISRALNERV - Route du Front de Terre - BP 2241, Dakar
Tel: +221 3 0108 1104; +221 77 502 67 79, Fax: +221 33 832 8262, E-Mail: famngom@yahoo.com

Sèye, Mamadou
Ingénieur des Pêches, Chef de la Division Gestion et Aménagement des Pêcheries de la Direction des Pêches Maritimes, 1, Rue Joris, Place du Tirailleur, Dakar
Tel: +221 33 823 01 37, Fax: +221 821 47 58, E-Mail: mamadou.seye@mpem.gouv.sn; mdseye@gmail.com

SOMALIA/SOMALIE

Mohamed, Istarlin
STAR Cooperative Fish
Tel: +252 616 662 333, E-Mail: istarcatering2@gmail.com

Warsame, Abdirasak
Director General, Ministry of Fisheries and Marine Resources
Tel: +252 618 822 243, E-Mail: dg@mfmr.gov.so; awarsame4@gmail.com

SRI LANKA

Gunawardane, Nuwam Dileepa Perera
Department of Fisheries and Aquatic Resources, Ministry of Fisheries and Aquatic Resources Development, Maligawatta, Colombo 10
Tel: +94 773 703 885, Fax: +94 342 222 482, E-Mail: Nuwan54@gmail.com

Punyadeva, Prasada Badathuruge Naidu
National Aquatic Resources Research & Development Agency, Crow Island, Mattakuliya, Colombo 15
Tel: +947 149 41499; +947 779 01499, E-Mail: nbprasada@gmail.com

SULTANATE OF OMAN/SULTANAT D'OMAN/SULTANATO DE OMÁN

Al Mazrui, Ahmed
SULTANATO DE OMÁN
E-Mail: ahmed.almazrui20@gmail.com

THAILAND/THAÏLANDE/TAILANDIA

Lirdwitayaprasit, Pattira
Overseas Fisheries and Transhipment Control Division, Department of Fisheries Kaset Klang, Chatuchak, Paholyothin RD., 10900 Bangkok
Tel: +66 835 407 848, Fax: +66 256 205 33, E-Mail: pattiral@hotmail.com

Yawanopas, Sawitre
Overseas Fisheries and Transhipment Control Division, 389/159 Nakorntonggrandview vullage Moo.6 Samutprakan, 10280; Tel: +66 855 692 624, E-Mail: sawitre_yawa@hotmail.com

TUNISIA/TUNISIE/TÚNEZ

Sohlobji, Donia
Direction Générale de la Pêche et de l'Aquaculture, 32 Rue Alain Savary, 1002
Tel: +216 71 890 784, Fax: +216 71 799 401, E-Mail: sohlobji_donia@yahoo.fr; doniasohlobji@gmail.com

Hajjej, Ghailen
Attaché de recherche, Laboratoire des Sciences Halieutiques, Institut National des Sciences et Technologies de la Mer (INSTM), Port de pêche, 6000 Gabès
Tel: +216 75 220 254, Fax: E-Mail: ghailen3@yahoo.fr; ghailen.hajej@instm.rnrt.tn

UNITED KINGDOM (OVERSEAS TERRITORIES)/ROYAUME-UNI (TERRITOIRES D'OUTRE-MER)/REINO UNIDO (TERRITORIOS DE ULTRAMAR)

Davies, Tim
Senior Consultant, MRAG Ltd., 18 Queen Street, London W1J 5PN
Tel: +44 20 7255 7787, E-Mail: t.davies@mrag.co.uk

UNITED STATES/ÉTATS-UNIS/ESTADOS UNIDOS

King, Melanie Diamond
NOAA - National Marine Fishery Service, Office of International Affairs and Seafood Inspection (F/IA1)1315 East West Highway, Silver Spring Maryland 20910
Tel: +1 301 427 3087, E-Mail: melanie.king@noaa.gov

Brown, Craig A.
Chief, Highly Migratory Species Branch, Sustainable Fisheries Division, NOAA Fisheries Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami Florida 33149
Tel: +1 305 586 6589, Fax: +1 305 361 4562, E-Mail: craig.brown@noaa.gov

Hallman, Brian S.
Executive Director, American Tuna Boat Association, Tuna Lane, San Diego 92101
Tel: +1 619 888 4960, Fax: +1 619 923 2355, E-Mail: bhallmanata@gmail.com

Piñeiro Soler, Eugenio
Chairman, Caribbean Fishery Management Council, 723 Box Garden Hills Plaza, Guaynabo, PR 00966
Tel: +1 787 234 8403, Fax: +1 787 834 8102, E-Mail: gpsfish@yahoo.com

Sousa, Jim
2535 Kettner Blvd. #1A2, California San Diego 92101
Tel: +1 619 993 2351, Fax: +1 619 239 6229, E-Mail: jim.sousa@marpacifico.net

RFMO SECRETARIATS / SECRÉTARIATS DES ORGP / SECRETARÍAS DE LAS OROP

INTER-AMERICAN TROPICAL TUNA COMMISSION - IATTC

Compeán Jimenez, Guillermo
Director, Inter-American Tropical Tuna Commission - IATTC, c/o Scripps Institute of Oceanography, 8901 La Jolla Shore Drive, La Jolla CA 92037-1508, United States
Tel: +1 858 546 7100, Fax: +1 858 546 7133, E-Mail: gcompean@iattc.org

Hall, Martin
Inter-American Tropical Tuna Commission - IATTC, 8901 La Jolla Shores Drive, La Jolla CA 92037, United States
Tel: +1 858 546 7100, Fax: +1 858 546 7133, E-Mail: mhall@iattc.org

INTERNATIONAL COMMISSION FOR THE CONSERVATION OF ATLANTIC TUNAS - ICCAT

Meski, Driss
Executive Secretary, ICCAT Secretariat, C/ Corazón de María, 8 - 6 Planta, 28002 Madrid, Spain
Tel: + 34 91 416 5600, Fax: +34 91 415 2612, E-Mail: info@iccat.int

INDIAN OCEAN TUNA COMMISSION - IOTC

Anganuzzi, Alejandro
Executive Secretary, IOTC Secretariat, Le Chantier mall (2nd floor), Victoria, Mahe, PO BOX 1011 Republic of Seychelles;
Tel: +39 05 5705 3313, E-Mail: alejandro.anganuzzi@fao.org

Fiorellato, Fabio
IOTC Secretariat, Le Chantier mall (2nd floor), Victoria, Mahe', PO BOX 1011, Republic of Seychelles
Tel: +248 256 6169; +39 349 362 5024, E-Mail: fabio.fiorellato@iotc.org

Martin, Sarah
IOTC Secretariat, PO Box 1011, Victoria, Republic of Seychelles; Tel: +248 261 3765, E-Mail: sarah.martin@iotc.org

OBSERVERS FROM INTERGOVERNMENTAL ORGANIZATIONS/ OBSERVATEURS D'ORGANISMES INTERGOUVERNEMENTAUX/ OBSERVADORES DE ORGANIZACIONES INTERGUBERNAMENTALES

FOOD AND AGRICULTURE ORGANIZATION - FAO
Million, Julien
FAO, Viale Delle Terme de Caracalla, 00188 Rome, Italy
Tel: +39 339 1255 637, E-Mail: julien.million@fao.org

OBSERVERS FROM NON-GOVERNMENTAL ORGANIZATIONS/OBSERVATEURS D'ORGANISATIONS NON GOUVERNEMENTALES/OBSERVADORES DE ORGANISMOS NO GUBERNAMENTALES

GREENPEACE
Chartier, François
GREENPEACE France, 13 rue d'Enghien, 75010 Paris, France
Tel: +331 44 64 0202; +33 684 250 828, Fax: +33 1 4464 0200, E-Mail: francois.chartier@greenpeace.org

Losada Figueiras, Sebastián
Oceans Policy Adviser, Greenpeace International, Ronda de Nelle, 96 - 9 Izq., 15004 A Coruña, Spain
Tel: +34 626 998 254, E-Mail: sebastian.losada@greenpeace.org

INTERNATIONAL SEAFOOD SUSTAINABILITY FOUNDATION – ISSF
Moreno Arriola, Gala
ISSF, 805 15th NW Suite 708, Washington DC 20005, United States
Tel: +1 703 226 8101, Fax: +1 215 220 2698, E-Mail: gmoreno@iss-foundation.org

Restrepo, Víctor
Chair of the ISSF Scientific Advisory Committee, ISS-Foundation, 601 New Jersey Avenue NW, Suite 220, Washington DC 20001, United States
Tel: + 1 703 226 8101, Fax: +1 215 220 2698, E-Mail: vrestrepo@iss-foundation.org; vrestrepo@mail.com

MARINE STEWARDSHIP COUNCIL - MSC
Montero Castaño, Carlos
Técnico de Pesquerías para España y Portugal del MSC, Marine Stewardship Council, Paseo de la Habana, 26 - 7ª planta puerta 4, 28036 Madrid, Spain
Tel: +34 674 071 053, Fax: +34 91 831 9248, E-Mail: carlos.montero@msc.org

PEW CHARITABLE TRUSTS - PEW
Galland, Grantly
Pew Charitable Trusts, 901 E Street, NW, Washington, DC 20004, United States
Tel: +1 202 540 6953, Fax: +1 202 552 2299, E-Mail: ggalland@pewtrusts.org

Gershman, David
PEW Charitable Trusts, 901 E Street NW, Washington DC 20004, United States
Tel: +1 202 748 6649, E-Mail: dgershman@pewtrusts.org

Jen, Sandra
Pew Charitable Trusts, Rue Dr. Dryepondt 27, B-1040 Brussels, Belgium
Tel: +32 498 10 80 96, E-Mail: sjen@sjenconsult.org; sjen.org@gmail.com

Nickson, Amanda
Pew Charitable Trusts, 901 E Street NW, Washington DC 20004, United States
Tel: +1 202 540 6953; +1202 674 9829, E-Mail: anickson@pewtrusts.org

SUSTAINABLE FISHERIES PARTNERSHIP - SFP
Tingley, Geoff
Sustainable Fisheries Partnership, 7 Kate Way, Karori, Wellington, New Zealand
Tel: +64 0 21 047 8587, E-Mail: geoff.tingley@sustainablefish.org

THE INTERNATIONAL POLE & LINE FOUNDATION - IPNLF
Kelling, Ingrid
Market Outreach Director, Pole & Line - IPNLF, 7-14 Great Dover Street, London, United Kingdom
Tel: +33 698 610 747, E-Mail: ingrid.kelling@ipnlf.org

Purves, Martin
Managing Director, Pole & Line Foundation - IPNLF, 6 Hamman Street, Stellenbosch, South Africa
Tel: +278 332 45828, E-Mail: martin.purves@ipnlf.org

TRI MARINE
Owens, Matthew
Director, Sustainability, TRI MARINE, 10500 NE 8th Street, Suite 1888, Bellevue WA, 98004, United States
Tel: +1 425 647 7531, E-Mail: mowens@trimarinegroup.com

WORLD WILDLIFE FUND – WWF
García Rodríguez, Raúl
WWF Mediterranean, Gran Vía de San Francisco, 8, 28005 Madrid, Spain
Tel: +34 630 834 267, Fax: +34 913 656 336, E-Mail: pesca@wwf.es

******

ICCAT Secretariat/ Secrétariat de l'ICCAT/ Secretaría de ICCAT
C/ Corazón de María 8 – 6th floor, 28002 Madrid – Spain
Tel: +34 91 416 56 00; Fax: +34 91 415 26 12; E-mail: info@iccat.int

ICCAT
Neves dos Santos, Miguel
De Bruyn, Paul
Palma, Carlos
Ortiz, Mauricio
Donovan, Karen
García-Orad, María José
Peyre, Christine
Fiz, Jesús
Moreno, Juan Ángel
Peña, Esther
Beare, Doug

SCRS CHAIRMAN
Die, David
SCRS Chairman, Cooperative Institute of Marine and Atmospheric Studies, University of Miami, 4600 Rickenbacker Causeway, Miami Florida 33149, United States
Tel: +1 673 985 817, Fax: +1 305 421 4221, E-Mail: ddie@rsmas.miami.edu

ICCAT INTERPRETERS
Baena Jiménez, Eva J.
Faillace, Linda
Leboulleux del Castillo, Beatriz
Liberas, Christine
Linaae, Cristina
Meunier, Isabelle

Appendix 2

1st Joint t-RFMO FAD Working Group Meeting

Meeting Goal

To promote discussions on tropical tuna FAD fishing and management relevant issues on an Ocean-wide perspective.

Framework and objectives

FAD management is an issue of common interest to tuna fisheries and is becoming increasingly important for the tropical tuna fisheries in general. As a response, some tuna RFMOs have created specific FAD Working Groups, which are promoting to address issues related to tuna FAD fishing. During the last meeting of the Kobe process Steering Committee, it was also noted that the European Union offered to finance a joint tuna-RFMO meeting and that some additional funding could be obtained from the FAO ABNJ Tuna Project. Accordingly, during 2016 the tuna-RFMO Secretariats held discussions regarding the possibility of holding a joint tuna RFMO meeting on FAD fishing issues, sometime in 2017. An agreement was achieved between ICCAT, IOTC and IATTC, to hold the First Joint Tuna-RFMO FAD Working Group meeting in Madrid, 19-21 April 2017. It should be noted that WPCFC has decided not to participate in this meeting.

With the aim of making the meeting appealing and efficient as regards the outputs, the three above mentioned tuna-RFMOs are committed to conduct a cross-cutting exercise between all stakeholders by covering a wide range of topics related to tuna FAD fisheries and promoting discussions regarding tuna FAD fisheries management among the three t-RFMOs.

The Working Group meeting will be Chaired by Mr. Stefaan Depypere, Chair of the Kobe Steering Committee.

Agenda

1. Opening and meeting arrangements
2. Adoption of Agenda and assignment of rapporteurs
3. Review of the state and available information on tuna (anchored and drifting) FAD fisheries at t-RFMOs
4. Assessment of the use of FADs in tuna fisheries in all three t-RFMOs Convention areas and relative contribution of FADs to overall fishing mortality in tropical tuna fisheries
5. Review and assessment of developments in FAD related technology and in the mitigation of its impact
6. Review of data requirements needs and data collection systems of relevant information on tuna FAD fishing
7. Review of current research plans on tuna FAD fisheries related issues
8. Consideration of possible common (and/or additional) actions related to FAD management and recovery
9. Recommendations
10. Other matters
11. Adoption of the report and closure

1st Joint t-RFMO FAD Working Group Meeting Annotated Agenda

Session (time)	***Theme***	***Titles for presentations received or themes for discussion***
Wednesday, 19/04/2017 9:00-9:30	1. Opening and meeting arrangements 2. Adoption of Agenda and assignment of rapporteurs Session Chair: Meeting Chair (Stefaan Depypere)	Welcome, meeting objectives and arrangements Adoption of the Agenda Assignment of rapporteurs
Wednesday, 19/04/2017 9:30-11:00	3. Review of the state of play and progress on tuna (anchored and drifting) FAD fisheries in all three t-RFMOs Session Chair: Guillermo Moran (IATTC Chair)	Keynotes: i. D. Die (ICCAT) (j-FAD-36): "Activities of the ICCAT ad-hoc Working Group on FADs during 2015-2016" ii. H. Murua (IOTC) (j-FAD-29): "Review of the state and available information on tuna (anchored and drifting) FAD fisheries at IOTC" iii. J. Santiago (IATTC) (j-FAD-40): "IATTC Ad hoc Working Group on FADs: summary of 1st year of activities and Work Plan for 2017" Discussion ***Document:*** j-FAD-32
Wednesday, 19/04/2017 11:30-13:00 14:30-15:30	4. Assessment of the use of FADs in tuna fisheries in all three t-RFMO Convention areas and impact of FAD fishing on the tropical tuna stocks Session Chair: Josu Santiago	Keynotes by: M. Hall (j-FAD-05): "The FAD fishery in the eastern Pacific" S. Adam (j-FAD-28): "Assessment of use of FADs in tuna fisheries of IOTC Convention area" D. Gaertner: "Assessment of the use of FADs in tuna fisheries in the ICCAT area and relative contribution of FADs to overall fishing mortality in tropical tuna stocks" Presentations: Fonteneau (j-FAD-25): "An overview of worldwide FAD fisheries and of their potential effects on tuna stocks" Maufroy *et al*. (j-FAD-17): "dFADs used by EU tropical tuna purse seiners in the Atlantic and Indian Oceans: increasing use, contribution to fishing efficiency and potential management" Group of experts (j-FAD-22): "FAD use and fishing mortality in tropical tuna fisheries" Discussion ***Documents:*** j-FAD-04 and j-FAD-21

Wednesday, 19/04/2017 15:30-16:30 17:00-18:30	5. Review and assessment of impacts on non-target species and mitigation of undesirable impacts on target and non-target species (developments in FAD related technology) Session Chair: Amanda Nickson (PEW)	Keynote by: Victor Restrepo *et al.*: "Impacts on non-target species and promising uses of technology to mitigate FAD impacts" Presentations: Oshima *et al.* (j-FAD-37): "New method that combines dead reckoning and acoustic telemetry to measure fine scale of tuna associated with FADs" Oshima *et al.* (j-FAD-38): "Size selectivity of tuna purse seine nets estimated from FAD sets data" Lopez *et al.* (j-FAD-30): "Main results of the Spanish Best Practices program: evolution of the use of non-entangling FADs, interaction with entangled animals, and fauna release operations" Murua *et al.* (j-FAD-09): "Adoption levels of entanglement-reducing FAD designs by tuna purse seine fleets in different Oceans" Discussion ***Documents:*** j-FAD-06, j-FAD-07, j-FAD-08, j-FAD-12, j-FAD-21, j-FAD-23 and j-FAD-34
Thursday, 20/04/2017 9:00-11:00	6. Review of data requirements needs and data collection systems of relevant information on tuna FAD fishing Session Chair: Ahmed Al Mazroui (IOTC Chair)	Keynote by: Miguel Herrera (j-FAD-41): "Review of data requirements needs and data collection systems of relevant information on tuna FAD fishing" Presentations: Ramos *et al.* (j-FAD-11): "Spanish FAD logbook: solving past issues, responding to new global requirements" Legorburu *et al.* (j-FAD-10): "Deployment of non-entangling FADs and related activities monitored by electronic monitoring system in the Indian Ocean" Santiago *et al.* (j-FAD-13): "Monitoring the number of active FADs used by the Spanish and associated purse seine fleet in the IOTC and ICCAT Convention areas" Lopez *et al.* (j-FAD-31): "Taking another step forward: system of verification of the code of good practices in the Spanish tropical tuna purse seiner fleet operating in the Atlantic, Indian and Pacific Oceans" Capello *et al.* (j-FAD-26): "Managing the number of FADs using fisheries-independent data: Principles and theories"

		Santiago *et al*. (j-FAD-14): "Buoy derived abundance indices of tropical tunas in the Indian Ocean" Discussion ***Documents:*** j-FAD-27 and j-FAD-31
Thursday, 20/04/2017 11:30-13:00	7. Review of current research plans on tuna FAD fisheries related issues Session Chair: David Die	Keynotes by: i. D. Die (ICCAT) (j-FAD-42): ICCAT Research Plans related to FADs ii. H. Murua (IOTC) (j-FAD-43): IOTC Research Plans related to FADs iii. M. Hall (IATTC) (j-FAD-44): IATTC Research Plans related to FADs Discussion
Thursday, 20/04/2017 14:30-16:30 17:00-18:30	8. Consideration of possible common (and/or additional) actions related to FAD management and recovery Session Chair: Meeting Chair (Stefaan Depypere)	Presentations: Group of experts (j-FAD-20): "Managing FAD capacity and impacts on marine ecosystems" Davies (j-FAD-19): "Potential environmental impacts caused by beaching of drifting fish aggregating devices and identification of management uncertainties and data needs" Galland (j-FAD-24): "Mitigating the impacts of FAD use on tropical tuna stocks" Purves (j-FAD-18): "The lack of a scientifically based definition of *FAD Set*" Morón (j-FAD-15): "Implementing Management Plans and Voluntary Initiatives regarding FADs: The OPAGAC experience" Goujon (j-FAD-16): "Evolution of the perception of the FAD issue by the French purse seine fleet since 2010 and perspectives for future management" Group of experts (j-FAD-35): "What does well-managed FAD use look like within a tropical purse seine fishery?" Discussion ***Documents:***
Thursday, 20/04/2017 18:30-19:30	9. Sessions Chairs and t-RFMOs FAD WG Chairs meeting Session Chair: Meeting Chair (Stefaan Depypere)	Draft recommendations

Friday, 21/04/2017 9:00-11:30 12:00-14:30	10. Recommendations 11. Other matters 12. Adoption of the report and closure Session Chair: Meeting Chair (Stefaan Depypere)	Presentation by the Chair: i. Wrap up of major discussions and presentation of recommendations ii. Priorities and next steps iii. 2nd Joint T-RFMO FAD Working Group Meeting Discussion

Appendix 3

LIST OF DOCUMENTS / LISTE DE DOCUMENTS / LISTADO DE DOCUMENTOS

Doc. Ref.	Title (ENG)	Titre (FRA)	Titulo (SPA)
j-FAD_01	Agenda	Ordre du jour	Orden del día
j-FAD_02	Annotated agenda	Ordre du jour annoté	Orden del día comentado
j-FAD_03	Internet Connection and Access to ownCloud	Connexion internet et accès au site ownCloud	Conexión a internet y acceso a ownCloud
j-FAD_04	Managing FAD capacity and impact: Review of the impacts of FAD use on fishing capacity in the Atlantic and Indian Oceans	Gestion de la capacité et de l'impact des DCP : examen des impacts de l'utilisation des DCP sur la capacité de pêche dans les océans Atlantique et Indien	Ordenación de la capacidad y del impacto de los DCP: Examen del impacto del uso de los DCP en la capacidad de pesca en los océanos Atlántico e Índico
j-FAD_05	The FAD fishery in the eastern Pacific	La pêcherie de DCP dans le Pacifique oriental	La pesquería con DCP en el Pacífico oriental
j-FAD_06	Promising uses of technology to mitigate FAD impacts	Utilisations prometteuses de la technologie pour atténuer les impacts des DCP	Usos prometedores de la tecnología para mitigar los impactos de los DCP
j-FAD_07	How far are we from discriminating tuna species at FADs?	La différenciation des espèces de thonidés présentes autour des DCP a-t-elle évolué ?	¿Cuán lejos estamos de diferenciar las especies de túnidos en los DCP?
j-FAD_08	FAD structure evolution: from biodegradable FADs to biodegradable FADs	Évolution de la structure des DCP : des DCP biodégradables aux DCP biodégradables	Evolución de la estructura de los DPC: de DCP biodegradables a DCP biodegradables
j-FAD_09	Adoption levels of entanglement-reducing FAD designs by tuna purse seine fleets in different Oceans	Niveaux d'adoption de modèles de DCP réduisant l'emmêlement de la part des flottilles de senneurs ciblant les thonidés dans les différents océans	Niveles de adopción por parte de las flotas de cerco de túnidos en los diferentes océanos de diseños de DCP que reducen el enmallamiento
j-FAD_10	Deployment of non-entangling FADs and related activities monitored by electronic monitoring system in the Indian Ocean	Déploiement de DCP non-emmêlants et activités connexes contrôlées par un système de suivi électronique dans l'océan Indien	Plantado de DCP no enmallantes y actividades relacionadas controladas a través de un sistema de seguimiento electrónico en el océano Índico
j-FAD_11	Spanish FADs logbook: solving past issues, responding to new global requirements	Carnets de pêche de DCP espagnols : résolution des problèmes passés, réponse aux nouvelles exigences mondiales	Cuadernos de pesca de DCP españoles: resolución de problemas pasados, respuesta a los nuevos requisitos globales
j-FAD_12	Drifting FADs contribution to marine litter and ghost fishing: a perspective from the Maldives	Contribution des DCP dérivants à la pollution marine et à la pêche fantôme : perspective depuis les Maldives	Contribución de los DCP a la deriva a los deshechos marinos y a la pesca fantasma: una perspectiva desde las Maldivas
j-FAD_13	Monitoring the number of active FADs used by the Spanish and associated purse seine fleet in the IOTC and ICCAT Convention areas	Suivi du nombre de DCP actifs utilisés par la flottille espagnole de senneurs et la flottille associée dans la zone de la Convention de la CTOI et de l'ICCAT	Seguimiento del número de DCP activos utilizados por las flotas de cerco española y asociada en las zonas del Convenio de la IOTC e ICCAT

j-FAD_14	Buoy derived abundance indices of tropical tunas in the Indian Ocean	Indices d'abondance des thonidés tropicaux obtenus par le biais des bouées dans l'Océan Indien	Índices de abundancia de túnidos tropicales obtenidos mediante boyas en el océano Índico
j-FAD_15	Implementing management plans and voluntary initiatives regarding FADs: the OPAGAC experience	Mise en œuvre de programmes de gestion et d'initiatives à titre volontaire en ce qui concerne les DCP: l'expérience d'OPAGAC	Implementación de planes de ordenación y de iniciativas voluntarias relacionados con los DCP: la experiencia de OPAGAC
j-FAD_16	Evolution of the perception of the FAD issue by the French and Italian purse seine fleet since 2010 and perspectives for future management	Évolution de la perception de la question des DCP de la part de la flottille française et italienne de senneurs depuis 2010 et perspectives pour la gestion future	Evolución de la percepción de la cuestión de los DCP por parte de la flota de cerco francesa e italiana desde 2010 y perspectivas de ordenación futura
j-FAD_17	dFADs used by EU tropical tuna purse seiners in the Atlantic and Indian Oceans: increasing use, contribution to fishing efficiency and potential management	DCP dérivants utilisés par les senneurs européens ciblant les thonidés tropicaux dans l'Océan Atlantique et l'Océan Indien : augmentation de l'utilisation, contribution à l'efficacité de la pêche et gestion potentielle	DCPd utilizados por los cerqueros de túnidos tropicales de la UE en los océanos Atlántico e Índico: incremento del uso, contribución a la eficacia de la pesca y ordenación potencial.
j-FAD_18	The lack of a scientifically based definition of "FAD set"	Absence d'une définition basée sur la science du terme « opération sous DCP »	La ausencia de una definición con base científica de "lance sobre DPC"
j-FAD_19	Potential environmental impacts caused by beaching of drifting fish aggregating devices and identification of management uncertainties and data needs	Impacts environnementaux potentiels causés par l'échouage des dispositifs de concentration de poissons dérivants et identification des incertitudes dans la gestion et des besoins en termes de données	Posibles impactos medioambientales causados por el varamiento de dispositivos de concentración de peces a la deriva e identificación de incertidumbres en la ordenación y necesidades de datos
j-FAD_20	Managing FAD capacity and impacts on marine ecosystems	Gestion de la capacité et de l'impact des DCP sur les écosystèmes marins	Ordenación de la capacidad y del impacto de los DPC en ecosistemas marinos
j-FAD_21	The impacts of FAD use on non-target species	Impact de l'utilisation de DCP sur les espèces non-ciblées	Impacto de la utilización de los DCP en especies no objetivo
j-FAD_22	FAD use and fishing mortality in tropical tuna fisheries	Utilisation de DCP et mortalité par pêche dans les pêcheries de thonidés tropicaux	Utilización de DCP y mortalidad por pesca en pesquerías de túnidos tropicales
j-FAD_23	Technological approaches to addressing tuna mortality associated with FAD fishing	Approches technologiques pour résoudre la question de la mortalité des thonidés associée à la pêche sous DCP	Enfoques técnicos para abordar cuestiones relacionadas con la mortalidad de túnidos asociada a la pesca con DCP
j-FAD_24	Mitigating the impacts of FAD use on tropical tuna stocks	Atténuation de l'impact de l'utilisation des DCP sur les stocks de thonidés tropicaux	Mitigación del impacto de la utilización de DCP en los stocks de túnidos tropicales
j-FAD_25	An overview of worldwide FAD fisheries and of their potential effects on tuna stocks	Vue d'ensemble des pêcheries sous DCP au niveau mondial et de leurs effets potentiels sur les stocks de thonidés	Una visión general de las pesquerías con DCP mundiales y de sus posibles efectos en los stocks de túnidos

j-FAD_26	Managing the number of FADs using fisheries-independent data: principles and theories	Gérer le nombre de DCP en utilisant des données indépendantes des pêcheries : principes et théories	Ordenación del número de DCP utilizando datos independientes de la pesquería: principios y teorías
j-FAD_27	Managing the number of FADs using fisheries-independent data: state of the art of data collection, analysis and modeling	Gérer le nombre de DCP en utilisant des données indépendantes des pêcheries : collecte des données, analyse et modélisation plus poussées	Ordenación del número de DCP utilizando datos independientes de la pesquería: recopilación de datos, análisis y modelación más avanzados
j-FAD_28	Assessment of use of FADs in tuna fisheries of IOTC convention area	Evaluation de l'utilisation des DCP dans les pêcheries de thonidés de la zone de la Convention de la CTOI	Evaluación de la utilización de DCP en las pesquerías de túnidos de la zona del Convenio de la IOTC
j-FAD_29	Review of the state and available information on tuna (anchored and drifting) FAD fisheries at IOTC	Examen de l'état et de l'information disponible sur les pêcheries de thonidés sous DCP (ancrés et dérivants) à la CTOI	Examen del estado y de la información disponible sobre las pesquerías de túnidos con DCP (fondeados y a la deriva) en la IOTC
j-FAD_30	Main results of the Spanish Best Practices program: evolution of the use of Non-entangling FADs, interaction with entangled animals, and fauna release operations	Principaux résultats du programme espagnol de pratiques exemplaires : évolution de l'emploi des DCP non-emmêlants, interaction avec les animaux enchevêtrés et opérations de libération de la faune	Principales resultados del programa español de mejores prácticas: evolución del uso de DCP no enmallantes, interacción con los animales enmallados y operaciones de liberación de la fauna
j-FAD_31	Taking another step forward: system of verification of the code of good practices in the Spanish tropical tuna purse seiner fleet operating in the Atlantic, Indian and Pacific Oceans	Un nouveau pas en avant : système de vérification du code de bonnes pratiques dans la flottille espagnole de senneurs tropicaux qui opère dans les océans Atlantique, Indien et Pacifique	Otro paso adelante: sistema de verificación del código de buenas prácticas en la flota española de cerqueros tropicales que opera en los océanos Atlántico, Índico y Pacífico.
j-FAD_32	FAD tuna fisheries in Tunisia: the case of dolphinfish (DOL)	La pêche thonière aux DCP en Tunisie : cas de la coryphène (DOL)	Pesca de túnidos con DCP en Túnez: caso del dorado (DOL)
j-FAD_33	Position Statement by the International Pole & Line Foundation	Déclaration de position de International Pole & Line Foundation	Declaración de posición de International Pole & Line Foundation
j-FAD_34	Mitigation of Silky shark bycatch in Tropical Tuna purse seine fisheries	Atténuation des prises accessoires de requins soyeux dans les pêcheries de senneurs ciblant les thonidés tropicaux	Mitigación de la captura fortuita de tiburón jaquetón en las pesquerías de cerco de túnidos tropicales.
j-FAD_35	What does well-managed FAD use look like within a tropical purse seine fishery?	A quoi ressemble une gestion correcte de l'utilisation des DCP dans une pêcherie de senneurs tropicaux ?	¿Cómo sería una gestión correcta del uso de DCP en la pesquería de cerco tropical?
j-FAD_36	Activities of the ICCAT ad-hoc Working Group on FADs during 2015-2016	Activités du groupe de travail *ad hoc* de l'ICCAT sur les DCP en 2015-2016	Actividades del Grupo de trabajo ad hoc de ICCAT sobre DCP en 2015-2016

j-FAD_37	New method that combines dead reckoning and acoustic telemetry to measure fine scale movement of tuna associated with FADs	Nouvelle méthode qui combine la navigation à l'estime et la télémétrie acoustique afin de mesurer les déplacements à petite échelle des thonidés associés à des DCP	Nuevo método que combina la navegación por estima y la telemetría acústica para medir los movimientos pequeños de los túnidos asociados con DCP
j-FAD_38	Size selectivity of tuna purse seine nets estimated from FAD sets data	Sélectivité de la taille des filets de senne thoniers estimée à partir des données des opérations sous DCP	Selectividad de tallas de las redes atuneras de cerco estimada a partir de los datos de lances en DCP
j-FAD_39	Key areas for future action for the joint t-RFMO FAD WG	Domaines clefs pour les actions à venir du GT conjoint sur les DCP des ORGP thonières	Áreas clave para las futuras acciones del GT conjunto sobre DCP de las OROP de túnidos
j-FAD_40	IATTC Ad hoc Working Group on FADs: summary of 1st year of activities and Work Plan for 2017	Groupe de travail ad hoc sur les DCP de l'IATTC : résumé de la première année d'activités et plan de travail pour 2017	Grupo de trabajo ad hoc sobre DCP de la IATTC: resumen del primer año de actividades y plan de trabajo para 2017.
j-FAD_41	Review of data requirements needs and data collection systems of relevant information on tuna FAD fishing	Examen des besoins en matière de données et systèmes de collecte des informations relatives à la pêche de thonidés sous DCP	Examen de las necesidades en cuanto a datos y sistemas de recopilación de información relacionada con la pesca de túnidos sobre DCP
j-FAD_42	ICCAT Research Plans related to FADs	Plans de recherche de l'ICCAT concernant les DCP	Planes de investigación de ICCAT relacionados con los DCP
j-FAD_43	IOTC Research Plans related to FADs	Plans de recherche de la CTOI concernant les DCP	Planes de investigación de IOTC relacionados con los DCP
j-FAD_44	IATTC Research Plans related to FADs	Plans de recherche de l'IATTC concernant les DCP	Planes de investigación de IATTC relacionados con los DCP

Original: English

**MANAGING FAD CAPACITY AND IMPACT:
REVIEW OF THE IMPACTS OF FAD USE ON
FISHING CAPACITY IN THE ATLANTIC AND INDIAN OCEANS**

Daniel Gaertner [1]

To assess the FAD capacity and impact of the FAD-fishing strategy on the tuna stocks in the Atlantic and Indian Oceans the trends of some simple fishery indicators were compared. It is showed that the number of dFAD sets by fishing day increased while at the same time the number of free school sets decreased. During the EU research project CECOFAD, the total number of dFADs deployed at sea over the last ten years was estimated from different methods for the Atlantic and Indian Oceans based on the number of active DFADs per vessel provided by the French tuna association and extrapolated to the other fleets. In both Oceans the number of active dFADs increased dramatically. From data collected within the frame of the Spanish FAD management plan, it was showed that the efficiency of a purse seiner is likely related to the number of dFADs seeded but information of relevant explanatory factors, such as type of buoys, level of assistance of a supply, shared information between vessels, percentage of buoys stolen, etc., is still lacking to refine this relationship. Changes over time in proportion of type of buoys implemented by the French fleet in both Oceans and an estimate of the number of support vessels operating in the Indian Ocean were also showed. A statistical analysis based on detailed information on which purse seiners are served by each buoy tender highlights how the efficiency of a purse seiner in terms of catch rate, frequency of dFAD sets, etc., is increasing from no assistance to the exclusive use of a support vessel. One of the major results achieved by CECOFAD was the definition of a floating object (FOB) and the homogenisation of the different terms used to collect information on FAD-fishing. A floating object was defined as a FAD (Fish Aggregating Device) if it is a man-made FOB specifically designed to encourage fish aggregation at the device, while any FOB other than a FAD, *i.e*. a natural (branches, carcasses, etc.) or artificial (wreckage, nets, washing machines, etc.) object will be termed a LOG. FADs and LOGs have been then broken down into different categories depending on their features. Finally a brief summary of the recommendation measures adopted by the ICCAT was presented. The dFAD management plans have been enforced only 20 years after the introduction of the dFAD-fishing strategy but recent progress has been demonstrated in recent years. Since 2010, it has been recognized that the activities of a support vessel and the use of FADs are an integral part of the fishing effort exerted by the purse seine fleet and consequently ICCAT recently adopted recommendations in terms of limits in number of active buoys and dFADs, as well as the adoption of the collection of unofficial data related to FAD-fishing, including from buoy tender activities.

[1] IRD-UMR MARBEC, CRH, CS 30171, Av. Jean Monnet, 34203 Sete Cedex, France

Original: English

THE FAD FISHERY IN THE EASTERN PACIFIC

M. Hall and M. Roman,[1]

The fishery for tunas in the eastern Pacific made a transition from pole and line to purse seines, and expanded geographically from the Baja California coast to Central and South America. The purse seiners made sets on free swimming tuna schools (**school sets**), on tuna schools associated with dolphins (**dolphin sets**), and also on tuna schools associated with floating objects. The fishers had discovered the tendency of tunas to associate with floating objects and took advantage of that. The fishery on floating objects started based on random encounters with objects of different types, but it evolved towards the fishers modifying the encountered objects (e.g. tying two together), and adding radio equipment to relocate them.

In the IATTC database, **Log sets** are sets on "encountered objects", and **FAD sets** are sets "on objects deployed by the fishers, or found and modified to increase their attraction and to facilitate their relocation". The Log sets include all types of floating objects, including man-made objects. There are also other types of sets (e.g. on live whales) that are not discussed because they are very infrequent. For some analyses, a category of **Floating object sets**, that includes Log and FAD sets is used. In recent years, the vast majority of the sets on floating objects are made on FADs.

The FAD fishery experienced a sudden increase in the early 1990s, because of a policy adopted by some canneries that refused to buy tuna caught in trips where dolphin sets were made. The boats that had been delivering tuna to those plants started exploring alternatives, and eventually found an area that was very productive for FAD fishing. The objects deployed by the fishers evolved over time, changing some characteristics. The areas fished expanded along the equator to the west, and more recently, the fishery in the Humboldt Current system is growing in intensity.

The presentation for the Eastern Pacific (IATTC) will describe these changes, and quantify some of the operations of the fleet fishing on FADs. Some of the variables included are: Number of sets by type over time, Number of FADs deployed by vessel, characteristics of FADs, geographical distribution of effort and catches, seasonality of deployments, location of deployments, etc. As the Catch Per Set on FADs has been declining in recent years, we will explore some hypotheses that may be causing the changes.

[1] IATTC Secretariat

Original: English

PROMISING USES OF TECHNOLOGY TO MITIGATE FAD IMPACTS

Victor Restrepo and Gala Moreno[1]

Technology has made purse seine fishing for tropical tunas ever more efficient through time. FAD use, and the technology associated with FAD fishing, is a substantial contributor to this. With these increases in efficiency, there have also been increases in impacts on target and non-target species, as well as habitats. This presentation looks at using technology for a different purpose: To mitigate those impacts.

Impacts on target tunas

Tropical tunas (skipjack, yellowfin and bigeye) are targeted by various fishing gears such as purse seines, longlines, pole-and-line, gillnet, and others. Skipjack stocks are generally in good shape globally. However, some bigeye and yellowfin stocks are subject to overfishing. Since large quantities of small individuals of these species (especially bigeye) are caught in FAD fisheries, it is useful to investigate whether technology can provide tools to reduce such impacts.

The primary focus of research on this is improving the information collected by echo-sounders for species discrimination. Acoustics are used by fishing masters onboard most industrial purse seine vessels to estimate the biomass of tuna schools before setting on them, and for chasing free-swimming schools. Echosounders are also used in the GPS buoys (also called "beacons") attached to many FADs (many fleets equip all of their FADs with these), to provide an estimate of the tuna biomass under each FAD remotely. This information is used by fleet managers and fishing masters to decide what areas and which FADs to visit. The research focuses on using multiple frequencies in order to discriminate skipjack (which have no swim-bladder) from bigeye and yellowfin (which do).

The promise that this technology holds is that fishers could make informed decisions to, for example, avoid areas with a high proportion of bigeye tuna, or with a high proportion of small bigeye and yellowfin individuals, based on remote readings from echo-sounder buoys. Similarly, decisions could be made *in situ* before a set using onboard equipment.

Impacts on non-target species

The tropical tuna purse seine fishery also impacts non-target species with all set types. By-catch tends to be higher on FAD sets and can impact vulnerable species such as silky sharks.

There are many different FAD designs being used in the different oceans. In some cases, the submerged structure of the FADs uses old nets with mesh sizes that are large enough to entangle sharks (particularly small specimens of silky sharks). This type of ghost fishing is very difficult to detect because an entangled shark may only last a couple of days in that situation before sinking to the bottom. Nevertheless, research shows that the magnitude of the problem could be very large if not properly addressed.

The floating structures of FADs ("rafts") can also be wrapped with netting, which can entangle sea turtles that want to rest on them.

Through collaboration between scientists and fishers, non-entangling FAD designs have been developed to minimize shark and turtle entanglement, while still catching tunas. Non-entangling FADs are now mandatory in ICCAT, and their partial introduction since 2014 is required in the IOTC. Some fleets elsewhere are adopting non-entangling policies voluntarily.

[1] International Seafood Sustainability Foundation <vrestrepo@iss-foundation.org>

Impacts on sensitive habitats

Some unknown proportion of FADs are lost or not recovered and end up sinking or drifting into coastal areas, often beaching in sensitive areas like coral reefs. FADs require flotation, and over the last few decades a good part of that flotation has been made of materials that use plastics, such as PVC pipes. In addition, the hanging structure is often made with old nets made of nylon. Therefore, lost FADs can contribute to marine debris.

Current research is focused on constructing FADs that use naturally biodegradable materials (wood, cotton ropes, etc.). Substantial research is ongoing by fleets and researchers alike, with some promising designs that are largely biodegradable and still aggregate tunas. One challenge for fuller biodegradability remains the need for the FAD to float with all of the weight it has underneath. But research on this is also ongoing.

Technology is also being used in some partnerships between fleets and environmental NGOs so that if a FAD is drifting towards a sensitive reef, the NGO is alerted automatically and the FAD can be intercepted.

One issue that has not received sufficient attention is that of lost echosounder buoys. These are made of plastics, microchips and batteries. In cases where FADs sink to the bottom of the ocean, it would be useful to have the buoys self-detach at a predetermined depth.

Original: English

HOW FAR ARE WE FROM DISCRIMINATING TUNA SPECIES AT FADS?

Gala Moreno[1], Guillermo Boyra[2], Igor Sancristobal[2], Jefferson Murua[2], Jeff Muir[3], Isabel Perez-Arjona[4], Victor Espinosa[4], Susana Cusatti[5], Vernon Scholey[5], Daniel Margulies[5], Kim Holland[3] and Victor Restrepo[1]

Most large-scale tropical tuna purse seiners have scientific-degree acoustic equipment onboard (sonars, echo-sounders and echo-sounder-buoys) that are used when searching for tunas. These acoustic tools have the potential to provide the technological means to fish in a more sustainable way using FADs, by providing species composition before the net is set and also by providing independent indices of abundance for the target species (Moreno *et al.*, 2016).

In order to effectively use this acoustic information and assess the abundance of any species, it is fundamental to have an estimation of the mean target strength (TS) value and the TS-length relationships of the fish species. TS values allow determining sizes while frequency response allows discriminating between species before fishing. TS values of other species are well known and are routinely being used to obtain independent indices of abundance and to study their behavior, while frequency response data are used to identify species prior to fishing. However, consistent TS-length relationships and frequency response for tropical tunas has not been studied in depth.

In order to untap the potential of the data provided by fishers' echo-sounder buoys and the equipment onboard purse seiners, ISSF in collaboration with AZTI, IATTC, the University of Hawaii and the University of Valencia, has been working since 2014 to obtain fundamental information of the acoustic properties of tropical tunas. This communication is a summary of where we stand today in terms of knowledge, technology, and suitability of this data to support science and address tuna mortality.

State of knowledge of acoustic properties of tropical tunas

Consistent TS-length relationships and mean TS for *in situ* skipjack and bigeye tunas have been obtained through two research cruises in the Central Pacific and Atlantic Oceans, where almost monospecific aggregations of skipjack and bigeye tunas where found at FADs (Restrepo *et al.* 2016). Measurements of yellowfin tuna TS where conducted for tunas in captivity at IATTC's laboratory in Achotines (Panama) and analyses are being conducted to obtain consistent TS-length relationship for yellowfin tuna.

Frequency response of skipjack (which has no swim-bladder), showed a stronger response at higher frequencies compared to bigeye and yellowfin tuna (which do have swim-bladders), which showed a stronger response at lower frequencies. The differences were substantial enough to give a robust pattern useful for acoustic discrimination between skipjack and the other two species caught at FADs. As soon as TS for yellowfin at different frequencies is available, it will be possible to obtain a discrimination mask algorithm to determine the proportion of the received echo that comes from non swim-bladder (skipjack) and swim-bladder (yellowfin and bigeye) tunas.

In order to discriminate between yellowfin and bigeye tunas and top help understand the variability of TS values, ongoing research comprises (i) the determination of longitudinal sound speed propagation, density and absorption for the three tropical tuna species´ tissues: fillet flesh and spine bone (ii) the development of numerical tests of TS simulation with models based in the Method of Fundamental Solutions (MFS).

State of technology of echo-sounder buoys

This new information on the frequency response of tunas has not been incorporated yet in the echo-sounders and sonars onboard purse seiners neither in echo-sounder buoys attached to FADs, thus there is

[1] International Seafood Sustainability Foundation (ISSF)
[2] AZTI, Spain
[3] University of Hawaii, USA
[4] Universidad de Valencia, Spain
[5] Inter-American Tropical Tuna Commission, USA

no echo-sounder buoy nowadays with discrimination capabilities for the different species of tunas found at FADs simultaneously. However, some brands have incorporated two contrasting frequencies (a low and a high frequency) in their new models, which demonstrates the evolution of the technology towards identifying species. Likewise, TS-length relationships have not been incorporated yet within the algorithms that echo-sounder buoy manufacturers use to convert the acoustic signal into biomass estimates, but existing and future projects between scientists and buoy manufacturers could provide the means to obtain better biomass estimates by species through this technology.

Suitability of echo-sounder buoys to support science

Although tuna species discrimination has not been achieved yet, echo-sounder buoys can be used in their current form to support science. Biomass estimates provided by fishers' echo-sounder buoys have been already used to study social and diel behavior of tunas at FADs and environmental preferences of tunas. Other promising areas of research using echo-sounder buoy data are studies on (i) the associative behavior of tunas at FADs; (ii) the effect of different densities of FADs on the associative behavior; (iii) independent indices of abundance of tunas, (iv) testing of the 'ecological trap hypothesis' and (v) FAD colonization processes, among others. The amount and quality of data provided by these tools could improve the management of tropical tuna fisheries by filling important knowledge gaps. For this purpose, an appropriate collaborative scheme between ship-owners, scientists and buoy manufacturers to share data and knowledge is needed.

Suitability of acoustic equipment (echo-sounder buoys and echo-sounders onboard) to address tuna mortality

Another potential use of these data is informing fishers - remotely - about the species composition found at their FADs, so that they can avoid catches of undesired species and sizes of tunas. Nowadays, there is no commercial echo-sounder with this capability, but the technology could be ready in the near future. However, in order to effectively use echo-sounders and acoustic equipment onboard to address tuna mortality, other conditions need to be met:

1. Variability exits between FAD-aggregations in skipjack-yellowfin-bigeye composition within the main PS fishing areas. If tuna species composition does not change among regions, the discrimination capability has no value to make the “good choice” of where to fish.
2. An objective system to inform about the species composition at FADs that is independent from the skipper's skill.
3. An incentive, either regulatory or market-based, to encourage skippers to make good choices.

Conclusion

In recent years, significant progress has been made to obtain fundamental information of acoustic properties of tropical tuna species to make available data from echo-sounder buoys and acoustic equipment onboard purse seiners to support science and to address tuna mortality. Likewise, models have been developed to obtain fishery-independent indices of abundance using this information. Technology can allow obtaining better quality data. It is time to build appropriate collaborative schemes between ship-owners, buoy manufacturers and scientists working with these data in different oceans, so that lessons are shared to effectively use this information for tropical tuna management.

References

Moreno, G., Dagorn, L., Capello, M., Lopez, J., Filmalter, J., Forget, F., Sancristobal, I., et al. 2016. Fish aggregating devices (FADs) as scientific platforms. Fisheries Research, 178: 122-129. http://dx.doi.org/10.1016/j.fishres.2015.09.021

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

Original: English

FAD STRUCTURE EVOLUTION: FROM BIODEGRADABLE FADS TO BIODEGRADABLE FADS

Gala Moreno[1], Riyaz Jauharee[2], Jeff Muir[3], Kurt Schaefer[4], Shiham Adam[2], Kim Holland[3], Laurent Dagorn[5] and Victor Restrepo[1]

In the 1980´s most "FADs" used in purse seine fishery were biodegradable: Logs and branches coming off rivers. During decades since then, FAD structure design has been modified in order to increase the efficiency of fishing with FADs, i.e. long-lasting, stronger materials at FADs and deeper and sophisticated structures for greater tuna aggregation power (from fishers' point of view).

In 2013, research conducted in the Indian Ocean quantified a major, previously unknown source of shark mortality: Entanglement in drifting fish aggregating devices (Filmalter *at al*., 2013). Action was urgently taken through the collaboration of scientists and European purse seine fleets to find a solution for this source of mortality of sharks. Nowadays, the solution is clear: The use of non-entangling FADs to avoid ghost fishing of sharks while allowing for successful tuna fishing.

Those events showed the efficacy of modifying the structure of FADs to address mortality on non-target species, as well as the effectiveness of the collaboration between fishers and scientists to find practical and agile solutions to impacts of FADs. In the same way, ISSF with the collaboration of fishers and scientists from different research institutes, is seeking solutions to address mortality of bigeye tuna and the impacts of FAD beaching events, by changing the structure and materials used in FADs. This communication summarizes ongoing research.

FAD structure modification to address tuna mortality

ISSF and IATTC together with the industry (NIRSA from Ecuador) is researching the potential effect of changing the structure of FADs to address tuna mortality, by assessing the performance of shallow versus deep structures of FADs on the capacity of aggregating bigeye tunas. For this purpose, 150 shallow FADs and 150 deep FADs have been deployed in the Eastern Pacific Ocean and are being monitored through echo-sounder buoy signals and catches made while setting on those FADs. Data from this project are still being collected (Restrepo *et al.,* 2016).

FAD structure modification to address impacts of lost FADs

Typically today, FADs are made using as main components petroleum products such as plastic, PVC, nylon nets, etc., that degrade slowly, causing a growing accumulation of these products in coastal areas year on year. The impacts associated to FAD beaching events are damages to sensitive coral reefs, marine pollution as well as ghost fishing. Since 2015, ISSF has been working on finding solutions to the impacts of lost FADs that become marine debris.

Biodegradable ropes tests at anchored FADs in Hawaii

This study, done in collaboration with ORTHONGEL (EU-France) and the University of Hawaii had the objective to evaluate the time evolution of natural materials that could be used to build biodegradable drifting FADs, deployed in tropical waters. Coir (coconut husk fiber) was tested at an anchored FAD offshore of Kaneohe, Oahu and in the lagoon at the University of Hawaii's Institute of Marine Biology. The experiment was conducted during 2015. The material tested decomposed quite quickly and in such a way that its impact on beaches and reefs could be expected to be minimal and quite short-lived. Further, very low biofouling was observed on any of the samples. This would indicate that it is suitable material for sub-

[1] International Seafood Sustainability Foundation (ISSF), 601 New Jersey Ave NW Suite 220 Washington DC 20001
[2] Marine research institute, Maldives
[3] University of Hawaii, USA
[4] Inter-American tropical tuna commission, USA
[5] Institut de recherche pour le development, France

surface "tails" on FADs if appropriate strand dimensions could be manufactured. However, the quite rapid decline in tensile strength suggests that this material would be sub-optimal for binding FAD float components together. This weakness could possibly be overcome by increasing the size (diameter) of the strands used for this function (Restrepo *et al*., 2016).

Biodegradable ropes tests in Maldives

The objective of this work, done in collaboration with the Marine Research Institute of Maldives, is to evaluate the time evolution of three different rope types made of (i) cotton, (ii) sisal and cotton and (iii) sisal, cotton and linen, in different configurations. Sample ropes were deployed in two different sites, in offshore waters attached to a mooring rope, simulating a FAD in oceanic waters and in the lagoon close to the reef in Maniyafushi island, simulating the arrival of a FAD to the coast. The aim is testing the evolution of the ropes in two different environments so that the behavior of the ropes while "at sea" in a drifting FAD and when a beaching event occurs is studied. This research is ongoing. Preliminary results show higher resistance for 100% cotton ropes and more degradation in the reef compared to the oceanic site.

Workshop on the use of biodegradable FADs

While experiments like the above in controlled conditions allow for obtaining results of the most appropriate materials to be tested in real fishing conditions, FAD design types using such materials as well as a protocol to test them in real at-sea conditions need to be addressed. ISSF organized a workshop in 2016 with scientists and fishing masters from the Indian, Atlantic and Pacific oceans with the following main objectives:

(i) to determine the lifetime required for a FAD to be used as an efficient fishing tool in the different oceans.
(ii) to design new biodegradable FAD structures for the different oceans.
(iii) to define the protocol (or strategy) to test biodegradable FADs in real fishing conditions through the cooperation of the fleets.

Main outcomes of this workshop were that FADs should last from five months to one year depending on the ocean. In total, seven different types of biodegradable FADs were designed during the workshop by fishers and scientist for the 3 oceans and a protocol for at-sea trials was defined (Moreno *et al*., 2016).

Tests of biodegradable FADs in real fishing conditions

One of the main difficulties that can be encountered when testing biodegradable FADs in real fishing conditions is that a high percentage of FADs deployed by a given vessel is usually set on and repurposed by other vessels. This high turnover makes it difficult to revisit individual FADs and get information on how the biodegradable structure evolves over time. Thus, in order to obtain a significant amount of data to achieve conclusive results, it is necessary to deploy a large number of FADs. Before such a large-scale endeavor is attempted, ISSF in collaboration with INPESCA (EU-Spain) has initiated a small-scale pilot to identify the potential difficulties that could be found in the large-scale experiment. Biodegradable FADs have been deployed in the Indian Ocean, utilizing lessons learned from the Hawaii and Maldives controlled tests as well as the recommendations from the 2016 workshop. This pilot has been recently initiated and data are being collected.

Conclusions

While the first floating objects used in the purse seine fishery were usually naturally biodegradable ones, they were largely replaced with more efficient FADs with man-made structures that often contain plastics and nylon netting. Today, there are concerns about marine debris and the potential damages by lost FADs that end up in sensitive habitats. For this reason, there is a need to return to biodegradable floating objects. An immediate obvious solution is not available and research is required in which scientists and fishers collaborate to come up with designs that minimize these impacts on the ecosystem, while still attracting tunas. This document presents several ongoing initiatives.

References

Filmalter, J.D., Capello, M., Deneubourg, J.-L., Cowley, P.D. and Dagorn, L. (2013). Looking behind the curtain: quantifying massive shark mortality in fish aggregating devices. Frontiers in Ecology and the Environment, 11: 291–296. doi:10.1890/130045.

Moreno, G., Restrepo, V., Dagorn, L., Hall, M., Murua, J., Sancristobal, I., Grande, M., Le Couls, S., Santiago, J., 2016. Workshop on the use of biodegradable fish aggregating devices (FAD). ISSF Technical Report 2016-18A. International Seafood Sustainability Foundation, Washington, D.C., USA.

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

Original: English

ADOPTION LEVELS OF ENTANGLEMENT-REDUCING FAD DESIGNS BY TUNA PURSE SEINE FLEETS IN DIFFERENT OCEANS

Jefferson Murua[1], Gala Moreno[2] and Victor Restrepo[2]

Extended abstract

Traditionally drifting FADs were constructed with netting to cover the floating raft and formed most of the underwater hanging structure. This net was recycled from old tuna purse seine nets, which have a large stretched mesh (e.g. > 3 inches). Unexpected high shark entanglement levels in FADs were found in a study conducted in the Indian Ocean at a time when loosely hanging panels of wide-mesh net were the norm, Scientists and fishers from many fleets have taken action to mitigate the problem caused by High Entanglement Risk (HER) FADs. Since 2010, large-scale pilot trials by the EU tuna purse seiner fleets to move away from HER FADs, fomented by industry-scientist participatory projects (e.g. MADE, Ecofad, ISSF Skipper Workshops) led to a voluntary shift towards FAD designs which minimized chances of "ghost fishing" of sharks, and turtles. In addition, acceptance levels for the idea of adopting Non-Entangling FADs (NEFADs) increased in many fleets, as skippers became more familiar with alternative FAD designs and learned that tuna catches for HER and NEFADs were equivalent. The need to limit the impact of FAD entanglement is further reinforced by the fact that numbers of FADs in all oceans have been increasing in the last decade.

In recent times, there have been substantial advances in the application of FADs that minimize entanglement. At present ICCAT has adopted measures that requires the use of non-entangling FADs (NEFADs) since January 2017, meanwhile IOTC regulations have provided for a gradual adoption of NEFADs from 2014 onwards, and IATTC encourages the utilization of NEFADs. The only tuna RMFO which has not explicitly advocated the adoption of NEFADs, despite their demonstrated conservation benefits of this design, is the WCPFC. This document describes the use of types of FADs according to their entanglement risk in different fleets of the world. The information is based on anonymous captain and navigator anonymous questionnaires and open question discussions with many fishers attending International Seafood Sustainability Foundation (ISSF) Skippers' Workshops for fleets including Spain, France, Ghana USA, South Korea, China, Taiwan, Indonesia, Peru, and Ecuador. ISSF scientists were also able to contrast some of this information through available observer information, research cruises, or vessel visits at ports where many of the FADs are constructed nowadays. Implementation of Lower Entanglement Risk (LER) FADs (i.e. FADs made with small mesh netting or netting tightly tied into bundles) and NEFADs (i.e. no netting used in their construction) is practically complete in the Indian and Atlantic Ocean, and is being increasingly adopted by fleets in the Eastern Pacific Ocean. In addition, The LER and NEFAD designs used by most fleets are inexpensive as for example they either use the same materials, like in FADs with netting tied into bundles, or require a lower amount of materials, like only ropes and no raft cover for NEFADs. In other instances, canvas materials or cheap second hand small mesh nets for small pelagics are used. According to skippers' comments, they have stopped seeing turtle or shark entanglements since they use these adapted FADs. Even if this general perception by fishers is true, scientific trans-oceanic studies that evaluate shark entanglement rates are lacking. Especially those including examination of "cryptic" entanglement events that go unobserved, as sharks may entangle in FADs only for a brief period of time (e.g. few days) before falling off. Also needed is research to evaluate if the rate of turtle or shark entanglement in LER and NEFADs is significantly different. These two categories may perhaps be an artefact and both could fall under the label of NEFADs if proven to have similarly low entanglements. This knowledge may also aid in the harmonization of standards and a clear definition of NEFADs across RFMOs.

At present only FADs in the WCPO are mostly of the HER type, made with wide mesh netting. In this Ocean FADs tend to be deep (e.g. 40-80 m), which means more entangling netting material is utilized. Note that FADs with modifications to reduce entanglement have continued to work and catch tuna well in three oceans already, so there is no apparent reason why drifting LER and NEFADs would not work in the WCPO. In fact, anchored FADs by WCPO fleets like Indonesia or Philippines are prime examples of NEFADs, as they are constructed with zero netting. Given that the WCPO is the largest tuna fishing region in the world and many inter-island regions are home to key shark populations, it would be advisable to move away from potentially entangling-FAD designs.

[1] AZTI-Tecnalia, Txatxarramendi Ugartea z/g, Sukarrieta – Bizkaia (Spain), Tel.: +34 946574000
[2] ISSF, 805 15th Street NW, Washington, DC, 20005, USA, Email: jmurua@azti.es

Original: English

DEPLOYMENT OF NON ENTANGLING FADS AND RELATED ACTIVITIES MONITORED BY AN ELECTRONIC MONITORING SYSTEM IN THE INDIAN OCEAN

G. Legorburu[1], J.P. Monteagudo[2]

Electronic monitoring systems (EMS) are used in some fisheries to collect the same types of scientific information that human observers can collect. Activities from five supply vessels operating in the Indian Ocean are being recorded with the Seatube EMS system from the company SATLINK. Recordings of the Seatube system are being reviewed by DOS (Digital Observer Services) by trained observers with previous at sea experience. In this paper, we present preliminary analyses for a combined total of 8 fishing trips and 370 days at sea, comparing 2129 activity events recorded on logbooks by skippers and 2244 activity events identified during EMS record review. The elements being compared include materials and FAD configurations at deployment and FAD related activities during the trip. Preliminary results show a significant level of coincidence, suggesting the system could be suitable to verify compliance with monitoring, design and deployment of FADs requirements set by IOTC CMM 15-08.

[1] Digital Observer Services (DOS), Spain
[2] Organización de Productores Asociados de Grandes Atuneros Congeladores (OPAGAC), Madrid, Spain

Original: English/Spanish

SPANISH FADs LOGBOOK: SOLVING PAST ISSUES, RESPONDING TO NEW GLOBAL REQUIREMENTS

Mª Lourdes Ramos[1], José Carlos Báez[1], Maitane Grande[2], Miguel A. Herrera[3], Jon López[4], Ana Justel[5], Pedro J. Pascual[1], María Soto[1], Hilario Murua[4], Anertz Muniategi[6], Francisco J. Abascal[1]

SUMMARY

A new renewed version of the Fish Aggregating Device logbook (FAD) is presented to compile data within the framework of the National FAD Management Plan conducted by the Spanish General Secretariat of Fisheries (Ministry of Agriculture and Fisheries, Food and Environment), in collaboration with the Spanish Institute of Oceanography (IEO - Ministry of Economy, Industry and Competitiveness). This updated version is intended for Spanish tuna freezer purse sein fleets that target tropical tunas (yellowfin, skipjack and bigeye) to comply in the Atlantic, Indian and Pacific Oceans.

The IEO, the AZTI Foundation, the International Seafood Sustainability Foundation (ISSF), OPAGAC-AGAC (*Organización de Productores de Atún Congelado*) and ANABAC (*Asociación Nacional de Armadores de Buques Atuneros Congeladores*) have collaborated since June 2016 with the intention of implementing a new format of the Spanish FAD logbook introduced in 2010. The objectives pursued in this process were as follows: i) resolve the problems encountered in the previous format, ii) develop simple instructions for the Spanish fleet and iii) respond to all the current requirements of tuna Regional Fisheries Management Organisations (RFMOs).

The Spanish tuna purse seine fleet have started to use this format at the beginning of 2017 and, since then, contact has been maintained with the captains through the shipowning companies, mainly ALBACORA S.A., collecting issues which were encountered and adapting suggestions to the format of this logbook. This work has been carried out in coordination with the companies stated in the abovementioned paragraph. This document describes the fields in the standard form, including the improvements obtained from these conversations.

The main reasons for the improvement of this FAD logbook were:

a) Provide the fleet with a version that includes a simple format adapted to its use on board, integrating concise guidelines to increase the quality of the data received by: i) merging the inventory and activity forms, ii) including instructions in the same file, iii) providing examples that include the main activities conducted by the FAD tuna purse seine fleet, iv) simplifying the identification of FADs, using the unique identifier of each buoy, as provided by the manufacturer, v) excluding unnecessary data and vi) providing a user's guide with photographs.

b) Facilitating data processing by: i) organizing data fields according to their subsequent processing, ii) including all required fields to comply with current RFMO FAD data requirements.

This document analyses the new format of the FAD logbook, field by field, pointing out the main problems encountered in previous versions and describing the improvements adopted.

A historical overview is presented of the measures adopted by the four competent RFMOs in the three oceans where tropical tuna purse seine fishing is conducted: The Inter-American Tropical Tuna Commission (IATTC), the International Commission for the Conservation of Atlantic Tunas (ICCAT), the Indian Ocean Tuna Commission (IOTC) and the Western and Central Pacific Fisheries Commission (WCPFC). This revision focuses on the request for data related to FAD characteristics and the activities carried out with them by this fleet.

[1] Spanish Institute of Oceanography. Canary Oceanographic Center. Post office box 1373. 38080 Santa Cruz de Tenerife. Canary Islands (Spain)
[2] ALBACORA S.A. C/ Polígono Landabaso, 48370 Bermeo, Bizkaia (Spain)
[3] OPAGAC. C/ Ayala, 54, 2º A, 28001 Madrid (Spain)
[4] AZTI-Tecnalia. Herrera Kaia, Portualdea z/g, 20110 Pasaia, Gipuzkoa (Spain)
[5] ISSF. Francisco Giralte, 2. 28002 Madrid (Spain)
[6] ANABAC. Txibitxiaga, 24 Entreplanta. Apartado 49. 48370 Bermeo, Bizkaia (Spain)

Likewise, the data currently requested by each RFMO and those provided, including this new format, are presented.

Although a lot of modifications have been made as regards to the content, the following are the most significant:

a) Use the number of the buoy as the FAD identifier as provided by the manufacturer. The number on board the floating structure caused problems as regards monitoring.

b) Add the "Modification over previous object" activity to monitor the life of FAD components.

c) Locate the drifting objects which are not "marked" by a buoy more easily.

d) Include catch data of the three main target species (yellowfin, skipjack and bigeye).

e) Incorporate drop-down menus aimed at adapting them to the experiment including new components (e.g.: biodegradable).

f) Deduct the non-drifting objects from the components registered on board (mesh size, open net or "in a sausage", net exposed to the sea or not, etc.).

All in all, this new FAD logbook format allows to collect all the different requirements by RFMOs with the aim of improving the quality of data, using simple tools that can be used on board.

This work concludes that the standardization of forms, tools and guidelines among the RFMOs is recommended to improve data integration and processing. Moreover, it should be underlined that there is little information to justify the numerous fields that are currently registered. Future analysis, feasible in the short-term, will enhance the commitment between the effort made to integrate and process the information and the benefits this provides. Finally, the importance of involving all the sectors in the development of successful FAD management plans should be pointed out. This work is an example of collaboration between scientists, shipowners and captains.

Appendix

SPANISH FADs LOGBOOK: SOLVING PAST ISSUES, RESPONDING TO NEW GLOBAL REQUIREMENTS

Mª Lourdes Ramos[1], José Carlos Báez[1], Maitane Grande[2], Miguel A. Herrera[3], Jon López[4], Ana Justel[5], Pedro J. Pascual[1], María Soto[1], Hilario Murua[4], Anertz Muniategi[6], Francisco J. Abascal[1]

1. Introduction

Drifting floating objects, not only man-made but also with a natural origin, have been regularly used by the tuna purse seine fishery in the tropical oceans of the world since the late 1980s and early 1990s (Fonteneau *et al*. 2015) to aggregate targeted species and increase fishing efficiency (**Figure 1**). Tuna catches associated to objects by the Spanish tropical purse seine fleet have accounted on average for 56%, 70%, 88% and 93% of the yearly catches in the Atlantic, Indian, Eastern Pacific (EPO) and Western Pacific Oceans (WPO), respectively for Spanish tropical tuna purse seine fishery (**Figure 2**). If these catches are grouped into five-year periods, a marked increase is observed in the global trend from almost a 60% in 1991-1995 period to nearly an 80% for the last five years analyzed (2011-2015) (**Table 1** and **Figure 3**).

The increasing use of drifting FADs by tropical tuna purse seiners and its potential effects on target and non-target species populations and ecosystem (i.e., marine pelagic and vulnerable coastal areas) is one of the major concerns of t-RFMOs. Evaluating the level of use and the operational changes of the fleet through time (i.e., number of FADs deployed and materials used for its construction) is essential for correct FAD-fishing assessment and the reliable analyses of tropical tuna catches. In this sense, efforts are being made to collect detailed information of FAD-related activities. Since 1999 the Inter-American Tropical Tuna Commission (IATTC) is collecting information on FAD structures and components in the EPO (**Figure 4**) and the International Commission for the Conservation of Atlantic Tunas (ICCAT) has been requesting this information since 2011 for the Atlantic Ocean FAD-fisheries (ICCAT 2011). Similarly, the Indian Ocean Tuna Commission (IOTC) has requested information on FADs since 2001 (IOTC 2001) (**Figure 5**). The Western and Central Pacific Fisheries Commission (WCPFC) FAD data are collected by the observers on board (WCPFC 2016).

Due to the complexity of this fishing strategy and activities and the lack of unified formats and criteria for the data collection, the information collected so far by the skippers and available for analysis has been of limited utility. Therefore, efforts from all the stakeholders are required to improve the collection of FAD-related data in a comprehensive way.

The FAD management plan resolution was agreed in ICCAT in 2011 and amended in 2013. The Spanish Ministry of Agriculture and Fisheries, Food and Environment, in close collaboration with the IEO and the Spanish tropical tuna purse seine fleet organizations (ANABAC/OPAGAC), laid down a Fish Aggregating Device Management Plan for its national fleet in 2010 which has been running since then. The preliminary data and results were presented in Delgado *et al.* (2015), where it was stated that "*it is worth to note that this plan has been the first initiative of this kind adopted by a CPC member of tuna RFMOs, and can be considered as a pioneer and the seed for the implementation of FAD management plans in Tuna RFMOs. In fact, the Spanish FAD Management Plan has been used as a template and model in Tuna RFMOs and the agreed FAD Management Plans of all Tuna RFMOs included the elements developed in the Spanish FAD Management Plan*".

From January 2017, the tropical purse seine fleet in the Eastern Pacific Ocean is recording FAD data in a new logbook form (IATTC 2016a), and the Spanish purse seiner fleet in the Atlantic, Indian and Pacific Oceans is beginning to use the new version of the Spanish FAD logbook presented in this document (**Annex 1**), an updated version of the logbook first introduced in 2010 (Delgado de Molina *et al.* 2013).

The aim of the present paper is to summarize the issues encountered when analyzing the data collected by skippers using the original FAD logbook, and discuss the solutions agreed in order to improve the data collection system and data quality. The new format presented here is the result of a collaborative work between the scientific bodies and the fishing industry, which integrates all the data requirements of the t-RFMOs in a single logbook with a user-friendly format for the skippers.

2. On the objectives, resolutions and FAD data required by t-RFMOs

The main objectives pursued and reasons to improve the current Spanish FAD logbook form are:

a) Providing a simple format adapted to be used by the crew on board with clear and concise guidelines which aim to increase data quality by: i) merging the inventory and activity forms, ii) including templates and instructions in a single file, iii) including examples of the main FAD operations performed by purse seiner vessels iv) simplifying the identification of FADs, using the unique identifier of the buoy, as provided by the manufacturer and followed by the skipper, v) avoiding filling in more data than needed and vi) attaching a user's guide with photographs.

b) Facilitating data processing by: i) organizing data fields according to their succeeding processing, ii) including all fields needed to comply with current FAD data requirements by t-RFMOs (**Figure 6**).

c) Having an easy to modify tool for future requirements and research.

The FAD report requests and data requirements by t-RFMO are detailed below:

IATTC data requirements:

- In 1998 and 1999, the IATTC expressed its concern about tuna catches and bycatch associated with FADs in two separate resolutions (IATTC 1998) (IATTC 1999). As a consequence, scientists recommended banning supply vessels in EPO and limiting the number of FADs on board. A working group was established to monitor the relationships between certain FAD characteristics and tuna catch rates. In 2004, the IATTC recommendations focused on non-entangling FAD designs, particularly for sea turtles (IATTC 2004). In 2013, this RFMO edited the first resolution on data collection and analyses on FADs (IATTC 2013), which was refined till ongoing C-16-01 resolution (IATTC 2016b). This resolution requests CPCs to collect the following information at each interaction with a FAD:

    i. Position;
    ii. Date;
    iii. Hour;
    iv. FAD identification[1];
    v. FAD type (e.g., drifting natural FAD, drifting artificial FAD);
    vi. FAD design characteristics (dimension and material of the floating part and of the underwater hanging structure);
    vii. Type of the activity (set, deployment, hauling, retrieving, loss, intervention on electronic equipment, other (specify));
    viii. If the activity is a set, the results of the set in terms of catch and bycatch; and
    ix. Characteristics of any attached buoy or positioning equipment (positioning system, whether equipped with sonar, etc.).

From January 2017, this information is being collected by the Spanish purse seine fleet in a logbook edited by the IATTC (**Figure 7**). This information has also been collected in the Spanish FAD logbook since 2012. Most recently, the IATTC Secretariat has also instructed the observer programmes to record the unique identifier established by Resolution C-16-01 in the Floating Objects Form (**Figure 4**).

[1] CPCs shall obtain unique alphanumeric codes from the IATTC staff on a periodic basis and distribute those numbers to the vessels in their fleets for FADs that may be deployed or modified, or in the alternative, if there is al-ready a unique FAD identifier associated with the FAD (e.g., the manufacturer identification code for the attached buoy), the vessel owner or operator may instead use that identifier as the unique code for each FAD that may be deployed or modified.
The alphanumeric code shall be clearly painted in characters at least 5 cm in height. The characters shall be painted on the upper portion of the attached radio or satellite buoy in a location that does not cover the solar cells used to power the equipment. For FADs without attached radio or satellite buoys, the characters shall be painted on the uppermost or emergent top portion of the FAD. The vessel owner or operator shall ensure the marking is durable (for example, use epoxy-based paint or an equivalent in terms of lasting ability) and visible at all times during day-light. In circumstances where the observer is unable to view the code, the captain or crew shall assist the observer (e.g. by providing the FAD identification code to the observer).

ICCAT reporting obligations on FADs and on support vessels (yearly):

- From 2011, ICCAT recommended to register FAD activities (deployments, retrievals and sets) in fishing logbooks, identifying these devices with a code (ICCAT 2011). The first guidelines for the preparation of FAD Management Plans were edited in 2013, and are continuously under revision since then (ICCAT 2013, 2014, 2015 and 2016). Currently, ICCAT requirements in FADs logbooks for purse seine, baitboat and support vessels are as follows (**Figure 8**) (ICCAT 2016a):

(a) Deployment of any FAD

i. Position
ii. Date
iii. FAD type (anchored FAD, drifting artificial FAD)
iv. FAD identifier (i.e., FAD Marking and buoy ID, type of buoy – e.g. simple buoy or associated with echo-sounder)
v. FAD design characteristics (material of the floating part and of the underwater hanging structure and the entangling or non-entangling feature of the underwater hanging structure)

(b) Visit on any FAD

i. Type of the visit (deployment of a FAD and/or buoy[1], retrieving FAD and/or buoy, strengthening/consolidation of FAD, intervention on electronic equipment, random encounter (without fishing) of a log or a FAD belonging to another vessel, visit (without fishing) of a FAD belonging to the vessel, fishing set on a FAD[2])
ii. Position
iii. Date
iv. FAD type (anchored FAD, drifting natural FAD, drifting artificial FAD)
v. FAD identifier (i.e., FAD Marking and buoy ID or any information allowing to identify the owner)
vi. If the visit is followed by a set, the results of the set in terms of catch and by-catch, whether retained or discarded dead or alive. If the visit is not followed by a set, note the reason (e.g. not enough fish, fish too small, etc.)

(c) Loss of any FAD

i. Last registered position
ii. Date of the last registered position
iii. FAD identifier (i.e., FAD Marking and buoy ID)

The Commission also focuses on supply vessels deployment activities, requesting the number of FADs deployed per month, area, type of object and type of beacon.

Following SCRS (Standing Committee on Research and Statistics) recommendation, the Commission requests the number of FADs actually deployed on a monthly basis per 1°x1° statistical rectangles, by FAD type, indicating the presence or absence of a beacon/buoy or of an echo-sounder associated to the FAD, as well as specifying the number of FADs deployed by associated support vessels, irrespective of their flag (ICCAT 2016a).

In response to Rec. 13-01 (ICCAT 2013), the form ST08-FadsDep was created in 2014 (**Figure 9**).

[1] Deploying a buoy on a FAD includes three aspects: deploying a buoy on a foreign FAD, transferring a buoy (which changes the FAD's owner) and changing the buoy on the same FAD (which does not change the FADs owner).
[2] A fishing set on a FAD includes two aspects: fishing after a visit to a vessel's own FAD (targeted) or fishing after a random encounter of a FAD (opportunistic).

IOTC data requests:

- The IOTC asks for FAD data through Form 3FA (**Figure 10**), requiring the number of FADs visits per month, type of FAD and type of activity (IOTC 2014).

- Type of FAD:

IOTC Code	English Description
LOG	Drifting log or debris NOT located using a tracking system (radio or satellite transmission)
LGT	Drifting log or debris located using a tracking system (radio or satellite transmission)
NFD	Drifting raft or FAD with a net NOT located using a tracking system (radio or satellite transmission)
NFT	Drifting raft or FAD with a net located using a tracking system (radio or satellite transmission)
FAD	Drifting raft or FAD without a net NOT located using a tracking system (radio or satellite transmission)
FDT	Drifting raft or FAD without a net located using a tracking system (radio or satellite transmission)
ANF	Anchored FAD
DFR	Other drifting objects NOT located using a tracking system (radio or satellite transmission) (e.g. dead animal, etc.)
DRT	Other drifting objects located using a tracking system (radio or satellite transmission) (e.g. dead animal, etc.)

- Type of visit:

IOTC Code	English Description
DD	Deployment of drifting FAD
AD	Deployment of anchored FAD
DH	Retrieval/encounter and hauling of drifting FAD
AH	Revisiting and towing of anchored FAD
DR	Retrieval of drifting FAD
AR	Revisiting anchored FAD
DL	Loss of drifting FAD (tracking signal lost)
AL	Loss of anchored FAD (detached from anchorage point or damaged heavily)
DI	Retrieval/encounter, hauling, and intervention on electronic equipment of drifting FAD

- Effort: Total number of FAD visits by purse seiners, support vessels, baitboats, or boats using other gears operating under the flag of the country reporting the data. Note that this number shall include all of the FADs visited, including visits to FADs set by the same vessel that reports the visit and other types of FAD, as defined in Type of FAD above.

- FAD sets: Indicate the number of FAD visits that ended up in a set; FAD sets can be performed following the retrieval of a FAD, drifting (DH, DR, and DI), or anchored (AH and AR).

- Catches by species: including:

  a) Retained catches: catches for each species retained on board in live weight and/or number. IOTC CPC's shall provide catches for IOTC species (**Table 3**) and other species identified by the Commission (**Table 4**) and are encouraged to provide catches for all other species that are retained on board (**Appendix V; Table 5 and Table 6**). The catches of specimens for which only part/s of their bodies is retained on board shall be always reported as retained catches, in live weight.

  b) Discard levels: discard levels for each species in live weight or number. IOTC CPC's shall provide discard levels for IOTC species (**Table 3**, page 16) and other species identified by the Commission (**Table 4**). IOTC CPC's are encouraged to provide discard levels for other species of bony fish (**Table 5**), sharks (**Table 6**), marine turtles (**Table 7**), seabirds (**Table 8**), and marine mammals (**Table 9**).

WCPFC:

In the case of the WCPFC, there are no requirements on data provision. Since 2010, purse seine vessels operating in the Convention Area of this t-RFMO have a 100% observer coverage since 2010 (as established by CMM2008-01 and following Conservation and Management Measures). The Regional Observer Program includes data collection on FAD activities (WCPFC 2017). Some preliminary data have been obtained as of these observer data (Abascal *et al.* 2014).

3. New Spanish FAD logbook

The FAD data collection forms have been reviewed, modified and adapted for its use on board purse-seine and supply vessels, in response to the t-RFMOs requirements and previous experiences on data collection and processing. The new model of the Spanish FADs logbook described in this document includes the main data requested by t-RFMOs (**Figure 6**). The specific analysis of the information recorded in the logbook is presented in this section, field by field:

- Position → A fundamental problem found with these data comes from its format. It is important to provide a field easy to fill, easy to use in data processing and in accordance with the one generally used on board.

Two fields are provided in FAD logbook with a familiar format for the captains:

FADs Logbook:

Position	
Lat	**Lon**
ggmm	**gggmm**
01º30'S	009º58'W

Instructions:

	Field	Format	Description	Example
POSITION	**Lat**	ggmm	Grades (gg): Two digits, e.g. 03 (*initial 0 is not needed*) Minutes (mm): Two digits, e.g. 08 Begin with **sign '-'** for *south latitude*. Format ggºmm'N/S will automatically appear in the field	-203 (for 02º03'S)
	Lon	ggmm	Grades (gg): Three digits, e.g. 050 (*initial 0 is not needed*) Minutes (mm): Two digits (e.g. 08) Begin with **sign '-'** for *western longitude*. Format gggºmm'E/W will automatically appear in the field	5023 (for 050º23'E)

- Date and hour → The variability in the formatting of date and time usually results in bugs in data processing. Two fields are included in FADs logbook, with a familiar format for the captains. Time is recorded in GMT:

FADs Logbook:

Date	**Time (GMT)**
DDMMYYYY	**HHMM**
01/12/2017	09:01

Instructions:

Field	Format	Description	Example
Date	DDMMYYYY	Day (DD): Two digits (e.g. 15) Month (MM): Two digits (e.g. 06) Year (YYYY): Four digits (e.g. 2017) *Format 'dd/mm/yyyy will automatically appear in the field*	28092017
Time (GMT)	HHMM	Hour **GMT** (HH): Two digits (e.g. 12) Minutes (MM): two digits (e.g. 08) *Format 'HH:MM' will automatically appear in the field*	603

- FAD identification → As buoys are often re-used and some vessels renumber them in order to have an easy to use inventory on board, in the 2nd FAD Working Group of ICCAT it was concluded that the FADs should be tracked by the buoy unique ID attached to the FAD (given by the buoy manufacturer), recording in the logbook details of all changes (ICCAT 2016b). Any modification on the tracking system (i.e. buoys) of a FAD is registered in a new line, following the initial activity with the object, as "modification over previous object", allowing the individual tracking of FADs.

These fields ask for this unique buoy ID and the model (manufacturer's brand) of the buoy in order to deduce its characteristics (echo-sounder, GPS, radar reflectors, visible distance…)

An open drop-down menu with the list of most frequent models has been included to facilitate data entry. It also allows for the inclusion of free text (new models) as this technology is constantly improving:

FADs Logbook:

Buoy	
Model	**Numeric ID**
m3i+	133259

Instructions:

	Field	Format	Description	Example
BUOY	**Model**		Select from the drop-down menu the model of the buoy (d+, dl+, ds+, dsl+, te7, m3i, m4i…) In case of not being included in the list, select **"Other"** and **overwrite** the new model. Avoid generic names as: Nautical, Tunabal, Satlink…	ds+
	Numeric ID	number	Register the unique ID number used to identify the buoy (the one usually written after the model) without spaces or symbols	13448

The previous FAD forms included both the FAD and buoy IDs. Several issues were identified when trying to track FADs by these codes. Since the practical totality of FADs used by the fleet are tracked with satellite buoys, most of the skippers named the FADs with the beacon ID. Once the buoy was reused in a new FAD, it resulted in a non-unique identifier. In other instances, captains used their own codes, but these were not usually kept by other skippers. Given its simplicity, this coding resulted in frequent duplicates, as well. Therefore, it was decided to use the buoy ID as the unique identifier.

The use of the buoy ID as unique identifier has the inconvenient that it is useful as long as these IDs are visible, the activity is carried out by, or with the permission of, the buoy owner or the FAD is hauled onboard. Of course, this does not cover activities with FADs tracked using other type of locating buoys, which may not have unique identification codes printed externally (not the case of the Spanish fleet).

Some solutions, like the labeling of the FAD/buoy are being explored by t-RFMOs, although its feasibility is still under discussion (e.g. readability, covering of solar cells, etc.).

- FAD type → It has been considered to distinguish between i) drifting (DFAD) and anchored (AFAD) objects (Field: 'FAD Type'), ii) own and external origin (Field: 'Owner'), iii) natural and artificial objects (commonly 'rafts') (Fields: 'Origin' and 'Buoy?' and the following FAD characteristics) and iv) tracked or not (Field: 'Buoy?').

FADs Logbook:

Owner	Buoy? (Y/N)	FAD Type
Vessel-1	Y	Drifting

Table 0:

Owner	
Own	Device belonging to the own vessel
"Vessel name"	If the object belongs to another known vessel, select this option and overwrite its name
Unknown	If the owner is unknown
Non aplicable	For objects (including rafts) without a tracking system **('logs')**

Table 2:

FAD Type	Description/Comments
Drifting	Any drifting object
Anchored	Supply vessel anchored to a seamount

Instructions:

Field	Format	Description/Comments	Example
Owner		Select from the drop-down menu depending on the origin of the object (see **Table 0**)	Own
Buoy?	S/N	Select '**Y**' (Yes) if the object has a buoy or '**N**' (No) if not *This field has been designed to easily register objects without buoys, not only with natural origin but also man-made (nets, carrion, herbs, pallet...)* *If a buoy or any other element is added, register a new line with the new FAD characteristics (See* ***Table 1*** *– Modifications over previous object and Examples Sheet)*	Y
FAD Type		Select from the drop-down menu the type of object (*See Table 2 and Examples Sheet*) *NOTE: The characteristics of FADs are not registered (floating part and hanging structure) if the activity is focused on an anchored FAD (e.g. supply vessel)*	Anchored

Any addition of a tracking system and/or modification in logs structure (e.g., joining a raft) is registered in a new line, associated to the activity: 'Modifications over previous object'. These records make viable tracking the modifications made.

- FAD design characteristics → For every activity on an object, captains register the materials located/employed, its characteristics and dimensions. With a view to identify entangling objects, it has been introduced two fields that detect nets mesh size not only in the more superficial part of the floating structure but also becoming part of the underwater structure. This is also effective for drifting nets (e.g., gillnets).

<u>FADs Logbook</u>:

Floating part					Underwater hanging structure				
Material / Structure	**Floating devices**	**Superficial covering material**	**Superficial covering net mesh**	**Dimensions** aaxbbxcc	**Material / Structure**	**Supplements**	**Ballast**	**Net mesh NOT 'in a sausage'**	**Depth (m)**
Bamboo	Corks	Net	< 3 cm	2x3x0,5	Sausage form	Man-made	Ring/Eyebolt	NO mesh	20.5

<u>Instructions</u>:

	Field	Format	Description	Example
FLOATING PART	**Material / Structure**		Select form the drop-down menu the main material of the floating (or half-submerged) structure of the object (See **Table 3**)	Bamboo
	Floating devices		Select form the drop-down menu the main material used to keep FAD buoyancy (See **Table 4**)	Corks
	Superficial covering material		Select form the drop-down menu the main material used to wrap **the most superficial** part of the FAD (See **Table 5**)	Net
	Superficial covering net mesh		Select *'NO mesh'* if **the most superficial** covering of the floating part has NO **any** net. If the superficial covering has, at any section, net mesh, select its range from the drop-down menu.	< 3 cm
	Dimensions	aaxbbxcc	Write down in this field the digits required to indicate the length (aa), the width (bb) and height (cc), in **meters**	2x1x0.3
UNDERWATER HANGING STRUCTURE	**Material / Structure**		Select form the drop-down menu the main material/structure used in the hanging structure (See **Table 6**)	Net with 'sails'
	Supplements		Select from the drop-down menu the group of materials added to the main structure. *If they are mixed (natural+man-made), select 'Both' option* (See **Table 7**)	Coloured tapes
	Ballast		Select from the drop-down menu the material used as ballast of the FAD (See **Table 8**)	None
	Net mesh NOT 'in a sausage'		Select from the drop-down menu the net mesh range if any **section** of the underwater hanging structure or any **supplement** presents a net. If there is no net, select 'NO mesh'	NO mesh
	Depth (m)	number	Write down, with digits, the maximum depth reached by the FAD	30

Tables:

Table 3. MATERIAL / STRUCTURE (Floating part)	Description/Comments
Bamboo	Floating part (or half-submerged) made of bamboo stalks
Metal	Floating part (or half-submerged) made of metal
Plastic / PVC	Floating part (or half-submerged) made of plastic and/or PVC
Bamboo + Plastic/PVC	Floating part (or half-submerged) made of bamboo and plastic/PVC
Bamboo + Metal	Floating part (or half-submerged) made of bamboo and metal
Natural logs	Any object with natural origin that was NOT DESIGNED to aggregate tuna (**carrion**, **trunk, herbs…**)
Man-made logs	Any object with a man-made origin that was NOT DESIGNED to aggregate tuna (**gillnet, pallet, ropes…**)
Mixed	Floating part (or half-submerged) combining the previously cited materials listed in this table or VARIOUS types of objects (e.g. rafts) joined, including natural objects (*describe in the 'Observations' field*)
Single buoy	Select if any activity is carried out a single buoy (NO object associated) *It is NOT required the registration of the rest of the components (floating part, hanging structure)*
Other	Floating part (or half-submerged) made of any material not included in the previously cited types (bamboo stalks and net in a 'sausage' form, corks and net in a 'sausage' form, big containers, ropes and net….)
Unknown floating structure	ONLY when there is no way to know or approximate the main material of the floating part

Table 4. FLOATING DEVICES	Description/Comments
Containers	Floating device made of plastic containers
Corks	Floating device made of corks or plastic floats
'Balls'	Floating device made of plastic spherical balls
Other	Floating device made of **any other material** or **mixed materials** *(describe in the 'Observations' field)*

Table 5. SUPERFICIAL COVERING MATERIAL	Description/Comments
Raffia/Nylon	Select if any kind of cloth is employed to cover the floating part of the object (raffia, nylon, sailcloth…)
Net	Select if any kid of net with any mesh is employed to cover the floating part of the object (purse seine, gillnet, trawl net…)
NO covering	Select if the floating part of the object lacks of a covering
Other	Select if the covering is made of **any other** kind of material or if it is made of **mixed** materials *(describe in the 'Observations' field)*

Table 6. MATERIAL / STRUCTURE (Hanging structure)	Description/Comments
Net in a 'sausage' form	Net in a 'sausage' form **along its entire length**
Open net	Open net **along its entire length**
Net with 'sails'	**Sections** of open net ('sails')
Ropes	Ropes / 'rope ends' as major or unique material
Other	**Any other kind** of material not listed in the previous lines of this table or **mixed materials** *(describe in the 'Observations' field)*
Unknown extension	ONLY when there is no way to know or approximate the main material of the hanging structure

Table 7. SUPPLEMENTS	Description/Comments
Natural origin	Palm leafs or any other natural component in the underwater hanging structure
Man-made origin	Coloured tapes, plastic bags, pieces of sacks, remains of orange floats… in the underwater hanging structure
Both	If both, natural and man-made components become part of the underwater hanging structure
None	If NO components were added to the structure selected from Table 6

Table 8. BALLAST	Description/Comments
Metal rings / Eye bolts	Metal rings, eye bolts or any other similar material as ballast
Metal wire	Metal wires (e.g., pieces of purseline) or any other similar material as ballast

Stone	Stones as ballast
Cinder block	Cinder blocks or pieces of them as ballast
None	If NO components were added as ballast to the structure selected from **Table 6**
Other	Select if the ballast is made of **any other** kind of material or if it is made of **mixed** materials *(describe in the 'Observations' field)*

Drop-down menu for the net mesh:

Net mesh
NO mesh
< 3 cm
3-7 cm
> 7 cm

These fields are designed to improve the knowledge about FAD characteristics since all of them are adjustable to the new situations on FAD fishing. One important improvement consists on registering modifications and replacements on the structure as new lines. New materials not included in the drop-down menu can be identified in the "Observations" field. In this sense, as the FAD design evolves, new materials will be included in the drop-down menus of the logbook.

- Type of activity → Keeping in mind the main activities performed by the purse-seine vessels with objects and taking into account the significance of tracking the objects paths, it has been considered to register the following activities. The combination of some of them point out the active FADs at any one time per vessel:

Logbook:

Activity
Set

Instructions:

Field	Format	Description	Example
Activity		Identify the activity performed on the object **(or buoy)** in the drop-down menu (see **Table 1** and the *examples sheet*)	Retrieval at sea

Tables:

Table 1. ACTIVITY	Description/Comments
Deployment	If a FAD is deployed (NO for markings of natural objects with a buoy. See 'Modifications over *previous object*') (*Check the rest of the fields in this table and the examples sheet)*
Verification (visit)	With every visit, **NOT** if the object is **retrieved** or if a **set** is performed, regardless of its modification (see the *examples sheet*)
Set	If a set is performed on any kind of object. Add **one line for every group of species** captured (see **Table 8**, filling in the following lines only those fields concerning to bycatch (see the *examples sheet*) If the object is **modified** or **retrieved** at sea, add a new line registering the activity '*Modifications over previous object*' or '*Retrieval at sea*'
Modifications over previous object	This activity should be registered in a new line **after a set or a verification** if: (i) a buoy is added to a log, (ii) a buoy is changed and/or (iii) the structure of the object is modified, filling in **only** the fields modified (see the *examples sheet*)
Retrieval at sea	If an object is retrieved and not returned to sea. **After a set**, this activity will be registered in a **new line** (see the *examples sheet*)
Loss	If the signal of the **buoy** is lost. Register the last position detected (fields '*Lat'* and '*Lon*'), '*Date*' and '*Time*'
Recovering at port	Recovering of **buoys** at port. Fill in only those data concerning to the buoy (fields '*Model*' and '*Numeric ID*' and those indicating the '*Date*', '*Time*' and position ('*Lat*' and '*Lon*')

Some Spanish purse-seine vessels work in collaboration with other purse seiners and/or with supply vessels. In these cases it is important to clarify that every vessel is obliged to register its own activities, even when they are supporting other vessels (e.g., deployment of buoys for another vessel).

- Catch and Bycatch → In order to get information and improve the knowledge about impacts on targeted and non-targeted species, it has been considered to include both fields. Though catch data are received in logbooks, it takes a year to process them. This way, catch data of target species (loads and discards together) associated to object schools are available in a shorter period.

Bycatch data are registered by observers on board purse seiner and the coverage of National Data Collection Program is only a 10% of the national fishing trips. So the FADs logbooks provide this data with a 100% of coverage, including supply vessels.

The list of groups of bycatch species includes small tuna and tuna-like species.

Logbook:

School estimate (tons)	Catch (tons)			Bycatch			
	SKJ	YFT	BET	Group	In number or weight (t)	N/W	Nº/Weight specimens released alive
30	10	2	1	Whale shark	1	N	1

Instructions:

	Field	Format	Description	Example
	School estimate (tons)	Round number	Note down a unique number of **tons** the catch of SKJ, YFT and/or BET estimated if the set is not performed. Register a '**0**' if any other kind of trick or fishes is detected (bony fishes, bait, garbage…)	5
Catch (tons)	SKJ	number	Catches of SKJ (*Katsuwonus pelamis*) loaded plus the discards of this species, in tons	10
	YFT	number	Catches of YFT (*Thunnus albacares*) loaded plus the discards of this species, in tons	2
	BET	number	Catches of BET (*Thunnus obesus*) loaded plus the discards of this species, in tons	1
Bycatch	**Group**		Select from the drop-down menu the group of species caught. If more than one group is caught, note them down in the following lines (one by group) (see the *examples sheet*) (see **Table 9**)	Bony fishes
	In number or weight (t)	number	Number of specimens or weight (*in tons*) of the group of species (one number for every group). It is not necessary to indicate numbers by species, only by group. **If part of the catch is estimated in number and part in weight, register them in two consecutive lines**	0.5
	N/W		Select '**N**' (number) or '**W**' (weight)	W
	Nº/Weight specimens released alive	number	Register, with number, the number or weight of the specimens of the group released alive. It is not necessary to indicate numbers by species, only by group	0.1

Tables:

Table 9. GROUP*	Description/Comments
Small tuna and tuna-like fish	Select small tuna if specimens of black skipjack (*Euthynnus lineatus*), kawakawa (*E. affinis*), frigate tunas (*Auxis thazard*), bullet tunas (*Auxis rochei*), bonito (*Sarda spp.*) or similar are caught, regardless of its destiny
Sharks (hammerhead, shortfin mako, silky shark…)	Select sharks if specimens of this group are caught, regardless of its destiny. *NOTE: DO NOT select for whale sharks*
Billfishes	Select billfishes if specimens known as spearfishes, sailfishes, marlins or swordfish are caught, regardless of its destiny
Turtles	Select turtles if any specimen of this group is caught, regardless of its destiny
Rays and manta-rays	Select this group if rays, mantas or manta-rays are caught, regardless of its destiny
Marine mammals (whales, dolphins…)	Select marine mammals if any specimen is rounded by the purse seine net, regardless of its destiny
Whale shark	Select whale shark if any specimen is rounded by the purse seine net, regardless of its destiny
Other bony fishes (triggerfishes, rainbow runner, dolphinfishes…)	Select bony fishes if any specimen not included in the previous lines is caught, regardless of its destiny
***NOTE: All those specimens rounded by the purse seine net at the eyebolts raising time (purseline closure) must be included, regardless of its destiny**	

4. Conclusions and recommendations

The analysis of data collected thanks to the Spanish Fish Aggregating Device Management Plan has allowed to detect the improvements needed in the data collection system for its adaptation to the use on board. The current version presented in this document integrates all the data requirements from t-RFMOs in a user-friendly format for the skippers, increasing the quality of the information obtained.

On the other hand, there is of course much room for improvement. In our view, the current system is excessively time-consuming, and the development of a specific tool for data entry is required (e.g., forms that upload the latest known configuration of a FAD, once the ID is entered, with checkboxes instead of dropdown menus, etc.).

Standardization of templates, tools and guidelines at the RFMO level and, if possible, among t-RFMOs, would be highly desirable, and would no doubt improve data usability. It must also be noted that there is little information that supports the collection of many of the current fields. Future analyses, feasible in the short-term, are required to fine-tune the trade-offs between the efforts and benefits in the acquisition of FAD-related information.

Finally, it is important to note the need of involving all the stakeholders in the elaboration of successful FAD management plans. The current work is an example of the collaboration between scientists and fishing companies, which has proved essential to develop a method for data compilation that is efficient and, at the same time, takes into consideration practicalities on-board.

References

Abascal, F., Fukofuka S., Falasi C., Sharples, P. and Williams, P. 2014. Preliminary analysis of the Regional Observer Programme data on FAD design. WCPFC-SC10-2014/ST-IP-09.

Delgado de Molina, A., Ariz, J., Murua, H. and Santana, J.C., 2015. Spanish Fish Aggregating Device Management Plan. Preliminary data. ICCAT Collective Volume of Scientific Papers, 71(1), 515-524.

Delgado de Molina, A., Ariz, J., Santana, J.C., Rodríguez, S., Soto, M., Fernández, F. and Murua, H. 2013. The Spanish Fish Aggregating Device Management Plan from 2010-2013. IOTC–2013–SC16–INF05.

Fonteneau, A., Chassot, E. and Gaertner, D., 2015. Managing tropical tuna purse seine fisheries through limiting the number of drifting fish aggregating devices in the Atlantic: food for thought. ICCAT Collective Volume of Scientific Papers, 71(1), 460-475.

IATTC, 1998. C-98-10. Resolution on fish-aggregating devices. October 1998.

IATTC, 2004. C-04-05 (Rev 2). Consolidated resolution on bycatch. June 2006.

IATTC, 2013. C-13-04. Collection and analyses of data on fish aggregating Devices. June 2013.

IATTC, 2016a. Fish-aggregating device form (FADS). 14 Oct 16. From web site: https://www.iattc.org/Downloads.htm; last visited: 31/03/2017.

IATTC, 2016b. Amendment of resolution c-15-03 on the collection and analyses of data on fish-aggregating devices. July 2016.

IATTC. 1999. C-99-07. Resolution on fish-aggregating devices. July 1999.

ICCAT, 2011. Recommendation by ICCAT to Clarify the Application of Compliance Recommendations and for Developing the Compliance Annex. Rec. 11-01.

ICCAT, 2013. Recommendation by ICCAT Amending the Recommendation on a Multi-annual Conservation and Management Program for Bigeye and Yellowfin Tunas. Rec. 13-01.

ICCAT, 2014. Recommendation by ICCAT on a Multi-Annual Conservation and Management Program for Tropical Tunas. Rec. 14-01.

ICCAT, 2015. Recommendation by ICCAT on a Multi-annual Conservation and Management Programme for Tropical Tunas. Rec. 15-01.

ICCAT, 2016a. Recommendation by ICCAT on a Multi-Annual Conservation and Management Program for Tropical Tunas. Rec. 16-01.

ICCAT, 2016b. Second meeting of the ad hoc Working Group on FADs (Bilbao, Spain, 14-16 march 2016).

IOTC, 2001. Resolution 01/05. Mandatory statistical requirements for IOTC members.

IOTC, 2014. Guidelines for the reporting of fisheries statistics to the IOTC. January 2014.

WCPFC, 2016. CMM-16-01. Conservation and Management Measure for bigeye, yellowfin and skipjack tuna in the Western and Central Pacific Ocean.

WCPFC, 2017. From web site: https://www.wcpfc.int/system/files/Table-ROP-data-fields-instructions.pdf; last visited: 31/03/2017.

Table 1. Percentages of catches associated to floating objects by t-RFMO areas and year for Spanish tropical purse-seine fishery and means of percentages in five-year periods. For WPO it has been taken into account 2002-2015 period to calculate averages.

YEAR / AREA	ATL	IND	EPO	WPO	
1991	53%	51%	46%		
1992	49%	60%	21%		
1993	46%	51%	71%		
1994	46%	53%	80%		
1995	53%	70%	91%		
1996	59%	58%	93%		
1997	42%	76%	100%		
1998	29%	74%	99%		
1999	35%	79%	95%	99%	
2000	52%	77%	99%	100%	
2001	46%	66%	97%		
2002	46%	76%	96%	100%	
2003	43%	63%	98%	100%	
2004	43%	55%	97%	100%	
2005	63%	62%	94%	94%	
2006	58%	74%	100%	100%	
2007	62%	72%	95%	71%	
2008	64%	68%	98%	100%	
2009	55%	83%	100%	89%	
2010	66%	87%	100%	97%	
2011	77%	83%	100%	97%	
2012	76%	73%	69%	95%	
2013	83%	88%	100%	90%	
2014	84%	86%	81%	84%	
2015	73%	78%	90%	90%	**AVERAGE of means**
TOTAL MEAN	**56%**	**71%**	**88%**	**93%**	
MEAN (1991-1995)	49%	57%	62%		**56%** (except for WPO)
MEAN (1996-2000)	44%	73%	97%		**71%** (except for WPO)
MEAN (2001-2005)	48%	64%	96%		**70%** (except for WPO)
MEAN (2006-2010)	61%	77%	99%	91%	**82%**
MEAN (2011-2015)	79%	82%	88%	91%	**85%**

Figure 1. Main types of objects visited by the Spanish tuna purse-seine fleet.

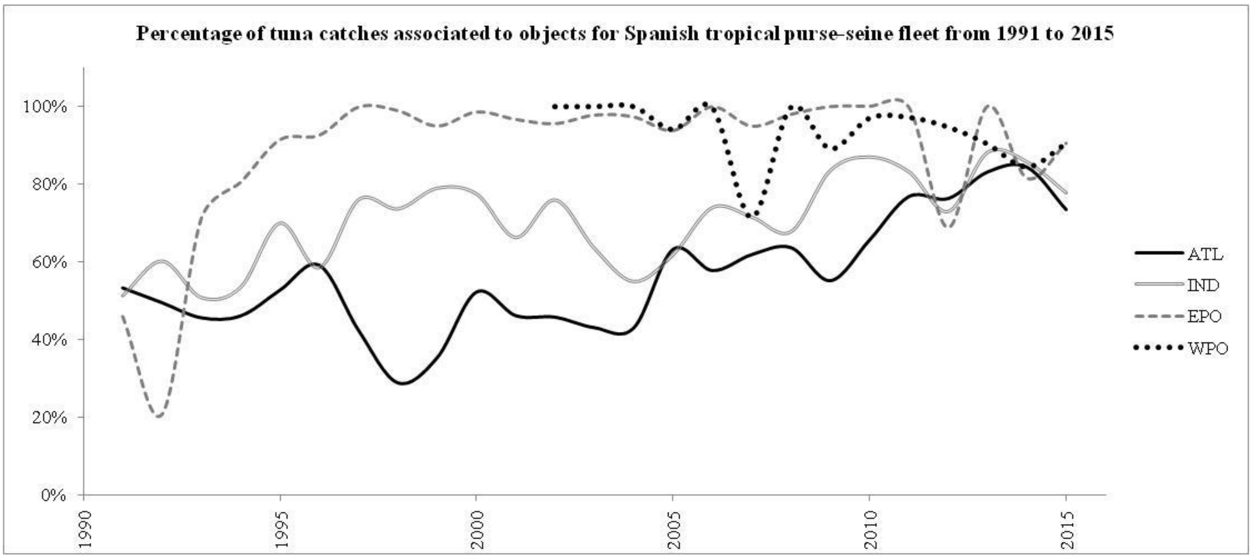


Figure 2. Percentages of tuna catches associated to objects by t-RFMO area for Spanish purse-seine fleet from 1991 to 2015. For WPO area data represented correspond to the 2002-2015 period.

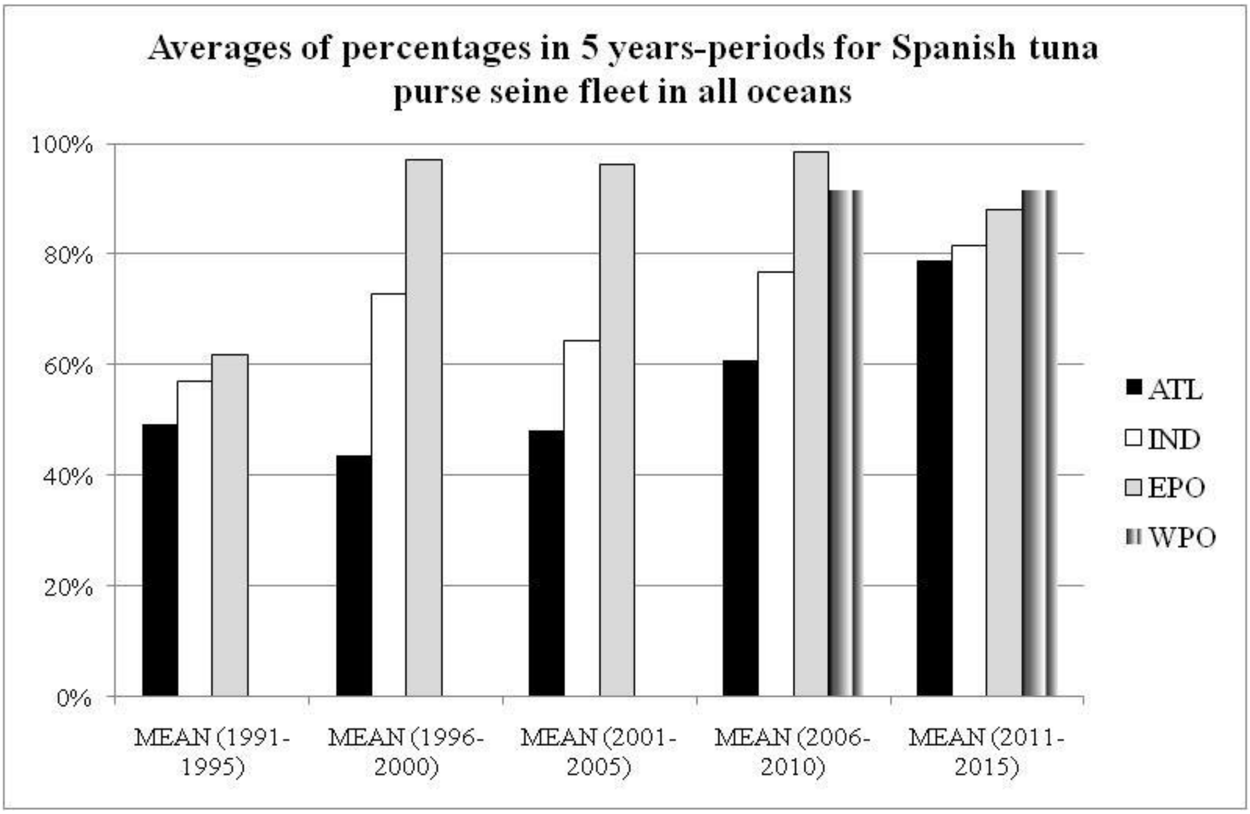
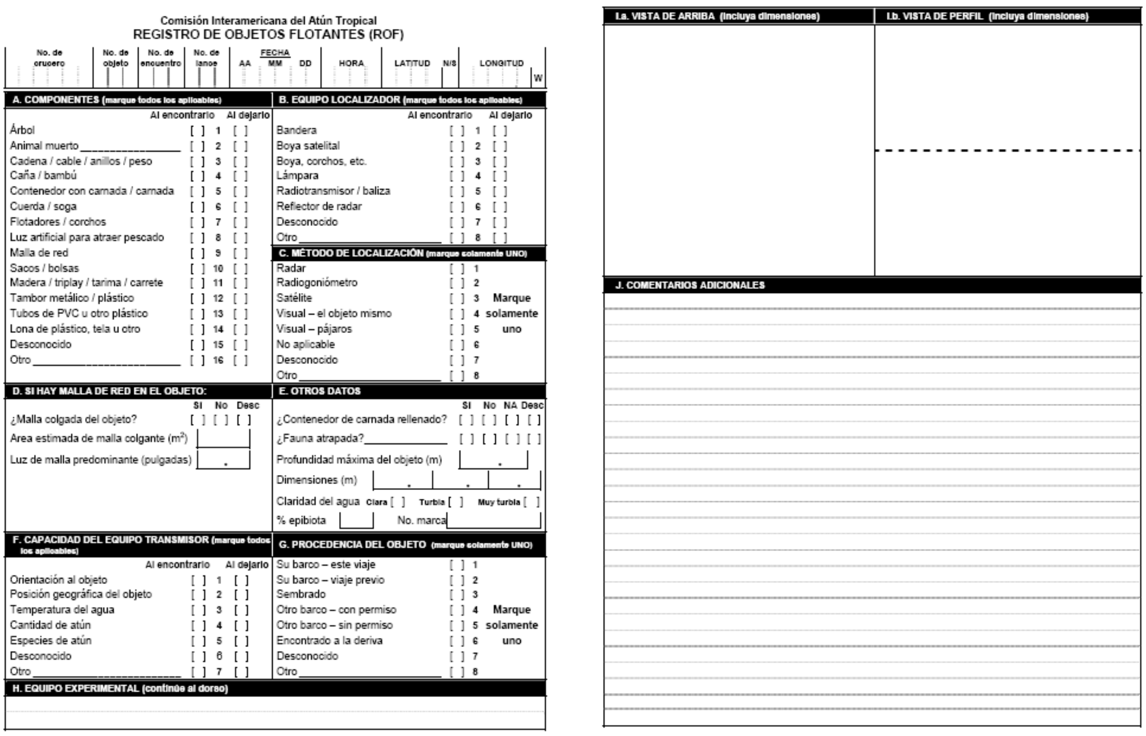


Figure 3. Means of percentages of tuna catches associated to objects by t-RFMO from 1991 to 2015, grouped in five-year periods. For WPO area data represented correspond to the 2006-2015 period.



Comisión Interamericana del Atún Tropical
REGISTRO DE OBJETOS FLOTANTES (ROF)

No. de crucero	No. de objeto	No. de encuentro	No. de lance	FECHA AA	FECHA MM	FECHA DD	HORA	LATITUD	N/S	LONGITUD	W

A. COMPONENTES (marque todos los aplicables)

	Al encontrarlo		Al dejarlo
Árbol	[ ]	1	[ ]
Animal muerto ___	[ ]	2	[ ]
Cadena / cable / anillos / peso	[ ]	3	[ ]
Caña / bambú	[ ]	4	[ ]
Contenedor con carnada / carnada	[ ]	5	[ ]
Cuerda / soga	[ ]	6	[ ]
Flotadores / corchos	[ ]	7	[ ]
Luz artificial para atraer pescado	[ ]	8	[ ]
Malla de red	[ ]	9	[ ]
Sacos / bolsas	[ ]	10	[ ]
Madera / triplay / tarima / carrete	[ ]	11	[ ]
Tambor metálico / plástico	[ ]	12	[ ]
Tubos de PVC u otro plástico	[ ]	13	[ ]
Lona de plástico, tela u otro	[ ]	14	[ ]
Desconocido	[ ]	15	[ ]
Otro ___	[ ]	16	[ ]

B. EQUIPO LOCALIZADOR (marque todos los aplicables)

	Al encontrarlo		Al dejarlo
Bandera	[ ]	1	[ ]
Boya satelital	[ ]	2	[ ]
Boya, corchos, etc.	[ ]	3	[ ]
Lámpara	[ ]	4	[ ]
Radiotransmisor / baliza	[ ]	5	[ ]
Reflector de radar	[ ]	6	[ ]
Desconocido	[ ]	7	[ ]
Otro ___	[ ]	8	[ ]

C. MÉTODO DE LOCALIZACIÓN (marque solamente UNO)

Radar	[ ]	1	
Radiogoniómetro	[ ]	2	
Satélite	[ ]	3	Marque
Visual – el objeto mismo	[ ]	4	solamente
Visual – pájaros	[ ]	5	uno
No aplicable	[ ]	6	
Desconocido	[ ]	7	
Otro ___	[ ]	8	

D. SI HAY MALLA DE RED EN EL OBJETO:

	SI	No	Desc
¿Malla colgada del objeto?	[ ]	[ ]	[ ]

Area estimada de malla colgante (m^2) ___
Luz de malla predominante (pulgadas) ___

E. OTROS DATOS

	SI	No	NA	Desc
¿Contenedor de carnada rellenado?	[ ]	[ ]	[ ]	[ ]
¿Fauna atrapada? ___	[ ]	[ ]	[ ]	[ ]

Profundidad máxima del objeto (m) ___
Dimensiones (m) ___ ___ ___
Claridad del agua Clara [ ] Turbia [ ] Muy turbia [ ]
% epibiota ___ No. marca ___

F. CAPACIDAD DEL EQUIPO TRANSMISOR (marque todos los aplicables)

	Al encontrarlo		Al dejarlo
Orientación al objeto	[ ]	1	[ ]
Posición geográfica del objeto	[ ]	2	[ ]
Temperatura del agua	[ ]	3	[ ]
Cantidad de atún	[ ]	4	[ ]
Especies de atún	[ ]	5	[ ]
Desconocido	[ ]	6	[ ]
Otro ___	[ ]	7	[ ]

G. PROCEDENCIA DEL OBJETO (marque solamente UNO)

Su barco – este viaje	[ ]	1	
Su barco – viaje previo	[ ]	2	
Sembrado	[ ]	3	
Otro barco – con permiso	[ ]	4	Marque
Otro barco – sin permiso	[ ]	5	solamente
Encontrado a la deriva	[ ]	6	uno
Desconocido	[ ]	7	
Otro ___	[ ]	8	

H. EQUIPO EXPERIMENTAL (continúe al dorso)

I.a. VISTA DE ARRIBA (incluya dimensiones)

I.b. VISTA DE PERFIL (incluya dimensiones)

J. COMENTARIOS ADICIONALES

Figure 4. IATTC Floating Objects Form for observers on board purse seiners in the IATTC area.

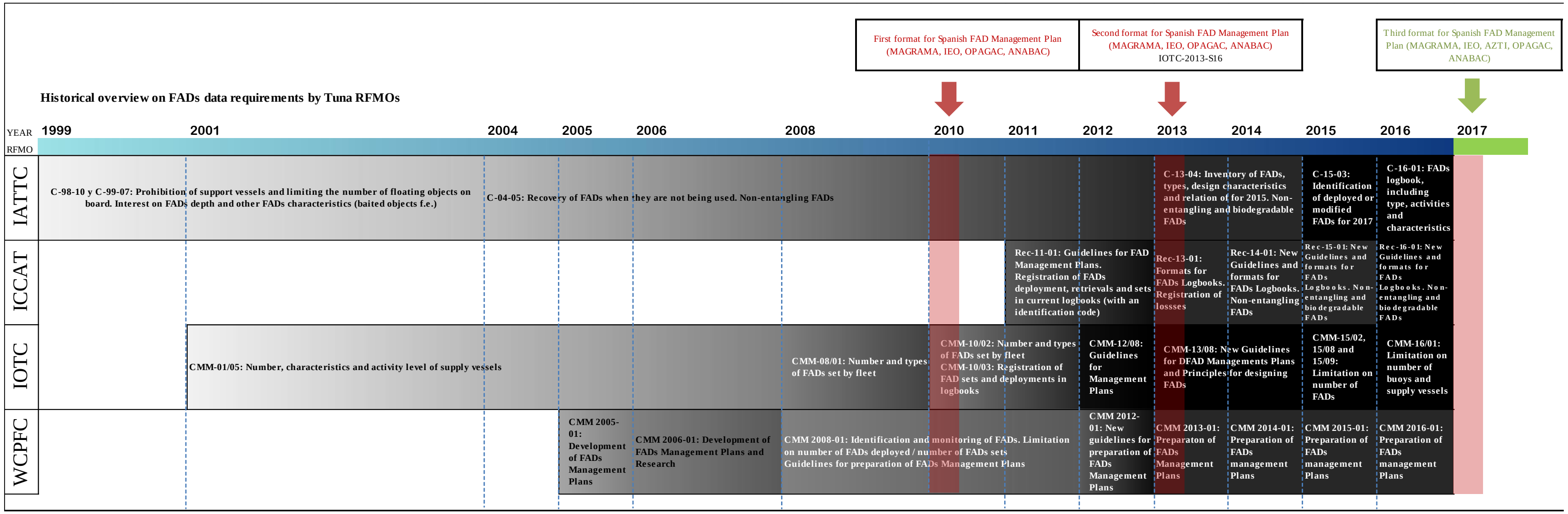


Figure 5. Historical overview on FAD data requirements and report requests by Tuna RFMOs. Remark of Spanish response.

	Vessel name	Number of trip	Registration	Position	Date	Hour	FAD identification	FAD type	General FAD design characteristics	FAD design characteristics: Raft	FAD design characteristics: Covering	FAD design characteristics: Floating devices	FAD design characteristics: Hanging structure materials	FAD design characteristics: Hanging structure configuration	Type of buoy	Type of the activity (hauling, intervention on electronic equipment, other (specify))	Type of activity with the buoy	If the activity is a set, the results of the set in terms of catch and bycatch	Characteristics of any attached buoy or positioning equipment	Observations
IATTC **RESOLUTION C-16-01 AMENDMENT OF RESOLUTION C-15-03 ON THE COLLECTION AND ANALYSES OF DATA ON FISH-AGGREGATING DEVICES**	☐	X	☐	X	X	X	Serial number	Natural, Own, External or Anchored	Dimension and material of the floating part and of the underwater hanging structure	Bamboo raft, bamboo in a sausage form, metallic, PVC/Plastic, no raft or other	Entangling net, non-entangling net, cloth, palm fronds, no wrapping, other	Corks, buoys, containers, no floats, other	Nylon, plam fronds, bamboo, no tail, other	Sausage, ropes, cloth, other	GPS, with echosounder, no echosounder, other...	Set, Deployment, Retrieving, Loss, Intervention on electronic equipment	Derived from the type of activity	Tuna catch (YFT, BET, SKJ, OTHER) and bycatch (sharks, billfishes, manta-rays, other) NUMBER or WEIGHT	Positioning system, whether equipped with sonar, etc.	☐
ICCAT **16-01-TRO RECOMMENDATION BY ICCAT ON A MULTI-ANNUAL CONSERVATION AND MANAGEMENT PROGRAMME FOR TROPICAL TUNAS**	☐	☐	☐	X	X	X	Mandatory readable buoy identification	Log (related or not with fishing activities, animals or plants), Artificial or Anchored	Material of the floating part and of the underwater hanging structure and the entangling or non-entangling feature of the underwater hanging structure	☐	☐	☐	☐	☐	Simple buoy (GPS) or associated with echo-sounder	Set (targeted or oportunistic), Deployment, Retrieving, Visit to an own or foreign object, Strengthening or consolidation	Tagging, Removing or Loss	Tuna catch (SKJ, YFT, BET) and bycatch (group, number or weight, nº of specimens released alive)	☐	☐
IOTC **GUIDELINES FOR THE REPORTING OF FISHERIES STATISTICS TO THE IOTC - 2014 AND RESOLUTION 15/08 PROCEDURES ON A FISH AGGREGATING DEVICES (FADS) MANAGEMENT PLAN, INCLUDING A LIMITATION ON THE NUMBER OF FADS, MORE DETAILED SPECIFICATIONS OF CATCH REPORTING FROM FAD SETS, AND THE DEVELOPMENT OF IMPROVED FAD DESIGNS TO REDUCE THE INCIDENCE OF ENTANGLEMENT OF NON-TARGET SPECIES**	☐	☐	☐	☐	☐	☐	Marking or beacon ID (unique and readable identificator)	Log, Raft with net, Raft without net, Anchored or Other (located or not with a tracking system)	Dimension and material of the floating part and of the underwater hanging structure	With or without a net. Detect entangling and not bidegradable materials	With or without a net. Detect entangling and not bidegradable materials	☐	With or without a net. Detect entangling and not bidegradable materials	With or without a net. Detect entangling and not bidegradable materials	☐	Set, deployment, retrieval, visiting, loss and intervention on FADs	Loss	Weight and/or number of retained catches and discard levels (nº/weight) of target and bycatch species	☐	☐
WCFC **CMM-2016-01 PREPARATION OF FAD MANAGEMENT PLANS (NO LOGBOOK)**	X	☐	☐	X	X	X	Marking and identifiers	Natural, Raft with or without a net, or Anchored	Dimension and material of raft and net. Description of design	☐	☐	☐	☐	☐	GPS, radio, visual	Deployment, verification, set, hauling (retrieval)	☐	☐		☐
NEW SPANISH PROPOSAL	X	X	X	X	X	X	Model and readable identification number	Drifting or anchored	Dimension, material and characteristics of the floating and underwater parts (entangling, biodegradable…)	Bamboo, metallic, PVC/Plastic, log (man-made or natural), mixed, other	Entangling or non-entangling nets, no coverng, other	Containers, corks or buoys, plastic balls, other, no floats	Addings: natural, man-made, both, other Ballast: ring, eyebolt, steel rope, stones, concrete blocks, other, no addings	Net in a 'sausage' form, open net, mixed net form (with 'sails'), ropes, other	Derived from model registration (radio, GPS, echo-sound…)	Deployment, verification, set, object modifications, retrieval, recovering at port, loss	Deployment, removing, recovering or loss	Tuna catch (SKJ, YFT, BET) and bycatch (group, number or weight, nº of specimens released alive) Groups: Sharks, billfishes, rays and manta-rays. marine mammals, whale-shark, bony fishes, small tuna	Derived from model registration (radio, GPS, echo-sound…)	X

Figure 6. Main Tuna RFMOs current requests on FAD characteristics and activity data. The '**X**' symbol means that the data is being collected. The '**-**' symbol means that the particular FAD design characteristic is not defined in the guidelines provided.

COMISION INTERAMERICANA DEL ATUN TROPICAL – INTER-AMERICAN TROPICAL TUNA COMMISSION

ACTIVIDAD DE LOS PLANTADOS

BUQUE		IATTC Ves. No		NO. VIAJE		Trip. No.		Matrícula	

				Posición Geográfica		Captura de túnidos				Captura incidental: Número [N] o tonelaje [t].										
Fecha	Hora	Identificación	Actividad	Latitud N/S	Longitud E/W	YFT	BET	SKJ	OTR	TIB	N/t	TORT	N/t	PIC	N/t	MANT	N/t	OTR	N/t	Comentarios / Observaciones
CAPTURA INCIDENTAL LIBERADA VIVA:																				
CAPTURA INCIDENTAL LIBERADA VIVA:																				
CAPTURA INCIDENTAL LIBERADA VIVA:																				
CAPTURA INCIDENTAL LIBERADA VIVA:																				
CAPTURA INCIDENTAL LIBERADA VIVA:																				
CAPTURA INCIDENTAL LIBERADA VIVA:																				
CAPTURA INCIDENTAL LIBERADA VIVA:																				
CAPTURA INCIDENTAL LIBERADA VIVA:																				
CAPTURA INCIDENTAL LIBERADA VIVA:																				
CAPTURA INCIDENTAL LIBERADA VIVA:																				

FAD FORM 3.1.3 SPN.DOCX 21-sep-16

COMISION INTERAMERICANA DEL ATUN TROPICAL – INTER-AMERICAN TROPICAL TUNA COMMISSION

INFORMACIÓN DE LOS PLANTADOS

		Materiales en superficie			Dimensiones (m)			Materiales y configuración de la parte sumergida (rabo)					
Identificación	Descripción	Balsa	Recubri-miento	Flotadores	A	L	P	Mat. 1	Mat. 2	Config.	Luz malla (mm)	Tipo de baliza	Comentarios / Observaciones

FAD FORM 3.1.3 SPN.DOCX 21-sep-16

Figure 7. IATTC FAD logbook

FAD logbook

FAD marking	*Buoys ID*	*FAD type*	*Type of visit*	*Date*	*Time*	*Position*		*Estimated catches*			*By-catch*				*Observations*
						Latitude	*Longitude*	*SKJ*	*YFT*	*BET*	*Taxonomic group*	*Estimated catches*	*Unit*	*Specimen released alive*	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(7)	(8)	(8)	(8)	(9)	(10)	(11)	(12)	(13)
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

(1,2) If FAD marking and associated beacon/buoy ID are absent or unreadable, report it in this section. However, if FAD marking and associated beacon/buoy ID are absent or unreadable, the FAD shall not be deployed
(3) Anchored FAD, drifting natural FAD or drifting artificial FAD.
(4) I.e., deployment, hauling, strengthening/consolidation, removing/retrieving, changing the beacon, loss and mention if the visit has been followed by a set.
(5) dd/mm/yy.
(6) hh:mm.
(7) N/S/mm/dd or °E/W/mm/dd.
(8) Estimated catches expressed in metric tons.
(9) Use a line per taxonomic group.
(10) Estimated catches expressed in weight or in number.
(11) Unit used.
(12) Expressed as number of specimen.
(13) If no FAD marking neither associated beacon ID is available, report in this section all available information which may help to describe the FAD and to identify the owner of the FAD.

List of deployed FADs and buoys on a monthly basis

Month:

FAD Identifier		*FAD & electronic equipment types*		*FAD*				*Observation*
FAD Marking	*Associated buoy ID*	*FAD Type*	*Type of the associated buoy and /or electronic devices*	*FAD floating part*	*FAD underwater hanging structure*			
(1)	(1)	(2)	(3)	(4)	(5)			(6)
...	...	...	...		...			...
...	...	...	...		...			...

(1) If FAD marking and associated beacon/buoy ID are absent or unreadable, the FAD shall not be deployed.
(2) Anchored FAD, drifting natural FAD or drifting artificial FAD.
(3) E.g. GPS, sounder, etc. If no electronic device is associated to the FAD, note this absence of equipment.
(4) Mention the material of the structure and of the cover and if biodegradable.
(5) E.g. nets, ropes, palms, etc., and mention the entangling and/or biodegradable features of the material.
(6) Lighting specifications, radar reflectors and visible distances shall be reported in this section.

Table 1. Codes, names and examples of different types of floating object that should be collected in the fishing logbook as a minimum data requirement. Table from 2016 SCRS report (section 18.2 Table 7).

Code	*Name*	*Example*
DFAD	Drifting FAD	Bamboo or metal raft
AFAD	Anchored FAD	Very large buoy
FALOG	Artificial log resulting from related to human activity (and related to fishing activities)	Nets, wreck, ropes
HALOG	Artificial log resulting from human activity (not related to fishing activities)	Washing machine, oil tank
ANLOG	Natural log of animal origin	Carcasses, whale shark
VNLOG	Natural log of plant origin	Branches, trunk, palm leaf

Table 2. Names and description of the activities related to floating objects and buoys that should be collected in the fishing logbook as a minimum data requirement (codes are not listed here). Table from 2016 SCRS report (section 18.2 Table 8).

	Name	*Description*
FOB	Encounter	Random encounter (without fishing) of a log or a FAD belonging to another vessel (unknown position)
	Visit	Visit (without fishing) of a FOB (known position)
	Deployment	FAD deployed at sea
	Strengthening	Consolidation of a FOB
	Remove FAD	FAD retrieval
	Fishing	Fishing set on a FOB[1]
Buoy	Tagging	Deployment of a buoy on FOB[2]
	Remove BUOY	Retrieval of the buoy equipping the FOB
	Loss	Loss of the buoy/End of transmission of the buoy

[1] A fishing set on a Fishing Object (FOB) includes two aspects: fishing after a visit to a vessel's own FOB (targeted) or fishing after a random encounter of a FOB (opportunistic).
[2] Deploying a buoy on a FOB includes three aspects: deploying a buoy on a foreign FOB, transferring a buoy (which changes the FOB owner) and changing the buoy on the same FOB (which does not change the FOB owner).

Figure 8. ICCAT logbook model

Flag (current) cod.	Month	FAD type	Lat	Lon	No. Deployed with beacons	Type of beacon deployed	Average No. Active beacons followed per vessel	Average No. Deactivated beacons followed per vessel	No. Deployed without beacons	Average No. of active lost FADs	No. Of FADs deployed by support vessels
FlagCodeCur	Month	FadType	Lat	Lon	NoDepBeaconsYes	BeaconType	NoBeaconsFollowed	NoDeactivBeacons	NoDepBeaconsNo	NoLostFADS	SuppFads

Table. Fad types

FadTypeCode	FadType
FAA	Anchored FAD
FADN	Drifting Natural FAD
FADA	Drifting artifical FAD

Table. Beacon types

BeaconCode	BeaconType
RDF	Radio direction finder
RDFGPS	Radio direction finder and GPS
GPS	GPS
SON	Sonar
SONES	Sonar with echo-sounder
SATES	Satellite and echo-sounder
SAT	Satellite without echo-sounder

Figure 9. ICCAT ST08 Form.

MONTH	GRID				AREA	ESTIMATION	Type of FAD	Type of Visit	NO. SET ON FAD	EFFORT	SPECIES
	SIZE	QUADRANT	LATITUDE	LONGITUDE							CATCH UNITS

Figure 9. IOTC 3FA Form

Annex

Annex 1. New Spanish FADs logbook form
(*see Excel file in original language only, available on the ownCloud*).

Excel description:

Sheet 1 - Registration

Sheet 2 - Instructions

Sheet 3 - Tables

Sheet 4 - Examples

Original: English

DRIFTING FADS CONTRIBUTION TO MARINE LITTER AND GHOST FISHING: A PERSPECTIVE FROM THE MALDIVES

Government of the Maldives

Introduction

The Maldives is an archipelago in the Indian Ocean, located southwest of the southern tip of India. There are twenty-six atolls containing 1,192 islands, of which 190 are inhabited by locals and over 121 are currently tourist resorts. The mainstays of the Maldives economy are its fisheries and tourism. Both are intrinsically related to the coral reefs and the overall health of the marine ecosystem. For this reason, net fishing is not allowed in the Maldives, yet drifting FADs (dFADs) regularly enter Maldivian waters. The dFADs wash up on our reefs and entangle vulnerable marine animals, like sea turtles and sharks that are critical to our tourism industry.

Marine Litter and Entanglement

In the Indian and Atlantic Oceans, an estimated 10% of dFAD deployments result in a beaching event (Maufroy et al. 2015). As to ghost fishing, dFADs also entangle vulnerable marine fauna, including sea turtles and sharks. In the Indian Ocean, it is estimated that entanglement mortality of silky sharks (480,000 – 960,000 silky sharks per year) was 5–10 times that of the known bycatch of this imperilled species from the region's purse-seine fleet (Filmhalter, 2013). No such estimates are available for other vulnerable marine species in the Indian Ocean, but there are undoubtedly impacts.

Turtle entanglements are also common and have been associated with dFAD netting. For example Olveridley Project[1], an international NGO Registered in the UK, who are actively fighting ghost nests in the Indian Ocean reports number of incidences of Oliveridley turtle entanglements in dFAD nettings.

Purse seine vessels act with impunity when it comes to the numbers of dFADs they deploy. There is no accountability for the fate of those devices, and it is left to the coastal states, often those that have the least resources, to clean up the litter and suffer the consequences of damage to coastal habitats, coral reefs, and endangered marine megafauna. While there is much discussion about non-entangling FADs and biodegradable FADs, these are still not mainstream in the Indian Ocean. Regardless, both biodegradable and non-entangling FADs can still damage reefs by destroying corals and other fragile organisms.

FAD tracking and warning systems – a possible solution

Balderston and Martin (2015) have found that lost dFADs used by the purse seine fleet in the Indian Ocean can have major impacts when becoming beached on reefs and other sensitive habitats. FAD WATCH is a collaborative programme between several organisations with the aim of preventing and mitigating dFAD beachings across islands in Seychelles where the Island Conservation Society (ICS) has a presence. A Memorandum of Understanding (MoU) was recently signed in July 2016 by the Spanish Purse Seining Fishing Fleet (OPAGAC/AGAC), Island Conservation Society (ICS), Islands Development Company (IDC) and Seychelles Fishing Authority. Under this system an automated alert system will be setup at ICS that will report whenever a FAD arrives within 5 nautical miles of any atoll where ICS has a permanent presence, and provide GPS co-ordinates, trajectory and estimated projected time of beaching. This will allow ICS staff time to plan and intercept these FADs before beaching occurs, damages reefs and/or impacts on key marine fauna.

The PNA[2], are already implementing FAD tracking in their waters. This tracking information will allow the PNA States to better monitor FAD fishing in their waters and implement similar systems as in the Seychelles to protect sensitive habitats from the impacts of lost dFADs. Ideally this is a system that should be implemented throughout all RFMO areas.

---

[1] http://oliveridleyproject.org/, accessed March 2017

[2] Parties to Nauru Agreement (PNA) controls the world's largest sustainable tuna purse seine fishery. PNA Members are Federated States of Micronesia, Kiribati, Marshall Islands, Nauru, Palau, Papua New Guinea, Solomon Islands and Tuvalu.

Original: English

MONITORING THE NUMBER OF ACTIVE FADS USED BY THE SPANISH AND ASSOCIATED PURSE SEINE FLEET IN THE IOTC AND ICCAT CONVENTION AREAS

J. Santiago [1], H. Murua[2], J. López[2] and I. Krug[3]

The purse seine vessels of the Spanish ANABAC and OPAGAC fleet owners organizations agreed in late 2014 to freeze the number of DFADs by 1st of January 2016. According to that agreement, each purse seine vessel could use simultaneously a maximum of 550 Drifting Fishing Aggregating Devices (dFDAs) at any time of the year. This limit to be evaluated through the number of active instrumented buoys, which implicitly established the prohibition of the use of DFADs without buoys. This voluntary agreement also established that the verification of the volume of the daily active beacons used by each purse seiner would be carried out by the independent scientific body AZTI and sanctions were also included in the agreement.

Furthermore, in 2015 IOTC adopted *the Resolution 15-08 Procedures on a Fish Aggregating Devices (FADs) Management Plan* that sets the maximum number of instrumented buoys active and followed by any purse seine vessels at 550 at any one time (and 1100 acquired purchased annually). In 2016, *Resolution 16-01 on interim plan for rebuilding the Indian Ocean Yellowfin tuna stock in the IOTC area of competence* decreased the limit to no more than 425 daily active instrumented buoys per purse seine vessel (and 850 purchased annually).

Likewise, in November 2015 ICCAT adopted the *Recommendation by ICCAT on a Multi-annual Conservation and Management Programme for Tropical Tunas* [Rec. 15-01], establishing a provisional limit of no more than 500 instrumental buoys active at any one time for each fishing vessel.

Since September 2015 AZTI is carrying out the verification of the compliance with the different FAD limit measures adopted; initially as a voluntary agreement and later as agreed IOTC Resolutions 15/08 and 16/01 and ICCAT Recommendation 15-01. The procedure and mechanisms developed to verify the compliance are briefly outlined in the present document.

Method used for the verification

The basic information utilized to monitor the number of active buoys and, hence, verify the compliance with the limits, is provided by the instrumented buoys manufacturers. Currently, three are the companies that supply instrumented buoys to the Spanish and associated fleet (i.e. vessels belonging to the Spanish fishing companies but operating under other flags). By means of a sworn statement issued by these three companies, manufacturers provide daily information on the position and speed of each individual active buoy. Buoys are given unique identifier codes provided by the manufacturer that are associated to a single purse seine vessel, irrespectively of whether they are deployed by the purse seine vessel itself or by a supply vessel.

AZTI receives the buoy data directly from the manufacturers in a monthly basis with a two-month delay. This means that the first day of the information received in month *m* is the information of month *m-2*. Data is received in csv files, independently for each vessel, and contains daily records of all the active buoys managed by each individual vessel in month *m-2*. The information gathered in the csv files is: date [dd-mm-yy], time [hh.mm], individual unique buoy identified code [the format varies with the manufacturer, although it is always alphanumeric], latitude and longitude [expressed in degrees and minutes in decimal values] and speed [knots].

[1] AZTI. Txatxarramendi ugartea z/g - 48395 Sukarrieta, Basque Country, Spain. jsantiago@azti.es
[2] AZTI. Herrera Kaia Portualdea z/g, 20100 Pasaia, Basque Country, Spain
[3] AZTI. Fishing Port, Victoria, Mahe, Seychelles

The agreement considers the following definitions for instrumented buoys, depending on their situation and condition:

- Operational active buoy: a beacon that, after leaving the factory and passing through transit, has been registered and has the ability to transmit.
- Active buoy at sea: operational beacon transmitting position reports deployed at sea.
- Deactivation: action of de-registering an active buoy at sea by the buoy supplier company after the request by the ship owner due to loss, theft or any other possible cause.
- Reactivation: action of re-registering a beacon previously deactivated by the buoy supplier company after the request by the vessel owner (note that a buoy that has been deactivated at sea needs to pass at least one time by the fishing port before it is reactivated).

In order to identify records that do not correspond to active beacons at sea different filters are applied to the data:

- Records outside the Convention Areas [Atlantic Ocean: -100 > longitude > 20; Indian Ocean: 20 > longitude > 120]
- Records on land: two conditions are required, 1) the position of the record overlays a land mask (shapefile http://www.naturalearthdata.com/downloads/10m-physical-vectors/10m-land/) and 2) speed = 0 knots.
- Records of operational active buoys that are onboard the vessel before deployment: speed > 4 knots.
- Records of deactivated buoys: The buoys manufacturers fill with NAs those that have been deactivated during the month of reference. Therefore, those records with NA values are excluded.

AZTI has put in place additional control mechanisms, if necessary, that include: random examination onboard purse seiners and supply vessels at port to check buoys that have previously been deactivated and retrieved on deck (and are, thus, able to be reactivated and used again), crosschecking the first activation of the buoy with VMS vessel position, comparisons with the information recorded in the FAD logbook and with the information collected by the observers onboard, among others.

Preliminary results

Some examples of the results of the verification are shown in **Figures 1** and **2**. **Figure 1** shows the daily evolution of the number of active buoys at sea of one vessel of the Spanish and associated fleet between September 2016 and January 2017 in the Indian Ocean. This trend illustrates the effect of the transition from Res. 15-08 to Res. 16-01 in the IOTC convention area. **Figure 2** shows the average daily density of FADs used by one of the vessels in the Indian Ocean in January 2017, by 1x1º statistical square. According to ICCAT Recommendation 16-01 CPCs shall ensure that this type of information is submitted for the bulk of the fleet every year to ICCAT.

Figure 1. Example of the evolution of the number of active buoys used by one vessel of the Spanish and associated fleet between September 2016 and January 2017 in the Indian Ocean. Limits adopted in Resolutions 15-08 and 16-01 are also shown.

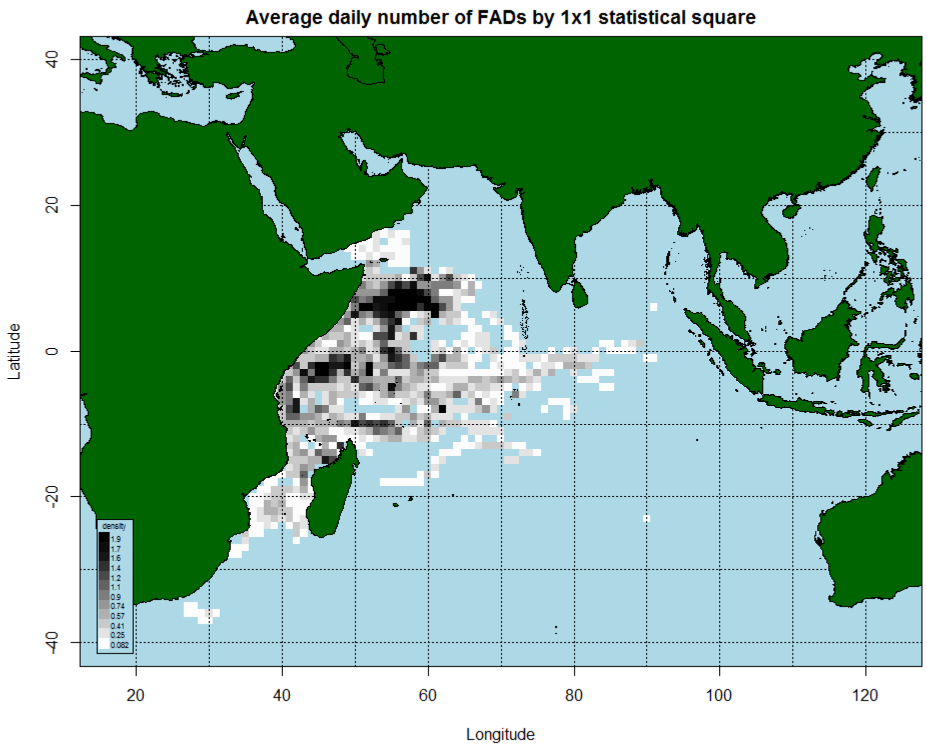


Figure 2. Average daily density of FADs used by one vessel of the Spanish and associated fleet in the Indian Ocean in January 2017, by 1x1º statistical square.

Original: English

BUOY DERIVED ABUNDANCE INDICES OF TROPICAL TUNAS IN THE INDIAN OCEAN

J. Santiago [1], H. Murua[2], J. López[2] and I. Quincoces[1]

One of the most important technological developments that have been recently introduced by the purse seine fleet fishing with FADs are the satellite linked echo-sounder buoys. Their generalized use is causing rapid changes in the fishing strategy and fleet behavior (Lopez *et al.,* 2015), as they continuously provide fishers with near real-time information about the accurate geolocation of the FADs and the presence and abundance of tuna aggregations underneath. Consequently, search time (i.e., the time devoted to the searching of tuna concentrations), the metric traditionally used to reflect nominal effort, is no longer useful. Those changes in fishing strategies and technology make it difficult to evaluate the effective effort of the purse seine fisheries and have therefore hindered the reliable estimation of standardized purse seine CPUE indices (Gaertner *et al*., 2016). However, echo-sounder buoys have also the potential of being a privileged observation platform to estimate abundances of tunas and accompanying species using fishery-independent data (Dagorn *et al*., 2006; Moreno *et al*., 2015, Lopez *et al*., 2013). In a recent work Santiago *et al*. (2016) discussed methodologies to use the acoustic records of the echo-sounder buoys of the FADs as a potential source of fishery independent indices of abundance of tropical tunas. Following their approach, this document presents some preliminary results of an overall index of abundance of tropical tunas in the Indian Ocean from 2013 to 2015. This potential source of information may be used by scientist in future stock assessments.

Methods

The database used in this preliminary analysis has been provided by the purse seine vessel company Echebastar. It comprises information from January 2013 to July 2015 and corresponds to records collected by one of the echo-sounder buoy brands Echebastar's fleet uses. The total number of records reached around 3.4 million including 720,111 acoustic valid records used in the analysis (**Table 1**).

During the data cleaning process, records without acoustic information (records with only position, speed and velocity), outliers (invalid, impossible or extreme values of acoustic information), erroneous positions, time, or other awkward general variables were removed. Apart from the regular exclusions due to data inconsistencies, the following criteria were also considered to select data for further analysis:

- Vertical range of the buoy: acoustic information from the shallower layers, <25m were excluded. According to Lopez (2016), Robert *et al.* (2013), the potential vertical boundary between non-tuna species and tunas can be considered at about 25 m. Excluding the information of the first layers (i.e. up to 25m) from the analysis the noise potentially corresponding to the non-tuna species biomass associated to the DFAD was unconsidered.
- Bottom depth: Using high resolution bathymetry data (British Oceanographic Data Centre, UK, www.gebco.net), acoustic records from buoys located in areas shallower than 200 m were excluded, as FADs that have drifted to shallow coastal areas may provide false positives.
- Speed of the buoy: Satellite linked buoys automatically records information on their trajectory values (speed and bearing). As buoys are usually turned on minutes or hours prior to their deployments and are turned off after an uncertain period when retrieved from the sea, some of their acoustic measurements could be compromised and correspond to false positives as well. In our dataset, values bigger than 6 knots were excluded.

The model used assumes that the signal from the echo-sounder is proportional to the abundance of fish: $BAI_t = \varphi \,.\, B_t$, where BAI_t is the Buoy-derived Abundance Index , φ is the coefficient of proportionality and B_t is the abundance in time t.

[1] AZTI. Txatxarramendi ugartea z/g - 48395 Sukarrieta, Basque Country, Spain. jsantiago@azti.es
[2] AZTI. Herrera Kaia Portualdea z/g, 20100 Pasaia, Basque Country, Spain.

To ensure that φ can be assumed to be constant (i.e. to control the effects other than those caused by changes in the abundance of the population), the nominal measurements of the echo-sounders were standardized using a Generalized Linear Mixed Modelling approach. Because of the significant proportion of records with zero abundance (54.5%) a Delta method was used. The Delta model estimates the predicted abundances as the result of two processes: i) the probability of encounter tropical tuna in the acoustic observations (proportion of positives) and, ii) the mean relative abundance given that a positive observation has been realized. Then the estimated Buoy-derived Abundance Indices (BAI) are the product of these two processes.

The following factors were considered in the analyses: year-quarter[2013Q1 to 2015Q2], area ["north" (LAT >= 10), "east"(LAT < 10 & LAT >-15 & LON<=65), "west" (LAT < 10 & LAT >-15 & LON>65), "Channel" (LAT < -15 & LON<50) and "South" (LAT < -15 & LON>50)], time of the day [UTC, <=06:00 and >06:00], days since deployment[3] [<=30, 30<days<=90, >90], buoy speed [<=1, 1<vel<=2, >2] and SST[4] [<=28, 28<SST<=29, 29<SST<=30, >30]. Some of these factors should be corrected in further analysis: UTC to time zone correction, days since deployment/visit to the FAD and try to incorporate new layers of information, i.e. catch and catch composition.

Interactions among factors were also evaluated. If an interaction was statically significant, and included the year-quarter factor in particular, it was then considered as a random interaction(s) within the final model

Preliminary results

The results of the model deviance are shown in **Table 2**. The most significant explanatory factors for the binomial model on the proportion of positives included area, time of the day, days since deployment, speed and the interactions year-quarter*area and year-quarter*vel. The most significant explanatory factors for the lognormal model on the positive records were year-quarter, area, days since deployment, speed and the interaction year-quarter*SST. Interactions were considered as random.

The estimates of the final Delta model are provided in **Figure 1**. The Buoy-derived Abundance Index (BAI) shows no clear trend. The CVs remain relatively stable (between 13-49%) during the whole time series.

With this document, we present some very preliminary results to remotely estimate a BAI for Indian Ocean tropical tunas. We will continue developing this index including data from more years and the information coming from other brands not already integrated in the current analysis, as well as refining the analysis and including other potentially significant variables. We greatly appreciate the collaboration of the Echebastar fleet who kindly provided the data recorded by their own buoys and we hope that other companies will join the project soon. Acoustic data from the echo-sounder buoys of the FADs can provide significant information to further complement current stock assessments of tropical tuna fisheries, assisting scientist and improving the knowledge between the biomass-CPUE relationship while providing indices less dependent on catch data or less affected by changes in the fishing technology or the fishing effort.

[3] "Deployment" does not correspond to a real deployment; it refers to the first appearance of the buoy in the data set.
[4] Weekly 1ºx1º NOAA_OI_SST_V2 data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their web site at http://www.esrl.noaa.gov/psd/

References

Dagorn L, Holland K, Puente E, Taquet M, Ramos A, Brault P, Nottestad L, Georgakarakos S, Deneubourg J-L, Aumeeruddy R , Josse E, Dalen J, 2006. FADIO (Fish Aggregating Devices as Instrumented Observatories of pelagic ecosystems): an EU funded project on development of new observational instruments and the behavior of fish around drifting FADs. *IOTC-2006-WPTT-16*

Gaertner D, Ariz J, Bez N, Clermidy S, Moreno G, Murua H and Soto M, 2015. Catch, effort, and ecosystem impacts of FAD-Fishing (CECOFAD). *Collect. Vol. Sci. Pap. ICCAT*, 71(1): 525- 539

Lopez J, Fraile I, Murua J, Santiago J, Merino G, Murua H, 2015. Technological and fisher's evolution on fishing tactics and strategies on FADs vs. non-associated fisheries. *IOTC–2015–WPTT17–32*

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. *Fishery Bulletin* 114: 166-178 doi doi:10.7755/FB.114.2.4

Moreno G, Dagorn L, Capello M, Lopez J, Filmalter J, Forget F, Sancristobal I, Holland K, 2015. Fish aggregating devices (FADs) as scientific platforms. *Fisheries Research (*doi http://dx.doi.org/10.1016/j.fishres.2015.09.021

Robert M., Dagorn L., Lopez J., Moreno G. and Deneubourg J.-L, 2013. Does social behavior influence the dynamics of aggregations formed by tropical tunas around floating objects? An experimental approach. *Journal of Experimental Marine Biology and Ecology* 440:238-243.

Santiago J , Lopez J, Moreno G, Murua H, Quincoces I, 2016. Towards a Tropical Tuna Buoy-derived Abundance Index (TT-BAI). *Collect. Vol. Sci. Pap. ICCAT*, 72(3): 714-724.

Table 1. Number of vessels operated by the Echebastar fleet, total number of records and acoustic records used in the analysis

	2013	2014	2015	TOTAL
VESSELS	6	6	6	6
NUMBER OF RECORDS	980,332	1,555,738	818,491	3,354,561
ACOUSTIC RECORDS	186,716	338,803	194,592	720,111

Table 2. Deviance tables for the binomial (top) and the lognormal (bottom) components of the Delta-lognormal model. Significant (p<0.05) factors and interactions of total deviance are highlighted.

a) **Model: binomial, link: logit** [Response: posit]

	Df	Deviance	Resid. Df	Resid. Dev	Pr(>Chi)		
NULL			635066	877751			
YEAR_QUARTER	9	678.8	635057	877072	< 2.2e-16	***	2%
AREA	4	2044.3	635053	875028	< 2.2e-16	***	5%
HOUR	1	6501.7	635052	868526	< 2.2e-16	***	15%
DAYS	2	5176.2	635050	863350	< 2.2e-16	***	12%
VEL	2	18072.7	635048	845277	< 2.2e-16	***	42%
YEAR_QUARTER:AREA	36	2765.2	635012	842512	< 2.2e-16	***	6%
YEAR_QUARTER:HOUR	9	367.7	635003	842144	< 2.2e-16	***	1%
YEAR_QUARTER:DAYS	18	1277.8	634985	840866	< 2.2e-16	***	3%
YEAR_QUARTER:VEL	18	2788.1	634967	838078	< 2.2e-16	***	6%
AREA:HOUR	4	399.2	634963	837679	< 2.2e-16	***	1%
AREA:DAYS	8	134.9	634955	837544	< 2.2e-16	***	0%
AREA:VEL	8	1359.6	634947	836184	< 2.2e-16	***	3%
HOUR:DAYS	2	435.3	634945	835749	< 2.2e-16	***	1%
HOUR:VEL	2	49.7	634943	835699	1.615E-11	***	0%
DAYS:VEL	4	1254.2	634939	834445	< 2.2e-16	***	3%

b) **Model: gaussian, link: identity** [Response: log(ECHO)]

	Df	Deviance	Resid. Df	Resid. Dev	F	Pr(>F)		
NULL			297070	710708				
YEAR_QUARTER	9	12509	297061	698199	841.497	< 2.2e-16	***	6%
AREA	4	10159	297057	688040	1537.699	< 2.2e-16	***	5%
HOUR	1	502	297056	687538	304.086	< 2.2e-16	***	0%
DAYS	2	44868	297054	642670	13582.867	< 2.2e-16	***	20%
VEL	2	109874	297052	532795	33262.05	< 2.2e-16	***	50%
SST	3	1717	297049	531079	346.44	< 2.2e-16	***	1%
YEAR_QUARTER:AREA	36	6282	297013	524797	105.65	< 2.2e-16	***	3%
YEAR_QUARTER:HOUR	9	1872	297004	522925	125.924	< 2.2e-16	***	1%
YEAR_QUARTER:DAYS	18	1988	296986	520937	66.877	< 2.2e-16	***	1%
YEAR_QUARTER:VEL	18	6047	296968	514890	203.401	< 2.2e-16	***	3%
YEAR_QUARTER:SST	27	18959	296941	495930	425.153	< 2.2e-16	***	9%
AREA:HOUR	4	526	296937	495405	79.558	< 2.2e-16	***	0%
AREA:DAYS	7	269	296930	495136	23.245	< 2.2e-16	***	0%
AREA:VEL	8	1484	296922	493652	112.297	< 2.2e-16	***	1%
AREA:SST	5	198	296917	493455	23.92	< 2.2e-16	***	0%
HOUR:DAYS	2	443	296915	493011	134.207	< 2.2e-16	***	0%
HOUR:VEL	2	547	296913	492465	165.48	< 2.2e-16	***	0%
HOUR:SST	3	98	296910	492367	19.807	7.839E-13	***	0%
DAYS:VEL	4	727	296906	491639	110.096	< 2.2e-16	***	0%
DAYS:SST	6	423	296900	491216	42.723	< 2.2e-16	***	0%
VEL:SST	6	853	296894	490363	86.038	< 2.2e-16	***	0%

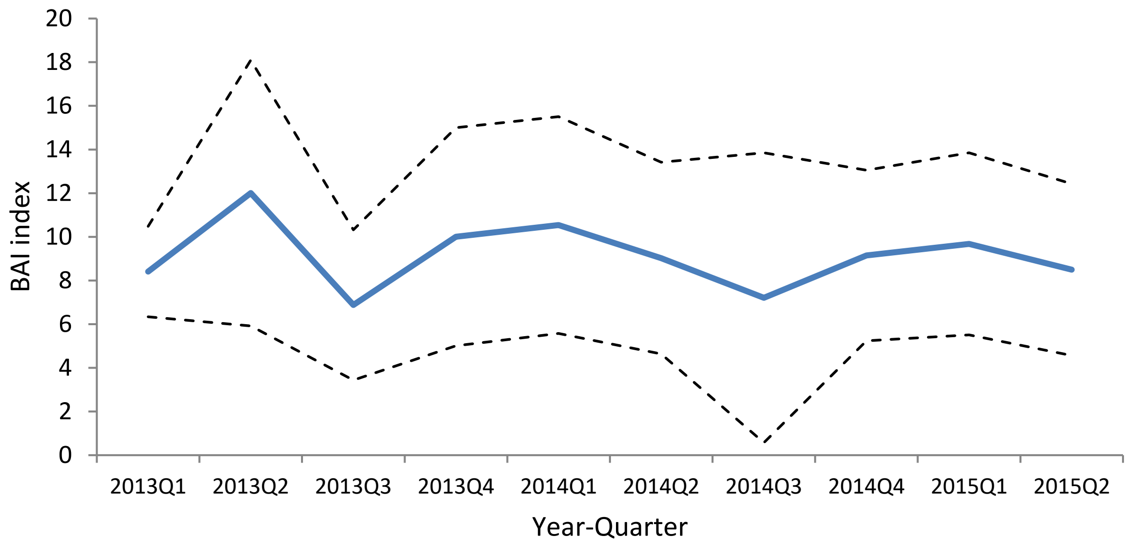


Figure 1. Time series of the quarterly values of the Tropical Tuna Buoy-derived Abundance Index (BAI) for the period 2013Q1-2015Q2. The upper and lower confidence intervals are also shown.

Original: English

IMPLEMENTING MANAGEMENT PLANS AND VOLUNTARY INITIATIVES REGARDING FADS: THE OPAGAC EXPERIENCE

Miguel Herrera and Julio Morón[1]

This document presents the range of actions undertaken by the fishing companies represented by the Producers' Association (PO) OPAGAC to evaluate and reduce, where required, the impact of the OPAGAC fishery on target and by-catch species, and the ecosystem.

OPAGAC represents the interests of eight fishing companies owning 40 industrial tuna purse seiners, which operate in tropical and subtropical seas, worldwide. Purse seines are used to target tropical tunas, in particular skipjack tuna (SKJ, *Katsuwonus pelamis*) and yellowfin tuna (YFT, *Thunnus albacares*). Other species caught using this gear are bigeye tuna (BET, *Thunnus obesus*), albacore (ALB, *Thunnus alalunga*), frigate and bullet tunas (*Auxis* spp.), kawakawa (*Euthynnus* spp.) and, to a lesser extent, other species of *Scombroidei*, billfish, sharks, rays, and marine fish. Some species of marine turtles can also be incidentally caught using purse seines, although catches are very low.

Catches of the fleet in recent years have been around 300,000 metric tons of tropical tuna species, worldwide (**Figure 1**). This represents 6% of the total catches of tropical tunas, across all fishing fleets, gear types, and oceans. The contribution of catches to the total catches of tropical tunas varies depending on the ocean, ranging from around 20% of the total catches in the Atlantic Ocean to 3% in the Western Central Pacific Ocean (**Figure 2**). Industrial purse seiners can catch schools of tuna free-swimming; aggregated beneath objects, stationary or drifting, purposely built (FAD) or not (floating objects of various types); swimming in the proximity of sea-mounts; or swimming along with various species of sharks and mammals, in particular whale-sharks, dolphins, and whales. While tropical tunas make the majority of the catches of tuna purse seiners, representing over 98% of the total catches, the remaining 1.4% is made by other species, especially other bony fish, sharks, rays, and other bycatch[2].

In recent years, the OPAGAC fleet has implemented a range of voluntary actions to improve monitoring of the fishery, be able to better evaluate its impact, and mitigate those impacts in a timely fashion, whenever they prove to be significant. Following implementation, OPAGAC advocated for RFMO to adopt new measures or amend existing measures leading RFMOs to incorporate some of the activities OPAGAC had implemented, and efforts for other measures to be adopted by the RFMO in the near future

In 2016, WWF agreed to support OPAGAC in the implementation of a Fishery Improvement Project (FIP), effective since September 2016. The OPAGAC-WWF FIP is now in transition and will last up to five years through which OPAGAC will consolidate the actions it has already implemented on its vessels, as well as initiating additional required actions, as identified in the FIP Action Plan. The main objective of the OPAGAC FIP is to prepare the ground for OPAGAC to be in a position to certify its fishery with the Marine Stewardship Council (MSC), as per MSC's minima standards and criteria.

OPAGAC's aim is the certification of its purse seine fishery using a single Unit of Assessment (UoA) per stock - i.e. regardless of the fishing mode used (unlike MSC which uses two UoA per stock, associated and unassociated) -, and its FIP has been designed to achieve this purpose. This is in line with the type of management that is promoted under the framework of the RFMO which, in adopting management measures, need to consider the impacts of all fisheries and fishing modes on each stock rather than limiting to specific fisheries or fishing modes.

A non-exhaustive list of the actions implemented by the OPAGAC fleet is presented below. This information includes also details concerning the timing of implementation, fleets involved (exclusively OPAGAC or also other fleets), and whether implementation came in response to regulations adopted at the flag state, coastal state, or regional organization, or by OPAGAC itself, including the actions in OPAGAC's FIP action plan.

---

[1] Organización de Productores Asociados de Grandes Atuneros Congeladores (OPAGAC), Madrid, Spain
[2] Justel-Rubio, A. and V. Restrepo. 2017. Computing a global bycatch Rate of non-target species in tropical tuna purse seine fisheries. ISSF Technical Report 2017-01. International Seafood Sustainability Foundation, Washington, D.C., USA.

1. Actions intended to improve management of tropical tunas by the Regional Fisheries Management Organizations (RFMO) concerned: The OPAGAC vessels operate in the areas of competence of four RFMO, including: the International Commission for the Conservation of Atlantic Tunas (ICCAT); Indian Ocean Tuna Commission (IOTC); Inter-American Tropical Tuna Commission (IATTC), and; Western and Central Pacific Fisheries Commission (WCPFC). Actions are four-fold:

   i) Actions devoted to strengthen the management of stocks of tropical tunas in the four RFMO, in particular participation, promotion and assistance to the implementation of Harvest Control Rules (HCR) by the RFMO (OPAGAC FIP Principle 1 Actions). The status of implementation of HCR varies depending on the stock and RFMO concerned, and therefore, the actions implemented by OPAGAC are tailored to each specific case. Actions include assistance to the design of HCR Agendas and adoption of those Agenda by the RFMO concerned; and support to the process of implementation of those Agendas, where required.

   ii) Actions devoted to ensure compliance of the OPAGAC fleet with the management measures adopted by the RFMO, and promote the same type of actions by other fleets (OPAGAC FIP Principle 3 Actions). This includes compliance with: fishing capacity limits, catch limits; effort limits; FAD limits; fishery closures; full or partial time-area closures (e.g. FAD closures); prohibition to surround whale sharks or cetaceans during purse seine sets; bans on discards of target species; bans on retention of sensitive bycatch (e.g. some species of sharks, marine turtles, etc.); implementation of FAD Management Plans, including data requirements on FADs (FAD logbooks); and other data requirements.

   iii) Actions implemented under the framework of the Tuna Transparency Initiative, intended to promote the adoption of regional programmes under the framework of the RFMO, with the aim of transferring the management of the existing observer, inspection, and VMS schemes to the RFMO concerned, where applicable (i.e. where those programmes are managed by the flag states rather than the RFMO). OPAGAC also advocates for RFMO to prohibit all transshipments at-sea, because they are considered to be a source of IUU.

   iv) Actions intended to strengthen the capacity of coastal states in MCS, through the implementation of pilot activities to evaluate the use of electronic monitoring systems in Seychelles and the Cook Islands. These activities are intended to strengthen the institutional capacity in these countries to monitor the activities of foreign licensed fishing vessels.

2. Actions intended to reduce the impact of the OPAGAC fleet on the marine ecosystem (OPAGAC FIP Principle 2 actions). This includes actions to:

   i) Reducing as much as possible the fishing mortality of species making the bycatch of purse seine fisheries, in particular species of sharks, marine turtles and other sensitive marine fauna, as identified by the RFMO. In particular adoption of non-entangling-FAD designs and guidelines for the safe release of bycatch species, from the net, upper, and lower decks of purse seiners. This is achieved through the implementation of a Code of Good Practices, which encompasses all Spanish tuna purse seiners. The Code was designed by the two Spanish POs and has been implemented since 2011. It is implemented onboard purse seiners by the vessel crew. Compliance with the Code is monitored by observers and verified by an independent research institute, AZTI-Technalia, using the information recorded by the observers. AZTI does also take care of ensuring high levels of quality in the implementation of the Code, including training of observers and review of the Code, where necessary. The OPAGAC fleet is using a combination of human and electronic observers to monitor the activities of its purse seine and support vessels. There has been a gradual implementation of the observer coverage on board OPAGAC tuna purse seiners and in 2014, the Spanish POs voluntary agreed to have 100% observer coverage on board purse seiners and support vessels. Thus, since January 2015 levels of coverage have been 100% in all oceans, well above those recommended by some RFMOs (i.e. IOTC and ICCAT). In addition, OPAGAC is involved in a number of research activities intended to assess levels of mortality following release of bycatch specimens caught in purse seine sets, evaluate levels of interaction between the OPAGAC fishery and some populations of whales recorded as threatened by the IUCN, and other research activities.

ii) Reducing as much as possible the impact of the fishery on the marine ecosystem. The only known adverse effects of the purse seine fishery are related to the use of FADs, which may lead to FAD loss and beaching events. OPAGAC has implemented several actions to evaluate and mitigate, where required, these impacts.

iii) Since 2016 OPAGAC has been supporting a local NGO in the Seychelles, the Island Conservation Society (ICS), and the Seychelles Fishing Authority (SFA), in a pilot to prevent and eliminate the impacts of FADs in sensitive marine areas in the Seychelles (referred to as FAD-Watch Project). This is especially intended to eliminate FAD beaching events, through prompt retrieval and reutilization of FADs likely to beach in the Seychelles sensitive marine areas defined. The main objective of this pilot is to create a FAD-Watch blueprint which, if successful, could be implemented in other sensitive marine areas.

iv) Since 2015 OPAGAC has been involved in research intended to design and try biodegradable FAD and will support and participate in a large-scale pilot to test biodegradable FAD in the Indian Ocean, involving purse seiners and support vessels flagged in EU countries and the Seychelles, research institutions in the EU (AZTI, IRD and IEO) and Seychelles, and the International Seafood Sustainability Foundation. Implementation of the large-scale pilot is expected in 2017 or beginning of 2018.

v) OPAGAC is also supporting research with satellite buoys, in order to assess the range of frequencies that would allow discrimination of the biomass beneath the FADs by species.

The activities under OPAGAC's FIP and Code of Good Conduct are under constant review with activities modified and new activities added as RFMOs adopt new measures or the results from pilot programmes and research activities become available. OPAGAC is providing scientists with the results obtained from the implementation of the activities covered in this document, and any new activities or initiatives resulting on the FIP implementation will be reported to the scientific committees of the RFMOs concerned.

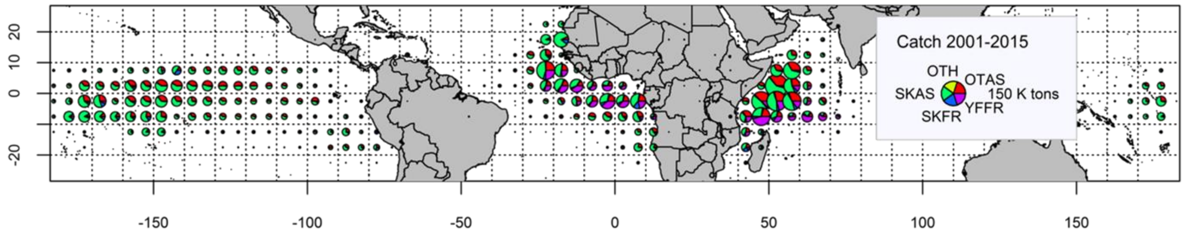


Figure 1. Total accumulated catches (metric tons) of tropical tunas recorded for OPAGAC purse seiners over the period 2001-2015. Source: OPAGAC Database (accessed December 2016).

- SKFR: Catches of skipjack tuna taken on free-swimming schools
- YFFR: Catches of yellowfin tuna taken on free-swimming schools
- SKAS: Catches of skipjack tuna taken on associated schools
- OTAS: Catches of yellowfin and bigeye tuna taken on associated schools
- OTH: Catches of tropical tunas not elsewhere included

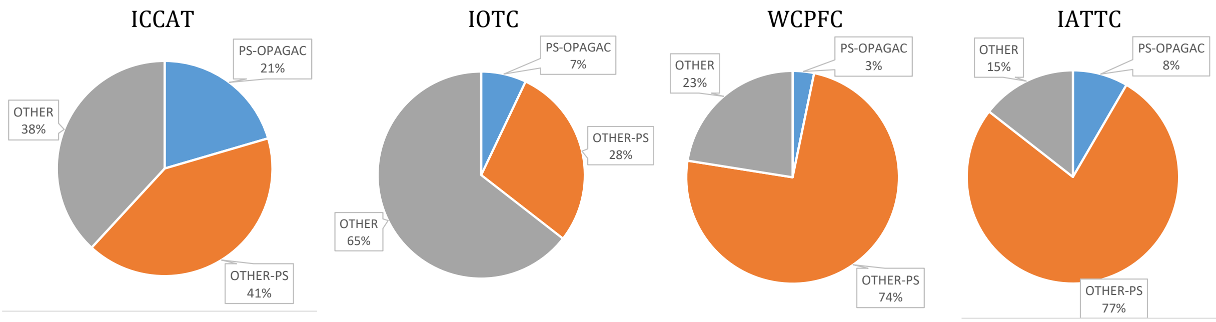


Figure 2. Contribution of the catches of tropical tunas recorded for the OPAGAC fleet (blue) other purse seiners (orange) and other fleets (grey), by RFMO area of competence (2013-15). Source: OPAGAC Database (accessed December 2016).

Original: English

EVOLUTION OF THE PERCEPTION OF THE FAD ISSUE BY THE FRENCH AND ITALIAN PURSE SEINE FLEET SINCE 2010 AND PERSPECTIVES FOR FUTURE MANAGEMENT

Goujon M.[1], Maufroy A.[1], Le Couls S.[2], Claude A.[3]

Abstract

FAD fishing has always been part of the activity of tropical tuna purse-seiners but the recent proliferation of DFADs and accelerated use of DFADs (and support vessels) are considered by French and Italian boat-owners as not only threatening the sustainability of the exploitation but also their economic model (based on a balanced targeting of free swimming and associated schools). This perception leaded them to take FAD management measures as soon as 2012 and to cooperate with scientists in order to improve knowledge and management of FAD fishing. Good practices related to FAD fishing have been initiated by the French fleet in the beginning of the 2010's. The first actions were the replacement of all DFADs by non-entangling DFADs and the identification and adoption of best practices to reduce sharks, rays and turtles' incidental mortality without altering crew safety conditions. Then the decision was made to build DFADs in workshops at port with confection rules allowing DFADs to remain non-entangling as long as possible and to experiment biodegradable DFADs. After adopting an auto-limitation on DFAD use, Orthongel and its member boat-owners have promoted the adoption of such limits by tuna RFMOs and consider that it is now important to improve data collection as well as the control and compliance of measures adopted by the RFMOs. Propositions based on the experience of Orthongel are made to achieve these goals.

1. ORTHONGEL, 5 rue des Sardiniers, 29900 Concarneau, mgoujon@orthongel.fr (corresponding author).
2. Compagnie Française du Thon Océanique, 9, rue Professeur Legendre - BP 639 - 29186 Concarneau Cedex.
3. Saupiquet, 7 rue des Chalutiers, 29000 Concarneau.

Appendix

EVOLUTION OF THE PERCEPTION OF THE FAD ISSUE BY THE FRENCH AND ITALIAN PURSE SEINE FLEET SINCE 2010 AND PERSPECTIVES FOR FUTURE MANAGEMENT

Goujon M., Maufroy A., Le Couls S, Claude A.

Introduction

This document presents the point of view of the French (22 vessels) and Italian (1 vessel) purse-seine fleet owned by 4 boat-owners (Compagnie Française du Thon Océanique, SAPMER S.A., Saupiquet et Industria Armatoriale Tonniera) gathered in the producer organization (PO) ORTHONGEL. The economic model of both these fleets is based on a balanced targeting of free swimming and associated schools. Measures exist within each boat-owner's fleet and at the level of the PO, to limit the catch of juvenile tunas. These measures include, at the level of the boat-owner, the payment of crewmen on the basis of the sale of the catch rather than on the basis of the volume of catch (incentive), the non-remuneration of fish smaller than 1.5 kg (disincentive), a limitation of the amount of catch on board intended to the local markets (too-small tunas refused by the canneries and bycatches, disincentive), and, at the level of Orthongel, a limitation in number of beacons attached to floating object used by each vessel since 2012 (superseded in 2015 by the limitations implemented by IOTC and ICCAT, disincentive).

Reasons for the adoption of these measures are first summarized and the measure taken by Orthongel are described. The authors then analyse how the context has evolved since and what are the consequences for the French and Italian fleets. They conclude on the lessons that can be learned for future tropical tuna management.

Rationales of the FAD management plan

For more than 20 years, scientists and managers of ICCAT and IOTC have stressed the need to collect accurate data on the fish aggregating devices (FADs) used by tropical tuna seiners and to monitor their use, i.e. when ICCAT recognized the urgent need to improve " scientific knowledge relative to bigeye tuna and to the effects of the fishing techniques with fish aggregating devices (FADs) on the multi-species fisheries of tropical tunas » considering that large increase in juvenile catches could present a danger to the stock of Atlantic bigeye tuna (ICCAT Rec. 96-01). These concerns were, to a large extent, at the origin of the moratorium on FAD fishing set up voluntarily by the three European tropical tuna producer organizations in 1997 (Goujon and Labaisse-Bodilis, 2000). Same concerns were subsequently clearly expressed in several international reviews (Le Gall J.Y. *et al.*, 2000; Bromhead *et al.*, 2002) as well as in the conclusions of the World Tuna Purse Seine Organization (WTPO) report on the impacts of FADs and the development of management strategies for responsible use of FADs by purse seine fleets (MRAG, 2009). Awareness of managers was also raised by the civil society (Morgan, 2011) and progressively the issue of FADs has become a paramount for the Regional Fisheries Management Organizations (RFMOs) leading to adopt FAD management measures.

Although the FAO Code of Conduct recommends implementing "management systems for ... fish aggregating devices" (Article 8.11.3, FAO, 1995), it is not until 2008 that the Central and Western Pacific Tuna Fisheries (WCPFC) recommended the establishment of the first FAD management plans (CMM 2008-01). Similar recommendations were then adopted by ICCAT (Rec. 11-01) and IOTC (Res. 12/08). In response to the ICCAT recommendation, a national FAD management plan was therefore implemented by Orthongel in 2012 based on the regulations already in place by Orthongel at the end of 2011 (Orthongel Decision No 10 and No 11). This FAD management plan was endorsed by the French administration and communicated to RFMOs the same year.

When the French FAD management plan was implemented, the first question was to clarify the notion of FAD (term hereafter used as a global term to define what is managed). It was agreed among Orthongel members that a floating object (FOB) could be any artificial or natural floating object (wreckage, lost fishing gears, branches, carcasses, rafts, etc.) used by fishermen to increase their fishing efficiency due to the aggregative behaviour of tropical tuna under these objects. Therefore, these objects could be found (natural or artificial logs) or deployed (drifting rafts[1] referred as DFADs) at sea by fishermen. In the 90's, fishermen started to attach radio beacon to floating objects (tracked FOBs) to facilitate their location. Nowadays, after several technical progresses, the last generation of beacons provide information to fishermen (GPS position and presence/absence of biomass under the tracked FOB). This effort of clarifying the notion of FADs (Goujon *et al*., 2014, **Figure 1**) contributed to one of the results of the EU-funded CECOFAD program (intended to provide insights into the fishing effort units to be used in the calculation of purse-seine CPUEs and to provide new knowledge on the impact of FAD-fishing on the pelagic ecosystems (Gaertner *et al.*, 2016). These harmonized definitions were adopted by ICCAT in Rec. 16-01. Because of its unique identifier, the beacon can be used to identify clearly the tracked DFAD as well as the user (or the owner) of this tracked DFAD.

Although French and Italian boat-owners are convinced that the use of FOBs in tropical tuna fisheries always existed (purse seiners have been using logs since the beginning of the fishery), is necessary for purse seiners targeting tropical tunas, and contributes to a balanced exploitation of those species by combining activities on FOBs and free swimming school, they are also aware of the potential negative impacts/disadvantages of FOB fishing.

Tunas are not easy to catch, especially when they are not aggregated. FOB fishing not only facilitate the search for tuna schools and reduce the rate of null sets (when the tuna escape), it is also the only alternative outside the schooling seasons and the most common way to catch skipjack (which represent more than half of our total catch). Increasing the number of FOBs used by fishermen by deploying DFADs could therefore improve the efficiency of the vessels. The contribution of DFADs to fishing efficiency is still to be clearly demonstrated however preliminary analyses during the CECOFAD program showed that vessel catch tends to increase with the number of DFADs used by the vessel (Gaertner *et al.*, 2016) and clearly increase with the association of the vessel with a support vessel (Maufroy *et al*., 2015a), as support vessels allow to deploy larger numbers of FOBs and assist purse seiners in their FOB fishing activity. The comparison of the evolution of catch and fishing capacity combined factors (number of vessels, number of support vessels, number of DFADs) in Indian Ocean also suggest that DFADs contribute to fishing efficiency (**Figure 2**).

The PS fleet relies more and more on this fishing strategy and the proportion of catch made under FADs has continuously increased since the mid 2000's (**Figure 3** from Fonteneau and Chassot, 2014 and Fonteneau, *et al.*, 2014).

However, this increasing use of the FOB strategy may have various negative consequences: schools associated with FOBs are often mixed schools of skipjack and juveniles of yellowfin and bigeye; bycatch rate are much higher for FOBs sets than for free swimming school sets (though still low compared to other fishing gears); skippers could be tempted to fish almost exclusively on FOBs due to their lower rate of null sets FOBs and lose their skills on free-swimming-school fishing; and finally DFADs (most of the FOBs used by fishermen) may represent a source of pollution, generate perturbation in the schooling behaviour of tunas and cause damage to fragile structures (such as coral reefs) in case of beaching (Balderson and Martin, 2015).

The perturbation in schooling behaviour of tuna is unanimously reported by French and Italian skippers when asked on the consequences of the increase of DFADs in the Ocean. For these skippers, the increase in DFAD density in fishing grounds has led to a diminution of the schools' size under DFADs and a decrease in the abundance of free swimming schools (Goujon, 2015a). **Figure 4** (derived from Fonteneau, 2014) illustrates best the perception by skippers, which echoes the conclusion of SCRS in 2008 which indicated that free swimming schools of mixed species were considerably more common prior to the introduction of FADs. Increasing the number of DFADs may alter the natural behaviour of tropical tunas for instance by trapping tunas in suboptimal areas (ecological trap; Hallier and Gaertner, 2008; Marsac *et al*., 2000; Ménard *et al*., 2000), modifying school composition (Fonteneau *et al*., 2000; Hall *comm. pers*.), fragmenting tuna schools (Sempo *et al*., 2013; Fonteneau, 2014) or reducing residence times of schools under individual FOBs (instability of schools, Maufroy *et al*., 2016).

---

[1]. Rafts generally consist of a floating part (often made of bamboo) and a submerged train (allowing the FAD to drift with currents rather than with winds). Traditionally this train was a piece of netting. Having noticed that these nets represented a risk of entanglement for turtles and sharks, the French and Italian fleet was the first to modify all the rafts that it put in the water so that such entanglements are no longer possible.

Orthongel approach was therefore to address two specific (and manageable) issues linked with FADs: the contribution of tracked DFADs (or tracked logs) to fishing effort (correlated to the beacon) and the environmental impact of DFADs (**Figure 1**), considering that fishermen (as well as managers) can control the quantity and quality of DFADs deployed at sea, while they have very little control over the abundance, distribution and quality of natural logs (whose environmental impact is often minor) and human-made logs (whose origin is mostly external to fisheries). While in the 80's, about 20% of the sets were made on floating objects, mostly logs, since the 2000's tracked DFADs are involved in more than 80% of the sets on floating objects by French and Italian fishermen. The plan established Orthongel should therefore significantly cover the FAD issue. Its objectives (in chronological order of implementation) were:

1) to reduce potential environmental impacts of DFADs such as incidental direct (catch) or indirect (entanglement in DFADs) mortality of sharks, rays and turtles, or FAD beaching,
2) to ensure that fishing with FADs is sustainable by avoiding an exclusive use of FADs generating disproportionate catch of juveniles, and
3) to preserve the economic model of the French and Italian fleet which relies on a balanced targeting of associated and free swimming schools and therefore needs abundant free swimming schools.

We also made sure that the Orthongel FAD management plan followed the guidelines provided by ICCAT Rec. 11-01 and IOTC Res. 12/08.

Implementation of the 2012-2015 Orthongel FAD management plan

Measures intending to mitigate potential environmental impacts of DFADs

Non-entangling DFADs

In 2010, Orthongel launched a program which objective was to eliminate turtle entanglement in the netting used in DFADs (cover of the raft and underwater train) and, as this program and the tagging of sharks realized in a concomitant program of Orthongel (see next chapter) revealed, the entanglement of sharks, which appeared to be of greater concern (Filmater *et al*., 2013). Each vessel's crew was explained the objectives and encouraged to test different designs either proposed by Orthongel based on previous European experiments, or imagined by the crewmen themselves. The data they were asked to collect during the program every time a DFAD was deployed or fished, allowed us to document the best (and most accepted) non-entangling FADs designs (**Figure 5**) and to demonstrate that catch rate were not altered by the modifications made (**Table 1**, Goujon *et al.,* 2012). By the end of the program, all French and Italian DFADs had been replaced by non-entangling ones so that the boat-owners voted in November 2011 a resolution prohibiting the deployment of entangling DFADs (*i.e.* that would not be designed to eliminate the risk of entanglement) for all French and Italian purse seiners (Orthongel Decision 11).

In addition to this first program, Orthongel launched in 2013 a program to establish two land-based workshops (one for each ocean) to manufacture non-entangling DFADs for the vessels with terms of reference that would guarantee on the permanent non-entangling nature of our DFADs. It also allowed us to test new materials or new designs and to monitor the number of DFADs ordered by each vessel (**Figure 6**). Various tests of biodegradable DFADs were also made: we experimented coconut fibre for the underwater structure and the cover of the raft. Around one hundred of these DFADs were deployed in the Atlantic and Indian Oceans, including at ports so that we could visit them regularly; some of these biodegradable DFDAs were also sent to be tested and monitored in Hawaii by an ISSF team. However, coconut fibre appeared to be not suitable as the fibre gets soaked (creating a problem of buoyancy) and is not enough resistant (the DFAD rapidly breaks up). Research continues today with tests of cotton ropes in both oceans and a project to test new materials developed in partnership with the textile industry.

Safe release of sharks, rays and turtles arrived alive on the deck

In 2010, simultaneously to the non-entangling DFADs program, Orthongel also implemented with IRD and Ifremer (as a complement of the MADE program) a program to test and document the best tools and procedures for the release of sharks, rays and turtles arrived alive on the vessel's deck in order to improve both the survival rate of the released animal and the safety conditions for crewmen. IRD and Ifremer scientists embarked on board purse seiners and 31 individuals were tagged with archival pop-up tags to measure the survival rates of individuals released with the identified best technics. These best practices have been documented in a guide edited by Orthongel in French, English and Spanish (Poisson *et al.*, 2012), each crew have also received a specific training and a series of 6 reminder posters were displayed aboard each purse seiner (**Figure 7**). Information on specific technics or tools and adoption of these best practices was rapidly spread amongst all the fleet (**Figure 8**). The comparison of the implementation of these practices reported by on board observers revealed the importance of the crew supervisor as a key person for systematic application of the good practices and search for improved technics. For turtles (which survival rate was already good), progress was made in the handling of the animals and curing of injured animals prior release (Goujon, 2015b). For sharks, best practices defined per species and size of sharks require relatively minimal effort by fishermen but could impact substantially and positively the by-catch post-release survival (Poisson *et al.*, 2014a). Adoption of these practices were encouraged since they reduced sharks post-release mortality by about 20% (Poisson *et al.*, 2014b).

The FAD-Watch project

Since January 2016, Orthongel has been intending to establish a specific cooperation with the Seychelles Fisheries Authorities aimed at reducing as much as possible the potential impacts of French and Italian DFADs beaching on coral reefs, events which occurrence was estimated by Maufroy (2015b). The project includes the automatic provision of GPS position of DFADs approaching coral reefs with a significant risk of beaching so that any vessel present in the area could intercept the DFAD and tow or recover it to prevent beaching. This information is also useful when planning campaigns of removal of DFADs from reefs and beaches. Recovered notified DFADs (and beacons allowing their identification) could be recycled by being bought back by the boat-owners, therefore providing an economic compensation for the time spent by the vessel having recovered the DFAD.

Measures intending to limit DFADs proliferation

In order to limit DFADs proliferation, French and Italian boat-owners voted in November 2011 a resolution to limit the number of tracked DFADs (and tracked logs) at sea to no more than 150 active beacons and to limit the number of new beacons bought every year for each vessel to 200 (Orthongel Decision 10). Because, it appeared essential that numbers and location of DFADs needed to be monitored, the decision also prohibited the use of beacons that did not provide a GPS position (e.g. radio buoys).

Since the French and Italian fleet is not the only one to use DFADs (see **Figure 2**), Orthongel actively contributed to raise awareness on the need to improve data collection on DFADs and to manage the use of DFADs (promoting in particular the principle of capping the number of DFADs) at the level of EU (Eurothon, Long Distance Advisory Council and DG MARE) and at the level of other CPCs (Riva, 2014; Riva, 2016) and tuna RFMOs. Progress has indeed been made by tuna RFMOs since IOTC has set a DFAD limit in 2015 (IOTC Res. 15-08, revised by IOTC Res. 16-01 with the inclusion of a limitation of the number of support vessels) as well as ICCAT in 2015 (ICCAT Rec. 15-01).

Although we still believe that the levels of these limitations are two high, we consider that tuna RFMOs FAD working groups should provide in the short term an advice to improve these management decisions, based on the contribution of DFADs to fishing effort and the level at which the fishing activity switches to a « cherry-picking » activity (which, obviously, cannot be evaluated and managed by traditional fisheries technical methods and measures). To facilitate the work of scientists and improve their knowledge on the consequences of DFAD use, Orthongel provide to IRD scientists, in addition to mandatory logbooks, VMS and landing data, DFAD's beacon activation/deactivation data (quarterly from 2010 to 2015, monthly in 2016 and daily since January 2017) reports, all FOBs related activities data on the ICCAT/IOTC logbook (including for the support vessel) since 2013, GPS tracks of all DFAD beacons since 2007 and echo-sounder data of these DFADs since 2014. In addition to the observers' data collected within the frame of the DCF program (10% coverage), IRD now recover scientific observers' data for 100% of the cruises (in the Atlantic since January 2014 and in the Indian Ocean since January 2016).

Since 2012, we also elaborated with our beacons providers a scheme of control and declaration of the number of active beacons at sea (requested by ICCAT and IOTC) and have continuously improved it. For instance, the term « active beacon » used to qualify the beacon as contributing to the fishing effort could create some unclarity since beacons can be activated/deactivated. It is therefore important to distinguish « active » from « activated » (**Figure 9**).

To provide an appropriate indicator of DFAD's contribution to fishing effort, we consider as active any beacon at sea transmitting at least a position in 24h and drifting at a speed greater than 0 and less than 6 knots: a null drift indicates that the beacon (and hopefully the associated DFAD) has beached while a drift greater than 6 knots means the beacon is on board a vessel (either on test before being attached to a FOB or stolen by another vessel which does not know how to deactivate it). Once a beacon stops transmitting at least a position in 24h, it is supposed to be lost and access to the communication of this beacon is terminated by the provider.

Current situation and perspectives for future FAD management

Due to the levels of limitation fixed by RFMOs and the lack of access of these RFMOs to DFADs data – for instance, it does not seem that quarterly declarations of active DFADs required by ICCAT since 2013 (ICCAT Rec 13-01) and IOTC since 2014 (IOTC Res. 13/08) were made available to the scientific committee of these RFMOs – it is difficult to assess whether the limitations implemented by tuna RFMOs have been effective in reducing the number of DFADs and, consequently, have contributed to reduce juvenile catch, as well as other environmental impacts.

On the contrary, Orthongel data (provided to IRD and our administrations) show that because of weariness of the French and Italian boat-owners to limit themselves way below other fleets and because of competition with other purse-seine fleet and the low price of tuna, the number of DFADs used by the French and Italian fleet has increased recently in the Indian Ocean. It is however not the case in the Atlantic Ocean (**Figure 10**).

When asked on the evolution of the FAD issue, French and Italian skippers report that the number of DFADs at sea does not seem to have decreased and illustrate this by observations of concentration of short-distanced DFADs (in a single set, one skipper counted more than 25 DFADs entangled together!). Last autumn, they observed a complete absence of free swimming school for several months. Many of them explain that they now have almost only access to DFAD schools and are obliged to change their strategy. Boat-owners also have to adapt to this situation (buying more beacons for their vessels) while at the same time, the presence of scientific observers accredited by Bureau Veritas allow them to get some premium on their production of « free-school » tuna, which demand is increasing on EU markets…

Moreover, many skippers observe that the exchange of beacons on their DFADs by other purse seiners but also support vessels – which number and efficiency has increased these last years (Fonteneau, *comm pers.*) – is more frequent, rising in some cases to 30% of their seeded DFADs within 45 days. This phenomenon also contributes to an increase of the number of DFADs deployed at sea.

In consequence, French and Italian boat-owners will continue to militate for a limitation of DFAD beacons per vessel at a more reasonable level (*i.e.* that will effectively reduce the total number of DFADs at sea) and will support the RFMO to improve the monitoring of these DFADs. To do so, RFMOs should adopt clear definition of the term « active beacon » used in their resolutions (for example, based on our proposed definition), require access to DFADs beacons' data (at least individual activation/deactivation dates of each beacon used by the fleet and ideally individual GPS data of each beacon with at least a position per day) and make mandatory a 100% coverage on board purse-seiners and support vessels to control the number of DFADs deployed and prohibit the deployment of DFADs without beacon).

Acknowledgements

The authors would like to thank the French and Italian skippers and crews, the boat-owners member of Orthongel and the scientists who worked together to establish, implement and monitor the FAD management plan of Orthongel. Some of the programs mentioned in this paper were possible thanks to the funding of the European fisheries fund and France Filière pêche.

References

Balderson S. and Martin L.E.C. (2015). Environmental impacts and causation of 'beached' Drifting Fish Aggregating Devices around Seychelles Islands: a preliminary report on data collected by Island Conservation Society. IOTC-2015-WPEB11-39: 15p.

Bromhead D., Foster J., Attard R., Findlay J., Kalish J. (2002). A Review of the impact of fish aggregating devices (FADs) on tuna fisheries. Report to Fisheries Resources Research Fund: 121 p.

Chassot, E., Goujon M., Maufroy A., Cauquil P., Fonteneau A., Gaertner D. (2014). The use of artificial fish aggregating devices by the French tropical tuna purse seine fleet: historical perspective and current practice in the Indian Ocean. IOTC-2014-WPTT16-20_Rev_1: 17 p.

Delgado de Molina A., Ariz J., Murua H., Santana J.C., Ramos L. and Soto M. (2014). Spanish Fish Aggregating Device Management Plan. Preliminary data in the Indian Ocean. IOTC-2014-WPTT16-19: 10p.

FAO (1995). Code de conduite pour une pêche responsable. Rome: 46 p.

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

Fonteneau A., Ariz J., Gaertner D., Nordstrom V., Pallares P. (2000). Observed changes in the species composition of tuna schools in the Gulf of Guinea between 1981 and 1999, in relation with the fish aggregating device fishery. *Aquatic Living Resources*, 13: 253-257.

Fonteneau A. (2014). On the recent steady decline of skipjack caught by purse seiners in free schools sets in the eastern Atlantic and western Indian oceans. (ICCAT-SCRS/2014/134) *Collect. Vol. Sci. Pap. ICCAT*, 71 (1): 417-425.

Fonteneau A., Chassot E. (2014). Managing tropical tuna purse seine fisheries through limiting the number of drifting fish aggregating devices in the Indian Ocean: food for thought. IOTC-2014-WPTT16-22: 26p.

Fonteneau A., Chassot E., Gaertner D. (2014). Managing tropical tuna purse seine fisheries through limiting the number of drifting fish aggregating devices in the Atlantic: food for thought. (SCRS/2014/133 Rev) *Collect. Vol. Sci. Pap. ICCAT*, 71 (1): 460-475.

Gaertner D., Ariz J., Bez N., Clermidy S., Moreno G., Murua H., Soto M. (2016). Objectives and first results of the CECOFAD project*. Collect. Vol. Sci. Pap. ICCAT*, 72 (2): 391-405.

Goujon M., Labaisse-Bodilis C. (2000). Effets des plans de protection des thonidés de l'Atlantique depuis 1997 d'après les observations faites sur les thoniers senneurs gérés par les armements français. (SCRS/2000/172) *Collect. Vol. Sci. Pap. ICCAT*, 52 (2): 575-589.

Goujon M., Vernet A.L., Dagorn L. (2012). Preliminary results of the Orthongel program 'eco-FAD' as June 30th 2012. Indian Ocean Tuna Commission, Working Party on Ecosystems and Bycatch. IOTC-2012-WPEB08-INF21: 7p.

Goujon M., Claude A., Le Couls S., Mangalo C. (2014). Premier bilan du plan de gestion des DCP mis en place par la France en Océan Atlantique. (SCRS/2014/187) *Collect. Vol. Sci. Pap. ICCAT*, 71 (1): 573-591.

Goujon M. (2015a). Orthongel contribution to CECOFAD. Proceedings of the Final Meeting of CECOFAD (Catch, Effort, and eCOsystem impacts of FAD-fishing), AZTI Pasaia, November 3-5, 2015.

Goujon M. (2015b). Mesures prises par Orthongel pour réduire l'incidence des thoniers senneurs sur les tortues marines. Actes du Colloque Tortues Marines. Maison des océans, Paris, 8-10 septembre 2015.

Guillotreau P., Salladarré F., Dewals P., Dagorn L. (2011). Fishing tuna around Fish Aggregating Devices (FADs) vs free swimming schools: skipper decision and other determining factors. *Fish. Res*. 109: 234–42.

Hallier J., Gaertner D. (2008). Drifting fish aggregation devices could act as an ecological trap for tropical tuna species. *Marine Ecology Progress Series*, 353: 255-264.

Le Gall J.Y., Cayré P., Taquet M., editors (2000). Pêche thonière et dispositifs de concentration de poisons. Actes Colloques-IFREMER.

Marsac F., Fonteneau A., Ménard F. (2000). Drifting FADs used in tuna fisheries: an ecological trap? In Pêche thonière et dispositifs de concentration de poissons, Caribbean-Martinique, 15-19 Oct 1999.

Ménard F., Stéquert B., Rubin A., Herrera M., Marchal E. (2000). Food consumption of tuna in the Equatorial Atlantic Ocean: FAD-associated versus unassociated schools. *Aquatic Living Resources*, 13: 233–240.

Maufroy A., Gaertner D., Kaplan D.M., Bez N., Soto M., Assan C., Lucas J. and Chassot E. (2015a). Evaluating the efficiency of tropical tuna purse seiners in the Indian Ocean: first steps towards a measure of fishing effort. IOTC–2015–WPTT17-14.

Maufroy A., Chassot E., Joo R., Kaplan D. M. (2015b). Large-scale examination of spatio-temporal patterns of drifting fish aggregating devices from tropical tuna fisheries of the Indian and Atlantic Oceans. *PLoS ONE* 10 (5).

Maufroy A. (2016). Drifting Fish Aggregating Devices of the Atlantic and Indian Oceans: modalities of use, fishing efficiency and potential management (PhD). University of Montpellier, Montpellier, France.

Maufroy A., Kaplan D., Bez N., Delgado de Molina A., Murua H., Floch L., and Chassot E. (2016). Massive increase in the use of drifting Fish Aggregating Devices (dFADs) by tropical tuna purse seine fisheries in the Atlantic and Indian oceans. *ICES J Mar Sci* 74 (1): 215-225.

Morgan A.C. (2011). Fish Aggregating Devices and Tuna: Impacts and Management Options. Ocean Science Division, Pew Environment Group, Washington, DC: 18 p.

MRAG (2009). FAD Management - A study of the impacts of fish aggregating devices (FADs) and the development of effective management strategies for their responsible use by industrial tuna fishing fleets. Prepared for the WTPO: 153 p.

Poisson F., Vernet A. L., Séret B., Dagorn L. (2012). Good practices to reduce the mortality of sharks and rays caught incidentally by the tropical tuna purse seiners. EU FP7 project #210496 MADE, Deliverable 7.2.; Convention DPMA 33246, CAT « Requins », 30p.

Poisson F., Séret B., Vernet A. L., Goujon M., Dagorn L. (2014a). Collaborative research: Development of a manual on elasmobranch handling and release best practices in tropical tuna purse-seine fisheries. *Mar. Policy* 44: 312-320.

Poisson F., Filmater J.D., Vernet A.L., Dagorn L. (2014b). Mortality rate of silky sharks (*Carcharhinus falciformis*) caught in the tropical tuna purse seine fishery in the Indian Ocean. *Can. J. Fish. Aquat. Sci*. Vol. 71: 1-4.

Riva Y (2014). Gérer les DCP Le temps d'agir ! 1st African Tuna Conference - Abidjan, September 25-26, 2014.

Riva Y (2016). Les défis de la gestion des DCP. 2nd African Tuna Conference - Abidjan, September 5-6, 2016.

SCRS (2008). Report of the Standing Committee on Research and Statistics (SCRS). *ICCAT Report for biennial period, 2008-2009*. Part I (2008) - Vol. 2: 275p.

Sempo G., Dagorn L., Robert M., Deneubourg J.-L. (2013). Impact of increasing deployment of artificial floating objects on the spatial distribution of social fish species. *Journal of Applied Ecology*, 50: 1081–1092.

RFMO resolutions cited

ICCAT Recommendation 96-01 on Bigeye and Yellowfin Tunas

ICCAT Recommendation 11-01 on a Multi-Annual Conservation and Management Program for Bigeye and Yellowfin Tunas

ICCAT Recommendation 13-01 amending the Recommendation on a Multi-Annual Conservation and Management Program for Bigeye and Yellowfin Tunas

ICCAT Recommendation 15-01 on a Multi-Annual Conservation and Management Program for Tropical Tunas

ICCAT Recommendation 16-01 on a Multi-Annual Conservation and Management Program for Tropical Tunas

IOTC Resolution 12/08 on a fish aggregation devices (FADS) management plan

IOTC Resolution 13/08 on Procedures on a fish aggregating devices (FADs) management plan, including more detailed specification of catch reporting from FAD sets, and the development of improved FAD designs to reduce the incidence of entanglement of non-target species

IOTC Resolution 15/08 on Procedures on a fish aggregating devices (FADs) management plan, including a limitation on the number of FADs, more detailed specifications of catch reporting from FAD sets, and the development of improved FAD designs to reduce the incidence of entanglement of non-target species

IOTC Resolution 16/01 on an Interim Plan for Rebuilding the Indian Ocean Yellowfin tuna Stock in the IOTC area of competence

WCPFC CMM 2008-01 on Conservation and Management Measure for Bigeye and Yellowfin Tuna in the Western and Central Pacific Ocean

Table 1. Indicators of fishing efficiency of non-entangling and traditional DFADs.

Parameters and indicators	*Non-entangling DFADs sets*	*All 2010-2011 FOB sets*	*2005-2010 FOB sets*
Number of observations	124	1349	11832
Average catch per set	25.5 t	25.2 t	25.0 t
Number of sets of less than 10 t	22.6 %	29.8 %	25.2 %
Number of sets of 10 to 50 t	62.9 %	57.6 %	60.6 %
Number of sets of more than 50 t	14.5 %	12.6 %	14.2 %

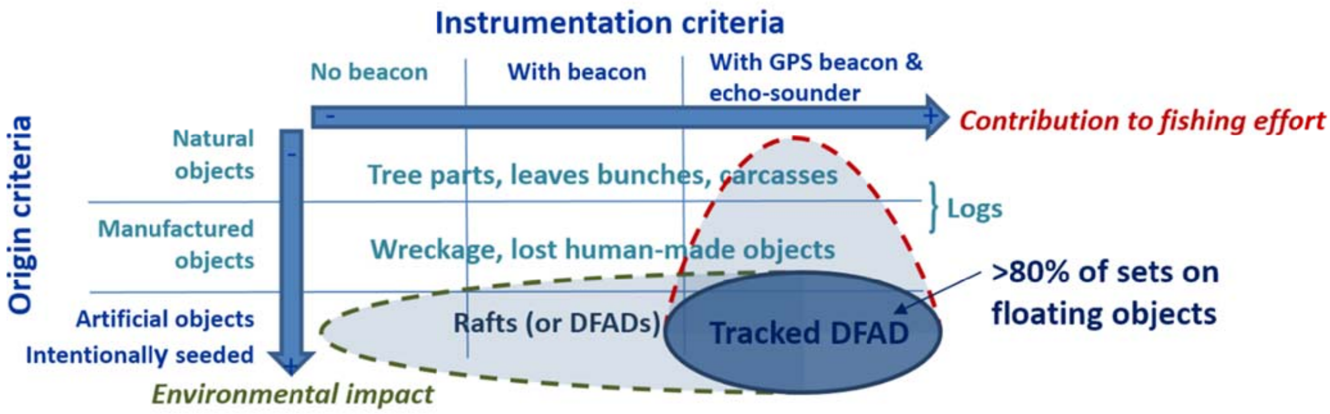


Figure 1. Typology of floating objects developed by Orthongel within the frame of CECOFAD.

Figure 2. Evolution of catch and different parameters of fishing effort on the Indian Ocean since 2007.

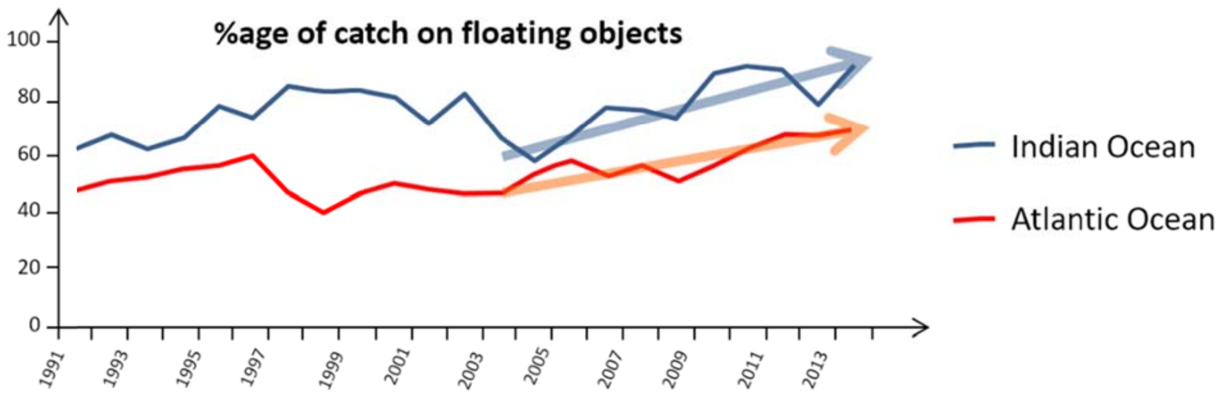


Figure 3. Evolution of the proportion of EU purse-seine catch on floating objects.

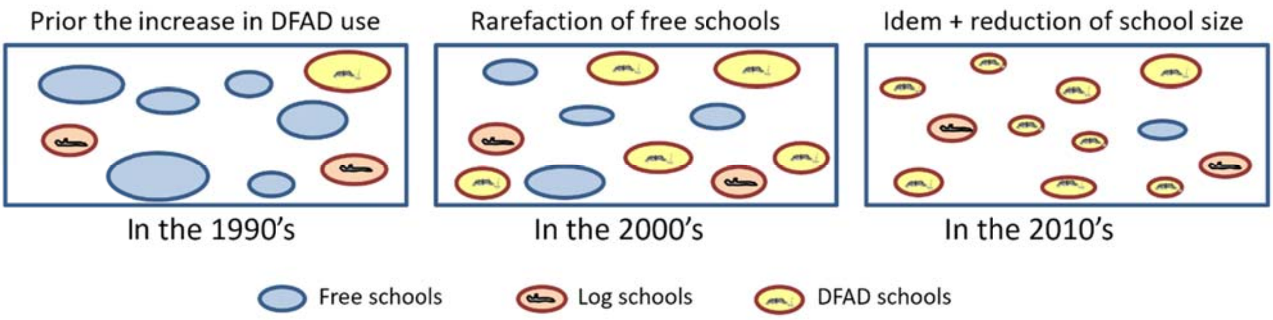


Figure 4. Representation of the effect of increasing abundance of DFADs on the distribution of tuna schools.

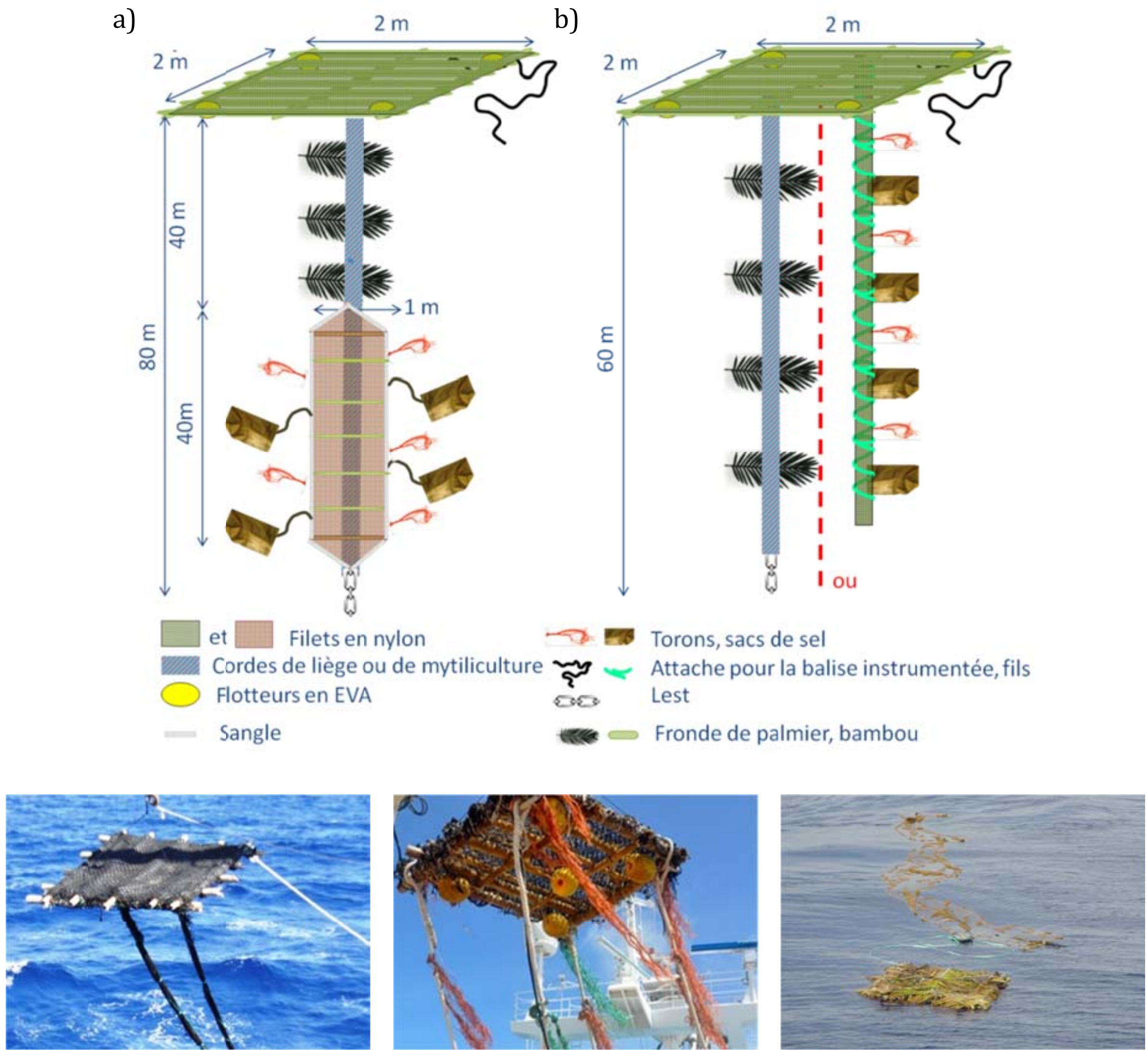


Figure 5. Schematic structure of a non-entangling DFAD used by French and Italian in the Atlantic Ocean (left) and in the Indian Ocean (right) and pictures of non-entangling DFADs with twisted net (left) or ropes (middle) and of a biodegradable DFAD.

Figure 6. Pictures of the land-based workshops in Abidjan (left) and in Seychelles (middle) and of the non-entangling DFADs prepared on demand of a French purse seiner (right).

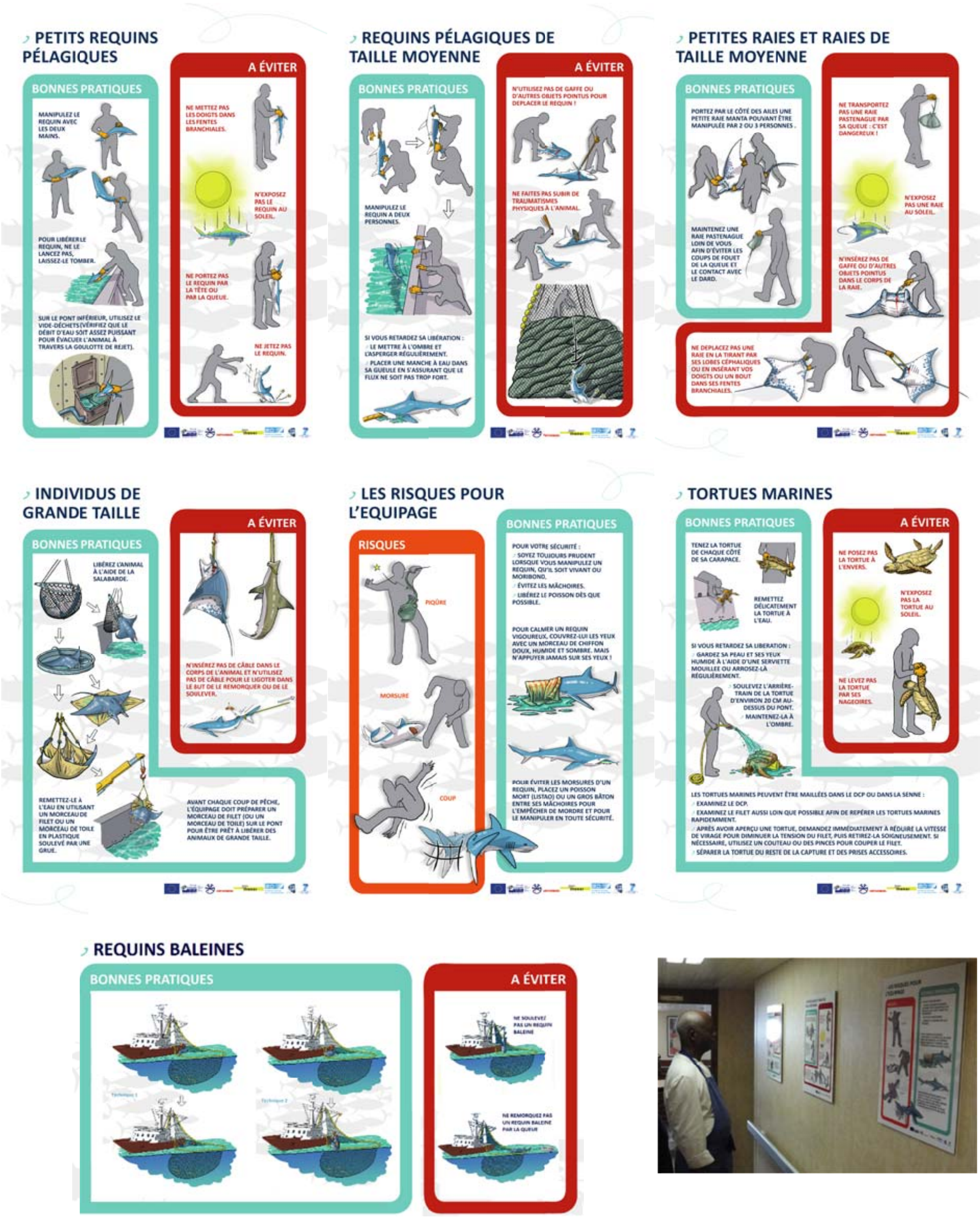


Figure 7. Six reminder posters displayed aboard each French and Italian purse seiners, an additional panel on best practices for shark whales and example of display aboard a vessel.

Figure 8. Examples of implementation of good practices documented by African scientific observers on board French and Italian purse seiners while manipulating turtles (left), rays (middle) or whale shark (right) to release them alive.

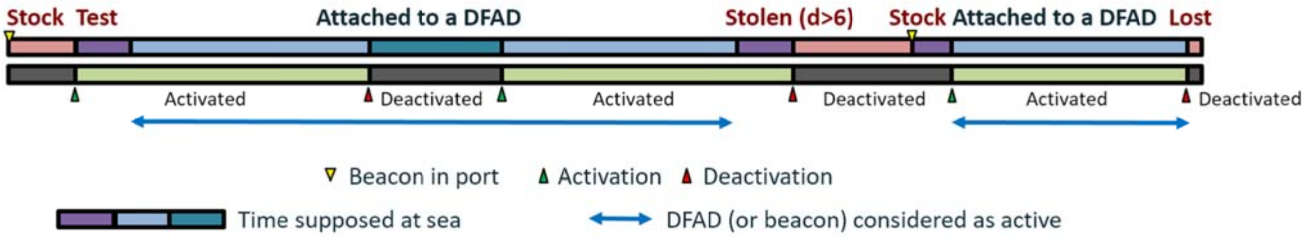


Figure 9. Schematic representation of the life cycle of a DFAD beacon identifying periods when it should be considered as active.

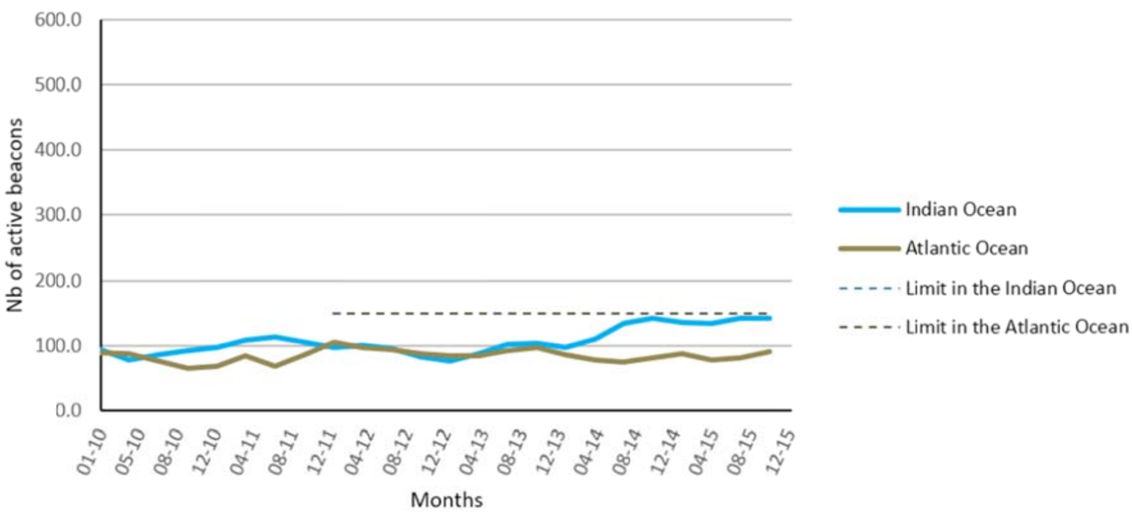


Figure 10. Evolution of the average number of active beacons per purse seiner for the French and Italian fleet.

Original: English

DFADS USED BY EU TROPICAL TUNA PURSE SEINERS IN THE ATLANTIC AND INDIAN OCEANS: INCREASING USE, CONTRIBUTION TO FISHING EFFICIENCY AND POTENTIAL MANAGEMENT

A. Maufroy[1], D.M. Kaplan.[2], N. Bez[3] and E. Chassot[4]

ABSTRACT

Since the mid-1990s, the use of drifting Fish Aggregating Devices (dFADs) by purse seiners, artificial objects specifically designed to aggregate fish, has become an important mean of catching tropical tunas. In recent years, the massive deployments of dFADs, as well as the massive use of tracking devices on dFADs and natural floating objects, such as GPS buoys, have raised serious concerns for tropical tuna stocks, bycatch species and pelagic ecosystem functioning. Despite these concerns, relatively little is known about the modalities of dFAD use, making it difficult to assess and manage the impacts of this fishing practice. The present paper provides an overview of a 4-year research on the use of dFADs by tropical tuna purse seiners in the Eastern Atlantic and Western Indian oceans. To fill existing knowledge gaps, GPS buoy tracks provided by the three French fishing companies operating in the Atlantic and the Indian Oceans, representing a large proportion of the floating objects monitored by the French fleet, were analysed. These data were combined with multiple sources of information: logbook data, information on support vessels and interviews with purse seine skippers to describe GPS buoy deployment strategies, estimate the total number of GPS buoy equipped dFADs used in the Atlantic and Indian Oceans, measure the contribution of strategies with FOBs and support vessels to the fishing efficiency of tropical tuna purse seiners, and finally to propose management options for tropical tuna purse seine FOB fisheries. Results indicate clear seasonal patterns of GPS buoy deployment in the two oceans, a rapid expansion in the use of dFADs over the last 7 years with an increase of 4.2 times in the Indian Ocean and 7.0 times in the Atlantic Ocean, and an increased efficiency of tropical tuna purse seine fleets from 3.9% to 18.8% in the Atlantic Ocean over 2003-2014 and from 10.7% to 26.3% in the Indian Ocean. Quantitative results (estimates of dFAD use, fishing efficiency and impacts of dFAD use) were discussed with French purse seine skippers during semi-structured interviews to understand their perception of the impacts of dFAD use and to propose adapted management options for tropical tuna purse seine dFAD fisheries. Interviews with French purse seine skippers of the Indian Ocean revealed the existence of competition between EU purse seine fleets, encouraging the recent increase in the use of dFADs. They underlined the need for a more efficient management of the fishery, including the implementation of catch quotas, a limitation of the capacity of purse seine fleets and a regulation of the use of support vessels.

[1] ORTHONGEL, 5 rue des Sardiniers, 29900 Concarneau, amaufroy@orthongel.fr (corresponding author).
[2] Virginia Institute of Marine Science, College of William & Mary, P.O. Box 1346 Gloucester Point, VA 23062, USA.
[3] Institut de Recherche pour le Développement, UMR MARBEC (IRD/Ifremer/CNRS/UM), Avenue Jean Monnet, BP 171, 34203 Sète Cedex France.
[4] TNC, Victoria, Seychelles.

Appendix

DFADS USED BY EU TROPICAL TUNA PURSE SEINERS IN THE ATLANTIC AND INDIAN OCEANS: INCREASING USE, CONTRIBUTION TO FISHING EFFICIENCY AND POTENTIAL MANAGEMENT

A. Maufroy, D.M. Kaplan., N. Bez and E. Chassot

1 Introduction

Fishers have long known that many species of fish, including tropical tunas, naturally associate with the objects drifting at the surface of the ocean. For centuries, they have known that fish associated with Floating Objects (FOBs) are easier to detect and easier to catch. They have long used natural FOBs as an indicator of higher abundance, better catchability and increased fish school size (Hall 1992, Fréon & Dagorn 2000, Castro et al 2002), until they had the idea to mimic the natural behaviour of fish with the deployment of man-made FOBs. At the end of the 1990s, these drifting Fish Aggregating Devices (dFADs) became an important mean of catching skipjack, and juveniles of yellowfin and bigeye tuna by purse seiners (Fonteneau *et al.*, 2000a). Increasing numbers of dFADs were deployed in the world oceans and specific FOB fishing technologies were introduced. Among others, the use of FOB tracking devices such as GPS buoys developed (Castro *et al.*, 2002; Fonteneau *et al.*, 2013) and support vessels began to assist purse seiners for dFAD deployment and searching (Fonteneau *et al.*, 2000a; Arrizabalaga *et al.*, 2001). In all oceans, these changes have supported the fast development of purse seine (PS) fleets (Miyake *et al.*, 2010; Fonteneau *et al.*, 2013).

Over time, FOB fisheries have become an increasing source of concern for tuna Regional Fisheries Management Organizations (RFMOs). Though FOBs have positive consequences for purse seine fishing, by improving the detection of tuna schools and the success of fishing sets (Fonteneau *et al.*, 2000), they have also a number of negative consequences for tropical tunas and marine ecosystems (Dagorn *et al.*, 2013). Among others, they contribute to increased catches of juveniles of yellowfin and bigeye tuna (Fonteneau *et al.*, 2000), strong modifications of the natural behaviour of tropical tunas (Marsac *et al.*, 2000; Hallier and Gaertner, 2008; Sempo *et al.*, 2013), increased levels of bycatch and discard (Amandè *et al.*, 2011, 2012), ghost fishing of fragile species (entanglements of sea turtles and sharks; Anderson *et al.*, 2009; Filmalter *et al.*, 2013) and potential damages to vulnerable habitats (Balderson and Martin, 2015; Maufroy *et al.*, 2015). Despite these concerns regarding the impacts of FOB use for tropical tuna and marine ecosystems, little information has previously been available on FOB use worldwide.

In addition, the massive, and increasing, use of FOBs by purse seiners since the 1990s, as well as the technologies used for FOB fishing, have had a particularly important impact on fishing efficiency (Hallier *et al.*, 1992; Ariz Telleria *et al.*, 1999; Fonteneau *et al.*, 2000a). In addition to the typical impacts of technological creep experienced in other modern fisheries (Torres-Irineo et al., 2014), the use of FOBs affects catchability in ways that make defining an index of fishing effort for purse seiners difficult. FOBs increase the availability of tropical tuna to purse seiners by concentrating schools (accessibility), increasing the proportion of successful sets (vulnerability) and facilitating location of tuna schools (detectability) (Fonteneau *et al.*, 2013). As FOBs reduce the time dedicated to randomly search for schools of tunas, traditional measures of fishing effort, such as days at sea or fishing time are inappropriate for tropical tuna purse seiners. This complicates the definition of indices of Catch Per Unit Effort (CPUE) to assess the stocks of skipjack, yellowfin and bigeye tuna in RFMOs. In the absence of an appropriate measure of fishing effort, tuna RFMOs mostly rely on indices based on longliners for the evaluation of skipjack, yellowfin and bigeye stocks. In addition, crucial information on the use of FOBs, GPS buoys, support vessels and changes in the efficiency of purse seiners are rarely taken into account and sometimes even not required by tuna RFMOs. Since the 1990s, they generally assume that there is a yearly increase of 2% to 3% of the fishing power of purse seiners (Gascuel *et al.*, 1993). It is more than likely that after more than 20 years, this assumption has become incorrect.

In recent years, considerable attention has been drawn by scientists and NGOs on the negative impacts of FOB fishing. In response to the growing pressure for specific management of FOBs, tuna RFMOs have started adopting FOB regulations. In the Atlantic and the Indian Oceans, purse seine fleets have now an obligation to adopt "FAD management plans" (ICCAT Res 15-01, IOTC Res 13-08). Purse seine fleets should report various information on their use of FOBs (types of FOBs, types of tracking devices, numbers per year or quarter, etc.) and are responsible for managing their use. Nevertheless, these "FAD management plans" can take various forms depending on the fleet and are not real management measures. More recently, the IOTC adopted for the first time in 2015 a limitation on the number of active and purchased GPS buoys (Res. 15-08), soon followed by the ICCAT (Rec 15-01). Whilst these decisions are obviously encouraging steps, a wide variety of other management tools (e.g. fleet capacity limitation, catch quotas) could be implemented. Each of these tools may have a different efficacy, depending on their relevance to address the issues of FOB fisheries but also due fast to changes in fishing behaviour. In theory, such management decisions should involve the various stakeholders of the fishery, including fishers to improve their success (Jentoft *et al.*, 1998).

Here, we combine multiple sources of information on the use of FOBs (GPS buoy tracks of FOBs, logbook data, observer data, characteristics of EU purse seiners, links between purse seiners and their support vessels as well as interviews with purse seine skippers) to (i) estimate the total number of dFADs used by PS fleets of the Atlantic and Indian Oceans over 2007-2013 (ii) estimate the contribution of strategies with FOBs and support vessels to the efficiency of EU tropical tuna purse seine fleets of the Atlantic and Indian Oceans over 2003-2014 and finally to (iii) understand the perception that fishers have of the impact of FOB fisheries and management in order to propose adapted management tools.

2 Understanding the use of dFADs in the Atlantic and Indian Oceans

2.1 Using fishers' knowledge to guide statistical analyses

Several sources of quantitative information were available to address a wide variety of questions on the modalities of dFADs and GPS buoy use, their consequences and their management (**Table 1**). These sources of information included among others an exhaustive dataset of the positions of GPS buoys used by the French purse seine fleet in the Atlantic and Indian oceans, information on catches of EU purse seiners in the Atlantic and Indian Oceans, as well as information on support vessels in the Indian Ocean. Available data provided complementary but not always overlapping information, due to partial coverage (e.g. when data was only available for the French fleet), differences in spatio-temporal scales (e.g. GPS buoy data was provided on a varying time scale), or the different nature of the activities that these data were describing (e.g. observer data provided information on all types of activities on FOBs while logbook data only provided information on fishing sets). To overcome the inevitable difficulties of combining these many different sources of information, fishers' knowledge was gathered to eliminate wrong assumptions and guide statistical analyses.

14 French speaking skippers (including 2 French skippers working for a Spanish company and 1 Spanish skipper), having a long experience of the functioning of the fishery in the Indian Ocean, were interviewed in June and July 2013, on their arrival in Port Victoria (Seychelles). Interviews were conducted aboard purse seiners as informal discussions. Rather than following a questionnaire, the guide of interview consisted of open-ended questions supplemented with examples of closed-ended questions only used to rephrase or clarify the discussion (**Table 2**). Among others, these interviews provided useful information to describe the strategies of FOB deployment by purse seiners and to examine changes in fishing strategies. They also suggested a strong increase in the use of dFADs and GPS buoys.

2.2 Strategies in dFAD and GPS buoy deployment

Semi-structured interviews of skippers provided some insights into deployment decision making. We discussed with skippers about the conditions that determined a deployment of a dFAD or of a GPS buoy on a FOB already drifting at sea. We identified the seasonality and the use of oceanic currents as key factors for these deployments and used French GPS buoy data to identify GPS buoy deployment seasons and FOB drift patterns.

A deployment season was defined as a group of successive months with similar relative spatial patterns of GPS buoy deployments. Mean monthly maps density maps of GPS buoy deployments over 2007-2013 (resolution 1 degree) were used in a cluster analysis to determine GPS buoy deployment seasons (**Figure 1**, Maufroy *et al.*, 2017). In the Atlantic Ocean, four seasons were detected, with deployments occurring in three main areas: January-February (Gulf of Guinea), March to May (Senegal), June to September (Gulf of Guinea and Gabon) and October to December (Gulf of Guinea). In the Indian Ocean, GPS buoy deployments moved clockwise on four distinct deployment grounds corresponding to four distinct deployment seasons: March to May (Mozambique Channel), June to July (Tanzania and Kenya), August to October (Somalia) and finally November to February (SE Seychelles).

In 2013, due to relatively restricted numbers of GPS buoys, French skippers indicated that they were selective in their GPS buoy deployments, avoiding deploying GPS buoys in areas where currents would extract FOBs from fishing grounds and mainly deploying dFADs and GPS buoys where they were actively fishing. Measures of the correlation between French FOB deployment and French FOB fishing confirmed that deployment and fishing on FOBs were correlated in time and space for the French fleet over 2007-2013 (Maufroy *et al.*, 2017). Speed vectors of GPS buoy equipped FOBs were used to represent seasonal drift patterns over 2007-2013 (**Figure 2**).

Two main behaviours were identified as French purse seiners either avoided (e.g. in the Atlantic Ocean, deployments occurred close to the coast all along the year to avoid the strong eastern currents) or targeted some currents (e.g. in the Indian Ocean, GPS buoys were deployed off Tanzania and Kenya with the objective of a northward drift, so that FOBs could reach the cold rich waters of the upwelling of Somalia).

2.3 Recent evolution of the number of dFADs and GPS buoys

Skippers also suggested a strong increase in the use of FOBs as well as important differences among EU purse seine fleets. Despite the recent implementation of FAD management plans by ICCAT and IOTC and their recent limitations of the number of active GPS buoys (ICCAT Recommendation 15-01; IOTC Resolution 15/08), it is still difficult to evaluate how many dFADs and GPS buoys are in use in the Atlantic and Indian Oceans. In a context of growing concerns for tropical tunas and pelagic ecosystems, these estimates are yet necessary for a proper management of the FOB fishery (Fonteneau and Chassot, 2014). Prior studies have attempted to provide such estimates but they were based on few information, did not separate dFADs from logs nor did they account for spatio-temporal variability in FOB use (Ménard *et al.*, 2000; Baske *et al.*, 2012). Following the interviews, tracks of French GPS buoys were combined with observations of GPS buoy-equipped FOBs aboard French and Spanish purse seiners to estimate the total number of dFADs and GPS buoys used within the main fishing grounds over the period 2007-2013 (Maufroy *et al.*, 2017). In the Atlantic and Indian Oceans, the total number of GPS buoy-equipped dFADs continuously increased over 2007-2013 (**Figure 3**).

In the Atlantic Ocean, estimates of dFAD and GPS buoy use per reached approximately 1175 dFADs and 1290 GPS buoys per day in January 2007. These numbers increased to reach 8575 dFADs and 8860 GPS buoy equipped FOBs per day in August 2013. On average, this represented an increase in the use of dFADs of a factor of 7.0. Differences were observed among fleets, the Spanish, French and non-European PS fleets accounting for 74.3, 8.3 and 17.4% of dFADs actively monitored by purse seine fleets in the Atlantic Ocean in 2013. In the Indian Ocean, we estimated that 2250 dFADs and 2680 GPS buoys were used at the end of October 2007. September was the main month of use of FOBs in 2013, with estimates of 10 300 dFADs and 10 930 active GPS buoys. Our estimates indicate that the use of dFADs has been multiplied by a factor of 4.2 over 2007-2013. Again, differences between purse seine fleets were observed, the Spanish fleet using more dFADs (87.5% in 2013) than the French fleet (10.2%) and non-European PS fleets (2.3%).

3 Contribution of FOBs and support vessels to an increased fishing efficiency

3.1 Definitions and data sources

Strategies and efficiency of tropical tuna purse seiners

Monitoring and managing FOB fisheries does not only require information on the number of FADs drifting at sea or on the number of GPS buoys active on dFADs or logs. Appropriate information is also required to understand why and how PS fleets are using these increasing numbers of dFADs and GPS buoys, as well as the consequences of this increasing use. This is particularly necessary as the contribution of FOBs to the fishing strategies of purse seiners has not been extensively examined in the past, though this may affect their fishing efficiency (Le Gall, 2000). Purse seiners combine two different métiers, either targeting skipjack tuna under FOBs or large yellowfin tuna in Free Swimming Schools (FSC). In 2013, interviews with skippers confirmed that FSC and FOB activities are not separated in time and space. Fishing strategies were therefore defined as the relative contribution of FOB and FSC activities on the medium-term (Torres-Irineo *et al.*, 2014). Changes in fishing strategies were measured with the proportion of fishing sets on FOBs per month.

Fishing efficiency was measured with five different statistics (**Table 3**). We assumed that the main objective of fishing activities is to maximize catches, whilst minimizing the time at sea (measured with CPUE1), the number of fishing sets (CPUE2), and fuel consumption (using travelled distance as a proxy, CPUE3). Fishing efficiency also relates to the size of fishing sets (CPUE2), the frequency of fishing sets (to avoid long periods without fishing, SPUE) and travelled distance (to increase the size of search areas, DPUE).

Vessel characteristics, use of support vessels and logbook data

Different sources of information were available to measure changes in fishing strategies and fishing efficiency. Information on the size of EU purse seiners active at least one month in the Atlantic and Indian Oceans were available over 2003-2014. 4 categories of vessel size were built (41.4-58 m, 59-72 m, 73-94 m, 95-116.2 m) and separated between French and Spanish fleets. An additional category was added for one of the French fishing companies of the Indian Ocean known to have a specific FSC strategy (category "73-94 m + FSC").

The link between purse seiners and support vessels of the Indian Ocean during 2003-2014 was established through Seychelles fishing licences and individual logbooks of support vessels under the Seychelles flag. A factor variable "support time" was built, with 4 categories of purse seiners: 0, if the purse seiner did not have a support vessel; 1/3 if the purse seiner shared the support vessel with 2 other purse seiners; 1/2 if the purse seiner shared the support vessel with another purse seiner; and 1 if the purse seiner had its own support vessel. This information was not available in the Atlantic Ocean.

Finally, logbook data were available for the French and the Spanish purse seine fleets from 2003 to 2014 in the Atlantic and the Indian Oceans. These data were aggregated by month, approximately corresponding to the average duration of a fishing trip, so as to carry the analyses at the scale of fishing strategies. These data were used to calculate the proportion of fishing sets on FOBs as well as the different measures of efficiency (see **Table 3**).

3.2 Fast changes in tropical tuna purse seiners' strategies with FOBs

Generalized Linear Models (GLMs) were used to explain fishing strategy as a function of the year, the month, vessel characteristics and the use of support vessels (Maufroy *et al.*, in preparation). In the Atlantic and Indian Oceans, the proportion of fishing sets on FOBs gradually increased over 2003-2014, indicating that the FOB strategy progressively became more important than the FSC strategy (**Figure 4**). The proportion of fishing sets on FOBs was generally higher in the Indian Ocean than in the Atlantic Ocean. In 2003, European Union purse seiners made 41.8% (SD among vessels of 13.2) and 50.9 % (SD 19.8) of their fishing sets on FOBs in the Atlantic and Indian Oceans, respectively. In 2014, these proportions reached 59.0% (SD 17.6) and 70.6% (SD 16.7), representing a relative increase of 41.1% and 38.7% respectively.

As suggested by skippers interviewed in 2013, differences in strategies with FOBs were observed between small and large purse seiners, between EU purse seine fleets and between purse seiners with or without a support vessel. The proportion of fishing sets on FOBs increased with the length of purse seiners, was higher for the Spanish fleet than for the French fleet and increased for purse seiners benefiting from a support vessel. In the Atlantic Ocean, French and Spanish purse seiners respectively made 39.2% (SD 13.2) and 58.9% (SD 12.8) of their fishing sets on FOBs over 2003-2014 (**Figure 5**). In the Indian Ocean, Spanish purse seiners were also significantly more specialized in FOB fishing with 63.0% of fishing sets on FOBs (SD 21.0) against 53.3% for French purse seiners (SD 21.8). Unsurprisingly, vessels of the French fishing company known to target FSC had the lowest proportion of fishing sets on FOBs (47.8%, S.D. 21.4).

There was no clear linear relationship between the proportion of fishing sets on FOBs and support time. However, purse seiners benefiting from a support vessel (support time 1/3, 1/2 or 1) made 61.0% (SD 21.6) of their fishing sets on FOBs against 55.2% (SD 21.9) for purse seiners without a support vessel. Similar results could not be obtained in the Atlantic Ocean where information on support vessels was not available.

3.3 Evolution of the efficiency of tropical tuna purse seiners

Factors affecting the individual efficiency of tropical tuna purse seiners

Generalized Linear Mixed Models (GLMMs) were used to explain the five dimensions of the fishing efficiency of individuals purse seiners as a function of the year, the month, vessel characteristics, the use of support vessels and the proportion of fishing sets on FOBs (Maufroy *et al.*, in preparation). Overall, the models indicated that the largest purse seiners were the most efficient. Such effect of the size of fishing vessels have long been described in various other fisheries (e.g. Marchal *et al.*, 2001). More interestingly, increasing the use of FOBs had a significant positive effect on the catch per day (CPUE1), catch per fishing set (CPUE2) and travelled distance (DPUE) while the catch per travelled distance (CPUE3) and the number of fishing sets per day (SPUE) decreased (**Table 4**). In the Indian Ocean for example, an increase of 1% in the proportion of fishing sets on FOBs improved the catch of purse seiners of 0.18% per day and 0.44% per fishing set while the number of fishing sets decreased of 0.28%, probably due to less frequent null fishing sets (as the frequency of null fishing sets is higher on FSC, Fonteneau *et al.*, 2000).

Specific strategies of fishing companies and fishing fleets also had an effect on the efficiency of individual tropical tuna purse seiners. In the Indian Ocean for example, purse seiners of the French fishing company known to target more FSC were generally less efficient (in terms of total catch but not necessarily in terms of the price of their catch) than other French purse seiners of the same size. Their efficiency decreased of 19.1% in terms of catch per day, 25.8% in terms of catch per distance and 21.5% in terms of and fishing sets per day. In addition, Spanish purse seiners, that were found to be more specialized in FOB fishing (see section 3.2), were more efficient than French purse seiners of the same size in terms of catch per day, catch per fishing set and travelled distance, but their efficiency decreased in terms of catch per travelled distance and fishing sets per day.

Overall, these results indicate that purse seiners increasing their use of FOBs were more efficient at maximizing their catches by decreasing the number of null fishing sets due to FSC fishing (SPUE) and undertaking regular fishing sets (CPUE1 and CPUE2). However, the increasing travelled distances (DPUE) may not indicate that purse seiners have become more efficient, especially as their efficiency was decreasing in terms of catch per distance (CPUE3). On the contrary, this may indicate that purse seiners were traveling longer distances from FOB to FOB to catch similar amounts of fish.

Finally, the use of support vessels had a significant effect on the efficiency of individual tropical tuna purse seiners of the Indian Ocean over 2003-2014, except in terms of travelled distance (DPUE, **Figure 6**). Purse seiners benefiting from their own support vessel (support time = 1) made 12.3% more catch per day (CPUE1), 15.3% more catch per fishing set (CPUE2) and 12.3% more catch per distance (CPUE3) compared to purse seiners without support vessel (support time = 0). In terms of numbers of fishing sets per day (SPUE), there was no clear relationship between the efficiency of tropical tuna purse seiners and support time, the most efficient purse seiners being those sharing their support vessel with another purse seiner (support time = ½, +7.0% fishing sets per day) and the least efficient being those with a full time support vessel.

Indices of total efficiency of tropical tuna purse seine fleets

The results of the GLMMs were then used to measure changes in the total fishing efficiency of EU purse seine fleets of the Atlantic and Indian Oceans over 2003-2014 (O'Neill and Leigh, 2007). In the Atlantic and Indian Oceans, the total efficiency of the tropical tuna purse seine fleets increased in terms of catch per day (CPUE1), catch per fishing set (CPUE2), catch per distance (CPUE3), fishing sets per day (SPUE) and travelled distance (DPUE). Among the 5 dimensions of fishing efficiency, the catch per fishing set increased fastest in the two oceans with an increase of 18.8% in the Atlantic Ocean and 26.3% in the Indian Ocean in 11 years, representing an annual increase of 1.6% and 2.2% respectively. The frequency of fishing sets remained almost constant in the Atlantic Ocean with an increase of +0.8% and strongly decreased in the Indian Ocean with a variation of -9.4% (**Figure 7**).

Though changes in the structure of the fleet partly explains this evolution (as the size of purse seiners is increasing over time and larger purse seiners are often the most efficient), the use of FOBs also greatly contributed to the increasing fishing efficiency of EU PS fleets. In terms of catch per fishing set for example, strategies with FOBs contributed to an increase of the total efficiency of tropical tuna purse seine fleets of 7.0% in the Atlantic Ocean and 15.4% in the Indian Ocean. In the Indian Ocean, support vessels contributed to an increase of 5.7%.

4 Managing the increasing use of FOBs and its consequences

4.1 Confronting results to fishers' perception to identify potential management tools

In recent years, FOB fisheries have undergone dramatic changes with a fast increase in the use of dFADs and GPS buoys, an increasing contribution of FOBs to PS fishing strategies and an increasing fishing efficiency of PS fleets. Over time, various issues have been raised regarding the various impacts of the increasing use of FOBs (fishing effort, bycatch, ghost fishing, etc.). As a single management tool is unlikely to address all these issues at the same time, managing FOB fisheries requires a prioritization of management objectives. The practical knowledge that fishers have of fisheries can be a valuable source of information to make such management decisions (Jentoft *et al.*, 1998; Neis *et al.*, 1999; Johannes *et al.*, 2000; Moreno *et al.*, 2007).

In 2013, fishers' knowledge had been used to improve scientific knowledge on the use of FOBs by purse seiners. From August to September 2015, the results of the ongoing research conducted were presented to 15 French skippers arriving in the port of Victoria (among which 6 had participated in the interviews in 2013). The objective of these additional interviews was to confront the knowledge derived from quantitative data to fishers' perception on the impacts and the existing management of the fishery, in order to propose adapted management tools (**Table 5**). Among others, seasons of dFAD deployment, estimates of dFAD use and dFAD beaching were presented to skippers. Results on fishing strategies and fishing efficiency were not available at this stage and were replaced with simplified information (e.g. the yearly catch per French purse seiner since the 1980s that remained stable in recent years though the number of dFADs was increasing).

In addition, two years after the first interviews, important changes had occurred for FOB fisheries of the Indian Ocean. Since 2014, pressure for the management of FOB fishing had increased with NGO anti-FOB campaigns. In 2015, important decisions had been made to limit the number of active GPS buoys to 550 per purse seiner in the Indian Ocean [Res 15-08]. At the same time, French fishing companies that had restricted their use of GPS buoys to 200 per year and per vessel since 2012, were about to abandon this voluntary limitation (as this was more restrictive than the IOTC limitation) and to use support vessels. The opinion of skippers on these changes was also solicited.

4.2 Skippers' perception of the recent changes in the use of FOBs in the Indian Ocean

French skippers confirmed the increasing use of FOBs by French fishing purse seiners identified by Maufroy et al. (2017). Although 69.2% of interviewed skippers were not in favour of the recent decision of French fishing companies to increase their use of GPS buoys, 80% of them also considered that they did not have any alternative. 12 skippers on 15 thought this was necessary to compensate for an increased competition with the more efficient Spanish purse seiners using more FOBs and benefiting from support vessels (**Figure 8**). Then came considerations on potential improvement of their catches (7 skippers), compensation for GPS buoys lost outside fishing grounds or FOBs appropriated by other fishing vessels (6 skippers), relative inefficiency of fishing on FSC compared to FOB fishing (5 skippers) and the virtual absence of management of FOBs (4 skippers). These answers confirmed that PS fleets have increased their use of dFADs (see sections 2.3 and 3.2) to improve their fishing efficiency (see section 3.3).

4.3 Skippers' perception of the impacts of the increasing use of FOBs

How do skippers perceive the impacts of dFADs on sensitive species and habitats?

In recent years, considerable attention has been drawn on the effects of dFADs on sensitive species (e.g. issues of bycatch and ghost fishing; Anderson *et al.*, 2009; Amandè *et al.*, 2011, 2012; Filmalter *et al.*, 2013) and sensitive habitats (e.g. beaching of dFADs; Balderson and Martin, 2015; Maufroy *et al.*, 2015). In 2015, French skippers were seemingly less concerned with the impacts of FOBs on bycatch species and marine ecosystems than for tropical tunas. Most skippers indicated that issues of bycatch and ghost fishing were minor ones for the purse seine fishery, due to relatively low volumes of bycatch (6 skippers), efforts to discard fish alive (4 skippers) and to use non-entangling dFADs (6 skippers). Most of them also had the impression to have made significant effort, by discarding sensitive species alive and using non-entangling dFADs. They also had differing points of view regarding the severity on the impacts of dFAD beaching events, as approximately 1/3 of them considered that these impacts were low, 1/3 considerate they were moderate and 1/3 considered they were high depending on their perception of the nature of these impacts (pollution, destruction of coral reefs, cost of lost GPS buoys, negative image of PS fleets).

How do skippers perceive the impacts of dFADs on the behaviour of tropical tunas?

Among the potential effects of FOBs, assumptions regarding the alteration tuna behaviour were discussed with skippers (**Figure 9**). First, the idea that the increasing use of dFADs may contribute to an ecological trap (Marsac *et al.*, 2000; Hallier and Gaertner, 2008), by trapping tunas in suboptimal zones, where their condition factors decrease (Ménard *et al.*, 2000) and their natural feeding migrations are altered (Marsac *et al.*, 2000) was proposed to skippers. Most skippers rejected this assumption. However, 7 skippers indicated that Free Swimming Schools of tunas were progressively disappearing, while 5 of them indicated that tuna migrations seemed altered, at least on short time scales.

Second, the potential fragmentation of tuna schools between FOBs was discussed (Sempo *et al.*, 2013). Half of the skippers agreed that the situation existed or could exist while the other half rejected this possibility (**Figure 9**). On the contrary, most of them had observed a high proportion of FOBs without fish and a greater instability of schools that constantly moved from one FOB to the other, indicating possible shorter time of residence under FOBs. During these discussions, skippers also explained the apparent decrease in the size of schools in catch data by improving technological means allowing to detect smaller schools of tunas (7 skippers) and a diminution of the preferred minimal size of schools to set the net (9 skippers).

Can the increasing use of FOBs lead to overfishing?

In addition to these potential changes in the behaviour of tropical tunas, we simultaneously presented the evolution of catch per French vessel and per year and the evolution of the number of French GPS buoys. French skippers had diverse points of view regarding the absence of increase in their annual catches following their increasing use of FOBs. Half of the skippers indicated a potential degradation of tropical tuna stocks (**Figure 9**), though their impressions were almost always related to relatively low catches during their last fishing trip. However, they provided other possible explanations such as the increasing competition with the efficient Spanish purse seine fleet (8 skippers on 15) and the increasing use of echosounder buoys that reduced the chances to find tuna under FOBs of other purse seiners.

4.5 French skippers' perception of the management of FOB fisheries

Why should we manage FOB fisheries?

Throughout the interviews, French skippers had the opportunity to express their opinion on the general management of the fishery, as well as on the management of some specific issues (see previous sections on bycatch and FOB fishing). 14 skippers felt there was a need to manage the fishery, primarily because they thought there were too many dFADs, GPS buoys, purse seiners and support vessels (**Figure 10**). Most skippers were concerned about the future of the fishery and their future catches and felt that management was virtually absent (7 skippers). However, their concerns were often not related to the state of tropical tuna stocks.

The virtual absence of management had created a strong resentment against other purse seine fleets. Many French skippers thought that other purse seine fleets were not obliged to follow the same rules as French skippers (9 skippers) and were even not complying with existing rules (10 skippers). Though similar regulations obviously apply to all EU purse seiners, this resentment may be explained by different factors. First, all French skippers indicated that other skippers benefited from better fishing tools with more tracking buoys and the assistance of support vessels. Therefore, they were more efficient and French skippers had the impression that there was an increased competition to get their share of catches. Second, there were increasing conflicts between French purse seiners and support vessels from other fleets, as 8 skippers thought support vessels would steal their GPS buoys even in time-area closures or in the Somali EEZ. Finally, French fishing companies had decided since 2012 to limit their use of GPS buoys to 200 per purse seiner and per year (Decision Orthongel n°11, 2011). This voluntary limitation had not been followed by other purse seine fleets, leading to a further impression of inequity between the two fleets.

Is a limitation of the use of GPS buoys an appropriate management tool?

13 of the 15 skippers agreed that regulating the use of dFADs and GPS buoys was necessary but none of them thought that the limitation of active GPS buoys could be effective (**Figure 11**). They felt that there was a high risk of non-compliance, primarily due to unclear definitions in IOTC Resolution 15/08 and issues in enforcement. They were not sure whether support vessels were included in the limitation (5 skippers) and wondered if purse seiners could hide a fraction of their GPS buoys by temporary deactivations (4 skippers). In order to be effective, additional regulations should be adopted, such as a limitation of the number of buoys purchased per year (3 skippers, measure already included in Res 15/08) or a reduction of the number of purse seiners (2 skippers) and support vessels should be included in the limitation (2 skippers).

Which management tools would be best adapted?

In addition to a limitation of the number of active GPS buoys, other management tools were discussed with skippers, to identify those that would be best adapted to the fishery and the conditions to make them efficient. Results are summarised in **Figure 12** and **Table 6**. By order of importance, potential management included a regulation of fleet capacity, support vessels, a limitation of the number of GPS buoys, catch quotas, and no-take zones. The potential for a ban of dFADs was also discussed but strongly rejected by skippers. They disagreed with the idea that dFADs are destructive fishing gears, and raised the importance of canned tuna. In addition, they highlighted the potential difficulties of a dFAD ban for purse seiners with a dominant FOB strategy, due to their potential lack of knowledge on FSC fishing or to the size of large purse seiners that mostly rely on FOBs to be profitable.

During the interviews, all skippers indicated that the fishery suffered of a problem of excess fishing effort and excess fishing capacity due to an excessive number of purse seiners (8 skippers) and their increasing size and capacity (6 skippers). They generally considered that this problem of capacity was somehow connected to the increasing use of dFADs, GPS and echosounder buoys, and support vessels. Though they agreed that decisions should be made to control fishing effort and capacity, they also indicated various conditions that would reduce the efficiency of fleet capacity limitations. First, several large purse seiners of the Eastern Pacific Ocean had recently left this ocean for the Indian Ocean, shifting the problem of capacity elsewhere. Second, the motivations of the governments of distant water fishing nations and coastal countries were questioned due to a possible race for fishing anteriority (in case catch quotas would be implemented, the objective would be to have more fishing vessels to have a larger share of TACs), EU subsidies and vessels flying flags of convenience.

French skippers also indicated that were growing problems with the use of support vessels and 73% of them agreed to the suggestion that their use could be banned. Most of the time, they considered that there was an insufficient control of these vessels, and even doubted that they were included in the limitation of 550 GPS buoys per vessel. In addition, they had observed high rates of "theft" of their GPS buoys in the Somali EEZ for example (purse seiners don not fish in this EEZ since the beginning of the issue of piracy) and attributed them to support vessels. However, French skippers also indicated that such a decision could have important consequences for large purse seiners that heavily rely on FOBs and indicated that French fishing companies had already decided to invest in support vessels.

Then, the question of catch quotas was discussed. Half of the skippers considered that they were an appropriate management tool for the fishery, as they could increase tuna market prices, improve the state of tropical tuna stocks or rebalance fishing effort between purse seine fleets. This tool has also been successful in other fisheries and would mechanically reduce, among other gears, the number of purse seiners, support vessels and dFADs. On the other hand, 50% of French skippers considered that catch quotas would not be a good solution. They discussed about the problem of allocation criteria and consensus, race for fishing anteriority and economic difficulties for purse seiners with a dominant FOB strategy.

Finally, the question of spatial management of the fishery, that has been the main tool used so far in the Indian Ocean (Fonteneau and Chassot, 2014), was discussed. French skippers provided different answers depending on the area that was considered. They generally considered that the past IOTC no-take area of November and the Chagos Archipelago MPA had little impact on the fishery because of inappropriate choice of zones and seasons. Purse seiners generally leave the Somali fishing ground before November and target Free Swimming Schools in the vicinity of the Chagos Archipelago. On the contrary, though the Somali EEZ is not strictly speaking a fishery closure, skippers considered that the absence of fishing agreements to access this area (due to problems of piracy) could protect tuna juveniles. However, their interest in the zone was not only for the protection of juveniles, as they also indicated that they could hide their GPS buoy equipped FOBs in the area and wait for them on the border of the EEZ (in a typical "fishing the line" strategy, Kellner et al., 2007).

5 Conclusions and recommendations

5.1 The success of the FOB strategy over the FSC strategy

In recent years, pressure for the management of FOB fisheries has increased, leading to the adoption of various management measures (e.g. FAD management plans, limitation of the number of active tracking buoys, limitation of the use of support vessels). However, because exhaustive information on dFAD, GPS buoy and support vessel use is rarely available to scientists, it is still difficult to identify changes in FOB use and to understand the consequences of these potential changes. In this study, using the first exhaustive dataset of French GPS buoy tracks in the Atlantic and Indian Oceans, we identified a strong increase in the use of dFADs by all PS fleets, that was multiplied by a factor of 7.0 in the Atlantic Ocean and a factor of 4.2 in the Indian Ocean over 2007-2013. Such a strong increase in the use of dFADs had been hypothesised (Davies *et al.*, 2014a; Fonteneau and Chassot, 2014) but could not be verified due to missing data. Using logbook data available for EU purse seine fleets over the period 2003-2014 we also confirmed the increasing contribution of FOBs to the strategies of purse seiners of the two oceans, as fishers increased their proportion of fishing sets on FOBs at an annual rate of 3.2% and 3.0% in the Atlantic and the Indian Oceans respectively. In addition, we measured the contribution of the FOB strategy and the use of support vessels to the different dimensions of the efficiency of tropical tuna purse seiners. Results indicate that adopting a dominant FOB strategy and using support vessels allowed PS fleets to improve their efficiency. Finally, during this period, fishing companies progressively redirected their investments towards a dominant FOB strategy with purse seiners of increasing size that rely on FOBs to reach profitability (according to skippers interviewed in 2015).

Though FSC catches are generally dominated by the high market value yellowfin tuna and FOB catches by the lower market value skipjack tuna, all these results indicate that the FOB strategy progressively supplanted the FSC strategy since the beginning of the 2000s. For some skippers, being able to 'hunt' the large and fast yellowfin tunas may be more rewarding but is also more risky than 'gathering' tuna 'cultivated' at FOBs, even though this may result in lower catches (Guillotreau *et al.*, 2011). However, with higher success rates of fishing sets on FOBs (50% against 90%) and higher catch rates than on FSC (Fonteneau *et al.*, 2013b), the FOB strategy may become more profitable, especially when the market price of yellowfin tuna is low. This may be even truer for Spanish vessels for which the remuneration is not based on the commercial value of the catch but on the tonnage and who therefore receive little economic incentive to catch large yellowfin tuna in FSC. Combined with a progressive deterioration of the state of yellowfin tuna stocks in the Atlantic and Indian oceans (ICCAT, 2015; IOTC, 2015), fishing skipjack tuna under FOBs had all the chances to become the dominant strategy.

5.2 The tragedy of the commons: once again?

During the interviews of 2013 and 2015, purse seine skippers pointed out a general problem of over-capacity. This problem is not a new one for tropical tuna fisheries and has been discussed since the end of the 1990s at least (Greboval and Munro, 1999; Morón, 2007; Reid et al., 2005). In 2015, excess fishing capacity was related to an absence of direct regulation of the capacity of the fleet (number, size and carrying capacity of purse seiners) but also an absence of indirect regulation, through a control of support vessels and a monitoring of FOB use. This virtual absence of efficient regulation seems to have created a generalized race-to-fish leading to a race-to-dFADs. This situation, well known in open access fisheries as the 'Tragedy of the commons" (Hardin, 1968) may have encouraged over-investment during the last decade. At first, the increasing number of dFADs and GPS buoys (Maufroy *et al.*, 2017) contributed to an increase in the size of purse seiners, as building larger vessels had become profitable (Maufroy *et al.*, in preparation; Le Gall, 2000). But at the same time, these large purse seiners became dependent on their FOBs and support vessels and induced a competition with purse seiners who did not benefit from equivalent FOB fishing tools.

For some time, French fishing companies decided to set an auto-limitation of their use of GPS buoys in the Atlantic and the Indian Ocean (200 per vessel and per year). This was rather an unexpected decision in the absence of regulation. In this typical case of "Tragedy of the Commons" (Hardin, 1968), each fishing company should normally choose to increase its use of FOBs to increase catches on the short term, regardless of the consequences for tropical tuna stocks on the long term. The decision of the IOTC to limit the use of GPS buoys per vessel led again to an unexpected decision of French fishing companies. As this number was rather high (550 buoys per day i.e. 5 times more than the 100 GPS buoys per day used by French purse seiners, Maufroy *et al.* 2017), instead of reducing the general use of FOBs, this contributed to an increase in the use of GPS buoys by French purse seiners. French skippers explained that they had no other choice due to the competition with other purse seine fleets. This situation indicates that a sole management of the use of FOBs may not be efficient, if other components of fishing efficiency and fishing capacity are not regulated. Though only skippers of the Indian Ocean were interviewed in 2013 and 2015, similar conclusions may be drawn for the Atlantic Ocean.

Since 2015 however, encouraging management decisions have been made. They include a more restrictive limitation on the number of active tracking buoys in the Indian Ocean (from 550 to 425 GPS buoys, IOTC Res 15/08), the adoption of a regulation of the number of support vessels in the Indian Ocean (maximum 1 support vessel for 2 purse seiners, IOTC Res 16/01), a limitation of yellowfin catches in the Indian Ocean, IOTC Res 16/01) and the adoption of a limitation on the number of active tracking buoys in the Atlantic Ocean (500 buoys per vessel, ICCAT Rec. 15-01).

5.3 Improving data collection and FOB management

Though tropical tuna purse seine fisheries have been increasingly criticised about the impacts and the management of their numerous FOBs (Fonteneau and Chassot, 2014), the results of the present study highlight the lack of crucial information to manage FOB fisheries. Among others, detailed GPS buoy positions of all fleets would considerably improve the monitoring of the modalities in FOB use and their consequences. Obviously, confidentiality of such data is important for fishing companies. A solution would be to provide anonymised data, aggregated at sufficiently fine spatio-temporal scales (1° and 1 month for example) to be used for scientific purposes. Another solution would be to provide detailed data of each fleet to corresponding scientific institutes with a few months of delay (for example 6 months that exceeds the average 1-2 month lifespan of GPS buoys, (Maufroy *et al.*, 2015b). This last solution has been adopted by the French purse seine fleet and the IRD since 2007.

Similarly, data on the collaboration between purse seiners and their support vessels is rarely available, even to tuna RFMOs in stock assessment working groups. For the present study, we only had access to this information for the Indian Ocean, through collaboration with the Seychelles Fishing Authority. Therefore, we could not compare the results we obtained for the Indian Ocean to the situation of the Atlantic Ocean. Getting information on support vessels may be slightly more difficult than collecting information GPS buoy use, as support vessels often operate under convenience flags. However, providing information on the number of support vessels and their activities is mandatory in tuna RFMOs. Ideally, this information should be routinely provided on logbooks of support vessels and/or on logbooks of purse seiners, either at the scale of the month or at the scale of the fishing trip.

As stated previously, tropical tuna fisheries have been increasingly criticised about their numerous FOBs. Since the beginning of the 2010s, there are growing pressures on tuna consumers and seafood brands to avoid tuna caught on FOBs (Davies *et al.*, 2015). However, prohibiting dFAD deployment and FOB fishing would be a rather radical solution that is unlikely to be adopted by tuna RFMOs. Such a decision may not be suitable as fishing on FOBs has become vital to tropical tuna purse seine fisheries (Davies *et al.*, 2014b). Nevertheless, the increasing criticism of FOB fishing may indicate that tuna RFMOs have failed in making the appropriate management decisions when they were necessary. Concerns regarding the consequences of FOB use have been discussed at least since the 1990s (e.g. Hallier *et al.*, 1992; Stretta *et al.*, 1998) and the lack of data to measure their magnitude has been pointed out at least since the 2000s (Fonteneau *et al.*, 2000a; Bromhead *et al.*, 2003).

Encouraging progress have been made with the implementation of FAD management plans (ICCAT Res 15-01, IOTC Res 15-09) or the recent limitation of the number of GPS buoys in the Atlantic and the Indian Oceans (ICCAT Res 15-01, IOTC Res 15-08). Yet, problems of overcapacity and overfishing are still insufficiently addressed by these recent decisions. In particular, interviews with French skippers revealed the potential counterproductive effect of setting a too high limitation on the number of active GPS buoys, especially if the number of purse seiners is not regulated at the same time. A wide variety of management tools could be implemented depending on the priorities set by tuna RFMOs for the management of FOB fisheries. Prioritisation of management options could be done by involving the different stakeholders of the fishery (managers and scientists but also fishers as in this study, fishing companies, canning industry and NGOs). Finally, as a single management tool may not be sufficient and interaction exist between management options (e.g. reducing the number of purse seiners can reduce the total number of active GPS buoys), the management of FOBs should be combine multiple tools.

Acknowledgements

The authors wish to thank each of the purse seine skippers who accepted to participate in this study as well as other stakeholders who shared their point of view on the fishery (environmental NGOs, fisheries managers in Seychelles, representatives of local longline fishers in Seychelles, the tuna cannery in Victoria and fishing companies). We also thank ORTHONGEL for pviding data on buoy positions, Freddy Lesperance and the MCS section of the Seychelles Fishing Authority (SFA) for providing information on the licences of support vessels and Alicia Delgado de Molina for the information on Spanish logbooks. This paper is a contribution of the European Project CECOFAD (Call DG MARE/2014/24).

Bibliography

Amandè, M. J., Ariz, J., Chassot, E., de Molina, A. D., Gaertner, D., Murua, H., Pianet, R., *et al.* 2011a. Bycatch of the European purse seine tuna fishery in the Atlantic Ocean for the 2003–2007 period. Aquatic Living Resources, 23: 353–362.

Amandè, M. J., Ariz, J., Chassot, E., de Molina, A. D., Gaertner, D., Murua, H., Pianet, R., *et al.* 2011b. Bycatch of the European purse seine tuna fishery in the Atlantic Ocean for the 2003–2007 period. Aquatic Living Resources, 23: 353–362.

Amandè, M. J., Chassot, E., Chavance, P., Murua, H., Molina, A. D. de, and Bez, N. 2012. Precision in bycatch estimates: the case of tuna purse-seine fisheries in the Indian Ocean. ICES Journal of Marine Science.

Anderson, R. C., Zahir, H., Jauharee, R., Sakamoto, T., Sakamoto, I., and Johnson, G. 2009. Entanglement of Olive Ridley Turtles *Lepidochelys olivacea* in ghost nets in the equatorial Indian Ocean. IOTC-2009-WPEB-07.

Ariz Telleria, J., Delgado de Molina, A., Fonteneau, A., Gonzales Costas, F., and Pallarés, P. 1999. Logs and tunas in the eastern tropical Atlantic: a review of present knowledge and uncertainties. *In* Proceedings of the International Workshop on the Ecology and Fisheries for Tunas Associated with Floating Objects February 11-13, pp. 21–65. Scott, M.D. et al., La Jolla, California.

Arrizabalaga, H., Ariz, J., Mina, X., de Molina, A. D., Artetxe, I., Pallares, P., and Iriondo, A. 2001. Analysis of the activities of supply vessels in the Indian Ocean from observers data. Doc. IOTC.

Balderson, S., and Martin, L. E. C. 2015. 1 Environmental impacts and causation of 'beached' Drifting Fish Aggregating Devices around Seychelles Islands: a preliminary report on data collected by Island Conservation Society. IOTC WPEB.

Baske, A., Gibbon, J., Benn, J., and Nickson, A. 2012. Estimating the Use of of Drifting Fish Aggregation Devices Around the Globe - Pew Environment Group.

Bromhead, D., Foster, J., Attard, R., Findlay, J., and Kalish, J. 2003. A Review of the impact of fish aggregating devices (FADs) on tuna fisheries. Final report to Fisheries Resources Research Fund. Australian Bureau of Rural Science, Canberra.

Castro, J., Santiago, J., and Santana-Ortega, A. 2002. A general theory on fish aggregation to floating objects: An alternative to the meeting point hypothesis. Reviews in Fish Biology and Fisheries, 11: 255–277.

Chalmers, N., and Fabricius, C. 2007. Expert and Generalist Local Knowledge about Land-cover Change on South Africa's Wild Coast: Can Local Ecological Knowledge Add Value to Science? Ecology and Society, 12: 10.

Dagorn, L., Holland, K. N., Restrepo, V., and Moreno, G. 2013. Is it good or bad to fish with FADs? What are the real impacts of the use of drifting FADs on pelagic marine ecosystems? Fish and Fisheries, 14: 391–415.

Davies, T. K., Mees, C. C., and Milner-Gulland, E. J. 2014a. The past, present and future use of drifting fish aggregating devices (FADs) in the Indian Ocean. Marine Policy, 45: 163–170.

Davies, T. K., Mees, C. C., and Milner-Gulland, E. J. 2015. Second-guessing uncertainty: Scenario planning for management of the Indian Ocean tuna purse seine fishery. Marine Policy, 62: 169–177.

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

Fonteneau, A., Pallares, P., and Pianet, R. 2000. A worldwide review of purse seine fisheries on FADs. *In* Pêche thonière et dispositifs de concentration de poissons, pp. 15–35. Le Gal, J.Y., Cayré, P., and Taquet, M.

Fonteneau, A., Chassot, E., and Bodin, N. 2013b. 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.

Fonteneau, A., and Chassot, E. 2014. Managing tropical tuna purse seine fisheries through limiting the number of drifting Fish Aggregating Devices in the Indian Ocean: food for thought. IOTC-2014-WPTT16-22.

Gascuel, D., Fonteneau, A., and Foucher, E. 1993. Analyse de l'évolution des puissances de pêche par l'analyse des cohortes : application aux senneurs exploitant l'albacore (*Thunnus albacares*) dans l'Atlantique Est. Aquatic Living Resources, 6: 15–30.

Guillotreau, P., Salladarré, F., Dewals, P., and Dagorn, L. 2011. Fishing tuna around Fish Aggregating Devices (FADs) vs free swimming schools: Skipper decision and other determining factors. Fisheries Research, 109: 234–242.

Hallier, J., and Gaertner, D. 2008. Drifting fish aggregation devices could act as an ecological trap for tropical tuna species. Marine Ecology Progress Series, 353: 255–264.

Hallier, J.-P., Parajua, J. I., and International Workshop on Fishing for Tunas Associated with Floating Objects, La Jolla (USA), 1992/02/11-14. 1992. Review of tuna fisheries on floating objects in the Indian Ocean. *In* Fishing for tunas associated with floating objects. IATTC, La Jolla.

ICCAT. 2015. Report of the Standing Committee on Research and Statistics. September 28 to October 2, 2015. Madrid, Spain.

IOTC. 2015. Report of the 17th session of the IOTC Working Party on Tropical Tunas. IOTC-2015-WPTT17-R[E]. Montpellier, France, 23–28 October 2015.

Jentoft, S., McCay, B. J., and Wilson, D. C. 1998. Social theory and fisheries co-management. Marine policy, 22: 423–436.

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

Le Gall, J. Y. 2000. Contribution des DCP fixes et derivants a l'accroissement de la puissance de peche des navires de peche thoniere.

Marchal, P., Nielsen, J. R., Hovgård, H., and Lassen, H. 2001. Time changes in fishing power in the Danish cod fisheries of the Baltic Sea. I C E S Journal of Marine Science, 58: 298–310.

Marsac, F., Fonteneau, A., and Ménard, F. 2000. Drifting FADs used in tuna fisheries: an ecological trap? *In* Pêche thonière et dispositifs de concentration de poissons, Caribbean-Martinique, 15-19 Oct 1999.

Maufroy, A., Gaertner, D., Kaplan, D. M., Katara, I., Bez, N., Soto, M., and CHASSOT, E. in preparation. Contribution of support vessels and Floating OBjects (FOBs) to the increasing efficiency of tropical tuna purse seiners in the Atlantic and Indian Oceans.

Maufroy, A., Chassot, E., Joo, R., and Kaplan, D. M. 2015b Large-Scale Examination of Spatio-Temporal Patterns of Drifting Fish Aggregating Devices (dFADs) from Tropical Tuna Fisheries of the Indian and Atlantic Oceans. PLoS ONE, 10: e0128023.

Maufroy, A., Kaplan, D. M., Bez, N., Molina, D., Delgado, A., Murua, H., Floch, L., *et al.* 2017. Massive increase in the use of drifting Fish Aggregating Devices (dFADs) by tropical tuna purse seine fisheries in the Atlantic and Indian oceans. ICES Journal of Marine Science, 74: 215–225.

Ménard, F., Fonteneau, A., Gaertner, D., Nordstrom, V., Stéquert, B., and Marchal, E. 2000. Exploitation of small tunas by a purse-seine fishery with fish aggregating devices and their feeding ecology in an eastern tropical Atlantic ecosystem. ICES Journal of Marine Science: Journal du Conseil, 57: 525–530.

Miyake, M., Guillotreau, P., Sun, C.-H., and Ishimura, G. 2010. Recent developments in the tuna industry: stocks, fisheries, management, processing, trade and markets. FAO Fisheries and Aquaculture Technical Paper, No.543. FAO, Rome. http://www.fao.org/docrep/013/i1705e/i1705e.pdf.

Moreno, G., Dagorn, L., Sancho, G., Garcia, D., and Itano, D. 2007. Using local ecological knowledge (LEK) to provide insight on the tuna purse seine fleets of the Indian Ocean useful for management. Aquatic Living Resources, 20: 367–376.

Neis, B., Schneider, D. C., Felt, L., Haedrich, R. L., Fischer, J., and Hutchings, J. A. 1999. Fisheries assessment: what can be learned from interviewing resource users? Canadian Journal of Fisheries and Aquatic Sciences, 56: 1949–1963.

O'Neill, M. F., and Leigh, G. M. 2007. Fishing power increases continue in Queensland's east coast trawl fishery, Australia. Fisheries Research, 85: 84–92.

Sempo, G., Dagorn, L., Robert, M., and Deneubourg, J.-L. 2013. Impact of increasing deployment of artificial floating objects on the spatial distribution of social fish species. Journal of Applied Ecology, 50: 1081–1092.

Stretta, J.-M., Delgado de Molina, A., Ariz, J., Domalain, G., Santana, J. C., and Le Gall, J. Y. 1998. Les espèces associées aux pêches thonières tropicales dans l'océan Indien. *In* Le thon : enjeux et stratégies pour l'océan Indien, pp. 369–386. Ed. by P. Cayré and Conférence Internationale Thonière de Maurice, Port Louis (MUS), 1996/11/27-29. ORSTOM, Paris.

Torres-Irineo, E., Gaertner, D., Chassot, E., and Dreyfus-Leon, M. 2014. Changes in fishing power and fishing strategies driven by new technologies : the case of tropical tuna purse seiners in the eastern Atlantic Ocean. Fisheries Research, 155: 10–19.

Table 1. Multiple sources of information combined to monitor the use and the consequences of FOBs in tropical tuna purse seine fisheries. Part of this information was only available for the French fleet whereas some other information was available for all European Union purse seiners (France and Spain).

source	fleet	ocean	period	information	precision
PS logbook data	all EU	AO + IO	2003-2014	- catch - number of fishing sets - travelled distance	1 m
PS VMS data	French	AO + IO	2010	purse seiners' positions	1 h
observer data	all EU	AO + IO	2006-2013	activities on FOBs	1 min
GPS buoy data	French	AO + IO	2007-2013	positions of FOBs	1 h, 2 h, 1 d, 2 d
support vessel data (logbooks + licences)	all EU	IO	2003-2014	links between PS and support vessels	1 y

min : minute ; h : hour ; d : day ; y : year

Table 2. Structure of the interview guide used in 2013.

Theme	Sub-theme	Question
1. modalities in FOB use	a) deployment	deployment factors
	b) monitoring	number of FOBs, dFADs/natural FOBs, French/Spanish FOBs
	c) fishing	searching activities, preference for FOB or Free Swimming Schools, size of fishing sets
2. changes for FOB fisheries	a) technological and strategic changes	changes in catches, seasons and zones, echosounder buoys
	b) management tools	IOTC time-area closure, Chagos MPA, Somali EEZ

Table 3. Different measures of fishing efficiency of tropical tuna purse seiners.

Efficiency measure	Designation	Meaning
Catch / Fishing days	CPUE1	Ability to maximize the catch over a certain period of time
Catch / Fishing sets	CPUE2	Ability to maximize the catch per fishing set
Catch / Distance (km)	CPUE3	Ability to choose the optimal area for search activities
Sets / Fishing days	SPUE	Ability to detect concentrations of tuna
Distance / Fishing days	DPUE	Ability to cover a large area during search activities / to leave zones without fish rapidly

Table 4. Effect of the proportion of fishing sets on FOBs on the 5 dimensions of the efficiency of individual tropical tuna purse seiners.

	Atlantic Ocean	Indian Ocean
CPUE1	n.s. (p= 0.17)	0.18 (p= 3.96e-6)
CPUE2	0.30 (p= 2.2e-16)	0.44 (p= 2.2e-16)
CPUE3	-0.27 (p= 3.11e-10)	n.s. (p= 0.29)
SPUE	-0.25 (p= 2.2e-16)	-0.28 (p= 2e-16)
DPUE	0.24 (p= 2.2e-16)	0.19 (p= 2.2e-16)

n.s. indicates that the parameter was not significant (p> 0.01, chi-squared test). Response and predictor variables were log transformed.

Table 5. Structure of the interview guide used in 2015.

Theme	Sub-theme	Question
1. modalities in dFAD use	a) deployment	seasons, currents
	b) number of dFADs	increase in dFAD use, recent changes in strategies
2. consequences of dFAD use	a) tuna catch	catch, yield of fishing sets
	b) other species	bycatch, ghost fishing
	c) ecosystems	lost GPS buoys, dFAD beaching, ecological trap
3. management tools	a) existing management	seasonal closures, 550 GPS active buoys/vessel
	b) options for management	limitation of dFADs/buoys, catch quotas, support vessels

Table 6. Potential management of FOB fisheries, positive outcomes and possible limitations.

Management tool	Pros	Cons
Number, size and carrying capacity of purse seiners	• too many vessels : 8 skippers • too large vessels: 6 skippers • fuel consumption: 3 skippers • regulation of GPS buoys: 1 skipper improve yield per vessel: 1 skipper	• vessels may leave for another ocean: 4 skippers • this creates a race for fishing anteriority: 2 skippers • flags of convenience: 2 skippers • EU subsidies: 1 skipper • economic consequences (investments made already): 1 skipper
Support vessels	• they do not comply with EEZs: 9 skippers • there is no regulation of support vessels: 7 skippers • they appropriate fish/FOBs: 4 skippers • this could regulate the use of GPS buoys: 3 skippers • they should be accounted for in the 550 buoys	• issues of profitability for large purse seiners: 2 skippers • support vessels could be used to limit beaching: 2 skippers • French companies will soon have support vessels too: 2 skippers
Catch quotas	• to regulate prices: 3 skippers • to improve stocks/yield: 2 skippers • some fishing companies do not consider the long term : 2 skippers • they may be easier to enforce: 1 skipper • they have proven successful in other fisheries: 1 skipper • this could regulate capacity, support vessels and FOB use: 1 skipper	• allocation criteria: 2 skippers • this creates a race for fishing anteriority: 2 skippers • difficult to choose between different fleets and their strategies: 2 skippers • obligation of regularity in catches (to avoid fast quota exhaustion): 2 skippers • problem of consensus: 1 skipper • ineffective if catches are not significantly reduced: 1 skipper
Spatial management (including no-take areas)	• spillover: 5 skippers • protect GPS buoys against theft: 5 skippers • protect juveniles: 3 skippers	• supply vessels do not comply: 5 skippers • inappropriate choice of period: 3 skippers • such management measures are only communication tools: 2 skippers

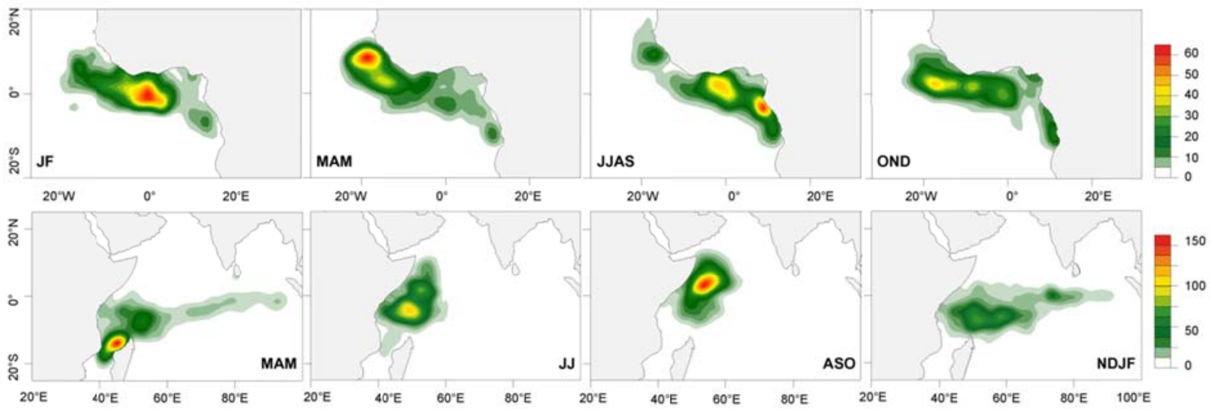


Figure 1. Seasonal density of French GPS buoy deployments on dFADs and logs (2007-2013). Top panel: in the Atlantic Ocean. JF: January-February; MAM: March-May; JJAS: June-September; and OND: October-December. Bottom panel: in the Indian Ocean. MAM: March-May; JJ: June-July; ASO: August-September; and NDJF: November-February.

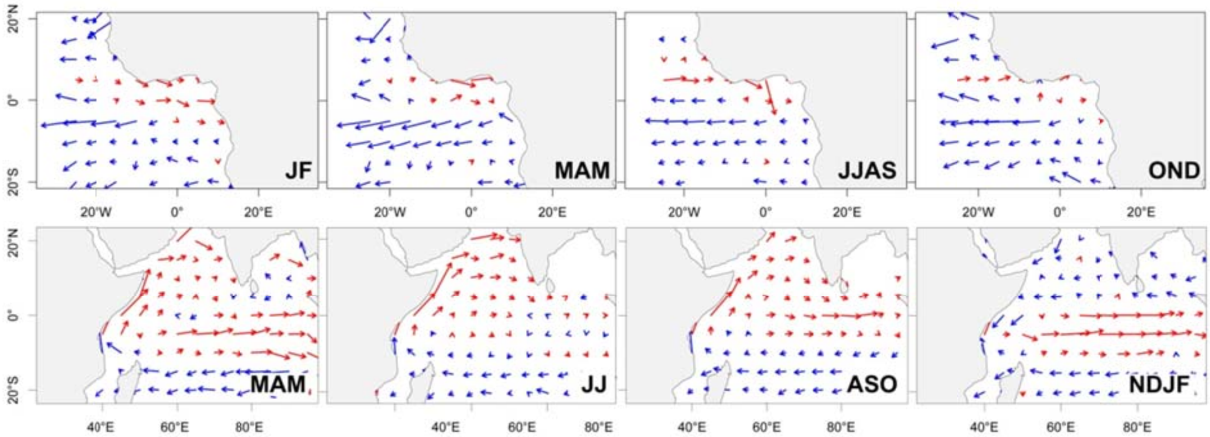


Figure 2. Seasonal currents transporting FOBs equipped with a French GPS buoy (2007-2013). Top panel: in the Atlantic Ocean. JF: January-February; MAM: March-May; JJAS: June-September; and OND: October-December. Bottom panel: in the Indian Ocean. MAM: March-May; JJ: June-July; ASO: August-September; and NDJF: November-February.

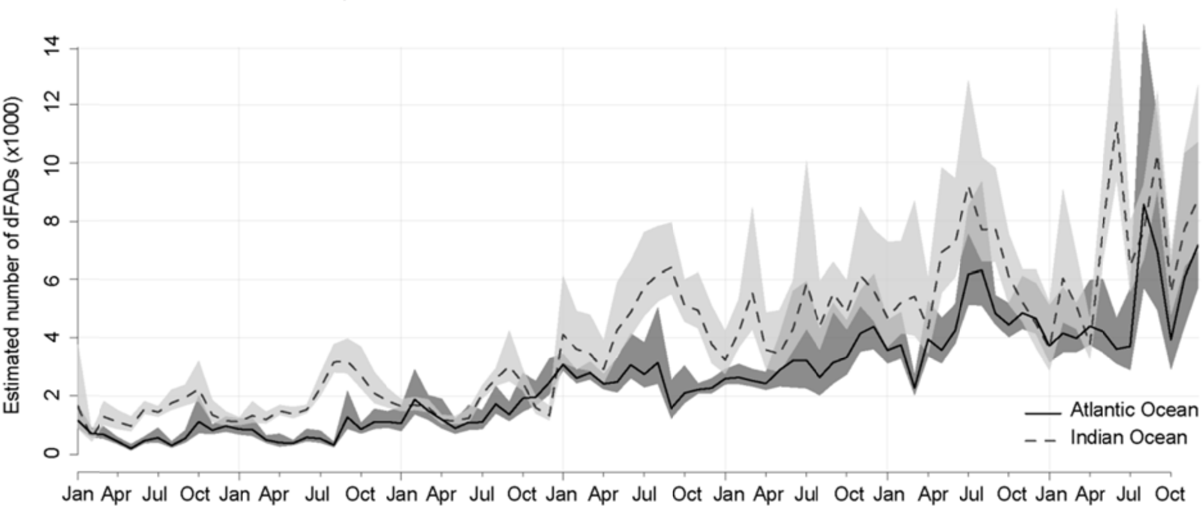


Figure 3. Estimation of the total number of GPS buoy-equipped dFADs in the main purse seine fishing grounds of the Atlantic (solid line) and Indian (dashed line) oceans, at the end of each month (2007-2013). Grey areas represent the 95% Confidence Intervals (CI).

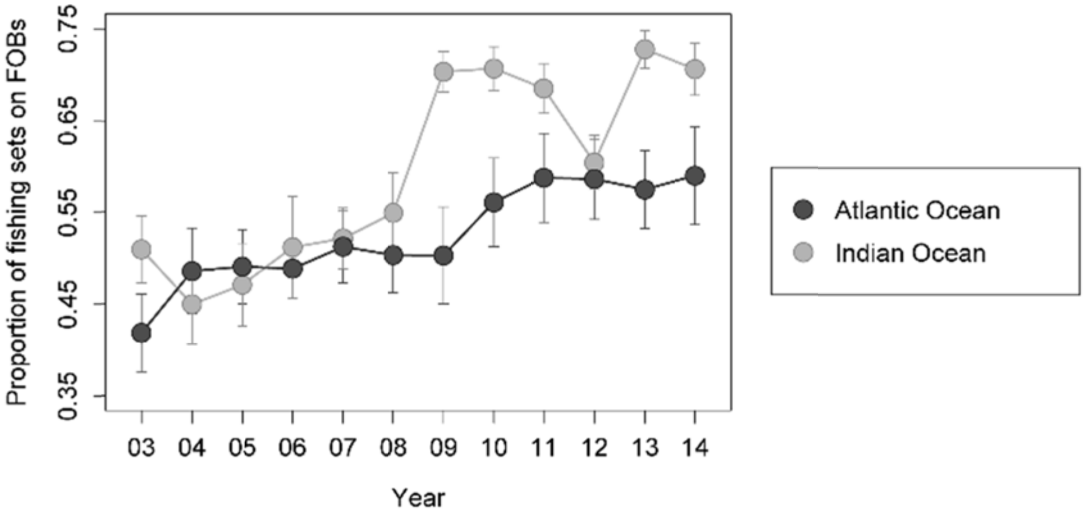


Figure 4. Effect of the year on the strategies of purse seiners with FOBs from 2003 to 2014 in the Atlantic and Indian Oceans. Error bars represent the standard error of the mean (Maufroy et al. *in prep*)**.**

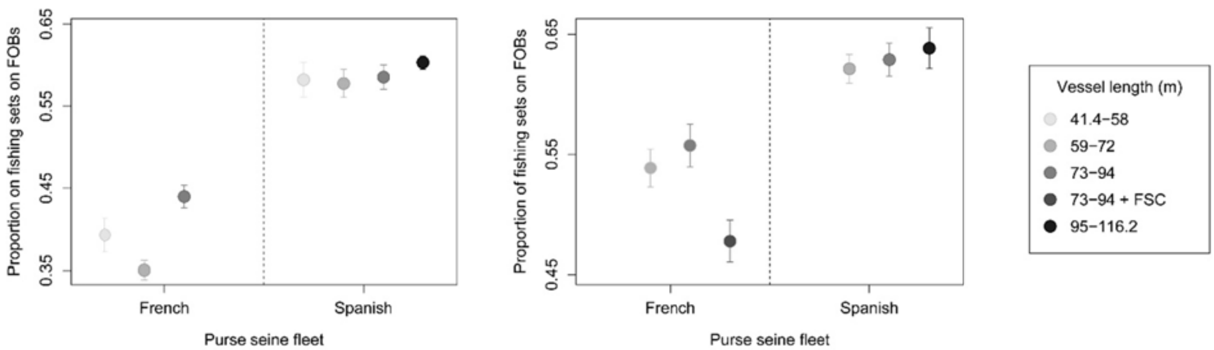


Figure 5. Effect of the fleet and the size of purse seiners on their strategies with FOBs from 2003 to 2014 in the Atlantic (left panel) and the Indian (right panel) oceans (Maufroy *et al.*, in preparation).

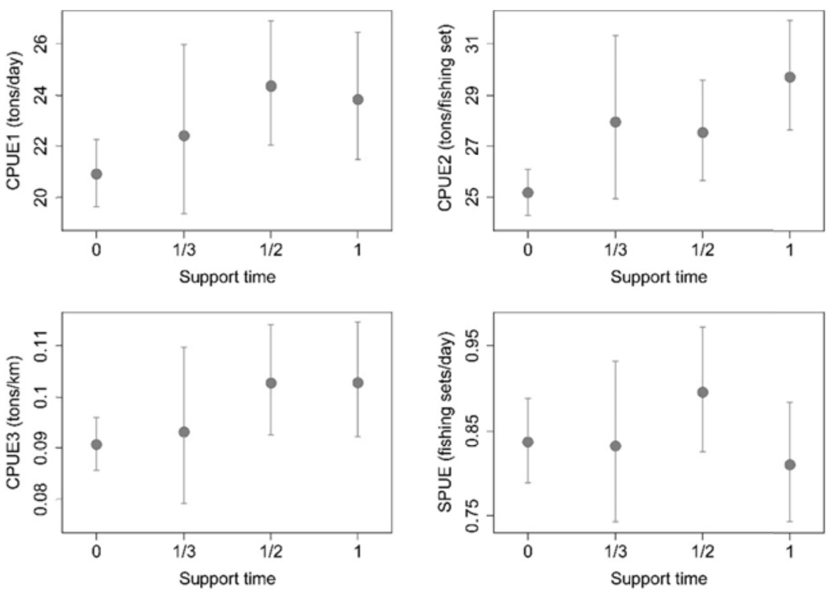


Figure 6. Effect of support vessels on the efficiency of EU tropical tuna purse seiners of the Indian Ocean over 2003-2014. Error bars represent the standard error of the mean (Maufroy *et al.*, in preparation).

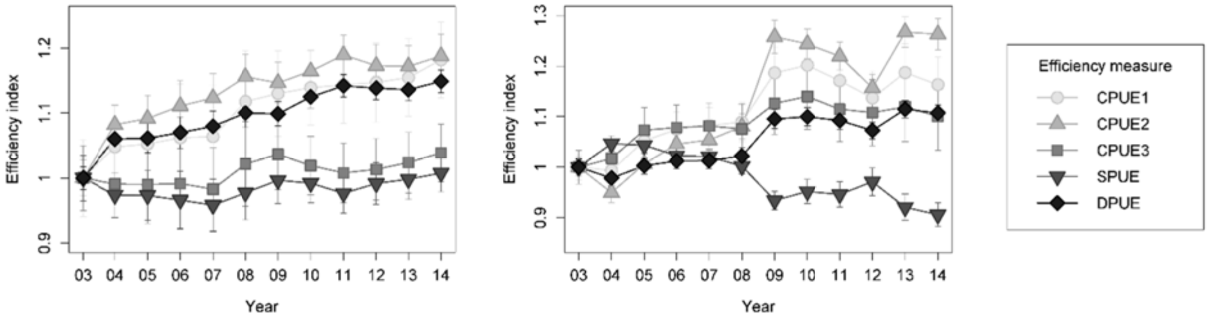


Figure 7. Evolution of the total efficiency of purse seiners over 2003-2014 in the Atlantic Ocean (left panel) and in the Indian Ocean (right panel). Error bars represent the standard error of the mean.

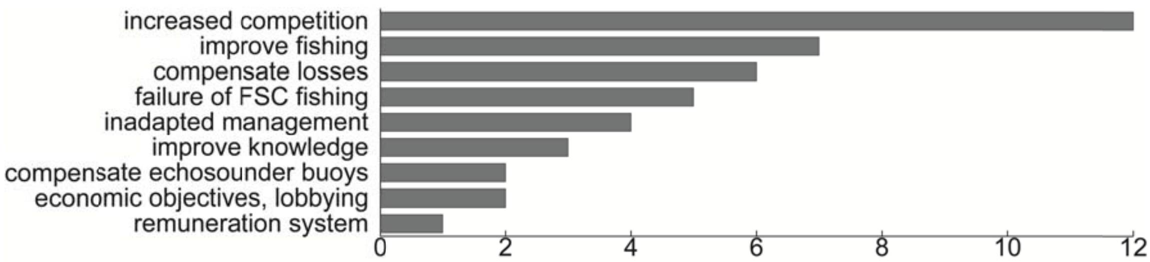


Figure 8. Reasons to increase the use of FOBs by French purse seiners in the Indian Ocean.

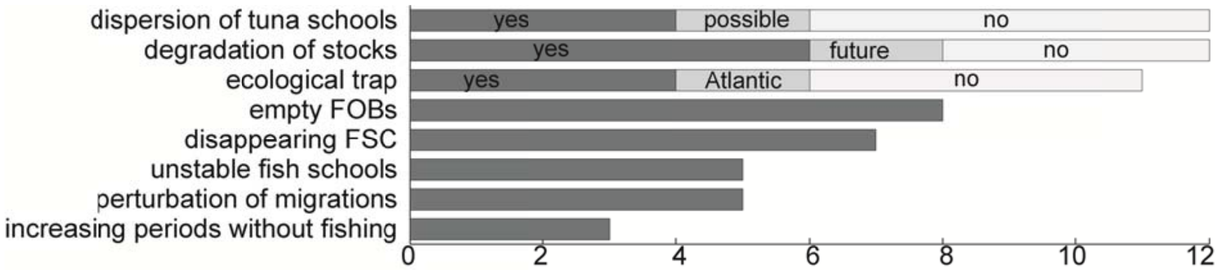


Figure 9. Perception of skippers of the impacts of FOBs on tropical tunas.

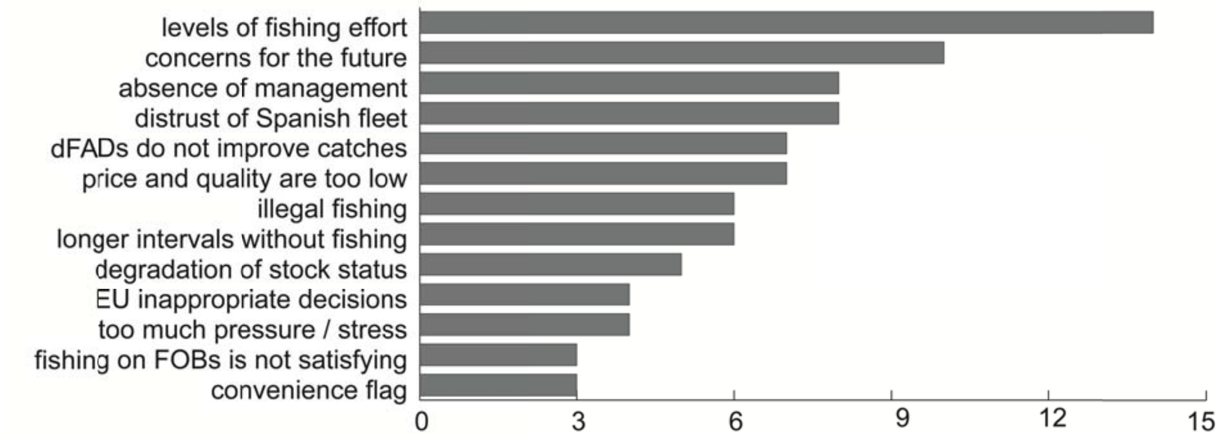


Figure 10. Reasons to manage FOB fisheries in the Indian Ocean.

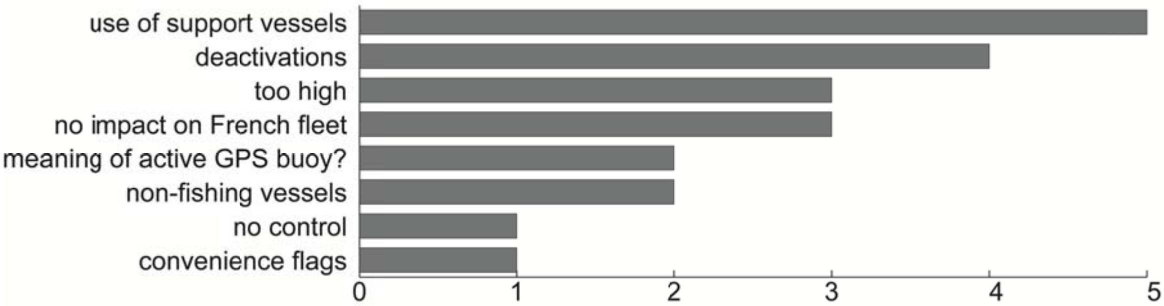


Figure 11. Problems with the limitation of active GPS buoys in the Indian Ocean.

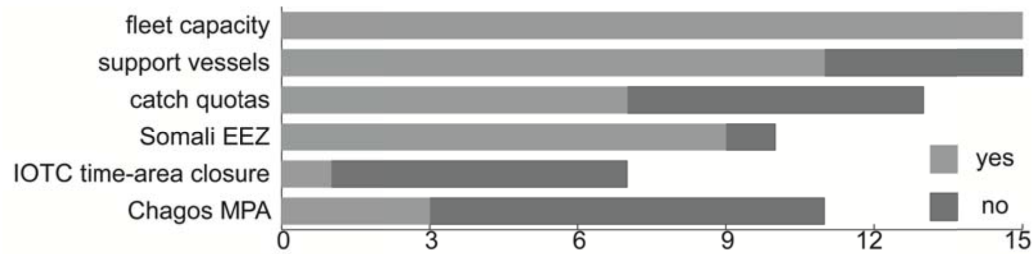


Figure 12. Agreement of skippers with potential and existing management tools.

Original: English

THE LACK OF A SCIENTIFICALLY BASED DEFINITION OF "FAD SET"

International Pole & Line Foundation[1]

Introduction

Tropical tuna purse seine fisheries around the world have been using drifting fish aggregating devices (dFADs) for decades. The advances in efficiency are undeniable, and the technology of dFADs continues to develop at a rapid pace. In fact, the developments are outpacing the management bodies tasked with managing these large-scale tuna fisheries. As the Joint Tuna RFMO FAD Working Group gathers for the first time, it will be important to have a robust scientific definition of what constitutes a "FAD set" versus an "unassociated set" and to ensure that there are mechanisms in place to enable a consistent and verifiable application of these definitions.

Research review

In a study conducted by Moreno *et al*. in 2007, researchers interviewed purse seine captains to obtain local ecological knowledge (LEK) to assist in the planning of future *in situ* studies of fish behaviour around drifting fish aggregating devices (dFADs). They found that "most fishing masters agreed that the maximum attraction distance of a dFAD is approximately 10 km...." and that "...the majority of fishers (48%) believe that the attraction distance of tuna to FADs is between 2 and 5 nautical miles". Studies have also shown that yellowfin tuna can detect anchored FADs from five to eight miles away (Holland *et al*. 1990; Dagorn *et al*. 2000) which seems to indicate that they could have a high level of association with FADs at these distances. Based on studies by Girard *et al*. (2004) and the interviews conducted with purse seine skippers (Moreno *et al*., 2007), Cabral *et al*. (2014), tuna can detect and orient themselves towards a FAD 10 km away. Based on this they recommended that FADs should then be no closer than 20 km from each other and estimated that a single FAD therefore can have an effective area of 20 km by 20 km equivalent to a total effective area of A_{FAD} = 400 km^2. Although it can be argued that detection ability does not necessarily obligate association, the precautionary approach would dictate that this issue is better understood before making such assumptions.

Moreno *et al*. (2016) also raised some concerns around the scientific rationale when defining a school as 'unassociated' when it is >1nm from a dFAD. They argued that a number of studies have "attempted to characterize this association with varying results. The range of influence of dFADs on tuna schools may vary from two to ten nautical miles and will vary according to local conditions". They further argue that "this suggests that tuna schools do not aggregate consistently with floating objects and that it is very difficult and subjective to assign a set distance to define association".

Varying definitions of "FAD sets" and "Unassociated"

In the WCPFC a distance of 1nm was adopted during the FAD closure period specified in CMM 2008-01, as "…no purse seine vessel shall conduct any part of a set within one nautical mile of a FAD. That is, at no time may the vessel or any of its fishing gear or tenders be located within one nautical mile of a FAD while a set is being conducted". A FAD is defined as "any object or group of objects, of any size, that has or has not been deployed, that is living or non-living, including but not limited to buoys, floats, netting, webbing, plastics, bamboo, logs and whale sharks floating on or near the surface of the water that fish may associate with". The 1nm definition seems to have been adopted as a compromise measure for compliance purposes rather than a measure underpinned by rigorous scientific studies.

[1] International Pole & Line Foundation.

In the Marine Stewardship Council (MSC) certified PNA fishery, unassociated sets were defined as "an unassociated set is defined as fishing on a free school, which may include a free school feeding on bait fish. There are no associations with objects (natural or man-made), with set distances from such objects of 1 nautical mile or greater".

The "unassociated set" definition applied in the assessment of the fishery seems to have been based on the 1nm definition adopted by WCPFC for the FAD closure conservation measure rather than any additional scientific evidence of what would reasonably constitute "association" with a floating object. It is also important to note that there is no consistent application of what constitutes an unassociated set across tuna-RFMOs.

The question should be asked whether in the absence of clear scientific evidence pointing to a 1nm definition as a credible classification of an unassociated school, it would not be better to rather produce rigorous scientific studies which show the ideal distance to fish from a FAD in order to minimise unwanted catches of non-target species and juvenile tunas.

In the IOTC, there is no standardized definition of a FAD set, however the issue came up when the Echebaster Indian Ocean purse seine skipjack, yellowfin and bigeye fishery underwent the process of MSC certification. The unit of certification according to the Public Comment Draft Report (PCDR) was unassociated free schools of skipjack, yellowfin and bigeye tuna. The Conformity Assessment Body (CAB) in that assessment defined free schools (section 5.2.6, page 116) "to be those made on schools of tuna, the presence of which is indicated by sea-surface bird activity or by the presence of bait fish in the water. Free schools sets are truly unassociated sets, meaning that they take place at some distance away from any FAD of other floating objects or megafauna. Associated sets are generally considered to be those that take place at a distance of 5nM [nautical miles] or less from a FAD."

With this definition, unassociated sets, or free schools of tuna could only be caught outside a five nautical mile radius from FAD, log, marine mammal, whale shark, and seamount. In other words, unassociated free school sets should only occur outside of exclusion zones around these objects and animals.

Monitoring and verification challenges

A further issue that was raised by Moreno *et al*. (2016) is the difficulty captains and observers might have in deciding whether any object is within the defined distance of what constitutes an unassociated set. If sea conditions are choppy or other situations where visibility is impaired such as foggy conditions or when sets are done at dusk or dawn, how would an observer be able to declare with certainty that no drifting object or another FAD was not within one or five nautical miles from a particular set? Even with clear skies and good visibility it might be impossible for an observer to determine whether a drifting object, log or FAD is within 1nm or 1.5 nm from a particular set, especially since dFADs are generally designed to have low detection levels and are unlikely to show up on the radar.

For an observer or a captain to make such an important determination - whether a set constitutes an unassociated set or not - in a high pressure environment, with the paucity of data they have and the high degree of uncertainty of the actual distances involved and the presence or not of semi-submerged objects, can place an unfair burden on their shoulders. This is not so much a chain of custody issue as it is an issue of deciding whether a particular set conforms to the definition of a "FAD set" or "unassociated set". In a global market with growing demands verifiable and traceable seafood, it is important to ensure that any claims being made to consumers are scientifically robust and verifiable.

Conclusion

In light of the challenges identified in determining if a school is "associated" or "unassociated", additional measures should be employed to ensure a higher level of certainty around fishing operations with supposedly lower levels of ecosystem impacts. The lack of robust science, and following the precautionary approach, would dictate that firstly, evidence be provided to determine the appropriate distance from a FAD that minimises unwanted catches and that secondly, such appropriate distances be implemented to describe unassociated sets. Additional measures, other than only relying on judgement calls made by observers and captains, should be employed to ensure greater certainty that there is not another vessel's FAD, marine mammal, whale shark, or other floating object within the required distance of the set.

References

Dagorn, L., Josse, E., and Bach, P. 2000. Individual differences in horizontal movements of yellowfin tuna (*Thunnus albacares*) in nearshore areas in French Polynesia, determined using ultrasonic telemetry. Aquatic and Living Resources 13:193-202.

Fonteneau, A., Chassot E., Bodin N. 2013. Global spatio-temporal patterns in tropical tuna purse seine fisheries on drifting fish aggregating devices (FADs): Taking a historical perspective to inform current challenges. Aquat Living Resour, 26 (1) (2013), pp. 37–48.

Holland, K.N., Brill, R.W., Chang, R.K.C. 1990. Horizontal and vertical movements of yellowfin and bigeye tuna associated with fish aggregating devices. Fisheries Bulletin 88:493-507.

Marine Stewardship Council, 2014. MSC Fisheries Standard and Guidance v2.0, 290 pp.

Moreno, G., L. Dagorn, G. Sancho and D. Itano 2007. Fish behaviour from fishers' knowledge: the case study of tropical tuna around drifting fish aggregating devices (DFADs). Canadian Journal of Fisheries and Aquatic Sciences, 2007, 64(11): 1517-1528.

Moreno, G., Herrera, M. and Morón, J. 2016. To FAD or not to FAD: A challenge to the Marine Stewardship Council and its conformity assessment bodies on the use of units of assessment and units of certification for industrial purse seine tuna fisheries. Marine Policy 73: 100-107.

Original: English

POTENTIAL ENVIRONMENTAL IMPACTS CAUSED BY BEACHING OF DRIFTING FISH AGGREGATING DEVICES AND IDENTIFICATION OF MANAGEMENT UNCERTAINTIES AND DATA NEEDS

Tim Davies[1], *David Curnick*[2], *Julien Barde*[3], *Emmanuel Chassot*[4,5]

SUMMARY

Drifting fish aggregating devices (dFADs) are widely used in tropical tuna purse seine fisheries to aggregate fish and make them easier to catch. The use of dFADs has been associated with a number of potential positive and negative impacts, touching on a range of ecological, economic and social issues. One negative environmental impact of dFADs is that they have the potential to wash ashore and become grounded or beached, potentially causing damage to marine habitats. However, other than anecdotal reports, this issue has received very little research attention to date. The lack of research on this topic means that the problem of beaching dFADs is not well defined, with the risk of beaching events mostly assumed and the extent and severity of impacts uncertain. The aim of this paper is to better characterise the potential problem of beaching dFADs. We examine the potential for dFAD beaching events to occur, which is determined by location of deployment, dispersal patterns, extent of efforts to prevent beaching events from occurring and, to a lesser extent, dFAD design. This discussion is illustrated with a case study examining the spatio-temporal dynamics of dFAD trajectories in the Indian Ocean and estimating the frequency of dFAD beaching events on coral reefs. The potential environmental impacts of beached dFADs are reviewed by looking at wider literature on other abandoned, lost, or otherwise discarded fishing gear, and we offer some thoughts on the classification of dFADs as marine pollution. Finally, we critically discuss a number of possible ways to reduce the number of dFAD beaching events on sensitive marine habitats. This includes regulatory measures, which would be applied by the tropical tuna Regional Fisheries Management Organisations or coastal and island state governments and advances in dFAD design, which would likely come from collaboration between fishing companies, researchers and NGOs/non-profit partnerships. Possible measures include reducing the overall number of dFADs in the water, i.e. though deployment limits, fee structures and reduced fleet capacity, or a localised reduction of dFAD deployments in sensitive areas; reduced lifetime of dFADs, through use of entirely bio-degradable materials; and the prevention of dFADs entering areas with sensitive habitats, through recovery initiatives (at sea and inshore) and innovative dFAD design.

[1] MRAG, 18 Queen Street, London, W1J 5PN, t.davies@mrag.co.uk
[2] Institute of Zoology, Zoological Society of London, Outer Circle, Regent's Park, London, NW1 4RY, david.curnick@zsl.org
[3] Institut de Recherche pour le Développement – MARBEC, Port Louis, Mauritius, julien.barde@ird.fr
[4] Institut de Recherche pour le Développement – MARBEC, Fishing Port, Victoria, Seychelles, emmanuel.chassot@ird.fr
[5] Seychelles Fishing Authority, Fishing Port, PO Box 449, Mahé, Seychelles

Appendix

POTENTIAL ENVIRONMENTAL IMPACTS CAUSED BY BEACHING OF DRIFTING FISH AGGREGATING DEVICES AND IDENTIFICATION OF MANAGEMENT SOLUTIONS AND UNCERTAINTIES

Tim Davies, David Curnick, Julien Barde, Emmanuel Chassot

1 Introduction

Drifting fish aggregating devices (dFADs) are widely used in tropical tuna purse seine fisheries to aggregate fish and make them easier to catch. A typical dFAD has a floating element, usually a bamboo raft or plastic float, and a subsurface structure, usually old fishing netting or rope, around which fish associate in schools. Almost all modern dFADs are fitted with instrumented buoys that contain a GPS unit, which allows it to be tracked remotely. At any given moment a skipper can monitor the location of many tens, or even hundreds, of dFADs in real time. The most recent generation of dFADs are also fitted with echo-sounders that transmit biomass estimates and sometimes size composition of an associated school swimming beneath it, and in some oceans[6], auxiliary 'supply' vessels are used to manage the network of dFADs belonging to one or more purse seiners (Ramos *et al*., 2010; Assan *et al*., 2015).

Fishers typically deploy dFADs at the edge of major ocean current systems and allow them to drift for a period of weeks or months before catching tuna schools aggregated beneath them. Historically, dFADs were used to increase the number of naturally occurring floating objects in the ocean and boost fishing opportunities, although some fleets have now become reliant on dFADs to achieve the very large catches needed to remain profitable (Guillotreau *et al*., 2011; Davies *et al*., 2014). As a result, the number of dFADs in the ocean has increased considerably in the past 30 years (Fonteneau *et al*., 2013; Maufroy *et al*., 2017).

The use of dFADs has been associated with a number of potential positive and negative impacts, touching on a range of ecological, economic and social issues (for a recent review see MRAG, 2017). One negative environmental impact of dFADs is they have the potential to wash ashore and become grounded or beached[7], potentially causing damage to marine habitats. Other than anecdotal reports (e.g. Stelfox *et al*., 2015), this issue has received very little research attention to date. On the occurrence of observed dFAD beaching events, Balderson and Martin (2015) present a detailed investigation into the location, characteristics and source of beached dFADs in Seychelles. They show categorically that dFADs used by fleets in the region are washing ashore, and that coral reefs are the most impacted habitat, with dFAD sub-surface structure becoming entangled on reef structure. However, their study did not attempt to quantify the damage caused to habitat during entanglement. From a different perspective, and using a large dataset of GPS buoy positions, Maufroy *et al*. (2015) estimated that almost 10% of all dFADs deployed by French vessels in the Indian and Atlantic Oceans ultimately became beached. In the Atlantic, dFAD beaching events were concentrated along the coastline of the Gulf of Guinea, adjacent to the main purse seine fishing grounds, although some travelled much further and stranded on the Brazilian coastline. In the Indian Ocean, beaching events occurred more widely, with most events observed in Somalia, the Seychelles, the Maldives, and Sri Lanka. Beaching events were also observed in the British Indian Ocean Territory (BIOT) marine protected area.

The lack of research on this topic means that the problem of beaching dFADs is not well defined, with the risk of dFADs beaching events being mostly assumed and the extent and severity of beaching impacts uncertain. The aim of this paper is to better characterise the potential problem of beaching dFADs. Three specific objectives are:

[6] With the exception of the Eastern Pacific Ocean where supply vessels were banned from 1999.
[7] For the purpose of simplicity, this is hereafter referred to as beaching, but while recognising that dFADs may wash up or become entangled in many different shallow water habitat types.

- To discuss the potential for beaching events to occur, to characterise beaching risk and to identify knowledge gaps. We illustrate this discussion with a case study examining the spatio-temporal dynamics of dFAD dispersal in the Indian Ocean, specifically estimating the probability of dFAD beaching events on coral reefs;
- To examine the potential environmental impacts of dFAD beaching in terms of physical damage to coral reef and other shallow water habitats; and
- To identify and critically discuss possible approaches to managing the issue of beaching dFADs.

The focus of this paper is on dFADs, although it is noted that anchored FADs can escape their mooring and also have potential to cause damage to marine habitats. However, management options for minimising habitat damage caused by anchored FADs are likely to be more straightforward than for dFADs, and there is presumably a greater incentive for anchored FAD owners to reduce incidences of loss. Furthermore, the impacts of sinking dFADs on deep water habitats (e.g. >100m) it not considered, although future research on this sub-topic is encouraged. There is also likely to be considerably fewer anchored FADs deployed in the oceans than dFADs (MRAG, 2017).

2 Potential for beaching events to occur

The risk of a dFAD beaching event occurring is determined by the number of dFADs in the ocean, the deployment location, dispersal patterns, the extent of efforts to prevent beaching events from occurring and dFAD design. Each of these different elements of risk are discussed below.

2.1 How many dFADs are in the ocean?

The number of dFADs in the ocean at any given time is not known with certainty. It has been estimated that between 81,000 and 121,000 dFADs were deployed globally in 2013, although this estimate is uncertain due to the need to make assumptions on dFAD usage between fleets and extrapolation to fill data gaps (Gershman *et al*., 2015). The total number of dFADs deployed varies between the tropical tuna Regional Fisheries Management Organisation (tRFMO) convention areas. Using the estimates of Gershman *et al*., the highest number of dFADs are deployed annually in the WCPFC area (36.9% total global deployments), followed by IATTC (23.6%), ICCAT (21.5%) and IOTC (18.0%). The differences between these regions are broadly consistent with differences in the size of purse seine fleets (A. Fonteneau, unpublished data), but also reflect variation in the relative use of dFADs by vessels (i.e. disproportionately high use of dFADs in the Atlantic and Indian Oceans). In term of trends, the number of sets made on dFADs (and other floating objects) has been increasing in all regions with the exception of the WCFPC area, where it has levelled out (Fonteneau *et al*., 2013; Gershman *et al*., 2015; WCPFC, 2015; Hall and Román, 2016).

The number of dFADs in the ocean is also determined by the number that are lost (beached, sunk or stolen but not redeployed) or recovered. This is more difficult to estimate than deployments because most dFADs that become lost (e.g. become waterlogged and sink), do so without trace, and there has been no obligation to record the recovery of dFADs. However, some national dFAD management plans, which are required by all tRFMOs, do require information on lost FADs to be recorded. For example, Spain and Korea require that the last location of the dFAD is recorded, and France requires that the number of lost dFADs is reported quarterly.[8]

a. What factors determine how many dFADs may beach?

The chance that any given dFAD will become beached, assuming for the moment it will not be recovered or sink, depends on the ocean region, the time and location of its deployment, and to a lesser extent, the depth of its subsurface structure and the material it is made from.

[8] http://iotc.org/documents/fad-management-plans

The pattern of ocean currents in some regions may moderate the risk of a dFAD beaching. The direction and speed of movement of a dFAD on the ocean surface is driven primarily by surface currents, but also by wind and wave action. The density of dFADs in an ocean region is therefore not uniform, and dFADs tend to accumulate along current fronts and in circulation systems (Dagorn *et al*., 2013; Maufroy *et al*., 2015). In ocean regions where these currents systems are strong, such as in northwest Indian Ocean, dFADs tend to get trapped inside ocean gyres and away from coastline and islands. This may reduce the risk of beaching to a certain extent if dFADs are lost or recovered while in these contained systems. However, such retention within current systems is usually only temporary, and many dFADs do eventually drift away and may disperse widely (e.g. see Maufroy *et al*., 2015)

The chance of a beaching event is likely to be considerably higher when a dFAD is deployed into a current system that passes through an island archipelago or along a coastline. For example, in the eastern Pacific Ocean fishers deploy dFADs to the east of the Galapagos into a westerly current that carries them directly through archipelago (Hall and Román, 2016), where they risk beaching as they pass close to shore and over shallow marine habitats.

b. Case study: simulated dFAD beaching events in the Indian Ocean

Here we present a case study to illustrate the discussion on dFAD beaching risk by examining the spatio-temporal dynamics of dFAD dispersal in the Indian Ocean and estimating the probability of dFAD beaching events on coral reefs in the region. The methods and results of this case stud analysis are presented below.

i. Material and methods

We used a Lagrangian transport model to simulate trajectories of dFADs deployed within the purse seine fishing grounds of the western Indian Ocean during 2006-2014 in order to evaluate the risk of beaching events on coral reefs. Ichthyop[9] is a Lagrangian tool distributed as a free Java software and offline simulations are conducted using surface currents available from hydrodynamic models or satellite remote sensing (Lett *et al*., 2008). In the present study, all simulations of dFAD drift were run using the Ocean Surface Currents Analyses Realtime (OSCAR) current data set accessible through OpenDAP protocol.[10] We used the 1/3-degree grid and 5-day interval resolution of the OSCAR data which have been shown to well describe the drift of FADs in near-surface currents of the Indian Ocean (Imzilen *et al*., submitted).

The dFAD purse seine fishery of the Indian Ocean is marked by a strong seasonality related to monsoon regimes (Davies *et al*., 2014; Kaplan *et al*., 2014). Areas of GPS buoy deployments have been shown to be highly correlated in time with FAD fishing grounds (Maufroy *et al*., 2017). Here, four distinct periods of GPS buoy deployments were considered to encompass the main patterns of seasonality of dFAD deployments at sea: (i) November-February, (ii) March-May, (iii) June-July and (iv) August-October (Maufroy *et al*., 2017). A buffer area of 200 km around the hotspots of dFAD deployment activities was used to introduce some spatial variability in the location of deployment within each season (**Figure 1**).

A set of 10 GPS buoy deployments was randomly selected among all deployments of French-owned GPS buoys observed within each season-specific buffer area during 2006-2014 (Maufroy *et al*., 2017). Selecting real deployments as starting points of the simulations allowed for assessment of the overall consistency of the simulations by overlaying observed dFAD trajectories with simulated drifts. The simulated duration of drift was set at 180 days since the great majority of dFADs have been shown to spend less than 100 days at sea in the Indian Ocean (Maufroy *et al*., 2015). For each of the 40 deployments (10 deployments x 4 seasons), 1000 simulations were conducted to account for uncertainties in ocean surface currents derived from OSCAR. Stochasticity in model runs was introduced through the means of horizontal dispersion implemented in Ichthyop through a horizontal diffusion coefficient (Peliz *et al*., 2007; Lett *et al*., 2008). All simulation results are provided for each season in **Appendix I**.

[9] http://www.ichthyop.org
[10] http://www.oscar.noaa.gov

To illustrate the utility of the approach, the probability of dFAD beaching and stranding in western Indian Ocean coral reefs was computed as the proportion of simulated trajectories intersecting with the coral reefs of BIOT, Comoros, Maldives, and Seychelles. Shapefiles for these coral reefs were obtained from the UNEP World Conservation Monitoring Centre.[11] Estimates should be seen as conservative as model simulations assumed that no sinking nor retrieval of the dFAD occurred during the period of drift. Also, dFAD transport was simulated all along the period even in the case of a beaching or stranding event, potentially resulting in a dFAD being beached or stranded several times in the course of the simulation.

ii. Results

Our simulations show that risk and location of dFAD beaching events are strongly dependent on areas and periods of deployment. Risks of beaching estimated as the proportion of six-month duration simulations intersecting with coral reef coverage of BIOT, Comoros, Maldives, and Seychelles are overall high (overall mean of 32.3%), with a large variability between seasons and simulations. Seychelles' coral reefs appear particularly exposed to dFAD beaching because of their prominent position within the main fishing grounds of the purse seine fleet. Simulations spanning six months result in a large variability of trajectories and final positions of dFADs (**Figure S1**). Horizontal dispersion modelled in Ichthyop resulted in some dFADs - deployed on the same day at the same position - to be transported along different currents and described by trajectories that diverged over time.

Overall, our simulations of dFAD dispersal are consistent with trajectories of floating objects observed from GPS buoy data (**Figure S1**). A few simulations however appear not able to capture the drift observed, e.g. simulation 19 which corresponds to a buoy deployed in April 2014 that drifted to the north of the western Indian Ocean before reaching the coast of Yemen (**Figure S1b**). Similarly, all runs of simulation 38 suggest a potential drift along the coasts of Somalia and Oman while the buoy deployed at the starting point of this simulation in October 2012 crossed the Indian Ocean and stopped emitting after having reached the north of Sumatra (**Figure S1d**).

Simulations show that most dFADs deployed around the Seychelles in November-February tend to drift toward the eastern Indian Ocean along the South Equatorial Countercurrent, which predominates during the winter monsoon (**Figure S1a**) (Schott *et al*., 2009). In such case, dFADs appear to slip along between the Maldives and BIOT coral reefs and the overall proportion of trajectories intersecting with these coral reef areas was estimated to be low at around 4.7%. Some simulations, however, resulted in higher probability of beaching, i.e. simulation 3 resulting in 18.7% probability of beaching in the Maldives and simulation 6 resulting in 14.2% probability of beaching in BIOT (**Figure S1a**). During March-May, simulated deployments of dFADs around the Seychelles resulted in the floating objects to first drift toward the east before making a loop south and start drifting toward the north of the Mozambique Channel (**Figure S1b**). In March-May, the probability of dFAD beaching in the coral reefs of BIOT and Maldives was estimated to be very low at 0.4%. By contrast, coral reefs of the Seychelles and Comoros were the most exposed during this deployment season with an overall probability of beaching of 45%. Most simulations conducted for the season June-July showed a concentration of the drifts in the central western part of the WIO, along the coasts of Tanzania, Kenya and Mozambique, associated with a risk of beaching of about 10%, mostly in Seychelles coral reefs. Finally, deployments of dFADs off the coast of Somalia during August-October was associated with a high risk of beaching in the Maldives (overall probability of 29%) in relation with the Great Whirl gyre, which is active during the summer monsoon (Schott *et al*. 2009). It is noteworthy that the lifespan of buoys and dFADs during August-October in the Somalia area is low (mean = 15 days at sea) as it is the main dFAD fishing season characterized by a high turnover of the rafts and buoys which can be collected and redeployed elsewhere.

Our results must be seen as part of a modelling exercise and a first step to propose tools for predicting risk associated with time-areas of dFAD deployment. In particular, areas of particle release (i.e. deployments) were limited in this case study to small areas derived from the analysis of GPS buoys for only one segment of the purse seine fishing fleet of the Indian Ocean. Support vessels have been shown to deploy dFADs in areas outside fishing grounds so as to anticipate their drift expected to last from a few weeks to a few months to aggregate tuna (Assan *et al*., 2015). Information on periods and areas of dFAD deployments for the whole fishery (including supply vessels) is crucial to study the dynamics of dFADs at

[11] http://data.unep-wcmc.org/datasets/1

ocean scale. Also, an arbitrary choice of 10 distinct positions of deployment and 1000 simulations accounting for horizontal dispersion was made for each season while this may have a strong impact on our results. Future work will focus on optimizing the simulation scenarios to assess the robustness of the results to such parameters. Considering currents of higher resolution available from oceanographic models might be required, particularly in areas such as the Mozambique Channel characterized by complex mesoscale and sub-mesoscale oceanographic features (Hancke *et al*., 2014). Finally, the use of climatology of ocean currents (i.e. mean over several years) should be considered for predictions to reduce annual variability and uncertainties associated with global products such as OSCAR.

3 Potential environmental impacts of beached dFADs

The beaching of dFADs has the potential to cause physical impacts to marine habitats, although these are not well documented. There is also a question of whether dFADs, which are primarily constructed from non-biodegradable materials, constitute marine pollution. These two separate issues are explored below.

a. Physical impacts of dFAD beaching to marine habitats

To date, research on the environmental impact of dFADs has primarily focused on either the consequences of an increased capture of juvenile tunas (Dagorn *et al*., 2013; Fonteneau *et al*., 2015) or the entanglement of pelagic species within the dFAD structure (Filmalter *et al*., 2013; Blasi *et al*., 2016). While the impact of this beaching is not well documented or understood, analogous studies on other abandoned, lost, or otherwise discarded fishing gear (ALDFG) could highlight the likely impacts caused by beached dFADs.

Old fishing nets are a common material used in dFAD construction and previous studies have shown ALDFG nets to entangle significant numbers of animals, a process termed 'ghost-fishing' (Laist, 1997; Stelfox *et al*., 2016). As ALDFG nets age, catch rates have been shown to decline (Revill and Dunlin, 2003; Tschernij and Larsson, 2003), possibly due to bio-fouling making nets more visible (Revill and Dunlin, 2003) or because bio-foul eventually weighs nets down, causing them to lose vertical height and come to rest on the sea floor where they have little to no fishing ability (Baeta *et al*., 2009). However, this is likely to be variable by habitat. For example, nets in shallow sandy bottom habitats may follow this pattern, yet nets caught on rocky bottoms, structures, or reefs could tear and form larger holes for larger animals to become entangled thus altering the catch selectivity of the net (Stelfox *et al*., 2016). In addition, ALDFG material may get colonised by smaller animals looking for food and shelter, which in turn could attract larger predators that may become entangled, potentially prolonging the fishing effect (Carr, 1987). Ghost fishing may be particularly damaging if it occurs in important foraging, spawning and nesting grounds, or if it intercepts migration routes (Gilman *et al*., 2010).

The design and nature of dFADs is widely variable but usually consist of sub-surface aggregating material made of old fishing nets tethered to a floating surface frame. Where nets are used, it is likely that monofilament nets are likely to have greater ghost fishing capacity. This is due to the higher visibility of the multifilament nets (Ayaz *et al*., 2006). Driven by concerns over shark and turtle entanglement within these nets, there has been a move towards changing dFAD designs to reduce entanglement (for details see MRAG, 2017). These consist of using smaller mesh sizes and replacing the sub-surface net curtains with rolled net 'sausages' (Franco *et al*., 2009; Balderson and Martin, 2015). However, these 'sausages' have been shown to unravel, questioning their efficacy at reducing entanglement rates. In addition, 'sausage' nets do not prevent the entanglement of corals, although dFADs built with synthetic rope appear to be less likely to become entangled (Balderson & Martin 2015). These factors have led to organisations, such as the International Seafood Sustainability Foundation (ISSF), calling for the term 'non-entangling' dFADs to be reserved for solely for those that contain no netting throughout their construction (ISSF, 2015).

ALDFG has also been shown to degrade benthic habitats (Macfadyen *et al*., 2009), such as coral reefs as nets are prone to snagging on rocks, sponges and corals. Once snagged, the wind and wave forces exerted on the net may break away from the reef, damaging habitat in the process (Donohue *et al*., 2001). Fishing gear is then free to snag on another coral and thus the process repeats itself. Depending on the species and size of coral colonies, it may take long periods for the reef to recover from intense physical trauma as corals grow between 0.4-1.5 cm per year for massive species and up to 20 cm per year for branching species (e.g. Crabbe and Smith, 2005). Recovery from other physical traumas have been estimated at between five and ten years to recover from blast fishing (Fox and Caldwell, 2006), or ten (Connell, 1997) to 40-70 years (Dollar and Tribble, 1993) to recover from storm damage. In some cases, recovery can then follow a different trajectory and the reef becomes an altered community (Hughes *et al*., 2005). It is difficult to ascertain the impact of nets on other habitats, such as seagrasses, as few have studied the impact of ALDFG. However, seagrass growth is known to be very slow, 0.4-7.4 cm per year (Boudouresque and Jeudy de Grissac, 1983), and previous studies have shown that seagrass communities take can between 1.4-9.5 years to recover from mechanical scarring from boats (Kenworthy *et al*., 2002).

However, the impact of ALDFG is not restricted to the sub-tidal zone. If the ALDFG is not caught within an ocean gyre or caught on the benthos, then it will most likely come to rest along coastal beaches and shorelines. In some areas, ALDFG can account for more than half of the litter found on beaches (Hong *et al*., 2014). Beached litter can have both economic and ecological consequences. For example, beach litter may reduce a beach's aesthetic appeal to tourists and possibly reduce visitor numbers. Alternatively, litter can form a significant proportion of sea-bird nest building material (Schernewski *et al*., 2017; Votier *et al*., 2011) and can negatively affect turtle hatchlings trying to reach the sea (Özdilek *et al*., 2006).

b. Are dFADs categorised as marine pollution?

Most dFADs are constructed from non-biodegradable materials, including nylon, polyethylene, metal, plastics and electronic components (**Figure 3**). These materials typically degrade very slowly, often only break up into smaller pieces through mechanical action, and have the potential to pollute the marine environment. Synthetic materials such as these can then enter food-webs through ingestion by plankton (Setälä *et al*., 2014), turtles (Schuyler *et al*., 2012) and corals (Hall *et al*., 2015), potential severely inhibiting animal fitness (Wright *et al*., 2013). In addition to this chemical pollution, ALDFGs also have the potential to biologically pollute ecosystems through the transportation of invasive species which can disrupt community structure and cause local extirpations of native species (Derraik, 2002; Macfadyen *et al*., 2009).

There is no clear consensus on whether dFADs breach international laws on marine pollution as it is difficult to define when it has become ALFDG. If a dFAD was deliberately discarded this would likely violate MARPOL Annex V, and would also likely contravene the London Convention, although the question of intentional discarding is complex and difficult to resolve. For instance, should a dFAD be considered as abandoned when it is no longer being used by a fisher? If so, at what point might that be, given that dFADs may be disregarded temporarily when they leave fishing grounds but tracked once again when they drift back in? Or, if a dFAD is considered as abandoned when its GPS buoy is detached, how should a dFAD deployed without a GPS buoy be classified? The definition is complicated further still by the frequent 'stealing' of dFADs at sea, when the GPS buoy belonging to one vessel is removed and replaced with another from the new vessel. Does the dFAD itself also change ownership, from a legal perspective?

Clearly the use of dFADs is subjective and the issue of abandonment is open to interpretation. In 2013, IOTC did not adopt a resolution proposed by EU-France to prohibit the abandonment of dFADs, presumably due in part to these uncertainties, and instead agreed that measures should be included in dFAD management plans of individual members. The issue of marine pollution is not a priority of tRFMOs, and indeed may be argued to fall outside the scope of international fisheries management, and consequently these questions may only be properly addressed when a legal case is brought against fishing companies.

4 Possible options for reducing dFAD beaching events

There are a number of possible ways to reduce the number of dFAD beaching events on sensitive marine habitats. This includes 1) regulatory measures, which would be applied by the tRFMOs or coastal and island state governments; 2) advances in dFAD design, which would likely come from collaboration between fishing companies, researchers and NGOs/non-profit partnerships; and 3) economic and market incentives, including penalties, which would be responded to by fishing companies and/or fishers. In this paper we focus only on regulatory measures and advances in dFAD design, although we encourage further discussion on the range of possible economic and market incentives (e.g. 'FAD-free' tuna produce) that could lead to a reduction in dFAD use. There may also be ways to minimise the severity of the impacts caused by a beached dFAD, such as using materials that cause minimal abrasion or that break apart easily. This may be an interesting avenue for research, with possible overlaps with current efforts to develop biodegradable dFADs, although is not discussed further here.

a. Fewer dFADs in the water

Fewer dFADs deployed and at liberty in the oceans would, following the law of averages, reduce the frequency of beaching events. This could be a reduction in dFAD numbers overall, or a localised reduction in dFAD deployments in areas with the highest risk of beaching events occurring.

i. Overall reduction in dFAD numbers

The concept of limits imposed by tRFMOs on the use of dFADs or on the capacity of purse seine fleets has been the subject of wider discussions on the sustainability of tropical tuna fisheries (Davies *et al*., 2014; Fonteneau *et al*., 2015; MRAG, 2017). We do not attempt to reproduce these discussions here, but pick out a number of possible management measures that would in theory reduce the number of dFADs in the ocean. We also note that, to date, three tRFMOs have implemented limits on dFAD use, either on the number of GPS buoys that can be actively monitored (IOTC and ICCAT) or the number of sets made on dFADs (WCPFC); however, none of these limits directly place a cap on the number of dFADs that can be deployed.

Deployment limits

Setting a limit on the number of dFADs that can be deployed per vessel in a given period (e.g. year, month) would directly restrict the number of dFADs entering in the oceans. Compliance with such a measure would require monitoring by observers, either on board or using an electronic monitoring system (EMS). Alternatively, dFAD deployments could be monitored by contracting parties and non-contracting parties (CPCs) or tRFMOs directly using data provided by satellite tracking companies. However, to ensure accurate accounting, any deployment limit monitored remotely in this way would need to be accompanied by the additional requirement that all dFADs are deployed with an activated GPS buoy. Again, compliance with this would need to be carefully monitored by fishery observers.

A challenge to this system, at least from the perspective of some fleet owners, is if and how to allow for replacement of dFADs that are lost at sea. Maintaining a predetermined maximum number of dFADs in the ocean would require a coordinated monitoring and accounting system along the lines of that described above, i.e. every dFAD is deployed with a GPS buoy, and, when the a vessel's deployment limit is reached, a replacement dFAD can be deployed only when it can be proven from tracking data that a previously deployed dFAD has been lost. This could be administered by fishing companies, but would require agreement within tRFMOs on when a dFAD is considered as lost and the protocol to establish this from GPS data. There would also need to be agreed standards for reporting initial and replacement dFAD deployments to allow for the monitoring of compliance.

Fees on FAD ownership

An alternative mechanism to reducing the total number of dFADs in use might be to introduce a fee on the deployment of dFADs beyond a pre-determined number set by the tRFMO. For instance, a vessel might be allowed to deploy 150 dFADs free of charge, but pay a fee for each additional dFAD deployed above this limit, possibly on an increasing sliding scale. This would raise the difficult question of how many dFADs should vessels be allowed to deploy for free, with fleet owners adopting a high-dFAD strategy presumably arguing for a higher limit than those with a more free school targeted strategy. The same challenges with respect to monitoring compliance and allowing for replacement dFADs would apply as described above for deployment limits.

A pay-per-dFAD model could in theory create an economic incentive against the proliferation of dFADs, or at least would encourage fishing companies to investigate the concept of an economically optimal number of dFADs for their operations. The revenue generated from deployment fees might also be used by tRFMOs to pay for dFAD recovery measures (see Section 0). However, such an incentive based approach may not significantly limit or reduce dFAD use if fishing companies determine that deploying additional dFAD is worth the cost.

Reduction in fleet capacity

In some regions, a reduction in the capacity of purse seine fleets – either through the number of vessels or their size – may result in an overall reduction in the use of dFADs. This is based on the observation that the use of dFADs has increased against a background of increasing fleet capacity, and that larger vessels are more dependent on high dFAD-use strategies (Davies *et al*., 2014). Similarly, a reduction in dFAD use may be achieved through a reduction in the number of supply vessels, which typically allow seiners to deploy and monitor a larger number of dFADs. However, this approach would only be effective assuming a linear relationship between the deployment of dFADs and the capacity of the fleet (or the number of supply vessels). While this has appears to be true for growth in dFAD use to date, at least in the Indian Ocean (Davies *et al*., 2014), there is a possibility that a shrinking fleet would attempt to deploy a greater number of dFADs per vessel in an attempt to maintain the number of dFADs in the water.

i. Localised reduction in dFAD deployments

Prohibiting the deployment of dFADs in certain zones and/or at certain times of the year may result in a disproportionate reduction in dFAD beaching events. This localised measure would not aim to reduce the overall number of dFADs deployed, but rather to prevent the practice (intentional or not) of deploying dFADs into areas that, due to the prevailing current systems, have a high probability of beaching on islands or coastlines. This would likely require agreement within tRFMOs on what is considered as 'high' probability (e.g. >50%, >90%). Proposed zones and time periods to prohibit dFAD deployment could be identified by analysing historical dFAD GPS tracks, or using simulation modelling that takes into account variability in oceanographic processes (see Section 0). It is likely that proposals for dFAD no-deployment zones would be submitted by coastal and island states that wish to reduce dFAD beaching events in their waters, although there may also be some interest from fishing companies that are seeking to reduce the risk of losing their dFADs and mitigate the environmental impacts of their operations (e.g. to achieve environmental certification standards).

b. Reduced lifetime of dFADs

There are currently initiatives aimed developing dFADs constructed using entirely biodegradable materials (e.g. Moreno *et al*., 2016). The purpose of these initiatives is ostensibly to avoid pollution when dFADs sink or wash up in coastal areas, but biodegradable dFADs would also be expected to break apart at sea more quickly than conventional dFAD designs and therefore reduce the overall risk of beaching events occurring. However, precisely how quickly biodegradable dFADs break apart, and to what extent this will reduce the rate of beaching events, it not known and will likely depend on the materials used, the location of deployment and the ocean region. The effective working life of a dFAD is a key question in developing biodegradable designs, with fishers generally requiring a lifetime of between 5 and 12 months depending on the ocean region (Moreno *et al*., 2016). With that in mind, this initiative would appear to be most relevant for those dFADs that drift for many months outside the main the fishing grounds (or the deployment locations that result in these trajectories).

c. Prevent dFADs entering sensitive areas

The most targeted approach to reducing the frequency of dFAD beaching events is to prevent dFADs from entering sensitive coastal areas. However, achieving this may also require particularly high investment of resources (by fishing companies, primarily) or innovative dFAD design concepts. Two possible initiatives are described below.

i. Recovery at sea

It may be possible for dFADs to be intercepted and recovered on board before they drift into coastal areas. This would be possible by real-time monitoring GPS buoy tracking data and establishing an alert system to warn of likely beaching events. The effectiveness of any such recovery initiative would likely require additional regulation on dFAD use, namely that the entire dFADs must be recovered from the water (i.e. both the GPS buoy and the raft component) and also the prohibition of GPS buoy deactivation until the dFAD is recovered. Together these measures would ensure that no dFAD structures are left in the water, and that compliance can be monitored using GPS buoy tracking data.

There are likely to be considerable practical challenges and limitations associated with this solution, including travel distances required to intercept dFADs, which types of vessel can undertake dFAD recoveries (e.g. must be equipped with crane for extraction from the water), and possibly the availability of space on board to store recovered dFADs. Realistically, fishing companies may choose to deploy specialist recovery vessels that could intercept 'rouge' dFADs, rather than task seiners or supply vessels to do this, which would likely be disruptive to fishing operations. These vessels may traverse whole ocean regions, or more likely, be based within one or more EEZs.

The geographic scope of at sea recoveries is likely to be determined by whether dFAD recovery is required by tRFMO conservation and management measures (CMMs), or established through bilateral agreements between fishing companies and individual coastal states. For the former, all potential beaching events in all areas would need to be avoided, which would present the greatest logistical challenge for fishing companies (even if a CMM specified avoidance of beaching events on sensitive habitats only). For the latter, only beaching events in certain locations would need to be avoided, and fishing companies are perhaps more likely to base recovery vessels in those countries with which they have agreements (although this may not be possible in some remote areas).

ii. Recovery post-beaching

The environmental impact of dFAD beaching could be minimised by recovering dFADs that have become entangled on habitat as swiftly as possible. One such inshore recovery initiative has been launched in the Seychelles, where a part of the purse seine industry has engaged with several Seychelles-based organisations[12] to develop a 'FAD Watch' initiative for reporting and retrieving dFADs that are approaching coral habitats and have, or are likely to become, beached. The system works on a proximity alert system, with a local organisation sent the position of a GPS buoy by the tracking service provider when it enters a buffer zone around a coral reef. In theory, the dFAD is then intercepted and recovered, and brought back to land for recycling. However, in reality there have been a number of challenges in accessing remote areas, locating dFADs in the water and safely disentangling netting caught on deeper habitat (e.g. requiring diving) (Island Conservation Society, pers. comm.).

While the intention of inshore recovery initiatives may be sound, there are questions on the effectiveness of this approach in minimising environmental impact, and whether locally-run initiatives can function in all areas. The majority of the environmental damage caused by dFAD netting and rafts to sensitive habitat may occur relatively quickly, for instance within hours or days, giving only a short window of opportunity make a meaningful recovery. However, more knowledge is needed on the timeline and severity of damage to different habitat features (e.g. reef, seagrass, mangroves), and subsequent recovery rates, to better determine what an appropriate recovery response time should be. More generally, at a regional and global level, inshore recovery initiatives are likely to be very limited in their geographic scope, as in many areas it may be difficult or impossible to recover beached dFADs due to an absence of local partners, lack of human resources or equipment and/or limitations on access.

[12] OPAGAC has entered into an agreement with the Island Conservation Society (ICS), Islands Development Company Ltd (IDC) and Seychelles Fishing Authority (SFA).

iii. FAD design

These has been some experiment with dFADs constructed with deep subsurface structures (e.g. >70m), which have been shown to drift with deeper currents that do not intersect coastal (D. Itano, pers. comm.). This passive method of dFAD self-avoidance may be relatively cheap to adopt, although there may be issues with storage space on board. However, there may be unintended fishing mortality and stock management consequences associated with deeper nets, e.g. increased catch of deeper-foraging species such as bigeye (WCPFC, 2015). Also, beaching events that do occur may be more severe given there will be a greater amount of subsurface structure to become entangled with habitat.

It may be possible to design self-propelled 'smart dFADs' that are able to actively avoid shorelines and shallow atolls. These could be remote-controlled or autonomous, for example following a pre-determined course or programed with a 'coastline avoidance' protocol. There are clear design challenges associated with this concept, although it is likely that much of the hardware and technology required does already exist (e.g. propulsion devices[13], satellite communication, autonomous programing). It is also very likely that smart dFADs would have a much higher unit costs than conventional (and even biodegradable) dFADs. This increased cost would be expected to affect uptake by the purse seine industry, although it would be interesting to explore whether smart dFADs would improve efficiency, for instance by remaining in the most productive zones, and to what extent this might offset the increased unit cost.

5 Acknowledgments

Many of the ideas and examples in this paper emerged from discussions at the Global FAD Science Symposium held in Santa Monica, California, 20th-23rd March 2017. This symposium was held under Chatham House rules and the names of those expressing opinions and ideas is not shared, although the authors are grateful to all of those who participated in the discussions. We also thank ORTHONGEL for routinely providing GPS buoy data for the French purse seine fishing fleet to IRD. We are grateful to Alexandra Maufroy and Laurent Floch for assistance with FAD data and Christophe Lett for fruitful discussions on the use of Ichthyop. The OSCAR plug-in of Ichthyop was developed by Philippe Verley through a grant of the IRD Observatoire Thonier (FIER-OT project).

6 References

Assan, C., Lucas, J., Augustin, E., Delgado de Molina, A., Maufroy, A., Chassot, E., 2015. Seychelles auxillary vessels in support of purse seine fishing in the Indian Ocean during 2005-2010: summary of a dacade of monitoring (No. IOTC-2015-WPTT17-41 Rev_1). Indian Ocean Tuna Commission, Victoria, Seychelles.

Ayaz, A., Acarli, D., Altinagac, U., Ozekinci, U., Kara, A., Ozen, O., 2006. Ghost fishing by monofilament and multifilament gillnets in Izmir Bay, Turkey. Fish. Res. 79, 267–271. doi:10.1016/j.fishres.2006.03.029.

Baeta, F., Costa, M.J., Cabral, H., 2009. Trammel nets' ghost fishing off the Portuguese central coast. Fish. Res. 98, 33–39. doi:10.1016/j.fishres.2009.03.009.

Balderson, S., Martin, L., 2015. Environmental impacts and causation of "beached" Drifting Fish Aggregating Devices around Seychelles Islands: a preliminary report on data collected by Island Conservation Society (No. IOTC–2015–WPEB11–39 1). Island Conservation Society, Mahe, Seychelles.

Blasi, M.F., Roscioni, F., Mattei, D., 2016. Interaction of Loggerhead Turtles (*Caretta caretta*) with Traditional Fish Aggregating Devices (FADs) in the Mediterranean Sea. Herpetol. Conserv. Biol. 11, 386–401.

Boudouresque, C., Jeudy de Grissac, A., 1983. L'herbier à Posidonia oceanica en Méditerranée: les interactions entre la plante et le sédiment. J. Rech. Océan. 8, 99–122.

Carr, A., 1987. Impact of nondegradable marine debris on the ecology and survival outlook of sea turtles. Mar. Pollut. Bull. 18, 352–356. doi:10.1016/S0025-326X(87)80025-5.

[13] For example, Wave Glider: https://www.liquid-robotics.com/platform/how-it-works/

Connell, J.H., 1997. Disturbance and recovery of coral assemblages. Coral Reefs 16, S101–S113. doi:10.1007/s003380050246.
Crabbe, M.J.C., Smith, D.J., 2005. Sediment impacts on growth rates of Acropora and Porites corals from fringing reefs of Sulawesi, Indonesia. Coral Reefs 24, 437–441. doi:10.1007/s00338-005-0004-6.
Dagorn, L., Bez, N., Fauvel, T., Walker, E., 2013. How much do fish aggregating devices (FADs) modify the floating object environment in the ocean? Fish. Oceanogr. 22, 147–153.
Davies, T.K., Mees, C.C., Milner-Gulland, E.J., 2014. The past, present and future use of drifting fish aggregating devices (FADs) in the Indian Ocean. Mar. Policy 45, 163–170.
Derraik, J.G., 2002. The pollution of the marine environment by plastic debris: a review. Mar. Pollut. Bull. 44, 842–852.
Dollar, S.J., Tribble, G.W., 1993. Recurrent storm disturbance and recovery: a long-term study of coral communities in Hawaii. Coral Reefs 12, 223–233. doi:10.1007/BF00334481.
Donohue, M.J., Boland, R.C., Sramek, C.M., Antonelis, G.A., 2001. Derelict fishing gear in the Northwestern Hawaiian Islands: diving surveys and debris removal in 1999 confirm threat to coral reef ecosystems. Mar. Pollut. Bull. 42, 1301–1312.
Filmalter, J.D., Capello, M., Deneubourg, J.-L., Cowley, P.D., Dagorn, L., 2013. Looking behind the curtain: quantifying massive shark mortality in fish aggregating devices. Front. Ecol. Environ. 11, 291–296. doi:10.1890/130045.
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. Aquat. Living Resour. 26, 37–48.
Fonteneau, A., Chassot, E., Gaertner, D., 2015. Managing tropical tuna purse seine fisheries through limiting the number of drifting fish aggregating devices in the Atlantic: food for thought. Collect Vol Sci Pap ICCAT 71, 460–475.
Fox, H.E., Caldwell, R.L., 2006. Recovery from blast fishing on coral reefs: A tale of two scales. Ecol. Appl. 16, 1631–1635. doi:10.1890/1051-0761(2006)016[1631:RFBFOC]2.0.CO;2.
Franco, J., Dagorn, L., Sancristobal, I., Moreno, G., 2009. Design of ecological FADs, IOTC-2009-WPEB-16. Indian Ocean Tuna Commission, Victoria, Seychelles.
Gershman, D., Nickson, A., O'Toole, M., 2015. Estimating the use of FADs around the world: an updated analysis of the number of fish aggregating devices deployed in the ocean. Pew Charitable Trusts, Philadelphia, USA.
Gilman, E., Gearhart, J., Price, B., Eckert, S., Milliken, H., Wang, J., Swimmer, Y., Shiode, D., Abe, O., Hoyt Peckham, S., others, 2010. Mitigating sea turtle by-catch in coastal passive net fisheries. Fish Fish. 11, 57–88.
Guillotreau, P., Salladarré, F., Dewals, P., Dagorn, L., 2011. Fishing tuna around Fish Aggregating Devices (FADs) vs free swimming schools: Skipper decision and other determining factors. Fish. Res. 109, 234–242. doi:10.1016/j.fishres.2011.02.007.
Hall, M., Román, M., 2016. The fishery on fish aggregating devices (FADs) in the Eastern Pacific Ocean - update (No. Document SAC-07-03e). Inter-American Tropical Tuna Commission.
Hall, N.M., Berry, K.L.E., Rintoul, L., Hoogenboom, M.O., 2015. Microplastic ingestion by scleractinian corals. Mar. Biol. 162, 725–732. doi:10.1007/s00227-015-2619-7.
Hancke, L., Roberts, M.J., Ternon, J.-F., 2014. Surface drifter trajectories highlight flow pathways in the Mozambique Channel. Deep Sea Res. Part II Top. Stud. Oceanogr. 100, 27–37.
Hong, S., Lee, J., Kang, D., Choi, H.W., Ko, S.H., 2014. Quantities, composition, and sources of beach debris in Korea from the results of nationwide monitoring. Mar. Pollut. Bull. 84, 27–34. doi:10.1016/j.marpolbul.2014.05.051.
Hughes, T.P., Bellwood, D.R., Folke, C., Steneck, R.S., Wilson, J., 2005. New paradigms for supporting the resilience of marine ecosystems. Trends Ecol. Evol. 20, 381–386. doi:10.1016/j.tree.2005.03.022.
Imzilen, T., Barde, J., Chassot, E., Demarcq, H., Maufroy, A., Rao-Pascuali, L., Ternon, J.-F., Lett, C., submitted. Fish aggregating devices drift like oceanographic drifters in near-surface currents of the Indian Ocean. Prog. Oceanogr.
ISSF, 2015. ISSF Guide for Non-Entangling FADs. International Seafood Sustainability Foundation, Washington D.C., USA.
Kaplan, D.M., Chassot, E., Amandé, J.M., Dueri, S., Demarcq, H., Dagorn, L., Fonteneau, A., 2014. Spatial management of Indian Ocean tropical tuna fisheries: potential and perspectives. ICES J. Mar. Sci. J. Cons. 71, 1728–1749.

Kenworthy, W., Fonseca, M.S., Whitfield, P.E., Hammerstrom, K.K., 2002. Analysis of Seagrass Recovery in Experimental Excavations and Propeller-Scar Disturbances in the Florida Keys National Marine Sanctuary. J. Coast. Res. 37, 75–85.

Laist, D., 1997. Impacts of marine debris: entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records, in: Marine Debris. Springer, New York, USA, pp. 99–139.

Lett, C., Verley, P., Mullon, C., Parada, C., Brochier, T., Penven, P., Blanke, B., 2008. Ichthyop: a Lagrangian tool for modelling ichthyoplankton dynamics. Environ. Model. Softw. 23, 1210–1214. doi:10.1016/j.envsoft.2008.02.005

Macfadyen, G., Huntington, T., Cappell, R., others, 2009. Abandoned, lost or otherwise discarded fishing gear. Food and Agriculture Organization of the United Nations (FAO).

Maufroy, A., Chassot, E., Joo, R., Kaplan, D.M., 2015. Large-Scale Examination of Spatio-Temporal Patterns of Drifting Fish Aggregating Devices (dFADs) from Tropical Tuna Fisheries of the Indian and Atlantic Oceans. PloS One 10, e0128023–e0128023.

Maufroy, A., Kaplan, D.M., Bez, N., Molina, D., Delgado, A., Murua, H., Floch, L., Chassot, E., 2017. Massive increase in the use of drifting Fish Aggregating Devices (dFADs) by tropical tuna purse seine fisheries in the Atlantic and Indian oceans. ICES J. Mar. Sci. 74, 215–225. doi:10.1093/icesjms/fsw175.

Moreno, G., Restrepo, V., Dagorn, L., Hall, M., Murua, J., Sancristobal, I., Grande, M., Le Couls, S., Santiago, J., 2016. Workshop on the Use of Biodegradable Fish Aggregating Devices (FADs) (No. ISSF Technical Report 2016-18A). International Seafood Sustainability Foundation, Washington D.C., USA.

MRAG, 2017. An analysis of the uses, impacts and benefits of fish aggregating devices (FADs) in the global tuna industry (No. A report produced for WWF-UK by MRAG Ltd). MRAG, London, UK.

Özdilek, H.G., Yalçin-Özdilek, Ş,, Ozaner, F.S., Sönmez, B., 2006. Impact of accumulated beach litter on Chelonia mydas L. 1758 (green turtle) hatchlings of the Samandağ coast, Hatay,Turkey. Fresenius Environ. Bull. 15, 95–103.

Peliz, A., Marchesiello, P., Dubert, J., Marta-Almeida, M., Roy, C., Queiroga, H., 2007. A study of crab larvae dispersal on the Western Iberian Shelf: Physical processes. J. Mar. Syst. 68, 215–236. doi:10.1016/j.jmarsys.2006.11.007.

Ramos, M., Delgado de Molina, A., Ariz, J., 2010. Analysis of activity data obtained from supply vessels' logbooks implemented by the Spanish fleet and associated in Indian Ocean (No. IOTC-2010-WPTT-22). Indian Ocean Tuna Commission, Victoria, Seychelles.

Revill, A.S., Dunlin, G., 2003. The fishing capacity of gillnets lost on wrecks and on open ground in UK coastal waters. Fish. Res. 64, 107–113. doi:10.1016/S0165-7836(03)00209-1.

Schernewski, G., Balciunas, A., Gräwe, D., Gräwe, U., Klesse, K., Schulz, M., Wesnigk, S., Fleet, D., Haseler, M., Möllman, N., Werner, S., 2017. Beach macro-litter monitoring on southern Baltic beaches: results, experiences and recommendations. J. Coast. Conserv. 2. doi:10.1007/s11852-016-0489-x.

Schott, F.A., Xie, S.-P., McCreary, J.P., 2009. Indian Ocean circulation and climate variability. Rev. Geophys. 47, RG1002. doi:10.1029/2007RG000245.

Schuyler, Q., Hardesty, B.D., Wilcox, C., Townsend, K., 2012. To eat or not to eat? Debris selectivity by marine turtles. PLoS ONE 7. doi:10.1371/journal.pone.0040884.

Setälä, O., Fleming-Lehtinen, V., Lehtiniemi, M., 2014. Ingestion and transfer of microplastics in the planktonic food web. Environ. Pollut. 185, 77–83. doi:10.1016/j.envpol.2013.10.013.

Stelfox, M., Hudgins, J., Ali, K., Anderson, C., 2015. High mortality of Olive Ridley Turtles (*Lepidochelys olivacea*) in ghost nets in the central Indian Ocean) (No. Technical Report). The Olive Ridley Project, Cheshire, UK.

Stelfox, M., Hudgins, J., Sweet, M., 2016. A review of ghost gear entanglement amongst marine mammals, reptiles and elasmobranchs. Mar. Pollut. Bull. 111, 6–17. doi:10.1016/j.marpolbul.2016.06.034.

Tschernij, V., Larsson, P.O., 2003. Ghost fishing by lost cod gill nets in the Baltic Sea. Fish. Res. 64, 151–162. doi:10.1016/S0165-7836(03)00214-5.

Votier, S.C., Archibald, K., Morgan, G., Morgan, L., 2011. The use of plastic debris as nesting material by a colonial seabird and associated entanglement mortality. Mar. Pollut. Bull. 62, 168–172. doi:10.1016/j.marpolbul.2010.11.009.

WCPFC, 2015. First meeting of the FAD Management Options Intersessional Working Group, Bali, Indonesia, 27 to 28 November 2015.

Wright, S.L., Thompson, R.C., Galloway, T.S., 2013. The physical impacts of microplastics on marine organisms: A review.

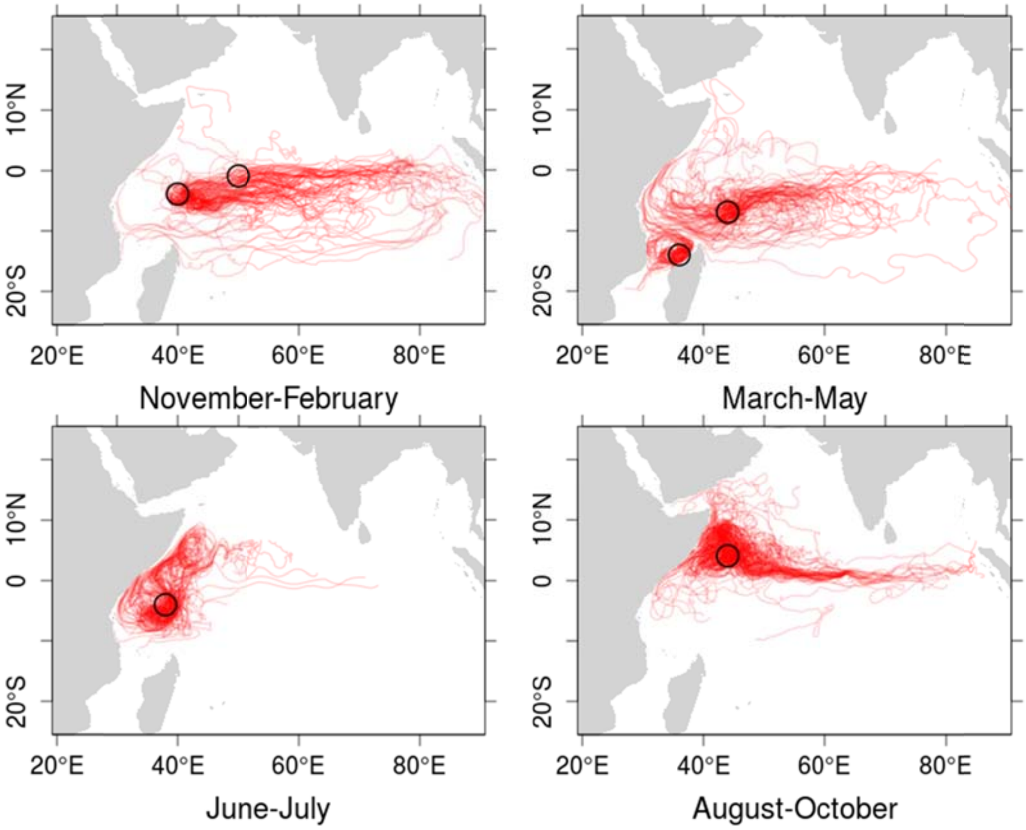


Figure 1. Observed long drifts (≥ 1 month) of floating objects equipped with French-owned GPS buoys and deployed during 2006-2014 within the seasonal hotspots of dFAD deployment activities (black circles) in the western Indian Ocean identified by Maufroy *et al*. (2017).

Figure 2. Examples of dFADs beaching events in British Indian Ocean Territory marine protected area: subsurface netting entangled on coral (left) and washed ashore (right) Photos: D. Curnick/ZSL; T. Franklin/MRAG Ltd.

Figure 3. Examples of different dFAD designs and construction materials used in the Indian and Atlantic Oceans. Materials used on the frame include bamboo (left), plastic tubing (middle) and metal tubing (right). Photos: E. Chassot – IRD; KR-C Kouakou - IRD/ORTHONGEL; Anon – IRD.

Appendix I. Simulations of dFAD dispersal from the main recent seasons and deployment areas of the purse seine fishing fleet operating in the western Indian Ocean.

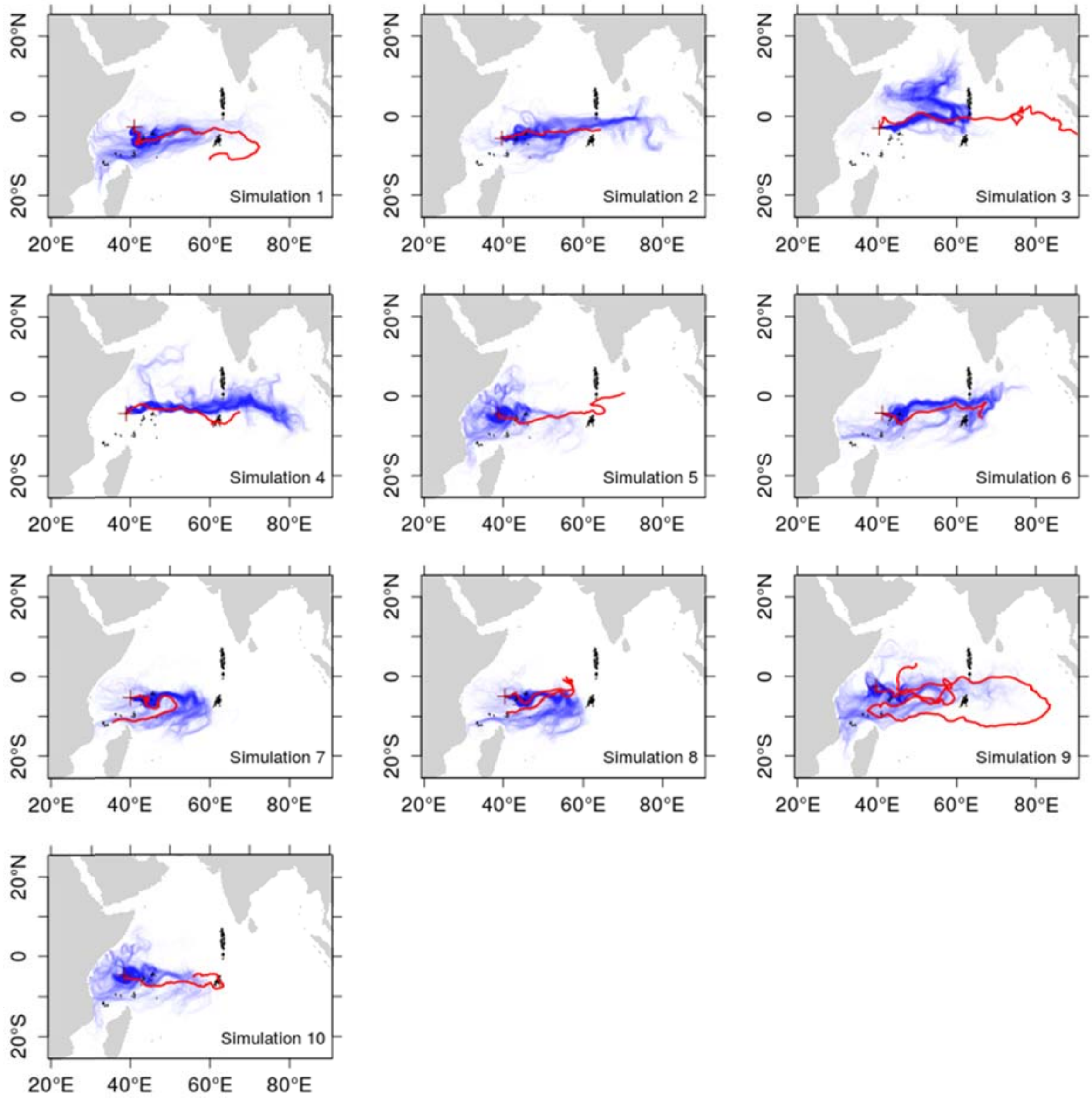


Figure S1a. Simulations of dFAD trajectories (blue lines) from deployment locations (+) in the Indian Ocean in the main deployment area of the season November-February (see text for details). Red lines indicate observed trajectories of dFADs deployed at sea and black areas indicate coral reefs.

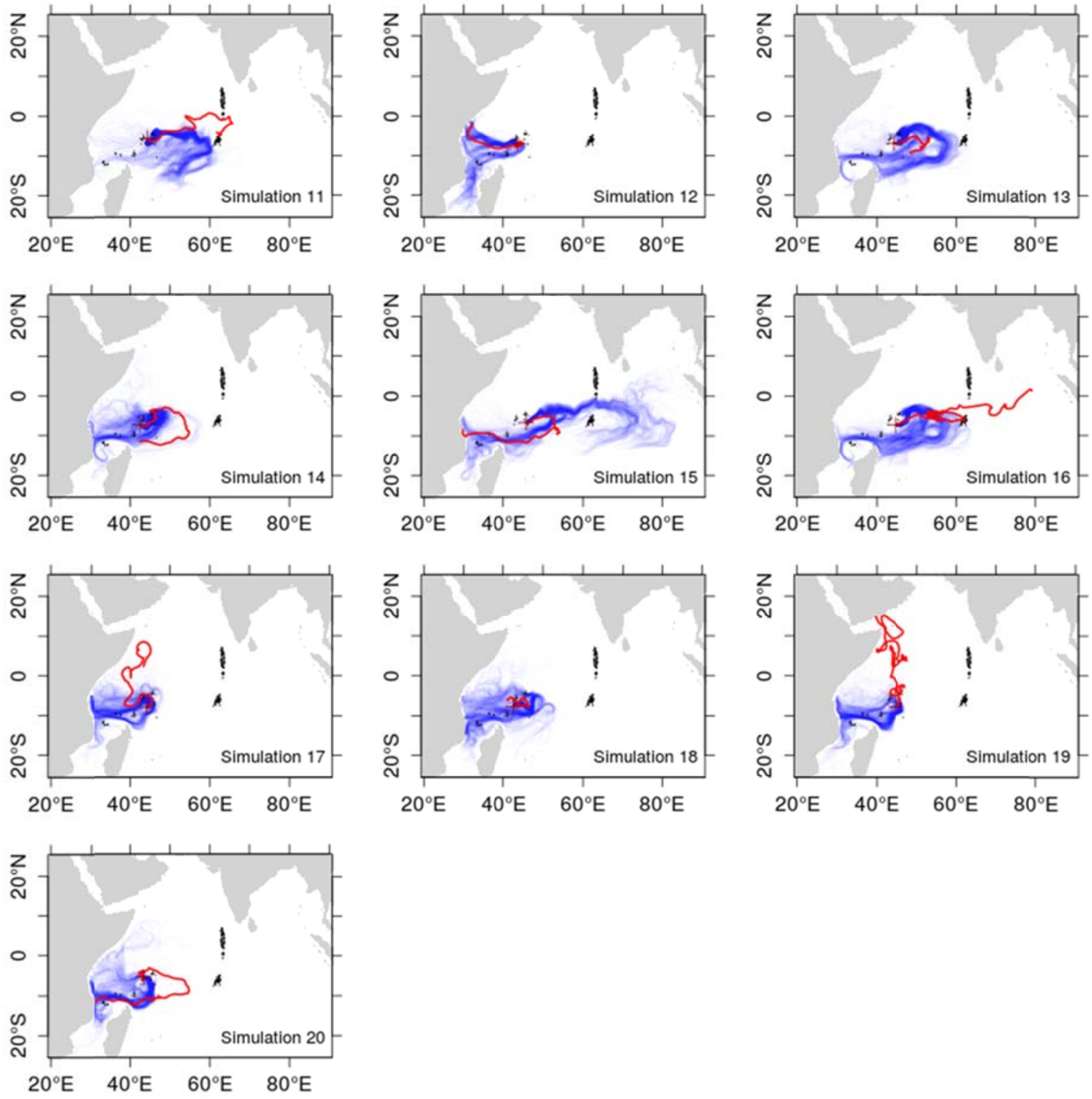


Figure S1b. Simulations of dFAD trajectories (blue lines) from deployment locations (+) in the Indian Ocean in the main deployment area of the season March-May (see text for details). Red lines indicate observed trajectories of dFADs deployed at sea and black areas indicate coral reefs.

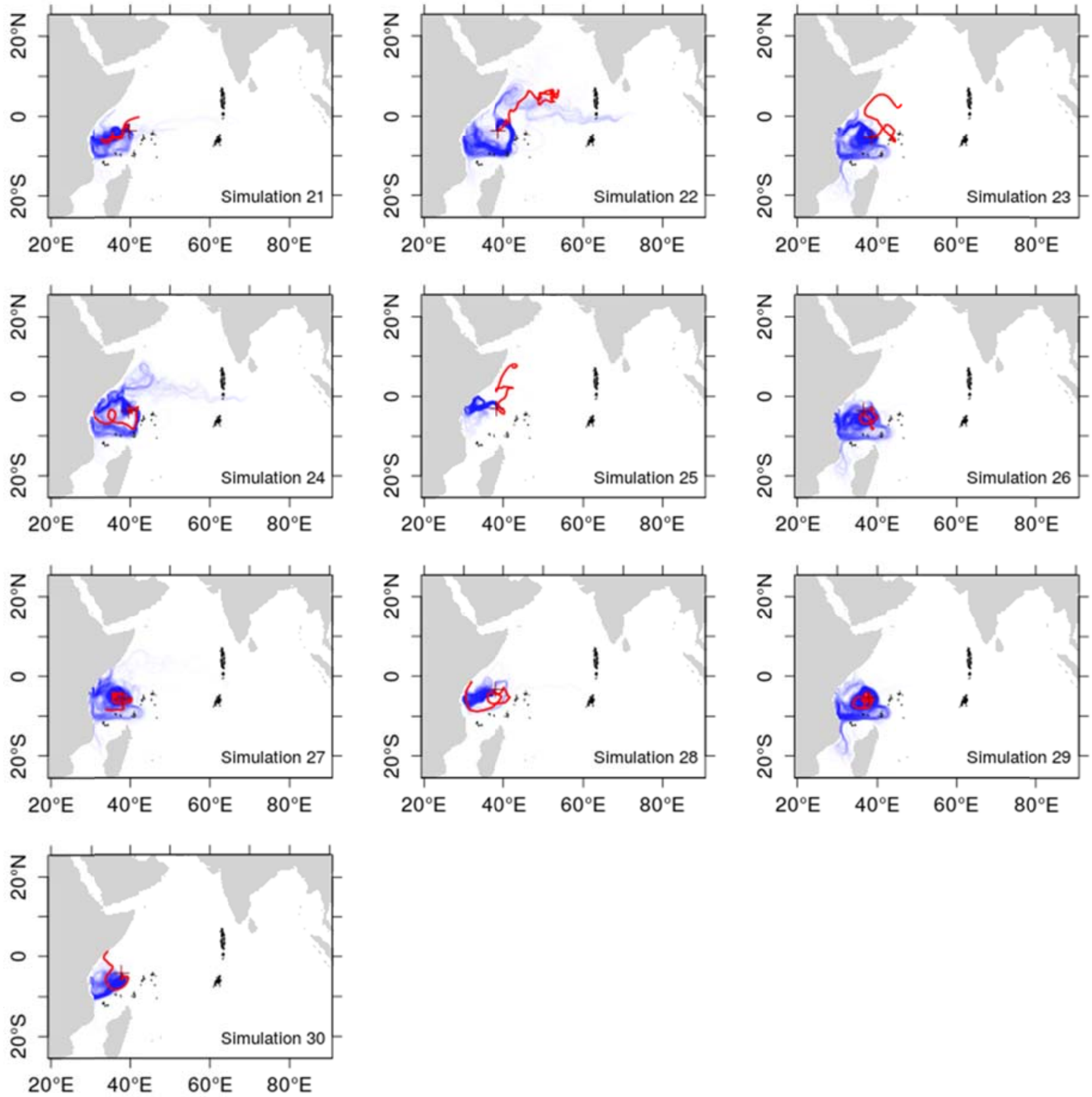


Figure S1c. Simulations of dFAD trajectories (blue lines) from deployment locations (+) in the Indian Ocean in the main deployment area of the season June-July (see text for details). Red lines indicate observed trajectories of dFADs deployed at sea and black areas indicate coral reefs.

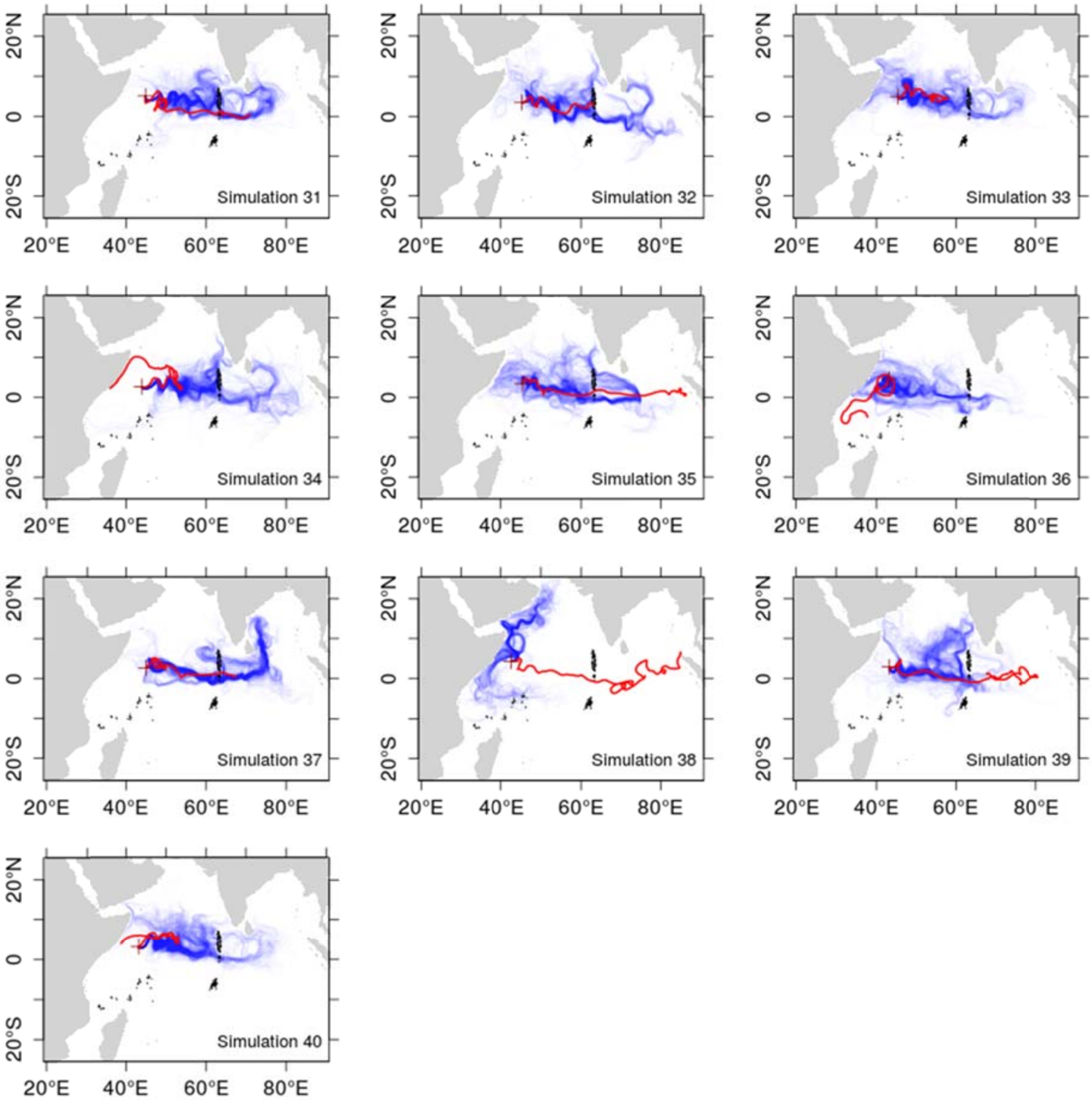


Figure S1d. Simulations of dFAD trajectories (blue lines) from deployment locations (+) in the Indian Ocean in the main deployment area of the season August-October (see text for details). Red lines indicate observed trajectories of dFADs deployed at sea and black areas indicate coral reefs.

Original: English

MANAGING FAD CAPACITY AND IMPACTS ON MARINE ECOSYSTEMS

John Hampton, Gerry Leape, Amanda Nickson, Victor Restrepo, Josu Santiago, David Agnew, Justin Amande, Richard Banks, Maurice Brownjohn, Emmanuel Chassot, Ray Clarke, Tim Davies, David Die, Daniel Gaertner, Grantly Galland, Dave Gershman, Michel Goujon, Martin Hall, Miguel Herrera, Kim Holland, Dave Itano, Taro Kawamoto, Brian Kumasi, Alexandra Maufroy, Gala Moreno, Hilario Murua, Jefferson Murua, Graham Pilling, Kurt Schaefer, Joe Scutt Phillips, Marc Taquet[1]

Abstract

The authors participated in the Global FAD Science Symposium, March 20-23, 2017 in Santa Monica, California and are presented without affiliation. This paper is one of several from the Symposium and does not represent an exhaustive discussion of the issue but includes points agreed by participants. The participants recognized that impacts of FADs and FAD management cannot be considered entirely independently of harvest strategies, issues related to fishing capacity, ecosystem structure, or management of all other fishing gears in tropical tuna fisheries. None of these points alone will address the management challenges associated with FAD use. The effectiveness of any of these points will depend on the levels of implementation and compliance and need to be connected to processes in the RFMOs. Participants underlined the need for data harmonization, standardization, and availability and stressed the need to develop standardized language and definitions to support consistent interpretation of what conservation and management measures intend to achieve across ocean basins. Participants noted that "best practices" are not necessarily "most practical" and will need to be assessed to determine which are most appropriate to apply in any particular management setting or geographic area. Finally, participants stressed the need for ongoing and close collaboration among scientists, managers, and industry in driving innovative solutions within and across RFMOs. The points presented here are not in an order of priority; priorities and solutions may change on a regional basis.

Introduction

The contribution of FADs to the overall effective fishing effort in tropical tuna fisheries is a combination of the number of FADs deployed by each vessel, the number of purse seine vessels deploying and fishing on FADs, and the number of supply vessels managing FADs *in situ*, including by deploying or recovering them. In recent decades, the numbers of all three of these components of FAD capacity have increased, leading to a situation where tens of thousands of new FADs are deployed each year in tropical waters around the world. Below, we highlight some of the agreed points highlighting the impacts of FADs on marine ecosystems that were discussed at the Global FAD Science Symposium.[1] We focus our points on three primary topics – key information, proven and promising approaches to mitigation, and gaps in the current scientific knowledge on the issue.

Key information

FADs increase the fishing efficiency of purse seine vessels and are now deployed wherever purse seine vessels target tropical tunas. However, there are several indicators that the current level of FAD fishing and FAD deployment may be negatively impacting tuna stocks – by contributing disproportionately to the removal of small tunas – and other non-target stocks. The wider impacts of FADs on marine ecosystems are not as well understood, scientifically, but generally cover potential negative changes to the pelagic environment associated with FAD deployment, use, and loss and to sensitive coastal and continental shelf environments associated with grounding or beaching. Recent studies suggest that approximately 10% of FADs deployed in the Atlantic and Indian oceans interact with coastal ecosystems. Impacts of FAD use on the pelagic environment require further research. With the constant exchange of FADs among fishing operations (via trading, selling, or stealing), it is difficult to know how many FADs are in the water, how long they last, and who is/should be responsible for mitigation and clean-up of the impacts of FADs on marine ecosystems.

[1] For more information about the Global FAD Science Symposium or about this paper, contact Grantly Galland (ggalland@pewtrusts.org).

Proven and promising approaches to mitigation

Most of the known ecosystem impacts of FADs stem from the large number of FADs in the water and the possibility that they are lost or abandoned. Therefore, management practices that limit the number of FADs deployed, reduce the likelihood that they are lost or abandoned, and encourage their recovery will all mitigate their impact on pelagic, bottom, and coastal environments. If vessel numbers are held constant, directly limiting the number of FADs that can be deployed each year may be a promising approach to addressing some of the issues associated with their use. However, there is general agreement that if a limit to FAD deployment is assigned on a per vessel basis (as opposed to per ocean basin) that it will not be effective without also limiting the expansion in number of vessels in a fishery (both purse seiners and support vessels). In order to determine what is an appropriate number of FADs in the water and/or to enforce deployment limits, it is necessary to be able to validate the number of FADs deployed by each vessel. Electronic monitoring of FAD deployments, both by purse seine vessels and support vessels, and FAD tracking in the ocean and post-stranding, are important components of FAD management.

Though there is not a widely adopted definition of biodegradable FAD, encouraging or requiring purse seine operations to use FADs that have a minimal chance of becoming part of the global marine debris problem is a promising approach to preventing interactions between this fishing gear and sensitive marine ecosystems. Use of non-entangling FADs should also reduce the unintended take of marine life by FADs that are lost or abandoned, though there is not currently a widely adopted definition of non-entangling FAD.

Most purse seine fleets are now required to produce FAD management plans, but recovery efforts are not often included. FAD management plans should include realistic FAD recovery provisions that minimize total FAD loss or FAD encounters with sensitive habitats. FAD tracking and recovery programs are promising approaches to preventing beaching or grounding in some regions. These programs may involve partnerships between fishing operations and local groups where GPS tracking data are passed to local groups who can intercept FADs before they reach sensitive areas. Support vessels may play a similar role in FAD recovery or interception. The success of these tracking and recovery efforts requires each FAD to be equipped with an active GPS buoy that should never be deactivated while in the water and should maintain a minimum reporting frequency (determined by scientific requirements) at all times. General FAD tracking data may also be useful in identifying regions where beaching or grounding is most likely to occur, supporting establishment of new recovery programs in these potential hotspots.

Self-propelled, remotely controlled FADs could be explored as a means of preventing FAD loss and FAD encounters with sensitive habitats. This new technology is currently in the earliest stages of development but may be a promising approach to consider.

All of the above proven and promising approaches to mitigating FAD impacts on marine ecosystems should be explored and developed in the context of clear management objectives so that scientists and managers know how to examine their effectiveness.

Gaps in current scientific knowledge

Most of the current knowledge on the impacts of FADs on marine ecosystems involves beaching or grounding of FADs in coastal and continental shelf systems. Less is known about the impacts of FADs on the pelagic environment. Several studies have tried to address whether habitat perturbation due to FADs may negatively impact populations of tropical tunas and other pelagic fishes, but scientists do not definitively agree on the conclusions. More research should be conducted on this issue and on the ecological impacts of FADs in the pelagic environment, in general, to understand the effect of FADs on that ecosystem.

Reliable, consistent data on FAD deployment and use continues to be difficult to obtain for many scientists. Though purse seine fishing operations often collect this information for their own purposes or to submit to their national authorities, much of it does not make it to the RFMOs under which their activities are managed. A revision of FAD data requirements at the tuna RFMOs may be necessary to begin to address this problem.

The management of FAD capacity and the contribution of FADs to the overall effective fishing effort in tropical tuna fisheries will require some clarification of FAD ownership issues. In addition to developing a common set of definitions necessary to manage FADs across multiple ocean basins, RFMOs will need to determine who owns a FAD and is therefore responsible for any impact that it has on marine ecosystems. A FAD's ownership could be assigned to the operation that deployed it, the operation that most recently fished on it, the operation that most recently attached an active GPS tracking buoy to it, or some other stakeholder. This clarification will assist RFMOs with compliance once FAD management measures are implemented.

Original: English

THE IMPACTS OF FAD USE ON NON-TARGET SPECIES

John Hampton, Gerry Leape, Amanda Nickson, Victor Restrepo, Josu Santiago, David Agnew, Justin Amande, Richard Banks, Maurice Brownjohn, Emmanuel Chassot, Ray Clarke, Tim Davies, David Die, Daniel Gaertner, Grantly Galland, Dave Gershman, Michel Goujon, Martin Hall, Miguel Herrera, Kim Holland, Dave Itano, Taro Kawamoto, Brian Kumasi, Alexandra Maufroy, Gala Moreno, Hilario Murua, Jefferson Murua, Graham Pilling, Kurt Schaefer, Joe Scutt Phillips, Marc Taquet [1]

Abstract

The authors participated in the Global FAD Science Symposium, March 20-23, 2017, in Santa Monica, California and are presented without affiliation. This paper is one of several from the Symposium and does not represent an exhaustive discussion of the issue but includes points agreed by participants. The participants recognized that impacts of FADs and FAD management cannot be considered entirely independently of harvest strategies, issues related to fishing capacity, ecosystem structure, or management of all other fishing gears in tropical tuna fisheries. None of these points alone will address the management challenges associated with FAD use. The effectiveness of any of these points will depend on the levels of implementation and compliance and need to be connected to processes at the RFMOs. Participants underlined the need for data harmonization, standardization, and availability and stressed the need to develop standardized language and definitions to support consistent interpretation of what conservation and management measures intend to achieve across ocean basins. Participants noted that "best practices" are not necessarily "most practical" and will need to be assessed to determine which are most appropriate to apply in any particular management setting or geographic area. Finally, participants stressed the need for ongoing and close collaboration among scientists, managers, and industry in driving innovative solutions within and across RFMOs. The points presented here are not in an order of priority; priorities and solutions may change on a regional basis.

Introduction

As is the case for vessels in most industrial fisheries, tuna purse seine vessels catch and sometimes land non-target species in addition to the tropical tunas that they target. Non-target species typically encountered by vessels fishing in association with fish aggregating devices (FADs) can be generally binned into three taxonomic categories: sea turtles, sharks, and non-target bony fishes. Below, we highlight some of the agreed points from the Global FAD Science Symposium,[1] dividing each taxonomic section into subsections on key information, proven and promising approaches to mitigation, and gaps in the current scientific knowledge on this issue. In addition to the specific points provided below, the value of crew training and communication to the fishing community were highlighted for turtles, sharks, and bony fishes.

Sea turtles

Key information

Sea turtle interactions with purse seine operations fishing in association with FADs are fairly uncommon, and mortality of turtles in purse seining operations is extremely low – more than 90% of sea turtles caught in purse seine nets are released alive. Best practices for sea turtle release are available and have proven successful. However, small numbers of turtles are entangled directly in FADs, either the portion of the FAD at the surface or the submerged netting hanging down into the water column. Priority turtle species may vary by region or ocean basin and should be established for each area, according to the stock condition of the species encountered by purse seine fishing operations. As a result of sea turtles' unique life history strategy (generally coming onshore only to nest), open ocean fishing operations may be a source of invaluable information on species or population occurrence at the ocean basin scale, particularly for life stages (juveniles and adults in pelagic environments) where data are generally not available.

[1] For more information about the Global FAD Science Symposium or about this paper, contact Grantly Galland (ggalland@pewtrusts.org).

Proven and promising approaches to mitigation

The majority of sea turtle mortalities resulting from purse seine fishing in association with FADs are the result of entanglement in the FAD itself. A proven approach to reducing this mortality involves FAD design. Though there is not a widely adopted definition of non-entangling FAD, it should be considered best practice to construct FADs with little or no risk of entangling sea turtles. This involves reducing the amount of netting used on the portion of the FAD at the sea surface (often called the "raft") or submerged below. The raft, in particular, should not include netting or should have a canvas cover over any netting, as sea turtles have a tendency to climb on them and subsequently become entangled. Reducing the surface area of the raft may also prevent turtles from attempting to "haul out" onto a FAD. For sea turtles encountered during fishing operations and encircled in the purse seine net, resuscitation/revival has proven successful at increasing survivorship of turtles that are released from the net or from the vessel deck. Some RFMOs already mandate specific care for sea turtles encountered during fishing operations (including mandating the use of recovery tanks on board).

Gaps in current scientific knowledge

As there are clear, proven methods to reduce or eliminate sea turtle bycatch by purse seine operations or FADs, there are currently no pressing gaps in the scientific knowledge of this issue.

Sharks

Key information

Sharks make up a small percentage of the catch (0.5% by weight) of purse seine operations fishing in association with FADs, low compared to other tuna fishing gears but higher than purse seine operations fishing on unassociated tuna schools. Though the relative numbers are low, the very large scale of these fisheries means that catch can be significant for some species, primarily silky shark – a common component of purse seine bycatch – and oceanic whitetip shark – less common in the catch but highly vulnerable to overexploitation. Though unintended shark catch is generally higher when fishing in association with FADS, some species (e.g., hammerhead sharks, mobulid rays, etc.) are more common in unassociated purse seine sets. The relative impact of purse seine fisheries on sharks varies by ocean basin. In addition to being captured directly during fishing activity, sharks may become entangled in the FAD itself if it is made of components in the water column that include loose netting with mesh size greater than approximately seven centimeters. The magnitude of this entanglement problem also may vary by ocean basin.

Proven and promising approaches to mitigation

A proven approach to reducing shark mortality from entanglement in the FAD itself involves FAD design. Though there is not a widely adopted definition of non-entangling FAD, it should be considered best practice to construct FADs with little or no risk of entangling sharks by avoiding using netting or other entangling materials. There are several steps that can be taken to reduce mortality of sharks encountered during fishing operations. Shifting fishing effort from FAD-associated tuna schools to unassociated schools reduces overall shark mortality (but may increase mortality of some sensitive species such as hammerhead sharks and mobulid rays). Avoiding setting on small FAD-associated tuna schools results in a lower bycatch rate since the abundance of non-target species is independent of tuna school size. These proven practices reduce the likelihood that sharks are encountered during fishing operations. Identification and avoidance of shark "hot spots" is a promising approach to further reduce the likelihood that sharks are encountered. For sharks that are encircled in the purse seine net, one promising approach is fishing the sharks out of the net using handline, longline, or other gear. This practice should be emphasized as encircled sharks are often still in good condition. If a shark makes it onto the deck of the purse seine vessel, there are published, proven practices for safe handling that can increase survival to 20% of individuals that reach the deck. These best handling practices should be implemented in all ocean basins.

Gaps in current scientific knowledge

In addition to the general data gaps associated with most shark fisheries, there are some specific areas of shark research that are particularly relevant to FAD fishing. Increased knowledge on the biology and life history of silky sharks and oceanic whitetip sharks would be useful in determining new methods to mitigate their bycatch in FAD-associated purse seine fisheries. Information on the FAD colonization rates and behaviors of these sensitive species would be particularly useful. There is a general need for more *in situ* studies on ways to discourage sharks of all species from aggregating to FADs or to scare them away from FADs before commencing fishing operations.

Non-target bony fishes

Key information

Non-target bony fishes represent 1-2.5% of the catch (by weight) of purse seine operations fishing in association with FADs, with some variability among ocean basins. Though non-target bony fishes are also caught in unassociated purse seine sets, there are more individuals, higher biomass, and greater diversity of these species caught in FAD-associated sets. There is little to no information on the stock status of most non-target bony fishes, and lack of data makes it difficult for scientists to conduct even rudimentary stock assessments. However, many of these species are considered to be of low conservation concern, as they are fast growing, highly fecund, abundant species. Non-target bony fishes are utilized by the crew for personal consumption or landed for sale in some regions but discarded in others. In cases where local markets for these species have become lucrative, prices may be higher than those for skipjack. As such, these species may be targeted in some areas and should be managed via the ecological approach to fisheries management.

Proven and promising approaches to mitigation

There are few proven methods to reducing incidental catch of non-target bony fishes. However, as is the case with sharks, a shift in fishing effort from FAD-associated tuna schools to unassociated schools reduces this unintentional catch, and avoidance of small FAD-associated tuna schools reduces the catch rate of these species. Reducing dead discards and promoting utilization could help improve monitoring, reduce waste, and potentially improve food security in some regions. Increased utilization, though, may lead to conflicts with local, artisanal fisheries and may indirectly encourage targeting by purse seiners of previously non-target species.

Gaps in current scientific knowledge

There is a lack of information on stock status for most non-target bony fishes caught in association with FADs. Collection of fisheries-related data for monitoring purposes will help RFMOs determine if and when mitigation measures are needed for any of these species. Research on non-target bony fish release or escape would be useful in determining ways to reduce morality of these species once they are already encircled in the purse seine net. Investigating the effect of purse seine net mesh size on bycatch rates of these species is one example of research that could improve the management of non-target bony fishes.

Original: English

FAD USE AND FISHING MORTALITY IN TROPICAL TUNA FISHERIES

John Hampton, Gerry Leape, Amanda Nickson, Victor Restrepo, Josu Santiago, David Agnew, Justin Amande, Richard Banks, Maurice Brownjohn, Emmanuel Chassot, Ray Clarke, Tim Davies, David Die, Daniel Gaertner, Grantly Galland, Dave Gershman, Michel Goujon, Martin Hall, Miguel Herrera, Kim Holland, Dave Itano, Taro Kawamoto, Brian Kumasi, Alexandra Maufroy, Gala Moreno, Hilario Murua, Jefferson Murua, Graham Pilling, Kurt Schaefer, Joe Scutt Phillips, Marc Taquet[1]

Abstract

The authors participated in the Global FAD Science Symposium, March 20-23, 2017, in Santa Monica, California and are presented without affiliation. This paper is one of several from the Symposium and does not represent an exhaustive discussion of the issue but includes points agreed by participants. The participants recognized that impacts of FADs and FAD management cannot be considered entirely independently of harvest strategies, issues related to fishing capacity, ecosystem structure, or management of all other fishing gears in tropical tuna fisheries. None of these points alone will address the management challenges associated with FAD use. The effectiveness of any of these points will depend on the levels of implementation and compliance and need to be connected to processes in the RFMOs. Participants underlined the need for data harmonization, standardization, and availability and stressed the need to develop standardized language and definitions to support consistent interpretation of what conservation and management measures intend to achieve across ocean basins. Participants noted that "best practices" are not necessarily "most practical" and will need to be assessed to determine which are most appropriate to apply in any particular management setting or geographic area. Finally, participants stressed the need for ongoing and close collaboration among scientists, managers, and industry in driving innovative solutions within and across RFMOs. The points presented here are not in an order of priority; priorities and solutions may change on a regional basis.

Introduction

Increasing use of FADs and development of associated technology has increased the impacts on juvenile and small bigeye and yellowfin tunas, which are caught in FAD-associated purse seine sets and mostly retained but occasionally discarded. Mitigating that catch has challenged tuna RFMOs. This paper presents conclusions agreed by participants at the Global FAD Science Symposium,[1] summarizing key contextual information related to catches and management of bigeye and yellowfin in the FAD fishery, proven and promising 'best practices' to mitigate those catches, and gaps in current scientific knowledge.

Key information

Since the 1990s, increasing use of FADs and improving technology related to the devices has fuelled improvements in the efficiency and profitability of the purse seine fishery, leading to greater catches of the primary target species skipjack tuna, but adding to the impacts on bigeye and yellowfin tunas, caught as juvenile or small fish. Scientific data collected by tagging and fishery observations indicate that bigeye, in particular, appears differentially vulnerable to being caught by sets on FADs. Management of FADs in RFMOs has sought to maximize the catch of skipjack at sustainable levels while mitigating catches of bigeye and yellowfin. Meanwhile, the development of FAD fisheries has occurred amidst increasing numbers of purse seine and support vessels entering the global fishery. More effective management of FADs needs to be placed within a greater context that considers the overall purse seine fleet capacity and effective fishing effort, as well as impacts from other gears, to achieve management objectives that should be clearly specified by the RFMOs.

[1] For more information about the Global FAD Science Symposium or about this paper, contact Grantly Galland (ggalland@pewtrusts.org).

Proven and promising approaches to mitigation

Currently available

Existing approaches to mitigate bigeye and yellowfin mortality, used singly or in combination, were reviewed for what works and what does not to identify a currently available 'best practice.' One approach establishes a closure that prohibits setting on FADs within a defined area and/or period of time. Although experience with closures in certain ocean areas shows they constrain the catch of bigeye, it is notable that the control is applied only during the terms of the closure. A second approach places total annual limits on the number of FAD sets or tonnage of bigeye and/or yellowfin. While effective at mitigating catches of bigeye and/or yellowfin, total annual limits may need to be allocated among fishing parties, or in some cases by zones, which could invite a negotiating process. A third approach establishes per-vessel FAD buoy limits. In practice, however, buoy limits set to date in certain ocean areas have not been restrictive at the fleet level and a lack of relevant scientific information does not allow for setting science-based limits that would be consistent with management objectives. Because establishing year-round control over FAD use is desirable and given experience with what works, this review shows that annual limits on FAD sets or bigeye/yellowfin catches constitutes a current 'best practice' approach. In this light, RFMOs should consider developing appropriate limits on FAD sets or bigeye/yellowfin catches for full-time application. These limits should be developed within a greater context of comprehensive tropical tuna management. If employing FAD set limits, an interim limit on the number of total FAD buoys deployed should be established to prevent unrestricted 'cherry picking' from amongst an unmanaged number of FADs and avoid undesirable changes in tuna aggregation dynamics. A buoy limit may also incentivize a vessel owner to operate efficiently to maximize profit from each buoy and minimize buoy loss. In addition, common standards for effective RFMO/national FAD management plans should be established to improve and harmonize data collection, which is discussed separately below. RFMOs should also adopt a common definition of a FAD set to enhance verifiability and compliance.

Promising and/or potential approaches

A range of additional approaches applying new technologies or incentives are being examined. One promising approach would identify the species composition before an operator commits to a set using data from the echosounder buoys on FADs and acoustic equipment on board the vessel to avoid setting on large quantities of juvenile and small bigeye and/or yellowfin. The technology requires further development to discriminate among the tropical tunas with reliability and a regulatory or market incentive to promote 'good choices' among vessel operators. Cooperation among fisheries scientists, vessel operators and buoy manufacturers could promote development of this technology to achieve pre-set species identification. Dynamic closures in use in other fisheries could be promising in tuna fisheries but require accurate real-time monitoring of species composition, catch rates and levels, and a management system capable of operating in short time-scales. Also promising are economic incentives that encourage greater effort on free school fish, such as through market certification or other pricing schemes that reward free school fish with greater prices. Enhancing the selectivity of the purse seine fishery through changes to net depth or operational characteristics appears not conducive to mitigating catches of juvenile and small bigeye or yellowfin, but could be promising in areas, such as portions of the Western and Central Pacific Ocean (WCPO), due to certain oceanographic conditions. Finally, other mitigation approaches being explored, such as changes to FAD design or the introduction of purse seine net sorting grids, have not been able to reliably mitigate undesirable tuna catch. Meanwhile, identification of bigeye hotspots in some ocean areas, such as the WCPO, requires greater investigation.

Gaps in current scientific knowledge

More information is needed to understand the interactions between FADs, vessel operations and fishery dynamics to improve scientific assessments and design improved management interventions. Critical data gaps exist. Some RFMOs, for instance, lack data on the total numbers, locations and designs of FADs deployed and set upon. RFMOs should close these data gaps as a matter of priority by implementing existing tools such as observer programs and/or e-monitoring of purse seine vessels and Vessel Monitoring Systems. Collecting new types of data on the operational and economic characteristics of purse seine vessels and acquiring data transmitted from FAD echosounder buoys – potentially with an appropriate time lag or other confidentiality measures – opens up new opportunities. Integrating those data with observer and catch data could lead to the identification of impacts of FAD densities on the fishery, locations of potential bigeye hotspots, and determine why the catch of bigeye varies among purse seine vessels fishing in the same ocean basin (i.e. why do some vessels catch more bigeye than others?). More information also is required to understand the associative behaviours of the tropical tunas in all ocean areas, including their spatial variability and vulnerability. A wide-scale collection of individual FAD deployment, tracking, and set-history data could also help scientists develop a purse seine catch per unit effort (CPUE) index, which could prove valuable for stock assessment and understanding stock dynamics. Most stock assessments for tropical tunas use only longline and pole and line CPUE indices, though most of the catch comes from purse seine operations. In addition, there remains a need to develop harmonized FAD fishery indicators (e.g., number of sets, ratio of FAD-associated sets to unassociated sets, etc.) to estimate the contribution of FADs to the overall effective fishing effort in tropical tuna fisheries across ocean regions.

Original: English

TECHNOLOGICAL APPROACHES TO ADDRESSING TUNA MORTALITY ASSOCIATED WITH FAD FISHING

John Hampton, Gerry Leape, Amanda Nickson, Victor Restrepo, Josu Santiago, David Agnew, Justin Amande, Richard Banks, Maurice Brownjohn, Emmanuel Chassot, Ray Clarke, Tim Davies, David Die, Daniel Gaertner, Grantly Galland, Dave Gershman, Michel Goujon, Martin Hall, Miguel Herrera, Kim Holland, Dave Itano, Taro Kawamoto, Brian Kumasi, Alexandra Maufroy, Gala Moreno, Hilario Murua, Jefferson Murua, Graham Pilling, Kurt Schaefer, Joe Scutt Phillips, Marc Taquet[1]

Abstract

The authors participated in the Global FAD Science Symposium, March 20-23, 2017 in Santa Monica, California and are presented without affiliation. This paper is one of several from the Symposium and does not represent an exhaustive discussion of the issue but includes points agreed by participants. The participants recognized that impacts of FADs and FAD management cannot be considered entirely independently of harvest strategies, issues related to fishing capacity, ecosystem structure, or management of all other fishing gears in tropical tuna fisheries. None of these points alone will address the management challenges associated with FAD use. The effectiveness of any of these points will depend on the levels of implementation and compliance and need to be connected to processes in the RFMOs. Participants underlined the need for data harmonization, standardization, and availability and stressed the need to develop standardized language and definitions to support consistent interpretation of what conservation and management measures intend to achieve across ocean basins. Participants noted that "best practices" are not necessarily "most practical" and will need to be assessed to determine which are most appropriate to apply in any particular management setting or geographic area. Finally, participants stressed the need for ongoing and close collaboration among scientists, managers, and industry in driving innovative solutions within and across RFMOs. The points presented here are not in an order of priority; priorities and solutions may change on a regional basis.

Introduction

Continuing improvements in FAD technology since the devices were embraced by the global tuna purse seine fleet in the mid-1990s has increased the efficiency of vessels and the catches of the main targeted species of skipjack tuna. At the same time, this trend has contributed to the undesirable impacts on juvenile and small bigeye and/or yellowfin tunas. This paper presents points agreed by participants at the Global FAD Science Symposium[1], where key information and suggested next steps were discussed on the potential for technology from echosounder buoys to be used to develop new approaches to mitigate the catch of juvenile and small bigeye and/or yellowfin.

Key information

Since the introduction of echosounder buoys about 10 years ago, the global purse seine fleet has rapidly moved to deploy them in greater numbers in FAD-associated fishing operations. Once simple floating objects, FADs are now sophisticated instruments, linked via satellite to purse seine operations that can track the global positioning devices on the buoys as they drift along the surface of the ocean. The introduction of echosounder devices on 75 to 100 percent of the buoys used in many fleets and their accompanying computer algorithms translates acoustic returns from the fish into a rough indication of total biomass in proximity to the FAD that is then displayed as an image to vessel operators in real time. At this time, the technology cannot reliably estimate species and size composition. Estimates of total biomass also can vary from the tonnages actually caught. Buoys of different manufacturers have different levels of reliability and range. However, improvements in the technology are feasible. Assessing species composition via echosounder buoys and acoustic equipment is increasingly promising as a means to mitigate the catch of undesirable species. With the ability to discriminate among species under a FAD, an operator could avoid large aggregations of juvenile and small bigeye and/or yellowfin, choosing to fish only on large aggregations of skipjack.

[1] For more information about the Global FAD Science Symposium or about this paper, contact Grantly Galland (ggalland@pewtrusts.org).

Next steps

Sharing information among scientists, vessel operators and buoy manufacturers would lead to the greatest improvements in the technology. Greater understanding of the acoustic properties of tunas is required to distinguish reliably among species and size. The lack of a swim bladder in skipjack holds promise for distinguishing that species from the other tropical tunas in a mixed aggregation, but more research is needed to identify a path forward to distinguish bigeye from yellowfin and to identify different size classes of these species. To be useful in providing information for the purpose of mitigating undesirable catch, biomass estimates need to be improved and displayed in an objective system that does not rely on the interpretative skills of a skipper to be reliable. In addition, vessel operators need incentives to make 'good choices' based on the biomass information displayed. Incentives could be regulatory – prohibitions on setting on large quantities of juvenile and small bigeye and/or yellowfin – or market-based.

Original: English

MITIGATING THE IMPACTS OF FAD USE ON TROPICAL TUNA STOCKS

Grantly R. Galland, David J. Gershman, Amanda E. M. Nickson[1]

Background

Compared to other methods of tuna fishing, purse seine operations that target skipjack using FADs often catch very high numbers of juvenile and small bigeye and yellowfin tunas that have not yet had the opportunity to reproduce. This catch contributes significantly to the overfishing of some stocks. As a result, some bigeye and yellowfin stocks are in an overfished condition and have been depleted to levels below those capable of producing maximum sustainable yield (MSY), the benchmark to which the tuna RFMOs have agreed to manage most stocks. Furthermore, the juvenile catch resulting from an increasing trend toward fishing with FADs has altered the overall selectivity of fisheries targeting tropical tunas. Formerly, most catch of the larger-bodied tropical species comprised adult individuals captured by longline (bigeye and yellowfin) or purse seine operations setting on unassociated tuna schools (yellowfin). Now, as much as 50% of the bigeye landings (by weight) or 90% (by number of individuals) comprises juveniles taken by purse seine operations setting on FAD-associated tuna schools. Fewer individuals reach adulthood, reducing MSY and increasing the number of adult fish that must be left in the water to reproduce and support MSY. A declining MSY and increasing biomass required to support MSY are both suboptimal for the fisheries that target these species, particularly when stock size is already below the biomass capable of supporting MSY. This is currently the case with bigeye in the Pacific and Atlantic oceans and yellowfin in the Indian and (to a lesser extent) Atlantic oceans.

Although changes to tropical tuna stocks and fisheries dynamics are arguably the most significant impact of unmanaged FAD use, management efforts to date have concentrated on other issues, including catch, effort and/or profitability in skipjack fisheries; catch and mortality of non-target species such as sharks; and impacts on marine ecosystems when FADs beach or ground in environmentally sensitive areas. This focus is particularly clear in the proceedings of the RFMO FAD working groups to date and the management measures implemented by RFMO commissions in the last five years. After a push by environmental NGOs and industry representatives to begin managing FADs, the member states of three RFMOs have opted to require or promote non-entangling FADs that reduce their impacts on non-target species or limit the number of FADs that can be actively monitored at any given time, improving the economics of skipjack fishing and reducing the likelihood that lost or abandoned FADs will interact with sensitive coastal ecosystems. As the ICCAT, IATTC, and IOTC FAD working groups meet jointly to discuss progress and future direction, it is time for these groups to take the more difficult step of addressing juvenile mortality associated with FAD use in order to recover depleted stocks, prevent overfishing of currently healthy stocks, and reduce the problems with fisheries dynamics associated with the changes in selectivity indicative of a growing reliance on FAD fishing.

Limit juvenile mortality

Catch limits on bigeye or yellowfin caught in association with FADs offer the most direct means of managing mortality of those species in the purse seine fishery. For depleted stocks, limits should be low enough to support recovery timelines that are as short as possible and with high probability of success. Recognizing that effort on bigeye and yellowfin occurs within a wider context, separate catch limits for juvenile and adult life stages could be established. In 2017, IATTC set a total annual juvenile catch limit for bigeye and yellowfin combined caught by its largest purse seine vessels, a first step to implementing this practice. A combined, multi-species limit, however, comes with the risk that catch of the more depleted of the two species remains too high. Catch limits should be implemented on a single-species basis.

[1] The Pew Charitable Trusts; 901 E St. NW, Washington, DC 20004, USA; ggalland@pewtrusts.org; dgershman@pewtrusts.org; anickson@pewtrusts.org

Allocation of catch among fleets could be analysed for several ratios of adult to juvenile mortality so that managers are able to choose allocation schemes that align with the management objectives of any particular fishery (see below). Reviewing a series of potential adult to juvenile ratios allows managers to directly tie management to the scientific advice. Juvenile catch limits encourage purse seine operations to catch fewer bigeye or yellowfin per set, incentivizing technological innovation or use of oceanographic information to avoid fishing on FAD-associated schools that include large numbers of these species. Furthermore, reducing juvenile mortality rather than simply overall mortality is likely to raise MSY levels, potentially making more tuna available to fishing. This management option is good for the stock and good for fishing and does not necessarily limit the amount of skipjack that can be landed by purse seine operations. Electronic reporting of logbooks and/or observer reports would give managers more access to real-time information as the purse seine industry approaches juvenile catch limits in a particular area.

FAD sets as a proxy for mortality

Implementing a limit on juvenile mortality requires the identification of juvenile bigeye and yellowfin tunas. Though this challenge could potentially be overcome through 100% coverage of observers trained to identify bigeye and yellowfin, port sampling, or partnerships with canning operations, it may be necessary to develop proxies for juvenile catch. Scientists agree that juvenile bigeye and yellowfin are caught more frequently and in higher numbers in purse seine sets on FADs than in sets on unassociated tuna schools. In the Western and Central Pacific Ocean, the total catch of bigeye in the purse seine fishery has been shown to correlate very closely with the total number of FAD sets. Although potentially less precise than a catch limit, a FAD set limit would be effective in limiting juvenile bigeye and yellowfin mortality. Such a limit reduces fishing mortality while also giving the purse seine industry more flexibility than a time-area closure by affording them the opportunity to choose when and where to fish, rather than limiting their activities, temporally or spatially. Furthermore, these limits should be relatively easy to implement, as purse seine operations are already required by RFMOs to report FAD sets in their logbooks, and observers can verify the number of FAD sets during each fishing trip. Electronic reporting of logbooks and/or observer reports would give managers more access to real-time information as the purse seine industry approaches a FAD set limit in a particular area.

The benefits of FAD tracking

Regardless of management protocols to address juvenile tuna mortality, as part of an improved approach to managing FADs, States and RFMOs should cooperate to collect electronic data from FAD buoys for use in science, management, and compliance. GPS devices and instruments on the buoys transmit a host of data to purse seine companies. A project undertaken by eight coastal States in the western and central Pacific Ocean – the Parties to the Nauru Agreement – shows the same data transmitted from the FAD to a purse seine company can be forwarded at no additional cost to a second party. Transmissions to the PNA include unique buoy identification numbers, ownership information, and the latitude/longitude location of the buoy. The data indicate the number of FADs deployed and can be displayed on a virtual map to show drifts, locations, and potential fates of FADs. Oceanographic data and estimates of biomass under echosounder buoys can also be transmitted, though they are not required at this time. The data are useful in developing a greater scientific understanding of FADs. When paired with logbook and observer data, scientists can pursue research into FAD effort and CPUE levels. The results can inform development of management measures and assist in determining their compliance. The PNA project is one example, but other institutional arrangements could be created among industry, States, and RFMOs to collect these data. Should FAD set limits be implemented as a means to manage juvenile mortality of bigeye and yellowfin, FAD tracking data can act as a secondary means to verify whether a FAD set was made. A software algorithm can be created to compare VMS locations of vessels against reported FAD locations, and generate alerts when a vessel is in proximity to a FAD. The absence of an alert could be used to bolster observer or logbook claims that a set was made on an unassociated tuna school rather than on a FAD.

A call for management objectives

Each of the FAD options described here should be implemented within a context of management objectives that are clearly stated and defined by managers. Without such objectives, scientists are unable to determine whether or not steps taken to recover overfished stocks will be effective. For example, in

2015, ICCAT set an Atlantic bigeye total allowable catch (TAC) with only a 49% chance at recovering the heavily depleted stock by 2028 and coupled the TAC with a time-area closure and FAD monitoring limit. The managers directed their scientists to analyse the effectiveness of the closure and the FAD limit, but did not define management objectives against which the scientists could test the additional measures. How can scientists test the effectiveness of a measure without having a clear definition of what 'effective' means? Would the recovery plan be successful if the additional measures increase the probability of success from 49%, and by how much? Would it be successful if the measures shorten the timeline to recovery, and by how much? These are the sorts of questions that clearly defined management objectives help scientists answer. It is clear that depleted stocks should be recovered; management objectives help to define how that recovery is achieved. For depleted tropical tuna stocks, recovery should occur within two generation times, with at least 70% probability of success.

Conclusions

It is time to effectively address the juvenile mortality of bigeye and yellowfin tunas in purse seine fishing operations. This mortality is arguably the most significant impact that unmanaged FADs have on the marine environment. The most direct way to address this issue is through juvenile catch limits of these two species, an option that does not directly limit the amount of skipjack that can be caught by purse seine industry. A limit on the number of FAD sets may serve as a proxy for juvenile catch limits in some areas, and limiting fishing in this way would benefit from a requirement for purse seine operations to share their FAD tracking data with the RFMOs. All of these options should be implemented within a management framework that includes clearly defined management objectives. This Joint Tuna RFMO FAD Working Group meeting is an important opportunity to advance FAD management in the Atlantic, Pacific, and Indian oceans. Direct management of juvenile tuna mortality should be the group's top recommendation for consideration at all of the tuna RFMOs.

Original: English

AN OVERVIEW OF WORLDWIDE FAD FISHERIES AND OF THEIR POTENTIAL EFFECTS ON TUNA STOCKS

Alain Fonteneau[1]

SUMMARY

This paper makes an overview of FAD fisheries developed worldwide, comparing fishing zones, and yearly catches by species and catch at size. This analysis is done on the 3 main tuna species targeted by FADs, yellowfin, skipjack and bigeye. It shows great similarities observed worldwide in many FAD fisheries, in terms of species composition and sizes caught. Most sets on FADs show, worldwide, a combination of the 3 species of tropical tunas: yellowfin, skipjack and bigeye. The heterogeneity in these species compositions observed in the multispecies samples of FAD catches obtained in each ocean are analyzed (using De Finetti ternary plots), this work being done in comparison to the species composition of free schools samples. This comparison shows that the FAD species composition is totally different from free schools in the Indian, Atlantic and Eastern Pacific ocean. The peculiarities of the FAD and free school fisheries in the Western Pacific, mainly their similar species composition and steadily increasing catches by both fishing modes, are discussed. The yearly world catches of skipjack and of small bigeye and yellowfin caught under FADs are examined and analyzed in relation with the trend in the steadily increasing fishing efforts exerted by purse seiners. While skipjack FAD catches have shown, during recent years, moderate increases, it is striking to observe that world bigeye FAD catches remained stable during the last 20 years while the FAD fishing pressure was widely increased, this flat trend being observed in each ocean. This stability of bigeye catches in a context of increasing fishing effort corresponds to a clear marked decline in the bigeye global CPUEs of purse seiners. It is hypothesized that this decline was due to an unexplained decline of the juvenile bigeye catchability in the FAD fishery, or/and to a decline in the bigeye recruitment. This striking relationship between FAD catches of small bigeye and fishing efforts of purse seiners should be carefully analyzed in each ocean. Catch at size of skipjack, yellowfin and bigeye caught on FADs and by the other fisheries in the various oceans are compared. Similar patterns of average sizes caught have been observed worldwide in most FAD fisheries of the 3 species. Most tuna caught under FADs show, worldwide, dominant sizes well under 80 cm and similar average weights for each of the 3 species. The optimal theoretical sizes that would maximize the biological productivity of each species are estimated using a simulation method, and compared to tuna sizes caught on FADs. Our conclusion is that skipjack FAD catches have been maximizing the biological productivity of the skipjack stocks, while the present large catches of small yellowfin and bigeye associated to FADs have reduced the biological productivity of heavily exploited stocks. This decline of biological productivity is due to the small sizes of yellowfin and bigeye caught on FADs, while the optimal sizes of these 2 species can be estimated between 1m and 1.2 m for yellowfin and between 1.2 and 1.4m for bigeye. These negative effects of FAD catches remain difficult to evaluate precisely, mainly because of the present major uncertainties in natural mortality at age, natural mortality assumed for each species by each RFO being often widely distinct without scientific reasons. The serious uncertainties faced in most tuna stock assessment models are also difficult to evaluate and to compare between oceans. A recommendation is made to better coordinate the international fishery statistics and scientific investigations on FADs, especially on the complex but important scientific question of the present interactions between the FADs and non-FADs fisheries. It is concluded that one of the major management problems faced today by each of the tuna RFMO is to take a full real control of their FAD fisheries: maintaining optimum levels and optimal fishing use of their FADs, since the present FAD fisheries are clearly the only way to obtain the MSY of all skipjack stocks worldwide. This future improved management of the FAD fisheries should also find the efficient methods that will allow the control of an excessive use of FADs in order to limit their negative impacts on the biological productivity of the valuable yellowfin and bigeye stocks. It is recommended that the optimal numbers of FADs seeded and followed by the purse seine fleets (and thus by each purse seiner) should be well studied and evaluated by scientists.

[1] alain.fonteneau@ird.fr

Appendix

AN OVERVIEW OF WORLDWIDE FAD FISHERIES AND OF THEIR POTENTIAL EFFECTS ON TUNA STOCKS

Alain Fonteneau

1 Introduction

Many scientific studies have been carried out since the early nineties on FADs, but most of these studies where based on local problems and seldom reviewed the FAD fisheries detailed data and their prospects at a worldwide level. For instance and *inter alia* in recent years the documents by Fonteneau & al 2001, Fonteneau & al 2011, Bromhead *et al* 2000, An. PEW 2015 and An. MRAG 2017, but the scope of these reviews was often quite limited and not enough based on the fishery data. The goal of this paper is to make an updated scientific review of FAD fisheries: analyzing the trend of world PS fishing efforts and comparing the yearly catches and sizes caught on FADs, comparing these FAD catches and the sizes caught by other fisheries on free schools+dolphins and by other fishing methods in each ocean, for instance longliners. This paper will also try to examine and to discuss at a global level the potential effects of FADs fisheries on the biological productivity of the skipjack, yellowfin and bigeye stocks.

2 Material and methods

This work is primarily based on a homemade data base of catch and effort data of the world tuna fisheries created by Fonteneau since 1995 in relation with his first atlas published on world tuna fisheries (Fonteneau 1998). This data base covers the 1950-2015 period and it has been built since 1995 based on the catch & effort and size data made available each year by each of the 4 tuna commissions: IATTC, ICCAT, IOTC and WCPFC. All the FAD catch data available in this catch and effort file by 5°-month have been tentatively extrapolated to the total catches by PS estimated in each ocean. This work is also based on the wide literature available on FADs and on the follow up of the stock assessment analysis done by the various tuna RFMOs on their yellowfin, skipjack and bigeye stocks.

3 Facts on FADs and non-FADs fisheries

3.1 Geographical distribution of FAD fisheries

It is important to first examine the geographical distribution of the FAD catches of skipjack, yellowfin and bigeye, knowing that FAD catches of yellowfin and of bigeye are mainly on juveniles. These FAD fishing areas of juvenile yellowfin & bigeye (**Figure 1a**) should also be compared to the fishing zones of adults by longliners (F**igyre 1b**). These maps have been done with a log scale in order to reduce the visual contrast between the 5° squares with large and small catches. These maps show that skipjack and juvenile yellowfin & bigeye are primarily caught on FADs only in the equatorial areas and in their potential nurseries while the adult yellowfin & bigeye are caught by longliners in a much wider area between 40°N & 40°S, in both their spawning areas (sub equatorial) and in their feeding areas (temperate & inter tropical).

Figure 2 shows that skipjack catches have been mainly obtained under FADs (in red), this species being dominant in the FAD catches in most fishing zones of the Atlantic, Indian and eastern Pacific oceans. However this map also shows that in the western Pacific there is an equilibrium close to 50/50 between the 5° squares that are dominated by FAD or by free schools skipjack catches. This major behavioural peculiarity of the Western Pacific skipjack remains poorly discussed and explained by scientists.

3.2 Fishing effort of PS fisheries: total and on FADs

It is important and difficult to estimate the trend of the yearly fishing effort exerted by the world purse seine fleets. A simple way to follow this trend is to keep track of the number of active PS and of their average carrying capacity in each ocean, allowing to estimate the carrying capacity of the PS fleets active worldwide. This figure (**Figure 3**) shows a steadily increasing capacity of world PS fleets. This fishing capacity can be somehow considered as a measure of the yearly fishing efforts exerted by purse seiners, and these yearly fishing efforts of the world PS fleets clearly show a quasi linear increase since 1980.

Furthermore, there is no doubt that the fishing efforts of most purse seiners targeting FADs have been also permanently increasing since the mid-eighties because of the major changes developed in the FAD fisheries:

1) Permanently increasing the number of FADS followed by PS, now probably reaching 100.000[2] or more FADs, and their improved design (especially under the water) and their stealth characteristics,
2) Major improvements in the equipment allowing to locate each FAD with great accuracy and at great distances, night and day,
3) the increasing numbers and improved equipment of the supply vessels used in the Indian & Atlantic oceans,
4) the improved capabilities of FADs to evaluate the amount of tunas associated to them: universal use today of echosounders on all FADs,
5) the improved knowledge of skippers concerning when & where the FADs should be deployed.

Most of these changes have been well examined in various documents, for instance during the CECOFAD program recently ran by EU scientists (Gaertner *et al* 2016). Following these major changes and increase in the use of FADs in the Atlantic and Indian oceans PS fisheries, it should be accepted that the fishing efforts on FADs have been permanently increased since the mid-eighties. A constant yearly increase of the FAD fishing efficiency at a rate of 2.5% yearly increase was estimated to be a minimal one, and it was kept as an hypothesis to illustrate this trend in **Figure 3**. This FAD fishing effort will also be used to examine the relationship between FAD catches by PS and the PS efforts. The fishing efforts exerted by the other gears targeting tunas (for instance longliners and artisanal gears) are very difficult to measure precisely and they are variable in each ocean, but there is no doubt that they have also showed most often similar increasing trend. These universal increases of fishing efforts targeting tuna stocks is the basic reason explaining why most tuna stocks are estimated to be fully exploited today.

3.3 Yearly catches by species and area of FAD fisheries

It should be first noted that the world tuna catches are dominated by purse seine fisheries that have been catching in recent years 66 % of tropical tunas total catches (**Figure 4**). It can also be estimated, based on our data, that about 50% of the PS catches were caught associated to FADs (average period 2006-2015).

It should be noted in particular that today more than 1 million tons of skipjack are taken yearly on FADs, while FAD fisheries are also catching yearly a total combined weight of about 400.000 tons of bigeye and yellowfin (**Figure 5**).

A comparison of the FAD and non FAD world catches by purse seiners, for each species, shows the following facts:

- Yellowfin catches (**Figure 6**): always dominated by non-FAD catches, most often of large yellowfin, and a paradox with quite stable yearly FAD & free schools catches by each fishing mode observed since 2000,
- Skipjack catches (**Figure 7**): always dominated by FAD catches, and since 2000: steadily increasing catches of each fishing mode, skipjack sizes caught on FADs & on free schools being nearly identical

[2] This hypothesis of 100.000 FADs followed by world tropical purse seiners would correspond to an average number of 140 FAD followed by each average PS (a number that is well under the numbers of FADs followed in the Atlantic and Indian oceans)

- Bigeye catches (**Figure 8**): always widely dominated by FAD catches. Since 2000: stable bigeye catches by each fishing mode; a strange paradox that bigeye FAD catches were very stable since 1995, this stability of the FAD bigeye catches being observed in each of the 4 oceans (**Figure 9**).

Yearly catches of purse seiners on FADs and by other fishing modes are shown by **Figure 10** and these catches are interesting to examine and to compare.

- **In the Western Pacific:** tuna catches are reaching their highest levels in both the FAD and in the free school fisheries, reaching levels close to 1 million tons for each fishing mode. Yearly catches of FADs and on free schools are showing steadily increasing trends during most of the period, but showing in recent years a plateau of FAD catches. This plateau was probably due to the management regulations introduced during recent years by WCPFC on FAD fishing. It should also be noticed that the species composition of the catches by the 2 fishing mode is very similar, simply showing a higher percentage of bigeye in the FAD catches (an average 6 % of bigeye during the 2010-2014 period, versus only 1 % of bigeye in the free school catches).
- **In the Eastern Pacific**: FAD catches have been permanently increasing in the area, reaching 300.000 tons in recent years, while the combined yearly catches on free schools and on dolphins are showing quite stable catches (FAD catches being larger since 2010). These figures also show the totally distinct species composition permanently observed in the FAD catches, showing a majority of skipjack (average percentage 2010-2014 of 68%) and a large percentage of bigeye (average percentage 2010-2014 of 18%), while the free schools and dolphin school catches were dominated by yellowfin and with very few bigeye.
- In the **Atlantic**: FAD catches have been steadily increasing in this ocean, reaching now levels that are nearly 4 times larger than the free school catches. On the opposite, the catches on free schools have been steadily declining between 150.000 tons 35 years ago, to only 50.000 tons nowadays. It should also be noticed that the species composition of free schools and FAD catches is most often totally distinct[3], free schools catches being dominated by catches of large yellowfin, that are nearly absent in the FAD catches. bigeye catches are significantly observed in each fishing mode, but FAD catches showing a larger percentage of bigeye (average 2010-2015=12%, most often small bigeye) compared to the average of 6% in the free school catches (most often large bigeye).
- In the **Indian Ocean**: Catches on natural logs and on FADs have been always much higher than on free schools (an average of 200.000 t. on FADs vs 100.000 t. on free schools since 1986), both series of catches showing some fluctuations, but without a marked trend during the last 30 years. It should be noticed that as in the EPO and Atlantic oceans, the species composition of FAD catches is most often totally distinct[4]: free school catches being dominated by catches of large yellowfin, that are nearly absent in the FAD catches. bigeye catches are significantly observed in each fishing mode, but FAD catches are most often showing a larger percentage of bigeye (average 2010-2015=8%, most often small bigeye) compared to an average of 3 % of bigeye in the free school catches (most often large bigeye).

Concerning skipjack caught by the world PS fisheries it is interesting to compare the yearly skipjack catches by FAD and by non-AD fishing that have been observed in the western Pacific and in the other 3 oceans (Atlantic, Indian & Eastern Pacific combined). This overview analysis of the skipjack catches by purse seiners in each of these 2 oceanic areas (**Figures 11** and **12**) summarizes the major peculiarities observed in the western Pacific and the marked similarities in the other 3 Oceans:

- In the 3 other oceans combined (EPO, Atl & IO), free school skipjack catches were quite stable and at very low levels since 1980: skipjack catches at about 100.000 t., while total skipjack FAD catches have been steadily increasing since 1990, but reaching today only 0.5 million t.,

[3] In the Atlantic ocean, the species composition of FAD and free schools catches is very similar only during the 3rd quarter in the Cape Lopez area.
[4] In the Indian ocean, the species composition of FAD and free schools catches is very similar only during the 2nd quarter in the Mozambique channel area.

- In the Western Pacific, PS fisheries have been showing steadily increasing skipjack catches, this increase being observed for both the FADs and free school catches reaching similar very high levels for the 2 fishing modes (reaching now a total of about 1.5 million tons of skipjack). These very large catches of skipjack in the WPO remain difficult to understand: In the Western Pacific, average skipjack catches have been reaching 30. 000 t. per million km2 fished by PS, i. e. at a level well above skipjack catches per area in any of the other oceans: 4.000 t. in the EPO, 6000 t. in the Atlantic and 11000 t. in the Indian Ocean. On the opposite, the average catches of yellowfin & of bigeye per million of km^2 fished by PS in the 4 Oceans are much less variable, the average catches per area being also high in the WPO, but at quite similar levels to the other 3 Oceans. These very high skipjack catches in the WPO are surprising because the biological productivity in this area is not larger than in the other oceans, even if various sources of biological enrichment have been identified in this ocean (SEAPODYM, Lehodey 2010).

3.4 Heterogeneity of species composition of FAD and free schools sets

Most sets on FADs show, worldwide, a combination of the 3 species of tropical tunas, yellowfin, skipjack and bigeye. It is of great scientific interest to examine the heterogeneity in these species compositions observed in the multispecies samples of the FAD associated catches obtained in each ocean and in comparison to free schools samples. This result is well shown comparing De Finnetti ternary plots (De Finetti 1937, Fonteneau *et al* 2009). These ternary plots have been used to show the frequencies of the species composition observed in the multi species samples done on each fishing mode, FAD & non FADs catches:

- In the Atlantic and Indian oceans, **Figure 13**: these ternary plots are built using pies, the surface of each circle being proportional to the frequency of the 3 species sampled; the blue fraction in each pie adds a 4th dimension to the figure, showing the fraction of the circle corresponding to large tunas over 10 kg (bigeye or yellowfin). In addition, the percentages of pure yellowfin, skipjack or bigeye samples is also shown for each figure.
- In the Western Pacific, **Figure 14** (taken from Hare *et al*. 2015) shows the same ternary plots for the FAD and free school catches, but based on a color plot obtained by krieging.

These figures show that FAD catches are very seldom monospecific: a great majority of FAD catches showing the 3 species (skipjack, bigeye & yellowfin) most often with small size tunas. On the opposite, these figures show, at least in the Atlantic and Indian oceans, that the free school catches often show a single species, most often large yellowfin over 10 kg. On the opposite, large bigeye have been very seldom sampled in the FAD catches. It should also be noted that the typical species composition pattern of free school catches observed in the Atlantic and Indian oceans was not observed in the Western Pacific, this area showing ternary plots of FAD & of free schools catches that are quite similar (FAD catches simply showing lower percentages of yellowfin and a higher proportion of bigeye). It is recommended that these ternary plots should be standardized and used in all oceans in order to analyze the heterogeneities of the species composition of FAD and free schools catches.

3.5 Catch at size of tunas caught on FADs compared to catches on free schools and by other fishing gears

3.5.1 Overview

Similar patterns of average sizes caught have been observed worldwide in most FAD fisheries of yellowfin, skipjack and bigeye. Most tuna caught under FADs are showing dominant sizes well under 1 meter (**Figure 15**) and similar average weights for each of the 3 species. Catch at size of the 3 species in the FAD fisheries show that small size yellowfin & bigeye between 30 and 70 cm are frequently associated to FADs in all the oceans, in a range of sizes similar to skipjack. On the opposite, the adult yellowfin or bigeye are very seldom caught on FADs.

Catch at size data (CAS) are the basis of all the stock assessment methods classified as Sequential Population Analysis (VPA and others). These CAS data are also very interesting to examine *per se* as they show the relative importance of FAD catches at each size in the landing of each species. If these CAS are based on good data (good total catches and good size sampling), they allow to show the relative CAS of the FAD fisheries compared to all the other fisheries, and then the relative fishing mortality of each fishing mode. As an example in the Indian Ocean bigeye fisheries, the CAS of FADs and of the non-FADs fisheries are showing that the FADs fishing mortality corresponds:

- to 84 % of the total mortality of small bigeye at sizes under 10 kg (or 74 cm),
- but to only 2 % of the Fishing mortality suffered by the adult bigeye at sizes over 1 m.

These CAS by the FADs and by the non-FAD fisheries have been estimated in the Atlantic, Indian and eastern Pacific oceans for yellowfin (**Figure 15**), skipjack (**Figure 16**) and bigeye (**Figure 17**). The same average CAS are shown by 2 distinct types of figures: figures showing the number of tunas caught at each size, and figures showing the weight caught at each size. These 2 types of results are estimated to be of great scientific interest, both in the stock assessment calculations and for fishermen.

3.5.2 Yellowfin

Small yellowfin under 70 cm are caught in similar proportions on FADs and by the other fisheries. On the opposite, large yellowfin are mainly caught by longliners, purse seiners in free schools and dolphin schools and also by other gears (for instance hand line), while large yellowfin are seldom significantly caught on FADs (**Figure 16**).

3.5.3 Skipjack

Skipjack landings show quite similar sizes caught under FADs & in the other fishing modes (free schools, baitboats and others), but sizes of skipjack caught on FADs are often caught at smaller sizes than on free schools, for instance in the Indian and Atlantic oceans (while skipjack caught on FADs are larger in the EPO) (**Figure 17**).

3.5.4 Bigeye

The numbers of small bigeye caught on FADs are widely dominant in all the oceans in the total catches of small Bigeye (for instance bigeye caught at sizes <70 cm). On the opposite, large bigeye are mainly caught by longliners, seldom by PS and very seldom by any other gear (**Figure 18**).

3.6 Optimal sizes of tropical tunas?

The biomass of each cohort as a function of its age shows, for each species, a typical pattern that is conditioned by its growth rate in weight of each species and by its natural mortality at each age. As a result, there is for each species and under given exploitation rates, an optimal age/size when the cohort weight is maximal, this peak of biomass being more or less marked depending of the species. As a result, when a species shows a marked peak of biomass at its adult ages, then the large catches of juvenile tunas tend to decrease the productivity of the stock (in addition to the reduction of recruitment in the spawning stock due to the catches of juveniles). However & of course, these optimal sizes are not constant for a given species, but decreasing at increasing exploitation rates of the stocks. The optimal sizes of tropical tunas can be estimated by simulation and from the results of the stock assessment models.

The consistent growth curves recently estimated in the Indian Ocean by Eveson *et al*. (2014) are also useful to compare the monthly growth rates in weight as a function of age for each species. This result has been summarized in **Figure 19**. Skipjack growth shows very low growth rates in weight and quite stable growth rates during the entire life: average growth rates close to only 100 g / month. Juvenile yellowfin and bigeye also show low growth rates when they are in the FAD fisheries: average growth estimated between only 150 to 200 g/month (then higher but still close to skipjack growth rates). Recent studies on the yellowfin and bigeye growth (as by Eveson *et al*., 2014) are also showing that after their slow growth rates stanza in the FAD fishery, these 2 species are showing a marked acceleration of their growth rates in the period before reaching their sexual maturity. Yellowfin & bigeye do show much higher growth rates, close to 1 kg /month for young adults. Yellowfin young adults at age 3 show a higher peak of average growth rates (estimated at levels > 2 kg/month), then a peak of growth rates at a larger level than for bigeye. The older adult bigeye also show quite high growth rates, over 500 g/month, even for the old adults between 6 and 9 years, while growth rates of adult yellowfin are showing a marked decline of their growth rates at ages over 5 years. The optimal sizes were tentatively estimated for each species in order to evaluate the profiles of biomass at age expected for each species and to evaluate the optimal size/age in each of our 3 species. This profile of biomass was estimated only for tuna stocks that are assumed to be heavily exploited at levels close to their MSY.

The simulation method proposed by Fonteneau 1974 was used to obtain these results, based on typical growth curves (VB model) and vectors of natural mortality at age of each tuna species. The simulation method follows the individual growth and statistical decay of individuals belonging to a large cohort: their individual growth (each individual with independent k, t_0 and L infinity), and their decay is due to a combination of fishing and natural mortality.

Typical patterns of biomass at size estimated by this method for each species are shown by **Figure 20**.

- Skipjack cohorts biomass never show a clear maximum of their biomass at age: as a result, FAD catches of skipjack do no reduce the productivity of the skipjack stocks, even if they may reduce the CPUEs and catches of other fisheries.
- On the opposite; yellowfin and bigeye cohort biomasses show similar & very clear patterns, always low biomass in the range of sizes exploited by FADs (30 to 70 cm) and a marked peak of biomass at adult sizes: for yellowfin, maximum productivity in a range of sizes between 90 & 120 cm and for bigeye at larger sizes, between 100 & 140 cm.

These preliminary results are mainly indicative bu probably quite strong; their uncertainties should be explored by further analysis based on simulations, but they appear to be highly logical ones and well in phase with the present biological knowledge of most tuna scientists and with the results obtained by statistical stock assessment results.

4 Discussion

World FAD catches of skipjack by purse seiners have been permanently increasing since the eighties, following the permanent increase of the PS fishing capacity and their increased use of FADs. This relationship between skipjack catches by PS and their fishing capacity (tentatively including their increasing use of FADs), is shown by **Figure 21**. This global relationship is showing an apparent dome of skipjack catches in recent years, while the marked increase in the FAD fishing capacity observed during the last 10 years did not produced visible large increases of the skipjack catches by PS.

The same relationship may also be analyzed between the PS FAD capacity & world bigeye FAD catches (**Figure 22**). This figure shows that the world bigeye FAD catches remained stable during the last 20 years (since 1996), while the FAD fishing pressure was widely increased. It should be noted that this phenomenon was observed in each ocean, the bigeye FAD catches were quite stable during this period in each of the 4 oceans. This stability of bigeye catches in a context of increasing fishing effort do correspond to a clear marked decline in the bigeye global CPUEs (total bigeye catch/total fishing capacity) of PS (**Figure 22**). It can be hypothesized that this marked decline was due to an unexplained & surprising decline of the juvenile bigeye catchability in the FAD fishery, or/and to a decline in the bigeye recruitment. This striking relationship between the FAD catches of small bigeye and PS fishing efforts should be carefully analyzed in each ocean.

Based on the present scientific knowledge, it appears that there is, for all bigeye stocks, a clear potential interaction between the FAD and non-FAD fisheries: FAD catches being now important everywhere and sizes caught by FAD & by the other fisheries being most often quite distinct. All the bigeye stocks are showing worldwide very similar potential interactions between FAD & LL fisheries, showing everywhere the same patterns summarized by the bigeye total CAS worldwide shown by **Figure 23**:

- bimodal catch at size: small bigeye caught on FADs and large bigeye caught by longliners, and FAD catches being well under the bigeye optimal sizes,
- bigeye catches have shown in each ocean and worldwide very large increases of FAD catches between the early eighties and today (multiplied worldwide by a factor of about 5),
- A simultaneous increase of adult bigeye catches was also observed worldwide in recent years (an average 60% increase).

In such a context: the major catches of small bigeye by FAD fisheries taken on the bigeye stocks that are fully exploited today should have a negative impact on the biological productivity of the bigeye stocks, and then reducing their MSY, but this negative impact remains difficult to estimate.

5 Conclusion

FAD fisheries have been clearly the major cause producing, since the early nineties and in all the oceans, major sustainable increases of the skipjack catches. A positive point is that these large FAD catches do not have a negative impact on the biological productivity of the skipjack stocks. On the other side, FAD fisheries have been also increasing the catches of small yellowfin and small bigeye: FAD fisheries have been the main source of major increases in the catches of small yellowfin and bigeye since the early eighties. There is no doubt that these large catches have been reducing the biological productivity of the bigeye and yellowfin stocks that are heavily fished today. However, and unfortunately, these logical negative effects of the increased bigeye & yellowfin FAD catches remain very difficult to estimate: they are widely dependent of the basic biological parameters estimated (Natural mortality by age and growth by sex) that are widely distinct (but often without clear scientific reasons) in the various stock assessment analysis done in the various oceans by the tuna RFMO, and also of the stock assessment model used. Two examples of these basic uncertainties:

1) the absurd large differences between natural mortality of the yellowfin stocks presently assumed by IOTC (very low M) and by the IATTC (very large M) (analyzed by Fonteneau 2011) in their recent Indian and Eastern Pacific oceans stock assessment analysis (Aires da Silva and Maunder 2011, Langley *et al* 2011).
2) the very low level of a constant Natural mortality of 0.8 that has been used in the Atlantic by ICCAT for skipjack until 2014 while very large (and logical) natural mortality were used in most other oceans to run the skipjack stock assessments.

In each of these 2 cases any potential differences between oceans concerning the effects of FAD fisheries are widely artificial, being mainly due to the major differences in natural mortality assumed in each analysis.

A recommendation should be made that an active cooperation between tuna RFMO scientists should be reinforced in order to better coordinate the international scientific investigations on this complex but basic question: what is the real negative impact of FAD fishing on the productivity of the skipjack, yellowfin and bigeye stocks? And what are the real effects of FAD fisheries on the recruitment of adults in the yellowfin and bigeye spawning stocks. The first necessary step in the increased scientific cooperation on FADs would be to promote a full transparency of the detailed fishery data on FADs[5] (catch, efforts, species composition and sizes).

One of major management problems faced today by each of the tuna RFMO is probably to take a full real control of their FAD fisheries: maintaining optimum levels and optimal fishing modalities of their FAD fisheries, since today FAD fisheries are clearly the only way to obtain the MSY of all skipjack stocks worldwide. This future improved management of the FAD fisheries should also find the efficient methods that will allow to reduce the catches of small yellowfin and of small bigeye, in order to maximise the MSY of these valuable stocks. This scientific endeavour will be difficult to reach at both the scientific and management levels. A first step in this efficient management of FAD fisheries would probably be to limit the number of FADs seeded in each ocean by PS at reasonable levels. This concept is quite an obvious one (we may for instance assume that it would probably be a tuna disaster if each of the PS active worldwide was following 1000 FADs as some PS today), but the optimal and maximal numbers of FADs seeded and followed by each PS and by the combined fleets should be studied by scientists.

[5] While today even the total yearly catches taken on FADs in each ocean are quite difficult to follow.

References

Anon. PEW 2015. Estimating the use of FADs around the world. Doc WCPFC12-2015-OP09. 25p.

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

Aires-da-Silva A. and M. N. Maunder, 2011, STATUS OF YELLOWFIN TUNA IN THE EASTERN PACIFIC OCEAN IN 2010 AND OUTLOOK FOR THE FUTURE, Document SAC-02-06, 89p.

Bromhead, D., Foster, J., Attard, R., Findlay, J. and Kalish, J. 2000. A review of the impact of fish aggregating devices (FADs) on tuna fisheries. Anonymous. Final report to Fisheries Resources Research Fund. Australian Bureau of Rural Sciences, Canberra.

De Finetti B. 1937. La Prévision: ses lois logiques, ses sources subjectives. In *Annales de l'Institut Henri Poincaré 7*, pages 1—68. Translated into English by Henry E. Kyburg Jr., Foresight: Its Logical Laws, its Subjective Sources. In Henry E. Kyburg Jr. and Howard E. Smokler (1964, Eds.), Studies in Subjective Probability, 53-118, Wiley, New York.

Fonteneau A. 1974. Simulation des structures démographiques. Application aux populations d'albacores. Col.Vol.Sci.Pap. ICCAT, 3: 173-179.

Fonteneau A. 1998. Atlas des pêcheries thonières tropicales, captures mondiales et environnement. Atlas of tropical tuna fisheries, world catches and environment. ORSTOM éditions, 191p.

Fonteneau A., P. Pallares et R. Pianet. 2000. A worldwide review of purse seine fisheries on FADs. In Pêche thonière et dispositifs de concentration des poissons. LeGall, Cayré et Taquet Ed., Editions IFREMER, pp15-35.

Fonteneau A., E. Chassot, S. Ortega-García, A. Delgado de Molina and N. Bez. 2009. On the use of the De Finetti ternary diagrams to show the species composition of free and FAD associated tuna schools in the Atlantic and Indian oceans. Collect. Vol. Sci. Pap. ICCAT, 65(2): 546-555.

Fonteneau A. 2011. A comparison between stocks and 2011 stock assessment results of yellowfin in the Indian and Eastern Pacific oceans. Doc IOTC SC14/2011/46. 12p.

Fonteneau A., E. Chassot and N Bodin 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. Aquat. Living Resour. 26, 37–48.

Gaertner D., J. Ariz, N. Bez, S. Clermidy, G. Moreno, H. Murua, M. Soto and F. Marsac. 2016. Results achieved within the framework of the EU research project: Catch, Effort, and eCOsystem impacts of FAD-fishing (CECOFAD)Doc IOTC-2016-WPTT18-35, 32p.

Hare S.R., S. Harley and J. Hampton 2015. Verifying FAD-association in purse seine catches on the basis of catch sampling. Fisheries Research 172 (2015) 361–372.

Langley A., M. Herrera and J. Million. 2011, Stock assessment of yellowfin tuna in the Indian Ocean using MULTIFAN-CL. Doc IOTC WPTT-2011-13-36, 79p.

Lehodey P., R. Murtugudde and I. Senina. 2010. Bridging the gap from ocean models to population dynamics of large marine predators: A model of mid-trophic functional groups. Progress in Oceanography 84 (2010) 69–84.

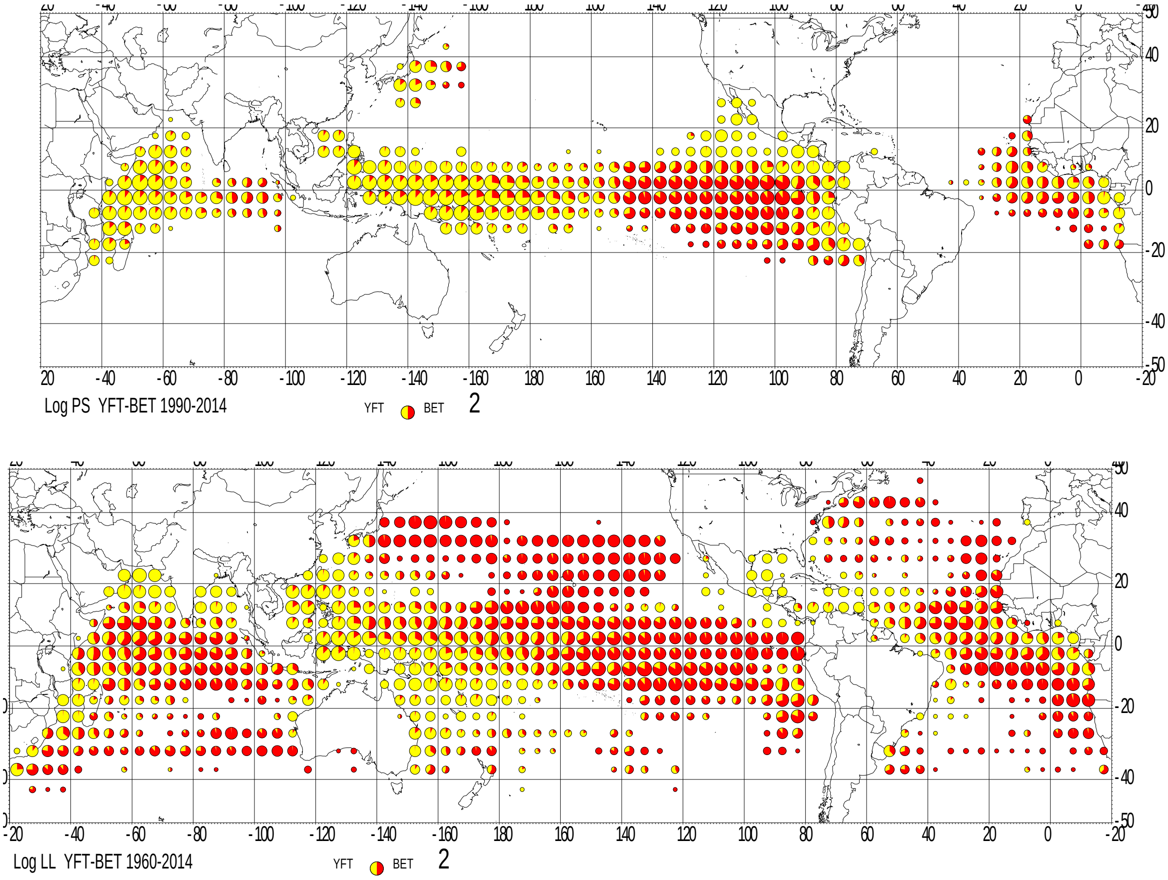


Figure 1. Map of the yellowfin and bigeye fishing zones of juvenile (PS FAD catches, upper fig. 1a) and of adult (longline catches, lower fig. 1b), shown by the log of the catch / 5° squares during the history of the PS and LL fisheries.

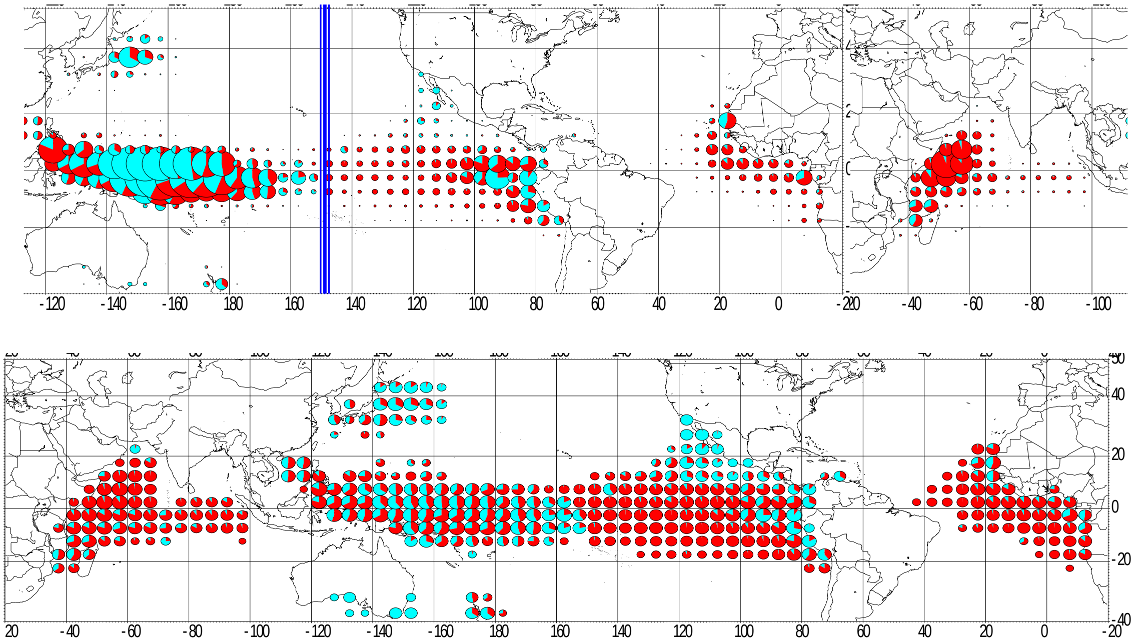


Figure 2. Skipjack catches by 5° caught in free schools and associated to FADs (average period 2000-2014, circles proportional to catches (upper map, fig. 2a), and proportional to log of the skipjack catches (lower fig. 2b).

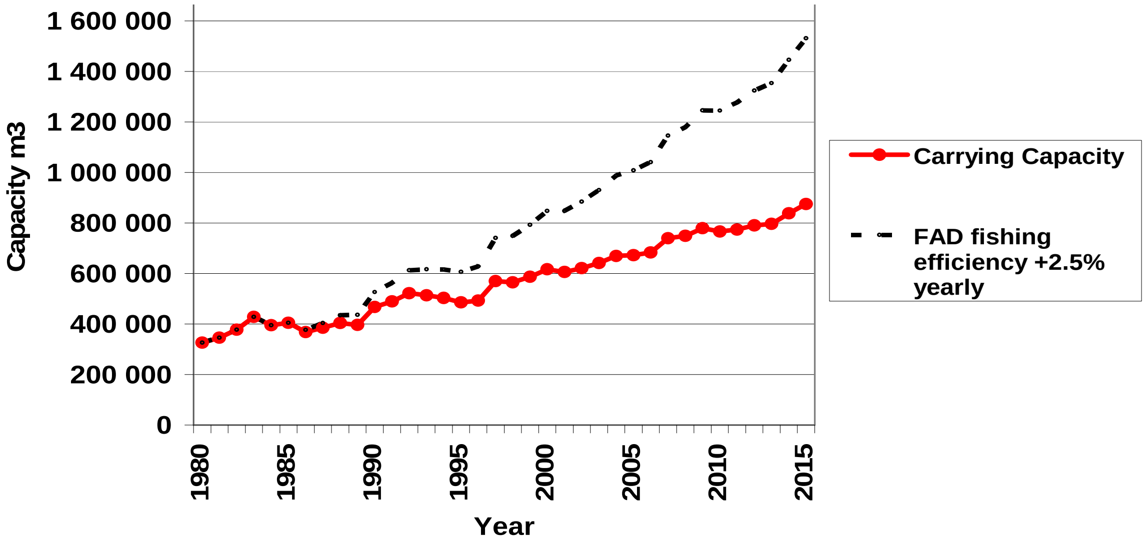


Figure 3. Estimated carrying capacity of tropical purse seine fleets worldwide (m³) and estimated of yearly fishing efforts on FADs.

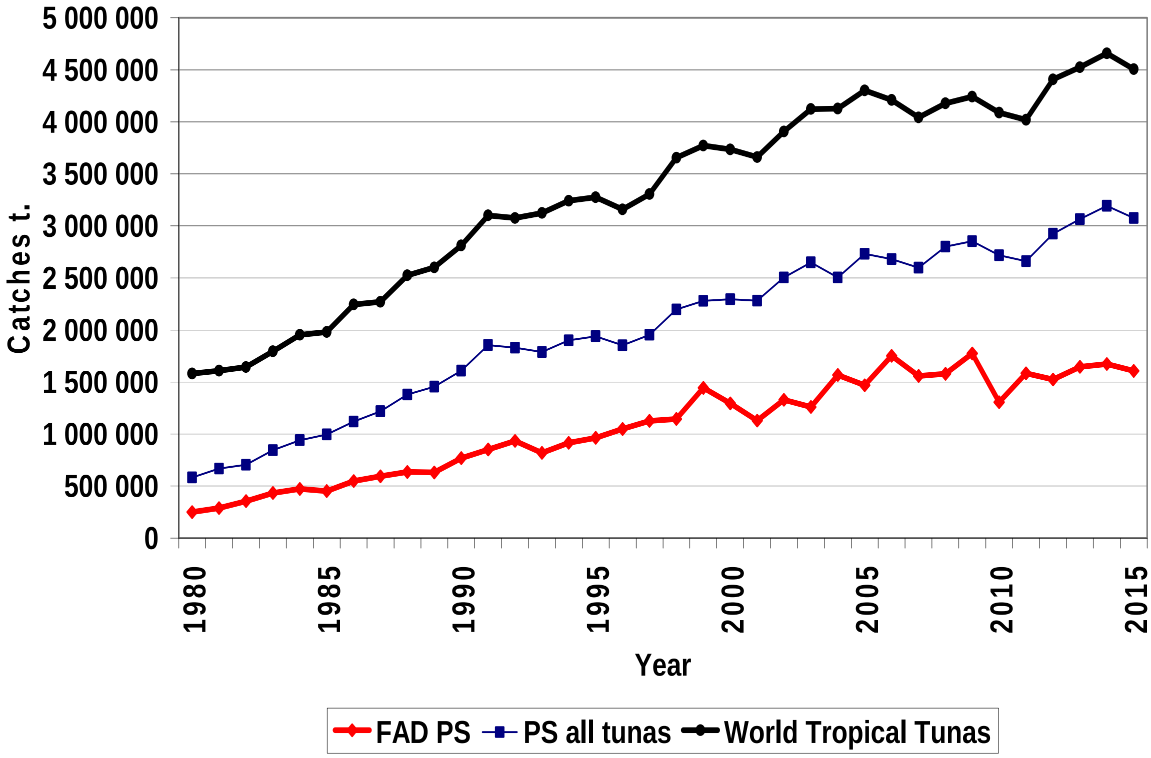


Figure 4. World tuna catches, total, by purse seiners and on FADs.

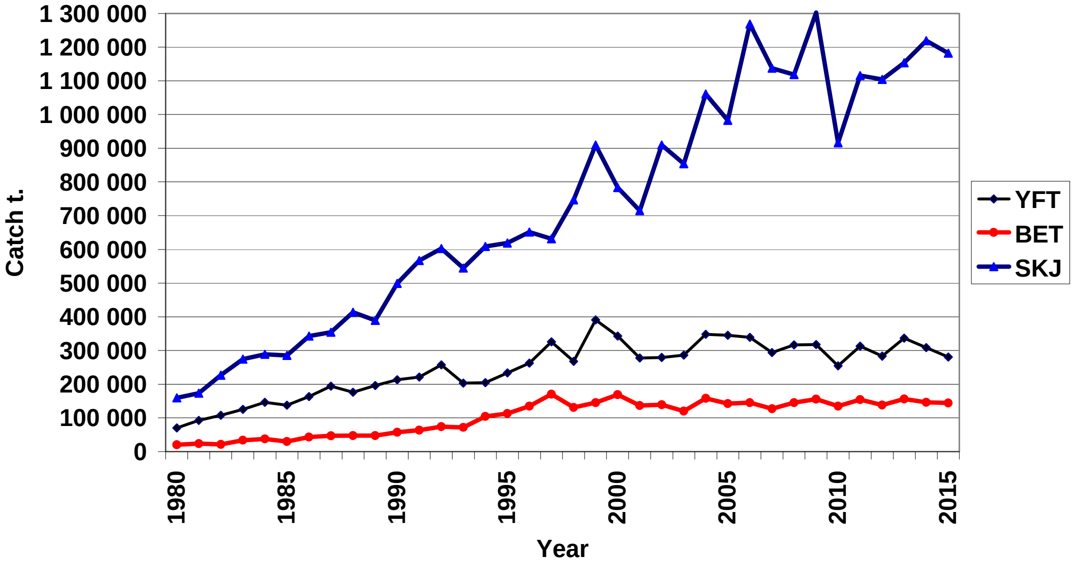


Figure 5. Yearly estimated FAD catches by species worldwide.

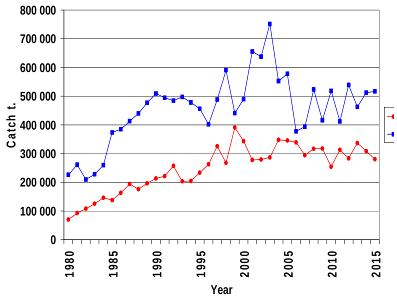


Figure 6. Yearly world catches of YFT by PS: on FAD and by others methods.

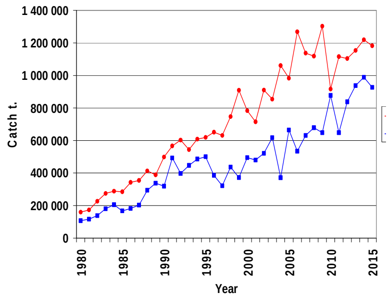


Figure 7. Yearly world catches of SKJ by PS: on FAD and by others methods.

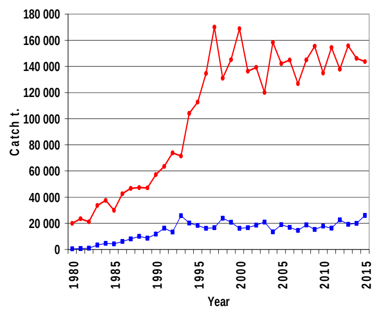


Figure 8. Yearly world catches of BET by PS: on FAD and by others methods.

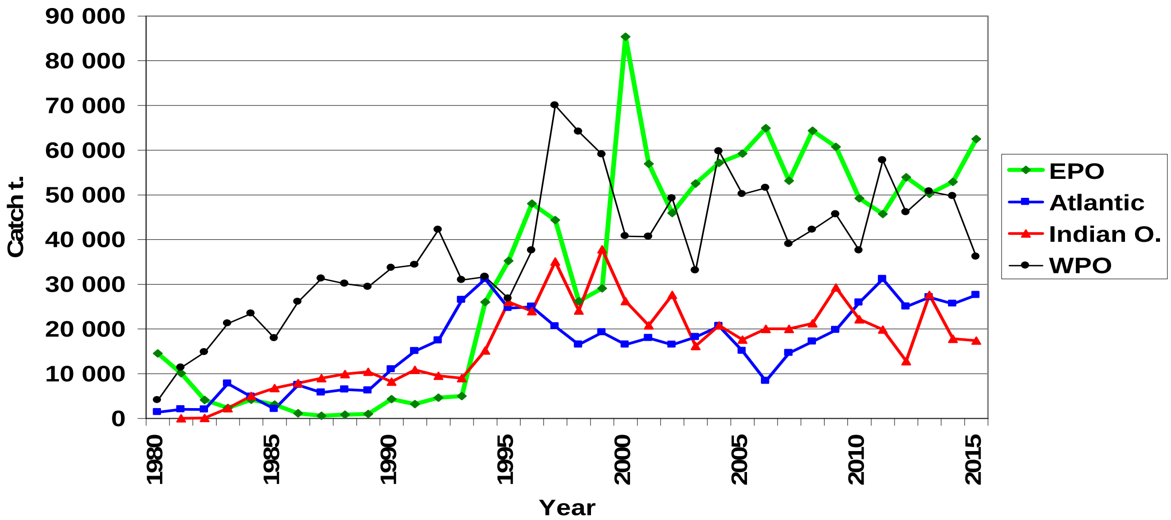


Figure 9. Yearly catches of bigeye caught on FADs in each of the four oceans.

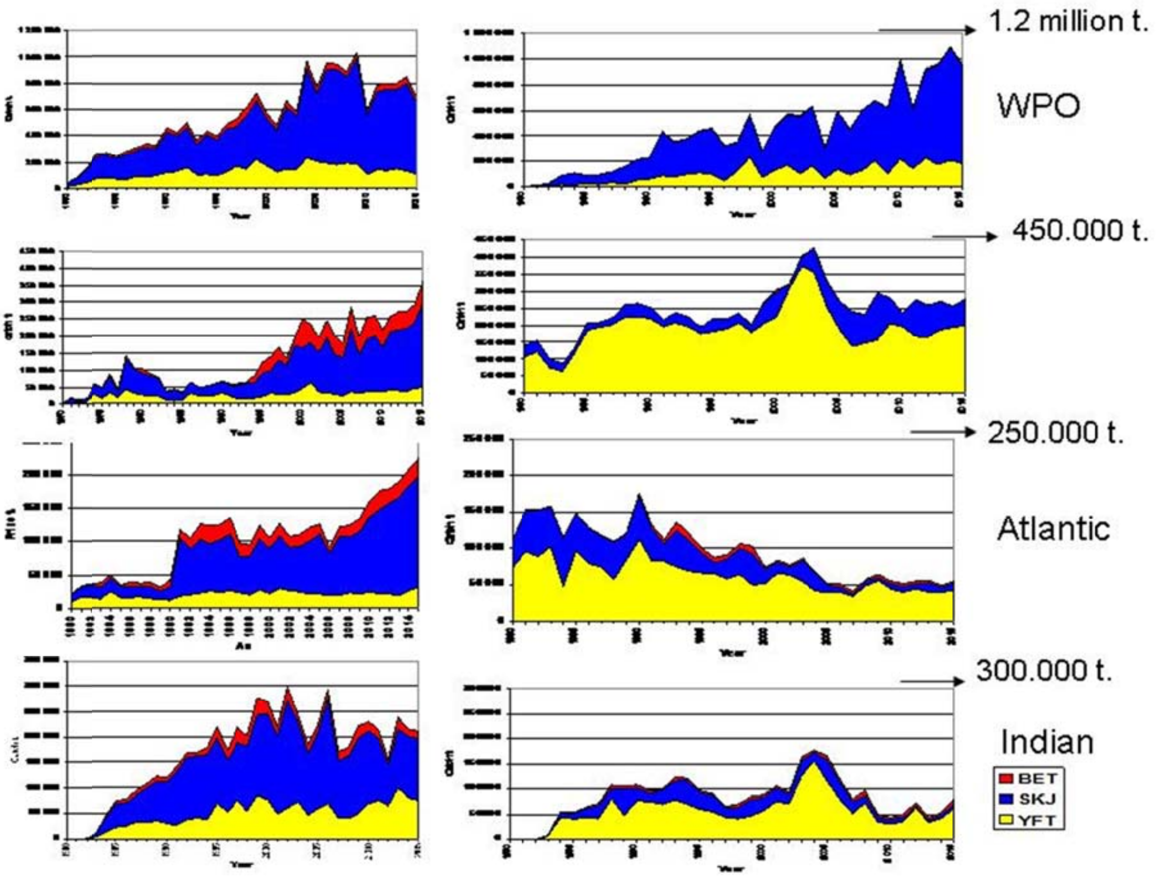


Figure 10. World yearly tuna catches of PS by species, on FADs and by other methods, in each Ocean.

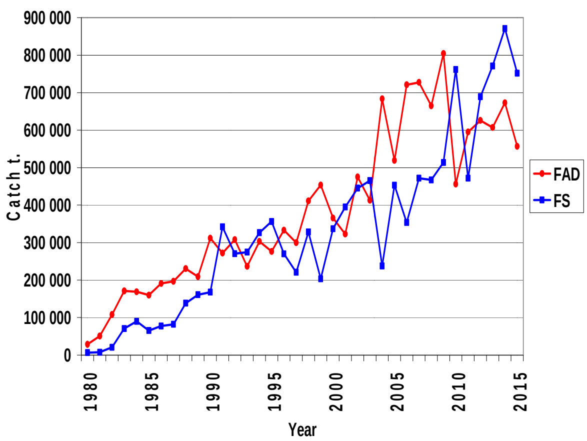


Figure 11. Skipjack catches on FAD (red) & free schools (blue) in the western Pacific.

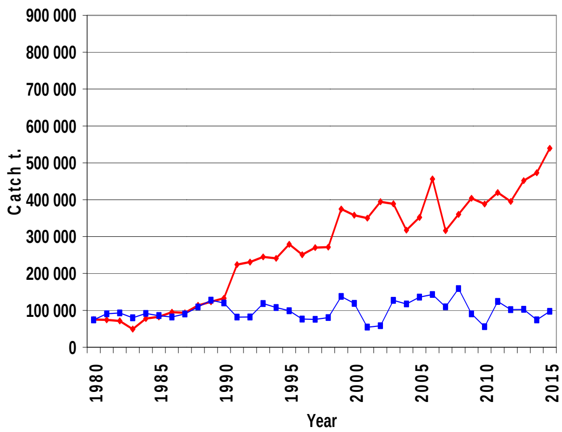


Figure 12. Combined skipjack catches on FAD & free schools in the EPO, Atlantic and Indian Oceans.

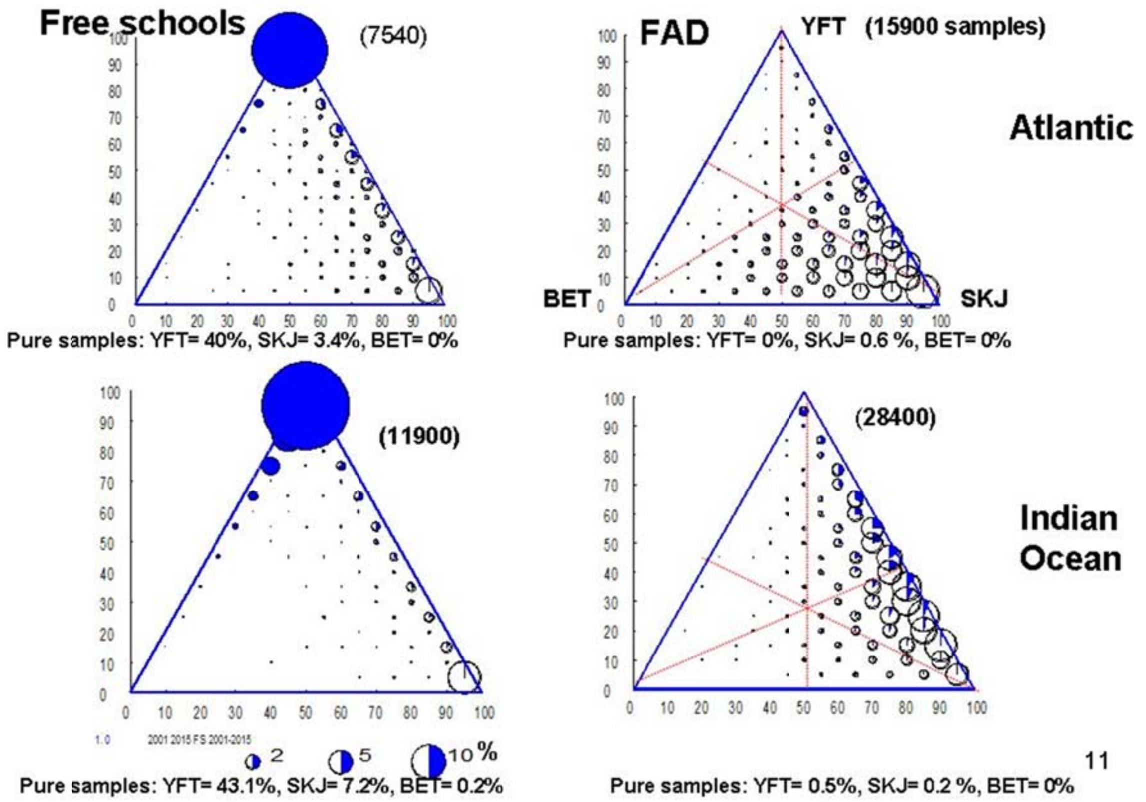


Figure 13. Average species composition of PS FAD and free schools catches sampled in the Atlantic and Indian oceans during the 2001-2015 period (large YFT&BET>10kg in blue).

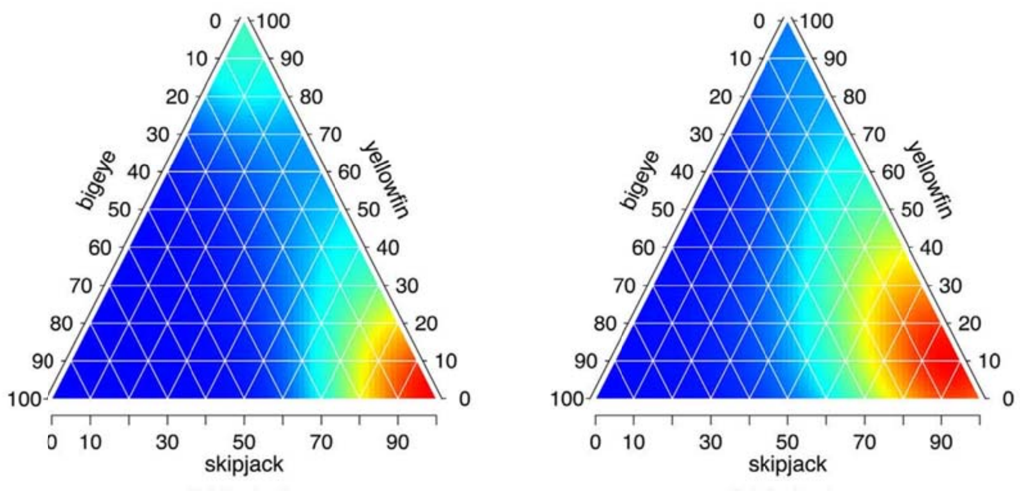


Figure 14. Average species composition of PS FAD & free schools catches sampled in the western Pacific during the XXX period (taken from Hare *et al* 2015).

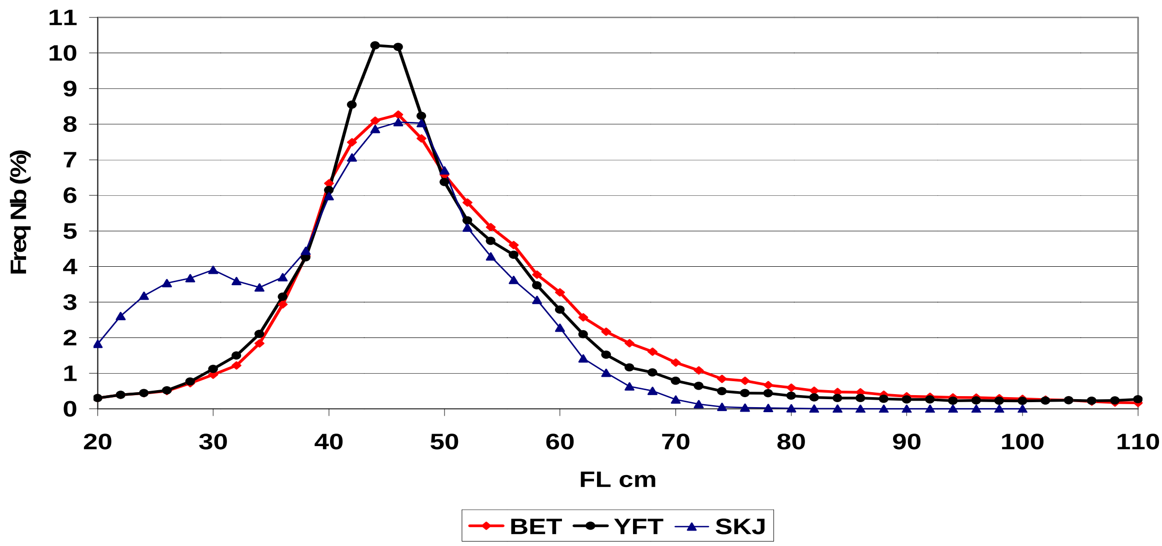


Figure 15. Average percentages of catch at size of small tunas sampled in the FAD catches YFT, SKJ and BET (worldwide average of the 4 oceans, period 2000-2009).

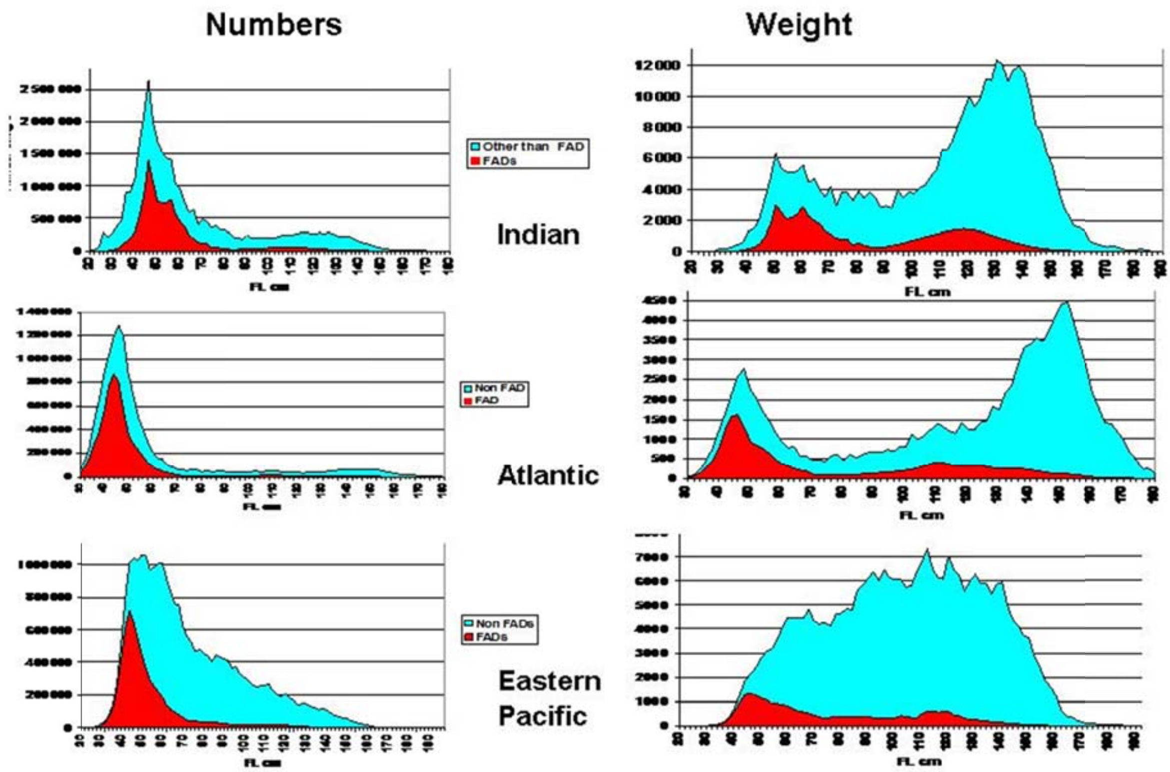


Figure 16. Average catch at size of Atlantic, Indian Ocean and eastern Pacific yellowfin by ocean, under FADs and in other fisheries, in numbers (left) and in weight (right).

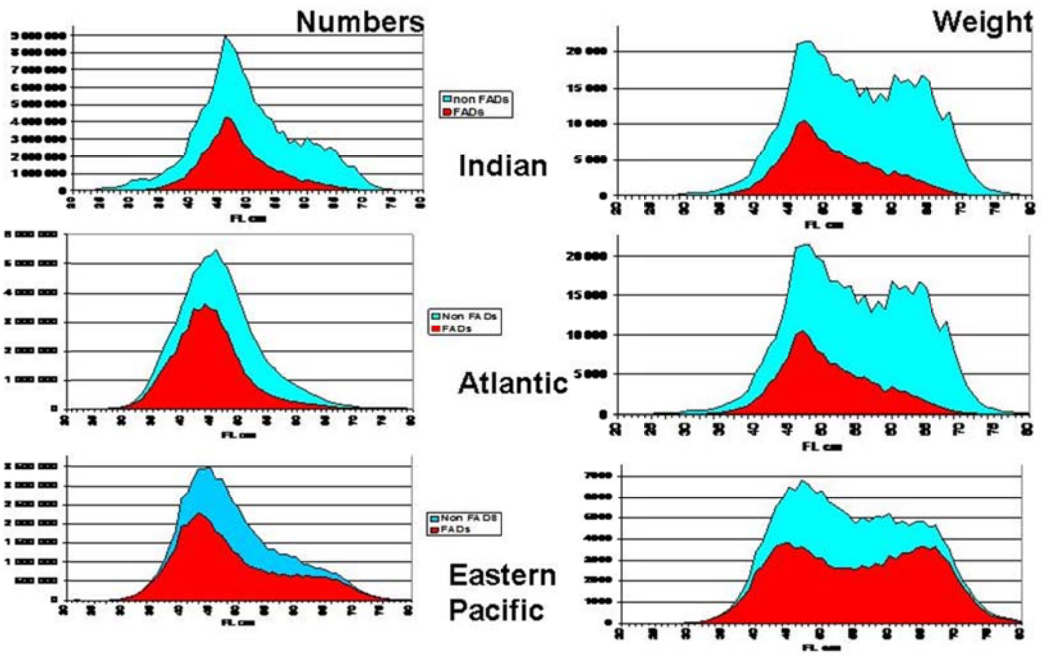


Figure 17. Average catch at size of Atlantic, Indian Ocean and Eastern Pacific skipjack by ocean, under FADs and in other fisheries, in numbers (left) and in weight (right).

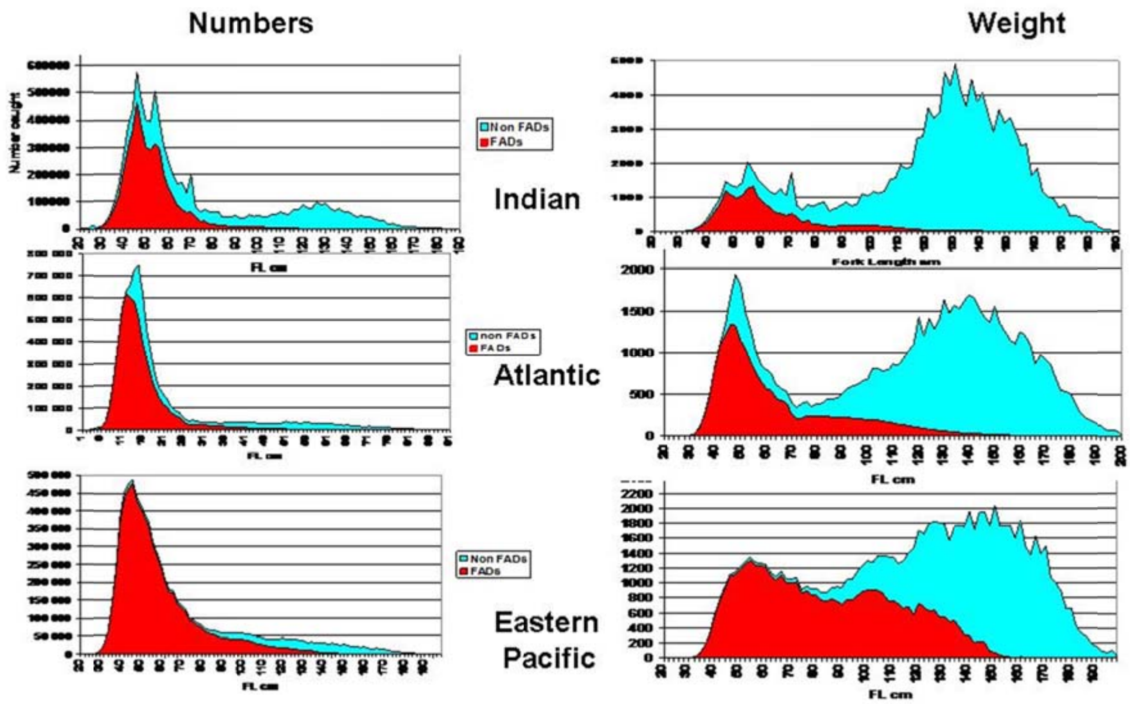


Figure 18. Average catch at size of Atlantic, Indian Ocean and eastern Pacific bigeye by ocean, under FADs and in other fisheries, in numbers (left) and in weight (right).

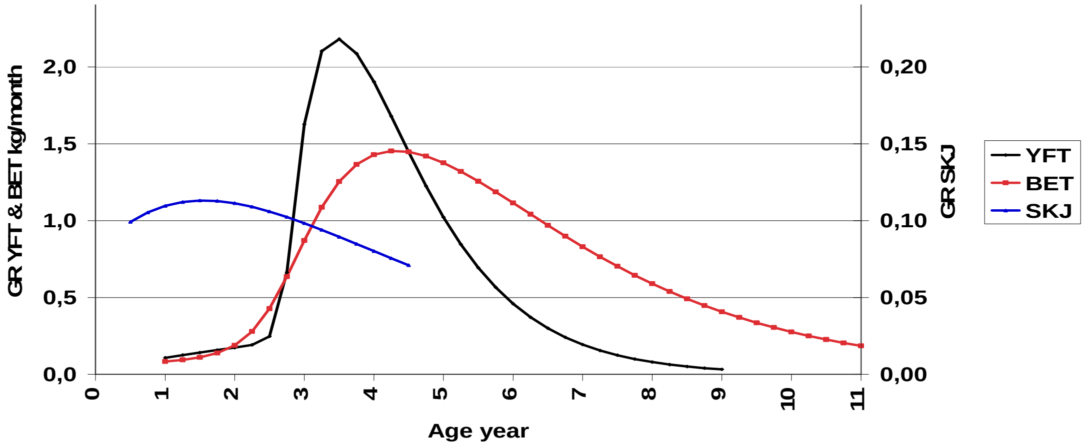


Figure 19. Monthly growth rates at age estimated for YFT, SKj and BET (in kg/month) in the Indian Ocean, mainly based on the tagging results, estimated by Eveson *et al*. (2014) (following LogVB growth curves).

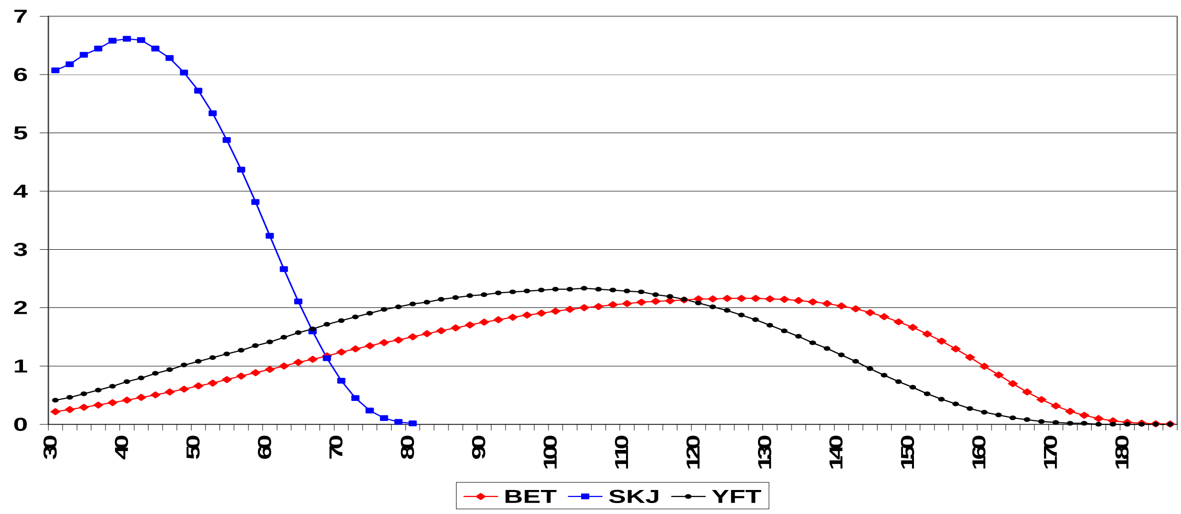


Figure 20. Typical relative biomass of YFT, SKJ and BET cohorts as a function of tuna sizes, estimated by simulation and based on typical growth curves and natural mortality at age of each tuna species estimated at exploitation rates close to FMSY.

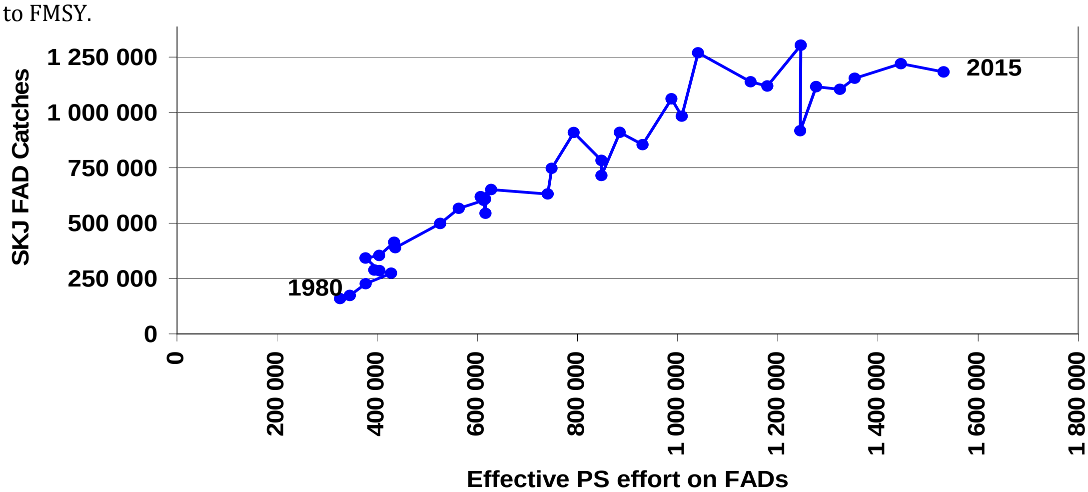


Figure 21. Relationship between world skipjack: catch & fishing effort of purse seiners (measured by the PS carrying capacity adding since 1985 a FAD efficiency factor).

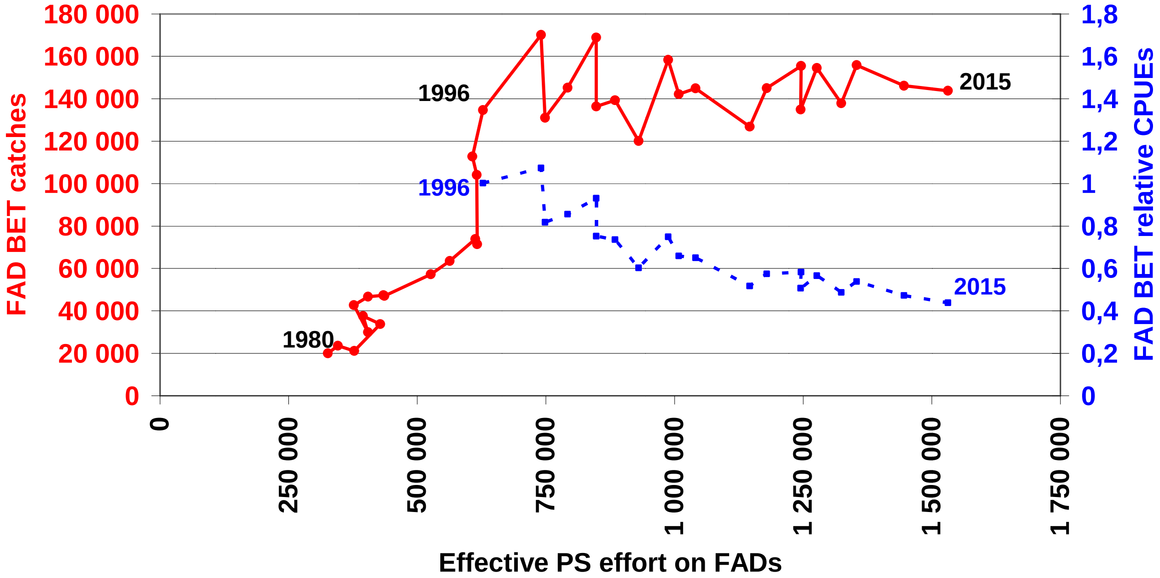


Figure 22. Relationship between world bigeye FAD catches & fishing effort of purse seiners, in red (measured by the PS carrying capacity adding since 1985 a FAD efficiency factor), and corresponding CPUE and effort relationship (in blue).

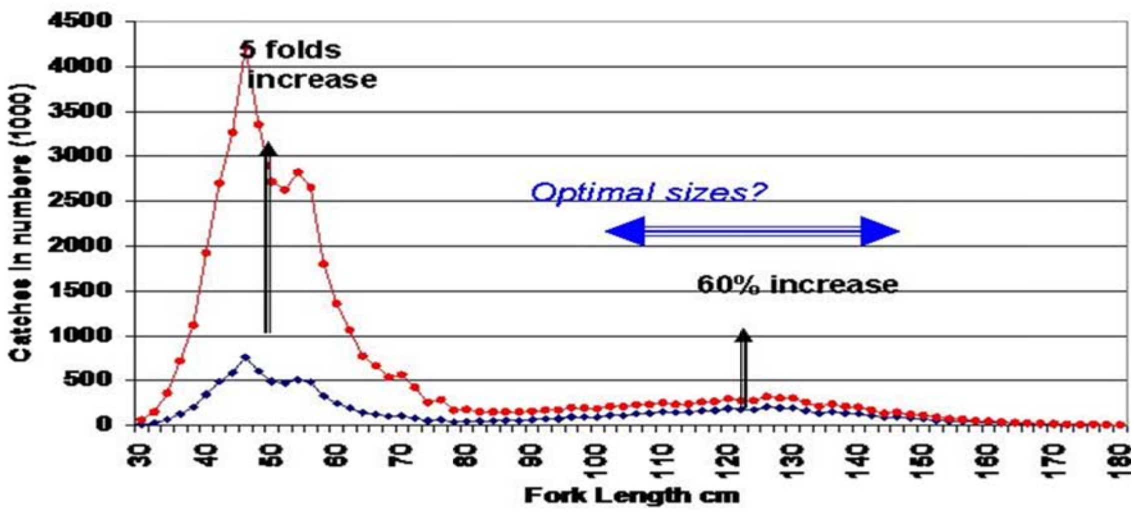


Figure 23. Average catch at size of world BET, in the80ies and today.

Original: English

MANAGING THE NUMBER OF FADS USING FISHERIES-INDEPENDENT DATA: PRINCIPLES AND THEORIES

L. Dagorn, M. Capello[1], Y. Baidai, C. Zarzar, J. Amandé, H. Andrade, M. Simier, N. Billet, L. Floch, F. Forget, M. Travassos

We present a general framework for deriving fisheries-independent abundance indicators for the populations of tropical tuna, based on their associative dynamics in an array of FADs. Our approach is based on three main components: (1) a behavioural model (2) the collection of field data (3) a set of analytical tools that allow to parameterize the model from field data. The behavioural model simulates the associative dynamics of tropical tuna in an array of FADs. We show how this model allows obtaining an association index (i.e., the ratio between the associated and total population), as well as an abundance index (i.e., an indicator of the overall population of tropical tuna that is located in the FAD-array region). The sensitivity of the two indices relative to the model parameters (number of FADs, individual tuna probability of association and to depart from the FAD) is studied theoretically. We show that two main sets of field data are necessary to parameterize the behavioural model: (i) electronic tagging (acoustic telemetry or archival tagging) and (ii) echo-sounder buoys data. This framework allows assessing the amount of associated and total population of tropical tuna as a function of the number of FADs, thus providing science-based advices for their management.

[1] manuela.capello@ird.fr (Corresponding author).

Original: English

MANAGING THE NUMBER OF FADS USING FISHERIES-INDEPENDENT DATA: PRINCIPLES AND THEORIES

M. Capello[1], L. Dagorn, Y. Baidai, C. Zarzar, J. Amandé, H. Andrade, M. Simier, N. Billet, L. Floch, F. Forget, M. Travassos

We review the state of the art of the research conducted in order to derive abundance indicators for the populations of tropical tuna in an array of FADs from fisheries-independent data. We review the type/amount of field data that has been collected/made available to scientists so far. We present how the approaches of survival analysis applied to electronic tagging data can be used to infer the association/departure probabilities to reach/depart from FADs and how this information can be inserted in a behavioural model to derive an abundance indicator. Moreover, we show the current progress in the quantification of the FAD-associated biomass from echo-sounder buoys data. Finally, we discuss the open questions and main challenges for future research actions that aim at providing science-based advices for the management of FADs.

[1] manuela.capello@ird.fr (Corresponding author).

Original: English

ASSESSMENT OF USE OF FADS IN TUNA FISHERIES OF IOTC CONVENTION AREA

M. Shiham Adam[1], Hilario Murua[2]

In the Indian Ocean use of fish aggregating devices (FADs) for commercial and industrial scale began with the inception of the purse seine fishery in the mid 1980s. Initially fishing took place on a combination of free swimming schools and schools associated with natural objects essentially originating from natural sources. During the 1990s a large number of floating objects, mainly bamboo rafts attached with pieces of old purse seine nets, were used which subsequently evolved into more purpose made drifting FADs (dFADs) with GPS tracking. More recently the standard is also to equip FADs with sonar buoys to obtain near-real time information on the nature and character of biomass underneath allowing captains to determine when and where to set the nets. Together with a secondary fleet of supply vessels assisting in deployment and retrieval of FADs, purse seine fishery have become extremely efficient in harvesting surface schooling tropical tuna species. Small numbers of anchored FADs (aFADs) are also used in some coastal States for more selective gear types.

In the IOTC purse seine catches are recorded as sets made under logs (associated) or free-swimming schools (un-associated). Roughly 80% of tropical species caught by purse seiners are now caught using dFADs. The most significant is the catch of skipjack, which in the last three years averages to 95% taken exclusively on dFADs. Skipjack targeted schools also take small amounts of juveniles of yellowfin and bigeye with is evidenced by an appreciable difference observed in the size distribution of the species caught on dFADs and free-swimming schools.

dFADs sets also catch various non-target, associated and dependent species, which includes sharks and ETP species. Lost and/or un-retrieved dFADs may end up as ghost gear entangling turtles and with unintended consequences damaging coral reefs during beaching events which needs to be investigated. Much work needs to be done on FAD fishery related data collection and harmonization

A number of conservation and management measures are in place. These include development and implementation of FAD management plans and use of non-entangling FADs. More recently limits of deployments of FADs were introduced and with reduction of that limit in 2016.

[1] Marine Research Centre, Ministry of Fisheries and Agriculture, Malé, Maldives.
[2] Azti Tecnalia, San Sebastian, Spain, European Union.

Original: English

REVIEW OF THE STATE AND AVAILABLE INFORMATION ON TUNA (ANCHORED AND DRIFTING) FAD FISHERIES AT IOTC

Hilario Murua[1]

Several resolutions in relation to FAD management and FAD data submission have been adopted in IOTC since 2013: Resolution 13/08 on Procedures on a Fish Aggregating Devices (FADs) management plan, including more detailed specifications of catch reporting from FAD sets, and the development of improved FAD designs to reduce the incidence of entanglement of non-target species; Resolution 15/07 prohibiting the use of artificial lights to attract fish in drifting FADs; Resolution 15/08 on procedures on a Fish Aggregating Devices (FADs) management plan, including a limitation on the number of FADs for the first time in a tuna RFMO; Resolution 16/01 on Yellowfin rebuilding plan further limiting the number of FADs to be used agreed on Resolution 15/08; Resolution 16/07 on the use of artificial lights to attract fish prohibiting fishing vessels to use artificial lights to aggregate fish; and Resolution 16/08 on the prohibition of the use of aircrafts and unmanned aerial vehicles as fishing aids. The provision of FAD Management Plans and information of FAD use (both for dFADs and aFADs) by Member Countries has been slow and the collection of yearly information on FADs in increasing with time. In the current presentation, the information available on tuna FAD fisheries (both anchored and drifting) is provided. These information will help the inter-tuna RFMO, as well as IOTC FAD Working Group (created in 2015 by Resolution 15/09), to assess the consequences of FADs in IOTC tuna fisheries and their ecosystems, in order to inform and advise on future FAD-related management options. Moreover, several research projects focused on FAD fisheries have been carried out in the Indian Ocean since 2003 including research aimed to improve the knowledge base of the FAD fisheries as well as the scientific based for FAD fishery scientific advice.

[1] IOTC SC Chair.

Original: English

MAIN RESULTS OF THE SPANISH BEST PRACTICES PROGRAM: EVOLUTION OF THE USE OF NON-ENTANGLING FADS, INTERACTION WITH ENTANGLED ANIMALS, AND FAUNA RELEASE OPERATIONS

Jon Lopez[1], Nicolas Goñi[1], Igor Arregi[1], Jon Ruiz[2], Iñigo Krug[3], Hilario Murua[1], Jefferson Murua[2], Josu Santiago[2]

About half of the tropical tuna caught worldwide annually is fished by purse seiners mainly using fish aggregating devices (FADs). These devices, although being a very effective fishing tool, are also controversial due to their potential impacts on the ecosystem. Since 2012, Spanish tuna freezer organizations OPAGAC and ANABAC have a voluntary self-regulated code for responsible tuna fishing. This agreement aims to decrease impacts and improve the long-term sustainability of the tuna fishery, with particular emphasis on FAD-related issues. The code promotes best fishing practices by reducing mortality of incidental catch of sensitive species (sharks, rays, mantas, whale sharks, and sea turtles) and the use of non-entangling FADs. In addition to that, the agreement is based on the following points: 100% observer coverage, continuous training of fishing crew and scientific observers, implementation of a FAD logbook, creation of a Steering Committee and continuous monitoring and data analysis by the independent scientific body AZTI.

In order to monitor and assess the level of compliance of these good practices, a system of monitoring and verification has being implemented since late 2014, and is continuously evaluated, in all the vessels of the ANABAC and OPAGAC fleets (64 purse seiners and 23 supply vessels), including Spanish and other flags, operating globally in 4 tuna RFMOs areas (ICCAT, IOTC, WCPFC and IATTC). The verification is based on specifically designed data-collection forms and in-situ observations recorded by trained scientific observers, and more recently, also by electronic monitoring systems (see the other document in this meeting by Lopez *et al.* to get details on the system of verification). Although several research institutes are involved in the program (e.g. IEO, Ocean Eye, SFA, TAAF, CSP…), AZTI is in charge of coordinating data collection and its posterior analysis by specifically developed R routines and programs. Significant results of the first two years of the Code of conduct are presented and discussed in this document.

Data

Since the introduction of AZTI in the program as independent research body, information on more than 450 fishing trips have been collected and analysed for 2015-2016 (a total of 899 fauna release and FAD-related forms; **Table 1**). Although some trials were conducted at the beginning of the program in the Pacific Ocean with the Good Practices forms, their use was not finally established, due to certain restrictions outside the program's control. However, the successful collaboration with IATTC and WCFPC permitted to obtain data of vessels operating under its observer programs, which also include certain information of interest on the interaction and faith of sensitive species and FAD data.

In this analysis, a total of 37879 FADs have been observed and analysed, as well as 30355 fauna release operations (**Table 2**).

Fauna release operations

In the Atlantic Ocean, a total of 13211 fauna release operations have been observed and analysed during 2015 and 2016. The level of conformity in the handling and releasing practices is very high, exceeding 80-90% of the conformity for most of the animal groups (sharks, whale sharks, rays and turtles) and reaching 100% in some cases (whales) (**Table 3**). Hammerheads and mantas, instead, showed values around 70% of conformity (66.5% and 70.6%, respectively). **Figure 1** shows the evolution and the boxplots of the level of conformity for each animal group throughout the first two years of the program in the Atlantic Ocean.

[1] AZTI. Herrera Kaia Portualdea z/g, 20100 Pasaia, Basque Country, Spain, jlopez@azti.es
[2] AZTI. Txatxarramendi ugartea z/g - 48395 Sukarrieta, Basque Country, Spain.
[3] AZTI. Laurier Rd, 361 Victoria, Seychelles.

Although variability can be observed between trips, the level of conformity is high for most of the vessels and animal groups. Similarly, the analysis of the releasing time showed that most of the vessels use reasonable times for fauna liberation (< 5 mins). In general, vessels showed improvements in this aspect in the last 6 months as well.

In the Indian Ocean, a total of 4646 fauna release operations have been observed and analysed during 2015 and 2016. The level of conformity in the handling and releasing practices is very high, exceeding 85% of the conformity for sharks and rays, and reaching 100% for turtles (**Table 4**). Mantas showed values around 70% of conformity. In the fishing trips analysed so far, no interaction with whale sharks, whales and hammerheads were observed. **Figure 1** shows the evolution and the boxplots of the level of conformity for each animal group throughout the first two years of the program in the Indian Ocean as well. The level of conformity observed for most of the groups was high and the time used to release animals was reasonable.

As mentioned previously, the data provided by the IATTC for the Pacific did not completely fit Good Practices data requirements. However, it contained interesting information on the faith of the sensitive species included in the program. The destiny of a total of 12498 animals was investigated. The percentage of animals released as "released alive", "returned to the sea", "released unharmed" or "not involved in set" categories was high for all the groups (~90% or even 100% in some cases), except for sharks and hammerheads (41 and 63%, respectively) (**Table 5**). **Figure 2** shows the evolution and the mean values of each releasing practice for each animal group considered in the program for Spanish vessels operating in the Pacific Ocean.

FAD-structures and components

During the first two years of the program, a total of 37879 FADs were observed and analysed (**Table 2**).

The number of FADs for which information was collected in the Atlantic Ocean and their entangling degree are shown in **Table 2** and **Figure 3**. Vessels use about 50-200 FADs in each fishing trip in this area, only considering FADs left at sea. As it can be seen in **Figure 3**, the degree of entanglement has been reducing through time and today many FADs are totally non-entangling. The major non-conformity in the construction is the use of non-permitted material in the upper part of the raft. Currently, there are very few FADs that present both raft and underwater part with certain non-conformity material (**Figure 3**). It is interesting to note that the number of FADs for which the total conformity cannot be evaluated appears to be somehow important (~35%). However, the analysis in the verification system is able to reflect vessels' behaviours and suggest vessel-specific changes where necessary.

In the Indian Ocean, the number of FADs used and analyzed for each fishing trip and vessel ranged between ~50 and 300. As for the Atlantic Ocean, FADs that are completely in non-conformity have almost dissapeared (**Figure 3**), and the main issue is related to the material used to cover the upper part of the raft. It is also interesting to note that the percentage of totally non-entangling FADs that are currently used has increased considerably through time (**Figure 3**). Likewise, there is a significant part of the FADs that cannot be completely evaluated, as certain parts of the FADs were not observed or recorded by the observer (~30%). As such, future efforts may be conducted to try to lift all FADs that are encountered at sea. This improvement would assist to better understand the deterioration of the underwater part of the FADs through time as well as assess their progressive entangling potential.

In the Pacific Ocean, the number of FADs observed and analyzed for each fishing trip was 25-250. The data collected in this region lack information on the mesh size used to construct the raft of the FAD. However, these data contain information on the mesh size used in the underwater part of the object. Because of this, the analysis conducted for this region was not identical to that applied in the Indian and Atlantic Oceans. **Figure 4** shows the evolution and use of the different mesh size nets (< 3 cm; > 3 cm) to construct FADs by the Spanish fleet. However, the ways nets are structured to construct the underwater parts are unknown, so the entangling potential cannot be accurately assessed for each FAD and thus, results are just descriptive. The 8872 FADs investigated in the two years data of the Pacific Ocean showed that 11 individuals were entangled at FADs (4 sharks, 7 turtles; **Table 6**). This means that the entangling ratio

was 0.12% for the analyzed data. Detailed results on the entangling potential by mesh size category are shown in **Table 6**.
Results of the assessed fishing practices are used six-monthly to provide scientific advice to fishing companies and the Steering Committee, who use corrective mechanisms where necessary.

Table 1. Number of fishing trips with forms of Good Practices (except *, which are data of the IATTC observer program) collected during 2015-2016 for the Spanish fleet operating in the Atlantic, Indian and Pacific Oceans.

	Atlantic Ocean	*Indian Ocean*	*Pacific Ocean*	*Total*
D2	341	53	77*	471 (394)
B2 & B3	278	33	117*	428 (311)
Total	619	86	194*	899 (705)

Table 2. Summary of the number of fauna release and FAD-structure events evaluated in the 2015-2016 period.

	Fauna Release	*FAD structure*
Atlantic Ocean	13211	22532
Indian Ocean	4646	6475
Pacific Ocean	12498	8872
Total	30355	37879

Table 3. Summary of the species caught and released by Spanish tropical tuna purse seiners in the Atlantic Ocean for the 2015-2016 period and its level of conformity in handling and releasing practices.

Group	*Incidental Catch (%)*	*Conformity*
Whales	0.03	100
Hammerheads	16.7	66.5
Mantas	4.9	70.6
Rays	0.8	89.9
Whale Sharks	0.5	90
Sharks	68.1	82.6
Turtles	8.9	94.9

Table 4. Summary of the species caught and released by Spanish tropical tuna purse seiners in the Indian Ocean for the 2015-2016 period and its level of conformity in handling and releasing practices.

Group	*Incidental Catch (%)*	*Conformity*
Mantas	0.6	69.2
Rays	0.3	86.7
Sharks	98.8	85
Turtles	0.3	100

Table 5. Summary of the animal groups caught and released by Spanish tropical tuna purse seiners in the Pacific Ocean for the 2015-2016 period and their corresponding values for each destiny category.

Group	*Incidental Catch (%)*	*Percentage*
Hammerheads	0.26	63.6
Mantas	0.06	100
Rays	0.10	100
Whale Sharks	0.06	87.5
Sharks	98.5	40.9
Turtles	1.01	92

Table 6. Summary of the number of entanglements and the category of the mesh size of the net used to construct the underwater part of the FADs analyzed in the first two years of the program in the Pacific Ocean.

Category	*Number*	*Freq.*	*Percentage*
(0,3]	3047	4	0.1
(3,10]	2483	1	0.0
(10,20]	2826	2	0.1
(20,Inf]	21	0	0.0
NA	495	4	0.8

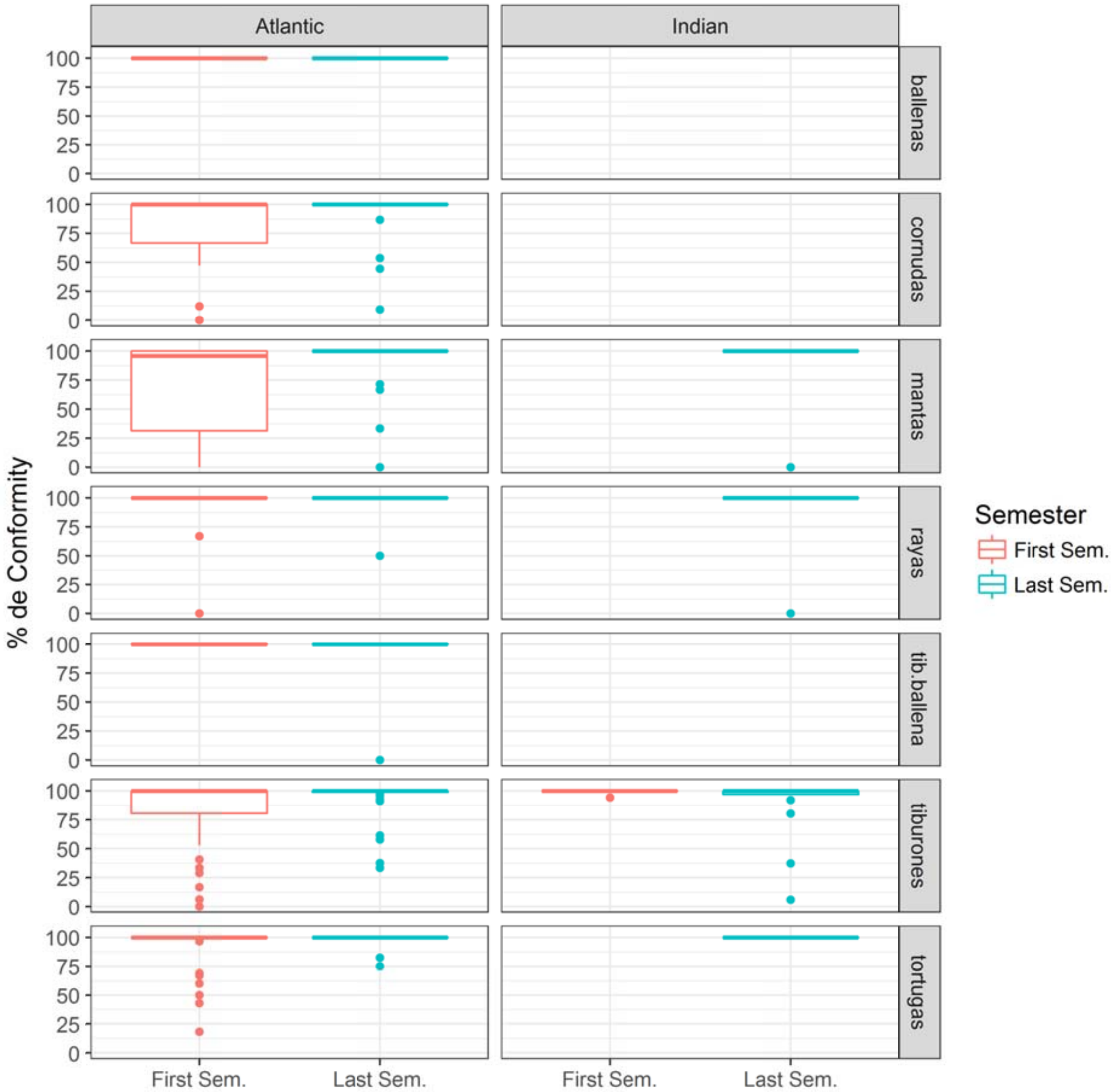


Figure 1. Evolution of the level of conformity of fauna release operations for each animal group in the Atlantic and Indian Oceans during the first years of the program. "First Sem." corresponds to the first semester of 2015 whereas "Last Sem." corresponds to the last semester of 2016.

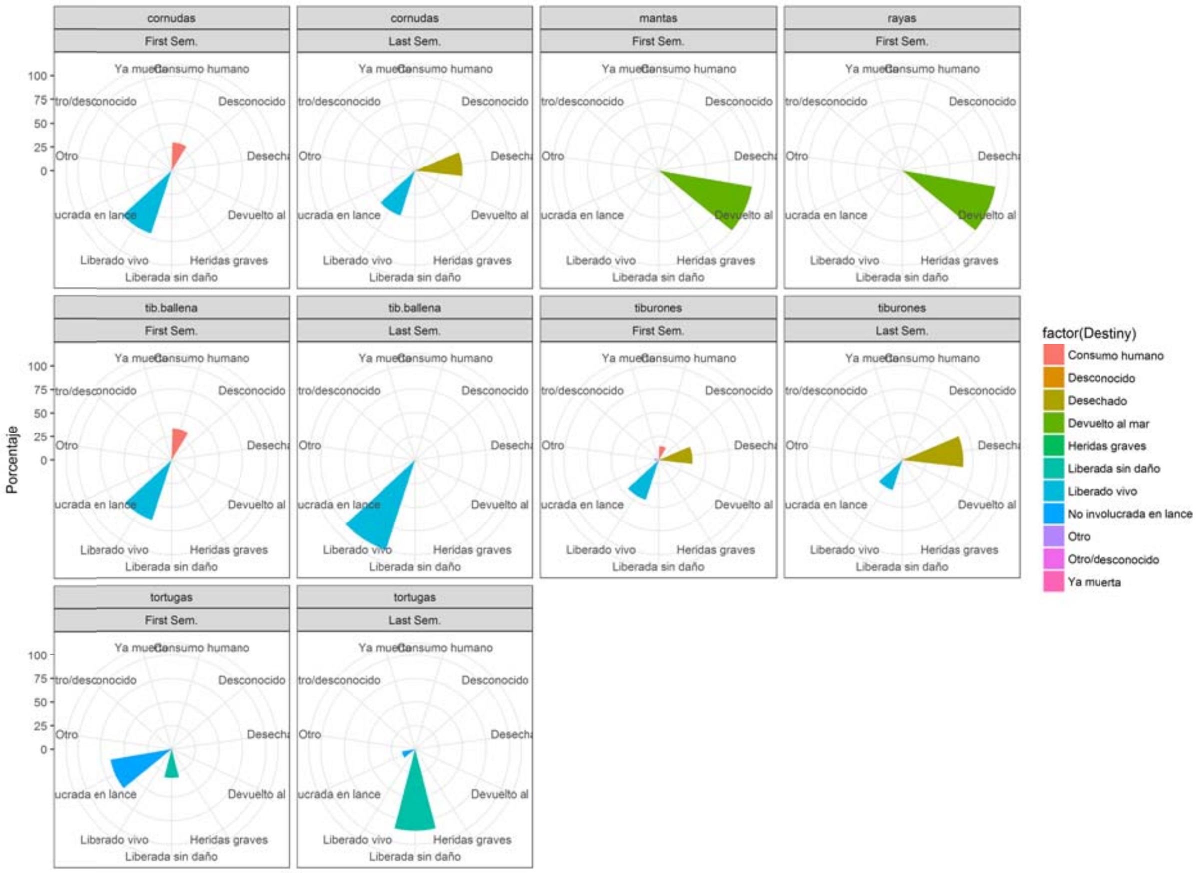


Figure 2. Evolution of destiny category for each animal group in the Pacific Ocean during the first years of the program. "First Sem." corresponds to the first semester of 2015 whereas "Last Sem." corresponds to the last semester of 2016.

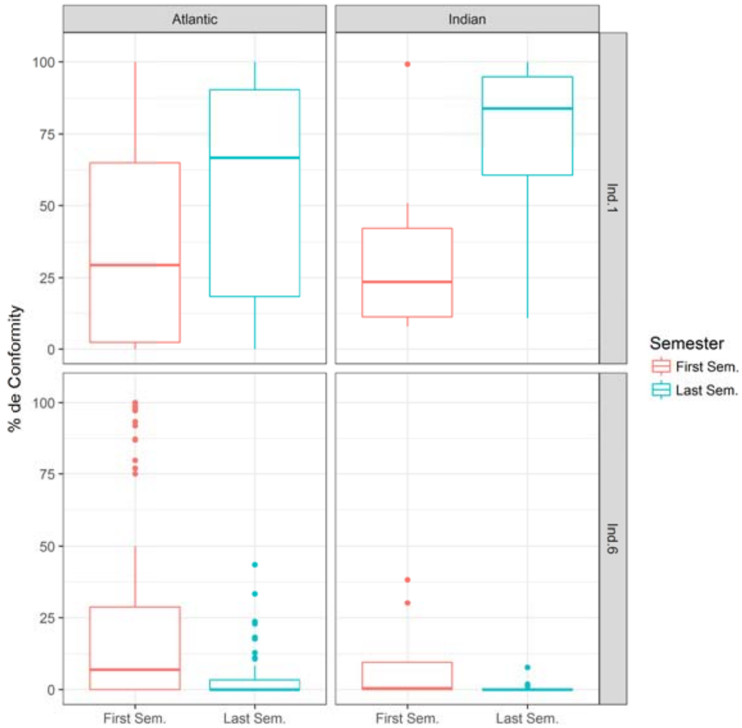


Figure 3. Evolution of the Index 1 (totally conform) and Index 6 (raft and underwater part non-conform) FAD categories in the Atlantic and Indian Oceans during the first years of the program (re-scaled with no consideration of unknowns [~35% of observations]). "First Sem." corresponds to the first semester of 2015 whereas "Last Sem." corresponds to the last semester of 2016.

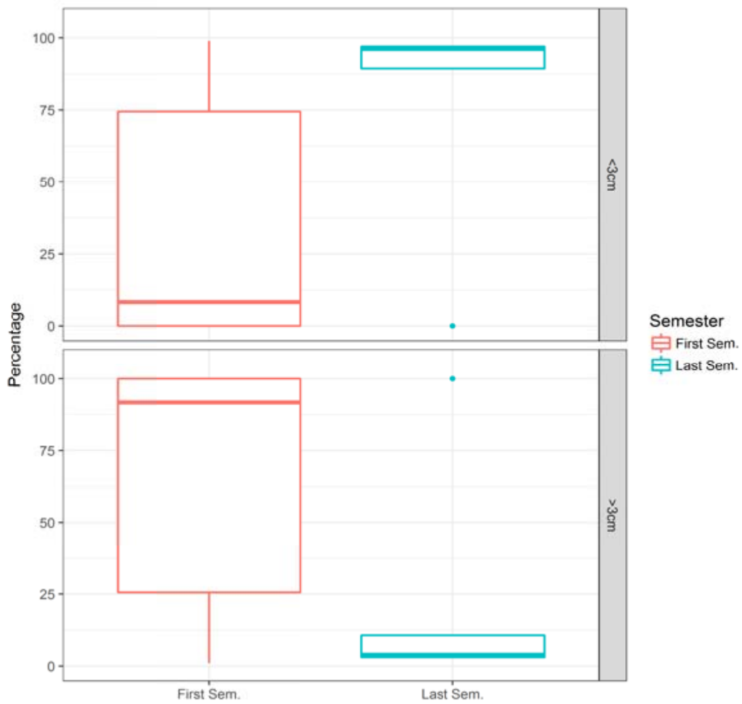


Figure 4. Evolution of the FAD underwater part mesh size categories (<3cm or >3cm) in the Pacific Ocean during the first years of the program (re-scaled with no consideration of unknowns [6.9% of the observations]). "First Sem." corresponds to the first semester of 2015 whereas "Last Sem." corresponds to the last semester of 2016.

Original: English

TAKING ANOTHER STEP FORWARD: SYSTEM OF VERIFICATION OF THE CODE OF GOOD PRACTICES IN THE SPANISH TROPICAL TUNA PURSE SEINER FLEET OPERATING IN THE ATLANTIC, INDIAN AND PACIFIC OCEANS

Jon Lopez[1], Nicolas Goñi[1], Igor Arregi[1], Jon Ruiz[2], Iñigo Krug[3], Hilario Murua[1], Jefferson Murua[2], Josu Santiago[2]

About half of the tropical tuna caught worldwide annually is fished by purse seiners mainly using fish aggregating devices (FADs). These devices, although being a very effective fishing tool, are also controversial due to their potential impacts on the ecosystem. In order to decrease impacts and improve the long-term sustainability of the fishery, the two Spanish tuna purse seiner associations, ANABAC and OPAGAC, established in 2012 a voluntary agreement for the application of good practices for responsible tuna fishing activities. The aim of this agreement is to use best fishing practices by reducing mortality of incidental catch of sensitive species (sharks, rays, mantas, whale sharks, and sea turtles) and the use of non-entangling FADs. The good practices defined in this agreement also comprise: best releasing practices for sensitive fauna, 100% observer coverage, continuous training of fishing crew and scientific observers, and the implementation of a FAD logbook. Moreover, the system also includes a Steering Committee to review the progress and functioning of the program and continuous monitoring and data analysis by the independent scientific body AZTI.

In order to monitor and assess the level of compliance of these good practices, a monitoring system was implemented, and is continuously evaluated, in all the vessels of the ANABAC and OPAGAC fleets (64 purse seiners and 23 supply vessels), including Spanish and other flags, operating globally in 4 tuna RFMOs areas (ICCAT, IOTC, WCPFC and IATTC). The monitoring is based on specifically designed forms and in-situ data recorded by trained scientific observers, and more recently, also by electronic monitoring systems. Fishing practices are assessed for each vessel every semester and results are used to provide scientific advice and identify correction mechanisms (i.e. when no-compliance is observed corrective actions are suggested to vessel owners/captains). These results also allow the Steering Committee to fine-tune the program. The Code of conduct as well as the verification mechanisms are presented and discussed in this document.

The Code

The agreed code of good practices is dynamic, flexible and based on scientific advice. Since it was first developed, the code has been constantly updated and improved. In 2014, AZTI was required by both Spanish tuna purse seiner organizations to coordinate the scientific monitoring of the program. In order to better understand the level of compliance of the fleet with the code at the beginning of the program, an initial evaluation was carried out in October 2014 through questionnaires tailored to collect information about the level of application of the best practices. This information was crucial and assisted with correct progress and development of the program in the very first stages. The most significant achievements of the program are shown in **Figure 1**, which reflects that the code and the program are alive and dynamic. Currently, the program includes the following points:

1 Design and deployment of non-entangling FADs (NEFADs)

As traditional FADs (mesh size >12 cm) are supposed to have higher risk of entanglement of sensitive species like sharks or turtles, the code forces the construction and deployment of FADs that eliminate or reduce as much as possible the potential of animal entanglement (mesh size <3 cm or >3 cm if constructed in sausages). As such, the replacement and use of lower entanglement risk FADs (and if possible NEFADs) is mandatory since February 2012 with minimum standards in designs and materials.

[1] AZTI. Herrera Kaia Portualdea z/g, 20100 Pasaia, Basque Country, Spain, jlopez@azti.es
[2] AZTI. Txatxarramendi ugartea z/g - 48395 Sukarrieta, Basque Country, Spain.
[3] AZTI. Laurier Rd, 361 Victoria, Seychelles.

2 *Safe fauna release operations*

The code develops appropriate species-specific handling procedures for sensitive fauna that always preserves crew's safety while discouraging other practices that are less favourable. These releasing procedures are based on the outputs of the EU project MADE, which have been used as standard best practice for safe release operations in tRFMOs.

3 *100% observer coverage*

All the vessels of the OPAGAC and ANABAC fleet, including auxiliary vessels, need to have an observer onboard, either physical or electronic, since January 1, 2015 (January 1, 2017 for auxiliary vessels).

4 *Implementation of a FAD logbook*

Both organizations agree to comply with the FAD Management Plan and the FAD logbook adopted by the relevant national fishing authority as well as obey the minimum data collection requirements adopted by the RFMOs.

5 *Training of fishing crew and scientific observers*

To ensure that practices are well monitored, transferred to and adopted by the skippers, crew and observers, various tools have been developed, including workshops, guidebooks, and on-line materials.

6 *External verification of all fishing activities*

AZTI coordinates data collection and conducts six-monthly reports based on in situ observations recorded by scientific observers. The level of compliance is measured through specifically prepared R routines.

7 *Creation of a Steering Committee*

The program is monitored by a Steering Committee formed by science-industry members that ensures the correct function of the agreed practices, suggesting ideas for improving and adopting changes if necessary.

The system of verification

Although many different research institutes of tropical Atlantic and Indian Ocean areas are involved in the data collection of the program, AZTI is in charge of coordinating, collecting, processing and analysing data. As such, AZTI developed specific forms in English, French and Spanish to collect detailed information on fauna release operations and FAD structure-related issues through scientific observers (**Annex I**). Once data are validated by the corresponding institute, they are sent to AZTI for double checking, storing and analysis. Several R routines have been developed for data manipulation and analysis, including scripts for data depuration, pre and post-processing and compliance analysis. Although trials were conducted to include forms in the Pacific Ocean, their use was not finally established in the region. However, the successful collaboration with IATTC and WCFPC permitted to obtain data of vessels operating under its observer programs, which included information on the interaction and faith of sensitive species and FAD data.

The level of conformity and the reason of non-conformity during fauna release operations (inevitable residual mortality; lack of specific material for liberation; real non-conform procedure), as well as the time used to release animals are computed for each fishing trip and vessel, which allows to see in detail vessel-specific behaviour and evolution for each animal group. FAD structures and components are also investigated by trip and vessel, only considering for the analysis FADs left at sea. In order to better monitor the level of compliance of vessels on FAD-related habits, 6 categories are established for analysis, from less to greater entangling potential (1: Completely Conform; 2: net of >3 cm in the inferior part of the raft; 3: net of >3cm in the upper part of the raft; 4: pieces of net >3cm in the underwater part; 5: underwater part with net >3cm; 6: raft and underwater part with net >3cm), and an additional category (0) to reflect the number of FADs at sea for which the total conformity cannot be evaluated (i.e. certain parts were not checked in detail by the observer).

Based on results from the analysis, AZTI develops six-monthly reports for each fishing company, where vessel and company-specific recommendations are provided. Results are also used as base information for the Steering Committee, which takes necessary actions to ensure the correct function of the program.

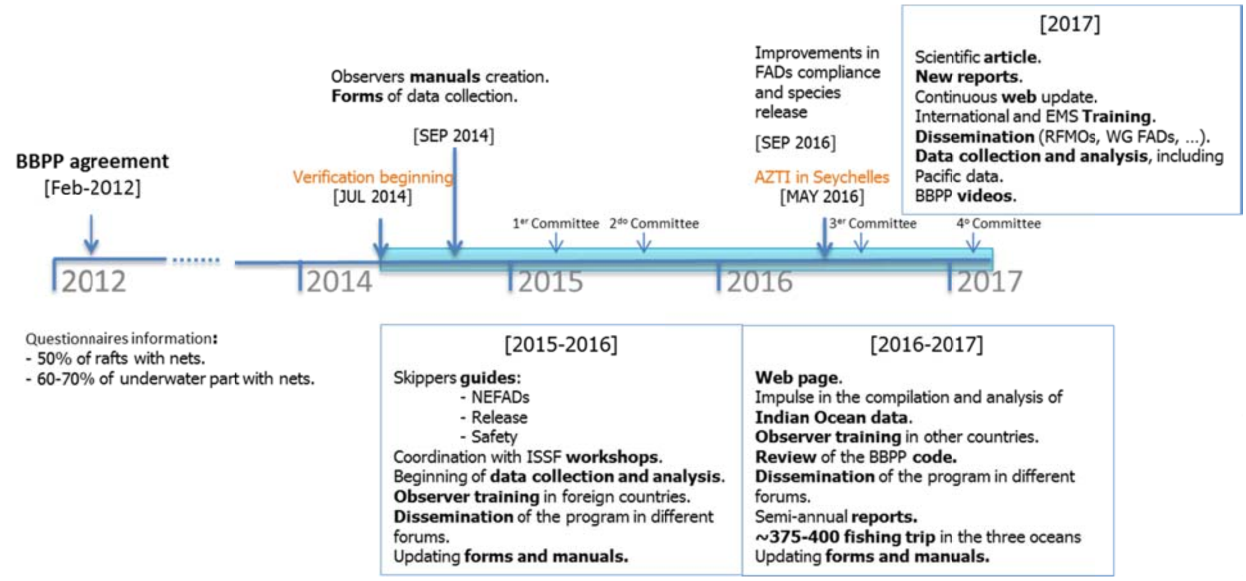


Figure 1. Timeline with the most important achievements and progress made on the Good Practices for responsible tuna fishing program since February 2012, which is when the Code was agreed and signed by both the Spanish organizations OPAGAC and ANABAC.

ANNEX I. Forms designed and used to collect information related to the Code of Good Practices.

azti tecnalia

Verification of Good Practices ANABAC/OPAGAC

RELEASE OF ASSOCIATED FAUNA

Form **B2**
version 2014

fishing set nº:

Date:

fishing trip code

route form nº:

route line nº:

fauna liberation form nº:

strapping start time			
h	h	m	m

Released fauna - sharks (1 line by individual, see example)

	individual			release mode						time		(4) state of the animal				
	(1) species	(2) size	(3) sex	using brailer	by stretcher, fabric, sarria, cargo net	with specific equipment	manual from deck	after disentangling	non conform	animal detected	animal released	eyes	head	fins	skin	gill slits
0	FAL	140	2				1			7:35	7:47	P	P	M	M	P
1																
2																
3																
4																
5																
6																
7																
8																
9																
10																
11																
12																
13																
14																
15																
16																
17																
18																
19																
20																
21																
22																
23																
24																
25																
26																
27																
28																
29																
30																

Notes (5):

(1) put species code - see usual observers handbook.

(2) in centimeters

(3) sex: 1 male; 2 female; 3 undetermined

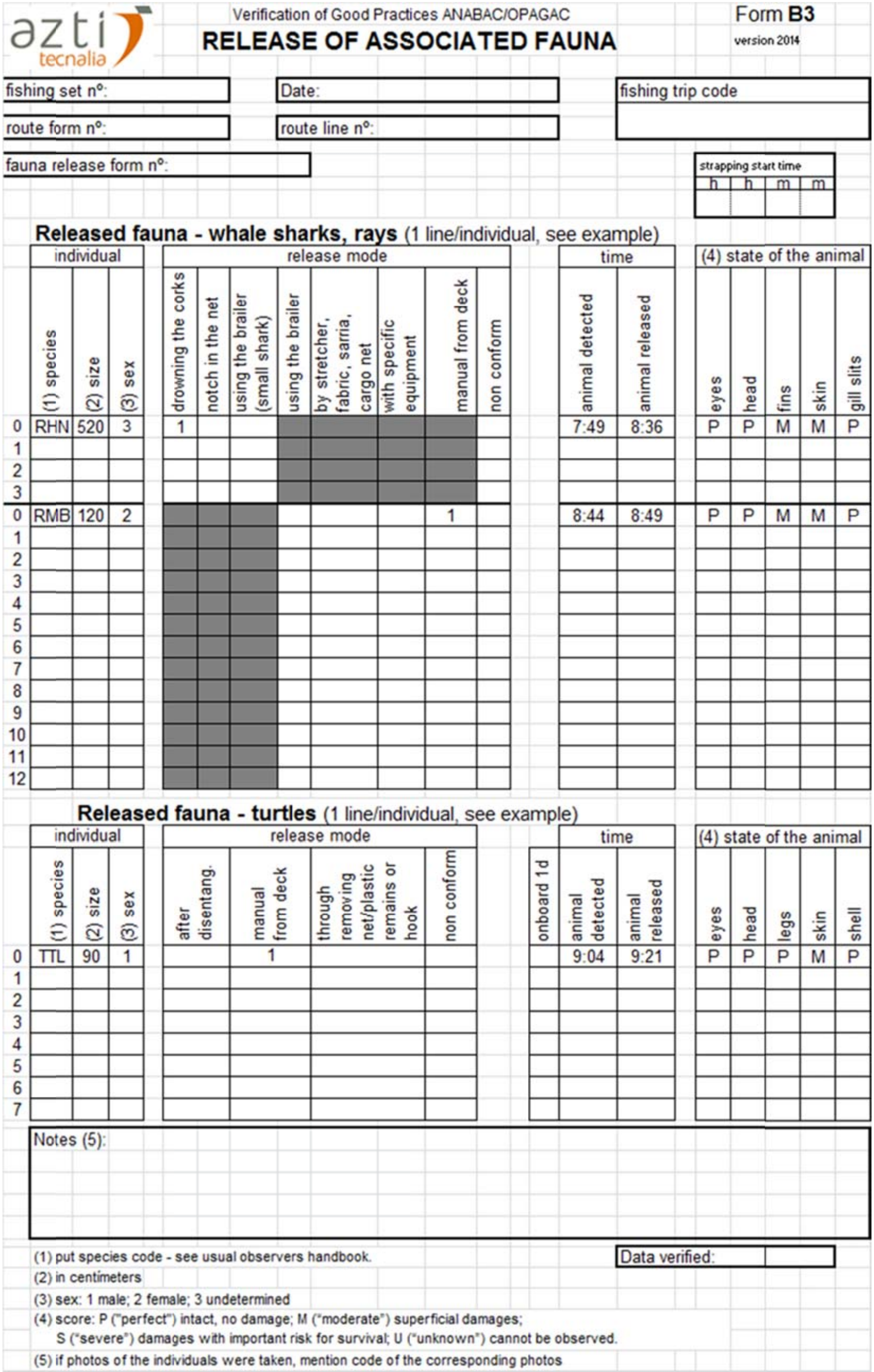
(4) score: P ("perfect") intact, no damage; M ("moderate") superficial damages;
S ("severe") damages with important risk for survival; U ("unknown") cannot be observed.

(5) if photos of the individuals were taken, mention code of the corresponding photos

Data verified

If more than 30 individuals are released, continue on a new form

Figure 2. Form B2 used to register the information on shark releases.



azti tecnalia

Verification of Good Practices ANABAC/OPAGAC

RELEASE OF ASSOCIATED FAUNA

Form **B3**
version 2014

fishing set nº:
Date:
fishing trip code
route form nº:
route line nº:
fauna release form nº:

strapping start time

h	h	m	m

Released fauna - whale sharks, rays (1 line/individual, see example)

	individual			release mode								time		(4) state of the animal				
	(1) species	(2) size	(3) sex	drowning the corks	notch in the net	using the brailer (small shark)	using the brailer	by stretcher, fabric, sarria, cargo net	with specific equipment	manual from deck	non conform	animal detected	animal released	eyes	head	fins	skin	gill slits
0	RHN	520	3	1								7:49	8:36	P	P	M	M	P
1																		
2																		
3																		
0	RMB	120	2							1		8:44	8:49	P	P	M	M	P
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		

Released fauna - turtles (1 line/individual, see example)

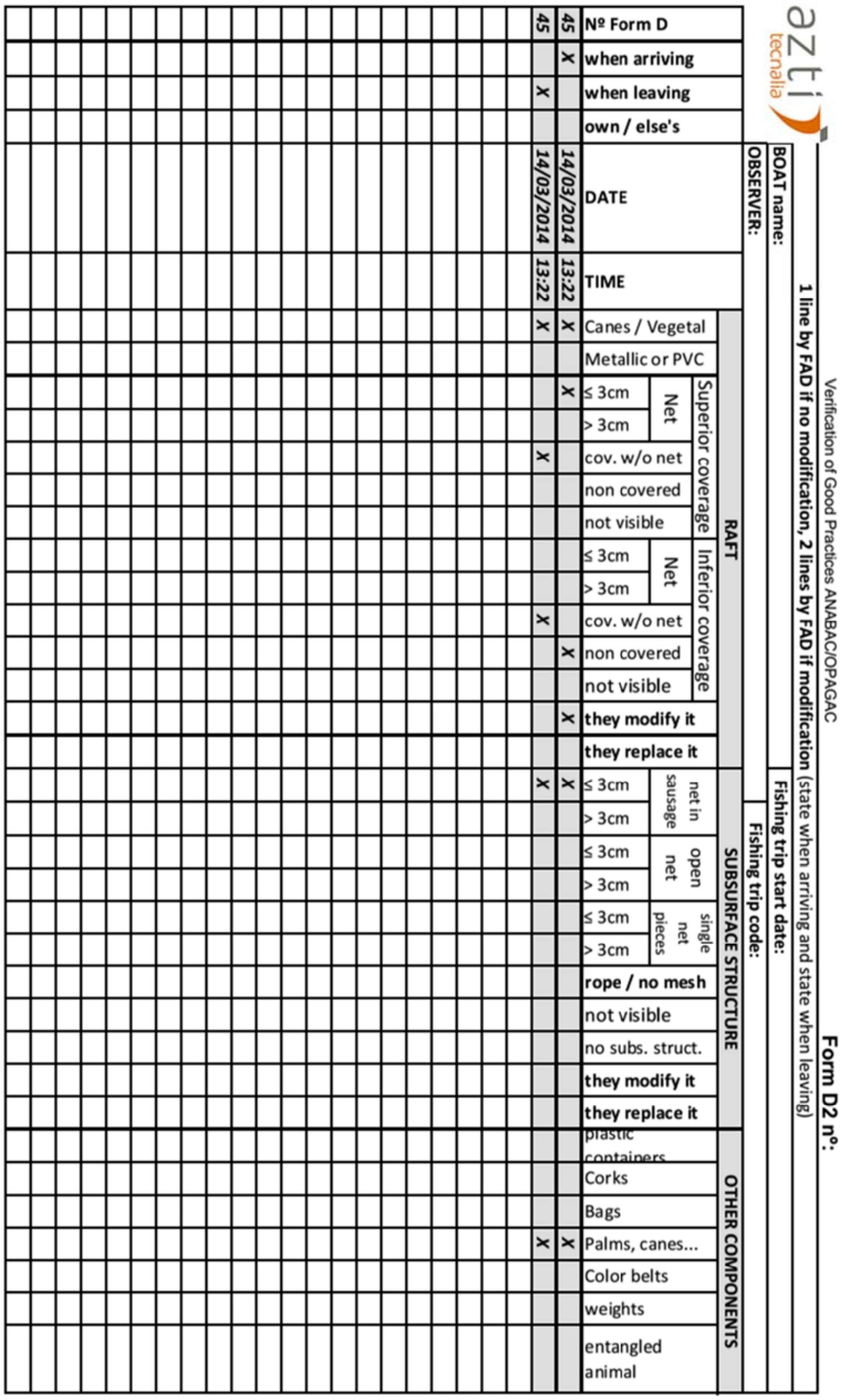
	individual			release mode					time		(4) state of the animal				
	(1) species	(2) size	(3) sex	after disentang.	manual from deck	through removing net/plastic remains or hook	non conform	onboard 1d	animal detected	animal released	eyes	head	legs	skin	shell
0	TTL	90	1		1				9:04	9:21	P	P	P	M	P
1															
2															
3															
4															
5															
6															
7															

Notes (5):

Data verified:

(1) put species code - see usual observers handbook.
(2) in centimeters
(3) sex: 1 male; 2 female; 3 undetermined
(4) score: P ("perfect") intact, no damage; M ("moderate") superficial damages;
S ("severe") damages with important risk for survival; U ("unknown") cannot be observed.
(5) if photos of the individuals were taken, mention code of the corresponding photos

Figure 3. Form B3 used to register the information of whale sharks, rays and turtle releases.



Nº Form D	when arriving	when leaving	own / else's	DATE	TIME	RAFT: Canes / Vegetal	RAFT: Metallic or PVC	RAFT: Superior coverage: Net ≤ 3cm	RAFT: Superior coverage: Net > 3cm	RAFT: Superior coverage: cov. w/o net	RAFT: Superior coverage: non covered	RAFT: Superior coverage: not visible	RAFT: Inferior coverage: Net ≤ 3cm	RAFT: Inferior coverage: Net > 3cm	RAFT: Inferior coverage: cov. w/o net	RAFT: Inferior coverage: non covered	RAFT: Inferior coverage: not visible	RAFT: they modify it	RAFT: they replace it	SUBSURFACE STRUCTURE: net in sausage ≤ 3cm	SUBSURFACE STRUCTURE: net in sausage > 3cm	SUBSURFACE STRUCTURE: open net ≤ 3cm	SUBSURFACE STRUCTURE: open net > 3cm	SUBSURFACE STRUCTURE: single net pieces ≤ 3cm	SUBSURFACE STRUCTURE: single net pieces > 3cm	SUBSURFACE STRUCTURE: rope / no mesh	SUBSURFACE STRUCTURE: not visible	SUBSURFACE STRUCTURE: no subs. struct.	SUBSURFACE STRUCTURE: they modify it	SUBSURFACE STRUCTURE: they replace it	OTHER COMPONENTS: plastic containers	OTHER COMPONENTS: Corks	OTHER COMPONENTS: Bags	OTHER COMPONENTS: Palms, canes...	OTHER COMPONENTS: Color belts	OTHER COMPONENTS: weights	OTHER COMPONENTS: entangled animal
45	X			14/03/2014	13:22	X		X								X		X		X														X			
45		X		14/03/2014	13:22	X				X					X					X														X			

Figure 4. Form D2 used to register the characteristics of FADs and to determine their entangling or non-entangling nature.

Original: French

TUNA FISHING WITH FADS IN TUNISIA: THE CASE OF DOLPHINFISH (DOL)

Ghailen Hajjej[1] and Donia Sohlobji

ABSTRACT

There is very limited use of FADs in fishing in Tunisia. They are used by artisanal fishers targeting mainly dolphinfish *Coryphaena hippurus* (DOL), taking amberjack as by-catch.

Dolphinfish aggregate around floating objects. Having noted this behaviour, fishers realised that fishing around floating objects often produced higher yields than those obtained in the open sea. As a result, some have started to rely on this tendency for fish to aggregate around naturally occurring floating objects to increase their catches.

The main focus of fishing for dolphinfish in Tunisia are juveniles. Adults are fished at the same time as tuna and using the same gears (longline, purse seine…) while juveniles (18 < FL < 50 cm) are fished seasonally, generally from August to December. Fishers use fish aggregating devices (FADs) called "Ganatsi". These devices are comprised of a wooden trapezoidal frame, to which either date palm leaves "jrid" are attached or an opaque plastic tarpaulin, providing shade. Between 20 to 70 of these structures are arranged in parallel lines on the water surface at intervals of between 50 to 80 metres. Each structure is fitted with a ballast and a float. The FADs are immersed in traditional fishing areas, whose average depth ranges from 30 to 60 metres in the eastern region, but which can reach a depth of 180 metres in some southern regions (Zaouali and Missaoui, 1999).

Monitoring of landings from 2011 to 2015 show annual variations. A minimum of 288 t was observed in 2012 and a maximum of 800 t in 2013. The annual average of the past five years is 540 t. However, the highest landings are produced in September and October, generally accounting for more than 40%. The bulk of these catches are taken in the eastern region i.e. 68% on average for the past eleven years.

[1] Institut National des Sciences et Technologies de la Mer (INSTM), Port de pêche 6000 Gabès, ghailen.hajej@instm.rnrt.tn (corresponding author).

Original: English

POSITION STATEMENT BY INTERNATIONAL POLE & LINE FOUNDATION

International Pole & Line Foundation[1]

SUBJECT: Key Areas for Action in FAD Management

Dear Joint RFMO FAD Working Group Delegates, Participants, and Observers,

This letter is submitted on behalf of the undersigned companies and fishing industry associations all of whom are Members of the International Pole & Line Foundation (IPNLF) and are involved in the supply chain of tropical tunas. In particular, we are writing to express our views on fish aggregating devices (FADs) in tropical tuna fisheries, and the need for improvements across the RFMOs and industry on management, data collection, and accountability.

As the tuna Regional Fisheries Management Organizations (RFMOs) embark on their respective processes to further examine FAD fisheries to improve the management of FADs, we encourage this working group to fully consider the following points:

- The impact of current FAD numbers on tuna populations and the broader ecosystem are poorly understood. In this context, RFMOs should apply the *Precautionary Approach* and, at a minimum, freeze the dFAD footprint until more is known. Adopting 'limits' that actually incentivise an increase in overall dFAD use are counterproductive.
- Mechanisms should be developed to take advantage of the valuable fishery information collected by dFADs that is currently not shared with fisheries managers or scientists. These data will provide clarity on dFAD numbers, benefit future stock assessments and other scientific endeavours, and aid in the development more effective FAD management measures. To accomplish this, dFAD data should be shared with relevant scientific bodies, secretariats, and research institutes, in line with confidentiality provisions of the RFMOs, not later than 6 months after they are collected.
- Better understand how FAD fishing and densities of dFADs in tropical areas impact the distribution and CPUEs of tropical tunas to higher latitude coastal fisheries. RFMOs should act to eliminate and reduce social and economic hardships on coastal communities that rely on stocks of tropical tunas.
- Coastal States allowing access to purse seine vessels to fish in their EEZs should consider stricter licensing requirements for the use of dFADs, including the sharing of tracking information with fisheries managers and scientists, limits on numbers of dFADs in their zone at a given time, rules on dFADs deployed outside their EEZ but drifting inside, and licensing schemes. Complementary mechanisms to track and monitor dFADs should be implemented on the high seas by the RFMOs.
- In looking at the impacts of fishing on associated schools, all data must be analysed and a range of options be considered including capacity limits (i.e. numbers and types of buoys, limits of supply vessels and daily/weekly/monthly deployment limits), effort limits (number of sets), as well as combination of both.
- Supply vessels and dFADs are a key component of fishing capacity and, as such, must be considered in any fishing capacity measures. As FADs are meant to attract tuna, they are constantly in the act of "fishing"[2] and the biomass under each buoy is constantly monitored by dFAD owners. This clearly enhances the ability and therefore the efficiency of purse seine vessels to catch tuna. Commitments to "freeze capacity" or "capacity limits" at the RFMOs should apply to dFADs and buoy numbers as well.

[1] International Pole & Line Foundation.
[2] All FADs, whether monitored or not, fit the definition of "fishing" adopted by ICCAT, IATTC, IOTC, and WCPFC.

- Vessels should be accountable for all of the FADs they deploy, and should plan to recover them as part of their fishing strategy. This is consistent with the UN Fish Stock Agreement, which calls on States to, "minimize pollution, waste, discards, catch by lost or abandoned gear, catch of non-target species, both fish and non-fish species, and impacts on associated or dependent species." When lost or stranded, dFAD owners should be liable for recovery and rehabilitation costs in case of damage to coastal habitats, such as reefs.
- Many FADs are still constructed of non-biodegradable materials, including plastic netting, and can be more than 100 m in length. If non-biodegradable dFADs are not recovered, then they should be considered abandoned and this should be recorded as a violation of MARPOL Annex V, reported to the Flag State, and appropriate action should be taken minimize losses in the future.[3]
- The use of dFADs disproportionately benefits industrialized fleets by increasing catch efficiency while their negative consequences (reduced availability of non-associated tuna, reduced profitability of less industrialized fleet segments, marine litter on beaches and reefs, loss of marine animals key to ecotourism, etc.) are borne by coastal communities, particularly in small island developing States. Mechanisms to offset these impacts should be considered and developed.
- Anchored FADs (aFADs) should be managed in line with the above recommendations, in particular when deployed and used by purse seine and ringnet operations. Since many aFADs are important for small scale, selective fisheries that support coastal communities and food security it is critical that they be clearly differentiated where appropriate.

We will continue to proactively engage in the upcoming discussions on FADs in our world's tuna fisheries, and we encourage industry to collaborate with scientists and coastal States in this process to improve the transparency of FAD fisheries while allowing for an improved understanding of the overall fishery impacts. We look forward to working with all stakeholders towards a more sustainable tuna fishery and healthier marine environment.

Sincerely,

world wise foods

FISH 4 EVER

M&S
EST. 1884

CERTIFIED AAFA QUALITY

HF Horizon Fisheries Private Limited

[3] Macfadyen, G.; Huntington, T.; Cappell, R. Abandoned, lost or otherwise discarded fishing gear. UNEP Regional Seas Reports and Studies, No. 185; FAO Fisheries and Aquaculture Technical Paper, No. 523. Rome, UNEP/FAO. 2009. 115p. See p 23.

Original: English

MITIGATION OF SILKY SHARK BYCATCH IN TROPICAL TUNA PURSE SEINE FISHERIES

Laurent Dagorn[1] , JD Filmalter[2], Fabien Forget[3], Melanie Hutchinson[4], David Itano[3], Jeff Muir[5], Igor Sancristobal[6], Manuela Capello[1], Kim Holland[5], Victor Restrepo[3]

ABSTRACT

Silky sharks are caught by a variety of fisheries. Although purse seining does not account for the majority of those catches, the impact by this fishing gear on silky shark populations can be important. This document notes some of the actions that can be taken to mitigate silky shark mortality.

Regarding unobservable mortality ("ghost fishing") due to entanglement, its magnitude has not been studied in every ocean, but it likely can occur everywhere. Some people argue that it needs to be quantified before action is taken. But, a simple solution exists: using non-entangling FADs can completely eliminate entanglement, while still attracting tunas efficiently. IATTC, ICCAT and IOTC already require a transition to non-entangling FADs, but WCPFC does not. ISSF has been advocating that WCPFC adopt a CMM transition to non-entangling FADs as the other three tuna RFMOs have done.

Regarding catches that are potentially brought onboard, there are several mitigation actions that can be taken. Shifting part of the effort from FADs to free schools will reduce shark mortality to varying degrees depending on the magnitude of the shift. As an example, a 20% effort shift could increase survival by 16% at least in the WCPO (the impact may vary by Ocean). Avoiding making sets on FADs that have tuna aggregations under 10 t could increase survival by 30%. Catching sharks inside the net with handlines and releasing them could increase survival by 21% (or more, as the technique is improved in the future). And, releasing sharks from the deck following best handling practices will increase survival by up to 20%.

Used in combination, the sequential survival following the same sequence of actions would be as follows:

- Shift 20% effort to free schools = +16%.
- Set only on FADs with > 10 t tunas = +25%.
- Fish sharks from the net = +12%.
- Release from the deck = +9%.

Altogether, these four actions in combination can increase silky shark survival in purse seine fisheries by 62%. And they will also increase the survival of other shark species.

Some of these mitigation actions will be easier to implement than others. For example, releasing from the deck following best handling practices is simple and would constitute a negligible cost during fishing operations (though crew safety must be ensured). Others, like not setting on small tuna aggregations and shifting effort to free schools, will incur costs to the fleets, as the total tuna catch could be affected. Fishing sharks from the net should not affect normal fishing operations, but there needs to be crew available to undertake the activity during the set. However, all of these activities are achievable and together would greatly contribute towards shark conservation.

[1] IRD, France, laurent.dagorn@ird.fr (corresponding author).
[2] SAIAB, South Africa.
[3] ISSF.
[4] NOAA, USA.
[5] University of Hawaii, USA.
[6] AZTI, Spain.

Original: English

WHAT DOES WELL-MANAGED FAD USE LOOK LIKE WITHIN A TROPICAL PURSE SEINE FISHERY?

John Hampton, Gerry Leape, Amanda Nickson, Victor Restrepo, Josu Santiago, David Agnew, Justin Amande, Richard Banks, Maurice Brownjohn, Emmanuel Chassot, Ray Clarke, Tim Davies, David Die, Daniel Gaertner, Grantly Galland, Dave Gershman, Michel Goujon, Martin Hall, Miguel Herrera, Kim Holland, Dave Itano, Taro Kawamoto, Brian Kumasi, Alexandra Maufroy, Gala Moreno, Hilario Murua, Jefferson Murua, Graham Pilling, Kurt Schaefer, Joe Scutt Phillips, Marc Taquet[1]

ABSTRACT

The authors participated in the Global FAD Science Symposium, March 20-23, 2017, in Santa Monica, California and are presented without affiliation. This paper is one of several from the Symposium and does not represent an exhaustive discussion of the issue but includes points agreed by participants. The participants recognized that impacts of FADs and FAD management cannot be considered entirely independently of harvest strategies, issues related to fishing capacity, ecosystem structure, or management of all other fishing gears in tropical tuna fisheries. None of these points alone will address the management challenges associated with FAD use. The effectiveness of any of these points will depend on the levels of implementation and compliance and need to be connected to processes at the RFMOs. Participants underlined the need for data harmonization, standardization, and availability and stressed the need to develop standardized language and definitions to support consistent interpretation of what conservation and management measures intend to achieve across ocean basins. In response, participants offer a glossary (**Appendix 1**) as a "straw man" for consideration and/or development, and underline the clear need for this standardization. Participants noted that "best practices" are not necessarily "most practical" and will need to be assessed to determine which are most appropriate to apply in any particular management setting or geographic area. Finally, participants stressed the need for ongoing and close collaboration among scientists, managers, and industry in driving innovative solutions within and across RFMOs. The points presented here are not in an order of priority; priorities and solutions may change on a regional basis.

Introduction

The topic of "FAD management" in tropical tuna purse seine fisheries has been the subject of considerable attention in recent years. However, with very few exceptions, there are no purse seine fleets that fish all year round on FADs only or on free schools of tuna only. Furthermore, the species of tuna targeted by purse seine fisheries (primarily skipjack, yellowfin and bigeye) are also targeted by other fisheries such as longline, pole-and-line, gillnet and troll. For these reasons, the impacts of FADs and FAD management cannot be considered entirely independently of harvest strategies, fishing capacity, ecosystem structure, or management of all other fishing gears in tropical tuna fisheries.

In this paper, we consider the issue of managing FAD use within tropical tuna purse seine fisheries. These considerations are separated into three general categories: (1) Managing impacts on target species; (2) managing impacts on non-target species, coastal habitats, and the pelagic marine ecosystem; and, (3) the management framework, including monitoring, compliance and surveillance (MCS).

1 Managing impacts on target tunas

A well-managed purse seine fishery has the following attributes regarding target species:

- Target stocks are maintained around the target levels and away from biological limits that could severely impact the stocks;

[1] For more information about the Global FAD Science Symposium or about this paper, contact Grantly Galland (ggalland@pewtrusts.org).

- Where a target stock is overfished, a rebuilding program is in place with a clear timetable and milestones to rebuild the stock to around the target level;
- Assessments of the target stocks are conducted regularly to inform decision makers.

Clearly, these cannot be achieved by managing FAD use alone. They require agreement on a number of elements such as management objectives for each stock (targets, limits, etc.) and decisions about allocation, both among gears and within the purse seine fishery. Nevertheless, there are a number of management actions for FAD use that are high priority and consistent with the above principles. These are actions that will mitigate the impact of FAD use on overfished target tuna stocks, including bigeye in the Atlantic and Pacific oceans and yellowfin in the Indian and (to a lesser extent) Atlantic oceans.

Examples of best practices for target species include:

- Setting catch limits specifically for juvenile tunas caught by purse seine operations, particularly of overfished stocks;
- Shifting some purse seine fishing effort from FAD sets to sets on unassociated tuna schools (free schools), either voluntarily or through annual FAD set limits;
- Avoiding setting on FADs with large concentrations of juvenile or overfished tunas, including by:
  - Avoiding hotspots, where overfished species are relatively abundant or vulnerable (this could include time-area closures);
  - Developing techniques to use FAD acoustic technology to avoid sets that are likely to contain high numbers of overfished species, recognizing that this practice will require technological and methodological advances;
- Avoiding purse seine setting techniques or equipment that are more likely to select overfished species (if such things can be identified);
- Using improved datasets to develop science-based, FAD deployment limits.

Some of these practices (e.g., avoiding hotspots or use of acoustic technology to inform purse seine captains) require market- or policy-based incentives to encourage or require operators to make good choices when setting their purse seine gear.

2 Managing impacts on non-target species, coastal habitats, and the pelagic marine ecosystem

A well-managed purse seine fishery has the following attributes regarding non-target species and marine ecosystems:

- Non-target stocks are maintained above biological limits that could severely impact the stocks. For endangered, threatened, and protected (ETP) species, measures are in place to minimize mortality;
- Where a non-target stock is overfished, the fishery will not hinder its recovery and there are timetables and milestones in place to rebuild the stock to around the target level;
- Operators collect and report data on interactions with non-target species and their fate (discarded, kept), at the species level;
- Waste is minimized;
- The fishery is operated so that it is unlikely to reduce the structure or function of habitats and the pelagic ecosystem.

Tropical purse seine tuna fisheries have relatively low bycatch rates compared to other industrial fisheries. However, impacts vary by set type and region, with FAD sets generally catching higher diversity, numbers, and biomass of non-target species (e.g., sharks, small tuna species, etc.). Though bycatch rates are relatively low, the large scale of the global purse seine fishery may lead to measurable impacts on non-target species, via entanglement in the FAD itself or encirclement by the purse seine vessel during a set.

Examples of best practices for non-target species include:

- Shifting some purse seine fishing effort from FAD sets to sets on unassociated tuna schools (free schools), either voluntarily or through annual FAD set limits;

- Avoiding interactions before a purse seine set by:
  - Using FADs that are not likely to entangle sharks, sea turtles, or other species;
  - Avoiding sets on small FAD-associated schools that generally have a higher bycatch rate than large schools;
  - Identifying and avoiding "hotspots" where the risk of catching non-target species is high;
- If encircled by a purse seine net, actively releasing sharks (via other fishing gear) and turtles (via manual capture);
- If brought on deck, practicing safe-handling techniques for sharks and resuscitation/revival techniques for sea turtles, to reduce mortality after release;
- Reducing dead discards and promoting increased utilization of non-target bony fishes, accounting for impacts on local markets and artisanal fisheries.

In addition to the impacts of FADs and FAD fishing on non-target species, there is some concern about the contribution of FADs to marine debris and direct impacts on sensitive habitats, such as coral reefs.

Examples of best practices for ecosystem impacts include:

- Using biodegradable FADs;
- Improving monitoring of FAD deployments and locations of drifting FADs for use in evaluating FAD density impacts on the pelagic ecosystem, including tuna aggregation dynamics;
- Using improved datasets to develop science-based, FAD deployment limits;
- Developing FAD recovery plans with provisions to minimize loss, abandonment, or interaction with sensitive habitats, including by partnering with coastal groups to use FAD location information to assist in recovery of FADs before they encounter sensitive areas.

3 Management framework, including MCS

A well-managed fishery has the following attributes regarding management:

- Short and long-term objectives are clearly stated and explicitly defined;
- The management system exerts effective cooperation with other fisheries for the management of shared stocks;
- Overall capacity of the fishery is limited, either directly or through effort or catch limits, in order to be commensurate with management objectives;
- An effective MCS system is in place to ensure compliance with management measures and collection of data necessary to inform management.

The effectiveness of any of the practices identified in (1) and (2) above will be dependent on implementation by management bodies and compliance by stakeholders and as such will need to be connected to those processes at the tuna RFMOs.

Examples of best practices for MCS include:

- Requiring 100% observer coverage (human or electronic) of purse seine vessels, in order to record FAD deployment, retrieval, set types, and catch numbers;
- Requiring 100% observer coverage (human or electronic) of supply vessels, in order to record FAD deployment and retrieval;
- Requiring 100% VMS coverage, with a reporting resolution sufficient to detect fishing;
- Implementing full tuna catch retention and effectively monitoring catch numbers during unloading;
- Using FAD positional data in combination with VMS data to identify FAD sets;
- Effectively and comprehensively addressing suspected non-compliance at the licensing authority, flag state, or RFMO, as appropriate.

Appendix

FAD GLOSSARY

NOTES:

(1) The purpose of this Glossary is to provide definitions of different terms that are used in the context of FAD use in tuna purse seine fisheries. In some cases, certain terms do not have a universally agreed definition, and their meaning may depend on the context in which they are used. The terms in this glossary are grouped by topic.

(2) Often, RFMOs adopt binding measures that contain terms which are not precisely defined, and this can lead to ambiguity and subjectivity in interpretation. One example is for "non-entangling FAD (NEFAD) designs" which are mentioned in measures for three RFMOs. However, the key attributes for the construction of NEFADs are not defined in the measures. Ideally, definitions of such terms would span management, scientific as well as industry interests. This would allow clarity for fishers, fishery managers, and compliance professionals.

Bycatch

There is no universally-agreed definition, although the connotation is usually one of undesired catch. Generally speaking, bycatch refers to the catch of anything that is not the main reason for which the skipper is fishing, whether retained or discarded.

Some of the terms related to bycatch are the following:

Target species: The tropical tuna purse seine fisheries, depending on their fishing strategy, target skipjack, yellowfin and/or bigeye tuna. Considerations such as size also matter, as tunas that are undesirably-small for processing are also sometimes called bycatch.

Non-Target species: These generally include minor tuna species (bullet and frigate tunas, Pacific black skipjack, little tunny), other bony fishes (mahi-mahi, rainbow runner, billfishes), sharks, rays, turtles, etc. Some of these species can be targeted opportunistically during a fishing trip.

Discarded/Retained: Any catch, whether target or non-target, can be either discarded or retained on board. Many scientific studies equate the term "bycatch" with discards.

Byproduct: This term is often used for catch of non-target species that is retained and utilized (e.g. consumed onboard, processed on board or given to the crew in port).

Efficiency

A vessel's or a fleet's fishing efficiency can change over time, resulting in greater amounts of fishing mortality. There are many factors that contribute to the efficiency of tuna purse seine vessels. If their adoption and resulting impact on catch rates cannot be quantified adequately, this results in "**effort creep**" (an unquantified increase in efficiency over time).

The following are some of the main factors that contribute to efficiency, with a focus on FAD fishing.

Beacon (also GPS Buoy): Drifting FADs can be fitted with transmitter beacons so that they can be located. In order to monitor the number of FADs used by a vessel or a fleet, the following terms are being proposed for use in RFMOs:

Operational beacon: a beacon that, after leaving the factory and passing through transit, has been registered and has the ability to transmit.

Active beacon: operational beacon located at sea and transmitting position reports.

Deactivation: Action of de-registering a beacon by the buoy supplier company after the request by the ship owner due to loss, theft or other cause.

Reactivation: action of re-registering a beacon previously deactivated by the buoy supplier company after the request by vessel owner.

Fleet size: If the number of vessels in a fleet increases, the fleet's capacity will increase.

FADs: The deployment and use of FADs allows skippers to fish in remote areas where tuna schools were not very abundant or easily accessible before, to plan trips with greater certainty and efficiency, to make fewer "skunk sets" (sets where the school of tuna escapes) and to catch more skipjack tuna (a very productive and abundant tuna). FADs are equipped with some type of location device, ranging from simple radio beacons to sophisticated GPS, enabling the skipper or fleet manager to locate them remotely. The number of FADs deployed by a vessel or company increases their capacity because of increased options for "cherry picking" the FADs with more biomass underneath. But, there may come a point where high FAD density in an area is counter-productive because of a saturation effect that reduces aggregation size.

Echosounder buoys: Many FADs (100% for some fleets) are being equipped with echosounder buoys that estimate the amount of fish biomass present underneath. This allows the skipper or manager to make decisions about what areas to visit in order to have access to FADs with high tuna biomass.

Supply (support) vessels: Some fleets use supply vessels to plant and check FADs and to maintain them. A supply vessel can work with one purse seiner or be shared by a group. Such activity allows a fishing vessel to access a larger number of FADs than it would otherwise be able to maintain.

Helicopters and radars: Helicopters and bird radars have traditionally been used to search for tuna schools. They are now also being used to search for FADs that are not controlled by the vessel.

Fishing Strategy

A fishing strategy is a plan followed by a vessel designed to achieve certain results in terms of catch. The strategy may be that of a skipper, a vessel owner, group of vessels, or a fleet. Fishing strategies can change seasonally or over time.

There are three main fishing strategies in tropical tuna purse seine fisheries:

Dolphin strategy (dolphin fishing): Vessels that primarily target schools of yellowfin tuna associated with dolphins. These tuna-dolphin associations are most common in the eastern Pacific Ocean.

FAD strategy (FAD fishing or Floating object fishing): Vessels that largely rely on FADs (floating objects) to catch tunas, primarily skipjack.

Free-school strategy (school fishing): Vessels that largely rely on free-school sets to catch yellowfin and/or skipjack.

Note: Most tuna purse seine vessels do not adhere to one of these strategies all of the time; for instance, a vessel typically makes both sets on floating objects and on free schools during a fishing trip. Thus, even if a vessel is following a strategy, it will deviate from it opportunistically or seasonally.

Floating Object (FOB)

An object floating at sea that attracts tuna underneath. A floating object can be natural, natural but altered by fishers, or man-made.

The following broad categories of floating objects are defined (adapted from CECOFAD):

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

DFAD (Drifting FAD): A DFAD typically has a floating structure (such as a bamboo or metal raft with buoyancy provided by corks, etc.) and a submerged structure (made of old netting, canvass, ropes, etc.).

AFAD (Anchored FAD): Anchored FADs usually consist of a very large buoy, anchored to the bottom with a chain. AFADs are called '**payaos**' in some regions.

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

FALOG (Artificial log resulting from human fishing activity): These artificial logs are usually abandoned or lost materials related to fishing activity (nets, wreck, ropes, vessels that act as FADs, etc.).

HALOG (Artificial log resulting from human non-fishing activity): Other artificial logs (e.g. a washing machine, oil tank, etc.).

ANLOG (Natural log of animal origin): A natural log such as a whale carcass or a living whale shark. Note: In some regions, sets on whale sharks are seen as being similar to FAD sets, whereas in other regions they are seen as more similar to free-school sets.

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

According to their design characteristics, the following categories of FADs are often used:

NEFAD (non-entangling FAD): FAD designed to minimize ghost fishing (entanglement of fauna, primarily sharks and turtles). For a FAD to be completely non-entangling, it must use no netting materials either in the surface structure (raft) or the submerged structure. Some organizations also consider NEFADs to be those using netting but built to minimize entanglement such as using netting tied in bundles or using small size netting (<7 cm stretched mesh); these are sometimes called **LERFADs** (Lower Entanglement Risk FADs).

Biodegradable FADS: FADs constructed with natural or biodegradable materials that reduce the impact of beaching and debris. The term biodegradable is applied to a material or substance that is subject to a chemical process during which microorganisms that are available in the environment convert materials into natural substances such as water, carbon dioxide, and decompose organic matter. The time required for biodegradation of different materials varies. Some fishers believe that a FAD should last up to one year before degrading.

Set types

A purse seine is a large wall of netting deployed around an entire area or school of tuna. The net is then "pursed" by closing the bottom, and the catch is harvested by hauling the net aboard.

There are three main set types in tropical tuna purse seine fisheries:

Free school (FS) set: The net is deployed around a free-swimming school of tuna, i.e. a school that is not associated with any floating object or a pod of dolphins.

Floating object set (Associated set): The net is deployed around a school of tuna that has aggregated under a floating object. The characteristics of the catch made in the presence of a floating object, whether a log or a FAD, tend to be similar and scientists tend to group the data resulting from these into the category "**Floating object set**." In recent years, the term "**FAD set**" has also been used interchangeably.

Dolphin set: The net is deployed around a tuna-dolphin association.

Note:

Attributing the catch to a set type is not always straightforward. For example, a floating object may be present in or near the set, but not visible. Or, a floating object may be at a distance beyond an RFMO's legal definition (e.g. 1 nautical mile in one RFMO), but the tuna school may still be under the object's attraction. Furthermore, the push by some markets to source "FAD-free tuna" (i.e. catch from anything other than floating object sets) can be a driver for misreporting of set type in logsheets or observer reports.

Original: English

ACTIVITIES OF THE ICCAT AD-HOC WORKING GROUP ON FADS DURING 2015-2016

David J Die[1] and Shep Helguile[2]

SUMMARY

The working group provided a summary of technical findings and a set of management recommendations to the Commission in 2016. As a result of such findings the Commission enacted a set of measures regarding management of tropical tuna fisheries that depend on FADs. The Commission recognized, however, that there are additional management challenges associated with FAD dependent fisheries and decided to extend the mandate of the ad-hoc working group for at least one more year. The current document briefly discusses the outcomes of the working group activities, the challenges that it has faced and the work planned for 2017.

[1] University of Miami. 4600 Rickenbacker C. Miami FL 33149. USA. ddie@rsmas.miami.edu
[2] Ministère des Ressources Animales et Halieutiques, Rue des Pêcheurs; B.P. V-19, Abidjan. Cote d'Ivoire; shelguile@yahoo.fr

Appendix

ACTIVITIES OF THE ICCAT AD-HOC WORKING GROUP ON FADS DURING 2015-2016

2015-2016

The ICCAT ad-hoc working group on FADs was set by the Commission in 2014 [Rec. 2014-03] to: 1) Gather information on FADs related to provisions in the relevant ICCAT conservation and management measures, 2) Assess the use of FADs in tropical tuna fisheries in ICCAT and of the relative contribution of FADs to overall fishing mortality, 3) Assess developments in FAD-related technology and 4) Consider recommendations to the Commission for possible additional actions relating to FAD management and recovery. In 2016 the working group (WG) completed its initial objectives and gathered enough information (ICCAT 2016a, ICCAT 2016b) to provide advice to the Commission on:

- Technological developments related to FAD fishing,
- New sources of population-level data provided from FAD fishing,
- Effects on vulnerable species,
- Development of biodegradable FADs,
- Preliminary estimates of the number of FAD deployments and their spatial distribution,
- FAD losses and their possible contribution to marine debris,
- Estimates of biomass of bycatch associated with FAD fishing,
- Differences in species and sizes of tropical tunas caught in FADs and free schools,
- Potential effects of FAD fishing on ecosystem structure and function.

Although the WG was successful in fulfilling its initial mandate, it faced some challenges, which are discussed below.

Ensuring balanced participation from different stakeholders

The WG was set up to give a voice to all kinds of expertise: scientific, operational, management and policy so as to advance the state of knowledge and help develop management recommendations. ICCAT provided a structure to facilitate this by assigning funding for the meetings and travel assistance for developing participants from developing Contracting Parties (CPCs). In spite of this, participation in the two WG meetings can be described as uneven. There were scientists associated with industry, research institutions and some NGOs, some industry managers and fishery managers but few Commissioners and no active fishermen. It has to be mentioned that fishermen often interact with scientists through the many collaborative research projects on FADs that have been conducted in recent years, and that their ideas and initiatives are often transmitted by their representatives to the meetings. It is unclear, however, whether fishermen see their voice well represented at these meetings. The same can be said about representation by NGOs, although a few NGOs were present at the meetings they were global institutions, and may not be necessary representing the views of local stakeholders in coastal CPCs that may be more affected by the consequences of FAD fishing and FAD management. It should be noted that appropriate stakeholder participation is an on-going challenge for ICCAT in general, not just for the work related to FADs.

Number of CPCs represented

Participation and input to the WG was mostly restricted to CPCs directly involved in FAD fishing or with intensive FAD fishing within their EEZ. There was a general lack of participation from other CPCs that have an important stake in the health of tropical tunas stocks and the ecosystem which support them. Many such CPCs provided their input during the ICCAT Commission meeting. Unfortunately, lack of participation in the WG often leads to more difficult negotiation of management measures during annual Commission meetings.

Format of meetings

As an ICCAT Commission body the WG is subject to the rules of procedure of the Commission. It was challenging for the WG to initially agree on a format for the annual meetings, namely whether the participants were there as experts or representatives of a given CPC or specific stakeholder. The first meeting was conducted mostly as a meeting of experts, with free flowing interventions and input. It was mainly a gathering of information and an initial discussion on whether it was possible to develop management options and recommendations to the Commission. The initial part of the second meeting was run also as a gathering of new information, but after the meeting was conducted more like a Commission meeting with CPC representatives presenting the views of their CPC and providing proposals for discussion and support, as it is done in Commission meetings. This mixed approach was successful in providing a draft set of recommendations to the Commission, however, by the end of the meeting there was still disagreement among participants on whether such recommendations would carry the same weight as others produced by other working groups of the Commission, or by meetings of the Commission panels.

Narrow scope of terms of reference

The WG terms of reference were purposely designed to have a narrow scope and to focus on the practice of fishing with FADs and its consequences on tropical tuna stocks and its ecosystem. Unfortunately, FAD fishing is only one type of operations that target tropical tunas or that impact the ecosystems that support them. Under the paradigm of ecosystem-based fishery management one has to consider all sources of mortality on harvested stocks and all fishing activities that affect a given ecosystem. The WG was often reminded of the difficulty of focusing on the activities of a single type of operation without being able to compare them to other fishing activities such as fishing by longlines and gillnets. The WG did consider comparisons between the different types of purse seine operations, on natural object, on free schools or on FADs. The WG did not address anchored FADs to any great extent. If ICCAT wanted to implement the principles of ecosystem-based management it would have to consider impacts of other types of fishing as thoroughly as it is considering those from purse seines.

2017 WG workplan

The Commission used some of the recommendations of the WG to modify tropical tuna management [Rec. 16-01]. This included expanding the size and duration of the FAD closure and enacting limits on the number of FAD actively used by an individual vessel. The Commission also decided to extend the life of the WG [Rec. 16-02] and challenged the WG to work on:

- Ways to reduce juvenile catches of bigeye and yellowfin tuna
- Estimating the past and current number of and different types of buoy
- Improving the use of information related to FADs in the process of stock assessments
- Reducing FADs' ecological impact through improved design
- Compliance with FAD related provisions including marking of buoys
- Identify management options and common standards for FAD monitoring, including, limits on FAD sets; deployment limits of FADs; characteristics of FADs; activities of purse seiners, baitboats and support vessels; options for and timing of recovery of FADs and/or mitigating FAD loss

The WG is due to meet again in September 2017 and provide input to the Commission at its annual meeting in November 2017.

References

ICCAT 2016a. Report of the first meeting of the Ad-Hoc Working group on FADs. ICCAT Report for biennial period, 2014-15, Part II - Vol. 1. Annex 4.3. pp 187-206.

ICCAT 2016b. Report of second meeting of ad-hoc working group on FADs. 21 p.

Original: English

NEW METHOD THAT COMBINES DEAD RECKONING AND ACOUSTIC TELEMETRY TO MEASURE FINE SCALE MOVEMENT OF TUNA ASSOCIATED WITH FADS

Tatsuki Oshima[1], Shoko Wada[1], Yuuki Shimizudani[1], Tsutomu Takagi[2], Kazuyoshi Komeyama[2], Yasuhiro Yoshimura[2], Ippei Fusejima[1]

ABSTRACT

Mitigating small tuna by-catch in FADs fishery is an urgent task for sustainable fishery. In developing a practical method for mitigating by-catch, the knowledge on the reaction of fish to the fishing gear (FAD, net) is necessary. New “Hybrid fish tracking method”, which is a combination of dead reckoning and acoustic telemetry, was introduced and tested in the FAD fishing site. Out of ten occasions that we tagged tunas with package of data logger and pinger, 4 fishes were successfully recaptured. As the results showed fine scale trajectory of tunas, the new method is considered to be good tool for understanding tuna behavior around FAD and net.

[1] Marine Fisheries Research and Development Center (JAMARC) of Fisheries Research and Education Agency (FRA).
[2] Faculty of Fisheries Sciences, Hokkaido University.

Appendix

NEW METHOD THAT COMBINES DEAD RECKONING AND ACOUSTIC TELEMETRY TO MEASURE FINE SCALE MOVEMENT OF TUNA ASSOCIATED WITH FADS

Introduction

The Fish Aggregating Devices (FADs) attract fish including small bigeye tunas. This nature results in by-catch of small bigeye tuna in purse seine fishery and causes negative impacts to its stock status. Effective method to mitigate the small tuna by-catch is necessary.

To mitigate small tuna by-catch, potential solutions may be changing the conventional method of setting net or letting small fish escape through large mesh of the net. In developing such method, however, there is an obstacle that is the lack of knowledge on the interaction of fish and fishing gear (FAD, net). By obtaining knowledge such as how fish move around a FAD or react to fishing net, we could develop practical ways to mitigate by-catch of small tunas. In this study, we introduced a new "Hybrid fish tracking method" that combines dead reckoning and acoustic telemetry to measure fine scale movement of tuna associated with FADs.

Materials & methods

1 *Hybrid fish tracking method*

Hybrid fish tracking method is a new way to measure fine scale movement of fish under water by combining dead reckoning and acoustic telemetry.

Dead reckoning is a method to estimate position of fish by calculating the distance and direction that travelled from a previously known position. The data loggers such as acceleration logger are used to measure fish speed, acceleration, direction, depth and so on. By calculating those data, the position of a fish is estimated from the previous position (one second before). The three-dimensional trajectory of a fish will be obtained by successive position estimates by such calculations. This procedure, however, can accumulate errors over time and results in large error in position, even if error in single step is very small.

The accumulated error can be corrected by combining position estimates with acoustic telemetry. The position of a fish attached with acoustic pinger can be estimated by calculating difference of the timing a pinger signal reaches to multiple receivers with known position.

2 *Field experiments*

A tuna purse seiner Taikei-maru No.1 was used for the study. Field experiments took place in October to November 2016 in the eastern Indian Ocean. Sample fishes were captured by lure fishing near FAD and was attached with logger package and then released. The tagging was done the day before the set or just before the set. The logger package includes Vemco acoustic pinger (V13 or V16) and Little Leonardo data logger (PD3GT or 3M-PD3GT). When PD3GT, which lacks direction sensor, was used Star Oddi direction sensor (DST-magnetic) was also added.

The acoustic signals from the pinger was received with 3 or 4 acoustic receivers (Vemco VR2W). The receivers were deployed to make triangle or rectangle formations. In recording before the set receivers were suspended from the work boats. In recording during the set 2 receivers were suspended by ropes that were tied to cork line of the net and another 2 receivers were suspended from the boats. When the experiment continued overnight, a VR2W receiver was attached to the FAD to collect data of presence / absence of the fish. All the receivers were set with GPS logger to record the position where pinger signals were received. When a pinger signal reached 3 or more receivers, the pinger position was calculated from the GPS position of the receivers. The estimated pinger position was used for correcting dead-reckon-estimated trajectory.

The tagged tunas were recaptured from the catch and the data were collected from the loggers.

Results

In 13 trials, we managed to tag 10 tunas. Of the ten, 4 fish were recaptured and its logger data were successfully collected.

An example of fish trajectory that was recorded overnight is shown below (bigeye tuna; FL62cm). **Figure 1** shows the horizontal movement of the fish. The blue line is the trajectory estimated from dead reckoning. Small circles show the positions estimated from simultaneous pinger reception. The red line is the corrected trajectory based on the pinger-estimated positions. The trajectory between pinger-estimated positions were linearly interpolated from dead reckon data. **Figure 2** shows the horizontal trajectory of the same fish overlaid to FAD position. **Figure 3** shows the three-dimensional trajectory of the same fish.

From these data, the fine scale movement of fish can be analyzed. For example, after being tagged and released the fish dived down to more than 200 m in depth. During the daytime fish stayed at deep layer most of the time and slowly swam away from the FAD. Just after the sunset it rapidly went up to the surface and seemingly "came back" directly to the FAD. The fish stayed near the surface until around 2:30. During the course of that, the fish went as far as 2,400 m from the FAD and finally managed to come back to it again.

Discussion

The new "Hybrid fish tracking method" worked well in the field experiments. The method can be utilized to obtain fine scale movement of target species like we presented here. Such fine scale data are essential in understanding the ecology of species that gather around FADs.

We will continue to analyze obtained data set for the better understanding of fish behavior. The next step will be overlaying the 3D trajectory of fish on the simulated 3D net model. That will allow us to understand how a fish react to fishing net and possibly lead to solutions of by-catch problems.

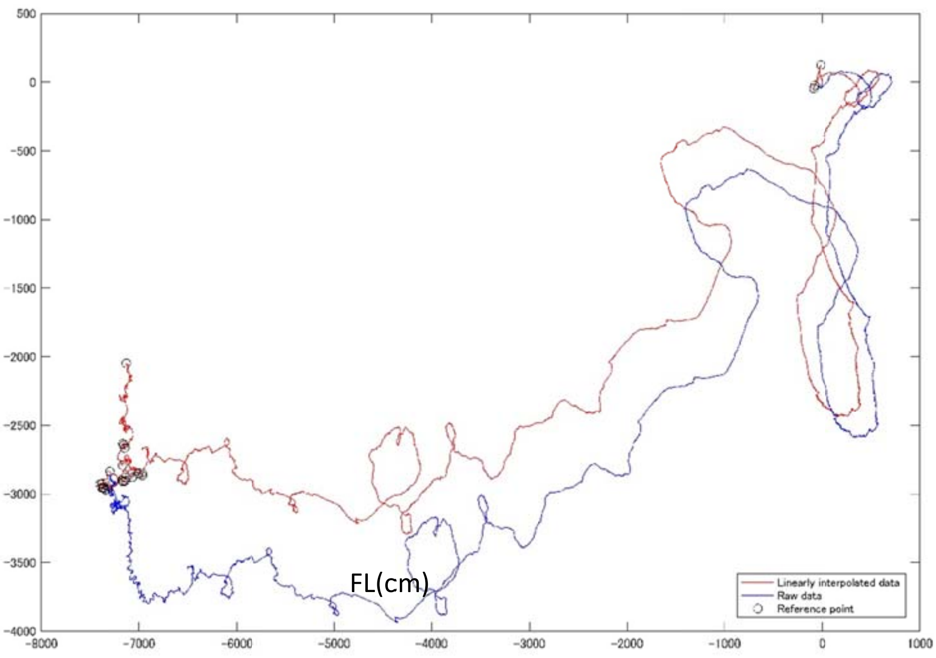


Figure1. Estimated trajectory of 62cm Bigeye tuna (red line).

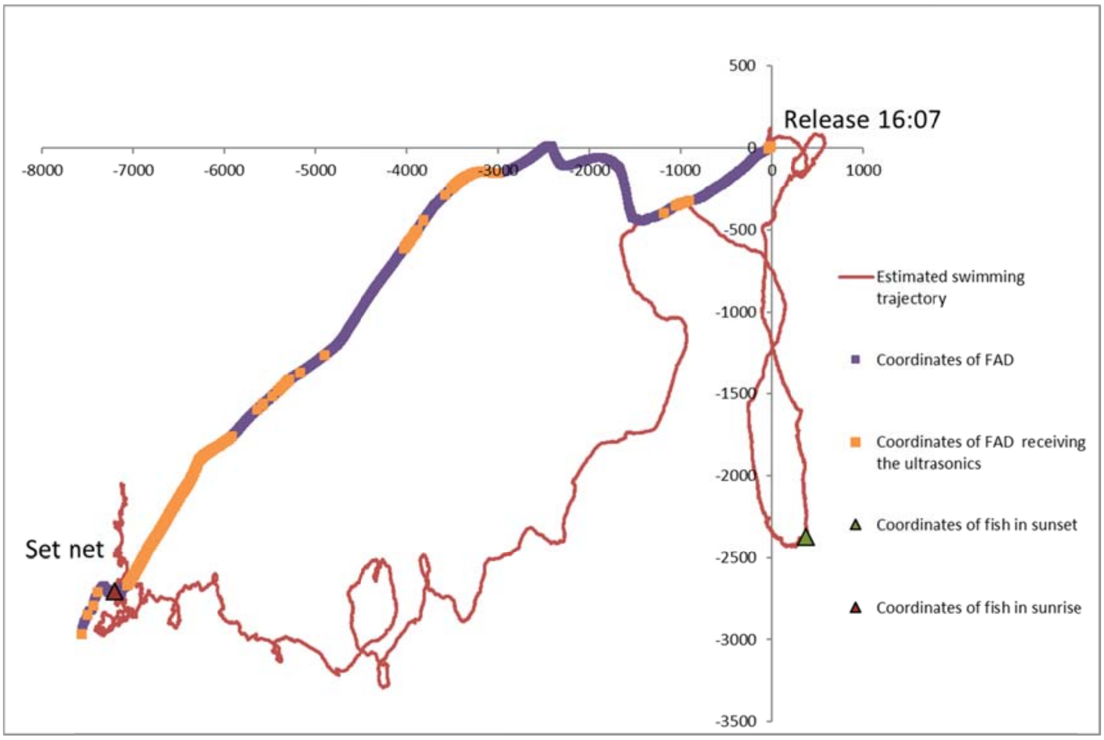


Figure 2. Horizontal trajectory of 62 cm bigeye tuna and FAD.

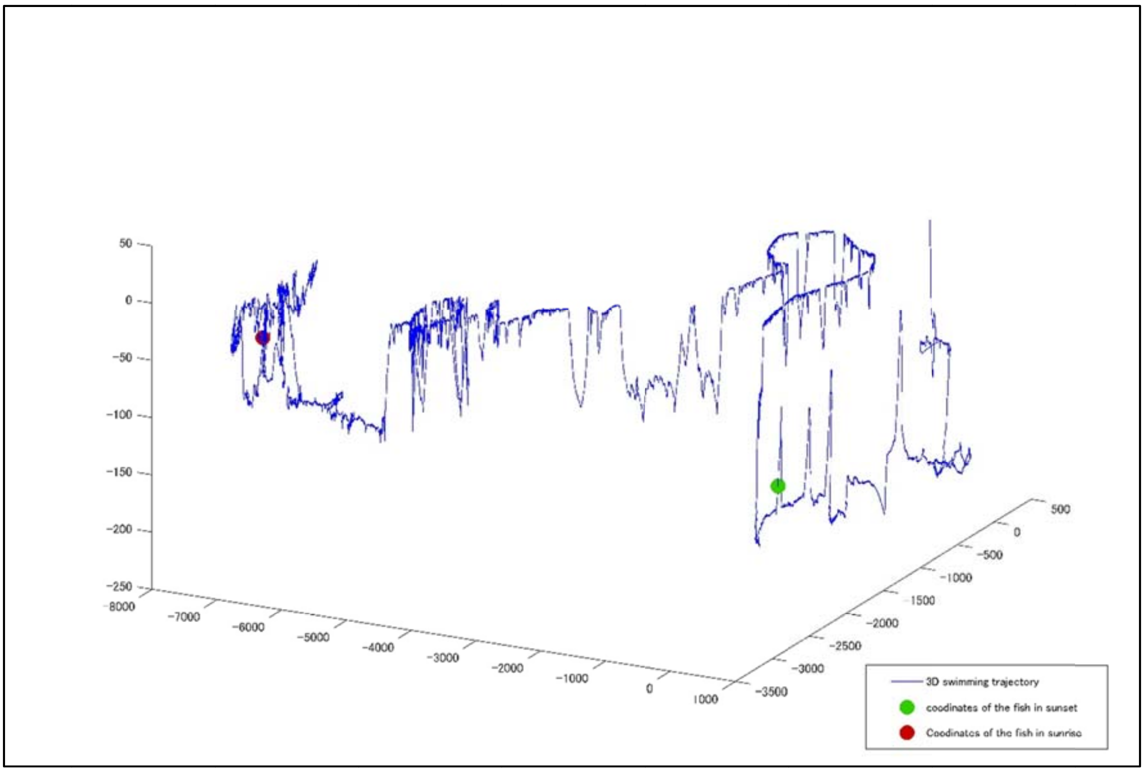


Figure 3. Three-dimensional trajectory of 62 cm bigeye tuna.

Original: English

SIZE SELECTIVITY OF TUNA PURSE SEINE NETS ESTIMATED FROM FAD SETS DATA

Tatsuki Oshima[1], Mitsunori Susuki[1], Shoko Wada[1],
Yasuyuki Sasaki[1], Takayoshi Uehara[1], Hajime Miyahara[1], Ippei Fusejima[1]

ABSTRACT

Mitigating small tuna by-catch in FADs fishery is an urgent task for sustainable fishery. Although using large mesh net might reduce small tuna catch, its impact is unknown as very few studies has been done on the size selectivity of purse seine nets. To obtain quantitative information on the size selectivity we compared the catch composition from two different mesh size nets. The catch of small mesh showed more catch of smaller fish of 25-35cm FL. The result suggests possible escape of small fish from large mesh openings.

[1] Marine Fisheries Research and Development Center (JAMARC) of Fisheries Research and Education Agency (FRA).

Appendix

SIZE SELECTIVITY OF TUNA PURSE SEINE NETS ESTIMATED FROM FAD SETS DATA

Introduction

The Fish Aggregating Devices (FADs) attract fish including small bigeye tunas. This nature results in by-catch of small bigeye tuna in purse seine fishery and causes negative impacts to its stock status. Effective method to mitigate the small tuna by-catch is necessary.

Generally, enlarging mesh size of nets can reduce by-catch of small fishes. In purse seine fishery, however, there have not been clear evidence that shows the size selectivity of the gear. We tried to compare the catch composition of two nets with different mesh sizes and to estimate the size selectivity curves for tune purse seine nets.

Materials and Methods

1 *Sampling*

Two tuna purse seiners were used for the study; Taikei-maru No.1 and Koyo-maru No.88. Two vessels have nets with different mesh size; smaller mesh (240mm) for Taikei-maru and larger mesh (300mm) for Koyo-maru. To make a comparison with uniform conditions, we used data of the sets from same area (eastern Indian Ocean) and from same period (November-December 2016). Also, only the data for FAD sets were used. Research scientists on board both ships measured the three-major species (skipjack, yellowfin and bigeye) to estimate the size composition of each catch. Spill sampling method were used to collect sample.

The size data from 14 sets with small mesh and from 28 sets with large mesh were summed up for each net and were used for the analysis.

2 *Estimation of size selectivity curves*

We estimated the size selectivity curve of the large mesh net using estimated split model of the SELECT method (Millar and Walsh1992, Tokai & Mitsuhashi 1998).

For selection function of the large mesh net, the logistic curve $\mathrm{r}(l)$ is applied.

$$\mathrm{r}(l) = \frac{\exp(a + bl)}{1 + \exp(a + bl)}$$

The "split parameter" p of the estimated split model is the relative fishing intensity of the large mesh net. In case of this study, for a fish caught, its probability of being caught in large mesh and small mesh net is p and $1 - p$ respectively.

Consequently, for a fish of length l, its probability of being caught in large mesh is $p * r(l)$. Similarly, its probability of being caught in small mesh is $1 - \mathrm{p}$ under the assumption that small mesh net captures all size classes. Then the probability that a fish of size l is caught in large mesh net is described in the following function.

$$\varphi(l) = \frac{p * r(l)}{1 - p + p * r(l)}$$
$$= \frac{p * exp(a + bl)}{1 - p + \exp(a + bl)}$$

The number of fish caught in large mesh net can be modelled as binomial distribution. The likelihood function L, that is multiplied overall length classes is:

$$L = \prod_{l} \frac{n_{L+}!}{n_{Ll}!\, n_{Sl}!} \varphi(l)^{n_{Ll}} [1 - \varphi(l)]^{n_{Sl}}$$

where n_{Ll} and n_{Sl} denotes the number of fish of length l caught in the large mesh and small mesh nets respectively. n_{L+} is the total number of fish of length l ($n_{L+} = n_{Ll} + n_{Sl}$). The log-likelihood function is:

$$log_e L = \sum [n_{Ll} log_e\, \varphi(l) + n_{Sl} log_e (1 - \varphi(l))]$$

The parameters a, b and p that maximize the $log_e L$ were estimated using Excel solver.

Results

Figure 1 shows the size composition of skipjack, yellowfin and bigeye tunas caught with two nets. For each species, the catch number of 25-35 cm size classes were generally larger in sample from small mesh net compared to that from large mesh. This suggests possible escape of smaller fish through mesh openings.

Figure 2 shows the fits of the estimated curves to the observed proportions of catch of large mesh net to total catch for the three species. **Figure 3** shows the preliminary result of size selectivity curve estimation for the three species. Size selectivity curve of skipjack tuna showed steeper selectivity than that of yellowfin and bigeye tunas.

Discussion

The large-scale field study showed, for the first time, clear difference in size composition between two mesh size nets in tuna purse seine fishery. Although the mesh size ratio was only 1.25 times, the catch of smaller tunas differed significantly.

As for the selectivity curve estimation, the result should be considered preliminary because the small mesh we used was not small enough that some part of smaller fish might have escaped through the mesh. Authors are planning to conduct another comparison study with nets with 150 and 300 mm mesh size.

For purse seine fishery, it is presumed that another factor such as time of the day (light condition) or the current speed affect the escaping of fish through mesh openings. Those factors should also be considered in further analysis.

References

Millar and Walsh 1992. Analysis of trawl selectivity studies with an application to trouser trawls. Fisheries Research, 13(1992) 205-220.

Tokai & Mitsuhashi 1998. SELECT Model for Estimating Selectivity Curve from Comparative Fishing Experiments. Bulletin of the Japanese Society of Fisheries Oceanography 62(3) 235-247 (in Japanese).

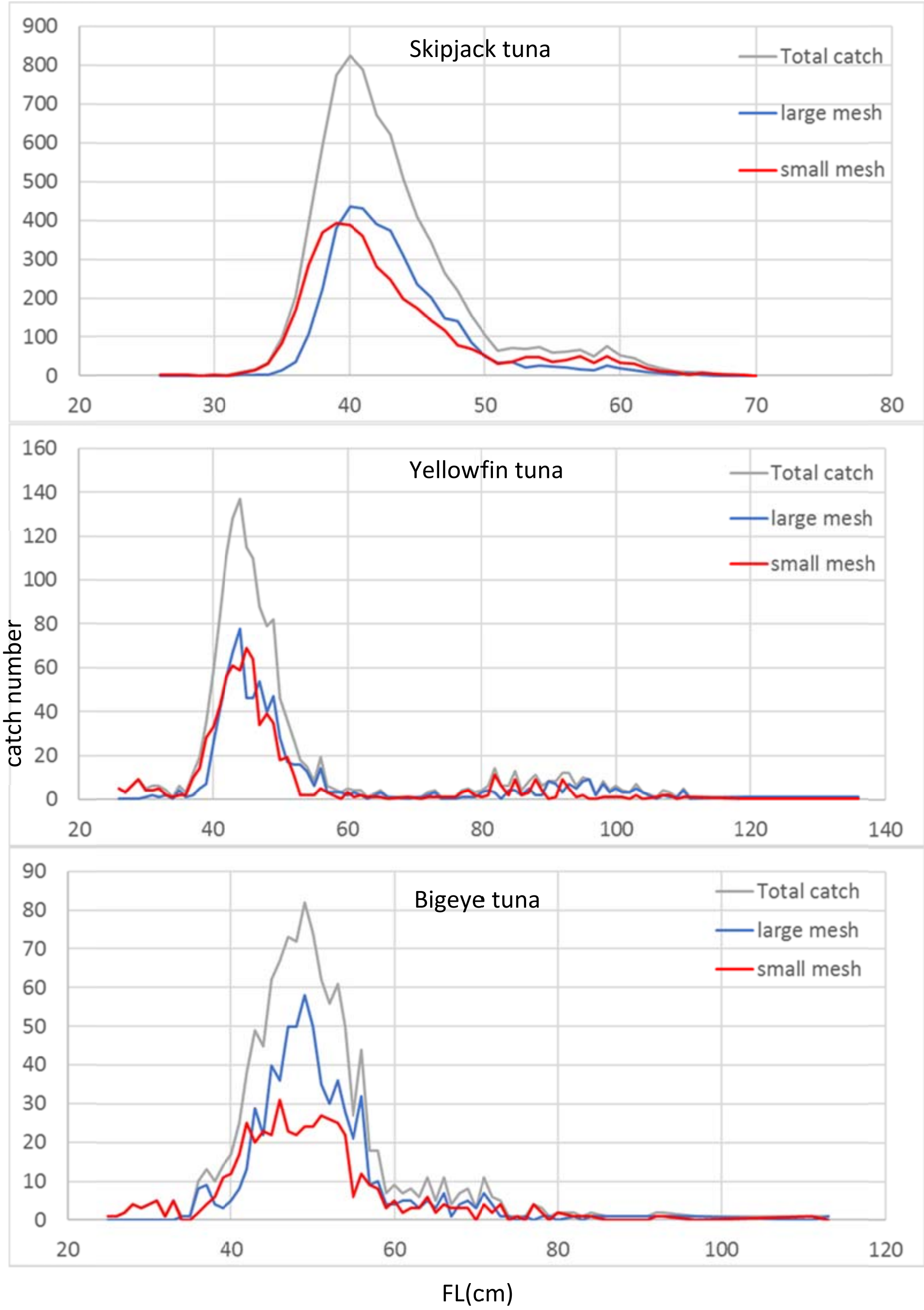


Figure 1. Size composition of skipjack, yellowfin and bigeye tunas caught with two nets.

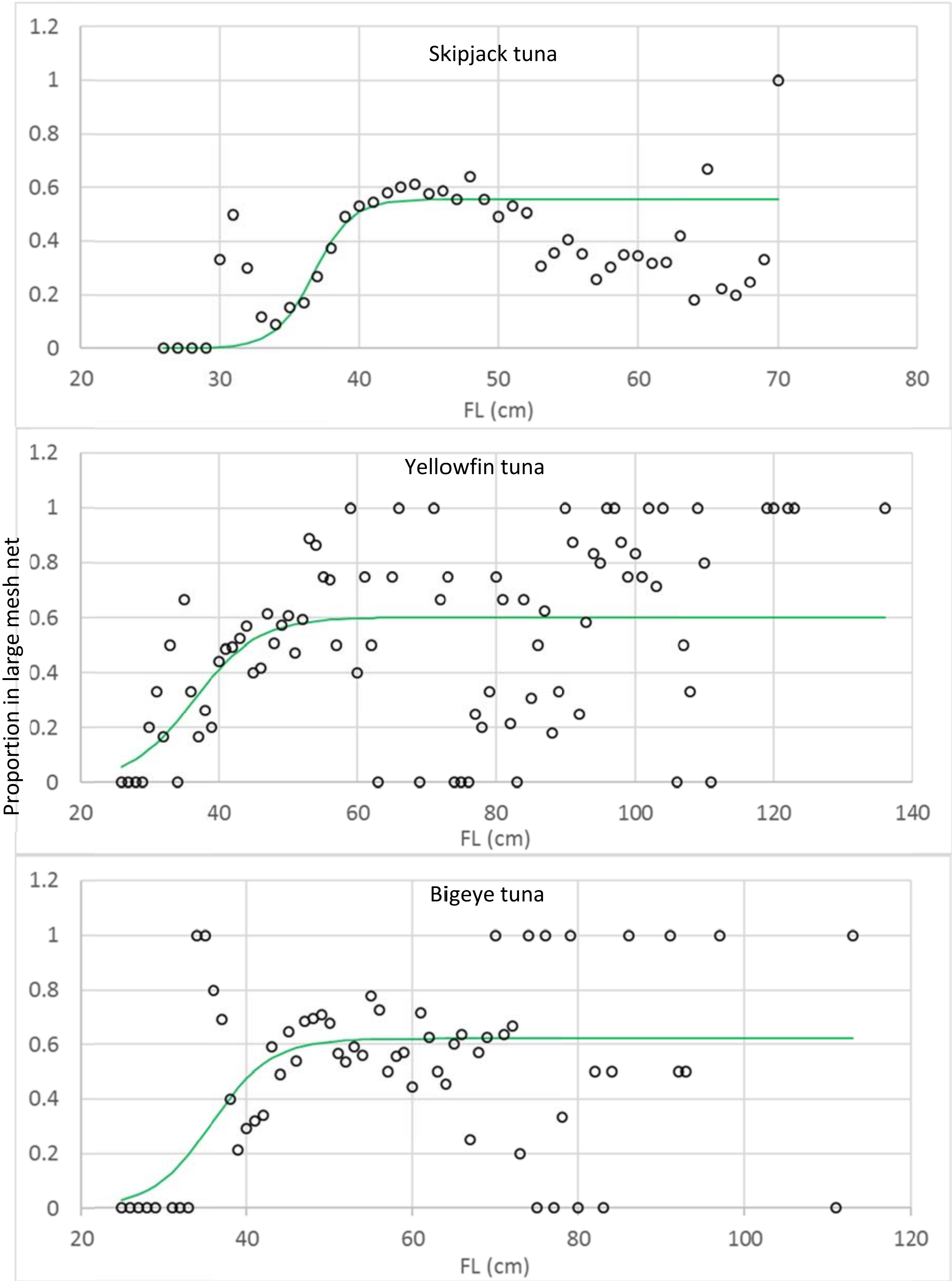


Figure 2. Fits of the estimated curves to the observed proportions of catch of large mesh net to total catch for the three species.

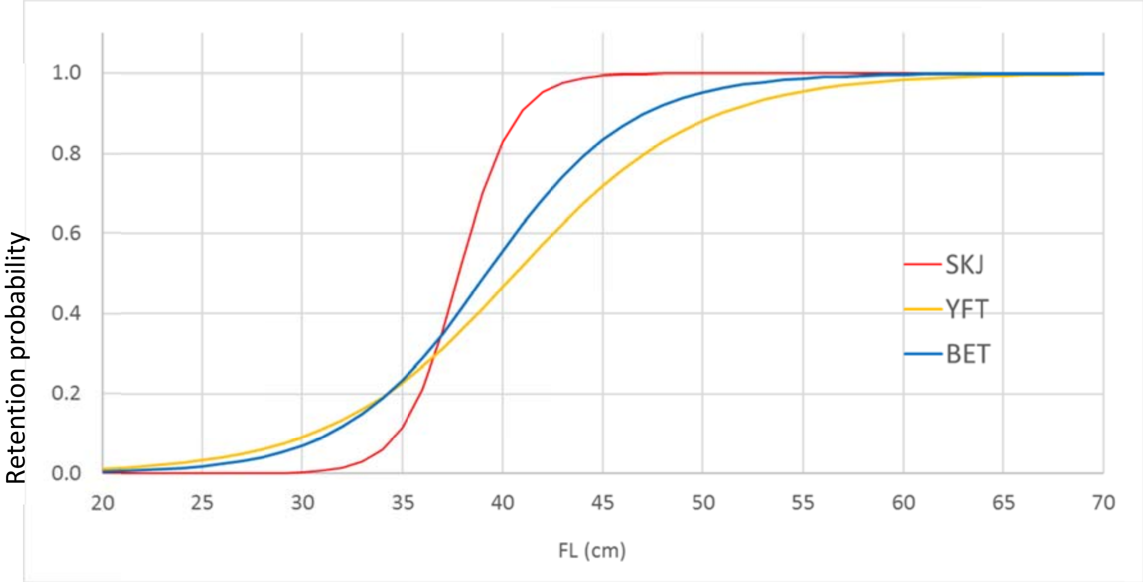


Figure 3. Preliminary result of size selectivity curve estimation for the three species; skipjack (SKJ), yellowfin (YFT) and bigeye (BET).

Original: English

KEY AREAS FOR FUTURE ACTION FOR THE JOINT T-RFMO FAD WG

KEY AREAS	SPECIFIC ACTIONS	KOBE	RFMO	CPC
GENERAL ISSUES	Legal aspects:			
	– Definition of a FAD	X	X	
	– Definition of ownership and responsibilities	X	X	
	Definitions and common indicators:			
	– Identify available sources for common definitions	X		
	– Harmonize definitions related to science and management of FADs: FAD set (associated vs non- associated), non-entangling, biodegradable, active buoy, type of operation at FADs etc. Prioritization should be given to those definitions with direct management implications and the science needed to guide that management	X	X	
	– Need to develop harmonized FAD fishery indicators (e.g. number of FADs, FAD sets, ratio of FAD-associated sets to unassociated sets, numbers of vessels deploying FADs and supply vessels etc.) to estimate the contribution of FADs to the overall effective fishing effort and capacity in tropical tuna fisheries across ocean regions	X	X	
	Enhanced cooperation:			
	– Collaboration between industry and scientists for the improvement of the collection of data, scientific research and to develop effective mitigation techniques			X
	– Coordination and collaboration on research plans on FADs across t-RFMOs	X	X	
	– Creation of a small technical working group of experts under the KOBE umbrella, with a focus on research and other technical aspects	X	X	
	Elaboration and implementation of appropriate management frameworks:			
	– Define clear management objectives	X	X	

	– Review existing FADs management plans and explore potential for harmonization across t-RFMOs	X	X	
	– Assess the effectiveness of various management options for FADs within the framework of general tropical tuna fisheries management (e.g. overall fishing capacity)		X	
	– Address monitoring (e.g. 100% observer and VMS coverage) and compliance issues		X	X
	– Consider adaptive, precautionary, management with respect to emerging issues with FADs, taking into account the best available science		X	X
DATA GAPS AND NEEDS	Data:			
	– Identify data gaps and needs		X	
	– Optimize and harmonize the collection of data and develop common minimum standards and formats	X	X	X
	– Improve data collection in FAD fisheries in general		X	X
	– Establish comprehensive systems to accurately quantify numbers of FADs and active buoys	X	X	
	– Need for development of robust FAD marking and tracking systems	X	X	
	– Establish wide-scale collection of individual FAD deployment, tracking, and set-history data		X	X
	– Collect new types of data on the operational and technical fleets´ characteristics, including on supply vessels		X	X
	– Facilitate access by scientists to acoustic records of the echo-sounder buoys as a potential source of fishery independent indices		X	X
	– Develop appropriate framework of confidentiality	X	X	X
	– Ensure/facilitate access to data for scientists and managers		X	X
	– Mitigate the impact of FADs, consider establishing limits on the number of FADs deployed, and consider feasibility and cost-effectiveness of FAD recovery practices	X	X	X
	– Evaluate economic incentives and disincentives in all FAD management measures	X	X	X

MITIGATION	Target species:			
	– Identification of hotspots for juvenile BET and YFT		X	
	– Evaluate benefits of gear modifications: net changes, FADs designs, etc.	X	X	X
	– Encourage further research on pre-set echo-sounder discrimination of species, and size, at a FAD	X	X	X
	– Consider the regional effectiveness of time-area closures, including adaptive closures, and catch and/or FADs sets limits and allow this to inform future management		X	
	Non-target species:			
	– Improve information on the impacts of FAD fisheries on vulnerable elasmobranch and turtle species	X	X	
	– Identification of hot spots for vulnerable species		X	
	– Implement best practices for handling and safe release of by-catch species as appropriate			X
	– Introduction of non-entangling FADs designs			X
	– Outreach and training of operators		X	X
	– Promote full utilization of low value bony fish by-catch, as appropriate, and reduction of discards			X
	Habitat:			
	– Mapping and recognition of sensitive areas using available information and identification of post-beaching impacts to inform mitigation initiatives		X	
	– Tracking positions and trajectories of FADs		X	X
	– Develop innovative FAD designs to mitigate the habitat impact of FAD fisheries such as prevention of FADs sinking and beaching, recovery at sea, “smart FADs”, biodegradable designs…		X	X
	– Assess the effect of establishing limits on numbers of FADs deployed as well as on areas or periods of deployment		X	X
	– Promote involvement of coastal communities in implementing actions or management measures		X	X
	– Consider anchored and drifting FADs in the overall analysis of impacts		X	X

Joint t-RFMO FAD Working Group meeting
19-21 April 2017, Madrid

IATTC Ad hoc Working Group on FADs.

Summary of 1st year of activities

Work Plan 2017

Josu Santiago
AZTI. Tuna Research Area

INTER-AMERICAN TROPICAL TUNA COMMISSION
89TH MEETING
Guayaquil (Ecuador)
29 June-3 July 2015

RESOLUTION C-15-03

COLLECTION AND ANALYSES OF DATA ON FISH-AGGREGATING DEVICES

Section 5. *Ad Hoc* Working Group on FADs

15. An *ad hoc* Working Group on FADs (Working Group) is established.
16. This Working Group shall be multi-sectorial, involving various stakeholders such as scientists, fishery managers, fishing industry representatives, administrators, representatives of non-governmental organizations, and fishers. Expressions of interest to participate in the Working Group shall be provided to the Director no later than 1 October 2015.
17. To the highest degree possible, the Working Group shall conduct its work electronically or, if convenient and cost-effective, in targeted face to face meetings that take place in conjunction with other Commission meetings.
18. The Working Group shall present an initial report of its findings at the 2017 meeting of the SAC.
19. The Terms of Reference of the Working Group are those indicated in Annex III.
20. The Working Group shall seek input from other similar working groups on FAD management established in other tuna regional fisheries management organizations (tuna-RFMOs).
21. The IATTC, at its 2017 annual meeting, will review the progress and outcomes of the Working Group and will decide on the necessity for its continuation.

Terms of reference [2015]

- Collect and compile information on FADs in the EPO, including but not limited to data collected by the IATTC and reports prepared by the scientific staff of the IATTC;
- Review the FAD data collection requirements established in Resolution C-15-03 to assess the necessity for revision;
- Compile information regarding developments in other tuna-RFMOs on FADs;
- Compile information regarding developments on the latest scientific information on FADs, including information on non-entangling FADs; and
- Prepare a preliminary report for the SAC, including specific recommendations, as appropriate.

2016 activities

- Electronically: Basecamp
- Face to face meeting:

  1st meeting, 2 sessions: 15 May & 26 June

2016 activities

1. Summary of the collection and compilation of information on FADs in the EPO; **identification of information gaps**
2. Progress regarding the **most recent scientific information on FADs**, including information on non-entangling FADs
3. Review of the data-collection requirements established in Resolution C-15- 03; proposal for **standard forms**
4. Progress regarding management of FADs in **other tuna RFMOs**
5. Identification of **potential management measures** for FADs: pros and cons

INTER-AMERICAN TROPICAL TUNA COMMISSION

90TH MEETING

La Jolla, California (USA)
27 June-1 July 2016

RESOLUTION C-16-01

AMENDMENT OF RESOLUTION C-15-03 ON THE COLLECTION AND ANALYSES OF DATA ON FISH-AGGREGATING DEVICES

INTER-AMERICAN TROPICAL TUNA COMMISSION

90TH MEETING

La Jolla, California (USA)
27 June-1 July 2016

RESOLUTION C-16-01

AMENDMENT OF RESOLUTION C-15-03 ON THE COLLECTION AND ANALYSES OF DATA ON FISH-AGGREGATING DEVICES

SECTION 5. *AD HOC* PERMANENT WORKING GROUP ON FADS

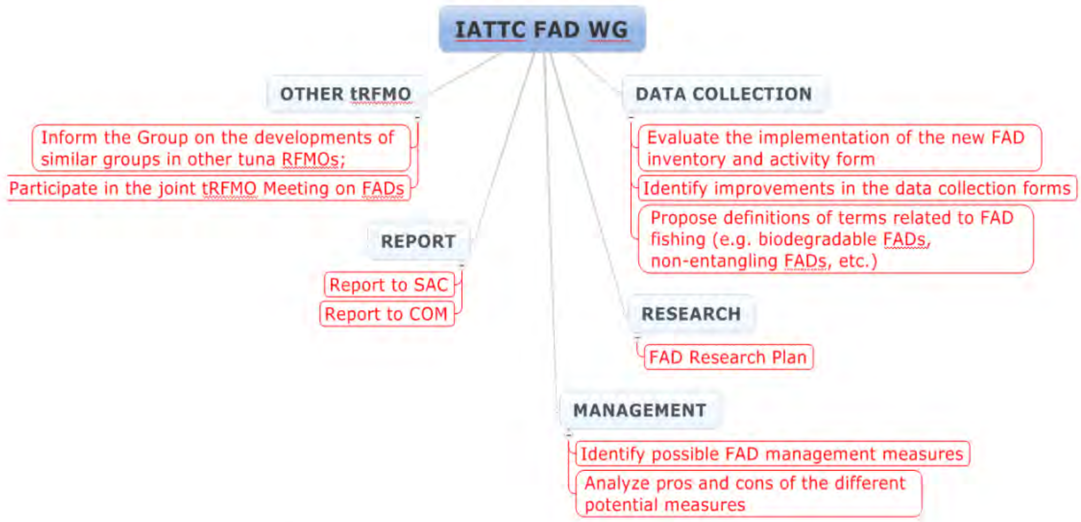
14. An *ad hoc* Permanent Working Group on FADs (Working Group) is established.
15. This Working Group shall be multi-sectorial, involving various stakeholders such as scientists, fishery managers, fishing industry representatives, administrators, representatives of non-governmental organizations, and fishers. Expressions of interest to participate in the Working Group shall be provided to the Director, who shall inform CPCs and the Chair of the FADs Working Group.
16. To the highest degree possible, the Working Group shall conduct its work electronically or, if convenient and cost-effective, in targeted face-to-face meetings that take place in conjunction with other Commission meetings.
17. The Working Group shall report on a regular basis to the Commission and present an initial report of its findings at the 2017 meeting of the SAC.
18. The Terms of Reference of the Working Group are those indicated in Annex III.
19. The Working Group shall liaise, as far as possible, with other similar working groups on FAD management established in other tuna regional fisheries management organizations (tuna RFMOs), in particular the Western and Central Pacific Fisheries Commission (WCPFC).
20. The IATTC, at its 2017 annual meeting, will review the progress and outcomes of the Working Group and will decide on the necessity for its continuation.
21. This Resolution replaces Resolution C-15-03.

Terms of reference [2016]

1. **Collect and compile** information on FADs in the EPO, including but not limited to data collected by the IATTC and reports prepared by the scientific staff of the IATTC;
2. **Review** the FAD data collection requirements established in this Resolution to assess the need for revision;
3. **Develop data reporting formats and definitions** of terms related to FAD fishing (e.g. biodegradable FADs, non-entangling FADs, etc.), to implement obligations under this Resolution, in cooperation with the scientific staff, to be submitted to the Commission for consideration;
4. **Compile information** regarding developments on FADs in other tuna RFMOs;
5. **Compile information** regarding developments on the latest scientific information on FADs, including information on non-entangling FADs, and identify priority areas for research;
6. **Prepare annual reports for the SAC**, including specific recommendations, as appropriate; and
7. **Identify and review possible FAD management measures**, in coordination with the scientific staff and the SAC, and make recommendations to the Commission, as appropriate.

Amended text in red

2016-2017 Work Plan



TASKS 2016-2017

2016-2017 Work Plan

- Electronically: Basecamp
- 5 Thematic Areas:
  - Data Collection
  - Research
  - Management
  - Other tRFMOs
  - General coordination [includes reporting]
- Face to face meetings 2017:

  1 meeting, 2 sessions:
  - May: before the SAC meeting [1 day]
  - June: before the Commission meeting [1 day]

2016-2017 Work Plan

2nd Meeting of the Ad Hoc Working Group on FADs

Session 1 (La Jolla, 7th May 2017)

1. Opening of the meeting
2. Adoption of the agenda
3. Review of the inter-sessional activities of the Working Group on FADs
4. Review the FAD data collection requirements established in Resolution C-16-01
5. Definitions of terms related to FAD fishing to implement obligations under Resolution C-16-01
6. Progress regarding scientific information on FADs, including information on non-entangling FADs
7. Priority areas for FAD research in the EPO
8. Progress with respect to management of FADs in other tuna RFMOs
9. Identification of potential FAD management measures (1)
10. Recommendations for the SAC

2016-2017 Work Plan

2nd Meeting of the Ad Hoc Working Group on FADs

Session 2 (Mexico, July 2017) - Provisional

11. Opening of the meeting (2)
12. Adoption of the agenda of Session 2
13. Summary and main conclusions of Session 1
14. Conclusions of the SAC in connection with the Working Group on FADs
15. Identification of potential FAD management measures (2)
16. Development Workplan of the Working Group for 2017-2018
17. Recommendations for the Commission
18. Other business
19. Adjournment

Joint t-RFMO FAD Working Group meeting
19-21 April 2017, Madrid

IATTC FAD management framework

IATTC management framework

- **C-99-07**, Resolution on FADs
- **C-02-03**, Capacity of the tuna fleet operating in the EPO
- **C-16-01**, on the collection and analyses of data on FADs
- **C-17-01**, Conservation of tuna in the EPO during 2017 - amends and replaces C-13-01
  - Yellowfin and bigeye tuna
  - Objective – maintain stocks at MSY levels
  - Scope – all purse seine vessels >182 mt carrying capacity, all longline vessels >24 m length overall, fishing in the IATTC Area, including EEZs and high seas

IATTC management framework

- Purse seine
  - 62 day total closure, choice of 2 periods
  - 1 month total closure of ‘Corralito’ area
  - Separate total catch limits (YFT + BET) for floating object sets (class 4-6) (97,711 mt) and dolphin sets (class 6) (162,182 mt)
  - Tender vessels prohibited
- Longline
  - Specified bigeye tuna catch limits for China, Japan, Korea and Chinese Taipei
  - Other flags choose 500 mt or their 2001 catch as limit

1st Joint t-RFMO FAD WG Meeting, Madrid 19-21 April 2017

6. *Review of data requirements needs and data collection systems of relevant information on tuna FAD fishing*

Keynote Speech

Miguel HERRERA

Outline

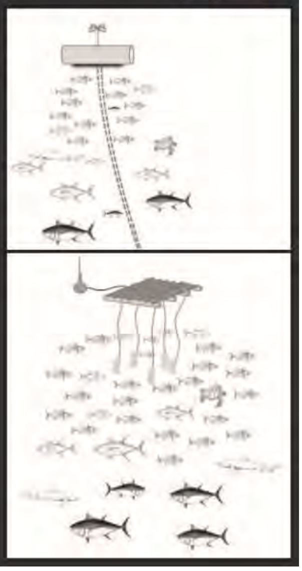
- Which data on FADs ?
- Where are RFMO's now ?
- Is it enough for Management ?
- Final thoughts

Documents

- 10. Legorburu, G. & Monteagudo, J.P. Deployment of non-entangling FADs and related activities monitored by electronic monitoring system in the Indian Ocean
- 11. Ramos, M.L. *et al.* Spanish FADs logbook: Solving past issues, responding to new global requirements
- 13. Santiago, J. *et al.* Monitoring the number of active FADs used by the Spanish and associated purse seine fleet in the IOTC and ICCAT convention areas
- 14. Santiago, J. *et al.* Buoy derived Abundance Indices of tropical tunas in the Indian Ocean
- 26. Dagorn, L. *et al.* & 27. Capello, M. *et al.* Managing the number of FADs using fisheries-independent data: Principles and theories
- 31. López, J. *et al.* Taking another step forward: System of verification of the Code of Good Practices in the Spanish tropical tuna purse seiner fleet operating in the Atlantic, Indian and Pacific oceans

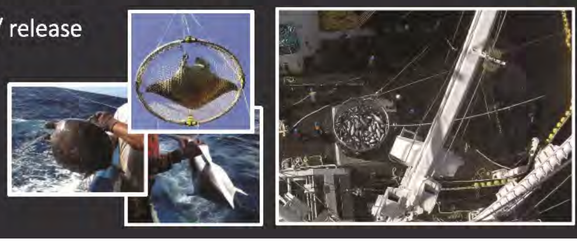
Which Data (i): FAD Design & Tracking

- Data shall be collected on both **anchored FAD** (aFAD) & **drifting FAD** (dFAD)
- **Design**: Materials and structure of FADs
  - Materials used to build the raft / platform, including those to increase its flotation, and dimensions
  - Materials used to build the hanging structure of the FAD, and dimensions
  - Any tools used to enhance the properties of the FAD to attract fish (e.g. lights)
- **Tracking**: Type of tracking device
  - Number of buoys purchased
  - Type of tracking: Radio or Satellite
  - Make, type and model of tracking device (including details on eco-sounder)
- **ID**: FAD/buoy ID and marking systems (if any), uniqueness, location



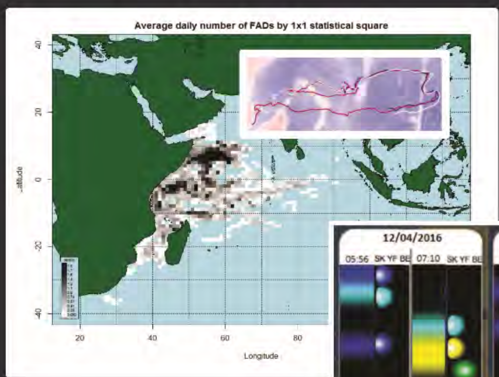
Which Data (ii): Fishery Dependent Data

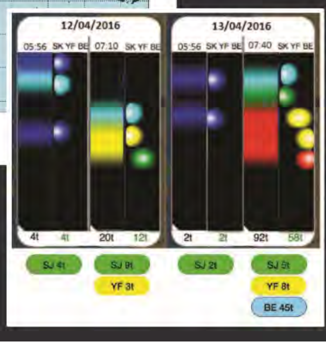
- **Deployment**
  - Boat, Date/Time, Position (LAT-LON), ID, Design & Tracking
- **Encounter/Visit**
  - Entity (sea or land), Date/Time, Position (LAT-LON), ID, Design & Tracking
  - Bycatch entangled on FAD netting
  - Changes made
- **Set**
  - Boat, Gear, Date/Time, Position (LAT-LON), ID, Design & Tracking
  - Retained catch (target and bycatch) / discards / release procedures / fate
  - Bycatch entangled on FAD netting
- ***Loss*** **(to the boat that deployed it)**
  - Date/Time, Position (LAT-LON), ID
  - *Reason lost (where known)*



Which Data (iii): Fishery [In]dependent Data

- **Tracks (dFAD only)**
  - Service provider
  - Make and Model of tracking device
    - Specifications
  - Date/Time, Position (LAT-LON), ID
    - Frequency of collection
- **Echo-sounder** readings
  - Service provider
  - Make and Model of echo-sounder(s)
    - Specifications & Biomass estimation procedure
  - Date/Time, Position (LAT-LON), ID
    - Frequency of collection
  - Estimates of total biomass beneath the FAD (by species [group] / size)





Where are RFMOs at present ?

RFMO & FAD Data	IOTC			ICCAT			IATTC			WCPFC			Document					
	Required	Source	Repository	Required	Source	Repository	Required	Source	Repository	Required	Source	Repository	10 EMS	11 Logbook	13 Comp.Lim.	14 Idx. Abund.	27 Mgt. #FAD	31 Mit.Byc.
#Buoy Purchased	Man Meas	Prov	Sec	No	Prov	Prov	No	Prov	Prov	No	Prov	Prov			X			
FAD Design/Activities	Data Req	Ind	FSt	Data Req	Ind	FSt	Data Req	Ind / Obs	Sec	Data Req	Obs	Sec	X	X		X	X	X
Buoy Density	Man Meas	Prov	FSt	Data Req	Prov	Sec	No	Prov	Prov	No	Prov	Prov			X	X	X	X
Echo-Sounder Reading	No	Prov	Prov	No	Prov	Prov	No	Prov	Prov	No	Prov	Prov				X	X	

Key

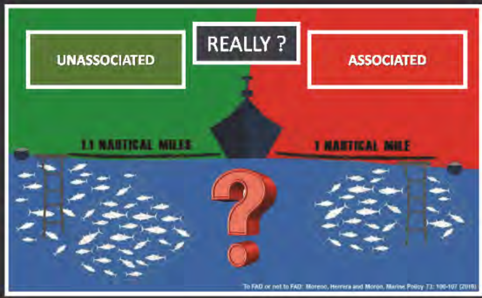
Data Req	The RFMO has adopted specific data collection and reporting requirements, which may include reporting of data to the RFMO in raw or aggregated form		
Fst	The raw data is kept by the administration of the flag state; the RFMO Secretariat may receive data in aggregated form	Ind	Data are collected by the fishing industry
Man Meas	Data has to be collected by the flag state to validate compliance with management measures adopted by the RFMO	Obs	Data are collected by scientific observers (regional programme)
Sec	The RFMO Secretariat keeps the data in raw form (as collected)	Prov	Data are collected / kept by the service provider

What is the RFMO agenda on FADs ?

- FAD Management Plans
- Marking & Identification of FADs
- FAD Logbook: Activities with FADs
  - Documents 10 & 11
- FAD density/capacity: # active buoys/(FAD ?) [per 1 degree square]
  - Documents 13, 14 & 26/27 (*plus eco-sounder data*)
- Bycatch mitigation: Use of Non-entangling FADs and safe release
  - Document 31
- Environmental impacts of FADs ([real] FAD Loss & beaching events)
  - Promote use of biodegradable FAD

Is it enough for management ? - Definitions

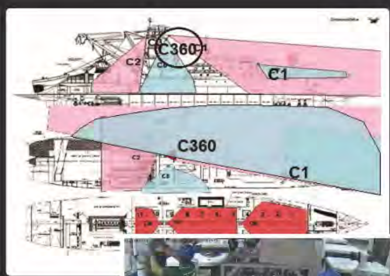
- What is a FAD set ?
  - WCPFC defines a FAD set as any set happening in presence of a FAD which is within 1NM from the fishing vessel
  - FAD sets have not been formally defined by other RFMO
  - The scientific literature says that a tuna school may be associated to a FAD at distances of up to 12NM from it
  - Identification of catches made on FAD sets is not possible from all RFMO data
    - ICCAT and IOTC break PS catch into associated/unassociated
    - aFAD catches are seldom reported for other gears



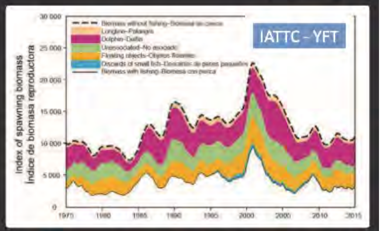
- What is a non-entangling FAD (NEFAD) ?
- What is a biodegradable FAD ?
- Are FAD data collected enough to stick each FAD into the above categories ?

Is it enough for management ? - Standards

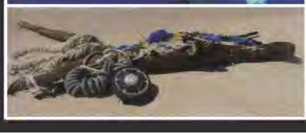
- FAD Management Plans: Some RFMO provide some guidelines: Is it enough ?
  - Sampling coverage
    - Total enumeration: Is it required / is it possible / can it be managed ?
      - FAD fishery [independent] data: FAD losses/density/echo-sounder readings
        - Only IOTC does not allow the use of non-instrumented FADs
        - FAD impacts difficult to assess due to FAD tiki-taka strategy
          - But tiki-taka helps reducing FAD loss
  - Data resolution and reporting standards & time-frames
    - Does the data need to be collected routinely ? (which frequency ?)
    - Under which resolution ? (minima standards)
    - Who does the collection ? (industry/observers)
    - How is it validated ? (e.g. [electronic] observers)
    - When has it to be reported ? (reporting time-frames)
  - Data repository, dissemination
    - Do RFMO Secretariats need to have it ? (Reporting resolution and data repository)
    - In which format can it be disseminated (raw, aggregated) and to whom (public domain, working groups)



Is it enough for management ? - Impacts



- Target species: Tropical tunas
  - Can FAD Data assist in the generation of scientific advice ?
    - Fishery dependent index of abundance (PS CPUE) (**logbook + FAD density** ?)
    - Fishery independent index of abundance (Biomass estimates buoy **echo-sounder**)
      - Estimates of biomass beneath FADs refer to total catch, not catch by stock
  - Impacts from each fishing method (e.g. FAD)
  - Contribution of FADs to PS and all fisheries fishing capacity
- Bycatch species: Sharks, marine mammals, marine turtles, other bony fish
  - Are data available enough to estimate retained bycatch & discards ?
  - Can rates of bycatch mortality from FAD netting / FAD sets be estimated ? (observers)
- Impacts on marine environment
  - Can FAD loss / beaching events be assessed using the existing data ?
    - Combination of logbook, tracks & beaching events data

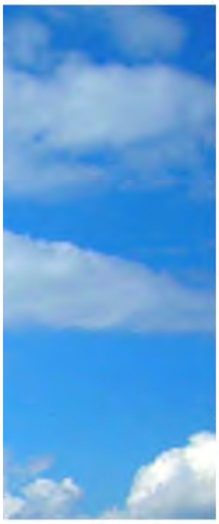


Final *FAD* for thought

- Shall guidelines for FAD Management Plans encompassing all RFMO be recommended ?
  - Need consistency in the definition FAD terms (FAD set, NEFAD, Biodegradable)
  - Harmonization of minima data collection / reporting / dissemination standards
  - Need data validation other than observers ? (e.g. electronic observers)
  - **Are RFMOs prepared to go along with harmonization ?**
- Are FAD data available enough or more is needed ?
  - Are FAD data reported by RFMO standards at present ?
    - How complete are the data currently available on FAD ? Which quality ?
      - Shall data requirements be extended ?
  - Is the available data enough to ensure compliance with existing RFMO management ?
    - FAD ID
    - Environmental Impacts (loss & beaching)
  - Are flag states / RFMO Secretariats in a position to manage more data ?
  - Are data from other fisheries more important for management at the moment ?
    - CE Data to build indices of abundance
    - Bycatch interactions longline, driftnet, etc.
- Everything cannot be answered here
  - Need further work on this (Guidelines created by Consultant and reviewed at a future meeting ?)


Thanks
for your
attention

ICCAT Research Plans related to FADs



- Process for Research Planning
- Science strategic plan
- Workplan for tropical tunas
- Atlantic Ocean Tropical Tuna Tagging Program (AOTTP)

Research Planning in ICCAT

- Research planning done by the Scientific Committee on Research and Statistics (SCRS)
- ICCAT has a science strategic plan for 2015-20120
- Each SCRS Working Group (WG) or sub-committee develops an annual workplan (research & statistics):
  - Workplan Tropical Tunas
  - Workplan Ecosystems
  - Workplan Stock Assessment methods
  - Workplan Statistics
- ICCAT does not have a research plan specific to FADs

SCIENCE STRATEGIC PLAN 2015-2020

Goal/Strategy	Description
Improve resolution and precision of total catch composition and distribution and fishing effort data across CPCs	Compiling comprehensive data on floating object sets (especially on FADs) and on fishing operations by: i). Cooperating with the industry for obtaining detailed FAD information (historical and present), under agreed confidentiality rules, ii). Proposing and adopting revisions to confidentiality protocols as needed.

SCIENCE STRATEGIC PLAN 2015-2020

Goal/Strategy	Description
Identify and fill knowledge gaps so as to be able to provide scientific advice including ecosystem considerations (e.g. assessment of bycatch species, mitigation strategies, environmental effects on population dynamics, fishing impacts on the ecosystem, socio economic aspects, etc.)	Subcommittee on Ecosystems and Bycatch to organize specific workshops (e.g. on tropical tuna issues including moratorium effects, mitigation aspects, multispecies stock assessments, FAD effects and management plans, etc.).

WORKPLAN Tropical tunas (2017)

Analyze the efficacy of the FAD Moratorium

- Analyzing the efficacy of the new area/time closure in relation with the protection of juvenile tropical tunas pursuant to Rec. 15-01 by reviewing the data collected through the AOTTP

- Evaluate how changes to the size structure of the catch affect recovery timelines for bigeye

- Analyze corrected historical data to advice appropriate time/area moratorium for FAD closure.

WORKPLAN Tropical tunas (2017)

Management Strategy Evaluation (MSE)

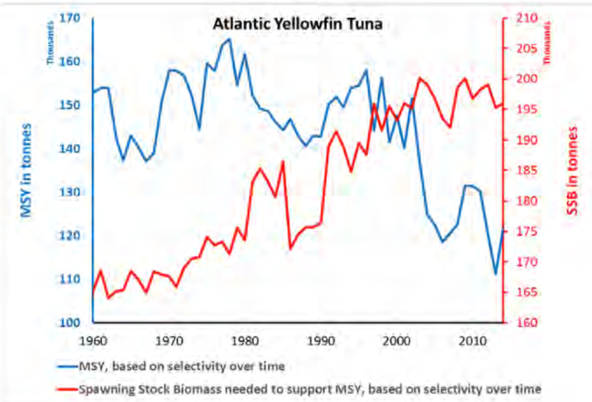
- Review performance indicators for yellowfin and bigeye
- Provide feedback regarding initial performance metrics for yellowfin and bigeye
- Initial developments of yellowfin / bigeye MSE
- Review existing operating models and provide feedback on potential operating model design issues
- Develop a programme to implement and fund MSE for tropical tunas for a minimum of three years.

Additions to WORKPLAN Tropical tunas

REC 16-01
RECOMMENDATION BY ICCAT ON A MULTI-ANNUAL CONSERVATION AND MANAGEMENT PROGRAMME FOR TROPICAL TUNAS

Address the Recommendations made by the FAD Working Group in 2016

- Provide advice on possible modifications of fishing patterns affecting the catch-at-size composition and their impact on MSY and relative stock status.



- impact on MSY, BMSY, and relative stock status for both BET and YFT resulting from reductions of the individual proportional contributions of longline, FAD purse seine, free school purse seine, and baitboat fisheries to the total catch.

WORKPLAN Tropical tunas (post 2017)

Stock Assessments **Recent Status**

Species	Stock	Last SA	Next SA		Most likely	Possibly
YFT		**2016**				
BET		2015	2018			
SKJ	E	2014	2019			
SKJ	W	2014	2019			

AOTTP
Atlantic Ocean Tropical Tuna Tagging Program

Overall objective:
contribute to food security and economic growth of the Atlantic coastal states by ensuring sustainable management of tropical tuna resources in the Atlantic Ocean.

Specific objective:
provide evidence-based scientific advice to help adopt appropriate Conservation and Management Measures for tropical tunas

Strategy:
Tagging program (Bigeye tuna, Yellowfin tuna, Skipjack tuna and Little tunny) to improve the estimation of key parameters for stock assessment (i.e. growth, natural and fishing mortality, migrations and stock-structure).

AOTTP
Atlantic Ocean Tropical Tuna Tagging Program

Potential scientific outputs related to FADs

- Population parameters of tropical tunas and little tunny
- Recapture rates from different gears (purse seines fishing on FADs/free schools, longlines, baitboats)
- Overlap between the migration paths of psat-tagged fish and the distribution of FADs
- Overlap between the migration paths of psat-tagged fish and the seasonal FAD closure
- Time spent in association with FADs of psat-tagged fish

Conclusion:

- Planning for research on FADs cannot be done in isolation to the planning to support management of tropical tunas and the ecosystems that support them
- There is substantial research being planned by ICCAT in relation to FADs but there is no FAD research plan
- Research needs are numerous and challenging, therefore ICCAT could benefit from research efforts conducted by other tRFMOs

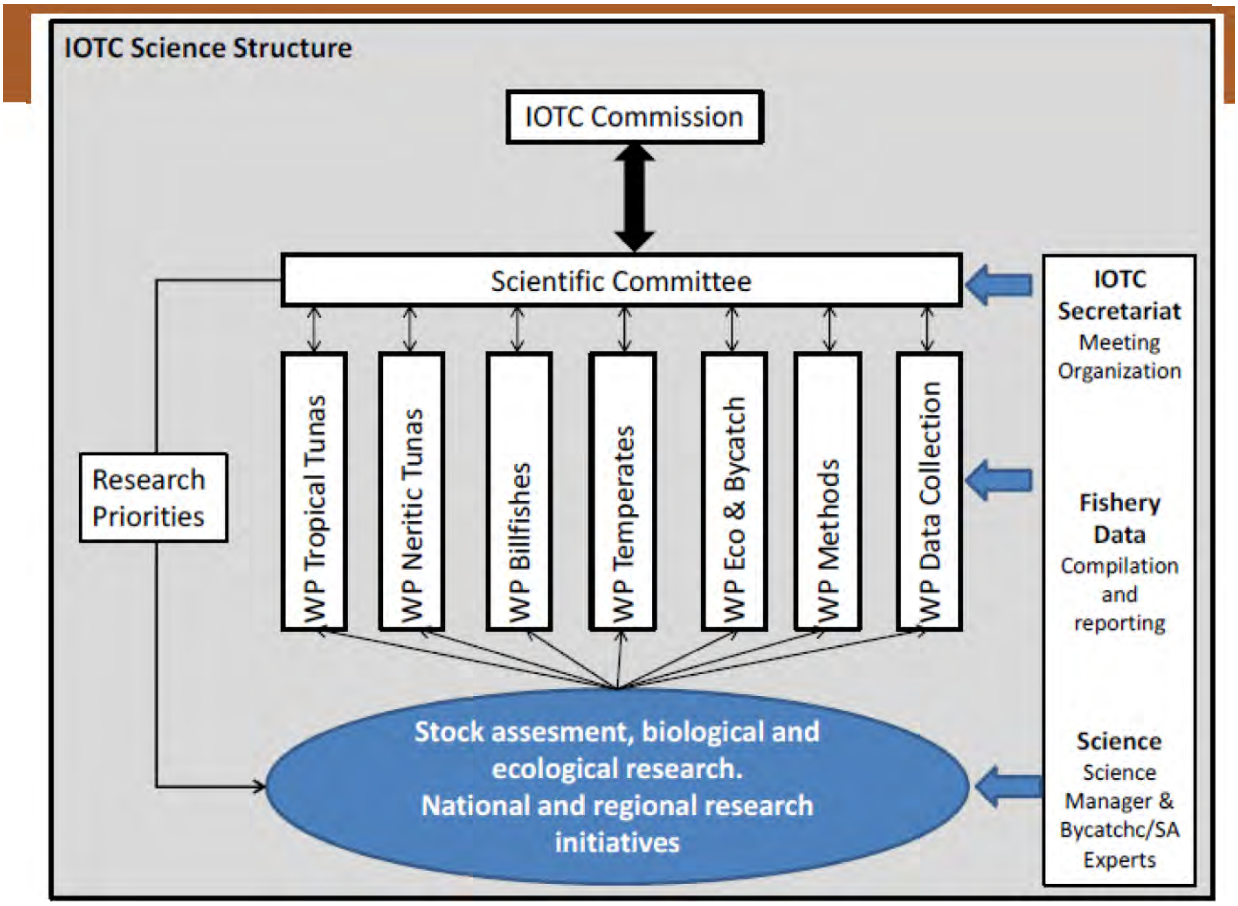
Possible discussion points

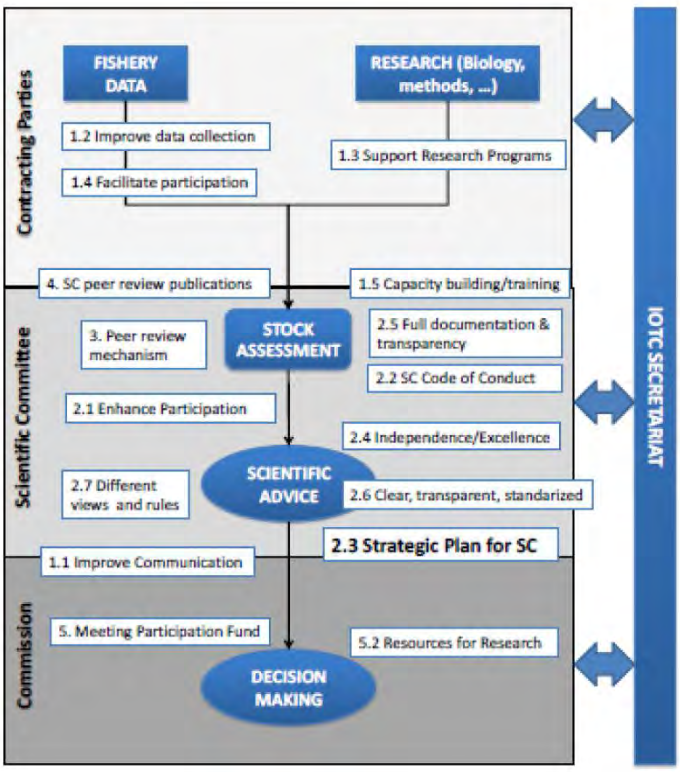
- Are the FAD –related research priorities for different tRFMO the same? Are there potential benefits from coordinating research across tRFMOs to increase the effectiveness and benefit of research programs to the individual Commissions?
- Are the research teams working in different tRFMOs collaborating already? Is there a mechanism to promote this collaboration, or should a mechanism be developed?
- There are a few research providers that can conduct research across oceans. Are there benefits on having such providers conduct a large part of the research on FADs? Is there a need to expand the number of institutions, national scientific organizations involved in this research to ensure tRFMO member countries embrace more the results of the research and participate in the development of mitigation solutions?

IOTC Research Plans related to FADs

iotc ctoi

Hilario Murua
Scientific Committee Chair
Joint t-RFMO Meeting
19-21 April 2017


IOTC Science Structure
IOTC Commission
Scientific Committee
Research Priorities
WP Tropical Tunas
WP Neritic Tunas
WP Billfishes
WP Temperates
WP Eco & Bycatch
WP Methods
WP Data Collection
Stock assesment, biological and ecological research.
National and regional research initiatives
IOTC Secretariat
Meeting Organization
Fishery Data
Compilation and reporting
Science
Science Manager & Bycatchc/SA Experts


Contracting Parties
Scientific Committee
Commission
FISHERY DATA
RESEARCH (Biology, methods, ...)
1.2 Improve data collection
1.3 Support Research Programs
1.4 Facilitate participation
4. SC peer review publications
1.5 Capacity building/training
3. Peer review mechanism
STOCK ASSESSMENT
2.5 Full documentation & transparency
2.2 SC Code of Conduct
2.1 Enhance Participation
2.4 Independence/Excellence
2.7 Different views and rules
SCIENTIFIC ADVICE
2.6 Clear, transparent, standarized
2.3 Strategic Plan for SC
1.1 Improve Communication
5. Meeting Participation Fund
5.2 Resources for Research
DECISION MAKING
IOTC SECRETARIAT

MARINE TURTLES

6. Marine turtle bycatch mitigation measures	6.1 Review of bycatch mitigation measures			
	6.1.1 Res. 12/04 (para. 11) Part I. The IOTC Scientific Committee shall request the IOTC Working Party on Ecosystems and Bycatch to: a) Develop recommendations on appropriate mitigation measures for gillnet, longline and purse seine fisheries in the IOTC area; [mostly completed for LL and PS] b) Develop regional standards covering data collection, data exchange and training; c) Develop improved FAD designs to reduce the incidence of entanglement of marine turtles, including the use of biodegradable materials. [partially completed for non-entangling FADS; ongoing or biodegradable FADs)]	High (9)	CPCs directly	US$?? (TBD)

Topic	Sub-topic and project	Priority ranking	Lead	Est. budget (potential source)	TIMING 2017	2018	2019	2020	2021
7. Fishery independent monitoring	7.1 All of the tropical tuna stock assessments are highly dependent on relative abundance estimates derived from commercial fishery catch rates, and these could be substantially biased despite efforts to standardise for operational variability (e.g. spatio-temporal variability in operations, improved efficiency from new technology, changes in species targeting). Accordingly, the IOTC should continue to explore fisheries independent monitoring options which may be viable through new technologies. There are various options, among which some are already under test. Not all of these options are rated with the same priority, and those being currently under development need to be promoted, as proposed below: i. Acoustic FAD monitoring, with the objective of deriving abundance indices based on the biomass estimates provided by echo-sounder buoys attached to FADs	High	CPCs directly	US$?? (TBD)					

WPEcosystem & Bycatch

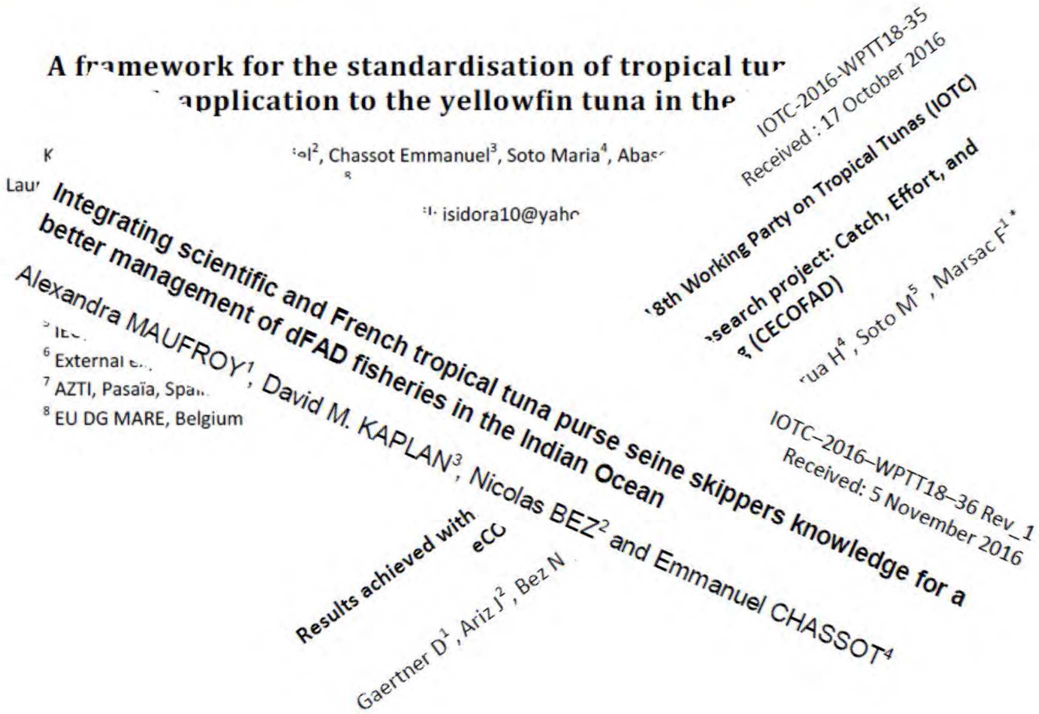
IOTC-2016-WPEB12-25 Rev_1

USING FADS TO ESTIMATE A POPULATION TREND FOR THE OCEANIC WHITETIP SHARK IN THE INDIAN OCEAN

Mariana Travassos Tolotti[1], Manuela Capello[1], Pascal Bach[1], Evgeny Romanov[2], Hilario Murua[3] and Laurent Dagorn[1]

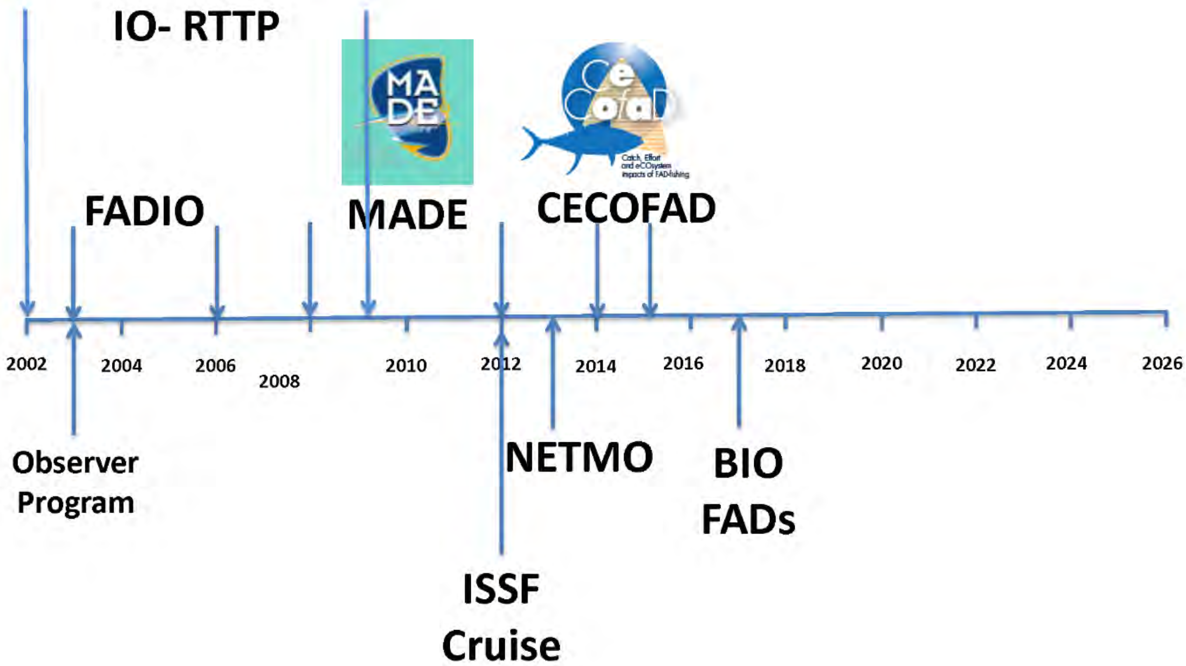
[1]Institut de Recherche pour le Développement, UMR MARBEC (IRD, Ifremer, Univ. Montpellier, CNRS)
[2] CAP RUN (Centre Technique d'Appui à la Pêche Réunionnaise) – HYDRÔ REUNION, Île de la Réunion
[3]AZTI Tecnalia, Pasaia, Spain

WP Tropical Tunas



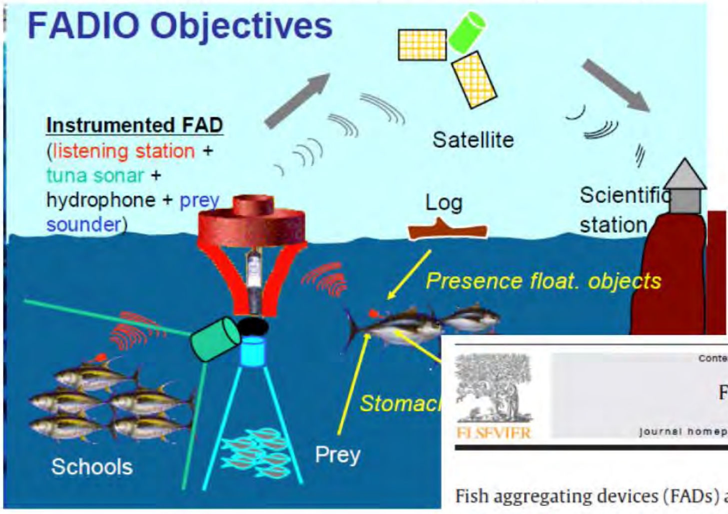

2
RESEARCH
azti tecnalia

Research


IO- RTTP
FADIO
MADE
CECOFAD
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
2024
2026
Observer Program
NETMO
BIO FADs
ISSF Cruise

Monitoring and Management of FADs

- FADs as scientific platforms (FADIO)



Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

Fish aggregating devices (FADs) as scientific platforms

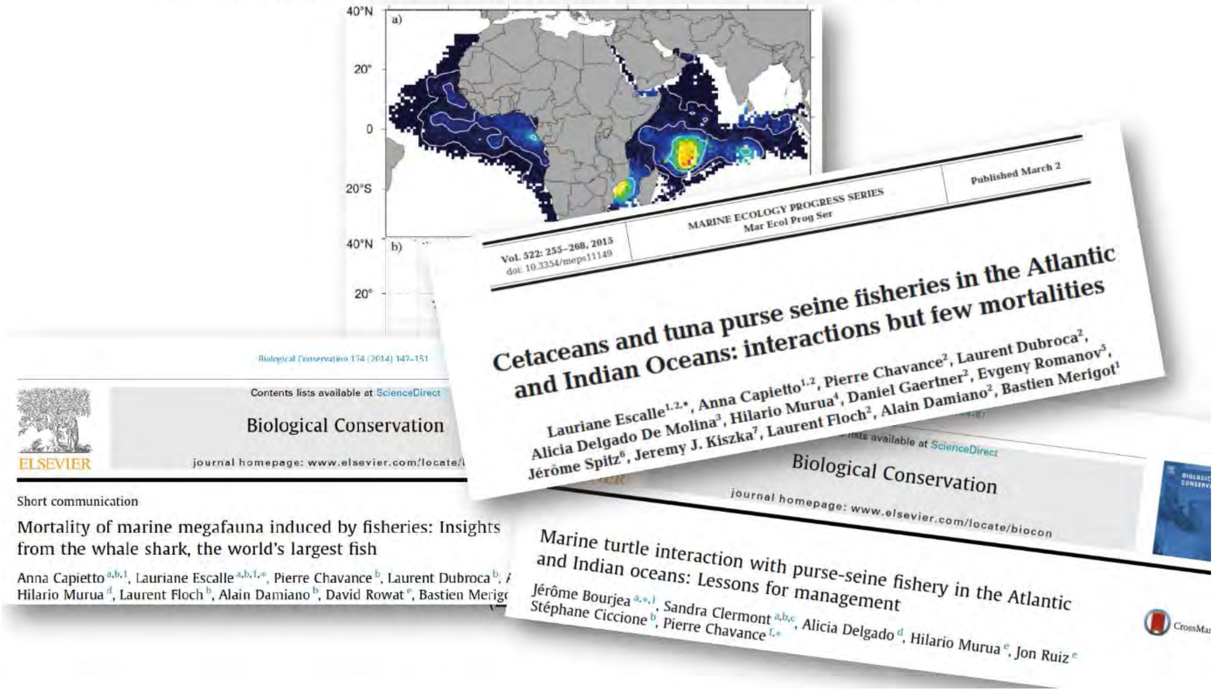
G. Moreno[a,b,*], L. Dagorn[c], M. Capello[c], J. Lopez[b,e], J. Filmalter[a,d], F. Forget[a,c], I. Sancristobal[b], K. Holland[f]

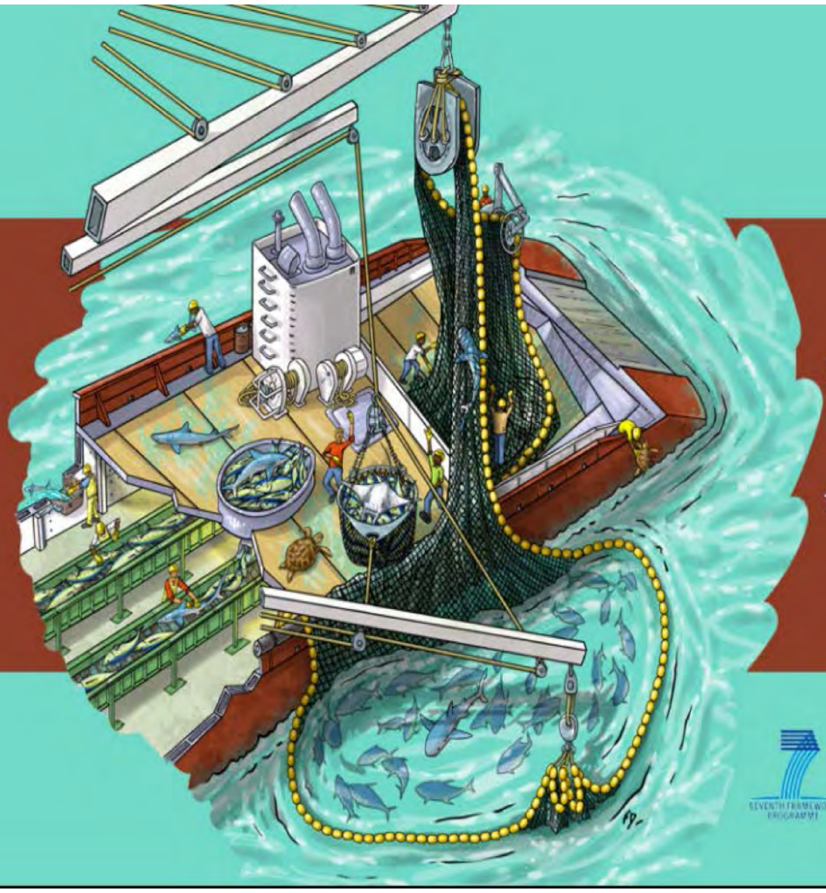
(Moreno et al. 2015)

azti tecnalia

Non-Target species / BC reduction

- Observer programs : collection of by-catch information





Good practices to reduce the mortality of sharks and rays caught incidentally by tropical tuna purse seiners.

Poisson F., Vernet A. L., Séret B., Dagorn L.

Non-Target species / BC reduction

- Observer programs : collection of by-catch information

795

NRC Research Press

RAPID COMMUNICATION

Mortality rate of silky sharks (*Carcharhinus falciformis*) caught in the tropical tuna purse seine fishery in the Indian Ocean

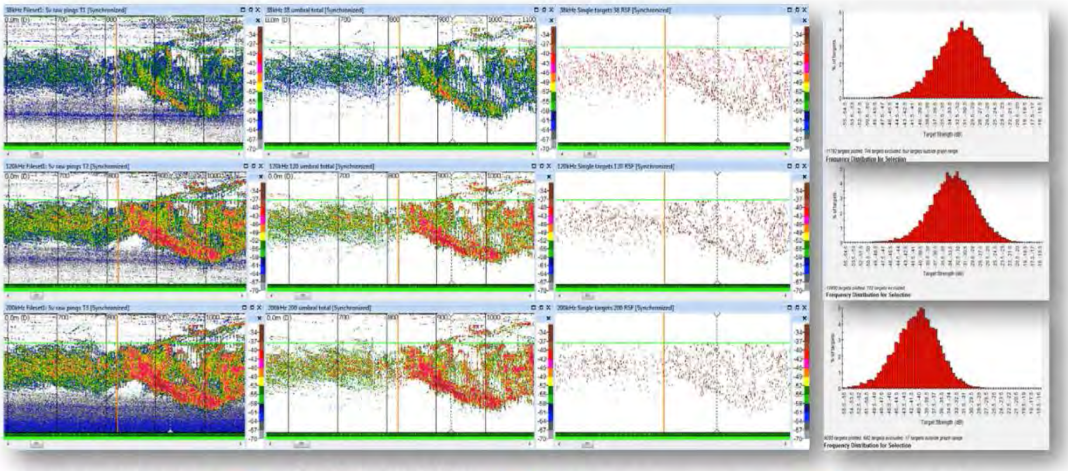
François Poisson, John David Filmalter, Anne-Lise Vernet, and Laurent Dagorn

72-85%

(Poisson et al, 2014)

Non-Target species / BC reduction

- ISSF in collaboration with other insitutes



1- Raw Echogram → 2- Plancton Filter → 3- Individual targets(TS) → 4- In situ TS

NETMO PROJECT

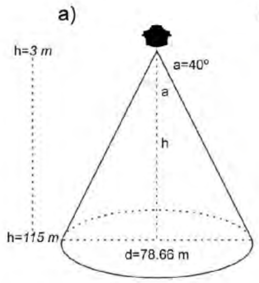
Non-Target species / BC reduction

- NON-ENTANGLING & BIODEGRADABLE FADs (NETMO 2013)

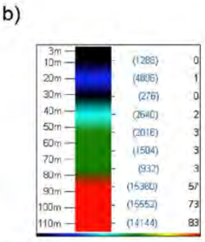
New designs of non-entangling and biodegradable FADs.

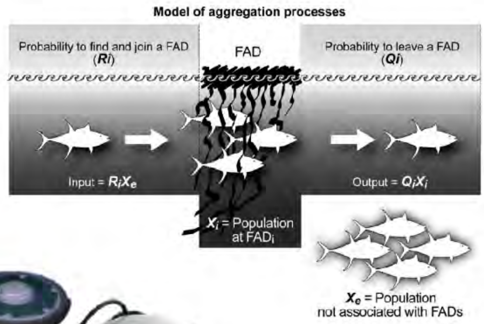
Population assessments

- Fishery independent abundance index from ES Buoys



(Lopez et al., accepted)





(Sempo et al., 2013)

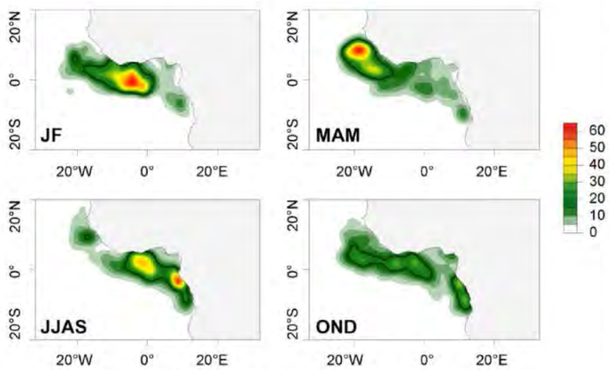
TUNABA

$$BAI_t = \varphi . B_t$$

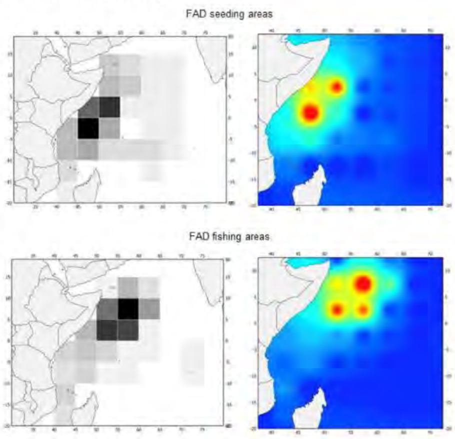
(Santiago et al., 2015)

CPUE Improvement

- Fishing strategy: seeding strategy, seasonality, etc.



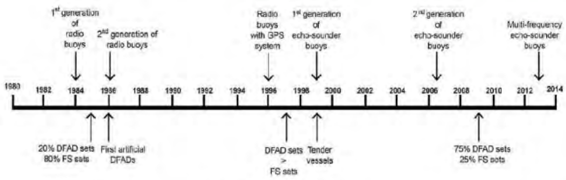
Deployment seasons (Maufroy, in prep)



Deployment and fishing areas (Lopez, in prep)

CPUE Improvement

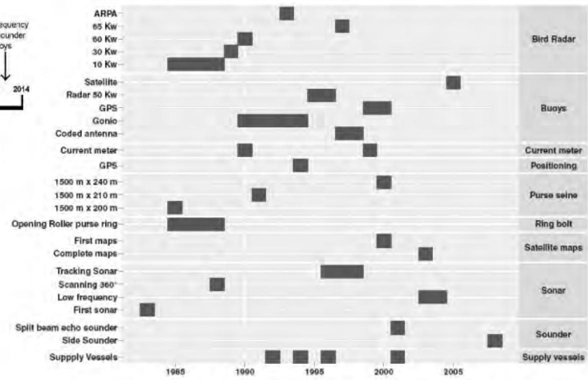
- Evolution of Fishing Technology



(Lopez et al., 2014)

(Lopez et al., 2015)

(Torres-Irineo et al., 2014)



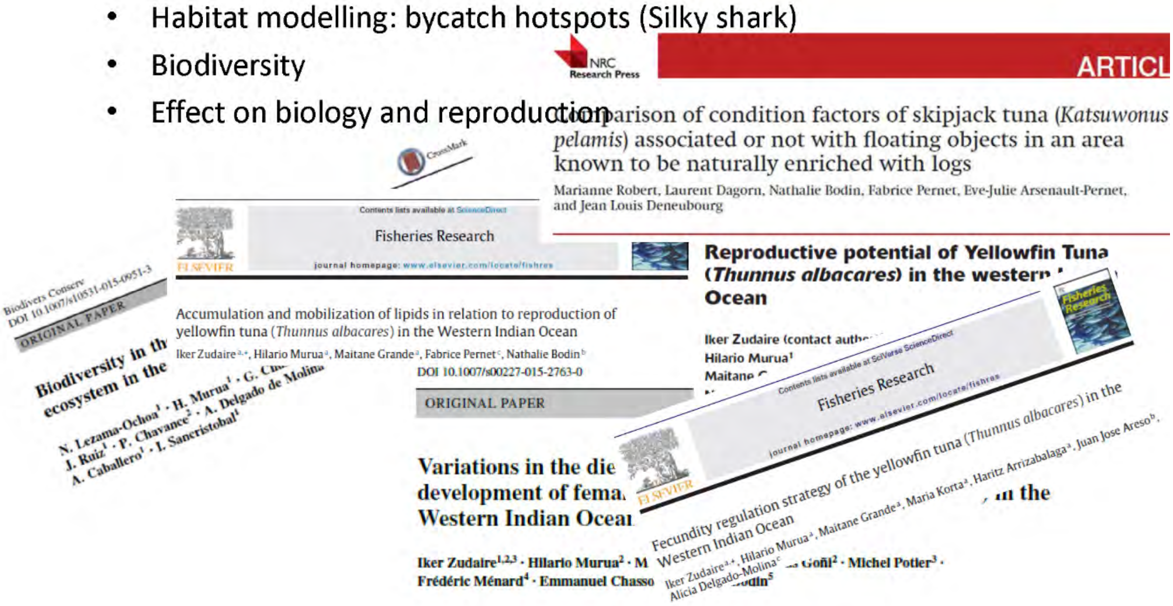
Received: 21 & 25 October 2015
IOTC–2015–WPTT17–32 Rev_1

Technological and fisher's evolution on fishing tactics and strategies on FADs vs. non-associated fisheries

Jon Lopez[1], Igaratza Fraile[1], Jefferson Murua[2], Josu Santiago[2], Gorka Merino[1], and Hilario Murua[1]

Biology - Habitat - Biodiversity

- Habitat modelling: bycatch hotspots (Silky shark)
- Biodiversity
- Effect on biology and reproduction



Transforming Science into Business

Txatxarramendi ugarte z/g
48395 Sukarrieta, Bizkaia

Herrera Kaia. Portualdea z/g
20110 Pasaia, Gipuzkoa

Astondo Bidea, Edificio 609
Parque Tecnológico de Bizkaia
48160 Derio, Bizkaia

AQUACULTURE TECHNICAL PAPER

568

Bycatch and non-tuna catch in the tropical tuna purse seine fisheries of the world

The definition of FAD

The fishers began to modify encountered objects, tying two or three together, adding buckets with fish entrails, and adding devices to facilitate re-encounters (radar reflectors, flags, radio buoys). When an encountered object is modified in some way to enhance its attraction, and especially to improve the chances of locating it again, it is called a FAD (short for fish aggregating device) to indicate the human intervention in its characteristics. This definition of FAD was adopted early on, in the different observer programmes, and it was quite consistent across oceans.

FADs and stock assessment

CPUE : need *local* distribution of FADs and effort ...
Action: marking of FADs (FAD tracks, vessel VMS)
What is "local"?

Track spatial dynamics of fleets

Regionalize impacts

FADs and stock assessment (cont.)

Understand decrease of CPPS. Hypotheses

- Abundance changes
- Too many attractors
- Operational changes (e.g. shorter soak time)
- Ecological or environmental changes (e.g. prey abundance, patchiness)

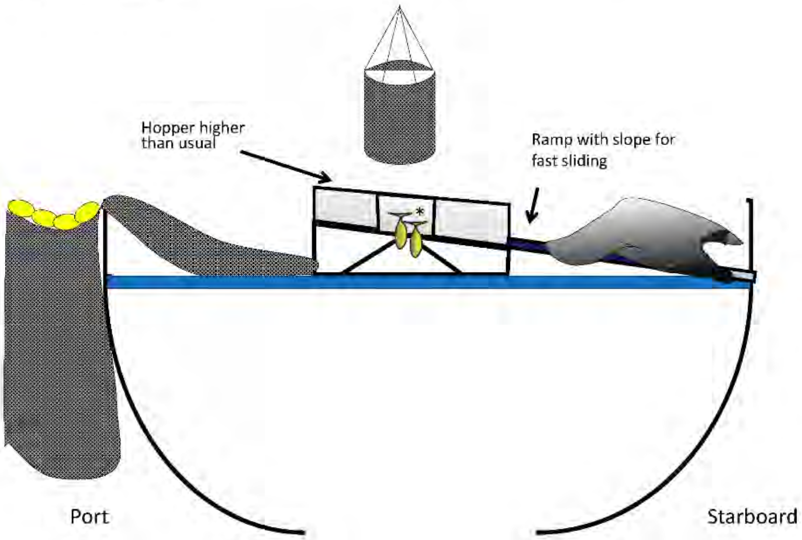
- Understand Nr FADs, Nr sets, fishing mortality
- Integrate impacts of all fleets, all Pacific in some cases

Mitigating impacts of FADs

- Modifications to seiners - skipper seminars+ISSF (good practices)
  - Ramps and escape doors
  - Hoppers, cargo nets
  - EM
- Operational changes
  - Areas closed to deployment (sensitive habitats, "especial places") ? Drift models
  - Recovery programs

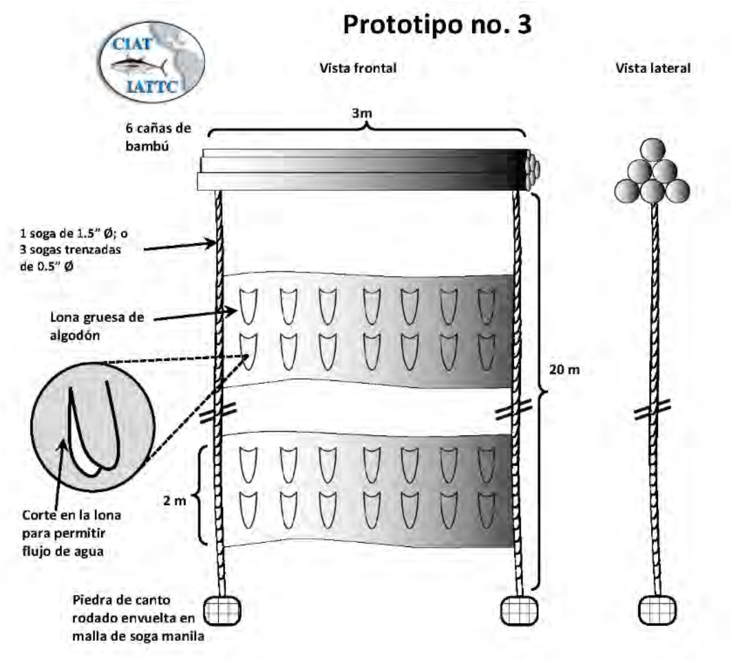
The modified hopper with ramp

Lateral view



Mitigating impacts of FADs

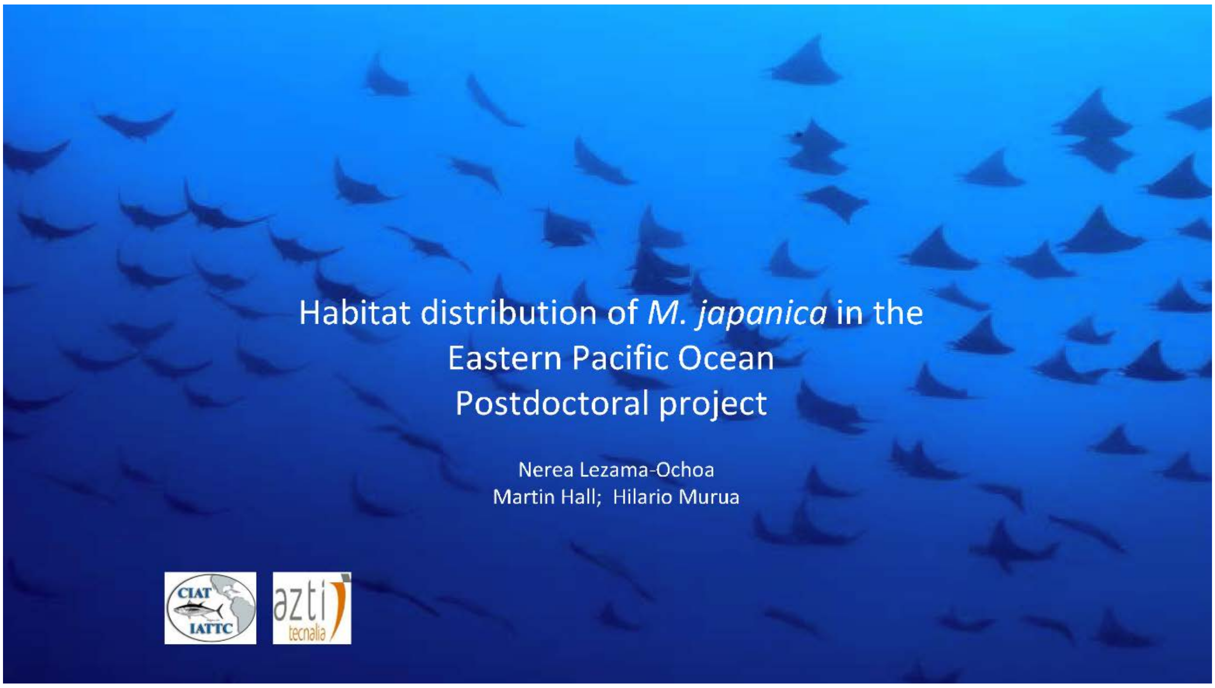
- Modifications to FADs
  - Short tail (Schaeffer)
  - Non-entangling, biodegradable (experiments in Panama, sea trials) EU support ISSF coordination, cooperating company
  - Exploration of materials for floatability
- Modifications to nets
  - Sorting grids
  - Large mesh at bottom (need net diagrams)


Prototipo no. 3
CIAT
IATTC
Vista frontal
Vista lateral
3m
6 cañas de bambú
1 soga de 1.5" Ø; o 3 sogas trenzadas de 0.5" Ø
Lona gruesa de algodón
20 m
2 m
Corte en la lona para permitir flujo de agua
Piedra de canto rodado envuelta en malla de soga manila

Mitigating bycatches in FAD sets

- Large pelagic species (mahimahi, wahoo, etc.)…. Utilization
- Sea turtles   small impact; successful release adopted; non-entangling FADs
- Manta and Mobula rays (more in other type of sets): improve release with auxiliary equipment and deck modifications (outreach w/ISSF, survival experiments, habitat studies)
- Whale sharks (ban on setting and good practices for release)

- Sharks: ban on retention, non-entangling FADs, but high mortality of captures….PENDING



Reducing catches of small bigeye and yellowfin tunas

- Spatial management (corralito)
- Quotas
- Shallower nets ?
- Shallower FAD webbing

Reducing catches of small bigeye and yellowfin tunas

- Dynamic closures
- Bycatch/catch ratios