Proceedings of the Global FAD Science Symposium

March 20-23, 2017

Santa Monica, California

Participants

Steering Group

John Hampton
Gerry Leape
Amanda Nickson
Victor Restrepo
Josu Santiago

Invited Participants (In alphabetical order)

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
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Brian Kumasi
Alexandra Maufroy
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Hilario Murua
Jefferson Murua
Graham Pilling
Kurt Schaefer
Joe Scutt Phillips
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Introduction

Over the past several years, fish aggregating device (FAD) management has become an increasing topic of research and dialogue in industry and management fora – including all of the tropical tuna Regional Fisheries Management Organizations (tRFMO) – as well as in discussions of certification for sustainability and in mitigation of the impact of bycatch on specific species. In order to inform the growing interest in science-based FAD management and a series of individual and joint meetings of the tRFMO FAD working groups, the Global FAD Science Symposium brought together 31 expert FAD scientists and associated stakeholders in FAD use for four days, to discuss and develop commentary in response to an underlying question: "what does well-managed FAD use look like within a tropical purse seine fishery?"

Themes of discussion (see **Agenda**) included:

- Balance and impact of tuna mortalities associated with FAD use in PS fisheries
- Impacts on non-target species
- Managing FAD capacity and impact

Participants attended the Symposium as experts independent of affiliation, and were not representing policies or positions of any employer. There was an open dialogue among everyone at the meeting. Through 20 presentations (see **Presentation Abstracts**), several panel discussions, and real time communication between participants, the group began to develop a series of key points on the current state of affairs regarding FAD science and management, gaps in knowledge, and management implications/recommendations. These points formed the basis for a series of five papers (see **Outputs: symposium papers for use in tropical tuna management**) that were coauthored by all 31 participants. The unanimous authorship on the five output papers indicates both the strength of the scientific information and quality of the dialogue and conclusions from the symposium.

As of the end of 2017, the papers developed at the Symposium have been presented by members of the Steering Group to a joint meeting of the FAD working groups for the International Commission for the Conservation of Atlantic Tunas (ICCAT), the Indian Ocean Tuna Commission (IOTC), and the Inter-American Tropical Tuna Commission (IATTC), to individual meetings of the ICCAT and IATTC FAD working groups, to the Western and Central Pacific Fisheries Commission Scientific Committee, and to a stakeholder meeting for the Marine Stewardship Council. In all instances, the papers have been well received and have informed the management discussions at those fora. In particular, the conveners of the joint tuna RFMO FAD Working Group Meeting publicly thanked the Symposium participants for doing so much work to advance the available scientific advice on global FAD management.

Financial resources for participation in the Symposium were provided by The Pew Charitable Trusts, with support from the International Seafood Sustainability Foundation.

Agenda

1: Opening session	Monday March 20, 1.30pm – 5.30pm
Topic/presentation	**Presenter**
Symposium Welcome **Aims & Review of Agenda** **Introductions**	Amanda Nickson & Steering Group
Review of the current state of FAD fisheries	Josu Santiago
Review of current challenges in managing FAD use in tropical tuna purse seine fisheries	Victor Restrepo
Review of the management frameworks for tropical tunas and FADs at tuna RFMOs	John Hampton
Summary of recent MRAG report: "An analysis of the uses, impacts and benefits of fish aggregating devices (FADs) in the global tuna industry"	Tim Davies[1]
Opening Panel: Tuna RFMO FAD Working Group Chairs: Progress & Challenges at Working Groups WCPFC – Western and Central Pacific Fisheries Commission IOTC - Indian Ocean Tuna Commission IATTC - Inter-American Tropical Tuna Commission ICCAT - International Commission for the Conservation of Atlantic Tunas	Chair: Gerry Leape Brian Kumasi Hilario Murua Josu Santiago David Die
Final points & wrap up Session 1	Amanda Nickson

2: Balance and impact of tuna mortalities associated with FAD use in PS fisheries	Tuesday March 21, 9.00am – 12.30pm
Topic/presentation	**Presenter**
Session Introduction	John Hampton
Review of overall impacts of FAD fishing on targeted tuna stocks	Emmanuel Chassot[2]
Review of technological approaches to addressing tuna mortality Tuna behavior and vulnerability in relation to FADs FAD characteristics and technology used to fish with FADs FAD design Purse seine net design Echosounder buoy characteristics	 Kurt Schaefer[3] Kurt Schaefer[4] Dave Itano[5] Martin Hall[6] Gala Moreno[7]
Review of methodological approaches to addressing tuna mortality Time-area closure for FADs FAD set limits vs FAD deployment Avoidance of bigeye hotspots Fleet behavior	Graham Pilling & Hilario Murua[8]
General discussion focused on issues	John Hampton

3: Impacts on non-target species	Tuesday March 21, 1.30pm – 5.00pm
Topic/presentation	**Presenter**
Session Introduction	Victor Restrepo
Review of FAD impacts on sharks	Laurent Dagorn [9]
Review of FAD impacts on sea turtles	Martin Hall[10]
Review of FAD impacts on non-tuna bony fishes	Justin Amande[11]
General discussion focused on issues	Victor Restrepo

4: Managing FAD capacity and impact	Wednesday March 22, 8.15am-12.30pm
Topic/presentation	**Presenter**
Session Introduction	Josu Santiago
Review of the impacts of FAD use on fishing capacity: Atlantic and Indian oceans Eastern Pacific Ocean Western Pacific Ocean	 Daniel Gaertner[12] Martin Hall[13] Graham Pilling[14]
Review of the ecological impacts of FAD use	Alexandra Maufroy[15]
Initiatives to address ecological impacts of FAD use and the current trials to manage FAD capacity Introduction / ISSF Research cruises and purse seine captains' workshops Purse seine tuna fisheries and Marine Stewardship Council (MSC) certification Good practices implemented by the OPAGAC-ANABAC purse seine fleet Good practices implemented by the ORTHONGEL purse seine fleet PNA FAD tracking and vessel day scheme efforts	 Jefferson Murua[16] David Agnew [17] Miguel Herrera[18] Michel Goujon[19] Maurice Brownjohn[20]
General discussion focused on issues	Josu Santiago

5: Reviewing/Drafting Session	Wednesday March 22, 1.30pm-5.00pm
Topic/presentation	**Facilitator**
Session Introduction	Amanda Nickson
Review of consolidated points from Session 2: Balance and Impact of tuna mortalities associated with FAD use in PS fisheries Points/concepts with agreement	John Hampton & Rapporteur

Points/concepts requiring qualification and commentary – agree on wording of both Key data/research gaps Implications for management	
Review of consolidated points from Session 3: Impacts on non-target species Points/concepts with agreement Points/concepts requiring qualification and commentary – agree on wording of both Key data/research gaps Implications for management	Victor Restrepo & Rapporteur
Review of consolidated points from Session 4: Managing FAD Capacity and Impact Points/concepts with agreement Points/concepts requiring qualification and commentary – agree on wording of both Key data/research gaps Implications for management	Josu Santiago & Rapporteur
Overflow and wrap up – plan for next day session	Amanda Nickson

6: Final Reviewing/Drafting Session , Next Steps & Symposium close	Thursday March 23, 9.00am - 12.30pm
Topic/presentation	**Facilitator**
Session Introduction	Amanda Nickson
Discussion: Review of draft proceedings language from facilitators Discussion by plenary of draft language and further development proceedings Adoption of document or assignment of lead authors to facilitate final drafting after the meeting Wrap up discussions and identify next steps	Steering Group

Presentation Abstracts

[1] **An analysis of the uses, impacts and benefits of fish aggregating devices (FADs) in the global tuna industry** – Tim Davies

Fish aggregating devices (FADs) are a topic of considerable interest in tuna fisheries science and management. The aim of this study was to complete an analysis of the most up-to-date research and opinions on the use of FADs in global tuna fisheries; their potential impacts and benefits, and their management at global and regional levels. FADs are associated with four main potential benefits, most of which are experienced by the tuna fishing sector: increased profitability for fishing fleets; increased contribution to food security through increased catch rates; reduced carbon emissions relative to free-school fishing and targeting of species more resilient to fishing pressure. However, the scale and intensity of these impacts is uncertain due to limited information. The use of FADs is also associated with several potential negative impacts, including the catch of small and juvenile bigeye and yellowfin tunas, bycatch of vulnerable non-target species, modification of tuna habitat, potential damage to coastal habitats and interference with other maritime activities. Industrial purse seine and pole and line fisheries that use FADs are managed primarily by the four tropical tuna RFMOs – ICCAT, IOTC, WCPFC and IATTC. Responding to the potential impacts of FADs, RFMOs have focused on protecting stocks of yellowfin and bigeye, typically by adopting measures aimed at reducing the mortality of juveniles, and reducing bycatch of non-target species, especially sharks. Several of these measures have been aimed directly at the practice of FAD fishing, such as limiting FAD sets or requiring more sustainable designs, while others have been less direct, such as implementing closures, catch limits or discard bans. The most urgent concern of tuna fishery managers and researchers, however, is the uncertainty surrounding the use and impacts of FADs; a priority, therefore, has been to gather data on the characteristics of FADs and how fishing fleets use them. Ad hoc RFMO FAD working groups are one of the key, albeit relatively recent, drivers with regards to the progress of FAD research and recommendations for improving management and regulation.

[2] **A review of overall impacts of FAD fishing on targeted tuna stocks** – Emmanuel Chassot

There has been an increasing trend in the number of large-scale purse seiners and global purse seine carrying capacity over the last decades. The overall increase in effort has resulted in an increase in purse seine catch to about 3 million metric tonnes in the recent years, with an increasing contribution of tuna caught in association with floating objects, now predominated by artificial FADs, that currently represents 50% of the purse seine catch. The increasing use of FADs has affected purse seine catchability and contributed to increasing overall fishing effort through (i) enhancing tuna aggregation, (ii) improving school detection, (iii) increasing spatio-temporal extent of fishing, and (iv) increasing the proportion of small-sized tunas in catch. The development and expansion of FAD fishing has resulted in a major increase in purse seine catch, with an increased contribution of skipjack that represented about 2/3 of the global purse seine catch in the recent years, i.e. about 2 million metric tonnes. Consequently, FAD-fishing has resulted in increased fishing mortality for all stocks of the 3 main tropical tunas accompanied by a major decrease in the weight of yellowfin and bigeye in catch. The increased harvest of yellowfin and bigeye juveniles has resulted in a reduction in stock productivity and represents a loss in overall yield-per-recruit which can lead to growth overfishing. Uncertainties in natural mortality rates in tropical tunas currently prevent accurately estimating the extent of change in stock productivity. Reduction in size of tunas caught also resulted in increased discarding practices although some management measures have recently been implemented to mitigate such effects. Overall, estimation of the contribution of FADs to fishing mortality remains difficult, impairing the estimation of abundance index time series from purse seine catch per unit effort.

[3] **Behavior of tropical tunas when associated with dFADs and their vulnerability to capture by purse-seine fishing** - Kurt M. Schaefer and Daniel W. Fuller

The behavior of skipjack, yellowfin, and bigeye tunas when associated with drifting fish-aggregating devices (dFADs) has been investigated utilizing ultrasonic telemetry, archival tags, and other technologies. Although there are some species-specific differences, and diel differences within species, the swimming depths of these three tropical tunas are predominantly within mixed layer depths when associated with dFADs, and shallower than the effective fishing depths of purse seine nets. Bigeye and yellowfin exhibit more confined horizontal distributions when associated with dFADs than skipjack and are thus more vulnerable to capture by purse seine fishing. The residence times of skipjack, yellowfin, and bigeye when associated with dFADs is only a few days on average for each event, but there are some records of events lasting 2-3 weeks for bigeye and yellowfin. Bigeye older than 2.5 years (105 cm) spend less total time associated with dFADs than fish less than 2 years (90 cm). Bigeye tuna are apparently more vulnerable than skipjack and yellowfin to high exploitation rates in purse-seine fisheries targeting aggregations associated with dFADs, as they appear to have a higher propensity to associate with floating objects based on tagging experiments.

[4] **Preliminary performance evaluation of shallow versus normal depth FADs in the eastern equatorial Pacific tuna purse-seine fishery; a collaborative effort of NIRSA, ISSF and IATTC** - Kurt M. Schaefer and Daniel W. Fuller

It has been reported in the scientific literature that the presence of bigeye tuna in the purse-seine catch of the eastern equatorial Pacific Ocean (EEPO) was more likely with deeper floating objects. In addition, participants at The International Seafood Sustainability Foundation (ISSF) "skipper's workshops" in Manta, Ecuador mostly agreed that deeper FADs will probably attract more bigeye but that shallow FADs would drift too fast and not attract tuna aggregations. A collaborative experiment was initiated in 2015 consisting of the simultaneous deployments by a purse seine vessel in the EEPO of 50 pairs of shallow (5m) and normal depth (36m) drifting FADs, to test the null hypothesis (Ho): there is no difference in the proportion of bigeye caught in sets on shallow and normal depth FADs in the EEPO. Seven purse-seine vessels of the Ecuador's Negocios Industriales Real (NIRSA) fleet made a combined 21 sets on the normal depth FADs and 16 sets on the shallow depth FADs from this experiment. Results thus far are encouraging because the shallow FADs have caught similar quantities of tuna per set as the normal depth FADs. Simultaneous deployments of 100 more pairs of shallow and normal depth FADs in the EEPO have recently been completed for a second experiment. We expect to obtain sufficient data from sets on both FAD types, from the second experiment combined with those from the first experiment, to conduct an appropriate statistical analysis of the null hypothesis using a general additive model.

[5] **FAD Design** – Dave Itano

Technical characteristics of FADs may influence their efficiency and the tuna aggregation. Both anchored (aFAD) and drifting FADs (dFADs) were considered due to the thousands of moored FADs that are found in the Philippines, Indonesia, Papua New Guinea and the Solomon Islands that support a variety of gears, including purse seine, ringnet and other surround net fisheries. The most important factor for aFADs is location and these aFADs are consistently set in depths of 2000m or more. Weighted lines with coconut fronds or bundles of nipa palm leaves are suspended from the aFAD floats and are believed to enhance tuna aggregation. A wide range of floats are used with drifting FADs that include bamboo rafts and bundles or strings of purse seine floats. Low profile dFAD floats are being promoted as a way to avoid turtle entanglement. Fishermen enhance dFADs with the addition of barrels filled with fish oil, chum, use of artificial light and various configurations of underwater structure (netting, netting rolled into tight rope-like “sausages”, rope, canvas panels, small mesh panels, etc.). The depth and form of these structures varies from ~15 m - ~100 m. Information from industry indicates that deeper structure is used in areas of high current and deep counter currents to slow drift speeds and reduce FAD loss. Many fleets attach plastic or rope streamers to underwater structure but it is not known what purpose these materials serve. The importance of enhancing both aFAD and dFAD aggregations with artificial light prior to pre-dawn sets was discussed. Issues related to competing and collaborative issues related to FAD design were noted. Fishers want long lasting, slow drifting, low visibility dFADs that efficiently aggregate tuna while management and NGOs promote the use of non-entangling, biodegradable and visible, easily identified dFADs. Scientists can serve a pivotal role in working with fishers to conduct studies to produce information acceptable for the development of effective and well informed management measures, i.e. studies on longevity of biodegradable materials, drift speeds and catch characteristics of non-entangling dFAD designs. Artificial lights are commonly used to enhance aggregation and have been banned in some regions. However, it was noted that the use of different frequencies of flashing light may be a way to mitigate bigeye catch. Further research is required but regulations against light usage would interfere in further research. The role of underwater structure and streamers to tuna aggregation is still not understood but may be related to visual or sound cues. Fundamental research on FAD aggregation dynamics is still required that may lead to more effective bycatch or bigeye mitigation efforts. If future management measures severely limit dFAD numbers, fishers will be incentivized to deploy more efficient FADs. The characteristics of an “ideal” FAD under this scenario include high attraction to skipjack, low attraction to bigeye and non-target species, non-entangling, remotely monitored and controlled and self-propelled to maintain in fishing area and reduce stranding potential.

[6] **Mitigating the impacts of FAD fishing: Technological approaches in fishing gear and operations to increase selectivity** – Martin Hall and M. Roman

While most research concludes that altering the depth of the purse seine net is not generally a reliable way to reduce incidental catch of non-target species or juvenile tunas, there are some modifications to the net that can improve survivability of these groups and increase the percentage of targeted tuna species and size classes taken during a set. Two methods that have been demonstrated to be successful are in-the-water sorting grids or escape windows and live capture/sorting on deck. Several designs of in-the-water sorting grids have been considered and some have been tested. Flexible PVC panels do not seriously alter the fishing operations and have proven successful at releasing small fish in salmon purse seine operations. Pressurized sorting panels can be left closed until the net is completely pursed and opened via air pressure once the net is alongside the purse seine vessel. This gives the captain more control over the operation. Circular escape windows may also be effective, but in order to be large enough to allow non-target species to escape, they may also lead to loss of the targeted tunas/size classes. Onboard sorting is a promising new approach to reducing incidental catch of non-target species or juvenile tunas. This method requires the catch to be brought on board alive, which can be accomplished in at least two ways. One experimental method is the use of a vacuum pump that sucks live fish out of the pursed net and through a sorting grid. The grid releases small or undesirable fish and retains the larger, targeted tunas. It is also possible that the pump could bring on board from the bottom of the seine the skipjack that die and sink first because of the smaller size and the lack of a swim bladder. A second promising method involves using a wet brail to bring the catch onboard to dump through a series of grids that direct the desirable catch toward the fish hold and the undesirable catch back to the water. Both of these live sorting methods may benefit from running water and aeration hoses into the pursed seine when it is alongside the vessel, in order to prevent pre-sorting mortality. While sorting the catch may be time consuming, it is possible to reduce non-target and juvenile tuna mortality without incurring significant costs to the operator, and the time required could be reduced significantly, depending on the specific methods that are implemented. These procedures are likely to result in major improvements in the quality of the catch, perhaps aiding the development of new markets with higher prices for the catch, that could make up for delays, costs and complications.

[7] **Echo-sounder buoys** – Gala Moreno, G. Boyra, J. Muir, J. Murua, V. Restrepo

Nowadays many of the geo-locating buoys attached to FADs are equipped with echo-sounders that provide a biomass estimate of the fish aggregated beneath the FADs. Currently these biomass estimates are not accurate enough to deliver information on species composition. Having accurate remote species biomass estimates from FADs would allow fishers the ability to avoid undesired catches of tunas and non-tuna species as well as allow scientists to have direct, fishery-independent, estimates of tropical tuna abundance. Recent research efforts have provided consistent target strength–length relationships for tropical tunas, which is a prerequisite to scale acoustic data into biologically relevant measures. Likewise, the potential to discriminate skipjack tuna from bigeye and yellowfin using multiple contrasting frequencies has been confirmed. This research encourages the use of fisher´s echo-sounder buoys to support science through studies on tuna behavior around FADs and to get independent estimates of tuna abundance. Using these tools to address tuna mortality requires some other issues to be met, as (i) variability in tuna species composition of FAD aggregations exists between different oceanic regions, (ii) an objective system to inform about the species composition at FADs that is independent from the skipper's skill. And finally (iii) an incentive, either regulatory or market based, to encourage skippers to make good choices.

[8] **Review of methodological approaches to address tuna mortality** – Graham Pilling and Hilario Murua

There are several available approaches to influence the level and species catch composition in tuna fisheries around the world. These include: time-area closure for FADs; FAD set limits vs FAD deployments; avoidance of bigeye hotpots; and examinations of fleet behavior. The challenges in identifying 'hotspots' in space and time in the different oceans were examined, along with examining the fleet and vessel-level impacts of bigeye catches. Identifying and managing these factors might be feasible in the western and central Pacific Ocean (WCPO), but in other oceans spatial 'hotspots' appears less well defined. Temporal and spatial closures to FAD fishing were discussed, noting that the spatial and temporal extent needed to be sufficient to reduce overall (e.g. annual) effort to be effective, while fishing on the margins of a closed area, or increased fishing at the end of a temporal closure, have been noted. The timing of associated and unassociated sets was also examined, with reasonably clear separating seen in the WCPO: generally pre-dawn for associated sets, and post-dawn for unassociated sets. Overall, limits on FAD deployments or FAD sets may be a practical approach, if they can be enforced, with FAD set limits appearing to provide a more direct control on fishing.

[9] **Purse seiners, FADs and sharks** – Laurent Dagorn

Sharks are not targeted by purse seiners. They are caught incidentally, especially around floating objects (logs and FADs). Shark bycatch-to-tuna catch ratio is quite small: < 0.5% in weight on average. Over 90% of that shark bycatch is composed of silky sharks, *Carcharhinus falciformis*. The other species of concern is the oceanic whitetip shark *C. longimanus*. Both species are listed in Appendix II of CITES. Other gear types such as longlines or gillnets have a larger impact on silky sharks than purse seine fisheries do. However, because of their low reproductive rates and other life history characteristics, sharks are vulnerable species and purse seiners must also reduce their impacts on these species. This includes developing methods to reduce catches of sharks by purse seiners, but also to reduce the mortality due to sharks being entangled in underwater appendages of FADs. Used in combination, four actions can increase silky shark survival in purse seine fisheries by 62%: (i) shift 20% effort to free schools, (ii) set only on FADs with > 10 t tunas, (iii) fish sharks from the net (with handlines), (iv) release from the deck. Future research should focus on improving the release of sharks from the net, investigate complementary methods (e.g. double FADs, attracting sharks away from FADs prior to setting, backdown procedure), as well as tools (e.g. buoys) to assess the number of sharks around FADs. In parallel, it is also necessary to understand the effects of different numbers of floating objects on the distribution of sharks, to ascertain the main drivers of shark movements, and to develop fisheries independent methods to estimate their abundance. Considering current scientific knowledge, management priorities are: implement non-entangling FADs (made with natural products) in all oceans, encourage the combined use of the 4 methods described above, and encourage research on the role of FADs on the ecology of sharks.

[10] **Review of FAD impacts on sea turtles** – Martin Hall

FAD fishing operations interact with sea turtles in three primary ways – entanglement in the FAD itself, entanglement in the purse seine net, or capture by the operation and brought onboard the vessel. Luckily, the most endangered sea turtle species (the leatherback, the hawksbill and the loggerhead) are very seldom associated with FADs, and their interactions are minimal. The large majority of these interactions involve the olive ridley, a species that numbers in the millions and is believed to be increasing in population abundance. These interactions typically occur with the FAD itself, something that can be almost entirely countered by use of a non-entangling FAD design. This design should include both the raft and the structure of the FAD that hangs into the water column. If these two portions are both made with non-entangling materials, sea turtle interactions are reduced substantially. Turtles are often encircled in purse seine nets, but mortality can be very low if fishing operators follow guidelines developed by the FAO and others. If turtles are entangled in the purse seine net, their timely removal will be critical to survival. As the purse seine is being lifted out of the water, it is mandated that operators should stop and remove any entangled turtles as they reach the surface, since continuing to lift the net while they are entangled can lead to mortality. If live turtles are observed inside the pursed net, dip nets should be used to remove them without bringing them onboard. If a turtle makes it to the deck of the purse seine vessel, it should be resuscitated (if necessary) and observed in an onboard holding area until it is strong enough to be released. Each of these techniques increases the likelihood of survival and has contributed to the very low catch ratio of sea turtles in purse seine fishing operations. The primary threat to turtles by this industry remains the use of entangling FADs by some fleets, particularly in the western and central Pacific Ocean.

[11] **Review of FAD impacts on non-tuna bony fishes** – Justin Amande

Non-tuna bycatches by purse-seiners in the world's oceans are mainly bony fishes in both quantity and specific composition. In the Indian and Atlantic Oceans, bony fishes represent 2-3% of the overall catch, and 0.5-1% in the Pacific Ocean. Bony fishes contribute to 10-30% of the non-tuna bycatch in free school sets and 70-80% in the floating object sets. Unfortunately, bony fishes are of very little interest for managers, fishermen or scientists because they are supposed to be of low commercial value and not at risk (ecologically). However, these are in fact only hypotheses. At this stage of knowledge and considering the scarcity of data, it seems difficult to think about stock assessment of these bony fishes but adopting a precautionary attitude could be useful because bony fishes certainly contribute to the community structure and trophic interactions in offshore ecosystems, and also because these species could contribute to food security in many countries. Thus, we recommend collecting and reporting detailed data on non-target bony fishes as well as target species. We also suggest to scientists to produce simple indicators to assess the levels of exploitation of these species. Finally, we suggest limiting the confidentiality of data that seriously undermines the common objective of sustainable exploitation of fisheries resources.

[12] **Managing FAD capacity and impact: Review of the impacts of FAD use on fishing capacity in the Atlantic and Indian oceans** – Daniel Gaertner

To assess the FAD capacity and impact on the FAD-fishing strategy in the Atlantic and Indian oceans, some simple fishery indicators were compared between FAD sets and free school sets. An opposite trend is evidenced between the increase in number of active dFADs and the decrease in number of free school sets. The change over time in catch per set and in catch rate per fishing days are mostly ocean- and species-specifics. It should be noted however that the decrease in catch rates for skipjack in the Indian Ocean is the consequence of a decrease of both fishery indicators for the two fishing modes. During the EU research project CECOFAD (Catch, Effort, and eCOsystem impacts of FAD-fishing), 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 vessel, shared information between vessels, % 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 support vessel highlights how the efficiency of a purse seiner in terms of catch rate, frequency of dFAD sets, etc. increases, from no assistance to the exclusive use of support vessels. Finally a brief summary of the measures adopted by the ICCAT and IOTC was presented. The dFAD management plans only entered into force after 20 years since the introduction of the dFAD-fishing strategy, but progress has been demonstrated in recent years. In 2010, the two tRFMOs recognized that the activities of supply vessels and the use of FADs are an integral part of the fishing effort exerted by the purse seine fleet and consequently adopted recommendations in terms of limits in number of active buoys, dFADs and support vessels as well as the adoption of the collection of non-conventional data related to FAD-fishing.

[13] **The evolution of the FAD fishery in the eastern Pacific** – Martin Hall and M. Roman

Like elsewhere, FAD use in the eastern Pacific has grown in the last 20 years, a result of the reliability that FAD use reduces search time and results in a high proportion of successful sets (as opposed to school sets, where failures are very frequent). The acoustic buoys that are currently added to the FADs also provide information on biomass present underneath. This is reflected in the low frequency of "skunk" sets: less than 10% of the sets on FADs but 25-35% of the sets on free schools. As FAD sets have increased, log sets and free school sets have decreased. FAD deployment has reached approximately 10 thousand per year in recent years, but deployments may be down after a peak in 2012. Fleets in this region recover many of their FADs each year, perhaps more so than in other regions. Within the region, fishing operations working in the waters of the Humboldt Current are particularly dependent on FADs. A ban on FAD use would essentially shut down tuna operations in the region west of Galapagos, where it is practically the only type of set made. Throughout the eastern Pacific Ocean (EPO), the catch per positive set (CPPS) has declined with higher FAD deployment. This may be due to there being too many FADs in the water, causing schools to be smaller under each FAD or causing operators to set on FADs sooner than in the past (out of fear of the catch being taken by another boat), due to environmental or ecological changes, or due to one or more species declining. As a result of the equatorial current, FADs deployed in the region often drift all the way into the fishing grounds of the WCPO. Some fleets that fish both regions are able to use this to their advantage. Other WCPO-only fleets may take advantage of the FADs that belong to their competitors in the EPO. Other potential impacts of FADs on the tuna populations could result from altering their vertical behavior (i.e. spending more time closer to the surface), having some directional drift that may affect their migration patterns, attracting and removing fauna from islands, etc., but we have no evidence of the impacts of these changes.

[14] **WCPO review of impacts of FAD use on fishing capacity** – Graham Pilling

Changes in purse seine fishing capacity in the WCPO were presented. The frequency of free school and associated sets made per day has increased over the period 1990-2015, with recent increases at around 2% (avg 2014/15 vs 2012/13). Nominal catch per unit effort (CPUE) of bigeye tuna has fluctuated over the last 25 years in four key purse seine fleets, but with no clear trend. In contrast, skipjack CPUE has shown general increases over the period. Catch per set has shown some increase in associated sets, but unassociated catch per set has generally declined over the last 10 years, which may reflect increased numbers of 'skunk' sets in free school fishing as vessels attempt to maximize fishing activity during a fishing day within management systems such as the Parties to the Nauru Agreement (PNA) Vessel Day Scheme. Purse seine associated and unassociated fishery catchability estimates derived during the stock assessment process have shown general increases over time, with some stabilization in recent years. Stock 'impact plots' for bigeye and skipjack show the impact of different groups of gears over time. Key gears for bigeye, associated sets and longline gears, have had comparable impacts in recent years. The number, size and length of purse seine vessels in the WCPO has also increased over time, with around 300 vessels present in 2015. Bunker and carrier vessels in 2015 on the Pacific Islands Forum Fisheries Agency (FFA) vessel register numbered around 130 vessels.

[15] **Review of the ecological impacts of FAD use** – Alexandra Maufroy

In recent years, increasing numbers of FADs have been deployed in the world oceans, potentially contributing to increasing levels of habitat modification and habitat destruction. In the Atlantic and Indian Oceans for example, a rapid expansion in the use of dFADs occurred over 2007-2013 with an increase of 4.2 times in the Indian Ocean and 7.0 times in the Atlantic Ocean. The impacts of the deployments of these large numbers of artificial Floating Objects (FOBs) were reviewed in terms of:

- Increased FOB density (leading to a potential situation of ecological trap or perturbation of tuna schooling behavior)
- Ghost fishing (leading to entanglements of sea turtles and sharks),
- Increased contribution to marine debris (leading to issues of pollution at sea)

- Beaching of FADs (leading to issues of pollution on land and destruction of sensitive habitats such as coral reefs).

The current management of these issues was discussed including a limitation on the use of FADs (numbers of GPS buoys and support vessels), changes in the design of FADs (non-entangling and biodegradable FADs) and recovery of FADs (by purse seiners and their support vessels at sea or locally to prevent beaching of FADs). Improvement in data collection was recommended to better measure the impacts of FAD use on the ecosystems and make appropriate management decisions. In particular, FAD tracking data, FAD echosounder buoy data as well as detailed information on the materials used to build FADs were presented as necessary sources of information.

[16] **ISSF Research cruises and purse seine captains' workshops** – Jefferson Murua

In 2009 the International Seafood Sustainability Foundation set up the Bycatch Project to mitigate bycatch and catch of undesirably small bigeye tuna in FAD tuna fisheries. The project combines the knowledge from expert fisheries scientists, the Bycatch Mitigation Steering Committee, and that of tuna fishers from all oceans, through dedicated Skipper Workshops, and tests the most promising bycatch mitigation activities during research cruises on commercial super-seiners. Since 2011 more than 15 research mitigation activities, focusing primarily on sharks and small bigeye tuna, have been studied on 10 purse seiner cruises in 4 oceans. Also, over 60 Skipper Workshops in 17 countries and with more than 2000 participants, mostly captains and navigators, have been conducted. This trans-oceanic collaborative approach aims to develop and transfer best available practices across tuna purse seine fleets globally and promote their adoption for the long-term sustainability of tunas and their ecosystems.

[17] **Purse seine tuna fisheries and MSC certification** – David Agnew

As of the timing of the Global FAD Science Symposium, the Marine Stewardship Council has certifications in place for 13 tuna fisheries, including multiple fisheries that use purse seine gear. Of these, one of the purse seine certifications covers anchored FADs, but none cover drifting FADs. [Note: since that time, an assessment that covers drifting FADs has reached the final stages of certification, but was not yet certified.] There are several issues that must be considered when assessing tropical purse seine tuna fisheries for potential certification, including the stock status of skipjack, yellowfin, and bigeye tunas, the implementation of harvest strategies and control rules, bycatch and its cumulative impact, and issues regarding supply chain custody, among other things. Tuna fisheries have, in the past, failed to achieve certification or have removed themselves from consideration before a final determination was made. These unsuccessful efforts have been the result of poor stock status or poor fisheries management within the fishery under consideration. Fisheries that achieve certification often have management conditions associated with this result. Open conditions placed on certified tuna fisheries most often require implementation of harvest control rules/harvest strategies, improved interactions with ETP species, or improved management frameworks. Under the current MSC standards, purse seine vessels can land certified and uncertified catch on the same fishing trip. In this circumstance, a strong chain of custody becomes one of the most important portions of the certified fishery's fishing activities. MSC has developed firm Chain of Custody (CoC) requirements for fishing operations that target both certified and uncertified tunas without offloading between activities.

[18] **Good practices implemented by the OPAGAC-ANABAC purse seine fleet** – Miguel Herrera

A range of initiatives that the Spanish purse seine fleet has been introducing in recent years to mitigate the impacts related to the use of FADs by this fleet was presented. This includes measures to ensure compliance with measures adopted by the flag states and the RFMO, in particular those specific or including FAD-related provisions; implementation of voluntary measures in response to issues identified by the fleet, NGO, or other research agencies; and support to the implementation of research activities, initiated directly by the fleet or by other parties. It was noted that Spanish purse seiners have demonstrated over the years high levels of compliance with the measures adopted by the RFMO, which includes, in particular, catch, effort, and FAD limits. Concerning FAD limits, the Spanish fleet has significantly reduced the number of FADs it uses, especially in the Indian Ocean, as the FAD limitation adopted in 2015 was further reduced in 2016. The verification of compliance is conducted directly by the government or through independent agencies. Regarding voluntary measures, participants were informed that OPAGAC is implementing a Fishery Improvement Project with the assistance of WWF, covering the three oceans, i.e. the areas of competence of the four RFMOs. Among the various actions implemented he stressed the importance of pilot programs in Seychelles and Cook Islands to strengthen monitoring, control and surveillance by those coastal states; and a FAD-Watch Project in the Seychelles intended to eliminate the risk of FAD-beaching events in sensitive areas, noting that these were initiatives exclusive to the OPAGAC fleet and represented a first in tuna purse seine fisheries. In addition, Miguel noted that the Spanish fleet has adopted a Code of Good Practices which includes actions to reduce as much as possible bycatch-rates, through changes in FAD design and guidelines for the safe release of sensitive species. Implementation of the Code is monitored through total enumeration of fishing trips by observers, including both human and electronic observers, and verification of compliance by the research institution AZTI. These levels of coverage extend beyond the requirements of some RFMO and are funded by the operators. The Spanish fleet participates in many other research activities, intended to reduce the catches of juvenile tunas on FADs, mitigate levels of bycatch, and reduce the impacts of FADs on the ecosystem. Among those he highlighted support to research on species discrimination; research to reduce post-release mortality levels of bycatch, including changes in gear configuration or fishing operations; and participation in a large-scale pilot to test biodegradable FADs. The need for more research on association of tuna-schools with FADs and whether the criteria used by RFMO and purse seine fleets to separate FAD, free-school, and other fishing mode events are consistent, across regions and time-periods, with what happens in nature was stressed. Finally, the need to evaluate the fishing capacity of FAD in the broad context of fishing capacity across all fleets, gear types, and fishing modes was highlighted.

[19] **Good practices implemented by the Orthongel purse seine fleet (in relation to FAD fishing)** – Michel Goujon

FAD fishing is part of the activity of tropical tuna purse-seiners and FAD management can therefore not be neglected. This is the conviction of the French and Italian fleet gathered under Orthongel. Since 2010, the producer organization has contributed to improve knowledge and management of different FAD-fishing-related aspects. This has been possible through a full transparency with scientists (providing all data related to FADs and increasing to 100% the observer coverage) as well as interviews with captains. For French boat-owners and captains, management is needed because the recent accelerated use of FAD (and supply vessels) is threatening not only the sustainability of the exploitation and/or vulnerable species but also the economic model of the French fleet (but also many other companies which have chosen this same model based on a balanced targeting of free and associated schools). Good practices related to FAD fishing have been initiated by the French fleet in the beginning of the 2010s. The first actions were the replacement of all dFADs by non-entangling dFADs (completed in 2012) and the identification and adoption of best practices to reduce shark, ray & turtle incidental mortality without altering crew safety conditions. Next steps led us to base the building of dFADs in a workshop on land and to experiment with biodegradable dFADs. After imposing on themselves a limitation of FADs, Orthongel and its member boat-owners have promoted the adoption of limits by the tuna RFMOs and consider that it is now important to improve definitions, data collection, control and compliance of measures adopted by the RFMOs.

[20] **PNA FAD Tracking and Economic Initiatives for Conservation – What we have learnt, where to next?** – Maurice Brownjohn

Annual industry declarations to the PNA have seen FADs deployed in PNA waters increase from 30,000 to near 80,000 in 5 years, yet FAD sets appear largely constant at below 15,000. Clearly sonar capability of modern buoys are changing the dynamics of the fishery, seeing mass deployments, “cherry picking” of targeted sets, and potential impacts on bycatch. PNA have this last year implemented FAD tracking for all FADs in their waters and are now tracking an estimated 20% of the FADs used by the fleets. Although compliance has been relatively low it is steadily improving, although some fishing companies are still refusing to comply or are registering the buoys and then stopping the data feeds. Clearly the intercompany trade of FADs, by area, stealing, and commercial deployment of FADs in the high seas is increasingly common place. FAD tracking allows managers to link vessels to FADs, proximity reports allow monitoring of closures, and FAD tracks document groundings/ discards / trade/ stealing, but as yet the “life of a FAD” and impacts of time, area and design on CPUE are not possible to assess. The apparent practices of “geofencing” data, where fishing companies direct the service provider to turn on or off their FADs’ feed to PNA when they pass between high seas and PNA waters is also a concern. Besides periodic FAD closures and economic incentives to limit FADs and bycatch, PNA also continue to explore the economic incentives of free school fishing, including the observed price premium that is made available after achievement of the Marine Stewardship Council certification of free school tuna caught in PNA waters. These economic and other incentives for targeting free school tuna contribute to an overall reduction in FAD dependency in the region, which is much lower than in other RFMOs.

Outputs: symposium papers for use in tropical tuna management

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

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.

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]

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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.

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.

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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

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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 fueled 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.

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.

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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]

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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.

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.

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WHAT DOES WELL-MANAGED FAD USE LOOK LIKE WITHIN A TROPICAL PURSE SEINE FISHERY?

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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;
- 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% vessel monitoring system(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.

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.

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.