Mitigating environmental impacts of Fish Aggregating Devices in the tropical tuna purse seine fisheries

3 authors:

Gala Moreno
ISSF

Laurent Dagorn
Institute of Research for Development

Victor Restrepo
International Seafood Sustainability Foundation

Mitigating environmental impacts of Fish Aggregating Devices in the tropical tuna purse seine fisheries

Gala Moreno[1], *Laurent Dagorn*[2], *Victor Restrepo*[1]

(1) International Seafood Sustainability Foundation (ISSF), 440 G Street NW Washington DC 20005 USA gmoreno@iss-foundation.org
(2) MARBEC, IRD, Ifremer, University of Montpellier, CNRS, Sète, France

Fish Aggregating Devices are efficient fishing gears that must be monitored and managed to achieve the sustainable and cost-effective harvest of pelagic marine resources. Over the last 15 years, marine scientists, purse seine (PS) skippers, fleet managers, observers, non-Governmental Organizations (NGOs) and RFMOs have dedicated a great effort to reduce impacts of FADs on the ecosystem. There are significant wins but also important issues to address (see Annex I). In this document, we present some of the lessons learnt.

When measuring FAD impacts on biodiversity, it is necessary to use the same definition of 'by-catch'. If not, it is possible that different concepts are compared leading to confusion (kept, discarded, utilized, undesired target species included or not included etc.). In general, the estimates done by observers at sea (the main source of by-catch data) are considered accurate. But these, as estimates, could always have some error/bias. It is important to include the uncertainty associated to the different by-catch estimates, including the degree of coverage. In general terms, this uncertainty is reduced with higher observation coverage. Electronic monitoring systems, implemented recently in some fleets, could be a good complement/alternative to human observer coverage and should be encouraged.

When reviewing by-catch by set type and ocean region and how this by-catch was conformed by species groups (minor tuna species, rays, sharks, billfishes, and other bony fishes), it is shown that PS by-catch for all the species is very minor compared to that of some other tuna fishing gears. Although the by-catch ratio[1] by PS is relatively low, its contribution to the overall by-catch of marine species is not so negligible because total PS catches are high.

Shark by-catch remains the main priority in terms of mitigating FAD fishing impacts on biodiversity. Although the by-catch rate is low (less than 0.5% by weight), some shark and mobulid species are highly vulnerable or at-risk, and the extent of the PS fishery justifies for developing efforts to mitigate this by-catch. Shark entanglement in traditional FADs that use open netting, was previously identified as the main threat to silky sharks. All RFMOs have now adopted measures to promote the use of non-entangling FADs (without netting) or FADs with lower risk of entanglement (small mesh netting or netting tied in bundles). Only FADs constructed without netting can completely eliminate the unintentional entanglement of animals. Besides non-entangling FADs, reducing shark mortality in the PS fishery will likely entail

[1] By-catch rate: by-catch relative to tuna catch

the use of several actions used in combination (avoiding sets on small tuna aggregations, fishing and releasing sharks from the net, safe handling and release from the deck, avoiding hot spots, etc.) (Annex II). Any by-catch arriving on the deck are usually in bad conditions and solutions should be prioritized for when animals are still in the water. However, defining good practices to reduce by-catch is difficult because PS vessels, fishing maneuvers and equipment have been designed exclusively to conduct tuna catch operation. By-catch avoidance or release maneuvers have rarely been taken into account when designing new vessels. Consequently, most of the current solutions to avoid/release by-catch are patches to fit as best as possible the current vessel design and maneuvers, which limits the innovation. In the future, the introduction of new devices, space for by-catch handling and technology to avoid/release by-catch should be considered when constructing new vessels.

Yellowfin, bigeye and skipjack are found in mixed aggregations around FADs and they are simultaneously encircled by the purse seining operation. One of the key challenges that face PS fleets fishing on FADs in all oceans is to be able to target species for which stocks are known to be in healthy condition such as skipjack while reducing their impact on bigeye and yellowfin stocks in regions where there is a need to reduce the fishery induced mortality of these species. To date, many behavioral studies to mitigate small tuna catches have been conducted (e.g. differences in residency times, depth distribution, movements in the net, catches modifying FAD structure depths, sorting grids etc.) (Annex II) but none have yielded yet a clear solution which would aid to reduce their catches. To date, the most promising solution is to use acoustics to better estimate the proportion of skipjack relative to yellowfin and bigeye tuna prior to setting.

The priority to mitigate the impacts of FADs should probably be to reduce the overall number of FADs deployed. In the case of FAD structure impact, even if FAD numbers are reduced, they will continue to be lost, so that other solutions as the use of biodegradable FADs and FAD recovery systems are necessary, unless FADs trajectories are fully controlled (e.g. FAD drones). Data on the position of FADs that are abandoned or lost should be accessible to scientists or RFMOs in order (i) to quantify their impacts on coastal environments, (ii) to develop models of risk areas and (iii) to measure the efficiency of the initiatives taken to mitigate the loss and abandonment of FADs. Ongoing projects that will deploy large numbers of biodegradable FADs at sea (in the AO, IO and EPO) will soon inform about the performance of the different biodegradable materials and FAD designs.

There is a need for more fundamental and applied research to understand the impacts of FADs on the ecology of tunas, sharks and other species. Research in large PS vessels is complex due to the expensive nature of cruises in the high seas and the mixing of many species of different sizes under FADs. However, there is great potential for using FADs and fishing vessels as scientific platforms. A lot of data are already being collected by fleets from FADs, but they are not all accessible to scientists. Once these data start becoming accessible to scientists routinely, scientists should be ready for Big Data tools and the use of Artificial Intelligence to better understand the tropical pelagic ecosystems.

The sustainability of the PS fishery cannot rely only on technical measures. Even if an efficient technical solution to a problem is found, it needs to be adopted by the fleets. This "uptake" tends to be slow and imperfect and it depends on the attitude of fleets, governments and other stakeholders (markets, NGOs, etc.). Involving fishers in the search for solutions is essential.

ANNEX I

Summary report of International Workshop on Mitigating Environmental Impacts of Tropical Tuna Purse Seine Fisheries

The following document summarizes some of the conclusions reached in a recent workshop co-sponsored by ISSF and the Common Oceans ABNJ Tuna Project (Restrepo et al. 2019). Participants included scientists, NGOs, tuna RFMOs, fishing technology manufacturers and PS fishing companies. The workshop reviewed progress made on research to mitigate environmental impacts of tropical tuna purse seine (PS) fisheries, with special focus on FADs and identified main focus areas for future mitigation activities.

Impacts of FADs on biodiversity (by-catch)

- The definitions of 'by-catch' should be clear whenever by-catch estimates are presented. If not, it is possible that different concepts are compared leading to confusion (kept, discarded, utilized, undesired target species included or not included etc.). For instance, if we look at by-catch rates in the Atlantic Ocean, they are higher compared to other oceans due to minor tuna species which are targeted and marketed.
- In general, the estimates done by observers at sea (the main source of by-catch data) are considered accurate. But these, as estimates, could always have some error/bias. It is important to include the uncertainty associated to the different by-catch estimates, including the degree of coverage. In general terms, this uncertainty is reduced with higher observation coverage.
- EMS, implemented recently in some fleets, could be a good complement/alternative to human observer coverage. By-catch cannot be fully covered by human observers that are measuring tuna catch during fishing operation.
- When reviewing by-catch by set type and ocean region and how this by-catch was conformed by five different species groups (minor tuna species, rays, sharks, billfishes, and other bony fishes), it is shown that purse seine by-catch for all the species and also species of concern such as sharks and marine mammals is very minor compared to that of other tuna fishing gears.
- Although the by-catch ratio[2] by PS is relatively low, its contribution to the overall by-catch of marine species is not so negligible because total PS catches are high.
- Some skippers voluntarily avoid small sets (< 10 tons) to reduce by-catch (as the amount of by-catch at FADs remains rather constant regardless the amount of tuna found), but it is difficult for many other skippers, in particular in the AO and IO.

[2] By-catch rate: by-catch relative to tuna catch

- Shark by-catch is the main conservation issue for purse seine fisheries. The species caught most commonly by PS are silky and oceanic whitetips sharks. Whale sharks are rarely caught at FADs.
- The tropical tuna PS fishery is certainly not the gear that catches most of the silky and oceanic white tip sharks, by-catch rate is less than 0.5% by weight. Still, some shark and mobulid species are highly vulnerable or at-risk, and the PS fishery should strive to mitigate this by-catch.
- Shark entanglement in traditional FADs that use open netting, was previously identified as the main threat to silky sharks. All RFMOs have now adopted measures to promote the use of non-entangling FADs (NEFAD guide).
- Animals arriving on the deck are usually in bad conditions and solutions should be prioritized for when sharks are still in the water.
- Besides non-entangling FADs, reducing shark mortality in the purse seine fishery will likely entail the use of several actions used in combination (setting on large tuna aggregations, fishing and releasing sharks from the net, safe handling and release from the deck, avoiding hot spots, etc.)

Impacts of FADs on small bigeye and yellowfin tunas

- Catching juvenile bigeye and yellowfin does not necessarily cause overfishing. Overfishing can occur by catching too many small fish, too many large fish, or too many of both. However, catching juveniles does result in loss of potential yield (lower MSY). There is a need to find solutions to catch less bigeye and yellowfin tuna specially for overfished stocks.
- Yellowfin, bigeye and skipjack are found in mixed aggregations around FADs and they are simultaneously encircled by the purse seining operation. One of the key challenges that face PS fleets fishing on FADs in all oceans is to be able to target species for which stocks are known to be in healthy condition such as skipjack while reducing their impact on bigeye and yellowfin stocks in regions where there is a need to conserve of these species.
- To date, many behavioral studies to mitigate small tuna catches have been conducted in research cruises (e.g. differences in residency times, depth distribution, movements in the net, moving away from FADs, catches modifying FAD structure depths, sorting grids etc.) but none have yielded yet a clear solution which would aid to reduce their catches.
- In the near future, research on acoustics can result in technology for fishers to be more selective in targeting FADs with higher proportion of skipjack relative to yellowfin and bigeye. Fishers are not able yet to discriminate well between species with current acoustic tools, but the technology is gradually improving. There is strong industry support (and hope) for improved acoustic technology that can discriminate sizes and species to be incorporated both in the acoustic equipment used onboard vessels and, in the echo-sounder buoys used to track FADs.
- The effect of FADs on tuna population, even if tuna are not caught, as the ecological trap hypothesis, is still a debate in the scientific community.

- There is heterogeneity across oceans and within oceans both in terms of FAD performance and the biology and ecology of tuna. While much has been learned in recent years regarding tuna physiology and behavior, there is much still to be learned before we fully understand how the resource behaves and the impact of FADs on those behaviors and these phenomena may be region-specific.

Impacts of FAD´s structure on the ecosystem

- The priority to mitigate impacts should probably be to reduce the overall use of FADs and to enforce existing limits. However, even if FAD numbers are reduced, they will continue to be lost, so that other solutions as the use of biodegradable FADs and FAD recovery would be necessary.
- Data on the position of FADs that are abandoned or lost is needed in order to (i) quantify the impact (ii) develop better models of risk areas and (iii) measure the efficiency of the initiatives taken to mitigate the loss and abandonment of FADs.
- One of the primary research areas to mitigate these impacts is to develop biodegradable FADs. Currently biodegradable FADs[3] should be made of only natural fibers/materials that are sustainably harvested, until other materials such as synthetic bio-plastics become available and proven to be non-toxic for the marine environment.
- In general, for the three oceans, FAD structure has evolved towards deeper ones mainly to slow down the drift, which fishers believe is better to aggregate tuna and also to make the FAD stay within the fishing grounds.
- FAD structure impact is proportional to its size and mostly produced by the tail (submerged part of the FAD structure). Thus, fleets should strive to reduce the size and weight of the FADs they build.
- Some fleets are testing biodegradable FADs themselves by deploying a limited number of biodegradable FADs. It is difficult to learn from those small-scale trials because most of experimental FADs end up lost or appropriated by other fleets. It would be good if these initiatives joined forces in some coordinated way that would allow tracking the life-time of FADs and catches around those experimental FADs.
- Ongoing projects that will deploy large numbers of biodegradable and traditional FADs at sea (in the AO, IO and EPO) will soon inform about the performance of the different materials and FAD designs (BIOFAD project in the IO, EU funded project in EPO and ISSF-ABNJ funded project in the AO) .
- There is no unique solution to reduce the impacts of FAD structure on ecosystems. Testing of biodegradable FADs, and "better FADs" in general, should be accelerated as well as the design of protocols to reduce the abandonment and loss of FADs. A combination of solutions adapted to each ocean and region may be necessary.

[3] This definition does not apply to the buoy used to track FADs

Conclusion

During the last 10 years, great progress has been done on documenting with facts what are the main impacts of PS fisheries that use FADs. Likewise, a great effort has been devoted to find technical solutions to these issues. But these fisheries are complex and there is a lot of variability by ocean, season, and even in vessel-specific strategies. There is no solution that fits all circumstances. Therefore, more of the same type of work that has been conducting needs to continue into the future, but perhaps with increased regional emphasis.

By-catch handling is difficult because PS vessels, fishing maneuvers and equipment have been designed exclusively to conduct tuna catch operation. By-catch avoidance or release alive has rarely taken into account when designing new vessels, which implies that currently, most of the solutions to avoid/release by-catch are patches introduced fitting as best as possible the current vessel design and maneuver. In the future, the introduction of new devices, space for by-catch handling and technology to avoid/release by-catch should be considered when constructing new vessels.

There is a need for more fundamental and applied research to understand the impacts of FADs on tunas, sharks and other species. Research in large PS vessels is complex due to the expensive nature of cruises in the high seas and the mixing of many species of different sizes under FADs. However, there is great potential for using FADs and fishing vessels as scientific platforms. A lot of data are already being collected by fleets (from FADs or fishing vessels), but they are not all accessible to scientists. Once this data starts becoming routine, scientists should be ready for Big Data tools and the use of Artificial Intelligence to better understand the tropical pelagic ecosystems.

The sustainability of the purse seine fishery cannot rely on the availability of technical measures alone. Even if a great technical solution to a problem is found, like was the case for shark entanglement on FADs, it needs to be implemented by the fleets. This "uptake" tends to be slow and imperfect and it depends on the attitude of fleets, governments and other stakeholders (markets, NGOs, etc.). And even if the RFMOs end up adopting a requirement for such solutions in a binding fashion, there still needs to be a rigorous and transparent mechanism to ensure implementation. At the same time, non-technical aspects such as the fishing capacity and efficiency of the fleets, need to be better managed.

One of the remarkable wins on the work to mitigate FAD impacts is the collaboration among scientist and fishers. Skippers are interested in reducing the by-catch generated in their fisheries and with all the at-sea knowledge that they accumulate, keeping them involved in the process is key.

ANNEX II

Reference documents on FAD impacts and associated solutions

Amande, M.J., Chassot, E., Chavance, P., Murua, H., de Molina, A.D. and Bez, N., 2012. Precision in bycatch estimates: the case of tuna purse-seine fisheries in the Indian Ocean. ICES J Mar Sci. 69, 1501-1510.

Baske A, Gibbon J, Benn J, Nickson, A. Estimating the use of drifting Fish Aggregation Devices (FADs) around the globe. PEW Environmental group, discussion paper, 8p, 2012.

Bourjea, J., Cleremont, S., Delgado, A., Murua, H., Ruiz, J., Ciccione, S., Chavance, P., 2014. Marine turtle interaction with purse-seine fishery in the Atlantic and Indian oceans: Lessons for management. Biological Conservation 178.

Boyra, G., Moreno, G., Sobradillo, B., Perez-Arjona, I., Sancristobal, I., Demer, DA. 2018. Target strength of skipjack tuna (Katsuwonus pelamis) associated with fish aggregating devices (FADs). ICES J. Mar. Sci. 75: 1790-1802. doi: 10.1093/icesjms/fsy041

Capietto, A., Escalle, L., Chavance, P., Dubroca, L., Delgado de Molina, A., Murua, H., Floch, L., Damiano, A., Rowat, D., Merigot, B. (2014). Mortality of marine megafauna induced by fisheries: Insights from the whale shark, the world's largest fish. Biological Conservation 174: 147–151.

Chavance, P., Dewals, P., Amande, M.J., Delgado de Molina, A., Damiano, A. Tamegnon, A. (2014). Tuna fisheries catch landed in Abidjan (Côte d'Ivoire) and sold on local fish market for the period 1982-2013 (preliminary data). ICCAT SCRS-2014-063. International Commission for the Conservation of Atlantic Tunas.

Dagorn, L., Bez, N., Fauvel, T., Walker, E., 2013. How much do fish aggregating devices (FADs) modify the floating object environment in the ocean? Fisheries Oceanography 22, 147-153.

Dagorn, L., Filmalter, J., Forget, F., Amandè, M.J., Hall, M.A., Williams, P., Murua, H., Ariz, J., Chavance, P., Bez, N., 2012. Targeting bigger schools can reduce ecosystem impacts of fisheries. Can. J. Fish. Aquat. Sci. 69.

Dagorn, L., Holland, K.N., Itano, D.G., 2006. Behavior of yellowfin (Thunnus albacares) and bigeye (T. obesus) tuna in a network of fish aggregating devices (FADs). Marine Biology 151, 595-606.

Dagorn, L., Holland, K.N., Restrepo, V., Moreno, G., 2013. Is it good or bad to fish with FADs? What are the real impacts of the use of drifting FADs on pelagic marine ecosystems?. Fish Fish. 14: 391-415. doi: 10.1111/j.1467-2979.2012.00478.x

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

Escalle, L., Capietto, A., Chavance, P., Dubroca, L., De Molina, A.D., Murua, H., Gaertner, D., Romanov, E., Spitz, J., Kiszka, J.J., Floch, L., Damiano, A., Merigot, B., 2015. Cetaceans and tuna purse seine fisheries in the Atlantic and Indian Oceans: interactions but few mortalities. Marine Ecology Progress Series 522.

Escalle, L., Muller, B., Brouwer, S., Pilling,G. and the PNA Office. Report on analyses of the 2016/2018 PNA FAD tracking programme. WCPFC-SC14-2018/MI-WP-09

Eddy, C., R. Brill and D. Bernal. (2015). Rates of at-vessel mortality and post-release survival of pelagic sharks captured with tuna purse seines around drifting fish aggregating devices (FADs) in the equatorial eastern Pacific Ocean. Fisheries Research 174 (2016) 109–117

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

Filmalter, J., M. Hutchinson, F. Poisson, W. Eddy, R. Brill, D. Bernal, D. Itano, J. Muir, A. L. Vernet, K. Holland, and L. Dagorn. (2015). Global comparison of post release survival of silky sharks caught by tropical tuna purse seine vessels. ISSF Technical Report 2015-10. International Sustainability Foundation, Washington, D.C., USA.

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

Forget, F.G., Capello, M., Filmalter, J.D., Govinden, R., Soria, M., Cowley, P.D., Dagorn, L. 2015. Behaviour and vulnerability of target and non-target species at drifting fish aggregating devices (FADs) in the tropical tuna purse seine fishery determined by acoustic telemetry. Can. J. Fish. Aquat. Sci. 72, 1398-1405.

Gaertner D, Ariz J, Bez N, Clermidy S, Moreno G, Murua H, Soto M, Marsac F. 2018. Results achieved within the framework of the EU research project: Catch, Effort, and eCOsystem impacts of FAD-fishing (CECOFAD). IOTC-2016-WPTT18-35. 18th Session of the IOTC Working Party on Tropical Tunas, Mahé, Seychelles.

Gilman, E.L. (2011). Bycatch governance and best practice mitigation technology in global tuna fisheries. Marine Policy 35, 590–609.

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

Hall M, Roman MH. The Fishery on Fish-Aggregating Devices (FADs) in The Eastern Pacific Ocean – Update. In: IATTC - 8th Meeting of the Scientific Advisory Committee. IATTC-SAC-08-03e, La Jolla, California. 2017. https://www.iattc.org/Meetings/Meetings2017/SAC08/PDFs/Docs/_English/SAC-08-03e_The-fishery-on-FADs-in-the-EPO-update.pdf

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

Hutchinson, M., Itano, D., Muir, J., Leroy, B., Holland, K. (2012). The post-release condition of FAD associated silky sharks (Carcharhinus falciformis) caught in tuna purse seine gear. WCPFC-SC8-2012/ EB-WP-12 Rev 1. Western and Central Pacific Fisheries Commission.

ISSF (2015). ISSF guide for non-entangling FADs. 7p. http://iss-foundation.org/download-monitor-demo/download-info/issf-guide-for-non-entangling-fads/

ISSF. (2014). Report of the ISSF workshop on FADs as ecological traps (Sète, France, 29–31 January 2014). ISSF Technical Report 2014-03. International Seafood Sustainability Foundation, Washington, D.C., USA.

Itano, D., Muir, J., Hutchinson, M., Leroy, B. (2012). Development and testing of a release panel for sharks and non-target finfish in purse seine gear. Scientific Committee 8th Regular Session, Busan, Republic of Korea, 7–15 August. WCPFC-SC8-2012/EB-WP-14.

Kelleher, K., 2005. Discards in the world's marine fisheries: an update. Food & Agriculture Organization.

Lennert-Cody CE, Moreno G, Restrepo V, Roman MH, Maunder MN. Recent purse-seine FAD fishing strategies in the eastern Pacific Ocean: what is the appropriate number of FADs at sea?. 2018. ICES J. Mar. Sci. 75 (5): 1748-1757. doi:10.1093/icesjms/fsy046.

Lennert-Cody, C.E., Roberts, J.J. and Stephenson, R.J. 2008. Effects of gear characteristics on the presence of bigeye tuna (Thunnus obesus) in the catches of the purse-seine fishery of the eastern Pacific Ocean. ICES J. Mar. Sci. 65(6), 970-978.

Lezama-Ochoa, N., Murua, H., Chust, G., Ruiz, J., Chavance, P., de Molina, A.D., Caballero, A., Sancristobal, I., 2015. Biodiversity in the by-catch communities of the pelagic ecosystem in the Western Indian Ocean. Biodiversity and conservation 24, 2647-2671.

Lopez, J., Moreno, G., Ibaibarriaga, L., Dagorn, L., 2017. Diel behaviour of tuna and non-tuna species at drifting fish aggregating devices (DFADs) in the Western Indian Ocean, determined by fishers' echo-sounder buoys. Mar. Biol. 164, 44.

Lopez, J., Moreno, G., Lennert-Cody, C., Maunder, M., Sancristobal, I., Caballero, A., Dagorn, L., 2017. Environmental preferences of tuna and non-tuna species associated with drifting fish aggregating devices (DFADs) in the Atlantic Ocean, ascertained through fishers' echo-sounder buoys. Deep Sea Res. Part 2 Top. Stud. Oceanogr.

Marsac, F., Fonteneau, A., Menard, F., 2000. Drifting FADs used in tuna fisheries: an ecological trap?, Proceedings of the Conference on Pêche thonière et dispositifs de concentration de poissons, Martinique, 15-19 October, Edited by J.Y Le Gall, P. Cayré and M. Taquet, IFREMER, Actes de colloques. no. 28, pp. 537-552.

Matsumoto, T., Satoh, K., Semba, Y., Toyonaga, M., 2016. Comparison of the behavior of skipjack (Katsuwonus pelamis), yellowfin (Thunnus albacares) and bigeye (T. obesus) tuna associated with drifting FAD s in the equatorial central Pacific Ocean. Fisheries oceanography 25, 565-581.

Matsumoto, T., Satoh, K., Toyonaga, M., 2014. Behavior of skipjack tuna (Katsuwonus pelamis) associated with a drifting FAD monitored with ultrasonic transmitters in the equatorial central Pacific Ocean. Fisheries Research. 157, 78-85.

Maufroy, A., Chassot, E., Joo, R., Kaplan, D.M., 2015. Large-Scale Examination of Spatio-Temporal Patterns of Drifting Fish Aggregating Devices (dFADs) from Tropical Tuna Fisheries of the Indian and Atlantic Oceans. PloS one 10 (5), e0128023. doi:10.1371/journal.pone.0128023

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

Ménard, F., Stéquert, B., Rubin, A., Herrera, M., Marchal, É., 2000. Food consumption of tuna in the Equatorial Atlantic ocean: FAD-associated versus unassociated schools. Aquat. Living Resour. 13, 233-240.

Moreno, G., Dagorn, L., Capello, M., Lopez, J., Filmalter, J., Forget, F., Sancristobal, I., Holland, K., 2015. Fish aggregating devices (FADs) as scientific platforms. Fish. Res. 178, 122-129. doi: 10.1016/j.fishres.2015.09.021

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

Moreno, G., Jauhary, R., Shiham, M.A. and Restrepo, V. 2017a. Moving away from synthetic materials used at FADs: evaluating biodegradable ropes' degradation. IOTC-2017-WPEB13-INF12.

Moreno, G., Boyra, G., Rico, I., Sancristobal, I., Filmater, J., Forget, F., Murua, J., Goñi, N., Murua, H., Ruiz, J., 2015a. Towards acoustic discrimination of tuna species at FADs. IATTC SAC-07-INF-C.

Moreno, G., Orue, B. and Restrepo, V. 2017b. Pilot project to test biodegradable ropes at FADs in real fishing conditions in Western Indian Ocean. IOTC-2017-WPTT19-51.

Murua, J., Itano, D., Hall, M., Dagorn, L., Moreno, G., Restrepo, V., 2016. Advances in the use of entanglement- reducing Drifting Fish Aggregating Devices (DFADs) in tuna purse seine fleets. ISSF Technical Report 2016-08. International Seafood Sustainability Foundation, Washington, D.C., USA.

Murua J, Moreno G, Itano D, Hall M, Dagorn L, Restrepo V. ISSF Skippers' Workshops Round 8. ISSF Technical Report 2019-01. International Seafood Sustainability Foundation, Washington, D.C., USA. 2018. https://iss-foundation.org/knowledge-tools/reports/technical-reports/download-info/issf-2019-01-issf-skippers-workshops-round-8/

Orue B, Lopez J, Moreno G, Santiago J, Soto M, Murua H. 2018. Aggregation process of drifting fish aggregating devices (DFADs) in the Western Indian Ocean: who arrives first, tuna or non-tuna species? PLOS ONE, 14(1): e0210435. https://doi.org/10.1371/journal.pone.0210435.

Pilling, G., Smith, N., Moreno, G., Van der Geest, C., Restrepo, V. and Hampton, J. 2017. Review of research into drifting FAD designs to reduce species of special interest bycatch entanglement and bigeye/yellowfin interactions. WCPFC-SC13-2017/EB-WP-02

Poisson F., Vernet A.L., Séret B., Dagorn L. 2012. Good practices to reduce the mortality of sharks and rays caught incidentally by the tropical tuna purse seiners. EU FP7 Project #210496 MADE, Deliverable 6.2., 30 pp.

Poisson, F., Filmalter, J.D., Vernet, A.L., Dagorn, L. 2014. Mortality rate of silky sharks (Carcharhinus falciformis) caught in the tropical tuna purse seine fishery in the Indian Ocean. Canadian Journal of Fisheries and Aquatic Sciences 71: 795–798.

Restrepo, V., L. Dagorn, G. Moreno, F. Forget, K. Schaefer, I. Sancristobal, J. Muir and D. Itano. 2018. Compendium of ISSF At-Sea Bycatch Mitigation Research Activities as of 9/2018. ISSF Technical Report 2018-20.International Seafood Sustainability Foundation, USA.

V. Restrepo, L. Dagorn, G. Moreno, J. Murua, F. Forget, and A. Justel. 2019. Report of the International Workshop on Mitigating Environmental Impacts of Tropical Tuna Purse Seine Fisheries. Rome, Italy, 12-13 March, 2019. ISSF Technical Report 2019-08. International Seafood Sustainability Foundation, Washington, D.C., USA

Schaefer, K.M., Fuller, D.W. 2013. Simultaneous behavior of skipjack (Katsuwonus pelamis), bigeye (Thunnus obsesus), and yellowfin (T. albacares) tunas, within large multi-species aggregations associated with drifting fish aggregating devices (FADs) in the equatorial eastern Pacific Ocean. Mar. Biol. 160, 3005-3014.

Scott, G., Lopez, J., 2014. The use of FADs in tuna fisheries. IP/B/PECH/IC/2013-123.Available at: http://www.europarl.europa.eu/studies.

Sempo, G., Dagorn, L., Robert, M., Deneubourg, J.-L., Blanchard, J., 2013. Impact of increasing deployment of artificial floating objects on the spatial distribution of social fish species. Journal of Applied Ecology, n/a-n/a.

Torres-Irineo, E., Amande, M.J., Gaertner, D., de Molina, A.D., Murua, H., Chavance, P., Ariz, J., Ruiz, J., Lezama-Ochoa, N., 2014. Bycatch species composition over time by tuna purse-seine fishery in the eastern tropical Atlantic Ocean. Biodiversity and conservation 23, 1157-1173.

Zudaire, I., Santiago, J., Grande, M., Murua, H., Adam, P.-A., Collier, P.N.T., Morgan, M., Khan, N., Baguette, F., Moron, J., 2018. FAD Watch: a collaborative initiative to minimize the impact of FADs in coastal ecosystems. IOTC-2018-WPEB14-12.

Zudaire et al. 2017. Testing designs and identify options to mitigate impacts of drifting FADs on the ecosystem. Indian Ocean tuna commission, IOTC-2017-SC20-INF07.