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FISH BEHAVIOUR FROM FISHERS´ KNOWLEDGE: THE CASE STUDY OF TROPICAL TUNA AROUND DRIFTING FISH AGGREGATING DEVICES (DFADS)

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Paper prepared by

Gala Moreno[1], Laurent Dagorn[2], Gorka Sancho[3] and David Itano[4]

1: AZTI – Tecnalia, Sukarrieta, Spain
2: IRD, Sete, France
3: College of Charleston, Grice Marine Laboratory, U.S.A.
4: PFRP, University of Hawaii, Honolulu, Hawaii, USA

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Fish behaviour from fishers´ knowledge: the case study of tropical tuna around drifting fish aggregating devices (DFADs)

Gala Moreno [1], Laurent Dagorn [2], Gorka Sancho [3], David Itano [4]

[1] AZTI – Tecnalia, Sukarrieta, Spain Email: gmoreno@suk.azti.es
[2] IRD, Victoria, Seychelles
[3] College of Charleston, Grice Marine Laboratory, U.S.A.
[4] University of Hawaii, Pelagic Fisheries Research Program, USA.

ABSTRACT

Purse seining for tropical tuna is one of the most technologically advanced fisheries in the world. The purpose of this study was to apply Local Ecological Knowledge (LEK) to assist in the planning of future in situ studies of fish behaviour around Drifting Fish Aggregating Devices (DFADs) by prioritizing research topics, thereby reducing the number of potential hypotheses to explore. Interviews of fishing masters of the purse seine fleets working in the Western Indian Ocean (WIO) provided an alternate, independent and previously unexplored source of behavioural information: specifically on the attraction, retention and departure behaviours of tuna schools in relation to DFADs. Most fishing masters agreed that the maximum attraction distance of a DFAD is approximately 10 km and generally agreed to the following statements: Tuna form distinct schools under FADs, commonly segregated by species and size. The main reasons for the departure of tuna aggregations from FADs are changes in currents or FAD movements and location in relation to physical or oceanographic features. The number of actively monitored DFADs at sea in the WIO was estimated at approximately 2100 drifting objects. Incorporating fishermen into the planning and design stages of future research projects will facilitate collaborative and integrated approaches.

1. INTRODUCTION

Concerns over targeted drifting FAD (DFAD) purse seining are related to the fact that (i) DFADs tend to attract juvenile as well as commercially undersized tuna and (ii) non-target species. Directed studies on the behaviour of tuna associated with DFADs are required. However, as opposed to anchored FADs (AFADs) which are easily accessible, DFADs are difficult and costly to access and monitor over time at offshore fishing grounds, which explains why FAD based research is devoted primarily to nearshore anchored FADs (Dempster and Taquet 2004).

For the commercial fishers, the behaviour of their quarry is a day-to-day concern that directly impacts their livelihood. Fishermen must understand the three dimensional spatial dynamics of the fish, schooling, swimming, and escape behaviours in order to decide where, when and how to operate at peak efficiency. This represents a large and valuable body of knowledge on fish behaviour that has rarely been tapped by fishery researchers. Likewise, few studies examining local ecological knowledge (LEK) (non-scientific information provided by local resource users) have dealt with fine-scale fish behaviour. Johannes and Hviding (2000) described fine-scale movements and behaviour of reef fish aggregations from fisher's knowledge, showing the high degree of detailed information gathered by fishermen, and therefore, the potential of LEK as a valuable source of knowledge of fine-scale behaviour and management.

Presently purse seining for tropical tuna is one of the most technologically advanced fisheries in the world. The high incidence of DFAD-based fishing in the Western Indian Ocean makes this fishery ideal for a study examining fishers´ perceptions on tuna behaviour and FADs.

Given the scarcity of knowledge on fish behaviour around DFADs and the difficulty to directly conduct research on DFAD aggregations, the objectives of the present study were:

i.) To collect information on fish behaviour based on fishers knowledge.
ii.) To provide an estimate of the number of DFADs in the Indian Ocean useful for research and fisheries management.
iii.) To use this knowledge to help prepare future *in situ* studies on fish behaviour around DFADs, by prioritizing research topics and reducing the *a priori* number of testable hypotheses.

More specifically, we examined the attraction, retention and departure behaviour of tuna associated with DFADs.

2. MATERIAL AND METHODS

2.1 **Identifying experts**

Spanish and French fishermen were the first to develop the Western Indian Ocean purse seine fishery and have been exploiting tuna schools found in association with DFADs since the beginning of the fishery in the early 1980’s. Fishing masters of these purse seiners are solely in charge of making all the long range planning and short-term decisions onboard; concerning where, when and how to proceed with fishing operations, to selecting fishing grounds and directing all operations during purse seine sets.

The initial goal of the study was to interview one primary fishing master from each vessel (n = 45) of the European purse seine fleet (Spanish and French) during the study period (2004 – 2005) to avoid bias due to differences in age, experience and vessel technology (Johnson 1992, Neis et al. 1999). A clear pattern of responses was reached after covering 75% (n = 34) of the fleet. Interviews were halted at this point as it was considered that a demonstrated “saturation point” had been reached and the sample size was presumed adequate (Felt 1994, Neis et al. 1999, Davis and Wagner 2003).

2.2 **Interview design and strategy**

Personal interviews of fishing masters were designed to gather information on their individual experience at sea (phase 1) and their knowledge on behaviour of fishes around DFADs (phase 2).

Although interviews were precisely structured with specific objectives in mind, their format remained informal and conversational to allow the fishing masters to feel as comfortable as possible. The interviewers avoided leading questions and never suggested answers, allowing in principle, a free flow of unbiased information from the fishers.

3. MAIN RESULTS & DISCUSSION

A total of 34 interviews of Spanish and French fishing masters of tuna purse seiners in the Western Indian Ocean were conducted in 2004 and 2005, covering 75% of the European fleet. Interviewed fishing masters had an average of 14 years of individual fishing experience in the Indian Ocean (standard deviation of 6 years, maximum of 26 years). The accumulated time spent at sea in the Western Indian Ocean, calculated by adding all interviewed fishing master’s years at sea and removing the time each fishing master spent on land, added up to 293 man-years.

3.1 **Number of DFADs in the Western Indian Ocean**

The estimated total number of actively monitored DFADs in the Western Indian Ocean was approximately 2100 drifting objects at any given time. This number is a highly dynamic estimate as FADs can sink or be taken by other purse seiners, plus fishermen regularly seed new artificial FADs and find natural FADs that are marked with buoys. As an anecdote, one of the most successful fishing masters with the highest catches in the fleet, and identified by other fishing masters as the most knowledgeable provided an estimated average of 2500 active buoys for the whole European fleet at a given time, suggesting the validity of the magnitude of our estimate.

3.2 **Attraction behaviour**

Most of the interviewed fishermen believe the attraction distance of tuna to FADs varies from 0 to 5 nautical miles (almost 10 km). From sonic tracking experiments conducted around AFADs, Girard et al. (2004) identified that yellowfin tuna are able to orient towards anchored FADs at a range of 4 to 19 km distance. Fishermen with no prior knowledge of attraction distance to AFADs provided similar attraction distances to DFADs.

It has been proposed that anchored FADs can more easily attract tuna because of the sounds produced by their anchoring chains or the influence of current on the mooring ropes (Fréon and Dagorn 2000), but our results suggest DFADs can also attract tuna from considerable distances without these structures (DFADs without sub-surface structures are also productive). This implies that structure or design of FADs might not play a key role in determining attraction processes and that the non-tuna fish aggregations around DFADs may play an important role in attracting tuna schools (Itano et al. 2004).

Half (50%) of the fishing masters consider natural floating objects (mainly logs) as the best platforms to aggregate fish. It is difficult to know if the perceived higher efficiency of natural DFADs is due to their morphological characteristics or their length of deployment and movements related to oceanographic features. A high percentage of fishers (32%) think that there is little difference between natural and artificial DFADs in their ability to aggregate fish. In AFADs´ studies, structure size and vertical profile were found as the most significant factors for attracting non-tuna species abundance, but no major characteristic of AFADs has explained the attraction of tuna species (Rountree 1989, Hall et al. 1992, Nelson 2003). Natural DFADs´ history may be a more relevant factor explaining their possible higher efficiency.

We hypothesize that the colonization process of FADs by different pelagic fish species plays an important role on their ability to attract tuna schools. In agreement with this hypothesis, fishermen clearly indicated that tuna are never found as the sole species aggregated around FADs.

The few fishermen who said that tuna are occasionally observed alone at FADs, explained that these rare events correspond to moving tuna schools that briefly visit a 'virgin' FAD that has not yet been colonized by other species. Non-tuna species likely influence the attraction and retention behaviours of tuna at FADs and some of these non-tuna species could first be attracted and retained due to the specific design of the FAD.

3.3 **Retention behaviour**

Tuna aggregation structure

Most fishers in this study believe that tuna aggregations around DFADs usually consist of several distinct schools of different tuna species, based on visual and sonar observations before setting the purse seine net. Some of them also suggested that distinct schools of the same species can occur around the same FAD, segregated by size or by their initial time of aggregating to the FAD.

Diel dynamics of tuna around DFADs

Fishing time around DFADs has changed in recent years: while fishermen originally made sets early in the morning, currently they have changed their fishing practices and set nets throughout the day. Is this the result of a change in fish behaviour or in fishers’ knowledge?

It should be noted that in other tropical regions, such as in the Western and Central Pacific Ocean, FAD related purse seining takes place before dawn and only free school fishing is carried out throughout the day. This is not because tuna are not present on FADs throughout the day, but due to the clarity of the water and the depth of the thermocline which allow easy escape of tuna before the net can be pursed close (Habib 1984, Doulman 1987).

Purse seiners began to use long range sonar a few years ago. These devices allow them to observe tuna schools that could be thousands of meters away from the FAD but not visually detectable with binoculars. The use of these sonars likely has improved the ability of fishermen to locate and track tuna schools in proximity to FADs.

Time residency of tuna around DFADs

Although they do not have direct knowledge or experience concerning the amount of time tuna spends associated to the FADs, indirectly, they provided some interesting information on factors that could help our understanding of residence time. They suggested that several distinct schools of the same species can occur around the same FAD, and a few of them advanced a theory of school segregation by the time of arrival at the FAD. If segregation by arrival order occurs then the history of each school may determine their residence time and keep it distinct from other schools due to, for instance, foraging differences. Dagorn et al. (2007), studying spatial behaviour of tuna in a network of AFADs suggest that FAD associated tuna aggregations are composed of sub-groups that might have different physiological states determining their residence time.

3.4 **Departure behaviour**

The majority of fishermen believe that a change in the speed or direction of a DFAD can cause fish to depart. Other factors mentioned included marine mammal predators or drift over the shallow Seychellois plateau. A change in the FAD drifting speed or direction would be indicative of a change of the water mass, which could affect oceanographic conditions surrounding the FAD. Researchers have little information on the causes or conditions under which tuna leave FADs. Researchers have generated multiple hypotheses to explain why fish associate with FADs (Fréon and Dagorn 2000, Castro et al. 2002), but none to explain why fish leave. This knowledge could provide a clue about the initial reasons which lead tuna to associate with a FAD.

Future research should focus on the consequences of DFADs subjected to rapid changes in drifting speeds or directions that can be remotely monitored by radio or satellite linked buoys and on the consequences of local marine mammal presence on DFAD aggregations. Studying departure processes will require the use of instrumented FADs for long periods to measure tuna biomass and environmental conditions.

4. CONCLUSION

Catches around DFADs have become so important during the last decade that researchers must determine the impacts of FADs on tuna behaviour and associated species. Development of experiments in the open ocean to study the behaviour of pelagic tuna around drifting FADs is a priority. Such studies are time consuming and expensive. Therefore, research priorities should be determined, and when possible, existent hypotheses should be critically examined and ranked. Interviewing fishing masters of the European tuna purse seine fleets working in the Western Indian Ocean provided an alternate, independent and previously unutilized source of behavioural information on tuna around DFADs. A great deal of the information given by fishermen is in agreement with scientific hypotheses obtained from research activities related to AFADs (i.e. attraction distance to FADs). In this case, conducting experiments at sea might not be an initial priority, as the agreement between estimates from fishers and research on AFADs suggests the validity of both. On the other hand, fishermen provided information that was previously unknown to science, such as possible reasons why fish may leave a FAD.

Calheiros et al. (2000) noted that involvement of the participants (fishers in this case) in research efforts invests them in the process and makes them more likely to accept resulting management and policy changes. Moreover, working in close association with fishermen could assist in the timely identification of behavioural changes in fish which could be indicators of changes in the population size or the environment. Incorporating fishers into the planning and design stages of research projects facilitates collaborative and integrated approaches and can lead researchers toward new and exciting areas of study. Fishermen then become active and recognized participants in research while acknowledging their years of experience with the credibility it deserves

References

Calheiros, D.F., Seidl, A.F., and Ferreira, C.J.A. 2000. Participatory research methods in environmental science: local and scientific knowledge of a limnological phenomenon in the Pantanal wetland of Brazil. J. Appl. Ecol. **37**(4): 684-696.

Castro, J.J., Santiago, J.A., and Santana-Ortega, A.T. 2002. A general theory on fish aggregation to floating objects: An alternative to the meeting point hypothesis. Rev. Fish Biol. Fish **11**: 255-277.

Dagorn, L., Holland, K.N., and Itano, D.G. 2007. Behavior of yellowfin (*Thunnus albacares*) and bigeye (*T. obesus*) tuna in a network of fish aggregating devices (FADs). Mar. Biol. **151**:595-606. doi: 10.1007/s00227-006-0511-1.

Davis, A., and Wagner, J. 2003. Who knows? On the importance of identifying "experts" when researching local ecological knowledge. Hum. Ecol. **31**: 463-489.

Dempster, T., and Taquet, M. 2004. Fish aggregation device (FAD) research: gaps in current knowledge and future directions for ecological studies. Rev. Fish Biol. Fish. **14**(1): 21-42.

Doulman, D.J. 1987. Development and expansion of the tuna purse seine fishery. *In* Tuna issues and perspectives in the Pacific islands Region. *Edited by* D.J. Doulman. East-West center, Honolulu, Hawaii. p. 314.

Felt, L. 1994. Two tales of a fish: The social construction of indigenous knowledge among atlantic Canadian salmon fishers. *In* Folk management in the World´s Fisheries: Lessons for Modern Management. *Edited by* C. Dyer and J. Mc Goodwin. University Press of Colorado, Niwot, CO. pp. 251-286.

Fréon, P., and Dagorn, L. 2000. Review of fish associate behaviour: toward a generalisation of the meeting point hypothesis. Rev. Fish Biol. Fish. **10**: 183-207.

Girard, C., Benhamou, S., and Dagorn, L. 2004. FAD: Fish Aggregating Device or Fish Attracting Device? A new analysis of yellowfin tuna movements around floating objects. Anim. Behav. **67**(2): 319-326.

Habib, G. 1984. An overview of the purse-seine tuna fishery in the Central/Western Pacific and development opportunities for Island States. Working Paper No. 15. Workshop on National Tuna Fishing Operations, Tarawa, Kiriabati. Man 28 - June 2, 1984. Forum Fisheries Agency, Honiara, Solomon Islands.

Hall, M., García, M., Lennert, C., and Arenas, P. 1992. The association of tunas with floating objects and dolphins in the eastern pacific ocean: III. Characteristics of floating objects and their attractiveness for tunas, Inter-American Tropical Tuna Commission, La Jolla, CA., USA.

Hall, M. 1998. An ecological view of the tuna-dophin problem: impacts and trade-offs. Rev. Fish Biol. Fish. **8**(1): 1-34.

Hampton, J., and Bailey, K. 1993. Fishing for tunas associated with floating objects: a review of the western Pacific fishery. SPC Tuna and Billfish Assessment Programme Technical Report No 31. South Pacific Commission, Noumea, New Caledonia.

Itano, D., Fukofuka, S., and Brogan, D. 2004. The development, design and recent status of anchored and drifting FADs in the WCPO. Information Paper INF-FTWG-3.17TH. Standing Committee on Tuna and Billfish, Majuro, Republic of the Marshall Islands.

Johannes, R.E., and Hviding, E. 2000. Traditional knowledge possessed by the fishers of Marovo Lagoon, Solomon Islands, concerning fish aggregating behaviour. SPC Traditional Marine Resource management and Knowledge information Bulletin **12**.

Johnson, M. 1992. Lore: Capturing traditional Environmental Knowledge. Hay River, NWT: Dene Cultural Institute 190p. ISBN: 0889366446 (pbk)

Neis, B., Felt, L., Haedrich, R.L., and Schneider, D.C. 1999. An interdisciplinary method for collecting and integrating fishers' ecological knowledge into resource management. *In* Fishing places, fishing people: issues and traditions in Canadian small-scale fisheries. *Edited by* D. Newell and R. Ommer. University of Toronto Press, Toronto, Ont. pp. 217-238.

Nelson, P.A. 2003. Marine fish assemblages associated with fish aggregating devices (FADs): effects of fish removal, FAD size, fouling communities, and prior recruits. Fish. Bull. **101**(4): 835-850.

Rountree, R.A. 1989. Association of fishes with fish aggregation devices: Effects of structure size on fish abundance. Bull. Mar. Sci. **44**(2): 960-972.