Fish Species Around Fish Aggregating Devices and other Floating Objects Used for Tuna Purse Seine Fishing in the Eastern Indian Ocean

Watcharapong Chumchuen[1*], Prasit Luesrithawornsin[2] and Aekkarat Wongkeaw[2]

ABSTRACT

Fish aggregating devices (FADs) and other floating objects (OTHs) are used in tuna purse seine fishing because they are effective in attracting tunas. The objective of this study was to describe the fish species associated with FADs and OTHs in the Eastern Indian Ocean. A total of 25 FADs were deployed during fishing surveys in March-May 2012 and March-April 2013 operated by FRV Mahidol. Fifteen deployed FADs were tracked and observed, and three OTHs with fish schools were found and recorded during the fishing surveys. A total of 15 species of fish, including three species of cartilaginous fish and 12 species of teleost fish were recorded through visual census technique, trolling line and purse seine fishing around FADs and OTHs. For tuna species, skipjack and yellowfin tunas were found around FADs and OTHs at similar frequency of occurrence, while bigeye tuna was found only around FADs. Results revealed that there was no statistically significant difference in taxa richness or frequency of occurrence of 11 species of fish between FADs and OTHs. This study demonstrated that FADs and OTHs can be used to attract tunas and also other fish species in the Eastern Indian Ocean. Among the 15 species of fish, silky shark and devil ray were considered as non-target species, which are listed on Appendix II of CITES. The findings of this study could support the establishment of subsequent conservation and management measures of the Indian Ocean Tuna Commission in reducing the impact of bycatch through the efficient use of FADs in the tuna purse seine fishery in the Indian Ocean.

Keywords: Fish aggregating device, Other floating object, Tuna purse seine, Indian Ocean, Fish species, Frequency of occurrence

INTRODUCTION

Tuna play an important role in the international seafood market, ranking second after marine shrimp (Campling, 2012). The average catch of tuna between 2012 and 2016 was 4,819,248 t from the Pacific, Atlantic and Indian Oceans (ISSF, 2018). Tuna products are demanded from many countries, and Thailand is the main importer and exporter in the world for tuna products. The raw materials are mostly caught by purse seine fishing (Kuldilok *et al*., 2013), including skipjack tuna (*Katsuwonus pelamis*), yellowfin tuna (*Thunnus albacores*) and bigeye tuna (*T. obesus*). Recently, more than 50% of all principal market tuna were caught by purse seine using fish aggregating devices (FADs) (Fonteneau *et al*., 2013).

FADs and other floating objects (OTHs) have been used by the tuna purse seine fishery since the 1980s (Lopez *et al*., 2014). FADs and OTHs are types of floating objects in the oceans that attract many organisms. FADs are artificial floating objects deployed by fishers, while OTHs

[1] Marine Fisheries Research and Development Division, Department of Fisheries, Lad Yao, Chatuchak, Bangkok 10900, Thailand
[2] Oversea Fisheries and Transshipment Control Division, Department of Fisheries, Lad Yao, Chatuchak, Bangkok 10900, Thailand
* Corresponding author. E-mail address: w.chumchuen@fisheries.go.th
Received 19 November 2018 / Accepted 6 February 2019

are natural or artificial floating objects in the ocean. Both FADs and OTHs serve as habitat, where a temporary food web exists, for pelagic fishes including the three species of tuna mentioned above. Reduced searching time for tuna schools (Fonteneau *et al*., 2013) and increased catch per unit effort of tuna (Fonteneau *et al*., 2005) are the benefits of FADs and OTHs to fishers. However, the catch from FADs or OTHs can also include bycatch, which are considered as non-target species (Hallier, 1995; Lopez *et al.*, 2014).

For the tuna purse seine fishery, FADs and OTHs can attract several species of fish, whether target or non-target species. In order to catch target species and avoid non-target species, the characterization of fish species around FADs and OTHs is necessary. The objective of this study was to describe the fish species found in the vicinity of FADs and OTHs used for purse seine fishing in the Eastern Indian Ocean.

MATERIALS AND METHODS

Study area and fishing surveys

The study area was located in the Eastern Indian Ocean and encompassed 1-5 °S and 85-96 °E (Figure 1). The fishing surveys were conducted during March-May 2012 and March-April 2013, which were within or close to the tuna purse seine fishing season (November-April) in the study area (DOF, unpubl. data). The fishing surveys were operated by the research vessel FRV Mahidol (1,270 GT and 62.53 m length overall) of the Department of Fisheries, Thailand, and involved deploying FADs, sighting OTHs and collecting data on fish species around FADs and OTHs.

Fish aggregating devices (FADs)

There were 13 and 12 FADs deployed for this study in 2012 and 2013, respectively. The FADs

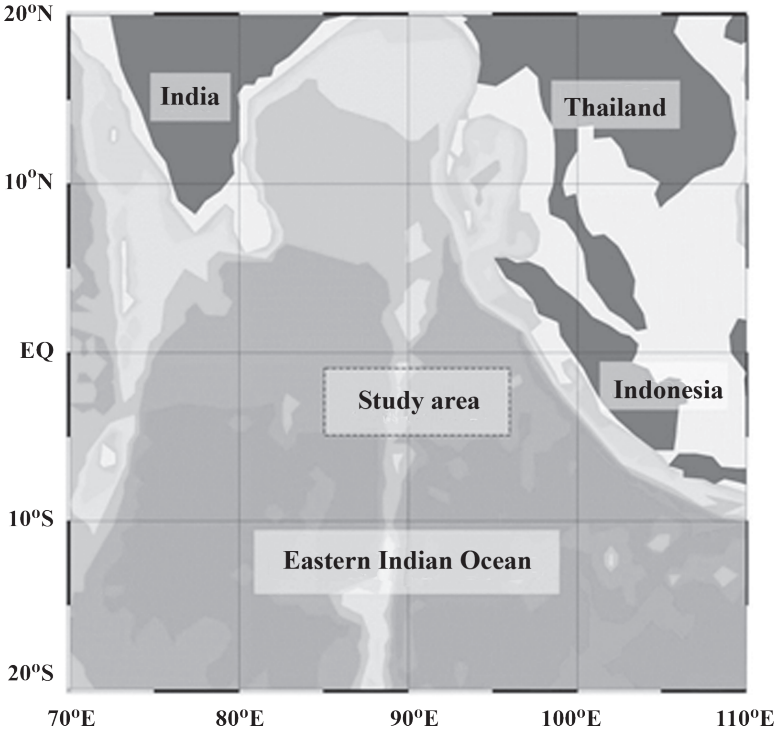

Figure 1. Study area in the Eastern Indian Ocean surveyed by FRV Mahidol in 2012 and 2013.

were deployed in the zone of 1-5 °S and 85-86 °E for tuna purse seine fishing surveys. Each of the 3 m × 3 m FADs was made of an iron frame (2.5 m × 3.0 m, using ~ 5 cm diameter iron pipe), bamboo (25-30 pieces of 7.5-12.5 cm diameter with 3 m length), iron wire rope (2.2 cm diameter with 6 m length), used net (knotless black polyamide netting with 9.0 cm mesh size and 15-20 m length) and a radio buoy (Figure 2). The used net was attached below the iron frame as a submerged substrate for small organisms. The iron wire rope was attached at the bottom of the used net as a sinker.

Other floating objects (OTHs)

OTHs include natural logs, oil tanks, styrofoam coolers and other objects that float in the ocean. During the fishing surveys, OTHs were sought by crew members for the tuna purse seine fishing operation. The crew members used binoculars for sighting any OTH in the study area, where tuna schools may associate with it. In this study, the OTHs associated with fish schools during the fishing surveys were natural logs (~15 cm diameter with 2-3 m length) and a group of abandoned fishing nets (approximately 3 m length and 1 m width).

Data collection

The FADs were tracked and observed between the 32nd day and 48th day after deployment. Fish observed in the vicinity of each FAD or OTH were recorded under calm or slight sea conditions (less than 1 m wave height) through visual census technique, trolling line fishing and purse seine fishing. The visual census technique was performed onboard while the research vessel was slowly approaching each FAD or OTH. Trolling line fishing was carried out using one of the work boats of the

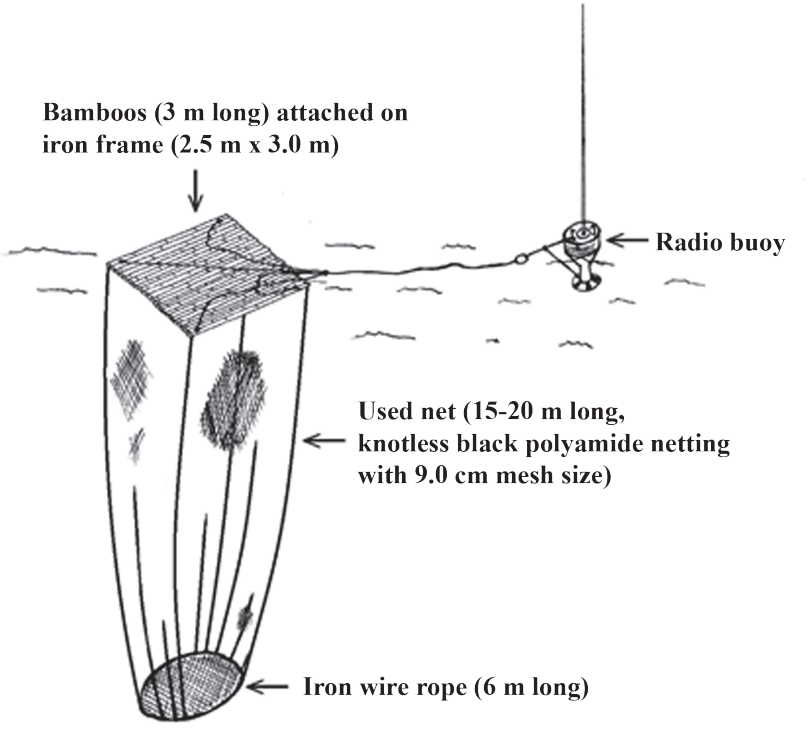

Figure 2. Design of fish aggregating device deployed by FRV Mahidol for tuna purse seine fishing in the Eastern Indian Ocean in 2012 and 2013.

research vessel within 20-250 m of each FAD or OTH. Purse seine fishing was operated when a large fish school was detected by echo-sounder or sonar. The species of fishes were identified according to Masuda *et al*. (1984a; 1984b), Smith and Heemstra (1986) and Nelson (2006).

Statistical analyses

Fish species aggregating around FADs and OTHs were described by taxa richness (Addis *et al*., 2006) and frequency of occurrence (%) (Workman *et al*., 1985). The comparisons between FADs and OTHs were performed using Independent Samples *t*-test for average taxa richness and Two Proportions Unpooled *z*-test for frequency of occurrence of each fish species (Zar, 2010). A significance level (α) of 0.05 was used for both statistical analyses.

RESULTS AND DISCUSSION

Seven of the 13 deployed FADs were found in 2012, whereas eight of 12 deployed FADs were found in 2013. The immersion time of the 15 FADs found in the ocean was between 32 and 48 days. The OTHs encountered in the study area were two natural logs and a group of abandoned fishing nets. The immersion time of the three OTHs was unknown.

Taxa richness

The fish species found in the vicinity of the 18 floating objects (15 FADs and three OTHs) are described in Table 1. A total of 15 species of fish belonging to 10 families were identified, including three species of cartilaginous fish and 12 species of teleost fish. The comparison of average taxa richness between FADs (4.07±0.66 taxa) and OTHs (4.33±2.40 taxa) was not statistically significant ($t = 0.150$; $df = 16$; $p = 0.882$). The result indicated that the average number of species of fish between FADs and OTHs in the study area was not different.

It was presumed that FADs and OTHs have similar attributes which influence the aggregation of several species of fish, including target and non-target species. In other words, these types of floating objects are not selective in attracting fish species. Thus, information on particular fish species around FADs and OTHs is necessary, which would guide fishers in making decisions on tuna purse seine fishing operations.

Frequency of occurrence

Frequency of occurrence was estimated for each fish species found in the vicinity of FADs and OTHs (Table 1). For FADs, dolphinfish (*Coryphaena hippurus*) had the highest frequency of occurrence, followed by rough triggerfish (*Canthidermis maculata*) and yellowfin tuna. For OTHs, requiem sharks under the genus Carcharhinus, dolphinfish and rough triggerfish had the highest frequency of occurrence.

FADs were effective in aggregating tuna species in tropical waters, and the frequency of occurrence of the three species of tuna found around FADs in this study was 20%, 47% and 27% for skipjack, yellowfin and bigeye tunas, respectively. For OTHs, the frequency of occurrence was 33% for both skipjack and yellowfin tunas, while bigeye tuna was not found around OTHs.

The results from this study are similar to Taquet *et al*. (2007) where dolphinfish had a high frequency of occurrence (96%) around FADs, while skipjack, yellowfin and bigeye tunas had frequencies of 18%, 46% and 9%, respectively.

The frequency of occurrence for 11 of the species of fish found near FADs or OTHs was not statistically different. For the other four species observed in this study, tripletail (*Lobotes surinamensis*) and bigeye tunas were found only around FADs, while the requiem sharks and rough triggerfish were found around both FADs and OTHs but their frequency of occurrence around OTHs were higher than around FADs. This revealed that the aggregations of fish species near FADs and OTHs were similar. For the three species of tuna, skipjack and yellowfin tunas were found around both FADs and OTHs, whereas bigeye tuna was found only in the vicinity of FADs.

Table 1. Fish species and their frequency of occurrence (%) in the vicinity of fish aggregating devices (FADs) and other floating objects (OTHs) in the Eastern Indian Ocean in 2012 and 2013.

Family/Species	Common name	FADs (n = 15)		OTHs (n = 3)		z-value for % (FADs vs OTHs)
		+/-	%	+/-	%	
Cartilaginous fish						
Carcharhinidae						
Carcharhinus falciformis	Silky shark	+	7	-	0	1.035
Carcharhinus spp.	Requiem sharks	+	20	+	100	7.746***
Mobulidae						
Mobula sp.	Devil ray	+	7	-	0	1.035
Teleost fish						
Balistidae						
Canthidermis maculata	Rough triggerfish	+	53	+	100	3.623***
Carangidae						
Elagatis bipinulata	Rainbow runner	+	27	+	33	0.226
Seriola dumerili	Greater amberjack	+	33	+	33	0.000
Coryphaenidae						
Coryphaena hippurus	Dolphinfish	+	87	+	100	1.519
Kyphosidae						
Kyphosus vaigiensis	Brassy chub	-	0	+	33	1.225
Lobotidae						
Lobotes surinamensis	Tripletail	+	40	-	0	3.162**
Monacanthidae						
Alutera monoceros	Unicorn leatherjacket	+	13	-	0	1.519
Scombridae						
Acanthocybium solandri	Wahoo	+	27	+	33	0.226
Katsuwonus pelamis	Skipjack tuna	+	20	+	33	0.458
Thunnus albacares	Yellowfin tuna	+	47	+	33	0.443
T. obesus	Bigeye tuna	+	27	-	0	2.335*
Sphyraenidae						
Sphyraena barracuda	Great barracuda	+	7	-	0	1.035

It should be noted that some species of fish were found only around FADs (*i.e.*, silky shark, devil ray, tripletail, unicorn leatherjacket, bigeye tuna and great barracuda), and one species of fish was found only around OTHs (*i.e.*, brassy chub). This may be due to the size of the floating objects (FADs and OTHs) and behaviors of such fish species. Further studies are necessary to confirm these assumptions.

The results indicated that FADs deployed by fishers can be used for attracting tunas and other teleost fishes, while the three species of cartilaginous fishes had low frequency of occurrence around FADs. However, attention should be paid to purse seine fisheries using FAD operations because silky shark (*Carcharhinus falciformis*) and devil ray (*Mobula* sp.) were found in the vicinity of FADs. Silky shark is commonly associated with floating objects and is regularly taken as bycatch in the FAD-based tuna purse seine fishery (Filmalter *et al*., 2017). These species were listed on Appendix II of Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (CITES, 2018). Although these fish species can be traded under the regulations of CITES, fishers must be cautious to avoid catching these fish species and adhere to the FAO technical guidelines for responsible fisheries (FAO, 1996).

Fishery management measures should include the appropriate use of FADs to support the sustainable utilization of fishery resources in the Indian Ocean. The Indian Ocean Tuna Commission (IOTC), the tuna regional fisheries management organization, has stipulated conservation and management measures for the reduction of bycatch and the appropriate use of FADs in the Indian Ocean to promote responsible fisheries and sustainable utilization of fishery resources. For bycatch management, the IOTC has established a resolution on banning discards of tunas and non-target species caught by purse seine vessels in the IOTC area of competence. The IOTC has imposed a resolution on the procedures of FAD management, including a limitation on the number of FADs, more detailed specifications of catch reporting from FAD sets, and the development of improved FAD designs to reduce the incidence of entanglement of non-target species (IOTC, 2018).

CONCLUSION

There were 15 species of fish gathered in the vicinity of FADs and OTHs. The average number of species of fish found between FADs and OTHs was not different. The results demonstrated that FADs and OTHs can be used to attract tunas for purse seine fishing in the Eastern Indian Ocean. However, other pelagic fish or non-target species are also attracted to both types of floating objects. Therefore, fishers must avoid catching non-target species, particularly the silky shark and devil ray which are listed on Appendix II of CITES. In promoting responsible fisheries and sustainable utilization of fishery resources, the IOTC should consider further the efficient use of FADs in the tuna purse seine fishery in the Indian Ocean to reduce the impact of bycatch in formulating subsequent conservation and management measures.

ACKNOWLEDGEMENTS

Authors would like to thank the crew members and fisheries biologists onboard FRV Mahidol for their assistance during the fishing surveys. We also thank Dr. Shiela Villamor Chumchuen for improving the English of this manuscript.

LITERATURE CITED

Addis, P., A. Cau, E. Massutí, P. Merella, M. Sinopoli and F. Andaloro. 2006. Spatial and temporal changes in the assemblage structure of fishes associated to fish aggregation devices in the Western Mediterranean. **Aquatic Living Resources** 19: 149–160.

Campling L. 2012. The tuna 'commodity frontier': business strategies and environment in the industrial tuna fisheries of the Western Indian Ocean. **Journal of Agrarian Change** 12: 252–278.

CITES. 2018. **CITES-listed species.** https://www.cites.org/eng/disc/species.php. Cited 22 Aug 2018.

FAO. 1996. **Precautionary approach to capture fisheries and species introductions.** Food and Agriculture Organization of the United Nations, Rome. 54 pp.

Filmalter, J.D., P.D. Cowley, M. Potier, F. Ménard, M.J. Smale, Y. Cherel and L. Dagorn. 2017. Feeding ecology of silky sharks *Carcharhinus falciformis* associated with floating objects in the Western Indian Ocean. **Journal of Fish Biology** 90: 1321–1337.

Fonteneau, A., J. Ariz, A. Delgado, P. Pallares and R. Pianet. 2004. A comparison of bigeye stocks and fisheries in the Atlantic, Indian and Pacific Oceans. **Collective Volume of Scientific Papers International Commission for the Conservation of Atlantic Tunas** 57: 41–66.

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

Hallier, J.P. 1995. Tropical tuna fishing with purse seine and log. **FAO Infofish International** 4: 53–58.

IOTC. 2018. **Compendium of active conservation and management measures for the Indian Ocean Tuna Commission.** Indian Ocean Tuna Commission, Mahé. 277 pp.

ISSF. 2018. **Status of the world fisheries for tuna: February 2018.** International Seafood Sustainability Foundation, Washington D.C. 101 pp.

Kuldilok, K.S., P.J. Dawson and J. Lingard. 2013. The export competitiveness of the tuna industry in Thailand. **British Food Journal** 115: 328–341.

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

Masuda, H., K. Amaoka, C. Araga, T. Uyeno and T. Yoshino (eds). 1984a. **The fish of the Japanese archipelago: text.** Tokai University Press, Tokyo. 437 pp.

Masuda, H., K. Amaoka, C. Araga, T. Uyeno and T. Yoshino (eds). 1984b. **The fish of the Japanese archipelago: plate.** Tokai University Press, Tokyo. 370 pp.

Nelson, J. S. 2006. **Fish of the World.** John Wiley and Sons Inc., New York. 601 pp.

Smith, M. M. and P. C. Heemstra (eds). 1986. **Smiths' Sea Fish.** Macmillan South Africa Ltd., Johannesburg. 1,047 pp.

Taquet, M., G. Sancho, L. Dagorn, J.C. Gaertner, D. Itano, R. Aumeeruddy, B. Wendling and C. Peignon. 2007. Characterizing fish communities associated with drifting fish aggregating devices (FADs) in the Western Indian Ocean using underwater visual surveys. **Aquatic Living Resources** 20: 331–341.

Workman, I.K., A.M. Landry, Jr., J.W. Watson, Jr. and J.W. Blackwell. 1985. A midwater fish attraction device study conducted from hydrolab. **Bulletin of Marine Science** 37: 377–386.

Zar, J.H. 2010. **Biostatistical Analysis.** Prentice Hall, New Jersey. 944 pp.