Performance of rumpon-based tuna fishery in the Fishing Port of Sendangbiru, Malang, Indonesia

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Abstract. Catch records on FADs-based tuna fishery (hand-line) in the southern of East Java was conducted in fishing base of Sendangbiru, from February 2016 to May 2017. Total 45 rumpon (FADs) were found within space area of 64,081 square nautical miles, with average between FADs distant of 25 nautical miles. All FADs were located outside Fisheries Management Areas, except one FAD of code 31. Hand-line fishery was designed for a maximum fishing trip of 14 days. Total catch biomass mainly determined fishing trip. When catch exceeded 1,000 kg, fishermen tend to turn back although with < 10 days fishing trip. Yellowfin tuna and skipjacks were two main species that formed total catch with average catch biomass varied amongst 425–1,360 kg trip⁻¹. Apart from baby-tuna, yellowfin tuna and albacore within catch were at size class higher than its first maturity stage. However, length-class of skipjack indicated that it still in immature stage. Despite of FAD license, Ministry of Marine Affairs and Fisheries neither informed nor aware the position of these FADs.

1. Introduction
The development of fishing gears and methods may not always based on the new concept of science [1]. It is rather due to the ingenuity of fishermen to cope with different fishing conditions and to meet their socio-economic requirements. It was long time ago before, fishermen have realized the drifting materials as a potentially good material for trolling [2]. They anchored the floating materials that lately known in science as Fish Aggregating Device, FADs [3, 4]. In Indonesia, traditional bamboo rafts anchored close to the coast have been practiced since early 1900s to attract pelagic fishes [5]. The device was locally named as ‘rumpon’ or ‘rumpong’. As fishing technology developed, more rumpon were deployed in deeper area using metal pontoon as floating device and with submerged coconut leaf frond. This technology was first introduced in the eastern part of Indonesia [6, 7]. Since early 1980s, many fishermen migrated to the southern coast of East Java, and settled in the East Java Province, and brought with them the deep-sea FAD’s technology.

Floating materials such as FAD can attract both juveniles and adult fishes in variety of number and diversity [8]. This ecological trap may result in negative impact to fishery. FADs associated fish stocks will quickly overfished as they more vulnerable to fishing pressure [9, 10]. Also, FAD acts as a catalyst
for cannibalism between large (> 90 cm length-frequency (FL)) and small (< 30 cm FL) size of yellowfin tuna as both groups aggregated at FADs [3]. Currently, the number of rumpon in Indonesia has grown rapidly. As a precautionary approach in fisheries management, the Ministry of Marine Affairs and Fisheries of the Republic of Indonesia has regulated the placement of FADs (through Decree No.30/2004 and No.26/2014) within the Indonesia’s marine jurisdiction and ZEE. The regulation stated that all of the FADs must be licensed and the distance between FAD should be minimum ten nautical mile (nmi), and do not result in hedge effect, such as zigzag placement. This study aims to assess the performance of FAD-based tuna fishery in the southern coast of East Java, operated by mainly migrant fishers from the South Sulawesi.

2. Materials and Methods
Catch species and biomass of FAD-based tuna fishery were monitored from February 2016 to May 2017. All the catches were landed at the fishing port of Sendangbiru, East Java (figure 1) and auctioned. So, the price and total revenue per species biomass were also recorded. Catch species was identified based on the general guideline mainly scombrid [11]. Weighing of the catch followed the auction system. Identified yellowfin (Thunnus albacares) and bigeye (Thunnus obesus) were measured individually, and albacore (Thunnus alalunga) per three individuals. The rest of the catches were weighed per group. On the willingness of fishermen to cooperate, position of each rumpon was recorded using GPS and all positions were digitized to calculate the total area of FADs within network (figure 1).

When a fishing boat went out for fishing, boat name and date were recorded. The date of the same boat came back to auction was also recorded. Total fishing trip for each fishing boat was calculated as total time (days) allocated by a boat from fishing auction to fishing ground, plus actual fishing time, and time to go back to fishing port of origin (Sendangbiru). The fishing boat dimension (GT, HP, and crews) was estimated based on sampling of 80 out of total 400 fishing boats. Analysis was conducted for total area of FADs within network, trip, catch species per month, and total revenue from catch auction. Length-frequency analysis was done for four dominant species in the catch, i.e. yellowfin, albacore, baby tuna, and skipjack.

3. Results and Discussion
3.1. Total area of FADs network
All 45 rumpon positions were mapped and formed a FADs network as shown in figure 1. Estimated total area within FAD network is 219.792 km². The closest distance of each FADs varied between 4 and 100 km, with an average distance of 46.8 ± 6.4 km or equal to 25.2 ± 4.4 nmi. Only three FADs are placed less than ten nmi one to the other. Each FAD, on average, occurred at around 1,800 nmi². All FADs are located outside the 12 nmi except one FAD (FAD 31) (figure 1). The license for these FADs should be given under central government in Jakarta. However, the Ministry of Marine Affairs and Fisheries was neither informed, nor aware the placement of these FADs (rumpon) in the southern coast of Java.

3.2. Fishing trip and catch species
The catch composed of at least eight different families, i.e. Scombridae, Istiophoridae, Xiphiidae, Coryphaenidae, Gempylidae, Lampridae, Carangidae, and Mobulidae. The most dominant species in the catch belong to family Scombridae, and auctioned together with family Istiophoridae and Xiphiidae. The first tuna group within scombrid consists of three species: yellowfin (Thunnus albacares), albacore (Thunnus alalunga), and big eye (Thunnus obesus). The smaller size of these species (< 50 cm FL) could not be separated properly and was categorized by buyers as baby-tuna. The second tuna group is swordfishes (Xipiidae) and billfishes (Istiophoridae). The third group composed of one species called skipjack (Katsuwonus pelamis). The last group is little tuna, composed of mixed species, but mainly kawa-kawa (Euthynnus affinis), frigate tuna (Auxis thazard thazard), bullet tuna (Auxis rochei rochei), striped bonito (Sarda orientalis), and leaping bonito (Cybiosarda elegans). To some extents, the Indo-
Pacific mackerel, that composed of *Scomberomorus commerson*, *S. guttatus*, *S. lineatus*, and wahoo (*Acanthocybium solandri*) is identified in the catch. Occasionally, fishermen caught species of Carangidae, specifically rainbow runner (*Elagatis bipinnulata*) and *Lepidocybium* sp. (Gempylidae) and the species of family Mobulidae (Rays). All of these species are sold locally.

**Figure 1.** Location of 45 FADs deployed by fishermen from which polygon was created to calculate the total area (km$^2$) covered by rumpon.

Fishermen designed fishing trip for a maximum of 14 days. In reality, average fishing trip varied amongst fishermen and changed times (figure 2a). The lowest fishing trip is found in March and this definitely influenced the total catch-per-unit-of-effort (figure 2b). Fishermen tend to stop fishing when they reach a total catch biomass of $>1,000$ kg (1 ton). On the other hand, when fishing trip is nearly 14 days, they would return home whatever the catch. Fishing capacity and limited time in fishing (trip) seemed to be the two main factors of the rumpon-based tuna fishery in Sendangbiru, East Java.

### 3.3. CPUE per species

Yellowfin tuna and skipjack are two main species that formed the total catch biomass (CPUE). Yellowfin is known as the strongest species that associated with floating materials such as FAD [3, 4, 9]. Bigeye tuna is caught occasionally, with N = 6 (present in the catch only six times out of 1,083 landings). The swimming depth of this species is likely deeper than fishermen hand-line could reach. Little tuna and Albacore are also found very rare in the catch (table 1). Little tuna species was more ecologically found in the coastal areas and formed a strong schooling compared to yellowfin and skipjack [11].

During February–April, catches are initially dominated by skipjack, little tuna, and baby-tuna respectively. Gradually, the yellowfin tuna replaced these smaller size fishes within catch (not shown in the table). Yellowfin tuna is known as a cannibal in the FAD area, apart from its normal behavior to follow floating materials [3]. The more the skipjacks and baby-tuna found in the FADs, it will give a strong sign of higher catch after the school of these smaller fish size.
Figure 2. Avarage fishing trip, in days (a) and Catch-per-unit-of-effort, in kg·trip⁻¹ (b) of rumpon-based tuna fishery (hand-line) in the southern coast of East Java.

Table 1. Catch-per-Unit-of-Effort, CPUE (kg·trip⁻¹) of rumpon-based tuna fishery in the Sendangbiru Fishing Port

| Species       | N  | CPUE (kg·trip⁻¹) |
|---------------|----|-----------------|
|               |    | Means + SE      | MIN | MAX  |
| Baby tuna     | 894| 221 ± 6       | 23  | 1.511|
| Skipjack tuna | 831| 277 ± 9       | 22  | 2.020|
| Yellowfin tuna| 802| 291 ± 11      | 13  | 1.857|
| Albacore      | 102| 225 ± 21      | 19  | 1.025|
| Bigeye tuna   | 6  | 117 ± 11      | 63  | 130  |
| Little tuna   | 17 | 240 ± 69      | 34  | 1.162|

3.4. Length-class distribution

Length-class distribution from four species and group within catches is shown in figure 3. Yellowfin tuna (locally madidihang) is mainly caught at size of 140 cm FL, although it is found at lower size (figure 3). Female yellowfin tuna mainly reproduced at minimal size of 94.8 cm FL [12, 13, 14]. So, apart from 8% of juveniles found in the catch (figure 3a), most of the adult yellowfin tuna in the catch are assumed to pass its first maturity and spawning cycle. Baby-tuna may consist of yellowfin species at length-class between 25 and 50 cm FL (figure 3c). All tuna species at this size category are immature and cannot be avoided from the catch.

Skipjacks found in the catch varied between 25 and 50 cm FL (figure 3d) with average length of 38.4 cm FL. Studies conducted around Philippines [14, 15] found that this female skipjack (Katsuwonus pelamis) usually matured at length size of 40–50 cm. So, most of the skipjacks within catch in the southern coast of Java would be immature considering the spawning size above. It is difficult to suggest the mature size of Albacore (Thunnus alalunga) around the area. Studies conducted around the Pacific up to South Africa showed that albacore usually matured at size between 85 and 95 cm FL [11, 15].
Length-classes of albacore within catch in the southern coast of East Java (figure 3b) are higher than first mature size.

Rumpon or FADs of tuna fishery in southern coast of East Java were deployed within EEZ, or outside the 12 nmi of the Indonesia’s Fisheries Management Area. Placement of each FAD is > 10 nmi one to the other. However, the central government is neither informed, nor aware on the position of each rumpon. Hand-line is the only gear operated by fishermen in the FADs. The catch composed of 8 families, totally comprised of more than 20 different species. Yellowfin tuna and skipjack are two main species in the catches. Fishing capacity is designed for a maximum fishing trip of 14 days. When total catch biomass exceeded 1,000 kg, fishermen tended to bring it to fishing auction, even the trip is less than ten days. Most yellowfin and albacore are estimated to pass its first maturity stage. However, most skipjacks are found to be at immature stage.

**Figure 3.** Length-frequency (FL) distribution of four species sampled from catches: a. Madidihang; b. Albacore; c. Baby-tuna; d. Skipjacks.
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