BIODIVERSITAS
Volume 23, Number 10, October 2022
Pages: 5481-5490

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d231060

Studying the relationship of immersion duration and characteristics of natural materials FAD to fish aggregation in the sea

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Manuscript received: 20 September 2022. Revision accepted: 22 October 2022.

Abstract. *Rumpa A, Najamuddin, Safruddin, Hajar MAI. 2022. Studying the relationship of immersion duration and characteristics of natural materials FAD to fish aggregation in the sea. Biodiversitas 23: 5481-5490.* An understanding of immersion duration and the characteristics of natural materials Fish Aggregating Devices (FAD) on fish aggregation in the sea is crucial in developing more effective fishing strategies in FAD areas. The aim of the study was to understand the relationship between immersion duration and characteristics of FADs made from natural materials on the schooling aggregation of mackerel scad (*Decapterus russelli*) in the sea. The research was conducted from April 2021 to March 2022 in Bone Bay, Indonesia. The type of research was experimental fishing 78 times down at sea to observe the relationship between FAD construction and fish schools. The results demonstrated that the growth of invertebrates in the construction component of FADs based on the period of immersion in the sea at the immersion period of >30 days showed a high growth rate of algae, hydrozoa and crustacean species at the bottom of the raft. The endurance of the coconut leaves attractor at a duration of 3-4 weeks was the best condition for immersion duration in the sea because schooling fish were more concentrated around the attractor at an average distance of 1.2 m, while at a duration of 5-6 weeks the attractor had damaged and the fish schooling was less concentrated. Based on the arrival of schooling fish in FAD areas, the fastest average duration was 3-4 weeks, namely in transitional season 1. The presence of crustacean species caused fish schooling only to be concentrated at a distance of 2-3 m at the time of fishing. In the fishing strategy, the treatment of FADs using dried coconut leaves attractors showed more concentrated fish schooling and calmer fish movement pattern compared to the use of fresh coconut leaves attractor. The characteristics of the components making up FADs had a direct impact on the effectiveness of attracting and concentrating fish. In addition, the characteristics also influenced the schooling distance of fish at the center point of the FAD raft before the fishing gear was lowered.

Keywords: Characteristics of FADs, coconut leaves attractor, *Decapterus ruselli*, schooling

INTRODUCTION

In the past, most of the floating objects used by fishermen as attractors to catch fish were logs. Many marine fish species congregate around these floating structures (Forget et al. 2015; Brehmer et al. 2019). Over time, the floating objects were modified by fishermen and referred to as man-made Fish Aggregating Devices (FADs) (Taquet 2013; Capello et al. 2016).

Like other floating objects, FADs can attract fish species to associate with them (Lezama et al. 2015; Matsumoto et al. 2016) so that fish are easier to find and easy to catch (Albert et al. 2014; Davies et al. 2014). According to Dagorn et al. (2013) and Cabral et al. (2014), there are two types of FADs developing in the world today, namely drifting FADs (free drifting FADs: dFADs) and anchored FADs (anchored FADs: aFADs).

Several studies have found that the association of fish species in the floating object area has several important roles, namely: playing a role in protecting fish from predators (Sinapoli et al. 2015; Kehayias et al. 2018). Acting as a reference point in navigation, acting as a meeting point and playing a role as a food source (Capello et al. 2012; Sinapoli et al. 2019).

The ability to attract fish may be triggered by the construction characteristics of the floating object. In fact, fishermen state that construction has a direct impact on the effectiveness of FADs, such as buoy size and attractor components (Moreno et al. 2016). In addition, the depth of attractors installed under the sea (Doray et al. 2001; Dempster and Taquet 2004).

In traditional FADs, attractors acting as fish-gathering media are basically made of coconut leaves midrib (*Cocos nucifera*) (Ibrahim et al. 2014), palm fiber leaves (*Arenga pinnata*) (Hasaruddin et al. 2021), and areca nut (*Areca catechu*) (Yusfiandayani 2013). These attractors are generally kept below sea level and tied to bamboo rafts (Cruz et al. 2015), cork drums (Widodo et al. 2020), or pontoon buoys (Wudianto et al. 2019) to float on the sea surface.

The difference in the construction of FADs is closely linked to the knowledge of fishermen about the behavior of associated fish in the FAD area based on placement locations (Mbaru et al. 2018; Matrutty et al. 2021) and target fish species (Yusfiandayani et al. 2015). In addition, FAD construction is also an integral part of developing fishing aid technology (Tenningen et al. 2017; Cody et al. 2018; Zhou et al. 2019).

Experienced fishermen say that traditional FADs with a construction made of bamboo, anchor ropes with natural fibers and coconut leaves attractors are not strong and not durable when used in water. However, fishermen believe that FADs are quite effective in collecting fish in the sea, especially mackerel scad (*Decapterus russelli*), which are dominantly caught in the FADs (Irawati et al. 2021; Jamal et al. 2021).

In the strategy of operating fishing gear, purse seine uses FADs. The factor that really needs to be taken into account is the distance of schooling fish from the center point on the FAD raft before the fishing gear is lowered. Several studies have revealed other external influencing factors, such as the influence of oceanographic factors (Khan et al. 2020), artificial lighting factors (Tsounis and Kehayias 2021), moonlighting (Suhariyanto et al. 2020) and the presence of predators (Kehayias et al. 2018).

Our initial research study, based on visual observations and interviews with fishermen, shows that there are several components of FAD construction that can affect the existence of schooling fish, aggregation of fish in the fishing area, namely: length of immersion, presence of algae species, hydrozoa and crustaceans, as well as the quality of the attractors used.

An understanding of the construction characteristics of FADs made from natural materials associated with immersion time and fish aggregation in the sea is very important to study in determining effective and efficient fishing strategies. Several studies related to the effectiveness of using natural FAD construction have been carried out in this study (Zudaire 2017; Lopez et al. 2019), but research is still focused on the object of species in large pelagic fish such as tuna.

Therefore, the construction of FADs made from natural materials are interesting enough to be identified and studied comprehensively. According to the statement of (Capello et al. 2013), the material form, chemical and biological substances of FADs play an important role in the phenomenon of gathering fish below of FADs.

MATERIALS AND METHODS

Study areas

This research was conducted in the waters of Bone Bay, precisely in Watampone, Bone District, Indonesia. Positioning S 4°30’00”, E 120°30’00”. This bay was used as a fishing base from April 2021 to March 2022. The type of research was experimental fishing by observing the construction and schools of fish in the type of FAD area (anchored). The tools and materials used were 34 units of FAD belonging to fishermen and the media that went to the FAD location at sea using a purse seine ship.

Procedures

The construction components making up FADs, such as life raft (bamboo), a fish attractor (coconut leaf), and anchor rope (sisal rope) were identified visually. For the durability of FAD construction caused by environmental influences, the soaking time associated with algae growth and the duration of schooling fish arrivals were carried out using a comparative test using the original lab 2018 software. This factor becomes the dependent variable. The independent variable that affects the dependent variable is the prevailing season in Indonesia, which consists of the comparative transition test. Based on the prevailing season in Indonesia, season (MP-1) exists in March-May, East season (MT) occurs in June-August, Transitional Season 2 (MP-2) occurs in September-November and West Season (MB) occurs in December-February.

Data collection related to the emergence of fish schools was observed and measured between the time since FADs were installed until the appearance of fish in the fishing area. The object of observation was the schooling mackerel scad. The effect of physical changes in coconut leaves attractors due to long immersion in the sea, the presence of invertebrates, and the color of coconut leaves attractors (old and new) on the schooling distance of fish at the center of FADs was observed using one underwater fishing camera 50 meters / 360º type CR110-7BDVR, four units of fish finder type Garmin map 585 with a frequency of 50-200 kHz, with a maximum depth of 1500 ft. In addition, the transducer was mounted under the sea, which could be directed vertically and horizontally.

The fish schooling distance would determine the concentration level of the fish. In this case, the schooling distance of fish in the range of 0-2 m was included in the concentrated category; fish schooling distance >2-5 m included in half concentrated category; and fish schooling distance >5 m indicated schooling fish that were not concentrated from FAD component units (coconut leaves attractor, attractor rope/anchor rope, and FAD raft). As a limiting factor, the observation of fish aggression was only carried out at the location of placement of fish FADs. Additional data to strengthen the experimental results were the results of interviews based on the knowledge and experience of fishermen (n: 20). Related to how long the durability of the components making up FADs and the category of distance schooling fish are said to be concentrated or away from the construction components of FADs.

Data analysis

Observational data were presented in the form of tables and figures, which were then analyzed descriptively to find a relationship between fish aggression in the FAD area and the construction materials making up the FAD.

RESULTS AND DISCUSSION

Identification of FAD construction characteristics

FAD construction commonly used in Bone Bay consisted of a life raft, fish attractor, anchor rope, ballast rope and ballast. The construction a raft of bamboo FADs with an average length of 5-6 m, a width of 1.2-1.5 m consisting of several woven bamboos totaling 24-30 sticks, with two styrofoam measuring 2x1 m inserted in the center of the raft. The ballast rope or anchor rope used a natural rope (*mandar* rope) measuring 1000-2500 m, depending on the depth of the waters. The attractor rope was also made of natural material (sisal rope). Local people said that the number of mandar ropes with fish attractors from coconut leaves midribs was 6-10 pieces that were installed to a depth of 5-10 m, while the weights or FAD anchors came from mountain rocks or limestone, totaling 25-40 pieces in one FAD unit. The binding or locking of the ballast stones came from used tires and *polyethylene* (PE) ropes as can be seen in Figure 1.

The durability of the components making up the FAD was tested to estimate the lifespan of the FAD and as an illustration regarding the ideal maintenance of the FAD construction.

Relationship between immersion period and growth of algae, hydrozoa and crustacean species on FAD construction

Based on the results of visual observations (n: 20), the immersion time influenced the emergence of aquatic organisms like Algae, Hydrozoa and Crustacean Species, especially. Goose barnacles (*Lepas anatifera*) (Figure 2).

In the construction of the raft materials (Figure 2.a1), samples were taken at the time of the initial descent of the FAD raft at sea for up to 2-4 weeks (Figure 2.a2). The inspections showed that the bamboo raft was still greenish brown and slightly overgrown with algae, hydrozoa and crustacean species. After FADs were soaked for >30 days, the character of the bamboo rafts turned dark brown. The bottom of the raft was overgrown with species of algae, hydrozoa and crustaceans (Figures 2.a3 and 2.a4).

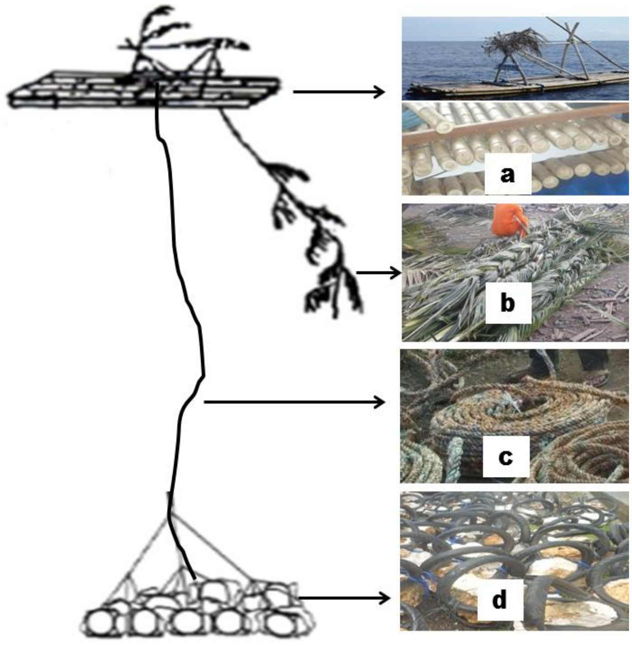


Figure 1. FAD construction components. A. Buoys (bamboo and cork rafts); B. Attractor from coconut leaves; C. Anchor rope from mandar rope; D. Weights/anchors of mountain rock

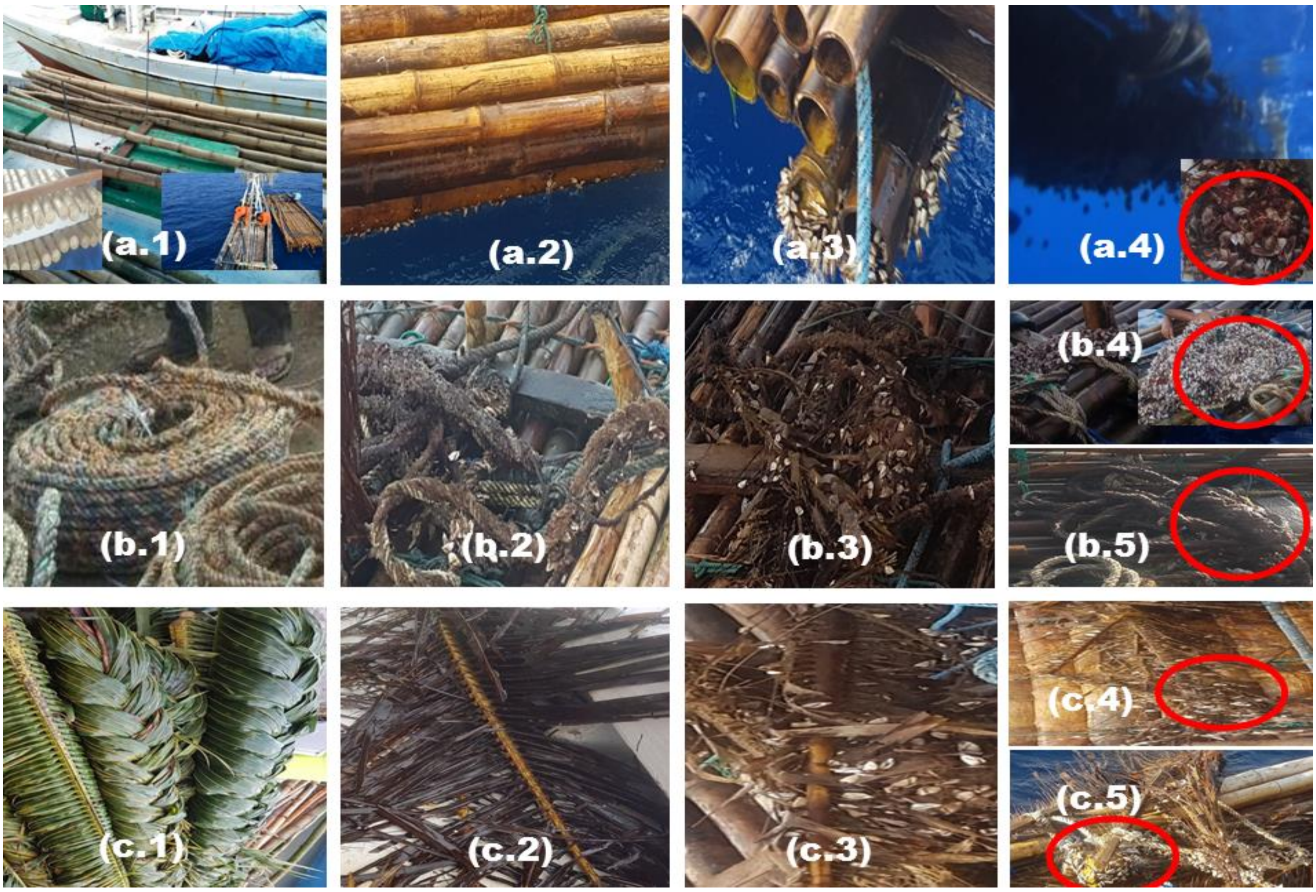


Figure 2. The relationship between immersion time and algae, hydrozoa and crustacean species growth in FADs construction during submersion at sea. A. Raft FADs; B. Anchor rope and FAD attractor rope; C. Coconut leaves attractor

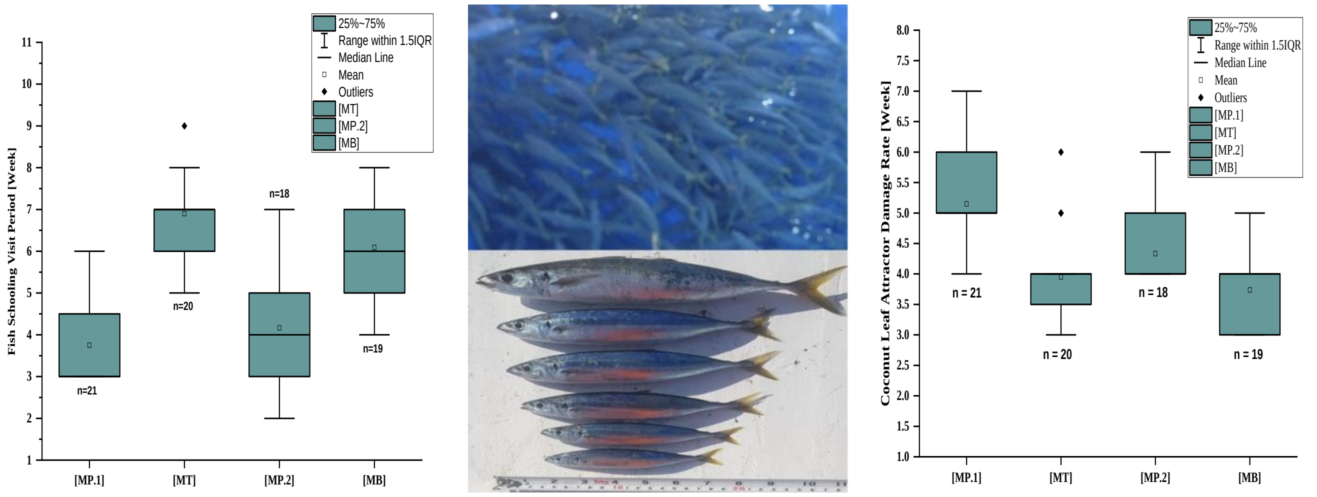
Table 1. Overview of the construction durability of FADs composing

Component	Lifetime	Description
Bamboo raft	6 months	Generally, bamboo stems are replaced every 6 months, overall in a year the entire bamboo raft is replaced, including the cork in the middle
Anchor rope	>1 year	The average lifetime is more than a year since installation (generally ±1 year), the rope is changed at the top along ± 80 m (1 roll)
Attractor rope	>1 year	Average lifespan of attractor rope is more than a year since installation
Coconut leaves attraction	±2 months	Generally, the change of the attractor is done every 3-5 weeks, depending on the region, season and damage

Note: The results of observations and interviews with fishermen who owned FADs (n: 20)

A B

Figure 3. A. The average physical changes of coconut leaves attractor. (a). Condition before immersion in the sea, (b). 1-2 weeks old, (c). 3-4 weeks old, (d). Age 5-6 weeks. (e). Age 7-8 weeks; B. Durability of coconut leaves attractor during submersion in the sea based on usage. (a.1). Fresh/green leaves (b.1). Dried leaves/brown



A B C

Figure 4. **A.** The average time of physical damage to coconut leaves, B. Average arrival time of schooling fish in FAD areas based on Transitional Season.1 [MP.1], East Season [MT], Transitional Season.2 [MP.2] and West Season [MB]

In the observation of anchor ropes, coconut leaves attractor rope and coconut leaves attractor showed almost the same characteristics as bamboo rafts at >30 days old. In this case, there were many attractors overgrown with species of algae, hydrozoa and crustaceans (Figure 2.b3,b4 and c3,c4). The fast and slow growth of these species was strongly influenced by environmental conditions and seasons, especially currents, water temperature including nutrient levels in the water will also have a significant effect. The interesting finding in the field was the discovery of anchor ropes at an average immersion of more than 20 months in a sea that was not overgrown by crustacean species (Figure 2.b.5). In such case, the anchor rope underwent stiff hardening and was slimy.

The durability of FAD attractors (coconut leaves) due to long immersion in the sea

The durability of coconut leaves midrib as an attractor was closely related to the duration of immersion in the sea. This can be seen visually from the physical changes (Figure 3). Physical observations of coconut leave attractors before immersion in the sea (Figure 3.A.a) and after being lowered/installed into the sea for 1-2 weeks (Figure 3.A.b) revealed that the coconut leaves were brownish in color with the leaves midribs still green and not damaged. The second sampling (Figure 3.A.c) showed that the coconut leaves were dark brown in color with the leaves stalks starting to break from the stems. The third sample (Figure 3.A.d) of coconut leaves detached from the midrib (rachis) of the leaves midrib. Furthermore, the sample (Figure 3.A.e) showed the rachis remaining in the goose barnacles-infested midrib.

Observation of the attractor endurance was carried out based on the use of coconut leaves that were still fresh and had been dried at the same time they were unloaded at sea, which was calculated from the first day to (4th and 5th week). Visually, (Figure 3.B.a3) showed that at the age of 3-4 weeks, the fresh leaves began to lose leaf fiber. Likewise, at the time of lifting upwards, FADs of fresh leaves were easily weathered and broken (Figure 3.B.a4). Therefore, it can be said that coconut leaves that had been dried and brown (Figure 3.B.a.1) were more resistant than fresh/green leaves (Figure 3.B.b.1)

Relationship of attractor endurance based on different seasons with aggregation of scad fish (*Decapteruss* sp.) in the baited area

Based on different seasons, the observation of the endurance condition of FAD attractors (coconut leaves) installed in waters referred to the level of damage (Figure 3.A.d) and (Figures 3.B.a.4 and b.4), which can be seen in Figure 4.

Figure 4.A show that in the 1st transitional season, the average physical damage occurred in the 5th week; in the east season, physical damage occurred in the 4th week; in the transitional season, physical damage occurred in the middle of the 5th week; while in the west season, physical damage occurred more quickly, which was under four weeks. Generally, in the east and west seasons, coconut leaves were damaged more quickly on the leaves and detached from the stems more quickly. This may be caused by the influence of stronger currents and ocean waves.

The average arrival time of schooling fish in the FAD area was in the Transitional Season 1, East Season, Transitional Season 2 and West Season, which can be seen in (Figure 4C). Based on the order of immersion duration of FAD construction with the fastest and longest duration, it was found that the fastest arrival of fish in the FAD area occurred in the Transitional Season 1, while the longest fish arrival occurred in the East Season.

Effect of physical changes of coconut leaves attractor, presence of invertebrates and color of coconut leaves attractor on fish schooling distance at the center point of FADs

Observations of physical changes in coconut leave attractors, the presence of crustacean species on coconut leaves and attractor ropes, anchor ropes and the presence of crustacean species under FAD rafts, as well as the results of trials using coconut leaves attractors (dry/brown and fresh/green) on fish behavior, especially the schooling of mackerel scad in the FAD area (Figure 5), demonstrated that there was a close relationship between the physical changes of coconut leaves attractors and the average distance of schooling fish, as can be seen from the results of the analysis in Figure 6.

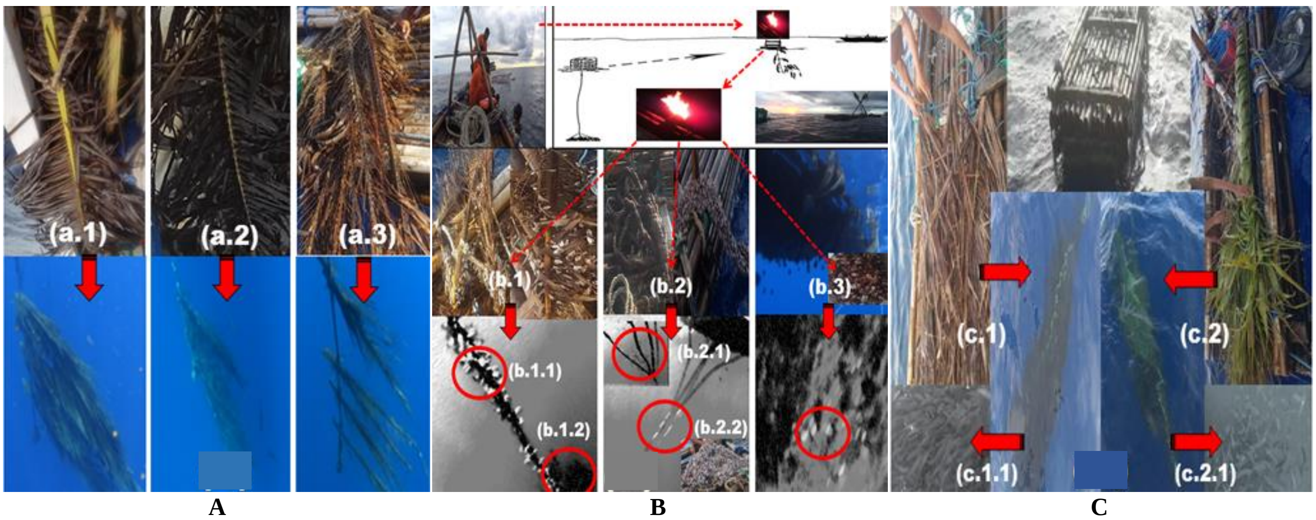
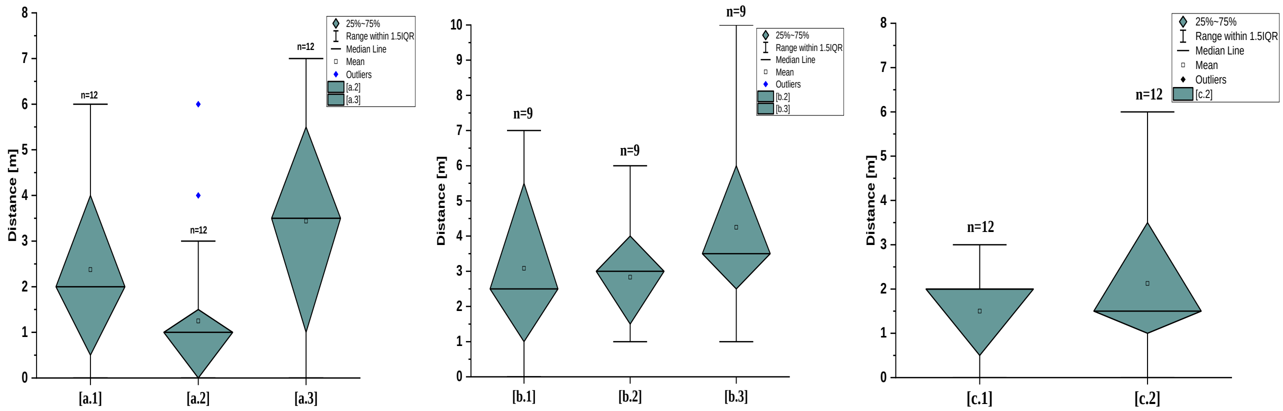


Figure 5. A. Appearance Effect of physical changes of coconut leaves attractor; B. Effect of Invertebrate presence; C. Effect of color of coconut leaves attractor (dry/brown and fresh/green) on fish behavior in FAD areas in the sea



A B C

Figure 6. The average distance of schooling fish to: A. Physical changes of coconut leaves attractor; B. Presence of goose barnacles; C. Color of coconut leaves attractor (dry/brown and fresh/green) on the behavior of mackerel scad (*Decapterus russelli*) in FAD area

The results of the trials (Figures 5A and 6A) related to the physical changes of the coconut leaves attractor illustrated that the scad fish schooling was more concentrated with an average distance of 1.2 m from the attractor with an immersion age of 3-4 weeks as shown (Figure 6.A.a.2) compared with the duration of immersion in the sea at the age of 1-2 weeks and 5-6 weeks.

Separate trials of the average distance of fish schooling horizontally due to the presence of goose barnacle species can be seen in (Figures 5B and 6B). In this case, (Figure 6.B.b.1 and b.2) demonstrate significant schooling of scad fish which were not concentrated in that area. Generally, fish schooling was only concentrated at a distance of 2-3 m. Meanwhile, observations at the bottom of the FAD raft (Figure 6.B.c.3) show that the average distance of fish schooling vertically was generally at an average depth of 4 m below the water.

In addition, the test of the effect of using dried coconut leaf attractor is brown and freshly green (Figure 5C) on fish aggregation showed that fish schooling was more concentrated under FAD rafts using brown/dried coconut leaves attractor (Figure 6.C.c.1) compared to green/fresh coconut leaves attractor (Figure 6.C.c.2). observation of the behavior of schooling fish, the condition of the movement pattern of fish in (Figure 5.C.c.1) looked calmer approaching the attractor than (Figure 5.C.c.2), where the condition of the movement pattern of fish was a bit wild on the coconut leaves attractor.

Discussion

Fishermen using purse seine fishing gear, especially in the waters of Bone Bay, still use traditional FADs and still maintain simpler construction forms, such as the construction of a bamboo raft buoy (Hamar and Bone 2021). In this case, the attractor underneath is made of coconut leaves midrib (Nurwahidin et al. 2016). In general, the types of FADs existing in Bone Bay waters are based on their construction and constituent components, including simple FAD types installed in deep sea waters.

Judging from the durability and service life of the construction of FADs (especially FAD rafts made of bamboo), the FADs' service life is not too long. The main difficulty with bamboo rafts is the loss of buoyancy due to water seepage in the air spaces on the bamboo culms. Fishermen generally slip the cork between the woven arrangement of FAD rafts to prevent loss of buoyancy. Another alternative suggested by Moreno et al. (2016) is to use natural oils, waxes or other treatments so that the lifespan can be extended up to one year.

Anchor ropes and attractor ropes made of natural materials (sisal ropes) used are categorized as very strong because the sisal rope is able to withstand a load of FAD rafts (including boats that are moored for fishing activities) for more than a year. This is in accordance with the findings of Moreno et al. (2018a) and Wang et al. (2019) that the most break-resistant ropes were sisal and cotton ropes, followed by cotton ropes which had the same performance when installed at sea. However, on the one hand, the use of natural materials absorbing water can weaken the hold rope of the FAD raft due to the additional weight.

Apart from the durability of FAD construction, generally, fishermen at the research site make FAD rafts from bamboo rafts. This is believed to provide a greater opportunity to attract fish schools concentrated below the surface of FAD rafts. According to Simbolon et al. (2013) found that fish the effectiveness and biomass were greater under the large raft buoy (bamboo raft) than under the small raft buoy (plastic/cork drums), this is probably caused by the use of bamboo rafts whose construction is larger than plastic drum float rafts.

Furthermore, the length and depth of installation of fisherman FAD attractors are an average of 5-10 m. According to Kawamura et al. (1996), fish species involve a visual process to be attracted to an object, so the depth of the attractor up to 10 meters is an ideal depth because at that level, the water depth tends to be brighter or not cloudy because it is far from physical fluctuations on the surface due to waves and wind. However, a recent study at the same location conducted by Nurwahidin et al. (2016) showed an insignificant relationship between the length of the attractor and the abundance of fish in the FAD area.

Observations in the immersion period showed that the immersion period was >30 days, there were many species of algae, hydrozoa and crustaceans growing at the bottom of the raft. These species live in colonies and make plants (algae) as hosts. This is believed to be one of the attractive factors for accumulating schooling fish in the FAD area (Castro et al. 1999). On the other hand, this can accelerate the damage/decay of bamboo rafts and the fall of the middle midrib (rachis) of coconut leaves as an attractor for fish.

The duration of immersion of FAD components in the sea and the behavior or aggregation of fish approaching FADs have an influence on the density of fish around FADs. This is probably caused by the activity of aquatic organisms on FADs that can attract fish species. Studies conducted by (Lopez et al. 2016; Orue et al. 2019) showed that longer immersion of FADs could increase the diversity of fish species. However, it is highly dependent on environmental conditions (Maufroy et al. 2015; Orue et al 2020). In this case, intratan and extranatant species usually need about 2-3 weeks to associate with FADs (Moreno et al. 2007).

For example, marine animals in FADs, such as algae, hydrozoa, and crustaceans at the study site, on average, grow on FADs soaked for 4-5 weeks at the bottom of bamboo rafts, anchor ropes and attractor ropes. The immersion time of the FAD construction can directly push the larger fish biomass towards the FAD raft (Taquet et al. 2007; Lopez et al 2016; Orue et al. 2019). Bamboo rafts on FADs that have been submerged for a long time in water usually produce odors or scents that are possible for fish species to naturally use in order to navigate towards the source of the scent from FADs even though they are outside the visual range of the fish species (Doving and Stabell 2003).

The sound produced by other animals (Dempster and Kingsfort 2003) or the sound on the retaining component of the FAD raft due to ocean currents and waves, such as the sound of anchor lines and attractor ropes, also contributes to the accumulation of fish in the FAD area (Popper et al. 2003; Ghazali et al. 2013).

Research conducted showed that the durability of coconut leaves attractors would be different in different seasons, where the fastest damage rate occurred in the east season, which was 3-4 weeks in duration and 5-6 weeks of soaking period. In this case, the leaves had started to detach from the middle of the ribs (rachis) and at 2 months of age, only the rachis was left on the midrib.

The rate of damage, especially in the east and west monsoons, was greater than in other seasons. This was influenced by oceanographic factors such as currents, waves and the presence of organisms in seawater, which were thought to accelerate decomposition. Wind and currents were very strong in the western season, so the decomposition process of attractor leaves became faster. A study conducted by Ibrahim et al. (2014) showed that the coconut leaves midrib would rot and be completely damaged in about three months. This is caused by the condition of the leaves' epidermis, which thins after 6 weeks at sea and the coconut frond will lose its epidermal cells in the water after two months.

Usually, prolonged decay causes the leaves to detach from the middle of the ribs (rachis), thereby reducing the number of fish that gather around FADs. In order to maintain the amount of biomass in the fish school around FADs, fishermen are advised to replace the coconut midrib attractor every month or after 4-5 weeks of immersion in the sea.

The findings during observation showed that dried coconut leaves (brown in color) were more resistant than fresh/green leaves. This is in line with the findings of (Ibrahim et al. 2014). The results of observations related to the quality of coconut leave attractors based on planting distance from the beach showed that coconut fronds taken from a distance of 500 m and 1000 m from the beach were more durable than fronds taken at a distance of 1500 m from the beach.

The selection of the type of coconut leaf extractor provides opportunities for the growth of microorganisms attached to the surface of the coconut leaves (which act as a food source for small pelagic fish). According to studies (Altinagac et al 2010; Hasaruddin et al. 2015), coconut leaves attractor is one of the main components of FADs that function as a real fish-gathering tool. But the latest research Hasaruddin et al. (2021), for attraction durability, suggested that fishermen use palm fiber attractors because the resistance of natural pullers such as coconut and areca fronds tends to be lower.

In the study, the researchers found that there was a relationship between the endurance of the coconut leaves attractor based on the season, the physical changes of the attractor and the aggression of the scad fish. In this case, the best duration of soaking the coconut leaves attractor was 3-4 weeks. This is associated with the fastest duration of schooling fish arrivals in the FAD area, which ranged 3 to 4 weeks, especially during the transitional season 1. The average distance of schooling fish to schooling aggregations, especially scad fish, revealed that fish were more concentrated around the attractor leaves with an average distance of 1.2 meters.

The duration of immersion of FADs in the sea affected the quantity of plankton around the FADs area, this is in accordance with the findings of (Ibrahim et al. 2014), who stated that the ability of organisms to settle in FAD areas varies, depending on the duration of immersion and the condition of the coconut leaves substrate texture. In this case, the condition of the adaxial and abaxial epidermal cells of the coconut leaves midrib at the age of 3-4 weeks was classified as good. However, the epidermal cells of the coconut leave midrib were degraded after >4 and 6 weeks, so this phenomenon affected the presence of and behavior of fish species in the sea.

In terms of fish behavior in the FAD area as described above (Yusfiandayani et al. 2015), the coconut leaves attractor will wave in the waters causing the fish to move closer to the FAD. Thus, the presence of attractors in FADs can produce new trophic areas for organisms in the sea. The presence of aquatic organisms such as plankton in coconut leaves attractors is thought to attract juvenile fish to gather around FADs and stimulate food chain processes (Bubun et al. 2015). The abundance of plankton will increase when combined with lights (Nguyen and Winger 2018), so fish resources in FAD areas will also increase significantly.

The growth of species of algae, hydrozoa and crustaceans on the bottom of the raft is one of the factors attracting the accumulation of schooling fish in the FAD area. However, regarding the fishing strategy in the FAD area (in terms of concentrating schooling fish), the fishermen of the Bone Bay waters catch fish at 05.00-06.00 in the morning using torches (Rumpa et al. 2022).

Our findings If exposed to light, goose barnacles species can affect the average distance of schooling fish both vertically and horizontally so that schooling fish is not concentrated under FADs. Where the average schooling fish is only concentrated horizontally/vertical at a distance of 3 and 4 m from the center point of the FAD raft, this is probably due to the influence of the light refraction on the white goose barnacles species, which causes schooling fish to be a bit afraid to approach the FAD attractor, but in the future, it is necessary to do a study related to this.

At the time of setting and hauling purse seine fishing gear, researchers replaced the dried coconut leaves midrib attractor, which was brown in color, or used fresh green coconut leaves attractor. The results showed that using dried coconut leaves attractor would increase the concentration of schooling fish and stimulate a quieter movement pattern compared to fresh and green coconut leaves attractor. This finding is different from the study of (Kawamura et al. 1996) who stated that fish species are more attracted to more contrasting attractors, such as blue and green. This may be due to the different fish species in the study.

In following up on the findings of this study, further studies need to be carried out in the future, as suggested by (Marcusi et al. 2017; Moreno et al. 2018b). In modifying the design and construction of FADs in the future, especially those made from natural materials, researchers and developers need to collaborate with fishermen. It can be in the form of knowledge-sharing activities.

In addition, Moreno et al. (2018c) and Zudaire et al. (2019) suggested that the development of the design and construction of fishing gear can also be done by combining components of natural and synthetic materials using a more modern, effective and efficient FAD design system. The conclusion of our findings is that the relationship between immersion time and the characteristics of natural FAD materials had a direct impact on the effectiveness of attracting and concentrating fish and on the schooling distance of fish at the center point of the FAD raft.

ACKNOWLEDGEMENTS

The authors sincerely thank to RISTEK-BRIN Dikti and Hasanuddin University, Indonesia, for assisting Doctoral Dissertation Research Grants, Crew. Vessel Karya Agung and Vessel Dia Lagi. The authors also thank to friends in the Fisheries Science Doctoral Program Universitas Hasanuddin who have motivated the research so that this research can be carried out well.

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