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A REVIEW OF THE EFFECTIVENESS OF FISH AGGREGATING DEVICES (FADs) IN INDONESIAN WATERS

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ABSTRACT

The utilization of Fish Aggregating Devices (FADs) in fisheries represents one of the most attractive and effective methods for increasing fishermen's catches. This review article aims to evaluate the use of FADs in enhancing sustainable catch outcomes and considers their role as an effective management tool. Various types of FADs have been designed and developed across different waters in Indonesia. There are several types of FADs commonly observed, including Squid FADs, Bio FADs, Sea urchins FADs, Electronic FADs, Bamboo raft FADs, Coconut leaf attractor FADs, Palm fiber attractor FADs, Light attractor FADs, FADs palm midrib, Rafia rope attractor FADs, Lubuk larangan FADs, and Fiber FADs. This paper reviews the different types of FADs, considering aspects such as the catch produced, technical specifications, and economic factors. Among these, portable FADs constructed from coconut leaves and raffia lines as attractors emerge as particularly effective and commonly used in Indonesian waters. FADs are also often combined with lift nets or electric fish attractors to enhance their effectiveness. Environmentally friendly fishing gears such as handlines and fishing rods are commonly operated around FADs. The types of fish caught typically include a mix of small and large pelagic species.

Keywords: Coconut leaves, FADs, Fisheries management, Pelagic species, Raffia lines,

INTRODUCTION

The use of Fish Aggregating Devices (FADs) is one of the most attractive and promising fishing methods for fishermen to attract fish for gathering, spawning, and providing a gathering place for plankton and other small fish, thereby inviting larger fish to forage for food (Jayanto *et al.,* 2018; Yusfiandayani *et al.,* 2013). FADs make fishermen more specific and efficient in determining their fishing grounds (Muhammad & Barata, 2012; Hidayat *et al.,* 2021).

There are three types of FADs based on the position or location of the fish collectors: shallow, bottom, and deep FADs. FADs commonly used in Indonesian waters include squid FADs, live FADs, sea urchin FADs, electronic FADs, and FADs made from natural and non-natural materials. The effectiveness of FADs can be determined by their endurance in different seasons and water conditions, as well as the productivity of the resulting catch. Variations influence the composition of fish caught around FADs in FAD installation locations, fish seasons, habitat characteristics, types of FADs, and the fishing gear used (Simbolon *et al.,* 2011). Numerous scientific studies regarding the design and construction of FADs have been conducted previously (Baskoro *et al.,* 2017; Yusfiandayani *et al.,* 2014). Baskoro et al. (2017) stated that the material and form of attractors significantly determine their effectiveness in attracting or stimulating the target catch. Moreover, the productivity of the catch is also influenced by the type of fishing gear used around FADs (Yusfiandayani *et al.,* 2014).

The issues surrounding the effectiveness of fish aggregating device (FAD) utilization in Indonesian waters encompass several challenges that must be addressed to improve sustainable fish catches. One of these is the lack of understanding and skills in the effective deployment and management of FADs among fishermen. Environmental issues like FAD damage due to natural factors like storms or strong ocean currents are expected. The high production and maintenance costs of FADs pose barriers to fishermen who seek to use this technology optimally. Furthermore, the lack of supervision and enforcement of regulations on unsustainable FAD usage exacerbates this issue (Matrutty *et al.,* 2021; Widyatmoko *et al.,* 2021).

If left unresolved, the issue of FAD utilization effectiveness can have broad implications for the fisheries sector. Significant declines in catch yields can threaten the sustainability of fish resources and lead to substantial economic losses for fishermen and coastal communities (Depari *et al.,* 2022). Additionally, ecosystem imbalance may occur due to overfishing certain species, ultimately disrupting marine food chains and environmental balance. Social impacts can also be felt, including increased unemployment in the fishing sector and decreased welfare of fishing communities (Onyango *et al.,* 2021).

In Indonesia, efforts to enhance the effectiveness of FADs utilization have involved various strategic measures. One of them is training fishermen on effective FAD deployment techniques and management. The government or non-governmental organizations often organize these programs to enhance understanding of the importance of FADs in increasing fish catches. Additionally, efforts are to raise awareness of sustainable practices in FAD usage, including using environmentally friendly materials and improving the FAD fabrication process (Salmarika *et al.,* 2023). Collaboration among the government, research institutions, and fishing communities is also crucial to optimizing the benefits of FADs for the fisheries industry in Indonesia (Widodo *et al.,* 2020).

Research on the effectiveness of FADs in Indonesian waters is critically important due to their significant impact on the sustainability of fish resources and the marine environment. The presence of FADs has altered fishing patterns in these waters, yet much remains to be understood about their impact on marine ecosystems and fish populations. This research will reveal whether sustainable FAD usage enhances fish catch outcomes without harming the marine ecosystem. Therefore, this paper aims to evaluate the performance and effectiveness of fish aggregating devices (FADs) in enhancing fish catch yields in Indonesian waters.

FAD DESIGN TYPE: A REVIEW

Based on the literature study, it is evident that the types of FADs used by fishermen vary widely. The design and construction of these FADs depend highly on the species of fish being targeted and the depth of the waters in which they are installed. The following types of FADs are commonly used in Indonesian waters:

Squid FADs

There are two types of squid FADs: box and cylindrical squid FADs. The box-shaped FADs have 75 x 50 x 35 cm^3 dimensions with a wooden frame. This box model squid FAD utilizes a waring cover, which can be either closed only on the top side or covered with a warning on the top, left, and right sides, aiming to create shady or slightly dark conditions inside the attractor (Figure 1). Each type of squid FAD is equipped with six lures (attractors) made of hemp rope (organic material), positioned vertically in the middle to attract squid for egg-laying within the submerged squid FAD (Syari *et al.,* 2004; Baskoro *et al.,* 2017).

The box-shaped frame of squid FADs can also be constructed using PVC pipe filled with cement cast inside the pipe, which serves as a sinker (Figure 2). Additionally, the attractor rope is positioned inside using palm fiber rope with a diameter of 1 cm, and the attractor cover is made of 40% PE net. The base frame and attractor poles are made of PVC pipes with a diameter of 2 inches, while the upper frame utilizes PVC pipes with a diameter of 1¼ inches. There are two types of attractors: Type 1 (T1), with the top and sides covered with 40% PE nets, and Type 2, with only the top covered with 40% PE nets (Danu *et al.,* 2019).

Another form of squid FAD is the cylindrical squid FAD, constructed from scrap iron drums with a diameter of 50 cm and a height of 90 cm. The squid attractor in this type of FAD is cylindrical and made from used drums, equipped with hemp ropes positioned vertically in the middle (Baskoro *et al.,* 2017).

Squid attractors are submerged at a depth of 3-5m during low tide, comprising six units of square attractors and six cylindrical attractors, totaling 12 units of squid attractors. These attractors are arranged alternately between the box-shaped and cylindrical ones, with a distance of 5m between each attractor, and they are mounted on the bottom of the water with a sand substrate (Figure 4).

Attachment of squid eggs was more effective on cylindrical FADs, particularly those placed at a depth of 3 meters during the east-west transition season (Syari *et al.,* 2004). Similarly, Baskoro et al. (2017) discovered a higher attachment of squid eggs (*Loligo* sp) to cylindrical attractors, reaching 95%, compared to only 5% for the box shape. The cylindrical squid attractor made from used drums is more effective due to its cave-like shape, which can attract and stimulate squid (*Loligo* sp) to attach their eggs

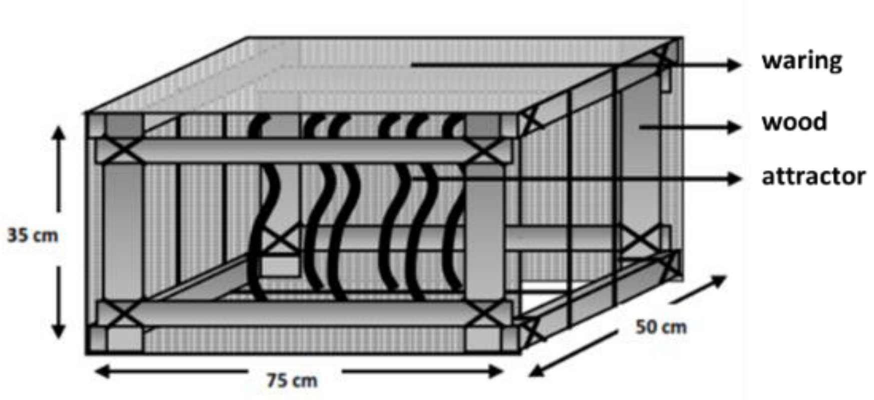
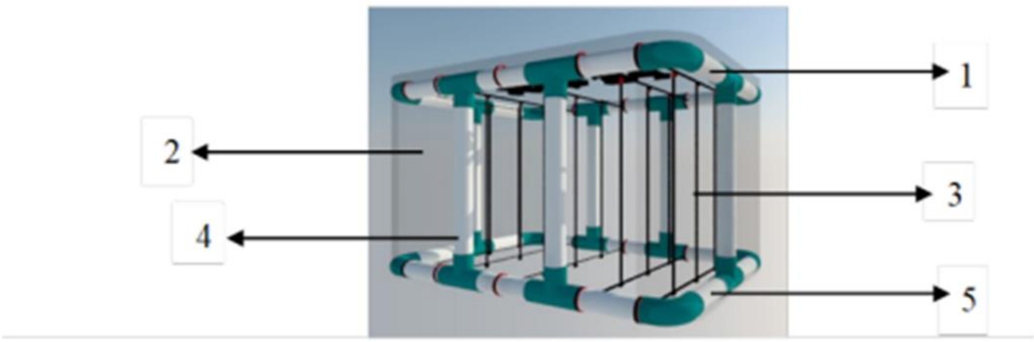


Figure 1. Design of a box-shaped squid FAD (Syari et al., 2014).



Description:
1. PVC pipe (270 mm)
2. Net cover waring PE 40%
3. Attractor rope (1 cm)
4. PVC pipe (450 mm)
5. PVC pipe (250 mm)

Figure 2. Design of a squid attractor made of PVC pipe cast with cement (Danu et al., 2019).

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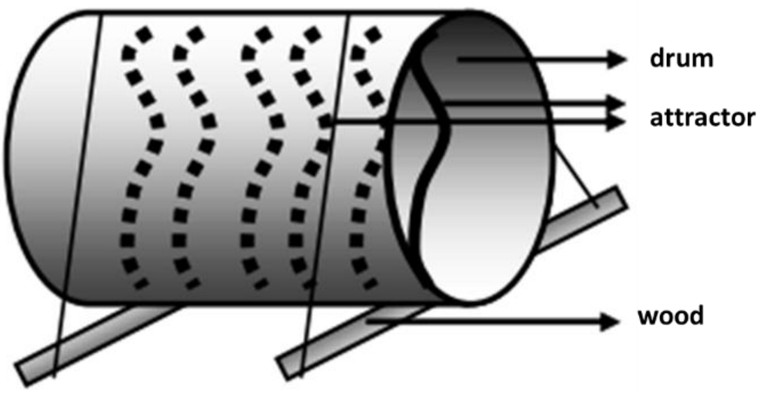

Figure 3. Cylindrical FAD design from used drum types (Syari et al., 2014

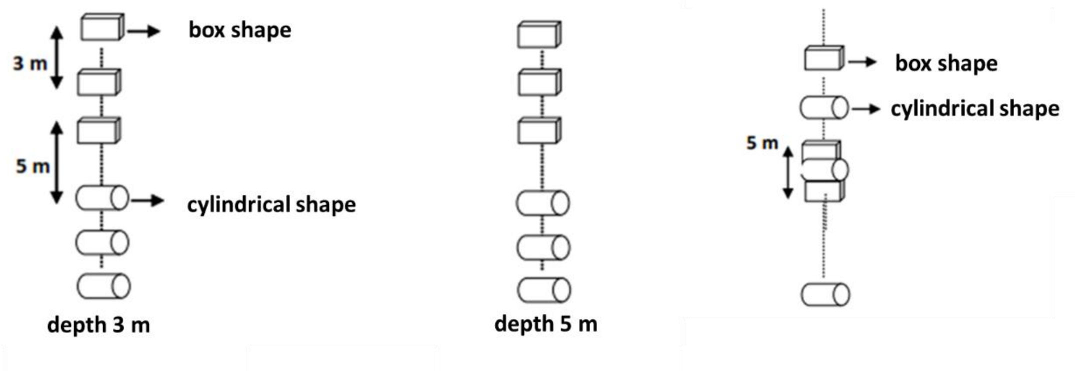

Figure 4. Patterns of arrangement of squid FADs in water areas (Syari et al., 2014)

Another type of squid FADs is cylindrical, constructed with palm fiber rope, 2.5-meter coconut leaves, 35 x 45 cm plastic bags, and 20 x 3 cm plastic tape as attractors. They include 60 cm rigging, buoys (styrofoam), and weights made of cast concrete weighing 15 kg (Jayanto *et al.,* 2018). These FADs are installed on a lift net measuring 8.5 x 8.5 x 3.5 m, with a fishing ground depth of 5 meters. They are positioned on all four sides of the lift net (Figure 5).

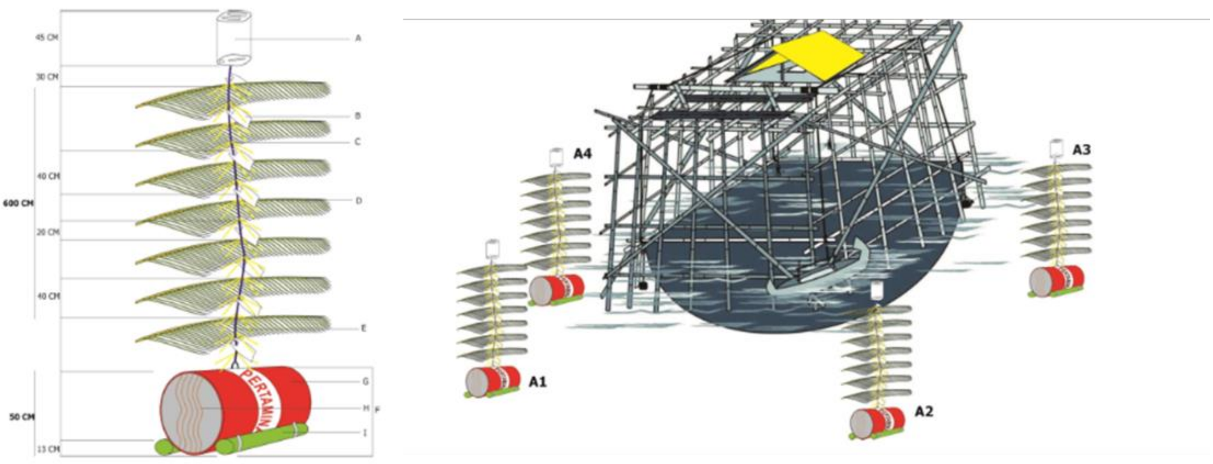

Figure 5. Construction and placement of FADs on lift net.

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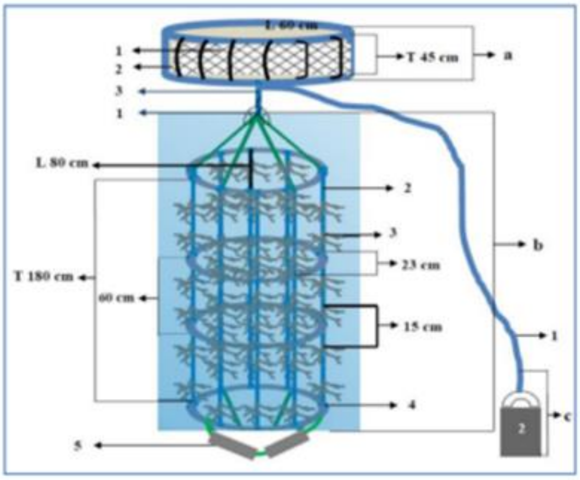
Bio FAD

Types of FADs targeting demersal or reef fish include live FADs (Wirawan *et al.,* 2019). Live FADs are constructed with a framework of bamboo and rattan, utilizing seaweed from *Eucheuma cottonii* and *Gracillaria* sp. as attractors. The buoy, made of cylindrical styrofoam with dimensions of 45 cm in height and 60 cm in width, is wrapped in waring with a mesh size of 0.5 inches. The swivel is crafted from an iron plate measuring 25 cm in length and 2 cm in width, with a concrete iron no. 6 fitted with a hole (ring) for attaching the life jacket and FADs. The sinker comprises two types: the main and FAD, weighing 50 kg and 2.5 kg, respectively. This apparatus is submerged at 3-10 m (Suadi *et al.,* 2019).



Description:

(a) Float	(b) FADs	(b) Sinker
1. Waring	1. Swivel	1. weight rope
2. waring strap	2. ribs (bamboo)	2. main sinker
3. float rope	3. Attractor	
	4. circle (rattan)	
	5. sinker	

Figure 6. Construction of Bio FADs (Suardi et al., 2016).

Sea urchin FADs

The Sea urchin FAD is a portable FAD suitable for sea and land use (Figure 7). Its construction comprises a central ball and legs made of pipe material, serving as a shelter or fishing aid tool. These FADs are typically operated at depths ranging from 10 to 15 meters, with each sea urchin construction weighing up to 3 kg (Murtado *et al.,* 2018).

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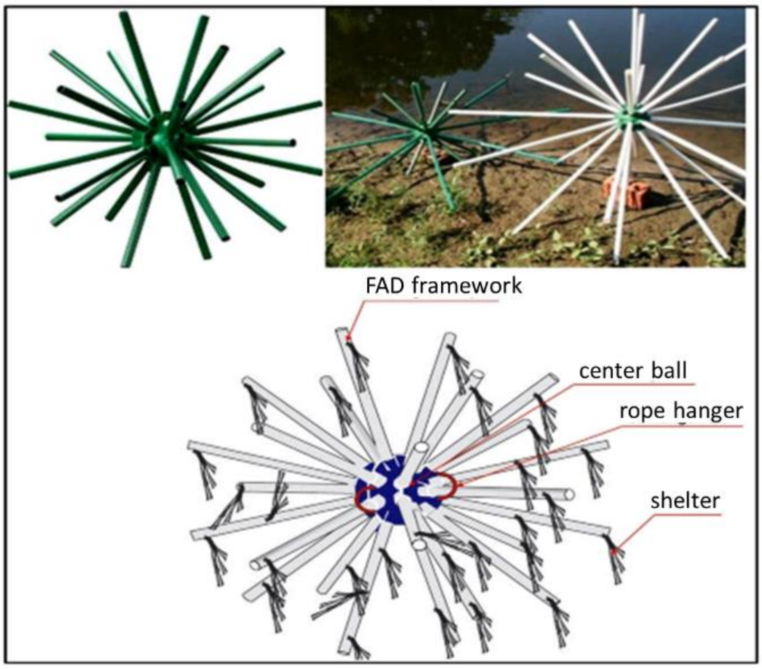

Figure 7. Sea urchin FAD (Murtado et al., 2018).

Electronic FADs

Electronic FADs are enhanced by incorporating LEDs with a total power of 120 watts, powered by 12V 12Ah batteries, and constructed using HDPE (High-Density Polyethylene) as the body material for the FADs (Figure 7). These electronic FADs have blue-red and white-red light attractors (Baswantara, 2017).

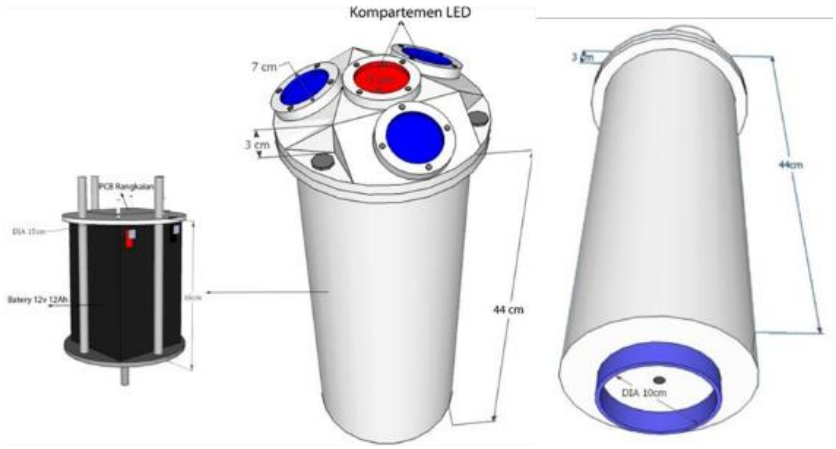

Figure 8. Electronic FAD design (Baswantara, 2017)

This tool operates on an elevator net at a depth of 13 m. Vertically, flux measurements were conducted at every 1 m depth at each point. Total measurements at each point were taken to a depth of 7 meters (Figure 8). The net is installed at the very bottom.

The catch of the blue-red light attractor is better, with a catch ratio of 20 kg per hauling, whereas the white-red light attractor has a catch ratio of 15 kg per hauling. Once installed, the electronic FAD operates for 1 to 2 hours. The total catch from electronic FADs is 133.5 kg. Compared to light from a typical chart lamp, electronic FADs have a catch of 74 kg, whereas chart lamps have a catch of 72 kg.

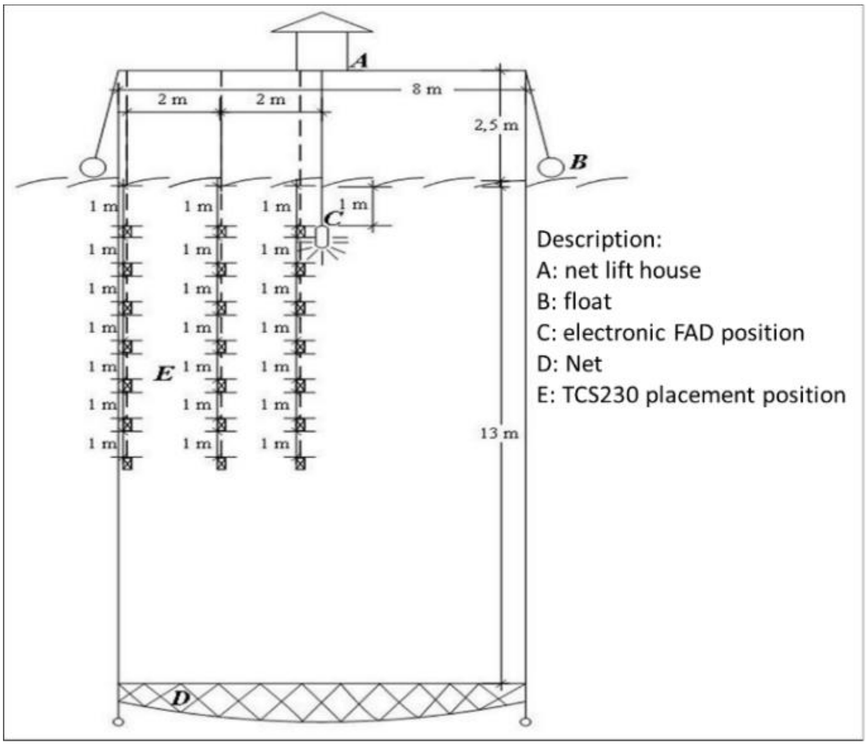

Figure 9. Electronic FAD installation design (Baswantara, 2017).

The second type of electronic FAD features a frame made of Stainless Steel 104, with the Main Box and Speaker Cover crafted from DOP PVC (Figure 9). This Electronic FAD stands at a total height of 86 cm, with a total width and length of 30 cm each. The Main Box measures 24 inches in height and 8 inches in diameter. A 12-volt battery powers it and utilizes a sound attractor in the form of a 4-inch Audax speaker and a light attractor consisting of a 5-watt LED. The frequencies employed range from 10-1000 Hz, 1-20 kHz, and 20-100 kHz, corresponding to infrasound, ordinary sound, and ultrasonic sound. The LED light emits white light with a power of 5 W. These electronic FADs are positioned at a depth of 3-5 m in waters with a depth of 14 meters. However, the effectiveness of their catch compared to lift nets remains insufficient, necessitating enhancements in the intensity and power of the light attractor, as well as further investigation into the fish's response to different sound frequencies (Yusfiandayani *et al.,* 2014).

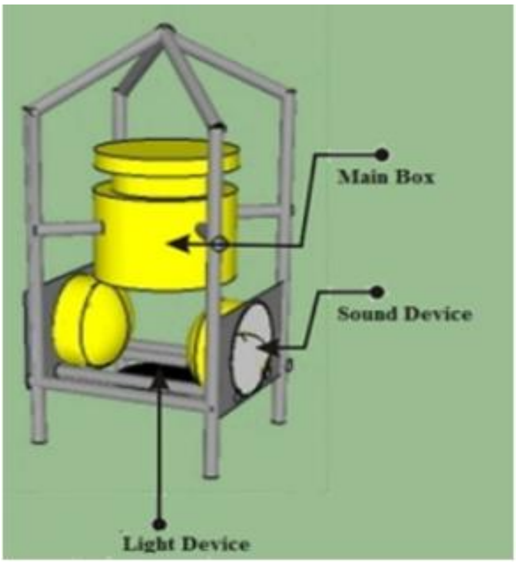

Figure 10. Electronic FAD Design (Yusfiandayani et al., 2014).

Bamboo Raft FAD

This FAD is constructed using 3-6 bamboo sticks as a float, each measuring 15 x 0.1 m (Figure 10). The attractors employed consist of natural materials sourced from three types of leaves: coconut leaves (*Cocos nucifera*), areca nut leaves (*Areca catechu*), and nipa leaves (*Nypa fruticans*), each with 25 midribs. The attractor rope and anchor extend to 63 m, while the stone weighs 50 kg. These FADs are deployed at a depth of 45 m. Among the three materials utilized, coconut leaves emerge as the most effective based on catch rate and durability across all seasons (Yusfiandayani, 2011).

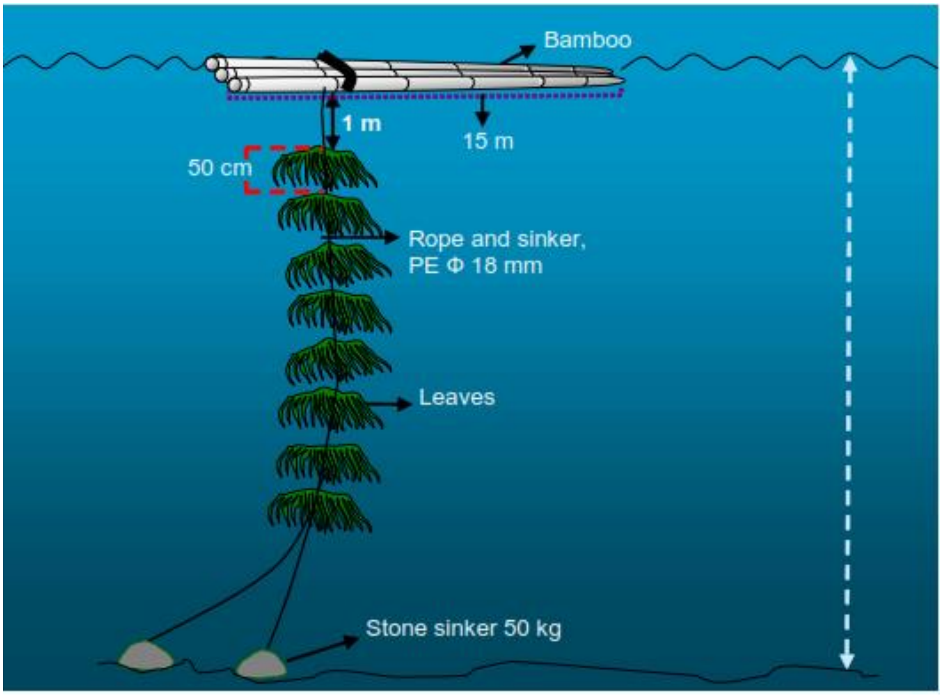

Figure 11. Bamboo raft FAD construction (Yusfiandayani, 2011).

Coconut leaf attractor FAD

These FADs are primarily crafted from coconut leaves as the main attractor, supplemented by plastic bag leaves and plastic tape (Figure 12). The assembly comprises 44 coconut leaves, each with a midrib length of 2.5 m. Rigging ropes tie and link buoys, attractors, and sinkers to the main rope. The setup includes four floats made of styrofoam, each measuring 20 x 20 x 25 cm, and sinkers made from cast concrete (Figure 11).

This FAD is installed alongside the lift net, which measures 9 x 9 x 3.5 m, with a fishing ground depth of 4.8 m (Figure 12). Each lift net is equipped with FADs, as detailed in studies by Darmin et al. (2017) and Jayanto et al. (2015).

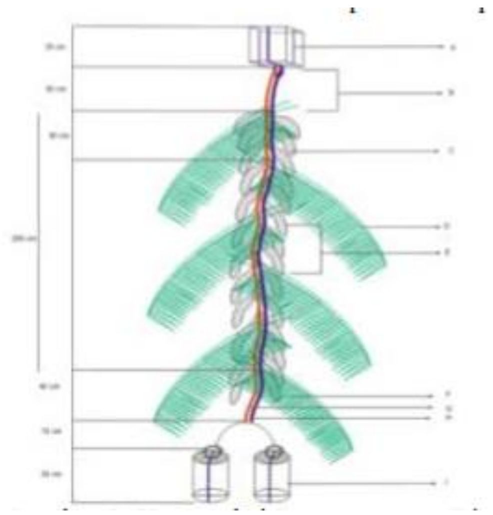

Figure 12. Coconut leaf attractor FAD construction.

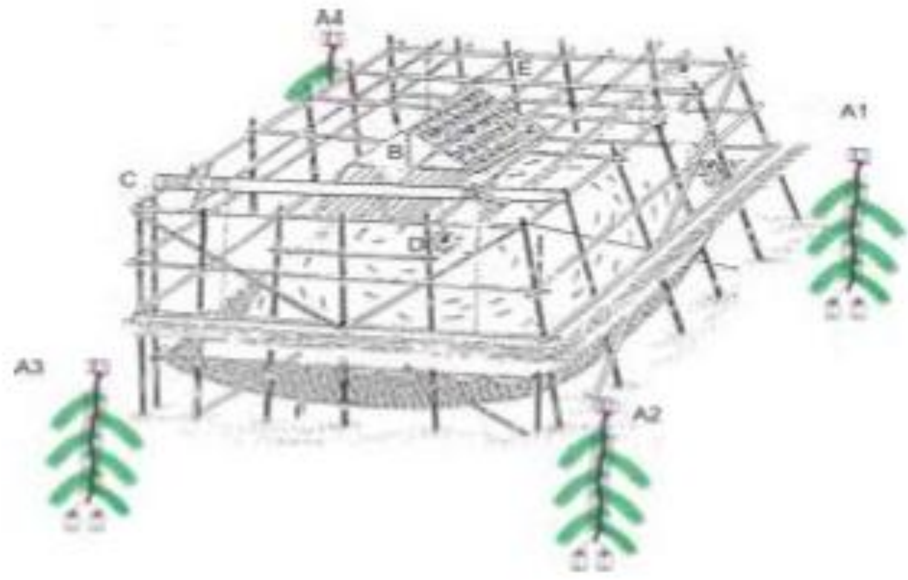

Figure 13. An overview of the placement of FADs on the lift net.

FADs crafted from coconut leaves are also deployed in deep-sea waters (Figure 13). These FADs typically feature a buoy and palm or palm leaf attractor measuring 2-3 m in size, along with a mooring line spanning 4,000-4,500 m and a sinker. They are installed within the territorial waters of the Indonesian Exclusive Economic Zone (EEZ), approximately 30-200 miles from the coast, at depths ranging from 3,000 to 5,000 m (Nurani *et al.,* 2014).

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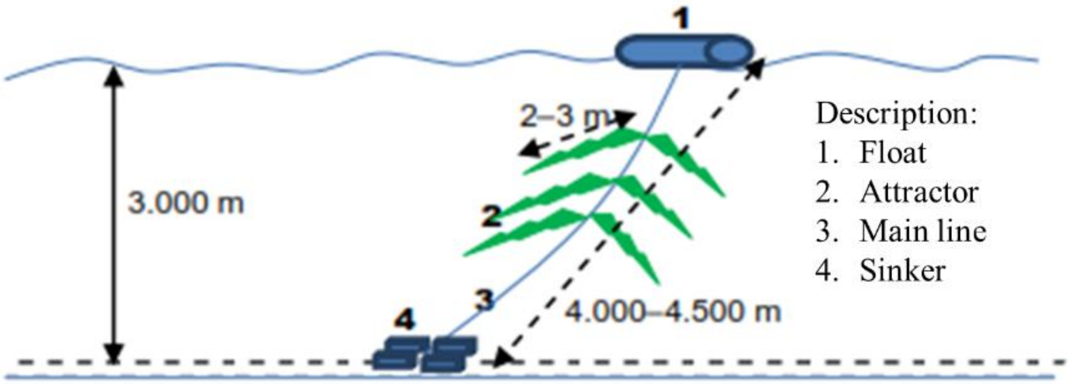

Figure 14. Construction of coconut leaf attractor FADs (Nurani et al., 2014).

Another design for the coconut leaf attractor FAD comprises a styrofoam float, waring, PE rope of 0.13 cm, and PE rope of 1 cm, incorporating a cylindrical model measuring 100 cm in height and 60 cm in width (Figure 14). The FAD body consists of a main rope made of polyethylene, ranging from 15 to 35 m in length, attached to a coconut leaf attractor measuring 3.7 m in length, comprising 8 to 25 strands. Additionally, it includes seven sinker stones weighing 35 kg each (Hikmah *et al.,* 2016).

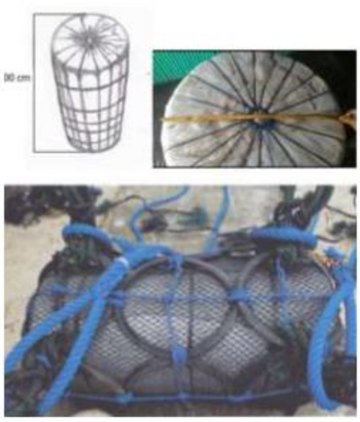

Figure 15. Styrofoam cylinder float (Hikmah, 2016).

Palm Fiber Attractor FAD

This FAD, measuring 3 x 3 x 2.5 m, is constructed with a wooden frame shaped like a cube, as described by Baihaqi (2014). The wooden frame consists of 22 pieces of wood, serving as the framework onto which the attractors are attached. Each of the lower ends of the frame is equipped with nine sinkers, each weighing approximately 10 kg, to prevent the FAD from being carried away by the current. The attractor utilized is made of palm fiber. These palm fiber FADs are deployed at 37.9 meters (Figure 15).

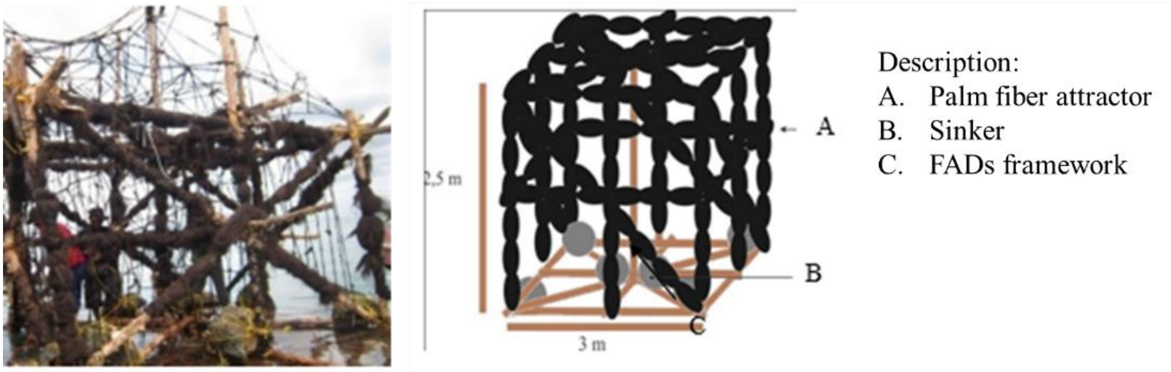

Figure 16. Palm fiber FAD construction

Light Attractor FAD

FADs featuring light attractors, including solar-powered LED lighting and fire/torch, have been documented by Mauko and Daga (2017) and Sondita and Purwangka (2018). The fabrication of LED fish FADs as fishing gear involves the construction of FAD buoys and anchors. FAD buoys are created using two plastic drums secured with 16 mm nylon rope, while the anchors are crafted from cast asphalt drums. These anchors serve as additions to FADs at sea, helping to prevent them from being quickly carried away by currents (Figure 16).

Figure 17. LED FAD construction.

In addition to LEDs, FADs can utilize torchlight to concentrate fish gathered under them, offering practical and efficient means. This method is highlighted by Rumpa & Isman (2018) and involves subsequently catching the concentrated fish using a purse seine (Figure 17).

Figure 18. Torchlight FAD construction.

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FADs palm leaf midrib

Broadly, the composition of palm leaf midrib FAD construction involves a buoy, main rope, attractor, and sinker, as outlined by Kurniawan and Syari (2016). The buoy, serving as a breakwater, is crafted from cork or repurposed bottles with a thickness of 3 mm. It typically has a torpedo or cone shape to mitigate current strength. The buoy's dimensions range from 50 to 100 cm long with an 80 cm diameter. Each buoy requires five floats, and the contents of the float are typically xeroform.

To increase the buoyancy of the buoy and prevent the float from sinking, ten sheets of xeroform, each with a length of 5 cm, are required. The main rope utilized is the DN brand Polyethylene, boasting a diameter of 22 mm. For constructing this deep-sea FAD, a main rope weighing 3000 m is employed, weighing approximately 1 kg. The rope connections are made by knotting it 3-5 times, followed by tight tying, and then attaching the main rope to four hill tires cast with cement. Each weight on the main rope weighs 15 kg.

The attractors on FADs are constructed using palm leaves, DN brand Polyethylene rope, and raffia rope. The rope measures 34 m in length with a diameter of 22 mm and has a total weight of 5 kg. Each deep-sea FAD incorporates 26-35 pieces of coconut leaves along with crushed raffia. Additionally, each attractor is equipped with a cement sack filled with sand weighing 15 kg to provide additional weight. Using palm leaf midrib as FADs has yielded significant results in increasing fish catch for fishermen compared to those who fish without using FADs.

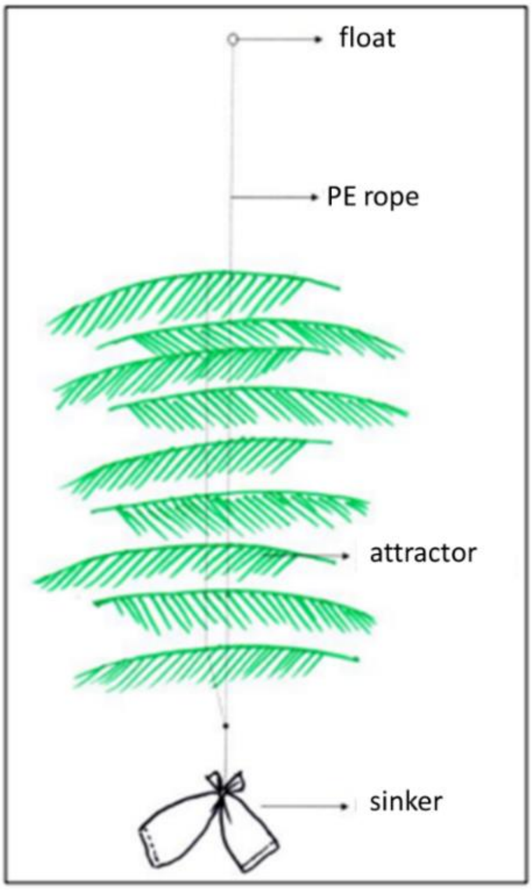

Figure 19. Palm leaf midrib FADs (Kurniawan & Syari, 2016)

Rafia rope attractor FAD

The construction of raffia FADs consists of buoys, attractors, and sinkers, as depicted in Figure 19. The attractor component is made of raffia rope, typically 2 m long (Zuriat *et al.,* 2019). Raffia rope FADs have a lifespan of up to six months, rendering them feasible for fishermen to utilize (Yusfiandayani, 2013). This type of FAD,

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incorporating a buoy, main rope, attractor, and sinker, is operated effectively at a depth of 30 m (Zuriat *et al.,* 2019). Raffia rope material is readily available in the environment, significantly easing the process for fishermen in constructing raffia rope FADs as a tool for fish collection purposes (Yusfiandayani, 2013).

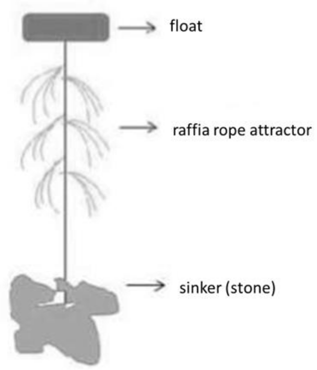

Figure 20. Rafia rope attractor FAD (Zuriat *et al.,* 2019).

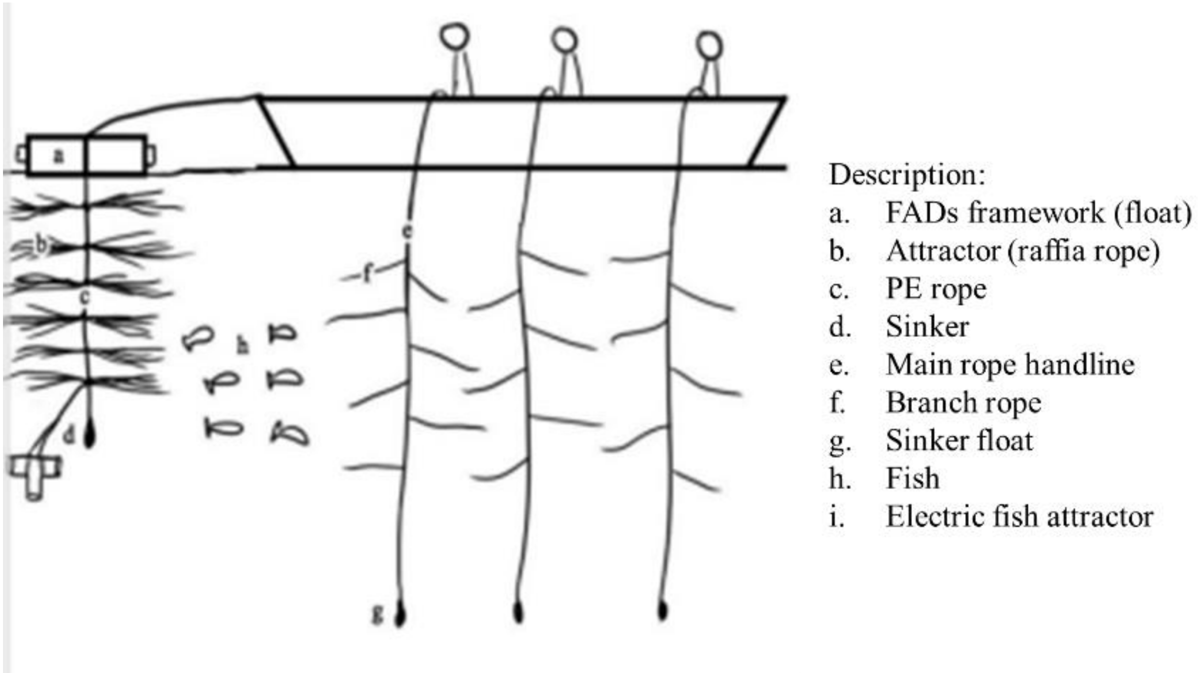

Figure 21. Installation of FADs with fishing rods

To attract the fish's attention, this FAD combines a raffia rope attractor with an electric fish attractor (Figure 20). This versatile tool can operate both during the day and at night. The fishing gear utilized around FADs primarily consists of handlines.

Lubuk Larangan FADs

The main components of the lubuk larangan construction, according to Kholis et al. (2020), include buoys, rigging, attractors, bodies, and sinkers. Lubuk larangan FADs are designed for shallow waters, with placement at the bottom. The buoy of the lubuk larangan FAD has a diameter of 1 m, a height of 40 cm, and weighs 2 kg. The rope utilized is made of PE, measuring 1.94 m in length and 1 cm in diameter. Attractors used in lubuk larangan FADs consist of raffia rope and pipe paralon. The

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body of the lubuk larangan FAD is constructed from an insulated iron frame, facilitating fish entry and exit. It has a rectangular shape, with dimensions of 1.4 m in length, 54 cm in width, and 1.94 m in height. Lubuk larangan FADs are made of cast cement, measuring 1.18 m long, 56 cm wide, 20 cm high, and weighing approximately 50 kg.

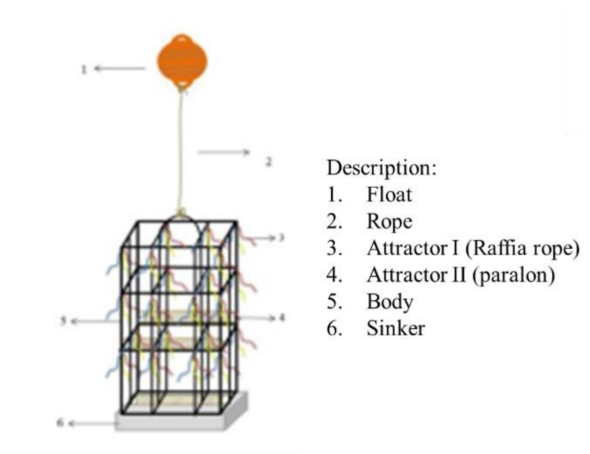

Figure 22. Lubuk Larangan FADs construction (Kholis et al., 2020).

Fiber FADs

The FAD framework is constructed from a suitcase measuring p x l: 3 x 2.50 m. The frame is crafted from 4.5 kg fiber, coated with stainless steel, forming a frame measuring p x l x h: 3 x 3 x 2.50 m (Figure 23). Raffia rope, with a length of 100 cm, is utilized as an attractor. The PE main rope measures 9 m. Liquid styrofoam is filled inside the FADs to serve as a float. The electric fish attractor is attached to a rope with a depth of 2 m from the water surface, with an attractor in the form of a raffia rope installed every 50 cm. The sinker weighs 1.44 kg of tin (Yusfiandayani *et al.,* 2014; Shadiqin, 2019).

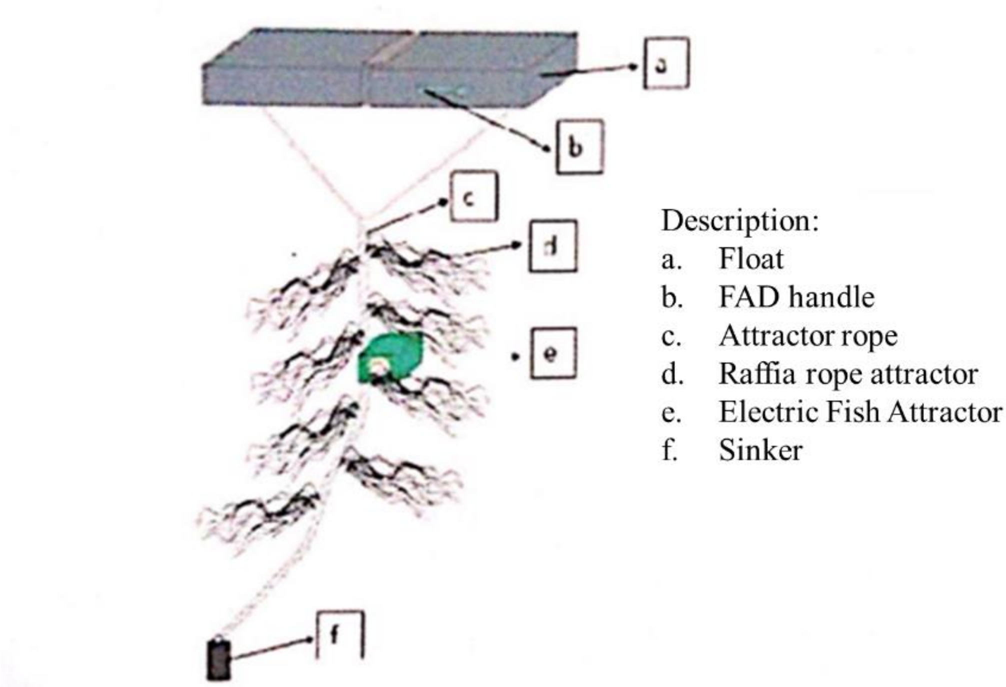

Figure 23. Fiber FADs (Yusfiandayani et al., 2014)

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Table 1. Types of FADs used in Indonesian waters.

FAD Types	Attractors	Number of sheets	Depth (meters)	Trip duration (time)	Type of fishing gear	Catch Composition	Fishing ground
Plastic drum	Coconut Leaf	10	200-300	14	Purse Seine	Scad mackerel (*Decapterus ruselli*), Frigate tuna (*Auxis thazard*)	Kei Kecil Maluku Tenggara Waters
Bamboo		15			Gillnet	Scad mackerel (*Decapterus ruselli*), Frigate tuna (*Auxis thazard*), Narrow-barred Spanish mackerel (*Scomberomorus commersoni*)	
					Fishing rod	Frigate tuna (*Auxis thazard*)	
Portable FAD from styrofoam	Coconut Leaf	25	15-35	50	Handline	Goldstripe sardinella (*Sardinella gibbosa*), Yellowstripe scad (*Selaroides leptolepis*), Shortfin scad (*Decapterus macrosoma*), Indian mackerel (*Rastrellinger kanagurta*), Imposter trevally (*Carangoides talamparoides*), Common ponyfish (*Leiognathus equulus*).	Pa'biringa Kabupaten Jeneponto Waters
Portable FAD made of liquid styrofoam	Raffia rope	8	2	-	Troll line	Yellowfin tuna (*Thunnus albacares*), Frigate tuna (*Auxis thazard*), Bigeye trevally (*Caranx sexfasciatus*), Hairtail (*Trichiurus* sp.)	Palabuhanratu, Jawa Barat
FADs palm leaf midrib	Palm leaf midrib	-	-	-	-	Goldband snapper, Silverbelly Malabar blood snapper, Crescent perch	Tuing Waters, Bangka Regency
Portable FADs from Fiber Material	*Electric Fish Attractor*	-	50-100	20	Gillnet	Shrimp, Snapper, Barred queenfish, Sagor catfish, Rough-flathead, Bigeye trevally, Indian halibut, Crab, Black pomfret, Stingray, Featherbacks, Greater lizardfish, Scad fish, Conch, Japanese threadfin bream, Catfish, Snapper	Serang District
Rumpon Palm fiber	Palm fiber	9	37,9	1	Handline	Yellowtail scad (*Atule mate*), Frigate tuna (*Auxis thazard*), Giant trevally (*Caranx* sp.), Indian mackerel (Rastrelliger kanagurta), Yellow stripe scad (*Selaroides leptolepis*), Kurisi Threadfin bream (*Nemipterus nemata*), Indian scad Layang (*Decapterus ruselli*), *Tetraodontidae*, Goldstripe sardinella, Bigeye trevally, Redbelly yellowtail fusilier	Tunda Island, Banten

FAD Types	Attractors	Number of sheets	Depth (meters)	Trip duration (time)	Type of fishing gear	Catch Composition	Fishing ground
Coconut Leaf FAD in the form of a box	Coconut Leaf	9	43,3	1		Yellowtail scad (*Atule mate*), Frigate tuna (*Auxis thazard*), Giant trevally (*Caranx* sp.), Indian mackerel (*Rastrelliger kanagurta*), Yellow stripe scad (*Selaroides leptolepis*), Threadfin Bream (*Nemipterus* sp.), Indian scad (*Decapterus ruselli*), Tetraodontidae, Great barracuda, Snapper, Redbelly yellowtail fusilier	
Bio FAD	Seaweed (*Eucheuma cottonii*) Seaweed (*Gracillaria* sp.)	-	0,6-2,1	-	*Gillnet*	White-spotted spine foot *(Siganus canaliculatus)*, *Valencienna* sp, Blacktail humbug (*Dascyllus melanurus)*, *Rudarius* sp, *Therapon jarbua*, *Caranx* sp, dan *Siganus javus*	The coastal waters of Uloulo, Luwu Regency
Portable FAD combination EFA	EFA (Electric Fish Attractor)	1	50-100	-	Handline	Celebes rainbowfish, Bluecheek silver grunt, Snapper, Grouper, Bigeye trevally, Goatfish, Yellow stripe monocle bream, Selar, Yellow stripe scad Goldstripe sardinella	Banten Bay waters
Portable FAD	Raffia rope	220	50	6	Handline	Kawakawa (*Euthynnus affinis*), Short mackerel (*Rastrelliger branchysoma*), Swordfish (*Xiphias gladius*), Great barracuda (*Sphyraena barracuda*), Redbelly yellowtail fusilier (*Caesio cuning*)	waters of Jepara, Central Java
Portable FAD	Raffia rope	220	50	30	Handline	Torpedo scad (*Megalaspis* sp), Giant trevally (*Caranx* sp), Grouper (*Epinephelus* sp), Trevally (*Selaroides* sp), Squid (*Loligo* sp), Goatfishes (*Upeneus* sp), Mackerel (*Scomberomorini* sp), Indian mackerel (*Rastrelliger* sp), Yellow stripe scad (*Selaroides* sp), Grouper (*Epinephelus* sp), Kawakawa (*Auxis* sp), Great Barracuda (*Sphyraena* sp), Bigeye trevally (*Caranx* sp)	North Aceh Waters

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TYPES OF FISHING GEAR AND THE COMPOSITION OF CATCHES

Based on the paper review, various fishing gear operating around FADs are observed (Table 1). Consequently, the catch obtained by fishermen exhibits considerable diversity. The catch can be influenced by factors such as the number of attractors, fishing trips, and fishing grounds. The fishing gear and the composition of the resulting catch are detailed as follows:

Handline

The handline fishing gear type is frequently utilized around FADs. This versatile tool can be employed with various types of FADs, including portable ones with attractors made of coconut leaves, raffia ropes, palm fiber, and electric fish attractors. It is suitable for operation in both bottom and shallow waters, ranging from 6 to 100 meters. The catch obtained with this method is notably diverse. It is characterized by small and large pelagic fish species such as mackerel, sardine, long-jawed mackerel, giant trevally, mackerel scad, tuna, and king mackerel. Besides pelagic fish, this fishing gear can also target reef fish such as grouper.

Fishing rod

This fishing gear is commonly operated around FADs in shallow water, mainly using plastic and bamboo drum FADs and liquid styrofoam portable FADs equipped with raffia rope attractors. Fishermen typically target fish at water depths ranging from 200 to 300 meters. The catch usually consists of pelagic fish species, including scad mackerel, tuna, and king mackerel.

Troll line

Troll line fishing is typically employed around portable FADs featuring liquid styrofoam floats and raffia attractors. This fishing method is usually conducted in depths of around 2 meters in bottom waters. The catch typically includes yellowfin tuna (*Thunnus albacares*), frigate tuna (*Auxis thazard*), bigeye trevally (*Caranx sexfasciatus*), and hairtail (*Trichiurus* sp.).

Gillnets

Gillnets are commonly used around FADs, particularly with portable FADs featuring coconut leaf and electric fish attractors and the Bio Fad type with seaweed attractors. These fishing operations span from bottom to deep waters, with depths ranging from 0.6 to 300 meters. The catch typically includes both pelagic and demersal fish species.

Ring seine

This fishing gear is utilized around bamboo FADs and plastic drums, often with attractors made of coconut leaves. Fishing operations occur in waters ranging from shallow to deep, typically at depths of 200-300 meters.

The catch commonly includes mackerel scad and tuna fish.

FAD EFFECTIVENESS AND PRODUCTIVITY OF FISHING EQUIPMENT

The effectiveness of FADs can be evaluated based on the optimal catch productivity aligned with fishing objectives. It is essential for the types of fishing gear operated around FADs to be environmentally friendly to ensure sustainable utilization of fish resources. Moreover, the effectiveness of FADs is heavily influenced by the type of attractor used.

In this paper, a comparison of the effectiveness of FADs is described as follows:

Squid FADs

According to Syari et al. (2014), the attachment of squid eggs was more effective on cylindrical squid FADs, particularly those deployed at a depth of 3 meters during the east-west transition season. This effectiveness is attributed to the design of the cylindrical squid attractor, typically crafted from used drums, which resemble a cave-like structure. This configuration has been observed to attract or stimulate squid (Loligo sp) to attach their eggs, as highlighted by Baskoro et al. (2018).

According to Danu et al. (2019), squid attractors constructed from PVC pipes, serving as artificial reefs, exhibit a greater diversity and uniformity of fish species when the attractors are covered with fishing nets on the top alone, compared to those covered on the top and left and right sides. However, attractors covered on the top left and right sides tend to have a higher dominance than those covered only on the top.

Combining squid aggregating devices (RAMI) with lift nets and incorporating lights as attractors to catch fish's attention is highly effective. This synergistic approach increases catch productivity (Jayanto *et al.,* 2018).

Bio FADs

Based on the results of research by Suardi *et al.* (2019), it was shown that the most effective live FADs were *Gracillaria* sp. based on abundance and percentage of total fish catch compared with FADs *Eucheuma cottonii* spatially and temporally. Furthermore, environmentally friendly FADs based on biological, technical, and socio-economic assessment also place *Gracillaria* sp. FADs are environmentally friendly FADs.

Electronic FADs

Modifications in the development of electronic FADs include the utilization of LEDs with a total power of 120 watts, energy sources in the form of 12V 12Ah batteries, and the use of HDPE (High-Density Polyethylene) as body materials for FADs. Results indicate that light penetration in the water from FADs with blue-red light attractors is superior to electronic FADs with white-red light attractors. While FADs with blue-red light attractors were slower to attract fish compared to electronic FADs with white-red light attractors, fish under FADs with blue-red light attractors lasted longer than those under FADs with white-red light attractors (Baswantara, 2017).

Furthermore, the combination of electronic FADs between light and sound attractors, employing attractors in the form of LED light (5 Watt) and sound (10-1000 Hz, 1-20 kHz, and 20-100 kHz) with a voltage source of 12-volt batteries, has not been as effective compared to catches using charts (Yusfiandayani *et al.,* 2014). However, other studies have demonstrated that the number of daily catches using low sound frequencies of 10 Hz -1,000 Hz is higher than that of medium frequencies of 1,000 Hz - 20,000 Hz (Yusfiandayani *et al.,* 2014). An electric fish attractor with a sound frequency of 11,000 – 15,000 Hz, employed with handlines, indicates that squid is the most dominant species caught among the overall catch (Shadiqin *et al.,* 2018).

Natural and non-natural leaf attractor FADs

Based on several research findings, coconut leaves from the *Cocos nucifera* species emerge as the best attractor material in terms of catch quantity and durability throughout all seasons, surpassing areca leaves from the Areca catechu species and nipa leaves from the *Nypa fructican* species. Nipa leaf attractors demonstrate greater resilience compared to areca nut leaves. Attractors made from areca nut leaves only last for 15 days, becoming transparent and thin, while nipa leaves turn dark brown within 19-21 days, and coconut leaves darken within 24-28 days (Yusfiandayani, 2011).

Coconut leaf FADs exhibit various types, including bamboo FADs and plastic drums. Among these, bamboo FADs prove to be more effective than plastic drum FADs (Simbolon *et al.,* 2011). Compared to palm fiber FADs, palm fiber FADs yield higher catch numbers, although coconut leaf FADs offer greater diversity (Baihaqi, 2014). Coconut leaf attractors outperform rope raffia attractors (Zuriat *et al.,* 2019). Moreover, using FADs employing raffia rope results in higher fish catch rates than fishing without FADs (Yusfiandayani, 2013). Palm leaf midrib attractors generally exhibit physical and chemical characteristics similar to coconut leaves (Ridhoni *et al.,* 2018).

Productivity of fishing gear

The fishing gear utilized around FADs encompasses a wide range, including handlines, tug lines, ring trawls, and gill nets. Each type of gear exhibits varying levels of selectivity, influencing the type and length of fish caught around FADs. Among these options, fishing lines, such as handlines, are noted for their effectiveness and environmental friendliness compared to nets.

Results from risk assessments suggest that handlines and rod lines are suitable fishing gear to be operated around FADs, with handlines proving more effective than rod lines. Handline productivity around portable FADs surpasses that of handlines without FADs. Deep layer handline fishing gear is particularly suitable for environmentally friendly tuna catching around FADs, resulting in desirable catch outcomes. Handline productivity around portable FADs is notably higher during the day, peaking between 09:00-12:00 (Yusfiandayani *et al.,* 2017).

Another fishing gear type, the purse seine, is observed to be more effective than gill nets and fishing rods when operating around FADs. However, it carries the highest risk due to significant catches of small pelagic species, particularly yellowfin and bigeye tuna, as bycatch (Wudianto *et al.,* 2019). While purse seining can be highly productive, it necessitates careful management to prevent overfishing and ensure the sustainability of fish resources.

Some fishermen combine FADs with lift nets, which proves much more effective than using lift nets alone. This combination enhances catch rates and demonstrates the potential for sustainable fishing practices (Jayanto *et al.,* 2013).

CONCLUSIONS

The utilization of FADs presents the potential to enhance fishing productivity across various Indonesian waters. The diversity of FAD designs and developments yields many fish types and catches. From this study, it is evident that efficient, durable, high-catching, and versatile FADs are predominantly of the portable type. Moreover, non-natural attractor materials such as raffia and palm fiber emerge as viable options, offering similar catch results as coconut leaves. Regarding fishing gear effectiveness, high catch rates, and environmental friendliness, handline fishing gear stands out as particularly effective.

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