Productivity innovation of portable fish aggregating devices using gillnet gear in Bugel Waters, Kulon Progo, Yogyakarta

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Abstract. Kulon Progo Regency has quite good fisheries resources, with capture fisheries production reaching 2,190,354 tons in 2022. Good fishery resources are supported by the many Fish Auction Sites across various waters, including Congot, Karangwuni, Trisik, Glagah, Sindutan, and Bugel. The geographical condition of the village, which is located on the seashore, makes most of its residents work as fishermen. The majority of fishermen in Bugel Village use gillnet fishing gear. Productivity is the value obtained from comparing the catch with the effort made. This study aims to calculate and compare the productivity of gillnet catches in Bugel waters using portable Fish Aggregating Devices (FADs). The composition and weight of the gillnet catch using portable FADs amounted to 1,550 kg with a total of 21 species, while without using portable FADs, only 920.4 kg with a total of 20 species. The average productivity of gillnet catch using portable FADs was 119.3 kg trip^{-1}, while without FADs was only 70.8 kg trip^{-1}. The increased catch volume and species diversity highlight the practical benefits of portable FADs in optimizing fishing operations. The use of portable FADs presents a promising innovation to enhance the efficiency and economic returns of small-scale fisheries. However, responsible implementation is necessary to ensure sustainable fishing practices and minimize potential environmental impacts.
Key Words: fish aggregating devices, gill net, Kulon Progo, innovation.

Introduction. Kulon Progo is one of the regencies in the Province of Yogyakarta Special Region. This regency has an area of 586.27 km^2 with the boundaries of Sleman Regency and Bantul Regency in the east, Purworejo Regency in the west, the Indian Ocean in the south, and Magelang Regency in the north. Kulon Progo Regency has quite good fishery resources, where in 2022, capture fisheries production reached a figure of 2,190,354 tons (Diantoro et al 2024). The good fishery resources are supported by the many Fish Auction Sites in various waters, including Congot, Karangwuni, Trisik, Glagah, Sindutan, and Bugel.

Bugel Waters is located in Bugel Village, Panjatan District, Kulon Progo Regency. Bugel Village has an area of 6.42 km^2, a coastline with a length of 2 km, and is located at the southernmost tip directly facing the Indian Ocean shoreline (BPS 2022). The geographical condition of the village, which is located on the seashore, makes most of its residents work as fishermen. The majority of fishermen in Bugel village use gillnet fishing gear.

A gillnet is a fishing gear in the form of a rectangular square net whose technical operation is to block the swimming direction of the fish. Fish that are blocked by the gillnet will be entangled and twisted by the net. A gillnet consists of several parts, including the main net, buoy, weight, upper riser rope, and lower riser rope (Muksid et al 2021). The gillnet used by Bugel fishermen is a surface gillnet and a bottom gillnet. The fish caught from gillnet fishing gear is very diverse; it can be pelagic fish and demersal fish, depending on where the gillnet is operated. Generally, gillnet fishing gear catches pomfret, ray, tuna, skipjack, and snapper. The number of fish species obtained will certainly affect the productivity of fishing.

Productivity is the value obtained from comparing the catch with the effort made. The higher the productivity value, the higher the catch. High and low catches can be influenced by several things, including the wealth of aquatic resources, weather, season, performance of fishing gear, and fishing aids (Hanafiah 1983).

Fishing aids are a technology or innovation that can be in the form of hardware or software that aims to improve the performance of a fishing gear and facilitate the fishing process (Hikmah et al 2016). Common fishing aids used since ancient times until now are lights and FADs. FADs are fishing aids consisting of buoys, ropes, attractors, and weights, which have the aim of gathering or concentrating fish around them. Based on the Regulation of the Minister of Maritime Affairs and Fisheries of the Republic of Indonesia Number 18 of 2021, FADs are fishing aids that become an integral part of a fishing vessel, using various forms and types of solid attractors, functioning to lure fish to gather, which are used to increase the efficiency and effectiveness of fishing.

Many innovations regarding FADs have been made according to the needs and technological advances. One of them is the innovation of portable FADs. Portable FADs are an innovation from conventional FADs that adopt a way of working by stimulating fish behaviour responses using a sound wave with a certain frequency and the use of raffia ropes on the attractor (Yusfiandayani et al 2020). The operation of portable FADs can be adjusted to the needs of fishing operations, anywhere, anytime, and does not require a long time to operate. When finished using FADs, they can be stored in a suitcase that has become a set and can be carried and moved to another place for further fishing (Yusfiandayani et al 2013).

This study aims to determine the catch composition and productivity of gillnet catches in Bugel waters using portable FADs. This is important to do because it determines the performance of fishing gear equipped with portable FADs, which can later increase the catch of Bugel fishermen and certainly improve their welfare.

Material and Method

Research time and place. The research was conducted from September 2023 to November 2023 in Bugel Waters, Panjatan District, Kulon Progo Regency, Yogyakarta Province. The research map can be seen in the following (Figure 1).

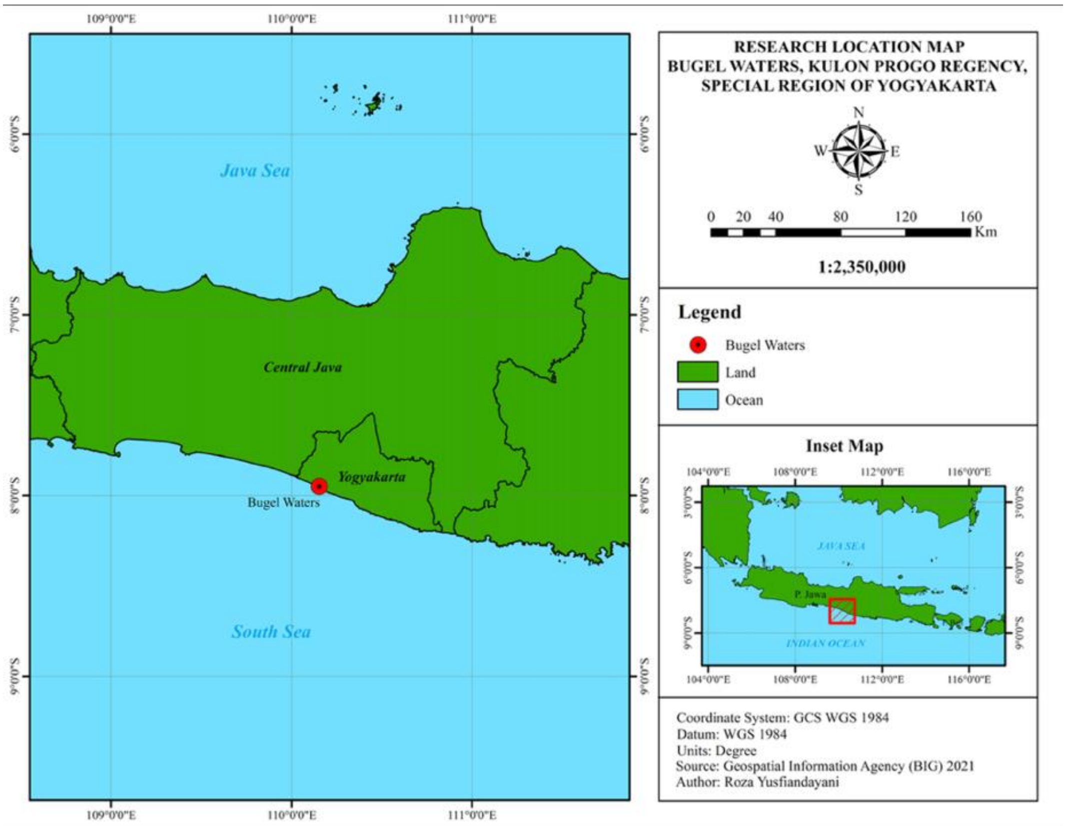
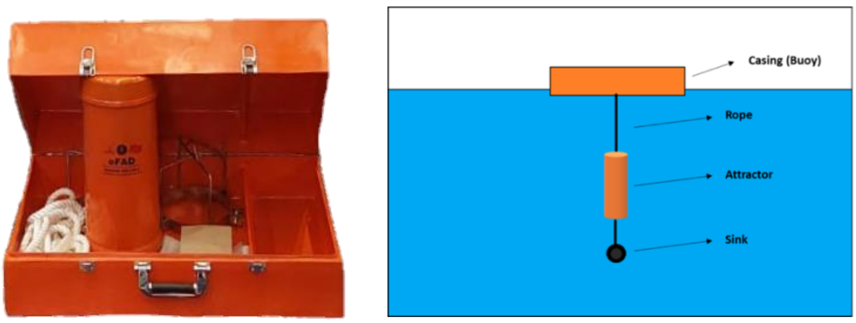


Figure 1. Research location map.

Portable Fish Aggregating Devices (FADs). The portable FADs used in this study are composed of several components, namely the Electric Fish Attractor (EFA), ropes, buoys, and weights. Portable FADs, along with ropes and weights, are placed in a fiberglass bag or suitcase that also functions as a buoy. The battery capacity of the portable FADs is 20,000 mAh; with this capacity, the portable FADs can be used for about 4-5 hours. Portable FADs use sound as an attractor to call fish. The sound emitted by portable FADs has a frequency of 11,000-15,000 Hz. The components of portable FADs can be seen in Table 1. A set of portable FADs and their application can be seen in Figures 2a and 2b.

FADs are operated by turning on the FADs machine using a remote placed in the fishing ground area. The fish will gather around the FADs, which is then followed by the setting of gillnet fishing gear. The use of these FADs will make it easier for fishermen to collect fish compared to the operation of gill nets in general, which takes hours.



(a) (b)

Figure 2. Prototype of (a) portable FADs, and (b) portable FADs are operated in waters.

Table 1

Components of portable Fish Aggregating Devices (FADs)

Component	*Material*	*Description*	*Quantity*
Bag (Buoy)	*Fiberglass*	70 x 60 x 25 cm	1
Rope	PE	10 m	1
Sound Attractor	*Speaker*, *SD card*	40 Watt, 8 GB	1
	Amplifier	1	1
	PipePVC, Battery	36 cm x 15,5 cm, 12 v	1
Ballast	Tin	5 kg	1

Data collection methods. The data collected in this study are catch data on each trip, data on the operating time of fishing gear, and data on the weight of the catch. Data collection was carried out by operating gillnet fishing gear with portable FADs, a total of 13 fishing trips. The gillnet operation was carried out using the one-day fishing method, which is fishing conducted in one day. One day, fishing can be done from morning until evening or night, and vice versa can be done from evening or night until morning (Sidiq et al 2023). The operation of the gillnet gear was conducted with two treatments, namely operation with and without portable FADs. The operation was carried out as many as 26 trips, with a division of 13 trips without portable FADs and 13 other trips using portable FADs.

Data analysis

Catch composition. Catch composition was analyzed using descriptive analysis through tabular or graphical presentation. Calculated based on the number of fish species caught against the total catch. The proportion of catch composition is known by the following formula (King 2007):

$$\text{P} = ni/N$$

Where: P = Proportion of one species of fish caught on fishing gear; Ni = Number of i-n fish species; N = Total catch.

Catch productivity analysis. Data collection in this study was carried out through interview methods and experimental fishing activities. Interviews were conducted directly with fishermen using gillnet fishing gear using questionnaires. Experimental fishing is carried out to test the effectiveness of fishing gear, fishing techniques, and the composition of the types of fish caught. The calculation of productivity is intended to determine the production capacity of a particular fishing gear, determined by the comparison between production and the length of the fishing trip. Productivity, according to Nelwan et al 2015, is calculated by the formula:

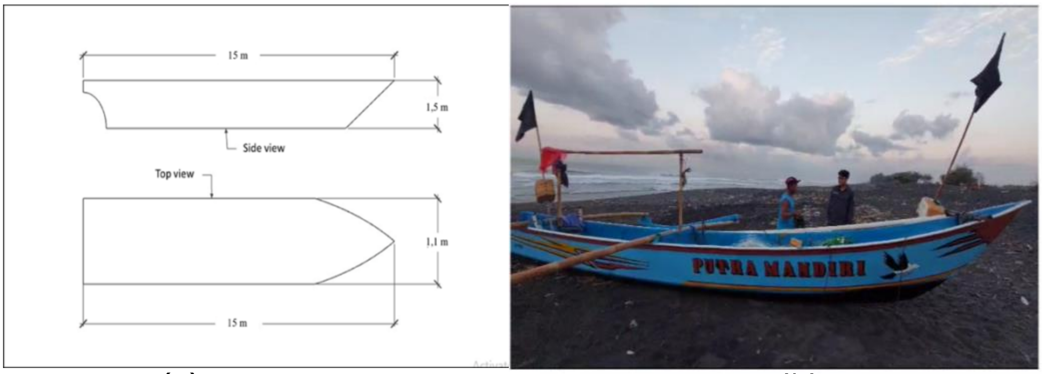
$$\text{Productivity} = c/f$$

Where: Productivity = Total catch (kg trip^{-1}); c = Catch (kg); f = Catch effort (trip)

Parametric and non-parametric static analysis. Productivity data will then be tested through parametric and non-parametric statistical tests. This statistical test aims to determine the comparison of a value between one value and another, so that it can be seen whether the data is significantly different or not. The data to be tested will first be tested for normality, after which it will be known whether productivity data can be tested through parametric or non-parametric. Parametric tests are statistical tests that require normally distributed data, while non-parametric tests do not depend on data normality (Tanjung et al 2023).

Results

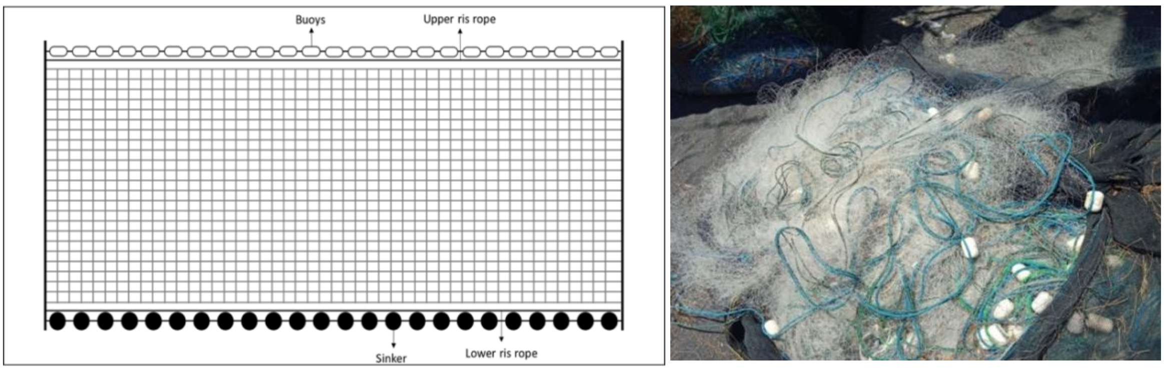
Fishing unit vessel. The vessel has a very vital role in the fishing process, used as a tool to catch fish, as a means of transportation for fishermen, and as a place where all fishing activities occur (Fachrussyah 2017). The vessel used for research purposes is a gillnet vessel with a capacity of 10 GT, having dimensions of length 15 m, width (B) 1.1 m, and depth (D) 1.5 m. The gillnet vessel is equipped with one gillnet with a capacity of 10 GT. This gillnet vessel is equipped with one main engine as a power source. An image of the gillnet vessel used in the study can be found in Figures 3a and 3b. To ensure stability and safety during fishing operations in the Indian Ocean, which is known for its strong currents and high waves, the gillnet vessel is also equipped with katir (outriggers). The katir functions as a balancing and stabilizing structure, particularly useful in minimizing roll and pitch movement in open sea conditions. The bed used on the gillnet ship consists of 2 pieces made of bamboo with a length of 5 meters (Renofati et al 2009).



(a) (b)

Figure 3. Vessels from (a) illustration of a gillnet vessel, and (b) gillnet vessel.

Fishing gear. The fishing gear that will be used in this research is a gillnet. A Gillnet is a fishing tool that is operated by casting a net, which is placed on the surface of the water as a fish passes. When a group of fish crosses the net, they will be trapped and twisted (Sari et al 2023). Specifications of the gillnet used in this study include a 25-meter-long upper ris rope, a long lower ris rope, a 3-meter tool depth, 25 buoys, and a mesh size of about 2.5 to 5.5 inches. The process of setting up gillnet fishing gear takes about 30 minutes to 1 hour. After that, the net will be soaked for 2 to 3 hours before being withdrawn. The design and construction of the gillnet can be seen in Figure 4a, and the gillnet used in Bugel waters can be seen in Figure 4b.



(a) (b)

Figure 4. Fishing gear from (a) design and construction of a gillnet, and (b) gillnet.

Catch composition. Total catch composition using gillnet gear: the catch included 27 different species. Some of the species caught include sin croaker, slipmouth, four-finger threadfin, belanger croaker, largehead hairtail, shovelnose guitarfish, saddle grunt, Indian mackerel, skipjack tuna, four-lined tonguesole, torpedo scad, moonfish, Indo Pacific swamp crab, Indian halibut, snapper, and lizardfish. The composition of catches using portable FADs can be illustrated in Figure 5.

Figure 5 shows the gillnet catch during 13 fishing trips using portable FADs. The number of species obtained in this catch is 21. Kawakawa is the most common catch with 29.2%, followed by Shovelnose Guitarfish with 24.0%, then Indian oil sardine with 16.8%, and Spanish mackerel 12.1%. The composition of the catch without using portable FADs can be seen in Figure 6.

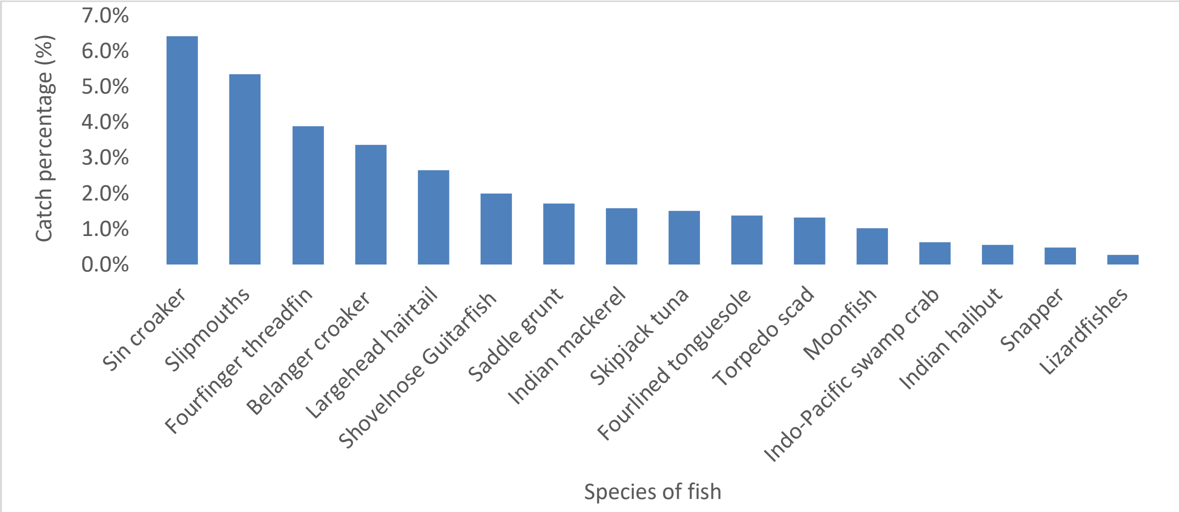


Figure 5. Catch with portable Fish Aggregating Devices (FADs).

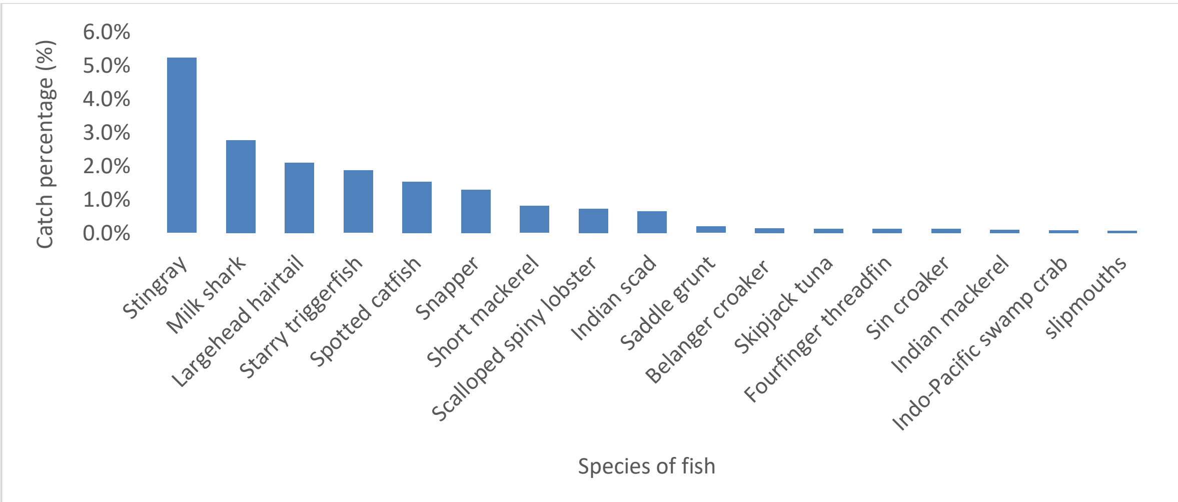


Figure 6. Catch without portable Fish Aggregating Devices (FADs).

Figure 6 shows the gillnet catch during 13 fishing trips without using portable FADs. The total catch reached 20 species, with mackerel being the most dominant species, accounting for 36.3% of the total catch, followed by Spotted Catfish with 13.7%, mackerel with 8.5%, button fish with 6.4%, and the rest filled by various other fish species. More information on the types and weights of catches can be found in Table 2.

Table 2

Percentage of catch with and without portable Fish Aggregating Devices (FADs)

No	Species caught		With portable FADs		Without portable FADs	
	Scientific name	Common name	Total	Percentage (%)	Total	Percentage (%)
1	*Rastrelliger kanagurta (Cuvier, 1816)*	Indian mackerel	1.4	0.1	14.6	1.6
2	*Katsuwonus pelamis* (Linnaeus, 1758)	Skipjack tuna	2	0.1	13.9	1.5
3	*Megalaspis cordyla* (Linnaeus, 1758)	Torpedo scad	3	0.2	12.2	1.3
4	*Pomadasys maculatus (Bloch, 1793)*	Saddle grunt	1.2	0.1	15.7	1.7
5	*Scylla serrata* (Forsskål, 1775)	Indo-Pacific swamp crab	23.7	1.5	5.7	0.6
6	*Cynoglossus bilineatus* (Lacepède, 1802)	Fourlined tonguesole	12.5	0.8	12.6	1.4
7	*Arius Maculatus* (Thunberg, 1792)	Spotted catfish	20	1.3	126.2	13.7
8	*Upeneus sulphureus (Cuvier, 1829)*	Sulphur goatfish	29	1.9	67.9	7.4
9	Rastrelliger kanagurta (Cuvier, 1816)	Short mackerel	10	0.6	78.1	8.5
10	Synodus saurus (Linnaeus, 1758)	Lizardfishes	32.5	2.1	2.5	0.3
11	*Lutjanus bitaeniatus*	Snapper	2.1	0.1	4.4	0.5
12	*Trichiurus lepturus (Linnaeus, 1758)*	Largehead hairtail	260.5	16.8	24.5	2.7
13	*Johnius belangerii (Cuvier, 1830)*	belanger croaker	11.2	0.7	30.9	3.4
14	*Pseudobatos productus (Ayres, 1854)*	Shovelnose Guitarfish	81.2	5.2	18.3	2.0
15	*Leiognathus equula (Forsskal, 1775)*	Slipmouths	372	24.0	49.3	5.4
16	*Mene maculata* (Bloch & Schneider, 1801)	Moonfish	1	0.1	9.4	1.0
17	*Eleutheronema tetradactylum (Shaw, 1804)*	Fourfinger threadfin	2	0.1	35.8	3.9
18	*Psettodes erumei* (Bloch & Schneider, 1801)	Indian halibut	452	29.2	5.1	0.6
19	*Johnius dussumieri (Cuvier, 1830)*	Sin croaker	2	0.1	59.2	6.4
20	*Scomberomorus plurilineatus (Fourmanoir, 1966)*	Spanish mackerel	3	0.2	334.1	
21	*Rhizoprionodon acutus* (Rüppell, 1837)	Milk Shark	43	4.1	-	-
	Total		1,550.3	100	920.4	100

Table 2 shows the composition and weight of each species caught by gillnet using portable FADs and without portable FADs. The catch with portable FADs was 21 species weighing 1,550 kg, while without portable FADs, 20 species weighing 920.4 kg were caught.

Catch productivity. The highest catch productivity of gillnet gear operation using portable FADs was on the 9th trip with a value of 489.7 kg trip^{-1}, while the lowest was on the 1st trip with 6 kg trip^{-1}. Meanwhile, the highest productivity without the help of portable FADs was achieved on the 5th trip with 181 kg trip^{-1}, and the lowest on the 12th trip with 6.5

kg trip^{-1}. On average, the use of portable FADs gave a productivity of 119.25 kg trip^{-1}, while without FADs it was only 70.8 kg trip^{-1}. From this study, it can be concluded that the utilization of portable FADs is effective in increasing productivity compared to not using FADs. The ups and downs of fishermen's catch productivity are influenced by various factors such as the type of fishing gear, fleet type, number of trips, and fish season (Restumurti et al 2016). The productivity comparison can be seen in Figure 7.

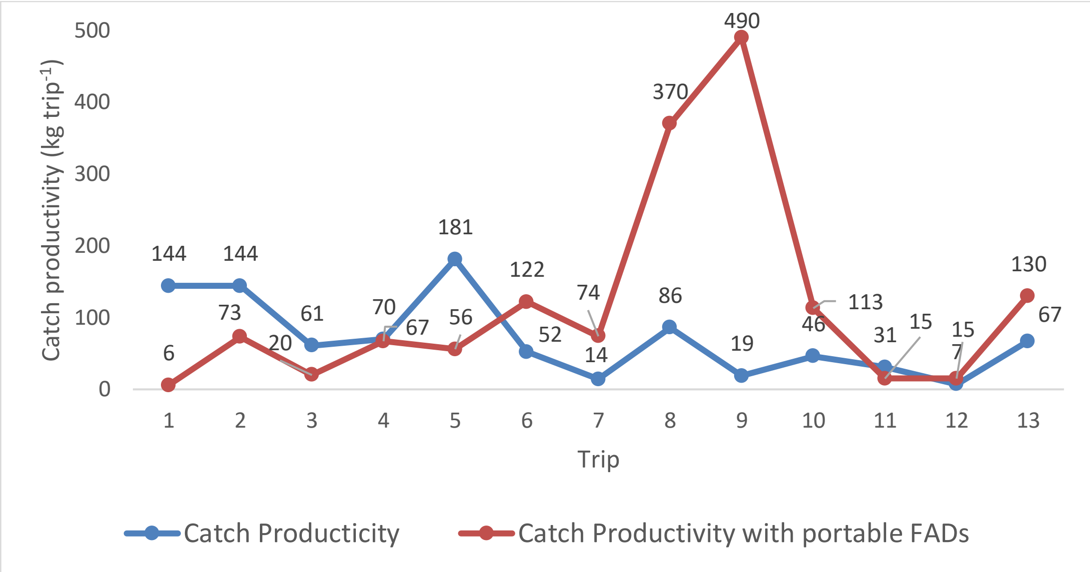


Figure 7. Comparison of catch productivity.

Productivity data is analyzed statistically to test the validity of a statement. The aim is to ascertain the truth of the statement through statistical analysis and determine whether the statement is acceptable or not. This research uses comparative hypotheses in response to issues involving two main variables. To evaluate whether the data or sample follows a normal distribution, a normality test is conducted. The results of the normality test can be found in Table 3.

Table 3

Normally test result

Tests of normality							
Treatment					*Shapiro-Wilk*		
		Statistic	*Df*	*Sig.*	*Statistic*	*Df*	*Sig.*
Productivity (kg trip^{-1})	Without portable FADs	0.202	13	0.151	0.901	13	0.138
	With portable FADs	0.318	13	0.001	0.720	13	0.001
a. Lilliefors Significance Correction							

Note: Df = Degree of freedom; Sig= Significance (p-value); (p-value) = 0.138 ≥ 0.05, data without portable can be considered normally distributed.

The tests of normality shows the results of the Shapiro–Wilk test (with Lilliefors correction) for productivity (kg trip^{-1}) in two treatments: without portable FADs and with portable FADs.

The Shapiro–Wilk Statistic = 0.901, with Df = 13 and Sig. (p-value) = 0.138. Since p-value = 0.138 ≥ 0.05, there is insufficient evidence to reject normality. The productivity data without portable FADs can be considered normally distributed (or at least not clearly non-normal). As the amount of data in the study was less than 50, the Shapiro-Wilk test was used to test whether the data had a normal distribution. The significant results of the productivity tests, both with and without portable FADs, were less than 0.05, indicating that the data did not follow a normal distribution. Consequently, the data did not meet the criteria for running a one-way ANOVA test. Alternatively, to assess whether there was a significant difference between the data when the distribution was not normal, the Kruskal-Wallis non-parametric test was conducted. Full information regarding the results of the Kruskal-Wallis test can be found in Table 4.

Table 4

Kruskal-Wallis test results

Test statistics^{a,b}	
Test statistic	*Weight (Kg)*
Kruskal-Wallis H	4.20
Df	1
Asymp. Sig.	0.04
a. Kruskal Wallis Test	
b. Grouping Variable: Treatment	

Note: Df = degree of freedom; Asymp. Sig. = asymptotic significance; p value = 0.04 ($p < 0.05$) : there is a statistically significant difference between catch productivity with and without portable FADs.

Based on the Kruskal–Wallis test, there was a significant difference in catch weight between the groups without portable FADs and with portable FADs, with a value of H = 4.20, df = 1, and p = 0.04 ($p < 0.05$). This indicates that catch productivity (kgtrip^{-1}) tends to be higher in the group with portable FADs compared to the group without portable FADs, which indicates that the application of portable FADs has the potential to increase catch efficiency per trip. Thus, it can be concluded that using portable FADs has an impact on productivity.

Discussion. The fish caught in Bugel waters were pelagic in Tegal that found 11 pelagic species congregating at portable fish aggregating devices, similar with Yusfiandayani et al 2024 that found 11 species fish around portable FADs, the species obtained include barracuda (*Sphyraena* sp.), Dorab wolf-herring (*Chirocentrus dorab*), Sin croaker (*Johnius* sp.), Indian mackerel (*Rastrelliger* sp.), Bigeye scad (*Selar crumenophthalmus)*, Fringescale sardinella (*Sardinella fimbriata*), Narrow-barred Spanish mackerel (*Scomberomorini* sp.), Indian anchovy (*Stolephorus indicus)*, kawakawa (*Euthynnus affinis)*, squid (*Loligo* sp.), and shrimp (*Caridea* sp.). Pelagic fish have a schooling nature, so the fish gather when they hear sounds around them, and they gather near the sound source. Bugel waters, Yogyakarta and Tegal, Central Java, share several similarities, but also significant differences in terms of oceanography, ecology, and fishing activities. Both are located on the North-South Coast of Java, facing directly onto the open sea (the Indian Ocean for Bugel, and the Java Sea for Tegal, although both are influenced by the monsoon system). Both are small- to medium-scale capture fisheries, with traditional fishermen using simple to semi-modern fishing gear. Both waters are influenced by seasonal patterns (west-east monsoons) that influence waves, currents, and fishing seasons. Both have potential demersal and pelagic fish resources, although their species composition differs (Yusfiandayani et al 2024). Fishing gear that used portable FADs resulted in greater catches than that which did not. On average, the use of portable FADs gave a productivity of 119 kg trip^{-1}, while without FADs it was only 70 kg trip^{-1}. From this study, it can be concluded that the utilization of portable FADs is effective in increasing productivity compared to not using FADs. The ups and downs of fishermen's catch productivity are influenced by various factors such as the type of fishing gear, fleet type, number of trips, and fish season. Different and fluctuating productivity values caused by the number of fishing efforts, weather, season, and water conditions (Yusfiandayani et al 2021). The positive impact of this service activity is that the application of portable FADs provides in-depth insight into the urgency of using technology to increase fish catches by fishermen (Yusfiandayani et al 2020). Apart from that, this service activity also provides important insight regarding the natural factors fishermen face in implementing portable FADs, such as weather uncertainty, increasingly scarce fish resources, and natural conditions, namely high waves, which are the main obstacles in achieving the expected results (Diantoro et al 2024). In the Java Sea, natural factors such as weather variability, wave conditions, and fluctuating fish resource availability strongly influence the deployment, effectiveness, and productivity of portable FADs. Weather and wave conditions, which are closely linked to the monsoonal system (West and East Monsoon), affect the operational window for deploying and retrieving portable FADs. During the West Monsoon, increased rainfall, stronger winds, and higher waves can limit fishing days, reduce FAD stability, and increase the risk of displacement or loss, leading to lower observed catches that are not necessarily related to fishing efficiency or stock condition. Conversely, calmer conditions during transitional and East Monsoon periods generally enhance accessibility and effectiveness of portable FADs use. Wave height and current strength also influence fish aggregation behavior around portable FADs. Moderate conditions in the Java Sea allow FADs to function effectively as aggregation points, whereas excessive turbulence can disrupt aggregation patterns and reduce catch rates. In addition, scarcity or uneven spatial-temporal distribution of fish resources, often driven by overfishing pressure, seasonal migration, or environmental variability, affects the productivity of portable FADs. During periods of low resource availability, portable FADs may attract fewer fish, resulting in reduced catches despite proper deployment and operation (Yusfiandayani et al 2021).

Productivity data that will be used in statistical tests must first be processed in a normality test. One of the main requirements in parametric statistical analysis is the fulfillment of data normality. The normality test is one of the data testing stages which the data is normally distributed or not (Sababalat et al 2021). The normality test was carried out using the help of SPSS software, using the Shapiro-Wilk test method. The Shapiro-Wilk normality test is accurate for small samples or fewer than 50 (Pongtiku 2021). The Shapiro-Wilk test obtained a significance value of 0.001 in the treatment with portable FADs and 0.138 without FADs. The data in the study were less than 50, so the Shapiro-Wilk test was used as a normality test. The value obtained using portable FADs or not using portable FADs is less than 0.05. "Sig" is a valid value or "p-value" representing the probability of rejecting an invalid H0. This proved that fishing productivity was not normally distributed. Therefore, these data did not meet the requirements for using the one-way test. If one or all of the data are not normally distributed, the researcher usually uses the Kruskal-Wallis test as an alternative to ANOVA. The normality test results on both data sets show that productivity data using portable FADs are not normally distributed. The significance value is said to be normal if the value is more than 0.005 (Rozi & Maulidiya 2022). Data that are not normally distributed cannot be continued with parametric tests, but there can be other alternatives, namely non-parametric tests. A non-parametric test is a statistical method that can be used when the data is not normally distributed. Non-parametric tests consist of several methods, one of which is the Kruskal-Wallis test. The results of the Kruskal-Wallis test are in Table 4. The data will be significantly different if the value is less than 0.05. The significance value of the productivity of the catch with FADs and without FADs is 0.04, which means that the productivity data is significantly different. Thus, the results of the analysis using Kruskal-Wallis state that portable FADs have a significant effect on catches, which is similar to Yusfiandayani et al (2022) that found there was a significant (significant) difference in the productivity value. It can be stated that the treatment using portable FADs and without portable FADs has different results, suggesting that the treatment with portable FADs can have a more significant effect on catches with handlines than that without portable FADs.

Conclusions. Portable FADs with gillnet fishing gear in the Bugel waters, Kulon Progo, Yogyakarta, have demonstrated significant potential in increasing catch productivity. Empirical data revealed that gillnet catches utilizing portable FADs yielded a substantial catch composition of 1,550 kg, consisting of 21 species. In contrast, catches without portable FADs totalled 920 kg with 20 recorded species. Of note is the marked difference in average catch productivity, with trips assisted by portable FADs yielding 119 kg $trip^{-1}$, a marked increase compared to 70 kg $trip^{-1}$ without FADs. Overall, the findings of this study highlight the promising potential of portable FADs as an innovative fishing gear, offering a practical solution to increase catch productivity and contribute to the economic well-being of fishing communities in the Bugel waters and potentially other coastal areas with similar conditions.

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Conflict of Interest. The authors declare that there is no conflict of interest.

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