The Environmental Friendliness Level of Boat *Bagan* Fishing Gear in Belitung Regency

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Authors' contributions

This work was carried out in collaboration among all authors. Author SBAT designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors DS and RR managed the analyses of the study. Author AMAK managed the literature searches. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

This research aimed to analyze the environmental friendliness level of boar *bagan* towards the amount of fish caught by the fishermen in Belitung Regency Waters and determined fish composition based on the type and the length of fish. The research was conducted in August 2019. The primary data collection technique used was purposive sampling technique while the secondary data was obtained from Tanjungpandan Archipelago Fisheries Port (*Pelabuhan Perikanan Nusantara Tanjungpandan/PPN*). The research analyzed types of fish composition, proportion of main and bycatches, proportion of biologically worth caught fish, proportion of utilized catches, and eco-friendly analysis. Based on the results of research on the environmental friendliness level of boat *bagan* fishing gear in Belitung Regency Waters, it can be concluded that the boat *bagan* catch during the study obtained 10 species including fringescale sardinella *(Sardinella fimbriata),* spotted sardinella *(Sardinella sirm)*, devis' anchovy *(Stoleporus devisi),* squid *(Loligo sp),* short mackerel *(Rastrelliger brachysoma),* common ponyfish *(Leiognathus equulus),* largehead hairtail *(Trichiurus sp),* and yellowstrip scad *(Selaroides leptolesis)*, large pelagic fish such as barracuda *(Sphyraena sp),* and demersal fish was also caught such as pufferfish (Tetraodo sp). Boat *bagan* fishing gear is

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classified as less environmentally friendly because 48% of fish caught was not mature, fish that are not the main target fish (bycatch) was 41%, and it catches more than 3 target fish species. However, the utilization of catch is quite good at 99,12%.

1. INTRODUCTION

Belitung Regency is one of the area that has fishery potentials and is located in Fisheries Management Area (*Wilayah Pengelolaan Perikanan* / WPP) 711. There are many kinds of important economic marine fish in Belitung Regency. Belitung Regency has fishing activity center namely Tanjungpandan Archipelago Fisheries Port (*Pelabuhan Perikanan Nusantara Tanjungpandan/ PPN*). The port location is very strategic because it is close to fishing ground area and marketing center, both domestic and abroad. Capture fisheries is still the mainstay of the marine fishery sector in Belitung regency after the end of tin mining. It consistently becomes the economic driver for Belitung. There are many important economic marine fish in Belitung Regency, such as spotted sardinella, fringescale sardinella, devis' anchovy, squid, and big fish like skipjack and mackerel. The abundant resources are due to its open location that directly faces South China Sea.

Lift net is a fishing gear that is operated by putting it down and lifting it up vertically. This net is usually made of nylon net that resembles a mosquito net. The net is then tied to square wooden frame. The mesh size is usually very small approximately 0,5 centimeter (cm). In the usage, lift net usually uses lamps or baits to attract fishes. It is usually operated on a boat, raft, or permanent building. From the shape and usage, lift net can include boat *bagan*, embedded *bagan* and lift net scoop [1].

Bagan is a fish fishing gear that uses artificial light to attract fish. Belitung Regency fishermen use boat *bagan* as a fishing gear for fishing. In the process of fishing using *bagan* boat, the artificial light used is aimed to collect fish that has positive phototaxis characteristic. According to Yuda, fish that has positive phototaxis characteristic will gather in the artificial light area so that it is easier for the fishermen to catch them [2].

According to Minister of Maritime Affairs and Fisheries Regulations No.71/2016 concerning Fishing Lane and the Placement of Fishing Equipment in the Fisheries Management Area of the Republic of Indonesia, boat *bagan* uses mesh size ≥ 1 milimeter (mm), length < 20 meter (m), and width < 20 m, uses additional fishing gear in the form of lamps with total power < 2,000 watt, uses one or two motor boats with total size > 5 until 10 GT.

The catch are divided into two, namely Main Target Catch (*Hasil Tangkapan Sasaran Utama* / HTSU) that means the species are the target of the fishing operation, and the other one is Bycatch (*Hasil Tangkapan Sampingan* / HTS) that means the fish is just an addition and not the target of the fishing operation.

Based on [3] research conducted in the Makassar Regency Waters of the stationary lift net (*bagan rakit*), the selectivity of the *bagan rakit* is very bad, both by size and by the type of fish caught. This is shown by the narrow limit ini size between the caught and the loose, indicating that the *bagan rakit* is not environmentally friendly. According to [2], raft lift net (*bagan apung*) in the gulf of Pelabuhanratu are less environmentally friendly because 56,44% of fish caught was not mature and bycatch was 45,33%.

Standardization for fishing gear on fish target is needed because the caught fish size varies. To improve environmental friendliness and *bagan* fishing gear standardization, it is important to note the initial fork length of the length at first maturity (LM).

2. MATERIALS AND METHODS

The method used in this research is survey method. Survey method is a direct data collection method in the field, and it conducts data collection by concentrating the research on a case intensively so that overall picture can be obtained as a result of data collection and data analysis in a certain period of time and limited to certain areas [4]. The primary data uses purposive sampling, which is a technique to determine research sample with certain considerations so that the obtained data can be more representative [5].
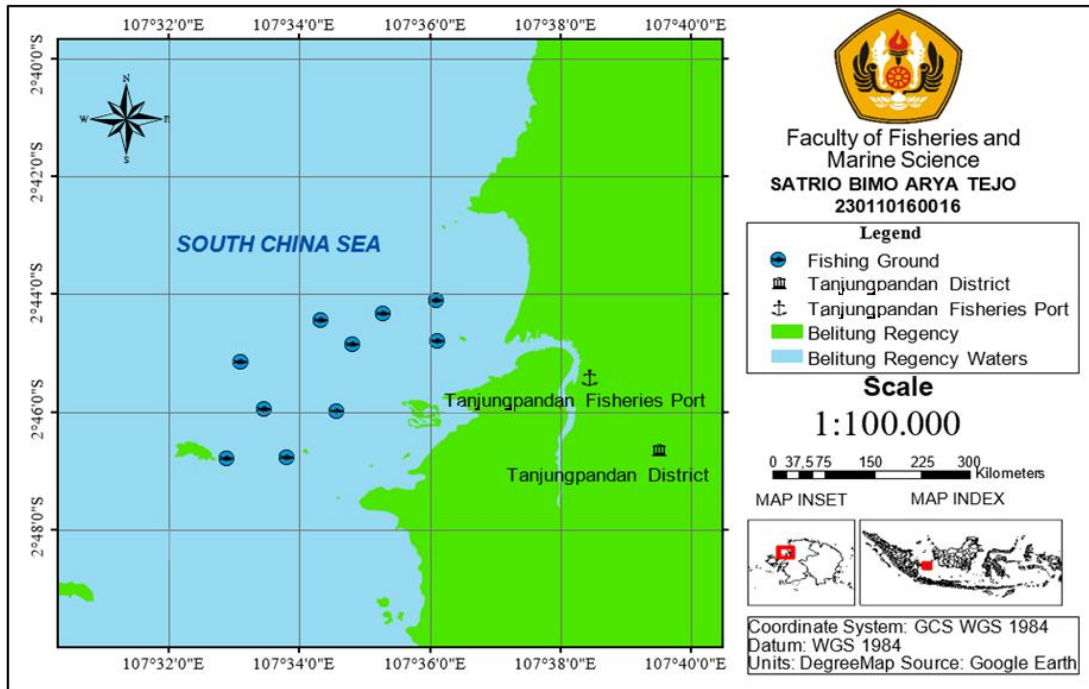
Fig. 1. Map location of research

This research was conducted in August 2019. The research location is Belitung Regency Waters. The materials and equipment used include boat *bagan* fishing gear, *rumpon,* lamp, measuring tape (1 mm scale), digital scale (1 gram scale), smartphone camera, stationary, and fish catch. The net used on the boat *bagan* is made of waring without a knot, in the form of a rectangular bag, measuring 16 x 6 x 13.5 m and a mesh size of 0,3 cm.

In this research, data collection is conducted in some stages, namely:

1. Directly followed fishing operation using boat *bagan* in August 2019 from three units of boats with a total of 10 trips in Belitung Regency Waters, with a size of 10 GT.
2. The primary data that is collected directly during the research namely catch composition, fork length, individual weight of the catch, the utilization of the catch, and the proportion of the Main Target Catch and Bycatch.
3. Interview with 21 fishermen of *bagan* boat by using prepared questionnaire such as characteristics of respondents, fishing gear, fishing vessels, and fishing operation.

2.1 Catch Type Composition

Before being analyzed, the catch is identified to determine the general and the latin name. The identification is in accordance with Fishbase. After being analyzed, the data is grouped according to the species and then the weight and the number are counted. The fish type is then tabulated to see the catch composition.

2.2 Main Target Catch and Bycatch Proportion

Each data of the number and weight of Main Target Catch and Bycatch from the fishing operation are counted in the form of percentage. Then, it is compared to see which of the catch has bigger proportion. The data of fork length of the catch is processed by counting the frequency distribution and is presented in the form of histogram.

2.3 The Proportion of Fish Eligible Catching Biologically

The fish size that is eligible for catching is determined by the length at first maturity. The length measurement is done with fork length (FL) measurement, which is the measurement from

Table 1. The assessment of environmental friendliness level

Observation	Assessment	Criteria	Score
Main Target Catch (%)	81-100	Very environmentally friendly	4
	61-80	Environmentally friendly	3
	41-60	Less environmentally friendly	2
	1-40	Not environmentally friendly	1
Length at First Maturity (%)	81-100	Very environmentally friendly	4
	61-80	Environmentally friendly	3
	41-60	Less environmentally friendly	2
	1-40	Not environmentally friendly	1
Utilized Catch (%)	81-100	Very environmentally friendly	4
	61-80	Environmentally friendly	3
	41-60	Less environmentally friendly	2
	1-40	Not environmentally friendly	1

Conclusion:
- *Total score between 3 and 5: not environmentally friendly*
- *Total score between 6 and 8: less environmentally friendly*
- *Total score between 9 and 11: environmentally friendly*
- *Total score 12: very environmentally friendly*

mouth to tail fork. The obtained data are presented in descriptive analysis using graphic and the average length value of the most caught fish to find out gonad fish maturity level. After analyzing all the obtained data, if the length of fish that is caught most (Lc) less than LM, it can be concluded that the fishing gear is not selective and vice versa, but this remains based on each species. To obtain data for LM the main target catch by referring to the previous research such as research of Bintoro [6] for fringescale sardinella, Nugraha [7] for spotted sardinella, and Fauziyah (2012) for devs' anchovy.

2.4 The Proportion of Utilized Catch

All the data of utilized catch is compared with the unutilized catch (discarded) in form of proportion. The measurement of the catch is presented in kg. The observation result of the catch handling process is analyzed to describe the catch that are utilized and unutilized or discarded.

2.5 The Analysis of Environemtal Friendliness Level

A fishing gear can be said as an environmentally friendly fishing gear if the main target catch is bigger than the bycatch. The friendliness factor that is used as research to see friendliness level is Mallawa method [8] of the calculated data and scores on the assessment of the level of fishing gear friendliness (Table 1).

3. RESULTS AND DISCUSSION

Based on the research activities, the following results are obtained:

3.1 Boat *Bagan* Catch

3.1.1 The fish type diversity of boat *Bagan* catch

From the identification of the fish type diversity of boat *bagan* catch during the fishing operation of this research, ten marine biota are obtained that consist of eight type of pelagic fish, one demersal fish, and one squid (Table 2).

Table 2. The fish type diversity of the catch

Name of fish	Latin name (*species*)
Barracuda	*Sphyraena* sp
Pufferfish	*Tetraodo* sp
Squid	*Loligo* sp
Short mackerel	*Rastrelliger brachysoma*
Common ponyfish	*Leiognathus equulus*
Largehead hairtail	*Trichiurus* sp
Spotted sardinella	*Sardinella sirm*
Yellowstrip scad	*Selaroides leptolepis*
Fringescale sardinella	*Sardinella fimbriata*
Devis' anchovy	*Stolephorus devisi*

The diversity shows that the *bagan* boat is a multispecies fishing gear; it catch more than one type of fish, which mean it has low selectivity.

Based on the results of interviews with *bagan* fishermen and the PPN Tanjungpandan

Syahbandar Chief, the main target of boat *bagan* fishing gear in the Belitung Regency Waters is fringescale sardinella (*Sardinella fimbriata*), spotted sardinella (*Sardinella sirm*), and devis' anchovy (*Stolephorus devisi*). These three commodities have high economic value that can increase people's income and are usually caught in large quantities.

3.1.2 The proportion of main target catch and bycatch

The total catch of ten trips is 504,4 kg. The number of main target catch is 71.530 fish (89%) with 298,3 kg of weight (59%) (Table 3). The main catch is devis' anchovy (*Stolephorus devisi*) that is 65.127 (81,1%), with 121,4 kg (24,1%) of weight, followed by spotted sardinella (*Sardinella sirm*) that is 3.200 (4%), with 100,9 kg (20%) of weight, then fringescale sardinella (*Sardinella fimbriata*) that is 3.203 (4%), with 75,9 kg of weight (15,1%) (Table 4).

The number of Bycatch is 8.809 fish (11%) with 206,14 kg (41%) of weight from the total catch (Table 3). The main catch is squid (*Loligo* sp) that is 3.535 (4,4%), with 141,4 kg (28%) of weight (Table 4).

Table 3. The weight and number of the catch

Category	Catch			
	Weight		Amount of fish	
	(kg)	%	(fish)	%
Main Catch	298,3	59	71530	89
Bycatch	206,1	41	8809	11
Total	504,4	100	80339	100

The *bagan* catch is very diverse ranging from fish that has positive phototaxis characteristic. Another factor that causes the variety of catch from a fishing gear is caused by a group of fish between target fish and non-target fish, so that migratory fish can be caught. The composition of this type of catch is obtained during the eastern monsoon in Indonesia (Start from July - August). Even though the *bagan* is operated in different season, fringescale sardinella, spotted sardinella, and devis' anchovy fish remain to become the main target of the fishing operation of boat *bagan* in PPN Tanjungpandan Belitung Regency.

According to [9], it is stated that the events of fish attracted to light can be divided into two, namely:

a. Direct event, the fish is attracted to light and then gather. This is related to phototaxis.
b. Indirect event, as there is light, plankton and other tiny fish gather, then the target fish gather to feed. Some fish are included in this category are mackerel tuna and barracuda.

To improve the level of environmental friendliness of the fishing gear, the mesh size must be modified so that it can catch the main target fish properly. Prevention can be done by efforts to improve the selectivity of fishing gear according to [10]. namely by modifying the size of the net mesh from a small size into a larger size so as not to catch fish that are not yet feasible to catch.

3.1.3 Frequency distribution of main catch fish fork length

Boat *bagan* are designed to catch small pelagic fish such as fringescale sardinella, spotted sardinella and devis' anchovy, the types of fish caught in boat *bagan* usually form a schooling. When this research was conducted, small-sized fishes were also caught, allegedly because the construction of the boat chart has a small mesh size, which ranges from 0,3 to 0,5 cm with nylon material so that it allows small fish to be

Table 4. The proportion of the catch

Name of fish	Amount of fish	%	Weight (kg)	%
Barracuda	91	0,1	11,5	2,3
Pufferfish	1	0,0	0,2	0,0
Squid	3535	4,4	141,4	28,0
Short mackerel	3737	4,7	32,7	6,5
Common ponyfish	629	0,8	5,5	1,1
Largehead hairtail	129	0,2	5,4	1,1
Spotted sardinella	3200	4,0	100,9	20,0
Yellowstrip scad	687	0,9	9,5	1,9
Fringescale sardinella	3203	4,0	75,9	15,1
Devis' anchovy	65127	81,1	121,4	24,1
Total	80339	100	504,4	100

entangled in the net. even the size that is still juvenile.

Fringescale sardinella caught have different fork lengths ranging from 100 to 155 mm. The sizes range from 121 to 127 mm are the most caught at the time of this research, which is as many as 39 fish, and the smallest amount obtained from the catch is size 149 to 155 mm where there are only 7 fish (Fig. 1).

Spotted sardinella caught during the research has different lengths of fork ranging from 104 to 166 mm. The sizesrange from 125 to 131 mm are the most caught at the time of this research, which is as many as 58 fish, and the smallest amount obtained from the catch ranges from 104 to 110 mm where there are only two fish (Fig. 2).

Devis' anchovy caught during research has different fork lengths ranging from 53 to 76 mm. The sizes range from 56 to 58 mm are the most caught at the time of this research, which is 29 fish, and the smallest amount obtained from the catch ranges from 74 to 76 mm where there are only 10 fish (Fig. 3).

The size of the fish caught will affect the applicable selling price. Besides that, more importantly, the size of the fish caught will affect the sustainability of the fish resources themselves in particular and the sustainability of the ecosystem in general. The nature of the pelagic fish in groups causes the captured pelagic fish to have several size groups [11]. If from a fishing operation conducted small-sized fish is caught, it can be estimated that other fish caught is small-sized fish as well.

### 3.1.4 The proportion of fish eligible for main catch

The length of the caught fish can be used to determine whether or not the fish is eligible for catching by knowing the length limit of the fish when the gonad (Length at first maturity) is first mature. Catching above the size of the fish when the gonad is first mature can provide an opportunity for the target fish to be able to reproduce and spawn before being caught so that the recruitment phase of small fish into the adult fish phase can run. Therefore, the size criteria for catching is the most important criteria for determining the environmental friendliness of a fishing operation.

Ningrum et al. (2015) stated that by comparing $Lc_{50\%}$ size with LM values, it can be assumed that the first fish caught has spawned or not [12]. If the size of the fish is bigger than LM, the fish have spawned. The length of the gonad's first mature length using an embedded *bagan* in the Sungsang Waters, South Sumatra for anchovies is 62 mm and the estimated age to reach LM is around 3,7 months [13]. Data on the distribution of the length of the devis' anchovy fork is sampled as many as 150 fish. There are 89 fish that are eligible for catching and 61 are not eligible for catching. The proportion of devis' anchovy that is eligible for catching is 59% (Fig. 4). Most of the devis' anchovy caught during the study is fish eligible for catching.

Nugraha (2015) stated that the LM values of male and female spotted sardinella in the Sunda Strait were 137,30 mm and 145,82 mm respectively [7]. In general, spotted sardinella experience gonad maturity, which first occurs in the range of 65-75% of the maximum length (Setyohadi 2010). Data on the distribution of the length of the spotted sardinella fork is sampled as many as 150 fish. There are 14 fish that are eligible for catching and 136 fish are not eligible for catching. The proportion of spotted sardinella catch that are eligible for catching is 9% (Fig. 5). Spotted sardinella caught during the study are mostly fish that are not eligible for catching.

Bintoro (2019) stated that the length of the first mature gonad fringescale sardinella in the Bali Strait for males and females was 11,95 cm and 10,79 cm respectively [6]. In the study of Aryuningka (2016) in the Sunda Strait, the first mature female fringescale sardinella gonad is 157 mm. Data on the distribution of the length of the fork of the fringescale sardinella is sampled as many as 150 fish. There are 131 fish that are eligible for catching and 19 fish that are not eligible for catching. The proportion of fringescale sardinella eligible for catching is 87% (Fig. 6). Fringescale sardinella caught during the study are mostly fish eligible for catching.

According to [8], the total number of fish eligible for catching has a proportion of 52% (Fig. 7), so it can be said that boat *bagan* is less environmentally friendly. This is because boat *bagan* has a mesh size that is too small, which is 0,3 cm, so that many small fish that are not mature are caught.
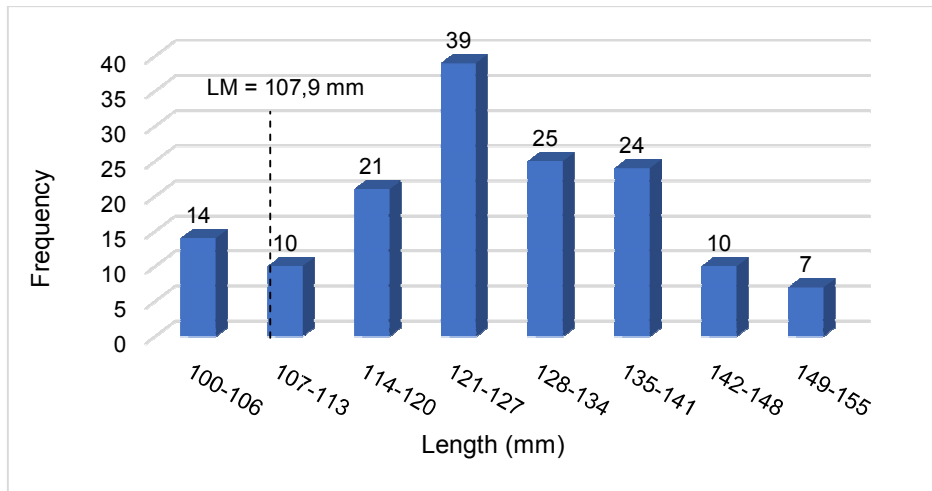
Fig. 2. The distribution of fringescale sardinella fork length
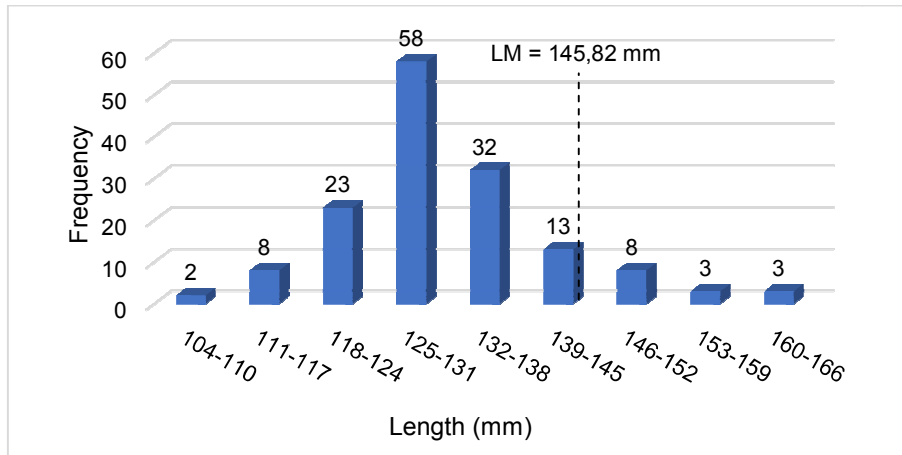
Fig. 3. The distribution of spotted sardinella fork length
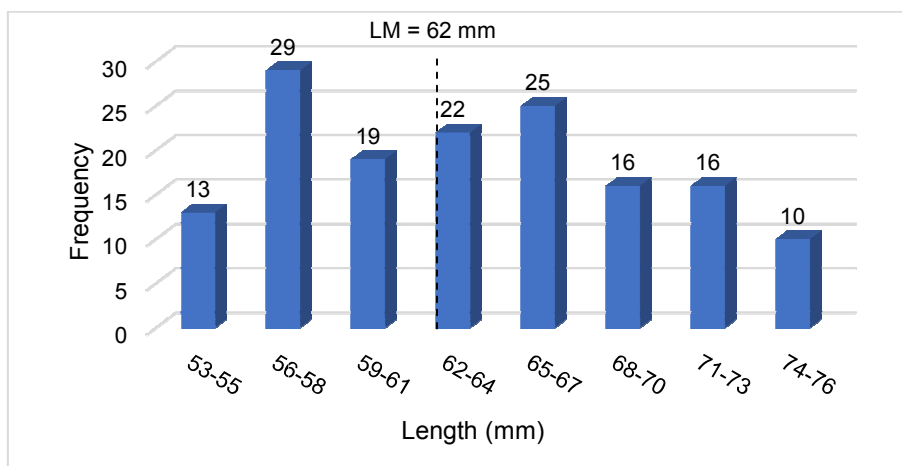
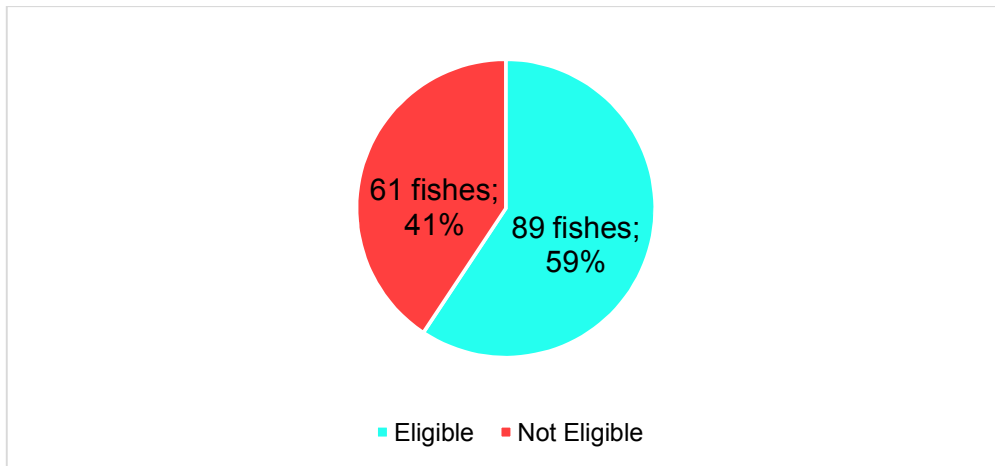

Fig. 4. The distribution of anchovy fork length

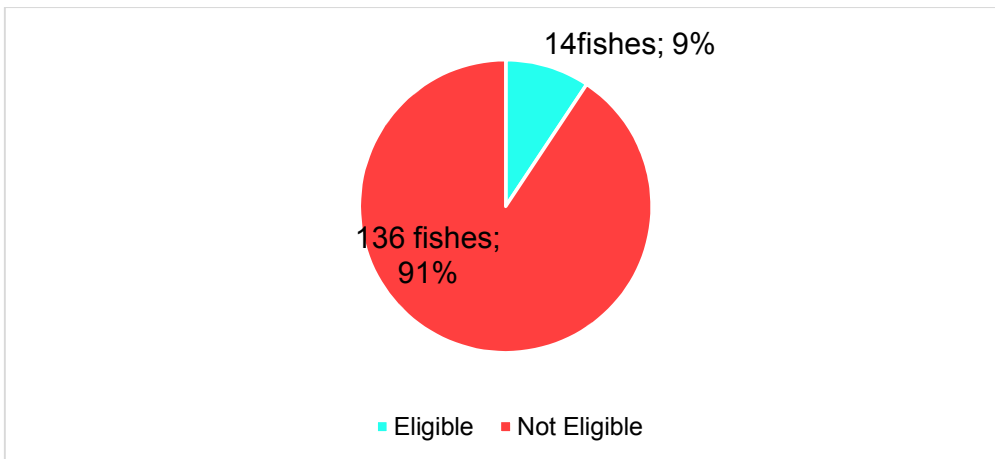**Fig. 5. The proportion of devis' anchovy that is eligible for catching**

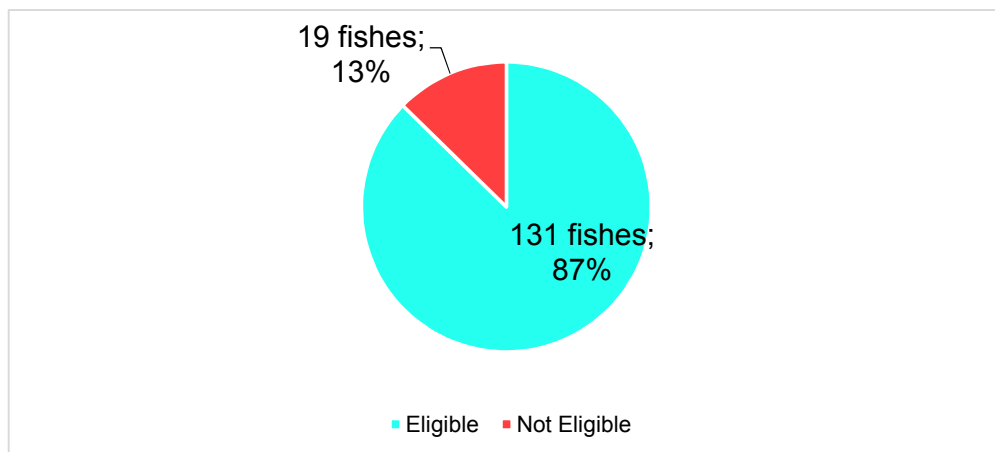**Fig. 6. The proportion of spotted sardinella that is eligible for catching**

Fig. 7. The proportion of fringescale sardinella that is eligible for catching

3.2 The Composition of Catch Utilization

Utilization of catch is a factor that can improve the level of environmental friendliness of a fishing gear. Some bycatch are utilized and some are not utilized by fishermen. The catch is usually used because of high economic value, safe for consumption and

demand by the community. Catch that are not utilized are usually not of economic value, dangerous to eat and less demanded by the community.

Catch caught are usually used by fishermen for sale and self-consumption. The catch sold is 388,1 kg (76,35%). The catch consumed is 114,9 kg (22,77%) (Table 5). Catch discarded are 4,4 kg (0,88%). The catch that are discarded of at the time of this research are due to the little weight that lacks economical value and the danger of the fish like pufferfish that is dangerous if consumed.

Overall, the catch obtained, both the main catch and bycatch, are mostly used by fishermen. Main catch utilized are 298,3 kg (100%), and bycatch used by fishermen are 201,7 kg (97,85%) and the bycatch that is not used is 4,4 kg (2,15%) from the total catch caught including pufferfish (*Tetraodo sp),* common ponyfish *(Leiognathus sp),* largehead hairtail

(*Trichiurus sp),* and yellowstrip scad *(Selaroides leptolepis).*

3.3 The Analysis of Environmental Friendliness Level

The analysis of environmental friendliness level of boat *bagan* is done to determine the level of friendliness to the environment of these fishing gear in order to implement sustainable fisheries in accordance with the provisions of responsible fishing practices.

The analysis environmental friendliness level can be seen from several parameters, namely the composition of the catch, the proportion of the main catch and bycatch, the proportion of fish eligible for catching, and the scoring value to determine the level of friendliness of the boat *bagan*. A summary of the results of an assessment of the level of environmental friendliness of the boat *bagan* unit is presented in Table 6.

Table 5. The utilization of main target catch and bycatch

Utilization		Main catch		Bycatch		Total	
		Weight (kg)	%	Weight (kg)	%	Weight (kg)	%
1	Utilized						
	On Sale	223,2	74,82	161,9	78,55	388,1	76,35
	Self Consumption	75,1	25,18	39,8	19,30	114,9	22,77
2	Not Utilized						
	Not Sold	0	0	0	0	0	0
	Discarded	0	0	4,4	2,15	4,4	0,88
Total		298,297	100	206,1	100	504,4	100%
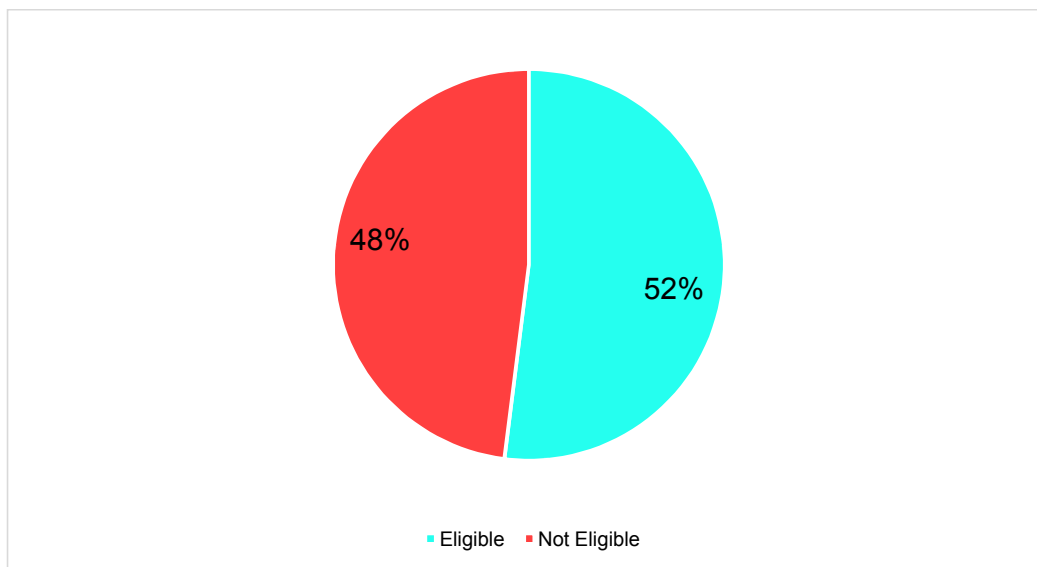
Fig. 8. The total proportion of catching eligibility

Table 6. Assessment results of the environmental friendliness level

Observation	Assessment	Criteria	Score
Main Catch	59%	Less environmentally friendly	2
Length at First Maturity	52%	Less environmentally friendly	2
Utilization of Catches	99,12%	Very environmentally friendly	4
Total Score			8

Based on the assessment of the level of environmental friendliness by using a score, the total score obtained from the three factors used is 8. 8 out of 6, 7 and 8, based on the scores obtained from the three factors used in determining the level of environmental friendliness of the boat *bagan*, the boat *bagan* in PPN Tanjungpandan is classified as less environmentally friendly.

The main catch of the boat *bagan* are devis' anchovy, spotted sardinella and fringescale sardinella as much as 298.3 kg (59%) of the total catch. According to [8], based on this proportion, the boat *bagan* unit is less environmentally friendly when viewed in terms of catch weight. The amount of bycatch obtained is too much. More than 3 species causes the selectivity value of the boat *bagan* is not environmentally friendly.

The level of environmental friendliness based on the length of the fork of the main catch can be seen from the long distribution of existing classes. Catching fish above the size of the first time the gonads mature can provide opportunities for the target fish to be able to reproduce and spawn before being caught, so the process of breeding and the phase of small fish into adult fish can run continuously. Thus, the determination of the eligibility of the fish to be caught is closely related to determining the level of environmental friendliness of the fishing operation. This is based on [10], that one of the selective fishing processes is that it does not endanger the sustainability of target fish resources. The number of fish eligible for catching during the research is 234 out of 450 fish of the target fish sampled, With a percentage of 52%, based on this information it can be seen that the target fish caught in the boat *bagan* mostly include fish that are eligible for catching, so the number of fish is eligible for catching is 52%, according to [8], the boat *bagan* is less environmentally friendly.

Based on the results of the study of environmental friendliness level of several criteria, it can be said that all criteria show less environmentally friendly, that is, if viewed from the composition of the catch and catch size, this is due to the size of the mesh used in fishing operations that is too small so that it can catch many non-target fish and can catch fish that are not yet eligible to catch. Boat *bagan* units operating in PPN Tanjungpandan have fulfilled Minister of Maritime Affairs and Fisheries Regulations No.71/2016 concerning Fishing Lane and the Placement of Fishing Equipment in the Fisheries Management Area of the Republic of Indonesia, so it is necessary to have law enforcement or legal rules in accordance with the implementation in the field so that the fishing gear is more selective so that it only catch the target fish, or renovates the boat *bagan* framework to increase its selectivity.

4. CONCLUSION

Based on the results of research on the environmental friendliness level of boat *bagan* fishing gear in Belitung Regency Waters, it can be concluded that the boat *bagan* catch during the study obtained 10 species including fringescale sardinella *(Sardinella fimbriata)*, spotted sardinella *(Sardinella sirm)*, devis' anchovy *(Stoleporus devisi)*, squid *(Loligo sp)*, short mackerel *(Rastrelliger brachysoma)*, common ponyfish *(Leiognathus equulus)*, largehead hairtail *(Trichiurus sp)*, and yellowstrip scad *(Selaroides leptolesis)*, large pelagic fish such as barracuda *(Sphyraena sp)*, and demersal fish was also caught such as pufferfish (Tetraodo sp).

Boat *bagan* fishing gear is classified as less environmentally friendly because 48% of fish caught was not mature, fish that are not the main target fish (bycatch) was 41%, and it catch more than 3 target fish species. However, the utilization of catch is quite good at 99,12%.

CONSENT

As per international standard or university standard, respondents' written consent has been collected and preserved by the author(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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