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Sustainable flying fish (*hirundichthys oxycephalus*) fishing with a drift gillnet in Makassar Strait, Indonesia

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Abstract. Flying fish is an important economic fish that many hunted fishermen, especially their roes. As a result, flying fish populations in the Makassar Strait was already experience high exploitation pressures. Gill nets were the dominant fishing gear with the net mesh size were varying depending on the season. The study aimed to compare the capture capability of gill nets with three different mesh sizes. The study used a field experimental approach to obtain gill nets selectivity on flying fish catch. Variables observed include different net mesh sizes (1, 1.25, and 1.5- inches), number, weight, and a fork length of flying fish catches. Data were analyzed using variance tests to compare treatments. The fish catch data shows that the highest fish catches were 1.25-inch, and the rest 1 inches and 1.5 inches. The results of the statistical test show that the number of catch fish is highly significant different ($P < 0.05$) on the mesh size of 1-inch, 1.25- inches, and 1.5- inches. There was an indication that flying fishes getting smaller, which is indicated by most of the fish catches, pass the length at the first maturity size. Gillnet of 1.25-inch mesh size should be used to maintain the sustainability of the flying fish population.

1. Introduction

Flying fish in the Makassar Strait waters have long experienced a decline in production as has been reported by some researchers: the utilization rate is already full to overexploited, have over-fishing with indicators such as decrease in production, catch per unit effort (CPUE), and maximum sustainable yield (MSY) [1,2], as well as [3] suggesting that there has been the highest utilization rate of sustainable potential. This also happened to the flying fish fishing in Takalar waters, indicating that the sustainability status is categorized less sustainably with the resulting index value of 30.93 [4]. The gill net is the most productive fishing gear for catching flying fish [5].

Flying fish in Makassar Strait were caught dominantly (86.45%) with gill net with mesh size were 1, 1.25, and 1.5 inches [2, 6]. Those gill nets were catching flying fish in mature gonad or spawning periods and a small portion of young fish. Furthermore, it was found the first maturity gonads of flying fish gonads *Hirundichthys oxycephalus* at the average length of 15.15 cm [2-7]. Flying fish fishing in Majene waters is generally done with drifting gill nets mesh size 1 and 1.25 inches intensively at peak fishing seasons while L_{50} (11.92 cm) and L_m (13.59 cm) for 1-inch mesh size were smaller compared to the length of the first mature gonad, in this case, most of the catch was still classified as



young fish [6,8]. Uncontrolled fishing can lead to disruption of the population's balance, due to the caught fish that have not spawned and mature gonad. The factors that threaten the decline of flying fish populations include excessive fishing effort, fishing gear which is not environmentally friendly, catching at spawning season, excessive catching fish at the reproductive phase [9].

In order to solve the problem, we deployed bigger gillnet mesh sizes to evaluate the selectivity of those gill nets as well as evaluate fish yield size compare to flying fish size at first gonad maturity. The purpose of this study was to analyze the fish yield of gill net with different net mesh sizes.

2. Material and methods

This research takes place in April 2017 until November 2017 in Somba Village, Majene District, West Sulawesi Province, Indonesia. The fishing ground at Majene waters around 10 – 20 miles away from the Somba village (figure 1).

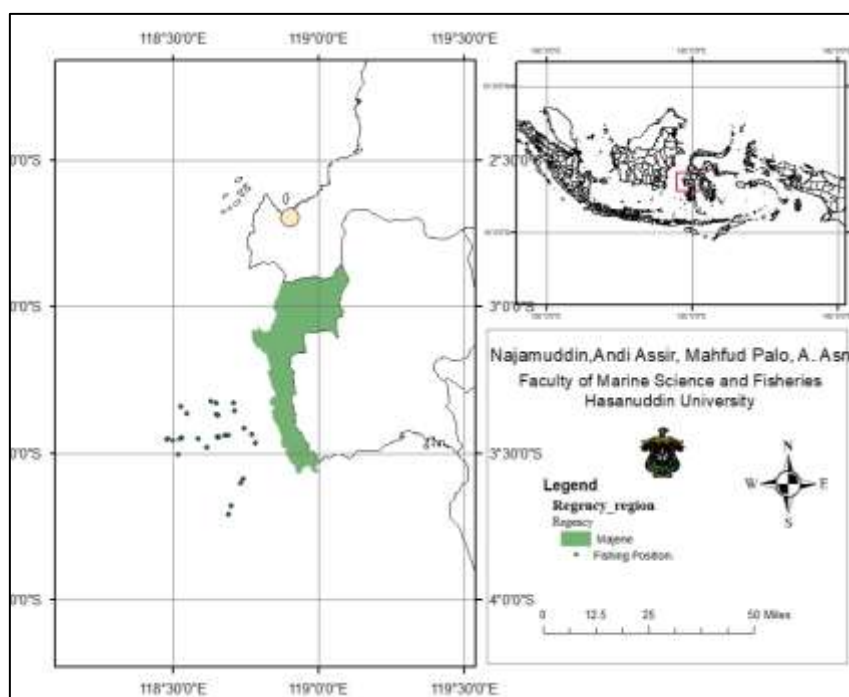


Figure 1. Research location at West Sulawesi Province

The equipment and materials used during the study were: a gill net with three mesh sizes 1, 1.25, and 1.50 inches, respectively, flying fishing unit, the sample measuring tools, fish samples, GPS, and map of the fishing area.

The fishing operation conducted in the daytime. The fishermen went out to the sea early in the morning. Moreover, it would take 2 hours to the fishing ground. Gillnet set for 20 minutes and then soaking for 2 hours. The gill net hauled and took out the fish from the net for about 30–60 minutes, depending upon the number of fish catches. After the hauling completed, fishermen observed the weather condition if the wave was not very rough, then looking for the new fishing ground and will take around 30 minutes. Net set again for the second time with the process as the first set. Usually, fishermen will return home base after the second net hauling and arrive at home around 2.00 pm. The fishermen will go fishing the next day if the weather looks safe for a trip. This experiment was conducted using the experimental fishing method, which is an experimental unit of drift gillnet with three mesh sizes 1, 1.25, and 1.50 inches respectively. Experimental units of 1 fishing unit and gill net were setting horizontally with three different net mesh sizes, conducted for six months in the fishing area. Different position placement of gill net mesh size was done randomly every day of fishing.

The main variables to be observed were the fishes caught, including the weight of the catch, the fork length, the position of the catching area, the water temperature, the salinity, the current velocity. The fish catch data were grouped based on the net mesh size.

The data of this study is primary data obtained by measuring the dimensions and construction of the net, the fork length, body circumference, the total weight of fish catches gill net of each mesh size and how to get the fish in the net mesh for each shortening value performed on each trip arrest. Capture and catch data (remaining units per trip) are used to analyze the difference in catches based on the mesh size.

The length of fish caught in the gills nets was grouped according to the mesh sizes and then presented in the histogram and analyzed descriptively. To analyze the difference in fish catches of each gillnet mesh size is used variance analysis. The calculation process is done with the help of the SPSS program, then continued with the LSD test [10]. In performing data analysis of research results used the following assumptions: (1) Every fish in the fishing area spreads evenly and has the same opportunity to be caught, (2) The design and construction of the net used in this study are the same, (3) Capture power, visibility, and mesh materials are the same

3. Results

Flying fishes caught at the fork length range 14.8 cm to 20.5 cm. Variations in size based on the net mesh size can be seen in Figures 2, 3, and 4. There is a positive correlation between the net mesh size and the size of the fish caught. At the size of 1-inch inches, the length of the dominant flying fish is caught in the range of 15.15-16.65 cm (figure 2), at 1.25-inch mesh size 17.65-18.65 cm (figure 3), and the 1.5-inch mesh size 19.65-20.15 cm (figure 4).

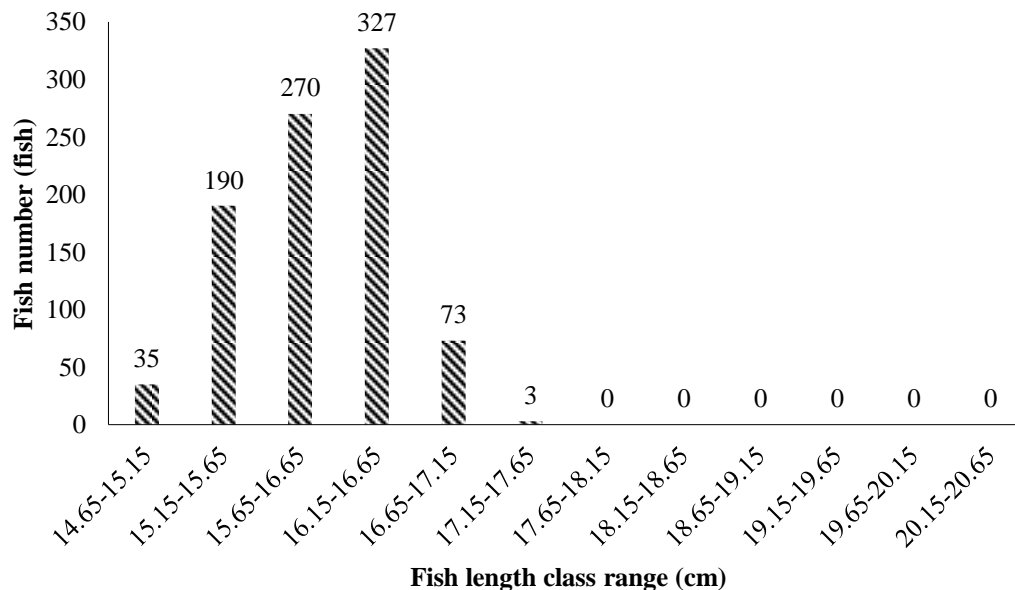


Figure 2. Length distribution of flying fish caught by 1-inch gillnet

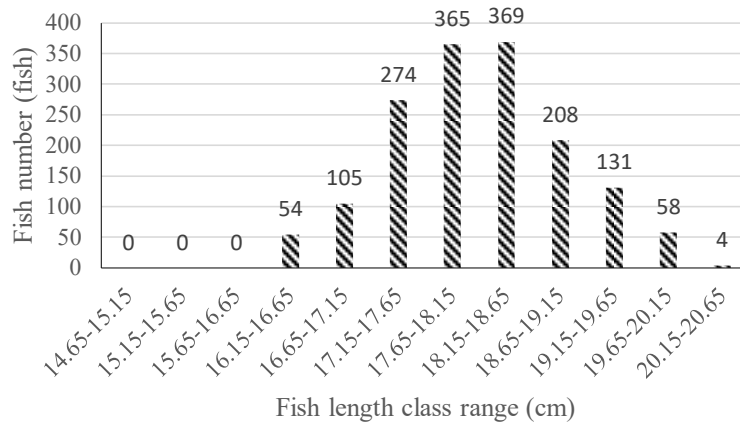


Figure 3. Length distribution of flying fish caught by 1.25 inches gillnet

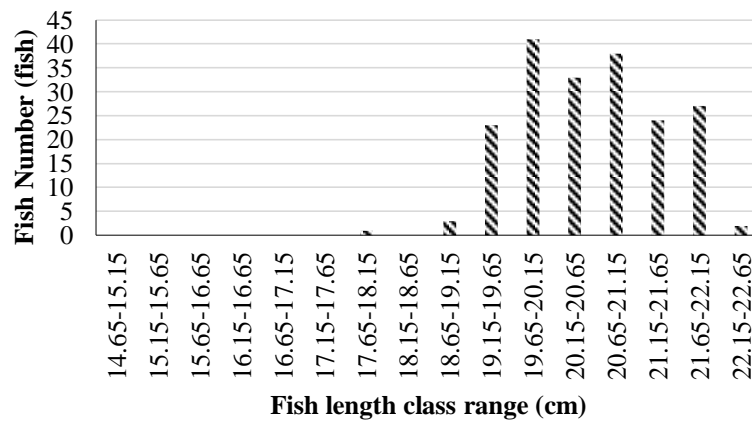


Figure 4. Length distribution of flying fish caught by 1.5-inches gillnet

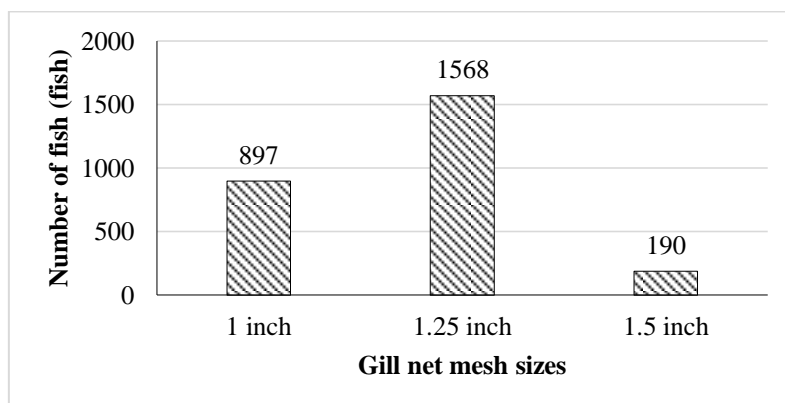


Figure 5. Number of fish catches based on net mesh size

The result of the present research that net mesh size of 1 inch caught 4.6% young fish. There was a trend that flying fish size decrease because of high fishing pressure. The flying fish were at first maturity gonad at length 15.15 cm [2].

The results of variance analyses showed that the difference in the net mesh size caused the number of flying fishes captured to be significantly different. Further LSD tests showed that the measurements of 1, 1.25, and 1.5 inches were significantly different.

4. Discussion

The distribution of the fish length that caught based on the net mesh size indicates that the larger the size of the net, the fish caught also tend to be larger (figure 2, 3, 4). This shows that in order to catch bigger fish, it is better to use a bigger net mesh size. However, it must also be seen from the tendency of existing fish resources and the potential of fishermen production. Gillnet fishing has been used successfully in analyzed selectivity an applied to many fish species [11-13]. Gillnet also very selective fishing gear so far fish catch at the gill net by gilled [12, 14].

The distribution of the size of the flying fish caught with gill nets shows that there are still flying fish that have never been spawn caught. Referring to [2] that the first-size matured gonad of fish flies 15.15 cm, the gonad's immature flying fish is caught in a 1-inch-mesh size net of 4.6%. This amount is relatively insignificant compared to some other fishing gear. While on the gill net, the mesh size of 1.25 and 1.5 inches is 100% past the original size of gonad maturity.

The number of catches between 1 inch, 1.25-inch, and 1,5-inch nets was significantly different ($p < 0.05$). So, in order to support sustainable fisheries, it is recommended to use the mesh size 1.25 inch.

The number of catches between 1 inch and 1.25-inch nets is not significantly different to support sustainable fisheries. It is recommended to use the mesh size 1.25 -inch. The 2.54 cm, 3.18 and 3.81 cm gill net operated in this study caught the flying fish of *Hirundichthys oxycephalus* type with a range of 14.5 to 20.5 cm long ranges similar to that of *H. oxycephalus* caught in southeastern coastal waters of Taiwan in 2009 of 13.3 - 22.9 cm with a gill net size of 2.8 cm, 4.0 and 5.6 cm [15], as well as *H affinis* captured in the waters of Barbados that is 14.0 - 24.8 cm in the gill size of mesh size of 2.54 cm, 3.18 cm, 3.81 and 4.45 cm [14]. However, it is somewhat different from the *H affinis* captured on the northeast coast of the Brazilian waters of total length in the range of 23.4 - 29.5 cm [17] and *H. oxycephalus* in the waters of Kaimana, East Seram and Fak-Fak with total length range 18.7 - 28.4 cm [18].

In this study also found that the gill net mesh size of 2.54 and 3.18 cm obtained a considerable catch of 46.8 and 45.9%, respectively, which is different from the results of Mahon et al. [14] study that the largest catch is obtained in gillnet size 3.18 and 3.81 cm respectively of 37.4 and 48.6%, indicating that *H affinis* in Barbados are larger than *H. oxycephalus* in the waters of Majene Strait Makassar. The size differences among places could be affected by the oceanographic condition and fishing pressure. As fishing pressure increase the fish size tend to decrease as a biological response to maintain their population [19-21].

The result of calculation of CPUE of the net mesh size of 2.54 cm is 13.15 kg hauling-1, 3.18 cm of mesh size 19.89 kg per hauling and mesh size 3.81 cm of 4.07 kg per hauling smaller than CPUE obtained by Palo [8] equal to 98.52 kg per hauling for the net mesh size 2.54 cm, 60.53 kg per hauling for mesh size 3.18 and 9.37 kg per hauling for mesh size 3.81 cm. This is allegedly caused by research conducted only observing the catch of flying fish species *H. oxycephalus* while Palo [8] for all types of flying fish caught. Similarly, in the coastal waters of Sri Lanka in January-April 2004 [16], obtaining CPUE in the range of 102 ± 37.8 to 224 ± 82.7 kg boats per day also with catches of all types of flying fish. From both kinds of research, the use of variations of mesh size for the fly mentioned above fishing shows a tendency to decrease the value of CPUE by increasing the net mesh size. However, most of the fish catches pass the size at the first gonad maturity, that means sustainable in term of size.

Sea not only as a physical environment but also has the spirit and strength which gives a reaction that can hurt or harm if treated well. The views *patorani*, especially *punggawa-sawi*, emphasizing the form of respect for what he has given they live in the ocean and fly fishing [13].

In the future, the government should employ collaborative measures at a regional level, including quota allocation based on scientific evidence, in order to maintain ecosystem balance and ensure the sustainability of fish resources. Activities to promote seafood, and the catching of adult fish on a large

scale, must be stringently managed according to the number of resources available. Finally, the most appropriate and least risky approach is to designate flying fish spawning grounds as marine protected areas [15].

The nets used today are similar except that the material has changed from cotton to monofilament nylon of stretched mesh size 41.3–44.5 mm (15/8–13/4 inches). Flying fish gillnets in Barbados differ from those used in other fisheries. They are hung such that the lead-line opens the mesh rather than closes it, and the hanging coefficient (the ratio of the length of the completed net to the stretched length of webbing used in it) is 1. A typical boat uses 2–3 nets of different mesh sizes (41.3–44.5 mm), 10–30m long, and 3m [21].

It is found out that the subgenus includes four species: oceanic *H. speculiger* from the Atlantic, Pacific and Indian Oceans, oceanic *H. indicus sp.n.* from the waters of the Indian Ocean, nerito oceanic *H. oxycephalus* from the waters of the Indo West Pacific and nerito oceanic *H. affinis* from Both within and outside of patches, flying fish occurred in schools Flyingfish fleets from eastern Caribbean islands presently fish across areas of both high and low *H. affinis* abundance. Moreover, *H. affinis* abundance did not appear to decrease towards the east or west boundaries of the survey area, suggesting that catch rates may be similar to current rates if fishing fleets expanded their present geographical range the Atlantic Ocean [20].

In the Caribbean islands, both within and outside of patches, flying fish occurred in schools flying fish fleets from eastern Caribbean islands presently fish across areas of both high and low *H. affinis* abundance. Moreover, *H. affinis* abundance did not appear to decrease towards the east or west boundaries of the survey area, suggesting that catch rates may be similar to current rates if fishing fleets expanded their present geographical range [22].

Flying fish fishing some time create conflict fishing ground due to open access and many fishing fleets complete to get fish and also fish roes. An appropriate management system should eliminate such a conflict. In this area, the conflict also arises when the fishing fleet from another village came with the main target flying fish roes. To implement the responsible fishing practice, the fishermen should use a gill net with 1.25 inches mesh size. Otherwise, the fishing pressure in this area will become higher and lead to over-exploitation.

The implications of this research are the basis for setting application standards for the application of responsible fisheries in research sites precisely and in Indonesia in general. The main problem faced so far in response to responsible fisheries is the reference to research results. It also can be used as a basis for references in other locations.

5. Conclusion

It can be concluded that the highest number of fish catches was 1-inch mesh size net, then 1.25 inch and 1.5 inches. The higher CPUE respectively were 1.25, 1, 1.5 inches net mesh sizes. There was no different significant number of fish catches between net mesh size 1 and 1.25 inches but significant with net mesh size 1.5 inch. It is recommended fishermen to use gill net mesh size minimum 1.25 inches to maintain fishing sustainability of flying fish.

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