Selectivity of drifting gillnet to *Hirundichthys oxycephalus* (bony flyingfish) in the Southern part of Makassar Strait

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Abstract. Flying fish is the main target for drifting gillnet fishing throughout the year in the Makassar Strait. In this fishing activity, *Hirundichthys oxycephalus* was the most dominant catch. This study used the experimental fishing by one experimental operating unit of drifting gillnet with mesh size of 2.54 cm, 3.18 cm and 3.81 cm within the study area. The difference of catches for each mesh size was analyzed by variant analysis then continued with the Tukey test, while net selectivity was analyzed by selectivity and CPUE (kg hauling^{-1}) curves. The results showed that the range of the fork length size of *H. oxycephalus* which was caught on the mesh size of 2.54 cm, 3.18 cm and 3.81 cm respectively was 13.6-17.5 cm, 16.5-20.5 cm, and 18.0-22.3 cm. The mesh size of 3.18 cm had a very significant effect on the weight of the catch, whereas the others mesh size had no effect. We also found that the optimum length of fish caught in the mesh size of 2.54 cm, 3.18 cm, and 3.81 cm were respectively 14.65 cm, 18.34 cm, and 22.97 cm, with the selection factor value of 5.7687. The highest CPUE was found in the mesh size of 3.18 cm following the mesh size of 2.54 cm and 3.81 cm. The mesh size of 3.18 cm was safe enough for capturing the fish considering the fish length of the first mature was 15.15 cm. This suggests that the mesh size of 3.18 cm was optimal for fishing the flying fish throughout study area.
Key Words: CPUE, mesh size, fishing gear selectivity, fishing gear design.

Introduction. Flying fish in the Southern of Makassar Strait have long experienced a decline in production as reported by several researchers (Ali et al 2004a; Ali et al 2004b). There has been an excess of catches with indicators such as decreased production, catch per unit effort (CPUE), and maximum sustainable yield (MSY) (Ali 2005; Ali et al 2005). The sustainability status of flying fish fisheries is categorized as less sustainable with the resulting index value of 30.93 in 2013 (Fitrianti et al 2014).

Hirundichthys oxycephalus is a prima donna of gillnets fishing in Southern of Makassar Strait with a unique characteristic of having relatively long pectoral fins, allowing them to fly at above the sea level. This fish has important economic value because in addition to being a consumption fish, it also produces eggs whose prices are much higher than the selling price of the fish. Based on that reason, *H. oxycephalus* was used as one of the leading commodities of the main export of fisheries in the Southern of Makassar Strait (Zainuddin 2011).

The fishing operation of *H. oxycephalus* in the Southern of Makassar Strait generally uses drifting gillnets with mesh size of 2.54 and 3.18 cm which are very intensive throughout the year. The operation of the 2.54 cm mesh size drifting gillnet catches small size *H. oxycephalus* which is not yet mature and has no time to spawn so it is feared that there will be a decrease in production due to overfishing (Palo 2009).

In this study, we did the H. oxycephalus capture test with mesh size of 2.54, 3.18 and 3.81 cm to obtain a more selective mesh size of gillnets against the size of H. *oxycephalus* as stated by Hutubessy et al (2005) that gillnets include fishing gear with a high degree of selectivity and can guarantee sustainable flying fish fishing activities.

The research of gillnets selectivity for flying fish is still rarely done in the Southern of Makassar Strait. In an effort to develop more selective fishing gear for sustainable fisheries, this research needs to be done. In this study, efforts were made to determine the gillnet selectivity pattern, optimal fish length, selection factors and 50% length of catch.

Material and Method. This research was conducted using experimental fishing methods, namely one experimental unit of drifting gillnet with the mesh size of 2.54 cm, 3.18 cm, and 3.81 cm which was operated in a fishing area of 56 trips in April-August 2017. The choice of fishing ground was carried out in 2 areas in Southern of the Makassar Strait. Somba as a fishing base of this research is the capital of Sendana Subdistrict, one of the coastal sub-districts in Majene Regency, West Sulawesi Province, which is located at coordinates 03^{o}22'51.8" S and 118^{o}50'47.8" E. The fishing area of drifting gillnets for the capture of *H. oxycephalus* is in the Southern of Makassar Strait, in 2 areas with coordinates of 2^{o}13'44.40" - 2^{o}35'31.20" S and 118^{o}31'15.60" - 118^{o}57' 14.40" E in the northern area and 2^{o}57'50.40" - 3^{o}53'45.60" S and 118^{o}7'4.8" - 118^{o}46' 19.20" E in the southern area as shown in Figure 1.

The main variables observed were H. *oxycephalus* weight and fork length captured on each mesh size of the tested gill nets as well as the length of the viable catch of H. *oxycephalus*. The difference in catch weight for each mesh size of gill nets was assessed by analysis of the SPSS variant program (Pratisto 2009) then continued with the Tukey test (Steel & Torrie 1989), while the size of the fork length for net selectivity was analyzed by selectivity curves.

In analyzing the catch per unit effort (CPUE), the catch data was used (kg) and the amount of effort (hauling) is the catch per unit effort (Ricker 1958):

$$CPUE = C/f$$

where: C = catches (kg);
f = effort (hauling).

Net selectivity was determined by using the catch length of each net through the selectivity curve (Sparre et al 1989):

$$S(L) = \exp\left[-\frac{(L-Lm)^2}{2\times S^2}\right]$$

where: S (L) = the chance of fish with a length of L caught in a net;
Lm = optimum length;
L = the length of the fish caught;
S = general standard deviation.

$$S.F. = -2\sum_{i=1}^{n-1}[a(i)/b(i)]\times\left[m(i)+m(i+1)/\sum_{i-1}^{n-1}\left[m(i)+m(i+1)^2\right]\right]$$

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n-1}\frac{2\times a(i)\times[m(i+1)-m(i)]}{b(i)^2\times[m(i)+m(i+1)]}}$$

$$Lmi = S.F.\times mi$$

where: SF = selection factor;
s = general standard deviation;
Lm = optimum length;
a = intercept;
b = slope;
m = net mesh size.

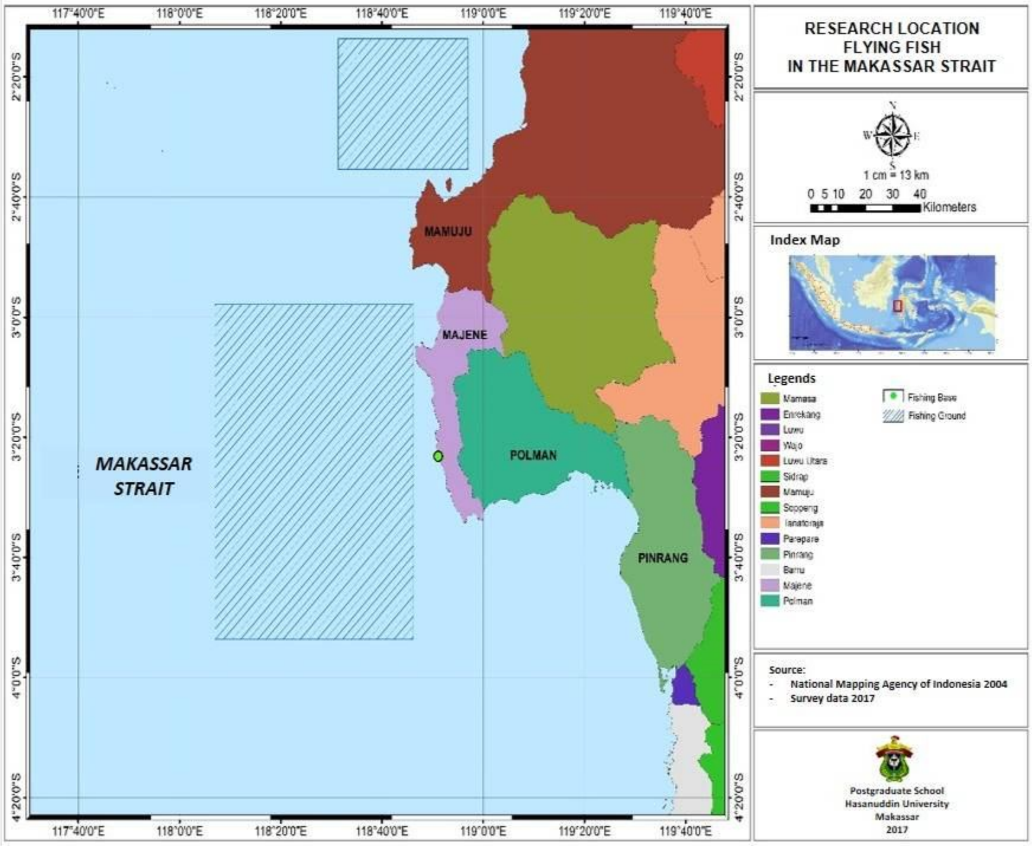

Figure 1. Fishing areas of drifting gillnet in the Southern of Makassar Strait.

The design of drifting gillnet which was operated in the trial of fishing H *oxycephalus* has the mesh size of 2.54 cm, 3.18 cm, and 3.81 cm with specifications and designs as shown in Table 1 and Figure 2.

Table 1

Specifications of drifting gillnet were used in the study

Variable	*Unit*	*Mesh size (cm)*		
		2.54 cm	*3.18 cm*	*3.81 cm*
Net length at top edge	m	70	70	70
Length of head line	m	42	42	42
Upper shortening	%	40	40	40
Floats number	float	85	85	85
Distance between floats	cm	50	50	50
Number of meshes between floats	mesh	32 & 33	26 & 27	21 & 22
Net length at lower edge	m	70	70	70
Length of foot line	m	43.4	43.4	43.4
Lower Shortening	%	38	38	38
Number of sinkers	sinker	92	93	94
Distance between sinkers	cm	47.7	47	46.7
Number of meshes between sinkers	mesh	30 & 31	23 &24	19 & 20
Number of mesh deep	mesh	70	56	47
Extra buoyancy	%	40	40	40
Net height	m	1.42	1.42	1.42

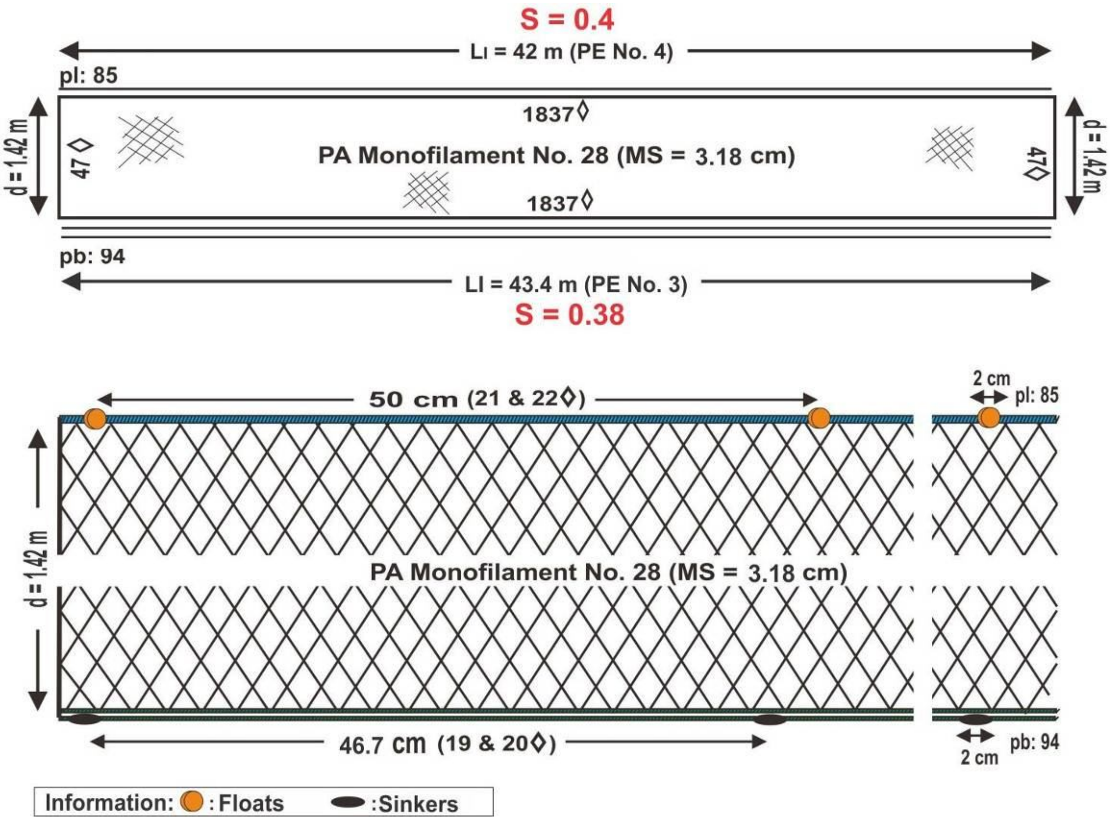

Figure 2. The gill net design of mesh size 3.18 cm was test.

Results. The weight of the catch per hauling of gillnet of mesh size 2.54 cm, 3.18 cm, and 3.81 cm respectively is in the range of 0.17-2.9 kg, 0.47-8.93 kg and 0-1.56 kg respectively with an average of 0.9489 kg, 3.1123 kg and 0.5239 kg. Figure 3 shows the comparison of the weight of the catch based on the mesh size. The results of the variance analysis found that the mesh size had a very significant effect on the weight of the catch. The Tukey test also showed a very significant difference between the catch weight of the mesh size of 3.18 cm with the mesh size of 2.54 cm and 3.81 cm, while the mesh size of 2.54 cm was no different from the mesh size of 3.81 cm.

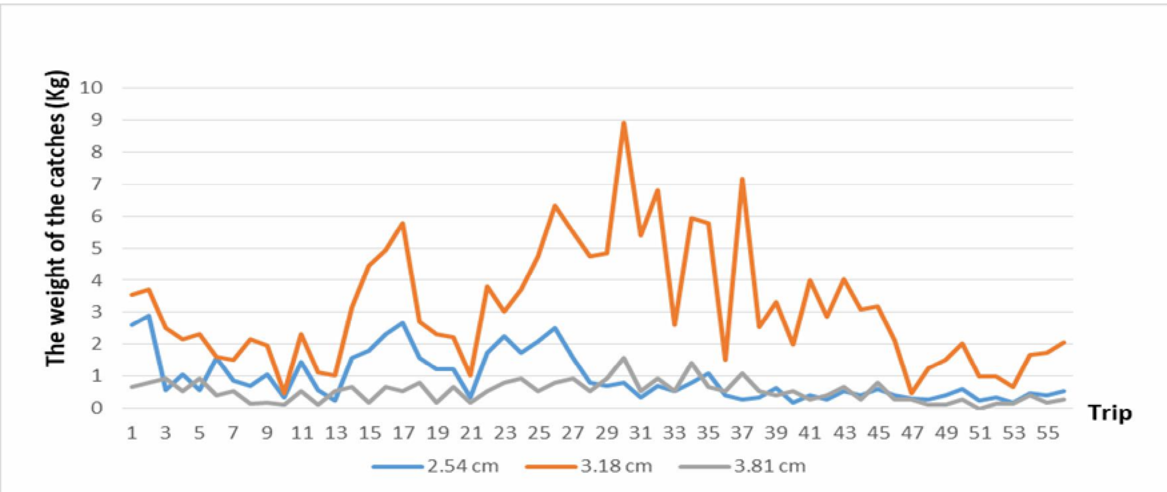

Figure 3. The comparison of the weight of the catch (kg) in mesh size of 2.54 cm, 3.18 cm and 3.81 cm per trip.

The fork length size of H *oxycephalus* which was caught in all three gillnets starts from the fork length classes 13.6-14.1 cm to 22.0-22.5 cm with the details of mesh size of 2.54 cm in the range of classes 13.6-14.1 to 17.2-17.7 cm with the highest frequency in the fork length classes 16.0-16.5 cm, mesh size of 3.18 cm with the range of classes 16.0-16.5 to 20.2-20.7 is the highest frequency in the class range 18.4-18.9 cm, while the mesh size of 3.81 cm with the class range 17.8-18.3 to 22.0-22.5 cm the highest frequency is in the class 20.2-20.7 cm (Table 2). In this study, it was also found that on the fork length of 16.3 cm H. *oxycephalus* had laid eggs, while the proper length of the catch of H *oxycephalus* must be greater than 15.15 cm (Ali 2005).

Table 2

The frequency of H *oxycephalus* caught in the fork length classes of each mesh size

Length range (cm)	*Mesh size (cm)*		
	2.54	*3.18*	*3.81*
13.6 - 14.1	2	0	0
14.2 - 14.7	6	0	0
14.8 - 15.3	55	0	0
15.4 - 15.9	310	0	0
16.0 - 16.5	447	55	0
16.6- 17.1	87	129	0
17.2 - 17.7	8	346	0
17.8 - 18.3	0	432	1
18.4 - 18.9	0	453	2
19.0 - 19.5	0	365	24
19.6 - 20.1	0	98	35
20.2 - 20.7	0	5	55
20.8 - 21.3	0	0	46
21.4 - 21.9	0	0	41
22.0 - 22.5	0	0	24
Number of samples	915	1883	228

The average of CPUE (kg hauling^{-1}) in Figure 4 for mesh size of drifting gillnet 3.18 cm was 3.11 kg hauling^{-1}. It was greater than the mesh size of 2.54 and 3.81 cm with the CPUE respectively of 0.95 kg hauling^{-1} and 0.52 kg hauling^{-1}.

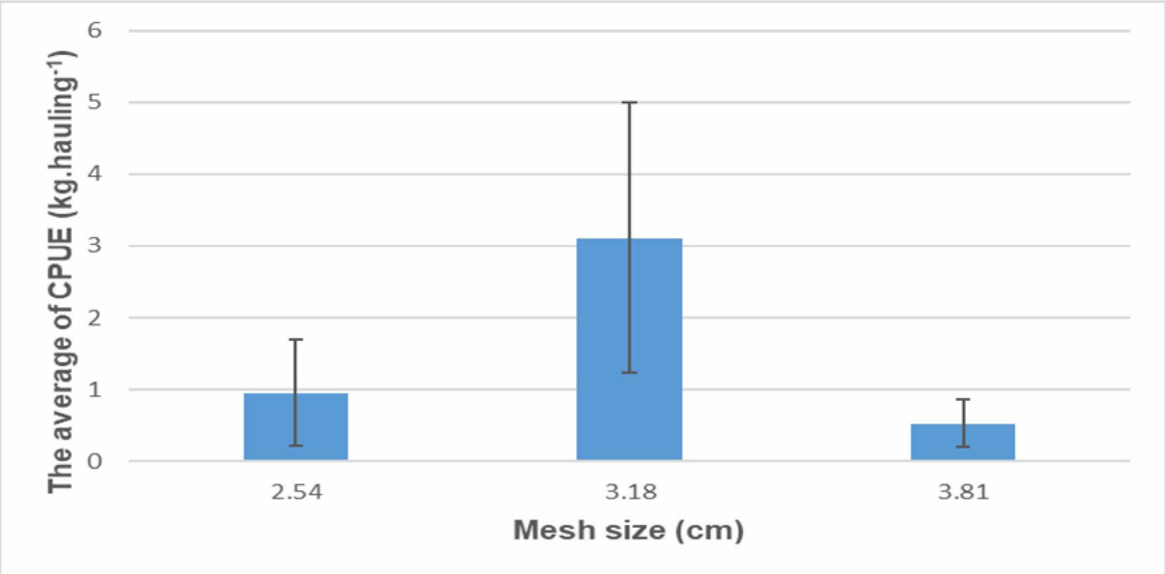

Figure 4. CPUE (kg hauling^{-1}) value of mesh size of 2.54 cm, 3.18 cm, and 3.81 cm.

The selectivity curve (Figure 5) was obtained from the calculation results with the empirical equation of the selectivity curve (Sparre et al 1989). The curve can be used to see the chance of catching H o*xycephalus* at the desired size in accordance with the purpose of fishing.

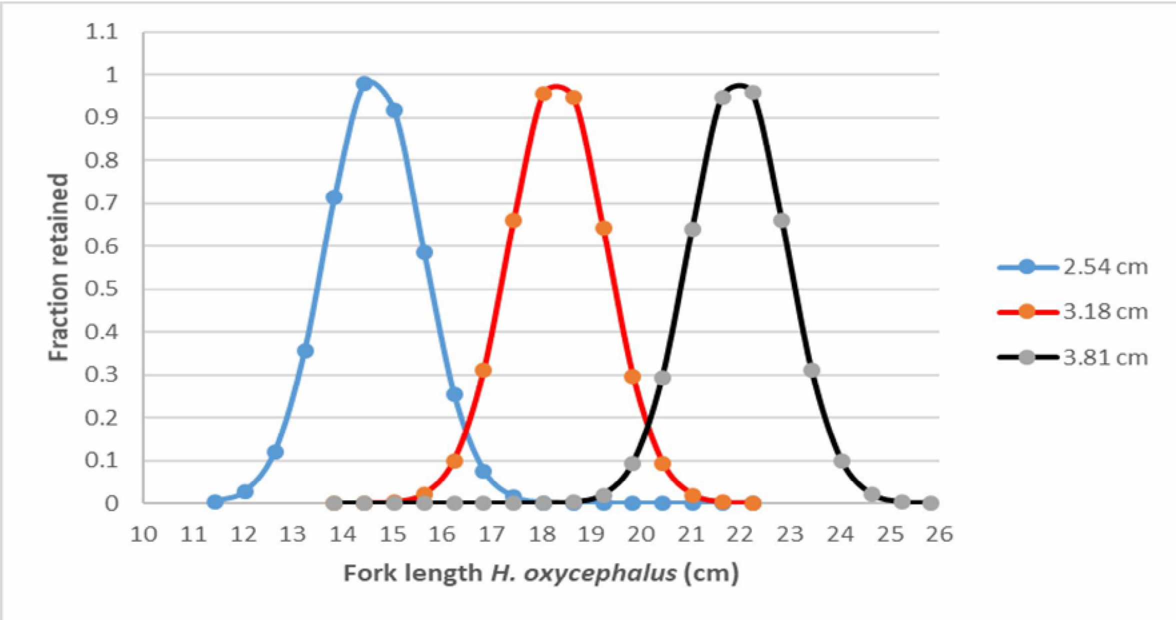

Figure 5. Gillnet selectivity curve with the mesh size of 2.54 cm, 3.18 cm, and 3.81.

Discussion. Flying fish caught by fishermen of drifting gillnets during the study was dominated by the *H. oxycephalus* as the target of this study; a similar thing was stated by Chang et al (2012) that one of the dominant flying fish species associated with kuroshio currents in the South China Sea was *H. oxycephalus*, as well as Tuapetel et al (2015) which obtained that *H. oxycephalus* was a dominating flying fish fishing of gillnet in the waters of Kaimana and Fak-Fak.

The average weight of catches with the mesh size of 3.18 cm was 3.11 kg larger than that of the mesh size of 2.54 and 3.81 cm namely 0.95 and 0.52 kg. This result was different from Mahon et al (2000) in Barbados who got the highest average catch occurred in the mesh size of 3.81 cm for flying fish namely *Hirundichthys affinis*. These results can also indicate that the average catch of *H. affinis* in Barbados is greater than that of *H. oxycephalus* in the Southern part of Makassar Strait. Both of these phenomena showed that the mesh size and hanging ratio were very influential on selectivity (Kumova et al 2015).

H. oxycephalus in the Southern of Makassar Strait was generally caught with gillnets in the depth range of 0-1.4 m. This is consistent with Kai Chang et al (2012) who suggested that the flying fish caught was *H. oxycephalus* (48% in the range of 0-1.2 m), *Cheilopogon cyanopterus* (50% in the range of 0-1.2 m), *Parexocoetus brachypterus* (69% in the range of 0-1.2 m).

The average length of *H. oxycephalus* caught with gillnets in the Southern part of Makassar Strait was smaller than the flying fish namely *Cheilopogon nigricans*, *Cypselurus poecilopterus*, *Cheilopogon suttoni* for the mesh size of 3.4 cm was 18.9-26.8 cm, 16.4-24.3 cm, 18.9-29.7 cm (De Croos 2009a). As well as the *Cheilopogon unicolor*, *Cheilopogon cyanopterus*, and *Cheilopogon atrisignis* (25-33 cm) (Chang et al 2012) and size of *H. oxycephalus* caught in Kaimana waters (19.5-24.3 cm), East Seram (20.6-28.4 cm) and Fak-Fak (18.7-24.3 cm) but suspected the catches were the flying fish which will or have spawned based on the principle of the fishing gear used (Tuapetel et al 2015). But not the *Cypselurus poecilopterus*, *H. oxycephalus*, and *Parexocoetus brachypterus* (10-23 cm) (Chang et al 2012).

CPUE (kg hauling^{-1}) gillnet with the mesh size of 3.18 cm was greater than the CPUE of the mesh size of 2.54 and 3.81 cm, also still larger than CPUE of flying fish fishing on the northwest coast of Sri Lanka using gillnets with mesh size of 3.4 cm (De Croos 2009b). This was presumably because the size of *H. oxycephalus* in the Southern part of Makassar Strait was smaller than the size of *H. affinis* of Barbados waters with using mesh size larger than 3.81 cm more effective (Mahon et al 2000) and *Cheilopogon nigricans*, *Cypselurus poecilopterus*, *Cheilopogon suttoni* in the northwest coast of Sri Lanka using the mesh size of 3.4 cm (De Croos 2009a).

The selectivity curve of drifting gillnets showed that the variation in the length of the fish caught was suitable with the mesh size of gillnet. The curve can be used to see the chance of catching *H. oxycephalus* at the desired size according to the catch target as the using of gillnets with mesh size of 3.18 cm in the study site with *H. oxycephalus* catches of 97% suitable for capture. This is in accordance with Laevastu & Favorite (1988), that the size of fish caught will have a maximum value or reaching the optimum fish sizes. It will be important to get the commercial fish sizes (fish market).

Estimations of optimum length of the gill nets mesh size of 2.54 cm, 3.18 cm, and 3.81 cm were respectively 14.65 cm, 18.34 cm and 21.97 cm with selection factors 5.7687. The optimum length estimation for mesh size of 3.81 cm was still smaller than the optimum length of mesh size of 3.4 cm for *Cheilopogon nigricans* (22.7 cm) and *Cheilopogon suttoni* namely 23.6 cm in the northwest coast of Sri Lanka (De Croos 2009a), as well as Hutubessy et al (2005) in Naku waters, Ambon Island obtained an optimum length of 22.7 cm in a mesh size of 3.18 cm and 26.24 cm in mesh size of 3.81 cm for *C. suttoni* and *H. oxycephalus* as the dominant catches.

In order to get caught with a total catch above 50%, *H. oxycephalus* for mesh size 2.54 cm must had a fork length greater than 13.5 cm, for mesh size of 3.18 greater than 17.2 cm, while the mesh size of 3.81 cm larger than 20.8 cm. During the study, *H. oxycephalus* which was caught on the mesh size of 2.54 cm was 93.5% deserved to be caught, while the mesh size of 3.18 cm and 3.81 cm 100% the catch was worth catching, but the mesh size of 3.18 cm had a greater CPUE value than the mesh size 2.54 cm and 3.81 cm. In this study we also found that only 10.3% of *H. oxycephalus* which was caught in the mesh size of 2.54 cm had laid eggs while the mesh size of 3.18 and 3.81 cm were 97% and 100% respectively. The results of this study indicate that the mesh size of 3.81 cm was still quite safe to operate for the sustainability of the potential of flying fish resources at the study site considering the length of the first gonad ripe *H. oxycephalus* was 15.15 cm (Ali 2005), still smaller than L 50% even for all the catches.

Conclusions. We conclude that the total catch of drifting gillnet with the mesh size of 3.18 cm was higher than that of the mesh size of 2.54 cm and 3.81 cm. Based on selectivity aspects, we recommend to use gillnet with the mesh size of 3.18 to catch *H. oxycephalus* for sustainability of this resource in the Southern part of Makassar Strait. The mesh size of 3.18 cm was safe enough for capturing the fish considering the fish length of the first mature was 15.15 cm.

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