Growth rate, mortality and exploitation for managing bar-cheeked coral trout grouper *Plectropomus maculatus* (Bloch, 1790) in Lepar Island and Pongok Island waters, South Bangka Regency, Indonesia

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Abstract. Exploitation of bar-cheeked coral trout grouper (*Plectropomus maculatus*) has affected its biomass abundance where is impacted sensitively on fishing effort of the fish. This research was aimed to know the exploitation rate of *P. maculatus* and overfishing symptom of the species. The research was conducted from November 2016 to October 2017 in Lepar Island and Pongok Island waters with coordinates at 02°57'00"S and 106°50'00"E and 02°53'00"S and 107°03'00"E, respectively. The groupers were sampled in 845 fishing trap spots using simple random sampling method. Result of this research shows that frequency distribution of the fish has total length (TL) in range of 220-650 mm, asymptotic length (L_∞), growth coefficient (K), and average sea temperature (T) values are 655.18; 0.520; 28.6°C, respectively. Data processing used FISAT II Software derived formula for L_t = 665.18 $(1 – e^{[-0.520(t-t0)]})$, to = -0.133572, and M = 0.495292. The females are abundant on March and April, while males are abundant on March, April, May, July, September, and October. The fish spawn starting with March, so that recruitments are available from April to August. Total mortality value (Z), fishing mortality (F), and exploitation rate (E), are 2.58; 2.08; and 0.81, respectively with R^2 as 0.9977. Exploitation rate (0.81) of fishing by fishermen is higher than natural mortality, which shows that overfishing symptoms (over exploitation) have been taken place. Proposing management strategy is addressed to restrict fishing on March and April because those two months are surmised as main spawning times.
Key Words: *Plectropomus maculatus*, growth, mortality, spawning, overfishing, protogynous.

Introduction. The most dominant area as fishing ground for small scale fishermen is coral reef ecosystem. Grouper is a top predator that plays an important role in ecosystem function (Ranjeet et al 2015). Predator fish is able to control coral fish population size where the dependency of temporal density consists of mortality number, survival until adult, and fecundity (Hixon et al 2012). Temporarily, groupers exploitation at fishing season affects its biomass abundance. In the area of fishing grouper intensively, its abundance and biomass are dominated by small size fish and non-target fish indicating changes in competition and predation (Chiappone et al 2000).

Population structure of groupers relating to natality and mortality is able to be tracked through a set of analysis about the fish body sizes. The population structure of *Epinephelus diacanthus* by length-weight analysis showed the somber stock condition of groupers in southwest coast of India (Ranjeet et al 2015). Fish mortality as a result of fishing has to be noticed its impact on sustainability fish management effort. Grouper with low somatic growth is very sensitive on overfishing and other environmental disturbances (Kindsvater et al 2017). Fish biomass has high sensitivity on human disturbances especially fishing activity (McClanahan et al 2016). This is related with reproduction rate of the fish to replace the existing stock in nature in order to be a balance where its condition depends on consumed time for growing and mortality, including mortality as a result of fishing. Overfishing is able to decrease total biomass in long term eventually decreasing small scale fishermen income.

Population of bar-cheeked coral trout grouper *Plectropomus maculatus* (Bloch, 1790) (Allen 1999; Froese & Pauly 2017) becomes vulnerable as a result of exploiting by catching small and big sizes of the fish that can change the fish size composition in totally. This matter significantly will affect reproduction process because the fish size is correlating to sex, that is able to disrupt its spawning time at the spawning ground and fishing ground. A number of researches were conducted in several areas in Indonesia relating to growth parameters of groupers such as in Wakatobi (Alamsyah et al 2013), Teluk Cendrawasih National Park (Mudjirahayu et al 2017; Bawole et al 2017), however data presentment is only for several months so as samples do not represent all seasons in a year, and South Bangka Regency waters is not observed yet about *P. maculatus* population structure for all seasons. This research is needed to manage coral fish leading up to sustainability uses. This research was aimed to know the exploitation rate of the *P. maculatus*, and overfishing symptom of the fish in two islands waters, Lepar Island and Pongok Island, South Bangka Regency, Indonesia.

Material and Method

The location and the time of study. This research was located in small islands around Lepar Island and Pongok Island, South Bangka Regency – Indonesia. The location was distributed geographically between Lepar Island (02^{o}57'00"S and 106^{o}50'00"E) and Pongok Island (02^{o}53'00"S and 107^{o}03'00"E). The research was carried out during 12 months interval, from November 2016 to October 2017.

Methods. Field surveys used simple random sampling method by following fishermen boats to save costs. Fishermen work by diving to set and take up fishing traps about 1800 coordinate spots in a year (about 15-20 days per month, 5-10 coordinate spots per day). They use the traps with emerging times in fishing ground locations about 4-6 days, between 4.2 m and 40.8 m of water depth. The used fishing trap is a device forming like a pentagon pyramid without any bait. It is made from a ram wire where in each corner is enforced by rattan and tied with ropes. Its dimension are about 90 cm length (l), 84 cm wide (w), 30 cm height (h), 35 cm front buds (fb), and a tunnel for fishing enter the trap 52 cm length (tl), the opening mouth trap 25 cm in length (ml) and 12 cm in wide (mw) (Figure 1).

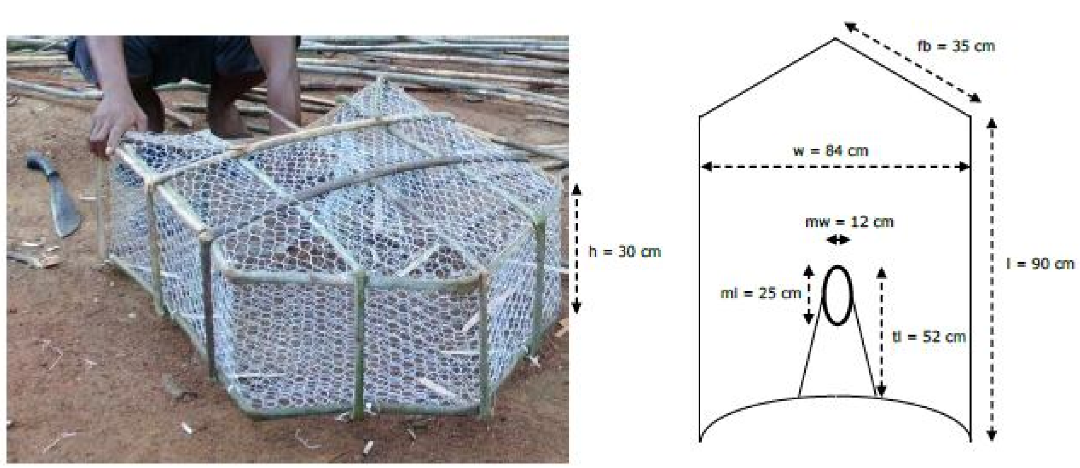

Figure 1. The used fishing traps in the research location.

Other tools and equipment aside from fishing traps were digital scales (SF-400; 10000 g), a roll meter (3m x 19 mm M-SMT-01 IWT), watch (s), scalpel, petri dish, digital camera (SJ CAM 4000 and BPRO BRICA), current meter (m s^{-1}), secci disk (m), boat ±5 GT completed with GPSmap 585 Garmin and a set of dive compressor for diving, Microsoft Office software, FISAT II, and ArcGIS 10.3.1. Length and weight data of *P. maculatus* catches were measured on the main land when those fishermen landing their boats. The used length was total length (TL) in mm unit and weight of fish in gram unit. Some of the fatty grouper fish had been dissected for gonad inspection. Additional data were measuring times, bathymetry, waters temperatures, water currents, and water brightness by using in-situ method, fish surgery, stakeholder interviews, and literature study.

Data analysis. Number of sampling spot coordinates used following formula (Krejcie & Morgan 1970):

$$n = \frac{\chi^2 . N . P(1-P)}{(N-1).d^2 + \chi^2 . P(1-P)}$$

where n is sample size, N is population size, χ^2 is a value of Chi-square, P is a population proportional, and d is estimation error.

Frequency analysis of length used FISAT II Software to derive growth parameter values through Elefan I procedure. The Von Bertalanfy growth with length of fish data used following formula (Sparre & Venema 1998):

$$L_t = L_\infty (1 - e^{[-K(t-t0)]})$$

where L_t is length of fish at age t (time unit), L_∞ is maximum length of fish theoretically (asymptotic length), K is growth coefficient (per time unit), t_0 is theoretical age when length is equal to zero.

Theoretical age of fish at length is equal to zero could be presumed separetly using Pauly empirical theory (Pauly 1983):

$$\text{Log}(-to) = -0.3922 - 0.2752 \log(L_\infty) - 1.0380 \log(K)$$

Natural mortality rate (M) was surmised by using formula:

$$\text{Log}(M) = -0.0066 - 0.279 \text{ Log}(L_\infty) + 0.06543 \log(K) + 0.4634 \log(T)$$

where t_0 is theoretical age when the fish length is equal to zero, L_∞ is asymptotic lenght, K is growth coefficient, M is natural mortality, and T is average sea surface temperature (^{o}C).

In acquering recruitment graphic we used FISAT II through Recruitment Pattern procedure with input values L_∞, K, and t_o. While to get total mortality (Z), fishing mortality (F), and exploitation (E) we used FISAT II by Mortality Estimation procedure, Length-converted Catch Curve by using the highest R^2 with input values L_∞, K, T, and Gulland (1983) states that $F_{optimum}$ is equal to M so that exploitation rate will be optimum ($E_{optimum}$) at 0.5. If the exploitation rate exceeds 0.5, that is claimed overfishing or over exploitation.

Results. Sample sizes are N = 1800, χ^2 = 3.841, level of confidence 95% at α = 0.05 and degree of freedom 1, P = 0.5, and d = 0.025 or 2.5%, respectively, so it is yield sample size as n = 829.1419 (rounded 830) coordinate spots. Sampling on average is derived 8 days per month with total samples about n = 845 coordinate spots exceeding minimum level about 830 coordinate spots. Sample size is determinated by using Slovin formula and Krejcie-Morgan to measure the proportion of the population (Setiawan 2007). The fishing traps used is a device forming like a pentagon pyramid without any baits. It is made from ram wire where in each corner is enforced by rattan and tied with ropes. Its dimension about 90 cm length, 84 cm wide, 30 cm height, 35 cm front buds, and a tunnel for fishing enter the trap 52 cm length, the opening mouth trap 25 cm in length and 12 cm in wide. Every coordinate spot is set two fishing traps and in a day, there will be 20 times of diving with hour works for each diver is about 5-10 coordinate spots for setting and taking up those traps. Average work hours spaning for fishing is about 8 hours starting from 09:00 until ending at 17:00 Western Indonesian Time. Those fishermen get break usually on Friday for praying and other social activities. The length, total and biomass of *P. maculatus* per month can be seen in Table 1.

Table 1

Number and biomass of *P. maculatus* per month

No	Month	Total length of fish (mm)	Total (individuals)	Biomass of the fish (kg)	Total length of dominant fish (mm)
1	Nov 2016	220-650	149	105.289	328-435
2	Dec 2016	230-530	120	81.530	328-435
3	Jan 2017	240-570	119	90.120	328-435
4	Feb 2017	300-570	95	78.857	328-435
5	Mar 2017	230-550	134	110.543	256-435
6	Apr 2017	220-540	155	101.189	292-435
7	May 2017	250-520	147	112.208	292-435
8	Jun 2017	230-510	121	81.404	328-399
9	Jul 2017	250-510	114	91.148	292-471
10	Aug 2017	230-550	136	94.281	292-435
11	Sept 2017	250-550	113	85.435	328-435
12	Oct 2017	250-530	172	146.624	328-507
	Total	220-650	1,575	1,178.628	

Source: Result of analysis 2017.

Based on the 12 months data, we can present information about fishing ground location map and bathymetry of submersing fish traps as seen in Figure 2.

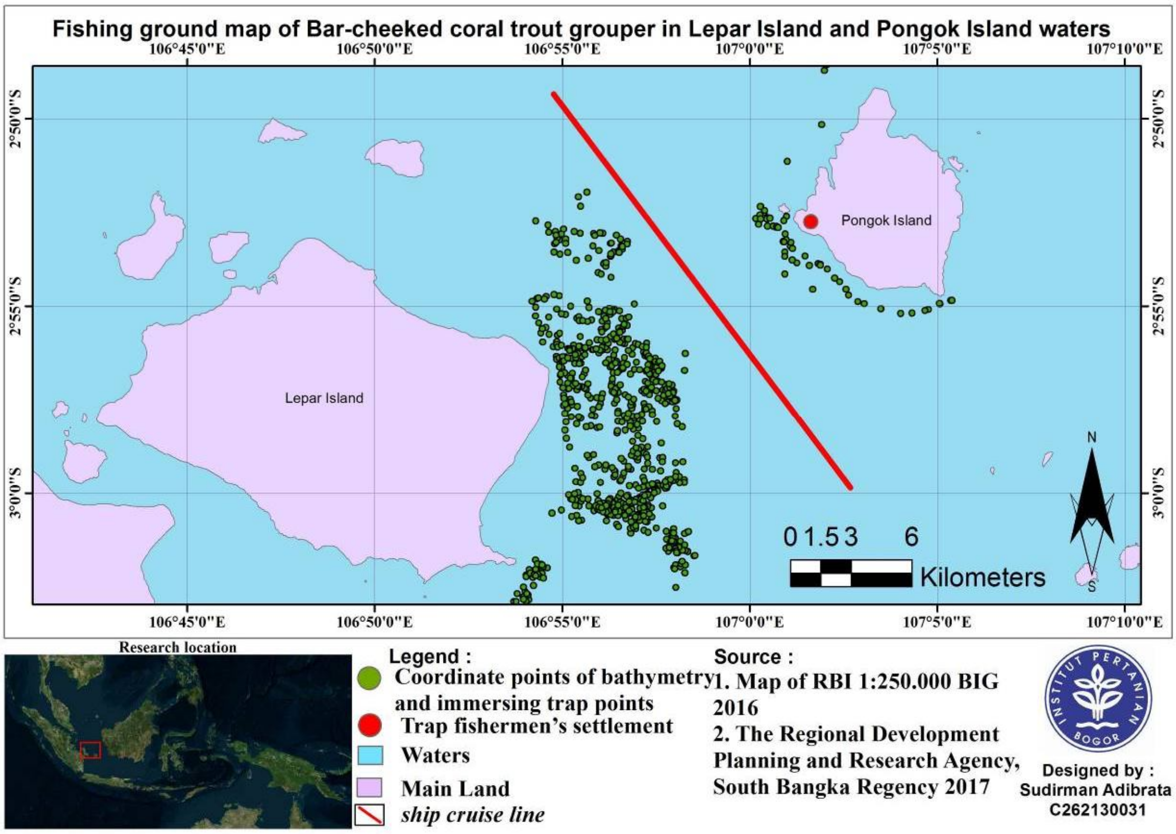

Figure 2. Map of fishing ground.

The length frequency distribution of *P. maculatus* during 12 months is presented in Figure 3.

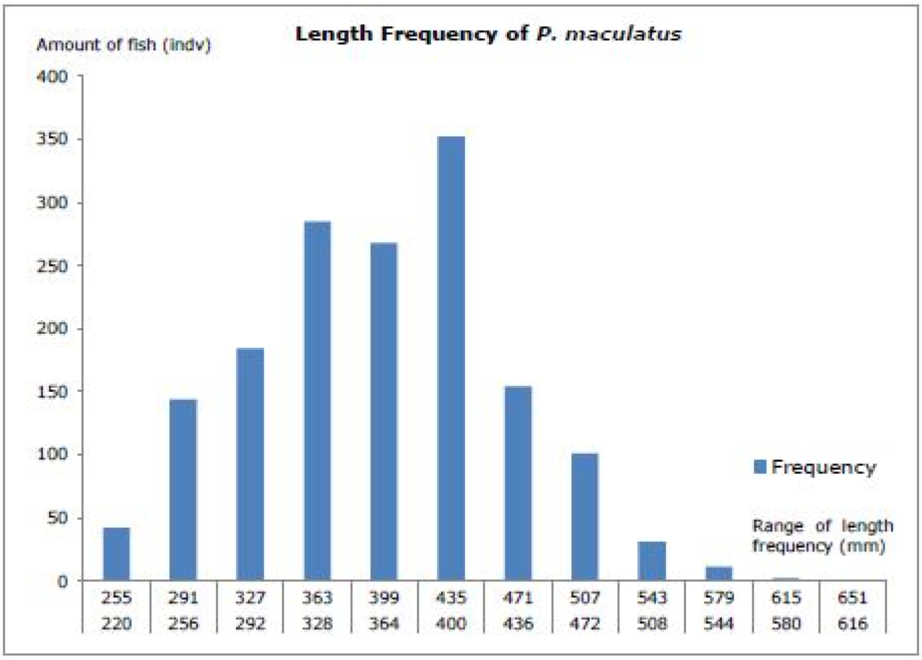

Figure 3. Length frequency of *P. maculatus*.

Based on the length frequency distribution of leopard coral grouper used FISAT II Software through Eleven I procedure is derived result as:

$$L_t = 665.18\ (1 – e^{[-0.520(t-t0)]})$$

Theoretical ages of fish (to) are obtained following result as:

$$\text{Log } (-to) = -0.3922 – 0.2752 \log (L_\infty) – 1.0380 \log (K)$$
$$\text{Log } (-to) = -0.3922 – 0.2752 \log (665.18) – 1.0380 \log (0.520)$$
$$\text{Log } (-to) = -0.874284$$
$$to = -0.133572$$

The growth rate of *P. maculatus* with input L_∞ = 655.18; K = 0.520; to = -0.133572 is presented in Figure 4.

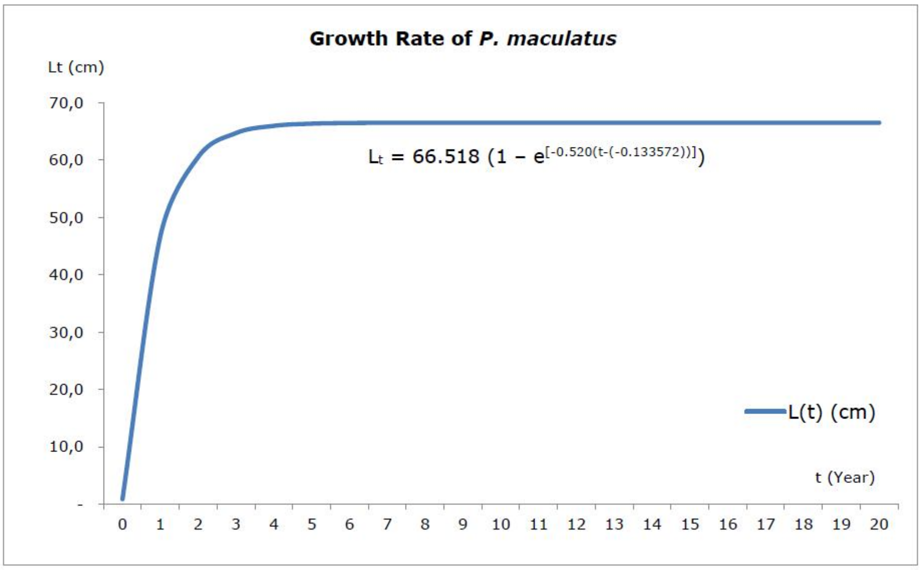

Figure 4. Growth rate of *P. maculatus.*

Fish recruitment is related to the adult fish. The recruitment pattern of *P. maculatus* is displayed in the FISAT II software with input L_∞ = 655.18; K = 0.520; to = -0.133572, is presented in Figure 5.

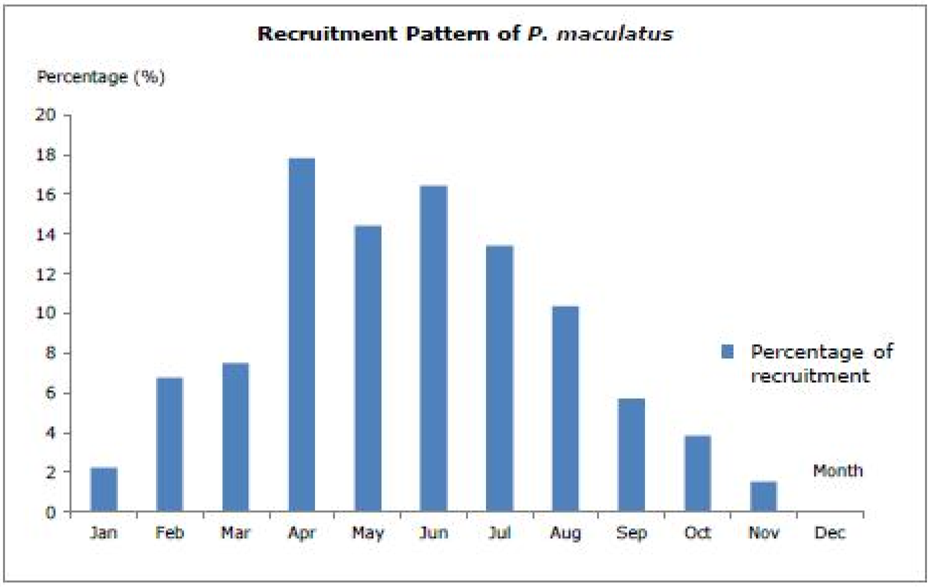

Figure 5. Recruitment pattern of *P. maculatus*.

Natural mortality rate (M) is derived following result as:

$$Log(M) = -0.0066 – 0.279 \; Log \; (L_\infty) + 0.06543 \; log \; (K) + 0..4634 \; log \; (T)$$

$$Log(M) = -0.0066 – 0.279 \; Log \; (665.18) + 0.06543 \; log \; (0.520) + 0.4634 \; log \; (28.6)$$

$$Log(M) = -0.305139$$

$$M = 0.495292$$

For total mortality value (Z), fishing mortality (F), and exploitation (E) of FISAT II with inputs L_∞ = 655.18; K = 0.520; T = 28.6°C; M = 0.495292 are attained as following values in Table 2.

Table 2

Values of exploitation and mortality of *P. maculatus*

No	*Z*	*F*	*E*	R^2
1	1.56	1.07	0.68	0.9376
2	2.08	1.58	0.76	0.9734
3	2.29	1.79	0.78	0.9763
4	2.43	1.93	0.80	0.9876
5	2.58	2.08	0.81	0.9977

Source: Result of analysis 2017.

Based on the Table 2 with R^2 0.9977 and Gulland (1983) that exploitation rate about E 0.81 is higher than 0.5 which infering can be said overfishing or over exploitation.

Discussion. Research location in Lepar district and Kepulauan Pongok district has areas about 172.31 km^2 and 89.67 km^2 respectively (BPS South Bangka Regency 2017). Uses of small islands in Indonesia are prioritized for purposes of conservation, education and training, research and development, seafarming, tourism, fishery and marine business and sustainable fishery industries, organic farming, livestock farming, and/or defense and security of nation (Laws No. 27 of 2007 jo Laws No. 1 of 2014). The two districts above were determined as capture and aquaculture fisheries centre of South Bangka Regency (Local Regulation of South Bangka Regency No. 6 of 2014). Fisheries and marine business and sustainable fishery industries include fishermen business that capture grouper by using fishing traps. Fishing ground location of fishermen as seen in Figure 2 can be accessed in one-day trip, go and back, from the fishermen's houses. The fishing ground in around Pongok Island waters can be reached for one-day trip only from the fishermen's houses, however sometimes there is strong wind blowing when those fishermen go to the or back from fishing. Fishing in further locations has began to be conducted although it is still rare where the fishermen have to stay overnight in near islands and provide enough food supplies.

Based on Table 1, frequency length distribution of *P. maculatus* has TL in range of of 220-650 mm. Frequency distribution graphic as shown in Figure 3 by using FISAT II Software derives formulas L_t = 665.18 (1 – $e^{[-0.520(t-(-0.133572))]}$) and it resulted growth rate graphic as in Figure 4 and recruitment graphic as in Figure 5. Based on Figure 4, the growth rate of *P. maculatus* indicates that the fish from t_o (birth of fish) to the second year, they grow quickly. Furthermore, the fish age from 2-4th year exhibits that they do not grow quickly again like the previous year. The growth rate of the fish after reaching 4th years points out that the growth of the fish is slow motion nearby asymptotic length (L_∞) where feeds are conversed to energy for motion and maintenance of body. Recruitment are fish with ages before entering the exploitation phase (Sparre & Venema 1998). The Figure 5 exhibits that the recruitment period is abundantly happened from April to August. *P. maculatus* is a protogynous hermaphrodite where the old female fish changes its sex becoming male (Kindsvater et al 2017; Easter & White 2016). There were no gonads found during dissecting some fatty groupers which means that those fish were males. According to information from the trap fishermen, they frequently dissect the rotten *P. maculatus* and find no gonads or fish egg inside. The rotten fish is not sold but discharged. Male fish is found having Gonad Maturaty Level (GML) I to GML IV (41-46 cm TL) and female fish has GML I until GML V (29-40 cm TL) (classification of GML is based on Tan & Tan (1974) in Alamsyah et al (2013), fecundity is in range of 13,950 to 880,892 eggs (Alamsyah et al 2013). Female is about ±30 cm standard length (SL) and male > 35.4 cm SL (Ferreira 1993), female having 476,000-6,962,000 eggs (Mayunar 1994). Based on TL of dominant fish (Table 1), the sample of fish suspected to be categorized as female (< 399 mm TL), male (> 435 mm TL), and plasticicity between female and male (399-435 mm).

The recruitment is linked to the existence of adult fish, the recruitment period on April to August and supposed that the spawning period on March to August and decreased in the following months. Those fish are supposed female that peak season happened from March to April. Furthermore, the fish that are presumed male are abundant in six months during a year such as March, April, May, July, September, and October. When the fish spawn starting with March, then it is reasonable that recruitment takes place on April to August.

Based on Table 2, the value of fishing mortality (F) 2.08 is higher than the natural mortality value (M) 0.495292. The high value of fishing mortality indicates that fishing activities conducting by fishermen is quite higher than the natural mortality rate. Furthermore, other indication also is shown by the high exploitation rate (E) as 0.81 that gives a consequence on overfishing symptoms (over exploitation) which has happened in the research area. While on the other hand, this exploitation rate is still high if it is compared to other conducted researches in other parts of Indonesia. Researches about exploitation rates of groupers have different values such as April to May 2016 in Cendrawasih Bay for species *P. maculatus* and *P. oligocanthus* are (E) 0.570, (E) 0.681, respectively (Mudjirahayu et al 2017), and April to May 2016 at the same location is (E) 0.530 for species *P. leopardus* (Bawole et al 2017). While the research conducted on January to June 2012 in Kolaka and Buton has a result of exploitation rate about (E) 0.70 for species *P. leopardus* (Landu 2013). The coral reef fish from WPP NRI 711 has (E) 0.88 (Kepmen KP No. 47 of 2016), and (E) 1.53 (Kepmen KP No. 50 of 2017). Results of those researches infer that in other locations above also overfishing have been happened. A low natural mortality and a high fishing mortality indicate overfishing is still taking place, so more young fish are captured than adult ones (Sparre & Venema 1998). Interviews to some fishermen in the research location inform that the catch biomass is increasing, while distance to be traveled to reach fishing ground is going further and also time consuming is high. This condition reveals that the production cost is increasing. The overfishing condition points out the fish mortality as a result of frequently fishing becomes a more destructive factor for population structure than natural one. This condition is not probably yet realized by local fishermen. Without any scientific studies relating to fishery management in the research location, there will be no any change to be carried out for a better direction and sustainable fishery.

Some theoretically and practically sustainable fishery management strategies have been proposed by many researchers. A precautionary approach is very important to be implemented in decreasing downside risks and provides opportunities for recovering of groupers (Epinephelidae) especially in the case of small scale commercial fisheries where management efforts and monitoring are less (Sadovy de Mitcheson 2016). Gruss & Robinson (2015) have mentioned that grouper *E. fuscoguttatus* population is able to increase in long term through recruiting subsidies when most of its spawning habits are protected. Fishing targets in aggregated spawning locations are the main risk contributors of the extinction for numerous grouper species (Robinson et al 2014). Separating aggregated spawning location with fishing ground needs advanced research where aggregated fish has to be monitored in detail including biological reproduction aspects and fishery oceanography aspects. Marine protected area becomes an alternative for facilitating stock recovery of overfished locations (Addis et al 2013). An effective fishery management depends on selective fishing methods, controlling fishing efforts, life history and mating system of species targets (Kindsvater et al 2017). Controlling on efforts of an exploited species requires various consideration especially biological sustainability and socio-economic aspects of fishermen. Gouezo et al (2015) report that to manage groupers and to protect its aggregated spawning locations in Palau applies closing catch seasons of the groupers for seven months in main spawning seasons and closing spatial seasons permanently for two locations of fish spawning aggregation. Various proposed practices about spatially and temporally management and learning from case studies in other locations or countries are able to become considerations to be implemented in the research location. Based on the consideration and analysis above, authors propose a management strategy to reduce the pressure on the resource of bar-cheeked coral trout grouper in the research location is that there is a need for restricting season of fishing in all fishing grounds during March to April which are presumably the two main spawning months.

Conclusions. The length frequency distribution of bar-cheeked coral trout grouper has total length (TL) in ranged of 220-650 mm and asymptotic length (L_∞), growth coefficient (K), and averaged sea temperature (T) values are 655.18, 0.520, 28.6^{o}C, respectively. Processing data using FISAT II Software results formula L_t = 665.18 (1 – $e^{[-0.520(t-(-0.133572))]}$). Fish are presumed being female and are abundant from March to April, while presumed male fish are abundant in six months such March, April, May, July, September, and October. The fish starts to spawn on March, and the young fish are being recruited on April to August. The natural mortality (M) is about 0.495292 and by using a FISAT II Software derives total mortality (Z), fishing mortality (F), and exploitation rate (E) values such as 2.58, 2.08, and 0.81, respectively, and R^2 = 0.9977. The fishing mortality value (F) is relatively higher indicating that fishing activity by fishermen in the research location is higher than the natural mortality. This value contributes an effect on increasing exploitation rate is about (E) 0.81 which implicates overfishing (over exploitation) symptoms which has occurred in the location. By this paper, a management strategy is proposed as a need for restricting fishing activities in all fishing grounds from March to April where those two months are surmised as the main spawning months.

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