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Population Dynamics and Exploitation Rate of Coral Grouper *Plectropomus leopardus* in the Sarappo Islands, Pangkep Regency, South Sulawesi

Ernaningsih, Asbar, Danial, A Hasrun and M Jamal

Department of Marine Resources, Faculty of Fisheries and Marine Science, Muslim University of Indonesia, Makassar 90231, Indonesia.

Email: ernaningsih36@yahoo.com

Abstract. The coral grouper *Plectropomus leopardus* is a fish which plays important ecological roles in coral reef ecosystems. It is also a well-known and sought-after commodity in both local and export markets, leading to pressure on wild *P. leopardus* populations. The aim of this study was to describe the population dynamics and determine the exploitation rate of coral grouper (*P. leopardus*) populations in the Sarappo Islands, Pangkep Regency South Sulawesi, Indonesia. Coral grouper samples from Sarappo Island were caught using hand-line gear. Class length and weight data were analysed using the Bhattacharya method, von Bertalanffy model and Pauly empirical equation incorporated in the FiSAT II program to determine growth rate, mortality, and exploitation rate. The length frequency distribution of coral groupers sampled had length class means ranging from 20.0 cm to 57.1 cm. The 30.1 cm midpoint class had the highest catch frequency (162 fish) while the 57.1 cm class had the lowest frequency (3 fish). The length-weight relationship indicated an allometric growth pattern ($b < 3$), with a growth coefficient (K) of 0.7. The total mortality (M), natural mortality (M) and fishing mortality (F) were 3.03, 1.28, and 1.75, respectively, giving an exploitation rate $E = 0.58$ which exceeded the MSY limit (0.5). Coral grouper (*P. leopardus*) size structure was dominated by fish with immature gonad indices, increase in body length was faster than weight gain, fishing mortality was high, and the rate of exploitation exceeded the sustainable limit.

1. Introduction

Plectropomus leopardus is classified amongst the groupers which play important ecological roles in coral reef ecosystems. It is known as a mesopredator in coral ecosystem food chains [1]. It also has been one of sought-after fisheries commodities for local and exported live fish product. Coral groupers have contributed significantly to commercial and recreational fisheries in the Sarappo Islands, providing an important source of income for local fishermen due to their high economic value in both local and international markets. Such a situation tends to place heavy pressure on wild populations, leading to overfishing [2]. The current level of fishing activity around nearby Lumulumu and Langkai Islands is high, and fish stocks status has been reported as overfished [3].

The coral grouper *P. leopardus*, also known as leopard grouper and coral trout, is listed in the Red List of Threatened Species as Near Threatened [4]. Like many mesopredators in the coral ecosystem, coral groupers are highly targeted by commercial, recreational, and subsistence fisheries [5]. Overfishing can lead to imbalance in coral ecosystems, particularly affecting diversity, and can



lead to the extinction of local species [6]. The increasing market demand for coral trout leads to high fishing intensity, and exceeding the maximum potential yield eventually leads to declining fish production. Hence, studies on population dynamics and exploitation rate are needed to understand the changes in fish populations through time, as well as providing estimates of key population dynamics parameters and greater insight into the current state of a stock, and can contribute significantly to fishing policy related to sustainability. This study aimed to determine the population dynamics and the exploitation of *P. Leopardus* in the Sarappo Islands.

2. Materials and methods

2.1. Sampling method

The sampling locations were representative coral grouper fishing grounds in the waters of the Sarappo Islands which form part of the Spermonde Archipelago (Figure 1). Conducted from February-October 2017, hand-line fishing gear was used for sampling, resulting in a total sample of 849 coral groupers (*P. Leopardus*). The length and weight of each fish were recorded.

2.2. Data analysis

Population dynamics and exploitation rate were analysed using the ELEFAN routine in FiSAT II [7]. Length data were analysed descriptively (graphically). The Bhattacharya method was applied for size class separation analysis, which also displayed several length frequency distribution cohorts, again using the FiSAT II program [10]. The length-weight formula $W=aL^b$ was determined using the linearized logarithmic transformation according to [7][9]:

$$\text{Log } W = \log a + b \log L$$

Where: W = body wet weight
 L = total length
 a and b are constants

The Growth parameter K was computed using Pauly's empirical equation [10]:

$$\text{Log } (-t_0) = -0.3922 - 0.2752 \log L - \log K$$

Total mortality (Z) [11][12] and natural mortality (M) [13] were estimated using equations

$$Z = \frac{K (L_{\infty} - L)}{L - L_c}$$

$$\text{Log } M = -0.0066 - 0.279 \log L_{\infty} + 0.6543 \log K + 0.4634 \log T$$

Where: L_{∞} = asymptotic length
 K is intrinsic growth coefficient
 T is average temperature by year ($^{\circ}\text{C}$)

Total mortality rate was obtained from the addition of natural mortality and mortality due to fishing pressure [14], enabling the exploitation rate E to be estimated [11], using the equations:

$$Z = F + M$$

$$E = \frac{F}{Z}$$

Length of fish at first capture (L_c) was estimated through catch curve analysis [13]. Relative yield per recruit Y/R and relative biomass per recruit B/R were estimated according to [11,14].

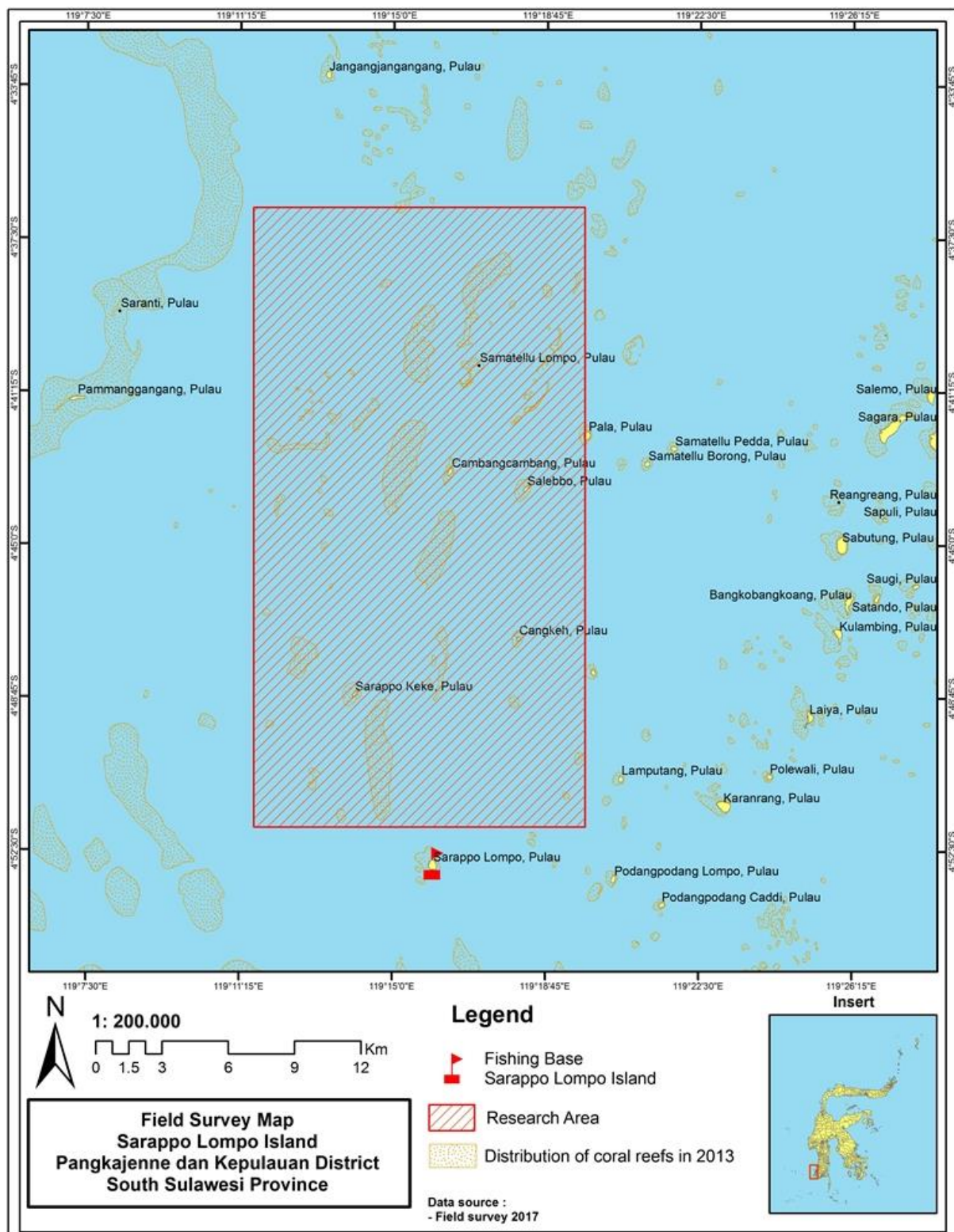


Figure 1. Map of the Study Area

3. Results

3.1. Size class

The length frequency distribution of the coral groupers sampled had length class means ranging from 20.0 cm to 57.1 cm (Figure 2). The most frequently caught class was 30.1 cm (162 fish) and least frequent was 57.1 cm (3 fish)

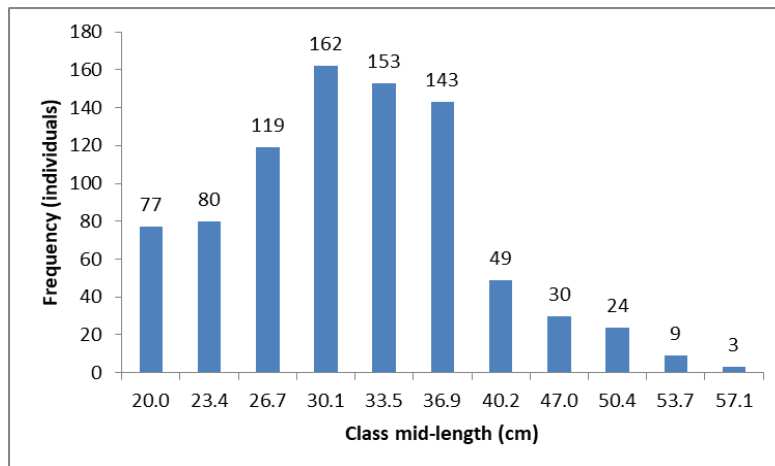


Figure 2. Length frequency distribution of coral grouper (*P. leopardus*) sampled

3.2. Length-Weight relationship.

The length-weight relationship of the 849 coral groupers sampled (Figure 3) resulted in the equation: $W = 0.22L^{2.23}$, ($r=0.88$). The growth pattern was allometric negative, as $b = 2.23$ ($b < 3$).

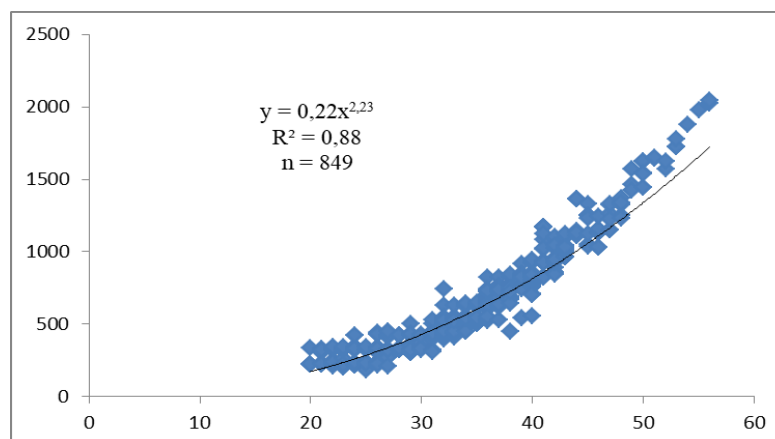
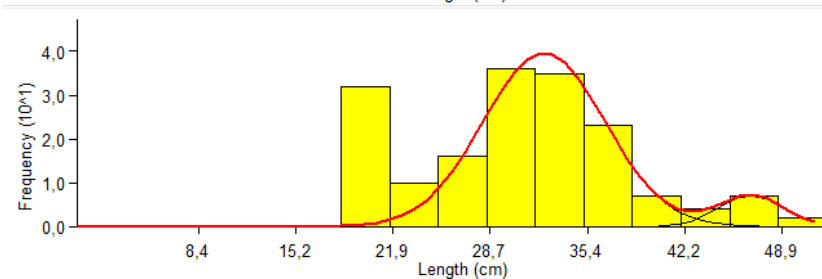
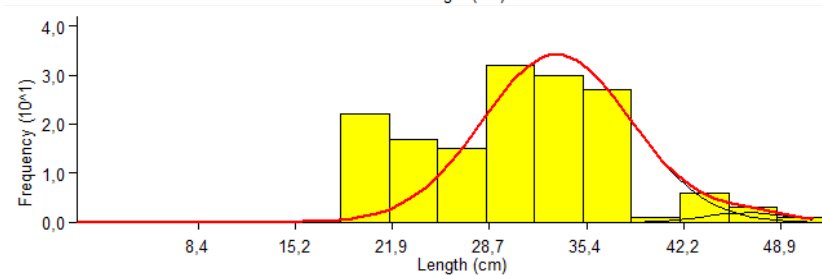
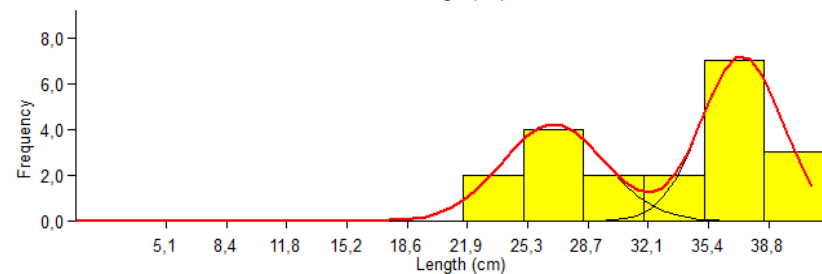
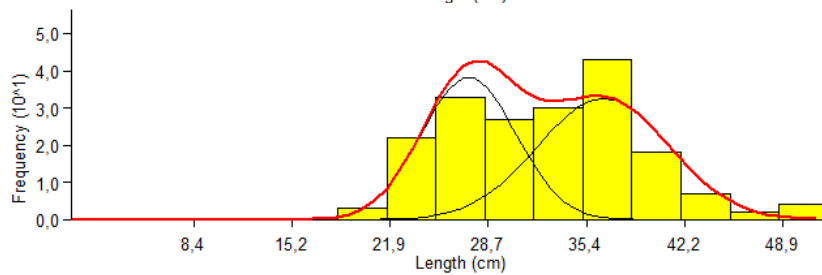
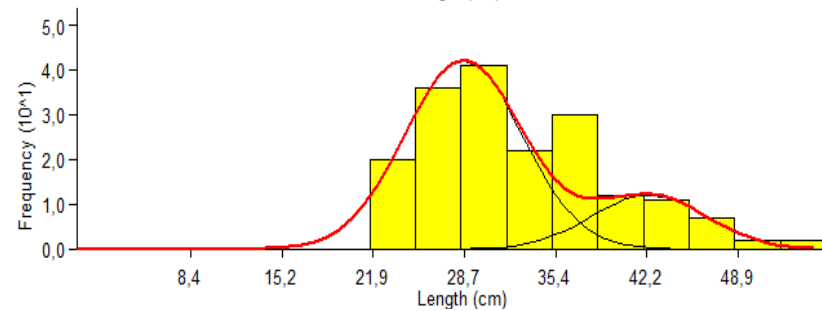
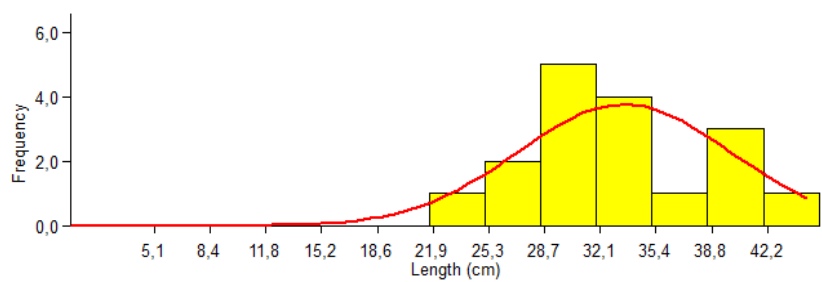


Figure 3. Length-weight relationship of the 849 coral groupers (*P. leopardus*) sampled from the Sarappo Islands (based on Total Length)

3.3. Coral grouper cohorts

The monthly cohort analysis of coral groupers from April to October 2017 (Figure 4) indicates the presence of either one or two cohorts in each month.



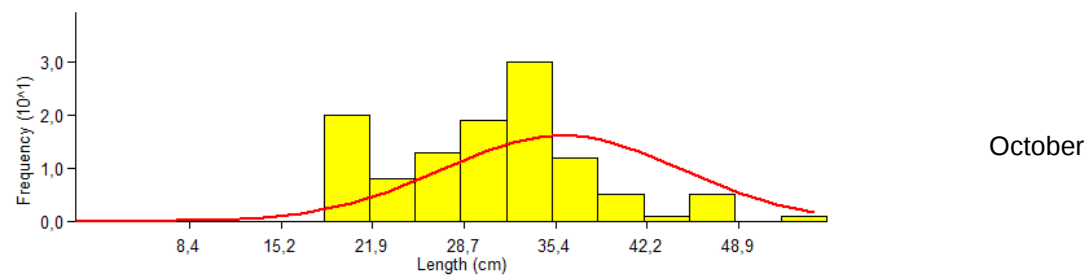
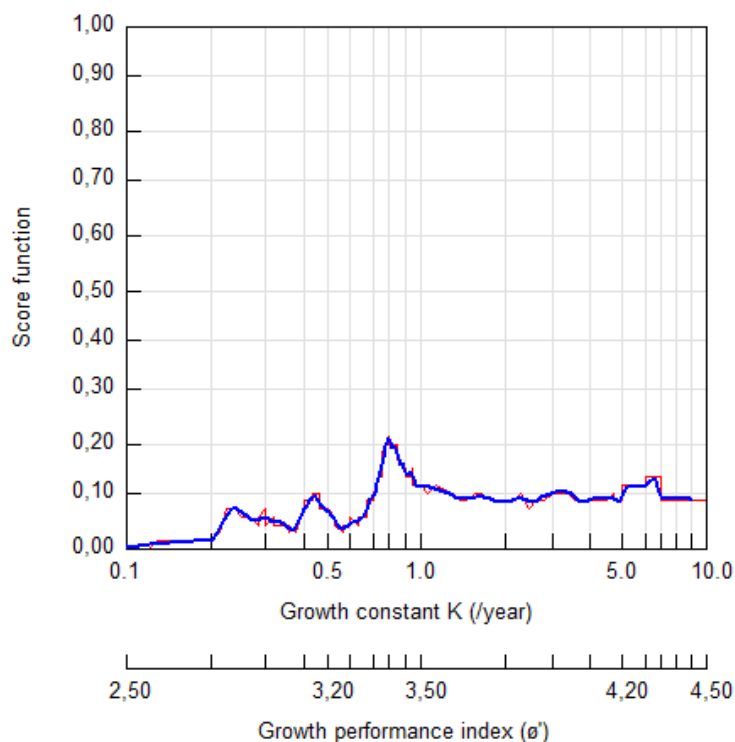


Figure 4. Monthly coral grouper cohorts

3.4. Growth parameters

The growth coefficient (K) and maximum (asymptotic) length (Max L or L_{∞}) were obtained using the Von Bertalanffy Model and Gulland Method (Fisat II Program). This resulted in a coefficient $K = 0.79$ per year and asymptotic length $L_{\infty} = 59.98$ cm with $t_0 = -0.212$. The value of K indicates the growth rate; the smaller the value of K , the longer the time required for a fish to reach its maximum length. The value $K = 0.79$ (Figure 5) indicates a relatively short-time to reach maximum length.

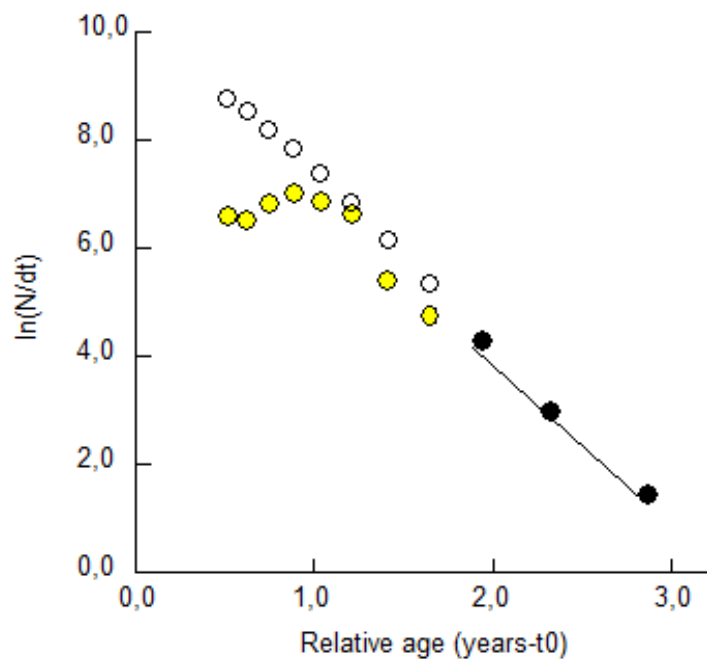
Figure 5. Determination of the value of K through ELEFAN Fisat II analysis

3.5. Mortality Rate and Exploitation Rate

Mortality is a process which affects population size; total mortality (Z) comprises both natural mortality (M) and fishing mortality (F). Total mortality can be estimated from length frequency data using the linearized catch curve (Figure 6). The estimation of total mortality (Z), natural mortality (M), fishing mortality (F) and exploitation rate (E) is presented in Table 1.

Table 1. Estimation of mortality and exploitation rate for coral groupers in the Sarappo Islands

Parameters	Value (<i>per year</i>)
Total mortality (Z)	3.03
Natural mortality (M)	1.28
Fishing mortality (F)	1.75
Exploitation rate (E)	0.58

Figure 6. Linearized length-converted catch curve based on the length composition of 849 coral groupers (*P. leopardus*) sampled from the Sarappo Islands (ELEFAN in FISAT II)

3.6. ² Yield per Recruit and Biomass per Recruit

The level of optimum sustainable yield ($E_{0.5}$) was 0.372, while maximum sustainable yield (E_{max}) was 0.779 and target economic yield ($E_{0.1}$) was 0.669. The current estimated exploitation rate of 0.58 is already above the maximum, optimum and economic yield indices (Figure 7).

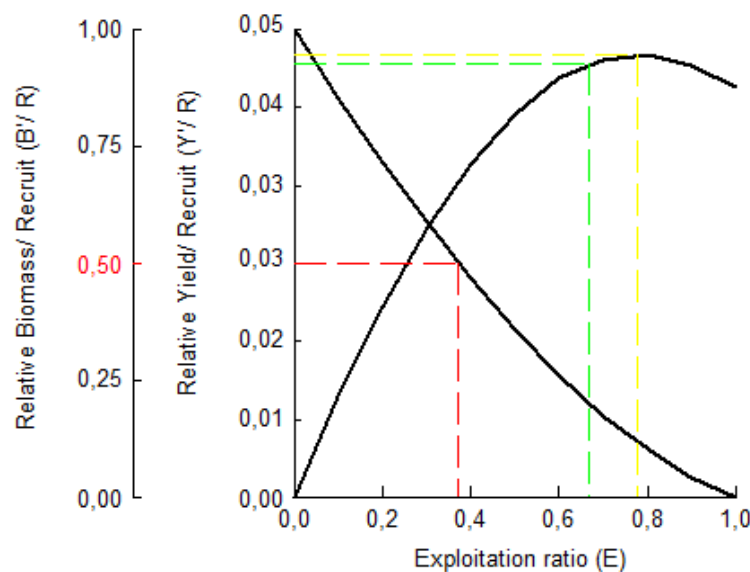


Figure 7. Beverton and Holt's relative yield per recruit and average biomass per recruit models based on length-frequency data for 849 coral groupers (*P. leopardus*) sampled from the Sarappo Islands (FISAT II)

4. Discussion

In the present study, the class mean length frequency distribution (20.0 - 57.1 cm), with a frequency peak in the juvenile size range (30.1 cm), indicates declining numbers of large coral groupers in the Sarappo Islands. The fishing yield is dominated by small size classes which do not meet trade standards. Nonetheless, fishermen keep on exploiting the grouper stock without regard or taking responsibility for sustainability. Increasing the exploitation rate of sub-standard sized coral groupers will result in the loss of economic advantages. As said by [15], the structure size of the fish can determine the effect of the current fishing pressure in particular species. However, the difference in length and weight may vary due to exploitation rates, geographical location, diet, season and tropic status [16]. Several similar studies have documented lengths for *P. leopardus* caught in the Spermonde Archipelago between 32.0 cm and 55.3 [17], with ranges of 17.5 cm - 52.5 cm around Lumulumu Island) and 22.5 cm - 62.5 cm around Langkai Island [18].

The length-weight relationship of for the 849 fish sampled ($W = 0.22L^{2.23}$) with a coefficient b of 0.230 defines the growth pattern as allometric negative. In other words, the increase in length is faster than the weight gain [19]. Similarly, the length-weight relationship of coral grouper (*P. leopardus*) caught in the water of Lumulumu Island and Langkai Island was allometric negative [18]. In addition, [20] reported an allometric negative growth pattern ($b = 2.639$) for *P. aerolatus* around three islands in the Wakatobi Archipelago, Southeast Sulawesi. The value of b can be highly affected by season, gonad maturity level, sex, spawning season and fishing activity [19].

The results of the cohort analysis using the Bhattacharya method indicate that cohorts are formed differently over each period of time (months). For instance, in April and October just one cohort was formed, while during May - September the samples formed 2 cohorts. The cohorts indicate the average growth in length of fish increase with an increase in age. In general, the length of the fish was between 20 cm and 40 cm. The difference in cohorts could be due to high fishing pressure leading to the loss of large fish [21].

The length-based stock assessment showed an asymptotic length (L_{∞}) of 58.98 cm FL, a K value of 0.79 per year and t_0 (the age at zero length) was estimated at -0.212 per year. In the present study, the relatively high value of K indicates that coral groupers in this population tend to attain maximum size (length) in a relatively short time. The growth in length might be fast, however the weight increase tends to be slower, with the coral grouper samples tending to be long and skinny. In comparison, the values of K in Lumulumu Island and Langkai Island were 0.30 and 0.18, respectively [21]. Furthermore, although coral trout (*P. leopardus*) captured around Kolaka in Southeast Sulawesi had a growth coefficient of 0.75 per year, with $L_{\infty} = 92.4$ cm, and $t_0 = -0.15$. In Sasongko Bay, *P.*

leopardus had a K value of 0.21 per year and $L_{\infty} = 75.68$ cm [4], while a K value of 0.22 and L_{∞} of 61.0 cm is reported for *Epinephelus diacanthus* in the Arabian Sea, Oman [21].

The exploitation rate estimated for coral groupers in the Sarappo Islands was 0.58, which is higher than optimal rate (0.5 according to [22]). This high rate of exploitation indicates overexploitation of *P. leopardus* in the waters of the Sarappo Islands. Similarly, high rates of exploitation for *P. leopardus* are reported from Sasongko Bay (0.51), Coron Island (0.78), Guiuan Philippine (0.89), and Spermonde Archipelago (0.42) [24]. Moreover, the exploitation rate of *P. leopardus* in Lumulumu Island and Langkai Island of Spermonde Islands was 0.87 and 0.70, respectively [3]. The results of interviews with local fishermen showed that daily fishing activity targeting groupers, especially *P. leopardus*, was very high and involved the use of various fishing gears. In addition, destructive fishing practices are still common in fishing activity around the Spermonde Archipelago, including the use of explosives, poisons, and substances inducing anesthesia [25].

In the present study, the total mortality rate ($Z = 3.03$), fishing mortality ($F = 1.75$), natural mortality ($M = 1.28$), and exploitation rate ($E = 0.58$) (Figure 6 and Table 1) are slightly different from those reported by Sudirman [24], who found fishing mortality $F = 0.53$ in the Spermonde Archipelago. The increase in fishing mortality compared to previous studies provides an overview of the heavy fishing pressure on the grouper *P. leopardus* in the Spermonde Archipelago today. Fishing mortality of *P. leopardus* in Banggai Bay is reported as 0.52 per year [4]. Exploitation pressure from fishing activity can also be associated with fish population dynamics parameters. Because of the relationship between exploitation pressure and mortality; if exploitation pressure increases the mortality will be higher [26].

The relative yield-per-recruit Y'/R (Figure 7) indicates that the increase in exploitation rate will lead to a decrease in Y'/R if current exploitation rates continue. Therefore, reducing the number of fishing gears, mesh size restrictions, and restocking are required for management.

5. Conclusion

The size structure of coral groupers caught during the study period ranged from 20.0 cm to 57.1 cm (class mean). The 30.1 cm midpoint class had the highest catch frequency (162 fish) while the 57.1 cm class had the lowest frequency (3 fish). The length-weight relationship was allometric negative. Growth coefficient (K) of the Sarappo Islands coral groupers (*P. leopardus*) was 0.79, indicating rapid growth. Fishing mortality rate was greater than natural mortality. The rate of exploitation for coral grouper (*P. leopardus*) in the study area has exceeded MSY.

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