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Growth and mortality rate of the Napan-Yaur Coral Trout, *Plectropomus leopardus* (Pisces: Serranidae), Cenderawasih Bay National Park, Indonesia

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Abstract. *Bawole R, Rahayu M, Rembet UNWJ, Ananta AS, Runtuboi F, Sala R. 2017. Growth and mortality rate of the Napan-Yaur Coral Trout,* Plectropomus leopardus *(Pisces: Serranidae), Cenderawasih Bay National Park, Indonesia. Biodiversitas 18: 758-764.* Coral trout, *Plectropomus leopardus*, is one of the important fishery resources in Cenderawasih Bay National Park, Papua, Indonesia. The catch production of this species has declined since 2015. This study aims to assess growth, mortality, and exploitation rate parameters of *P. leopardus* taken from Napan Yaur water, Cenderawasih Bay National Park (CBNP), Indonesia. The data were collected during periods of February to March 2016. Growth and mortality parameters were analyzed using von Bertalanffy method. Some fish samples used in this study was 123 individuals, with the average length of 32.34 ± 5.13 cm, the maximum length of 48.00 cm and minimum length of 24.5 cm. The von Bertalanffy analysis showed that the growth coefficient (K) was 0.34 $year^{-1}$, $L\infty$ was 47.78 cm and t_0 was-0.09 $year^{-1}$. The estimation of total mortality (Z) was 1.61 $year^{-1}$, natural mortality (M) was 0,75$year^{-1}$ for fishing mortality (F) was 0.86 $year^{-1}$, and exploitation rate (E) was 0.53 $year^{-1}$. The results indicated that most *P. leopardus* caught were at the pre-maturity size (age) and have been exploited at slightly above its optimum exploitation level. Nevertheless, *P. leopardus* is categorized as fast growing and long-lived fish species. These findings are important to fisheries management and conservation authorities to fish exploitation in the future.

Keywords: Growth, mortality, exploitation rate, grouper, Cenderawasih Bay

INTRODUCTION

Groupers are coral fish species and are distributed in tropical and subtropical waters.The majority of the species (110 species) can be found in Indo-Pacific waters (Randall et al. 1997). Coral trout or leopard coral trout, *Plectropormus* spp., spread in marine shallow tropical and subtropical Indo-Pacific region (Randall and Hoese 1986). *Plectropomus leopardus* is the most abundant species in inshore reefs and coral islands (Randall and Hoese 1986). At present, this species is one of the main commercial catches, which are mainly taken from mid shelf and outer-shelf reefs. It is one of the most popular targets of commercial fishermen in Cenderawasih Bay National Park (CBNP) (Bawole et al. 2014; Bawole et al. 2016).

Ecologically, Coral trout is at the top of the food chain and plays a major role in community structure of corals (Randall 1987) and relatively abundant in coral reefs in the CBNP (Bawole et al. 2016). Since the groupers are favoured for consumption or sale commercially, they are commonly targeted by fishermen. Their aggressive nature and relatively large body size make them more vulnerable to fishing gears (Munro and Williams 1985). Moreover, their biological reproduction and demography aspects may predispose them to overexploitation (Sadovy 1996).

Coral trout are caught especially for live reef fish for consumption (LRFC). Commercial coral trout fisheries have spread throughout the world, Since the 1990s, the fisheries have spread from Southeast Asia to the Indo-Pacific (Sadovy et al. 2003). This has led to the increased trading capacity of the catch from 30,000 tons in the 1980s to 140,000 tons in 2000 (FAO 2010). Consequently, the increase in the LRFC led to a reduction of target fish of various species of groupers and Napoleon wrasse (Sadovy and Domeier 2005; Sodovy 2005), and a damage to the habitat of fish spawning aggregations (FSA) (Wilson et al. 2010). In order to protect this species, in 2015, the International Union for the Conservation of Nature and Natural Resources (IUCN) noted *P. leopardus* as Red List of Threatened species along with several other groupers *P. maculatus* and *P. oligocanthus*.

Coral trout comprises 40% of the total catch of CBNP commercial line fishing fleet (Bawole et al. 2016). However, there has been very limited information about population dynamics, such as age, growth, and mortality of this species in the CBNP. The only available information in the GNBP is about the length-weight relationship of *P. leopardus* (Suruan et al. 2015). In the Great Barrier Reef, Goeden (1978) estimated the growth rate of this species at Heron Island by length-frequency data. Assessment of population dynamic characteristics, such as growth and mortality, is important for the purpose of fishery resource evaluation. Given the declining status of the population of this species and the problems associated with the use of size frequency data, basic investigations on fish length, and weight are needed in order to improve the robustness of stock assessment for this species. Therefore, the aim of this study is to develop demographic parameters including fish growth rates and natural mortality rates, longevities, and parameters of the von Bertalanffy growth function based on fish length data. This information will be valuable when attempting to understand the harvesting process of groupers and when developing conservation strategies for enhancing the recovery of threatened populations.

MATERIALS AND METHODS

Site and sample collection

This study was carried out in Napan Yaur waters (Figure 1) at Cenderawasih Bay National Park (CBNP) Indonesia, from April to May 2016. It is located in the territorial waters of the Teluk Umar District, Nabire District, Papua Province, Indonesia. Coastal ecosystems of Napan Yaur are potential for aquatic and fisheries resources. The coral reef ecosystems cover almost the entire area with the good coral condition, especially in the western, northern and eastern parts of this region. This region is also known as the core zone of CBNP. It provides habitats for marine biotas such as fish and mollusks.

Coral trouts were caught using handlines with baited hooks set in approximately 30 m to 70 m depth. Total length (L_T) and fork length (L_F) were measured using a board and recorded to the nearest centimeter (cm). Sex of the fish could not be determined due to as all samples taken had been gutted and cleaned. Weight (W) of 135 coral trouts was recorded to the accuracy of 0.1 gram.

Length-weight relationships

Parameters of the length-weight relationship were obtained by fitting the power function $W = aL^b$ to length and weight data. W denotes individual fish weight, *a* and *b* are constants, *L* is fish body length. If *b* value is close to 3.0, indicating isometric growth for the species.

$$t = \left(\frac{SD_y}{SD_x}\right)\left(\frac{|b-3|}{\sqrt{1-r^2}}\right)\left(\sqrt{n-2}\right)$$

Growth model

The growth model was fitted to von Bertalanffy growth function (VBGF) using the FISAT II software (Gayanilo et al. 2005) to estimate the size-at-age using non-linear least squares estimation procedures. The VBGF is defined as:

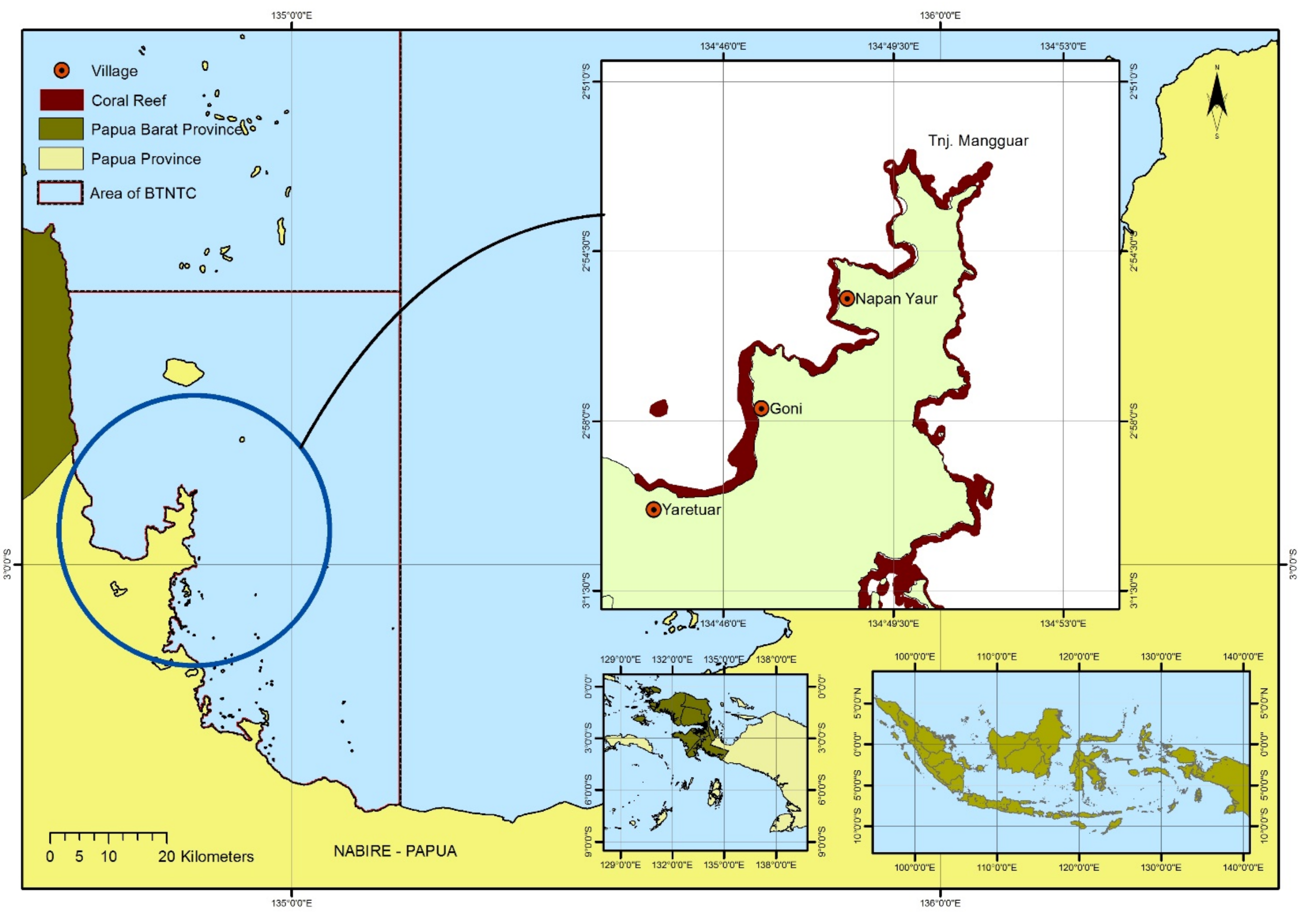

Figure 1. Map of study area in the Napan Yaur waters, from Cenderawasih Bay National Park, Papua, Indonesia

$$L(t) = L\infty\ (1-e^{-k(t-to)})$$

Where: Lt is the fish length at age t; L∞ is asymptotic length; K is growth coefficient; t denotes the age of fish and t_o is hypothetical age at which a fish would have zero length. In this research, the values of L∞ and K were estimated using ELEFAN I method in FiSAT II package and t_o was calculated using the Pauly'sequation(1982) as follows:

$$\text{Log}\ (-t_o) = -0.3922-0.2752\ \text{Log}\ L\infty-1.038\ \text{Log}\ K$$

The estimated ages for a variety of fish lengths were obtained using formula derived fromVBGF (Sparre & Venema 1998) as follows:

$$t = t_0 \frac{1}{K}.\text{Ln}\frac{(1 - Lt)}{L\infty}$$

Natural mortality

Fish mortality consists of natural mortality (M) and fishing mortality (F). The total mortality rate is given the symbol of Z (Sparre & Venema 1998). Z was determined using Beaverton-Holt method based on the length frequency distribution data. The functional relationship between Z and L is as follows:

$$Z = K.\frac{(L\infty - L)}{(L - Lc)}$$

Where Z = total mortality, L∞ = asymptotic length, K = growth coefficient, L = mean length of the fish (cm), Lc = length of fish caught (cm). Natural mortality of fish may be caused by predation, disease, age and environmental factors (Prasetya 2011). Pauly (1982) states that empirically there is a positive relationship between natural mortality and sea water temperature. The increase in water temperature will lead to an increase in natural mortality of fish. Therefore, Pauly (1982) suggests the following formula for natural mortality estimation.

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

Where, M = natural mortality, L∞ = asymptotic length, K = growth coefficient, T = Mean water surface temperature (°C). Mean value of 31°C was used for water surface temperature in CBNP (Bawole 2012). Pauly (1982) states that the total mortality rate (Z) is the sum of M and F, then F can be estimated when Z and M are known.

The rate of exploitation (E) is the ratio of fishing mortality (F) and total mortality (Z) (Pauly 1982). Gulland (1971) states that the optimal exploitation of fish stocks occurs when F equals M, and written as: $F_{optimum}$ = M. Thus, the optimal E is 0.5 and fish stock is categorized as overexploitation when the rate of exploitation is greater than 0.5.

RESULTS AND DISCUSSION

Length-weight relationship

The individual number of *P. leopardus* used for the analysis of length-weight relationship was 123, with an average length of 32.34 ± 5.13, the maximum length of 48 cm, and minimum length of 24.5 cm. Most fish caught were small-sized (Figure 2). There was a positive relationship between the length and weight (Figure 3), which followed the equation W = 1.44, L = 1.48 with R^2 = 0.91. It indicated a strong correlation between fish length and weight.

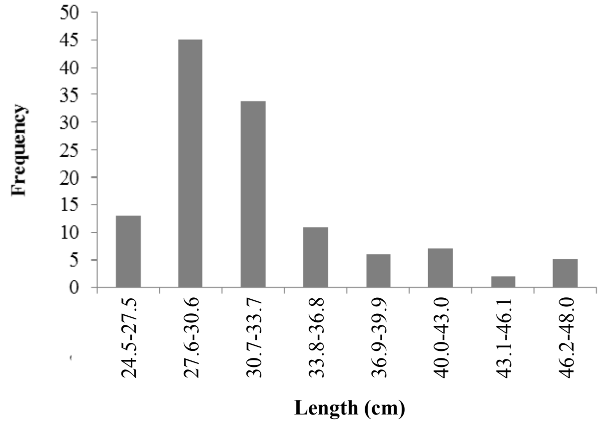

Figure 2. Body length distribution of coral trout (*Plectropomus leopardus*) from Cenderawasih Bay National Park, Papua, Indonesia

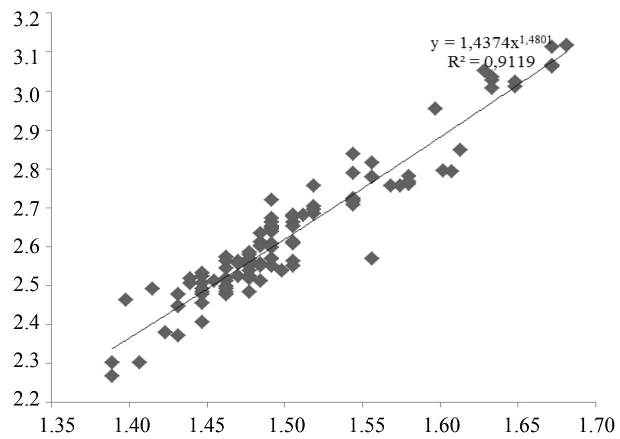

Figure 3. Length-weight relationship of coral trout (*Plectropomus leopardus*) from Cenderawasih Bay National Park, Papua, Indonesia

Growth of *P. leopardus*

Fitting fish length data to VBGF obtained the estimated growth parameters as shown in Table 1. The value of the instantaneous growth coefficient (K) was 0.81 year^{-1}, L∞ = 47.78 cm and t_0 =-0.01 year^{-1}. Based on growth parameters, the growth of *P. leopardus* formed a curve as shown in Figure 4. It was estimated that the species reached maximum length at age about five years.

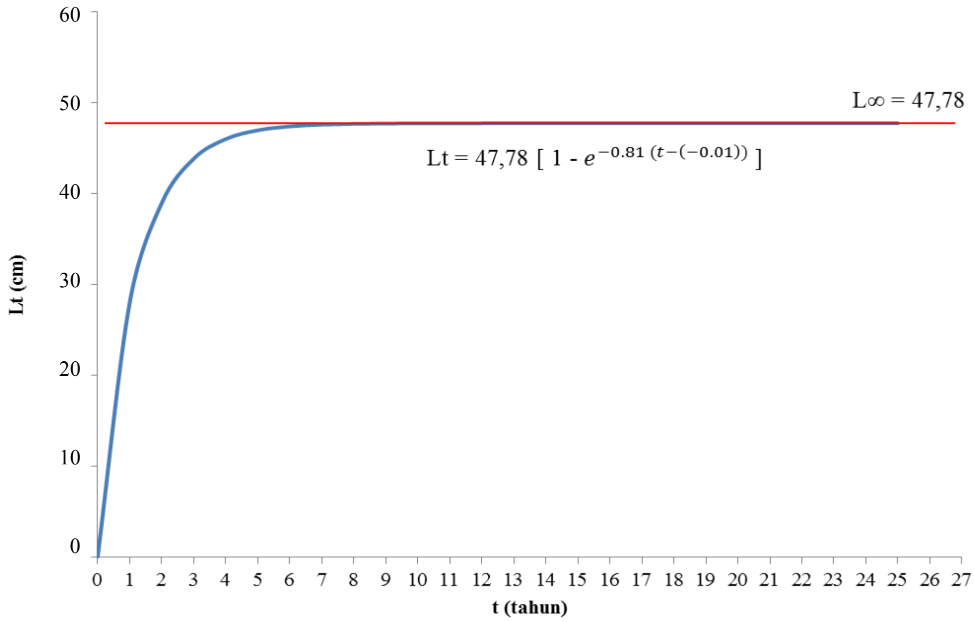

Figure 4. Growth curve of coral trout (*Plectropomus leopardus*) from Cenderawasih Bay National Park, Papua, Indonesia

Table 1. Growth parameters of *Plectropomus leopardus* from Cenderawasih Bay National Park, Papua, Indonesia

Parameter	Value
L∞ (cm)	47.78
K (year-1)	0.81
t0(year)	-0.01

Table 2. Mortality and exploitation rate of *Plectropomus leopardus* from Cenderawasih Bay National Park, Papua, Indonesia

Parameter	Value ($year^{-1}$)
Rate of total mortality (Z)	1.61
Rate of natural mortality (M)	0.75
Rate of fishing mortality (F)	0.86
Rate of fish exploitation (E)	0.53

Mortality rate

Total mortality rate (Z) of *P. leopardus* estimated using Beaverton-Holt method was 1.61. The value of the natural mortality rate (M) was obtained using Pauly's equation by applying estimated K = 0.81, L∞ = 47.75 cm, and the average water temperature at CBNP (Bawole 2012) of 31 °C. Then, natural mortality was estimated about 0.75 and fishing mortality (F) was about 0.86. Lastly, using the estimated mortality values, it was calculated that the rate of exploitation (E) of *P. leopardus* taken from Napan Yaur water was 0.53 (Table 2).

Discussion

Because of the interests of groupers in tropical fisheries worldwide (Ralston 1987), some researchers pay attention to the growth of fish (family Serranidae), especially on Epinephelinae subfamily members. Several studies have estimated the demographic parameters (e.g., Grandcourt et al. 2005; 2008), such as age structure, growth rate, the approximate length and age, and characteristics of the population of various species of grouper (Manooch 1987; Munro and Williams 1985). In general, the value of the constant *b* of length-weight regression equation depends on several factors, such as physiological condition, and environment, such as temperature, pH, salinity, geography and sampling techniques (Jenning et al. 2001). The growth of fish is relative, which means that it can change with time. If there is a change in the environment and food availability, the estimated length, and weight values will also change. Moreover, fish growth is also affected by several factors, such as heredity, sex, age, temperature and food availability. The size of *P. leopardus* caught in Napan Yaur water was 32.34 ± 5.13 cm, which is almost the same as the results of a study undertaken in the Gulf Lasongko (Buton) Indonesia (Prasetya 2010). Prasetya (2010) found the length of the fish of 39.34 ± 5.03 cm, with the size class interval range from 37.1-42.0 cm. Also, Landu (2013) reported that size *P. leopardus* was 41.30 ± 10.8, with the size of the dominant fish caught around 31-35 cm for females and 61-65 cm for males, respectively.

In formulating grouper fishery management strategies, the length of the fish can be used in determining management recommendations for *P.leopardus*. Length at first mature gonad of *P. leopardus* is 21 cm and 21-60 cm for active spawn (FishBase 2014). Based on these guidelines, *P. leopardus* in CBNP is categorized as productive and active spawner. Prasetya (2010) found that the minimum size of *P. leopardus* was 13 cm in the waters of the Gulf of Lasongko Buton in Southeast Sulawesi. Grandcourt et al. (2005) found a minimum size of 28.9 cm in the waters of South Gulf Arab, Landu (2013) reported that the minimum size of *P. leopardus* caught was 21 cm. In the present study, the minimum size of *P. leopardus* was 18 cm. The results of these studies show that fish are caught at their pre-spawning or pre-maturity ages. A study by Elevati and Aditya (2001) revealed that at a size about 42 cm, *P. leopardus* tends to change sex from female to be male. The size of the first maturity for a female is about 43.5 cm (Grandcourt 2005). This means that the fishery mostly catches the pre-mature size (illegal size). This will result in a lower proportion of males in the population and adversely will affect the reproductive activity. Also, the decline in some males in a spawning location will lead to limitation of sperms in the reproductive process (Landu 2013).

Parameters derived from length-weight relationships have utilized fishery-independent estimation methods (eg., Jennings et al. 1995). Reviews of these methods improve assessments of reef fishery resources and reporting length-weight relationships is important for species when there is no published estimate of parameters available, such as in CBNP. The parameters provided here might be useful for length estimation and monitoring studies of the fish in the future. The rapid growth of the fish in CBNP might be due to suitable water environment (food availability and optimum environmental condition) to support the fish life.

Asymptotic length ($L\infty$ = 47.78 cm) found in this study is lower than that found by other researchers elsewhere. However, the growth coefficient (K = 0.81 $year^{-1}$) in this study is greater than that in other studies. Hemsta and Randaal (1993) states that *P. leopardus* can reach 120 cm. Furthermore, Grandcourt et al. (2005) found the value K of *Epinephelus fuscoguttatus* at Aldabra Atoll, Seychelles, at 0.20 $year^{-1}$ and $L\infty$ about 71.3 cm. Tharwat (2005) reported that K for *E. coioides* in the Arabian Gulf was 0.15 $year^{-1}$and $L\infty$ was 102.7 cm, while Grandcourt et al. (2008) found K of 0.14/year and $L\infty$ of 97.9 cm for *E. coioides* in the southern part of the Arabian Gulf. Mamauag et al. (2000) found the value of K for *P. leopardus* in the Philippines at 0.18 $year^{-1}$ and $L\infty$ about 95.4 cm. Thus it can be said that *P. leopardus* in CBNP has the potential of high growth compared to the same species elsewhere (Table 3). Landu (2013) also reported K of 0.75 $year^{-1}$ with $L\infty$ of 92.4 cm in Kolaka, Southeast Sulawesi, Indonesia. Similarly, Prasetya (2010) found K of 0.21 $year^{-1}$ for *P. leopardus* with $L\infty$ of 75.70 cm in the Gulf of Lasongko, Indonesia.

Plectropomus leopardus has relatively high growth which indicates favorable water condition for fish growth (Hernandez and Seijo 2003), as found in the CBNP region. Growth is influenced by several internal and external factors. Internal factors are difficult to control, such as heredity, gender, age, the number of fish, type of food, parasites, and diseases. External factors that might affect the fish growth are temperature and food. Genetics is another factor that can instantly determine the individual growth. Vrijenhoek (1998) stated that genetic factors were formed in the species.

Natural mortality (M) found in this study was 0.75 $year^{-1}$. It was relatively high compared to other studies (Table 4). However, the rate of natural mortality was smaller than that from fishing activities (F). This means that the cause of the fish dead is predominantly due to fishing activities. Fishing mortality in CBNP has increased significantly since 2010 (Bawole 2012). Burton (2002) suggested that high levels of fishing activity may destabilize the fish stock. Low natural mortality and high fishing mortality may show symptoms of growth overfishing of *P. leopardus*, which means more young fish are caught than those of older fish. The rate of exploitation (E) for *P. leopardus* taken from CBNP was 0.53 $year^{-1}$. Gulland (1983) stated that the optimum rate of exploitation of a resource was 0.5. Therefore, the exploitation level for this species in CBNP has marginally exceeded its optimum exploitation rate. Other studies in some places in the world also reported overexploitation of groupers. For example, Tharwat (2005) reported that exploitation rate of *Epinephelus coioides* in the Arabian Gulf was 0.56 $year^{-1}$, Grandcourt et al. (2008) obtained exploitation rate of 0.80 $year^{-1}$ for *E. coioides* in the southern part of the Arabian Gulf, Mamauag et al. (2000) found the exploitattion rate of 0.78 $year^{-1}$ for *P. leopardus* in Oron, and 0.89 $year^{-1}$ for *P. leopardus* in Guiuan Philippines.

Reducing exploitation rate can be done through output control management, such as determination of total allowable catch (TAC), as well as input control management, such as restrictions on the number of fishing fleets targeting groupers to maintain the sustainability of the fish stock. For grouper fisheries in CBNP, the regulation to control fishing activities should get serious attention from various stakeholders of CBNP. For example, efforts should be more intensive to control the size of *P. leopardus* captured and the number of fishing fleets allowed to catch fish in the region. Also, protection on the location of fish spawning aggregation should be done. Sadovy (2005) stated that the location and time for spawning aggregation of groupers were fixed for the long term and the aggregation involved tens of thousands of fish individuals. These make the aggregation vulnerable to fishing activities. Uncontrolled fish exploitation can lead to structural changes in the fish stock, and the fishermen tend to catch large-sized fish. Reduction in the number of fish because of fishing could lead to a reduction of fish biomass. Continuous fishing on the large-sized fish or fish that are spawning could reduce genetic characteristics and change in fish behavior. Hurtado et al. (2005) stated that the fish population suffering from high exploitation would tend to change its size composition and be dominated by smaller fish. This could result in a reduction of the reproduction quality; large fish is more productive than small fish. Furthermore, Vrijenhoek (1998) suggested that reduction in genetic diversity could also affect the production potential and subsequently reduce the resilience of the population towards environmental change. Nevertheless, the results suggest that groupers, in general,

Table 3. Growth parameter of groupers from various locations

Location	Species	Parameter of Growth			Reference
		K (year^{-1})	L∞(cm)	t_0	
CampecheMexico	*Epinephelus morio*	0.21	82.7	-0.07	Hurtado et al. 2005
Southern Arabian Gulf	*Epinephelus coioides*	0.14	97.9	-1.50	Grandcourt et al. 2005
West coast of Florida	*Epinephelus morio*	0.23	80.00	-1.12	Carlson et al. 2008
Lasongko, Indonesia	*Plectropomus leopardus*	0.21	75.70	-0.24	Prasetya 2010
Kolaka, Buton. Indonesia	*Plectropomus leopardus*	0.75	92.40	-0.15	Landu 2013
Cenderawasih Bay National Park, Indonesia	*Plectropomus leopardus*	0.81	47.78	-0.01	**Current research**

Table 4. Mortality and exploitation parameter of groupers

Location	Species	Parameter of mortality and exploitation				Reference
		Z (year-1)	M (year-1)	F (year-1)	E (year-1)	
Campeche, Mexico	*Epinephelus morio*	-	0.15	-	-	Burgos and Defeo 2004
Aldabra Atoll, Seychelles	*Epinephelus polyphekadion*	-	0.13	-	-	Grandcourt 2005
	Variola louti	-	0.28	-	-	
West coast of Florida, USA	*Epinephelus morio*	-	0.15	-	-	Carlson et al. 2008
Lasongko, Indonesia	*Plectropomus leopardus*	1.01	0.49	0.52	0.52	Prasetya 2010
Kolaka, Buton, Indonesia	*Plectropomus leopardus*	1.90	0.60	1.30	0.70	Landu 2013
Cenderawasih Bay National Park, Indonesia	*Plectropomus leopardus*	1.60	0.75	0.86	0.52	**Current research**

are long-lived slow-growing species that have low rates of natural mortality. The findings are important to fisheries management and conservation authorities as they support the contention that these species have a low resilience to exploitation and their populations may be particularly vulnerable to overfishing.

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