Exploitation rate of *Plectropomus leopardus* (Pisces: Serranidae) taken from Rumberpon Island water, Cenderawasih Bay National Park, Indonesia

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Abstract. Fishing pressure on *Plectropomus leopardus* in Cenderawasih Bay National Park (CBNP) becomes intensive due to increasing demand for live groupers for consumption purposes. However, the status of *P. leopardus* on the potential fishing grounds in the CBNP has not been exposed. As Marine Protected Areas (MPAs), CBNP has not yet maximal in providing protection on threatened species, including protection for no take zone or core zone. Therefore, this study aims to determine the status of *P. leopardus*, including its growth characteristics, mortality rates and exploitation rate. Result of study showed that *P. leopardus* had a total length ranged of 33.0-41.0 cm (34.70±17.33 cm) and weight of 500-1.000 g (572.41±105.31 g). This species was able to reach asymptotic length ($L\infty$) of 41.58 cm, growth coefficient (K) of 1.2 per year with age t_0 of -0.06 year. Exploitation rate (E) of this species was 0.79 year^{-1}. The high E value indicates that the species has a low endurance on exploitation and is susceptible to excessive fishing. Thus, management strategy is required to perform by reducing the exploitation rate through the control of input, process, and output of fishing activity which consists of the determination of total allowable catch, limitation on the number of fishing fleet and regulation on allowable hook size used, as well as formulating rules and norms (code of conduct) in grouper fishing and strict protection for grouper spawning areas.

Key Words: *Plectropomus leopardus*, growth, mortality, exploitation rate, Cenderawasih Bay National Park.

Introduction. As an instrument of conservation, Marine Protected Areas (MPAs) have various effects and often become unclear in achieving their management goals (Côte et al 2001; Bawole et al 2011). It depends on the protected species, community and habitat (Roberts & Sargant 2002). Moreover, the obedience of stakeholders should be anticipated (Gerber et al 2003; Bawole 2012b) and have to be considered in designing and evaluating the effectiveness of MPAs as fisheries management tool. Studies on MPAs show that the management activity done successfully provided effect and obedience to the applicable rules. The studies that discussed this problem indicate the importance of fisherman behavior. Smith & Wilen (2003), for example, show that MPAs without management invention become less profitable fishing grounds and are avoided by fishermen. Previously, Jennings et al (1996) show that violation of fishing regulation might reduce the stock of fish, but minor violation could benefit species selected as the target of management although the species are also the target of fishing. Establishment of small No Take Zone (NTZ) may results in easier effort to the management, yet it is also possible that many small NTZs that spread over a large area could cause difficulty in the management compared to a larger NTZ. Each decision to apply NTZ regulation in MPAs has to be taken based on various studies that can be empirically assessed.

Cenderawasih Bay National Park (CBNP) is the largest marine conservation area in Indonesia, which is managed through the system of zonation (BBTNTC 2009). Apart from having a function as conservation and protection area, CBNP provides utilization zone, both for public interest and for traditional fishing activity conducted by the local community. The small scale fishing activity is not managed well and has resulted in numerous management problems. This fishing activity contributes to the poor CBNP management activity, both in term of the governance aspect (Bawole et al 2011; Bawole et al 2015), the low performance of coral reef management (Bawole et al 2013) and creating conflict between the stakeholders who utilize it (Bawole 2012b). The small scale fisheries often catch fish at the core zone or no take zone, where fish are more abundant. Groupers are the fishing targets by fisherman in CBNP due to their high demand from local traders that purchases the fishermen's catch in form of live fish and then export to other cities outside Papua.

Groupers are coral fish species which are distributed in the tropical and subtropical waters. The majority of 110 grouper species can be found in Indo-Pacific waters (Randall et al 1997) and is distributed in the shallow tropical and subtropical area of Indo-Pacific (Randall & Hoese 1986). *Plectropomus leopardus* is one of abundant species in inshore reefs and coral islands (Randall & Hoese 1986). Today, this species is one of the main commercial catches, which is caught in the mid shelf and outer-shelf reefs. *P. leopardus* becomes the most popular fishing target by commercial fishermen in CBNP (Bawole et al 2014; Bawole et al 2017) since *P. leopardus* is favorable to be consumed or commercially sold. Ecologically, grouper is at the top of food chain, plays an important role in coral community structure (Randall 1987) and is also relatively abundant in the coral reefs in CBNP (Bawole et al 2014). The aggressively feeding characteristics and its relatively big body size make it highly vulnerable to fishing (Munro & Williams 1985). Furthermore, considering the aspect of biological reproduction and demography, grouper is excessively exploited (Sadovy 1996).

Groupers are caught particularly as live reef fish for consumption (LRFC). This commercial activity has been spread over the world and since 1990s, it has been spread from Southeast Asia to Indo-Pacific (Sadovy et al 2003). This has resulted in the increasing in trade capacity of fish catch, namely from 30,000 ton in 1980s to 140,000 ton in 2000 (FAO 2010). As a result, increase in LRFC has caused decreasing in number of various grouper species and Napoleon wrasse (Sadovy & Domeier 2005; Sodovy 2005), as well as the destruction of fish spawning aggregation (FSA) habitat (Wilson et al 2010). To protect the species, in 2018 the International Union for the Conservation of Nature and Natural Resources (IUCN) recorded *P. leopardus* as the Red List of Threatened Species (IUCN 2018).

Groupers contribute to almost 40% of the total catch of commercial fishing fleet in CBNP (Bawole et al 2017). However, information on the population dynamic of *P. leopardus*, including age, growth, and mortality in CBNP is still limited, such as the body weight relationship in Kwatisore (Suruan et al 2015), the growth and mortality rate in Napan Yaur (Bawole et al 2017). Characteristic of fish population dynamic like growth and mortality becomes essential for fishery resource evaluation, as well as the determination of fish exploitation rate. Basic research on fish length and weight is required to improve the performance of stock analyses. Roberts et al (2001) show the importance of managing MPAs in supporting fishing activities. Increasing fishing activities in CBNP requires other information on current exploitation rate of *P. leopardus*. The status of this species will further be a reference in controlling grouper fishing in CBNP. Therefore, the aim of this study was to determine the status of exploitation rate of *P. leopardus*. This information is greatly important to understand the grouper fishing process, and instantly as the basis of decision in an effort to develop the conservation strategy to increase the recovery of the threatened population.

Material and Method

Description of the study sites. The study was conducted in water around Rumberpon Island, CBNP Indonesia (Figure 1) during March 2, 2015 – April 4, 2015. Collection of fish data was done in live fish trading location, which collected live groupers from local fishermen. The fishermen used small boat and most of them were not equipped with engines, but they used paddle (man power), so the fisheries were categorized as small-scale fisheries or traditional fisheries.

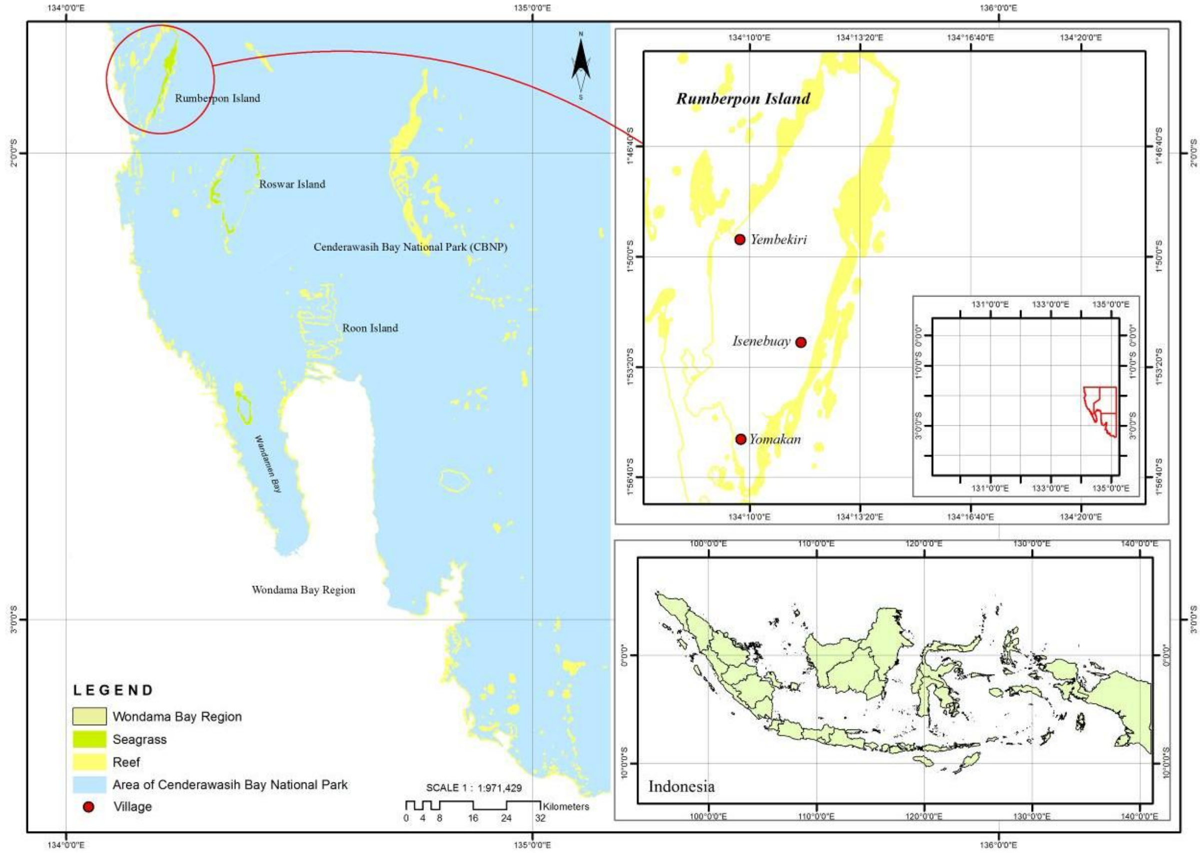

Figure 1. Research area in Rumberpon Island, Cenderawasih Bay National Park, Indonesia.

Data analysis. Data collection activity was performed by adjusting with the time of the fishermen landed the fish to the local collectors. *P. leopardus* was measured its weight with accuracy of 0.01 g and its total length with accuracy of 0.10 mm. After being measured, fish were put back into the floating net cage for temporary maintenance, before being sold outside the CBNP area.

Estimation of growth parameters were done by using the growth formula of Von Bertalanffy. This model applied the formula (Sparre & Venema 1998) as follows:

$$L_t = L_\infty \left(1 - e^{-k(t-to)}\right)$$

where: L_t is the length size of fish at t years old; L_∞ is the asimptotic length of fish; K is the coefficient of growth rate (per year), and t_0 is the age of fish in theory when the length equals zero.

Total mortality rate (Z) of fish consists of natural mortality (M) and fishing mortality (F). The total mortality rate was estimated by using Beverton-Holt method which was based on the length frequency distribution data (Sparre & Venema 1998), in which Z and L follow functional relationship:

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

where: Z = total mortality, L_∞ = asymptotic length, K = growth coefficient, L = mean length of the fish (cm), Lc = length of fish caught (cm).

Estimation of natural mortality used empirical equation of Pauly (1984) as shown in the following equation.

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

where: M = natural mortality, L∞ = asymptotic length, K = growth coefficient, T = mean sea surface temperature (°C). The equation shows a positive relationship between natural mortality, growth parameters and sea water temperature. We used mean sea surface temperature of 31°C as suggested by Bawole (2012a) for water surface temperature in CBNP.

When Z and M are known, then fishing mortality rate (F) can be estimated by using formula F = Z – M. Furthermore, the exploitation rate (E) can also be estimated since E is the ratio of fishing mortality (F) and total mortality (Z) Craig (2015). The optimal exploitation rate of fish stocks occurs when F equals M (Gulland 1983). Thus, when E is larger than 0.5, it indicates that the fish stock is experiencing overexploitation.

Results and Discussion

Sizes of length and weight. A total of 87 individuals of *P. leopardus* with total length of 330-410 mm (347.0±173.3 mm) and weight of 500-1,000 g (572.41±105.31 g) were sampled from fishermen catch. The largest number of *P. leopardus* was obtained at range of 330-341 mm with total number of 49 fish, followed by the length range of 354-365 mm with total number of 13 individuals (Figure 2).

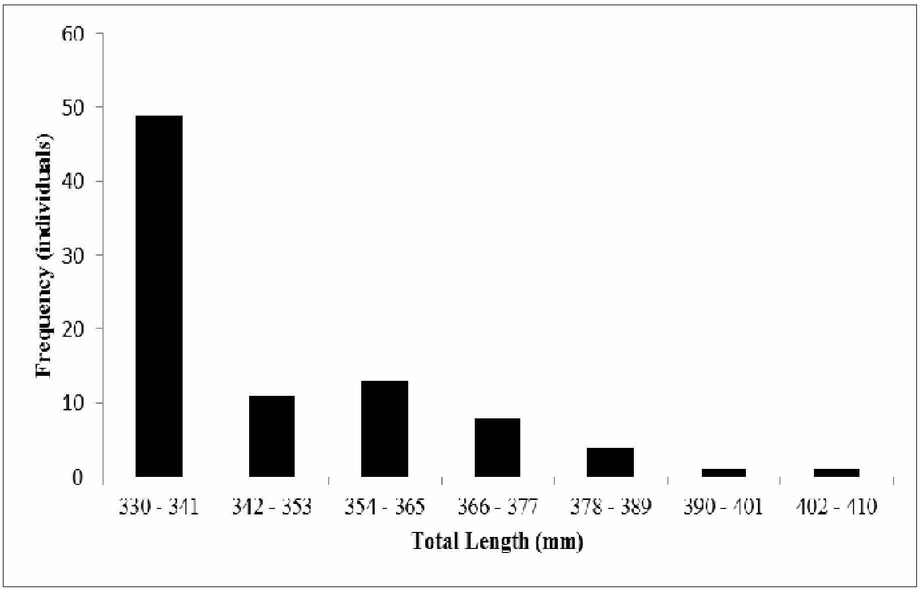

Figure 2. Total length distribution of *Plectropomus leopardus* from Rumberpon Island water, Cenderawasih Bay National Park, Indonesia.

In formulating the management strategy, the length and weight size of fish caught can be used in determining the recommendation for grouper management. Result of this study showed that the mean length of *P. leopardus* caught was 347 mm. Fishbase (2014) stated that *P. leopardus* experiences first maturity at size of 210 mm and actively spawns at size of 210-600 mm. It indicated that the groupers caught by fishermen in Rumberpon Island water were included in the category of productive phase of actively spawn or minimally have spawn. Previously, Bawole et al (2017) found *P. leopardus* in Napan Yaur-CBNP at smaller size (323.4±51.3 mm). Prasetya (2010) in Southeast Sulawesi found the fish length of 393.4±50.3 mm, with size class interval ranged from 371 to 420 mm. Also, Landu (2013) reported that the size of *P. leopardus* was 413±10.8 mm, with the size of the dominant fish caught around 310-350 mm for female and 610-650 mm for male. These results indicate that fish caught in Indonesian waters commonly have relatively small size. Nevertheless, the fish sizes are bigger than the size at first maturity.

Fish growth rate. Data of fish length were used to estimate the parameters $L\infty$, K and t_0 in Von Bertalanffy equation. Result of the analysis showed that *P. leopardus* was able to achieve $L\infty$ of 415.8 mm. The growth rate (K) was 1.2 year^{-1} with age t_0 of -0.06 year. Despite $L\infty$ tended to be lower than that of other studies (Table 1), as found in most waters in Indonesia (Prasetya 2010; Landu 2013; Bawole et al 2017), *P. Leopardus* in this study showed a rapid growth. Food availability and favorable oceanographic environmental conditions in CBNP might support the rapid growth of grouper fish (Bawole et al 2014) since fish growth is influenced by physiological and environmental conditions such as temperature, pH, salinity and water geography (Jennings et al 2001).

Table 1

Growth parameters of *P. leopardus* from some studies

Parameters			*References*
L_∞ (mm)	*K (year^{-1})*	*t_0*	
757.0	0.21	-0.24	Prasetya (2010)
924.0	0.75	-0.15	Landu (2013)
477.8	0.81	-0.01	Bawole et al (2017)
415.8	1.20	-0.06	Current research

By knowing the parameter of K, $L\infty$, and t_0, the length of *P. leopardus* at time t (L_t) can be obtained through the equation of Von Bertalanffy and is presented in the form of growth curve (Figure 3). The growth curve showed that the length growth of *P. leopardus* rapidly occurred at young age and kept slowing down with age until it reached its asymptotic length in which the fish length stopped growing. The slower body growth at old age fish might be related to the use of energy mostly for body maintenance and movement.

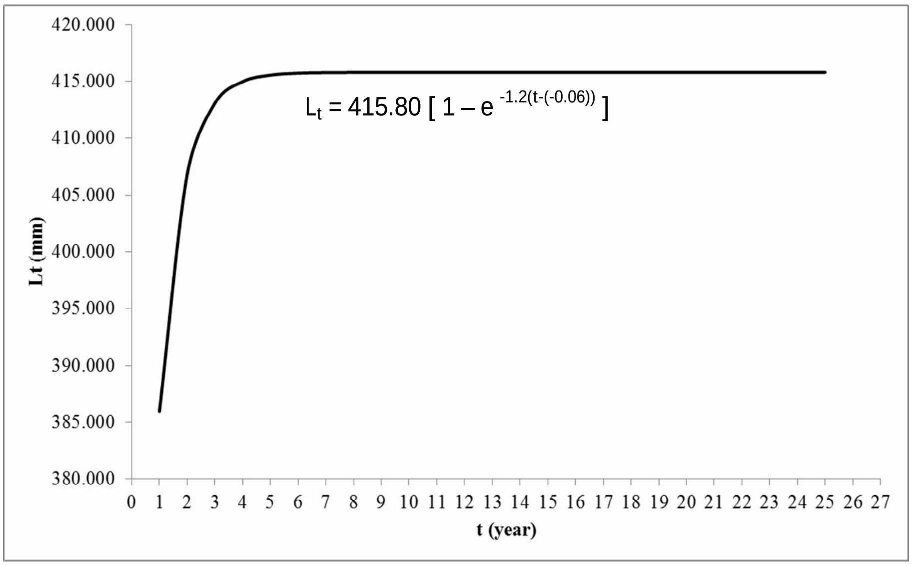

Figure 3. Growth curve of *Plectropomus leopardus* from Rumberpon Island, Cenderawasih Bay National Park, Indonesia.

Fish growth is affected by the condition of water environment. A rapid growth rate indicated that there was food abundance and suitable habitat condition to fish. Fish growth fluctuates and varies in responding to the condition of water environment such as the availability of food (Lorenzen & Enberg 2002), water temperature (Brander 1995; Daufresne et al 2009; Baudron et al 2014) and coral reef condition (Hukom & Bawole 1999). Hunter et al (2016) show how the water condition and class of fish length influence $L\infty$ and K. Energy surplus from food is used by fish for growth and reproduction; thus, fish will grow fast as long as the food availability in nature is high.

Food availability from each individual depends on the abundance of prey and competition between fish (Ward et al 2009). Increase in food competition may decrease the food availability for each individual. Hence, fluctuation of fish size class may result in growth variation as a result of density-dependent growth factors in regulating the mechanism of population stability (Lorenzen & Enberg 2002).

Water temperature is one of the main environmental factors that influence the growth. In fishing grounds with low temperature (cold regions), fish tends to grow slower than that in area with warm climate (warm regions), yet fish commonly live longer and reach larger size (Angilletta et al 2004). Short term variation in growth may be affected by the fluctuation of water temperature, and in the long term, increase in temperature is able to determine the maximum length that is specific for several fish species (Baudron et al 2014).

Growth rate is also able to be genetically inherited and naturally occurs in nature. High genetic variability can be inherited in determining the fish growth rate naturally (Carlson & Seamons 2008); therefore, fish will develop as a response against the natural selective pressure of water environment (Conover & Munch 2002; Enberg et al 2012).

Fish mortality and exploitation rate. Estimation of total mortality rate (Z) was analyzed using the method of Beverton-Holt (Sparre & Venema 1998). From the analysis result, it was obtained that the estimate value of total mortality (Z) of *P. leopardus* was 4.85. The value of natural mortality rate (M) was derived from the equation of Pauly (1984). By inserting the estimate value of K = 1.2, $L\infty$ = 4415.80 mm, and the mean water temperature (T) of 31°C (Bawole 2012a), the estimate value of natural mortality was 0.99 year^{-1}. Furthermore, the rate of fishing mortality (F) was calculated by subtracting the value of natural mortality (M) from the estimate value of total mortality (Z), and resulted in fishing rate (F) of *P. leopardus* of 3.86 year^{-1}.

The value of exploitation rate (E) was estimated by dividing the F value by Z, which further generated the estimate value of E for *P. leopardus* of 0.79 year^{-1}. This value shows that the mortality factor of *P. leopardus* was more due to fishing activity. The low value of natural mortality (M) and high fishing mortality (F) reflect the condition of growth overfishing; that more young fish were caught. This finding has supported previous research on the pressure of fishing activities of groupers that have been studied by Mudjirahayu et al (2017).

The estimated E value indicated that the fishing status was not in optimum condition or being over exploited. According to Gulland (1983), optimum exploitation rate of a resource is 0.5 (50%). The rate of exploitation, fishing, and natural mortality in this research was higher than that found in other locations in Indonesia (Table 2). The fishing rate of *P. leopardus* in Rumberpon Island water of CBNP was high, in particularly for small size fish. It certainly relates to the use of fishing gears, that were hand line with small hook size (number 9 and 10). The use of this hooks was evenly spread over the entire fishing ground area in CBNP (Bawole et al 2017). Control of fishing activity should be performed to prevent the capture of small fish.

Table 2

Total mortality rate (Z), natural mortality rate (M), fishing rate (F), and exploitation rate (E) of *P. leopardus*

Parameters (year^{-1})				*References*
Total mortality rate (Z)	*Natural mortality rate (M)*	*Fishing rate (F)*	*Exploitation rate (E)*	
1.01	0.49	0.52	0.52	Prasetya (2010)
1.90	0.60	1.30	0.70	Landu (2013)
1.60	0.75	0.86	0.52	Bawole et al (2017)
4.85	0.99	3.86	0.79	Current research

Decision making in controlling fish population can be done by considering the initial growth phase of fish since fish at that phase tend to have high population density.

Application of hand line fishing with bigger hook sizes (number 6-7) can be designed to enable small fish not to get caught. Therefore, fishing gears will be more selective on small fish as a result of predation system but targeted more on larger fish (Edeline et al 2007) .

The results of this study in addition to showing high exploitation rate of *P. leopardus*, also showed that the fish caught were mostly on the fish at the category of maturity stages. As a consequence, fish population has a potential to lose the genetic variability at the initial level of growth. It means that fish are caught as young fish, and fish production is relatively low after spawning season (Trippel 1995; Jorgensen et al 2007). The competition ability of fish often relates to the growth rate; thus, fishing activities can be managed by selectively choosing target size of fish.

Small fish is more vulnerable to predation compared with larger individual since small fish is easier to eat and as slow swimmer that is easily caught by predator (Scharf et al 2000). Therefore, the cohort of young individual with average growth rate tends to survive than its predator. The ability of fish to compete is often related to the growth rate; thus, fish catch can be directed to choose fish that have slow growth by applying different selection considering the ability of fish to compete (Biro & Post 2008).

Conclusions. Despite *P. leopardus* needs long time in reaching its maximum size, this fish is considered to have a good growth rate (recruitment), yet its current exploitation rate is high. This finding is important to provide awareness to all parties who have the authority in the management and sustainability of the grouper. This species also has low durability against exploitation and the population is vulnerable to excessive fishing. Management strategy is required to reduce the exploitation rate through output control, such as the determination of total allowable catch, and input control such as limitation on the number of fishing fleet and regulation on allowable hook size used. Control of process can be done by formulating rules and norms (code of conduct) in grouper fishing and strict protection for grouper spawning areas. Grouper fishing in CBNP requires serious concern from various stakeholders of CBNP.

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