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Growth, mortality and exploitation rate of *Plectropomus maculatus* and *P. oligocanthus* (Groupers, Serranidae) on Cenderawasih Bay National Park, Indonesia

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ABSTRACT

The present study aims to determine whether the rate of exploitation for grouper stocks is in accordance with their biological attributes (growth and mortality). The results showed that *Plectropomus maculatus* and *P. oligocanthus* taken from Cenderawasih Bay National Park (CBNP) were in the size category of actively productive spawning phase. *P. maculatus* could reach a maximum length ($L\infty$) of 484.05 mm and growth rate (K) of 0.34 per year. *P. oligocanthus* was capable of reaching $L\infty$ of 481.95 mm and K of 0.66 per year. Estimation of total mortality (Z) for *P. maculatus* was 0.988 and *P Oligocanthus* was 2.056. In addition, fishing mortality (F) for *P. maculatus* and *P. oligocanthus* were 0.564 and 0.399 respectively. Based on the estimated mortality values, it was estimated that the exploitation rate (E) of *P. maculatus* was 0.570, and *P. oligocanthus* was 0.681. Management settings for *P. maculatus* and *P. oligocanthus* can be separately based on the species so that the fishing can be sustainable. The introduction of minimum size limits for fish caught can be applied as a protection from hook and hand line fishing activities in CBNP.

Introduction

The high demand for groupers has led to an increase in the sale value of the fish and has brought about substantially high profits for trading business of this commodities. As consequently, this has been pushing an increase in fishing intensity for groupers and become primary fishing target of fishery in coral reef areas. Groupers are caught in the wild by traditional fishermen using hook and lines, and fish traps. High fishing intensity brings consequences to grouper sustainability. That is, grouper population experiences high fishing pressure. In some regions of Indonesia, it has been reported that total catch of groupers has decreased and the stock has been overexploited (Sadovy, 2005).

Fishing continuously on large sizes of fish or spawning fish stock could reduce the genetic characteristics and could change fish shape and behavior. The genetic diversity of the population would be likely affected thereby reducing its resilience in confronting with environmental change and variability (Vrijenhoek, 1998). Hurtado et al. (2005) and Nelson (2007) note that populations experiencing high exploitation is characterized by a change in the fish size composition, which is dominated by smaller sizes. This would significantly affect reproductive outcome since small fish size has less production potential than the large fish size. Large-scale of exploitation could cause structural changes in the fish. Sanchez (2000) suggests that in overfishing state of fish stock, the fish population are dominated by small sizes or young fish since fishermen tend to catch large size of fish.

Aside from fishing activities, the production of groupers in nature is strongly influenced by geomorphology and hydrographic characteristics of water; these affect the overall productivity and spawning aggregation (Coleman et al., 2011). Fish spawning areas of groupers, nowadays, become the target fishing areas by fishermen in order to increase their catch per unit effort. Although fisheries production increases in short term, such fishing practices in long term are likely to lessen fishery production as a result of the damage of spawning habitat, the decrease in reproductive output and the changes in sex ratio (Heyman et al., 2005; Koenig et al., 2000, 2005; Sadovy and Domeier, 2005). To protect grouper from

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overfishing and extinction, the International Union for the Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Species 2015 declared several species of groupers such as *Plectropomus leopardus*, *P. maculatus*) and *P. oligocanthus* as endangered species.

Groupers known as reef fish are the main component of reef fisheries in Cenderawasih Bay National Park (CBNP) (Bawole et al., 2014). There are three species in CBNP, *P. leopardus*, *P. maculatus* and *P. oligocanthus*, that are marketed commercially and are purchased by a commercial company. *P. leopardus* is the main target species for commercial fishermen (Bawole et al., 2017). However, other reef fish species known to be the fishing target are of *P. maculatus* and *P. oligocanthus*. These species are managed as a single species. Although as a group of high-economic species, little information is known about the two species. Numerous studies conducted on several places concerning the parameter of grouper growth, e.g. northwest coast of Africa (Burtos et al., 2009), west coast of Florida (Carlason et al., 2008), western Mediterranean Sea (Renones et al., 2001) and eastern Pacific (Craig et al., 1999), but no studies of *P. maculatus* and *P. oligocanthus* in the CBNP region. Information on the growth parameters of *P. maculatus* in the Great Barrier Reef was provided by Ferreira and Russ (1992) but there is no information about the mortality and exploitation aspects. The CBNP area has been a potential commercial fishing area of the grouper species since 2010. Yet, there is no specific-biological information available for the species in the fishing areas that could be used in assessing whether different species have the same response to fishing pressure. Therefore, this study aimed to determine whether the rate of exploitation is in accordance with the biological attributes (growth and mortality) of groupers in CBNP. The research is needed for the management of reef fish as a single species group and necessary management actions for the species in the fishing areas.

Material and method

The research location is situated in waters around Napan Yaur, a grouper fishing areas. Fishing area is inside CBNP. Geographically the study site is located at position of 02°54′43.00 S and 134°49′57.00 E (Fig. 1). In the area is also found coral reef ecosystem which is in good condition, in particularly in the west, north and east of Yaur Napan water. Because of the good condition of coral, this area is designated as one of core zone in CBNP area. As a core zone, Napan Yaur water functions as protection area for a variety of organisms that lives in association with coral reef.

This study was conducted in April and May 2016. Fish samples were collected from fishermen and local traders, who buy living groupers from local fishermen every day started from 4 April 2016 to 2 May 2016. Fishermen fished by using small boats (canoe, outboard engine) and handlining. The presence of local traders made fishing activities for the grouper become more intensive. There were 10 fishing fleets with the frequency of fishing 3–4 times per week during the study period. The groupers were recorded by species and number of individuals. Each individual was measured its total length by using a caliper with an accuracy of 1.0 mm. Then, it was weighed using hanging scales with accuracy of 5 g.

Analysis of growth models used von Bertalanffy growth model where fish length is a function of age (Pilling et al., 1999; Jennings et al., 2001). This growth model has become one of the bases in fisheries biology since it uses as a sub model in a number of more complicated models to explain various fish population dynamics (Sparre and Venema, 1998). The mathematical model of von Bertallanffy equation is:

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

where:
- $L(t)$ = Length at time t
- $L\infty$ = Asymptotic length
- K = Growth coefficient
- t_o = Theoretical age at length equals to zero.

The values of $L\infty$ and K were calculated using ELEFAN in FiSAT II package program. The value of t_O was calculated using empirical equation of Pauly (1984) as follows:

$$\mathrm{Log}(-t_o) = -0.3922 - 0.2752\mathrm{Log}L_\infty - 1.038\mathrm{Log}K$$

The relative age at a variety of lengths was estimated by using derivative of von Bertalanffy formula (Sparre and Venema, 1998), as follows:

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

The estimation of total mortality rate used length frequency distribution data which was applied to Beverton-Holt method in which shows the functional relationship between Z and L (Sparre and Venema, 1998). The formula is as follows:

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

where:
- Z = Rate of total mortality
- L_∞ = Asymptotic length
- K = Growth coefficient
- L = Average length of the fish (mm)
- L_c = The smallest length of fish caught (mm)

Natural mortality of fish could occur due to predation, disease, age and environmental factors. Pauly (1984) suggests relationship between the natural mortality and water temperatures. An increase in water temperature will lead to the increase in natural mortality of fish. The natural mortality (M) can be estimated by using Pauly empirical equation (Pauly, 1984) as follows:

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

where:
- M = Natural mortality
- L_∞ = Asymptotic length
- K = Growth coefficient
- T = Average surface temperature of the water (°C)

Pauly (1984) state that the total mortality rate is summation of natural mortality and fishing mortality (F) or written as:

$$F = Z - M$$

Rate of exploitation (E) is ratio of fishing mortality (F) and total mortality (Z) (Pauly, 1984), and written as follows:

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

Gulland (1983) states that the optimal exploitation for a fish stock occurs when fishing mortality (F) is proportional to the natural mortality:

$$F_{optimum} = M$$

Thus, the optimal rate of exploitation ($E_{optimum}$) is 0.5. Resource is said to suffer from overexploitation (overfishing) if the rate of exploitation is greater than 0.5.

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