On the assessment of white-spotted rabbitfish (*Siganus canaliculatus* Park, 1797) stock in the Inner Ambon Bay, Indonesia

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Abstract. Information pertaining stock assessment of the white-spotted rabbitfish (*Siganus canaliculatus* Park,1797) in the Inner Ambon Bay has been limited to the last study conducted more than two decades ago. The present study was aimed to estimate the stock parameters of this species emphasizing on estimated growth, mortality, recruitment, and exploitation rate. The study was conducted in the Inner Ambon Bay during August 2018 - July 2019 with monthly interval sampling campaign. Fish collection was made by beach seine from which the white spotted rabbitfish total length was measured. Analysis and calculation were largely based on the FISAT II package. The following results were obtained: asymptote length (L_∞) 30.55 cm, growth coefficient (K) 1.51 year^{-1}, and the theoretical age when the fish length is zero (t_0) was -0,243 years, therefore the growth equation is $L_t = 30.55[1 - e^{-1.51(t+0.243)}]$. The natural mortality rate (M), fishing mortality (F) and total mortality (Z) was 2.37 year^{-1}, 2.18 year^{-1} and 4.54 year^{-1}, at the current exploitation level of (E_{curr}) 0.48, maximum economic yield (E_{10}) was 0.47 and maximum sustainable yield (E_{max}) was 0.56, indicating that exploitation rate has exceeded its sustainable conditions, therefore limitation of fishing effort should be adopted as a management measure.
Keywords: growth parameters, mortality, exploitation rate, yield per recruit, *Siganus canaliculatus.*

Introduction. Baronang is the local common name in Indonesia for the white-spotted rabbitfish (*Siganus canaliculatus* Park, 1797). The white-spotted rabbitfish is a demersal fish that is often associated with seagrass beds (Munira et al 2010; Latuconsina et al 2013; Latuconsina & Ambo-Rappe 2013; Suardi et al 2016), but is also present amongst mangrove and coral reefs habitats (Allen & Erdmann 2012; Suardi et al 2016). They feed mainly on seagrass leaves, macroalgae, and animals attached to seagrass, such as isopods, polychaetes, crustaceans, and bivalves (Munira et al 2010; Latuconsina et al 2013, Kwak et al 2015). Its distribution area is the Indo-Pacific region, encompassing the Persian Gulf, Indo-Malaya, Ryukyus Islands of Japan and all the way to Australia. Woodland (2001) found that in Australia the white spotted rabbitfish forms a larger aggregation at juvenile stage compared to adults.

White-spotted rabbitfish *S. canaliculatus* is considered an important fishery in Indonesian waters, for example in South Sulawesi (Andy Omar et al 2015; Halid et al 2016; Suardi et al 2016; Suwarni et al 2019), Inner Ambon Bay, Kotania Bay and the Banda Archipelago-Mollucas (Manik 1998; Munira et al 2010; Latuconsina & Wasahua 2015). In Inner Ambon Bay, this species is caught by hand line, bottom gillnet and beach seine. The white-spotted rabbitfish is also being exploited worldwide in places such as Oman, in the Arabian Sea (Al-Marzouqi 2013), Jubail Sea, Saudi Arabia (Al-Qishawe et al 2014), Southern Arabian Gulf (Grandcourt et al 2007), and Gulf of Mannar-South India (Anand & Reddy 2012).

For a better management, information on exploited stock is an important aspect from which the potential and magnitude of utilization might be estimated. Therefore, a good estimation on growth, mortality, and exploitation are the key parameters from which this fishery might be better managed. Population reduction or losses caused by fishing (F) and natural mortality (M) is an expression of remaining fish stock for utilization (Sparre & Venema 1998). In terms of mortality estimation, Manik (1998) has reported from the Inner Ambon Bay that M was higher than F with 1.96 compared to 0.45. However, such a low fishing pressure might have changed after two decades, along with a variety of environmental factors and anthropogenic activities comprising of fishing, floating net cage aquaculture, organic wastes disposal, as well as sedimentation and sand dredging (Selano et al 2009; Irawan & Nganro 2016). In comparison with other areas and similar species, Halid et al (2016) has estimated that F was higher than M in the Bone Bay, South Sulawesi-Indonesia. On the contrary a lower value was recorded by Al-Qishawe et al (2014) in Jubail Marine Wildlife Sanctuary, Saudi Arabia, showing the importance of marine protected areas to avoid overexploitation.

The present research aimed to update the information on stock condition of the white-spotted rabbitfish in the Inner Ambon Bay and the results provide valuable input for the fishery management. Widodo & Suadi (2006) pointed out on the importance of biological production of a stock, that is a function of the size of the stock and environmental changes, natural and anthropogenic.

Material and Method

Description of the study sites. The study was carried out in the Inner Ambon Bay where 4 stations were determined, i.e. Tanjung Tiram, Halong, Poka, and Nania. These sites represent the habitat and typical fishing ground for white-spotted rabbitfish (Figure 1). For sample collection, a one-year sampling was performed with monthly intervals from August 2018 - July 2019.

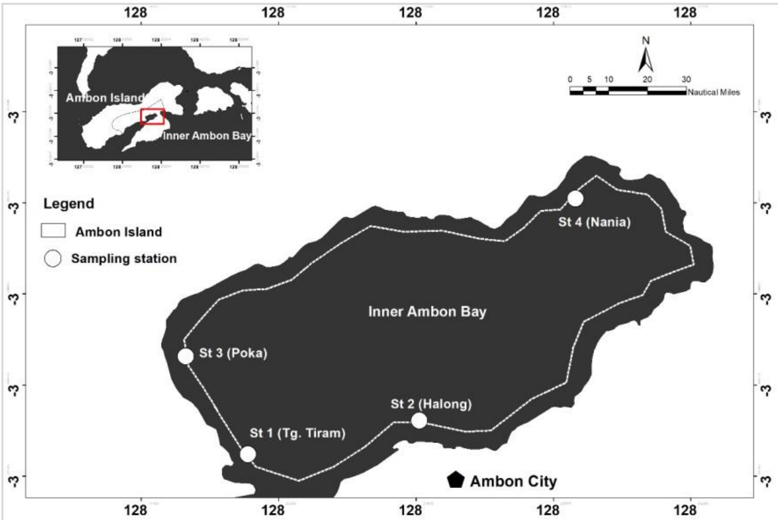

Figure 1. Sampling sites for white-spotted rabbitfish *S. canaliculatus* in the Inner Ambon Bay.

Fish collection was done using a beach seine, with a net length of 30 m, wings with a length of 14 m, mesh size of 1.88 cm, bag with a length and mouth opening width of 3 m, with mesh size of 1.63 cm, and a net height/width of 2 m. Each collected white-spotted rabbitfish had the total length (TL) measured.

Data analysis. Data analysis was done using ELEFAN I (Electronic Length Frequency Analysis) and FISAT II (FAO-ICLARM Stock Assessment Tools) (Gayanilo et al 2005). Length data of the white-spotted rabbitfish was used as input for von Bertalanffy equation to estimate growth (Sparre & Venema 1998):

$$L_t = L_\infty \left(1 - \exp^{-K(t-t_0)}\right)$$

At the initial stage, the theoretical age (t_0) is determined by the formula of Pauly (1983):

$$\text{Log}(-t_0) = -0.3922 - 0.2752 (\log L_\infty) - 1.308 (\log K)$$

L_t (cm) is the length of the fish at age t, L_∞ (cm) is the asymptotic length, and K is the growth coefficient (year^{-1}). Based on von Bertalanffy's growth equation and estimated growth parameters, the recruitment pattern of *S. canaliculatus* is projected. Estimating total mortality (Z) is based on the body length conversion curve of the catch fish. In doing this, the natural mortality rate (M) is calculated according to formula of Pauly (1983), where M is the natural mortality (year^{-1}) and T is the average annual water temperature (°C):

$$\text{LnM} = -0.0152 - 0.279 \,\text{LnL}_\infty + 0.6543 \,\text{LnK} + 0.463 \,\text{LnT}$$

After Z and M are determined, the fishing mortality rate (F) is calculated as:

$$F = Z - M$$

Exploitation rate (E) is calculated based on Beverton & Holt formula (Sparre & Venema 1998):

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

Relative yield per recruit (Y'/R) is estimated using Beverton and Holt Model (Sparre & Venema 1998) in FISAT II program package and in Office Excel worksheet. From this, the values of exploitation rate at maximum relative yield per recruit (E_{max}) could be estimated. Also E_{10}, the value of E at which the marginal increase in Y'/R is 10% of its value at E = 0; also E_{50}, the value of E corresponding to 50% of the relative biomass per-recruit (B'/R), were estimated. The formula of Y'/R is the following:

$$Y'/R = E.U^{M/K} \left[1 - \frac{3U}{1+m} + \frac{3U^2}{1+2m} - \frac{U^3}{1+3m}\right]$$

$$\text{where } E = \frac{F}{Z}, \quad U = 1 - \frac{Lc'}{L\infty}, \quad m = \frac{1-E}{M/K}$$

Results and Discussion

Catch composition. The total amount of white-spotted rabbitfish *S. canaliculatus* collected was 1,050 individuals, and based on its size range those fishes were categorized into juveniles, pre-adults, and adults of which the individual number of each stadia was 494, 244, and 312 fishes, respectively. The size range of each group was between 2.50-6.9 cm, 7.0-12.9 cm, and 13.0-18.0 cm and their distribution percentages were 47.05%, 23.24%, and 29.71%. Length at first capture (L_c) was 10.51 cm, that was smaller compared to length of first maturity (L_m) recorded by Tharwat (2004), of 18 cm for males and 19 cm for females; Al-Marzouqi et al (2011) recorded a length of first maturity (Lm) of 22.6 cm for males and 23.9 cm for females; Latuconsina & Wasahua (2015) recorded the length of first maturity of 18.6 cm (ranged 17.9 - 19.4 cm) for males and 17.5 cm (ranged 16.9 - 18.1 cm) for females.

By summing up the stadia composition, it showed that more than 70% of collected fishes were immature, confirmed by L_c which was significantly smaller than L_m. In such an exploited fish population, there will be less opportunities for fish to reproduce, hence insufficient recruit to build the stock before it is caught. According to Al-Qishawe et al (2014) the sustainable exploitation of fisheries can be achieved when L_c is larger than L_m.

This implies that more selective fishing gear must be used in the fishery, to catch fishes at the size at which reproductive biology processes and following recruitments are maintained. In this context, Muhammad (2011) pointed out that imposing fishing gear selectivity in fishery policy is an appropriate management measure, so that the most productive growth and age structure in certain fish stocks is continued with optimal catch and economic value.

Growth, mortality, and exploitation. Growth coefficient (K) value was 1.51 $year^{-1}$, with an asymptotic length (L_∞) of 30.55 cm that was achieved within approximately 3 years, with theoretical age (t_0) - 0.243 years. Thus, the growth equation is formulated as $L_t = 30.55\left[1 - e^{-1.51(t+0.243)}\right]$ (Figure 2). By comparing K value of white-spotted rabbitfish with that recorded by Manik (1998), current growth coefficient has been doubled during the last two decades. Sparre & Venema (1998) stated that fish with K value ≥ 0.5 is typical for rapid growth pattern; the higher the growth coefficient the faster they reach the asymptotic length. However, Table 1 shows an irregular pattern between K and L_∞. According to Beverton & Holt (1959) the asymptotic length is highly modified by the available food supply but does not affect the growth coefficient. The difference in environmental temperature will affect K and L_∞, thus, an increase in water temperature will proportionally increase the values of K and L_∞.

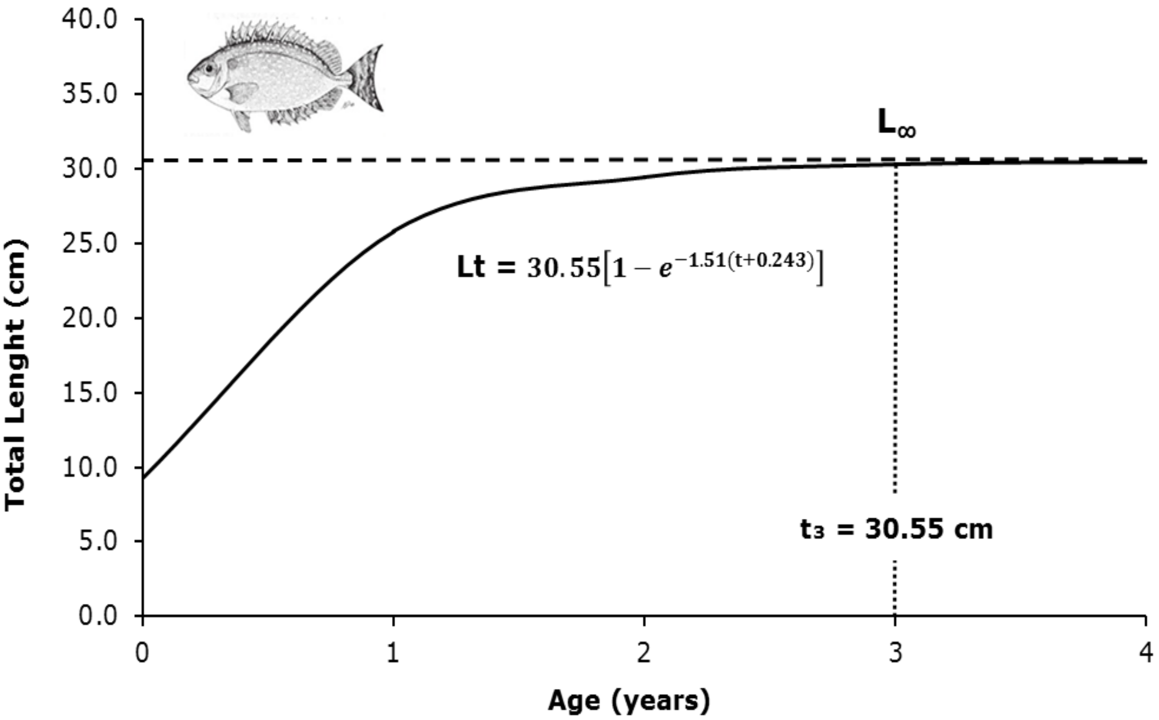

Figure 2. The length and age relationship of white-spotted rabbitfish *S. canaliculatus* in the Inner Ambon Bay showing L_∞ after 3 years period.

In Figure 2 at the end of the first year the size of *S. canaliculatus* is 25.9 cm and in the second and third years, 29.5 and 30.3, respectively. Comparable to Al-Marzouqi (2013), which found that *S. canaliculatus* can reach 26-28 cm TL by the end of the first year, 33-36 cm by the end of the second year and 38 cm during the third year of his life.

In Figure 3, it is shown that mortality rate of *S. canaliculatus* at average temperature of 29°C was 2.37 $year^{-1}$, which corresponds to a fishing mortality of 2.18 $year^{-1}$, and accordingly total mortality was 4.54 $year^{-1}$. The catch was in the range of relative age between <1 year >1 year, and yet it remains less than 2 years. Comparable to Al-Marzouqi (2013) which determined a fish life span of around 3.5 years and a commercial catch mainly based on individuals aged 1-2 years.

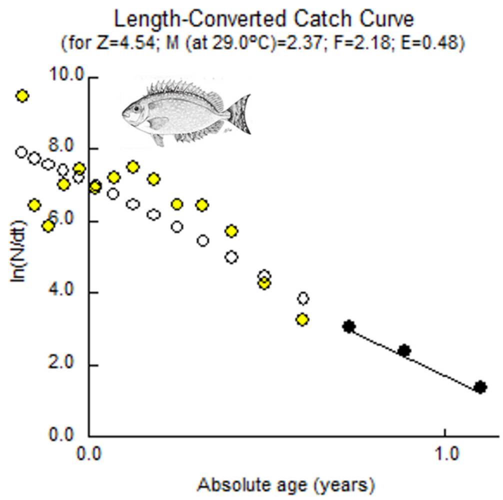

Figure 3. Curve conversion length of white-spotted rabbitfish *S. canaliculatus* catches in the Inner Ambon Bay. Black circles describe groups of fish being exploited.

Table 1

Geographic variation of length frequency-based growth parameters, mortality, and exploitation rate of white-spotted rabbitfish *S. canaliculatus*

Location	*L∞*	*K*	*M*	*F*	*Z*	*E*	*Source*
East coast of Saudi Arabia	42.20	0.28	0.75	0.75	1.50	0.50	Tharwat (2005)
Southern Arabian Gulf	24.80	1.00	0.66	0.85	1.51	0.56	Grandcourt et al (2007)
Oman, Arabian Sea	40.13	0.85	1.36	1.30	2.66	0.49	Al-Marzouqi (2013)
Jubail, Saudi Arabia	35.38	0.58	1.02	0.93	1.95	0.48	Al-Qishawe et al (2014)
Bone Bay, South Sulawesi-Indonesia	30.58	0.15	0.61	1.08	1.69	0.64	Halid et al (2016)
Inner Ambon Bay, Mollucas-Indonesia	26.00	1.12	1.96	0.45	2.41	0.19	Manik (1998)
Inner Ambon Bay, Mollucas-Indonesia	30.55	1.51	2.37	2.18	4.54	0.48	Present study

Referring to Gulland (1969), there was a positive relationship between K and M, where fast growing fish tend to reach higher natural mortality rates compared to fish that grow slowly and consequently have a lower natural mortality value. Table 1 shows that a high K value can explain the high natural mortality (M). Regarding to F, Table 1 also shows that lower fishing mortality corresponds to larger maximum size. This is probably the case for white-spotted rabbitfish, for example Burton (2001) compares the growth and mortality of *Lutjanus griseus* in different fisheries, where South Florida fisheries areas with high catches (F = 0.66 > with M = 0.35) had L_∞ = 625 and K = 0.13 which was much lower than that of North Florida fisheries (L_∞ = 717, K = 0.17) with lower fishing pressures (F = 0.16 < M = 0.33).

According to Beverton & Holt (1959), with a ratio of total mortality to growth coefficient (Z/K) of more than 1.0 is dominated by growth and if more than 2, then it is dominated by total mortality. With a Z/K ratio of 3.01 obtained in this study, it indicates that white-spotted rabbitfish fishery in the Inner Ambon Bay has been dominated by mortality. As shown in Table 1, the discrepancies in mortality and exploitation rate might be addressed to environment or habitat variability, fishing pressure, and impact from anthropogenic activities. Bone Bay of South Sulawesi-Indonesia has a fishing mortality higher than natural mortality (F = 1.08 > M = 0.61) and high exploitation rate (E) = 0.64 and *S. canaliculatus* is the main fishing target (Halid et al 2016). In comparison, the Inner

Ambon Bay where fishing mortality is lower than natural mortality (F = 2.18 < M = 2.37) and corresponds to E = 0.48. Seagrass habitat in the Inner Ambon Bay is the feeding ground and nursery habitat for *S. canaliculatus* (Latuconsina et al 2013), but the Inner Ambon Bay is threatened by a high sedimentation rate. The area influenced by sedimentation has increased from 102.56 hectares in 1994 to 168.13 hectares in 2007. Sedimentation area reached 65.57 hectares in 13 years or 5.43 hectares per year in average (Irawan & Nganro 2016). Other threats are physical destruction caused by sand dredging and organic waste pollution (Selano et al 2009).

Growth and recruitment pattern relationships. Figure 4 shows the growth model of white-Spotted rabbitfish *S. canaliculatus,* showing the onset of recruitment occurred between February and March 2019. Figure 5 shows the recruitment of this species happened twice throughout the year. The recruitment rate is higher in the month of March compared to October, which is 15% versus 9.90%. As pointed out by Widodo & Suadi (2006) the dynamics of fish populations in the wild are highly dependent on growth and recruitment to increase stock and stock reduction through natural mortality and fishing mortality, so to maintain fish stocks in the wild it is necessary to maintain a balance between growth and recruitment with mortality (fishing mortality and natural mortality). The recruitment pattern information can be a reference point to find out the potential recruitment of fish that can be exploited.

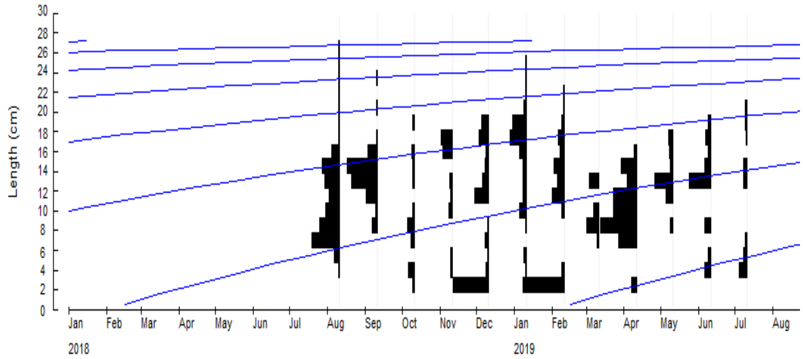

Figure 4. The growth model of white-spotted rabbitfish *S. canaliculatus* in Inner Ambon Bay.

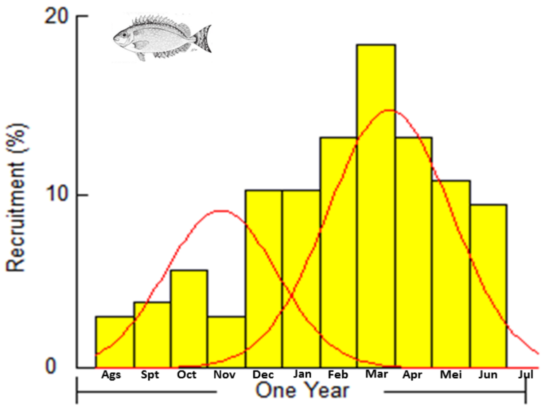

Figure 5. Recruitment pattern of white-spotted rabbitfish *S. canaliculatus* in Inner Ambon Bay.

Exploitation rate (E) and relative yield per recruit (Y'/R). Figure 6 explains the relationship between exploitation rate (E) and relative yield per recruitment (Y'/R). There are three reference points to the current level of exploitation (E_{curr}), i.e. optimal exploitation (E_{50}), maximum economic yield (E_{10}) and maximum sustainable yield (E_{max}). At the point of E_{curr} of 0.48 (Y'/R_{curr} 0.039 g), E_{curr} has passed E_{50} of 0.33 (Y'/R_{50} 0.027 g), and E_{curr} has exceeded E_{10} of 0.47 (Y'/R_{10} 0.038 g). Nonetheless, E_{curr} remains below E_{max} of 0.56 (Y'/R_{max} 0.045 g). In the condition where $E_{curr} > E_{max}$, this implies that recruitment to population of

S. canaliculatus has been greatly reduced and is unable to support an increase in fishing yields, if the rate of exploitation continues to be increased.

According to Gulland (1969), in an optimally exploited stock, if fishing mortality is equal to natural mortality E is 0.5. Thus, if referring to the reference point E_{50} where the biomass Y'/R is 50% of the value of existing stock biomass, E_{curr} must be reduced from 0.48 to 0.33, so that it will reduce Y'/R by 15% = 0.012 g. If referring to the reference point E_{10}, E_{curr} must be reduced from 0.48 to 0.47 so that it will reduce Y'/R by 1% = 0.00092 g, whereas if it refers to E_{max}, E_{curr} must be increased from 0.48 to 0.56 so that it will increase Y'R by 8% = 0.0065 g.

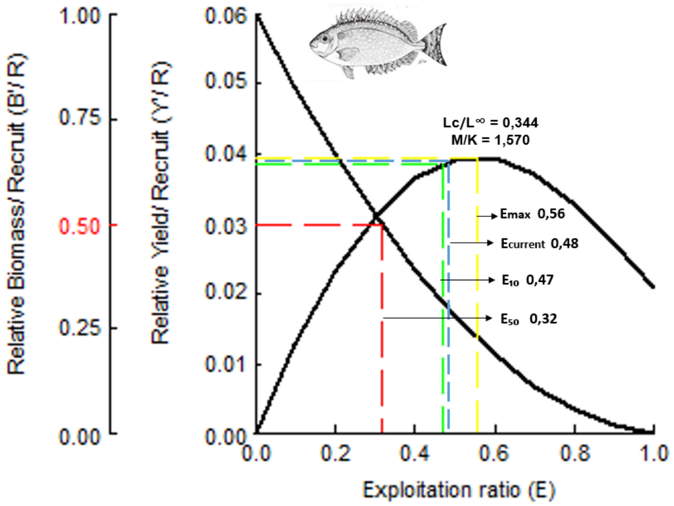

Figure 6. Relative yield per recruit (Y'/R) curve of white-spotted rabbitfish *S. canaliculatus* showing exploitation values in Inner Ambon Bay.

By considering maximum economic profit, E_{curr} is unfeasible to be increased to achieve its E_{max}, because the rate increase exploitation is not proportional to the yields. According to Widodo & Suadi (2006), if an increase of fishing effort turns out the yield is constant, then it is necessary to regulate the fishing effort, and if the addition of fishing effort is followed by a decrease in yield, then it is necessary to limit fishing efforts. By comparison, Halid et al (2016) obtained E_{curr} of 0.64, E_{max} of 0.50 in the Bone Bay (unmanaged fisheries areas), whereas Al-Qishawe et al (2014) in marine wildlife sanctuary from Saudi Arabia waters obtained E_{curr} of 0.48, i.e. smaller than E_{10} of 0.55, and far below E_{max} of 0.649. This phenomenon might be the result of level of exploitation of white-spotted rabbitfish *S. canaliculatus* being functionally governed by the presence of conservation area.

Conclusions. The population of white-spotted rabbitfish (*Siganus canaliculatus*) in Inner Ambon Bay has large growth coefficient and natural mortality values, inversely proportional to the age and the asymptotic length, which is relatively short. The fishing mortality (F) rate is lower than natural mortality (M), with the current exploitation level (E_{curr}) higher than the optimal exploitation rate (E_{50}) and the maximum economic yield (E_{10}). Although still below the level of maximum sustainable yield (E_{max}), it does not bring maximum benefits if the rate of exploitation continues to be increased through the addition of fishing effort.

Thus, a fisheries management strategy is needed to regulate fishing efforts to ensure sustainable and economically beneficial utilization and consideration should be given to the development of conservation areas and rehabilitation of fish habitats that have begun to degrade due to various anthropogenic activities.

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