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Population Dynamic Parameters and Length Based Spawning Potential Ratio (LB-SPR) of Red Snapper (*Lutjanus malabaricus*) in The Eastern Java Sea

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Abstract. Decision in fisheries management must be made based on the best scientific evidence available. In the poor data fisheries, the fish length data can be useful to determine the status of fish population after its exploitation. The target species of the studied fisheries is the red snapper (*Lutjanus malabaricus*) in the eastern Java Sea. This study aims to analyze the stock status of red snapper in the eastern Java Sea using Length Based Spawning Potential Ratio (LB-SPR) method. Data collection was done from November 2020 until April 2021. This study separated the analysis of the population dynamic parameters between male and female fish. The growth parameters of male fish was $L_t = 92.20\ (1 - e^{-0.27(t-0.07)})$, with natural mortality (M) of 0.35, fishing mortality (F) of 0.63, and total mortality (Z) of 0.98 per-year. Whereas for female fish, $Lt = 91.09\ (1 - e^{-0.29(t-0.44)})$, with M of 0.38, F of 1.40, and Z of 1.78. The exploitation rate (E) for males was 0.64, and for the female was 0.79. The spawning potential ratio (SPR) was 17%, below the limit reference point of 30% SPR. The current utilization rate of the red snapper in the eastern Java Sea must be reduced to ensure its sustainability.

1. Introduction

Indonesian fisheries are dealing with multispecies which characterized by high species diversity and operated by multiple fishing gears, leading to a viable management strategy to overcome such complex conditions. Managing fisheries starts with defining decision control based on the proper scientific study in accordance with biology, ecology, and management structure conditions [1]. The right decision control will be obtained if it begins with the right data collection as a basic stock assessment for the managed fisheries resource. However, multispecies fisheries are commonly dealing with a lack of data which leads to the use of alternative approaches in estimating fish stocks, such as exploitation rate and Spawning Potential Ratio (SPR) methods [2]–[5].

Fish length data is a fundamental parameter in fishery management [6], from which this parameter is primarily important information to calculate population dynamic based on asymptotic length (L_∞), growth coefficient (k), and length at first maturity 50% (Lm_{50}) comparing between fished and unfished

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stock, as well as mortality and exploitation rate (F/M) prior to SPR determination [4]. The spawning potential ratio (SPR) describes stock status from the reproduction capacity of fish resources [7]. SPR is also known as the proportion of the unfished reproductive potential left by any given level of fishing pressure. The unfished stock has an SPR of 100% ($SPR_{100\%}$), and the fishing pressure will reduce it to $SPR_{x\%}$, depending on how much the fishing activities [3].

Red snappers (*Lutjanus malabaricus*), also known as Malabar blood snapper, is an economically important commodity and highly demanded both for domestic and export markets. Based on UN COMTRADE in 2019, together with grouper, the export volume of snapper from Indonesia was world 9^{th} rank marketed particularly to USA, China, and Singapore [8]. The potential fishing grounds for red snapper in the Java Sea are waters around Tuban, Rembang, Madura, Pati, and Jepara. The catch is mainly landed at Brondong Fishing Port situated in Lamongan District, near Tuban Regency [9]. The red snapper population in the Java Sea, particularly around Tuban and its adjacent areas, has been defined as one unit stock and has greater genetic distance from other locations (stock) in the Java Sea [10].

On average, Indonesia exported 4,367 tons of red snapper annually from 2015 to 2019. East Java Province contributed 47% of red snapper total export in 2019 [11]. The export volume fluctuates according to fishing effort. For instance, the catch volume of red snapper in 2019 was 34,336 tons of which as much as 875 tons of this species derived from the Java Sea [12]. In 2019 the biomass landing of red snapper was 158 tons or approximately IDR 11.5 billion in price [13], a lower value compared to the last five years period, in which a significant decrease occurred from 2017 to 2018 [13]-[15].

A decrease in fish size and biomass or catch indicates a depletion of fish stock. In the absence of historical catch data, an important step in the process of management decision making is to estimate length-based SPR, as an alternative in quantitative stock assessment [16]. Therefore, this paper deals with the stock status of red snapper using the SPR method to develop any recommendation of fisheries management options. This research aimed to determine the population dynamic parameters and the stock status of red snapper in the eastern part of the Java Sea.

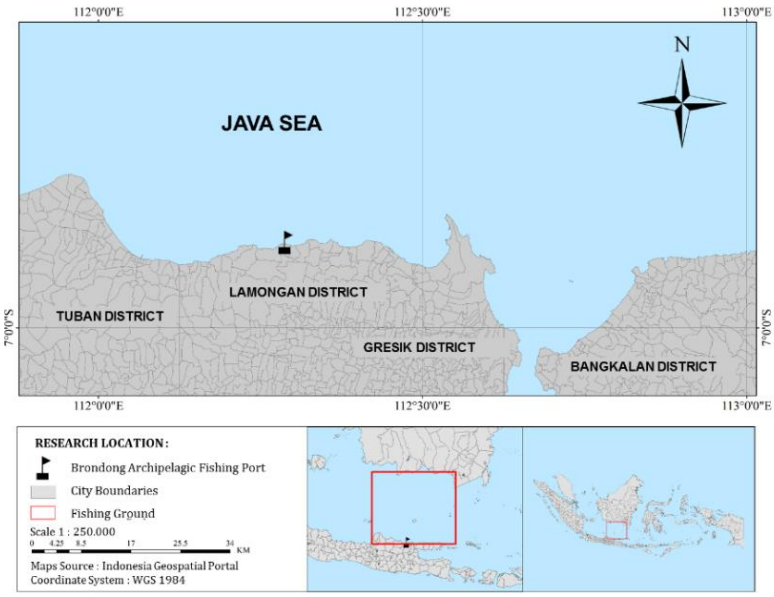

Figure 1. The research location in the eastern Java Sea as the fishing ground ( ) and Brondong Archipelagic Fishing Port as the location of the data collection ( )

2. Materials and methods

The data were collected by the Indonesian Demersal Association (ADI) covering the catch of the fishery management area (FMA) 712 in the eastern water of the Java Sea (Figure 1). Several ADI members provided data for the period of November 2020 until April 2021.

2.1. Materials

The total samples in this research were 993 fish, consisting of 500 males and 493 females, with an average of 166 fish each month. The length (cm) and weight (g) data were collected in a processing unit. Fish gonads were visually observed for weight and sex, while the maturity stages were defined based on Holden and Raitt (1974) [17].

2.2. Data analysis

Calculations of growth parameters (L_∞, k, and t_0), mortality, and exploitation rate, were carried out using Rstudio 1.3.1073 version with TropfishR and fishmethods packages [18], [19]. Growth parameters were estimated using ELEFAN (*Electronic length frequency analysis*), ELEFAN SA (*ELEFAN with simulated annealing*), and ELEFAN GA (*ELEFAN with genetic algorithm*) methods. Based on Rn_max value, the ELEFAN_SA was fitted to be the best model. The growth parameters were estimated following von Bertalanffy growth model [20]:

$$L_t = L_\infty \times \left[1 - e^{(-K(t-t_0))}\right] \quad (1)$$

L_t and L_∞ define as the fish length at age-t (cm) and asymptotic length (cm), respectively. While K is growth coefficient ($year^{-1}$), and t_0 is hypothetical fish age at zero-length (year).

The natural mortality or M ($year^{-1}$) was estimated using updated Pauly non linier least square estimator by Then (2015) as follow [21]

$$M = 4.118 \times K^{0.73} \times L_\infty{}^{-0.333} \quad (2)$$

Calculation of total mortality (Z) was carried using the length-converted catch curve method [22]. The fishing mortality (F) was obtained by subtracting total mortality with natural mortality, then exploitation rate was formulated according to Pauly (1980) [22].

$$E = \frac{F}{F+M} = \frac{F}{Z} \quad (3)$$

E in the formulation above is exploitation rate ($year^{-1}$).

The spawning potential ratio (SPR) is a ratio between the proportion of spawning potency after and before exploitation. To proceed length-based SPR (LB-SPR), life history data is required, i.e. the ratio of natural mortality and growth coefficient (M/K), length of maturity (Lm_{50} and Lm_{95}), and asymptotic length (L_∞). The formula estimated LB-SPRs follows [3], [4].

$$SPR = \frac{SSB_F}{SSB_{F=0}} \quad (3)$$

The SPR is spawning potential ratio (%), SSB_F is current spawning stock biomass, and $SSB_{F=0}$ is spawning stock of unfished biomass. The SPR was analyzed using Microsoft Excel and used $SPR_{30\%}$ as the limit reference point, at which point fish resources can be sustainable [2]

3. Results and discussion

3.1. Growth parameters

Fish lengths ranged between 27-81 cmTL and 33-80 cmTL for males and females, respectively. The modus lengths of female fish were 60-68 cmTL, while the male fish were 36 cmTL. Sixty eight percent male fish were 32-48 cmTL whereas 74% female were 52-68 cmTL. The average lengths of male fish samples was smaller than the female ones (Figure 2).

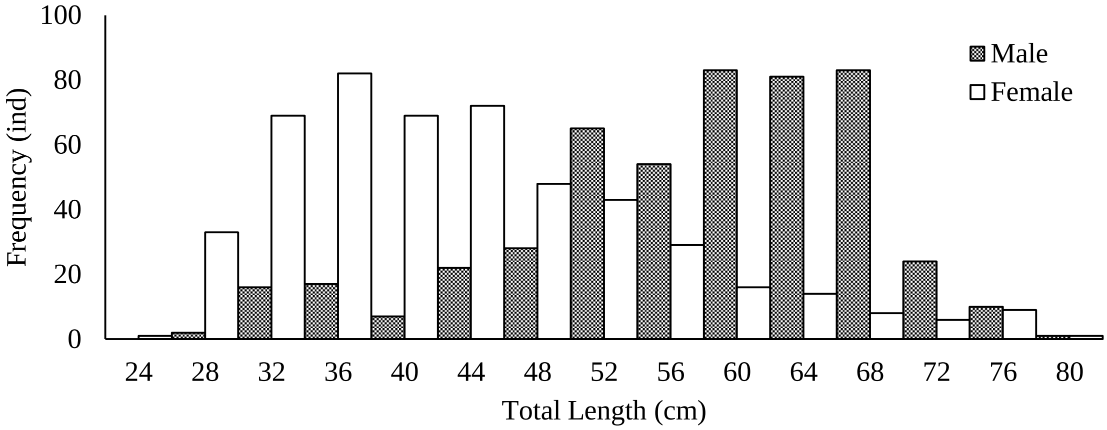

Figure 2. The Length Frequency Distribution of Red Snapper in the Eastern Java Sea

The asymptotic lengths was 92.20 cmTL for males and 91.09 cmTL for females. These values are smaller compared to 2012 data in the eastern Java Sea of which 97.65 cmFL [9]. In other areas, the red snappers in the western South Sulawesi was 73.98 cmTL [23], while in Sinjai was 77.30 cmTL [24], and in the South China Sea was 86.10 cmTL [25]. Based on k value, red snapper showed slightly different growth ability between male and female with 0.27 compared to 0.29 per year. In 2012, this value in similar location was 0.22 per year [9], while in the western South Sulawesi was 0.245 per year [23].

Length at zero of the eastern Java Sea red snapper was slightly differed by 0.27 and 0.29 years old, respectively. Accordingly von Bertalanffy Growth model for the two is defined as, consecutively, $L_t = 92.20\ (1 - e^{-0.27(t-0.07)})$ for male and $L_t = 91.09\ (1 - e^{-0.29(t-0.44)})$ for female (Figure 3).

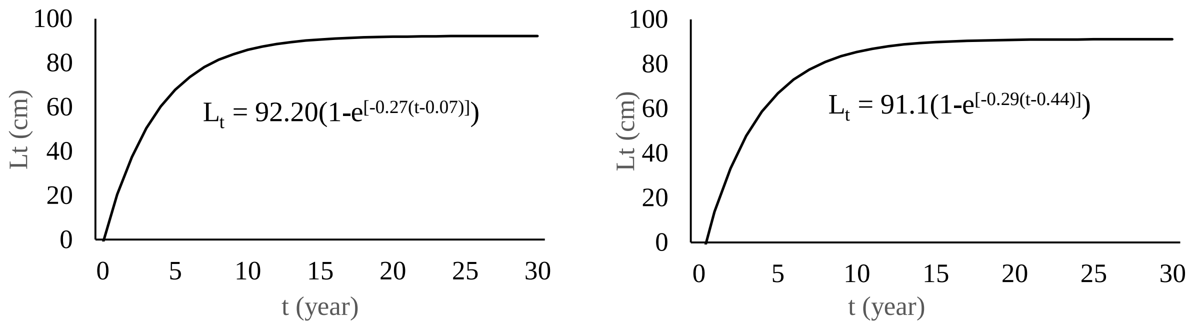

Figure 3. Growth model for the red snapper (*L. malabaricus*) shown by von Bertalanffy Growth Curve in males (left) and females (right) in the eastern Java Sea of FMA 712

The value of growth coefficient of *L. malabaricus* was smaller than 1.00 [9], [23], [24], [26], [27], indicating a slow growth species, therefore, it takes years to reach their asymptotic length [20] which approximately 35 years. A maximum age estimate of similar species reported from Kupang waters in 1999-2002 was 48 years [28].

3.2. Mortality and exploitation rate

The mortality rate of fish is caused by fishing (F) and natural (M) mortality. Natural mortality is caused by predation, diseases, starvation, old, and many more [20]. This research used Then (2015) equation [21] to estimate natural mortality, with the result for males and females are 0.35 and 0.38 per year, respectively. The length-converted catch curve method was used to estimate the total mortality rate (Z). The total mortality (Z) and fishing mortality rate (F) for male fish were 0.98 and 0.63 per year, whereas for females were 1.78 and 1.40 per year.

Based on the mortality rate, we found that the red snapper population in the eastern Java Sea was fully exploited level (0.64 for males and 0.79 for females). Previous research found that the exploitation rate in the same location was at the optimum level (0.53) [9], while in Sinjai waters was under the optimum level (0.35) [24].

3.3. Length Based - Spawning Potential Ratio (LB-SPR)

The population dynamic parameters and length-frequency data were used to estimate the SPR value, This research used population dynamic parameters and length-frequency data to estimate the SPR value; the result was 17% (Figure 4). It shows that the stock of red snapper in the eastern Java Sea has been over exploited. If the SPR is below the limit reference point (30%), the recruitment rate will face a risk of decline [2], [7]. The conditions can threaten the sustainability of red snapper stocks in the eastern Java Sea.

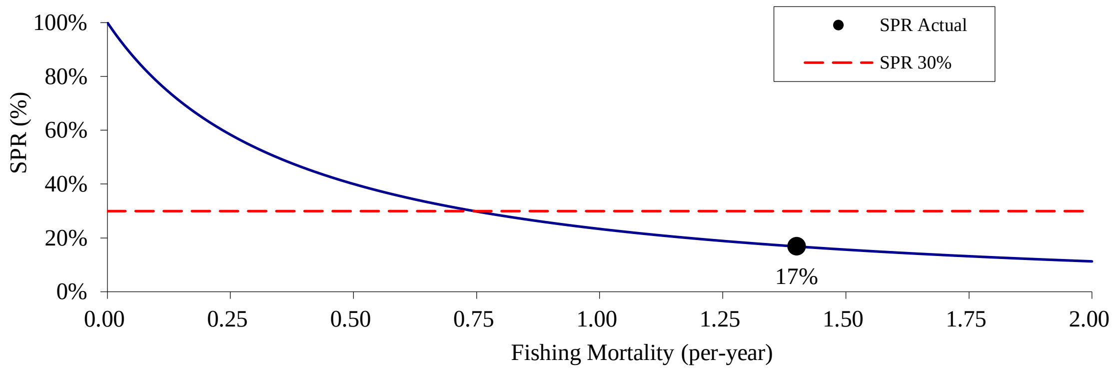

Figure 4. The Actual SPR of *L. malabaricus* in the eastern Java Sea with fishing mortality rate 1.40 compared with limit reference point ($SPR_{30\%}$ = red line).

Recently, the SPR value for this species was 6% [29]. The discrepancy in SPR between the previous and the current results may be addressed to the different sample size. The previous research has collected 65,156 samples, while the current results have 993 samples. In western South Sulawesi, the SPR was 30% level, which means that this species is at optimum level [23]. The other condition in FMA 713 covering Makassar strait, Bone bay, Flores sea, and Bali sea and FMA 718 covering Arafura Sea are 11% and 7%, respectively [29].

4. Conclusion and recommendation

The growth parameter of *Lutjanus malabaricus* in the eastern Java Sea is $L_t = 92.20\ (1 - e^{-0.27(t-0.07)})$ for male and $L_t = 91.09\ (1 - e^{-0.29(t-0.44)})$ for female. The exploitation rate of red snapper in the eastern Java Sea is fully-exploited, so maintaining the fishing efforts at the existing number is recommended. The SPR of *Lutjanus malabaricus* in the eastern Java Sea is over-exploited, with a value is 17%. It needs special attention from stakeholders to arrange proper management. As export commodities, the management effort of red snappers could be arranged based on the Marine Stewardship Councils' (MSC) fisheries standard, i.e., sustainable fish stocks, minimizing environmental impacts, and effective management [30].

The management efforts that can be proposed are related to increasing reproductive capacity, such as the close open season and limiting catch size above length at first maturity. It will give the red snapper time to spawn at least once before capture. The preparation of this management effort needs to be carried out by considering the results of other studies, including those related to the spawning season, the distribution of red snapper migration, and the socio-economic conditions of fishers in the eastern Java Sea.

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