Life history and length base spawning potential ratio (LBSPR) of malabar snapper *Lutjanus malabaricus* (Bloch & Schneider, 1801) in western of South Sulawesi, Indonesia

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Abstract. *Lutjanus malabaricus* is an economically important fish species having high market demand especially in Indonesia and the Asian region. Due to over exploitation this species is collapsing. Accordingly, it is important to understand their status. This study was aimed to assess its status according to their life history parameters in Western of South Sulawesi, Indonesia. We recorded length and maturity stage of *L. malabaricus* from Sumpang Binange (Barru) landing base which landed by bottom-longliners. The data were collected from 2018 to 2019 in as daily sampling. The spawning potential ratio (SPR) was analyzed using LBSPR method and considering the uncertainties. We found that the growth coefficient (K), length asymptotic (*L*∞) and natural mortality (M) were 0.245 year⁻¹, 73.98 cm of total length and 0.323 respectively. Length at maturity in 50% level (*L*₅₀) was 41.35 cm and 95% level (*L*₉₅) was 53.2 cm. Based on these parameters and determining uncertainties resulted the stochastic SPR is mostly met to the threshold of reference point at level 30%. It means that stock status of *L.malabaricus* is at the optimum level.

Keywords: life history parameters, *Lutjanus malabaricus*, spawning potential ratio

1. Introduction

Indonesian water were divided into eleven Fisheries Management Areas (FMA), one of them is FMA 713. Based on the decree of Ministry Marine Affairs and Fisheries (MMAF) of the Republic of Indonesia No. 18 2014, FMA 713 consists of Makassar strait, Bone bay, Flores sea, and Bali sea. Moreover, FMA 713 has possessed the potency of the reef fish resource which was recorded 19 856 tons per year. The exploitation rate in aggregated of the reef fish was in a level of over-exploited.

The reef fish is an essential commodity of commercial and artisanal fisheries (Ault *et al* 2018). Reef fish are mostly identified as a low migratory species, constructed in small schooling, not too far for the activity movement (Aoyama 1973) and they live in and associate with coral reef habitats. Their distribution is widespread throughout the world within coastal areas in the tropical and subtropical waters. Indonesian
The archipelago well known as the richest fish fauna in the world. It has been identified 113 families which are composite of 2057 species. There are 10 of the largest group, which one of them is Lutjanidae (43 species) (Allen and Adrim 2003). The Malabar Snapper (Lutjanus malabaricus) is distributed throughout the Indo-Pacific region and from Australia to southern Japan (Allen 1985). Snappers (Lutjanidae) are one of the reef fish fauna group which have an economically high value, include species of L.malabaricus. Snappers are continuously exploited using drop-lines, bottom long-line, fish traps, bottom gillnets, and others. The fishing gear have a great variety in Indonesian waters (Fenner 2012), mostly drop-lines or hand-lines and bottom long-lines are used in FMA713 especially in Western of South Sulawesi part of Makassar strait.

Furthermore, the characteristic of artisanal fisheries is restricted information of historical catches, fishing effort, and population abundance-based (Fenner 2012) and low data quality (Ault et al 2008). These matters cause estimating the fish stock assessment highly difficult while numerous models have been introduced for poor-data conditions which are effective for length-size data to estimate life history parameters (growth, longevity, natural mortality, maturity) and stock status (Pauly and Morgan 1987, Ault et al 2005, O’Farrel and Botsford 2005, Gedamke and Hoenig 2006, Ault et al 2008). The length-based techniques dominantly used for species in tropical waters which are the otoliths ring for defining annual growth are not clear (Hordyk et al 2015). The information of life history on specific species are important to ensure effective management in fish resources (Fry et al 2006).

One important interest in analyzing life-history parameter is beneficial to estimate stock status for instance, spawning potential ratio or SPR (Ault et al 2018). SPR is a reproduction relative rate index in an exploited stock, while generally used as reference points for fisheries (Hordyk et al 2014a). The principle of SPR is a ratio of the unfished reproductive potency left by fishing impact which has a 100% SPR (SPR_{100%}) of virgin stock then fishing causes mortality that can reduce SPR_{100%} from the unfished level to SPR_{SPR} (Prince et al 2014).

The life history and stock status information of the L.malabaricus in the Western of South Sulawesi is limited, therefore this paper described the status according to the life history and spawning potential ratio that could be beneficial to inform management judgments in a very limited data fisheries.

2. Material and methods

The data collection were conducted in daily, between April 2018 and April 2019 generally from bottom long-liners which fished in surrounding Barru and Pangkep waters, the coast of Western South-Sulawesi (119–120º E; 3.5–5º S) (figure 1).

2.1. Materials

Samples of L.malabaricus (n = 2988) were obtained generally from bottom long-liners. All fish were measured to the nearest centimeter total length (TL) and weighed to the nearest gram. For maturity estimation, additional samples (n=136) were also determined by macroscopic observation of the gonads which consisted of 64 females and 72 males.

2.2. Methods

Study on life-history parameters were determined of growth parameters (length asymptotic and growth coefficient), mortality, and size at first maturity (L_m). Total mortality is estimated using length catch curve model (Sparre and Venema 1993). Size at first maturity (L_m or L_{50}) describes the length where 50% of the individuals caught by fishing are adults or having mature gonads. The L_m was estimated by
calculating coefficients a and b respectively, in the following equation of logistic curve by maximizing likelihood of binomial distribution by using “solver” tool in Excel (Tokai and Mitsuhashi 1998):

$$M(TL) = \frac{1}{1+\exp(-aTL+b)}$$

(1)

Growth parameters estimated by von Bertalanffy growth model (Sparre and Venema 1999):

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

(2)

Lt is the fish length at size-t (cm); L∞ is asymptotic length (cm); K is growth coefficient (year⁻¹), and t₀ is hypothetical fish age at zero-length (year).

Natural mortality was estimated using a method provided by Hoenig (1983) with a formula for estimating fish:

$$M = \exp(1.46 - 1.01 \times \ln(t_{max})$$

(3)

M is natural mortality (year⁻¹) and t_{max} is the maximum age of fish (year).

**Figure 1.** Map showing the area of data collection in the Western of South Sulawesi coast.

Spawning potential ratio (SPR) required some inputs based on life-history parameters which are natural mortality (M), growth coefficient (K), asymptotic length (L∞), and length at maturity in level 50% (L_{50}) and 95% (L_{95}). The analysis requires length data as input which follow the formula of SPR (Hordyk et al 2014b):
SPR = \frac{\sum(1-L_x/M)\left[(F/M)+1\right]/F^b}{\sum(1-L_x/M)\left(k/L_x\right)^b} \quad \text{for} \quad x_M \leq x \leq 1 \quad (4)

Where \( L_x \) is total length; \( M \) is natural mortality; \( k \) is growth rate; \( F \) is fishing mortality and \( b \) is exponent usually close to 3. Considering the uncertainty is needed because of the poor quality of length data. To describe the uncertainty of SPR estimation, we used a bootstrap where one thousand iterations were run which specified prior distributions for the \( M/k \) with CV 0.2 and \( L_\infty \) with CV 0.1. We assumed that CV could fix without error.

3. Results and discussion

3.1. Length distribution, Size at capture (\( SL_{50} \& SL_{95} \)) and size at maturity (\( L_{50} \) and \( L_{95} \))

The length distribution of \( L.malabaricus \) were examined for life history analysis ranging from 12 to 81 cm TL with the mean length of 34.2 cm (±12.04, deviation standard). The distribution of length-frequency shows that there is one modus of length which obtained at size 33 cm TL representing the age group of this fish. The length at capture in the level 50% (\( SL_{50} \)) and 95% (\( SL_{95} \)) were defined as selectivity. The selectivity analysis was determined using logistic function which defined \( SL_{50} \) 26.14 cm TL and \( SL_{95} \) 36.79 cm TL, respectively (figure 2).

Information of size at maturity of fish are basically need related to provide effective management for ensuring the recruitments process of species. Length at maturity were resulted in \( L_{50} \) 41.35 cm TL and \( L_{95} \) 53.2 cm TL (figure 2). These results showed that most fish were captured by bottom long-lines before being spawned at least once. From previous research in the Java Sea was recorded \( L_{50} \) 50 cm FL (Wahyuningsih et al. 2013) and 45.6 cm TL in surrounding Sinjai (Tirtadanu et.al 2018). Based on length at maturity (\( L_m \)) of \( L.malabaricus \) identified that these fish matured relatively late (Fry et al 2006). This type is quite difficult to reach sustainable since the high of fishing tension and the resource would be immediately over-fished (Fry et al 2006).

![Figure 2](image)

Figure 2. The distribution of total length \( L.malabaricus \), size at capture (blue line) and maturity (dashed red line) which landed by bottom-longliners in western of South-Sulawesi coast.

3.2. Growth parameters and natural mortality

Estimating growth of the fish in tropical waters can often be difficult, consequently using length-based method is as a good option. Although, length data are simple to collect, life history parameters information
of *L.malabaricus* in the Makassar strait which based on length-data are still limited. Growth parameters analysis of *L.malabaricus* was performed by pooled length data (without differentiating the sex). Based on the length distribution analysis, we determined the asymptotic length (*L*∞) of *L.malabaricus* was 73.98 cm TL which could be reached by the growth rate (k) of 0.245 years⁻¹ and the maximum age (*A*max) was 13 years. The theoretical age (*t*0) of the Malabar snapper was obtained about -0.5339 and the natural mortality (M) was estimated 0.323 years⁻¹ by Hoenig (1983) equation. The von Bertalanffy growth curve of the species presented in figure 3. From previous researches in Sinjai coast, Java Sea and Pilbara coast of North-western Australia were obtained various life history parameters. These results showed in table 1.

![Figure 3. The von Bertalanffy growth curve of *L.malabaricus* in western of South Sulawesi.](image)

**Table 1.** Growth parameters and natural mortality of *L.malabaricus* in some waters area.

| Location                   | *L*∞ (cm) | k (year⁻¹) | *t*0 | *A*max (years) | M (years⁻¹) | Source                  |
|----------------------------|-----------|------------|------|----------------|-------------|-------------------------|
| Sinjai coast (Bone bay)    | 77.3      | 0.29       | -0.34| 10             | 0.47        | Tirtadanu et al 2018    |
| Eastern Java Sea           | 97.65     | 0.22       | -0.02| 15             | 0.49        | Wahyuningsih et al 2013 |
| Pilbara coast              |           |            |      |                |             |                         |
| female                     | 56.6      | 0.26       | -0.09| 26             | 0.23        | Newman 2000             |
| male                       | 68.6      | 0.18       | -0.33| 31             | 0.32        |                         |
| Western South-Sulawesi     | 73.98     | 0.25       | -0.53| 13             | 0.32        | Current research        |

Noted: *L*∞ = asymptotic length, K = growth coefficient (year⁻¹), *t*0 = hypothetical fish age at zero length, *A*max = maximum age and M = natural mortality

Overall, based on the results of the growth of *L.malabaricus* categorized as slow growth that is indicated by lower k. The differences in maximum age could be explained by the length size ranges of fish sampled. *L.malabaricus* is grouped as deepwater tropical species which found in the continental shelf associated with both inshore and offshore reef areas (Newman 2000). Prior studies of deep-water tropical fish for their life histories were seen that they were usually slow growth and long-lasting species (Manooch 1987, Haight et al 1993, Pilling et al 2000).
Natural mortality (M) in this study has relatively lower rates. It is a characteristic of long-lived snappers in tropical waters (Fry et al 2009). Fish which have these types tend to be had low productivity and vulnerable to overfishing (Newman 2002). Therefore exploitation of this species needs to be careful and managers should be more conservative in determining fisheries management. The manager provides protection of spawning stock biomass of _L. malabaricus_, considering low species productivity.

3.3. Spawning Potential Ratio

Estimation of SPR using LB-SPR method requires length distribution frequency as its input (Hordyk et al 2014a). A single growth of females and males are not different, therefore we assumed they have equal catchability (Prince et al 2015). Because of _L_∞, k and M plausible causing the uncertainty due to the poor data quality, so it is necessary to define SPR with uncertainty of _L_∞ and M/k. It is called as stochastic SPR, while SPR without considering the uncertainty is named as deterministic SPR. The result of deterministic SPR is ranging between 0.13 and 0.16 with median 0.15, while stochastic SPR results lower SPR, upper SPR and median SPR with 0.12, 0.81 and 0.30 respectively (figure 4). The deterministic SPR is systematically lower than the bootstrapped value of stochastic SPR. The stochastic SPR consider a wider range of _L_∞ and M/k than the single bootstrap estimate. The LB-SPR models are especially sensitive to the under-estimation of _L_∞ (Hordyk et al 2014a) since the largest length fish in a sample start to reach _L_∞ estimates of SPR will increase rapidly (Prince et al 2015).

Though the LBSPR estimation has uncertainties, this is a good method to determine the poor data fisheries. We used SPR threshold in 0.3 as reference point which is under the threshold, a stock is no longer sustainable at current exploitation level (Ault et al 2008). Through the stochastic SPR, the results are mostly met to the threshold. It means that stock status of _L. malabaricus_ is in the optimum level that needs management, which is no added effort and maintain in that level. Considering the probability of SPR was under 0.3, it is necessary to implement minimum size limits to gain a higher SPR level to meet the sustainability.

![Figure 4](image-url)  
**Figure 4.** Two set boxplots, first stochastic SPR with the uncertainty of _L_∞ and M/k, second deterministic SPR with use only single parameter of life history and blue line is a threshold of reference point.
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