

Length-based stock status assessment of *Lutjanus malabaricus* in Saleh Bay, Indonesia

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Abstract. Malabar blood snapper (*Lutjanus malabaricus*) is a key target species in the small-scale fisheries in Saleh Bay, prized for its high market value. However, persistent fishing pressure has rendered it vulnerable to overexploitation. To address this issue, the West Nusa Tenggara (NTB) Provincial Government implemented Governor Regulation No. 32 of 2018 in September 2018. This study aims to estimate the stock status of *Lutjanus malabaricus* under the implementation of the current policy using TropFish R and length-based spawning potential ratio (LB-SPR). Results reveal sustained overfishing of *Lutjanus malabaricus*, with an exploitation rate above 0.5 (0.61). The estimated SPR showed a declining trend from 0.33 in 2016 to 0.25 in 2025, with $F/M > 1$ indicating high fishing pressure. To safeguard this resource, we recommend enhancing existing measures (e.g., enforcing minimum legal size and gear restrictions), implementing seasonal/spatial closures, and adopting ecosystem-based fisheries management. These steps are critical to reversing stock decline and ensuring long-term sustainability.

1 Introduction

Saleh Bay, a semi-enclosed marine ecosystem along Sumbawa Island's coast in West Nusa Tenggara (WNT), harbors rich biodiversity supported by critical habitats including coral reefs, seagrass beds, and mangrove forests [1]. This ecosystem plays a crucial role in supporting small-scale fisheries, providing a livelihood for around 5,800 local fishermen who depend on the bay's resources [2]. Based on WNT's annual statistical data, snapper and grouper fisheries contribute significantly to regional production, with Saleh Bay contributing 4.4% of the province's total production with snapper (*Lutjanidae*) comprises almost 17.7% of the total catch in this bay [3].

Malabar blood snapper (*Lutjanus malabaricus*), locally known as "kakap merah or bambangan" is a demersal fish found at depths of 50–180 m and targeted by bottom longlines

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and bottom trawls. As a high-value export commodity, this species is one of the main targets of fishing in Saleh Bay, alongside grouper like leopard coral grouper (*Plectropomus leopardus*), orange-spotted-grouper (*Epinephelus coioides*), and spotted coral grouper (*Plectropomus maculatus*), due to its availability throughout the year [3-6]. However, its exploitation rate in Saleh Bay increased from 0.46 to 0.64, exceeding the sustainability threshold of 0.5 [7]. To address the problem of overfishing, the West Nusa Tenggara Government issued Regional Regulation No. 32/2018 to control catches.

Stock assessment can be estimated using the Spawning Potential Ratio (SPR), which measures the reproductive capacity between fished and unfished populations [8]. In Saleh Bay, snapper fisheries are dominated by small-scale fisheries which generally have data limitations. This condition causes difficulty in finding an analysis method for matching stock to use in situations with a lack of data. This constraint complicates the stock analysis, requiring alternative methods such as Length-Based SPR (LB-SPR) which uses fish length-frequency data [8]. This approach is particularly useful for assessing high-value species such as *Lutjanus malabaricus*, which faces excessive fishing pressure. Accurate population parameter estimates are critical to prevent stock collapse and guide recovery efforts. This study evaluates the status of grouper fisheries under the prevailing management policies in Saleh Bay.

2 Method

2.1 Study site and data source

This study was conducted in Saleh Bay, West Nusa Tenggara Province. This bay is one of the main fishing grounds for snapper species including *Lutjanus malabaricus* [3-4]. The research location is focused on five villages, namely Labuhan Sumbawa, Labuhan Kuris, Labuan Sanggoro, Labuhan Jambu (Sumbawa Regency), and Soro (Dompu Regency), which are the main landing sites for snapper fishing vessels (Figure 1).

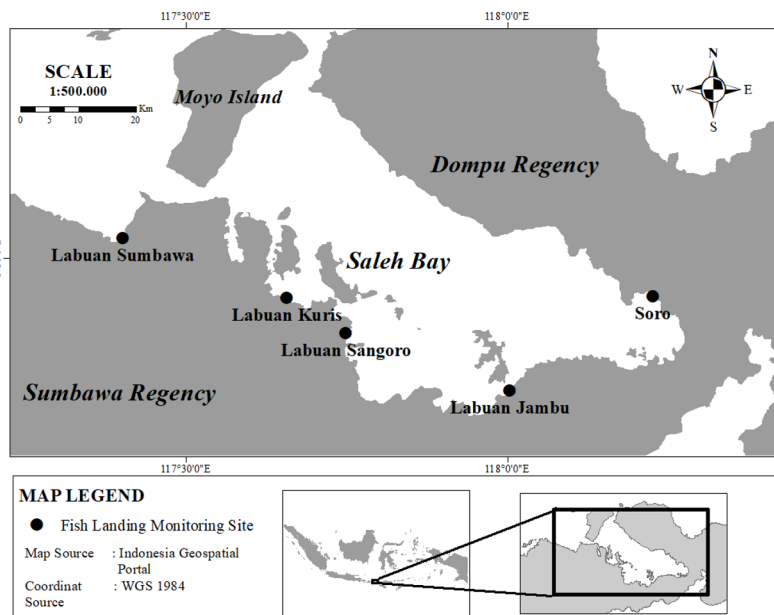


Fig. 1. The location of Saleh Bay, West Nusa Tenggara.

The data used in this study are length data which obtained from secondary data fish landings monitoring (FLM) database from FIP2B WNT (Forum Ilmiah Pengelolaan Perikanan Berkelanjutan) organization, covering the period from April 2016 (when FLM began) to December 2023. Length data 2024 to 2025 are a primary data obtained from sampling from September 2024 to February 2025.

2.2 Data analysis

The growth parameters estimation of *Lutjanus malabricus* are determined by using the Von Bertalanffy model to determine the growth coefficient (K) and the asymptotic length of the fish (L_{∞}) [9].

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

Growth parameters were determined using the 'R' software with the R package 'TropFishR' which implements length frequency analysis with genetic algorithms (ELEFAN GA), including the VBGF (Von Bertalanffy Growth Function) method with a growth curve model optimization approach [10]. t_0 was calculated following the empirical equation by Pauly [11]:

$$\log(-t_0) = -0.3922 - 0.2752 \log L_{\infty} - 1.038 \log K \quad (2)$$

Where L_t - the length at age t (cm); L_{∞} - asymptotic length (cm); K - the growth coefficient (year^{-1}); t_0 - the hypothetical fish age at zero-length (years).

Natural mortality (M) was calculated using the empirical formula of Alverson & Carney 1975 (Equation 3) in [12]; Pauly 1980 (Equation 4) [13]; Hoenig 1983 in [14] (Equation 5); Then et al. (2015) based on the t_{max} value (Equation 6); and Then et al. (2015) based on growth parameters (K and L_{∞}) (Equation 7) [14] with the mode value used to estimate the natural mortality rate.

$$M = \frac{3k}{e^{(0.38 * t_{max} * k) - 1}} \quad (3)$$

$$\log M = (-0.0066) - 0.279 \log L_{\infty} + 0.6543 \log K + 0.4634 \log T \quad (4)$$

$$M = \exp(1.46 - 1.01 \times \ln(t_{max})) \quad (5)$$

$$M = 4.899 t_{max}^{-0.916} \quad (6)$$

$$M = 4.118 K^{0.73} L_{\infty}^{-0.33} \quad (7)$$

Meanwhile the mortality rate due to fishing (F) and the exploitation rate value (E) are estimated by using the Pauly equation [11], namely by comparing the F value with Z . The estimated calculation of M , Z , and F is as follows:

$$F = Z - M \quad (8)$$

$$E = \frac{Z}{M} \quad (9)$$

Where: L_{∞} - asymptotic length (cm); K - growth coefficient (year^{-1}); T - mean annual water temperature ($^{\circ}\text{C}$); t_{max} - maximum age; and Z - total moratlity.

The length at first maturity (L_m) is calculated using the Froese & Binohlan [15] equation:

$$\log(L_m) = 0.8979 * \log(L) - 0.0782 \quad (10)$$

The SPR was calculated using *barefootecologist.com* by entering parameters such as M/K , L_∞ , L_{50} and L_{95} which were estimated using length-based frequency data. Some of the estimated parameters were the F/M , SL_{50} , SL_{95} and SPR values [8].

$$SPR = \frac{\sum (1-L_x)^{\left(\frac{M}{K}\left(\frac{F}{M}\right)+1\right)} L_x^b}{\sum (1-L_x)^{M/K} L_x^b} \text{ for } y_m \leq y \leq l \quad (11)$$

Where: L_x – total length of fish (cm); y – standard age of fish (year); y_m – standard age of fish at length at maturity (L_m); and b – exponent, generally approaching 3

3 Result and discussion

Information on the stock status of *Lutjanus malabaricus* in Saleh Bay is crucial for effective fisheries management. This includes key life history parameters such as growth rate, mortality, exploitation rate, and Spawning Potential Ratio. With the availability of basic biological information, it becomes possible to implement management strategies capable of reversing the concerning trends observed.

3.1 Growth parameters

The growth parameters were estimated using length-frequency distribution data. The estimated growth parameters for grouper and snapper species in Saleh Bay are summarized in Table 1.

Table 1. Growth parameters of *Lutjanus malabaricus* in Saleh Bay.

Species	L_∞ (cm)	k (year ⁻¹)	t_0 (year)	Lifespan (year)
<i>Lutjanus malabaricus</i>	85.55	0.25	-0.50	12

The analysis results show that the growth parameters for *Lutjanus malabaricus* indicate an asymptotic length (L_∞) of 85.55 cm and a growth rate (k) of 0.25 year⁻¹. The K value < 1 indicates that these species are relatively slow growing [9]. The species has a lifespan of approximately 11 years, meaning that *L. malabaricus* tends to reach L_∞ at 12 years age. These values indicate a slow growth rate and a relatively long lifespan, characterized by late sexual maturation and spawning aggregation, which is typical of many demersal fish species [6]. The asymptotic length reflects the maximum potential size the species can achieve under optimal conditions, while the growth rate indicates how quickly they reach this size. The slow growth rate and long lifespan imply that *Lutjanus malabaricus* may be vulnerable to overfishing, as slower-growing species often take longer to recover from population declines.

3.2 Mortality and exploitation rate

Fish mortality can result from both natural causes, such as predation, starvation, disease, and ageing, as well as fishing activities [9]. Based on length-frequency data, the estimated natural mortality rate (M) was 0.4, which is lower than the fishing mortality rate (F) of 0.43, suggesting significant fishing pressure resulting in an exploitation rate (E) of 0.52. These values indicate that the species is experiencing fishing pressure, as the exploitation rate as the fishing mortality exceeds natural mortality and the exploitation rate already reach the recommended sustainable threshold (0,5)[16].

Table 2. Mortality and exploitation rate of *Lutjanus malabaricus*.

Species	M	Z	F	E
<i>Lutjanus malabaricus</i>	0.4	0.83	0.43	0.52

From a fisheries management perspective, an exploitation rate equal to 0.5 is often considered as fully exploited [11]. The high exploitation rate ($E = 0.52$) suggests that *Lutjanus malabaricus* is fully exploited. This situation could lead to population decline if not managed properly. Sustainable fishing practices, such as reducing catch quotas or implementing size limits, may be necessary to mitigate this pressure and ensure the long-term health of the stock [7].

3.3 The length at first capture (L_c) and estimated fish length at first gonad maturity (L_m)

To prevent overfishing, the length at first capture (L_c) should exceed the mean length at first maturity (L_m), ensuring that fish could spawn before being harvested. A comparison of L_c and L_m values for *Lutjanus malabaricus* is provided in Table 3. *L. malabaricus* showed a sustainable pattern, with the majority of catches exceeding their maturity size. From the 7582-length data obtained, 13.5% or 1024 fish caught were below the average length at first maturity.

Table 3. The length at first capture and fish length at first gonad maturity of *Lutjanus malabaricus*.

Species	L_c (cm)	L_m (cm)	L_{opt} (cm)
<i>Lutjanus malabaricus</i>	55.61	45.37	54

Based on sample data collected from 2016 to 2025, the average length of *Lutjanus malabaricus* in Saleh Bay reached maturity at a length of 45.37 cm (L_m), which matches the L_m value reported by Efendi et al. [7] for 2017–2018. Similarly, in Sinjai and Belitung waters, red snapper had a length at first gonadal maturity of 45.6 cm [17-18]. Meanwhile, in the Makassar Strait, L_m is reached at 47.2 cm and in the waters of western South Sulawesi, red snapper reaches L_m at 41.35 cm, and [6, 19]. The differences in the length of first maturity are influenced by depth, habitat type, and food availability [20].

The L_c value of *Lutjanus malabaricus* in 2025 is 55.61 cm, while L_m , the average length of fish when they first mature, is marked by gonad maturity at 45.37 cm. The analysis results show that during 2016-2025, the length of red snapper in Saleh Bay when first caught was greater than the size of red snapper when first gonad maturity or $L_c > L_m$. The results of research by Efendi et al. [7] in 2016-2018, red snapper in Saleh Bay had an L_c value $> L_m$ with a L_c value of 50 cm and a L_m value of 45.37 cm. The average length of fish recommended for capture is 54 cm. One of the efforts to support sustainable fisheries management to prevent overfishing is to ensure that the length at first capture (L_c) of fish is greater than the length at first maturity (L_m). This is intended to ensure that each individual fish has the opportunity to reproduce at least once before being caught, thus contributing to population recovery to ensure that fishing activities take place sustainably [21].

3.4 Spawning potential ratio

The trends in Spawning Potential Ratio (SPR) and relative fishing mortality (F/M) from 2016 to 2025 show significant variability. SPR values range from 0.25 to 0.35, with a general decline over time, while the F/M ratio fluctuates widely, peaking at 3.84 in 2018 and reaching 3.2 in 2025. SPR values below 0.3 in recent years indicate potential overfishing, as they do not reach the threshold of 0.3, which is often considered sustainable [22].

Table 4. Estimation of spawning potential ratio and relative fishing mortality of *Lutjanus malabaricus*.

Years	SPR	F/M
2016	0.35 (0.28 - 0.42)	1.22 (0.82 - 1.62)
2017	0.34 (0.27 - 0.4)	1.88 (1.27 - 2.49)
2018	0.27 (0.14 - 0.4)	3.84 (1.37 - 6.31)
2019	0.26 (0.18 - 0.34)	3.49 (1.96 - 5.02)
2020	0.28 (0.16 - 0.4)	3.81 (1.55 - 6.07)
2021	0.33 (0.27 - 0.38)	3.07 (2.25 - 3.89)
2022	0.28 (0.24 - 0.31)	1.69 (1.41 - 1.97)
2023	0.25 (0.22 - 0.29)	2.05 (1.72 - 2.38)
2024	0.25 (0.14 - 0.36)	1.83 (0.73 - 2.93)
2025	0.26 (0 - 0.58)	3.2 (0 - 8.44)

The estimation results show that *Lutjanus malabaricus* in Saleh Bay has an SPR ranging from 0.25 (25%) to 0.35 (35%). Based on Figure 2, the SPR of red snapper shows a downward trend each year. The average SPR is below the target reference point (30%) but above the limit reference point (20%). In 2025, red snapper in Saleh Bay had an SPR of 26%. This condition puts the stock at moderate risk of declining recruitment rates [23-24]. According to [22], SPR values below 30% or 0.3 are no longer sustainable at that level of exploitation. Meanwhile, according to [25], SPR values that are still within the range of 25-40% are considered to be in a fully exploited exploitation status. SPR relates closely to recruitment because recruits depend on the eggs produced by spawning fish. If the SPR falls, the number of eggs—and thus recruitment—will decline [6]. Fisheries managers should consider ways to maintain or raise SPR, such as regulating catch or protecting spawning fish, to prevent significant losses of spawners in fished populations.

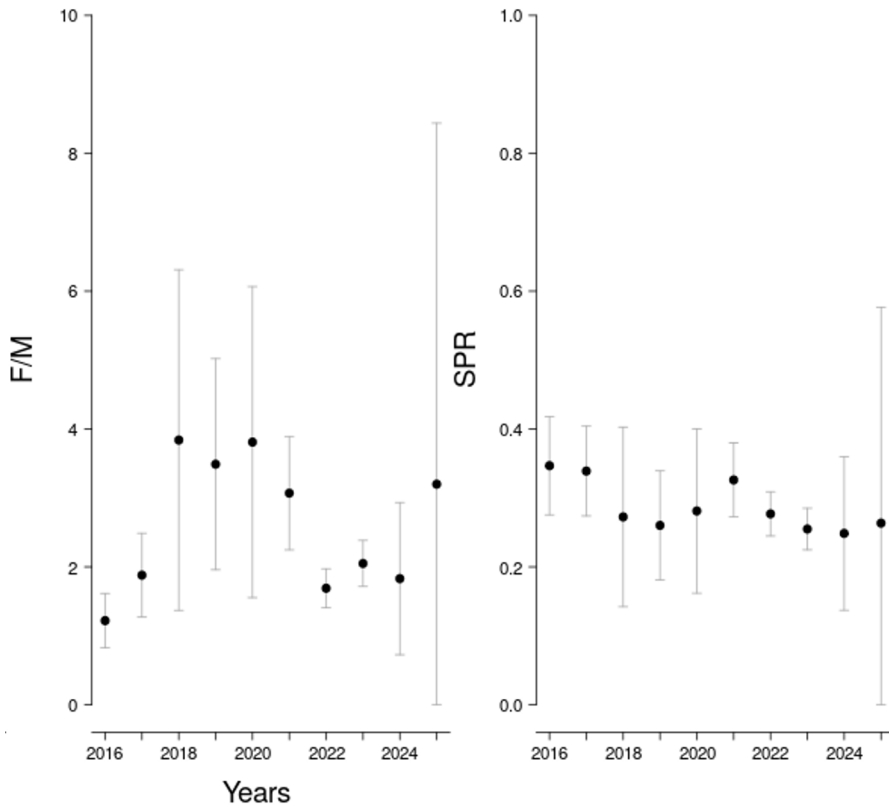


Fig. 2. F/M and SPR values of *Lutjanus malabaricus* from 2016 to 2025.

4 Conclusion

The analysis reveals that *Lutjanus malabaricus* in Saleh Bay exhibits slow growth characteristics, with a von Bertalanffy growth coefficient (K) of 0.25 year^{-1} and asymptotic length (L_{∞}) of 85.55 cm. The estimated natural mortality rate ($M = 0.4 \text{ year}^{-1}$) was substantially lower than fishing mortality ($F = 0.43 \text{ year}^{-1}$), resulting in an exploitation rate ($E = 0.52$) equal to the threshold. Over the past decade, the spawning potential ratio (SPR) has declined from 0.35 to 0.26, indicating the stock is currently fully exploited. These findings suggest that without immediate management intervention, *Lutjanus malabaricus* populations face imminent risk of collapse—a pattern consistent with observed declines in other overexploited demersal fisheries.

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