UMT PRESS

Journal of Sustainability Science and Management
Journal Homepage: https://jssm.umt.edu.my
eISSN: 2672-7226
DOI: http://doi.org/10.46754/jssm.2026.05.002

TOWARDS SUSTAINABLE MANAGEMENT OF THE MALABAR BLOOD SNAPPER (*Lutjanus malabaricus*) IN KARIMUNJAWA, CENTRAL JAVA, INDONESIA

MARTIEN ANDEW SIHOTANG[1,3], BUDY WIRYAWAN[1,2], DOMU SIMBOLON[1,2], IRFAN YULIANTO[1,2,3], SUKMARAHARJA AULIA RACHMAN TARIGAN[4], JAMALUDIN[4], RIPANTO[4], ISNAINI MARLIANA[4], TEZAR RAFANDI[4], ROHMANI SULISYATI[5] AND PRIHATIN IKA WAHYUNINGRUM[1,2]*

[1]Marine Fisheries Technology Study Program, Faculty of Fisheries and Marine Sciences, IPB University, 16680 Bogor, West Java, Indonesia. [2]Department of Fisheries Resources Utilization, Faculty of Fisheries and Marine Sciences, IPB University, 16680 Bogor, West Java, Indonesia. [3]Rekam Nusantara Foundation, Fisheries Resource Center of Indonesia, 16129 Bogor, West Java, Indonesia. [4]Wildlife Conservation Society, Indonesia Program, 16128 Bogor, West Java, Indonesia. [5]Balai Taman Nasional Karimunjawa, 50273 Semarang, Central Java, Indonesia.

**Corresponding author: piwahyuningrum@apps.ipb.ac.id*

ARTICLE INFO

Article History:
Received: 29 November 2024
Revised: 27 November 2025
Accepted: 9 December 2025
Published: 15 May 2026

Keywords:
Lutjanus malabaricus, data limited, spawning potential ratio, management, Karimunjawa.

ABSTRACT

The Malabar blood snapper (*Lutjanus malabaricus*) has become increasingly vulnerable to overfishing, driven by rising export demand. This study aimed to evaluate the exploitation status of *L. malabaricus* around Karimunjawa Islands off Central Java in Indonesia and recommend management options. Fish samples were collected from 2017 to 2022. The data analysed included length-frequency, growth and mortality parameters, exploitation rates, and Spawning Potential Ratio (SPR). The study found that the species' Total Length (TL) ranged from 19 cm to 80 cm, with an average of 43.18 ± 11.32 cm. Growth parameter estimation yielded an asymptotic length ($L\infty$) of 83.4 cm TL, a growth coefficient (K) of 0.23 year^{-1}, and a theoretical age at zero length (t0) of -0.56 years. Mortality analysis showed a total maturity rate (Z) of 0.72 year^{-1}, with estimated fishing mortality (F) and natural mortality (M) of 0.42 and 0.30 year^{-1}, respectively, resulting in an exploitation rate (E) of 0.59. The stock was considered fully exploited with an SPR of 20% only. To prevent further decline, we recommend immediate measures such as enforcing minimum catch sizes above the length at maturity (Lm), limiting vessel permits to reduce fishing pressure, and expanding protected areas to safeguard spawning habitats in Karimunjawa.

Introduction

Snappers are an important commodity of Indonesia's capture fisheries, with high economic value and consistently increasing global demand (Pérez-Jiménez *et al*., 2022; Panggabean *et al*., 2023; Purushothaman *et al*., 2025). In 2022, Indonesia's snapper export experienced a significant increase, reaching 6,441 tonnes valued at US$19.8 million, which was a 54.4% rise from the previous year (Ministry of Marine Affairs and Fisheries [MMAF] Statistics, 2022).

Among the most economically valuable species is the Malabar blood snapper (*Lutjanus malabaricus*), commonly found in coral reefs at depths ranging from 10 metres to 100 metres. Its distribution spans the Indo-Pacific region, from Australia to southern Japan (Allen, 1985). This species plays a crucial role in supporting coastal livelihoods and food security in Indonesia, especially for small-scale fishermen (Amorim *et al*., 2019; Halim *et al*., 2020; Herdiana *et al*., 2023).

Karimunjawa is an archipelago north of Central Java (5°49′09″S 110°27′32″E) that comes under Indonesia's Fisheries Management Area (FMA) 712, a key fishing ground for *L. malabaricus*. Over 110,000 hectares of this area have been designated as marine conservation zones (Balai Taman Nasional Karimunjawa, 2012). Landing data of *L. malabaricus* in Karimunjawa from 2017 to 2022 demonstrates a steady upward trend. Production peaked at 93.7 tonnes in 2022, rising significantly from roughly 35.8 tonnes in 2017, likely driven by increasing market demand (Wibisono *et al*., 2021; Karimunjawa Fishing Port, 2023).

According to the Indonesian Ministry of Marine Affairs and Fisheries (MMAF) Regulation 123/2021, the condition of coral reef fisheries, including snappers in FMA 712 has reached its optimum limit and is fully-exploited. While the IUCN currently lists *L. malabaricus* as a species of "Least Concern" (LC), there remains a significant gap in data regarding its exploitation status. Previous biological studies have shown that many individuals are caught before reaching reproductive maturity, suggesting overfishing may already be occurring (Ernawati & Budiarti, 2020; Ernawati *et al*., 2024).

The overfishing of *L. malabaricus* indicates a need for an exploitation status assessment to determine effective management based on its stock condition. Fisheries stock assessment is fundamental for developing appropriate and targeted management for the current state of fishery resources. Therefore, this study aims to evaluate the exploitation status of Malabar blood snapper (*Lutjanus malabaricus*) and recommend management options for its fishery in Karimunjawa waters.

Considering that the fishing grounds in Karimunjawa waters are dominated by small-scale fisheries (< 10 Gross Tonnes) that use traps and handlines, the available data are very limited due to the absence of mandatory production reporting by fishermen. This lack of data on production and fishing effort makes fish stock assessment difficult and results in inadequate management, which is a condition that applies in Karimunjawa waters. Consequently, this study utilises length-based indicators to determine growth and mortality parameters, as well as the spawning potential ratio as an indicator of its exploitation status (Hordyk *et al*., 2015; Prince *et al*., 2015).

This research may be beneficial for fisheries managers, especially policymakers in the Karimunjawa National Park Agency and MMAF, to serve as a basis for considering the management of *L. malabaricus* fishery in Karimunjawa. Ultimately, this will support sustainable fishing and ensure the livelihood of fishermen in Karimunjawa waters.

Materials and Methods

Data Collection

Sampling of *L. malabaricus* was conducted in the waters of Karimunjawa and adjacent areas over a six-year period (2017-2022). Field sampling was carried out for 14 days each month by trained enumerators recruited by the Wildlife Conservation Society (WCS), resulting in a total of 3,087 specimens collected. Length measurements were performed using a scaled measuring board and documented. Figure 1 shows the map of Indonesia and the location of Karimunjawa archipelago north of Central Java, where the study was conducted.

The collected data consisted of the fish's total length, with the number of samples each month presented in Table 1. The fish samples were obtained from the catch of fishermen who used traps and handlines. Around 78% and 22% of the samples were caught using these gears, respectively.

Length Distribution

The length-size distribution of the *L. malabaricus* was analysed using simple descriptive statistics, namely minimum, maximum, mean, and standard deviation. This study also presented the length-frequency distribution of the snapper

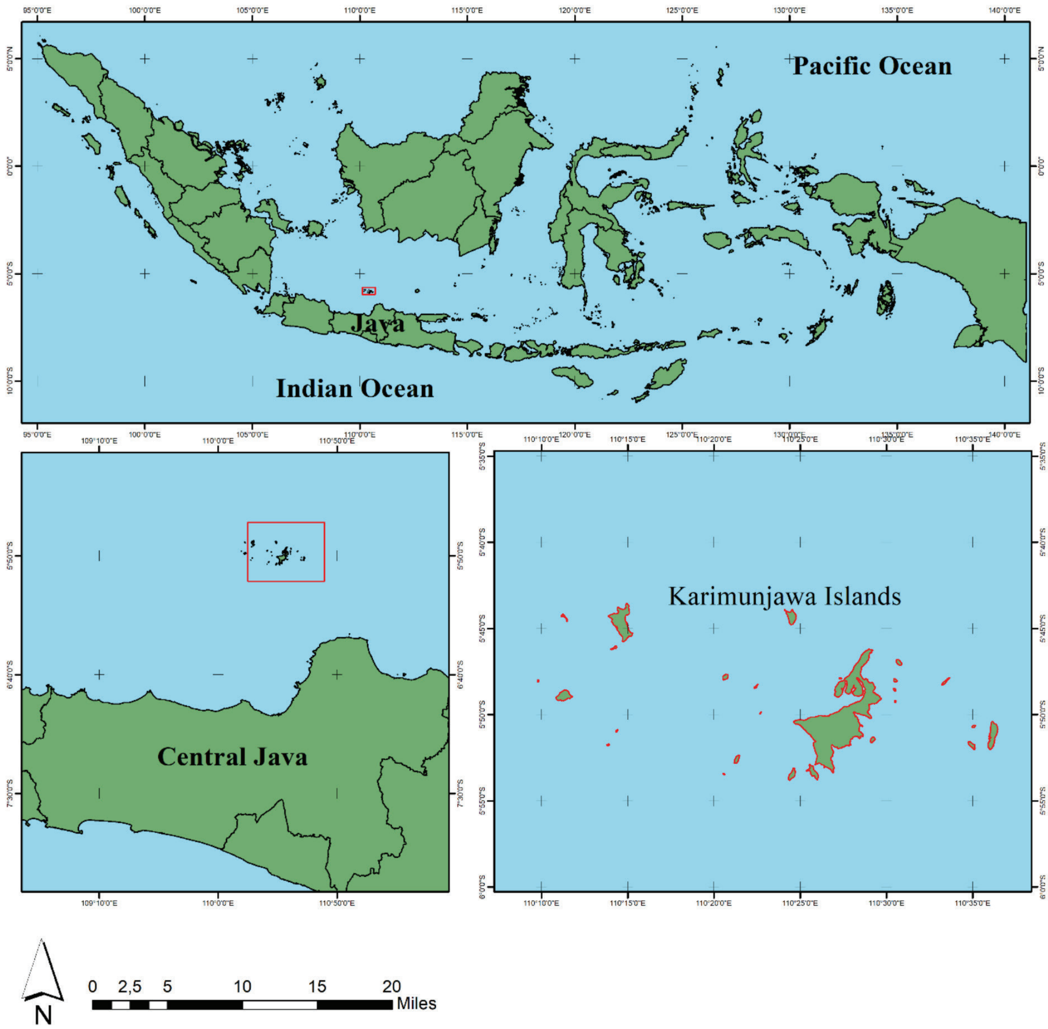

Figure 1: Research location panels showing the Karimunjawa Islands within the Indonesian archipelago (top), their proximity to Central Java (lower left), and a detailed view of the islands (lower right)

based on the fishing gear used by fishermen in Karimunjawa.

The data used to calculate the length at first maturity (Lm) in this study were the collected length samples of *L. malabaricus*. The length at which the fish reached the proportion of 50% mature gonads (Lm_{50}) and the proportion of 95% reaching gonad maturity (Lm_{95}) were calculated using the TropFishR Package software according to the equation by Froese and Binohlan (2000) based on fish asymptotic length (L∞). The empirical equation for the calculation is stated in Equation 1 (Eq. 1):

$$\log Lm = 0.8979 * \log L\infty - 0.0782 \quad \text{(Eq. 1)}$$

Growth and Mortality

The population parameters observed in this study included growth parameters, lifespan, mortality, exploitation rate, mean length at first capture, length at first maturity, optimal length, and Spawning Potential Ratio (SPR) (Sparre & Venema, 1996). The growth parameters

Table 1: The number of samples used in this study

Month	Sample Size Distributions (ind)					
	2017	**2018**	**2019**	**2020**	**2021**	**2022**
January	162	175	21	7	66	31
February	43	202	31	41	13	17
March	66	115	12	21	69	17
April	54	48	5	38	12	3
May	0	24	20	45	11	20
June	56	63	6	23	13	43
July	72	29	8	20	9	126
August	229	44	35	34	19	8
September	105	59	16	18	3	1
October	159	62	20	0	7	12
November	36	77	23	11	50	11
December	97	69	17	0	8	0
Total	**1,079**	**967**	**214**	**258**	**280**	**289**

observed included asymptotic length ($L\infty$), which was the theoretical maximum length a fish could reach, the growth coefficient (K), and the theoretical age (t_0), which was the age of a fish when its length is equal to zero. The growth coefficient was estimated using the ELEFAN GA II (with seasonal) method within the TropFishR Package, selected based on the highest Goodness of Fit (Rn) value (Sparre & Venema, 1996; Mildenberger *et al*., 2017). The growth coefficient followed the von Bertalanffy model, as formulated in Equation 2 (Eq. 2):

$$Lt = L\infty\,[1 - e^{(-K(t-t_0))}] \qquad \text{(Eq. 2)}$$

The estimation of the theoretical age of the fish (t_0) was calculated based on the empirical equation of Pauly (1984) in Equation 3 (Eq. 3):

$$Log\,(-t_0) = -0.392 - 0.275\,Log L\infty - 1.038\,Log\,K \qquad \text{(Eq. 3)}$$

Mortality is a measure of the total death rate of individual fish (Z), which consists of natural mortality (M) and fishing mortality (F). Total mortality (Z) was estimated using the catch curve method, which is a linear regression approach on linearised catch data based on fish length distribution, using the TropFishR Package in RStudio (Mildenberger *et al*., 2017).

The natural mortality (M) was estimated by Pauly (1984) using Von Bertalanffy parameters (K and $L\infty$) and temperature (T) as the annual mean of the water temperature (29°C) in Equation 4 (Eq. 4):

$$Log(\mathrm{M}) = -0.0066 - 0.279\,Log(L\infty) + 0.6543\,Log(\mathrm{K}) + 0.4634\,Log(T) \qquad \text{(Eq. 4)}$$

Fishing mortality (F) can then be estimated with the following Equation 5 (Eq. 5):

$$F = Z - M \qquad \text{(Eq. 5)}$$

The known mortality parameters were then used to estimate the exploitation rate (E). The exploitation rate (E) is an indicator for measuring fishing pressure, with a limit reference point of 0.5 from the maximum sustainable yield (Gulland, 1982; Pauly, 1984). The exploitation rate was obtained using the following empirical formula in Equation 6 (Eq. 6) (Pauly, 1984):

$$E = \frac{F}{Z} \qquad \text{(Eq. 6)}$$

Spawning Potential Ratio

The calculation of the SPR parameter required values of natural mortality (M), growth coefficient (K), asymptotic length (L∞), and the length at which fish first reached gonad maturity (Lm). The SPR value was analysed using the Length-Based Spawning Potential Ratio (LB-SPR) method, which used length indicators (Hordyk *et al*., 2014). The calculation of the ratio began by determining the biomass for each length group and the Spawning Stock Biomass (SSB) as stated in Equation 7 (Eq. 7):

$$SSBR_{fished} = \sum_{t=tm}^{t\lambda} N_t \; x \; W_t \qquad \text{(Eq. 7)}$$

Subsequently, the spawning biomass is calculated using Equation 8 (Eq. 8) according to Goodyear (1993):

$$SPR = \frac{SSBRfished}{SSBRunfished} \qquad \text{(Eq. 8)}$$

The Length-Based Spawning Potential Ratio (LB-SPR) analysis calculations were performed online at http://barefootecologist.com.au/lbspr (Hordyk *et al*., 2015). The SPR values were then classified according to Hordyk *et al*. (2015) and estimates of SPR could be used to inform management decisions for data-poor fisheries. Simulations were used to investigate the utility of the length-based model (LB-SPR, with values below 20% indicating overexploitation (Limit Reference Point), 20% - 30% indicating full exploitation and values above 40% suggesting underexploitation (Target Reference Point).

Results and Discussion

Length Distributions and Maturity

The size of *L. malabaricus* caught in Karimunjawa waters ranged from 19–80 cmTL using traps and handlines. The overall mean size of the caught fish was 43.18 ± 11.32 cmTL with a mode of 40 cmTL and the detailed size distribution for each fishing gear is presented in Table 2 and Figure 2.

Table 2: Length-size distribution of *L. malabaricus* samples

Fishing Gear	Min. (cmTL)	Max. (cmTL)	Mode (cmTL)	Mean ± SD (cmTL)
Trap	19	80	40	44.43 ± 11.45
Handline	21.5	77	30	38.83 ± 9.68
All	19	80	40	43.18 ± 11.32

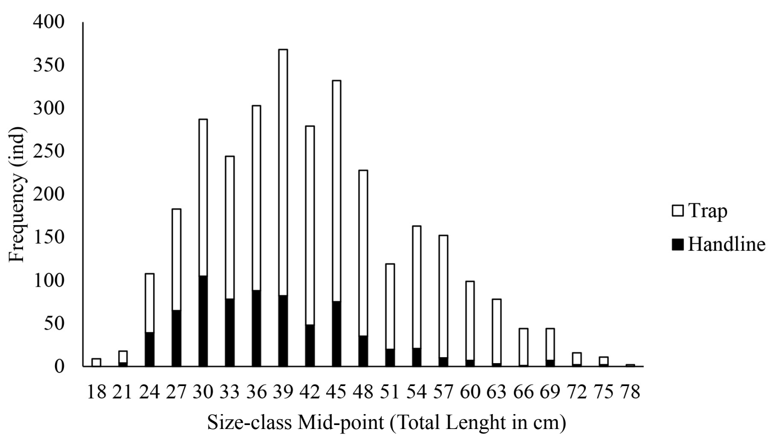

Figure 2: Distribution of *L. malabaricus* caught by by fishing gear types

The size of the Malabar blood snapper at first gonad maturity, based on the empirical equation by Froese and Binohlan (2000) was determined to be 44.34 cmTL (Lm50) and 55.43 cmTL (Lm95). The average length of fish caught by handline was 38.83 cmTL, which was smaller than the Lm_{50} with 73 % of the catch consisting of immature individuals. In contrast, although the average size of fish caught by traps exceeded the size at maturity, 54% of the catch still fell below the size at first maturity. These findings indicated that the Malabar blood snapper fishery was leaning towards overfishing (Zhang *et al*., 2023).

The comparison of size composition between fishing gears revealed that traps could capture significantly larger fish (mean: 44.43 cmTL), compared with handlines (mean: 38.83 cmTL). This disparity was likely driven by differences in fishing depth and gear selectivity. *L. malabaricus* exhibited ontogenetic migration, where adults inhabited deeper offshore waters while juveniles preferred shallower reefs (Allen, 1985; Newman, 2002).

In Karimunjawa, traps were typically deployed on the seabed in deeper waters targeting demersal adults, whereas fishermen using handlines might operate in shallower columns, where smaller, more aggressive schooling fish were prevalent. Furthermore, the selectivity of trap mesh size might have allowed smaller individuals to escape, effectively filtering the catch, whereas handlines—depending on hook size—were susceptible to aggressive strikes from a wider size range, including immature fish.

Growth and Mortality

The growth parameters of *L. malabaricus* are shown in Table 3. They included the asymptotic length ($L\infty$), the growth coefficient (k), and theoretical time at which fish length was zero (t_0).

The study showed that the asymptotic length of *L. malabaricus* was 83.4 cmTL with a growth coefficient of 0.23 $year^{-1}$ and a t_0 of -0.56. The growth coefficient value was smaller than in East Java but larger than in South Sulawesi and the Pilbara coast in Western Australia (Newman, 2002; Ernawati & Budiarti, 2020).

Differences in the growth parameters could occur due to variations in stock units, environmental conditions, sampling periods, sample composition, and the number of samples (Herwaty *et al*., 2023). Additionally, fishing pressure and using different fishing gear could influence the growth parameters of the same species in different locations (Vrijenhoek, 1998; Tirtadanu *et al*., 2018). This species generally exhibited a relatively low growth coefficient, typically below 0,3 0.3 $year^{-1}$. Such a value suggested that *L. malabaricus* grew slowly and required a longer time to reach its maximum theoretical size or asymptotic length (Pauly, 1984; Sparre & Venema, 1996).

Total mortality (Z) is the sum of natural mortality (M) and fishing mortality (F). Additionally, the exploitation rate (E) was calculated as the ratio of F to Z to assess the exploitation status of the stock. The estimated mortality and exploitation parameters for *L.malabaricus* are presented in Table 4.

Table 3: Growth parameters of *L. malabaricus* in Karimunjawa waters

Study Area	$L\infty$	K ($year^{-1}$)	t_0 (year)	References
Pilbara Coast				
Male	68.64 cmFL	0.18	-0.33	Newman (2002)
Female	56.58 cmFL	0.26	-0.09	
East Java	96.65 cmFL	0.22	-0.024	Wahyuningsih *et al*. (2013)
South Sulawesi	73.98 cmTL	0.25	-0.53	Ernawati & Budiarti (2020)
Karimunjawa	83.4 cmTL	0.23	-0.56	Current research

Table 4: Mortality and exploitation rate of *L. malabaricus* in Karimunjawa

Mortality Value	Estimated Value ($year^{-1}$)
Total mortality (Z)	0.72
Natural mortality (M)	0.3
Fishing mortality (F)	0.42
Exploitation rate (E)	0.59

The natural mortality of *L. malabaricus* in Karimunjawa (M = 0.3 $year^{-1}$) was lower than its fishing mortality (F = 0.42 $year^{-1}$), which indicated high fishing effort by fishermen. The small mortality value was also aligned with its slow growth rate, as Fry and Milton (2009) stated that snappers in tropical waters were characterised by low natural mortality. The current exploitation rate value of 0.59 $year^{-1}$ indicated that the utilisation pressure had already exceeded its optimum limit of 0.5 (Gulland, 1982).

Spawning Potential Ratio

The SPR in this study was calculated using the LB-SPR method, which utilised fish length frequency data as its input (Hordyk *et al*., 2015). The SPR showed a value of 20% (Figure 3).

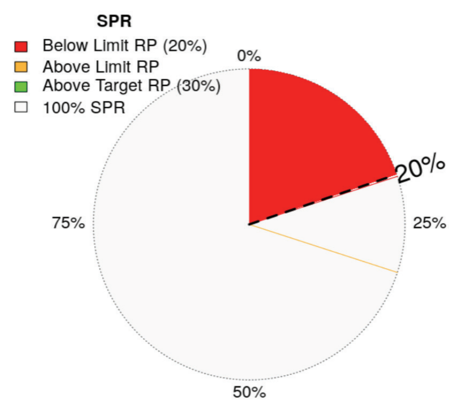

Figure 3: Spawning potential ratio of *L. malabaricus* in Karimunjawa

The Limit Reference Point (LRP) for SPR was 20% to prevent the risk of recruitment overfishing, a state where fish stocks would experience a loss of long-term reproductive capacity (Badrudin, 2015; Prince *et al*., 2015; Amorim *et al*., 2019). *L. malabaricus* in Karimunjawa is currently at this LRP value. This figure was critical but did not indicate a stock collapse; however, it represented the minimum threshold rather than the optimum. Therefore, given the species' slow growth, this level suggested a high risk of recruitment impairment.

The exploitation rate of 0.59 $year^{-1}$ in Table 4 clearly surpasses the optimum utilisation limit of 0.5 (Gulland, 1982; Pauly, 1984). This exploitation rate value was influenced by mortality, indicating that fishing mortality was greater than natural mortality. This scenario suggested that since the SPR value was precisely at the optimum limit (20%), the excessive fishing pressure confirmed that the stock was in an overexploited state (Gulland, 1982; Hordyk *et al*., 2015; Prince *et al*., 2015).

Intervention Management

Based on the population parameters and SPR results, current management recommendations included limiting the issuance of new fishing permits and reducing the number of active fishing vessels. Additionally, regulating fishing gear use—such as standardising hook sizes (e.g., size 5 for handlines) and implementing escape gaps in trap—would be essential to reduce juvenile mortality and improve selectivity.

To strengthen these measures, evidence suggested that the implementation of minimum size limits on catches based on the length at first maturity (Lm_{50}) could effectively protect reproductive capacity (Shephard *et al*., 2020). Establishing no-take areas that preserved the full-size structure of populations could also significantly enhance local recruitment (Harrison *et al*., 2012).

Furthermore, seasonal closures during spawning peaks were recommended for snappers to safeguard spawning biomass (Sadovy de Mitcheson *et al*., 2012). Adaptive management frameworks that combined SPR monitoring with exploitation rate (E) assessments had been proven effective in data-limited tropical fisheries (Hordyk *et al*., 2015; Prince *et al*., 2015).

In summary, this study recommends a coordinated strategy involving size limits, spatial closure, seasonal closures and stricter gear, and effort controls to support both the ecological resilience and sustainable harvest of the Malabar blood snapper in Karimunjawa.

Conclusions

The findings of this study revealed that *L. malabaricus* in Karimunjawa was commonly caught at smaller sizes before maturity, indicating substantial pressure on local fish stocks. The species had slow growth rate (Linf = 83.4 cmTL, K = 0.225), with an SPR of 20% (limit reference point) and an exploitation rate of 0.59, indicating excessive exploitation. These findings highlighted an urgent need for management measures, including setting of minimum catch size limits, effort control, habitat protection, and regular stock monitoring to ensure sustainability.

Acknowledgements

Special gratitude goes to the Wildlife Conservation Society and the Karimunjawa National Park Office, which provided the fisheries data and research permits for this study.

Conflict of Interest Statement

The authors declare that they have no conflict of interest.

References

Allen, G. (1985). *Snappers of the world: An annotated and illustrated catalog of lutjanid species known to date* (FAO Species Catalogue, Vol. 6). FAO.

Amorim, P., Sousa, P., Jardim, E., & Menezes, G. M. (2019). Sustainability status of data-limited fisheries: Global challenges for snapper and grouper. *Frontiers in Marine Science*, *6*, Article 654. https://doi.org/10.3389/fmars.2019.00654

Badrudin, M. (2015). Pedoman teknis estimasi Spawning Potential Ratio (SPR). In *Protokol pengkajian stok sumberdaya ikan: Komisi nasional pengkajian stok sumber daya ikan*. Pusat Penelitian dan Pengembangan Perikanan, Badan Penelitian dan Pengembangan Kelautan, Kementerian Kelautan dan Perikanan.

Ernawati, T., Boer, M., Kamal, M. M., Butet, N. A., Satria, F., & Perdanahardja, G. H. (2024). Length-based stock assessment for Malabar blood snapper in Makassar Strait, Indonesia: Status and recommendation for sustainability. *Regional Studies in Marine Science*, *73*, Article 103485. https://doi.org/10.1016/j.rsma.2024.103485

Ernawati, T., & Budiarti, T. W. (2020). Life history and length base spawning potential ratio (LBSPR) of Malabar snapper Lutjanus malabaricus (Bloch & Schneider, 1801) in western South Sulawesi, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *404*(1), Article 012023. https://doi.org/10.1088/1755-1315/404/1/012023

Froese, R., & Binohlan, C. (2000). Empirical relationships to estimate asymptotic length, length at first maturity and length at maximum yield per recruit in fishes, with a simple method to evaluate length frequency data. *Journal of Fish Biology*, *56*(4), 758–773. https://doi.org/10.1111/j.1095-8649.2000.tb00870.x

Fry, G. C., & Milton, D. A. (2009). Age, growth, and mortality estimates for populations of red snapper Lutjanus erythropterus and L. malabaricus from northern Australia and eastern Indonesia. *Fisheries Science*, *75*, 1219–1229.

Gulland, J. (1982). *Manual of methods for stock assessment*. FAO.

Halim, A., Loneragan, N. R., Wiryawan, B., Hordyk, A. R., Sondita, M. F. A., & Yulianto, I. (2020). Evaluating data-limited fisheries for grouper (Serranidae) and snapper (Lutjanidae) in the Coral Triangle, eastern Indonesia. *Regional Studies in Marine Science*, *38*, Article 101388. https://doi.org/10.1016/j.rsma.2020.101388

Herdiana, Y., Wiryawan, B., Wisudo, S. H., Tweedley, J. R., Yulianto, I., Retnoningtyas, H., & Loneragan, N. R. (2023). Untangling the complexity of small-scale fisheries: Building an understanding of grouper-snapper fisheries dynamics in Saleh Bay, West Nusa Tenggara, Indonesia. *Fishes*, *9*(1), Article 2. https://doi.org/10.3390/fishes9010002

Herwaty, S., Mallawa, A., Najamuddin, N., & Zainuddin, M. (2023). Age, growth, mortality, and population characteristics of the red snapper (*Lutjanus malabaricus*) in the Timor Sea waters, Indonesia. *Biodiversitas Journal of Biological Diversity*, *24*(4). https://doi.org/10.13057/biodiv/d240434

Hordyk, A., Ono, K., Sainsbury, K., Loneragan, N., & Prince, J. (2014). Some explorations of the life history ratios to describe length composition, spawning-per-recruit, and the spawning potential ratio. *ICES Journal of Marine Science*, *72*(1), 204–216. https://doi.org/10.1093/icesjms/fst235

Hordyk, A., Ono, K., Valencia, S., Loneragan, N., & Prince, J. (2015). A novel length-based empirical estimation method of spawning potential ratio (SPR), and tests of its performance, for small-scale, data-poor fisheries. *ICES Journal of Marine Science*, *72*(1), 217–231. https://doi.org/10.1093/icesjms/fsu004

Mildenberger, T. K., Taylor, M. H., & Wolff, M. (2017). TropFishR: An R package for fisheries analysis with length-frequency data. *Methods in Ecology and Evolution*, *8*(11), 1520–1527. https://doi.org/10.1111/2041-210X.12791

Newman, S. J. (2002). Growth rate, age determination, natural mortality and production potential of the scarlet seaperch, *Lutjanus malabaricus* Schneider 1801, off the Pilbara coast of north-western Australia. *Fisheries Research*, *58*(2), 215–225. https://doi.org/10.1016/S0165-7836(01)00367-8

Panggabean, A. S., Prihatiningsih, Taufik, M., Nurdin, E., Mahulette, R. T., Nurulluddin, Chodrijah, U., & Pane, A. R. (2023). The stock status of *Lutjanus gibbus* (Forsskål, 1775) in Kupang waters, East Nusa Tenggara. *E3S Web of Conferences*, *442*, Article 01001. https://doi.org/10.1051/e3sconf/202344201001

Pauly, D. (1984). *Some simple methods for tropical fish stock*. FAO.

Pérez-Jiménez, J. C., Núñez, A., González-Jaramillo, M., Mendoza-Carranza, M., Acosta-Cetina, J., Flores-Guzmán, A., & Rocha-Tejeda, L. (2022). Inferring ecosystem impacts of a small-scale snapper fishery through citizen science data, productivity and susceptibility analysis, and ecosystem modelling. *Fisheries Research*, *250*, Article 106269. https://doi.org/10.1016/j.fishres.2022.106269

Prince, J., Hordyk, A., Valencia, S. R., Loneragan, N., & Sainsbury, K. (2015). Revisiting the concept of Beverton–Holt life-history invariants with the aim of informing data-poor fisheries assessment. *ICES Journal of Marine Science*, *72*(1), 194–203. https://doi.org/10.1093/icesjms/fsu011

Purushothaman, K., Vu, N. T., Qing, S. D. T. R., Koh, J., Mohamed, M. H. B., Wen, R. H. J., Liang, B., Loo, G., Domingos, J. A., Jerry, D. R., & Vij, S. (2025). Genetic evaluation of nutritional traits in Malabar red snapper (*Lutjanus malabaricus*): Heritability and genetic correlations of fatty acid composition. *Aquaculture*, *599*, Article 742144. https://doi.org/10.1016/j.aquaculture.2025.742144

Sadovy de Mitcheson, Y., Craig, M. T., Bertoncini, A. A., Carpenter, K. E., Choat, J. H., Cornish, A. S., Fennessy, S. T., Ferreira, B. P., Heemstra, P. C., Liu, M., Myers, R.

F., Pollard, D. A., Rhodes, K. L., Rocha, L. A., Russel, B. C., Samoilys, M. A., & Sanciangco, J. (2012). Fishing groupers towards extinction: A global assessment of threats and extinction risks in a billion dollar fishery. *Fish and Fisheries*, *14*(2), 119–136. https://doi.org/10.1111/j.1467-2979.2011.00455.x

Shephard, S., Valbo-Jorgensen, J., Abadia, J., Baigun, C., Doria, C. R., Fabre, N. N., Isaac, V. J., Bun, N. P., Ruffino, M. L., & Funge-Smith, S. J. (2020). *Size-based assessment of data-limited inland fish stocks — Review and applications* (FAO Fisheries and Aquaculture Circular No. 1214). FAO. https://doi.org/10.4060/cb1594en

Sparre, P., & Venema, S. C. (1996). *Introduction to tropical fish assessment* (2nd ed.). Food and Agriculture Organization of the United Nations.

Tirtadanu, T., Wagiyo, K., & Sadhotomo, B. (2018). Pertumbuhan, hasil per penambahan baru dan rasio potensi pemijahan ikan kakap merah (*Lutjanus malabaricus* Schneider, 1801) di perairan Sinjai dan sekitarnya. *Jurnal Penelitian Perikanan Indonesia*, *1*(1), Article 1. https://doi.org/10.15578/jppi.1.1.2018.1-10

Vrijenhoek, R. (1998). Conservation genetics of freshwater fish. *Journal of Fish Biology*, *53*, 394–412.

Wahyuningsih, Prihatiningsih, & Ernawati, T. (2013). Parameter populasi ikan kakap merah (*Lutjanus malabaricus*) di perairan laut Jawa bagian timur. *BAWAL*, *5*(3), 175–179.

Wibisono, E., Puggioni, G., Firmana, E., & Humphries, A. (2021). Identifying hotspots for spatial management of the Indonesian deep-slope demersal fishery. *Conservation Science and Practice*, *3*(5). https://doi.org/10.1111/csp2.356

Zhang, K., Zhang, J., Zhang, P., Su, L., Hong, X., Qiu, Y., & Chen, Z. (2023). This is what we know: Assessing the stock status of the data-poor skipjack tuna (*Katsuwonus pelamis*) fishery in the South China Sea. *Frontiers in Marine Science*, *10*, Article 1095411. https://doi.org/10.3389/fmars.2023.1095411