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The Stock Analysis of *Scarus psittacus* Resources in the Karimunjawa Waters, Indonesia

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ABSTRACT

Scarus psittacus, or the common parrotfish, has an ecological role in coral reef ecosystems. However, this species is also a target of artisanal fisheries, including in the Karimunjawa Islands, where expanding tourism has intensified demand for reef fish and heightened pressure on coastal resources. This research aims to assess the stock status of *S. psittacus* resources in the waters of the Karimunjawa Islands, including analyzing growth and mortality parameters. Data collection was carried out from July 2024 to May 2025 from 259 fish samples. The growth rates, recruitment peak, mortality, and exploitation level were measured using FiSAT II. The results showed that the length-weight relationship of S. *psittacus* fish in the Karimunjawa Islands was rather negative isometric (b=2.43). The first size caught ($Lc_{50\%}$) was 22.94cm TL, with a total infinite length (L_∞) of 29.9cm TL. The peak recruitment period is estimated to occur in June-July. The exploitation rate of 0.18 indicates that the utilization of *S. psittacus* in Karimunjawa waters remains underexploited. Therefore, fish production can be increased by carefully applying environmentally friendly and sustainable management principles.

Keywords: Exploitation rate, Growth, Karimunjawa islands, Recruitment, *Scarus psittacus.*

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INTRODUCTION

Parrotfish (*Scarus psittacus*) are important to the coral reef ecosystem and are widely captured for their high economic value (Sitorus et al., 2020; Annandale et al., 2024; Husain et al., 2025). Parrotfish are herbivorous fish that feed on algae attached to coral reefs, thereby improving the health of these reefs (Viviani et al., 2022; Taylor et al., 2022). Dead coral consumed by parrotfish is later excreted in coastal areas and forms white beach sand (Russ et al., 2015; Holbrook et al., 2016; Yarlett et al., 2018; Asriyana et al., 2020; Deeng et al., 2022; Dafitri et al., 2023; McClanahan et al., 2025).

S. psittacus fish is widely distributed across tropical Indo-Pacific waters, from the Red Sea and East Africa to the Central Pacific Islands, southern Japan, and the northern coast of Australia (Borsa et al., 2016; Amin et al., 2019; Xiao et al., 2022; Mar'ie & Welson, 2025). Parrotfish generally inhabit shallow waters up to 30m deep around coral reefs, seagrass beds, mangroves, and algae beds (Minton et al., 2022; Arungla'bi et al., 2025). *S. psittacus* fish live in groups, have a relatively fast growth rate, and can live up to 5 years. *S. psittacus* are protogynous hermaphrodites, beginning life as females and transitioning to males at a certain age and size (Morgan et al., 2016; Tambunan et al., 2020; Rumping et al., 2023; Vidal et al., 2023; Hernandez & Shervette, 2025).

The Karimunjawa Islands are a marine conservation designated in 1986 under the Decree of the Minister of Forestry Number 123/Kpts II/1986 (BTNKJ, 2019). The development of the Karimunjawa Islands as a tourism area poses risks to the conservation program. Tourism activities may interfere with the coral reef ecosystems and increase the exploitation of fish resources for consumption, including parrotfish (Vanderklift et al., 2019; Zega et al., 2024; Charendoff et al., 2023; Wibowo et al., 2024; Wijayanto et al., 2025b; Ayu et al., 2025). It is necessary to keep the exploitation of *S. psittacus* under control to preserve ecosystem sustainability. This study was conducted to test the hypothesis that the stock of *Scarus psittacus* in the waters of Karimunjawa remains sustainably exploited under current fishing pressure. Accordingly, the objectives of this research were to estimate key population parameters of *S. psittacus*, including growth, mortality, recruitment pattern, and exploitation rate; This study also aimed to determine the first capture size ($Lc_{50}\%$) in relation to biological characteristics; and evaluate the stock status of *S. psittacus* as a scientific basis for developing sustainable and ecosystem-based fisheries management in the Karimunjawa marine conservation area.

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MATERIALS & METHODS

Research Location and Time

This research was conducted at Karimunjawa Archipelago, Central Java, Indonesia (Fig. 1), which lies within the geographic coordinates of approximately 5°45′–5°55′S and 110°30′–110°37′E. These coordinates cover the main coastal zone surrounding Karimunjawa Island and Kemujan Island, including the Karimunjawa Coastal Fishing Port (CFP) where all observations were carried out. The CFP serves as the central hub for fish landing and trading activities in the archipelago, making it the primary location for collecting biological and fisheries information. Surveys and interviews with fishermen and fish traders were conducted to gather data on fish stocks. At the same time, measurements of the total length and weight of *S. psittacus* were recorded over 11 months from July 2024 to May 2025.

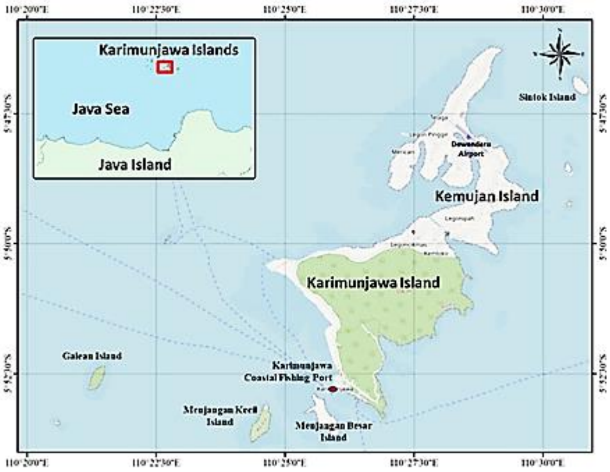

Fig. 1: Karimunjawa Islands.

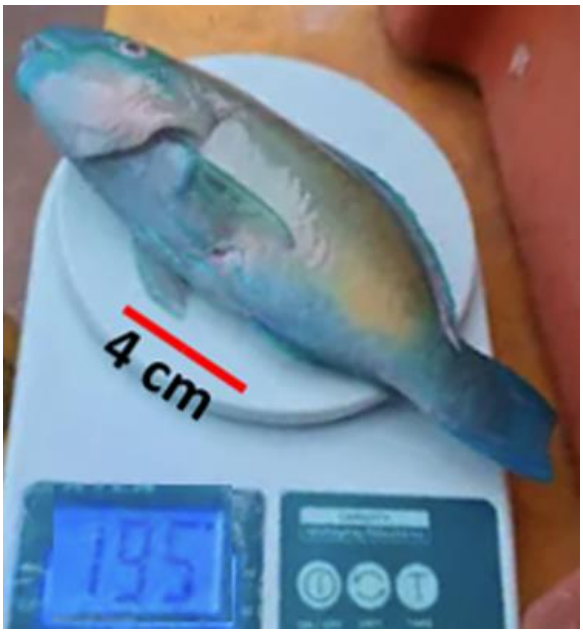

Fig. 2: *S. psittacus.*

Research Materials

A total of 259 individuals, representing 10% of the estimated total fish caught in the research area at the time of sampling, were randomly selected to measure the total length and weight of *S. psittacus* (Fig. 2) (King, 1995; Sparre & Venema, 1998).

Analysis Method

This quantitative descriptive research employed a fish population dynamics approach, based on direct observations and field surveys. Several parameters were analyzed: length-weight relationship, growth, mortality, and exploitation rate (Sparre & Venema, 1998; Bhakta et al., 2024; Wijayanto et al., 2025a). Each fish sample was measured for total length (TL in cm) and weight (in g) to assess the population dynamics of the species.

The length-weight relationship was analyzed to determine the growth pattern of fish using the following formula (Le Cren, 1951; King, 1995; Effendie, 1997; De Robertis & William, 2008):

$$Wt = a.Lt^b \quad (1)$$

$$Ln\, Wt = Ln\, a + b.Ln\, Lt \quad (2)$$

where:

Wt = fish weight at age "t" (in g);
Lt = fish length at age "t" (incm);
a = intercept; and
b = slope

The growth parameters (L_∞, K, and t_0) were estimated using the ELEFAN I (Electronic Length Frequency Analysis) method based on the von Bertalanffy growth model. Data analysis was conducted using FISAT II software. Several standard formulas were applied in the analysis (Gulland, 1983; Gayanilo et al., 2005) as follows.

$$Lt = L_\infty(1 - e^{-k(t-t_0)}) \quad (3)$$

$$Log(-t_0) = -0.3922 - 0.2752\, Log\, L_\infty - 1.038\, Log\, K \quad (4)$$

where:

L_∞ = asymptotic total length (incm);
K = growth coefficient (year^{-1});
t = age of fish (years);
t_0 = the fish age when it is 0 mm in total length (year).

The value of the total mortality index (Z) was estimated using FiSAT II software. The natural mortality value (M) was calculated based on Pauly's empirical formula (1980) using the following formulas (Sparre & Venema, 1998; Dutta, 2023; Wijayanto et al., 2025a):

$$Log\,(M) = -0.0066 – 0.279\, Log\, L_\infty + 0.6543\, Log\, K + 0.4634\, Log\, T \quad (5)$$

$$F = Z – M \quad (6)$$

$$E = \frac{F}{Z} \quad (7)$$

$$\text{If } E_{MSY} = 0.5 \quad (8)$$

$$F_{MSY} = 0.5\, Z \quad (9)$$

$$\frac{F_{MSY}}{F} = \frac{C_{MSY}}{C} \quad (10)$$

$$c_{MSY} = \frac{0.5\, Z}{F}.C \quad (11)$$

where:

M = natural mortality index;
T = average water temperature (°C), assumed to be 30°C.
F = fishing mortality index;
Z = total mortality index;
E = exploitation rate;
E_{MSY} = exploitation rate at MSY;
F_{MSY} = fishing mortality index at MSY;
C_{MSY} = capture production at MSY (kg); and
C = existing capture production (kg)

RESULTS

The results of the analysis of the length-weight relationship of *S. psittacus* fish are presented in Fig. 3.

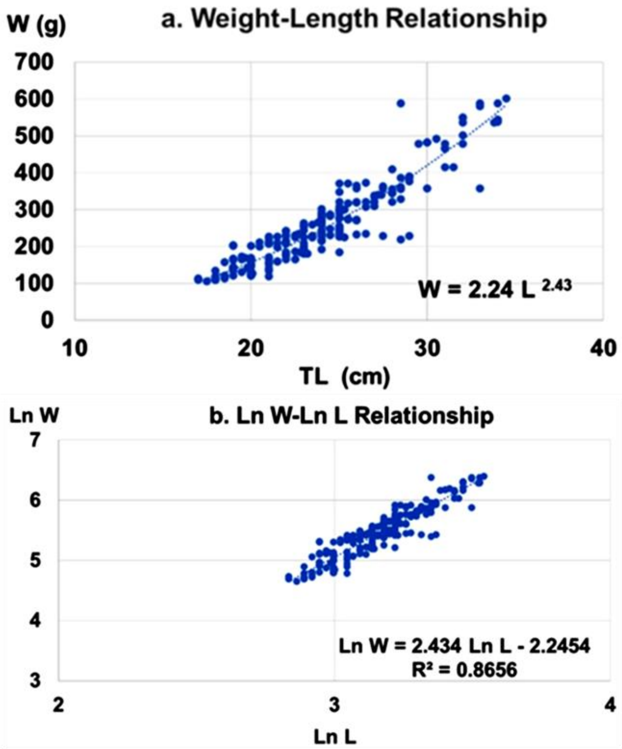

Fig. 3: Weight-length relation of *S psittacus*.

The length-weight relationship of *S. psittacus* fish caught in Karimunjawa waters indicates a negatively allometric growth rate (b value less than 3). Body length tends to grow faster than body weight. The detailed size composition of S. psittacus fish is shown in Table 1.

Table 1: Composition of *S. psittacus* size caught in Karimunjawa waters

Total length interval (cm)	Median	Frequency	Percentage	Cumulative percentage
16.0-17.9	17.0	3	1.16	1.2
18.0-19.9	19.0	30	11.58	12.7
20.0-21.9	21.0	44	16.99	29.7
22.0-23.9	23.0	54	20.85	50.6
24.0-25.9	25.0	63	24.32	74.9
26.0-27.9	27.0	23	8.88	83.8
28.0-29.9	29.0	19	7.34	91.1
30.0-31.9	31.0	9	3.47	94.6
32.0-33.9	33.0	9	3.47	98.1
34.0-35.9	35.0	5	1.93	100.0

The size of *S. psittacus* is within a range of 17cm TL and 34cm TL. Medium-sized fish with TL length class of 24.0–25.9cm were found dominant (24.32% of the total samples). The results of the Lc50% analysis of 22.94cm TL fish are presented in Fig. 4.

The Lc_{50}% value is essential for sustainable fisheries management, as it sets the minimum catch size to prevent harvesting fish before they reach gonadal maturity, allowing them to reproduce (King, 1995; Sparre & Venema, 1998; Wijayanto et al., 2025a). The results of the mortality and exploitation rate analysis are shown in Table 2.

This research found that the growth rate (K) of *S. psittacus* is 1.19 per year, with a total mortality rate (Z) of 2.53 and an exploitation level (E) of 0.18 (Table 2). An E value below 0.5 indicates that *S. psittacus* in Karimunjawa waters is still under-exploited, with most mortality attributed to natural causes. The estimated maximum sustainable yield (MSY) is 11,325kg, valued at IDR 906.01million. To ensure effective management, further studies are needed to inform policies on catch quotas, minimum size limits, fishing seasons, and the protection of spawning stocks and habitats (Zhang et al., 2021; Ondes & Unal, 2023). Fish growth based on the von Bertalanffy model is shown in Fig. 5, while recruitment patterns are presented in Fig. 6.

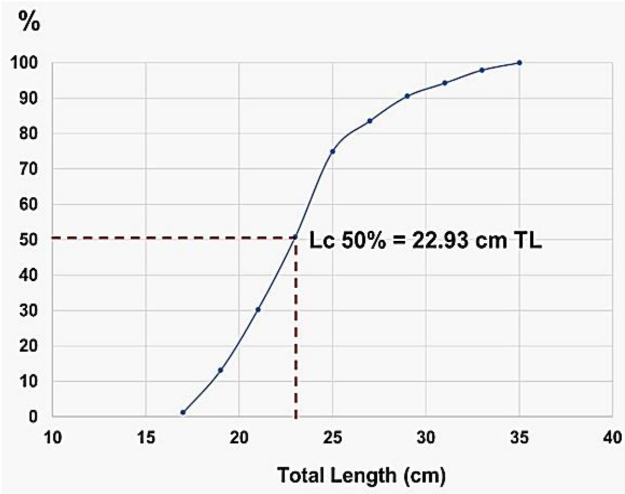

Fig. 4: Lc 50% analysis.

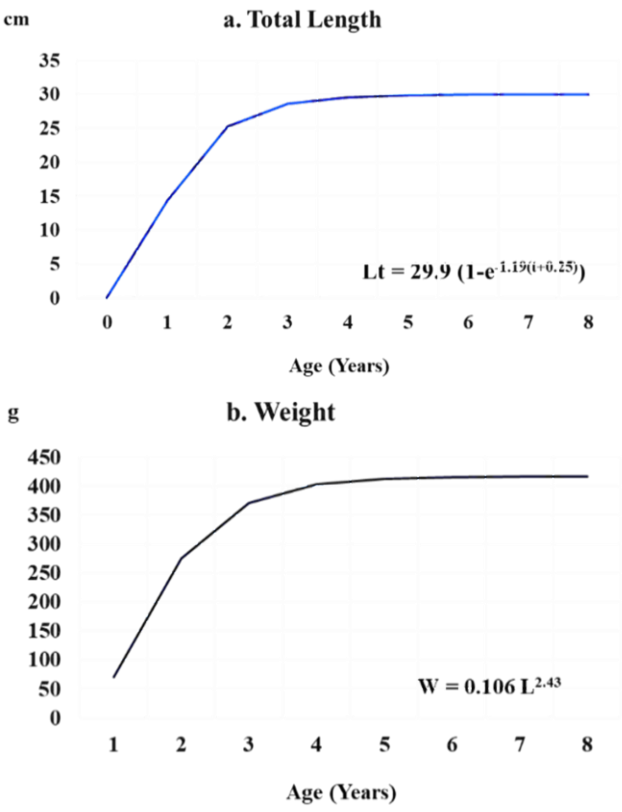

Fig. 5: The von Bertalanffy growth curve of *S. psittacus*.

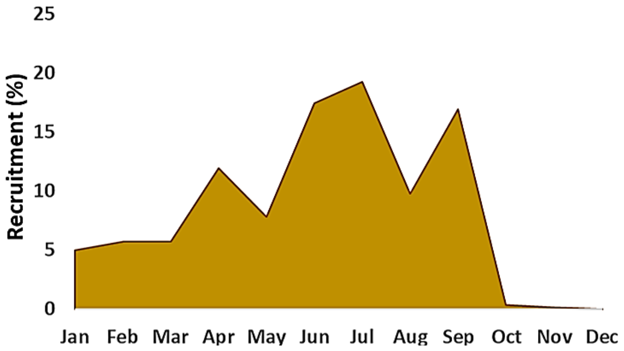

Fig. 6: Estimated recruitment time.

Table 2: Estimation of L_∞, K, mortality, and exploitation rate

Parameter	Value
L_∞	29.9cm TL
K	1.19
t_0	-0.25
Total mortality (Z)	2.53±0.08 (R^2=0.91)
Fishing mortality (F)	0.46
Natural mortality (M)	2.07
Exploitation rate (E)	0.18 (under-exploited)
Assumption of fishing mortality*	4,118kg
Estimated maximum sustainable yield (MSY) production**	11,325kg
Estimated economic value of MSY production	IDR. 906.01 million

Note: * using average production data during the research converted into production in a year; ** using the assumption of fish price at fishermen of IDR 80,000/kg.

The peak of recruitment is estimated to occur in June-July. Based on the results of age estimation using the von Bertalanffy growth equation (Lt=29.9 $(1-e^{-1.19(t+0.25)})$, *S. psittacus* fish with a total length of around 25cm (the dominant median value) are estimated to be five months old. With this assumption, the peak spawning time of this population is likely to occur in January to February.

DISCUSSION

The Karimunjawa Islands in Jepara Regency, Central Java Province, face complex development challenges due to the involvement of multiple stakeholders across fisheries, marine culture, tourism, and conservation sectors. Effective conservation must go hand in hand with the welfare of local communities, as conservation programs risk failure without addressing local livelihoods (Yuliana et al., 2016; Fafurida et al., 2020; Kennedy et al., 2020; Wijayanto et al., 2023).

Overfishing is a global threat to the marine resources that should be carefully prevented and addressed, including in Karimunjawa waters (Pereira et al., 2021; FAO, 2022; Setiyanto et al., 2024). In Karimunjawa waters, *S. psittacus* catch is dominated by fish of 20.0-25.9cm TL (44.6%), with Lc50% value of 22.94cm TL (Fig. 1). The Lc_{50}% value is 22.94cm TL, which exceeds the length at first maturity (Lm) of 15cm TL reported by the Hawaii Cooperative Fisheries Research Unit (2008). This suggests that the regeneration of *S. psittacus* stocks in Karimunjawa is likely being maintained (Ramadhan & Apriliani, 2016; Wibowo et al., 2022; Wijayanto et al., 2025a).

De Martini & Howard (2016) mentioned that *S. psittacus* undergoes sex change at a size of 258g. Using the length-weight relationship W=2.24 $L^{2.43}$, the length of *S. psittacus* in Karimunjawa waters is estimated to be approximately 24.6cm TL. To compare, the daisy parrotfish (*Chlorurus sordidus*) changes sex at a size between 35.1 and 47.2cm (De Martini et al., 2005). The L maximum size of *C. sordidus* is 40cm TL, while the L maximum of *S. psittacus* is 43cm TL (Matthews et al., 2019). The alleged sex change of *S. psittacus* at a size of 24.6cm TL (greater than Lc50%) needs to be taken into consideration in the policy design (harvest strategy).

The male and female broodstock in nature affect the success of the reproduction process and regeneration of fish resource stocks, including *S. psittacus* (Achmad et al., 2021; Wijayanto et al., 2025a). The body size relationship pattern varies in different fish. Hawaii Cooperative Fishery Research Unit (2008) found that the relationships between total length (TL), fork length (FL), and standard length (SL) of S. psittacus are: FL = 0.957 TL; SL = 0.784 TL; and SL = 0.819 FL. Meanwhile, the length-weight relationship of *S. psittacus* in Hawaiian waters has a b value of 3.005 (isometric). The length-weight relationship of *S. psittacus* in this study is characterized by a b-value of 2.43 (negative allometry). Whereas, Matthews et al. (2019) in Samoa found the b-value of S. psittacus to be 3.03 (isometric), with a maximum length of 43.0cm TL. Gust et al. (2001) showed that *S. psittacus* in Australia exhibits positive allometric growth, with a b value of 3.1. Meanwhile, Choat et al. (1996) in Australia and Amin et al. (2019) in the Red Sea found a relatively similar growth pattern of *S. psittacus* to this research (negative allometry), where the increase in length is faster than the increase in weight, with b values of 2.9 and 2.2, respectively. Zulfahmi et al. (2024) examined several types of parrotfish in Aceh (Sumatra Island). They found a negative allometric growth pattern, including *S. quoyi*, *S. rubroviolaceus*, and *S. niger*, with b values between 2.44 and 2.54. The length-weight relationship of fish is influenced by multiple complex factors, including feeding habits, food availability, water depth, oxygen levels, water temperature, season, predators, gonad development, spawning season, and water quality, which affect fish growth. Parrotfish eat green algae (including *Caulerpa racemosa and Ulva lactuca*), brown algae (including *Padina australis*), and seagrass (including *Thalassia hemprichii*) (Froese, 2006; Asriyana et al., 2020; Li et al., 2023; Wijayanto et al., 2024).

In this research, the K value of *S. psittacus* fish was 1.19 while L_∞ was 29.9cm TL. According to Sparre & Venema (1998), the lower the growth coefficient (K), the longer the time required for a fish species to reach its asymptotic length (L_∞). Fish species with a growth coefficient (K) greater than 1 are generally classified as fast-growing. Typically, juvenile fish grow more rapidly than adults. As fish mature, a portion of their energy intake is redirected toward gonad development, reducing body weight growth. Consequently, growth slows as fish approach their asymptotic length (Nadiarti et al., 2015; Muller-Karanassos et al., 2021).

This research indicates that the recruitment of *Scarus psittacus* occurs year-round, with a peak in June–July, while spawning is estimated to peak in January–February. Further research on gonadal maturity is necessary to support the development of evidence-based fishing season policies. In 2009, the density of *S. psittacus* in the waters of Karimunjawa was estimated at 900 individuals per hectare (Choat et al., 2012; Zhang et al., 2021). Updated data are needed to assess current stock conditions and trends (Houk & Taylor, 2025).

Natural mortality (M) and fishing mortality (F) are the primary causes of *S. psittacus* mortality. Sustainable exploitation is generally achieved when F does not exceed 50% of total mortality (Z), or $E \leq 0.5$ (Tuda & Wolff, 2018; Wijayanto et al., 2025a). This research found an E value of 0.18, indicating underexploitation. However, increasing production must still consider habitat carrying capacity, population dynamics, and interspecies ecological interactions on coral reefs.

Environmentally friendly fishing practices are essential and should include protecting spawning and nursery grounds, enforcing minimum size limits, banning destructive fishing gear, and releasing egg-bearing broodstock if caught. Production targets must align with the ecosystem's carrying capacity and the principles of Maximum Sustainable Yield (MSY) (Shimose et al., 2019; Gatouillat et al., 2024). Additionally, the growth of marine tourism in Karimunjawa must be carefully managed to prevent degradation of coral reefs (Schligler et al., 2021; Gernez et al., 2023). With coral reef health declining globally, parrotfish conservation has become increasingly critical (Welsh & Bellwood, 2012; Santi et al., 2019; Ross et al., 2020).

Despite providing important insights into the biological characteristics and stock status of *S. psittacus* in Karimunjawa, this study has several limitations that should be acknowledged for future improvement. First, the analyses rely solely on fish sampled from landing sites, which may not fully represent spatial variability in the natural population across different reef habitats. Second, the absence of sex-ratio and gonadal maturity data limits the ability to evaluate reproductive dynamics, particularly in relation to sex change and spawning patterns. Third, habitat-specific density surveys were not conducted, preventing direct comparison with historical density estimates and limiting the assessment of current abundance across reef zones. Addressing these limitations in future studies will strengthen the foundation for developing more comprehensive and ecosystem-based management strategies for *S. psittacus* in the Karimunjawa Islands.

Conclusion

The first capture size ($Lc_{50\%}$) of *Scarus psittacus* in Karimunjawa waters was 22.94cm TL, with an asymptotic length (L_∞) of 29.9cm TL. Peak recruitment occurred in June–July, and the exploitation rate (E) of 0.18 indicates that the population remains underexploited. The growth coefficient (K) was 1.19, and the theoretical age at zero length (t_0) was estimated at -0.25. These findings suggest that the exploitation of *S. psittacus* can be increased; however, any such increase must be guided by sustainable management principles. These include enforcing minimum catch sizes, promoting the use of environmentally friendly fishing gear, and protecting broodfish during spawning seasons. Effective resource management must also involve local communities, incorporating local wisdom to support coral reef conservation and ensure the long-term sustainability of *S. psittacus* populations.

DECLARATIONS

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Conflict of Interest: The authors declare there is no conflict of interest.

Data Availability: All the data is present inside the article.

Ethics Statement: This study did not involve any experimental procedures on live animals. All fish samples were obtained from routine fish landing activities at the Karimunjawa Coastal Fishing Port. Therefore, ethical approval was not required for this research.

Author's Contribution: DW, FK, and HAS designed the study. DW and FK collected and analyzed the data, DW and DJK wrote the manuscript.

Generative AI Statement: The authors declare that no Gen AI/DeepSeek was used in the writing/creation of this manuscript.

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