

Exploitation status and stock assessment of daisy parrotfish (*Chlorurus sordidus*) in Karimunjawa Marine National Park, Central Java, Indonesia

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Abstract. Wijayanto D, Bustamam A, Arkerman Y, Amri K, Tirtadanu, Winarso G, Hermadi I, Kailaku SI, Kurohman F, Putranto MR, Kurnia DJ. 2025. Exploitation status and stock assessment of daisy parrotfish (*Chlorurus sordidus*) in Karimunjawa Marine National Park, Central Java, Indonesia. *Biodiversitas* 26: 4821-4827. Daisy parrotfish (*Chlorurus sordidus*) play a crucial ecological role in maintaining coral reef health and resilience by grazing on algae, which prevents algal overgrowth and promotes coral recruitment. This study evaluated the exploitation status of *C. sordidus* in the Karimunjawa Marine Protected Area, Central Java, Indonesia, using biological indicators, including length at first capture ($L_{c50\%}$), growth parameters, and mortality rates. Field sampling was conducted from March 2024 to February 2025, involving fisher interviews and morphometric measurements of 1,032 individuals. Results showed a $L_{c50\%}$ of 24.8 cm and an asymptotic length (L_{∞}) of 51 cm, exceeding the size of first maturity but below the sex-change size range, potentially affecting reproductive dynamics. Further analysis revealed total mortality (Z) of 4.31 year⁻¹, with fishing mortality ($F = 2.33$) higher than natural mortality ($M = 1.20$), reflecting intensive fishing pressure on the stock. The exploitation rate ($E: 0.54$) indicates that the species is currently overexploited, which may reduce herbivory functions, weaken coral reef resilience, and threaten long-term fishery benefits. These findings highlight the urgent need for effective management measures, including minimum size limits, seasonal fishing restrictions, and community-based compliance, to ensure population sustainability. Continuous monitoring and further research on reproductive biology and critical habitats, particularly nursery grounds and spawning aggregations, are essential for informed conservation strategies, ensuring not only population sustainability but also the maintenance of ecosystem services that support local livelihoods and marine ecotourism in Karimunjawa.

Keywords: Coral reef conservation, daisy parrotfish, length-based methods, stock assessment

INTRODUCTION

The Karimunjawa Islands, located in Central Java Province, Indonesia, represent one of the most ecologically rich marine landscapes in the country. This archipelago comprises diverse habitats, including coral reefs, mangrove forests, and seagrass beds, which support high biodiversity and ecological processes (Munasik et al. 2021; Wijayanto et al. 2022). The area harbors over 430 species of reef fish, 178 species of hard corals, and 23 species of soft corals, reflecting its status as a marine biodiversity hotspot in the Java Sea (BTNKJ 2021). Recognizing its ecological significance, the government designated Karimunjawa as a

marine conservation area in 1986 under the Decree of the Minister of Forestry No. 123/Kpts II/1986. In addition to coral reef ecosystems, the area also protects mangrove forests, seagrass meadows, and endangered fauna such as sea turtles and dolphins, which further underline its conservation value. Despite its protected status, the islands face challenges from competing interests among conservation, fisheries, and tourism activities, which often generate conflicts and place additional pressure on marine resources (Hartati et al. 2017; BTNKJ 2019, 2022; Hapsari et al. 2020; Purwanto and Nugroho 2021; Ayu et al. 2025).

Tourism is a major driver of economic development in Karimunjawa, providing significant benefits to local

communities through job creation and small-scale enterprises such as accommodations, boat rentals, and culinary enterprises (Samy-Kamal et al. 2015; Muawanah et al. 2020; Suryawan et al. 2025). However, unregulated tourism exerts considerable pressure on fragile marine ecosystems, leading to habitat degradation, coral reef damage, water pollution, and deterioration of mangrove areas (Heery et al. 2018; Vanderklift et al. 2019; Azzahra et al. 2023; Makled et al. 2024). Tourist-related pressures also include physical destruction of corals by snorkeling and diving, anchoring of boats in reef areas, and increased generation of plastic waste that accumulates along coastlines. Poor waste management, overuse of coastal resources, and insufficient enforcement of conservation policies further exacerbate these problems (Fafurida et al. 2020; Perera et al. 2022; Setiyanto et al. 2024; Shaw et al. 2024). Although several local initiatives such as eco-tourism programs and zoning regulations have been introduced, their implementation often faces limitations due to lack of awareness, weak supervision, and conflicts of interest among stakeholders.

Fishing activities also contribute significantly to ecological stress. The increasing demand for reef fish has led to overexploitation of several key species, notably the daisy parrotfish (*Chlorurus sordidus* (Forsskål, 1775)), a herbivorous fish highly valued for consumption. This species plays an essential ecological role by grazing on algae, regulating algal growth on coral surfaces, and preventing coral suppression, while also contributing to sediment production through bioerosion, which supports beach formation and coastal stability (Choat et al. 2012; Perry et al. 2015; Hollbrook et al. 2016). Local fishermen often target parrotfish using spearfishing techniques, which are efficient but potentially destructive when applied continuously without regulation. Overfishing of *C. sordidus* threatens both its population and the broader integrity of coral reef systems, reducing herbivory, disrupting ecological processes, and diminishing ecosystem services that support tourism and fisheries (Morgan and Kench 2016). The decline of this species may also shift coral reef dominance toward macroalgae, leading to reduced biodiversity and declining attractiveness of reefs for tourism.

Balancing conservation goals with community needs is crucial in Karimunjawa. Successful conservation requires integrating ecological data with socio-economic considerations to ensure both biodiversity protection and local welfare (Johannesen 2007; Rakotonarivo et al. 2017; Demirovic et al. 2018; Wijayanto et al. 2022). The livelihoods of Karimunjawa residents largely depend on fisheries and tourism, creating a dual reliance on marine resources that must be carefully managed. In this context, the present study evaluates the biological status and exploitation level of *C. sordidus* in Karimunjawa. By analyzing growth parameters, length at first capture, and mortality rates, the research aims to provide a scientific basis for fisheries management and conservation policies that promote sustainable herbivorous fish populations,

enhance coral reef resilience, and support community livelihoods. Ultimately, the findings are expected to inform adaptive strategies that align ecological protection with economic benefits, ensuring that conservation programs can gain long-term support from local communities and stakeholders.

MATERIALS AND METHODS

Research site

This research was conducted from March 2024 to February 2025 on Karimunjawa Island and Kemujan Island, Central Java, Indonesia (Figure 1). Researchers visited both fishermen and fish traders on the islands. The object of this research is the daisy parrotfish (Figure 2) caught by fishermen using the spearfishing method. The fishing is mainly performed on an outboard motorboat for a day of fishing. The fishermen caught 1,032 fish over 12 months, and 10% of them were measured for length each month (King 1995; Sparre and Venema 1998).

Data analysis

This study involved interviews with 30 parrotfish fishermen from Karimunjawa Island and Kemujan Island. Length data were analyzed using Microsoft Excel and FiSAT II software. The first growth function was calculated based on von Bertalanffy's equation (Sparre and Venema 1998), with L_{∞} (infinite length) and K (growth coefficient) parameters using the ELEFAN (Electronic length frequency analysis) I method, and the t_0 values estimated using the formula by Gulland (1983). Total mortality (Z) was assessed using FiSAT II (Gayanilo et al. 2005), while natural mortality (M) was calculated using the empirical formula by Pauly (1980), which considers maximum length, growth coefficient, and water temperature. The water temperature (T) of 30°C represents the average SST in the Java Waters, particularly in Karimunjawa, which remains relatively stable throughout the year (Tanto 2020; Dwiyantri et al. 2022).

Fishing mortality (F) and exploitation rate (E) were then derived from these values as follows. In addition, E_{MSY} represents the exploitation rate at MSY , F_{MSY} is the fishing mortality index at MSY , C_{MSY} denotes capture production at MSY (kg), and C refers to the existing capture production (kg) (Sparre and Venema 1998; Fatma et al. 2021; Dutta 2023; Wijayanto et al. 2025).

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

$$\text{Log}(-t_0) = -0.3922 - 0.2752 \text{Log } L_{\infty} - 1.038 \text{Log } K$$

$$\text{Log } (M) = -0.0066 - 0.279 \text{Log } L_{\infty} + 0.6543 \text{Log } K + 0.4634 \text{Log } T$$

$$F = Z - M$$

$$E = F/Z$$

$$\text{If } E_{MSY} = 0.5, \text{ then } F_{MSY} = 0.5 Z$$

$$\text{If } F_{MSY}/F = C_{MSY}/C, \text{ then } C_{MSY} = (0.5Z/F) C$$

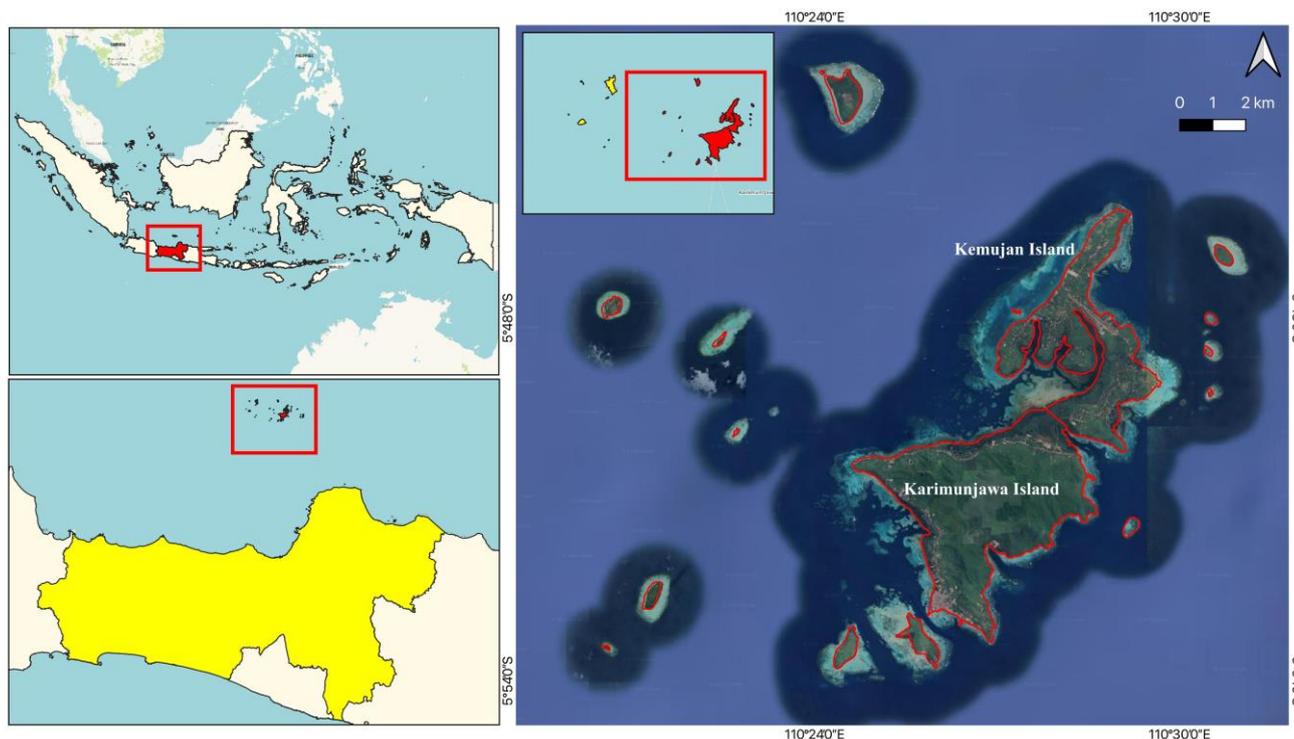


Figure 1. Karimunjawa Islands, Central Java, Indonesia

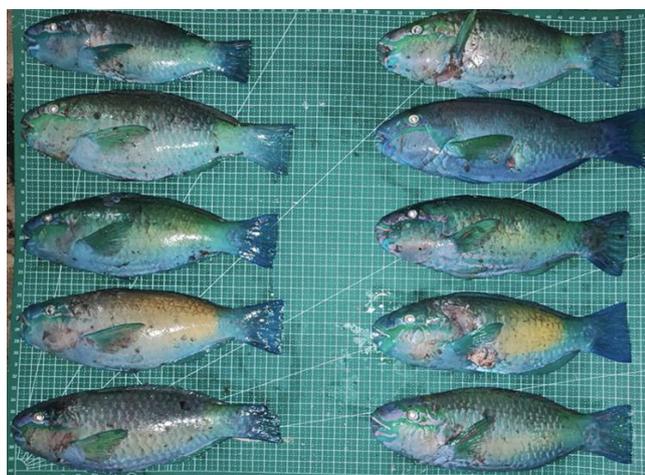


Figure 2. Daisy parrotfish

between daisy parrotfish and its weight is presented in Figure 3. The analysis shows that the length-weight relationship between daisy parrotfish follows the equation $W: 0.08 L^{2.534}$ (negative allometric), indicating that the length growth of Daisy parrotfish is faster than the weight growth. The average length ranged from 16 cm to 52 cm (total length). The most common size of the daisy parrotfish was in the class interval of 22.0-24.9 cm total length (33.3%). Length frequency is an important parameter that determines the growth patterns of fish species (Sparre and Venema 1998). To determine the length at first capture ($L_{C50\%}$), the cumulative percentage of fish caught was plotted against their length (Figure 4).

RESULTS AND DISCUSSION

Results

Karimunjawa Islands are located at $5^{\circ}40'39''$ - $5^{\circ}55'00''$ South Latitude and $110^{\circ}05'57''$ - $110^{\circ}31'15''$ East Longitude. The management of the marine area surrounding the Karimunjawa Islands involves multiple stakeholders with potentially conflicting interests. These include conservation authorities, tourism operators, seaweed farmers, and fisheries enterprises (Campbell et al. 2013; Sulardiono et al. 2018; BTNKJ 2019; Wijayanto et al. 2022; Azzahra et al. 2023).

Table 1 presents the results of the length measurement of the daisy parrotfish. The length-weight relationship

Table 1. Size composition of daisy parrotfish caught in Karimunjawa, Central Java, Indonesia

Interval of total length (cm)	Middle value	Frequency	Percentage	Cumulative percentage
16.0-18.9	17.5	29	2.8%	2.8%
19.0-21.9	20.5	192	18.6%	21.4%
22.0-24.9	23.5	345	33.3%	54.7%
25.0-27.9	26.5	231	22.3%	77.0%
28.0-30.9	29.5	117	11.3%	88.3%
31.0-33.9	32.5	52	5.0%	93.3%
34.0-36.9	35.5	29	2.8%	96.1%
37.0-39.9	38.5	13	1.3%	97.4%
40.0-42.9	41.5	15	1.4%	98.8%
43.0-45.9	44.5	7	0.7%	99.5%
46.0-48.9	47.5	2	0.2%	99.7%
49.0-52.0	50.5	3	0.3%	100.0%

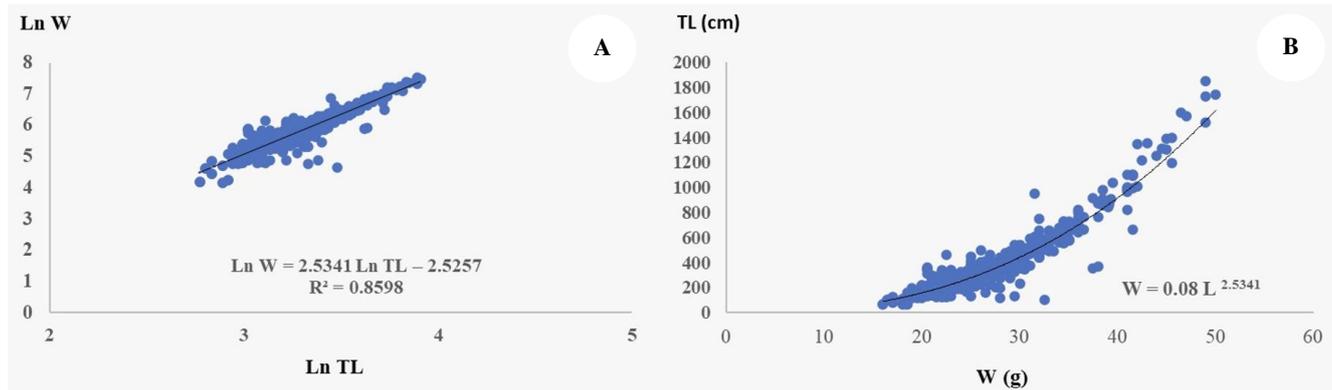


Figure 3. Length-weight relationship of daisy parrotfish. A: Ln TL-Ln W relation, B: TL-W relation

The results of this research indicate that the length frequency distribution of daisy parrotfish (*C. sordidus*) showed the $L_{c50\%}$ (length at first capture) of 24.8 cm. According to Randall et al. (1990), daisy parrotfish reach gonadal maturity (L_m) at a size of approximately 15 cm. Since $L_{c50\%}$ exceeded the L_m , most individuals were captured after reaching sexual maturity, which is important for supporting population regeneration. However, daisy parrotfish are protogynous hermaphrodites and switch sex from female to male at a size between 35.1 cm and 47.2 cm (De-Martini 2005). To ensure the availability of male individuals for reproduction in the wild, harvesting practices should avoid capturing individuals smaller than 35.1 cm. Further research is necessary to determine the specific size range at which sex change occurs among daisy parrotfish populations in the Karimunjawa Islands, highlighting the potential for future discoveries and the need for continued research in this field.

According to the von Bertalanffy model, the smallest captured size was 16 cm, and the estimated age was about 0.3 years (2.4 months). The peak spawning period is estimated to occur from May to July. These formations guide the implementation of seasonal fishing restrictions, especially during peak spawning times. The mortality analysis results (Table 2) also assist in managing the sustainability of this fish species.

The species's growth curve is presented in Figure 5. The asymptotic length (L_∞) is estimated at 51 cm, which corresponds to an approximate age of five years. The growth coefficient (K) is 1.4 cm/year, with a theoretical age at zero length (t_0) of -0.0969. For comparison, parrotfish populations in Guam exhibit a lower K value of 1.083 and an L_∞ of 22.9 cm, with this size estimated to occur at approximately nine years of age (McIlwain and Taylor 2019).

Recruitment refers to the addition of new individuals to the population, marking the transition of small fish to sizes vulnerable to fishing. As seen in Figure 6, the recruitment season lasts between August and October, with a peak in September (33.65%). This recruitment pattern is important for fisheries management, particularly in regulating the fishing season to ensure sustainable fish populations.

Based on the results of interviews with fishermen, we've identified the specific parrotfish fishing areas near the islands. These include several sites commonly occupied for spearfishing, such as the waters near Nyamuk Island, Krakal Kecil Island, Burung Island, Menjangan Besar Island, Menjangan Kecil Island, Seruni Island, Genting Island, Cendikian Island, and Bengkoang Island. This detailed information provides a comprehensive understanding of the fishing landscape in the Karimunjawa region. Karimunjawa fishermen generally support marine conservation activities, and they avoid fishing in the core zone of the conservation area (Setiyanto et al. 2024).

The results of the research showed the estimated total mortality value (Z) of 4.31 per year, and fishing mortality of 2.33, which is greater than natural mortality (which is 1.20). The utilization rate of 0.54 falls under the over-exploited category (Sparre and Venema 1998) (Table 2). Those parameters show the need for stronger control over the exploitation of daisy parrotfish to maintain the sustainability of coral reef ecosystems and the beach aesthetic around Karimunjawa Islands. Karimunjawa Islands should be protected as a marine conservation area by determining the minimum catch size and fishing seasons.

Table 2. Mortality and exploitation level

Note	Value
L_∞ (cm)	51
K	1.4
Total mortality (Z)	4.31
Fishing mortality (F)	2.33
Natural mortality (M)	1.20
Exploitation level (E)	0.54 (over-exploited)
Assumption of fishing mortality (production)* (kg)	38,088
Total mortality estimation (kg)	70,455
Production estimation at maximum sustainable yield (MSY) (kg)	35,227
Economic value at MSY** (IDR)	634 million

Notes: *: Using 2023 production data, **: Using the assumption that the price of daisy parrotfish for fishermen is IDR 18,000/kg

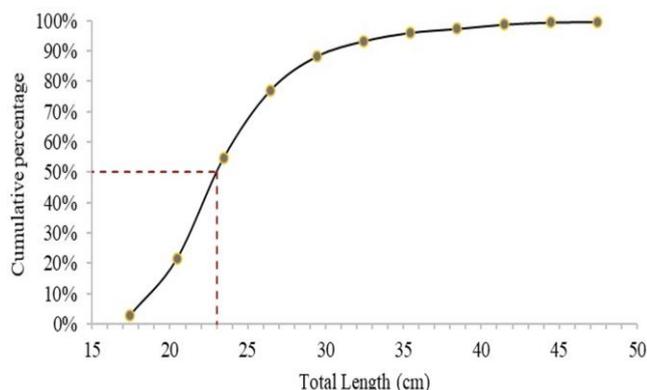


Figure 4. Lc 50% analysis

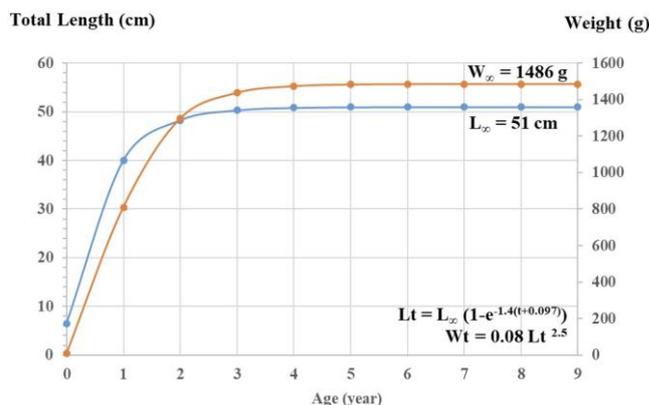


Figure 5. Estimated age, fish growth, and L infinity

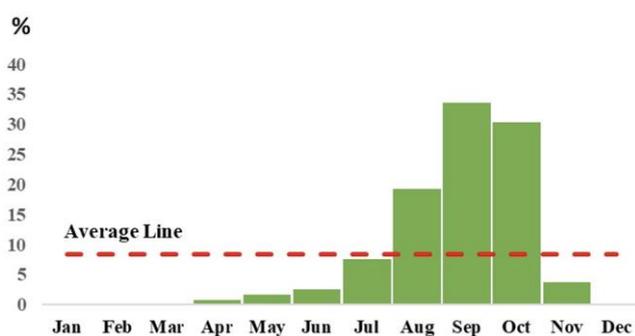


Figure 6. Recruitment pattern

Discussion

Daisy parrotfish (*C. sordidus*) inhabit coral reefs up to a depth of 30 m (White et al. 2013). As herbivorous fish, they play a crucial role in maintaining coral reef health and resilience by controlling algal overgrowth, which facilitates coral regeneration and sustains habitats for a wide variety of fish species (Choat et al. 2003; Hughes et al. 2003; Hawkins and Roberts 2004; Mumby and Harborne 2010; Hollbrook et al. 2016; Morgan and Kench 2016). Through their grazing and bioerosion activities, parrotfish also produce substantial amounts of carbonate sediment from digestion, influencing the calcium carbonate cycle and supporting beach formation and coastal stability (Alwany et al. 2009; Goatley and Bellwood 2010; Choat et al. 2012; Hollbrook et al. 2016; Morgan and Kench 2016; Zulfahmi et al. 2022; Panda et al. 2023; Abbas and Alnasser 2025).

The length-weight relationship of *C. sordidus* shows a negative allometric pattern, influenced by genetics, feeding habits, food availability, predation, and environmental conditions. They feed primarily on green algae, brown algae, and seagrass (Froese 2006; Ebisawa et al. 2016; Asriyana and Irawati 2020; Li et al. 2023). In Karimunjawa, most individuals caught were 22.0-24.9 cm TL, below the size at which sex change occurs, indicating potential disruption of male broodstock and reproduction (De-Martini 2005). Growth analysis reveals an asymptotic length (L_{∞}) of 51 cm (~5 years old) with a K value of 1.4 cm/year, classifying the species as fast-growing (Gulland

1983; Sparre and Venema 1998). Recruitment occurs mainly from August to October, peaking in September (33.65%), while spawning peaks from May to July, information critical for regulating fishing seasons.

Mortality estimates (Z : 4.31/year, F : 2.33, M : 1.20) indicate an exploitation rate of E : 0.54, placing the species in the overexploited category (Sparre and Venema 1998). The $L_{c50\%}$ value of 24.8 cm exceeds the L_m of 15 cm (Randall et al. 1990) yet remains below the sex change size range of 35.1-47.2 cm (De-Martini 2005), suggesting that current fishing practices may hinder successful reproduction. Overfishing can lead to reduced population sizes, disruption of reef cleaning, sediment transport, and shifts from coral dominance to macroalgae dominance, threatening overall reef resilience (Hollbrook et al. 2016; Vanderklift et al. 2019; Callwood 2021).

Effective management of *C. sordidus* requires reducing fishing pressure through size and seasonal regulations, alongside strengthened protection of the Karimunjawa Islands as a marine conservation area. Active participation of local communities, including fishers, traders, and processors, is crucial to developing and enforcing sustainable fisheries policies (Shimose et al. 2019). The Karimunjawa community comprises multiple ethnic groups who have lived in the islands prior to its conservation designation, necessitating integrated approaches that consider legal, social, economic, and ecological dimensions to avoid conflicts (Rakotonarivo et al. 2017; Suliyati et al. 2017; Kennedy et al. 2020; Wijayanto et al. 2022; Setiyanto et al. 2024; Sianipar et al. 2024).

Overall, the local population supports tourism, which contributes to household incomes and the regional economy (Alves et al. 2013; Chang et al. 2018; Brankov et al. 2019; Quevedo et al. 2021; Saragi 2023). Integrating traditional wisdom with formal policies is therefore essential for sustainable and effective management of daisy parrotfish and coral reef ecosystems in Karimunjawa.

In conclusion, daisy parrotfish (*C. sordidus*) play a key role in sustaining coral reef ecosystems by controlling algal growth and supporting coral regeneration. This study assessed their exploitation status in Karimunjawa using biological indicators, including $L_{c50\%}$, growth parameters, and mortality rates. Data collected from 1,032 individuals

between March 2024 and February 2025 revealed an L_{c50} of 24.8 cm and an asymptotic length (L_{∞}) of 51 cm, indicating that current fishing practices target individuals below the sex-change size, potentially affecting reproduction. The exploitation rate of 0.54 confirms that the species is overexploited. Effective management, including minimum size limits, seasonal restrictions, and community-based compliance, is essential to maintain population sustainability and reef resilience. Periodic monitoring and research on reproductive biology and critical habitats will further support policies to protect spawning adults and ensure long-term stock replenishment.

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