

Stock assessment of barred-chest grouper (*Epinephelus faveatus* (Valenciennes, 1828)) in Karimunjawa waters

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Abstract. This research assesses the stock status of *Epinephelus faveatus* in the sea waters of Karimunjawa Islands based on field observations and surveys that were conducted from July 2024 to May 2025 at the Karimunjawa Coastal Fishing Port. A total of 498 specimens were collected, with measurements of total length and weight recorded for analysis. Key parameters analyzed include the length–weight relationship, growth, recruitment, mortality, and exploitation levels. The species exhibited an isometric growth pattern ($W = 0.052L^{2.987}$). The estimated growth parameters were $L_{\infty} = 36.75$ cm TL, $K = 0.84$, and $t_0 = -0.18$. The length at first capture (L_c 50%) was 21.83 cm TL, and recruitment occurred year-round with a peak in July. The exploitation rate ($E = 0.24$) suggests the stock is underexploited. The maximum sustainable yield (MSY) was estimated at 15,190.3 kg per year, corresponding to an economic value of approximately IDR 455 million.

Key Words: *Epinephelus faveatus*, exploitation rate, Karimunjawa Islands, L_c 50%, recruitment.

Introduction. Karimunjawa Islands is a marine tourism destination with 27 islands located in the north of Java Island, Indonesia (BTNKJ 2019; Wibowo et al 2022). Its white sandy beaches and beautiful coral reefs offer magnificent views, which also serve as important habitat for various types of reef fish, including *Epinephelus faveatus* (Valenciennes, 1828), or barred-chest grouper within Serranidae family (BTNKJ 2019; Wijayanto et al 2025). At the present, grouper fish has been widely-exploited reef fish for its high economic value and demand (Heemstra & Randall 1993; de Mitcheson et al 2013; Sumathi et al 2015; Ohta et al 2017; Achmad et al 2023; Wijayanto et al 2025). Grouper fish live at depths of 1-125 m, and they are mostly protogynous hermaphrodite fish which will switch sex from female to male at certain age. Grouper fish are solitary and only gather in groups when they are about to spawn. Grouper fish are widespread in tropical to subtropical waters, including in India, Sri Lanka, and Indonesia (Heemstra & Randall 1993; Mariskha & Abdulgani 2012; Bawole et al 2017; Russell 2018). In Indonesian waters, Kadir et al (2023) recorded 23 species of *Epinephelus* spp. in the waters of South Sulawesi, including *E. faveatus*. Hasan et al (2023) also found *E. faveatus* in the estuary of the Bengawan Solo River (southern waters of Java Island) along with other *Epinephelus* species. *E. faveatus* was also found in the waters of Peukan Bada Aceh (Astuti et al 2016).

Overfishing is a general threat to global fisheries which can weaken the food security and the sustainability of fish resources unless properly addressed (FAO 2022; Pham et al 2023; Wijayanto et al 2025). Karimunjawa Islands has been designated as a conservation area since 1986 to protect the habitat of various aquatic biota, including *E. faveatus* (BTNKJ 2019; Wijayanto et al 2023a; Setiyanto et al 2024). More comprehensive data and information related to *E. faveatus* fish resources should be collected and analyzed to determine the most effective marine resource management. The stocks of *E. faveatus* in Karimunjawa marine conservation area are not yet widely measured. To address this gap, this research was performed to analyze the stocks of *E. faveatus* resources in Karimunjawa Islands. The results of this research were expected to be used as a reference in determining

proper conservation programs and sustainable management of coral fish resources in Indonesia.

Material and Method

Research location and time. This research was conducted in two largest islands in the Karimunjawa Islands, namely Karimunjawa Island and Kemujan Island that are connected by a bridge. Karimunjawa Island is the center of government and economy activities of the Karimunjawa Islands, where Karimunjawa Coastal Fishing Port (CFP) from which research data were collected from is located (see Figure 1) (Wibowo et al 2022; Wijayanto et al 2023a). The catch from all islands are sold by fishermen to fish traders at the CFP. In this research, field surveys and interviews were conducted from July 2024 to May 2025.

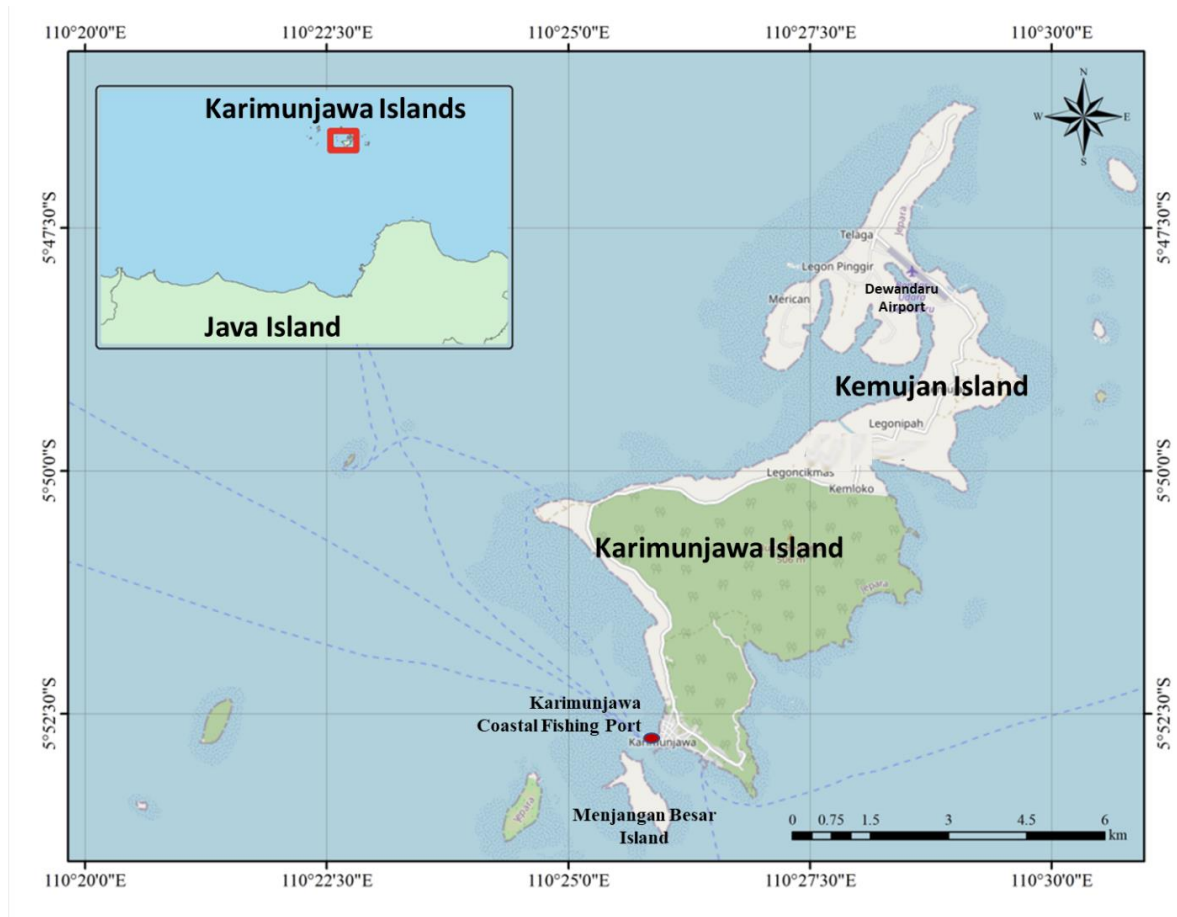


Figure 1. Karimunjawa Islands (research location).

Research materials. This research analyzed 498 individuals of *E. faveatus* (Figure 2) caught by traditional fishermen using outboard motorboats in one-day fishing method. *E. faveatus* fish were caught using various fishing gears, including handlines, gill nets, and traps (Setiyanto et al 2024; Wijayanto et al 2025). The fish length (total length or TL) was measured from 10% of the fish catch during the survey that were selected using systematic random sampling method (King 1995; Sparre & Venema 1998).



Figure 2. *Epinephelus faveatus*.

Analysis method. This quantitative descriptive research was also administered using a population dynamics approach (Setiyanto et al 2024; Wijayanto et al 2025). Several examinations were performed to determine the length-weight relationships, growth, mortality and exploitation rates (Sparre & Venema 1998; Dutta 2023; Bhakta et al 2024; Wijayanto et al 2025).

The length-weight relationship was examined using the following equation (Le Cren 1951; King 1995; Sparre & Venema 1998; Froese 2006):

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

$$\ln Wt = \ln a + b. \ln Lt \quad \dots\dots\dots (2)$$

where: Wt = weight of fish at age t (g);
 Lt = length of fish at age t (cm);
 a, b = constant.

The L_{∞} and K values were calculated using the ELEFAN (Electronic Length Frequency Analysis) I method with FISAT II. The t_0 value was obtained using the Gulland (1983) growth model using von Bertalanffy. Some of equations used in this research were specified as follows (Sparre & Venema 1998; Gayanilo et al 2005; Grandcourt 2005; Fatma et al 2021; Dutta 2023; Bhakta et al 2024; Wijayanto et al 2025):

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

$$\log(-t_0) = -0.3922 - 0.2752 \log L_{\infty} - 1.038 \log K \quad \dots\dots\dots (4)$$

where: L_{∞} = asymptotic total length (cm);
 K = growth coefficient (year);
 t = age of fish (years);
 t_0 = measure the fish when it is 0 cm TL (year).

The total mortality (Z) was estimated using FiSAT II software, while the natural mortality (M) was calculated based on empirical formula proposed by Pauly (1980), which regarded the relationship between water temperature and fish growth parameters (Sparre & Venema 1998; Fatma et al 2021; Dutta 2023; Wijayanto et al 2025):

$$\log(M) = -0.0066 - 0.279 \log L_{\infty} + 0.6543 \log K + 0.4634 \log T \quad \dots\dots\dots (5)$$

where: M = natural mortality index;
 L_{∞} = asymptotic total length (cm);
 K = growth coefficient (year);
 T = average surface water temperature (°C), assumed to be 30°C.

The mortality rate was also calculated using the following equation (Sparre & Venema 1998; Dutta 2023; Bhakta et al 2024; Wijayanto et al 2025):

$$F = Z - M \quad \dots\dots\dots (6)$$

Hence, the exploitation rate equation (E) was obtained as follows (Wijayanto et al 2025):

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

if:

$$\text{If } E_{MSY} = 0.5 \quad \dots\dots\dots (7)$$

then

$$F_{MSY} = 0.5 Z \quad \dots\dots\dots (8)$$

if:

$$\frac{F_{MSY}}{F} = \frac{C_{MSY}}{C} \quad \dots\dots\dots (9)$$

then

$$C_{MSY} = \frac{0.5 Z}{F} \cdot C \quad \dots\dots\dots (10)$$

where: F = fishing mortality index;
 Z = total mortality index;
 M = natural 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);
 C = existing capture production (kg).

Results. *E. faveatus* is a species of grouper fish that inhabits shallow coral reef ecosystems in tropical and subtropical regions. This species can be found in rocky and coral waters with shallow depths that provide protection and food sources (Heemstra & Randall 1993; Russell 2018). Based on the results of examinations from this research, the relationship between weight and length of *E. faveatus* follows the equation $W = 0.052 L^{2.987}$ (Figure 3). The coefficient b value of 2.987 which is close to 3 indicates that the growth of *E. faveatus* is isometric, where the increase in body length and increase in body weight are proportional (King 1995; Jisr et al 2018; Achmad et al 2023). The relatively high R² value (coefficient of determination) on the LnW-LnTL relationship curve (R² = 0.887) indicates a relatively good model to be used as a prediction tool. The correlation coefficient (r) is 0.930. It implies a strong relationship between the length and weight of *E. faveatus* (King 1995; Sparre & Venema 1998).

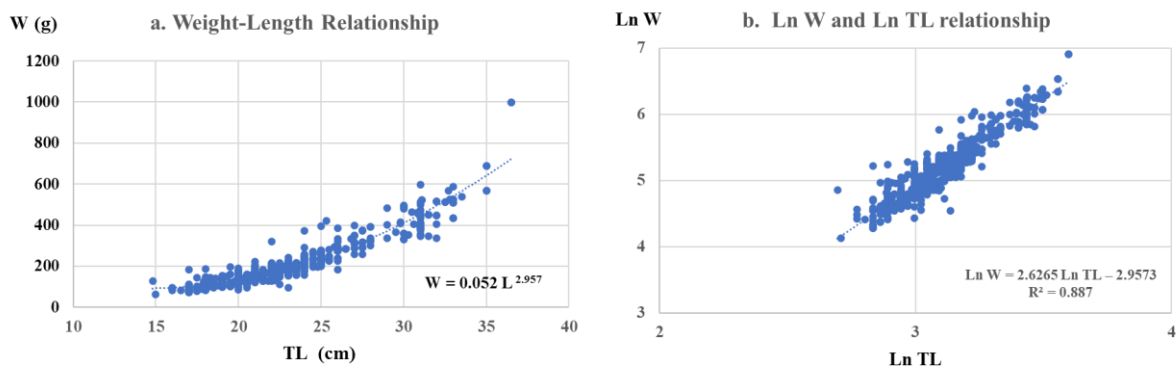


Figure 3. The length-weight relationship of *E. faveatus*.

The TL measurement ranged from 13 to 37 cm (Table 1). One hundred fifteen (115) individuals of the *E. faveatus* specimens (23.57%) had a TL of between 21.0-22.9 cm. The data were then used to estimate the values of K, L_∞, t₀, mortality and recruitment of fish resources.

The estimated length of the first fish catch (Lc50%) is at TL 21.83 cm (see Figure 4). The Lc50% value can be compared to length at first maturity (Lm) as a reference in sustainable fisheries management, with the expectation of Lm < Lc50% (Ernawati et al 2017; Bhakta et al 2024; Wijayanto et al 2025). In this research, Lm value was not estimated. Unfortunately, research on *E. faveatus* size related to Lm and sex change time for *E. faveatus* in Indonesia waters is still minimal. Mangi & Roberts (2006) obtained the Lm value of *E. faveatus* in Kenya waters of TL 27.03 cm. Referring to the Lm value, the Lc50% value in this research was less environmentally friendly (Lc50% < Lm) (King 1995; Sparre & Venema 1998; Bhakta et al 2024; Wijayanto et al 2025).

Table 1

Size composition of *E. faveatus* caught in Karimunjawa waters

<i>Interval TL (cm)</i>	<i>Median</i>	<i>Frequency</i>	<i>Percentage</i>	<i>Cumulative percentage</i>
13.0-14.9	14.0	1	0.20%	0.2%
15.0-16.9	16.0	5	1.00%	1.2%
17.0-18.9	18.0	61	12.25%	13.5%
19.0-20.9	20.0	75	15.06%	28.5%
21.0-22.9	22.0	117	23.49%	52.0%
23.0-24.9	24.0	85	17.07%	69.1%
25.0-26.9	26.0	58	11.65%	80.7%
27.0-28.9	28.0	26	5.22%	85.9%
29.0-30.9	30.0	17	3.41%	89.4%
31.0-32.9	32.0	34	6.83%	96.2%
33.0-34.9	34.0	8	1.61%	97.8%
35.0-36.9	36.0	7	1.20%	99.0%
37.0-39.0	38.0	5	1.00%	100.0%

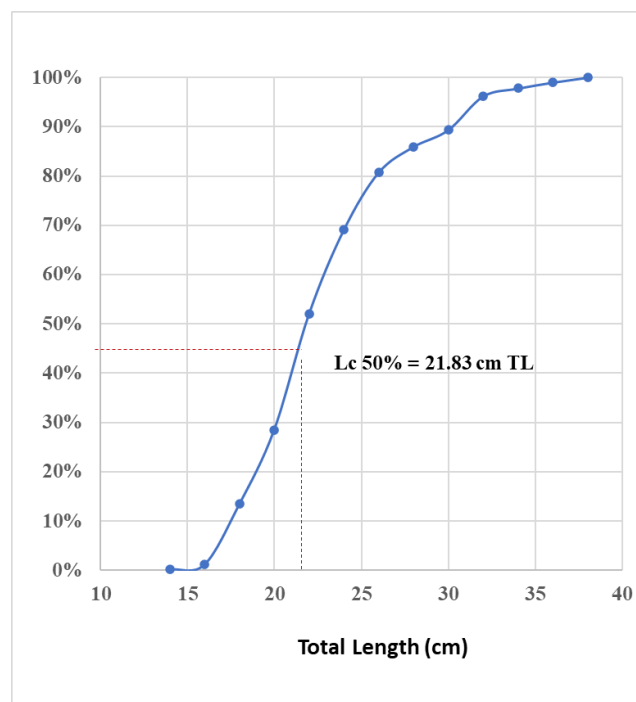


Figure 4. Lc50% analysis.

The estimated L_{∞} , K , mortality index and exploitation levels are presented in Table 2. The L_{∞} value of *E. faveatus* fish is 36.75 cm TL (W_{∞} is 671.04 g). Nadiarti et al (2015), categorized the life cycle of fish into 3: juveniles (sizing less than 1/3 of the maximum length), sub-adults (sizing 1/3 to 2/3 of the maximum length), and adults (sizing greater than 2/3 of the maximum length). In reference to this theory, *E. faveatus* in this research were classified as adult as its sized longer than 24.5 cm TL. Therefore, it can be inferred that the Lc50% in this research is still below the adult category size. The description of fish growth based on the von Bertalanffy model can be seen in Figure 5.

Estimation of L_{∞} , K , mortality and exploitation rate

Description	Value
L_{∞}	36.75 cm TL
K	0.84
t_0	-0.18
Total mortality (Z)	2.05
Fishing mortality (F)	0.50
Natural mortality (M)	1.56
Exploitation rate (E)	0.24 (under-exploited)
Assumption of fishing mortality*	7,410 kg
Estimated MSY production	15,190.3 kg
Estimated economic value of MSY production**	IDR. 455,708,607

Note: * using average production data during the research converted into production in a year; ** using the assumption of grouper prices at fishermen of IDR 30,000/kg.

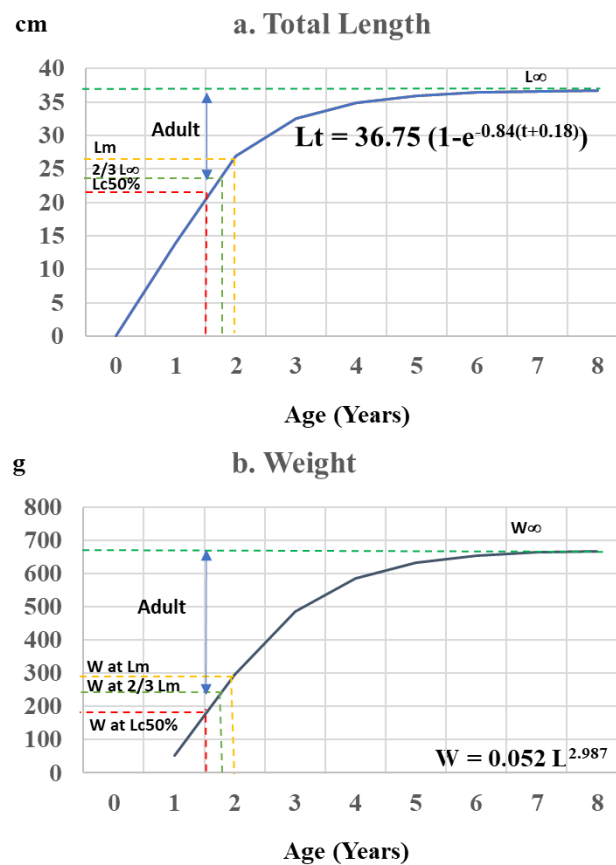


Figure 5. The von Bertalanffy growth curve of *E. faveatus*.

The natural mortality index (Z) of *E. faveatus* is estimated at 1.56 per year, while the mortality index due to fishing (F) is 0.5 and the exploitation rate (E) is 0.24. Thereby, the utilization of the *E. faveatus* in Karimunjawa waters is classified underexploited (Sparre & Venema 1998; Dutta 2023; Wijayanto et al 2025). The annual recruitment pattern is shown in Figure 6. The results of this research indicate that *E. faveatus* recruitment occurs throughout the year with the highest intensity in July (17.98%), June (14.76%) and September (14.65%). It is necessary to understand the recruitment pattern to determine the right fishing season in order to avoid disrupting the regeneration process of the fish population in the nature (Fatma et al 2021; Wijayanto et al 2025).

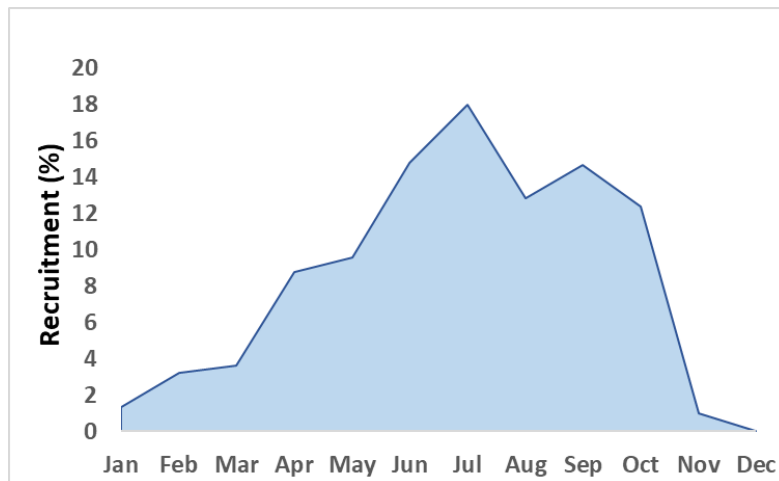


Figure 6. Estimated recruitment time.

Discussion. Karimunjawa Islands is one of the marine conservation areas in Indonesia with rich biodiversity, including fish, coral reefs, and mangroves. Karimunjawa Islands is the home to 42 types of mangrove forest flora, 9 types of seagrass flora, 31 types of macroalgae, 430 types of fish, 178 types of hard coral, and 23 types of soft coral (Hartati et al 2017; BTNKJ 2019; Hapsari et al 2020). Without adequate support from local community, marine conservation programs are vulnerable to failure (Ramadhan et al 2022; Wijayanto et al 2022). Local community have lived in the Karimunjawa Islands for generations, prior to the designation of Karimunjawa Islands as a conservation area. Without adequate and sustainable livelihoods, local community have the potential to carry out destructive activities that undermine the marine conservation efforts (Wijayanto et al 2021; Wibowo et al 2022). Therefore, the management and preservation of sustainable fishery resources are not only vital for ecological sustainability but also directly aligned with the short- and long-term socio-economic interests of the local population.

In general, grouper fish are at the top of the food chain in coral reef ecosystems (Grandcourt 2005; Bawole et al 2017). There are 39 species of grouper fish in Indonesia and seven species are found in Karimunjawa Islands: namely *Epinephelus malabaricus*, *E. fasciatus*, *E. ongus*, *Plectropomus areolatus*, *P. leopardus*, *P. maculatus* and *P. oligochantus* (Mujiyanto & Sugianti 2014). *E. faveatus* fish live in shallow waters on coral reefs and waters with rocky bottoms and can reach a maximum TL of around 32 cm (Russell 2018). However, the maximum TL of *E. faveatus* caught in this research was 39 cm.

Grouper fish, including *E. faveatus*, are main fish catch in coral reef areas in the world due to their high selling value, including in the Karimunjawa Islands (Heemstra & Randall 1993; de Mitcheson et al 2013; Wijayanto et al 2025). The price of *E. faveatus* fresh in Karimunjawa at the time of the research was around IDR 30,000 per kg. Prices fluctuate depending on the season, demand, size, and quality of the fish. The status of *E. faveatus* is categorized as Least Concern (LC) based on the International Union for Conservation of Nature or IUCN (Russell 2018). However, monitoring and controlling *E. faveatus* stocks are important to protect its sustainability.

In this research, the analysis of the weight-length relationship of *E. faveatus* fish resulted in a coefficient b value of 2.987 (approaching 3), that indicates an isometric growth pattern in length and weight. In isometric growth, weight gain is directly proportional to body length gain (King 1995; Grandcourt 2005; Jisr et al 2018; Haser et al 2022; Achmad et al 2023). The weight-length relationship is one of the indicators for researching the biological, physiological, ecological, and stock characteristics of fish resources. The results of the weight-length relationship analysis can be used to compare the characteristics of fish resources between regions. Herbivorous fish tend to be shorter and fatter than carnivorous fish. The length-weight relationship of fish is also influenced by feeding habits, availability of food sources, water depth, dissolved oxygen, water temperature, and season (Froese 2006; Li et al 2023). Environmental parameters, such as food availability, predators, and water quality also significantly affect the growth and development of fish.

In addition, water quality is one of the determinants of fish health and growth (Venkatachalam et al 2018; Haser et al 2022; Wijayanto et al 2024).

The size distribution of *E. faveatus* caught in Karimunjawa waters shows a fairly dominant pattern, with TL range of 21.0-22.9 cm (23.57%), while the Lc50% value is at a size of 21.83 cm TL. The Lc50% value is lower than the Lm value of *E. faveatus* from Mangi & Roberts' (2006) research, which is 27.03 cm TL. The Lc50% value is also lower than the 2/3 L_{∞} value (adult category) set by Nadiarti et al (2015). To promote more environmentally responsible exploitation of *E. faveatus*, it is essential for the Indonesian government to establish a minimum legal catch size that exceeds the Lm, thereby ensuring that individuals have the opportunity to reproduce at least once prior to capture (Sparre & Venema 1998; Ernawati et al 2017; Bhakta et al 2024; Wijayanto et al 2025). Furthermore, the reproductive biology of groupers, including their protogynous hermaphroditism, must be taken into account in fisheries management. The availability of male broodstock plays a critical role in the successful regeneration of grouper populations, as sex change from female to male occurs later in life and under specific social conditions (Rhodes 2018; Achmad et al 2021; Yamaguchi et al 2023; Wijayanto et al 2025). A healthy sex ratio, often requiring a higher proportion of females to males, is essential for sustaining viable breeding populations (Adams et al 2000).

The exploitation level index found in this research was $E = 0.24$, indicating that *E. faveatus* resources in Karimunjawa waters are regarded under-exploited (Sparre & Venema 1998; Dutta 2023; Bhakta et al 2024; Wijayanto et al 2025). This category allows for further exploitation of *E. faveatus* in the Karimunjawa Islands with adherence to specific regulations regarding the use of environmentally friendly fishing gears, minimum size, and protection of the spawning areas. Fishing activities are not allowed in the core zone of the Karimunjawa conservation area (Yuliana et al 2016; BTNKJ 2019). Without strict control, the exploitation of the fish can exceed the environmental carrying capacity and regeneration capacity of fish resources. The development of marine tourism in the Karimunjawa Islands can also lead to over-exploitation of grouper fish as demand for culinary tourism increases (Heemstra & Randall 1993; de Mitcheson et al 2013; Sumathi et al 2015; Ohta et al 2017; Wijayanto et al 2023b; Wijayanto et al 2025).

The results of this research indicate that the recruitment pattern of *E. faveatus* grouper is continuous throughout the year, with a peak in July (17.89%). Based on von Bertalanffy growth model simulations, individuals measuring 22.0 cm TL - the midpoint of the most dominant size class - are estimated to be approximately 11 months old. This implies that the corresponding peak in spawning likely occurs in August. Kadir et al (2023) note that mature female groupers exhibit visibly distended abdomens and may show signs of oviposition, such as eggs protruding from the oviduct.

To date, there is no research explaining the specific location of the *E. faveatus* grouper spawning ground in Karimunjawa Islands. Meanwhile, comprehensive information on the time and location of spawning is highly important in the determination of policies to protect the spawning broodstock.

Anthropogenic activities can be detrimental to the marine ecosystems from the declined fish resource stocks (Gernez et al 2023; Soeprbowati et al 2024). The sustainability of fish resources is a shared responsibility of stakeholders, as it relates to bigger issues of food security, employment, and the welfare of local community in the short and long terms. Sustainable fisheries management strategies should apply fishing quotas, minimum size limits, prohibition of destructive fishing gears, protection of spawning female fish, and the establishment of marine protected areas. Conservation programs also need to align ecology with the welfare of local communities since the success of conservation is also affected by the community involvement and support (Johannesen 2007; Kennedy et al 2020; Wijayanto et al 2025).

Conclusions. Based on the results of this research, the estimated length at first capture (Lc50%) of *E. faveatus* in Karimunjawa waters is 21.83 cm TL, suggesting that some of the fish caught were not yet suitable for capture. The length-weight relationship follows the equation $W = 0.052 L^{2.987}$, indicating an isometric growth. The recruitment pattern occurs throughout the year, with a peak recruitment in July and peak spawning in August.

The exploitation level is classified as underexploited ($E = 0.24$), indicating potentials of the exploitation to be improved with adherence to the environmentally friendly fishing principles. The maximum sustainable yield (MSY) is estimated at 15,190.3 kg per year, with a potential production value of approximately IDR 455 million, assuming a market price of IDR 30,000 per kg. Future research should focus on assessing the spawning potential ratio and identifying key spawning areas, as such information is crucial for formulating effective and sustainable management strategies for *E. faveatus* in the Karimunjawa region.

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Conflict of interest. The authors declare that there is no conflict of interest.

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