The exploitation status of white-streaked grouper (*Epinephelus ongus*) in Karimunjawa waters

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Abstract. This field research examined the level of exploitation of white-streaked grouper (*Epinephelus ongus*) in the waters of the Karimunjawa Islands from July 2024 to January 2025. In this research, growth, mortality and exploitation rates were analyzed from 388 systematically sampled fish (10% of the population caught by fishermen). The initial average size of white-streaked grouper fish caught was 19.95 cm TL (total length), and the highest recruitment occurred in November. This research revealed an exploitation rate of 0.37, implying that the exploitation rate of white-streaked grouper in the waters of the Karimunjawa Islands was categorized under-exploited. The sustainable production was estimated below 12,290 kg per year, equivalent to IDR 737,399,094 at an average price of IDR 60,000/kg.
Key Words: *Epinephelus ongus*, exploitation rate, Karimunjawa Islands, Lc 50%, recruitment.

Introduction. Overfishing is a global threat that can inhibit the food security unless properly addressed (Wijayanto et al 2019; FAO 2022; Pham et al 2023). Environmentally friendly fishing practices should be encouraged by involving active roles of stakeholders, including fishermen and fish traders in the Karimunjawa Islands (Chaliluddin et al 2021; Yulisti et al 2024). The Karimunjawa Islands are marine conservation areas with significant biodiversity that should be protected. Traditional fishing practices within the traditional fisheries zone are allowed in the area (Yuliana et al 2016; BTNKJ 2019; Wijayanto et al 2023a; Setiyanto et al 2024).

Groupers (family Serranidae) are among the global-most exploited reef fish resources due to their relatively high price and demand (Heemstra & Randall 1993; de Mitcheson et al 2013; Ohta et al 2017). Groupers are also one of the targets of fishermen's catches in the Karimunjawa Islands, including the white-streaked grouper (*Epinephelus ongus*). Groupers are protogynous hermaphroditic fish distributed across tropical to temperate marine waters (Rhodes 2018; Yamaguchi et al 2023). Continuous overexploitation can lead to a decline in fish biomass (Gernez et al 2023; Liu et al 2024; Soeprobowati et al 2024). Therefore, assessing the stock condition of white-streaked grouper is crucial for fish resource conservation as it has significant socio-economic implications for fishermen in the short and long terms.

Material and Method

Research location and time. The research was conducted on two largest islands in the Karimunjawa Islands: Karimunjawa Island and Kemojan Island (Figure 1). These islands are the center of the economic activities of the community (BTNKJ 2019; Wijayanto et al 2023a; BPS-Statistics of Jepara Regency 2024). Field surveys and interviews with fishermen and fish traders were performed to gain extensive data. The researchers also measured the total length (TL) of white-streaked grouper from July 2024 to January 2025.

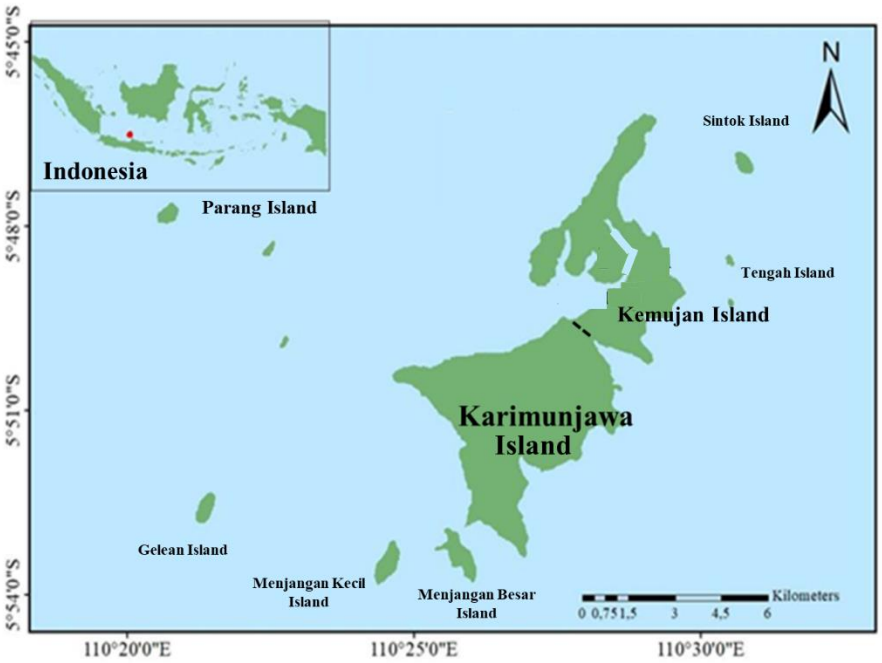

Figure 1. Karimunjawa Islands (research location).

Research materials. This research examined 388 white-streaked grouper fish caught by fishermen in Karimunjawa (Figure 2). The fishermen in this region are predominantly small-scale operators who utilize outboard motorboats and employ a one-day fishing pattern. They capture white-streaked grouper using various fishing gear, including handlines, traps (locally known as 'bubu'), and spears (King 1995; Sparre & Venema 1998).

Figure 2. White-streaked grouper.

Analysis method. Fish growth rate was measured using the von Bertalanffy equation (Sparre & Venema 1998) based on growth parameters, including asymptotic length ($L\infty$) and growth coefficient (K) which were calculated using the ELEFAN I (Electronic Length Frequency Analysis) method. The t_0 value (theoretical age when fish length is equal to zero) was estimated using the Gulland (1983) formula. Meanwhile, the total mortality (Z) was estimated using FiSAT II software. Furthermore, the natural mortality (M) was calculated based on empirical formula of Pauly (1980) that regarded the relationship between water temperature and fish growth parameters. The formulas used in this research are shown as follows (Gayanilo et al 2005; Dutta 2023; Bhakta et al 2024):

$$Lt = L\infty \left(1-e^{-k(t-t0)}\right)$$

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

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

$$F = Z - M$$

$$E = F/Z$$

If E_{MSY} = 0.5, then F_{MSY} = 0.5 Z

If $\frac{F_{MSY}}{F} = \frac{C_{MSY}}{C}$, then $C_{MSY} = = \frac{0.5\,Z}{F}.C$

where: Lt is the total length at age "t" (cm); L∞ is the asymptotic total length (cm); K is the growth coefficient; the notation t is the age of the white-streaked grouper (years); the notation t_0 is the estimated theoretical age of the white-streaked grouper when it has a total length of 0 cm (years); T is the average water temperature (°C), assumed to be 30°C; F is fishing mortality index; Z is total mortality index; M is natural mortality index; E is the exploitation rate; E_{MSY} is the exploitation rate at MSY (maximum sustainable yield); F_{MSY} is the fishing mortality index at MSY; C_{MSY} is the capture production at MSY (kg); and C is the existing capture production (kg).

Results. White-streaked grouper (local name: '*Kerapu*' and '*Kerapu Karet*') can be found in sea waters, lagoons, and brackish waters, including in the waters of the Karimunjawa Islands. The habitat of white-streaked grouper is in coral reef waters, and waters with a depth of 20-60 m (Kuiter & Tonozuka 2001; Craig et al 2012). The TL of white-streaked grouper measured in this research is presented in Table 1.

Table 1

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

Interval total length (cm)	*Median*	*Frequency*	*Percentage*	*Cumulative percentage*
12.1-22.0	17.0	128	32.99%	33.0%
22.1-32.0	27.0	224	57.73%	90.7%
32.1-42.0	37.0	32	8.25%	99.0%
42.1-52.0	47.0	4	1.03%	100.0%

The highest size frequency was observed in the TL class interval of 22.1-32.0 cm, with 224 individuals, accounting for 57.7% of the total sample. The length at first capture (Lc50%) was determined by plotting the cumulative frequency percentage of captured white-streaked grouper against total length (Figure 3).

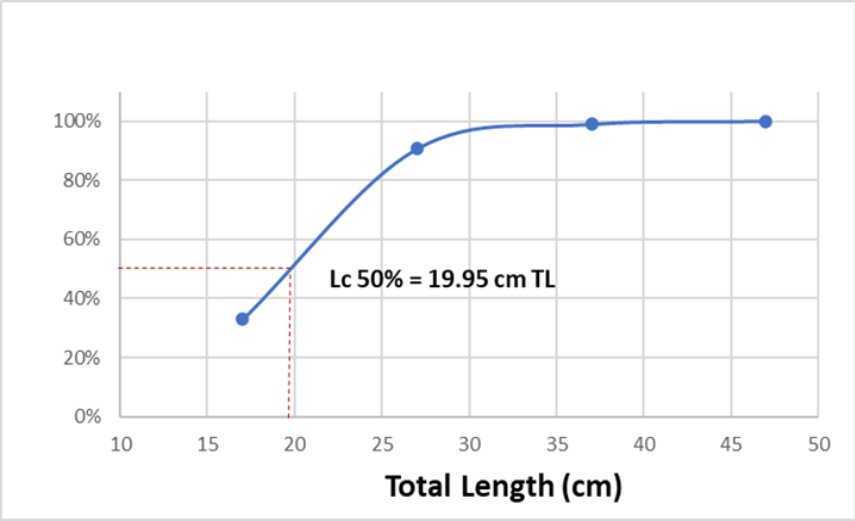

Figure 3. Lc 50% analysis.

The findings of this research indicate that the mean length at first capture (Lc50%) of white-streaked grouper is 19.95 cm TL. Lc50% can be compared with Lm, where Lm is the length of the fish at first gonadal maturity. The smallest mature female is 18.9 cm TL (Ohta & Ebisawa 2016). Generally, Lc50% values exceeding the Lm suggest environmentally sustainable fishing practices (Ernawati et al 2017; Bhakta et al 2024). However, white-

streaked grouper exhibits protogynous hermaphroditism, with approximately 50% of individuals transitioning from female to male at a size of approximately 27.2 cm TL, an event estimated to occur at around seven years of age. This species has a lifespan exceeding 20 years (Mapleston et al 2009; Ohta & Ebisawa 2016; Nanami et al 2017). Given the size at sex transition, harvesting white-streaked grouper at a size greater than 27.2 cm TL would be more sustainable, ensuring a sufficient number of mature males remain in the wild. The estimated values for L∞, (K), M, E, and MSY are presented in Table 2.

Table 2

Estimation of L∞, K, mortality and exploitation rate

Description	*Value*
L∞	49.35 cm TL
K	0.86
Total mortality (Z)	2.29
Fishing mortality (F)	0.84
Natural mortality (M)	1.45
Exploitation rate (E)	0.37 (under-exploited)
Assumption of fishing mortality*	93 ton
Estimated MSY production	12,290 kg
Estimated economic value of MSY production**	IDR. 737,399,094

Note: * using average production data during the research converted into production in a year; ** using the assumption of grouper prices at fishermen of IDR 60,000/kg.

The estimated Z for white-streaked grouper is 2.29 per year, with an exploitation rate of 0.37. This suggests that the species in the Karimunjawa Islands remains under-exploited (Sparre & Venema 1998; Dutta 2023; Bhakta et al 2024). The estimated recruitment pattern is illustrated in Figure 4, showing that recruitment occurs year-round, with peak recruitment observed in November (15.39%), followed by September (13.16%), July (12.68%), May (11.5%), and April (10.47%). In other months, recruitment levels were relatively lower, accounting for less than 10% of total recruitment. These recruitment patterns should be considered in fisheries management strategies, particularly concerning the regulation of fishing seasons.

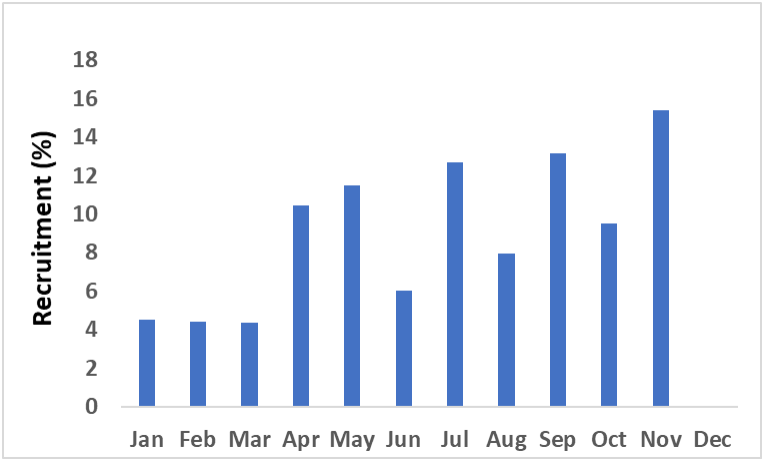

Figure 4. Estimated recruitment time.

Furthermore, the results indicated that the estimated L∞ of white-streaked grouper in the waters of the Karimunjawa Islands was 49.35 cm TL. However, according to Randall et al (1990), the maximum TL of this species is reported to be 40 cm. Differences in the biological characteristics of fish populations across geographic regions may arise due to complex environmental factors, including the availability of natural food sources, water temperature, and light intensity (Nikolsky 1963; Nanami et al 2017).

Discussion. The Karimunjawa Islands consist of 27 islands, with the two largest islands: Karimunjawa Island and Kemujan Island, where 82% of the population (10,609 people in 2023) resided (BPS-Statistics of Jepara Regency 2024). Since 1986, the Karimunjawa Islands have been designated as a marine protected area to protect its biodiversity and vital ecosystems such as mangroves and coral reefs that are home to several fish species, including white-streaked grouper (BTNKJ 2019). White-streaked grouper inhabits coral reef ecosystems. This species belongs to the Epinephelidae family. Adult fish can be found at depths of 20 to more than 60 meters. Its maximum total length can reach 40 cm and can live for more than 20 years. This fish spawns in sandy substrate waters near coral reefs (Rhodes 2018).

In this study, the TL of white-streaked grouper was measured using a sample of 388 individuals, with a recorded length range of 17 to 48 cm TL. The highest size frequency was observed in the 22.1-32.0 cm TL range, accounting for 57.7% of the total sample. Fish length frequency is a key parameter for assessing growth patterns (Sparre & Venema 1998). The findings indicate that the exploitation of white-streaked grouper in the Karimunjawa Islands remains in the under-exploited category. However, implementing regulations on minimum catch size is necessary to ensure population sustainability, particularly in maintaining the availability of mature males in the wild.

In this study, $L\infty$ of white-streaked grouper in Karimunjawa waters was 49.35 cm TL, and K 0.86. As a comparison, Craig's (2007) study showed that white-streaked grouper in Okinawa waters (Japan) had $L\infty$ 43.83 cm and K 0.04334. The K coefficient can be influenced by the availability of natural food and genetic factors. The K value of less than 1 is classified as a slow growth rate. Slower growth of fish resources is associated with slower regeneration and recovery of resources (Gulland 1983; Islam et al 2024). The white-streaked grouper primarily feeds on crustaceans and small fish. It is commonly caught using hand-lines, spears, and traps, including in Indonesia (Heemstra & Randall 1999; Craig et al 2012). Its habitat encompasses coral reef waters, lagoons, and brackish environments, with a distribution spanning the Indo-West Pacific, from East Africa to the Marshall Islands and Fiji, and from Australia to Japan, including Indonesia. Indonesia remains a major global producer of grouper. Studies have reported declining catches in various regions, including Malaysia, Indonesia, the Solomon Islands, and Papua New Guinea, largely due to unsustainable fishing practices and habitat degradation (Heemstra & Randall 1993; Hamilton 2003; Randall et al 2003; de Mitcheson et al 2013; Neubert et al 2016; Rhodes 2018; Nadia et al 2024).

Research on the Great Barrier Reef by Mapleston et al (2009) indicates that 50% of sex changes in white-streaked grouper occur at a TL of 27.2 cm, corresponding to an estimated age of seven years. The species reaches first gonadal maturity (Lm) at approximately three years, with a TL of 19 cm. Several factors influence Lm, including depth, food availability, temperature, and light. Spawning typically occurs on sandy substrates near coral reefs (Nikolsky 1963; Nanami et al 2017).

Identifying the determinants of fish population dynamics and estimating recovery rates of declining populations are fundamental to effective fisheries management. Temperature is a key environmental variable influencing fish physiology, with Karimunjawa waters ranging from 27.0 to 32.4°C. Overexploitation depletes fish stocks, reducing catch yields and impacting fishermen's livelihoods (Wibawa et al 2021; Gernez et al 2023; Dutta 2023; Liu et al 2024; Soeprobowati et al 2024; N'obrega et al 2025). Natural mortality in fish populations may result from predation, disease, and aging, whereas fishing mortality is directly influenced by fishing activities. The balance of fish biomass stocks is strongly affected by environmental factors, including water temperature and primary productivity. Water temperature plays a crucial role in regulating physiological processes in marine organisms, while primary productivity influences the structure of the food chain within the marine ecosystem (Azra et al 2018; Bhakta et al 2024). Monitoring and managing exploited fish populations, particularly in spawning areas, is critical for sustainability (Rhodes 2018). Anthropogenic activities that degrade marine ecosystems contribute to stock declines, while reducing fishing intensity can facilitate biomass recovery (Makwinja et al 2021; Umam et al 2021; Gernez et al 2023; Liu et al 2024; Soeprobowati et al 2024).

The estimated production of white-streaked grouper at the MSY level in Karimunjawa is 12,290 kg per year (equivalent to IDR. 737,399,094). The MSY production level is important as a policy reference for the sustainability of white-streaked grouper resources. Sustainable fisheries management strategies include implementing fishing quotas, minimum size limits, restrictions on destructive gear, protection of egg-bearing females, and establishing marine protected areas (Johannesen 2007; Rakotonarivo et al 2017; Suliyati et al 2017; Kennedy et al 2020; Zhang et al 2021; Wijayanto et al 2022). Gear modifications, such as escape vents in traps, enhance selectivity and reduce bycatch (Leland et al 2013; Zhang et al 2021; Liu et al 2024; Yu et al 2024). Conservation efforts must align ecological sustainability with the well-being of local communities, as the success of marine protection initiatives depends on community engagement and support (Wijayanto et al 2022).

Karimunjawa's diverse population, including Javanese (the majority), Bugis, Banjar, Bajo, Betawi, Buton, Madurese, and Sumbawa ethnic groups, has long inhabited the region, predating its designation as a marine protected area (Wibowo et al 2022; Wijayanto et al 2022). Effective conservation management must therefore integrate social, economic, legal, and cultural considerations (Suliyati et al 2017; Kennedy et al 2020; Wijayanto et al 2023a; Setiyanto et al 2024). Most adult males in Karimunjawa engage in fishing, with their catches distributed locally, to culinary businesses catering to tourists, and to Java. The region's coastal fishing port serves as the hub of capture fisheries (Wibowo et al 2022; Wijayanto et al 2023b). Involving local leaders and adopting culture-based approaches enhance conservation initiatives, with traditional knowledge complementing formal policies to optimize fisheries management in Karimunjawa.

Conclusions. The research findings indicate that the initial capture size of the white-streaked grouper is 19.95 cm total length. Recruitment occurs year-round, with peak recruitment observed in November. The exploitation rate of 0.37 suggests that the white-streaked grouper population in the Karimunjawa Islands remains underexploited. The estimated sustainable yield should not exceed 12,290 kg per year, equivalent to IDR 737,399,094, based on an average market price of IDR 60,000/kg.

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

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