SIZE STRUCTURE AND LENGTH-WEIGHT RELATIONSHIP OF EMPEROR FISH (LETHRINIDAE)

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Abstract

The emperor fish is a reef fish that constitutes the main catch of traditional fishermen in Wakatobi National Park (WNP). This study aimed to analyze the size structure and exploitation rate of emperor fish. The research was conducted on Kaledupa Island, WNP. The study used a survey method, identifying fishermen's catches and measuring the length and weight of the emperor fish found at the study locations. Data analysis used description analysis for measuring fish diversity; length-weight relationship (LWR) of fish; and measurement of the fish growth indicators. The results indicated that fish diversity in the two study locations (Balasuna and Tampara) was nearly identical. The species of emperor fish found were Lethrinus harak, L. ornatus, L. variegatus, L. lentjan, L. erythropterus, and L. genivittatus. Of the five types of fish found there, was L. harak (505 ind), 210 L. variegatus and 172 L. ornatus. L. harak was the longest in size at 29.5 cm, L. variegatus at 29 cm, and L. ornatus at 19 cm. Analysis of the LWR conducted on the L. harak, L. ornatus, and L. variegatus species indicated that the growth pattern of the three fish is negative allometric (a < b), meaning that their growth in length exceeded their growth in weight. The growth indicators (K, L_∞, t_0) of emperor fish in WNP when compared with previous research are not significantly different. In order to maintain the sustainability of fish resources, there is a need to increase fishermen's education and improve supervision of fishing activities.

Keywords: *Wakatobi, emperor fish, reef fish, exploitation*

1. INTRODUCTION

Reef fish are the main catch in Wakatobi National Park (WNP), with emperor fish (Lethrinidae) being a dominant reef fish caught (Yuliana et al., 2022). The emperor fish requires observation of biological aspects and has a long lifespan of up to 19 years (Restiangsih & Muchlis, 2019). These fish usually live in coral reefs and their surroundings, feeding mainly on bottom-dwelling invertebrates such as crustaceans and worms, small fish, and sometimes plankton (Bergbauer & Kirschner, 2020). Several species of emperor fish live in Indonesia's coral reef ecosystems, including those in WNP.

WNP is a marine conservation area in Indonesia and a national park approved through the Decree of the Minister of Forestry Number 7661/KPTS-II/2002, 19 August 2002. WNP covers an area of 1.39 million ha and has 25 clusters of coral reefs 600 km long (Yuliana et al., 2022). WNP comprises 97% sea area (Elliott et al., 2001), and, on account of its size, is included in the large-scale conservation category (Ban et al., 2017).

The coral reef is a habitat for reef fish, especially as a feeding, spawning, and nursery ground. The increase in population and intensified activity (including fishing activities) in WNP will have an impact on the health of coral reef ecosystems (Al Azhar et al., 2018). Fishing activities within WNP must be regulated in such a way as to protect the coral reef habitat and water areas within the national park in general. The fishing policy in the national park only allows traditional fishermen to catch fish. Likewise, fishing in the waters around Kaledupa Island WNP is limited to traditional fishermen using traditional fishing gear. Fishing, as their main livelihood, is the main activity in WNP waters. Fishing activities not properly regulated will result in the degradation of fish resources. Therefore, it is important to monitor the sustainability of fish resources. Moreover, traditional fishermen (small-scale fishermen) in Indonesia are not yet required to obtain permits. This situation could potentially threaten the sustainability of fishery resources, as it allows for the unreported increase of fishing fleets (Halim *et al.*, 2020).

Monitoring of fish resource sustainability can be conducted in several ways, for example measuring the length and weight of fish caught to then analyze the length and weight relationship (Mehanna & Farouk, 2021) and fish stock structure. The size structure of the fish caught illustrates the development of fish size from year to year. The decreasing trend in fish size structure suggests fish resource degradation. To estimate the biomass of different fish populations, it is necessary to know the length-weight relationships (LWRs) of the studied species. LWR is of great importance in fish stock assessments to estimate the biomass of fish (Mehanna et al., 2018b; Mehanna & Farouk, 2021). Monitoring can also be conducted by identifying the diversity of fish caught. Fish diversity is also an indicator of the sustainability of fish resources (Mujiyanto et al., 2023; Yuliana et al., 2019) and the health of aquatic ecosystems (Mujiyanto et al., 2023). In this case, abundance and biomass are two important indices for measuring reef fish diversity (Ault et al., 2008). In terms of monitoring coral fish diversity, it also means measuring the health of the coral reef ecosystem that is their habitat.

This study aimed to analyze fish stock through fish diversity, fish size structure and the length-weight relationship of emperor fish as one of the reef fish caught on Kaledupa Island, Wakatobi National Park. It is hoped that the results of this analysis can be considered in determining policies and actions related to the sustainability of emperor fish resources.

2. MATERIALS AND METHODS

2.1. Study Location

This research was conducted in the coastal waters of Balasuna Village (a) and Tampara Village (b) on Kaledupa Island, TNW, Southeast Sulawesi (Figure 1). These locations were selected to represent areas with distinct characteristics: located in the Eastern region, Balasuna Village faces the waters of the Banda Sea, while Tampara Village faces the waters of the Flores Sea. The differences in these characteristics are influenced by the winds blowing from their respective seas.

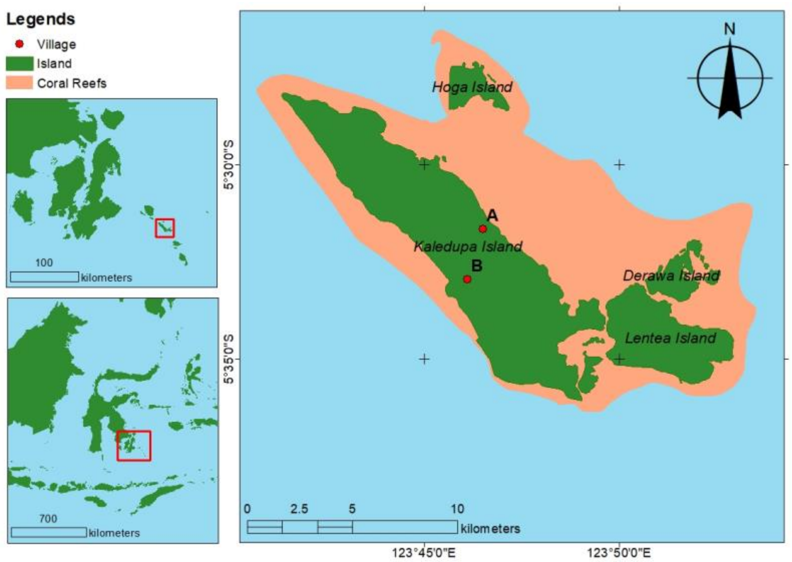

Fig. 1. Study locations on Kaledupa Island, Balasuna Village (A) and Tampara Village (B)

Source: Yuliana et al., Hayati, vol. 29, no. 2 (January 2022), p. 246.

2.2. Data collection

The data were collected by identifying fishermen's catches. After identifying the emperor fish species, the length and weight of the fish were then measured. Identification was also conducted on fish abundance (the number of individuals), frequency, and fish biomass (g). Identification of all these parameters was recorded for two weeks each month over a duration of 6 months.

2.3. Data Analysis

Fish diversity was analyzed through the number of individual fish, frequency of discovery, and fish biomass. The fish size structure was analyzed descriptively based on the size groups of fish caught. After grouping by size, analysis was carried out by counting the number of fish within each size group.

The LWRs were calculated based on the following formula:

$$W = aL^b$$

W is the fish's weight (g), L is the fish's total length (mm), a is a constant, and b is the estimator of the fish's growth pattern. The values of a and b are obtained from a simple linear equation.

$$Y = b_0 + b_1 X$$

Y as Log W and X as Log L. The constants b_1 and b_0 can be calculated using the following equation.

$$b_1 = \frac{\sum_{i=1}^{n} x_i y_i - \frac{1}{n}\sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{\sum_{i=1}^{n} x_i^2 - \frac{1}{n}\left(\sum_{i=1}^{n} x_i\right)^2}$$

and

$$b_0 = \overline{y} - b_1 \overline{x}$$

3. RESULTS

Six species of emperor fish were found in the waters of Kaledupa Island: *L. lentjan*, *L. genivittatus*, *L. erythropterus, L. variegatus, L. ornatus, and L. harak*. During the study, 908 individual emperor fish were found for all six species (Table 1). The occurrence frequency during the study period was 557 for the six species (Table 2). The total biomass for the six species was 103077 g (Table 3).

Fish Diversity

Fish diversity was measured through fish abundance, frequency and fish biomass. The abundance of fish at both study locations was dominated by *L. harak*, while the fish with the lowest abundance was *L. lentjan* at both study locations (Table 1). *L. harak* abundance reached its peak in October at both study sites.

The frequency of fish appearances in the two research locations shows that the most frequently found fish is *L. harak* while the least frequently found is *L. lentjan* (Table 2). This frequency data aligns with the fish abundance data in Table 1.

Fish Species	**Balasuna (ind)**							**Tampara (ind)**							**Total A+B (ind)**
	Jun	Jul	Aug	Sep	Oct	Nov	Total (A)	Jun	Jul	Aug	Sep	Oct	Nov	Total (B)	
L. erythropterus	0	0	0	0	3	2	5	0	0	0	0	2	4	6	11
L. genivittatus	2	2	0	0	0	0	4	1	0	1	0	0	0	2	6
L. harak	8	2	18	58	104	40	230	4	4	1	108	114	44	275	505
L. lentjan	0	0	0	0	0	0	0	0	0	4	0	0	0	4	4
L. ornatus	0	0	11	21	43	3	78	0	0	0	37	49	8	94	172
L. variegatus	0	0	0	49	11	9	69	0	0	1	91	49	0	141	210
						Total	386							522	908

Table 1. Fish abundance per observation month

Fish Species	**Balasuna (ind)**							**Tampara (ind)**							**Total A+B**
	Jun	Jul	Aug	Sep	Oct	Nov	Total (A)	Jun	Jul	Aug	Sep	Oct	Nov	Total (B)	
L. erythropterus	-	-	-	-	2	1	3	-	-	-	-	1	1	2	5
L. genivittatus	1	1	-	-	-	-	2	1	-	1	-	-	-	2	4
L. harak	3	1	2	3	7	2	18	1	2	1	2	7	5	18	36
L. lentjan	-	-	-	-	-	-	0	-	-	1	-	-	-	1	1
L. ornatus	-	-	1	3	3	1	8	-	-	-	5	4	2	11	19
L. variegatus	-	-	-	-	-	-	0	-	-	1	91	49	-	141	141
Total							31							175	206

Table 2. Frequency of fish found per month of observation

L. harak had the largest biomass in both study locations and *L. lentjan* (Table 3) had the lowest biomass. The data in Table 3 shows that fish biomass trends at the study locations were consistent with those of fish abundance (Table 1) and frequency (Table 2). This shows that the size of the fish in the study locations was almost the same. None of the fish were exceptionally large, differing from the average size of fish in the study locations.

Fish Species	**Balasuna (g)**							**Tampara (g)**							**Total A+B**
	Jun	Jul	Aug	Sep	Oct	Nov	Total (A)	Jun	Jul	Aug	Sep	Oct	Nov	Total (B)	
L. erythropterus	0	0	0	0	1084	268	1352	0	0	0	0	511	617	1128	2480
L. genivittatus	118	219	0	0	0	0	337	263	0	46	0	0	0	309	646
L. harak	935	407	5126	7985	17027	5018	36498	491	412	40	14020	16095	5623	36681	73179
L. lentjan	0	0	0	0	0	0	0	0	0	550	0	0	0	550	550
L. ornatus	0	0	2954	3139	6792	346	13231	0	0	0	5544	7110	1093	13747	26978
L. variegatus	0	0	0	2676	779	480	3935	0	0	105	4811	3013	0	7929	11864

Table 3. Biomass of the fish found per month of observation

Analyses of the size structure and length-weight relationship, based on the fish abundance, frequency, and biomass presented in Tables 1, 2, and 3 were conducted for the three dominant types of emperor fish caught: *L. harax*, *L. ornatus*, and *L. variegatus*.

Fish Size Structure

L. harak

A total of 499 *L. harak* were found at the study location. The maximum fish length was 29.5 cm while the minimum was 11 cm (Figure 2). The dominant fish length range was 18.6 – 20.4 cm. Based on data on fishbase.org, length at first maturity (L_m) is 19.5 cm, the maximum length of *L. harak* is 54.9 cm, the common length is 30.0 cm, the maximum published weight is 2.9 kg, and the maximum reported age is 15 years. The fish inhabit coral reef ecosystems at depths of 5 - 30 m. Based on L_m data from fishbase.org, out of the 499 individuals found, as many as 249 individuals were not suitable for catching and as many as 250 individuals were suitable for catching.

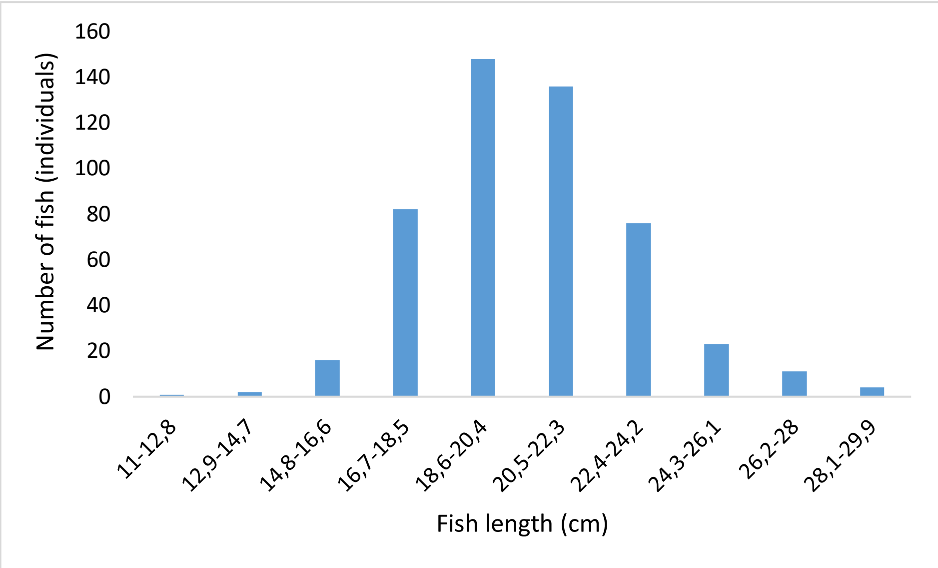

Fig. 2. Size structure of *L. harak* (n = 499)

L. ornatus

A total of 173 *L. ornatus* individuals were found at the study location. The maximum fish length was 29 cm while the minimum was 15 cm (Figure 2). The dominant length range was 18.2 – 19.7 cm. Based on data on fishbase.org, the maximum length of *L. ornatus* is 45.0 cm. They inhabit coral reef ecosystems at depths of 5 - 30 m. L_m value of *L. ornatus* is 18.10 cm (Anas et al., 2023). Of the 173 individuals found, 65 individuals were not suitable for catching, while as many as 108 individuals were suitable for catching based on L_m data (Anas et al., 2023).

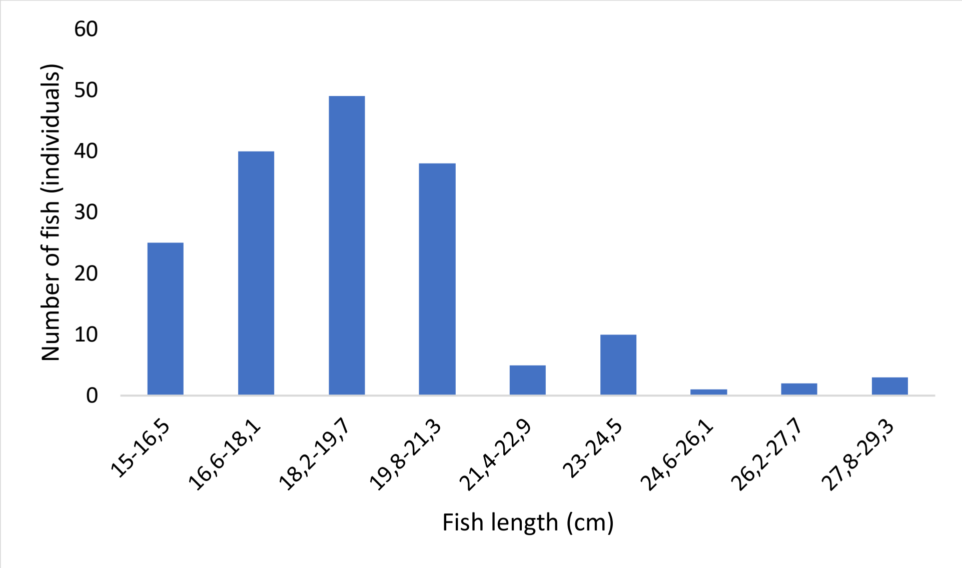

Fig. 3. Size structure of *L. ornatus* (n = 173)

L. variegatus

There were 220 *L. variegatus* individuals found at the study location. The maximum fish length was 19.5 cm, while the minimum was 12 cm (Figure 6). The dominant fish length range was 13.8 – 14.6 cm. Based on data on fishbase.org, the maximum length of *L. variegatus* is 20.0 cm, and the maximum reported age is 15 years. They inhabit coral reef ecosystems at depths of 0 – 150 m. The L_m value of *L. variegatus* is 15.36 cm (Heneish and Sabrah, 2021). Of the number of *L. variegatus* caught (220 individuals), 90 were suitable for catching, while 130 were not suitable.

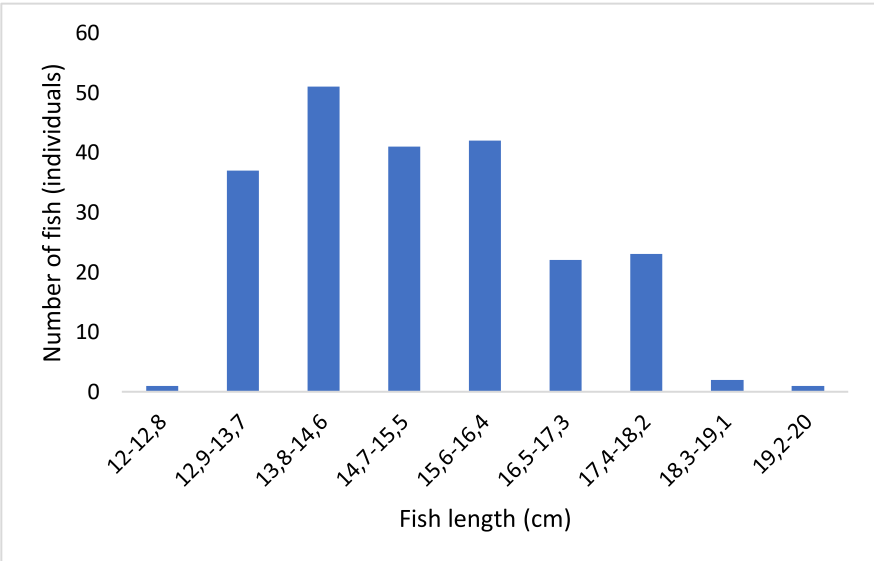

Fig. 4. Size structure of *L. variegatus* (n= 220)

Fish Length-Weight Relationship

The results of the length-weight relationship analysis show that *L. harak* has a length-weight relationship of $W = 0.0001L^{2.641}$, with a = 0.0001 and b = 2.641 (Figure 5), where a < b. The calculation results for the length-weight relationship for *L. ornatus* ($W = 0.0009L^{2.2955}$), the values a = 0.0009 and b = 2.2955

(Figure 6), with the value a < b. The calculation results of the length-weight relationship for *L. variegatus* ($W = 0.00001L^{3.0743}$), with a = 0.0001 and b = 3.0743 (Figure 7), with the value a < b. This shows that the three types of fish (*L. harak*, *L. ornatus*, and *L. variegatus*) have a negative allometric growth pattern, meaning that the increase in total body length is faster than the increase in weight.

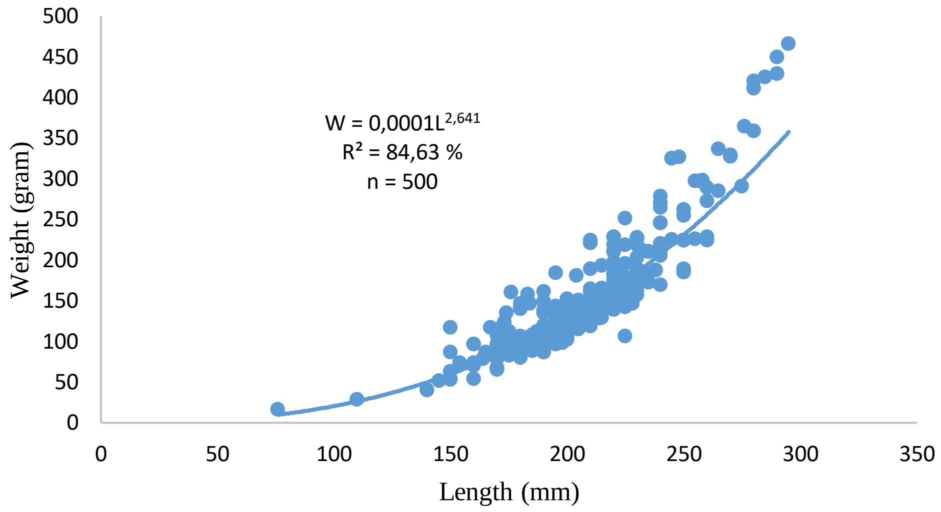

Fig. 5. Weight-length relationship in *L. harak*

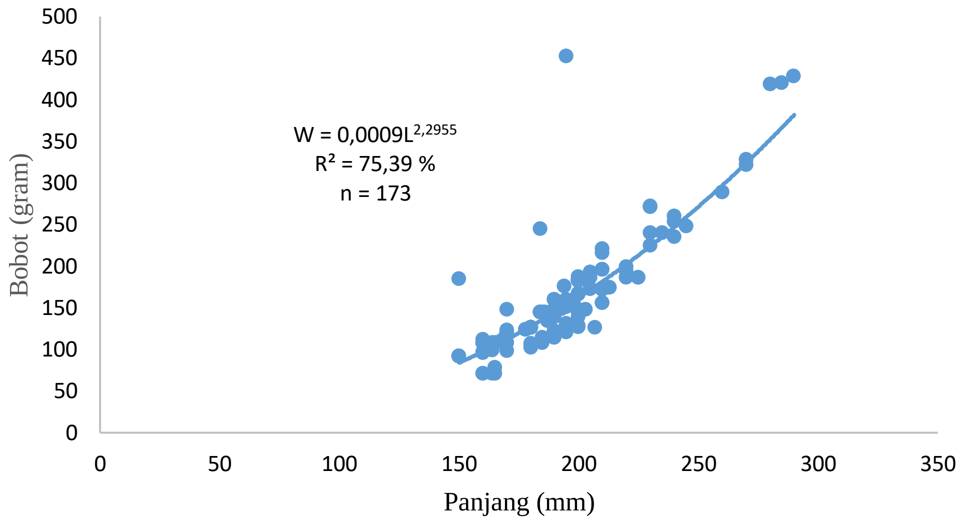

Fig. 6. Weight-length relationship in *L. ornatus*

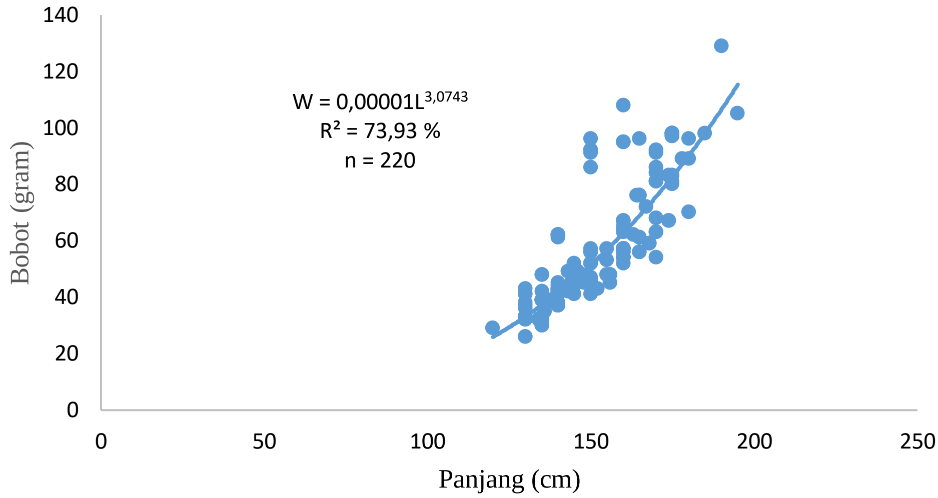

Fig. 7. Weight-length relationship in *L. variegatus*

Growth indicators for the three types of fish are presented in Table 4. The data findings on the asymptotic length of fish (L_∞) in this study are not significantly different from data on fishbase.org. This consistency shows that fish growth in WNP is undisturbed, allowing the fish to grow properly.

Fish species	Growth indicators			Location
	k (years)	L_∞ (mm)	t_0 (years)	
L. harak	0.50	315.2	-0.32	WNP, Indonesia (this study)
	0.23	291	-1.30	Tanzania (Midway *et al.*, 2018)
	0.25	342.2	0.00	Zanzibar, Tanzania (Mussa *et al.*, 2024)
L. ornatus	0.55	315.2	-0.29	WNP, Indonesia (this study)
L. variegatus	0.47	210.5	-0.38	WNP, Indonesia (this study)
	0.60	230.4	-	Gulf of Suez, Egypt (Heneish and Sabrah, 2021)

Note: k = growth coefficient; L_∞ = infinity length; t_0 = fish's age at 0 years

Table 4. Growth indicators

4. DISCUSSION

Fish diversity is an indicator of the sustainability of fish resources. Natural factors, such as water quality, climate change, and sedimentation, along with human activities on land and sea can influence coral reef health (Madduppa et al., 2020) and fish diversity. Fish diversity in WNP in the two study locations (Balasuna and Tampara Villages) has almost identical characteristics in terms of fish abundance, frequency, and biomass. The most numerous species was *L. harak*, while the least was *L. lentjan*. *L. harak* is a common marine species across the Indo-Pacific region occupying a range of habitats, including mangroves, seagrasses, and reefs (Midway et al., 2018). Consequently, even in WNP, *L. harak* is found in dominant numbers compared to other emperor fish. However, in total, the abundance of fish in Tampara Village (522 individuals) was higher than in Balasuna Village (386 individuals) (Table 1). This indicates that the environmental conditions in Tampara Village were relatively better than in Balasuna Village.

The frequency of fish occurrence and fish biomass in Tampara Village were greater than in Balasuna Village (Tables 2 and 3), indicating that the waters of Tampara Village provide better opportunities for fishing. Fish size structure is a tool for analyzing fish diversity (Boll et al., 2023) and is also related to fish stocks (Jaliadi et al., 2017). The size structure of the *L. harak* found at the study location follows the normal distribution, while for the other two fish species, the distribution was less normal (Figure 2). There were 249 individuals of *L. harak* unsuitable for catching, and 250 individuals suitable for catching, out of a total of 499 individuals found. This indicates that there is a balance between the numbers that are suitable for catching and those that are not. For *L. ornatus*, the size structure leans to the left (Figure 3), meaning that many fish caught are up to L_m, 18 cm (Anas et al., 2023). However, the number of fish suitable for catching (108 fish) is greater than those not worth catching (65 fish). *L. variegatus* also has a size structure that leans to the left (Figure 4), which indicates that the fish found are mostly small. The L_m size of *L. variegatus* is 15.36 cm (Heneish & Sabrah, 2021). Of the 220 *L. variegatus* caught, 90 were suitable for catching, and 130 were not. The curve for *L. ornatus* and *L. variegatus* skewed to the left, indicating that the fish found were predominantly small. This requires attention from WNP management authorities to regulate fishing only at mature sizes. Fishermen need to be educated intensively and approached persuasively.

The analysis of the length-weight relationship (Figures 5, 6, and 7) shows that the three emperor fish species analyzed have negative allometric growth patterns ($a < b$), meaning that the increase in length is faster than the increase in weight, indicating that the fish are relatively thin. This shows that the aquatic environment influencing fish growth has the same conditions. Fish growth patterns are important to analyze because they affect fish stocks (Mehanna et al., 2018a) and will ultimately provide information about the sustainability of fish resources.

The growth indicators (K, L_∞, t_0) of emperor fish in WNP when compared with previous research are not significantly different. This means that the emperor fish at the research location have normal growth. Specifically for *L. variegatus*, it has a smaller L_∞ value, i.e. 210.5 mm (Table 4) when compared to previous research conducted in the Gulf of Suez, Egypt, i.e. 230.4 mm (Heneish & Sabrah, 2021). A larger L_∞ value indicates slower fish growth (Soukotta & Saputra, 2023). This means that *L. variegatus* in WNP has faster growth than previous findings. For *L. harak*, the L_∞ value in WNP is greater than the L_∞ value in previous research conducted in Tanzania (Midway et al., 2018), indicating that *L. harak* has slower growth than the results of previous research.

Recommendations for WNP management authorities include: 1) increasing fishermen's education regarding catching fish below catch size or below L_m; 2) enhancing monitoring and supervision of fishing activities by monitoring the size of fish caught and using environmentally friendly fishing gear; 3) collaborating intensively with fishermen to create environmentally friendly fishing activities.

Fish diversity in terms of abundance, frequency and fish biomass shows that *L. harak* is the most dominant species, while *L. lentjan* has the lowest diversity. Tampara Village presents better diversity than Balasuna Village. There were 499 *L. harak* individuals found at the research location, with 249 individuals not suitable for catching and 250 individuals suitable for catching based on L_m = 19.5 cm. There were 173 *L. ornatus* individuals found at the research location, with 65 individuals not suitable for catching and 108 individuals suitable for catching based on L_m = 18.10 cm. There were 220 *L. variegatus* found at the research location, with 90 individuals suitable for catching and 130 individuals unsuitable based on L_m = 15.36 cm. Specifically for *L. variegatus*, it was found that the number of fish that were worth catching was smaller than those not worth catching. Therefore, *L. variegatus* requires serious attention from the WNP management authorities. The analysis of the length-weight relationship revealed that the three emperor fish analyzed had a negative allometric growth pattern ($a < b$), where the growth in length was faster than the increase in weight, indicating a relatively thin body shape. The growth indicators (K, L_∞, t_0) of emperor fish in WNP when compared with previous research are not significantly different. Specifically, *L. variegatus* has a smaller L_∞ value than previous research, indicating faster growth in WNP. *L. harak* has an L_∞ value greater than in previous research, indicating slower growth. WNP management authorities need to pay attention to fishing activities in the WNP area, especially for fish that show the potential for stock decline. Improving fishermen's education and supervision of fishing activities is necessary to ensure sustainable fish resources.

5. CONCLUSIONS

Fish diversity in terms of abundance, frequency and fish biomass shows that *L. harak* has the dominant diversity, while *L. lentjan* has the lowest diversity. Tampara Village has better diversity than Balasuna Village. There were 499 *L. harak* individuals found at the research location, 249 individuals were not suitable for catching and 250 individuals were suitable for catching based on L_m = 19.5 cm. There were 173 *L. ornatus* individuals found at the research location, with 65 individuals not suitable for catching and 108 individuals suitable for catching based on L_m = 18.10 cm. There were 220 *L. variegatus* found at the research location, those that were suitable for catching (90 individuals) and those that were not suitable for catching (130 individuals) based on L_m = 15.36 cm. Specifically for *L. variegatus*, it was found that the number of fish that were worth catching was smaller than those that were not worth catching. Therefore, *L. variegatus* needs serious attention from the WNP management authorities.

From the analysis of the length-weight relationship, it was found that the three lencam fish analyzed had a negative allometric growth pattern ($a < b$), the growth in length of the fish was faster than the increase in weight, indicating that the fish had a relatively thin body shape.

The growth indicators (K, L_∞, t_0) of lencam fish in WNP when compared with previous research are not significantly different. Specifically, *L. variegatus* has a smaller L_∞ value than previous research, which means its growth is faster in WNP. *L. harak* has an L_∞ value greater than the L_∞ value in previous research, which means that *L. harak* has slower growth than the results of previous research.

WNP management authorities need to pay attention to fishing activities in the WNP area, especially for fish that show the potential for stock decline. Increasing fishermen's education and supervision of fishing activities is needed to create sustainable fish resources.

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REFERENCES

1. Al Azhar, AA, Damar, A, Bengen, DG, Atmadipoera, A 2018, "Shallow-water habitat change detection of Kaledupa Island Wakatobi National Park (WNP) for 14 years", *Jurnal Ilmu dan Teknologi Kelautan Tropis*, vol. 10, no. 2, pp. 475–488. https://doi.org/10.29244/jitkt.v10i2.21316
2. Anas, A, Gigentika, S, Marliana, I, Aini, M, Hilyana, S, Nurliah 2023' "Stock condition of coral fish in marine protected area at TWP Gita Nada, West Nusa Tenggara Province", *Marine Fisheries*, vol. 14, no. 2, pp. 169–181. https://doi.org/10.29244/jmf.v14i2.47024
3. Ault, JS, Smith, SG, Luo J, Monaco, ME, Appeldoorn, RS 2008, "Length-based assessment of sustainability benchmarks for coral reef fishes in Puerto Rico", *Environmental Conservation*, vol. 35, no. 3, pp. 221–231. https://doi.org/10.1017/S0376892908005043
4. Ban, NC, Davies, TE, Aguilera, SE, Brooks, C, Cox, M, Epstein, G, Evans, LS, Maxwell, SM, Nenadovic, M 2017, "Social and ecological effectiveness of large marine protected areas", *Global Environmental Change*, vol. 43, pp. 82–91. https://doi.org/10.1016/j.gloenvcha.2017.01.00 3

5. Bergbauer, M, Kirschner, M 2020, "Reef Fishes of the Indo-Pacific", John Beaufoy Publishing Limited, 2014.
6. Boll, T, Erdogan, S, Bıçkı, ÜA, Filiz, N, Özen, A, Levi, EE, Brucet, S, Jeppesen, E, Beklioglu, M 2023, "Fish Size Structure as an Indicator of Fish Diversity: A Study of 40 Lakes in Türkiye", *Water*, vol. 15, no. 2147, pp. 1–12. https://doi.org/10.3390/w15122147
7. Elliott, G, Mitchell, B, Wiltshire, B, Manan, IA, Wismer, S 2001, "Community participation in marine protected area management Wakatobi National Park, Sulawesi, Indonesia", *Coastal Management*, vol. 29, no. 4, 295–316. https://doi.org/10.1080/089207501750475118
8. Halim, A, Wiryawan, B, Loneragan, NR, Hordyk, A, Sondita, MFA, White, AT, Koeshendrajana, S, Ruchimat, T, Pomeroy, RS, Yuni, C 2020, "Developing a functional definition of small-scale fisheries in support of marine capture fiheries management in Indonesia", *Journal of Fisheries and Marine Research*, vol. 4, no. 2, pp. 239–262. https://doi.org/10.21776/ub.jfmr.2020.004.02.9
9. Heneish, RA, Sabrah, MM 2021, "Fisheries biology of the slender emperor Lethrinus variegatus (valenciennei, 1830) inhabitant in the Gulf of Suez, Egyptian Red Sea", *Egyptian Journal of Aquatic Biology & Fisheries*, vol. 25, no. 339, pp. 339-352.
10. Jaliadi, Yusfiandayani, R, Baskoro, MS 2017, "Catch lenght weight relationship around portable and tradisional FADs in Aceh Barat Waters", *Albacore*, vol. 1, no. 1, pp. 1–9.
11. Madduppa, HH, Koropitan, AF, Damar, A, Subhan, B, Taufik, M, Minsaris, LOA, Taurusman, AA, Ramli, A, Purwanto, AB 2020, "Ecological vulnerability of coral reef ecosystem in wakatobi national park during Indian ocean dipole event", *HAYATI Journal of Biosciences*, vol. 27, no. 1, pp. 57–70. https://doi.org/10.4308/hjb.27.1.57
12. Mehanna, SF, Farouk, AE 2021, "Length-Weight Relationship of 60 Fish Species From the Eastern Mediterranean Sea, Egypt (GFCM-GSA 26)", *Frontiers in Marine Science*, vol. 8, pp. 1-7. https://doi.org/10.3389/fmars.2021
13. Mehanna, SF, Osman, AGM, Farrag, MMS, Osman, YAA 2018a, "Age and growth of three common species of goatfish exploited by artisanal fishery in Hurghada fishing area, Egypt", *Journal of Applied Ichthyology*, vol. 34, no. 4, pp. 917–921. https://doi.org/10.1111/jai.13590
14. Mehanna, SF, Osman, AGM, Farrag, MMS, Osman, YAA 2018b, "Age and Growth of Three Common Species of Goatfish Exploited by Artisanal Fishery in Hurghada Fishing Area, Egypt", *Journal of Applied Ichthyology*, vol. 34, no. 4, 917–921. https://doi.org/10.1111/jai.13590
15. Midway, SR, Ostrowski, A, West, L, Hernandez, M, Robertson, MD 2018, "Improved growth estimates for *Lethrinus harak*: Measuring increments, adjusting ages, and fitting flexible growth models", *Fishes*, vol. 3, no. 31, pp. 2–11. https://doi.org/10.3390/fishes3030031
16. Mujiyanto, M, Syam, AR, Suharti, RS, Sugianti, Y, Sharma, S 2023, "Reef Fish Biodiversity at Different Depths in Tunda Island, Banten Province, Indonesia", *HAYATI Journal of Biosciences*, vol. 30, no. 2, pp. 257–270. https://doi.org/10.4308/hjb.30.2.256-270
17. Mussa, TA, Yahya, SAS, Castro, JJ, Chauka, LJ 2024, "Age, growth and mortality of the thumbprint emperor (*Lethrinus harak*) in Zanzibar", *WIO Journal of Marine Science*, vol. 23, no. 1, pp. 9–18. https://doi.org/10.4314/wiojms.v23i1.2
18. Restiangsih, YH, Muchlis, N 2019, "Biological aspects of pink ear emperor, Lethrinus lentjan (Lacepede, 1802) in Bangka and adjacent waters", *Jurnal Iktiologi Indonesia*, vol. 19, no. 1, pp. 115–126. https://doi.org/10.32491/jii.v19i1.349
19. Soukotta, IV, Saputra, SW 2023. Parameter pertumbuhan (L_∞, K , t_0) dan tingkat kematangan gonad ikan cakalang (*Katsuwonus pelamis*). *Jurnal Laut Pulau*, vol. 2, no. 1, pp. 59–66. https://doi.org/10.30598/jlpvol2iss1pp59-66

20. Yuliana, E, Boer, M, Fahrudin, A, Kamal, MM, Pardede, ST 2019, "Using ecosystem approach indicators for assessing the ecological status of reef fisheries management in a marine protected area", *Biodiversitas*, vol. 20, no. 7, pp. 1802–1810. https://doi.org/10.13057/biodiv/d200703

21. Yuliana, E, Winata, A, Adimu, HE, Hewindati, YT, Djatmiko, WA 2022, "Reef fish in the mudflats in Kaledupa Island, Wakatobi National Park, Indonesia", *Hayati Journal of Bioscience*, vol. 29, no. 2, pp. 246–254. https://doi.org/10.4308/hjb.29.2.245-254