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LENGTH-WEIGHT RELATIONSHIP AND CONDITION FACTORS OF EIGHT FISH SPECIES CAUGHT BY TRADITIONAL PAPUAN FISHERS IN YOUTEFA BAY, INDONESIA

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Abstract.
In this study, data on length and weight of fish were used to determine the length-weight relationship and condition factors of eight commercially important fish species targeted by traditional Papuan fishers in Youtefa Bay, Papua Province, Indonesia: Lutjanus fulvus, Gerres oyena, Parupeneus barberinus, Siganus spinus, Siganus canaliculatus, Pelates quadrilineatus. Mugil cephalus*, and* Hemiramphus far. *A total of 245 fish specimens were collected from Papuan fishermen during the period from January to March 2020. The total body length and weight ranged from 15.2 to 32.1 cm (average 20.26±3.73 cm) and 42.72 to 371.86 g (average 124.10±52.45 g), respectively. The b value ranged from 2.6919 to 3.0791, with the coefficient of determination (R^2) ranging from 0.9022 to 0.9947. The growth patterns of the eight fish species were allometric ($b \neq 3$; t-test < t-tab), where* L. fulvus *(2.824)*, P. barberinus *(2.9136)*, S. canaliculatus *(2.989)*, P. quadrilineatus *(2.9577)*, M. cephalus *(2.9096), and* H. far *(2.6919) have negative allometric growth ($b < 3$), while* G. oyena *(3.0596) and* S. spinus *(3.0791) have positive allometric growth ($b > 3$). The relative condition factor and Fulton condition factor values ranged from 0.874 to 1.201 (average 0.999±0.321) and 0.204 to 2.726 (average 1.612±0.515).* M. cephalus *had a higher relative condition factor, while* L. fulvus *had a higher Fulton condition factor compared to other fish species.*

*Key words***:** *Growth patterns, negative allometric; positive allometric, relative condition factor, Fulton condition factor*

Introduction

Youtefa Bay is a semi-enclosed bay located in Jayapura City, Papua Province, Indonesia (Figure 1). Youtefa Bay has mangrove and seagrass ecosystems that function as important habitats for various fish species (Tebaiy et al., 2014; Hamuna et al., 2020; Rumahorbo et al., 2020; Sari et al., 2020), and have the direct potential to increase the economic income and wealth of the community around Youtefa Bay through the fisheries sector (Rumahorbo et al., 2020). On the other hand, the intensive use of fish resources can lead to overfishing. Therefore, management measures are needed to conserve fish resources in Youtefa Bay so that they can be exploited sustainably. To support appropriate and sustainable fisheries management and utilization, information is needed on various aspects of fish biology, including fish growth patterns.

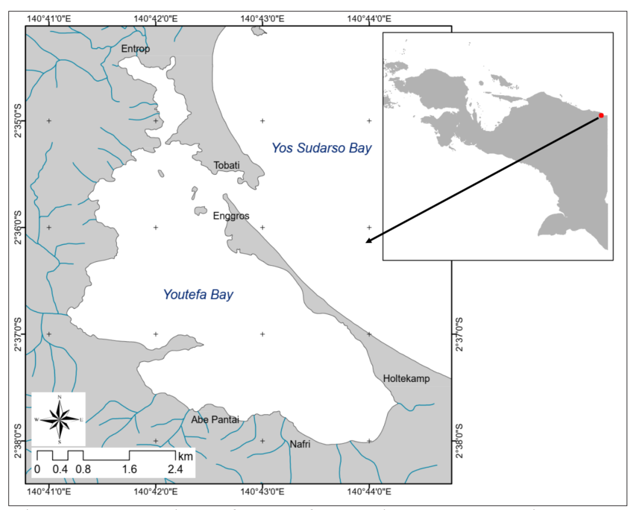

Figure 1. Location of Youtefa Bay in Papua Province, Indonesia

Growth patterns of different fish species can be determined using fish length and weight measurements (Froese, 2006; Shalloof & El-Far, 2017; Sunarni et al., 2019; Sentosa & Chodrijah, 2020; Reis & Ateş, 2020). Length-weight relationship (LWR) describes the correlation between body length and weight (Froese, 2006). Fish body length is often more convinient to measure, and is used to determine fish weight (Harrison, 2001). LWR has an important and significant role in providing information on fish population dynamics, distribution, stock estimates, mortality, and morphology (Froese 2006; Rábago-Quiroz et al., 2017; Jafari-Patcan et al., 2018; Akter et al., 2019; Reis & Ateş, 2020), including the morphological differentiation between different populationts of the same fish species (Binohlan & Pauly, 2000). LWR can also provide information on fish maturity, growth patterns, fish biomass (Schneider et al., 2000), and play an important role in fisheries status assessment (Eagderi et al., 2020) and environmental monitoring (Morey et al., 2003). Another important data in fisheries studies is the condition factor of each fish species. Condition factors are used as growth and feeding indices for fish (Fagade, 1979), so they can serve as valuable guides for tracking fish feeding habits and abilities, as well as fish growth rates (Oni et al., 1983). There are two conditional factor values that can be used, namely the Fulton condition factor which assumes that the weight and length of fish increase isometrically (Fulton, 1904; Cone 1989), and the relative condition factor assumes allometric fish growth (not isometric) as the ratio between the observed fish weight and predictive weight (Le Cren, 1951).

Until now, there have been no research results on LWR and the condition factors of the fish found in Youtefa Bay. In fact, LWR data and condition factors are very important in sustainable fisheries assessment studies. In addition, the high utilization of fishery resources and the lack of information regarding the biological aspects of fish are feared to disrupt the sustainability of fish resources in a waters. Therefore, it is necessary to study the LWR and factors condition of fish in Youtefa Bay. Aim of this study is to determine the LWR and condition factors of several economically important fish species for Papuan fishermen in Youtefa Bay. This data is important to support optimal and sustainable management of fisheries resources in Youtefa Bay.

MATERIALS AND METHODS

Data collection and measurements

Specimens of commercially important fish species that are a target catch of Papuan fisherman were sampled every two weeks during the period from January to March 2020. A total of 245 specimens of fish from eight species of fish caught by local Papuan fishermen in Youtefa Bay have been measured in length and weight. Six species of fish are demersal fish, namely *Lutjanus fulvus* (Forster, 1801), *Gerres oyena* (Forsskål, 1775), *Parupeneus barberinus* (Lacepède, 1801), *Siganus spinus* (Linnaeus, 1758), *Siganus canaliculatus* (Park, 1797), and *Pelates quadrilineatus* (Bloch, 1790), while the other two species are pelagic fish, namely *Mugil cephalus* (Linnaeus, 1758) and *Hemiramphus far* (Forsskål, 1775). This fish specimen was caught by Papuan fishermen using fishing rods and gill nets. To avoid data inaccuracies, only fish specimens that are in good condition and fresh are selected for measurement of fish length and weight. This was done because there was a long time lag between the time of catching (from afternoon to midnight) and the measurement of fish samples in the morning or afternoon. Total length of each specimen was measured with a caliper ruler (accuracy 0.1 cm). Body weight was measured with a digital balance (accuracy 0.001 g).

Analysis of LWR and growth pattern

The growth pattern of each fish species is determined based on LWR analysis. The *LWR* equation is as follows (Le Cren, 1951):

$$W = a \times TL^b$$

where *W* is the weight (g) of the fish for a given total length (cm), *TL* is the total length of the fish (in cm), *a* is the intercept, and *b* is the slope of the relationship (regression coefficient). LWR of each fish species will be presented in the form of a power curve equation. Value of the coefficient *b* represents fish growth. If *b* equals 3 (b=3) the growth is isometric and if it significalntly differs ($b \neq 3$) the growth is allometric ($b<3$ negative allometric; $b>3$ positive allometric) (Ricker & Carter, 1958).

Condition factors

The relative condition factor for each fish species is determined based on the equation (Le Cren, 1951):

$$K_R = W / (a \times TL^b)$$

where K_R is the relative condition factor, W is the body weight (g), TL is the total length (cm), *a* and *b* are the LWR parameters.

Fulton condition factor is determined based on the equation (Fulton, 1904):

$$K_F = 100 \times (W / TL^3)$$

where K_F is the Fulton condition factor, *W* is the body weight (g) and *TL* is the total length (cm)

Statistical analysis

Statistical analysis was used to determine the growth pattern of each fish species by comparing the *b* value obtained with the isometric value using the t-Student test (Zar, 2014). To confirm whether the *b* value obtained is significantly different from the isometric value (*b*=3), a comparison between the statistical values of the *t*-test and the *t*-table at a 95% confidence interval is used. The hypothesis is to test the null hypothesis (H0) : *b*=3 (isometric) against the alternative hypothesis (H1) : *b*≠3 (allometric). If the value of *t*-test > *t*-table then the decision rejects H0; and if the value of *t*-test < *t*-table then the decision is to accept H1. The equation for determining the value of the *t*-test is as follows (Sokal & Rohlf, 1987):

$$t\text{-test} = (b - 3) / S_b$$

where b is the LWR parameter and S_b the standard error of the *b* value.

Results

The LWR and growth pattern of fish

Fish total length ranged from 15.2 to 32.1 cm (average 20.26±3.73 cm) and fish weight ranged from 42.72 to 371.86 g (average 124.10±52.45 g) (Table 1). The graph of the power curve equation showing the LWR of eight fish species is presented in Figure 2. The *a* and *b* values obtained ranged from 0.0062 to 0.041 and 2.6919 to 3.0791, respectively. The coefficient of determination (R^2) ranged from 0.9022 to 0.9947, which indicates a very strong relationship between fish length and weight. The results of statistical analysis for fish growth patterns are presented in Table 2. All fish species have allometric growth (*b*≠3; *t*-test<*t*-tab). Negative allometric growth is *L. fulvus* (2.824), *P. barberinus* (2.9136), S. *canaliculatus* (2.989), *P. quadrilineatus* (2.9577), *M. cephalus* (2.9096), and *H. far* (2.6919) have negative allometric growth (*b*<3; *t*-test<*t*-tab), whereas *G. oyena* (3.0596) and *S. spinus* (3.0791) have positive allometric growth (*b*>3; *t*-test<*t*-tab).

Condition factors

The condition factors for eight fish species, both the relative condition factor and the Fulton condition factor are presented in Table 3. These values indicate the health and welfare conditions of the fish species studied. The minimum and maximum values of relative condition factor for the eight fish species studied were 0.874 (*L. fulvus*) and 1.201 (*G. oyena*), with an average value of the relative condition factor of 0.999±0.321. Meanwhile, the minimum and maximum values of Fulton condition factor for the eight fish species studied were 0.204 for *H. far* and 2.726 for *L. fulvus*, with an average value of the Fulton condition factor of 1.612±0.515. *M. cephalus* had a higher relative condition factor value, while *L. fulvus* had a higher Fulton condition factor value than other fish species.

Discussion

In this study, LWR estimates (mainly for growth patterns) for eight fish species from Youtefa Bay were determined, where the *b* value obtained ranged from 2.6919 to 3.0791. Although it does not meet the minimum number of specimens for each fish species (100 fish specimens) (Froese, 2006; Froese et al., 2011), the estimated *b* value for the LWR of the eight fish species studied were considered valid because it was within the specified standard range of 2.50 to 3.50 (Froese, 2006) or 2.0 to 4.0 (Tesch, 1971). The results of this study indicate that the growth patterns of all fish species are allometric, in which six species (*L. fulvus*, *P. barberinus*, *S. canaliculatus*, *P. quadrilineatus*, *M. cephalus*, and *H. far*) are allometric negative (the increase in fish length was more dominant than the increase in fish weight) and two species (*G. oyena* and *S. spinus*) were allometric positive (weight gain was more dominant than the increase in fish length). In negative allometric growth, the fish will become thinner as the fish length increases. Conversely, fish growth conditions will be optimal if the fish growth pattern is positive allometric (Ricker & Carter, 1958).

The results of previous studies that have been summarized in the FishBase database (fishbase.se) reported variable *b* values indicating different growth patterns for *L. fulvus* (2.928–3.120), *P. barberinus* (2,803–3,195), *S canaliculatus* (2.460–3.169), *P. quadrilineatus* (2.958–3.108), *M. cephalus* (1.740–3.580), *H. far* (1.831–3.576), *G. oyena* (2.960–3.337), and *S. spinus* (2,870–3,122) (Froese & Pauly, 2020). Various studies report that differences in growth patterns for the same fish species (difference in *b* values) are strongly influenced by biological and ecological factors, such as differences in geographic location, food availability, sex, population density, environment or habitat, season, disease, and species phenotype (Schneider et al., 2000; Muchlisin et al., 2010; De Giosa et al., 2014; Hossain et al., 2015; Jisr et al., 2018; Sunarni et al., 2019; Santos et al., 2020). Differences in the number and length range of fish specimens, as well as sampling procedures also affect differences in *b* value (Froese, 2006). Various factors that influence the growth patterns of fish are discussed above, but none of these factors were considered in this study.

Figure 2. The length-weight relationship of eight fish species: (a) *L. fulvus,* (b) *G. oyena,* (c) *P. barberinus*, (d) *S. spinus,* (e) *M. cephalus,* (f) *S. canaliculatus*, (g) *H. far*, and (h) *P. quadrilineatus*.

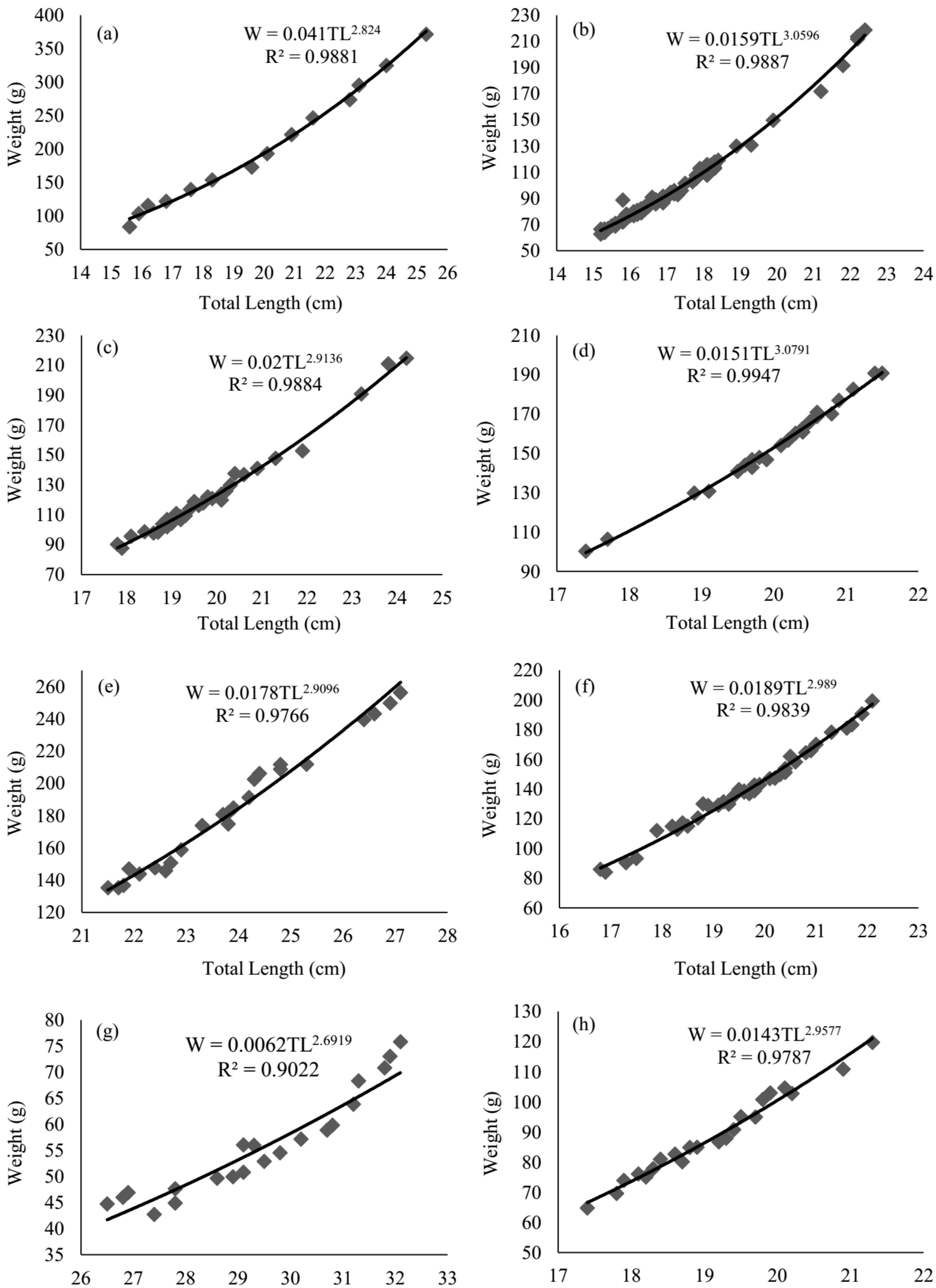

Table 1. The length and weight of eight species of fish caught by Papuan fishermen in Youtefa Bay, Indonesia

Species	n	Total length (cm)		Weight (g)	
		Range	Mean ± SD	Range	Mean ± SD
L. fulvus	14	15.6–25.3	19.84±3.21	83.87–371.64	201.42±89.76
G. oyena	71	15.2–22.4	17.36±1.79	62.85–218.85	101.85±36.55
P. barberinus	32	17.8–24.2	19.90±1.57	87.62–214.72	123.77±31.28
S. spinus	23	17.4–21.5	20.01±1.02	100.28–190.77	154.24±23.30
S. canaliculatus	38	16.8–22.1	19.60±1.36	84.11–199.27	139.76±28.25
P. quadrilineatus	22	17.4–21.3	19.22±1.01	64.72–119.72	88.52±14.08
M. cephalus	24	21.5–27.1	23.87±1.69	135.25–256.13	184.01±38.37
H. far	21	26.5–32.1	29.41±1.76	42.72–75.82	55.73±9.83

Table 2. Summary of statistical analysis of fish growth patterns using *t*-Student's test (A^+ = positive allometric; A^- = negative allometric)

Species	*b*	*t*-test	*t*-tab	Growth patterns
L. fulvus	2.8240	1.9695	2.1788	A^-
G. oyena	3.0596	1.5099	1.9949	A^+
P. barberinus	2.9136	1.4978	2.0423	A^-
S. spinus	3.0791	1.6178	2.0796	A^+
S. canaliculatus	2.9890	0.1725	2.0281	A^-
P. quadrilineatus	2.9577	0.4341	2.0860	A^-
M. cephalus	2.9096	0.9409	2.0739	A^-
H. far	2.6919	1.5157	2.0930	A^-

Table 3. Condition factors (K_R and K_F) of eight fish species in Youtefa Bay, Indonesia

Species	K_R		K_F	
	Range	Mean ± SD	Range	Mean ± SD
L. fulvus	0.874–1.085	1.002±0.049	2.209–2.726	2.434±0.141
G. oyena	0.946–1.201	0.998±0.033	1.786–2.252	1.882±0.064
P. barberinus	0.949–1.051	0.999±0.024	1.454–1.619	1.544±0.038
S. spinus	0.974–1.018	0.999±0.012	1.863–1.954	1.911±0.024
S. canaliculatus	0.951–1.069	1.001±0.027	1.741–1.956	1.830±0.049
P. quadrilineatus	0.966–1.037	0.997±0.023	1.214–1.307	1.259±0.029
M. cephalus	0.951–1.076	1.011±0.032	1.263–1.418	1.336±0.043
H. far	0.929–1.077	0.994±0.053	0.204–0.241	0.218±0.013

Condition factors for various fish species, including Fulton's condition factors and relative condition factors, can be used to determine the condition and health of certain fish species, and can also be used as a growth and feeding index (Fagade, 1979; Oni et al., 1983). In this study, the value of the condition factor varied between individuals in the same fish species. This indicates that the conditions and growth rates, including the feeding ability of each fish, are different even within the same fish species. According to Le Cren (1951), the deviation of the relative condition factor value from 1 can provide information about differences in food availability for each fish species. The relative condition factor values for *M. cephalus*, *L. fulvus*, and *S. canaliculatus* were higher than 1 which indicates abundant food availability for the three species. If the fish get enough food, it can cause the growth of these fish to be optimal (Jisr et al., 2018). On the other hand, the Fulton condition factor can be used as a comparison of the health status of various fish species in the same habitat because the calculation does not require *a* and *b* values. In general, larger fish individuals tend to be in a healthier physiological state. Various factors can affect the condition and growth of fish, including feed availability, reproductive cycle, and habitat or environmental factors (biotic and abiotic factors) (Morato et al., 2001; Anene, 2005), as well as the influence of variations in water temperature (De Giosa et al., 2014; Jisr et al., 2018).

Based on the TL size of fish obtained in this study, the fish caught by traditional Papuan fishermen are dominated by small fish. Policies from the local government or area managers are needed to ensure the availability and utilization of fish resources in Youtefa Bay. A policy regarding the minimum size of fish caught is very necessary because it can provide opportunities for small fish to breed into adults, so as to ensure the availability of sustainable fish stocks. This policy can also be supported by regulations to increase the mesh size so that small fish are not caught. In addition, continuous LWR studies (especially seasonal LWR) are needed to estimate the spawning season of fish in Youtefa Bay. Fish spawning season information is very important to determine the fishing season which is closely related to fish size, fish stock, and fish condition. Also, to avoid catching fish when the fish are about to spawn so as to give the fish an opportunity to regenerate.

Conclusion

This study has provided the first information on LWR and the condition factors of the eight economically important fish species targeted by Papuan fishermen in Youtefa Bay, Jayapura Province, Indonesia. The results showed a negative allometric growth pattern for *L. fulvus*, *P. barberinus*, *S. canaliculatus*, *P. quadrilineatus*, *M. cephalus*, and *H. far*, while the rest were allometric positive (*G. oyena* and *S. spinus*). However, we hope that the results of this study can be used as information and supporting data for local governments to formulate policies for planning for sustainable fisheries resource management in the study location and its surroundings, such as the policy on the minimum size of fish that may be caught and the prohibition on fishing for certain fish in their spawning season.

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