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Length-weight relationship and condition factor of bullet tuna (*Auxis rochei* Risso, 1810) in the waters of Mamuju District, West Sulawesi Province, Indonesia

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Abstract. *Nur M, Tenriware, Nasyrah AFA. 2023. Length-weight relationship and condition factor of bullet tuna* (Auxis rochei *Risso, 1810*) *in the waters of Mamuju District, West Sulawesi Province, Indonesia. Biodiversitas 24: 5253-5259.* Bullet tuna (*Auxis rochei* Risso, 1810) is a fish species with a wide distribution and high socioeconomic value. Furthermore, it serves as a primary catch for fishermen, offering a crucial protein source to the community and generating employment opportunities in various sectors, including fresh fish sales, fish freezing, drying, and smoking industries. To maintain the sustainability of bullet tuna, it is necessary to know basic information regarding the study of length-weight relationship and condition factors because it is related to the fish growth and condition of fish in their habitats. Therefore, this study aimed to determine the growth pattern of bullet tuna, fundamental data for sustainable management efforts. The investigation was conducted from May to August 2023, and the sample fish were collected at the Fish Landing Port (PPI) Kasiwa, Mamuju District, West Sulawesi Province. Analysis was conducted in the Fisheries Department Laboratory, Sulawesi Barat University. The study procedures involved determining the total length and weight of the fish using a measuring instrument and digital scale, respectively, with accuracies of 0.1 mm and 0.01 g. Based on the data collected, 302 samples were obtained, consisting of 187 males and 115 females. The results showed that the relationship between the length and weight of bullet tuna yielded the equations of $W = 0.027L^{3.4783}$ for male fish, $W = 0.0052L^{3.2732}$ for female fish, and $W = 0.0033L^{3.4141}$ when combined. A t-test was conducted on the coefficient b, showing a calculated t-value greater than the tabulated values. It indicated that bullet tuna belongs to the negative allometric growth type (minor) ($b<3$), where body weight increased faster than body length. Condition factors for male and female fish ranged from 0.3186 to 1.6961 and 0.6990 to 1.5011, respectively, with averages of 0.9957 and 0.7997. It indicates that the bullet tuna fish are in good condition in Mamuju District water.

Keywords: Bullet tuna, growth pattern, Makassar Strait, management, West Sulawesi

Abbreviations: LWR: Length-Weight Relationship

INTRODUCTION

Bullet tuna, classified in the Scombridae family, is an epipelagic fish discovered in worldwide distribution, particularly in tropical waters (Sandoval-Ramírez et al. 2020; Mardlijah et al. 2021). Furthermore, it is a major target during fishing activities (Ollé-Vilanova et al. 2022) and holds high economic value due to its nutritional content. This fish is considered a commodity for export to various countries such as the United States, Japan, Thailand, Italy and Saudi Arabia (Baliwati and Putri 2012) because it possesses high protein content, essential amino acids, unsaturated fats crucial for nutritional needs, growth enhancement, cognitive benefits, cholesterol reduction, and various health advantages (Nepomuceno et al. 2020; Rampazzo et al. 2020; Wibowo et al. 2020; Artetxe-Arrate et al. 2021; Husain et al. 2021; Bintoro et al. 2023).

Bullet tuna has a pivotal value as the market demand for this fish is high. In West Sulawesi Province, bullet tuna holds significant socioeconomic value, serving as the primary catch for fishermen, a protein source for communities, and a source of employment in the fresh fish sales, freezing, drying, and smoking industries. Moreover, to supply the local consumption needs of the community, most catches of the bullet tuna in West Sulawesi are also transported to support the community's fish needs in neighboring provinces such as South Kalimantan, Central Sulawesi and South Sulawesi. Specifically in South Sulawesi, bullet tuna originating from West Sulawesi is the primary raw material for processing bullet tuna products such as freezing, canning and other preparations, then exporting them to various countries.

The bullet tuna is one of many species managed by the Indian Ocean Tuna Commission (Asrial et al. 2021). The exact global catch specifically for bullet tuna is not yet known, but the data in 2020 showed that the potential fish catch from Scombridae groups such as albacore, bigeye, bluefin, yellowfin, skipjack and bullet tuna in the world reached 5.3 million tonnes (ISSF 2021). In the same year, Indonesia specifically produced bullet tuna, with production reaching 20907 tons in 2020 and the transaction value reached IDR 457.34 billion (BPS 2021). Presently, a

pressing concern is its overexploitation in the waters of West Sulawesi. This is evidenced by decreased catch production, reduced fish size, and a shift in capture locations. Production data from 2014 to 2021 showed a drastic decreasing trend in Catch Per Unit Effort (CPUE), with the peak in 2015 at 11505 tons per year, declining to 5723 tons in 2021 (48% decrease) (Marine and Fisheries Office 2022). Studies conducted in 2016 showed that bullet tuna mainly fell within the 21-22 cm size range (Dahlan et al. 2019). However, in 2018, it reduced to young individuals within the 11-12 cm size range, which had not yet matured regarding gonad development (Kantun et al. 2018). There are indications of population decline; hence, population-based management efforts are needed. The relationship between length and weight, as well as condition factors, are the basis for population management (Moslen and Miebaka 2017). To address these concerns, investigations on various biological aspects, such as growth, should be carried out to gather essential information necessary for effective management and future sustainability (Oyebola et al. 2022).

Fish growth is commonly understood by examining the relationship between length and weight, which are variables used to determine population development (Srithongthum et al. 2020). Estimating fish growth is one indicator to determine the sustainability of fish resources (Rahmatullah et al. 2022). Among various tools and methods in fisheries management, the length-weight relationship is an essential and frequently reported tool (Mahmood et al. 2012; Ndiaye et al. 2015; Seiyaboh et al. 2016). Furthermore, it serves two purposes: establish a mathematical relationship between dependent and independent variables and determine whether the growth type isometric or allometric (Shukla and Mishra 2017). Another biometric index used to assess fish status in their environment is the condition factor, a standard method to evaluate the overall species (Lim et al. 2013; Kumar et al. 2014; Seiyaboh et al. 2016) and to know the growth ideal of fish (Latuconsina et al. 2022). Based on the calculated length-weight relationship, the relative condition factor can be computed to determine when the observed and expected condition of the fish aligns (Srithongthum et al. 2020) and the food reserves change (Datta et al. 2013). This research is pivotal for bioecological studies (Paujiah et al. 2023).

Knowledge about the Length-Weight Relationship (LWR) for most tropical fish species remains limited (Baitha et al. 2018). Specifically, an investigation on the length-weight relationship of bullet tuna has not been conducted in West Sulawesi. This is because previous studies have been limited to species and size composition (Kantun et al. 2018), as well as size structure (Dahlan et al. 2019) and biological aspects such as size distribution and stomach content (Kantun et al. 2019). From this information, the primary data about the biology of bullet tuna, particularly in West Sulawesi, is limited. Therefore, this study aimed to examine the length-weight relationship for growth pattern and condition factor of bullet tuna in the waters of Mamuju, West Sulawesi, to provide fundamental data for implementing sustainable fisheries management.

MATERIALS AND METHODS

The study was conducted from June to August 2023. Sample fish were collected from the Fish Landing Port (PPI) in Kasiwa, Mamuju District, West Sulawesi Province, Indonesia (Figure 1), a fishing base for bullet tuna fishermen, using the purse seine method.

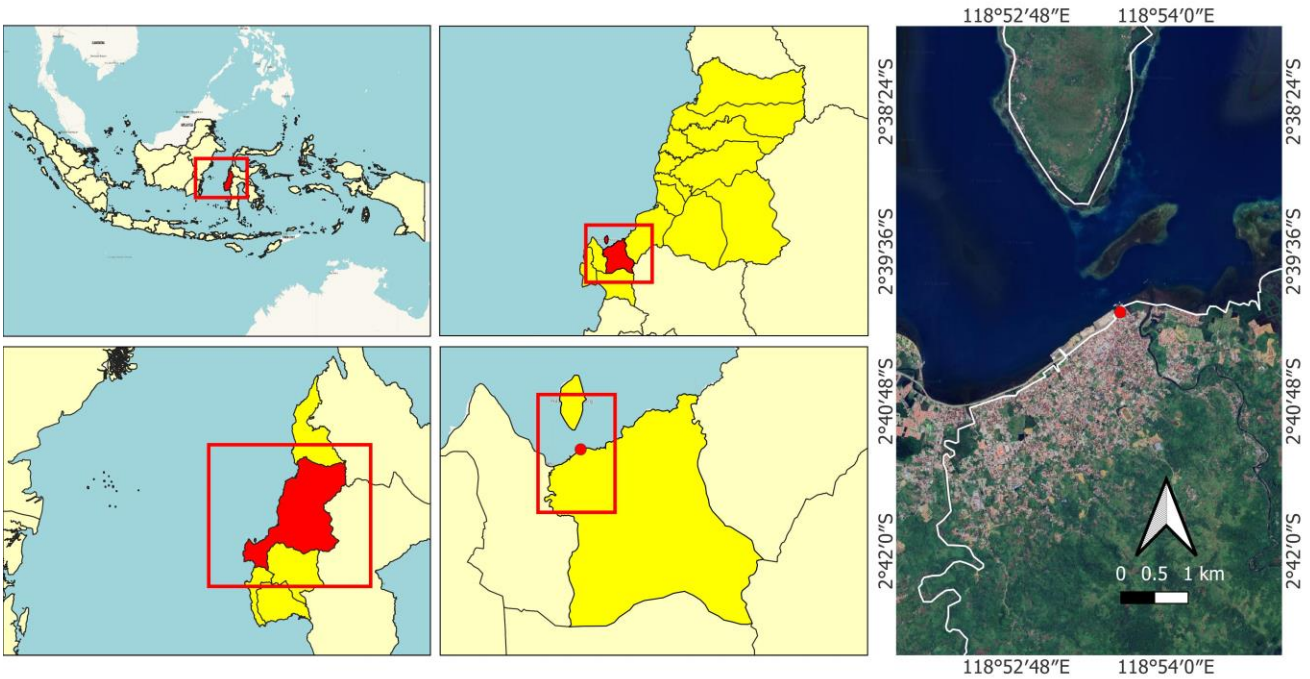

Figure 1. Sampling location of Mamuju waters, West Sulawesi, Indonesia

A purse seine is the dominant fishing gear for catching the bullet tuna. Based on the interview result with bullet tuna fisherman in Fish Landing Port Kasiwa Mamuju District, the fishing ground of bullet tuna is still in Makassar Strait, a distance of 12-40 miles from Mamuju District to the southwest of Majene District. Fishing vessels with purse seine have a habit of catching fish within 2 weeks to 1 month at the fishing ground with a set number of times by day, while the catch obtained is transferred to mining/transport in land port Kasiwa every one to two days depending on the catch obtained. Furthermore, regarding the fishing ground of bullet tuna, according to Yani and Susaniati (2018) the location analysis of fishing base bullet tuna in Mamuju waters is very closely related to sea surface temperature and chlorophyll-a concentration. The temperature in the fishing base of bullet tuna ranges between 28.69-30.31 with an average of 29.84°C and the chlorophyll-a concentration ranges between 0.13-0.50 mg/m^3 with an average of 0.19 mg/m^3 (Yani and Susaniati 2018).

The fish are taken randomly, representing the size of the fish caught. The fish were placed in a cold box with ice and transported to the Integrated Fisheries Laboratory of the Department of Fisheries, West Sulawesi University, Indonesia, for analysis. The sampled fish were cleaned, placed on a preparation board, labeled with sequential numbers, and subjected to measurements. Total length and fish weight were measured using a digital caliper and scale, respectively, with 0.01 mm and 0.01 g precisions. The measurement of total length was taken by measuring from the leading of the head of the fish to the rear of the end caudal fin of the fish. The specimens were dissected, and the sex was determined morphologically by macroscopic examination of the gonad.

The following presents the data analysis in this study:

To determine growth type, the length-weight relationship was analyzed using the formula established by (Le Cren 1951):

$$W = aL^b$$

Where:
W : Fish body weight (g)
L : Total length of the fish (mm)
a : Intercept
b : Slope (gradient)

The value of b indicated whether growth is isometric or allometric. Isometric growth occurs when b = 3, while negative and positive allometric growth was exhibited with b<3 and b>3, respectively. A t-test was performed to determine when b = 3 or b ≠ 3. The isometric is the growth balance between the length and weight of fish, while allometric is unbalanced growth between length and weight (one of the dominant parameters). Allometrics can be positive and negative. A positive allometric can be found if the value b>3 (it means the weight gain is more dominant than the length gain), and a negative allometric is obtained if the value b<3 (it means the length gain is more dominant than the weight gain).

The condition factor was calculated based on the growth pattern.

An isometric growth uses the following formula (Effendie 2002):

$$K = \frac{10^5 W}{L^3}$$

An allometric growth was calculated using the following:

$$K = \frac{W}{aL^b}$$

Where:
K : Condition factor
W : Fish weight (g)
L : Total length of the fish (mm)
a and b: Constants obtained from regression

RESULTS AND DISCUSSION

The bullet tuna, known as bullet tuna lisong, is a type of fish that is predominantly caught by fishermen in Mamuju, West Sulawesi. Some of the morphometric and meristic characters of bullet tuna are the total length range (cm) ranging from 15-25.02 cm in male fish, 15.9-29.9 cm in female fish, dorsal spines 9-12; Dorsal soft rays 10-13; Anal soft rays: 12-14. Back bluish, turning to deep purple or almost black on the head. Scaleless area with a pattern of 15 or more fairly broad, nearly vertical dark bars. Belly white. Pectoral and pelvic fins are purple, their inner sides black. Body robust, elongated and rounded. The morphology of bullet tuna can be seen in Figure 2.

The length-weight relationship was crucial in assessing fish resources, providing insights into growth patterns. Length-weight relationships are useful in stock assessment models, estimating biomass from length measurements, and comparing fish conditions between regions (Herath 2019). Length was the easiest to measure among the two variables and can be converted into weight (Mariyasingarayan et al. 2018). Based on observations, 302 sample fish were collected, comprising 187 males and 115 females. The results of the length-weight relationship analysis for bullet tuna in Mamuju waters of West Sulawesi are presented in Table 1.

Figure 2. Specimen of bullet tuna (*Auxis rochei* Risso, 1810)

Based on Table 1, the equations of the length-weight relationship obtained in this study for bullet tuna were $W = 0.027L^{3.4783}$, $W = 0.0052L^{3.2732}$, and $W = 0.0033L^{3.4141}$ for male, female, and combined genders, respectively. Furthermore, the t-test results for the obtained b values for male (3.4783), female (3.2732), and combined gender (3.4141) showed that the calculated t-value was more significant than the tabulated t-value. It indicated that bullet tuna in the waters of Mamuju belongs to the category of positive allometric growth (minor) (b<3), where body weight increased faster than length.

This positive allometric growth pattern was attributed to adaptation to conditions in those waters, such as environmental factors, exploitation rates, and food availability. According to Effendie (2002), the growth of fish species was influenced by internal (genetics, gender, disease, hormones, and feeding ability) and external factors (food availability, competition for resources, and water temperature).

Factors affecting fish growth patterns include temperature, salinity, food supply, genetics, gender, age, and density (Faghani-Langroudi et al. 2014; Fatma et al. 2022; Nur et al. 2022). Gonad maturation, seasonal variations, and fishing activities in an area can also influence different b values. These factors impact the growth of fish populations, specifically in areas characterized by intensive fishing activity (Ya et al. 2015).

The length-weight relationship of fish was expressed in a formula where Weight (W) and Length (L) were dependent and independent variables, respectively. This relationship can be applied to studies related to gonad development, feeding rate, and maturity condition (Jisr et al. 2018). However, it varies among fish species depending on the inherited body shape and physiological factors such as maturity and spawning (Schneider et al. 2000). The length-weight relationship of bullet tuna over different sampling periods is presented in Figure 3.

As indicated in Figure 1, the length-weight relationship of bullet tuna showed varying b values across different sampling periods. In May, June, July, and August, b = 3.1936, 3.2608, 3.3196, and 3.1800, respectively. The t-test results for the obtained values also show that $t_{count} > t_{table}$. It is indicated that bullet tuna in all months exhibit a positive allometric growth pattern (minor) (b>3), where body weight increases faster than body length.

As illustrated in Figure 1, the length-weight relationship of bullet tuna reveals varying b values across different sampling periods. In May, b = 3.1936; June, b = 3.2608; July, b = 3.3196; and August, b = 3.1800. Furthermore, t-test results for these b values consistently indicate that $t_{count} > t_{table}$. Bullet tuna in all months exhibit a positive allometric growth pattern (minor), where b>3, signifying that body weight increases faster than body length.

Many factors influence the value of b throughout the life of a fish (Ya et al. 2015). The shift in the growth pattern of bullet tuna was related to the monthly change in environmental conditions. It aligns with the study of (De Giosa et al. 2014) that the length-weight relationship of fish varied with seasons or even fluctuated daily. Flura et al. (2015) stated that b changes with periods due to stomach fullness, general feeding habits, and the gonadal development stage. (Nugroho et al. 2016) stated that the different growth patterns are due to environmental factors and fishing pressures' exploitation. Additionally, polluted and unpolluted environments can influence fish's various aspects (Ya et al. 2015).

The pattern of positive allometric growth has also been discovered in bullet tuna of Bone Bay (Wahana et al. 2021), in the Makassar Strait (Kantun et al. 2019), and in Parangipettai, Southeast Coast of India (Mariyasingarayan et al. 2018). Meanwhile, isometric and negative allometric growth was observed in Tunisian waters (Allaya et al. 2013), the eastern region of the Sri Lanka coastal waters (Herath 2019), Kedongan waters (Rahmatullah et al. 2022), Bali Strait (Bintoro et al. 2023) and in the waters of Prigi, Trenggalek, West Java, respectively (Lelono et al. 2023). Differences in patterns exist not only among species but within the same species due to factors like gender, maturity, seasons, and even the time of day, often linked to variations in stomach fullness. (Froese 2006) explained that the parameters of the length-weight relationship in fish can be influenced by environmental conditions, gonadal maturity, gender, condition factor, season, population, and species variations. Furthermore, Ya et al. (2015) found that the different results for the growth pattern in the genus and fish species are affected by fishing season, habitat, distribution, and area where fish search for food.

Table 1. Length-weight relationship of bullet tuna in the waters of Mamuju, West Sulawesi Province

Parameter	Male	Female	Combination
Number of sample fish (head)	187	115	302
Total length range (cm)	15-25.02	15.90-29.90	15-29.90
Mean ± SD	22.16±3.16	23.05±3.12	22.5±3.17
Body weight range (g)	25.02-376	38-378	25.02-378
Mean ± SD	139.61±68.22	159.99±69.42	147.37±69.28
Log a	-2.574	-2.2865	-2.4845
A	0.0027	0.0052	0.0033
Regression coefficient (b)	3.4783	3.2732	3.4141
Correlation coefficient (r)	0.9616	0.9603	0.9326
Regression equation	$W=0.027L^{3.4783}$	$W=0.0052L^{3.2732}$	$W=0.0033L^{3.4141}$
t-test	$t_{count} > t_{table}$	$t_{count} > t_{table}$	$t_{count} > t_{table}$
Growth type	Positive allometric	Positive allometric	Positive allometric

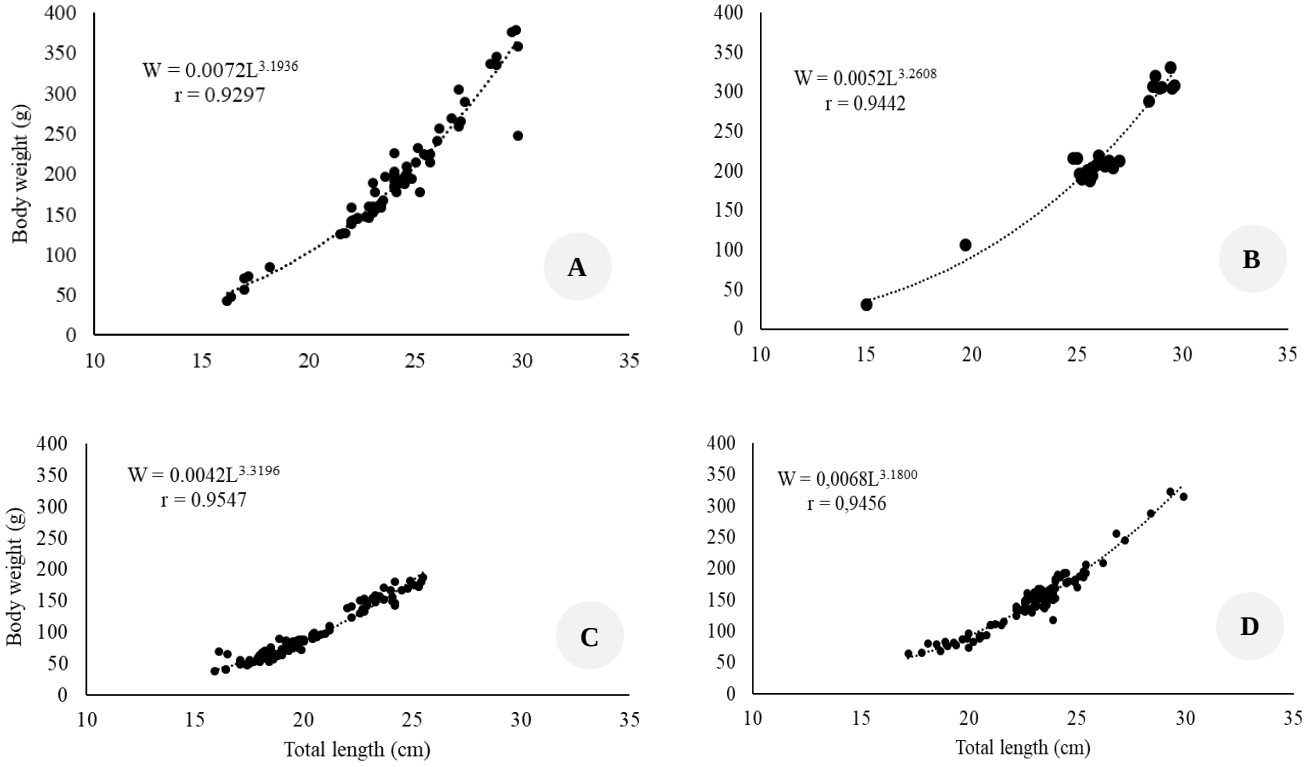

Figure 3. Length-weight relationship of bullet tuna over different sampling periods in Mamuju, West Sulawesi waters. Labels: A. May, B. June, C. July, D. August

Referring to Figure 1, bullet tuna in the waters of Mamuju, West Sulawesi Province, have correlation values of r = 0.9616, r = 0.9603, and r = 0.9326 for males, females, and the combined genders, respectively. These values indicated that the relationship between the fish's total length and body weight was very strong (correlation scale 0-1). It is consistent with (Dahlan et al. 2018; Dahlan et al. 2019) that values ranging from 0.70 to 0.89 and 0.90 to 1.00 imply a strong and very strong correlation. Based on the strength of this relationship, total length significantly influences the body weight of bullet tuna. Generally, length and body weight for fish are directly proportional.

Condition factor or ponderal index indicates the state of the fish, both in terms of physical capacity and survival and reproduction aspects. During growth, as weight was gained, length increased, and the linear relationship remained constant (Effendie 2002). Determining condition factors is done to detect changes that occur suddenly in water that affect the condition of fish. If the condition factor is not good, it can be indicated that the population is too dense, or vice versa if the condition is good. It allows for a population reduction, thereby causing an increase in food availability. The fish's condition factor measures all variations related to food supply, sexual maturity, and the overall condition in the environment (Gomez 2020).

Based on observations and data analysis, the observed condition factor values for male and female bullet tuna ranged from 0.3186 to 1.6961 and 0.6990 to 1.5011, respectively, with average values of 0.9957 and 0.7997. It is shown that the range of these values for female fish was higher than for males. The condition was attributed to the smaller size of male fish and the dominance of immature gonads. Additionally, it suggests an increase in fat deposition due to higher adaptation ability and feeding activity in males. An increase in the value of the condition factor in female bullet tuna is indicated by an increase in the length of the fish and the body weight. In the lowest range of tuna, namely 40-50 mm, condition factor values obtained ranged from 0.5308-1.7901 with an average of 1.1453, and in the highest range of tuna, 100-110 mm, condition factor value obtained ranged from 0.7913-1.1853 with an average 1.5431. The same result was also conveyed by Faghani-Langroudi et al. (2014) that the condition factor will peak when the fish are young and decrease again when they are old; in females, the factor condition tends to increase with an increase in the total length of the fish, including the average length and also the gonad of fish. This is confirmed by some studies based on the gonad maturity of bullet tuna that this fish spawns in June to August (Ardelia et al. 2016) and the peak of spawning in August (Dahlan et al. 2019).

Furthermore, the condition factor based on the time of catching shows fluctuations every month. In May, the condition factor values were obtained from 0.82-1.23 with an average of 1.02; then, in June, the condition factor values were obtained from 0.87-1.24 with an average of

1.01; in July, the factor values were condition 0.81-1.63 with an average of 1.11, and finally in August the condition factor value was 0.81-1.63 with an average of 1.13. Several factors that are thought to cause fluctuations and variations in the value of the fish condition factor are differences in fish size. During the spawning season, fish do not engage in feeding activities but use fat reserves in their bodies for energy supply and parasite pressure (Datta et al. 2013). Effendie (2002) stated that the condition factor of fish tends to be influenced by size, food availability, timing, and body weight. An increase in the condition factor of a fish can occur during gonadal development and peak during spawning. They were related to the influence of food availability on condition factors. When the amount of food decreases, fish will use their fat reserves as an energy source during gonad maturation and spawning so that the condition of the fish decreases (Srithongthum et al. 2020).

In conclusion, the current findings present data of bullet tuna was categorized under the pattern of positive allometric growth, where body weight increased faster than body length. Furthermore, the condition factor of male fish was higher than in females. The suggestion for this research is to carry out further research related to other biological aspects and over a longer period of time.

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