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Research Article

Growth and Mortality Models of Mozambique Tilapia (*Oreochromis mossambicus*; Peters, 1852) Wildly Enter Inside the Fish Farming Ponds in Tarakan City, North Kalimantan

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Abstract

Exploring the length-weight relationship of fish and characterising growth parameters is essential in fisheries as they offer fundamental biology and population dynamics data to establish good management strategies for fisheries resources. This study examines the growth and mortality patterns of *Oreochromis mossambicus.* Data was collected between September and December 2022 using quantitative descriptive survey sampling. The study involved 20 repeats and deliberate random sampling of 30-50 fish per sample, emphasising total length, weight, and sex parameters. Based on 726 samples of *O. mossambicus* (352 fish identified as male and 374 fish identified as female). The growth model study revealed the typical negative allometric growth for both sexes (male and female). Male individuals attained a length of 33.449 cm after 37 days has a growth trend ± 0.3265 year^{-1}, and females reached 21.150 cm in 34 days with a growth rate around 0.3135 year^{-1}, as per the von Bertalanffy growth model. There were complex mortality patterns, with males contributing to most total deaths. This study emphasizes the complex biology of tilapia and its untapped potential in the aquaculture pond system ecology in Tarakan.

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1. Introduction

Tarakan City is located at 3° 4' 23'' - 3° 26' 37'' North Latitude and 117° 30' 50''- 117° 40' 12'' East Longitude, with an area of 657.33 km^2, consists of 250.80 km^2 of land and 406.53 km^2 of ocean, divided into four sub-district administrative areas (Situmorang and Sulaiman, 2023). Furthermore, Tarakan City is a coastal (Rozaki *et al.*, 2023) ecosystem region consisting of the sea and river estuaries (Salim *et al.*, 2021), which boasts a diversity of aquatic biota. Marine biological resources in Tarakan City include seaweed (Azis *et al.*, 2022), Bivalves (Duisan *et al.*, 2021), Crabs (Salim *et al.*, 2018; Indarjo *et al.*, 2020a), Lobsters (Indarjo *et al.*, 2023a; 2023b), Ribbon fish (Indarjo *et al.*, 2020c), *Periophthalmus barbarus* (Indarjo *et al.*, 2020b), *Harpiosquilla raphidea* shrimp (Salim *et al.*, 2020), *Penaeus monodon* (Salim *et al.*, 2021), *Vannamei shrimp* (Setyaningrum *et al.*, 2023), Nomei fish (*Harpodon nehereus*) (Salim *et al.*, 2022; 2023a; 2023b), and *Mozambique tilapia*, that also known as Mujair (*Oreochromis mossambicus*, Peters, 1852) (Mikael, 2012).

Oreochromis mossambicus in Indonesia is easy to find, explained Mangitung *et al.* (2021) that *O. mossambicus*, as a common "Tilapia" has generally spread in mainland Indonesia, where the use is closely related to aquaculture activities. Likewise, in several other countries, such as Australia, Venezuela, and Brazil, this fish, as well as other alien species, have been studied to have severe impacts that harm the ecosystems, threatening the native biota and disrupting the trophic web (Rodriguez *et al.*, 2021; Sunarto *et al.*, 2022; O'mara *et al.*, 2023). However, in Indonesia and some other countries, this fish plays an important role as a trade commodity (Naim, 2010). This species is widely distributed in Indonesia, both in freshwater and estuaries (Muchlisin, 2012; Nastiti *et al.*, 2021). The Tilapia exists in Indonesian waters through stocking (Hendrawan *et al.*, 2021) and aquaculture activities (Herawati *et al.*, 2019). This fish also entered the traditional ponds during high tide (Harefa *et al.*, 2022) and was originally considered a nuisance in traditional fishponds (Padilla, 1985; Naim, 2010) establish social hierarchies and aggressively excavate and defend nests to control the area (Ashouri *et al.*, 2023). However, tilapia fish are still caught and consumed due to its economic value (Indarjo *et al.*, 2020d), providing income for the local community. This fish is a popular and affordable choice among consumers, known for its delicious taste. It is commonly available in traditional and modern markets (Suhadi *et al.*, 2020).

Tilapia sold in the fish market of Tarakan City are accidentally discovered in the pond. It is suspected the fry enters the pond through the inlet from the surrounding river. In most stock analysis models, such as in (Cardin *et al.*, 2023) certain assumptions made include (a) no movement of fish into or out of the stock area at any life stage, (b) vital rates (somatic growth, maturity, natural mortality (M), and selectivity fishing mortality (F)) are relatively homogeneous within the stock area, and (c) individual fish are extensively mixed throughout the stock area. Fish stock studies typically analyse various factors such as species and size composition, sex ratio distribution, growth rates (Robisalmi *et al.*, 2021), condition index, the von Bertalanffy model, and mortality rates over time (Indarjo *et al.*, 2023b), need to be analysed (Setyanto *et al.*, 2021). In this context, growth models and condition index (Duisan *et al.*, 2021) can be determined using length-weight relationships (LWR), which estimates biomass from length-weight observations, as well as stock assessment models based on body shape (condition index) (Yulianto *et al.*, 2020; Salim *et al.*, 2020, 2021, 2023b; Indarjo *et al.*, 2020a, 2020b, 2020c). The von Bertalanffy model (Pasisingi *et al.*, 2021) estimates the maximum growth of aquatic biota (Salim *et al.*, 2022; Indarjo *et al.*, 2023a). Furthermore, analysis of fish length-weight relationships (Asrial *et al.*, 2021a) and estimation of growth parameters are basic information for biology and population dynamics (Asrial *et al.*, 2021b) to determine appropriate utilization and management patterns of existing resources. Mortality data from the availability of fish stocks in nature are needed to support sustainable management (Hlungwani, 2023). Therefore, this study aims to analyse the relationship between the growth and mortality of wild Mozambique tilapia fish (*O. mossambicus*) in the pond waters of Tarakan City. The results are expected to project stock characteristics and assess future populations. An impact of the input of wild species on farmers is the reduction in the proportion of feed on fish in the pond.

2. Materials and Methods

2.1 Materials

The materials used in this study were tilapia fish (*O. mossambicus*), tissue, gloves, scissors/scalpel, block millimeter paper, analytical scales with an accuracy of 0.01 grams or 0.1 grams, and a ruler with an accuracy of 0.1 cm.

2.1.1. Ethical approval

This research was performed on the basis of ethical clearance approval number 035a/UN51.2/S.Ket/2023 by the ethics committee of the Faculty of Fisheries and Marine Sciences, University of Borneo Tarakan, Indonesia.

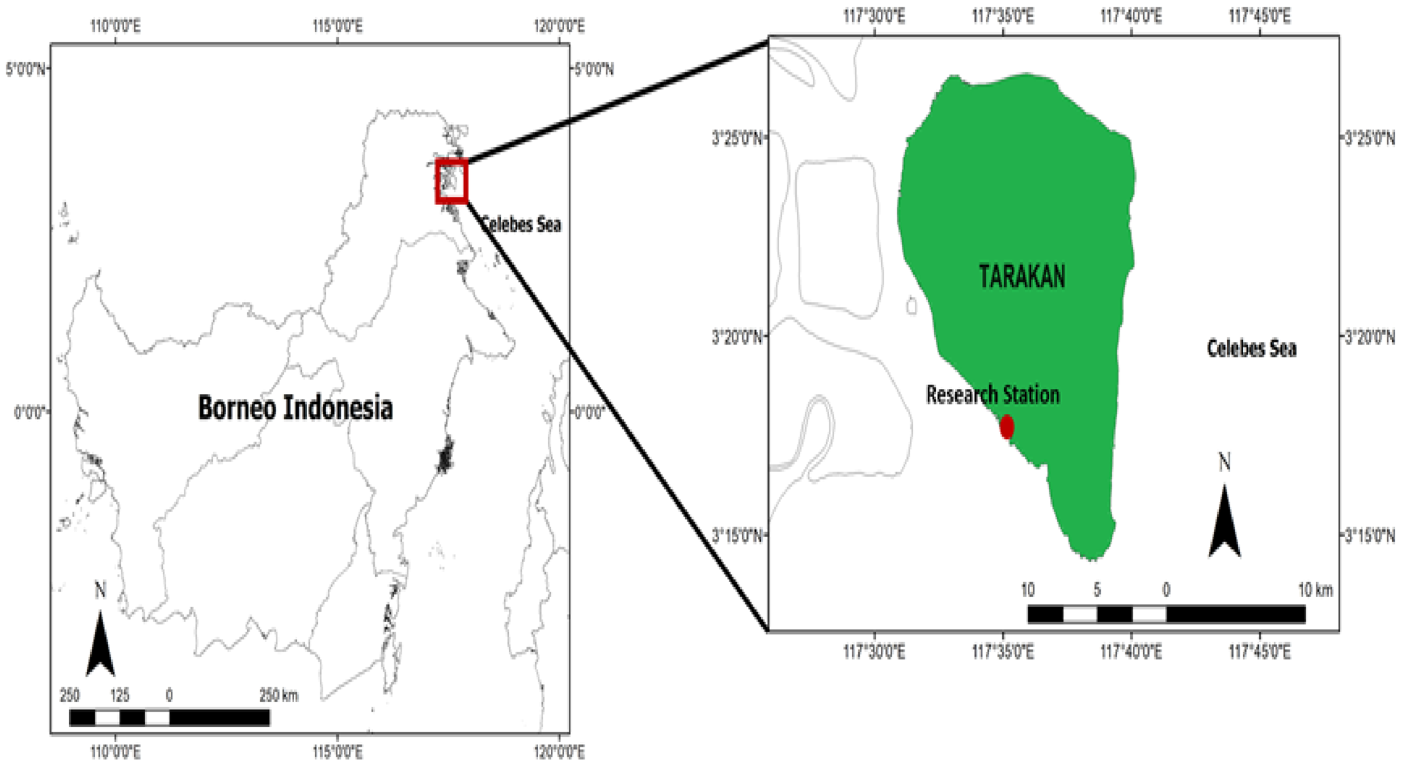


Figure 1. Map of research stations

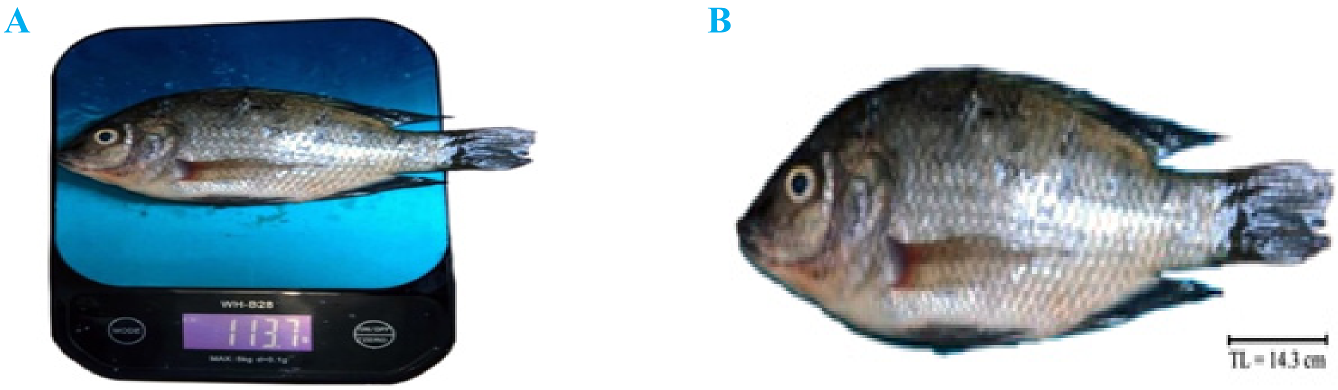


Figure 2. Measurement (a) weight of the samples of the (b) *O. mossambicus,* (Peters, 1852)

2.1.2. Study description

Samples of *O. mossambicus* were purchased from the Tarakan City fish market and delivered to the Beringin market, Tarakan City, as detailed in (Figure 1). According to personal interviews conducted with fishermen during sampling, the products sold at the market were fish that accidentally entered the pond. While *C. chanos* species were primarily cultivated by farmers, *O. mossambicus* entered the pond through the inlet from the surrounding estuarine waters (Indarjo *et al.,* 2020e). The sampling process was conducted 20 times over 4 months, from September to December 2022. The fish samples were selected in detail to ensure that the products sold were farm-raised. Finally, measurement and observation, as shown in (Figure 2) were conducted at the Laboratory of Fish Biology, Borneo University Tarakan, Indonesia.

2.1.3. Research data collection methods

The research conducted in testing total length and total weight used the Manual Of Fisheries Science Part 2 - Methods of Resource Investigation and their Application from Holden and Raitt (1974) and (Laevastu, 1965) regarding the Manual of methods in fisheries biology. The International Council for the Exploration of the Sea (ICES) and the International Commission for the North West Atlantic Fisheries (ICNAF) at a Sampling Meeting held in 1965 recommended that the length dimension to be measured for all species (except tunas and salmonids), for which length composition data are reported to the two commissions should be total length. The 1968 meeting of the Regional Fisheries Advisory Commission for the Southwest Atlantic (CARPAS) approved the same standard for use in the Southwest Atlantic, and the General Fisheries Council for the Mediterranean (GFCM) (1963) adopted total length dimension for sardine. There thus seems to be already substantial agreement that fork length should be measured for tuna and mackerel, and maximum total length for nearly all other species (Holden and Raitt, 1974). In the laboratory, length measurements were independently taken to the nearest millimeter in a straight line via meter board by experienced ichthyologists (Laevastu, 1965). All measurements were performed using the following procedure (Laevastu, 1965): TL = from the anterior tip of the longest jaw to the most posterior part of the caudal fin. Whichever length measurement is chosen the metric system is used for recording it (Laevastu, 1965).

It is important to establish length-weight relationships for all species because at some stage in the stock assessment, fish lengths must be converted to fish weights. It is important to have seasonal length-weight relationships for the whole. The only reliable transportable instruments are steel scales and small pocket spring balances in various ranges (e.g. 0.1 kg and 0–10 kg) (Holden and Raitt, 1974) or weighed to the nearest 0.01 g accuracy using an electronic balance (Simon and Mazlan, 2008).

Determination of the sex of male and female tilapia by looking at its morphological characteristics by determining the primary sexual characteristics which are sexual characteristics that are directly related to the reproduction process, in this case the reproductive organs and hormones that influence them. The reproductive organs that produce sex cells are called gonads. Sex determination is done by surgery by determining the characteristics of tilapia based on guide Effendie (1979).

2.2 Research method

The method adopted was descriptive quantitative, while sampling was conducted using the purposive random sampling. Primary data including sex, length, and weight, were collected through direct field surveys in the Beringin market, 3° 17’ 21.8” - 3° 27’ 94.8” North Latitude, 117° 35’ 05.5” - 117° 58’ 49.9” East Longitude, as presented in Figure 1. Based on personal interviews with fishermen, *O. mossambicus* species sold in the market were taken from the pond. It was strongly suspected that fish entered through the inlet from the river flow around the farming area.

2.3 Analysis data

Data analysis of *O. mossambicus* growth variables was conducted using an allometric growth model through the von Bertalanffy growth formula using Total Length (TL) and Weight (W) based on sexuality (male and female) (Salim *et al.*, 2022; Salim *et al.*, 2024a; 2024b; Indarjo *et al.*, 2023a; 2023b). The analytical approaches of total mortality, fishing mortality, natural mortality, and exploitation rate were used for data processing between variables at the mortality level. The analyses were based on the von Bertalanffy formula (Salim *et al.*, 2022; 2024a; 2024b; Indarjo *et al.*, 2023b).

2.3.1 O. mossambicus population

Analysis to determine the population of *O. mossambicus* fish species used the absolute growth formula approach through the equation of with the von Bertalanffy (Sparre and Venema, 1999) formula as follows:

$$L_t = L_\infty \ (1- e^{-k} (t- t_o) \qquad \text{................Eq 1}$$

Where L_t describes fish length (at age t in cm); L_∞ is the Asymptotic of average size (at infinite in cm); k is the Coefficient of growth rate (per year); to is the Estimation of the theoretical age of fish (at zero), and e is a constant value with a value of 2.71828.

2.3.2 Age structure

The analyses of the lifespan structure used an analysis method based on the mode class shift through the formulaic approach of the von Bertalanffy model Sparre and Venema (1999), as explained below:

$$\left(\frac{\Delta L}{\Delta t}\right) = \frac{(L_2 - L_1)}{(t_2 - t_1)} \text{ and } L_{(t)} = \frac{(L_2 + L_1)}{2} \qquad \text{.....Eq 2}$$

The symbol (ΔL/Δt) is Relative growth; ΔL is the fish length of *O. mossambicus*; Δt is the period of *O. mossambicus*; and L(t) is the average length of *O. mossambicus*. Continuing analysis by plotting the values of $L_{(t)}$ and (ΔL/Δt), a regression linear formula is obtained:

$y = a + b_x$ ....Eq 3

The analysis of the "a" value is generated from ((∑y/n) - (b (∑x/n))), while the "b" value is from the calculation of (n∑(xy) - (∑x) * (∑y)) / (n∑x2 - (∑x)2); "n" is the total samples; while "x" is the value of L(t); and "y" is the value of (ΔL/Δt). The average value of the length mode of the method was used to calculate the asymptotic length (L_∞) and the growth coefficient (K):

$K = - b$ ....Eq 4

$L_\infty = - a / b$ ....Eq 5

To determine the value of the theoretical age t_0 (the theoretical time at zero fish length) the Pauly (1984) model was used:

$\text{Log}(-t_0) = 0.3922 - 0.2752 \text{ Log } (L_\infty) - 1.0382 \text{ Log } k$...Eq 6

Where k = growth coefficient

Further analysis to determine the relative age based on fish length data used the approximation of the von Bertalanffy model. Its equation used refers to Gulland (1976); Gulland and Holt (1959):

$$-\ln\left(1-\frac{L_t}{L_\infty}\right) = -K_{(t_0)} + K_{(t)}$$ ....Eq 7

$$t = t_0 - \ln x\left(1-\frac{L_t}{L_\infty}\right)$$ ....Eq 8

2.3.3 Growth pattern

Length-weight correlation analysis was analysed to determine growth patterns (Achmad *et al.,* 2023). The analysis is done by entering length and weight data, which is then converted into logarithmic form. The analysis was processed using SPSS 24.0 software (Suyono, 2015) at the linear regression analysis level. Analysing the relationship between length and weight using the formula referred to in Effendie (1979):

Y=a x b ....Eq 9

$\text{Log}_Y = \text{Log}_a + b \text{ Log}_X$ ......Eq 10

$W = aL^b$ ......Eq 11

2.3.4 Condition factor

The Condition Factor ($K_{(TI)}$) analysis for knowing of an isometric growth determined through the approach of Effendie (1979) with the formula:

$K_{(TI)} = 10^5 \text{ x } W/L$ ....Eq 12

Where $K_{(TI)}$ is shown as the condition factor value, W is the Weight (gr) data, and L is the Length (cm) data. The formula's result will be taken so that $K_{(TI)}$ approaches "1". Regarding Weatherley (1972) to know the fish condition factor indicated by allometric growth (negative or positive), the following formula:

$K_n = W/\hat{W}$ ....Eq 13

Where the symbol description of the formula explains that K_n is the Condition factor; W is Weight (g) divided by Total Weight (g); Ŵ is Weight estimation (g) divided by Weight ideal estimate (g), and the value of Ŵ is derived from the regression equation of the Total Length-Total Weight. Criteria value of condition index referred to Indarjo *et al.* (2023a); Salim *et al.* (2023b) described some criteria as follows: (a) Value range from 0.1 to 1.51 for thin body shape, (b) Range from 0.1 to 0.49 for thin body shape, (c) Value range with value 1 is proportional body shape, (d) Value range from 1.01 to 1.50 for fat body shape, and (e) Value range >1.50 is fat body shape.

2.3.5 Natural mortality

The natural mortality (M) of *O. mossambicus* was analysed using formula based on Pauly (1984), as follows:

$\text{Log } M = 0{,}0066 - 0{,}279 \log L_\infty + 0{,}6543 \log K + 0{,}4634 \log T$ ....Eq 14

The total mortality (Z) was analysed followed by the Beverton and Holt formula (Sparre and Venema, 1999). The fishing mortality (F) of *O. mossambicus* was estimated according to the following equation:

$F = Z - M$ ....Eq 15

Note that F is the natural mortality rate in each symbol, Z is the total mortality value, and M is the natural mortality value found during data and information collection. Finally, the exploitation rate (E) of the *O. mossambicus* in sampling sites was estimated following Pauly (1984) as follows:

E= F/((F+M)) ....Eq 16

Where E is the level of exploitation of *O. mossambicus*, F is the value of mortalities due to fishing, and M is the value of natural mortality.

3. Results and Discussion

3.1 Results

In this study, a total of 726 *O. mossambicus*, consisting of 352 males and 374 females at a ratio of 1:1.0625, were measured. The total length of the male and female fish ranged from 13.2 to 28.9 cm and 13.5 to 20.10 cm, respectively, with the averages being 16.47 cm and 16.16 cm. Meanwhile, the total weight ranged from 20.5 to 195.7 and 40.5 to 160.3 grams for males and females, respectively, with averages of 88.9 and 89 grams. Figure 3 showed that both sexes were dominated by sizes between 15 to 16 cm.

In fisheries biology, the length-weight relationship was significant information to evaluate the resource condition, specifically in selecting fishing gear. These correlations also provided the isometric of the species' growth at a particular population level. According to Figure 2, "b" values from length and weight analysed for male and female species were 1.8622 and 1.7687, respectively. This signified a negative allometric pattern of growth. Length-weight relationship for 352 male specimens led to 'a' of -0.3281 and 'b' of 1.8622, with a correlation value of 70.6%, as detailed in Figure 4.

Using a regression equation, Figure 4 provides the length-weight relationship showed by the total length logarithm (x-axis) and the total weight (y-axis), found in regression lines for male and female fish, with values of y = 1.8622x-0.3281 (r = 70.6%) and y =

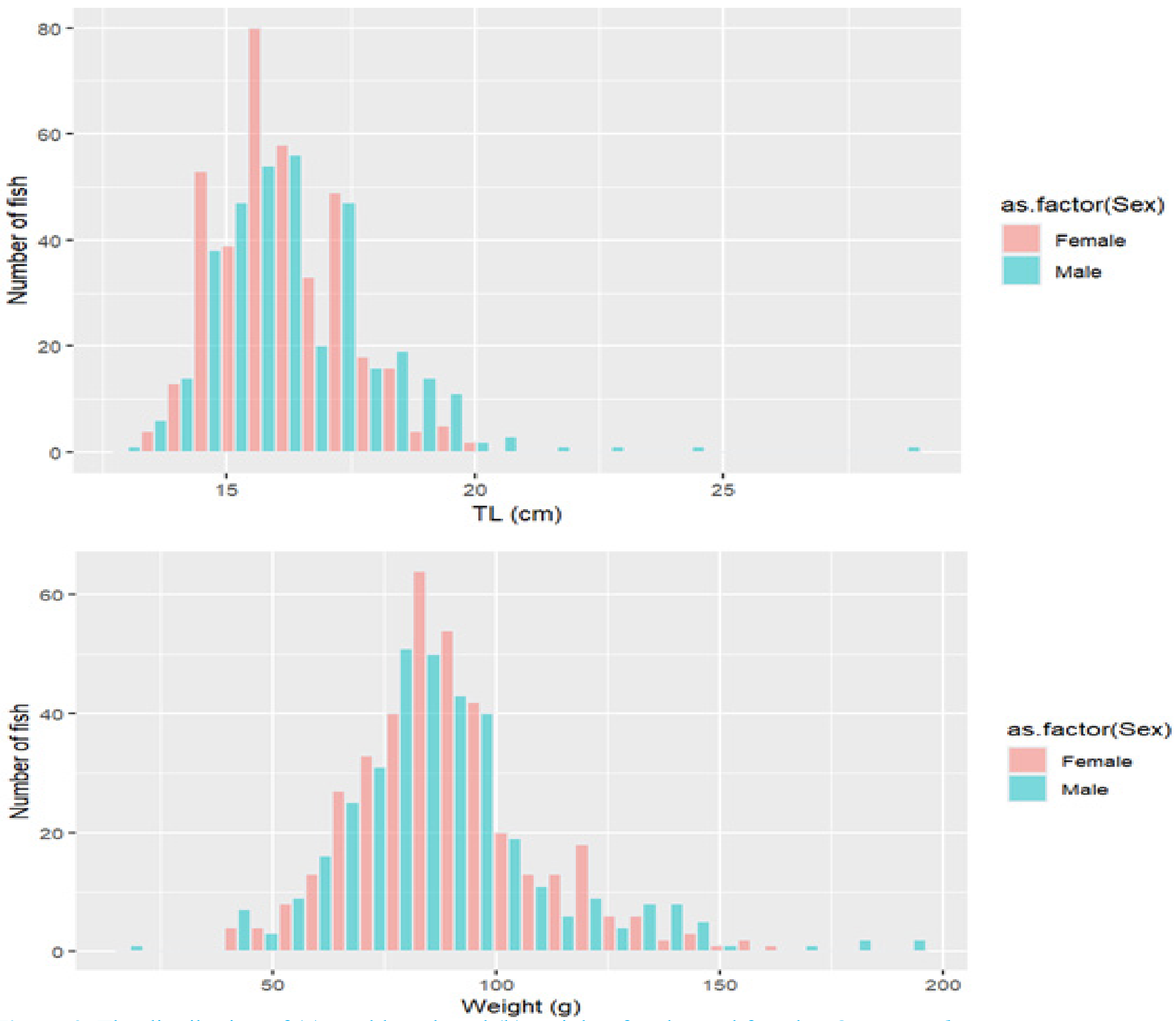


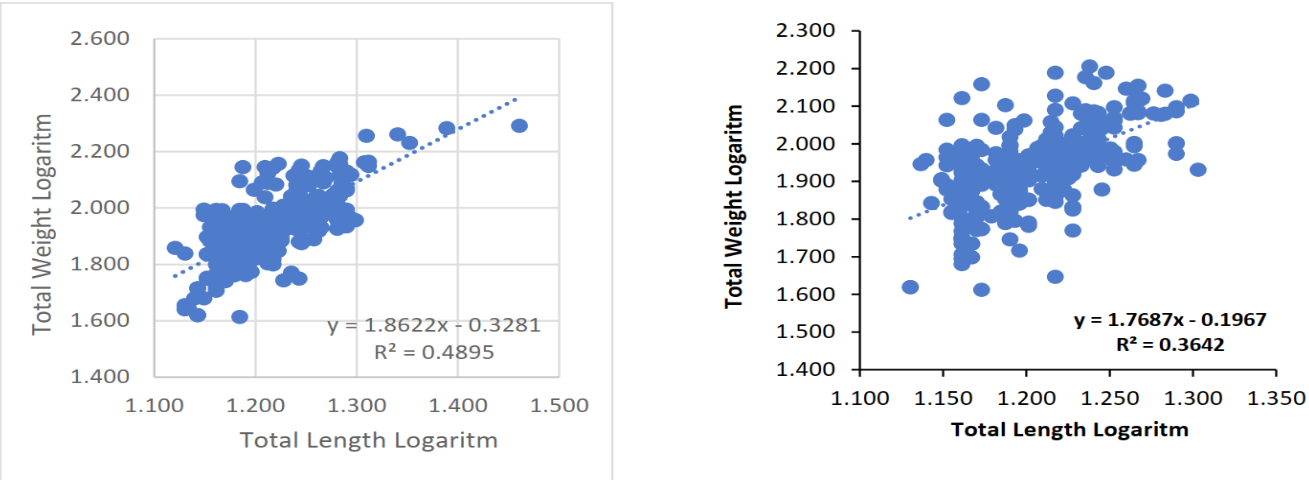
Figure 3. The distribution of (a) total length and (b) weight of males and females *O. mossambicus*

1.7687x-0.1967 (r = 60.3%), respectively.

The research revealed that the length data of the dominant major corresponded to weight values falling between the condition index range of 0.50 to 0.99 (male = 168, female = 177) and 1.01 to 1.50 (male = 169, female = 174). This number indicates that the tilapia in Tarakan have a less flat and more plump body. Fish with less flat bodies have a K value between 1 and 3. When the criteria condition index value is greater than 1.51 for males and greater than 1.15 for females, there are 7 males and 9 females. The complete sample's classification as described in Table 1.

growth rate. Found results of the models both male and female regression equations y = -0.0466x + 1.5601 R^2 = 0.3629 with an R^2 value of 36.29% (Figure 5a), and y = -0.0448x + 0.9472 with an R^2 value of 0.5508 or 55.08% (Figure 5b). The age structure model was estimated using regression coefficients to generate a von Bertalanffy model using a type 6 orthogonal polynomial model that uses two variables: time (days) and total length (cm) of males and females.

The analysis results under the Von Bertalanffy Model (Pasisingi *et al.*, 2021) equation for male and female *O. mossambicus* shown in Figure 6 showed the



(a) Male (b) Female

Figure 4. Length-weight relationship of the allometric model for Male and Female *O. mossambicus*

Table 1. Criteria condition index of *O. mossambicus*

Index of Criteria Condition*	Body Form	Male	Female	Percentage Value (%)	
				Male	Female
0	No Found	0	0	0.0	0.0
0.1 to 0.49	Very thin	1	1	0.3	0.3
0.50 to 0.99	Thin	169	177	48	47.3
1	Proportional	6	13	1.7	3.5
1.01 to 1.50	Fat	169	174	48	46.5
>1.51	Very Fat	7	9	2	2.4

*The value of the Criteria Condition Index value following Salim (2013, 2015); Firdaus and Salim (2018); Salim *et al.* (2021, 2022); Indarjo *et al.* (2020a; 2020b; 2020c; 2021; 2023a' 2023b).

Size structure model analysis of male and female *O. mossambicus* obtained from fish markets sold from traditional fish farming ponds into fish markets in Tarakan City. The sample of *O. mossambicus* was not a fish type that fishermen farm. The occurrence of suspected introduction of *O. mossambicus* was thought to enter through the inlet of fish farming ponds. Therefore, the fish samples analysed were not cultured fish but for the rivers around fish farming location, and linear regression analysis used the ratio between TL and

behavioural relationship between the length and age (by X and Y). The equation of orthogonal polynomial for male type 6 was explained on $Y = -4E\text{-}07x^6+5E\text{-}05x^5-0.0028x^4+0.0763x^3-1.1123x^2+8.5589x+5.0808$ with a correlation value (r) of 0.9996. Meanwhile, the equation of the female orthogonal polynomial type 6 is $Y = -3E\text{-}07x^6+4E\text{-}05x^5-0.0019x^4+0.0483x^3-0.6845x^2+5.2367x+3.4538$ with R^2 = 0.9998 and its correlation value (r) of 0.99 (Figure 6). According to these results, the importance of the correlation between the two variables is very high.

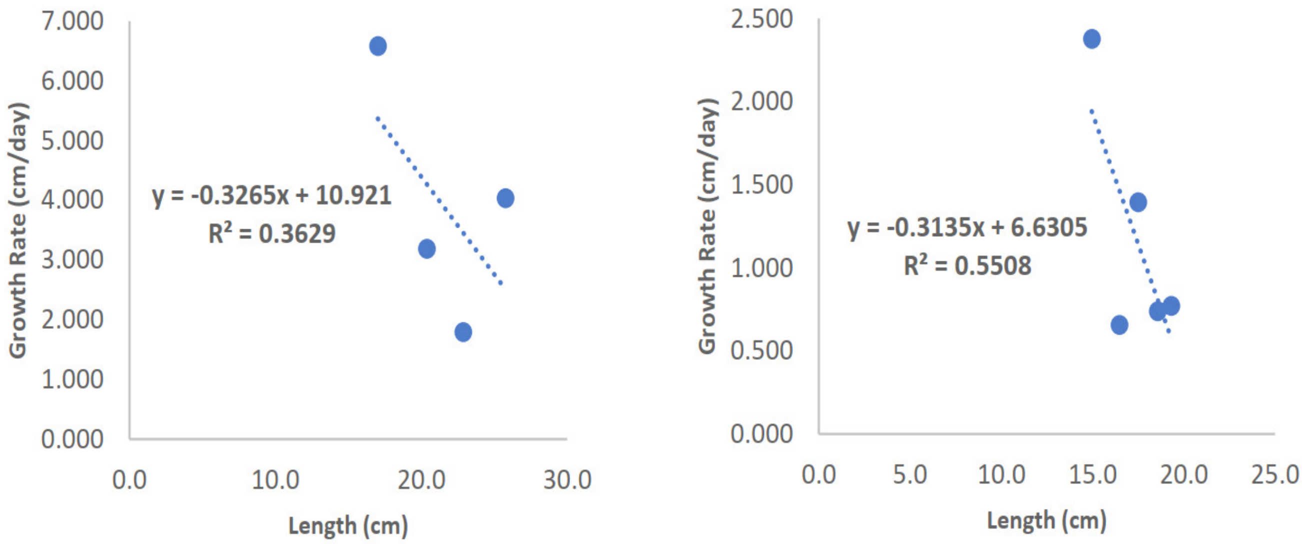


Figure 5. Age structure in male and female *O. mossambicus*

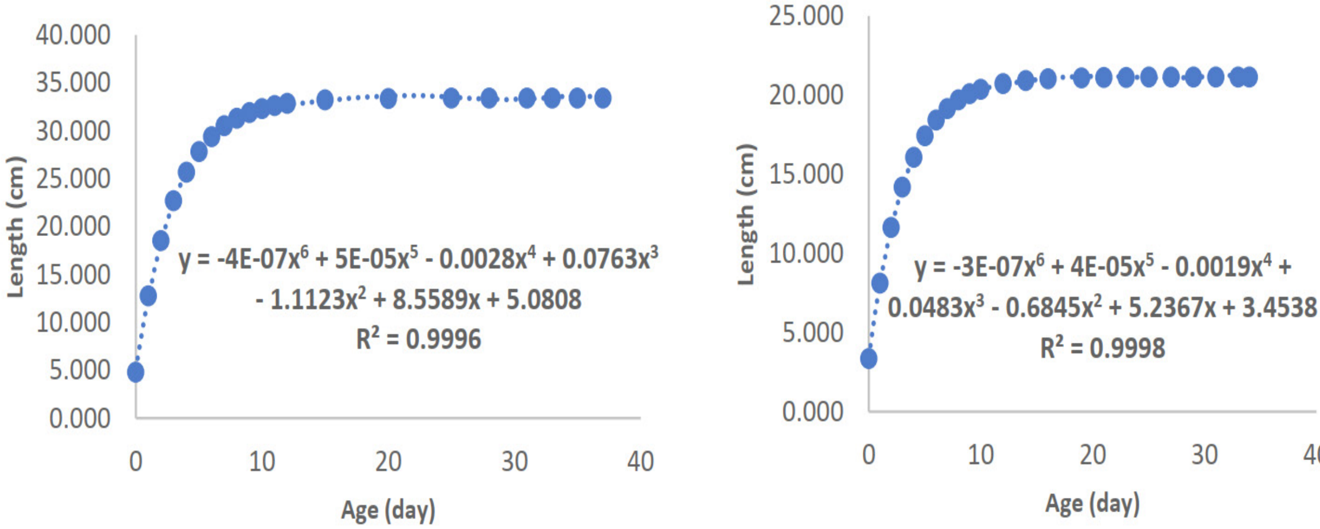


Figure 6. Von Bertalanffy model for male and female *O. mossambicus* Fish

Table 2. Mortality of males and females *O. mossambicus*

Variable	Value		Percentage (%)	
	Male	Female	Male	Female
Z (Total mortality)	2.554	2.373	255.4	237.3
F (Fishing mortality)	2.392	2.183	239.2	218.3
M (Natural mortality)	0.163	0.190	16.3	19.0
E (Exploitation rate)	0.936	0.920	93.6	92.0

The Beverton and Holt method was used to analyse the results, estimating the total mortality (Z) between males and females in traditional ponds in the Tarakan region at 2.554 and 2.373, respectively. The ishing mortality rates were calculated as 2.392 year^{-1} and 2.183 year^{-1}, respectively. The natural mortality rates for male and female fish can be approximately 0.163 year^{-1} and 0.19 year^{-1}, respectively. The male exploitation rate was 0.936 year^{-1}, and the female exploitation rate was 0.92 year^{-1} (Table 2).

3.2 Discussion

Based on the length-weight relationship, 'b' values for males and females were 1.8622 and 1.7587, respectively. According to Effendie (1997), Salim *et al.* (2022; 2023b); Indarjo *et al.* (2023a), 3 categories of allometric growth were identified by Achmad *et al.* (2023). These included negative allometric, isometric, and positive allometric, signified by 'b' values of < 3, 3, > 3, respectively. Based on the data analysis, 'b' values for both male and female *O. mossambicus* were less than 3. This signified negative allometric and reflected growth pattern (Akmal, 2024) of fish. At b = 3, isometric growth was observed, or weight gain was equal to length growth, while b≠ is 3 was considered to be allometric (Muttaqin *et al.,* 2016). The propensity of allometric growth is divided into positive and negative. Furthermore, b < 3 and > 3 are considered harmful (length growth is faster than weight growth), and positive allometric (weight gain is faster than length gain), respectively. Study conducted by Bhanbhro *et al.* (2017) presented the value of length-weight relationship of tilapia in the Indus River in Sukkur, Sindh, Pakistan. The results showed an estimated b value of 2.856, less than 3, signifying a negative allometric. In comparison with the value of male tilapia (at M rate) in Flag Boshielo Dam, Olifants River, South Africa (Hlungwani *et al.,* 2023), length-weight relationship for *O. mossambicus* showed negative allometric (b < 3; R^2 = 0.96). In cases where the b value obtained was low at 2.59, the catch was marginally skewed towards males, with females accounting for 47.9%. Based on observation, no significant difference existed between the size of the two sexes (Kruskal-Wallis p = 0.451).

According to Salim *et al.* (2023b), when "b" = 3, <3, and >3, it implies isometric, negative allometric, and positive allometric growth, respectively. Achakzai *et al.* (2013) reported *O. mossambicus* with a positive allometric b value of 3.055 and R^2 of 0.963 from Pakistan. Riedel *et al.* (2007) showed that male and female *O. mossambicus* from Salt Lake, California with b values of 2.942 and 2.993, were close to the positive allomatric growth. Shendge (2005) observed a negative allometric of *O. mossambicus* from India with a b value = 2.884 and stated the possibility of low food competition in the Bhima River.

The results showed that the Determination (R) values for male and female tilapia, were 0.4896 and 0.3642, respectively. In this study, tilapia has a low correlation value, signifying that the total body length is directly proportional to the total weight. This condition was due to water environment quality factors affecting fish growth. Djaelani *et al.* (2023) it outlined environmental factors that influenced the growth. The study focused on analysing the body weight gain, length, and height of the Red tilapia (*O. niloticus*) reared on aeration and different stocking densities. The record, at the Centre for Fish Seedling Siwarak, Ungaran, Semarang Regency, in the K2A1 group treatment showed a relatively high weight gain, length, and height. This is attributed to environmental factors suitable for the life of red tilapia. Environmental factors and feed provided by pond farmers were also believed to be significant influencers. This was in line with the study by Robisalmi *et al.* (2023), which examined the effect of species, environment, and life stage on growth and reproductive survival. The growth rate is directly proportional to the amount of feed intake. In other cases, such as fish enlargement efforts in ponds (Azhari, 2017), high density in a particular medium interfered with the physiological process and behavior of fish due to limited space for movement. It is important to acknowledge that the nutrients and energy needed for growth are contained in feed (Pratiwi *et al.*, 2011). Growth occurs when there is excess energy after the available amount has been used for standard metabolism, digestion, and activity.

Analysis of the condition index describes fish size, as shown in Total Length and Weight. It presents an excellent physical capacity to survive and reproduce. Based on Salim *et al.* (2020); Indarjo *et al.* (2023a), condition index was a unitless value/number that determined fish body shape based on the comparison of the actual and proportional body weight (based on linear regression analysis). Salim *et al.* (2022) and Indarjo *et al.* (2022) elucidated that the index was determined from the processing of data obtained during length-weight relationship calculation. As explained by Indarjo *et al.* (2020c); Salim *et al.* (2021); Salim *et al.* (2024a); and Salim *et al.* (2024b), the condition index is categorized into 6 classes, where values of 0, 0.1-0.49, 0.50-0.99, 1, 1.01-1.50, and >1.50, signifies zero, very thin, thin, proportional, fat, and very fat body shape, respectively. The condition index analysis could measure fisheries utilization represented by length and weight data. This index can also represent good criteria in terms of physical ability to reproduce and behavior in the waters. The condition factor (Ningsih *et al.*, 2023) more than one *O. mossambicus* also showed that the observed samples were in good condition and population, ensuring the usage for consumption. As described in the study of Robledo *et al.* (2024), the genetic diversity of *Oreochromis niloticus* in a population in open waters (wild fish species) has a higher heterozygosity estimate than fish in aquaculture ponds, signifying good genetic health. According to

Migiro *et al.* (2014), sex, season, environmental conditions, stress, and food availability affect the condition factor (Ningsih *et al.*, 2023) of fish. Furthermore, Olurin and Aderibigbe (2006) observed that stress impacted the very low condition factor of tilapia, in Lake Turkana, Kenya.

The von Bertalanffy growth equation of *O. mossambicus* in the farming pond at the coastal areas of Tarakan, presented in the form of curves, reached a maximum length (L_{∞}) = 33.449 cm (male) and L_{∞} = 21.150 cm (female). The values of growth coefficient (K) for males and females were 0.3265 year^{-1} and 0.3135 year^{-1}, respectively. Weyl and Hecht (1998) analysed 602 *O. mossambicus* sourced from a subtropical lake in Mozambique with lengths between 83-364 mm. The results showed that Wt (g) = 0.00021 TL (mm) 2.981 at R^2 value of 99.1 ($p < 0.001$), while TL (mm) = 31.41 OD (mm) 1.270 at R^2 = 95.0 with each p-value < 0.001. Study by van Zyl *et al.* (1997) showed growth of *O. mossambicus* in salt pans along the Namib coast, which was discovered to have a smaller weight gain than fish in Hardao Dam. On an annual basis, the scale and value of the von Bertalanffy growth parameters presented usual and reasonable growth. The results of de Silva (1991) stated that the growth parameters of 12 reservoir populations were determined using samples from commercial gill net fisheries. This led to L∞ and K ranging between 267 to 393 mm (TL) and 0.32 to 0.70 year^{-1}, with average values of 311 mm and 0.50 year^{-1}, respectively. According to Tirtadanu (2024), the growth of *O. niloticus* fish in Lake Batur has an asymptotic length of 37.59 cm with a growth rate of 0.58 year^{-1}. The von Bertalanffy parameters showed that growth of *O. mossambicus* in Sri Lanka reservoirs was better compared to African populations de Silva (1991), where L∞ values were significantly correlated with maximum size L_{max} (average of the ten largest fish) and average size at capture. According to Weatherley (1972), differences in (K) values were affected by factors such as food, temperature and environmental conditions. In addition to environmental factors, a large abundance of food impacts rapid growth (Sulistiono *et al.,* 2001). The von Bertalanffy model was used to analyse the length growth of Beronang tulis (*Siganus javus*) based on fish sex. The maximum lengths of male and female fish were 30.409 cm and 30.0544 cm, respectively (Salim, 2010). This model was used by Firdaus *et al.* (2013) to analyse the growth and age composition of Nomei fish. The results showed that male and female fish reached a maximum length of 33.847 cm and 35.742 cm, at ages of 206 and 603 days, respectively. In the study of Sravistha *et al.* (2018), the length of fish caught in Lake Buyan Bali, was estimated. In some other analyses, such as in *Selaroides leptolepis*, a slight difference was observed in the steepness of the curve. Specifically, the growth rate of male fish was slower than female, leading to a relatively shallower curve (Pasisingi *et al.,* 2021).

The parameter values are 0.163 year^{-1} (male) and 0.19 year^{-1} (female) naturally occurring mortality (M) annually, 2.392 year^{-1} (male) and 2.183 year^{-1} (female) fishing mortality (F), as well as 0.936 year^{-1} (male) and 0.92 year^{-1} (female) exploitation rate (E). When compared with the study by Muhtadi *et al.* (2022) conducted in Siombak Tropical coastal Lake, North Sumatra, Indonesia, the estimated total mortality (Z) for Mozambique tilapia and M. tilapia, were 3.20 year^{-1} and 3.04 year^{-1}. The value of M values for these species was lower than the fishing mortality rates (F). The capture rate slightly exceeded the optimum value of 0.50, at 0.936 and 0.92, respectively. In pond waters in the Tarakan area, the decline in water quality was caused by high levels of pollutants and a lack of dissolved oxygen. Novaes and Carvalho (2012) reported that *O. niloticus* from Brazil had an exploitation level (E) of 0.57, higher than the recommended optimum level of 0.5. Ahmed *et al.* (2011) reported *O. mossambicus* from Bangladesh with an E of 0.42. The estimated ratio for *O. mossambicus* was 0.21 year^{-1}, which was less than the optimal ratio (E) of 0.5 (Gulland, 1971; Putri and Tjahjo, 2010). Therefore, the stock of this fish species in the Indus River was considered sustainable.

4. Conclusion

In conclusion, growth models of *O. mossambicus* were classified under the allometric category. This criterion showed that the weight of tilapia did not increase similar to length. The sex ratio of *O. mossambicus* was 1:1.0625, signifying a higher proportion of male fish. The total length of male and female fish were 13.2-28.9 cm and 13.5-20.10 cm, with averages of 16.47 cm and 16.16 cm, respectively. Based on regression linear analysis, the x-axis (TL logarithm) and the y-axis (TW logarithm) evidenced growth. Furthermore, regression lines for male and female fish were obtained with the equations y = 1.8622x-0.3281 (r = 70.6%) and y = 1.7687x-0.1967 (r = 60.3%). The mortality rates for males and females, were Z = 2.554 year^{-1} and 2.373 year^{-1}, with corresponding M values of males 0.163 year^{-1} and females 0.190 year^{-1}. The proportion of *O. mossambicus* from the river estuary around Tarakan City into farming ponds was significant. These fish effective utilized the available natural food, potentially impacting the growth pattern of the cultivated target species. To mitigate the issue, it was recommended to install inlet filters, to minimize the entry of foreign species into the pond, thereby protecting the cultivated fish as well as ensuring optimal growth and productivity.

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Authors' Contributions

All authors agree with their respective contributions to the preparation and writing of this scientific article. The contribution of each author is as follows: Rama Iranda, Gazali Salim, Mujianto Mujianto, Yayuk Sugianti, Suryanti, Zahidah, Daud Nawir, Sitti Hartinah, Nurjanah, Rose Dewi, Mochamad Candra Wirawan Arief, Masayu Rahmia Anwar Putri, Abdur Rahman, Agus Indarjo, Julian Ransangan, Ariel E San Jose and Rozi; collected the data, drafted the manuscript, and designed the figures. Rama Iranda, Gazali Salim, Mujiyanto, Yayuk Sugianti, Suryanti, Zahidah, Daud Nawir, Sitti Hartinah, Nurjanah, Rose Dewi, Mochamad Candra Wirawan Arief, Masayu Rahmia Anwar Putri, Abdur Rahman, Agus Indarjo, Julian Ransangan, Ariel E. San Jose and Rozi devised the article's main conceptual ideas and critical revision. The authors have discussed the research results and contributed to the completion of this scientific article.

Conflict of Interest

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References

Achakzai, W., Sadozai, M. S., Baloch, W. A. & Memon, N. (2013). Length-height relationships and condition factor of *Oreochromis mossambicus* (Peters, 1852) from Manchar Lake Distt. Jamshoro, Sindh, Pakistan. *Sindh University Research Journal (Science Series)*, 45(2):201-206.

Achmad, D. S., Nurdin, M. S., Azmi, F., Indrianti, M. A., Hulukati, E., Jompa, J., Haser, T. F., & Achmad, N. (2023). Species composition and growth pattern of a multi-species grouper in Kwandang Bay, Sulawesi Sea, Indonesia. *Jurnal Ilmiah Perikanan dan Kelautan*, 15(1):31-43.

Ahmed, K. K. U., Amin, S. M. N., Haldar, G. C., & Dewan, S. (2011). Population dynamics and stock assessment of *Oreochromis niloticus* (Linnaeus) in the Kaptai Reservoir, Bangladesh. *Indian Journal of Fisheries*, 50(1):47-52.

Akmal, Y. (2024). Growth patterns and ecological classification of *Tor tambra* (Valenciennes 1842) in the Mamis River, Leuser Ecosystem

Area, Aceh Province, Indonesia. *Jurnal Ilmiah Perikanan dan Kelautan*, 16(2):483-495.

Ashouri, S., Da Silva, J. P., Can´ario, A. V. M., & Hubbard, P. C. (2023). Bile acids as putative social signals in Mozambique tilapia (*Oreochromis mossambicus*). *Physiology & Behavior*, 272(15):1-11.

Asrial, E., Arapat, Y., Hadi, U. K., Kalih, L. A., Liliyanti, M. A., Rosadi, E., Khasanah, R. I., & Rathnayake, I. N. (2021a). The length-weight relationship and condition factors of bullet tuna landed at the Tanjung Luar Fishing Port, Indonesia. *Jurnal Ilmiah Perikanan dan Kelautan*, 13(1):1-10.

Asrial, E., Khasanah, R. I., Fathrurriadi, F., Arapat, Y., Hadi, U. K., Kalih, L. A. T. T. W. S., Rizal, L. S., Liliyanti, M. A., Rosadi, E., Setyohadi, D., Junaidi, M., & Rathnayake, I. N. (2021b). Population dynamics of bullet tuna (*Auxis rochei* Risso 1881) from the Indian Ocean, West Nusa Tenggara, Indonesia. *Jurnal Ilmiah Perikanan dan Kelautan*, 13(2):144-155.

Azhari, A., Muchlisin, Z. A., Dewiyanti, I. (2017). Stocking density effect on survival and growth of seurukan (*Osteochilus vittalus*) fry. *Jurnal Ilmiah Mahasiswa Kelautan Perikanan Unsyiah*, 2(1):12-19.

Azis., A. M., Indarjo, A., Salim, G., & Rozi. (2022). Identification of bacteria in seaweed (*Kapapphycus alvarezii*) affected by the ice-ice disease in Amal and Tanjung Tarakan Waters, Indonesia. *AACL Bioflux,* 15(6):3061-3068.

Bhanbhro, R., Memon, K. H., Qun, L., Ursani, T. J., Ujjan, S. A., Ujan, J. A., Shaikh, M. A., Qazi, F., Bhanbhro, H., Noonari, A. K., & Soomro, T. (2017). Estimation of growth and mortality parameters of *Oreochromis mossambicus* from Indus River Sukkur, Sindh, Pakistan. *Lasbela University Journal of Science &.Technology*, 6(1):100-108.

Cadrin, S. X., Goethel, D. R., Berger, A., & Jardim, E. (2023). Best practices for defining spatial boundaries and spatial structure in stock assessment. *Fisheries Research*, 262(6):1-12.

de Silva, K. H. G., M. (1991). Growth rate and the role of *Oreochromis mossambicus* (Peters) in the fishery of a tropical, upland, deep reservoir in Sri Lanka. *Fisheries Research*, 12(2):125-138.

Djaelani, M. A., Kasiyati, K., & Sunarno, S. (2023). Body weight gain, body length and body height gains of red tilapia (*Oreochromis niloticus*) reared at different aeration and stocking densities. *Buletin Anatomi dan Fisiologi,* 8(2):106-113.

Duisan, L., Salim, G., Soon, T. K., & Ransangan, J. (2021). Sex ratio, gonad and condition indices of mangrove clam, Polymesoda (*Geloina erosa*) (Bivalvia: Corbiculidae) in Marudu Bay, Sabah, Malaysia: Implication for broodstock selection in Artificial Breeding Program. *Journal of Fisheries and Environment*, 45(1):106-119.

Effendie, M. I. (1979). Fisheries Biology Methods. First Printing. Bogor: Dewi Sri Foundation.

Effendie, M. I. (1997). Fisheries Biology. Yogyakarta: Nusatama Library Foundation.

Firdaus, M., & Salim, G. (2018). Study population of mudskipper (*Periophthalmus barbarus*) in Bekantan and Mangrove Conservation Area, Tarakan City, North Kalimantan. *Borneo Saintek of University of Borneo Tarakan Journal*, 1(3):68-78.

Firdaus, M., Salim, G., Maradhy, E., Abdiani, I. M., & Syahrun, S. (2013). Growth analysis and age structure of Nomei fish (*Harpodon neherus*) in Juata Waters, Tarakan City. *Jurnal Akuatika*, 4(2):159-173.

Harefa, M. S., Nasution, Z., Mulya, M. B., & Maksum, A. (2022). Silvofishery: In what mangrove coverage condition can this system provide benefits for the community. *Universal Journal of Agricultural Research*, 10(3):249-265.

Hendrawan, A. L. S., Hedianto, D. A., & Sentosa, A. A. (2021). Risk assessment of introduces fish species in Ir. H. Djuanda Reservoir, West Java. *Zoo Indonesia*, 30(1):58-68.

Herawati, V. E., Ayu, R., Darmanto, Y. S., Rismaningsih, R., Windarto, S., & Karnaradjasa, O. (2019). Amino acid and fatty acid profiles of Mozambique tilapia (*Oreochromis mossambicus*) in different aquaculture systems from Indonesian waters. *AACL Bioflux*, 12(5):1771-1778.

Hlungwani, H. A., Marr, S. M., Weyl, O. L. F., & Sara, J. R. (2023). Biological and life-history parameters for *Labeo rosae* Steindachner, 1894 and *Oreochromis mossambicus* (Peters,

1852) from Flag Boshielo Dam, Olifants River, South Africa. *African Journal of Aquatic Science*, 48(2):1-14.

Holden, M. J. & Raitt, D. F. S. (eds) (1974). Manual of fishery science. Part 2. Methods of resource investigations and their application. Rome: Food and Agriculture Organization of the United Nations.

Gulland, J. A. (1971). The fish resources of the ocean west polyfleet, survey fishing news (Books) Ltd. FAO Technical Paper No. 97.

Gulland, J. A. (1976). The scientific basis for the management of fisheries. In K. Tiews, German Foundation for International Development. Fisheries resources and their management Southeast Asia. (pp. 155-167). Rome: FAO.

Gulland, J. A., & Holt, S. J. (1959). Estimation of growth parameters for data of unequal time intervals. *ICES Journal of Marine Science*, 25(1):47-49.

Indarjo, A., Salim, G., Zein, M., Septian, D., & Bija, S. (2020a). The population and mortality characteristics of mangrove crab (*Scylla serrata*) in the mangrove ecosystem of Tarakan City, Indonesia. *Biodiversitas*, 21(8):3856-3866.

Indarjo, A., Salim, G., Zein, M., Susiyanti, S., Soejarwo, P. A., Nugraeni, C. D., Bija, S., & Pham, Y. T. H. (2020b). Characteristics of von Bertalanfy growth, allometric, condition index and mortality of *Periophthalmus barbarus* in Mangrove and Probiotics Conservation Area (KKMB), Tarakan, North Kalimantan. *Ilmu Kelautan*: *Indonesian Journal of Marine Sciences*, 25(1):31-38.

Indarjo, A., Salim, G., Amir, F., Supriadi, S., Soejarwo, P. A., Nugraeni, C. D., Prakoso, L. Y., Ambariyanto, A., Firdaus, M., & Ransangan, J. (2020c). Growth characteristics layur fish *Lepturacanthus savala* in Juata Waters, Tarakan, Indonesia. *Ilmu Kelautan*: *Indonesian Journal of Marine Sciences*, 25(3):127-134.

Indarjo, A., Salim, G., Nugraeni, C. D., Zein, M., Prakoso, L. Y., Daengs, G. S. A, Hariyadi, & Wiharyanto, D. (2020d). The analysis of economic feasibility from bubu dasar fishing gear (*Bottom fish pots*) in Tepian Muara Sembakung, Nunukan (Indonesia). *IOP Conference Series*: *Earth and Environmental Science,* 564(1):1-17.

Indarjo, A, Salim, G, Nugraeni, C. D., Prakoso, L. Y., Soejarwo, P. A., Rukisah, R., Pham, T. H. Y, Hariyadi, H., & Jabarsyah, A. (2020e). Analysis model of giant prawns population (*Macrobrachium rosenbergii*) in estuary edge of Sembakung Waters, Nunukan, Indonesia. *Jurnal Ilmiah Perikanan dan Kelautan*, 12(2):236-249.

Indarjo, A., Salim, G., Nugraeni, C. D., Zein, M., Ransangan, J., Prakoso, L. Y., Suhirwan., Anggoro, S. (2021). Length-weight relationship, sex ratio, mortality and growth condition of natural stock of *Macrobrachium rosenbergii* from the estuarine systems of North Kalimantan, Indonesia. *Biodiversitas,* 22(2):846-857.

Indarjo, A., Salim, G., Maryanto, T. I., Ngungut, Linting, L. A., Firdaus, M., Rozi, & Rukisah. (2023a). Growth patterns and mortality of lobster *Panulirus ornatus* from the catch of bottom gill net fishers in the Western Waters of Tarakan Island. *Hayati Journal of Biosciences*, 30(3):532-542.

Indarjo, A., Salim, G., Prakoso, L. Y., Pramono, B., Meiryani., Maryanto, T. I., Suriyanti., Firdaus, M., & Rozi. (2023b). Population growth model and mortality of Pakistan lobster (*Panulirus polyphagus*) in Estuary Waters of Tarakan City. *Hayati Journal of Biosciences*, 30(6):1043-1053.

Laevastu, T. (1965): Manual of methods in fisheries biology. Rome: Food and Agriculture Organization of the United Nations.

Mangitung, S. F., Hasan, V., Isroni, W., Serdiati, N., & Valen, F. S., (2021). Mozambique tilapia *Oreochromis mossambicus* (Peters, 1852) (Perciformes: Cichlidae): New record from Masalembo Island, Indonesia. *Ecology Environment & Conservation*, 27(3):1091-1093.

Migiro, K. E., Ogello, E. O., & Munguti, J. M. (2014). The length-weight relationship and condition factor of Nile tilapia (*Oreochromis niloticus* L.) broodstock at Kegati Aquaculture Research Station, Kisii, Kenya. *International Journal of Advanced Research*, 2(5):777-782.

Mikael. (2012). Fish diversity of tradisional shrimp pond in Tarakan Island dan Tibi Island East Kalimantan. Undergraduate thesis. Tarakan: Universitas Borneo Tarakan.

Muchlisin, Z. A. (2012). First report on introduced freshwater fishes in the waters of Aceh, Indonesia. *Archives of Polish Fisheries*, 20(1):129-135.

Muhtadi, A., Nur, M., Latuconsina, H., & Hidayat, T. (2022). Population dynamic and feeding habit of *Orechormis niloticus* and *O. mossambicus* in Siombak Tropical Coastak Lake, North Sumatra, Indonesia. *Biodiversitas Journal of Biological Diversity*, 23(1):151-160.

Muttaqin, Z., Dewiyanti, I., & Aliza, D. (2016). Study of long-weight relationship and condition factor of *Oreochromis niloticus* and *Mugil cephalus* in Matang Guru River, Madat Subdistrict, East Aceh District. *Jurnal Ilmiah Mahasiswa Kelautan dan Perikanan Unsyiah*, 1(3):397-403.

Naim, S. (2010). 74 years of tilapia culture and development in Indonesia (1936 – 2010). Thesis. Tucson, Arzona: College of Agriculture and Life Sciences University of Arizona.

Nastiti, A. S., Hediato, D. A., Putri, M. R. A., & Krismono. (2021). The metal concentrations in several fish species on the coast of Muara Gembong, Bekasi Regency, West Java, Indonesia. *E3S Web of Conferences*, 322(1):1-10.

Ningsih, N. R., Omar, S. B. A., Haris, A., Nur, M., & Larasati, R. F. (2023). Length-weight relationship and condition factors of endemic fish, *Lagusia micracanthus* Bleeker, 1860 (Pisces: Terapontidae) in Gilireng River, Wajo Regency, Indonesia. *Jurnal Ilmiah Perikanan dan Kelautan*, 15(2):290-302.

Novaes, J. L. C., & Carvalho, E. D. (2012). Reproduction, food dynamics and exploitation level of *Oreochromis niloticus* (Perciformes: Cichlidae) from artisanal fisheries in Barra Bonita Reservoir, Brazil. *Revista de Biología Tropical (International Jornal of Tropical Biology and Conservation)*, 60(2):721-734.

Olurin, K. B., & Aderibigbe, O. A. (2006). Length-weight relationship and condition factor of pond reared juvenile *Oreochromis niloticus*. *World Journal of Zoology*, 1(2):82-85.

O'Mara, K., Venarsky, M., Marshall, J., & Stewart-Koster, B. (2023). Diet-habitat ecology of invasive tilapia and native fish in a tropical river catchment following a tilapia invasion. *Biological Invasions*, 26(2):489-504.

Padilla, J. A. (1985). Economic of technology adaption: The case of Brackishwater aquaculture in Bulacan, Philippines. Serdang, Selangor, Malaysia: Universiti Putra Malaysia.

Pasisingi, N., Kasim, F., & Moo, Z. A. (2021). Estimation of fishing mortality rate and exploitation status of yellowstrip scad (*Selaroides leptolepis*) in Tomini Bay using Von Bertalanffy growth model approach. *Jurnal Ilmiah Perikanan dan Kelautan*, 13(2):288-296.

Pauly, D. (1984). Fish population dynamics in tropical waters: A manual for use with programmable calculators. Manila, Philippines: International Center for Living Aquatic Resources Management.

Pratiwi, P., Rostika, R., & Dhahiyat, Y. (2011). Effect of feeding level on the growth rate of heavy metal deposition in nilem fish in floating cages culture of the Ir. H. Djuanda reservoir. *Jurnal Akuatika*, 2(2):1-11.

Putri, M. R. A., & Tjahjo, D. W. H. (2010). Length weight relationship analysis and growth parameters estimation of Nile tilapia (*Oreochromis niloticus*) in Ir. H. Djuanda Reservoir. *Bawal*, 3(2):85-92.

Riedel, R., Caskey, L. M., & Hurlbert, S. H. (2007). Length-weight relations and growth rates of dominant fishes of the Salton Sea: Implications for predation by fish-eating birds. *Lake and Reservoir Management*, 23(5):528-535.

Robisalmi, A., Alipin, K., & Gunadi, B. (2021). Effect of different feed restrictions on growth, biometric, and hematological response of juvenile red tilapia (*Oreochromis* spp). *Jurnal Ilmiah Perikanan dan Kelautan*, 13(2):243-254.

Robisalmi, A., Gunadi, B., & Setyawan, P. (2023). Evaluation of growth performance and improving genetic gain of blue tilapia

(*Oreochromis aureus*) fourth-generation (F-4) at brackish water pond. *Jurnal Ilmiah Perikanan dan Kelautan*, 15(1):189-200.

Robledo, D., Ogwang, J., Byakora, E., Schulze, J. N., Benda, K. K., Fraslin, C., Salisbury, S., Solimo, M., Mayega, J. F., Peter, B., Masembe, C., Houston, R., & Mukiibi, R. (2024). Genetic diversity and population structure of farmed and wild Nile tilapia (*Oreochromis niloticus*) in Uganda: The potential for aquaculture selection and breeding programs. *Genomics*, 116(1):1-12.

Rodríguez, E., Ron, E., Mikolji, I., Fuentes, J. L., & Lasso-Alcalá, O. M. (2021). Invasive Mozambique tilapia (*Oreochromis mossambicus*), dominates Southeastern Caribbean Sea Island estuary. *Memoria de la Fundación La Salle de Ciencias Naturales*, 79(188):75-104.

Rozaki, Z., Ariffin, A. S., Ramli, M. F., Nurrohma, E., Ramadhani, N. N., Setyoasih, W. I., & Senge, M. (2023). Optimizing coastal management: A comprehensive value chain analysis approach for sustainable economic development in Java, Indonesia. *Jurnal Ilmiah Perikanan dan Kelautan*, 16(1):165-179.

Salim, G. (2010). Study on growth of wrangled fish (*Siganus javus*) using the von Bertalanffy approach. *Jurnal Harpodon Borneo*, 3(1):45-52.

Salim, G. (2013). The condition index value of the *Siganus javus* fish is based on the catches of fishermen in Juata waters, Tarakan City. *Jurnal Harpodon Borneo*, 6(1):37-42.

Salim, G. (2015). Analysis of allometry growth and caesio cunning condition index obtained from Tarakan City fishermen catches. *Jurnal Harpodon Borneo*, 8(1):35-42.

Salim, G., Azis, Prasetia, A. M., Bong, M., Rukisah, Indarjo, A., Fatwa, A. T., Wulandari, E., Jalil, A., Fauzi, M. A., & Toha, T. (2023a). Growth pattern and the condition index of Nomei fish *Harpodon nehereus* captured with mini-trawl in Tarakan Waters. *IOP Conference Series: Earth Environment Science*, 1260(1):1-11.

Salim, G., Azis, Prasetia, A. M., Indarjo, A., Rukisah, Bong, M., Lailaturrif'ah, Wulandari, E., Jalil, A., Fauzi, M. A., Toha, T., Anggoro, S., Ransangan, J., & Mujiyanto, M. (2023b). Growth, mortality, and reproductive model of Bombay duck (*Harpodon nehereus*, Hamilton 1822) in Juata Laut Waters, North Kalimantan. *AACL Bioflux*, 16(4):1864-1877.

Salim, G., Handayani, K. R., Anggoro, S., Indarjo, A., Syakti, A. D., Ibrahim, A. J., Ransangan, J., & Prakoso, L. Y. (2020). Morphometric analysis of *Harpodon nehereus*, *Harpiosquilla raphidea*, and *Scylla serrata* in the coastal waters of Tarakan, North Kalimantan, Indonesia. *Biodiversitas*, 21(10):4829-4838.

Salim, G., Handayani, K. R., Indarjo, A., Ransangan, J., Rizky, R., Prakoso, L. Y., & Pham, Y. T. H. (2021). Characteristic of population growth and mortality of windu shrimp (*Penaeus monodon*) in Juata waters Tarakan City, Indonesia. *Jurnal Ilmiah Perikanan dan Kelautan*, 13(1):114-120.

Salim, G., Indarjo, A., Sugianti, Y., Anggoro, S., Ransangan, J., Nawir, D., Bong, M., Hartinah, S., Nurjanah, San Jose, A. E., Dewi, R., Arief, M. C. W., Rusman, & Mujiyanto, M. (2024a). Model of growth and mortality of otek fish (*Netuma thalassina* (Rüppell, 1837)) in Tarakan waters, North Kalimantan. *AACL Bioflux*, 17(1):219-234.

Salim, G., Indarjo, A., Mujiyanto, M., Sugianti, Y., Anggoro, S., Ransangan, J., Nawir, D., Bong, M., Hartinah, S., Nurjanah, Jose, A. E. S., Dewi, R., Balqis, Z., Arief, M.C.W., Putri, M. R. A., Rahman, A. (2024b). Growth and mortality model of *Chacunda gizzard* shad *Anodontostoma* chacunda (Bleeker, 1852) in Tarakan Waters, North Kalimantan, Indonesia. *Biodiversitas*, 25(2):770-780.

Salim, G., Rachmawani, D., & Septian, D. (2018). Model analysis of growth traits and condition indices of mangrove crabs (*Scylla serrata*) from estuarine waters of Tarakan City. *Jurnal Borneo Saintek*, 1(3):1-12.

Salim, G., Rukisah, R., Azis, A., Firdaus, M., Toha, T., Awaludin, A., Prasetia, A. M., Nugraeni, C. D., Al-Hafizh, M. F., Rahmatsyah, R., Ipa, H., Muslikah, V., Safira, R., Sastri, S. S., Jati, T. S., Jalil, A., Fauzi, M. A., Rif'ah, L., & Wulandari, E. (2022). Processing of Nomei fish (*Harpodon nehereus*) into nugget in Juata Laut Area, Tarakan City. *Jompa Abdi*: *Jurnal Pengabdian Masyarakat* 1(3):126-136.

Setyaningrum, E. W., Yuniartik, M., & Yuniari, S.

H. (2023). The livelihood vulnerability of vannamei shrimp culture as the impact of climate change in Banyuwangi Regency, East Java Province, Indonesia. *Jurnal Ilmiah Perikanan dan Kelautan*, 16(1):136-151.

Setyanto, A., Sambah, B., Widhiastika, D., Soemarno, D. G. R., Wiadnya., & Prayogo, C. (2021). Population structure and biological aspects of lobster (*Panulirus* spp) of the Madura Strait landed in Situbondo of East Java, Indonesia. *IOP Conference Series: Earth and Environmental Science*. 919(1):1-8.

Shendge, A. N. (2005). Length-weight relationship and relative condition factors in *Oreochromis mossambicus* (Peters) of Bhima River. *Journal of Indian Fisheries Association*, 32(1):135-139.

Simon, K. D., & Mazlan, A. G. (2008). Length-weight and length-length relationships of archer and puffer fish species. *The Open Fish Science Journal*, 2008(1):19-22.

Situmorang, M. T. N., & Sulaiman. (2023). Management of mangrove eco-tourism area in Tarakan. *Jurnal Ilmu Lingkungan*, 17(1):36-44.

Sparre, P., & Venema, S. C. (1999). Introduction to tropical fish stock assessment. Jakarta: Centre for Agricultural Research and Development.

Sravistha, I. M. S. K., Arthana, I. W., & Prariwi, M. A. (2018). Patterns and growth parameters of dominant caught fish (*Oreochromis niloticus*, *Osteochilus* sp. and *Xiphophorus helleri*) in Lake Buyan Bali. *Journal of Marine and Aquatic Sciences*, 4(2):204-212.

Suhadi, S., Atika, P., Sugiyatno, S., Panogari, A., Handayanto, R. T., & Herlawati, H. (2020, November). Mobile-based fish quality detection system using K-Nearest Neighbors Method. *Conference*: *2020 Fifth International Conference on Informatics and Computing* (*ICIC, Gorontalo, Indonesia*).

Sulistiono, S., Arwani, M., & Aziz, K. A. (2001). Growth of mullet, *Mugil dussumieri* in Ujung Pangkah, East Java. *Jurnal lktiologi Indonesia,* 1(2):39-47.

Sunarto, A., Grimm, J., McColl, K. A., Ariel, E., Nair, K. K., Corbeil, S., Hardaker, T., Tizard, M., Strive, T., & Holmes, B. (2022). Bioprospecting for biological control agents for invasive tilapia in Australia. *Biological Control*. 174(10):1-12.

Suyono. (2015). Regression Analysis For Research. Jogjakarta: Deepublish.

Tirtadanu, Chodrijah, U., Prihatiningsih, Hartati S. T., Soeprobowati T. R., Purnomo A. H., Prasetyo S., Jumari, & Wahyono, A., (2024). Assessing stock status of tilapia (*Oreochromis niloticus*) and Midas cichlid (*Amphilophus citrinellus*) in Batur Lake, Indonesia. *AACL Bioflux,* 17(3):960-970.

Weatherley, A. H. (1972). Growth and ecology of fish populations. London: Academic Press.

Weyl, O. L. F., & Hecht, T. (1998). The biology of *Tilapia rendalli* and *Oreochromis mossambicus* (Pisces: Cichlidae) in a subtropical lake in Mozambique. *South African Journal of Zoology*, 33(3):178-188.

Yulianto, D., Indra, I., Batubara, A. S., Efizon, D., Nur, F. M., Rizal, S., Elvyra, R., & Muchlisin, Z. A. (2020). Length–weight relationships and condition factors of mullets *Liza macrolepis* and *Moolgarda engeli* (Pisces: Mugilidae) harvested from Lambada Lhok waters in Aceh Besar. *F1000Research,* 9(1):1-16.

van Zyl, B. J., Hay, C. J., & Steyn, G. J. (1997). The successful introduction of *Oreochromis mossambicus* in salt pans along the Namib coast. *Madoqua,* 19(2):87-89.