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Growth and mortality model of Chacunda gizzard shad *Anodontostoma chacunda* (Bleeker, 1852) in Tarakan waters, North Kalimantan, Indonesia

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Abstract. *Salim G, Indarjo A, Mujiyanto M, Sugianti Y, Anggoro S, Ransangan J, Nawir D, Meiryani, Hartinah S, Nurjanah, Jose AES, Dewi R, Balqis Z, Arief MCW, Putri MRA, Rahman A. 2024. Growth and mortality model of Chacunda gizzard shad* Anodontostoma chacunda *(Bleeker, 1852) in Tarakan waters, North Kalimantan, Indonesia. Biodiversitas 25: 770-780.* The Chacunda gizzard shad *Anodontostoma chacunda* (Bleeker, 1852) possesses numerous spines and is economically valued, with prices ranging from USD 0.64-0.96/kg. This study aimed to analyze the growth and mortality models of the *A. chacunda* from the waters of Tarakan Island. The research was conducted over four months, from July to October 2022, using a quantitative descriptive method. Sampling was performed using purposive sampling, with 20 sessions over four months, each yielding 40-50 individuals. The results showed a total sample of 789 fish, with 463 males and 326 females, yielding a males-to-females ratio of 1.42:1. The allometric model revealed negative allometry with a body shape from the condition index indicating leanness. The Von Bertalanffy model shows that the asymptotic length of males is higher than that of females with the growth rate of females being higher than that of males. In reaching the asymptotic length, the males is faster by reaching the age of 47 days compared to the females reaching the age of 37 days. The numerical data of total mortality, fishing mortality and natural mortality of females is higher compared to males, but for exploitation rate in males and females has the same value is 0.91. The current exploitation rate of *A. chacunda* was higher than the optimum exploitation rate (E=0.5), showed that over-exploited *A. chacunda* requires sustainable management.

Keywords: *Anodontostoma chacunda*, growth model, mortality, reproductive, traditional fishing

INTRODUCTION

Indonesian waters, with their expansive area, harbor a diverse array of biological resources (that can enhance the local community's economic income) (Hasan and Widodo 2021; Indarjo et al. 2022; Hasan et al. 2022; Meiryani et al. 2023; Serdiati et al. 2023), both domestically and internationally (Gani et al. 2021; Ndobe et al. 2023; Indarjo et al. 2022; Hasan et al. 2023; Nurjirana et al. 2023). This condition also applies to the waters of Tarakan Island (Indarjo et al. 2023a). Administratively, Tarakan is a city area geographically covering 657.33 km^2, located at coordinates 3°19'-3°20'N and 117°34'-117°38'E (Central Agency of Statistics Tarakan 2021), with a marine area of about 406.53 km^2 (62%) and a land area of approximately 250.8 km^2 (38%) (The Audit Board of The Republic of Indonesia 2022).

Ecologically, Tarakan boasts a diverse range of coastal ecosystems (Dau et al. 2023), beach ecosystems, marine ecosystems, mangrove ecosystems (Zheng et al. 2023), and estuarine ecosystems (Salim et al. 2020a). Tarakan's waters are part of the estuarine ecosystem category, with a salinity range of about 15-18 ppt (Indarjo et al. 2023a). Nevertheless, this region is known for its abundant biological resources (Salim et al. 2022). Tarakan's waters are adjacent to the waters of Bunyu (Firdaus et al. 2022), and both areas are directly connected to three major waters: the South China Sea (Larvet et al. 2023), the Sulawesi Sea (Pratasik et al. 2022), and the Pacific Ocean (National Academies of Sciences, Engineering, and Medicine 2022).

Chacunda gizzard shad (*Anodontostoma chacunda*, Hamilton, 1822) is distributed in Indo-West Pacific Waters (Froese and Pauly 2021), such as The Bay of Bengal, Bangladesh (Hanif et al. 2019), The Cua Tieu River, Mekong Delta, Vietnam (Dong et al. 2022), Coastal Area in Duyen Hai District, Tra Vinh Province, Vietnam (Dong and Tu 2021), Shatt Al-Arab River, Southern Iraq (Taher et al. 2019), Bali (Agustiana et al. 2023), South of Bangka Waters (Aisyah et al. 2022), Lamongan Waters (Anam et al. 2023), and also Tarakan waters, North Kalimantan (Jabarsyah et al. 2021). *Anodontostoma chacunda* has a significant economic value (Meiryani et al. 2023), with a price range of about USD 0.64-0.96/kg. According to Agustiana et al. (2023), the protein concentration from *A. chacunda* has the best base material of ash and carbohydrate content. A drawback of this fish is its numerous bones (André et al. 2023), which are similar to those found in the fish Puput (*Ilisha elongata*) (Liu et al. 2022), where *I. elongata* and *A. chacunda* have something in common, namely numerous bones and a flat shape (Firdaus and Salim 2011). The ecological habitat of *A. chacunda* is located in coastal waters (Amran and Daming 2023) and estuaries (Salim et al. 2022), with a substantial population feeding primarily on benthic organisms (Barrera-Oro et al. 2019) and Bacillariophyceae (Wang et al. 2022) detritus (Liu and Yao 2023), thus this species categorized as omnivores and pelagic feeders (Hein et al. 2018).

Research that has been done on *A. chacunda* is Length-weight relationships of four fish species from a coastal artisanal fishery, southern Bangladesh (Siddik et al. 2016); morphometric and meristic characters of *Anodontostoma* sp. from Bangka Belitung, Indonesia (Aisyah and Syarif 2019); growth pattern and condition factor of *A. chacunda* from Tanjungpinang, Indonesia (Zahid et al. 2022).

The growth model of *A. chacunda* was analyzed using the length-weight relationship (Ferdoushi et al. 2022) to determine fish stock conditions (Zahid et al. 2022). The condition index value is an indicator value in analyzing the physiological and nutritional status of aquatic biota (Panicker and Katchi 2021), characteristics of growth patterns and age (Salim et al. 2020a; Indarjo et al. 2023b) using the Von Bertalanffy model (Indarjo et al. 2022), and condition index analysis (Indarjo et al. 2020a) used in fish physiology (Panicker and Katchi 2021) to analyze individual fish body shape (Salim et al. 2021) or relative fish health within a specific population or individual (Salim et al. 2020a). A mortality analysis model (Pauly 1984) was used Beverton and Holt formula to determine total mortality (Sparre and Venema 1999), catch mortality, natural mortality, and exploitation rate (Pauly 1984), indicating whether the fish has been optimally utilized (Ray et al. 2023). The research aims to analyze the growth and mortality models in *A. chacunda* from the waters of Tarakan City. This research has a role in the population stock in terms of growth, growth rate, mortality, or exploitation rate in the development of aquatic biological resource management in nature.

MATERIALS AND METHODS

Study area

Geographically, the research location is the Traditional Beringin Market in Tarakan City, North Kalimantan, Indonesia (3°17'22.3"N 117°35'06.1"E). The Beringin Traditional Market is a fish market and a common landing site for *A. chacunda* in Tarakan City (Balqis 2023) (Figure 1).

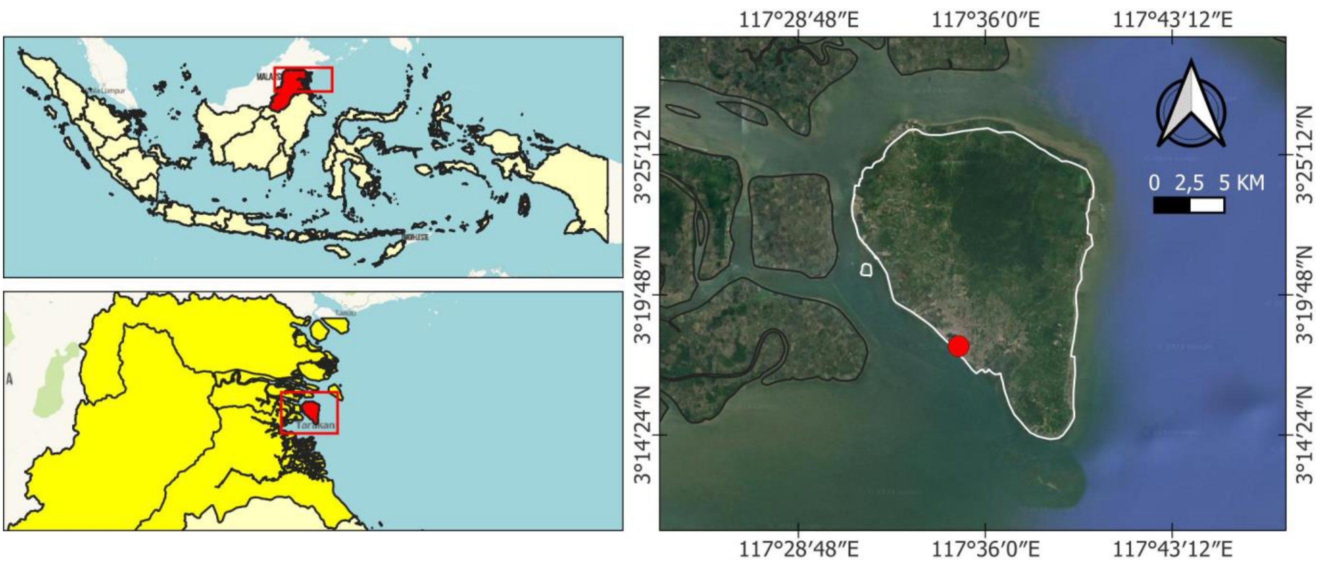


Figure 1. Map of research stations in the Traditional Beringin Market, Tarakan Island, North Kalimantan, Indonesia

The quantity of *A. chacunda* species landed in the city is uncertain depending on the catch of Gill Net fishermen with a location in the waters area of Patok Merah Depan, Muara Bulungan, Tanjung Karis and Bulungan of North Kalimantan, Indonesia.

Procedures

The methodology used in this study is descriptive quantitative, with data collection from fishermen's catch landed at the Traditional Beringin Market in Tarakan City. The sampling method uses the purposive sampling method by following fishermen with gill nets to the location of the fishing ground of *A. chacunda* with a location in the area of Patok Merah Depan, Muara Bulungan, Tanjung Karis, Bulungan District. Descriptive quantitative research involves using observational methods or approaches to describe conditions with variables of nature or characteristic values (Sugiyono 2017). This research was conducted over four months, from July to October 2022. The research was conducted in July-October 2022 which is the dry season period (Rapi et al. 2022). The subject of this study was *A. chacunda*, with data collected from samples including total length, total weight, and fish sex.

Samples of *A. chacunda* were obtained from fishermen's catches sold in the traditional Beringin market in Tarakan city. The sampling method employed in this study was purposive sampling (Samples that are determined to be mature/clarity of differences in the sex of the fish). Sugiyono (2017) stated that purposive sampling is a technique for determining samples based on specific considerations. This method was carried out by selecting samples in line with the research objectives, which were to obtain data on the sex of fish or those with developed gonads for analyzing the sex ratio, growth, and condition index of *A. chacunda*. Sampling was conducted 20 times for four months, during which each collection of *A. chacunda* involved the observation of approximately 40-50 individual fish. This method aligns with the guideline that for a descriptive quantitative study, the sample should be 10% (minimum number requirement) of the population, or if the population (research subjects) exceeds 100, the sample can constitute 10-15%. However, if the population does not exceed 100 (individuals/units), the entire population can be used as a sample (Sugiyono 2017).

Data analysis

Data analysis of *A. chacunda* using the growth parameter model consists of various variables: length distribution, growth pattern, condition factor, growth parameters, and mortality parameters. According to Salim et al. (2022) and (Indarjo et al. 2021; 2023a), in determining the growth model parameters using total length data, total weight, and sex with a total of 789 individuals, consisting of 463 males and 326 females. Variable mortality model in *A. chacunda* fish using natural mortality model variables, fishing mortality model, total mortality model, and exploitation rate model according to Salim et al. (2022) and Indarjo et al. (2020b; 2023b). The mortality model used is a continuation of Von Bertalanffy model with the addition of water environmental temperature measurement from *A. chacunda* which is 28.6°C.

Length distributions

The length class of *A. chacunda* was analyzed for differences between sexes using Mann Whitney U test (for non-normal distributed length data, $p<0.05$) and performed using software R 4.2.2 (R core team 2022).

Growth pattern

The length-weight relationship (LWR) correlation was analyzed to determine the growth pattern by input length and weight data converted into logarithmic form and then processing using Microsoft Excel software with linear regression method (Sugiyono 2017). The length-weight relationship model used the following Effendie (1979) formula:

$$\text{Log } Y = \text{Log } a + b \text{ Log } X \text{ or } W = a L^{b}$$

A function, $ts = (b-3)/Sb$ (Olagbemide and Owolabi 2023), was used to examine the statistical significance of the isometric exponent (b). In this function, ts represents the "t" student statistics test value, "b" represents the slope, and Sb is the standard error of "b." The statistical significance of 'b' values was determined by comparing the resultant t-test values with the corresponding critical values. This allowed for their inclusion in either the negative allometric range ($b<3$), allometric positive range ($b>3$) or the isometric range ($b=3$) (Salim et al. 2023b).

Condition factor

The value of K_{TI} (Condition Factor) for an isometric growth was determined by using the following formula Effendie (1979):

$$K_{(TI)} = 10^5 \times \frac{W}{L}$$

Where:
$K_{(TI)}$: condition factor;
W : apparent weight of fish (g);
L : fish length (mm).

The value of the formula is taken so that $K_{(TI)}$ approaches the value of 1.

According to Weatherley (1972), the condition factor of fish with allometric growth properties can be determined by the following method:

$$Kn = \frac{W}{\widehat{W}}$$

Where:
Kn : condition factor;
W : total fish weight (g)
$\hat{W}$: estimated fish weight (g)
$\hat{W}$: a L^b ($\hat{W}$ was derived from the length-weight regression equation).

The condition index criteria, according to Salim et al. (2020a), are as follows:

1. The range of condition index values is from 0.1 to 1.51 for a skinny body shape,
2. The condition index values range from 0.1 to 0.49 for a thin body,
3. The condition index value is 1 for a proportional body shape,
4. The condition index values range from 1.01 to 1.50 for a fat body shape,
5. The condition index values are >1.50 for an obese body shape.

Growth parameters

The growth parameters of *A. chacunda* were analyzed using an absolute growth approach using the Von Bertalanffy Equations with data processing using Microsoft Excel (Sparre and Venema 1999) :

$$L_t = L_\infty\ (1\text{-}e\text{-}^{k\ (t\text{-}to)})$$

Where:
L_t : expected length of fish at age t (cm);
L_∞ : asymptotic average length (at infinite; in cm);
k : growth rate coefficient (per year);
t_o : estimated theoretical age of fish at zero length;
e : constant.

Age structure

The age structure analysis uses the mode class shift method with the Von Bertalanffy model as described in (Sparre and Venema 1999):

$$(\Delta L/\Delta t) = (L_2\text{-}L_1) / (t_2\text{-}t_1) \text{ and } L_{(t)} = (L_2 + L_1) /2.$$

Where:
$(\Delta L/\Delta t)$: relative growth;
ΔL : fish length;
Δ_t : time period (days);
$L_{(t)}$: the average length mode.

By plotting the values of $L_{(t)}$ and $(\Delta L/\Delta t)$, a regression linear formula is obtained:

$$y = a + bx$$

Where:
a : $((\sum y/n)\text{-}(b\ (\sum x/n)))$;
b : $(n\sum(xy)\text{-}(\sum x) * (\sum y)) / (n\sum x^2\text{-}(\sum x)^2)$;
n : total samples;
x : value $L_{(t)}$;
y : value $(\Delta L/\Delta t)$.

The average value of the length mode of the method was used to calculate the asymptotic length (L_∞) and the growth coefficient (K):

$$K = -b$$
$$L_\infty = -a / b$$

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

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

To derive the relative age at various lengths from the Von Bertalanffy model the following equations were used, according to Gulland (1975):

$$-\ln (1\text{-}Lt/L_\infty) = -K\ (t_0) + K\ (t)$$
$$t = t_0\text{-}\ln * (1\text{-}(Lt / L_\infty)$$

Mortality

The natural mortality (M) of *A. chacunda* was estimated using the empirical formula of Pauly (1984). Research on Mortality (Z) using the formula based on Pauly (1984) is used to estimate the value of t_0. According to Beverton and Holt (1959) it is assumed that the growth curvature parameter (K) is related to the age of the fish, because K describes the time needed to reach L∞, and long life is related to mortality. The empirical formula of Pauly (1984) as follows:

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

The total mortality (Z) of *A. chacunda* was estimated using the Beverton and Holt formula (Sparre and Venema 1999) as follows:

$$Z = K\ x\ \left[\frac{L_\infty - L}{L - L'}\right]$$

The fishing mortality (F) of the *A. chacunda* was estimated according to the following equation:

$$F = Z - M$$

Where: F: fishing mortality, Z: total mortality and M: natural mortality

Finally, the exploitation rate (E) of the *A. chacunda* in sampling sites was estimated following Pauly (1984) as follows:

$$E = F/(F+M)$$

Where:
E : Exploitation rate *A. chacunda*
Z : Total mortality *A. chacunda*
F : Fishing mortality *A. chacunda*
M : Natural mortality *A. chacunda*

RESULTS AND DISCUSSION

Identification, size distribution and length-weight relationship

The identification results of the sample fish show that the sample fish has an almost oval body shape, the mouth is inferior, there are large black spots behind the gill opening; most of the nape is yellowish, otherwise the sides are silvery; fins are generally pale, tail fin yellowish (Figure 2) (Balqis 2023).

The study on *A. chacunda* yielded results from the catch of fishermen using Gill Net in a location in the area of Patok Merah Depan, Muara Bulungan, Tanjung Karis, Bulungan District. The length and weight of the males *A. chacunda* ranged from 10-15.9 cm and 12.5-53 g, respectively. The female specimens were measured between 8 and 14.5 cm and weighed 16.3-60 g. The research on *A. chacunda* in this study revealed a sex ratio between males and females of 1.42:1. The mean total length of female specimens (13.7 cm) was higher than males (13.5 cm). The female samples collected were dominated by specimens with a total length range of 13.5-14.4 cm. Meanwhile, males were dominated by specimens with a total length range of 13-13.9 cm (Figure 3). Length distributions significantly differed between sexes (p-value<0.0001).

Microsoft Excel data processing (Figure 4) determined the length-weight correlation model for males *A. chacunda* with a regression equation that is found in Figure 4. All regressions of the length-weight relationship were highly significant, with the coefficient of determination (r^2) ranging from 0.80 to 0.99 ($p<0.01$). The b values were 2.6423 for male specimens and 2.5965 for female specimens. According to the t-test, the growth type of both sexes had negative allometric growth (Table 1).

Condition index

Based on the research results presented in Table 2, the condition index criteria for *A. chacunda* in both males and females are dominated by three body shapes: thin, proportional, and fat. However, according to the research data, the thin body shape predominates in both males 52.9% and females .9%, compared to the proportional (males 17.7% and females 9.5%) and fat body shapes (males 29.4% and females 35.6%), respectively.

Growth parameters

Based on the age structure from the Von Bertalanffy model, it was found that Figure 5 explains the relationship between two variables, total length and growth rate, for both male and female fish. Figure 5 shows that the X-axis represents the total length (cm) of *A. chacunda,* and the Y-axis represents the growth rate (year). The relationship between these two variables yielded a linear regression for males and females which explains that the graph is a representation of the growth rate with size (fish length) which has a negative trend with a very strong correlation level of the growth rate variable on a linear line, when it touches the x-axis then you will get the maximum length (x-axis) with the growth rate (y-axis) is zero. The maximum length (x-axis) found in Figure 5 to get the infinitive length (L_∞).

In Figure 5, the value of k is obtained from the linear regression equation with $y = a+bx$, so that the value of k that comes from the value of-b is obtained, in males it is equal to 0.2855/year and in females it is equal to 0.2875/year. The value of L_∞ is obtained from the equation $L_\infty = -a/b$, in males it is equal to 16.094 and in females it is equal to 15.045. As for the to value obtained based on Pauly's formula (1984) for males equal to-0.6253 and females equal to-0.6302.

The correlation between time and total length of *A. chacunda* was shown on Figure 6. The Von Bertalanffy growth model was determined using orthogonal linear regression type 6 for male fish, represented by the equation $y = -6E\text{-}08x^6+1E\text{-}05x^5-0.0006x^4+0.0209x^3-0.3732x^2+3.4411x+2.7646$, with an R square value of 0.995 and a correlation value of 0.9999 (99.99%). For female fish, the orthogonal linear regression type 6 from the Von Bertalanffy model yielded the equation $y\text{-}1E\text{-}07x^6 + 2E\text{-}05x^5-0.0009x^4+0.0258x^3-0.402x^2+3.3801x+2.5532$, with an R square value of 0.9999 and a correlation value of 0.9999 (99.99%).

A B

Figure 2. The Chacunda gizzard shad *Anodontostoma chacunda* (Bleeker, 1852). A. Weight measurement process, B. Morphology

Table 1. Length-weight relationship of males and females of *Anodontostoma chacunda*

Sex	Length-weight relationship			Test-$t_{0.05(2)}$		Growth pattern
	Regression equation	Value p	r^2	$t_{calcutated}$	$t_{critical}$	
Males	y = 2.6423x-1.4381	p < 0.01	0.97	59.803	1.965	b < 3 (Negative Allometric)
Females	y = 2.5965x-1.3731	p < 0.01	0.955	45.326	1.967	b < 3 (Negative Allometric)

Table 2. Condition Index Criteria for *Anodontostoma chacunda*

Criteria condition index*	Body shape	Males	Females	Percentage (%)	
				Males	Females
0	There isn't any	0	0	0.0	0.0
0.1 to 0.49	Very thin	0	0	0.0	0.0
0.50 to 0.99	Thin	245	179	52.9	54.9
1	Proportional	82	31	17.7	9.5
1.01 to 1.50	Fat	136	116	29.4	35.6
>1.51	Very Fat	0	0	0.0	0.0

Note: *The value of the Criteria Condition Index follows Firdaus et al. (2020); Salim et al. (2020a, 2021, 2023b); Indarjo et al. (2020a, b; 2021; 2022; 2023a, b)

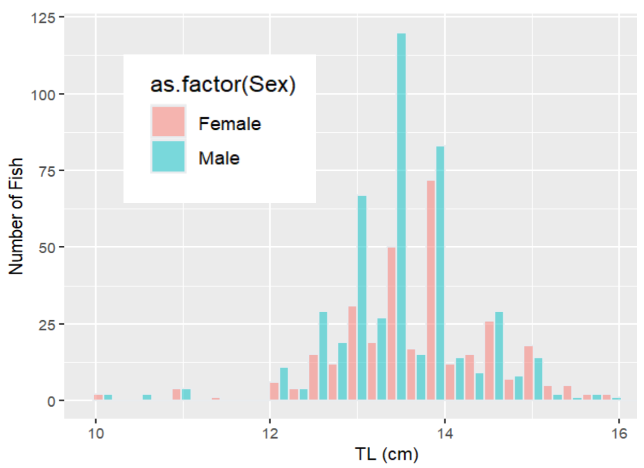


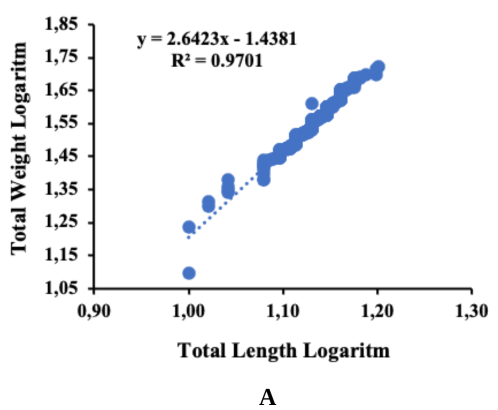
Figure 3. The length frequency distribution of males and females of *Anodontostoma chacunda*

Mortality

Based on Table 3, the data elucidates the variable mortality rates in a comparative analysis between males and females *A. chacunda* fish. For total mortality (Z), fishing mortality (F), and natural mortality (M), the values for females are higher than those for males *A. chacunda*, with values of 2.460/year; 2.239/year; 0.221/year for females and 2.429/year; 2.211/year; and 0,221/year for males. However, the exploitation rate (E) for males and females has the same value, namely 0.910/year.

Table 3. Variable mortality between male and female *Anodontostoma chacunda*

Variable	Value	
	Male	Female
Mortality Total (Z)	2.429	2.460
Mortality Catch (F)	2.211	2.239
Mortality Nature (M)	0.218	0.221
Exploitation rate (E)	0.910	0.910



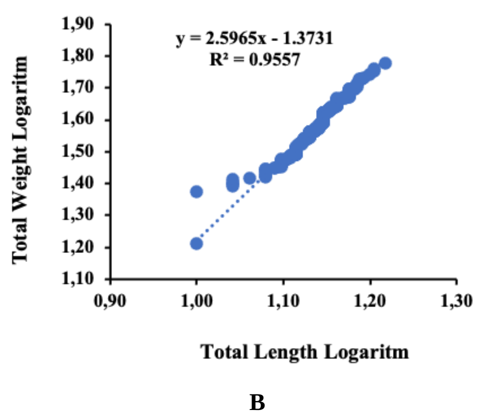


Figure 4. Logarithmic relationship between length and weight with regression equation of *Anodontostoma chacunda*. A. Males, B. Females

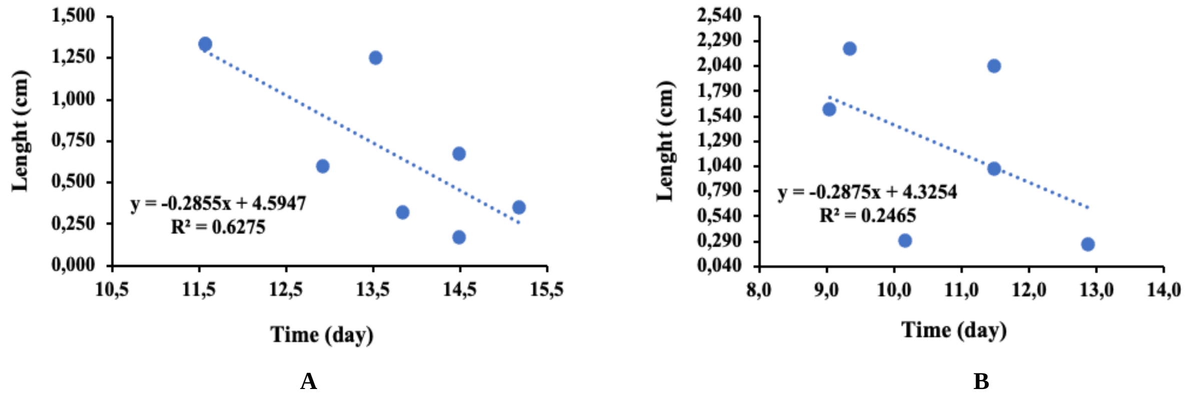


Figure 5. Age structure model of *Anodontostoma chacunda*. A. Males, B. Females

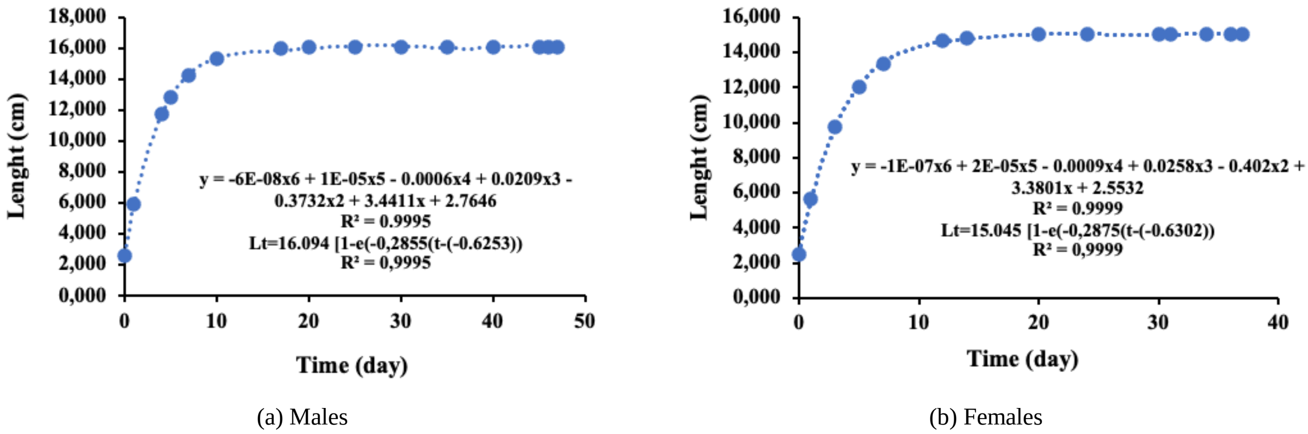


Figure 6. Von Bertalanffy model for males (a) and females (b) *A. chacunda*

Discussion

Size distribution and length-weight relationship

The present study of length-frequency distributions offers some insight into the size distribution of *A. chacunda* found in Tarakan's waters. *Anodontostoma chacunda* from Tarakan has a mean length of 13.5±0.78 cm for males and 13.7±0,9 cm for females, which is known to be almost similar to fish from Johor, Malaysia (13.6±0.23 cm). However, they are smaller than fish from the coast of Mumbai (16.38±0.13 cm) and larger than fish from Tanjung Pinang waters (12.88±2.19 cm) (Dar et al. 2014; Das et al. 2021; Zahid et al. 2022).

Based on Table 1, it is elucidated that the growth model of both sexes is negative allometric. Effendie (2002) explains that negative allometry signifies that the length growth of males and females *A. chacunda* fish is faster than their weight gain. Meretsky et al. (2011) explained that changes in the weight of fish, whether large (b>3) or small (b<3) depend on the intake of food in the environment and the use of energy for the body and reproduction, which can affect the weight of different fish even though they are the same length. According to Gunadi et al. (2021) explained that if value b<3 there are environmental conditions that do not match the environmental needs for normal growth. According to Gunadi et al. (2021) explained that the existence of various variations in the value of b, both negative allometry, positive allometry and isometry, has various factors that can affect one of them, namely the availability of food in the waters, adaptation to the aquatic environment in the ecosystem habitat (Salim et al. 2023b), fish sex (Safran 1992), growing season, body shape (Firdaus and Salim 2011), and fish physiological factors (Salim and Anggoro 2019).

Similar findings regarding the negative allometric of *A. chacunda* were reported by Das et al. (2021) from Mersing Coastal Waters, Malaysia, and Dar et al. (2014) from Mumbai Coast, India, with b values 2.534 and 1.985, respectively. A different growth pattern was found in *A. chacunda* from Tanjung Pinang, Indonesia, showing an isometric growth pattern with a b value of 3.04 (Zahid et al. 2022). Growth pattern *A. chacunda* a coastal artisanal fishery, southern Bangladesh, obtained isometric growth with a value of b = 3.04 (Siddik et al. 2016).

According to Mehanna and Farouk (2021), within a species, the robustness (health) of individual fish determines the link between length and weight (Prestes et al. 2019). Variations in the length-weight relationship may also be influenced by variables such as water temperature, salinity, food (amount, quality, and size), time of year, sex, gonad maturity, stomach fullness, health and habitat, stage of maturation, and length ranges of the specimen captured (Froese 2006).

Condition index

According to Salim et al. (2023a) explained that the index condition is still related to the length-weight relationship with the regression equation and b value. The results of research on the growth pattern of male and female fish have a negative allometric growth pattern. Information about the physiological (Diao et al. 2023) state of fish concerning its welfare can be found in the condition factor (K) (Oyetunji et al. 2022). The present study's result revealed that most fishes have a thin body shape. No significant differences in the sexes' relative condition factor (Kn) were observed. The Kn values calculated for males and females were 0.7804-1.165 (0.99±0.03) and 0.937-1.421(0.09±0.04), respectively. Meanwhile, the Kn value of *A. chacunda* from other locations (Mersing Coastal Waters, Johor, Malaysia) ranged between 1.075-1.204 (Das et al. 2021) and 0.84-1.04 (Zahid et al. 2022). The condition factor of fish may differ spatially (Kazarinov et al. 2023) and temporally (Zahid et al. 2022; Jisr et al. 2018), among them are caused by differences in food (Orlov and Frenkel 2019) and physicochemical parameters (Wuave and Sabo 2023). Because these biometric units help to understand the general well-being and growth trend of the fish population, the condition factor is significant in fishery evaluation and management (Pathak et al. 2022).

Das et al. (2021) explained that Malaysian waters have a stable temperature, so the main factor in growth is not caused by the change of season and photoperiod of the catch. According to Salim et al. (2023a), the growth pattern is influenced by the environmental conditions and where the fish live. The success of finding food has an impact, and the first time the gonads mature can determine and influence their growth because the food consumed and digested by the fish is the energy used for the development of the gonads. Salim et al. (2023b) added that their bodies' energy has been divided between length growth and gonads, which is important for maintaining stability and avoiding predators, including fishermen. Paujiah et al. (2022) stated that the condition factors between males and females differ due to gender, research location, and aquatic ecological habitat.

Growth parameters

According to Yonvitner et al. (2021) and Achmad et al. (2023), fish growth is an important indicator for assessing the potential for recruitment and recovery of fish population biomass. Based on the von Bertalanffy analysis model in Figure 5, it is found that the growth of an asymptotic length (L_∞) for males is 16.094 cm and females L_∞ is 15.045 cm. In males, it takes about 47 days to reach a size of 16.094 cm with a growth rate of 0.2855/year. While the females in reaching the size of 15.045 cm takes about 37 days with a growth rate of about 0.2875/year. This is different from the asymptotic growth of research Michaletz (2014) regarding the Von Bertalanffy Model of *A. chacunda* in reservoir eutrophic Missouri, USA, obtained curves for gizzard shad in Long Branch (LOB), Mark Twain (MTL), and Thomas Hill (THL) lakes. Equations are L_t =24.553 $(1\text{-}e^{-0.284(t\ +1.863)})$ for LOB ($r^2 = 0.98$; $p < 0.0001$), L_t =23.347$(1\text{-}e^{-0.412(t+ 0.830)})$ for MTL ($r^2 = 0.99$; $p < 0.0001$), and L_t = 24.428$(1\text{-}e^{-0.346(t\ +0.755)})$ for THL ($r^2 = 0.99$; $p < 0.0001$).

Although the distribution of this fish can be found in almost all Indonesian waters (Froese and Pauly 2021), data related to the growth parameters of this fish is still limited. From Fishbase, only data from two locations were published. Based on Figure 6, it is explained that *A. chacunda* males fish that is obtained at the smallest size of 10 cm has an age of about 4 days while *A. chacunda* females obtained at the smallest size of 8 cm has an age of about 4 days. *A. chacunda* males reach a size of 16 cm with an age of 20 days, while *A. chacunda* females reach a size of 15 cm with an age of 20 days. This explains that the growth conditions of *A. chacunda* both males and females have a long life cycle to reach the asymptotic length of males in reaching 16.094 cm at the age of 47 days while the asymptotic length of females in reaching 15.045 cm at the age of 37 days. This is in accordance with the very strong correlation value found in Figure 6 with a p value of 0.01. According to Ahti et al. (2020), there is a strong correlation between the von Bertalanffy growth parameters L_∞ (asymptotic length) and k (the intrinsic individual growth rate). Wandira et al. (2018) stated that the faster the growth rate, the faster the fish approaches the asymptotic length, and the faster the fish dies. Salim et al. (2023b) explained that the number of fish in each class at a certain time depends on the recruitment that occurs every year, and most of the lost species are caused by human exploitation or natural causes.

Mortality

The mortality parameters from this study seem to be the first data published for *A. chacunda.* There are no differences in mortality parameters between males and females. The fishing mortality of both sexes of this fish was significantly higher than the natural mortality (F>M). The high value of fishing mortality and exploitation rate reflects the high level of exploitation of *A. chacunda* in Tarakan Waters by estimating fishing mortality (F=2.211-2.239/year), natural mortality (N=0.218-0.221/year) and total mortality (Z=2.429-2,460/year) which causes exploitation rate (E=0.910). According to Sparre and Venema (1999), if based on the value of Fishing mortality caused by excessive fishing, it is higher than the natural mortality rate, this explains that the higher growth rate of excessive fishing has resulted in the discovery of a small number of adult *A. chacunda*. Sibagariang et al. (2023) added that a high exploitation rate value indicates vulnerability to overfishing. The difference in mortality rates in different waters can be caused by fishing pressure and environmental conditions.

The natural mortality (M) value can influence the stock condition of *A. chacunda* and the ecological habitat in waters in Tarakan. Some factors that may influence natural mortality are diseases, old age, predation, spawning stress, and starvation (Nadia et al. 2023). However, the results of the research on the negative allometric growth pattern and the index of conditions that have a thin body shape in males and females that occur are caused by the low amount of food for *A. chacunda* and the environment of the aquatic ecological habitat of *A. chacunda* with a range of values natural mortality (M=0.218-0,221) which is believed to be caused by an unbalanced food chain (predation). According to Sparre and Venema (1999) explained that the factors that cause mortality in the decrease of population stock are caused by fishing, predation, disease, and old age.

According to Dienye et al. (2023), the exploitation rate ranges from 0 to 1. It is optimum at 0.5 (E=0.5), under-exploited when less than 0.5 (E<0.5), and over-exploited when the estimate is above 0,5 (E>0.5). The current exploitation rate (E) of *A. chacunda* in males and females has the same value of around 0.910 was higher than the optimum exploitation rate (E>0.5). This result showed that the stock of *A. chacunda* in Tarakan Water is over-exploited. This is in accordance with the results of this study showing that fishing mortality is higher compared to natural mortality (F>M). the occurrence of over-exploited is caused by high fishing mortality. According to Patterson (1992) explained that the value of exploitation is 0.5 where fishing activities can have an impact on the occurrence of a decrease in the abundance of fish stocks. According to Salim et al. (2020b) explained that the optimal exploitation level is 0.4 to prevent the depletion of the fish population stock in nature.

Based on the research results, it is concluded that the allometric growth model of *A. chacunda* is negative allometric, with the body shape from the condition index model being dominated by a thin body form. The Von Bertalanffy model for males revealed an asymptotic length of 16.094 cm at the age of 47 days with an average growth rate of 0.2855cm/year, and for females, an asymptotic length of 15.045 cm at the age of 37 days with an average growth rate of 0.2875cm/year. The fishing mortality of both sexes was significantly higher than the natural mortality. The current exploitation rate of *A. chacunda* was higher than the optimum (E=0.5). This result showed that the stock of *A. chacunda* in Tarakan Water is still over-exploited. Gulland (1971) and Pauly (1983) explained that if the value of E = 0.5 shows that the value is optimal (E_{opt}), this is based on the assumption that the balanced result is optimal when F=M. Aulia et al. (2023) explained that differences in mortality rates in different waters in different ecological habitat areas are caused by differences in fishing pressure and environmental conditions. According to Michaletz (2014) explained that the waters have a dynamic nature, the population stock of the ecosystem is also varied and complex from time to time so there is a need for research on ecosystem dynamics within the scope of temporal effects in ecosystem habitats. Therefore, knowledge information regarding stock size conditions and exploitation will be important in the coming years from an ecological point of view (Daban et al. 2023). This can be done for sustainable management which is important for *A. chacunda*. Information on growth patterns and mortality has important information for the management of fishery resources for sustainable development (Indarjo et al. 2023b).

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