Food, Feeding Habits and Reproductive Biology of the Red Belly Tilapia (Tilapia zillii) in Lake Tinishu Abaya, Ethiopia: Implication for Food Security and Income

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Abstract

Understanding food, feeding habits and the reproductive dynamics of fish species is essential for fishery management. This study examines food, feeding habits and the reproductive biology of the red belly tilapia (Tilapia zillii) in Lake Tinishu Abaya sampled from February 2023 to January 2024. Stomach content analysis was conducted using frequency of occurrence and volumetric methods of analyses. The diet primarily consisted of phytoplankton (52.9%), detritus (21.2%), and macrophytes (20.8%) by volume. Seasonal shifts noted variation was slight during the study period. Smaller fish consumed zooplankton and insects, while adults fed on macrophytes and detritus. Of the 620 fish captured, 65.3% were males, resulting in a male-to-female ratio of 1:0.53, significantly differing from a 1:1 ratio. The length at which 50% reached sexual maturity was 14.1 cm for males and 14.2 cm for females, with an average fecundity of 284.8 eggs per female. Breeding peaked from February to June, with continuous breeding observed year-round. These findings underscore the importance of effective management strategies to enhance fish populations and promote sustainable fishery practices. Such initiatives are vital for supporting local communities that depend on these resources for their livelihoods. Additionally, further research is needed on the dynamics of sex ratios in Lake Tinishu Abaya.

Keywords: *Tilapia zillii, Breeding season, Feeding behaviour, Fecundity, Sex ratio, Sexual maturity*

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1. Introduction

The redbelly tilapia (*Coptodon zillii*), formerly known as *Tilapia zillii*, is a Cichlid fish native to northern Africa and parts of the Middle East (Philippart and Ruwet, 1982). Its native range includes the southern coast of Morocco, the Congo River basin, and most of the Nile River basin. It is now widely distributed and established in many countries, including Ethiopia, (Temesgen *et al*., 2024). *Tilapia zillii* plays a vital role economically and ecologically as a food source, in aquaculture, and in recreational fisheries (Mehanna, 2004). However, it is also known for its aggressive and invasive nature, which can negatively impact native ecosystems and species due to its high adaptability (Nico *et al*., 2020). This species thrives in various environmental conditions, tolerating saline waters and providing a low-cost source of nutritious protein with excellent fillet quality (Oladimeji & Olaosebikan, 2017).

Fisheries are crucial for food security and nutrition, offering high-quality protein and income (Kurien *et al*., 2013, cited in Breuil & Grima, 2014). Effective fisheries management, informed by scientific research, is essential for balancing resource use with conservation, ultimately supporting sustainable development goals. Understanding the feeding habits and reproductive dynamics of fish species is fundamental for enhancing productivity and managing aquatic ecosystems (Otieno *et al*., 2014; Shalloof & Khalifa, 2009).

Lake Tinishu Abaya harbors a diverse range of fish species, including *Tilapia zillii*, which is native to the lake (Yirga & Brook, 2018). Despite previous studies on the feeding habits (Alemayehu & Abebe, 2004; Elias et al., 2014) and reproductive biology (Alemayehu & Padanillay, 2008) of *T. zillii* in Lake Ziway, no studies have been conducted on this species in other Ethiopian lakes. Therefore, there has been no prior research on these aspects in Lake Tinishu Abaya. This study aims to investigate the feeding habits and reproductive biology including sex ratio, breeding season, gonadosomatic index, length at sexual maturity, and fecundity of *T. zillii* in Lake Tinishu Abaya, Ethiopia.

2. Materials and methods

2.1 Description of the study area

Lake Tinishu Abaya (local name; Siltie Abaya hayk) is located approximately 160 km southwest of Addis Ababa, the capital city of Ethiopia. The lake is situated in the Siltie Zone (East Silti District, Gebrie–Ber Town) of Central Ethiopian Region. It is found in a small village located about 15 km in the eastern direction from the town of Kebet. The geographical coordinates of Lake Tinishu Abaya are 7°29'03.65''N latitude and 38°03'17.79''E longitude, at an altitude of 1,835 meters above sea level.

Lake Tinishu Abaya is a small-sized (12.53 km^2) inland freshwater system (Yirga and Brook, 2018). It is a shallow lake with a maximum depth of 3.7 m and a mean depth of 2.9 m. The lake is almost oval in shape (Fig 1). Lake Tinishu Abaya has two feeder rivers and a single outlet. The Dacha River in the northern corner and the Boboda River in the southern corner are the main tributaries to the lake, while the Badober River in the northern corner serves as the outlet. Both the Dacha and Boboda Rivers are perennial, and the Badober River is always active. The fish species found in the lake include the Nile Tilapia, *Oreochromis niloticus* (L. 1758), *T. zillii*), and the African big barb (*Labeobarbus intermedius*) (Rüppel, 1836) (Yirga & Brook, 2018).

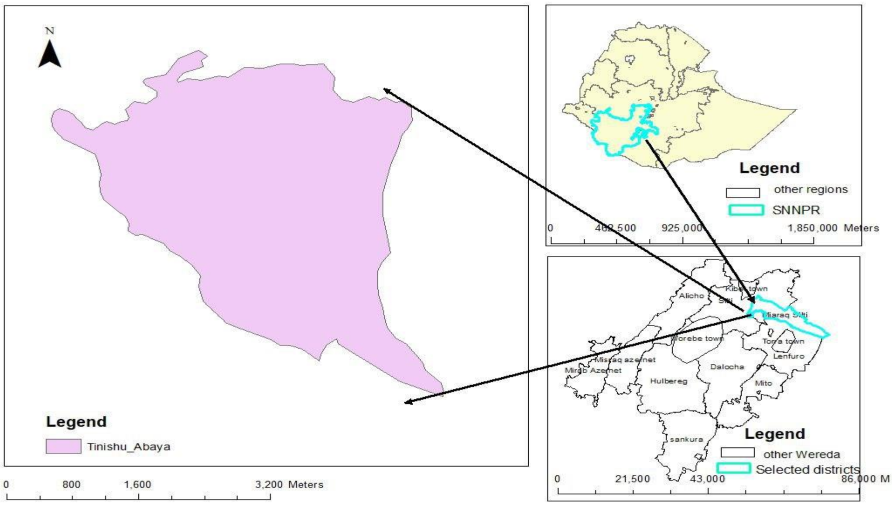

Figure 1. Map of Tinishu Abaya location in Central Ethiopia (A) and Map of Lake Tinishu Abaya Map of Central Ethiopia location in Ethiopia (B) (Source: Authors' conceptualization, 2023)

2.2 Fish sample collection and measurements

Fish samples were collected monthly from Lake Tinishu Abaya for a 12-month period from February 2023 to January 2024. Experimental monofilament gillnets with stretched mesh sizes of 3, 4, 6, 8, and 10 cm were used for sample collection. Immediately after being captured, the total length (to the nearest mm) and total weight (to the nearest gram) of each fish were measured using a measuring board and a sensitive balance, respectively. After this, the fish were dissected and then the gonads and stomach contents were preserved in 5% formalin solution.

2.3 Food and feeding habits

2.3.1 Stomach content analysis

The stomach contents of the collected fish samples were preserved in 5% formalin solution and transported to the Aquatic Sciences, Fisheries and Aquaculture laboratory at Hawassa University for analysis. The stomach contents were dispersed in a small amount of distilled water, and sub-samples were observed and identified under a dissecting and compound microscopes. The relative importance of the different food items found in the stomach contents was determined using the frequency of occurrence and volumetric method of analysis (Hyslop, 1980).

2.3.2 Frequency of occurrence

The number of stomach samples containing a particular food item was expressed as a percentage of all non-empty stomachs examined. This method provides an estimate of the proportion of the population that feeds on a specific food item. The formula used was:

$$Fi = (Ti/Si) * 100 \quad \text{......eq5}$$

Where: Fi= Frequency of Occurrence, Ti= Number of fish with a particular food item

Si = Total number of stomachs with food

2.3.3 Volumetric analysis

The water displaced by each food item sample was measured in a partially filled graduated cylinder (Hyslop, 1980). The volume of water displaced by each category of food items was then expressed as a percentage of the total volume of the stomach contents. The frequency of occurrence (%Fi) and volumetric contribution (%Vi) were used to calculate the index of food preponderance (IPi), which is a method of grading the food elements in the stomach analysis of fishes (Tomojiri *et al*., 2019). The formula used was:

$$IPi = (\%Fi * \%Vi) / \Sigma(\%Fi + \%Vi) * 100 \quad \text{......eq6}$$

Additionally, the ontogenetic dietary shift was analyzed by classifying the fish into three different length groups and determining the importance of various food categories using the volumetric method.

2.4 Reproductive biology

2.4.1 Sex ratio

The sex of each fish specimen was initially determined by visual examination. This was later confirmed by dissecting the fish and directly examining the gonads. The sex ratio was calculated as the number of females divided by the number of males (Oso *et al*., 2013).

2.4.2 Length at first maturity

The average length at which 50% (Lm50) of the fish had mature gonads (stages III, IV, and V) was estimated using a logistic relationship between the proportion of mature fish per length class and fish length (King, 1995). The logistic equation used is:

$$P=1/(1+\exp(\alpha-(\beta*L))) \qquad \text{eq.1}$$

Where:

P = the proportion of mature fish in the length groups

L = the length groups (cm)

α and β are the intercept and slope of the relationship, respectively

The parameters for this relationship were obtained by fitting a logistic regression procedure using the equation:

$$\ln(1/(Mn/Tn)+1)=\alpha\beta L \qquad \text{eq.2}$$

Where:

Mn = the number of mature fish in each size class

Tn = the total number of fish in each size class

The average length at which 50% of the fish possessed mature gonads (Lm50) was then estimated by dividing the intercept (α) by the slope (β) of the above relationship. The fish were grouped into 2- cm size classes (Omotosho, 1993).

2.4.3 Fecundity

Fecundity, which represents the number of eggs produced by a female fish during a single spawning season, was estimated using a direct counting method. Ripe female fish were collected, and their ovaries were preserved in a formalin solution for subsequent fecundity analysis. The total number of eggs per ovary was determined by counting. The relationship between fecundity and the fish's total length (TL) as well as total weight (TW) was determined using the following regression equations (Crim and Glebe, 1990):

$F=a\times TL^b; F=a\times TW^b$……………………………………..eq3

Where: F = Fecundity (total number of eggs), TL = Total length of the fish, TW = Total weight of the fish, a = Constant, b = Exponent

2.4.4 Breeding Season

Breeding season was determined based on the seasonal catch of individuals with fully ripe (stage IV) gonads.

2.4.5 Gonad somatic index (GSI)

The gonad-somatic index (GSI) was calculated to determine the seasonal variations in the spawning activity of the fish species. The GSI was estimated as the ratio of gonad weight (GW) to total body weight (TW), expressed as a percentage:

$GSI=(GW/TW) \times 100$……………………………………..eq4

2.5 Data analysis

The data collected during the study were analyzed using Microsoft Excel software, and various descriptive statistics were employed to summarize the findings. One-way ANOVA was used to examine the monthly variations in breeding season and gonad-somatic index. The relationships between fecundity and total length (TL) as well as total weight (TW) were estimated using regression analysis. The length at 50% maturity (L_{m50}) was determined by applying a logistic function to the relationship between the percentage of mature fish and different size classes. Additionally, the chi-square test was utilized to assess the sex ratio of the fish population. For the dietary analysis of *T. zillii*, the frequency of occurrence and volume of the food items were used to calculate the percent contribution of each food category. Furthermore, the index of preponderance was determined to rank the importance of the different food elements in the stomach contents.

3.Results

3.1 Food and feeding habit

3.1.1 Stomach content analysis (Diet composition)

Out of 620 *T. zillii* samples collected, 538 (86.77%) had food in their stomachs, while 84 (13.5%) had empty stomachs. The size range of the fish analyzed was 6.5-25 cm total length and 20.5-185.5 g total weight. The identified food items in *T. zillii* stomachs included phytoplankton, zooplankton, detritus, macrophytes, insects, fish parts, fish eggs, ostracods, and nematodes. Phytoplankton, detritus, and macrophytes were the dominant food items, occurring in 99.1%, 98.0%, and 86.03% of the stomach contents, respectively and volumetrically constituting 52.91%, 21.20% and 20.84%, respectively (Table 1). Zooplankton and insects were minor components, occurring in 32.22% and 27.9% of the stomach contents, respectively and volumetrically comprising 3.31% and 0.91%, respectively. The contributions of other food categories, namely ostracods, nematodes, fish and fish scales were negligible where they collectively constituted less than 1% of the total volume of food consumed. The Index of Preponderance (IP) analysis further confirmed the dominance of phytoplankton (36.69%), followed by detritus (14.53%), and macrophytes (12.54%) in the *T. zillii* diet.

Table 1. Diet composition of *T.zillii* from Lake Tinishu Abaya

	Frequency of occurrence		Volume contribution		Index of Preponderance	
Food Item	Frequency	%	Volume	%	IP	%IP
Phytoplankton	**532**	**99.07**	**300.05**	**52.91**	**5232.22**	**36.69**
Diatoms	*519*	*96.65*	*102.52*	*18.08*	*1744.02*	*12.23*
Blue green algae	*527*	*98.14*	*111.08*	*19.59*	*1918.79*	*13.46*
Green algae	*481*	*89.57*	*76.39*	*13.47*	*1204.37*	*8.45*
Euglinoids	*250*	*46.56*	*10.06*	*1.77*	*82.45*	*0.58*
Zooplankton	**173**	**32.22**	**18.74**	**3.31**	**106.27**	**0.75**
Rotifers	*114*	*21.23*	*13.95*	*2.46*	*52.13*	*0.37*
Copepods	*69*	*12.85*	*4.55*	*0.80*	*10.29*	*0.07*
Ostracods	**76**	**14.15**	**1.5015**	**0.27**	**3.74**	**0.03**
Insects	**150**	**27.93**	**5.183**	**0.91**	**25.48**	**0.18**
Diptera	*87*	*16.20*	*1.77*	*0.31*	*5.05*	*0.04*
Ephemeroptera	*62*	*11.55*	*0.4845*	*0.09*	*0.99*	*0.01*
Anisoptera	*54*	*10.06*	*1.314*	*0.23*	*2.33*	*0.02*
Hemiptera	*42*	*7.82*	*0.7885*	*0.14*	*1.09*	*0.008*
Coleoptera	*46*	*8.57*	*0.8205*	*0.15*	*1.24*	*0.009*
Nematodes	**55**	**10.24**	**1.4047**	**0.25**	**2.53**	**0.02**
Fish eggs	**22**	**4.1**	**0.407**	**0.07**	**0.29**	**0.002**
Fish scales	**70**	**13.04**	**1.3963**	**0.25**	**3.20**	**0.02**
Detritus	**526**	**97.95**	**120.24**	**21.20**	**2073.08**	**14.53**
Macrophytes	**462**	**86.03**	**118.16**	**20.84**	**1789.34**	**12.54**

(Source: Authors′ data, 2023)

3.1.2 Ontogenetic dietary shift

The ontogenetic dietary shift of *T. zillii* in Lake Tinishu Abaya showed a distinct pattern. Phytoplankton, detritus, zooplankton, and macrophytes were the dominant food items across all size classes, while the contribution of other food items, such as insects, nematodes, ostracods, and fish scales, was relatively low. In the smaller size class

(6.0-11.9 cm TL), phytoplankton (50.0%) was the most dominant food item, followed by detritus (19.9%), zooplankton (15.9%), and macrophytes (12.16%), with insects contributing only 1.22% of the total volume. As the fish grew larger (12.0-17.9 cm TL), the contribution of detritus (27.0%) and macrophytes (19.6%) increased, while the importance of zooplankton (13.2%) and phytoplankton (39.0%) decreased (Fig. 2). In the largest size class (>18 cm TL), the importance of detritus (32.4%) and macrophytes (29.9%) increased further, while the contribution of phytoplankton declined to 25.0%. The overall trend indicates that the importance of macrophytes and detritus increased with the size of *T. zillii*, whereas the importance of phytoplankton and zooplankton decreased with increasing fish size.

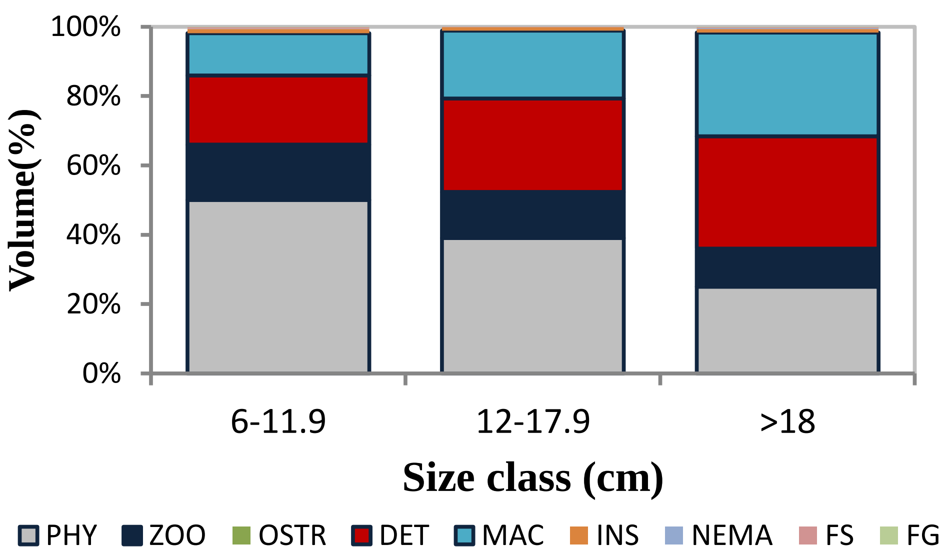

Figure 2. Ontogenetic dietary shift of T. zillii from Lake Tinishu Abaya(PHY- Phytoplankton, ZOO- Zooplankton, OSTR- Ostracods, DET- Detritus, MAC- Macrophytes, INS- Insects, NEMA- Nematodes, FS- Fish, FG- Fish eggs) **(**Source: Authors′data, 2023**)**

3.1.3 Seasonal variation of feed items

The seasonal variation in the diet of *T. zillii* in Lake Tinishu Abaya revealed clear differences between the dry (October-March) and wet (April-September) seasons. During the dry season, phytoplankton was the dominant food item, occurring in 100% of stomachs and contributing 59.98% of the total volume, whereas in the wet season its occurrence and volumetric contribution decreased to 96.97% and 47.09%, respectively (Table 2). Conversely, macrophytes had a higher contribution in the wet season, both in terms of occurrence (87.5%) and volume (25.24%), compared to the dry season (84.31% occurrence, 18.44% volume) (Table 2). Detritus also showed a seasonal pattern, with higher frequency of occurrence (99.27%) and volumetric contribution (22.38%) in the wet season than the dry season (96.95% occurrence, 18.44% volume). Zooplankton exhibited a similar seasonal trend, being more prevalent in the wet season (47.45% occurrence, 3.99% volume) than the dry season (16.41% occurrence, 0.98% volume). The contribution of insects, nematodes, ostracods, and fish eggs remained relatively small across both seasons.

Table 2. Seasonal variation of food item of *T. zillii* from Lake Tinishu Abaya (%)

Food item	Frequency		Volume		Index of preponderance	
	Wet	Dry	Wet	Dry	Wet	Dry
Phytoplankton	**96.97**	**100**	**47.09**	**59.98**	**34.23**	**39.26**
Diatoms	*93.56*	*99.27*	*14.29*	*18.19*	*10.02*	*11.82*
Blue green algae	*96.59*	*99.27*	*21.22*	*23.18*	*15.36*	*15.06*
Green algae	*86.36*	*92.34*	*10.36*	*16.34*	*6.70*	*9.88*
Euglinoids	*33.71*	*58.76*	*1.23*	*2.28*	*0.31*	*0.88*
Zooplankton	**47.45**	**16.41**	**3.99**	**0.98**	**0.49**	**0.31**
Rotifers	*11.74*	*30.29*	*0.23*	*0.79*	*0.02*	*0.16*
Copepods	*6.44*	*18.98*	*0.06*	*0.13*	*0.003*	*0.02*
Ostracods	**10.99**	**17.15**	**0.21**	**0.31**	**0.02**	**0.04**

Insects	**19.7**	**35.77**	**0.56**	**1.24**	**0.08**	**0.29**
Diptera	*14.39*	*17.88*	*0.18*	*0.28*	*0.02*	*0.03*
Ephemeroptera	*9.47*	*13.50*	*0.10*	*0.07*	*0.02*	*0.01*
Aniseoptera	*7.2*	*12.77*	*0.12*	*0.34*	*0.01*	*0.03*
Hemiptera	*5.30*	*10.22*	*0.07*	*0.20*	*0.003*	*0.01*
Coleoptera	*4.55*	*12.41*	*0.04*	*0.24*	*0.002*	*0.02*
Nematodes	**10.23**	**10.22**	**0.25**	**0.25**	**0.02**	**0.02**
Fish eggs	**2.65**	**5.47**	**0.04**	**0.10**	**0.001**	**0.004**
Fish scales	**11.36**	**14.6**	**0.25**	**0.25**	**0.02**	**0.02**
Detritus	**99.27**	**96.95**	**22.38**	**18.45**	**16.14**	**11.99**
Macrophytes	**87.5**	**84.31**	**25.24**	**18.44**	**16.55**	**10.18**

3.2 Reproductive biology (Dynamics)

3.2.1 Sex ratio

The sex ratio of *T. zillii* in Lake Tinishu Abaya was examined based on a total sample of 620 fish, comprising 405 males and 215 females (Tables 3 & 4).The overall sex ratio was skewed towards males, with a significantly higher proportion of males compared to females for the medium size class ($p<0.05$). This trend was particularly evident from 10.0-13.9 cm to 18-21.9 cm size class, where the sex ratio showed a statistically significant difference from 1:1 ($p<0.05$). Furthermore, the sex ratio exhibited temporal variations, in the months of February, March, April, October, November, December and January displaying significant differences ($p<0.05$) between the male and female proportions.

Table 3. Male to female sex ratio of T. zillii at different size class from Lake Tinishu Abaya

Size class	Males	Females	Sex ratio(M:F)	Chi-square(χ^2)
6.0-9.9	0	1	1:0.0	1
10.0-13.9	84	40	1:0.48	15.6^{*}
14.0-17.9	284	157	1:0.55	36.57^{**}
18.0-21.9	35	17	1:0.49	6.23*
>=22.0	2	0	1:0.0	2

Total	405	215	1:0.53	58.23***

** indicates significant p value (Source: Authors′data, 2023)*

Table 4. Male to female sex ratio of T. zillii at different months of the year from Lake Tinishu Abaya

Month	Males	Females	Sex Ratio(M:F)	Chi- Square(χ^2)
F	40	21	1:0.5	5.92*
M	34	19	1:0.56	4.3*
A	37	9	1:0.24	17.04**
M	29	21	1:0.72	1.28
J	27	23	1:0.85	0.32
J	31	19	1:0.61	2.88
A	27	23	1:0.85	0.32
S	30	23	1:0.77	0.93
O	38	14	1:0.37	4.92*
N	33	17	1:0.52	5.12*
D	43	10	1:0.23	20.55**
J	36	16	1:0.44	7.7*
Total	405	215	1:0.53	58.23***

* indicates significant p value (Source: Authors′data, 2023)

3.2.2. Length at first maturity (L_{m50})

The length at first sexual maturity (L_{m50}) of *T. zillii* in Lake Tinishu Abaya is given in Figure 3. The smallest sexually mature male and female *T. zillii* captured during the study were 10.5 cm and 11.4 cm in total length (FL), with corresponding total weights of 30.1 g and 35.2 g, respectively. The length at which 50% of the *T. zillii* population attained sexual maturity (L_{m50}) was 14.4 cm total length (TL) for males and 14.8 cm TL for females. This indicates that males and females of *T. zillii* in Lake Tinishu Abaya reached their first sexual maturity at approximately the same body size.

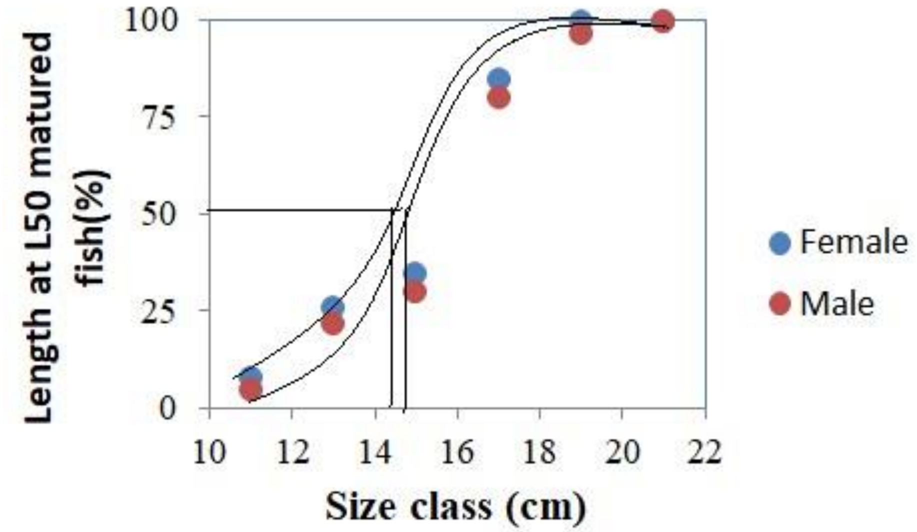

Figure 3. Length at first sexual maturity Lm50 of T. zillii from Lake Tinishu Abaya (Source: Authors' data, 2023)

3.2.3. Fecundity

The relationship between fecundity and TL, as well as fecundity and TW, of the *T. zillii* population in Lake Tinishu Abaya is presented below (Fig 4a &b). Fecundity analysis was conducted using 30 ripe female *T. zillii*, which ranged in TL from 12.1 cm to 18.1 cm and in TW from 34.1 to 97.4 g. The results showed that the total fecundity (F) varied widely, even among individuals of similar size. The total fecundity ranged from 102 to 586 eggs, with a mean (±SE) of 284.8 ± 104.9 eggs. The relationship between fecundity and TL as well as fecundity and TW was not statistically significant ($P > 0.05$). However, fecundity was found to be positively correlated with both TL ($r^2 = 0.9197$, $b = 3.01$) and TW ($r^2 = 0.8351$, $b = 1.16$), exhibiting a curvilinear relationships in both cases.

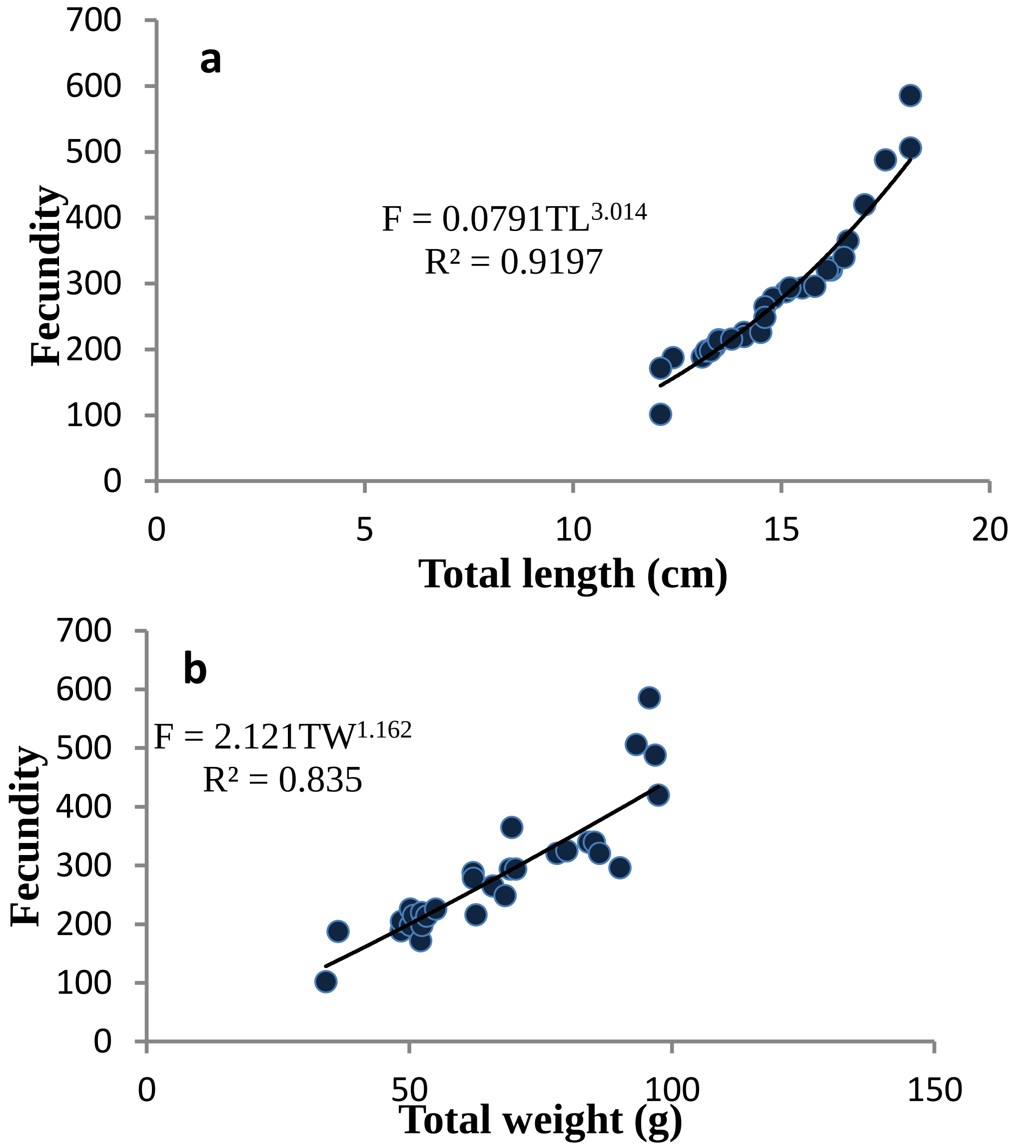

Figure 4. The relationship between fecundity and total length (a) and fecundity and total weight (b) of *T. zillii* from Lake Tinishu Abaya (Source: Authors′data, 2023)

3.2.4. Breeding season

The seasonal variation in the proportion of *T. zillii* with ripe gonads is shown in Figure 5. The results indicate that the highest number of *T. zillii* with fully mature gonads was collected between the months of February and June. In contrast, the lowest number of fish with ripe gonads was observed from October to December. Despite this seasonal pattern, ripe *T. zillii* individuals were captured throughout the year. However, the frequency of ripe males and females varied considerably between months.

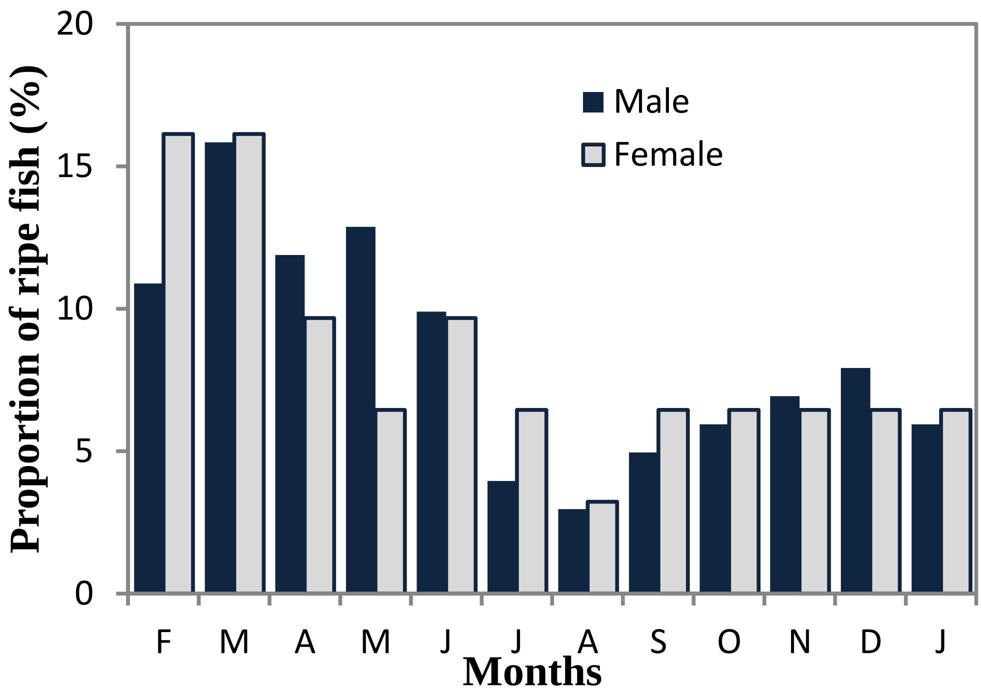

Figure 5. The breeding season of T. zillii from Lake Tinishu Abaya(Source: Authors'data, 2023)

3.2.5. Gonado somatic index (GSI)

The monthly variation in the gonado somatic index (GSI) of *T. zillii* in Lake Tinishu Abaya is presented in Figure 6. The GSI values provide an indication of the reproductive activity of the fish population. The mean (± SD) GSI values ranged from 0.15 ± 0.11 for males in October to 0.31 ± 0.59 for females in October. The highest GSI values were recorded for males in March and for females in February, suggesting these were the peak spawning months for the *T. zillii* population. Statistical analysis revealed no significant difference in GSI values between the sexes ($P>0.05$). However, the monthly mean GSI values for both males and females varied significantly between months ($P<0.05$).

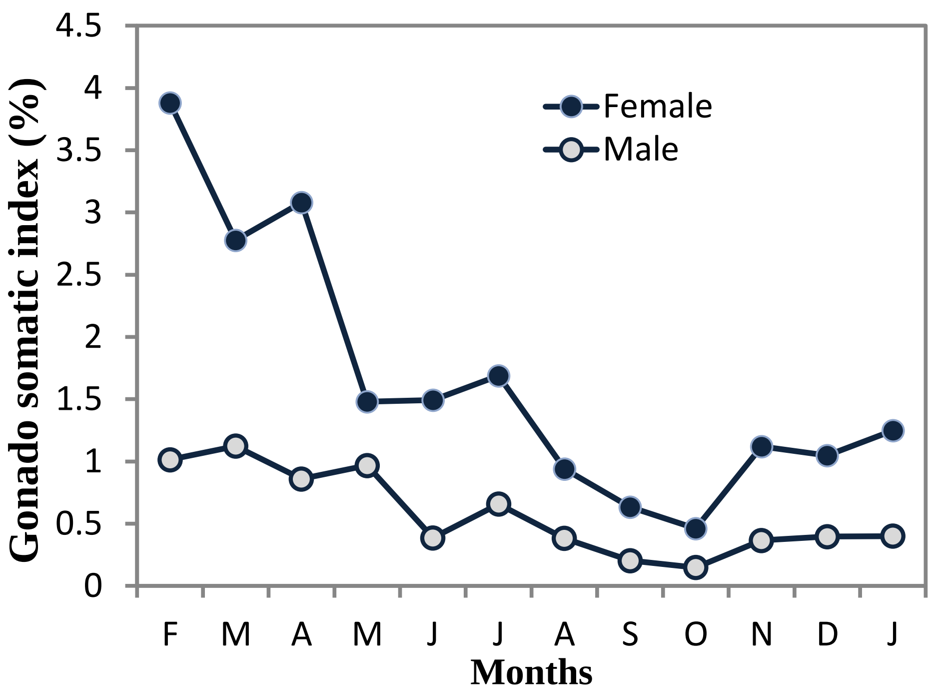

Figure 6. Average GSI of Tilapia zillii from Lake Tinishu Abaya (Source: Authors'data, 2023)

4. Discussion

The diet of *T. zillii* in the study area consisted of macrophytes, detritus, phytoplankton, insects, zooplankton, nematodes, ostracods, fish scales, and fish eggs. This diverse diet is likely due to itspreference for the shoreline habitat and its herbivorous feeding habits (Spataru, 1978; Alemayehu and Padanillay, 2008; Shalloof *et al,* 2009; Elias *et al*. 2014; Abdul-Razak and Al-Wan 2020). The variation in diet composition between lakes can be attributed to factors such as season, spatial differences, and ontogenetic dietary shifts (Workiye and Abebe, 2015). In general, phytoplankton, detritus, and macrophytes were the dominant dietary components, while zooplankton and insects were intermediate, and nematodes, fish scales, fish eggs, and ostracods were low in abundance.

The present study revealed that an ontogenetic dietary shift of the species. As the fish grew in size, the importance of macrophytes and detritus in the diet increased, while the contribution of phytoplankton and zooplankton decreased. Smaller individuals (6-11.9 cm total length) had a higher reliance on zooplankton, whereas larger fish (≥12 cm total length) predominantly consumed macrophytes and detritus. This shift in dietary preferences is consistent with the findings of other studies on *T. zillii* in Lake Ziway (Alemayehu and Padanillay 2008; Elias *et al*. 2014) and Lake Kinneret (Spataru, 1978). The most plausible explanation for this ontogenetic dietary shift is the fish's increasing energy demands and the development of its morphological and physiological characteristics.

As *T. zillii* grows, its wider mouth gape and more developed digestive system enable it to efficiently process and utilize more complex plant materials, such as macrophytes and detritus, which cannot be easily digested by younger fish. This shift from a predominantly omnivorous diet in juveniles to a more herbivorous diet in adults is likely driven by the need to meet the growing energy demands as the fish increases in size. The availability of food resources in the littoral zone of the lake, where *T. zillii* is known to prefer, also contributes to the observed dietary changes (Elias et al., 2014).

The present study on the feeding ecology of *T. zillii* in Lake Tinishu Abaya revealed notable seasonal variations in the fish's dietary composition. The proportions of different food items fluctuated considerably between the dry and wet seasons. During the wet season, the diet of *T. zillii* was dominated by higher proportions of macrophytes and detritus. This can be attributed to the increased availability of these food resources in the lake due to factors such as floods, which introduce plant materials and leaf litter, and the fish's tendency to move to the shallow, littoral zones for feeding and reproduction (Yirga et al., 2023).

In contrast, during the dry season, phytoplankton constituted a higher proportion of the fish's diet. This shift in dietary preferences is likely driven by the fish's movement towards the pelagic region of the lake, where increased light penetration into the photic zone may lead to higher phytoplankton production (Yirga and Brook et al., 2018). The seasonal variation in the dietary composition of *T. zillii* is a reflection of the fluctuations in the availability and abundance of food resources in the lake throughout the year. This adaptability in feeding behavior allows the fish to optimize its energy intake and exploit the diverse food sources available in the dynamic tropical aquatic ecosystem (Elias *et al*., 2014).

The sex ratio of *T. zillii* in the present study revealed a significant deviation from the expected 1:1 ratio ($\chi 2=58.23$; $P< 0.05$), with males outnumbering females at a ratio of 1:0.53 indicating that the sex ratio observed in the lake favors males. This trend agrees with the findings from various Ethiopian water bodies, such as Lake Ziway (1:0.78, Alemayehu & Abebe, 2004), and Lake Timsah (1:0.9, Mahomoud *et al*., 2011), as well as the Garmat Ali River in Iraq (1:0.81, Abdul-Razak and Al-Wan 2020). Males typically dominate Cichlid populations due to their greater growth rates, which may be influenced by the lake's size and the active pursuit of mates, making them more vulnerable to gill nets (Kassahun *et al*., 2011). Additionally, females tend to grow more slowly as they invest more energy in reproduction.

Brook and Yirga (2018) noted that males grow larger in smaller water bodies, a pattern supported by Lowe-McConnell (1958). Nikolsky (1963) further noted that sex ratios can vary significantly between species and across years within the same population.

The length at first sexual maturity (L_{m50}) for *T. zillii* in Lake Tinishu Abaya was estimated to be 14.5 cm TL for males and 14.8 cm TL for females. These values are consistent with the findings from other studies, such as 12.4 cm for males and 13.2 cm for females in Al-Swaib marsh (Qadoory 2012), but larger than the values reported for the Lake Timsah (8.4 cm for males and 7.5 cm for females (Mahomoud *et al*., 2011) and Garmat Ali River (8.2 cm for males and 8.4 cm for females) (Abdul-Razak and Al-Wan, 2020). In crowded environments, male tilapia tends to exhibit faster growth than females (Lowe-McConnell, 1982).

The total fecundity of *T. zillii* in the present study ranged from 102 to 586 eggs per fish, with a mean of 284.8 ± 104.9 eggs. This is lower than the fecundity estimates reported for *T. zillii* in other water bodies, such as Abu Qir Bay (2139 ± 652 eggs) (El-Sayed and Moharram 2007), the Nile River (3036 ± 157 eggs) (El-Kasheif *et al*. 2013), and Lake Edku (2367 ± 903 eggs) Phillips (1994). The variation in fecundity may be attributed to differences in ecological conditions, genetic factors, and energy allocation to gonad maturation Wootton (1990). Fecundity was positively correlated with both total length (r^2 = 0.9197, b = 3.01) and total weight (r^2 = 0.8351, b = 1.1), consistent with other studies (Qadoory, 2012). Environmental pollutants, agricultural waste, and pesticides may have a negative impact on the reproductive tissues, leading to decreased fecundity (Agumassie *et al*., 2023).

The peak breeding season of *T. zillii* observed in this study was February and March. This could be attributed to the high water temperatures and solar radiation from January to May. The variation in peak breeding seasons across different water bodies may be due to differences in water temperature, water level, and food availability (Lemma *et al*., 2015). Comparative studies have reported varying peak breeding seasons for *T. zillii*. Alemayehu and Abebe (2004) investigated that *T. zillii* in Lake Ziway, Ethiopia, exhibited year-round peak activity during the rainy season between April and September.

The highest GSI values were recorded in March and April for males and February and April for females, indicating the spawning period of *T. zillii* (Alemayehu & Padanillay, 2008; Tabasian *et al*., 2022). Previous studies have reported varying peak spawning periods for *T. zillii*. Alemayehu and Abebe (2004) observed year-round breeding with peak activity between April and September in Lake Ziway, Ethiopia. Mahmoud *et al*. (2011) reported the spawning period of *T. zillii* in Lake Timsah, Egypt, to be from January to August. The main breeding season of *T. zillii* in the current study, was found to be during the onset of the rainy season, which provides favorable conditions for food availability and nutrient inputs (Kassahun *et al*., 2011).

Previous studies indicated that fishery has an important role in achieving food security at national (Agumassie, 2019), regional (Derese & Teshale, 2021) and global (Azra *et al*., 2021) level. However, the fishery production in developing countries is challenged by a number of factors including lack of improved fish feed and breeds (Chan *et al*., 2019). Scholars advised that effective fisheries management is important during breeding season in order to sustain fish resources for food security (Agumassie, 2019; Alemayehu & Abebu, 2003). Particularly, Agumassie (2019) boldly argued that “fishing during the peak spawning season for each species in their respective water bodies should be banned or closed”, p.13.

In the present study, the breeding in *T. zillii* was found to reach at its peak during February and March in the Lake Tinishu Abaya while it was found to be year-round peaking during the season from April to September in Ziway (Alemayehu & Abebu, 2003). This variation may be attributed to variation in temperature and availability of food. This suggests that identifying the breeding season of each fish species is important for conservation and aquaculture development which has implications for food security and household income (Agumassie. 2019; Derese & Teshale, 2021). Thus, the findings of the present study have implications for fishery management and then food security.

5. Conclusion

The study of Lake Tinishu Abaya's T. *zillii* community showed its diet primarily consisted of phytoplankton, detritus, and macrophytes, with seasonal shifts in proportions. A male-dominated population and year-round breeding with seasonal peaks influenced by food availability was observed for this fish species. This finding underscores the importance of effective management strategies to enhance fish populations and promote sustainable fishery practices. *T. zillii* showed early sexual maturation and lower fecundity compared to other regions that associated with environmental conditions. Therefore, the outcomes of this study highlight the need for an effective management system and further research is needed in this lake.

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Conflict of interest

The authors declare that there is no conflict of interest It has also not been changed because it is similar to the first version

Ethical statement

The authors declare that this study was conducted in accordance with ethical guidelines

Author Contributions

The First Author Mesobework Kassa, led the research project, designed the study, and was primarily responsible for data collection and analysis. The second and third Author's Prof. Elias Dadebo and Dr. Girma Tilahun, provided critical guidance throughout the research process, contributed to the study design, and offered valuable insights during manuscript preparation and revision. All authors reviewed and approved the final manuscript.

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