





Research Article

Length–Weight Relationship, Length–Length Relationship, and Relative Condition Factors of Three Ecologically Important Fish Species From Lake Hawassa, Ethiopia

Girma Tilahun ¹, Teshome Belay ², Elias Dadebo ¹, and Degsera Aemro ³

¹Department of Aquatic Sciences, Fisheries and Aquaculture, Hawassa University, Hawassa 05, Ethiopia

²Department of Animal Sciences, Dilla University, Dilla 419, Ethiopia

³Department of Fisheries and Aquatic Sciences, Bahir Dar University, Bahir Dar 5501, Ethiopia

Correspondence should be addressed to Teshome Belay; teshimeansc@gmail.com

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Length–weight relationship (LWRs), length–length relationships (LLRs), and relative condition factor (Kn) are fundamental biological indices for fisheries stock assessment, sustainable management, and monitoring ecosystem health. This study determined the LWRs, LLRs, and Kn of three ecologically important fish species: the straightfin barb *Enteromius paludinosus*, the stone-lapping minnow *Garra quadrimaculata*, and the black lampeye *Aplocheilichthys antinorii* from Lake Hawassa, Ethiopia. A total of 1,420 samples (449 *E. paludinosus*, 176 *G. quadrimaculata*, and 795 *A. antinorii*) were collected using beach seine and hand nets in two rainy (May and June) and two dry (October and November) months of 2023. The data were analyzed using MS Excel Office 10 and IBM SPSS 27 software. The results showed that the LWRs of all considered species have a strong relationship ($r^2 = 0.96, 0.95, \text{ and } 0.85$) for *E. paludinosus*, *G. quadrimaculata*, and *A. antinorii*, respectively, and exhibit strong nonlinear relationships. The growth exponent (b) of *G. quadrimaculata* showed positive allometric growth ($b > 3$) and was significantly different from three ($p < 0.05$). However, *E. paludinosus* and *A. antinorii* showed negative allometric growth ($b < 3$) and were significantly different from the cube value ($p < 0.05$). Regarding their LLR, the coefficient of determination showed a very strong correlation ($r^2 > 0.95$) and linear relationship. No significant differences in Kn were found between sexes for *E. paludinosus*, *G. quadrimaculata*, and *A. antinorii* ($p > 0.05$). The mean relative condition factor (Kn) of all species displayed > 1 , indicating favorable Kn relative to the population average during the study period. This study provides essential baseline biological parameters for *E. paludinosus*, *G. quadrimaculata*, and *A. antinorii* in Lake Hawassa.

Keywords: *A. antinorii*; *E. paludinosus*; *G. quadrimaculata*; growth; Lake Hawassa

1. Introduction

In fishery sciences, understanding the length–weight relationship of fish species is considered a basic tool for transforming updated information for management purposes [1]. It also provides valuable insights into the condition of the fish population in a specific water body [2]. The calculated value of the growth exponent (b) from the length–weight data also helps to estimate the biomass of fish species for modeling [3]. Researchers clearly understand the

growth status of fish species; either the fish grows following isometric or allometric status depending on the exponent (b) value of the length–weight relationship, and it is expected to know whether a fish grows isometrically or allometrically [2]. Furthermore, the value of b derived from the regression line of the length–weight relationship graph helps in understanding the trophic interactions of the water bodies at all or between fish species [4]. In addition to the length–weight relationship of fish species, finding the length–length relationship (LLR) of fish species plays a vital role in fish

taxonomic studies [5] and phenotypic characterizations [6]. Other parameters, such as finding the Fulton condition factors or relative condition factor, are helpful for understanding the well-being of fish species within their aquatic environment [1]. In Ethiopian inland water bodies, findings of the length–weight relationship and condition factor of fish species have a long history and are well documented as a bibliographic profile [7]. However, the information on length–length relationships of fish species from Ethiopian inland water bodies is scarce compared to length–weight relationships.

Lake Hawassa is one of the Central Rift Valley Lakes of Ethiopia, with a haven of six different fish species, including the Nile tilapia *Oreochromis niloticus*, the African catfish *Clarias gariepinus*, the African big barb *Labeobarbus intermedius*, *Enteromius paludinosus*, *Garra quadrimaculata*, and *Aplocheilichthys antinorii* [8]. The lake also contributed 7% to the national fish production depending on the three commercially significant species, including *O. niloticus*, *C. gariepinus*, and *L. intermedius* [9]. For the commercially important fish species, the morphometric relationships were well documented, such as the length–weight relationship of *O. niloticus* [10, 11], *C. gariepinus* [8], and *L. intermedius* [12]. Regarding the length–weight relationship, length–length relationship, and relative condition factors of the smaller-sized and ecologically important species considered for this study from Lake Hawassa, data are scarce and open for discussion. However, there is sufficient information needed to examine the overall conditioning of such species. For instance, from *E. paludinosus*, a concentration of mercury was reported [13]. Similarly, from *G. quadrimaculata*, high chromium concentrations were seen [14], but all the above-mentioned authors did not elaborate about the growth and overall conditioning of the species considered for this study. These smaller-sized and ecologically significant fish species are considered an environmental marker to study the status of the aquatic environment with various aspects [15]. Additionally, they serve as prey for larger commercially important species, such as *C. gariepinus* [8] and *L. intermedius* [12]. Therefore, finding their growth conditions plays a vital role in maintaining the lake's condition and overall suitability.

However, these species are mostly found in macrophyte impounded and shore areas to escape from predators [13]. However, Lake Hawassa is exposed to different problems. Some of them are exhibiting signs of degradation of the shore area for different investment activities and advanced agriculture [16], stress-causing factors, such as the entrance of pollutant effects from various industries found around Lake Hawassa [17, 18], and signs of eutrophication of the lake [19]. All the above issues are critical conditions that require this study. Therefore, this study aimed to establish the first baseline data on length–weight relationships, length–length relationships, and relative condition factors of *E. paludinosus*, *G. quadrimaculata*, and *A. antinorii* in Lake Hawassa, Ethiopia. The information considered for this study helps scholars who need to develop Ecopath–Ecosim studies, population dynamics studies, and revised management-related legislation.

2. Materials and Methods

2.1. Description of Study Area. Lake Hawassa is one of the Ethiopian Rift Valley lakes, which is found within the watershed between the Sidama and Oromia regional states [20]. It is situated 275 km from Addis Ababa, the capital of Ethiopia, at an elevation of 1,680 m above sea level [21] (Table 1). Geographically, the lake is positioned at 6° 58'0" to 7° 6'0" N latitude and 38°22'0" to 38°30'0" E longitude (Figure 1). Due to its proximity to Hawassa City, Lake Hawassa is the most extensively studied lake by the scientific community. The lake receives water from the Tikur Wuha River but lacks a clear outlet; it is considered an endorheic lake [22]. Lake Hawassa covers a surface area of 90 km² with a maximum, minimum, and mean depth of 23 m and 10.7 m, respectively [21].

In terms of fish production potential, Lake Hawassa supports three commercially important fish species, including *O. niloticus*, *C. gariepinus*, and *L. intermedius*, and three other ecologically important cyprinids targeted in this study: *E. paludinosus*, *G. quadrimaculata*, and *A. antinorii* [8]. With the above-mentioned commercially important fish species, the lake yields 5.8 tons per square kilometer, which is higher than the production potential of larger lakes, such as Lake Tana (4.3 tons per square kilometer) and Lake Abaya (4.7 tons per square kilometer) [9]. Beyond its contribution to fish production, Lake Hawassa plays a significant role in the livelihoods of local communities. It provides employment for fishers, serves as a key food source, generates income from tourists, and supports various economic activities.

Lake Hawassa exhibits distinct seasonal physicochemical and biological characteristics influenced by stratification [23], wind effect [22], and rainfall [24] (Table 2). The lake is slightly alkaline and has a high silicate concentration (38.6 mg/L) compared to other Rift Valley lakes, such as Zwai, Abaya, and Chamo [25]. Phytoplankton diversity exceeds 100 species, dominated by green algae and blue-green algae [23, 26], that sustain herbivorous and omnivorous fish species [14, 27, 28]. Zooplankton communities mainly consist of rotifers, copepods, and cladocerans [29–31]. The lake also supports rich biodiversity, including 76 bird species from 11 orders [32], hippopotamuses [33], and different macro-invertebrate groups [34]. Those different taxa of macro-invertebrates contributed as food items for different fish species found in the lake [8].

2.2. Fish Sampling. The specimens of *E. paludinosus*, *A. antinorii*, and *G. quadrimaculata* are smaller in size and found at the vegetated shore area. Two rainy months (May and June) and two other dry months (October and November) in 2023 were considered for sampling (Figure 2). Sampling was conducted with a beach seine from the shore area of Amora Gedel vegetated sites (see Figure 1, pointed out with the red color). Two beach seine nets used were 30 m long with a 6 mm mesh size and were deployed and retrieved with the help of experienced fishers. The beach seine was set at 1:00 a.m. and moved with the aid of a red boat and fishers

TABLE 1: Morphometric characteristics of Lake Hawassa.

Parameters	Kebede et al.[21]
Elevation (masl)	1,680
Surface area (Km^2)	90
Mean depth (m)	10.7
Maximum depth (m)	23
Catchment area (Km^2)	1250
Secchi depth (m)	0.7–0.8

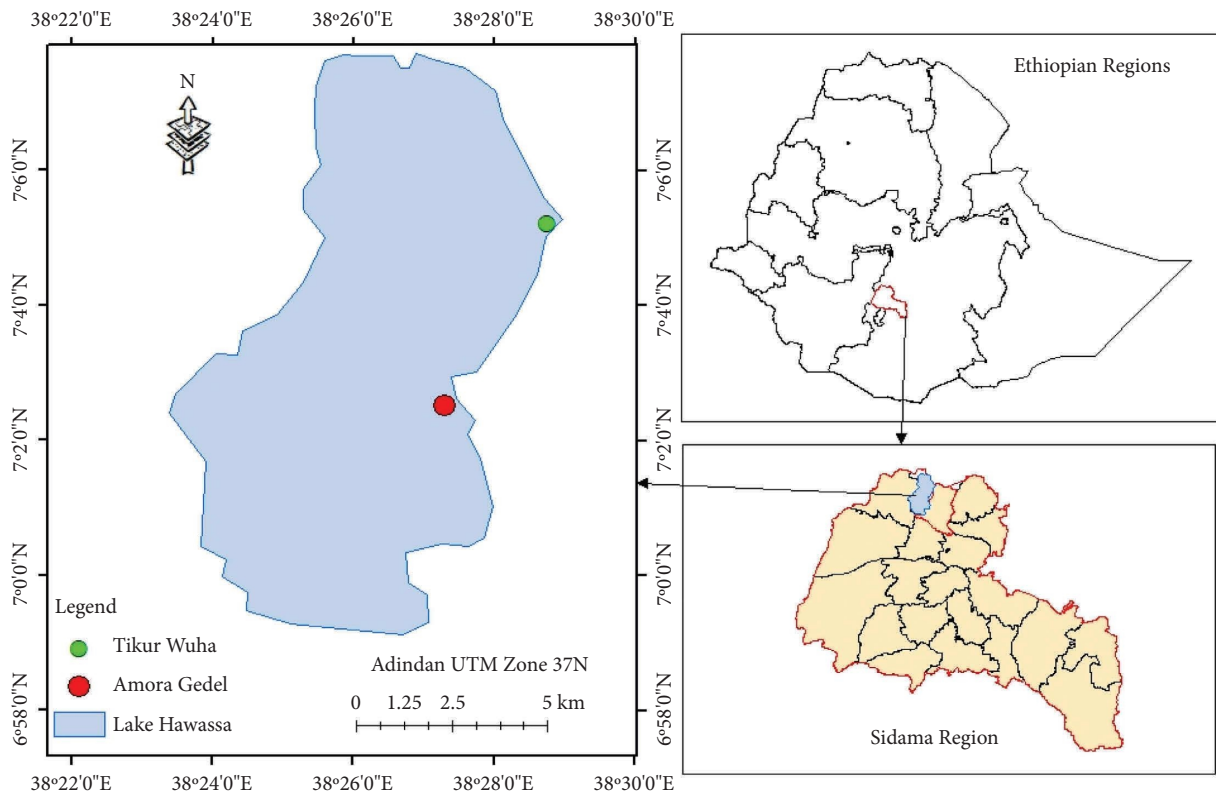


FIGURE 1: Geographic locations of Lake Hawassa.

TABLE 2: The physicochemical characteristics of Lake Hawassa.

Characteristics	Kebede et al. [21]	Mariam et al. [25]	Tilahun and Ahlgren [22]
pH	8.75	8.8	8.66 ± 1.8
T°			$23.5 \pm 1.8^\circ C$
SRP		$16.9 \mu g L^{-1}$	
K^+	$0.69 meq l^{-1}$	$0.7 meq l^{-1}$	
Mg^{2+}	$0.48 meq l^{-1}$	$0.5 meq l^{-1}$	
Ca^{2+}	$0.4 meq l^{-1}$	$0.5 meq l^{-1}$	
Na^{2+}	$5.96 meq l^{-1}$	$7.1 meq l^{-1}$	
Silicate (SiO_2)	$42.6 mg l^{-1}$	$38.6 mg l^{-1}$	$37.6 \pm 11.6 mg l^{-1}$
Conductivity	$830 \mu scm^{-1}$	$846 \mu scm^{-1}$	$844 \pm 6.5 \mu scm^{-1}$
Alkalinity	$8.25 meq l^{-1}$	$7.8 meq l^{-1}$	$7.73 \pm 0.47 meq l^{-1}$
$PO_4 P$	$12.4 \mu g L^{-1}$		$15.4 \pm 3.9 \mu g L^{-1}$
Sulfate (SO_4^{2-})	$0.73 meq l^{-1}$	$0.2 meq l^{-1}$	
Chlorophyll a		$23.4 \mu g L^{-1}$	$18.7 \pm 5.2 \mu g L^{-1}$
\sum Cations	$7.56 meq l^{-1}$	$8.8 meq l^{-1}$	
\sum Anions	$9.37 meq l^{-1}$	$8.8 meq l^{-1}$	

Note: The SI unit of considered parameters is accessed directly as the mentioned authors used.



FIGURE 2: Sampling of the species from Lake Hawassa.

against the wind action to the shore area. Additionally, to get different sizes of species, a circular hand net with a diameter of 0.2 mm was also applied. During hand net sampling, we moved around the vegetated area, which was not considered during the beach seine sampling, with the aid of a red boat and picked up the species. After collecting all the specimens, they were transferred to an icebox and immediately transported to Hawassa University, Fisheries Laboratory, for morphometric measurement.

2.3. Morphometric Measurement. The morphometric measurements of each species were conducted at the Fisheries Laboratory of Hawassa University immediately after being transported from the field. Before conducting morphometric measurements, the species were grouped into each species (Figure 3, 4 and 5). After grouping the species, the length and weight of each species were measured using a measuring board to the nearest 0.1 cm and 0.1 g, respectively. However, the smaller size of each species and *A. antinorii* was measured with an electronic sensitive balance (coded as ADAMS) to the nearest 0.0001 g at the fishery laboratory.

2.4. Data Organization and Transformation. The collected data were organized and prepared for interpretation based on the morphometric nature of each fish species. For example, *G. quadrimaculata* and *E. paludinosus* have fork length. Therefore, for those species, their total length, fork length, standard length, and total weight were measured, whereas *A. antinorii* has no fork length. For such cases, only their total length, standard length, and total weight were sorted for analysis. For length–weight relationship analysis, the sorted data were run using the power function as follows: $TW = aTL^b$ [35]; where TW = total weight of fish (g), TL = total length of fish (cm), a = the constant value of the regression line, and b = the growth exponent of the regression line. However, to calculate the significance value of slope (b) from the power function of the length–weight relationship, the data were transformed into $\log_{10}(TW)$ versus $\log_{10}(TL)$ to filter some outlier samples depending on Cook's distance [3]. Based on the value of the exponent (b) of the log-transformed equation, the fish growth was categorized into three groups [36]. When the slope value $b = 3$, the species is considered to have isometric growth; when $b < 3$, the species is considered to have negative allometric growth;



FIGURE 3: Sample of *Enteromius paludinosus* from Lake Hawassa.



FIGURE 4: Sample of *Garra quadrimaculata* from Lake Hawassa.



FIGURE 5: Sample of *Aplocheilichthys antinorii* from Lake Hawassa.

and when $b > 3$, it is considered to have positive allometric growth. Considering their length–length relationship, linear regression comparisons were applied [37]. The value was set as $Y = aX + b$, where Y and X represent the length of fish of fish species (including total length, fork length, and standard length in cm), a is the intercept, and b is considered as the slope of a regression.

2.5. Statistical Analysis and Interpretation. Descriptive statistics, such as mean, standard error, and range of the considered sample size for each species, were calculated using IBM SPSS Statistics V27. Preliminary data organization and visualization were conducted in Microsoft Excel 2010. Deviations of the length–weight growth exponent (b) from the isometric growth ($b = 3$) were assessed for each species using Student's t -test. The equation considered for t -test comparisons was calculated as $ts = (b-3)/SEb$ [37], where ts is the t calculated value, b is the slope, and SEb is the standard error of b , which was obtained from the regression analysis of the log-transformed data. Finally, the goodness of fit of the length–weight regression models was evaluated using the coefficient of determination (r^2), which represents the proportion of variance in $\log_{10}(\text{weight})$ explained by

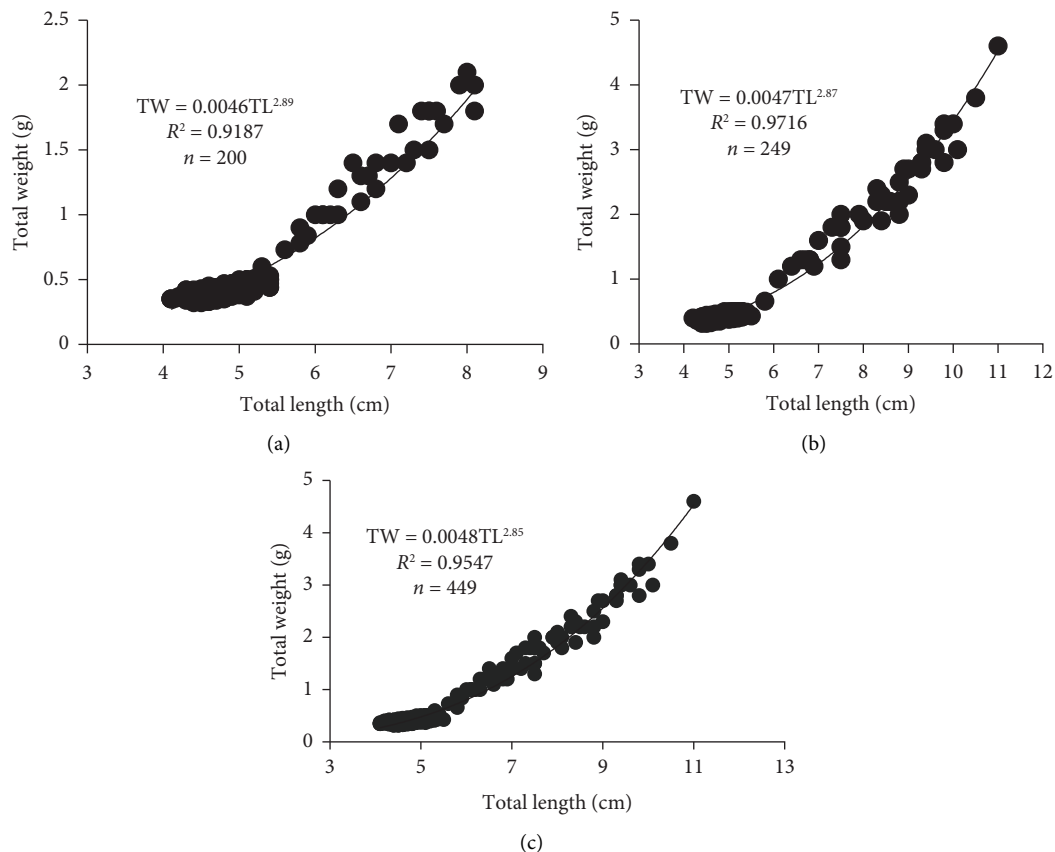


FIGURE 6: The relationship between total length (TL) and total weight (TW) of male (a) *Enteromius paludinosus* from Lake Hawassa. The relationship between total length (TL) and total weight (TW) of female (b) *E. paludinosus* from Lake Hawassa. The relationship between total length (TL) and total weight (TW) of both sexes (c) of *E. paludinosus* from Lake Hawassa.

$\log_{10}(\text{length})$. Finally, the goodness of fit of the length–weight regression model was interpreted based on the value of their coefficient of determination (r^2).

3. Results and Discussion

3.1. Length–Weight Relationship of *E. paludinosus*. After removing the outliers' samples, 449 mixed sexes of *E. paludinosus* were considered for length–weight relationship analysis. Male *E. paludinosus* ranged from 4.1 to 8.1 cm in total length and from 0.35 to 1.8 g in total weight, respectively, while female ranged from 4.1 to 11.0 cm in total length and from 0.37 to 4.6 g in total weight, respectively. A curvilinear relationship was observed between total length and total weight of males, females, and both sexes, respectively (Figures 6(a), 6(b), 6(c)). In addition to their curvilinear interactions, the relationship was also significant ($r^2 > 0.88$, $p < 0.05$). The growth exponent (b) for males, females, and mixed sexes was 2.89, 2.87, and 2.85, respectively. The equation was fitted as follows: $TW = 0.0046TL^{2.89}$, $r^2 = 0.9187$, $n = 200$ for males; $TW = 0.0047TL^{2.87}$, $r^2 = 0.9716$, $n = 249$ for females; and $TW = 0.0048TL^{2.85}$, $r^2 = 0.9547$, $n = 449$ for mixed sexes, respectively. Male *E. paludinosus* exhibited a more positive allometric growth pattern than female *E. paludinosus*. However, the growth exponent of both sexes of

E. paludinosus considered for this study indicated a negative allometric growth and was significantly different from the cube value 3 (t -test, $p < 0.05$). These values suggested that *E. paludinosus* grows slimmer as its length increases. However, the b -value for males was significantly higher than that for females, reflecting a common trend among fish species where female fish often allocate more energy to metabolic activities, such as egg production and maternal behaviors, which may impact growth [38].

The present negative allometric growth for *E. paludinosus* in Lake Hawassa contradicts findings from other inland water bodies that reported positive allometric growth from different inland water bodies. For example, studies in Lake Ziway reported that b -values of *E. paludinosus* were 3.34, 3.37, and 3.36 for males, females, and both sexes, respectively [39]. Similarly, positive allometric growth was reported in the Bangweulu Swamps of Zambia ($b = 3.319$) for mixed sexes [40], from Lake Naivasha, Kenya, for mixed sexes ($b = 3.23$) [41], and from the upper Munwahuku reservoir, Zimbabwe ($b = 3.01$), indicating nearly isometric growth [42]. However, the present negative allometric growth from Lake Hawassa for the same species showed a coinciding result from different inland water bodies. For instance, b -value of 2.85 was reported for mixed sexes of *E. paludinosus* in the lower Munwahuku reservoir, Zimbabwe [42]; b -values of 2.83 and 2.87 were

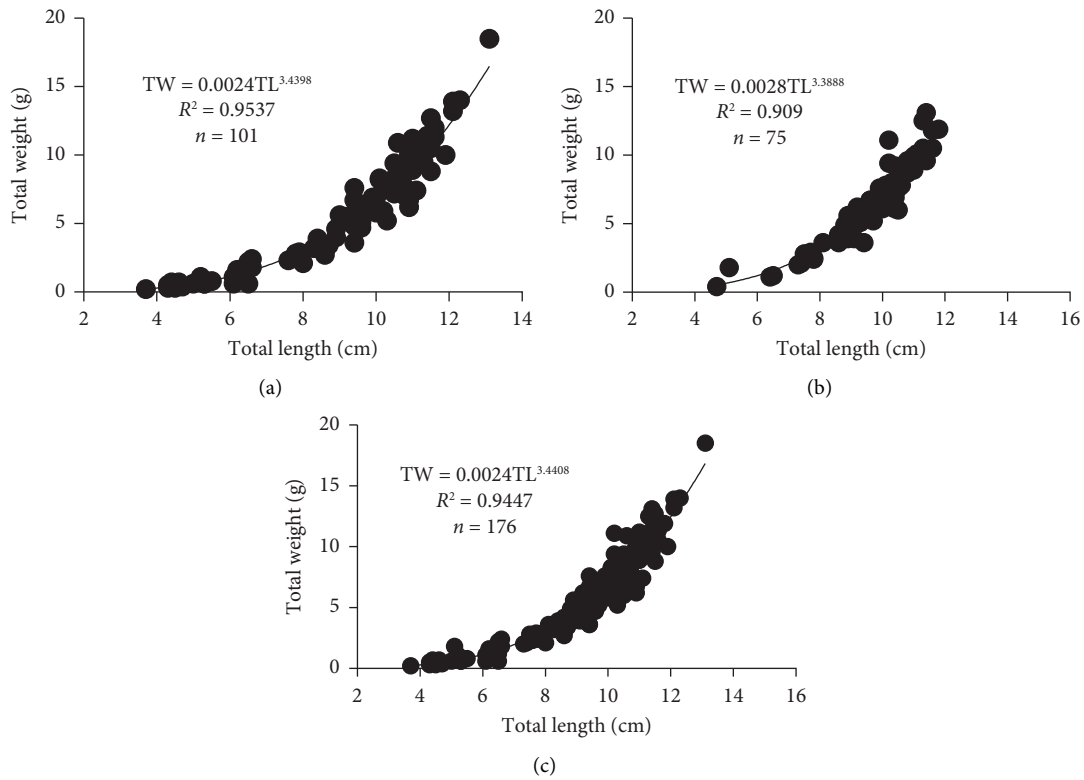


FIGURE 7: The relationship between total length (TL) and total weight (TW) of male (a) *Garra quadrimaculata* from Lake Hawassa. The relationship between total length (TL) and total weight (TW) of female (b) *G. quadrimaculata* from Lake Hawassa. The relationship between total length (TL) and total weight (TW) of both sexes (c) of *G. quadrimaculata* from Lake Hawassa.

reported for males and females, respectively [41], in Lake Naivasha, Kenya; and b-value of 2.7 was reported for mixed sexes in Lake Jibe [43]. The smaller b-values observed in this study might also be linked to pollution-related effects, where *E. paludinosus* is recognized as an environmental sensor due to its feeding habits [44]. In case of Lake Hawassa, previous studies on different areas showed a threat of several pollutants reaching the lake related to anthropogenic activities [17, 18]. Additionally, strong intraspecific competition could be another probable factor contributing to the observed poor growth in this population [45].

3.2. Length-Weight Relationship of *G. quadrimaculata*. A total of 176 samples of *G. quadrimaculata* were considered for the length-weight relationship analysis. Male *G. quadrimaculata* ranged from 3.7 to 13.1 cm in total length and from 0.2 to 18.5 g in total weight, whereas female ranged from 4.7 to 11.8 cm in total length and from 0.4 to 11.9 g in total weight, respectively. A curvilinear relationship was observed between total length and total weight (Figures 7(a), 7(b), 7(c)) and significantly interacted ($r^2 > 0.90$, $p < 0.05$). The growth exponent (b) for males, females, and both sexes was 3.45, 3.39, and 3.44, respectively. The equation displayed from the length-weight relationship was fitted as follows: $TW = 0.0024TL^{3.44}$, $r^2 = 0.95$, $n = 101$ for males; $TW = 0.0028TL^{3.39}$, $r^2 = 0.91$, $n = 75$ for females; and $TW = 0.0024TL^{3.44}$, $r^2 = 0.95$, $n = 176$ for mixed sexes of *G. quadrimaculata*. The growth exponent value of male

G. quadrimaculata in Lake Hawassa was higher than female *G. quadrimaculata*. However, the growth exponent of both sexes of *G. quadrimaculata* considered for this study indicated a positive allometric growth and was significantly different from the cube value 3 (t -test, $p < 0.05$).

The present positive allometric growth of *G. quadrimaculata* is found within the expected range of 2.5–3.5 [1]. This finding indicated a contradictory result from some findings in the Upper Awash River of Ethiopia on the same population, which was identified as negative allometric growth ($b = 2.74$) [46] and 2.9 in the same study area for mixed sexes of *G. quadrimaculata* [46], respectively. Additionally, studies from River Debbis, Ethiopia, reported that a negative allometric growth ($b = 2.62$) for mixed sexes of *G. quadrimaculata* was reported [47]. Compared to the above authors, the exponent (b) value of *G. quadrimaculata* in this study shows a higher value. This might be due to some environmental and trophic factors [48]. The prey item is another critical issue for those variations [1]. Both physicochemical characteristics and the biota that contribute as prey items of *G. quadrimaculata* at lentic and lotic water bodies might be different [49] and the probable factor for such growth variations [50].

3.3. Length-Weight Relationship of *A. antinorii*. For the analysis of length-weight relationship of *A. antinorii* from Lake Hawassa, 795 mixed sexes of *A. antinorii* were considered. Male *A. antinorii* ranged from 2.8 to 5.7 cm in total length and from 0.24 to 0.57 g in total weight, respectively, while female ranged

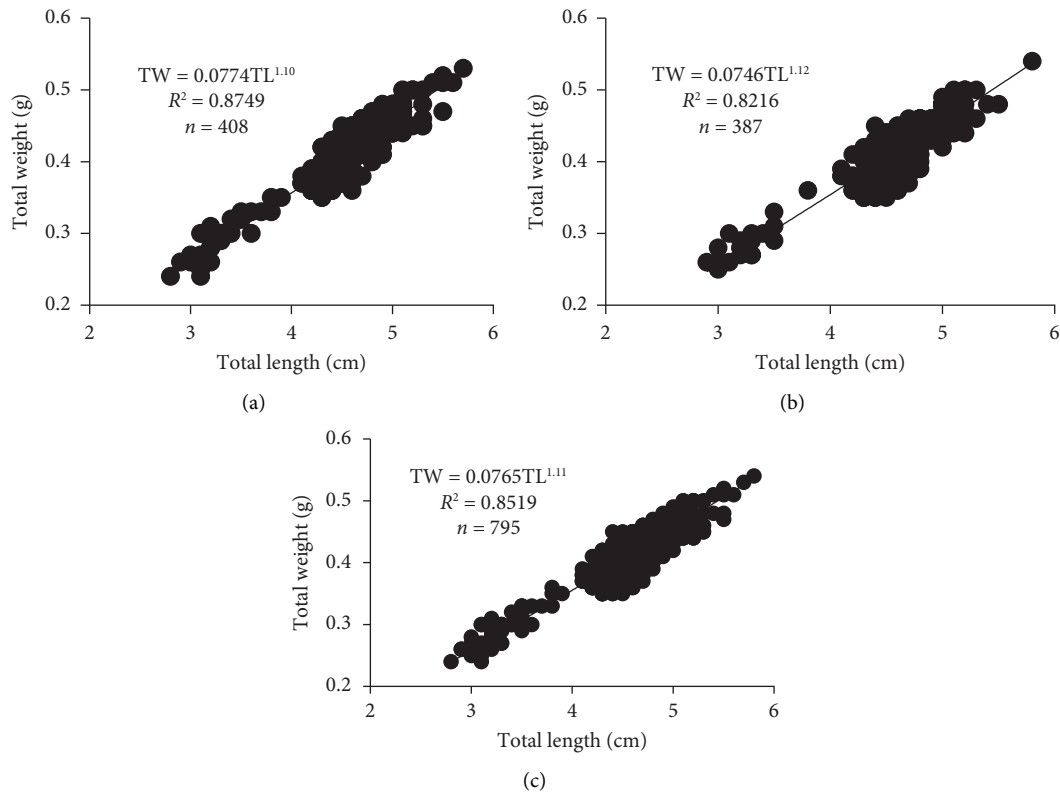


FIGURE 8: The relationship between total length (TL) and total weight (TW) of male (a) *Aplocheilichthys antinorii* from Lake Hawassa. The relationship between total length (TL) and total weight (TW) of female (b) *A. antinorii* from Lake Hawassa. The relationship between total length (TL) and total weight (TW) of both sexes (c) of *A. antinorii* from Lake Hawassa.

from 2.9 to 5.8 cm in total length and from 0.26 to 0.54g in total weight, respectively. The length–weight relationship of males, females, and mixed sexes of *A. antinorii* in Lake Hawassa considered for this study showed a slight curvilinear relationship (Figures 8(a), 8(b), 8(c)) and strongly interacted ($r^2 > 0.80$, $p < 0.05$). The growth exponent (b) for males, females, and both sexes was 1.10, 1.12, and 1.11, respectively. The equation displayed from the power function was fitted as follows: $TW = 0.0774TL^{1.10}$, $r^2 = 0.8749$, $n = 408$ for males; $TW = 0.0746TL^{1.12}$, $r^2 = 0.8216$, $n = 387$ for females; and $TW = 0.0765TL^{1.11}$, $r^2 = 0.8519$, $n = 795$ for mixed sexes, respectively. However, the growth exponent of both sexes of *A. antinorii* considered for this study indicated a negative allometric growth and was significantly different from 3 (t -test, $p < 0.05$). Considering the *A. antinorii*, this study is the first report about the length–weight relationship of this species from Lake Hawassa at all. The length–weight relationship shows a slight curvilinear relationship, with a significant interaction ($r^2 > 0.82$, $p < 0.05$). The growth exponent (b) was 1.10, 1.12, and 1.11 for males, females, and mixed sexes, respectively. To compare this result of the growth exponent of *A. antinorii*, there is no published information. However, the value of b is very small compared to the argument of b -value for fish which ranges between 2.5 and 3.5 [1]. The poor value of b suggested that the length grows more compared to the weight, and their lengths are limited within a small range of size class [1]. The present considered sample length ranged from 2.8 to 5.8 cm, and their weight ranged from 0.24 to 0.54 g, respectively. Both

their length and weight are in a fixed range. This might be the reason for this poor b -value [1]. This type of situation was observed for red band *Cepola macrophthalmma* fish species in the Marmara Sea of Turkey in which the value of b was 1.2563 [51]; for round sardinella *aurita* species, the value of b was 1.6831; and for Madeiran sardinella *Sardinella maderensis*, the value of b was 1.8355 from Gambia [52]. Similarly, the poor growth exponent ($b = 2.231$) was identified for *Barbus lineomaculatus* species from the Rift Valley of Kenyan lakes [53].

3.4. Length–Length Relationship of Three Ecologically Important Fish Species From Lake Hawassa. The overall length–length relationships of all considered fish species for this study are summarized in Table 3 below. In all cases, their relationship indicated a linear association and strongly interacted ($r^2 > 0.90$, $p < 0.05$). This indicated, in fish species at normal growth conditions, that linear relationships between their length–length relationships with strong interaction are common [1].

3.5. Relative Condition Factors. The relative condition factors of *E. paludinosus* considered for this study indicate a slight individual variation based on sex-based comparisons. Male *E. paludinosus* relative condition factor ranged from a minimum value of 0.824 to 1.544 with a mean value of 1.1498 ± 0.01042 , whereas female *E. paludinosus* relative condition factor ranged from a minimum value of 0.6874 to 1.386

TABLE 3: The length–length relationship of three ecologically important fish species from Lake Hawassa.

Fish species	Sex	Y Versus X	Equation displayed	No	r ²
<i>Enteromius paludinosus</i>	Combined	SL versus TL	SL = 0.815TL + 0.2682	449	0.989
	Combined	SL versus FL	SL = 0.9094FL + 0.0902	449	0.991
	Combined	FL versus TL	FL = 0.8932TL + 0.2116	449	0.992
	Male	FL versus TL	FL = 0.8977TL + 0.1777	200	0.985
	Male	FL versus SL	FL = 0.8981SL + 0.1376	200	0.982
	Male	SL versus TL	SL = 0.8115TL + 0.2704	200	0.981
	Female	FL versus TL	FL = 0.8906TL + 0.2341	249	0.994
	Female	SL versus FL	SL = 0.9097FL + 0.0928	249	0.993
	Female	SL versus TL	SL = 0.8124TL + 0.294	249	0.993
<i>Garra quadrimaculata</i>	Combined	FL versus TL	FL = 0.9082TL + 0.0654	176	0.992
	Combined	SL versus FL	SL = 0.9273FL – 0.0538	176	0.991
	Combined	SL versus TL	SL = 0.845TL – 0.0175	176	0.989
	Mal	FL versus TL	FL = 0.9144TL – 0.0167	101	0.994
	Male	SL versus FL	SL = 0.9258FL – 0.031	101	0.994
	Male	SL versus TL	SL = 0.8482TL – 0.0625	101	0.992
	Female	FL versus TL	FL = 0.8822TL + 0.347	75	0.985
	Female	SL versus FL	SL = 0.9357FL – 0.1412	75	0.982
	Female	SL versus TL	SL = 0.8309TL + 0.1366	75	0.978
<i>Aplocheilichthys antinorii</i>	Combined	SL versus TL	SL = 0.938TL – 0.2148	795	0.952
	Male	SL versus TL	SL = 0.9433TL – 0.2368	408	0.960
	Female	SL versus TL	SL = 0.9319TL – 0.189	387	0.942

Abbreviations: FL = fork length, SL = standard length, TL = total length, TW = total weight.

with a mean value of 1.0018 ± 0.0074 , respectively. However, the analysis of variance (ANOVA) of relative condition factors of *E. paludinosus* between sexes showed a significant difference at a 95% confidence interval ($p < 0.001$). Regarding *G. quadrimaculata*, the relative condition factor of male populations ranged from a minimum value of 0.39965 to 1.7591 with a mean value of 1.0078 ± 0.0211 , while female *G. quadrimaculata* relative condition factors ranged from a minimum value of 0.6489 to a maximum value of 2.5755 with a mean value of 1.013994 ± 0.023 , respectively. The ANOVA of relative condition factors with sexes at a 95% confidence interval did not show a statistically significant p -value of 0.854, which is > 0.05 probability of a comparison.

The relative condition factors of *A. antinorii* from Lake Hawassa considered for this study were also found within the range of 0.86–1.115. Male *A. antinorii* relative condition factors were seen between a range from 0.866 to 1.115 with a mean value of 1.00159 ± 0.025 , while female *A. antinorii* relative condition factors ranged from a minimum value of 0.866 to 1.112 with a mean value of 1.0069 ± 0.022 , respectively. The result showed that the interactions of sexes for the relative condition factor did not show any significant difference ($p = 0.975$) at 95% confidence interval. Based on this study, the mean relative condition factor value for all considered species from Lake Hawassa was above the threshold limit ($K_n > 1$), indicating good condition [54]. There is no comprehensive information to compare and discuss the relative condition factors of these mentioned fish species.

4. Conclusion

All the three ecologically significant fish species found in Lake Hawassa were examined in this study to address their length–weight relationship, length–length relationship, and

relative condition factors. From this result of the growth exponent value, further research taking into account ecological modeling, Ecopath-based research, and phenotypic characterization for taxonomists is needed. The finding also incorporates the first finding examining three fish species that was not formerly addressed. From the result, fish classified as having negative allometric growth (*E. paludinosus* and *A. antinorii*) need to be given careful consideration. Those species have a strong role for commercially important fish species as prey. Therefore, attention should be given to keep the continuity of the lake's production potential.

Data Availability Statement

Upon reasonable request, the data set of this study can be made available from the corresponding author.

Ethics Statement

This study does not involve human subjects (human-related experimentation) but involves fish sampling from non-protected areas. However, ethical clearance to carry out field observation and laboratory work was ethically granted by the Hawassa University College of Natural and Computational Sciences under reference number CNCS-REC/012/23.

Conflicts of Interest

The authors declare no conflicts of interest.

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