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Research Articles

The Assuan labeo or Labeo horei Heckel (Pisces: Cyprinidae) in Lake Chamo, Ethiopia: Reproductive biology and condition factor

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Abstract

The Labeo horei (Heckel, 1847), the Assuan labeo, is an ecologically and economically important fish of Lake Chamo; thus, reproductive biology and condition factors of the fish were investigated in order to provide information essential for appropriate stock exploitation and sustainable management. Fish specimens were collected monthly from sampling stations at Lake Chamo between July 2022 and January 2023. A total of 462 specimens were collected for analysis. The mean condition factor was 1.11, which indicates a good state of wellbeing in the habitat during the period of study. The overall male to female sex ratio (1: 0.83) did not deviate substantially from the anticipated value of 1:1 ($x2 = 3.82$, $P < 0.01$). The fecundity of L. horei ranged from 200,000 to 1000,000 eggs and was found in mature ovaries (mean 261,045.8 eggs). These results confirm the suitability of Lake Chamo for the survival of L. horei. There is, however, a need for a systematic closed fishing regime to be employed in order to make way for sustainable growth of L. horei fisheries in the lake Chamo as the fish candidate for future aquaculture development.

Keywords: Breeding season; Condition factor; Fecundity; Fishery; Labeo horei; Lake Chamo

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1. Introduction

The *Assuan labeo*, or *Labeo horei* (Heckel, 1847), is found across Northern Kenya and the majority of the Ethiopian drainage basin (Elias et al., 2013). It is extensively dispersed in Ethiopia's Rift Valley basin, Abay basin, and Baro-Akobo basin (Awoke, 2015). It is one of Ethiopia's economically important fish species (LFDP, 1997; Zerihun et al., 2006). According to LFDP (1997), the yearly production of *L. horei* from Ethiopia's inland water bodies is estimated to be around 365 tons per year. Fish are less readily available in local markets as a result of the reduction of fish species brought on by overfishing and parasite infection (Zerihun et al., 2006; Elias et al., 2013).

The most frequent *Labeobarbus* species in freshwater, *Labeo horei*, possesses morphological and physiological characteristics that set it apart from other members of the species (Nagelkerke, 1997). The length-weight relationship is one of the most important biological tools for controlling fisheries. It is used to calculate the average weight of a fish at a certain length (Lawson et al., 2013). It also provides important data for aquatic ecosystem modeling, such as the influence of environmental variables, habitat changes, species interactions, and food availability (Dan-Kishiya, 2013).

As a result, the length-weight relationship of fish in various environmental conditions should be identified. One of the most commonly utilized analyses in fisheries is the length-weight relationship. Fish length-weight data are useful for examining the length and age structures, population dynamics, growth, mortality rate, and fish well-being (Temesgen, 2017). They are also key instruments for accessing data on length frequency distribution, fish welfare, stock evaluation, and fish population management (Abowei et al., 2009).

Numerous aspects of the biology and ecology of economically significant fish species have been studied in Lake Chamo (Hailu & Seyoum, 2001; Elias et al., 2003; Elias et al., 2012; Hailu, 2013). Nevertheless, there is a scarcity of information on biometric traits such as length-weight relationships and condition factors. This necessitates an investigation into the biometric characteristics (sex ratio, breeding season, and fecundity), length-weight relationship, and condition factor of *L. horei* from Lake Chamo, with the aim of providing scientific information for appropriate stock exploitation and management in the wild and underculture, given that *L. horei* is one of the most commercially important fish in Lake Chamo's catches, Southern Ethiopia, Ethiopia.

2. Materials and Methods

2.1. Description of the study area

This study was carried out in Lake Chamo, Arba Minch, Ethiopia (Figure 1). Lake Chamo, located in (Lat.: 5°42' - 5°48' N; Long: 36°30' - 38°30' E), is located at an elevation of 1108 m, about 518 kilometres south of Addis Ababa. The lake has a surface area of 551 km^2 and is the second largest among the rift valley lakes and the third largest in the country. Lake Chamo had a maximum depth of 20 meters according to older data (Amha & Wood, 1982); however, Elizabeth (1996) claimed a maximum depth of 13 meters.

As the lake has retreated by nearly half a kilometer over the past two decades, Beadle (1981). Which significantly reduces the surface area, the mean depth of the lake may have altered. The Kulfo River, which enters from the north, and two less significant rivers, Sile and Sego, which enter from the west, are the main sources of water for Lake Chamo. In spite of the fact that it now lacks a visible surface outflow (Yirga et al., 2000).

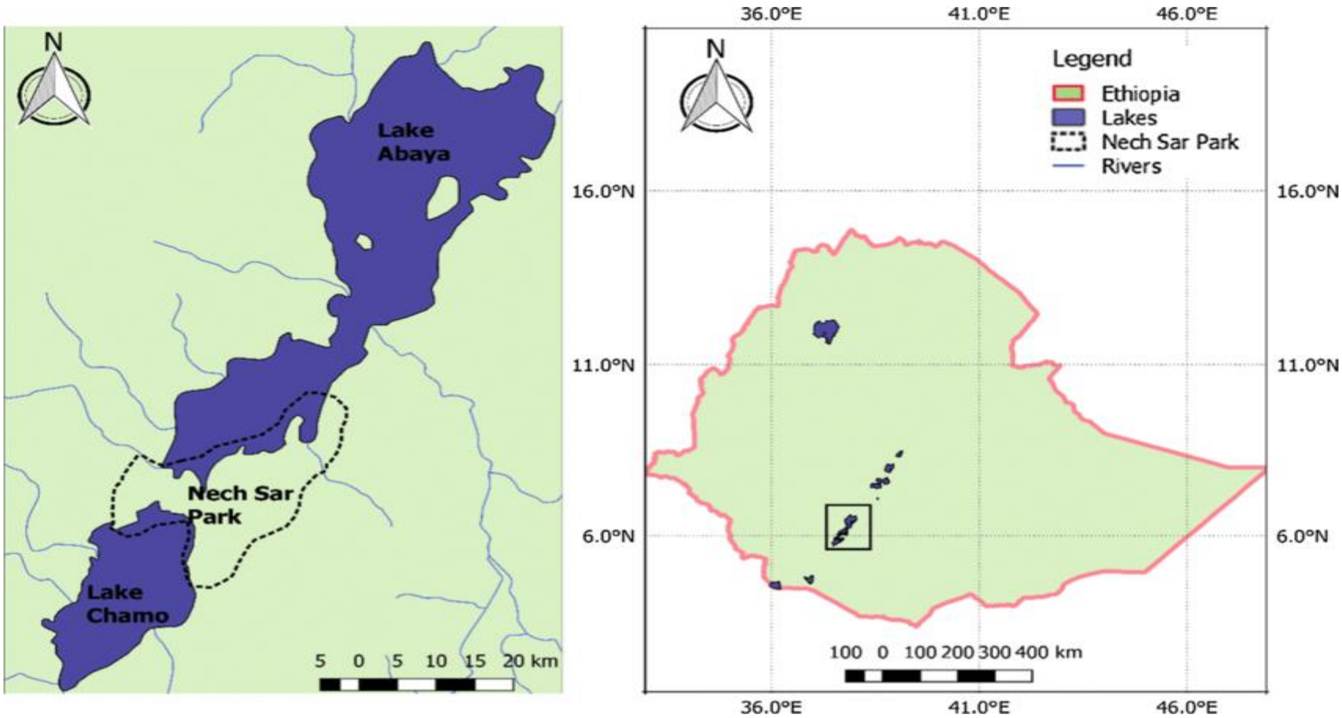

Figure 1. Map of Lake Chamo, the research area

2.2. Sampling of fish and measurement

Monthly fish samples were taken from the lake and brought to the Fishery Laboratory of Hawassa University from July 2022 to January 2023. The landing points at Letto (1, 2, 3, 4, and 5) were used to acquire fish for commercial purposes.

The mesh size used in commercial gill nets ranges from 6 to 8 cm. Gill nets were deployed late in the day and removed the next morning. To the closest centimeter and gram, the TL and TW of each fish were measured immediately following being captured. Each fish was then dissected, and the gut contents were transferred to a labeled plastic bottle containing a 5% formalin solution. Those fish with no gut content were noted as empty gut. The preserved gut contents were delivered to the laboratory. According to a five-point maturity scale (immature, maturing, ripening, ripe, and spent) that was used for this purpose (Holden & Raitt, 1974), the gonads of each fish were removed, weighed to the nearest 0.01 gram, and their maturity stages were visually rated and recorded. The ovaries were split longitudinally and turned inside out to ensure the penetration of the preservative before they were stored in labeled jars. At the end, the ripe ovaries were preserved in a 5% formalin solution for fecundity estimation (Bagenal, 1978).

2.3. Reproductive biology

2.3.1. Sex-ratio

The sex-ratio (female: male) was computed for each month, for the various length classes, and for the entire sample. As in Demeke (1994) monthly samples, different size classes, and the entire sample were tested to see if the sex ratio varied from one to one using the chi-square test.

2.3.2. Breeding season

The monthly frequency of fish with mature gonads and the calculation of the gonado somatic index (GSI) were used to identify the breeding season of *L. horei*. The GSI for each fish was calculated using the following formula (Eq. 1):

$$GSI = \frac{GW}{TW} \times 100 \tag{1}$$

Where; GSI stands for the gonado somatic index. GW stands for gonad weight in grams, TW stands for "total weight" in grams.

2.3.3. Fecundity

Gravimetrically, the fecundity of ripe gonads preserved in 5% formalin solution was evaluated (Bagenal, 1978). To calculate fecundity, the preservative was replaced with water, and the eggs were washed repeatedly while the supernatant was decanted. The fecundity estimate was then produced by weighing the complete egg sample and taking three sub-samples of each egg sample, all of which were dried in the same manner. The eggs were weighed and counted using a balance. The eggs were counted and the average weight was estimated after they were extracted from various sections of the ovary. Extrapolation from the estimated mean resulted in the total number of eggs per ovary. The sum was calculated using the following ratio (Eq. 2):

$$N/n = W/w \tag{2}$$

Where; N = denotes the unknown total number of eggs, n = the total number of eggs counted in three subsamples, W = Total egg weight (g), w = the weight of the three subsamples on average (g)

2.3.4. Fulton's condition factor

Fulton's condition factor (FCF) is an essential growth measure that determines the fish's well-being (Bagenal, 1978). The mean FCF for each month was calculated by sex. ANOVA was utilized to discover significant differences by sex and month of capture. It was determined using the following formula (Eq. 3):

$$FCF = \frac{TW}{TL^3} \times 100 \tag{3}$$

Where; FCF stands for Fulton condition factors, TW is the total weight of the fish (g), and TL is the total length of the fish (cm).

2.4. Data analysis

Data was collected and entered into SPSS and Microsoft Office Excel 2007 for Windows version 19 in order to evaluate the breeding season, sex ratio, length-weight connections, and fecundity. Ultimately, a table, scatter plot (x, y), and graph were created from the results. One-way ANOVA and chi-square tests were among the statistical tests used to ascertain the significance between the variables.

3. Results

3.1. The Fulton's condition factor

Fulton's condition factor (k) gives information on the state of the fish in relation to general well-being. According to Fulton (1904), $k < 1$ means that the fish are in poor condition and $k > 1$ means the fish is in healthy condition. There was no difference in the results between the sexes, and Fulton condition factors were both equal at 1.11±0.01 (2, $P > 0.01$).

Additionally, *L. horei* overall condition factor result was 1.11±0.01. This implies that the fish were in good health condition.

3.2. Reproduction

3.2.1. Sex ratio

About 252 (54.5%) of the 462 *L. horei* fish samples were males, while the remaining 210 (45.5%) were females. The total male to female sex ratio (1:0.83) did not deviate substantially from the anticipated value of 1:1 ($x^2 = 3.82$, $P < 0.01$) (Table 3). There was no significant variation in sex ratio in all size class except in size class between was highly significant (i.e., 35 - 39.9; $\chi^2 = 9.31$, $P < 0.01$) (Table 1).

Table 1. The number of female and male *L. horei* collected in Lake Chamo between July 2022 and January 2023, as well as their sex ratio (Male: Female)

Size class (cm)	Males	Females	Sex ratio (M:F)	X^2
30.0-34.9	10	0	-	-
35.0-39.9	12	1	1: 0.08	9.31**
40.0-44.9	52	36	1: 0.69	2.91
45.0-49.9	134	106	1: 0.79	3.27
50.0-54.9	40	57	1: 1.43	2.98
55.0-59.9	4	10	1: 2.50	2.57
Total	252	210	1: 0.83	3.82

** = Highly significant at 1% level

3.2.2. Breeding season

Despite the fact that some ripe fish were taken throughout the year, the proportion of fish with ripe gonads was highest between September and November, when 67.7%–72.0% of males and 23.5%–100% of females had ripe gonads (Figure 2).

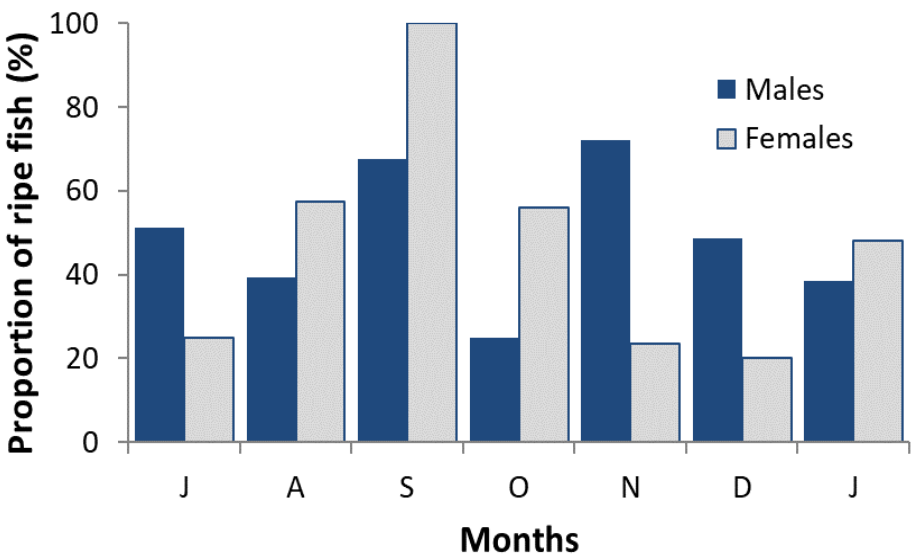

Figure 2. Proportion of ripe *L. horei* in Lake Chamo in 2022

Between December and July the proportion of fish with mature gonads was somewhat low, with 48.6%–51.1% of males and October and January 48%–56% of females having ripe gonads (Figure 2). And also during the months of August and October, the proportions of fish with ripe gonads were likewise low, with 25–39.3% of males, whereas in December and November, 20%–23.3% of females had ripe gonads (Figure 2). As a result, *L. horei* Lake Chamo breeds vigorously from September and November, with relatively small breeding activity at other periods of the year.

3.2.3. Fecundity

Only 107 of the 462 fish that were captured had mature ovaries in the females. Between 200,000 and 1,000,000 eggs were found in mature ovaries, with a mean of 261,045.8.

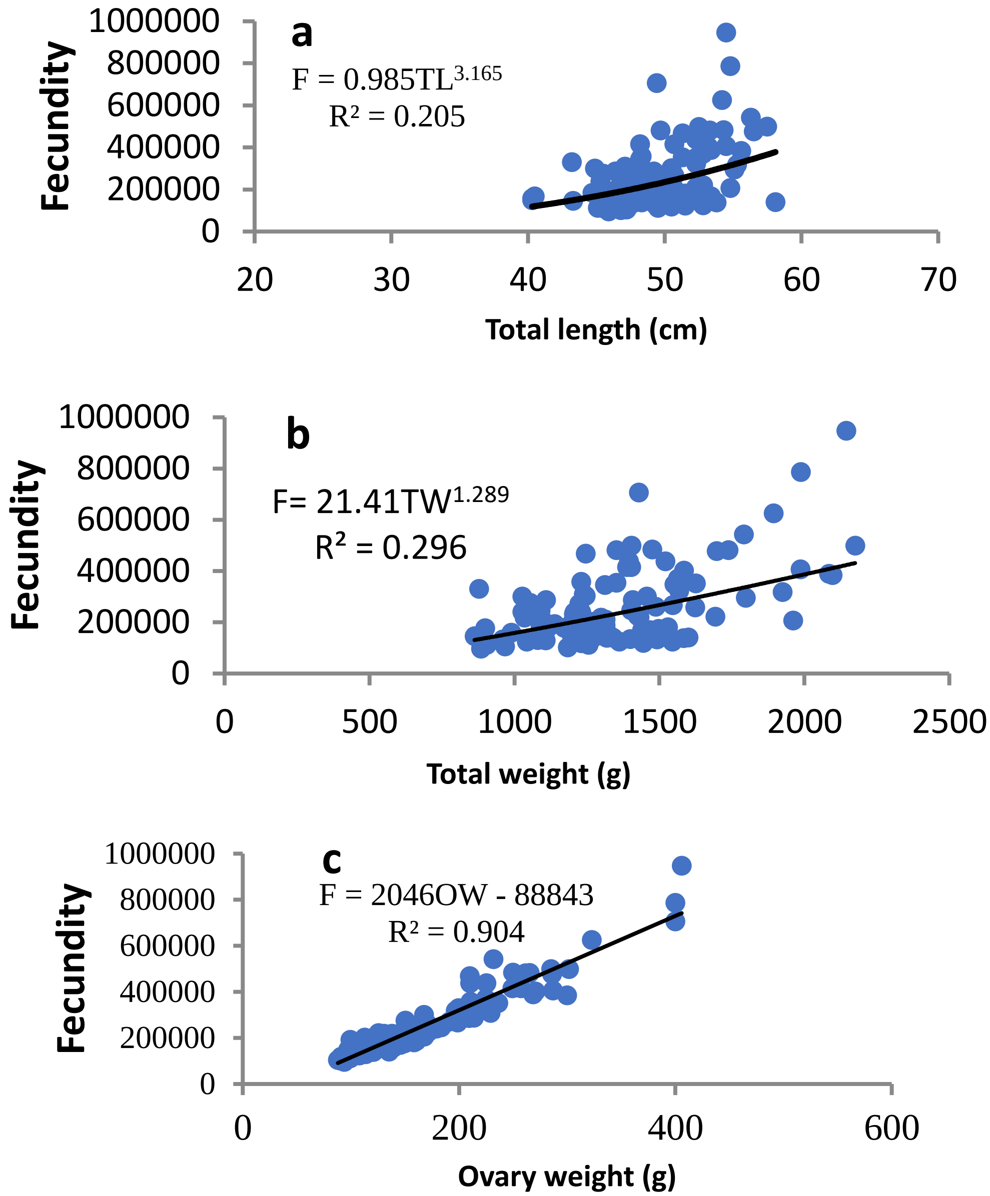

Figure 3. The relationship between fecundity and total length (a) fecundity and total weight (b) and fecundity and ovary weight of *L. horei* in Lake Chamo

Between 973 and 2875 eggs were present per gram of preserved wet weight of ovary, with 1464.4 being the average. In a fish that measured 45.9 TL and weighed 884 g, the lowest fecundity was 96511. A fish with a TL of 54.5 cm and a TW of 2145 g had the maximum fecundity of eggs, 947543 with a mean of 318580.8. In contrast, the curved correlations between

F and TL and TW were slightly curvilinear (Figures 3a and 3b), whereas the relationship between F and OW was linear (straight) (Figure 3c).

4. Discussion

4.1. The Fulton's condition factor

Fulton’s condition factor (k) gives information on the state of the fish in relation to general well-being. According to Fulton (1904), k means that the fish are in poor condition, and k > 1 means the fish is in healthy condition. According to Dadebo *et al*. (2003) and Ogamba *et al*. (2014), the condition factor is used to measure the overall welfare of fish in their environment and that at a given length, larger fish have a better condition than lighter fish. When the condition factor is close to or equal to one, it portrays a fish's overall well-being (Abobi, 2015; Nazek et al., 2018).

The mean condition factor observed in this study was more than one (i.e., 1.11), indicating that the fish in the lake were physiologically stable over the study period. In line with this, the average Fulton's condition factor found in this study (1.11) was in agreement with Fulton's (1904), if k > 1, the fish are in poor condition, and if k > 1, the fish exhibit good condition, similar to the results from Lake Ziway (1.73) that were previously reported. Lake Langeno (2016), Lemma (1.33), Shewit *et al*. (2012) in the Infranz River (1.27), Shewit *et al*. (2013) in the Geba and Sor Rivers (1.21), and Mathewos et al. (2018) in the Arno-Garno River (1.3) are a few others. Genanaw (2006) in the Beles and Sanja Rivers (1.1, 1.05), Zeleke (2007), Simagne *et al*. (2017) in the Angereb River (1.14), Shewit et al. (2014) in the Aveya River (1.18), and Genanaw (2007). This suggests that *L. horei* in Lake Chamo has a good body condition in comparison to the above water bodies.

4.2. Reproduction

4.2.1. Sex ratio

The male-to-female ratio of *L. horei* did not deviate from the predicted 1:1. In most circumstances, such sex ratio variation is uncommon in fish. Fecundity success is highly dependent on sex ratio, and bias on either sex can create behavioral, biochemical, and physiological changes in fish, which may influence reproduction success (Manal et al., 2017; Maskill et al., 2017). In the size group between 35.0 and 39.9 (x^2 = 9.31, P < 0.01), there was also a statistically significant fluctuation in sex ratios. All other size groups did not show any significant difference.

Generally, males were more numerous than females. A high male-to-female ratio might cause stress due to competition during pursuing, limiting spawning and decreasing fertilization success (Maskill et al., 2017). Additionally, Gizachew *et al*. (2015) reported a male preponderance in some of the Lake Tana tributary rivers. According to the reports of Shewit *et al*. (2012), Dereje (2014) in Lake Tana and Awoke *et al*. (2015) in the Blue Nile River, female predominance is in contradiction to the findings of the current study. The aforementioned authors claimed that the majority of females were likely due to the spawning behaviors of the fish species, in which females may spend more time in the breeding locations than males. Various authors (Shewit et al., 2014; Tadlo et al., 2015; Simagnew et al., 2017; Agumassie, 2018) claim that, there is also no discernible difference in the species' sex ratio across different water bodies in Ethiopia.

L. horei breeds in Lake Chamo throughout the dry seasons of the year, unlike other Ethiopian lakes. Mathewos et al. (2018), Shewit *et al*. (2012) and Gizachew *et al*. (2015) all noted that *L. horei* breeds during wet seasons (Elias et al., 2003). Multiple spawning over a long season has significant benefits in aquaculture because it offers a regular supply of high-quality larvae (Dorostghoal et al., 2009) and *L. horei* reproductive behavior makes it an ideal choice for aquaculture.

4.2.2. Fecundity

Fecundity varied throughout years, months, and zones; this variation may be related to variations in fish size and food availability (Inyang and Ezenwaji, 2004). Fish may move from inter-confluences to confluences for spawning, particularly during floods during the rainy season, as fecundity is higher in confluences than in inter-confluences. The correlations between fecundity and fish sizes or gonad mass recorded for *L. horei* are also noted for the fish species in a natural West African lake by Inyang and Ezenwaji (2004).

The positive correlations between fecundity and length (r^2 = 0.21) and fecundity and somatic mass (r^2 = 0.30) were recorded for *Labeo horei* (r^2 = 0.90). However, these values were higher than those recorded for *Labeo coubie* (r^2 = 0.18, 0.10, and 0.80, respectively) (Ikpi and Okey, 2010). The coefficient of determination for the correlation between fecundity and gonad mass (r^2 = 0.90) for *L. horei* is greater than the values obtained with fish size.

It is evident that the gonad weight has a stronger correlation with reproductive ability than fish size. These interactions allow fish species to develop quickly and reproduce prolifically

(Demska-Zakes and Dlugosz, 1995) traits that are crucial for aquaculture species. Similar findings were observed for other cyprinids like *Garra rufa* (Abedi, 2011), *Barbus holotaenia* (Mutambue, 1996), and *Labeo parvus* ($r^2 = 0.87$) (Montchowui et al., 2011).

5. Conclusions

Studies on the reproductive biology and condition factor have practical significance for the *L. horei* fishery. The condition factor of *L. horei* indicates the fish are in good health condition. Potential implications for population dynamics are indicated by the sex ratio. Breeding predominantly occurred during the dry seasons, with fecundity exhibiting variation across years, months, and capture zones, correlating closely with gonad mass. These biological traits underscore *L. horei*'s suitability for aquaculture endeavors. Expanding upon these findings, continuous research efforts are crucial to enhance our understanding of *L. horei's* biology and its ability to adapt to evolving ecological conditions. Establishing robust monitoring systems for fishery resources, particularly in high-potential water bodies like Lake Chamo, is crucial. Consequently, the implementation of regulatory measures is necessary to ensure the sustainable management of *L. horei* fisheries. During breeding seasons, prohibiting shore fishing activities can help protect breeding stocks, while specifying gear requirements, such as minimum mesh sizes, is essential to facilitate the escape of mature individuals and support recruitment processes. Integration of these management strategies is essential to promote the sustainable utilization of *L. horei* resources while conserving ecological balance.

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Conflict of Interest

The authors declare that they have no competing interests.

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