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Length-Weight Relationship, Condition Factor, and Reproductive Biology of *Carasobarbus luteus* in Greater Zab and Lesser Zab Rivers in the Kurdistan Region-Iraq

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ABSTRACT
A comparative study was conducted to evaluate certain environmental and biological aspects of *Carasobarbus luteus* in the Greater Zab and Lesser Zab Rivers for the first time. A total of 163 and 200 specimens were collected from the Greater Zab and Lesser Zab Rivers, respectively, between December 2022 and November 2023. In the Greater Zab River, fish lengths ranged from 133 to 267 mm and weights from 30 to 276 g. In the Lesser Zab River, lengths ranged from 117 to 309 mm and weights from 30 to 417 g. The length–weight relationship (LWR) indicated positive allometric growth in the Greater Zab River, with a b value of 3.17. In contrast, growth in the Lesser Zab River was isometric, with a b value of 2.97. The condition factor (K) in the Greater Zab River was 1.421, slightly lower than that in the Lesser Zab River, which was 1.458. Condition factor values were similar between males and females at both sites. The sex ratio was skewed toward females in both rivers, with a male-to-female ratio of 1:2.26 in the Greater Zab River and 1:2.22 in the Lesser Zab River. The gonadosomatic index (GSI) for males peaked in May, reaching 3.3 and 3.6 in the Greater and Lesser Zab Rivers, respectively, with the lowest values recorded in November (1.1 and 0.9). For females, the highest GSI values were observed in April—9.3 in the Greater Zab and 9.7 in the Lesser Zab—while the lowest values occurred in December (2.0 and 2.2, respectively). Overall, the results indicate that both rivers provide suitable conditions for the growth of *C. luteus*. However, individuals from the Lesser Zab River exhibited better overall condition, as reflected by higher numbers, greater weight ranges, and a higher condition factor compared to those from the Greater Zab River.

INTRODUCTION

The **Cyprinidae** family is the most widespread and diverse group of freshwater fishes, comprising approximately 8.5% of all known fish species globally. In Iraq, this family includes the most abundant freshwater fish species, with native cyprinids accounting for 72% of the total freshwater fish population **(Coad, 2010)**.

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Carasobarbus luteus (Heckel, 1843), a member of the family Cyprinidae, is endemic and widely distributed in the rivers and lakes of Iraq **(Coad, 2010)**. According to a report by the Food and Agriculture Organization (FAO), this species—previously referred to as *Barbus luteus*—represented approximately 43.6% of the total fish sold in seven major Iraqi markets in 1965 **(Mohamed *et al.*, 2015)**. It is a highly valued species due to its popularity as a food fish **(Borkenhagen *et al.*, 2011)**.

Despite its economic importance, only a few studies have examined the biology of *C. luteus* in Iraq. Previous research has focused on aspects such as the length–weight relationship (LWR), growth, condition factors, and gonadosomatic index (GSI), and has been conducted in water bodies such as the Hilla River, Al-Tharthar Lake, Al-Diwaniya River, Al-Shirqat, Samarra, and Al-Qala'a **(Al-Ammari *et al.*, 2012; Wahab & Shaker, 2017; Abdullah & Mohamed, 2019; Abdul Qader, 2019; Wahab & Abdul Qader, 2020; Shaker, 2023)**.

Water temperature is one of the most critical environmental factors affecting fish biology, as it influences growth rate, metabolic processes, and overall activity. Other important environmental variables include floods, water currents, climate cycles, pressure, rainfall, spawning grounds, nutrient availability, disease, parasites, egg adhesion, and the presence of other fish **(Coad, 2010)**.

Studies of the LWR have multiple applications in fish biology, physiology, ecology, and fisheries assessment. In biological research, LWRs help monitor seasonal variations in growth and support the calculation of condition factors. They allow life-history and morphological comparisons between different fish species or populations, provide estimates of weight from length data, and assist in identifying stock variations within the same species **(Froese & Pauly, 2023; Al Sulivany *et al.*, 2024)**. LWR is also useful in estimating the average weight corresponding to specific length groups **(Ndome *et al.*, 2012)**.

The condition factor (K) is an essential index for comparing growth across populations and environmental conditions. It reflects the well-being of fish, based on the principle that heavier individuals of the same length are in better condition **(Moutopoulos & Stergiou, 2002)**. It also serves as an indicator of feeding intensity and growth **(Fagade, 1979)**. The condition factor can provide insights into the physiological health of populations across seasons or between habitats with similar or differing ecological characteristics **(Lizama & Ambrosio, 2002)**. As it is influenced by both biotic and abiotic factors, it can also be used to evaluate the degree of disturbance within aquatic ecosystems **(Baby *et al.*, 2011)**.

The gonadosomatic index (GSI) is another important biological parameter that reflects the reproductive status of fish. It provides insights into spawning periods and reproductive cycles **(Sindhe & Kulkarni, 2004)**. The production of gametes is highly sensitive to environmental conditions, and water pollution is considered a major factor in reproductive decline. The quality of gametes is critical for successful breeding, and stress

may delay gonadal development and, consequently, the spawning season **(Saksena, 1987)**. Therefore, identifying breeding seasons is essential for the biological study and management of fish populations.

To date, no biological studies have been conducted on *C. luteus* in the Kurdistan Region of Iraq. Consequently, the present study aims to describe key biological aspects of this species in the Greater Zab and Lesser Zab Rivers. The research includes analyses of length-frequency distribution, length–weight relationships, condition factor, sex ratio, and gonadosomatic index.

MATERIALS AND METHODS

Ethical approval and consent

The authors provided verbal informed consent for their involvement in the study. The research design and methodology were evaluated and approved by the Animal Ethics Committee at Salahaddin University- Erbil, ensuring adherence to ethical guidelines (SUE2025AREC/6A).

Description of the study area

The Greater Zab and Lesser Zab rivers are considered the largest branches of the Tigris River and are located within latitudes between 34°and 36° and longitudes between 43°and 46° (Fig. 1). The two areas were characterized by clay covered with fine gravel, with grasses and shrubs suitable for grazing animals, other sandy and clay areas suitable for agriculture, and small parts represented by rocky hills **(Abdullah & Mhaisen, 2010)**.

The total length of the Greater Zab River from its source to its estuary is 392 km, with a total catchment area of 26,473 km², of which 16,600 km² lies within the Kurdistan Region. In comparison, the Lesser Zab River has a total length of 400 km and a drainage area of 21,475 km², with 15,975 km² located within the Kurdistan Region **(Talib, 2005)**.

Fig. 1. Map showing the lakes and river routes in Iraq **(Sediq, 2023)**

Field work

Physicochemical parameter measurements

Environmental parameters were recorded monthly from December 2022 to January 2023 during daylight hours (9:00–11:00 AM) from the surface layer (30 cm depth). The measurements included:

- Water temperature (°C): Measured using a standard mercury thermometer.
- pH, dissolved oxygen (mg/L), and electrical conductivity (mS/cm): Measured using a portable multi-parameter meter (HI-9811-51 pH/EC/TDS, with HI-1285-51 probe, Roman origin).
- Water transparency (cm): Assessed using a handmade Secchi disc, an iron disc with a diameter of 35 cm attached to a rope. The disc was lowered into the water until it disappeared from sight, and the depth was recorded. It was then slowly raised until it reappeared, and the depth was recorded again. The average of the two readings was used to calculate water clarity **(Preisendorfer, 1986)**.

- Water current speed (cm/s): Measured using a locally made cork ball. The cork was placed in the water, and the time taken to travel a set distance was recorded. Flow speed was calculated by dividing distance by time **(Hundt & Blasch, 2019)**.
- **Salinity (g/L):** Calculated using the formula proposed by **Mackereth *et al.* (1978)**:

Salinity (gm/L) = Electrical conductivity (mS/cm) * 0.00064

Collection of fish

A total of 363 specimens of *C. luteus* from both sexes were collected monthly from two sites, 163 samples from the Greater Zab River at Aski-Kalak City and 200 samples from the Lesser Zab River at TaqTaq City, Samples were collected using trawl, gill and casting nets with mesh dimensions 3.5-5 cm at depths ranging from 5 to 30 meters and electrofishing was also used. Then, fish were classified according to **Coad (2010)** and **Agha *et al.* (2021)**.

Laboratory work

Morphometry

The fish were arranged according to their length, and they were numbered for taking the length and weight measurements. The total length (TL) of each species was measured by millimeters by using tape measure. Fish were also weighed using a digital sensitive balance (OHAUS, China).

Anatomical measurement

Each specimen was dissected by making a longitudinal incision along the ventral side using scissors, following the method described by **Amlacher (1970)**. The gonads were carefully examined to determine the sex and distinguish males from females. Subsequently, the gonads were weighed to calculate the gonadosomatic index (GSI).

Measurements and calculations

Length-weight relationship

The statistical relationship between total length and weight was calculated using the following exponential equation.

$$\mathbf{TW = a\ TL^{b}}$$

Where, TW = weight of fish in (g), TL =total length of fish in (mm), a = proportionality constant (intercept), and b = regression coefficient (slope). The association degree between L and W was calculated by the determination coefficient (r^2). The value of the exponent b provides information on fish growth. The level of r^2 and the b-value were estimated and tested to verify if it was significantly different from the isometric (b = 3). The growth is isometric if b = 3 and the growth is allometric if $b \neq 3$ (negative allometric if $b < 3$ and positive allometric if $b > 3$), **(Beverton & Holt, 1957)**.

Fulton condition factor

Fulton's condition factor (K) was used to compare the condition, fatness, or overall well-being of the fish. It was calculated using the following formula **(Abdulrahman and Al Sulivany, 2025)**:

$$K = (W / L^3) * 100$$

Where, K = Condition factor, W = weight of fish (g), L = total length of fish (mm), and 100 is a factor to bring the value of K near unity.

Gonads-Somatic index (GSI)

The Gonadosomatic index (GSI) was calculated using the relationship according to the formula described by **Omar and Al Sulivany (2025)**:

$$GSI = (GW / TW) *100$$

Where, GSI = Gonads-Somatic index, GW = Gonads weight, TL= Total length.

RESULTS

Environmental properties

Table (1) illustrates the ranges and average values of some physical and chemical properties of water in the two sites during the study period. The water temperature in the Greater Zab River ranged from 8.9 to 28.9ºC, while in the Lesser Zab River it ranged between 9.9 to 28.9 ºC.

The pH values in both study sites during most of the study periods were alkaline, ranging from 7.1 to 8.2 in the Greater Zab River and 6.6 to 7.8 in the Lesser Zab River.

The dissolved oxygen content ranged from 7.1 to 12.6 mg/L in the Greater Zab River and 6.8 to 12.4 mg/L in the Lesser Zab River.

The salinity value showed very slight changes in both locations, but its concentration in the Lesser Zab River was higher than in the Greater Zab River, as it ranged between 0.22 to 0.41 g/liter in the Greater Zab River and 0.41 to 0.5 g/liter in the Lesser Zab River.

On the other hand, the level of transparency ranged from 16 to 61 in the Greater Zab River and from 15 to 50 in the Lesser Zab River.

Table 1. Ranges and average values of some physical and chemical properties of water in the current study areas

Location / Property	**Greater Zab River**	**Lesser Zab River**
Water Temperature (C^0)	8.9 - 28.9 19.092 ± 1.038	9.90 – 28.9 20.092 ± 1.042
pH	7.1 - 8.2 7.708 ± 0.049	6.60 – 7.80 7.158 ± 0.056
Dissolved Oxygen (mg/L)	7.1 - 12.6	6.80 – 12.40

	9.625 ± 0.283	9.233 ± 0.278
Salinity (g/L)	0.22 - 0.41 0.305 ± 0.010	0.41 – 0.50 0.462 ± 0.004
Transparency (cm)	16.0 - 61.0 32.250 ± 2.427	15.00 – 50.00 26.917 ± 1.631
Current speed of water (cm/s)	23.0 - 43.0 31.250 ± 1.130	26.00 – 46.00 35.750 ± 1.213

Biological study

Catch rates

Tables (2 and 3) show the ranges of TL and TW observed for fish *C. luteus* caught in the Greater Zab and Lesser Zab Rivers during the study period. 163 samples were collected at the Greater Zab River, as shown in Table (2), with a total weight of 27580 g. The ranges of their TL ranged between 133 – 267 mm, and the ranges of their weights were between 30 - 276 g. Table **(3)** shows that a total of 200 *Carasobarbus luteus* specimens were caught from the Lesser Zab River, with a combined weight of 36,272 g. The total length (TL) of these specimens ranged from 117 to 309 mm, while their weights ranged from 30 to 417 g. The same table also indicates that the number of fish caught decreased during the winter months—specifically in November and December—in both the Greater and Lesser Zab Rivers. In contrast, catch numbers increased with rising water temperatures in the spring and summer seasons, reaching a peak in March and April.

Table 2. Ranges of total lengths and total weights observed for *Carasobarbus luteus* fish in the Greater Zab River

Month	No. of fish	% of number	Weight of fish (g)	% of weight	Ranges of lengths(mm)	Weight ranges(g)
December	3	1.8	293	1.1	175 - 222	65 – 150
January	5	3.1	374	1.3	160 - 185	49 – 94
February	14	8.6	2805	10.2	186 - 265	91 – 262
March	29	17.8	5537	20.1	133 - 267	91 – 265
April	21	12.9	4526	16.4	213 - 267	146 – 276
May	19	11.7	3800	13.8	190 - 265	91 – 269
June	17	10.4	2738	9.9	177 - 263	79 – 254
July	18	11	3130	11.3	192 - 263	99 – 251
August	11	6.75	1397	5.1	133 - 262	29 – 240
September	11	6.75	1094	4	117 - 252	30 – 210
October	9	5.5	1263	4.6	185 - 244	85 – 200
November	6	3.7	623	2.2	167 - 213	65 – 131
The total	**163**	**100**	**27580**	**100**	**133 – 267**	**30 – 276**

Table 3. Ranges of total lengths and total weights observed for *Carasobarbus luteus* fish in the Lesser Zab River

Month	No. of fish	% of number	Weight of fish (g)	% of weight	Ranges of lengths(mm)	Weight ranges(g)
December	3	1.5	385	1.1	194 - 234	102 – 178
January	11	5.5	1826	5.1	160 - 277	48 – 280
February	15	7.5	2904	8	167 - 307	73 – 395
March	23	11.5	4553	12.5	192 - 300	104 – 373
April	25	12.5	5721	15.7	145 - 309	50 – 417
May	24	12	4112	11.3	133 - 292	30 – 339
June	20	10	3723	10.4	171 - 286	69 – 318
July	20	10	3155	8.7	14.6 - 257	43 – 237
August	19	9.5	2578	7.1	117 - 287	29 – 306
September	18	9	3486	9.6	136 - 288	35 – 311
October	15	7.5	2717	7.5	160 - 296	55 – 339
November	7	3.5	1112	3	168 - 283	56 – 287
The total	**200**	**100**	**36272**	**100**	**117- 309**	**30 – 417**

1. Length - weight relationship

The relationship between total length (TL) and total weight (TW) of *Carasobarbus luteus* during the study period followed the exponential equation below for the Greater Zab and Lesser Zab Rivers, respectively:

$W = 5E\text{-}06L^{3.1721}$ ……..(1)

$W = 2E\text{-}05\ L^{2.9698}$ ……..(2)

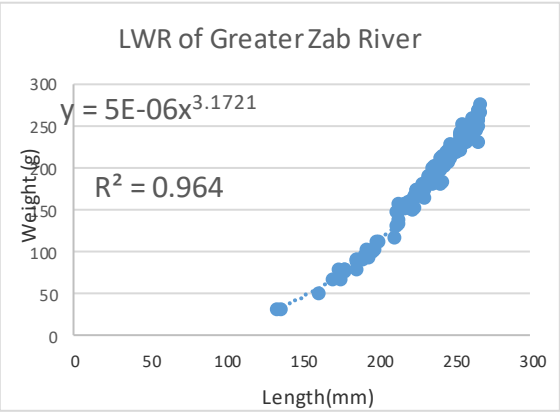

Fig. 2. Length-weight relationship of *C. luteus* of Greater Zab River

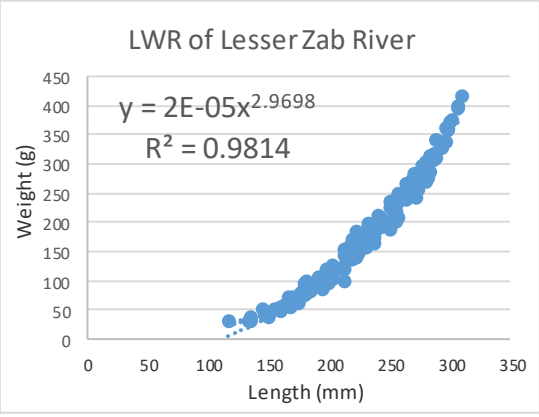

Fig. 3. Length-weight relationship of *C. luteus* of Lesser Zab River

It is clear from the two equations above, as shown in Figs. (2 and 3) that the b value was 3.172 and 2.969 in the two locations, respectively. This indicates that the growth in the Greater Zab River was allometric, and the value of b was higher than 3, meaning the increase in weight is greater than the cube of length. However, in the Lesser Zab River, the growth was allometric as well, but the value of b is less than 3, which means the increase in weight is less than the cube of length **(Bagenal & Tesch, 1978)**.

2- Fulton condition factor (K)

It is clear from Table (4) that the Fulton condition factor of *C. luteus* in the Lesser Zab River, which was 1.458, is higher than that of the Greater Zab River, 1.421. It was observed that the condition factor K value was close in females and males in the Greater Zab River, which was 1.42 and 1.422, respectively, while in the Lesser Zab River, the K value for females was higher than its value in males, 1.46 and 1.457, respectively.

Table 4. Relative condition factor values calculated for females and males *Carasobarbus luteus* fish in Greater Zab and Lesser Zab rivers

Months	K values in Greater Zab River		K values in Lesser Zab River	
	Female	**Male**	**Female**	**Male**
December	1.337	……	1.385	1.389
January	1.371	1.352	1.469	1.423
February	1.43	1.42	1.472	1.476
March	1.472	1.447	1.511	1.502
April	1.51	1.5	1.545	1.52
May	1.489	1.482	1.525	1.584
June	1.448	1.469	1.49	1.488
July	1.445	1.445	1.467	1.475
August	1.423	1.428	1.459	1.479
September	1.418	1.411	1.438	1.421
October	1.366	1.36	1.384	1.391
November	1.341	1.336	1.377	1.342
Average	**1.42**	**1.422**	**1.460**	**1.457**
Total K	**1.421**		**1.458**	

Table 5. Comparing the relative condition factor values in the current study with previous studies of *Carasobarbus luteus* fish

Researcher	Location	(K) Male	(K) Female	(K) Male and Female
Baboli *et al*. (2013)	Karkheh River, Iran	1.26	1.23	……
Abdullah and Mohamed (2019)	Al-Diwaniya River, Iraq	1.95	1.96	……
Wahab and Abdulkader (2020)	Tikreet\Salahaddin, Iraq	1.38	1.35	1.37
Wahab and Shaker (2017)	Al-Tharthar lake	…..	…..	1.46
Abdul Qader (2019)	Tigris River- Alshirqat /Iraq	……	…..	1.539
Abdul Qader (2019)	Tigris River- Samrraa /Iraq	……	…..	1.39
Shaker (2023)	Al-Qalaa area, Iraq	…..	…..	1.6

2. Sex ratio and (GSI) index

The sex of *C. luteus* was determined by examining the gonads, and it was found that the number of males was 50 and 62 in the Greater Zab and Lesser Zab rivers, respectively, while the number of females was 113 and 138, respectively. As the sex ratio (males: females) reached 1: 2.26 in the Greater Zab River, which was close to the sex ratio in the Lesser Zab River, that reached 1:2.22.

Figs. (4 and 5) show the monthly changes in values of the *C. luteus* GSI in Greater Zab and Lesser Zab rivers for males and females throughout the study period.

Fig. (3) shows that in the Greater Zab River, the gonadosomatic index (GSI) for males reached its highest value of 3.3 in May and the lowest value of 1.1 in November. For females at the same location, the highest GSI was 9.3 in April, while the lowest was 2.0 in December.

Similarly, Table (4) shows that in the Lesser Zab River, the highest GSI value for males was 3.6 in May, and the lowest was 0.9 in November. For females, the highest value was 9.7 in April, and the lowest was 2.2 in December.

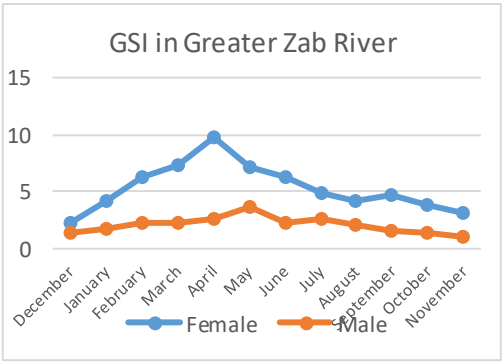

Fig. 4. Monthly changes for GSI of *C. luteus* in Greater Zab River

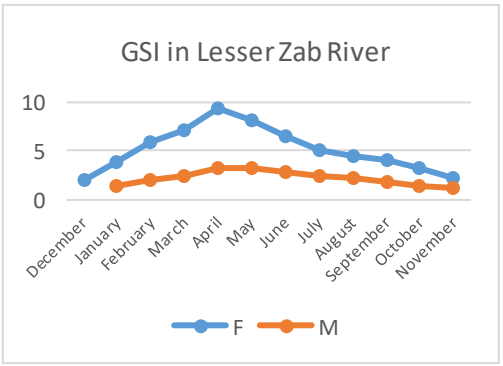

Fig. 5. Monthly changes for GSI of *C. luteus* in Lesser Zab River

DISCUSSION

Water temperature differences observed in the current study are likely due to fluctuations in air temperature, a finding consistent with those reported by **Abdullah and Mhaisen (2002)** in the Greater Zab River. The recorded pH values align with the findings of **Ali (2010)**, who noted that most Iraqi inland waters tend to be on the alkaline side of neutrality. Dissolved oxygen levels showed an inverse relationship with water temperature, which also agrees with observations by **Abdullah and Mhaisen (2002)**. Salinity values in the present study correspond to the expected electrical conductivity (EC) ranges reported for Iraqi freshwater systems **(Ali, 2010)**.

Transparency levels fluctuated significantly, likely due to seasonal factors such as heavy rainfall, floods, and strong wave activity. Additionally, anthropogenic influences—including gravel and sand extraction operations, water purification facilities, and infrastructure development—may have contributed to reduced water clarity.

The study also showed a decline in the number and weight of *Carasobarbus luteus* specimens caught in the Greater Zab River compared to the Lesser Zab River. These findings support previous local studies that reported increased fish abundance during warmer months in various Iraqi freshwater bodies **(Abass & Al-Rudayni, 2004; Al-Ammari *et al.*, 2012; Abdullah & Mohamed, 2019)**.

The importance of the length–weight relationship (LWR) lies in its ability to assess the condition and growth pattern of fish within a given environment. It also facilitates the creation of predictive equations for estimating one variable from the other **(Beckman, 1945)**.

In the current study, the b value in the Greater Zab River was 3.1721, indicating positive allometric growth. This value is slightly lower than **Mohamed *et al.* (2015)** (3.224), close to that reported by **Wahab and Shaker (2017)** (3.153), and higher than **Abdullah and Mohamed (2019)** (3.047). In the Lesser Zab River, the b value was **2.969**, which is close to **Muhamed *et al.* (2010)** (3.007), but lower than **Wahab and Shaker (2017)** (3.153), and higher than the values reported by **Al-Asadiy (2018)** (2.850) and **Shaker (2023)** (2.79). These differences may be attributed to variations in fish sizes across studies, as the b value tends to increase with a higher proportion of small fish in the sample.

Differences in Fulton's condition factor (K) between males and females may be explained by the heavier ovary weight in females compared to the testicular weight in males. The K values observed at both sites in this study were higher than those reported in earlier local studies such as **Abdul Qader (2019)**, **Wahab and Abdul Qader (2020)**, and **Baboli *et al.* (2013)**. However, they were lower than those reported by **Wahab and Shaker (2017)**, **Wahab and Abdul Qader (2020)**, and **Shaker (2023)**, as detailed in Table **(5)**. According to **Nikolsky (1963)**, variation in the K value is influenced by several

factors, including fish age, feeding intensity, sex, maturity, parasite load, and environmental conditions. Differences in sample sizes and the monthly size distribution of fish likely contributed to the variation in K values across studies.

The observed sex ratio in this study was higher than that reported by **Al-Ammari *et al.* (2012)**, who recorded a male-to-female ratio of 1:1.32. In the same study, the highest female GSI value was 11.05 in April, while the lowest value in that month was 7.13. Such variation in GSI values between studies can be attributed to differences in environmental factors, which significantly affect gonadal development and weight across different life stages and habitats.

CONCLUSION

The waters of the two rivers are suitable for *C. luteus* growth. However, the fish in the Lesser Zab River are in better condition than those in the Greater Zab River, in terms of numbers, weights, and condition factor.

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