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Growth patterns and reproductive biology of *Alburnus sellal* (Cyprinidae) in the Little Zab River, Tigris River basin, Iran

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ABSTRACT

Understanding the reproductive biology and growth characteristics of native freshwater fishes is essential for developing effective conservation and fisheries management strategies. This study aims to assess reproductive biology and growth in *Alburnus sellal* from the Zab River in western Iran. Fish samples were collected every month from November 2021 to December 2022. Standard morphometric measurements, age determination from scales, length–weight relationships, condition factor (K), gonadosomatic index (GSI), hepatosomatic index (HSI), oocyte diameter, and fecundity were evaluated. Based on the results, the total length of sampled male fish ranged from 6.76-16.18 (10.80±2.02) cm, and that of female fish ranged from 7.78-15.17 (12.00±1.66) cm, and the total weight ranged from 2.7-34.3 (11.95±6.88) g to 4.1-35 (15.55±7.02) g, respectively. The total length-weight relationships were estimated as $W = 0.0104 L^{2.90}$ ($r^2 = 0.87$) for males and $W = 0.0085 L^{2.99}$ ($r^2 = 0.80$) for females, indicating near-isometric growth in both sexes. The mean condition factor values were 0.86 and 0.85 for males and females, respectively. The dominant age class was 1+, and the overall sex ratio did not differ significantly from the expected 1:1 ratio. Seasonal changes in GSI, HSI, and oocyte diameter indicated that the reproductive season extended from March to June, with peak reproductive activity in late spring. Oocyte diameter ranged from 0.10 to 1.00 mm, reaching a maximum of 0.62±0.22 mm in May. Absolute fecundity ranged from 9,566 to 14,236 eggs (11,846±1,943 eggs), whereas relative fecundity varied from 558 to 1,324 eggs g^{-1} body weight (904±316 eggs g^{-1}). The reproductive traits observed in *A. sellal*, including prolonged spring spawning, group-synchronous ovarian development, multiple-batch spawning, and relatively high fecundity, indicate a reproductive strategy adapted to the seasonal hydrological conditions of the Little Zab River.

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Introduction

Freshwater ecosystems harbor a remarkable diversity of fish species that perform essential ecological functions and contribute significantly to the stability and functioning of aquatic environments; their conservation is therefore vital to overall biodiversity. Freshwater fishes regulate the abundance of aquatic organisms through predator–prey interactions, facilitate energy transfer across trophic levels, and serve as a major food source for other aquatic organisms, thereby maintaining the integrity and resilience of aquatic food webs (Northcote, 1988; Macadam and Stockan, 2015; Olden *et al.*, 2020). However, freshwater biodiversity is currently declining at an unprecedented rate due to habitat degradation, river regulation, overexploitation, pollution, invasive species, and climate change (Dudgeon *et al.*, 2006; Reid *et al.*, 2019). The loss of freshwater fish populations can disrupt ecological processes, reduce ecosystem resilience, and ultimately compromise the ecosystem services upon which human societies depend (Dudgeon, 2010). Therefore, understanding the life-history characteristics of freshwater fishes is fundamental for developing effective conservation and sustainable fisheries management strategies.

Among life-history traits, reproductive biology and growth characteristics are key components for understanding fish population dynamics and resilience. Information on reproductive seasonality, sexual maturity, fecundity, gonadal development, growth patterns, and condition status provides essential knowledge for evaluating population health, estimating recruitment potential, and designing appropriate conservation and fisheries management programs (Lowerre-Barbieri *et al.*, 2011). This information is particularly important for native freshwater fishes in river systems increasingly affected by anthropogenic disturbances.

The family Cyprinidae represents the most species-rich family of freshwater fishes in Iran, accounting for approximately one-quarter (74 species, 25.34%) of the country's inland ichthyofauna (Eagderi *et al.*, 2022). Within this family, the genus *Alburnus* comprises eight recognized species distributed across several Iranian drainage basins, including the Caspian Sea, Lake Urmia, Namak Lake, Zayandeh-Rud, Tigris, Persis, and Hormuz basins (Esmaeili *et al.*, 2018). Among them, *Alburnus sellal* is endemic to the Middle East and Central Asia; it plays the role of a prey and predator in these ecosystems (Mohammadian-kalat et al., 2017), and in Iranian inland waters, this species occurs in the Tigris, Zohreh, Persis, and Hormuz basins (Keivany *et al.*, 2016; Esmaeili *et al.*, 2018; Eagderi *et al.*, 2022). The species has also been reported from Iraq (Çiçek *et al.*, 2023), the Qweik River in Turkey, and the Persian Gulf drainage, including the Karun River basin (Eagderi *et al.*, 2019).

Alburnus sellal is an ecologically important component of riverine fish assemblages and contributes to energy transfer within freshwater food webs (Mohammadian-Kalat *et al.*, 2017). Although Alburnus species generally spawn from spring to early summer on stone beds in rivers and usually reach sexual maturity at 2–3 years of age (Keivany *et al.*, 2016), biological information on *A. sellal* remains scarce. Previous investigations have focused primarily on taxonomy, morphology, and feeding ecology (Mohammadian-Kalat et al., 2017; Freyhof et al., 2018; Eagderi et al., 2019; Ghafouri et al., 2021), but comprehensive studies on its reproductive biology and growth characteristics remain lacking. In addition, *A. sellal* is caught by the locals for sport fishing. Therefore, in terms of environmental management (to preserve genetic diversity) and fisheries (to exploit), various aspects, especially its reproductive biology, should be carefully investigated, and the results obtained should inform conservation and exploitation. Therefore, the aim of this study was to determine the reproductive characteristics of *A. sellal*, including length-weight relationship, condition factor, sex ratio, Gonadosomatic and Hepatosomatic Indices, ovum diameter, absolute fecundity, and relative fecundity in the Little Zab River, to provide basic data for its management and conservation in this basin.

Material and Methods

Study area: This study was conducted in the Little Zab River, a major tributary of the Tigris River basin in western Iran. The sampling site was located near Sardasht, West Azerbaijan Province (36°07′19″N, 45°29′00″E). The Little Zab River drainage encompasses the cities of Piranshahr and Sardasht in West Azerbaijan Province and extends into parts of Baneh County in Kurdistan Province. Originating from the northwestern highlands of Piranshahr, the river flows through the Alan Mountains before entering Iraq, where it joins the Tigris River (Binandeh *et al.*, 2012; Khezri, 2000).

Fish sampling and biological measurements: Specimens of *A. sellal* were collected monthly from November 2021 to December 2022 using a backpack electrofishing device (Samus MP 750). Immediately after capture, all specimens were fixed in 10% buffered formalin and transported to the laboratory for subsequent analyses.

The age of each specimen was determined from scales collected from the left side of the body, between the lateral line and the origin of the dorsal fin. The scales were mechanically cleaned using a fine brush, rinsed with distilled water, dried on filter paper, and mounted between glass slides for 2–3 days to prevent curling. Age was determined by counting annuli under a stereomicroscope using reflected light. For each fish, four to five scales were examined, and the final age was determined from the consensus of annulus counts.

Total length (TL, cm) was measured with a digital caliper (±0.01 mm), and total body weight (W, g) was recorded on an electronic balance with a precision of 0.01 g. The monthly condition factor (*K*) was calculated according to Biswas (1993): $K = 100 \times W/L^3$, where *W* is total body weight (g), and L is total length (cm).

Length–weight relationship: The length–weight relationship (LWR) was estimated using the equation: $W=aL^b$, where *W* is the total body weight (g), *L* is the total length (cm), *a* is the intercept, and b is the allometric growth coefficient (Froese *et al.*, 2011). After a logarithmic transformation, the relationship was expressed as $\log W = \log a + b \log L$, where *W* is the total weight in grams, L is the total length, a is a coefficient related to body form, and b is an exponent indicating allometric growth when unequal to 3. The parameters a and *b* were estimated by linear regression of log-transformed length and weight data (Bagenal, 1978). The significance of the regression model was evaluated using analysis of variance (ANOVA). Departure of the growth coefficient (b) from the isometric value (b= 3) was assessed using Student's *t*-test according to Pauly (1984):

$$t = \frac{SD(\ln L)}{SD(\ln W)} \times \frac{|\, b-3 \,|}{\sqrt{1-r^2}} \times \sqrt{n-2}$$

Where n is the number of specimens; b is the slope of the regression line; *SD*(ln *L*) and *SD*(ln *W*) are the standard deviations of length and weight, respectively; and r is the regression coefficient.

Reproductive indices: The sex ratio was evaluated using the chi-square (χ^2) test to determine whether the observed male-to-female ratio significantly deviated from the expected 1:1 ratio.

The gonadosomatic index (GSI) was calculated for both sexes following Dopeikar et al. (2015): GSI= Wg / Wb × 100, where *Wg* is the gonad weight (g) and *Wb* is the eviscerated body weight (g). The hepatosomatic index (HSI) (the proportion of the weight of the liver to the weight of the eviscerated body in percent) was calculated as: HSI= Wh / Wb × 100, where *Wh* is the liver weight (g), and *Wb* is the eviscerated body weight (g).

Fecundity and oocyte diameter: The ovaries were fixed in Bouin's solution for histological examination. Oocyte diameter was measured using an ocular micrometer with a precision of 0.01 mm. Absolute fecundity was estimated using the gravimetric method by counting the number of mature oocytes in a weighed subsample of the ovary: F= (G×n) / g, where *F* is the absolute fecundity, *G* is the total ovary weight (g), g is the weight of the subsample (g), and n is the number of oocytes counted in the subsample. Relative fecundity was expressed as the number of mature oocytes per gram of body weight.

Statistical analysis: Unless otherwise stated, statistical analyses were performed using SPSS version 20 (IBM Corp., Armonk, NY, USA). Data are presented as mean±standard deviation (SD). Differences were considered statistically significant at $P<0.05$.

Results

A total of 95 specimens of *A. sellal* were collected during the study period, comprising 51 males and 44 females. The mean total length (TL) was 10.80±2.02 cm for males and 12.00±1.66 cm for females, whereas the corresponding mean body weights were 11.95±6.88 g and 15.55±7.02 g, respectively (Table 1). The length-frequency distribution showed that individuals in the 12.1–14.0 cm length class were the most abundant in the population (Fig. 1).

Age determination using scale annuli revealed that the oldest individuals in both sexes were in the 2+ age class (Fig. 2). The mean condition factor (K) was 0.86 in males and 0.85 in females. Monthly variation in K was significant in males ($P<0.05$), whereas no significant monthly differences were observed in females except during June (Figs. 3–5).

The length–weight relationship showed a strong positive correlation between total length and body weight in both sexes. The estimated equations were: Males: $W = 0.0104L^{2.90}$ ($r^2 = 0.87$), and Females: $W = 0.0085L^{2.99}$ ($r^2 = 0.80$) (Figs. 6–8).

The overall male-to-female sex ratio was 1:0.7, which did not differ significantly from the expected 1:1 ratio ($\chi^2 = 1$, $P>0.05$). However, significant deviations from the expected sex ratio were observed during April and July ($P< 0.05$) (Table 2). The mean gonadosomatic index (GSI) was 2.62±1.47 in males and 2.74±1.20 in females. Female GSI exhibited significant monthly variation ($P<0.05$), whereas monthly differences in males were not significant ($P>0.05$). In both sexes, GSI values were highest in June (Figs. 9 and 10). The mean hepatosomatic index (HSI) was 0.61±0.30. In females, the highest HSI (1.02 ± 0.80) was observed in March, with significant monthly variation ($P< 0.05$).

Table 1. Total length (TL) and body weight (W) (mean ± SD) of male and female specimens of *Alburnus sellal* from the Little Zab River.

Gender	Total length (cm)	Total weight (g)

	Mean±SD	range	Mean±SD	range
Male	10.80±2.02	6.76-16.18	11.95±6.88	2.7-34.3
Female	12.00±1.66	7.78-15.17	15.55±7.02	4.1-35
Total	11.36±1.95	6.76-16.18	11.8±7.14	2.7-35

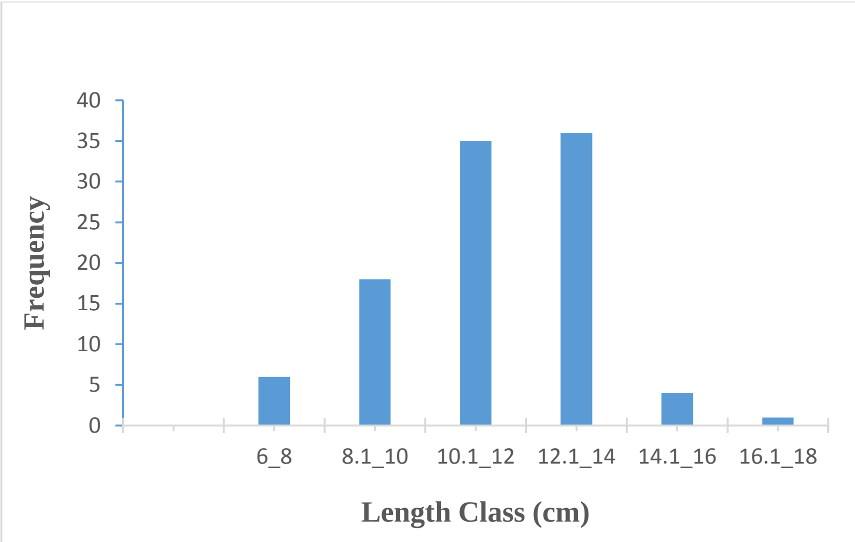

Figure 1. Length frequencies of *Alburnus sellal* in the Little Zab River.

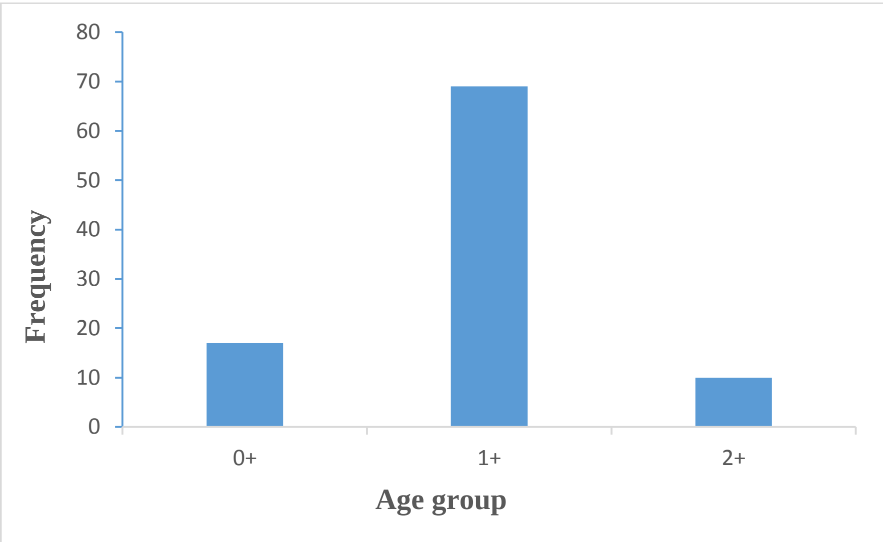

Figure 2. Age group frequency of *Alburnus sellal* in the Little Zab River.

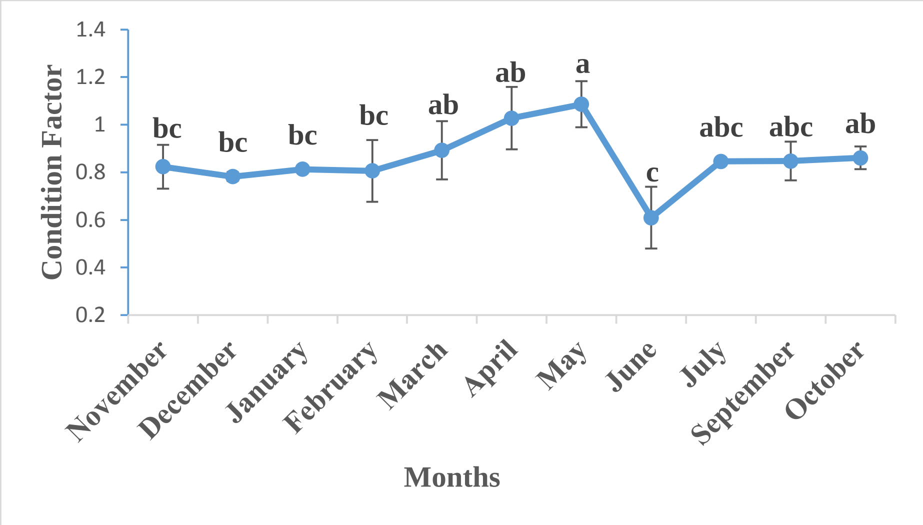

Figure 3. Mean condition factor and standard error in different months for males of *Alburnus sellal* in the Little Zab River.

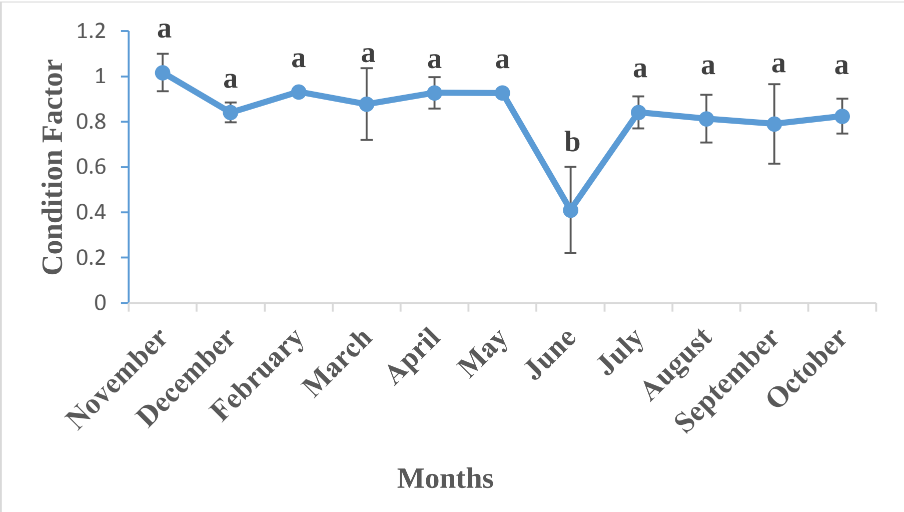

Figure 4. Mean condition factor and standard error across months for females of *Alburnus sellal* in the Little Zab River.

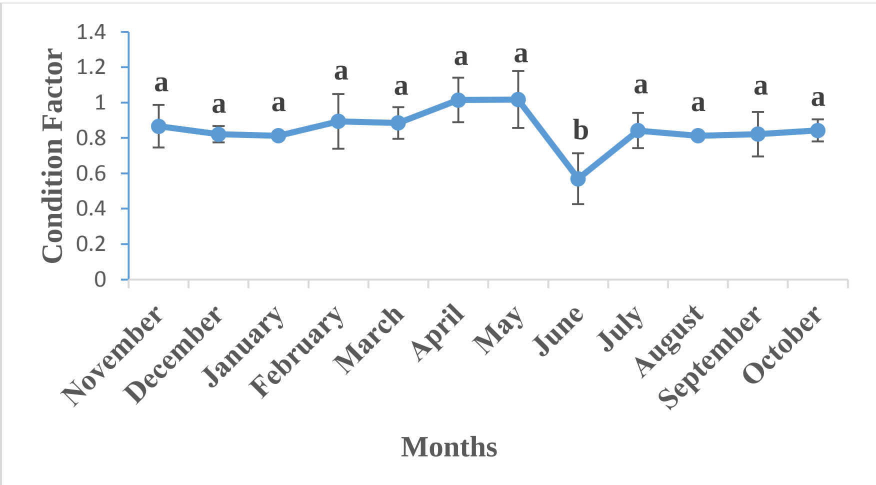

Figure 5. Mean condition factor and standard error in different months for all fishes of *Alburnus sellal* in the Little Zab River.

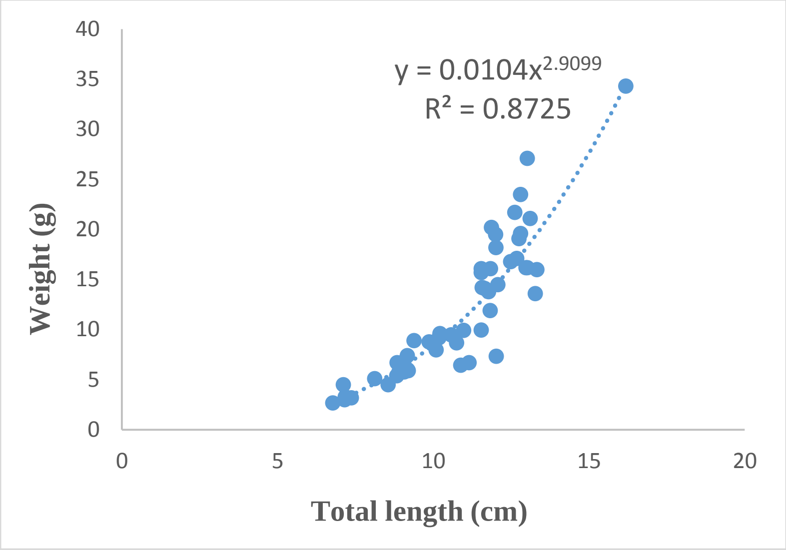

Figure 6. Length-weight relationships in males of *Alburnus sellal* in the Little Zab River.

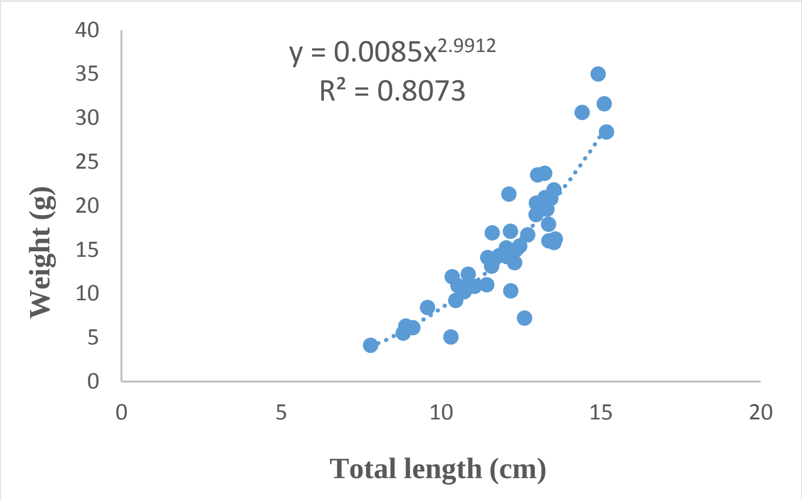

Figure 7. Length-weight relationships in females of *Alburnus sellal* in the Little Zab River.

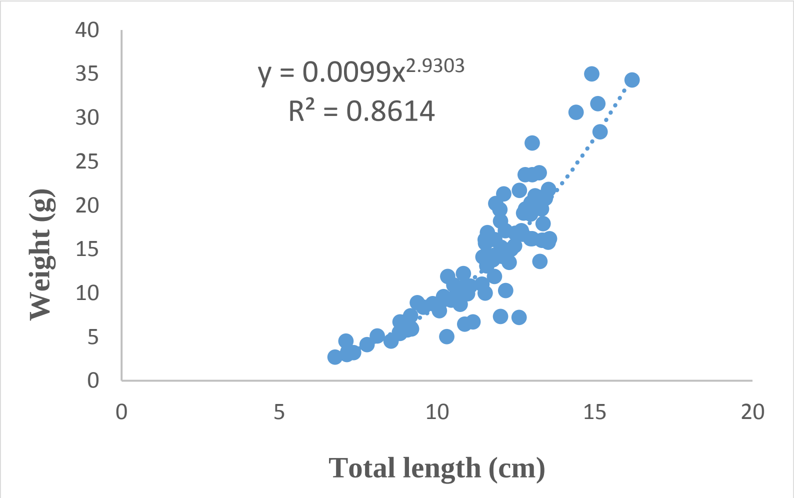

Figure 8. Length-weight relationships of all *Alburnus sellal* in the Little Zab River.

Table 1. Number and sex ratios of *Alburnus sellal* specimens in different months in the Little Zab River.

Months	Sex	Number	M:F ratio	*P*= 0.05
November	M F	7 2	3.5	*P*>0.05
December	M F	4 8	0.5	*P*>0.05
January	M F	2 0	0	-
February	M F	3 7	0.42	*P*>0.05
March	M F	3 3	1	*P*>0.05
April	M F	7 1	7	*P*<0.05
May	M F	7 3	2.33	*P*>0.05
June	M F	8 2	4	*P*>0.05
July	M F	1 9	0.11	*P*<0.05
August	M F	0 1	0	-
September	M F	5 4	1.25	*P*>0.05
October	M F	4 4	1	*P*>0.05
Total	M F	51 44	1.15	*P*>0.05

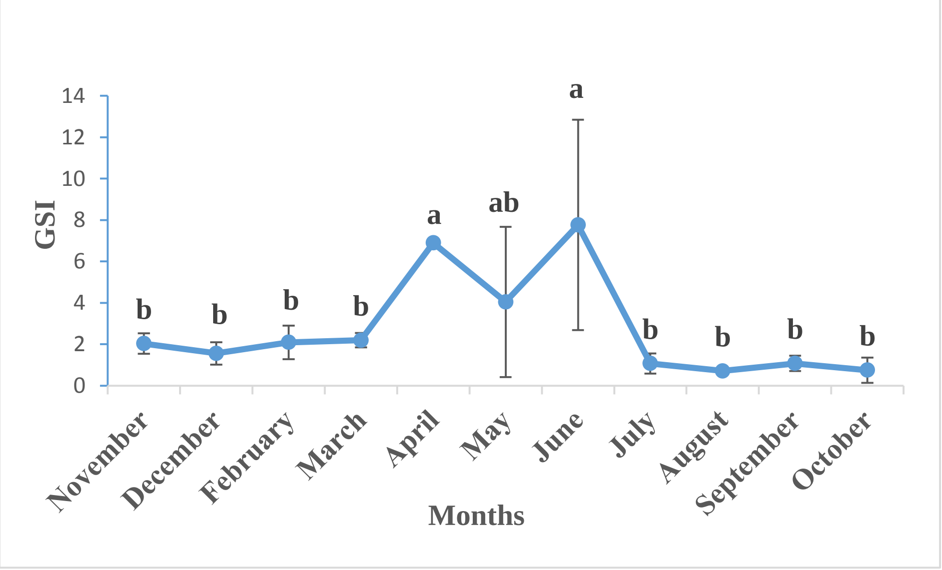

Figure 2. Variation in the mean gonadosomatic index (GSI) of females of *Alburnus sellal* from the Little Zab River across different months.

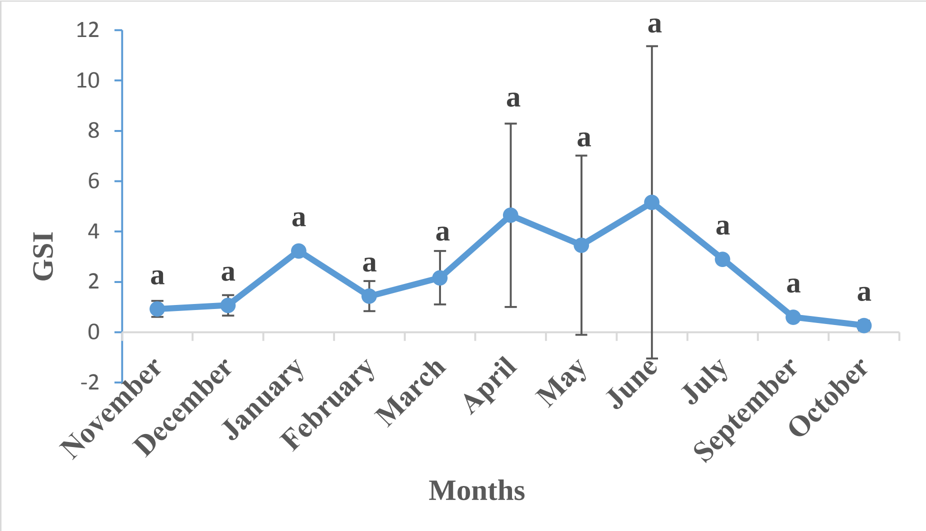

Figure 3. Variation in the mean gonadosomatic index (GSI) of males of *Alburnus sellal* from the Little Zab River in different months.

In males, the maximum HSI (3.22± 0.14) was likewise significantly higher than values recorded in other months (P <0.05) (Figs. 11 and 12). Based on monthly changes in GSI, HSI, ovarian development, and direct macroscopic examination of the gonads, the reproductive season of *A. sellal* in the Little Zab River was estimated to extend from March to June.

Oocyte diameter ranged from 0.10 to 1.00 mm, with a mean value of 0.33 ± 0.19 mm. The largest mean oocyte diameter (0.62±0.22 mm) was recorded in May. Monthly variation in oocyte diameter closely paralleled changes in GSI, increasing gradually from March to June, with significant differences among months (P<0.05) (Fig. 13; Table 3). Absolute fecundity ranged from 9,566 to 14,236 eggs, with a mean of 11,846 ± 1,943 eggs. Relative fecundity ranged from 558 to 1,324 eggs g^{-1} body weight, with an average of 904 ± 316 eggs g^{-1}.

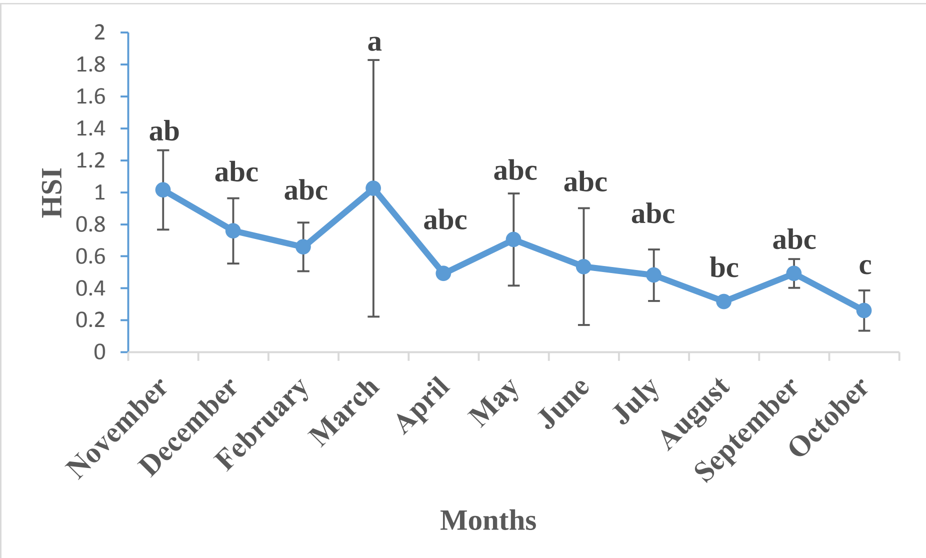

Figure 4. Variation in the mean hepatosomatic index (HSI) of females of *Alburnus sellal* from the Little Zab River across different months

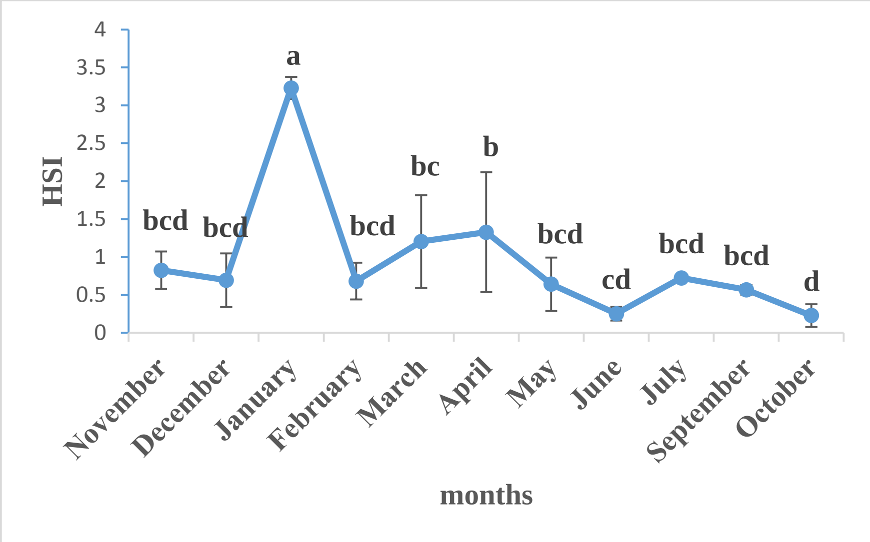

Figure 5. Variation in the mean hepatosomatic index (HSI) of males of *Alburnus sellal* from the Little Zab River across different months.

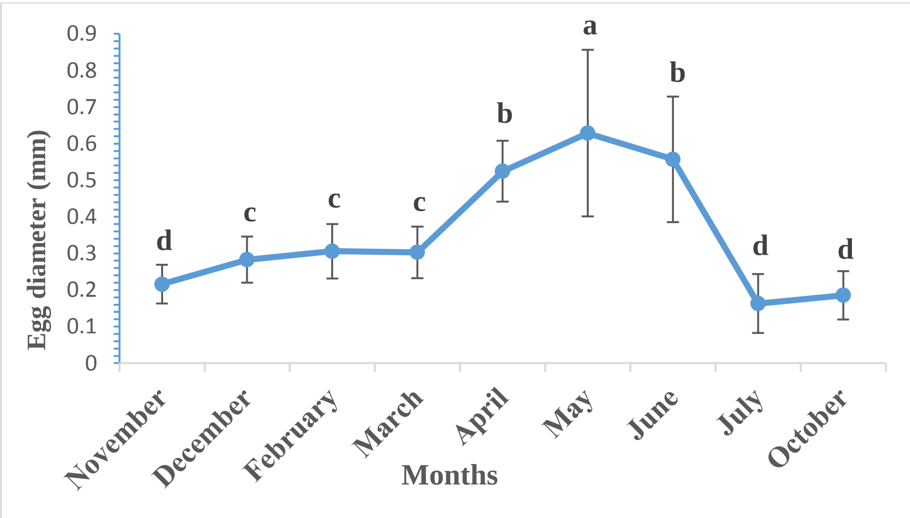

Figure 6. Variation in mean ova diameter (mm) of female *Alburnus sellal* from the Little Zab River across different months.

Table 2. Variation in mean ova diameter (mm), range egg diameter, and total length in female *Alburnus sellal* from the Little Zab River in different months.

Months	Total length±(SD) (cm)	Range egg diameter (mm)	Mean egg diameter±(SD) (mm)
November	9.95±0.54	0.12-0.37	0.21±0.05
December	11.39±1.34	0.17-0.50	0.28±0.06
February	11.97±1.08	0.17-0.50	0.30±0.07
March	12.43±0.38	0.20-0.45	0.30±0.07
April	12.98±0	0.32-0.67	0.52±0.08
May	11.60±0.01	0.25-0.97	0.62±0.22
June	11.45±1.62	0.25-1.00	0.55±0.17
July	14.41±0	0.1-0.57	0.16±0.08
October	12.10±0.97	0.1-0.37	0.18±0.06

Discussion

Females of *A. sellal* attained significantly larger body size than males, as reflected by their greater mean total length and body weight. Sexual size dimorphism is common among cyprinid fishes and has been reported for several *Alburnus* species and other freshwater fishes (Ghorbani, 2011; Koyun and Karadavut, 2010; Keivany *et al.*, 2017a). Larger female size is generally associated with higher reproductive investment, as increased body size enables females to produce larger ovaries and more oocytes, thereby enhancing reproductive success (Sarkar and Lakra, 2010). Differences in habitat utilization, growth rate, feeding behavior, and energy allocation between sexes may also contribute to the observed sexual dimorphism (Dopeikar *et al.*, 2015).

The length-weight relationship is widely recognized as an important indicator of fish growth patterns, physiological condition, and habitat suitability (Keivany *et al.*, 2015; Jafari-Patcan *et al.*, 2018; Abbasi *et al.*, 2019; Mouludi-Saleh *et al.*, 2021). In the present study, the estimated allometric coefficient (b) was 2.90 for males and 2.99 for females, indicating almost isometric growth in both sexes ($b = 3$). Variations in growth pattern among fish populations are expected because the length–weight relationship is influenced by numerous intrinsic and extrinsic factors, including sex, age, reproductive status, food availability, habitat characteristics, seasonal variation, and environmental conditions (Ricker, 1979; Froese, 2006; Abedi *et al.*, 2011; Keivany *et al.*, 2017). In contrast, Keivany *et al.* (2017) reported isometric growth in male *A. sellal* and positive allometric growth in females from the Bibi-Sayyedan River. These differences likely reflect environmental variation among river systems, population-specific growth strategies, and differences in food resources and habitat quality. In general, the value of b lies between 2.5 and 4 and can vary with changes in fish shape, season, age, and food availability (Ricker, 1979).

Age composition provides valuable information on population structure, recruitment, and survival. The age of *A. sellal* in the Little Zab River ranged from 0+ to 2+ years, with the 1+ age class dominating the population. Previous studies have reported maximum ages of four to five years for species of the genus *Alburnus sellal* (Alkan Uçkun and Gökçe, 2015; Fazli *et al.*, 2019; Keivany *et al.*, 2017a). The predominance of younger individuals observed in the present study may indicate strong annual recruitment, relatively high mortality of older fish, or environmental conditions that favor rapid population turnover. Differences in fishing pressure, habitat quality, and hydrological characteristics among river systems may also contribute to regional variation in age structure (Sarkar and Lakra, 2010).

The overall sex ratio did not differ significantly from the expected 1:1 ratio, suggesting a balanced population structure. Balanced sex ratios generally indicate stable reproductive populations and are commonly reported for cyprinid fishes (Zohar, 2021). Nevertheless, the significant monthly deviations in April and July likely reflect seasonal reproductive behavior, differential habitat use, or sex-specific vulnerability to electrofishing during the spawning season. Similar temporal fluctuations in sex ratio have been documented in other freshwater fish species and are often attributed to behavioral differences between males and females during reproduction rather than to true demographic imbalances (Liao and Chang, 2011; Shehu Jeg *et al.*, 2017).

Gonadosomatic indices (GSI), which are good estimators of energy allocation to gamete production, calculated for large numbers of ripe fish, indicate that females allocate more energy than males (Dadebo *et al.*, 2003). In the present study, females exhibited slightly higher mean GSI values than males, indicating greater energetic investment in oogenesis than in spermatogenesis. This difference is expected because oocyte production and maturation require substantially greater energy reserves than sperm production, a pattern commonly observed in cyprinid fishes and other teleosts (Dadebo *et al.*, 2003).

Based on the maximum recorded GSI values, the reproductive season of *A. sellal* extends from late March to late July. The GSI peaked in April and June, coinciding with the first observations of spawning individuals. Following the spawning period, GSI declined sharply, indicating the completion of gonadal development and spawning. Similar reproductive timing (higher GSI values from March to June, peaking in April) has been reported for *A. sellal* in several Iranian basins (Keivany *et al.*, 2017b; Mousavi-Sabet *et al.*, 2017). The similarity among these populations probably reflects comparable climatic conditions, photoperiod, and seasonal increases in water temperature, all of which are recognized as primary environmental cues regulating reproduction in temperate freshwater fishes. In males, the gonadal index increased from March through June, then immediately decreased; however, because males allocated less energy, there was no significant difference between months. This observation is consistent with the lower energetic cost of spermatogenesis compared with vitellogenesis and ovarian development (Dadebo *et al.*, 2003). Similar sex-specific patterns have been documented in numerous freshwater teleosts and are considered a common characteristic of species exhibiting prolonged spawning seasons (Bhat *et al.*, 2021).

The HSI values ranged from 0.08 to 3.33 in male fish. The highest HSI value was recorded in the month of January, while the lowest value was in the month of October. For females, the HSI values ranged from 0.14 to 1.95. The maximum value was observed in March, gradually decreased to the lowest in October, and thereafter increased. The maximum HSI value was recorded in March, indicating greater fat accumulation in the liver during the winter months; i.e., it exhibited marked seasonal variation, with the highest values occurring during the pre-spawning period, particularly in females. This finding supports the close physiological relationship between liver activity and ovarian development (Yaron & Levavi-Sivan, 2011). During vitellogenesis, the liver synthesizes vitellogenin under stimulation by estradiol-17β, after which this precursor protein is transported through the bloodstream and incorporated into developing oocytes as yolk proteins. Consequently, seasonal fluctuations in HSI frequently parallel changes in reproductive activity and reflect the mobilization of hepatic energy reserves for egg production (Le Menn *et al.*, 2007). Recent advances in fish reproductive physiology have further highlighted the central role of vitellogenin synthesis in determining oocyte quality, fecundity, and reproductive success (Yilmaz *et al.*, 2024). Taken together, GSI, HSI, ovarian development, and macroscopic gonadal examination consistently indicate that *A. sellal* is a spring-spawning species in the Little Zab River, with reproductive activity extending from early March to late June. This reproductive strategy likely reflects an adaptive response to favorable spring conditions, when rising water temperatures, increased food availability, and suitable hydrology enhance larval survival and recruitment.

Based on the results, oocyte diameters were highest in May (0.62 mm) and lowest in July (0.16 mm). Oocyte diameter is widely recognized as a reliable indicator of ovarian maturation and reproductive status in teleost fishes. In the present study, oocyte diameter increased progressively from March, peaked in May, and then declined after the spawning period. The close correspondence between seasonal changes in oocyte diameter and the gonadosomatic index (GSI) confirms that oocyte growth accurately reflected the progression of gonadal maturation. Similar seasonal patterns have been reported for *A. sellal* from the Bibi-Sayyedan

(0.952 ± 0.228 mm) and Gamasiab (0.11-0.84 mm) rivers (Keivany *et al.*, 2017b; Mousavi-Sabet *et al.*, 2017), as well as for *A. chalcoides* in Turkish inland waters (Unver and Yildirim, 2011). Oocyte diameter varies among populations because egg size is influenced by multiple biological and environmental factors, including female body size, age, nutritional condition, habitat characteristics, and local environmental conditions (Siami et al., 2017). Recent studies have further demonstrated that maternal energy allocation and environmental variability can substantially influence oocyte development and egg quality, ultimately affecting larval survival and recruitment success (Kamler, 2021; Rideout *et al.*, 2022).

Based on the results of the current study, the average absolute fecundity of female *A. sellal* from the Little Zab River was 11846 eggs (±1943), ranging from 9566 to 14236 eggs; the relative fecundity ranged from 558 to 1324 (904±316) eggs per gram of total body weight. Relative and absolute fecundity are associated with female body size, age, gonad weight, and the amount of energy available for reproduction, whereas environmental factors such as food availability, habitat quality, and population density may also influence annual egg production (Bagenal, 1978; Thorpe *et al.*, 1984). The substantially higher fecundity observed in the present study compared with that reported for *A. sellal* by Mousavi-Sabet *et al.* (2017) may reflect differences in female size structure, environmental productivity, or habitat conditions between the two river systems.

The relatively high values observed in the present study suggest that *A. sellal* allocates a substantial proportion of its available energy to reproduction during the spawning season. This reproductive investment is characteristic of opportunistic freshwater fishes in dynamic riverine environments, where successful recruitment depends on maximizing reproductive output under favorable conditions. Recent life-history studies emphasize that reproductive plasticity, including variation in fecundity and egg characteristics, is an important adaptive mechanism that enables freshwater fishes to cope with fluctuating environmental conditions and hydrological variability (Winemiller and Rose, 1992; Lowerre-Barbieri *et al.*, 2023).

Overall, evidence from seasonal changes in GSI, HSI, oocyte development, and fecundity indicates that *A. sellal* exhibits group-synchronous ovarian development with multiple batch spawning during an extended reproductive season from March to June. This reproductive strategy, together with its relatively high fecundity, likely maximizes reproductive success under the seasonal hydrological conditions of the Little Zab River and may represent an adaptive life-history response to the environmental variability characteristic of the Tigris River basin.

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