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Evaluating Growth, Reproductive Indices and Environmental Adaptability of the Common Carp (*Cyprinus carpio*) in Mechraa Sfa Dam, Tiaret Region, Algeria

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ABSTRACT

This study evaluated the health and growth patterns of fish in the Mechraa Sfa Dam, Tiaret, in 2022. Analysis showed slight allometric growth, with the b-value below 3, indicating asymmetry. Statistically significant hepato-somatic, gonado-somatic ($P< 0.05$) highlighted variations in liver condition, reproductive health, and body form. The condition factor averaged 2.0476±1.2356, reinforcing the asymmetric growth pattern. The environmental parameters recorded no effect on the biological indices, except for a positive correlation of GSI with pH and dissolved oxygen as well as HIS with orthophosphate ($r> 0.5$). These findings establish a baseline for assessing fish health, supporting future conservation and fishery management efforts in the region.

INTRODUCTION

By 2030, nearly all around 90% of the world's aquatic animal production is expected to be used directly for human consumption, representing a 15% rise relative to that registered in 2020. This shift should increase annual per capita consumption from 20.2 to 21.4kg, influenced by several factors: more people moving to cities, rising income levels, shifting dietary habits, better production, and more efficient distribution. While most regions are likely to experience higher consumption, sub-Saharan Africa may undergo a slight decline, which raises concerns about food security in this area **(FAO, 2022)**.

The common carp, *Cyprinus carpio*, which belongs to the Cyprinidae family, is an important species in freshwater fisheries around the globe. It's origion is traced back to Southeast Asia and China but has now spread to Europe and North America, primarily because of its significance in aquaculture **(Dieuzeide *et al*., 1951)**.

Growth patterns in species such as the common carp are often influenced by environmental conditions, with water quality being an important factor affecting their health and size. A commonly used measure, Fulton's condition factor (K), evaluates fish health by correlating their weight to their length, aiding in the assessment of their health status within the ecosystem **(Derbali *et al.*, 2012)**.

This study investigated the common carp in the Mechraa Sfa Dam in Tiaret, analyzing how seasonal variations and water parameters, such as pH, influence their growth and health indicators.

MATERIALS AND METHODS

1. Study area

The Bekhadda Dam (Fig. 1), situated 40 kilometers west of Tiaret in Algeria's Mechraa Sfa municipality at an elevation of 665 meters, is essential for water management in the area. Its primary function is to supply drinking water to Tiaret and nearby towns Rahouia, Mechraa Sfa, Djillali Ben Ammar, Kharouba, Guertoufa, and Temda. The dam collects water from the Mina River, which feeds into the Chellif River, and assists the irrigation of 500 hectares of agricultural land. Constructed with a 45-meter-high rockfill design and a waterproof upstream face of flexible reinforced concrete, the dam was raised in 1960, increasing its capacity by 14 million cubic meters, from 37 to 51 million cubic meters, at a low cost. This enhancement has considerably bolstered its contribution to sustainable water resources, allowing it to effectively address agricultural, drinking water, and environmental requirements in the area **(ANBT, 2021)**.

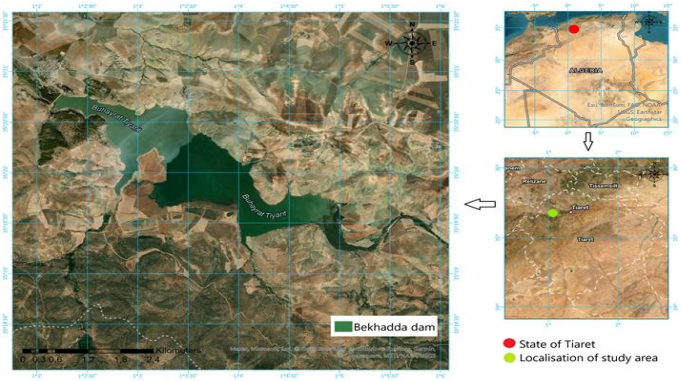


Fig. 1. Geographical location of the study area **(Original map, 2024)**

2. Sampling and sample processing

Throughout 2022, a monthly sampling of common carp was conducted, yielding 120 fish caught with gillnets. Individual weighings in grams and measurements in centimeters were carried out on each individual. Moreover total weight (Wt), eviscerated weight (Wev), total length (Lt), fork length (Lf), maximum height (Hmax), standard length (Ls). Following dissection, the sex macroscopically was identified, and carefully removed and weighed both gonads and livers. Reproductive metrics such as sex ratio (SR), gonado-

somatic index (GSI), hepato-somatic index (HIS), profile index (IP) and the condition factor (K) were then calculated. Additional water quality data were sourced from Algerienne Des Eaux (ADE) in Tiaret.

3. The calculated parameters

Study of the growth

The morphometric relationship between parameters was analyzed using a multiple regression model ($Y = aX^b$), which was linearized using a logarithmic function as follows:

$\log Y = b \log X + \log a$ **(Ricker, 1973)**.

Sex ratio

The numerical proportion of the sexes was expressed by the ratio of the number of females to that of males (sex ratio; SR). SR = F/M, with F = number of females; M = number of males **(Kartas & Quignard, 1984)**.

The condition factor of Fulton

The physiological and physical states of a fish, along with any changes resulting from interactions between feeding conditions and other variables, are reflected in its condition factor **(Le Cren, 1951)**.

Fulton's condition factor was calculated as follows:

$$C=(W*100)/L3$$ **(Fulton, 1904).**

Where, "*W*" is the total weight (g) and "*L*" is the total length (cm).

The hepatosomatic index

According to **Bougis (1952)**, the liver of some fish species performs an essential function in the physiological mechanisms that control the development of sexual products, and the environment surrounding reproduction largely determine changes in its weight. The hepatosomatic index (HIS) was calculated according to the formula below

$$\mathbf{HIS = (Wl \times 100) / Wev}$$

The gonadosomatic index

During the common carp's sexual cycle, spawning periods were identified using the gonadosomatic index (GSI). The following formula was used, which was supplied by **Parmeswaran *et al.* (1974):**

$$\mathbf{GSI= WG \times 100/WT}$$

The profile index

The profile index characterizes the degree of selection of fish according to its external appearance using the following equation **(Charpy, 1943):**

***IP*=Standard length/ body height**

Water's physicochemical parameters

The data of the physicochemical parameters of the water were obtained from the Algerian water company ADE Tiaret.

4. Statistical analysis

To understand the relationships among the biometric factors (total weight, eviscerated weight, total length, and fork length), Pearson correlation was used alongside linear regression based on the least squares method. One-way analysis of variance (ANOVA) was conducted to compare growth and biological indices and the student's t-test was used for pairwise mean comparisons.

The relationships between the biological indices of *C. carpio* and the environmental parameters were assessed using the PCA. All analyses were set with a significance level of 5%.

RESULTS

1. The frequencies of distribution of morphometric characteristics

Table (1) provides an overview on the frequency distribution the in common carp, showing that male specimens have a total length between 28 and 40cm, while female specimens range from 29 to 43cm, and those of indeterminate sex measure between 29.5 and 37cm. Seasonal changes appear to significantly affect total length, as indicated by a *P*-value of 0.001 and an F-value of 7.775.

For fork length, male measurements span from 24 to 38cm, female measurements from 24 to 43cm, and indeterminate specimens from 24 to 34cm. Seasonal effects on Lf were also significant, with a *P*-value of 0.000 and an F-value of 11.961.

Total weight in males varied from 278 to 1415g, in females from 329 to 1180g, and in indeterminate individuals from 320 to 765g. Seasonal influence on Wt is marked by a *P*-value of 0.003 and an F-value of 6.323.

Eviscerated weight ranged from 236 to 1088g in males, 271 to 955g in females, and 269 to 681g in indeterminate specimens, with seasonal variation significantly influencing Wev (*P*=0.000, F=8.523).

Additionally, sex does not influence the seasonal variation in any of the four studied parameters (*P*-value > 0.05). This suggests that carp size and weight are useful indicators of growth rate, with larger fish often showing better adaptability to their habitats.

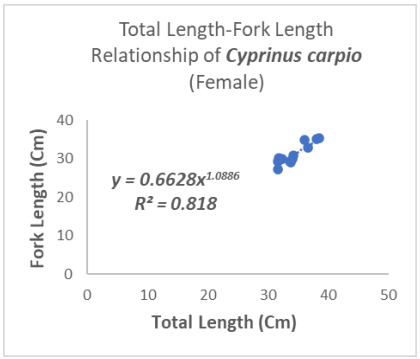
The degree of association between the parameters was evaluated with the correlation coefficient (r^2), while Pearson correlation determined a statistical significance, where (Y) represents total length (Lt); (X) represents either fork length (Lf) or total weight (Wt); with (a) as the slope of the regression line; and (b) as the regression coefficient.

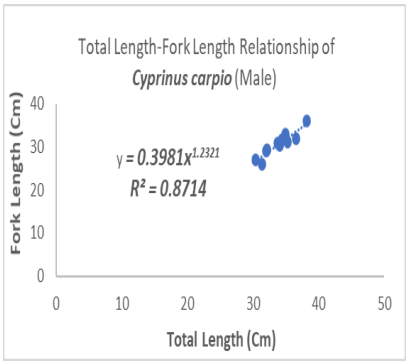
Table 1. Different measurements of morphometric parameters for *Cyprinus carpio*

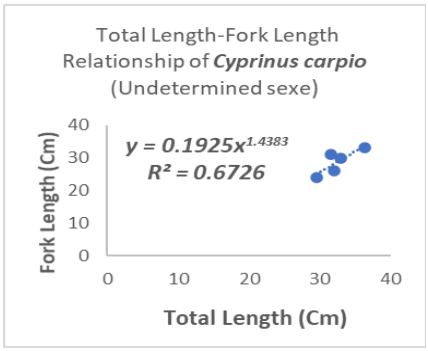
Sex	N	Total length (Cm)	Fork length (Cm)	Total weight(g)	Eviscerated weight(g)
Male	31	40.0±28.0	38.0±24.0	1415.0±278.0	1088.0±236.0
Female	82	43.0±29.0	43.0±24.0	1180.0±329.0	955.0±271.0
Undetermined	7	37.0±29.5	34.0±24.0	765.0±320.0	681.0±269.0

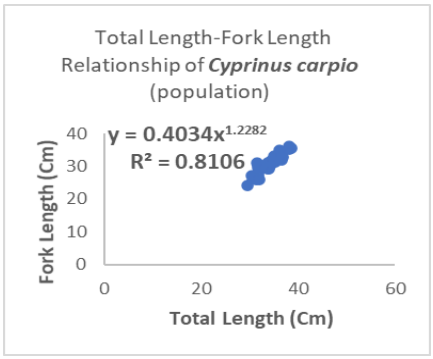
Relationship between total length-fork length

The total length-fork length relationship in the population of *Cyprinus carpio* from the Bekhadda dam was very highly significant (*P* =0.000). The regression equation was Log Lt=1.2282Log Lf+ Log 2.3239, R^2 =0.8106. With b=1.2282 and a minor allometry.



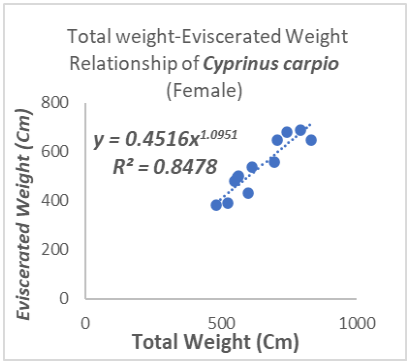


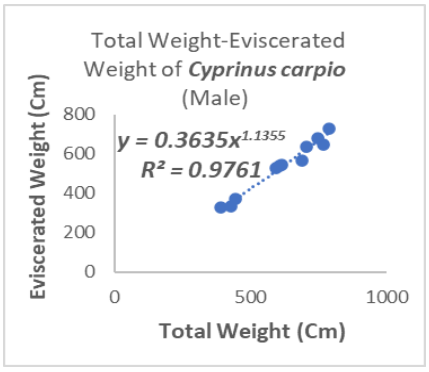


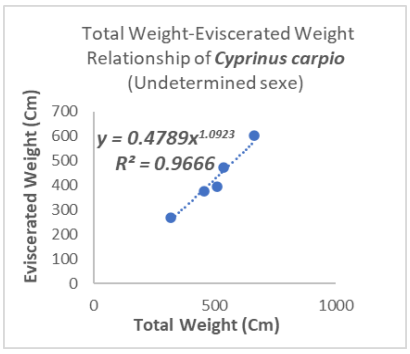


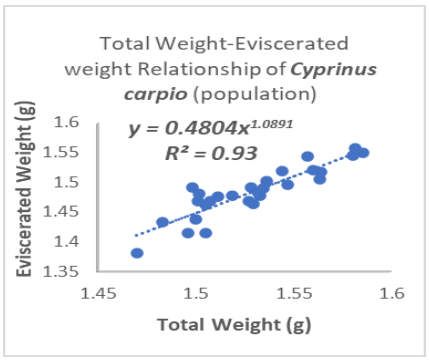
Relationship between total weight-eviscerated weight

The total weight-eviscerated weight relationship in the population of *Cyprinus carpio* was very highly significant (*P*=0.000). The regression equation was LogWt=1.0891LogWev+Log2.2163, R^2=0.933, with b=1.0891 and a minor allometry.



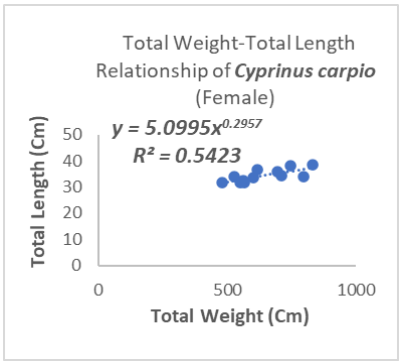


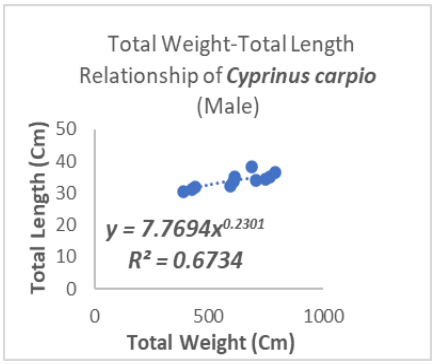


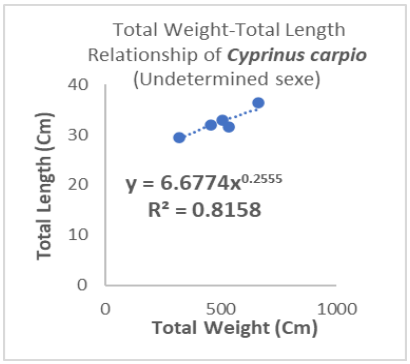


Relationship between total weight-total length

The total weight-total length relationship in the population of *Cyprinus carpio* was highly significant (*P*=0.001). The regression equation was LogWt= 0.2471Log Lt+Log2.2942, R^2=0.6595, with b=0.2471 and a minor allometry.







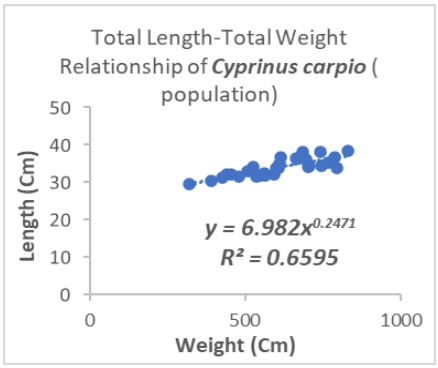


Table 2. Linear regression between biometric parameters weight-weight, length-length, weight-length (Lt=total length, Lf=fork length, Wt=total weight, Wev=eviscerated weight, K=condition factor, the test value=0.05)

Sexe	N	Equation	A	b	R^2	Pvalue	K	
Male	31	LOGLt=1.2321LOGLf+LOG2.3182 LOGWt=1.1355LOGWev+LOG2.1127 LOGLt=0.2301LOGWt+LOG2.4203	2.3182 2.1127 2.4203	1.2321 1.1355 0.2301	0.8714 0.9761 0.6734	0.000 0.000 0.002	1.559	Minorant allometry
Female	82	LOGLt=1.0886LOGLf+LOG2.5396 LOGWt=1.0951LOGWev+LOG2.4691 LOGLt=0.2957LOGWt+LOG1.9231	2.5396 2.4691 1.9231	1,0886 1.0951 0,2957	0.8180 0.8478 0.5423	0.007 0.000 0.000	1.575	Minorant allometry
Undeterminated	7	LOGLt=1.4383LOGLf+LOG2.0027 LOGWt=1.0923LOGWev+LOG2.3145 LOGLt=0.2555LOGWt+LOG2.2414	2.0027 2.3145 2.2414	1.4383 1.0923 0.2555	0.6726 0.9666 0.8158	0.002 0.003 0.000	1.431	Minorant allometry
Population	120	LOG Lt=1.2282LOG Lf+ LOG2.3239 LOGWt=1.0891LOGWev+LOG2.2163 LOG Lt=0.2471LOGWt+ LOG2.2942	2.3239 2.2163 2.2942	1.2282 1.0891 0.2471	0.8106 0.93 0.6595	0.000 0.000 0.001	1.543	Minorant allometry

2. Gender identification and sex-ratio

The 120 specimens in the study were divided into 82 females (68.33%), 31 males (25.83%) and 7 indeterminates (5.83%). The global sex ratio (SR) determined during the

annual cycle is 2.64: (t-test = 15.872; $P \leq 0.001$). The significance rate was calculated with the student t-test, it was constantly in favor of females throughout the sampling.

3. Variation of the biological indices according to sex and season

Four biological growth and ecological indicators were calculated and used to categorize individuals, as well as evaluating the ecological environment of the species.

The condition factor of Fulton

The one-way ANOVA statistical test shows that sex has no effect on condition K in the population ($P > 0.05$). The seasonal variation of the condition factor ranges from 1.1714±1.246 to an average of 1.431 for both sexes, 2.047±1.246 and 1.575 for females, 1.841±1.235 and 1.559 for males.

The Hepatosomatic index

Statistics derived from ANOVA indicate that the hepatosomatic index's seasonal variation is highly significant for the entire population, with a *P*-value of 0.000 and an F-value of 25.748. Nevertheless a *P*-value greater than 0.05 suggests that there is no significant correlation between this metric and the fish's sex.

The gonadosomatic index

According to statistical calculations, the GSI's seasonal variation is extremely significant for the total population, with a *P*-value of 0.000 and an F-value of 25.748. In contrast a significant relationship exists between the sex of the fish and this parameter with a *P*-value less than 0.05.

The profile index

The average profile index in the entire population is 2.58 and the seasonal variation of the IP is highly significant according to the statistical analyses of ANOVA in the entire population with (*P*-value=0.003, F=5.959), and the sex of the fish has no relationship with this parameter whose *P*-value>0.05.

4. The environmental data

Impact of the environmental data on the biological indices

Table (3) presents the results of the physicochemical analyses of the raw water from the Bekhadda Dam carried out by the ADE Tiaret.

Table 3. The physico-chemical parameters of Bekhadda Dam in Tiaret region **(ADE, 2022)**

Date	January	February	March	April	May	June	July	August	September	October	November	December
T°C	9.9	9.9	15.8	15.9	16.1	16.2	17.8	17.9	18.2	18.6	13.8	10.9
Dissolved oxygen	110.12	115.2	108.2	106.23	107.25	108.2	107.3	101.2	102.3	106.3	110.63	111.25
Turbidity NTU	3.1	4.1	4.3	4.2	4.08	4.11	4.03	3.91	3.89	3.91	5.6	5.14
pH	7.79	7.77	7.76	7.75	7.76	7.77	7.78	7.79	7.79	7.78	7.78	7.79
Conductivity µsm/cm	1012	1009	1007	1005	1006	1005	1012	1010	1009	1009	1010	1012.6
Organic matter mg/l	4.8	4.7	4.6	4.8	5.2	5.1	4.9	4.8	4.5	4.5	4.8	4.6
Orthophosphate mg/l	0.08	0.08	0.08	0.04	0.08	0.06	0.06	0.08	0.07	0.09	0.08	0.07
Nitrite mg/l	0.211	0.204	0.211	0.218	0.221	0.21	0.211	0.2	0.187	0.199	0.208	0.221

The effect of abiotic factors were tested on biological indices, and the results shown in Fig. (2) are as follows:

-Negative correlation of HIS, GSI with the environmental parameters (Nitrite, MO, conductivity, turbidity and temperature)

-A positive correlation of GSI with pH and dissolved oxygen as well as HIS with ortho phosphate (r> 0.5).

-Negative correlation of K and IP with all parameters.

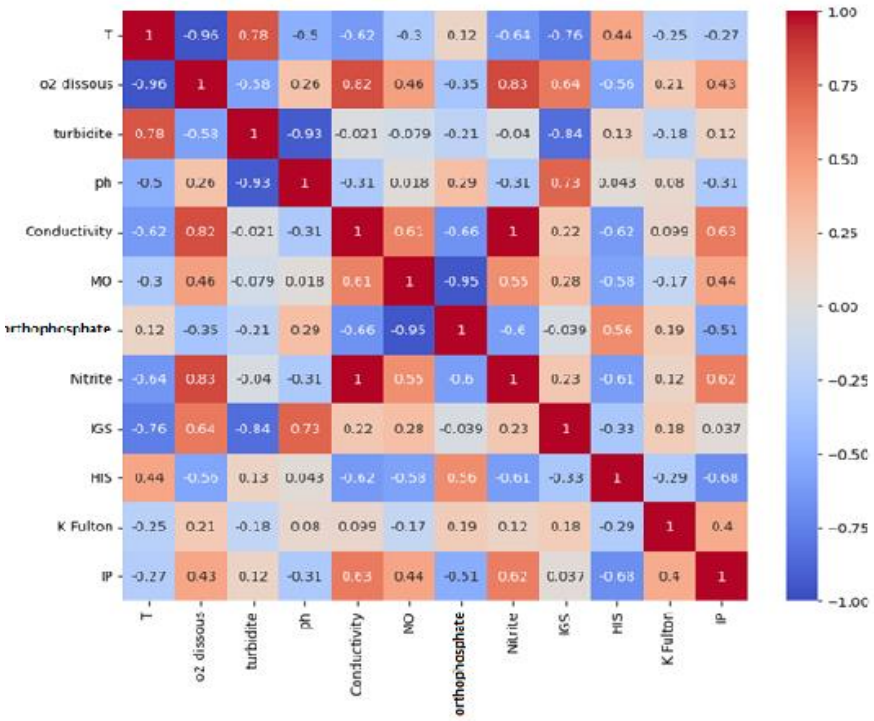


Fig. 2. Correlation matrix between biological indices and environmental parameters

DISCUSSION

In our study the average length of the population was 38.5 ± 29.5cm and the average weight was 832.85 ± 320.0g. **Hadjlaoui *et al*. (2022)** reported a maximum length of 58.5 ± 12cm and an average weight of 2620 ± 24.7g for the common carp in the Sidi Saad reservoir in Tunisia. **Askri *et al*. (2013)** observed an average length of 47.8 ± 13.8cm and weight of 1275 ± 40.9g in the Dahmouni Dam in Algeria. The length-weight relationship for the entire population was b = 1.2282, the total weight-total length was b = 0.2471, and the total weight-eviscerated weight was b = 1.0891. This indicates that carp experience negative allometric growth, meaning they grow in weight faster than they increase in size. This finding aligns with **Hadjlaoui *et al*. (2016)**, who reported all b values below 3, and corroborates the result of **Gasmi *et al.* (2023)**, who found that b= 1 for length-weight in Lake Oubeira and b= 2.235 in Tonga. **Özcan (2008)** reported that b= 3.112 in Hatay province, Turkey. Various factors can influence the b value in the length-weight relationship in fish, such as environmental conditions (temperature and salinity), sex, gonadal maturity, habitat, season, nutrition, and geographic location **(Froese, 2006)**.

Regarding the effect of sex on biometric parameters (weight and length), the *P*-value was superior to 0.05, showing no important effect, likely due to the skewed sex ratio of 82 females to 31 males or the age structure of the population. The study evidenced a female dominance over males, as reported by **Dereli *et al*. (2022)**, who found 328 females out of 650 common carp in Lake Marmara, Western Anatolia, Turkey. This numerical superiority of females in the catches could be explained by several factors such as foraging movement, differential growth, environmental factors and mortality rate. **Mimeche *et al*. (2015)** noted a 76% male-biased sex ratio.

The condition factor for the current study was 2.0476 ± 1.2356 for the entire population, indicating asymmetrical growth ($b \neq 3$). **Aera *et al*. (2014)** found that larger sizes of both male and female fish (31 – 60cm) had higher condition factors and were in better health compared to smaller individuals.

Seasonal changes in the gonadosomatic index (GSI) were highly important for the total population (*P*-value = 0.000, F = 25.748), and sex showed an important relationship with this parameter. This concurs with that of **Barakov *et al*. (2024)**, who identified April and May as the primary spawning months for *C. carpio* in Kapchagay Reservoir in 2022, with gonadal activity gradually declining until October.

Seasonal variation in the hepatosomatic index (HIS) was also highly important for the total population (*P*-value = 0.000, F = 25.748), albeit no important relationship was detected with sex (*P*-value > 0.05). This contrasts with **Sharma *et al.* (2020)**, who found important differences ($P < 0.05$) in HIS values between two age groups for both sexes.

The profile index's seasonal variation is highly significant, with IP<2.8 indicating very heterogeneous slowing of growth in our study area. This could be due to insufficient food, the presence of illnesses, or other factors that need further investigation in the dam. This coincides with the findings of **Hantanirina *et al.* (2019)**, who conducted research on the common carp in Madagascar's fishing areas.

In the current research, no influence of physicochemical parameters was found on reproductive parameters, except for a positive correlation between pH and the GSI (r = 0.73). This contrasts with the findings of **Agnes and Thirumathal (2018)**, who reported a negative correlation between pH and the gonadosomatic index, as well as a positive effect of dissolved O2 on the GSI. This is in agreement with the study of **Siraj *et al.* (2016)**, who also found a positive effect of orthophosphate on the hepatosomatic index (r> 0.5). Additionally, these results are consistent with those of **Attal *et al.* (2023)**, whose research in the Ghrib Dam in the Ain Defla region of Algeria showed that the condition factor was negatively correlated with water and air temperature. Spatial and temporal reproductive strategies in fish may, therefore, be adaptations to certain environmental factors that optimize larval survival **(Fréon, 1988)**.

CONCLUSION

This study is the first thorough investigation concerning the biological characteristics of common carp in the Mechraa Sfa Dam located in the Tiaret region. The findings indicated that the average total length of the population was 38.5 ± 29.5cm, while the average total weight was 832.85 ± 320.0g. These results differ from data obtained from other areas, such as the Sidi Saad reservoir in Tunisia, where the maximum mean size recorded was 58.5 ± 12cm and the total weight was 2620 ± 24.7g. The research uncovered significant correlations between biometric parameters and the growth patterns of *Cyprinus carpio*. It was noted that the growth patterns of carp in this population displayed negative allometry, with b-values suggesting that the fish grew at a faster rate than their size increased. Sex did not significantly influence biometric parameters (P> 0.05), which may be attributed to a skewed sex ratio of 82 females to 31 males. Additionally, the condition factor varied between 2.0476 ± 1.2356 throughout the population, indicating asymmetric growth ($b \neq 3$). Seasonal variation was significant for both the hepatosomatic index (HIS) and the gonadosomatic index (GSI), with ANOVA results demonstrating high significance ($P = 0.000$). The GSI was related to the sex of the fish, underscoring the importance of these indices in understanding reproductive cycles. The profile index (IP) also exhibited significant seasonal variation ($P = 0.003$), but did not correlate with fish sex. Overall, this research enhances the understanding of the growth dynamics and reproductive characteristics of *Cyprinus carpio* in the Mechraa Sfa dam, offering valuable insights that could guide future conservation and management efforts.

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