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RESEARCH ARTICLE

BIOMETRY, LENGTH-WEIGHT RELATIONSHIPS AND CONDITION FACTORS OF SARPA SALPA FROM BIZERTE LAGOON, NORTHERN TUNISIA

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ABSTRACT

This study provides the first assessment of the morphometry, length–weight relationship, and condition factor of *Sarpa salpa* in the Bizerte Lagoon, northern Tunisia, to enhance understanding of its population structure and growth dynamics. Morphometric traits, including body shape, fin dimensions, and eye and orbital measurements, were analyzed to provide a detailed description of the species' morphology. The length-weight relationship indicated negative limitations in food availability, although the satisfactory condition index suggests that allometric growth, suggesting that fish grow more in length than in weight, whereas the Fulton condition factor reflected an overall good physiological state. The observed negative allometry may indicate potential the lagoon environment remains generally suitable for the species. These contrasting results emphasize the complex interaction between growth patterns and environmental conditions. The findings offer valuable baseline data on the biology and health of *S. salpa* populations, contributing to the sustainable management and future ecological monitoring of lagoonal ecosystems.

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INTRODUCTION

Length-weight relationships (LWRs) represent a fundamental component of fish biology and fisheries science. They are used to estimate body weight from a given length, describe growth patterns, and support stock assessment and biomass estimation (N. Jisr *et al.*, 2018; S. F. Mehanna & A. E. Farouk, 2021; E. Ragheb, 2023). In parallel, condition factors are important indicators of fish well-being and the ecological quality of their habitats. They integrate the combined effects of biotic and abiotic factors, such as food availability, reproductive status, and environmental stress, on the overall health and nutritional state of fish populations (B. G. Blackwell *et al.*, 2000; G. Guidelli *et al.*, 2011). A higher condition factor generally reflects better feeding conditions or physiological status, whereas lower values may signal nutritional stress or environmental degradation (E. Ragheb, 2023). Lagoons are among the most productive aquatic ecosystems in the world and have been exploited by humans for thousands of years (M. Fetouh & A. El-Far, 2023). The Bizerte Lagoon, located in northern Tunisia and connected to both the Mediterranean Sea and Lake Ichkeul, represents one of the country's largest and most ecologically important transitional ecosystems. It hosts a rich diversity of marine organisms, serving as a nursery and feeding ground for numerous fish and invertebrate species. Despite its ecological value, the lagoon faces increasing anthropogenic pressures from urbanization, industrial effluents, agricultural runoff, and port activities (S. Mili *et al.*, 2023; W. Ben Ameer *et al.*, 2025).

These inputs have altered its water quality and nutrient balance, with potential implications for the health and population structure of resident species. The family Sparidae, which includes seabreams, is widely distributed throughout the Mediterranean and constitutes an important commercial and recreational fishery resource (M. Trojette, 2015). Members of this family inhabit a wide range of habitats, from rocky and sandy substrates to seagrass meadows, typically at depths below 150 m (J. M. S. Gonçalves, 2000; J. Ribeiro *et al.*, 2006). Among them, the salema, *Sarpa salpa* (Linnaeus, 1758), is a benthopelagic, gregarious species occurring in shallow coastal waters of the eastern Atlantic, Mediterranean, and western Indian Ocean (C. Jadot *et al.*, 2006; W. Bakkari *et al.*, 2024). Juveniles feed mainly on small crustaceans, whereas adults are predominantly herbivorous, grazing on macroalgae and seagrasses (W. Bakkari *et al.*, 2024). This species plays a critical ecological role in controlling algal biomass and maintaining the balance and productivity of seagrass ecosystems. In addition to its ecological function, *S. salpa* represents a valuable economic resource in Mediterranean fisheries, including the Bizerte Lagoon, where it is locally consumed and commercially exploited. However, population dynamics and growth characteristics of this species in Tunisian lagoons remain poorly documented. Previous studies have mainly focused on the Adriatic, Aegean, and western Mediterranean regions (J. Dulčić & M. Kraljevic, 1996; A. Pallaoro *et al.*, 2008; B. Bayhan & A. Kara, 2015), with little or no data available from Tunisian waters. Understanding the length-weight relationship and condition factor of *S. salpa* in the Bizerte Lagoon is therefore crucial for evaluating its population health and establishing sustainable management strategies. These parameters provide essential baseline information on growth patterns, environmental

influences, and habitat suitability. To the best of our knowledge, this work represents the first study investigating the morphometric traits, length-weight relationship, and condition factors of *S. salpa* in the Bizerte Lagoon. In this study, we aimed to evaluate the morphometric characteristics, determine the length-weight relationship parameters, and identify the growth pattern of *Sarpa salpa* from the Bizerte Lagoon. The findings provide crucial baseline data on the species' biological traits, enhancing our understanding of its population structure and supporting informed management and conservation measures for the sustainable use of fishery resources in this Mediterranean lagoon ecosystem.

MATERIALS AND METHODS

Sampling area and specimen collection: A total of 30 specimens of *Sarpa salpa* were collected during commercial fishing operations in the Bizerte Lagoon (Figure 1) in March 2020. The lagoon, located in northern Tunisia between latitudes 37°08' and 37°14' N and longitudes 9°46' and 9°56' E, covers approximately 128 km², with dimensions of 13 km in length and 11 km in width, making it the third-largest lagoon in the country (W. Ben Ameer et al., 2025). Fish samples were obtained from local fishing landings using gillnets and trammel nets commonly employed by artisanal fishers. Immediately after capture, specimens were placed on ice and transported in insulated containers to the laboratory. Upon arrival, they were stored at -20 °C until further analysis. Before measurements, each fish was thawed, carefully rinsed, and dried with absorbent paper.

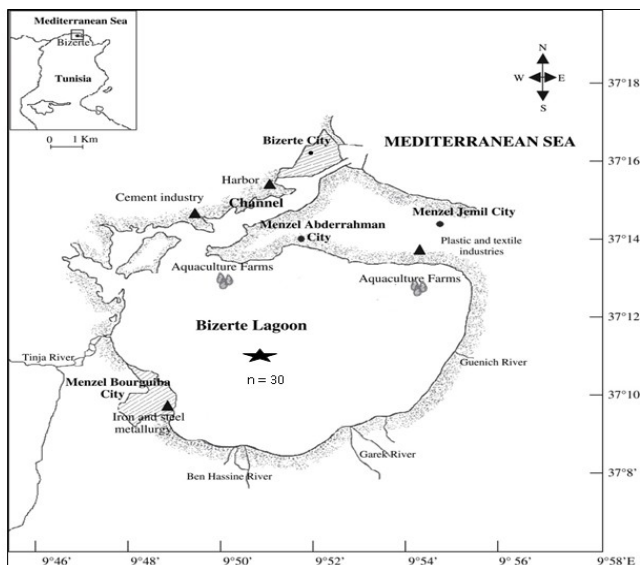


Figure 1. Sampling location

Biometric analysis: Each specimen was subjected to a detailed morphometric analysis using a digital caliper (accuracy 0.1 cm), and body weight (BW) was recorded using an electronic balance with 0.1 g precision. Morphometric measurements followed standard ichthyological methods (Figure 2) and included total length (TL), measured from the tip of the snout to the end of the caudal fin lobe; standard length (SL), from the snout tip to the base of the caudal fin; and body height (BH), representing the maximum vertical body depth excluding fins. Predorsal length (PreDL) was measured from the snout tip to the origin of the dorsal fin, while dorsal fin length (DFL) corresponded to the maximum distance between the base of the first and last dorsal fin spines. Anal fin length (AFL) was taken as the horizontal distance between the anterior and posterior extremities of the anal fin. Pectoral (PFL) and pelvic (PvFL) fin lengths were measured from the base of the first ray to the tip of the longest ray of each respective fin. Preorbital length (PrOL) and postorbital length (PoOL) were determined as the distances from the snout tip to the anterior eye margin and from the posterior eye margin to the operculum edge, respectively, while eye diameter (ED) represented the maximum horizontal diameter of the eye. To maintain

measurement consistency, all morphometric parameters were taken on the left side of each specimen. These measurements were used to describe the body proportions and general morphological characteristics of *Sarpa salpa* populations inhabiting the Bizerte Lagoon.

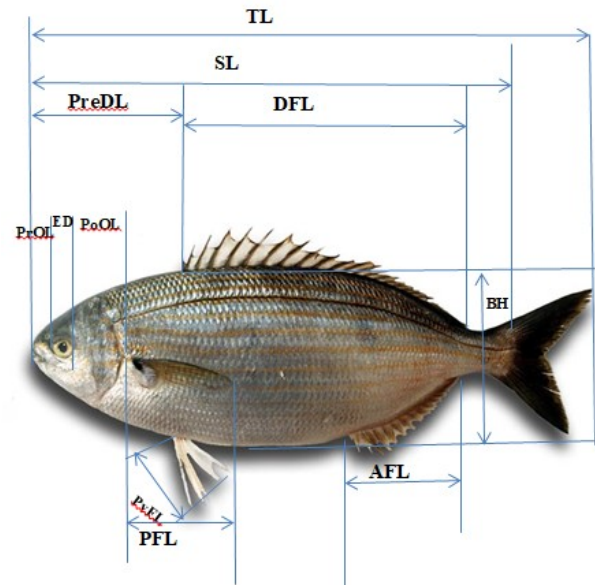


Figure 2. Morphological parameters of *Sarpa salpa*

Length-weight relationship (LWR): The length-weight relationship was calculated using the equation: $BW = aTL^b$, where BW is the body weight (g), TL is the total length (cm), and a and b are the regression coefficients (E. D. L. Cren, 1951). The parameters a and b were estimated through least-squares linear regression of the log-transformed data according to the equation: $BW = \log a + b \log TL$ (C. Lațiu et al., 2023). The exponent b describes the growth pattern of the fish: $b > 3$ indicates positive allometric growth (weight increases faster than length), $b < 3$ indicates negative allometric growth (length increases faster than weight), and $b = 3$ reflects isometric growth (proportional increase in both) (R. Froese, 2006). The 95% confidence interval (CI) for b was calculated to assess whether it significantly deviated from the isometric value of 3.

Relative condition factor (Kn): The relative condition factor (Kn) was calculated for each specimen using the formula: $K_n = W_o W_e^{-1}$, where W_o is the observed body weight and W_e is the expected weight derived from the length-weight relationship (C. Lațiu et al., 2023). A value of $K_n \geq 1$ indicates that the fish is in good physiological condition, whereas $K_n < 1$ suggests a less favorable condition (E. D. L. Cren, 1951).

Statistical analysis: A t-test was performed to assess whether the estimated b value significantly differed from the isometric value of 3 and to classify the type of growth. The null hypothesis of isometric growth ($H_0: b = 3$) was tested at a significance level of $\alpha = 0.05$ (C. Lațiu et al., 2023). The coefficient of determination (r^2) was used to evaluate the goodness of fit of the linear regression, with values closer to 1 indicating a stronger predictive power of the model.

RESULTS AND DISCUSSION

Morphometric characteristics: The morphometric analysis of *Sarpa salpa* specimens collected from the Bizerte Lagoon is summarized in Table 1. The total lengths of individuals ranged from 27.3 to 30.9 cm, with a mean of 29.46 ± 1.45 cm, while body weights varied between 270.63 and 378.08 g (mean 332.03 ± 44.57 g). These findings indicate a relatively homogeneous size class, likely representing adult individuals. The low standard deviations for both length and weight further confirm the limited size variation among the sampled fish. The standard length represented approximately 84.4% of the total length, reflecting the elongated body shape typical of the species, which is

adapted for moderate swimming activity in shallow coastal environments. The mean body height was 8.86 ± 0.29 cm, accounting for roughly 30% of the total length, suggesting a stable body form and overall good condition. The predorsal length averaged 8.92 ± 0.45 cm, closely matching body height and demonstrating the characteristic morphometric balance of *S. salpa*. Fin measurements showed moderate variability, with the dorsal fin being the largest (mean 13.16 ± 0.77 cm), followed by the anal fin (5.62 ± 0.45 cm), pectoral fin (4.84 ± 0.21 cm), and pelvic fin (4.04 ± 0.11 cm). These proportional relationships align with previous morphometric studies of the species and suggest that fin development supports effective maneuverability and stability in the lagoon's variable hydrodynamic conditions. Cranial measurements revealed a preorbital length of 1.92 ± 0.16 cm and a postorbital length of 2.52 ± 0.22 cm, resulting in a postorbital-to-preorbital ratio of approximately 1.31, consistent with herbivorous sparids. The eye diameter (1.38 ± 0.08 cm) was moderate relative to head size, reflecting adaptation to the moderate light penetration in lagoonal waters.

Table 1. Morphometric Data of *Sarpa salpa* samples from the Bizerte Lagoon

Parameter	Mean \pm SD	Range
Weight (g)	332.03 \pm 44.57	270.63-378.08
Total length (cm)	29.46 \pm 1.45	27.30-30.90
Standard length (cm)	24.86 \pm 1.47	22.60-26.20
Body height (cm)	8.86 \pm 0.29	8.50-9.20
Predorsal length (cm)	8.92 \pm 0.45	8.20-9.30
Dorsal fin length (cm)	13.16 \pm 0.77	12.00-14.00
Anal fin length (cm)	5.62 \pm 0.45	5.00-6.10
Pectoral fin length (cm)	4.84 \pm 0.21	4.70-5.20
Preorbital length (cm)	1.92 \pm 0.16	1.70-2.10
Postorbital length (cm)	2.52 \pm 0.22	2.20-2.80
Eye diameter (cm)	1.38 \pm 0.08	1.30-1.50
Pelvic fin length (cm)	4.04 \pm 0.11	3.90-4.20

Length-weight relationship and condition factor: The LWR for *Sarpa salpa* from the Bizerte Lagoon was assessed using the equation $\log(W) = \log(a) + b \cdot \log(L)$, where W represents body weight (g) and L represents total length (cm) (Table 2). The estimated parameters were $a = 0.0525$ and $b = 2.586 \pm 0.072$, with a coefficient of determination (r^2) of 0.981. The high r^2 indicates a strong positive correlation between length and weight, confirming that body mass increases predictably with length within this population. The regression analysis was statistically significant ($P = 0.000$), demonstrating the robustness of the model. The 95% confidence interval for b (2.33–2.84) excluded the theoretical isometric value of 3, indicating a significant deviation ($P < 0.05$) and confirming that *S. salpa* in the Bizerte Lagoon exhibits negative allometric growth. This means that as individuals increase in length, their weight does not increase proportionally, leading to a more elongated body form. Negative allometry is commonly observed in populations inhabiting environments that favor elongation over mass accumulation, potentially influenced by habitat structure, food availability, or reproductive activity (D. Alcando, 2021). The intercept ($a = 0.0525$) reflects the body form coefficient and can vary according to environmental conditions such as water temperature, salinity, and habitat productivity. The relatively low a value suggests that *S. salpa* in Bizerte Lagoon are slightly lighter for a given length than conspecifics in more open marine habitats, likely due to differences in diet composition or lagoon hydrodynamics.

The relative condition factor (Kn) averaged 0.998 ± 0.0042 , ranging from 0.972 to 1.020, indicating that most individuals were in good physiological condition and exhibited balanced growth. Values of Kn near 1 generally reflect favorable environmental conditions and adequate food supply (R. Froese, 2006; D. Alcando, 2021). Interestingly, the observed negative allometric growth contrasts with the high condition factor values. While $b < 3$ indicates a tendency toward slenderness with increasing length, the Kn results suggest that individuals maintain overall good health. This apparent discrepancy may arise because relative condition factors and LWR parameters reflect different aspects of fish physiology and environmental interaction. Previous studies have reported similar observations,

highlighting that growth patterns are influenced by a combination of ecological, physiological, and biological factors including feeding behavior, parasitism, sexual maturity, age, and sex, which were not considered in this study (D. Alcando, 2021; M. Y. Hossain *et al.*, 2012; D. Alcando, 2021). LWR and condition factors are also highly sensitive to population variability, seasonal sampling, and methodological differences. Factors such as food availability, feeding intensity, age, sex, maturation stage, muscular development, fat reserves, and gut fullness can significantly influence the values obtained for b and Kn (A. Al Nahdi *et al.*, 2016; O. O. Famofo & W. O. Abdul, 2020). Overall, the LWR and condition factor analyses indicate that *S. salpa* in Bizerte Lagoon form a healthy population with negative allometric growth, reflecting a complex interaction between fish biology and environmental conditions, which is characteristic of lagoonal habitats with fluctuating ecological dynamics. The length-weight relationship is influenced by numerous factors, including population variability (A. Al Nahdi *et al.*, 2016), the season in which samples are collected, and the methods used for estimation (O. O. Famofo & W. O. Abdul, 2020). In addition, biological and ecological parameters such as food availability, feeding intensity, fish size, age, sex, reproductive stage (e.g., gonad development), data handling, classification into size classes, gut fullness, muscular development, fat reserves, and overall life history can significantly affect the calculated values of the condition factor (K) (O. O. Famofo & W. O. Abdul, 2020). The IUCN status of *Sarpa salpa* is classified as Least Concern (LC). This designation indicates that the species is currently widespread and abundant, and there are no immediate threats causing a significant global population decline.

Table 2. Length-weight relationship and relative condition factor for *Sarpa salpa* collected from Bizerte Lagoon

Parameter	Value
Sample size (N)	30
Total length (Lmin–max, cm)	27.3-30.9
Weight (Wmin–max, g)	270.63-387.77
a	0.0525
b	2.586
Standard error of b SE (b)	0.072
Confidence interval of b CI (b)	2.33-2.84
Coefficient of determination (r^2)	0.981
Significance of regression ($P < 0.05$ considered significant) P	0.000
t-test significance (t-test sig)	0.000
Growth type	Negative allometry
Kn	0.998
Relative condition factor with range (Kn Min–Max)	0.972-1.020
Standard error SE (Kn)	0.0042
IUCN status	LC

When compared to other Mediterranean and Atlantic populations (Table 3), this value falls within the general range reported for the species (2.75-3.28). Most studies, however, report b values around or slightly above 3, suggesting isometric or mildly positive allometric growth, such as populations from the Eastern Adriatic Sea ($b = 3.10-3.26$; Dulčić & B. Glamuzina, 2006; A. Pallaoro *et al.*, 2008) and Homa Lagoon, Turkey ($b = 3.14$; D. Acarli *et al.*, 2014). Lower b values, similar to the present study, have been observed in female specimens from Karakulak *et al.* (2006) ($b = 2.77$) and in Izmir Bay by B. Bayhan & A. Kara, (2015) ($b = 2.84$). Variation in b across studies is likely influenced by environmental factors, including temperature, salinity, food availability, hydrodynamics, as well as specimen size, sampling season, and reproductive stage (N. Jisr *et al.*, 2018). The relatively low b in the Bizerte Lagoon suggests that the local population is more elongated and less bulky than conspecifics from open marine environments, reflecting adaptations to shallow, vegetated lagoon habitats where streamlined bodies aid in agility and energy-efficient swimming. The high coefficient of determination ($r^2 = 0.981$) demonstrates a strong linear relationship between length and weight, consistent with values reported elsewhere ($r^2 = 0.92-0.99$). The intercept ($a = 0.0525$) is slightly higher than many previously reported values (0.004–0.029), indicating a marginally different

Table 3. Length-weight relationships of *Sarpa salpa* from different localities

Area	Sex	Length range (cm)	Length type	N	a	b	r ²	Reference
Natal, South Africa	Unsexed	–	–	–	0.059	2.79	–	F. Torres Jr (1991)
Eastern Adriatic, Croatia	Unsexed	13.9–41.6	TL	437	0.021	3.12	0.98	J. Dulčić & M. Kraljevic(1996)
Off Alexandria, Egypt	Unsexed	8.9–13.0	TL	39	0.014	2.90	0.97	M. Abdallah (2002)
Kyclades, Greece	Mixed	14.9–25.1	TL	48	0.014	2.94	0.98	D. K. Moutopoulos & K. I. Stergiou(2002)
Stryman estuary, Greece	Mixed	7.9–11.7	TL	10	0.010	3.19	0.99	E. T. Koutrakis & A. C. Tsikliras(2003)
Kornati Archipelago, Adriatic	Juvenile	1.6–14.2	TL	1515	–	3.28	0.99	S. Matic-Skoko <i>et al.</i> (2004)
Middle Adriatic, Croatia	Unsexed	12.5–30.2	TL	77	0.004	3.26	0.93	Dulčić and Glamuzina (2006)
Northern Aegean Sea, Turkey	Female	24.6–31.2	TL	25	0.028	2.77	0.69	Karakulak <i>et al.</i> (2006)
	Male	11.1–30.8	TL	39	0.011	3.06	0.97	
	Female + male	11.1–31.2	TL	80	0.008	3.13	0.97	
Mar Menor Lagoon, Spain	Mixed	35.0–59.0	TL	138	0.012	3.00	0.92	D. Verdiell-Cubedo & F. J. Oliva-Paterna(2006)
Eastern Adriatic Sea, Croatia	Female	23.7–43.9	TL	209	0.007	3.17	0.95	A. Pallaoro <i>et al.</i> (2008)
	Male	16.2–36.8	TL	601	0.012	3.00	0.98	
	Immature	10.3–13.8	TL	83	0.001	4.04	0.97	
	All fish	10.3–43.9	TL	898	0.008	3.10	0.98	
Homa Lagoon, Turkey	Juvenile	6.7–12.4	TL	67	0.006	3.14	0.99	D. Acarli <i>et al.</i> (2014)
Izmir Bay, Turkey	Female	15.6–42.6	TL	234	0.021	2.84	0.98	B. Bayhan & A. Kara (2015)
	Male	17.6–38.0	TL	303	0.029	2.75	0.96	
	Hermaphrodite	18.2–38.0	TL	390	0.011	3.05	0.93	
	All fish	15.6–42.6	TL	927	0.018	2.89	0.96	
Bizerte Lagoon, Tunisia	All fish	27.3–30.9	TL	30	0.0525	2.586	0.981	Present study

proportionality between weight and length, likely shaped by local ecological conditions. Overall, the *S. salpa* population from the Bizerte Lagoon exhibits negative allometric growth, a pattern commonly observed in semi-enclosed or estuarine environments such as Izmir Bay and the Aegean coasts. This growth pattern reflects the influence of habitat-specific environmental factors and feeding behavior. Additionally, phenotypic traits, including the species' inherently elongated body, likely contribute to the observed growth pattern, as body shape and morphology strongly influence length-weight relationships (P. K. Karachle & K. I. Stergiou, 2012; N. Jisir *et al.*, 2018). These findings underscore the species' morphological and ecological plasticity across different habitats. The observed similarities and discrepancies with previously published data may be influenced by intrinsic characteristics of the species, including its phenotype, as well as by its specific geographic location and local environmental conditions (N. Jisir *et al.*, 2018). In *Sarpa salpa*, phenotypic traits, particularly its naturally elongated body, can significantly impact allometric growth patterns. This species tends to increase more in length than in weight, meaning that body shape and morphology play a critical role in shaping the length-weight relationship (P. K. Karachle & K. I. Stergiou).

CONCLUSION

In this study, detailed analyses of morphometric characteristics, length-weight relationships, and condition factors have provided valuable insights into the population structure of *Sarpa salpa* in the Bizerte Lagoon. The results indicate that the specimens analyzed exhibited negative allometric growth ($b < 3$), suggesting that individuals increase in length faster than in weight, and had stable condition factors ($Kn \approx 1$), reflecting a generally healthy population. These findings offer important baseline information for understanding the biology and growth patterns of this species in lagoonal environments. The observed growth patterns may be influenced by environmental factors, including food availability, hydrodynamics, and habitat characteristics, as well as biotic factors, such as reproductive stage. The results emphasize the need for continued monitoring of *S. salpa* populations to assess the effects of fishing pressure and environmental changes on their growth and condition. Future research should expand the sample size and include seasonal variations to obtain more comprehensive data on morphometry, length-weight relationships, and population dynamics.

Additionally, studies on other lagoonal fish species and the physico-chemical parameters of the Bizerte Lagoon are recommended to support sustainable fishery management and inform local stakeholders in decision-making processes. Such measures are essential to ensure the long-term conservation and optimum exploitation of *S. salpa* and other lagoonal resources.

Ethical Statement: No live specimens were used in the present investigation.

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Statement of conflict of interest: The authors have declared no conflict of interest.

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