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RESEARCH ARTICLE

PRELIMINARY INVESTIGATION OF MORPHOMETRIC CHARACTERISTICS, LENGTH-WEIGHT RELATIONSHIPS AND CONDITION FACTORS OF SARPA SALPA FROM GHAR EL MELH LAGOON, NORTHERN TUNISIA

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ABSTRACT

This study presents the first assessment of the morphometric traits, length-weight relationship, and condition factors of *Sarpa salpa* from the Ghar El Melh Lagoon in northern Tunisia. Specimens were sampled using traditional fishing gears to evaluate growth characteristics and population health. The results revealed a strong correlation between length and weight, with the species exhibiting isometric growth, indicating proportional increases in body dimensions. The relative condition factor reflected a healthy physiological status, suggesting favorable environmental conditions in the lagoon. These findings provide valuable baseline information on the morphometric and growth patterns of *S. salpa*, contributing to the understanding of its population dynamics, ecological adaptation, and sustainable management within this Mediterranean coastal ecosystem.

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INTRODUCTION

Biometric measurements provide essential information on fish growth, physiological condition, and other key life-history characteristics (G.F. De Carvalho-Souza *et al*, 2023; D. Khatun *et al*, 2025). In modern fisheries science, management strategies increasingly rely on detailed biological assessments, with fundamental parameters such as the length–weight relationship (LWR) and condition factors serving as important tools for evaluating population status and informing stock management decisions (N.T. Truong *et al*, 2021; D. Khatun *et al*, 2025).Length-weight relationships (LWRs) are widely used in fish biology as they allow estimation of body weight from commonly measured length data (J. Simon *et al*, 2023) and have diverse applications in physiology, ecology, and fisheries management. LWRs can reveal seasonal variations in growth and provide insights into the nutritional status of fish through condition indices, such as the mean condition factor (R. Froese, 2006; J. Simon *et al*, 2023). They are also useful for determining whether somatic growth is isometricwhen weight increases proportionally with lengthor allometric, when weight does not scale proportionally to length (Simon *et al*, 2023). Additionally, LWRs facilitate comparisons of life history traits and morphology between species or among populations of the same species across different habitats or geographic regions (Simon *et al*, 2023). In fisheries assessment, LWRs are commonly applied to estimate stock biomass from limited samples, calculate weight-at-age, or convert length-based growth to weight-based growth (Simon *et al*, 2023). Condition factor is a key indicator of fish health and nutritional status, reflecting the balance between length and weight as well as adaptation to the surrounding environment (R. Froese, 2006; Khatun *et al*, 2025). It provides quantitative insights into growth, survival, and reproductive success, and is widely used to monitor feeding intensity, age, and the overall ecological status of aquatic habitats (E. ÇiÇek *et al*, 2022; Khatun *et al*, 2025).Fisheries remain a vital subsector of agriculture, contributing substantially to national Gross Domestic Product through agricultural activities (O.O. Famoofo & W.O. Abdul, 2020). However, their importance extends beyond economic value, as fisheries resources and products are essential for human nutrition and employment (Emygdio, 2003). Lagoon fisheries, in particular, play a crucial role in the economy, culture, traditions, and dietary practices of communities. Fish represent an affordable source of high-quality protein and provide essential nutrients necessary for human health (O.O. Famoofo & W.O. Abdul, 2020). Additionally, fish consumption can have medicinal benefits, supplying vitamins A and D, minerals such as calcium and phosphorus, and amino acids including lysine and sulfur (O.O. Famoofo & W.O. Abdul, 2020). Consequently, understanding fish biology and ecology is critical for effective fisheries management and the conservation of aquatic resources (O.O. Famoofo & W.O. Abdul, 2020).The Ghar El Melh Lagoon, located in northern Tunisia, is an ecologically and economically important aquatic ecosystem. Recognized as a Ramsar wetland, it provides diverse habitats for

migratory fish and birds (W. Ben Ameur *et al*, 2025). Historically, it supported a diverse fish community of around 45 species, as well as cephalopods like cuttlefish and octopus (A. Hzami *et al,* 2025). Annual fishery yields, approximately 80 tons, have primarily consisted of mullets and eels. However, anthropogenic pressuresincluding domestic and industrial wastewater discharges, drainage outflows, and fishing activitieshave contributed to a decline in species diversity and fishery resources, leading to reduced fishing revenues (A. Hzami *et al*, 2025). However, this ecosystem faces multiple anthropogenic pressures, including the discharge of municipal and industrial wastewater, drainage releases, and intensive fishing activities, which have contributed to a decline in biodiversity and fishery resources, resulting in reduced fishing income (W. Ben Ameur *et al*, 2025).The Sparidae family, which includes seabream species, is widely distributed across the Mediterranean Sea and represents an important resource for both commercial and recreational fisheries (J.M.S. Gonçalves, 2015).

Species of this family occupy various habitats, including rocky and sandy bottoms as well as seagrass meadows, usually found at depths shallower than 150 m (J.M.S. Gonçalves, 2000; J. Ribeiro *et al*, 2006).Among them, the salema *Sarpa salpa* (Linnaeus, 1758) is a benthopelagic and gregarious fish commonly found in shallow coastal waters of the eastern Atlantic, Mediterranean, and western Indian Ocean (C. Jadot *et al*, 2006; W. Bakkari *et al*, 2024). Its feeding habits vary with age: juveniles mainly consume small crustaceans, while adults feed primarily on macroalgae and seagrasses (W. Bakkari *et al*, 2024). Through this herbivorous activity, *S. salpa* contributes significantly to the regulation of algal biomass and the ecological stability of seagrass ecosystems.Beyond its ecological significance, *S. salpa* is also of considerable economic importance in Mediterranean coastal fisheries, where it is regularly exploited for local consumption. Despite this, information on its population structure and growth patterns in Tunisian lagoons remains scarce, as most existing research has concentrated on populations from the Adriatic, Aegean, and western Mediterranean seas (J. Dulčić & M. Kraljevic, 1996; A. Pallaoro *et al*, 2008; B. Bayhan & A. Kara, 2015).

Understanding the length-weight relationship and condition factor of *S. salpa* is essential for evaluating the health of its populations and supporting sustainable management efforts. These biological parameters offer key insights into growth patterns, environmental influences, and habitat suitability. To the best of our knowledge, this study provides the first assessment of the morphometric characteristics, length-weight relationship, and condition factors of *S. salpa* in a Tunisian lagoon. In this context, the objective of this study was to assess the morphometric traits, estimate the length-weight relationship parameters, and characterize the growth pattern of *Sarpa salpa* inhabiting the Ghar El Melh Lagoon. This work provides essential baseline information on the species' biological characteristics, contributing to a better understanding of its population structure and supporting effective management and conservation of fishery resources within 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 Ghar el Melh Lagoon (Figure 1) in March 2020. The lagoon, located in Northeast of the Gulf of Tunis between the coordinates 37°06′-37°10′ N latitude and 10°08′–10°15′ E longitude on the eastern coast of the Mediterranean.It extends over an area of 150 km^2 with an average depth of 7 m and with a width of 11 km and a maximum length of 13 km (W.B. Ameur *et al*, 2023; W. Ben Ameur *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.

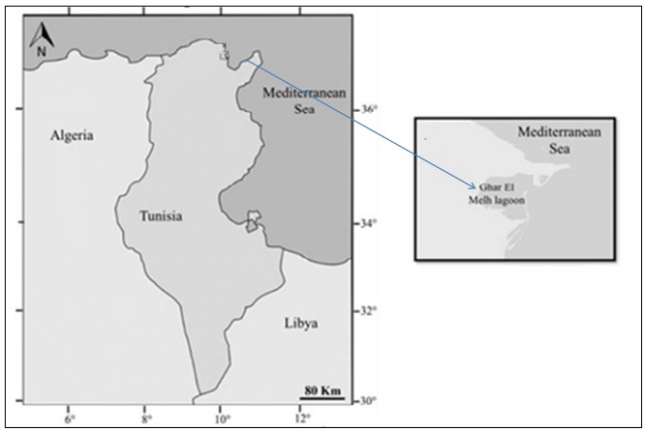

Figure 1. Sampling location

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 Ghar El Melh Lagoon.

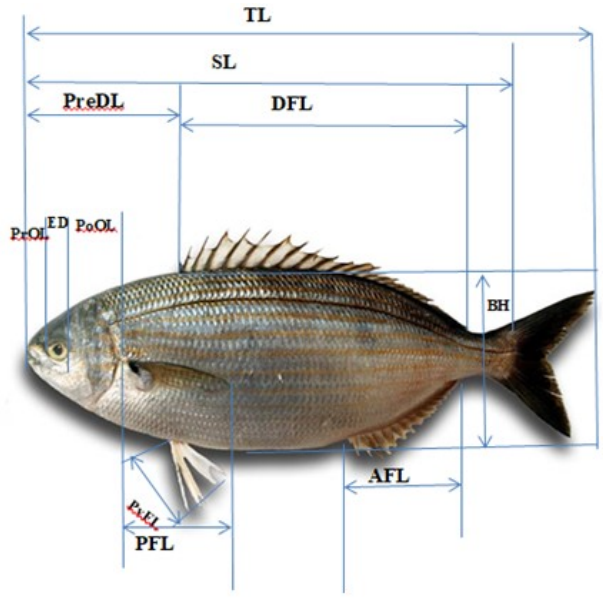

Figure 2. Morphological parameters of *Sarpa salpa*

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 Wo is the observed body weight and We is the expected weight derived from the length–weight relationship (C. Lațiu *et al*, 2023). A value of Kn ≥ 1 indicates that the fish is in good physiological condition, whereas Kn < 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 α = 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 Analysis:The morphometric characteristics of *Sarpa salpa* specimens collected from the Ghar El Melh Lagoon are presented in Table 1. The total length of the fish ranged from 25.7 to 29.5 cm, with a mean of 27.39 ± 1.22 cm, while body weight varied between 258.36 and 351.11 g (mean 299.36 ± 29.19 g). These values indicate a relatively narrow size range, suggesting that the sampled individuals belong predominantly to an adult cohort. The low standard deviations observed for both parameters confirm a limited degree of morphological variation within the population. The standard length represented approximately 83.6% of the total length, illustrating the elongated body shape typical of *S. salpa*, which is well suited to swimming in calm, shallow lagoonal waters.The average body height was 8.44 ± 0.21 cm, corresponding to nearly 31% of the total length, indicating a stable body conformation and good physical condition. The predorsal length averaged 8.46 ± 0.38 cm, a value very close to body height, reflecting the morphometric symmetry characteristic of this species.Fin measurements exhibited low variability, with the dorsal fin being the longest (mean 12.36 ± 0.51 cm), followed by the anal fin (4.93 ± 0.26 cm), pectoral fin (4.59 ± 0.25 cm), and pelvic fin (3.73 ± 0.26 cm). This fin arrangement indicates a well-balanced hydrodynamic profile, allowing efficient swimming and maneuverability in the lagoon's relatively stable water column.

Table 1. Morphometric Data of *Sarpa salpa* from the Ghar El Melh Lagoon

Parameter	Mean ± SD	Range
Weight (g)	299.36 ± 29.19	258.36-351.11
Total length (cm)	27.39 ± 1.22	25.70-29.50
Standard length (cm)	22.87 ± 1.00	21.50-24.50
Body height (cm)	8.44 ± 0.21	8.10-8.80
Predorsal length (cm)	8.46 ± 0.38	8.20-9.20
Dorsal fin length (cm)	12.36 ± 0.51	11.70-13.00
Anal fin length (cm)	4.93 ± 0.26	4.40-5.30
Pectoral fin length (cm)	4.59 ± 0.25	4.30-5.00
Preorbital length (cm)	2.06 ± 0.09	1.90-2.10
Postorbital length (cm)	2.39 ± 0.16	2.20-2.60
Eye diameter (cm)	1.34 ± 0.07	1.20-1.40
Pelvic fin length (cm)	3.73 ± 0.26	3.30-4.10

Length-weight relationship and relative condition factor

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

Parameter	Value
Sample size (N)	30
Total length (Lmin–max, cm)	25.7-29.5
Weight (Wmin–max, g)	258.36-351.11
a	0.0107
b	3.084
Standard error of b SE (b)	0.072
Confidence interval of b CI (b)	2.92-3.25
Coefficient of determination (r^2)	0.985
Significance of regression (P < 0.05 considered significant) P	0.000
t-test significance (t-test sig)	0.128
Growth type	Isometry
Kn	0.997
Relative condition factor with range (Kn Min–Max)	0.972-1.021
Standard error SE (Kn)	0.0041
IUCN status	LC

Regarding head morphometry, the preorbital length measured 2.06 ± 0.09 cm, while the postorbital length averaged 2.39 ± 0.16 cm, yielding a postorbital-to-preorbital ratio of about 1.16. The eye diameter (1.34 ± 0.07 cm) was proportionally large relative to head size, consistent with adaptation to the moderately turbid and variable light conditions of Ghar El Melh Lagoon.The length-weight relationship for *Sarpa salpa* collected from the Ghar El Melh Lagoon was determined using the equation log(W) = log(a) + b·log(L), where *W* is the body weight (g) and *L* is the total length (cm) (Table 2). The calculated regression parameters were a = 0.0107 and b = 3.084 ± 0.072, with a coefficient of determination (r^2) = 0.985. The high r^2 value reflects a strong positive correlation between fish length and weight, confirming that weight increases proportionally with body length in this population. The regression was statistically significant (P = 0.000), demonstrating that the model accurately describes the growth pattern of *S. salpa* in the lagoon.

The 95% confidence interval for the slope parameter b (2.92–3.25) includes the theoretical value of 3, and the t-test (P = 0.128) revealed no significant deviation from isometry. This indicates that *S. salpa* from Ghar El Melh Lagoon exhibits isometric growth, meaning that weight increases proportionally to the cube of length. In other words, as individuals grow longer, their body form remains balanced without a tendency toward elongation or stoutness. Isometric growth generally characterizes populations inhabiting stable environments with favorable feeding conditions and minimal physiological stress.The intercept a (0.0107), often referred to as the condition coefficient or body form factor, reflects the general body shape and may vary among populations depending on environmental parameters such as salinity, temperature, food availability, and habitat productivity. The relatively low a value recorded for this population indicates that *S. salpa* in Ghar El Melh Lagoon maintain a streamlined body form typical of herbivorous sparids, which may reflect adaptation to foraging within seagrass and algal habitats characteristic of this lagoon.The relative condition factor (Kn) averaged 0.997 ± 0.0041, with values ranging from 0.972 to 1.021, suggesting that most individuals were in good physiological condition. Condition factor values near unity typically indicate a population with adequate energy reserves and access to sufficient food resources (R. Froese, 2006; D. Alcando, 2021). The uniformity in Kn values across individuals also reflects the relatively homogeneous size structure observed in the sample, implying consistent growth conditions throughout the lagoon.The high Kn and isometric growth observed at Ghar El Melh suggest that the population experiences favorable ecological conditions, possibly linked to optimal trophic resources, stable water parameters, and low competition. However, it is important to recognize that LWR and condition factor parameters can be influenced by several intrinsic and extrinsic factors, including sex, gonadal development, feeding intensity, parasitic load, seasonal changes, and sampling period (H. Liao *et al*, 1995; M. Y. Hossain *et al*, 2012; Al Nahdi *et al*, 2016;

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

Area	Sex	Length range (cm)	Length type	N	a	b	r²	Reference
Natal, South Africa	Unsexed	–	–	–	0.059	2.79	–	Torres (1991)
Eastern Adriatic, Croatia	Unsexed	13.9–41.6	TL	437	0.021	3.12	0.98	Dulčić & Kraljević (1996)
Off Alexandria, Egypt	Unsexed	8.9–13.0	TL	39	0.014	2.90	0.97	Abdallah (2002)
Kyclades, Greece	Mixed	14.9–25.1	TL	48	0.014	2.94	0.98	Moutopoulos & Stergiou (2002)
Stryman estuary, Greece	Mixed	7.9–11.7	TL	10	0.010	3.19	0.99	Koutrakis & Tsikliras (2003)
Kornati Archipelago, Adriatic	Juvenile	1.6–14.2	TL	1515	–	3.28	0.99	Matić-Skoko *et al*. (2004)
Middle Adriatic, Croatia	Unsexed	12.5–30.2	TL	77	0.004	3.26	0.93	Dulčić & Glamuzina (2006)
Northern Aegean Sea, Turkey	Female	24.6–31.2	TL	25	0.028	2.77	0.69	Karakulak *et al*. (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	Verdiell-Cubedo *et al*. (2006)
Eastern Adriatic Sea, Croatia	Female	23.7–43.9	TL	209	0.007	3.17	0.95	Pallaoro *et al*. (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	Acarlı *et al*. (2014)
Izmir Bay, Turkey	Female	15.6–42.6	TL	234	0.021	2.84	0.98	Bayhan & 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	
Ghar El Melh Lagoon, Tunisia	All fish	25.7–29.5	TL	30	0.0107	3.084	0.985	Present study

Famoofo & Abdul, 2020).Overall, the LWR and condition factor analyses indicate that *Sarpa salpa* from Ghar El Melh Lagoon maintain healthy growth dynamics and stable morphometric proportions, reflecting well-balanced ecological conditions. These findings provide valuable insight into the growth patterns of the species in Tunisian lagoonal systems and emphasize how local environmental variability can influence population structure and body condition.The IUCN status of *S. salpa* remains Least Concern (LC), confirming that this species is currently widespread and abundant throughout the Mediterranean, with no evidence of significant population decline at the regional or global scale.Regarding head morphometry, the preorbital length measured 2.06 ± 0.09 cm, while the postorbital length averaged 2.39 ± 0.16 cm, yielding a postorbital-to-preorbital ratio of about 1.16. The eye diameter (1.34 ± 0.07 cm) was proportionally large relative to head size, consistent with adaptation to the moderately turbid and variable light conditions of Ghar El Melh Lagoon. The length-weight relationship of *Sarpa salpa* from Ghar El Melh Lagoon showed a growth exponent b = 3.084, indicating isometric growth, with a high coefficient of determination ($r^2 = 0.985$) and a relative condition factor (Kn = 0.997) suggesting good physiological condition. When compared with other Mediterranean and Atlantic populations summarized in Table 3, b values generally range from 2.75 to 3.28, with values around 3 reflecting isometric growth, as observed in the Eastern Adriatic Sea (b = 3.10-3.26; J. Dulčić & B. Glamuzina, 2006; A. Pallaoro *et al*, 2008) and Homa Lagoon, Turkey (b = 3.14; D. Acarli *et al*, 2014). Slight deviations from 3, as seen in some populations (F.S. Karakulak *et al*, 2006; B. Bayhan & A. Kara, 2015), typically indicate populations with more elongated or slender body forms.Variation in b is influenced by environmental factors such as water temperature, salinity, habitat structure, food availability, and hydrodynamics, as well as biological factors including size, age, reproductive stage, and sampling season (N. Jisr *et al*, 2018). The Ghar El Melh population's b value close to 3 suggests proportional weight-length scaling, meaning the body shape remains relatively consistent as fish grow. The intercept a = 0.0107 reflects the population's streamlined body form, characteristic of lagoon habitats where maneuverability and energy-efficient swimming are advantageous.Overall, the isometric growth pattern, high r^2, and Kn near 1 indicate a healthy and morphologically stable population of *S. salpa* in Ghar El Melh Lagoon. The naturally elongated body of the species contributes to proportional growth in length and weight, highlighting its morphological and ecological adaptability to lagoonal environments (P.K. Karachle & K.I. Stergiou; N. Jisr *et al*, 2018).

CONCLUSION

This study provides detailed insights into the morphometric traits, length–weight relationship, and condition factors of *Sarpa salpa* in the Ghar El Melh Lagoon. The analysis revealed isometric growth, indicating that individuals increase in weight proportionally with length. This pattern reflects favorable environmental conditions and sufficient food availability within the lagoon.The sample analyzed allowed for reliable estimation of population-level growth parameters and condition indices. However, future research should expand the sample size to improve statistical power, capture greater variability among age classes and sexes, and enable more robust assessments of temporal and spatial dynamics.Continuous monitoring of morphometric traits, growth patterns, and condition factors is essential, as fluctuations in these parameters may serve as early indicators of ecological changes, such as shifts in habitat quality, water parameters, or anthropogenic pressures. Collecting comprehensive datasets over multiple seasons and across different habitats within the lagoon will provide a clearer understanding of the biological and ecological drivers influencing the species.These measures are critical for evaluating population health, informing sustainable fisheries management, and guiding conservation strategies to ensure the long-term stability of *S. salpa* and the overall productivity of this ecologically important Mediterranean lagoon

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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