Acta Aquatica Turcica

Home Page: https://dergipark.org.tr/actaquatr
E-ISSN: 2651-5474
22(3): 220305, 2026
DOI: 10.22392/actaquatr.1908595

Research Article
Araştırma Makalesi

Spermatological Parameters and Length–Weight Relationship of *Saurida lessepsianus* from the Gulf of Antalya, Mediterranean Sea

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Received: 12.03.2026 **Accepted:** 23.06.2026 **Published:** 01.09.2026

How to Cite: Güngör, Ş., Herdoğan, M., Mart, F., İnanç, M. E.,. & İnnal, D. (2026). Spermatological parameters and Length–weight relationship of *Saurida lessepsianus* from the Gulf of Antalya, Mediterranean Sea. *Acta Aquatica Turcica, 22*(3), 220305. https://doi.org/10.22392/actaquatr.1908595

Abstract: Members of the family Synodontidae are demersal teleosts of ecological and commercial importance in marine ecosystems. *Saurida lessepsianus*, a Lessepsian lizardfish, is an established component of demersal fish assemblages in the Eastern Mediterranean. Although its distribution, growth, and general reproductive biology have been investigated, detailed spermatological information on this species has not yet been reported. This study evaluated the length–weight relationship and spermatological parameters of *S. lessepsianus* from the Gulf of Antalya, Mediterranean Sea. A total of 24 individuals collected during the March–April sampling period were examined for biometric measurements and length–weight relationship analysis, while spermatological parameters were evaluated in six male individuals. The length–weight relationship was calculated as $W = 0.0047TL^{3.126}$, with a strong coefficient of determination ($R^2 = 0.924$), indicating positive allometric growth. The mean GSI of males was 2.64 ± 1.62. The average spermatozoon head width and tail length were 3.07 ± 0.54 µm, and 41.57 ± 14.20 µm, respectively. Spermatozoa concentration was 871.83 ± 37.65 × 10^6 spermatozoa/ml, and flow cytometric analysis showed a viability rate of 61.76 ± 22.67%. Correlation analysis showed significant positive relationships among total length, body weight, gonad weight, and GSI, whereas spermatozoa viability and concentration were not significantly correlated with biometric or gonadosomatic parameters. To the best of our knowledge, this study provides the first detailed spermatological examination of *S. lessepsianus* and preliminary baseline data for future reproductive studies.

Keywords
- Invasive
- Non-indigenous
- Synodontidae
- Spermatological parameters
- Reproductive biology

1. INTRODUCTION

Lizardfishes of the family Synodontidae are demersal teleosts with ecological and fisheries relevance in marine ecosystems. The genus *Saurida* Valenciennes includes several species distributed mainly in the Indo-West Pacific region, including *Saurida lessepsianus*, which has become established in the Mediterranean through Lessepsian migration (Fricke et al., 2024; Froese & Pauly, 2024; Silpa et al., 2021). Among these species, the Lessepsian lizardfish *Saurida lessepsianus* Russell, Golani, & Tikochinski, 2015 has become an increasingly important component of demersal fish assemblages in the Eastern Mediterranean.

The taxonomic status of *S. lessepsianus* has been clarified relatively recently. Populations previously reported from the Red Sea and Mediterranean as *Saurida undosquamis* were shown to represent a distinct lineage and were subsequently described as *S. lessepsianus* (Russell et al., 2015). This clarification is important because

earlier biological records may have included misidentified populations within the *S. undosquamis* species complex (Inoue & Nakabo, 2006; Silpa et al., 2021).

In the Mediterranean, *S. lessepsianus* has expanded successfully and has gained both ecological and commercial importance, particularly in the Eastern Mediterranean and Turkish coastal waters (Bilecenoğlu, 2016; Dilgin & Başusta, 2023; Uyan et al., 2024). Previous studies on this species and closely related records have mainly focused on distribution, growth, length–weight relationships, otolith biometry, reproductive seasonality, and general reproductive biology (Golani, 1993; Işmen, 2003; Dilgin & Başusta, 2023; Uyan et al., 2024). However, cellular-level male reproductive traits, particularly spermatozoon morphology and sperm quality parameters, have not been sufficiently characterized.

Spermatological parameters such as spermatozoon morphometry, spermatozoa concentration, and viability provide fundamental information on male gamete quality and may contribute to future studies on reproductive biology, fertilization capacity, cryopreservation, and genetic resource conservation in fish. To the best of our knowledge, this study represents the first detailed spermatological examination of *S. lessepsianus*, focusing on spermatozoon morphometric dimensions, spermatozoa concentration, and viability in male individuals collected from the Gulf of Antalya during the March–April sampling period. Therefore, the findings provide preliminary baseline data for future reproductive studies on this Lessepsian species.

2. MATERIAL AND METHODS

2.1. Material

Samples were collected from trawl surveys conducted in the Gulf of Antalya (Mediterranean-Türkiye) between March and April 2024. Fish samples were immediately transported to the laboratory at the Department of Biology, Burdur Mehmet Akif Ersoy University.

2.2. Sample Collection

The length (total length, TL; to the nearest 1 mm) and weight (total weight, W; to the nearest 0.1 g) of 24 fish were measured. Gonads were carefully dissected from the abdominal cavity and weighed. Sex was determined macroscopically and microscopically by examining the gonads. After sex determination, spermatological analyses were performed at the Reproduction and Artificial Insemination Clinic, Burdur Mehmet Akif Ersoy University. A total of six male fish were analyzed. Testicular spermatozoa were obtained by testis dissection, which is one of the sperm collection approaches used in fish (Beirão et al., 2019). Briefly, the testes were gently minced in a tube containing 1 ml PBS at room temperature and kept for 2 min to obtain a testicular sperm suspension. The suspension was used immediately for spermatological analyses.

2.3. Length–weight relationship and frequency distribution

The length–weight relationship (LWR) of *S. lessepsianus* was estimated for both sexes combined using the equation described by Ricker (1975):

$$W = aTL^b$$

where W is the total body weight in grams, TL is the total length in centimeters, a is the intercept of the regression curve, and b is the allometric growth coefficient. The parameters a and b were estimated by regression analysis after logarithmic transformation of the equation:

$$\log W = \log a + b \log TL$$

The coefficient of determination (R^2) was calculated to evaluate the strength of the relationship between total length and body weight. The growth pattern was interpreted according to the estimated b value, where b = 3 indicates isometric growth, b > 3 indicates positive allometric growth, and b < 3 indicates negative allometric growth. Size-frequency distributions were also generated for all individuals combined.

2.4. Gonadosomatic Index

Gonadosomatic index (GSI) of male specimens were calculated as previously described (Wootton, 1990).

$$GSI = \frac{Gonad\ weight\ (g)}{Total\ body\ weight\ (g)} \times 100$$

2.5. Sperm Viability

The viability of spermatozoa was analysed using a CytoFLEX Flow Cytometry device (Beckman Coulter, CA, USA) and a Sybr-14/PI (L7011, Invitrogen, CA, USA) double staining method. 50 µL of sperm sample and 5 µL of SYBR-14 and 3 µL of PI stain were added to 442 µL of PBS solution. The mixture was incubated in

the dark at room temperature for 5 minutes. The ratio of viable to non-viable sperm was determined using CytExpert 2.3 software.

2.6. Sperm Morphometric Measurements

For spermatozoon morphometric measurements, the head length, head width, and tail length of the spermatozoon were measured. The measurements were performed on spermatozoa taken from random areas at 1000X magnification under a Nikon Eclipse E600 (Tokyo, Japan).

2.7. Sperm Concentration

Spermatozoa concentration in the testicular sperm suspension was determined using the haemocytometric counting method (Caille et al., 2006). An aliquot of the testicular sperm suspension prepared as described above was used for concentration analysis. Briefly, 10 µl of sperm suspension was diluted with 490 µl of Hayem's solution, and spermatozoa were counted using a Thoma counting chamber (Avlar & Bozkurt, 2022; Bozkurt, 2011). Hayem's solution was used only as a dilution medium for haemocytometric counting. Spermatozoa concentration was expressed as spermatozoa/ml.

2.8. Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows, version 25.0 (IBM Corp., Armonk, NY, USA). Before statistical analysis, the distribution of each variable was evaluated for normality. The Shapiro–Wilk test was used to assess normality, and skewness and kurtosis values were also examined to obtain additional information on the distribution shape. Variables with skewness or kurtosis values exceeding the ±2 range were not considered normally distributed (George & Mallery, 1999). Descriptive statistics were calculated for biometric, gonadosomatic, and spermatological parameters.

For the length–weight relationship, regression analysis was performed using the log-transformed equation $\log W = \log a + b \log TL$. The coefficient of determination (R^2) was calculated to evaluate the strength of the relationship between total length and body weight. The standard error of the regression coefficient (SEb) and 95% confidence intervals of the b value were calculated. The growth pattern was evaluated by testing whether the estimated b value differed significantly from the isometric value of 3 using a t-test, according to Zar (1999). A b value equal to 3 was interpreted as isometric growth, whereas $b > 3$ and $b < 3$ were interpreted as positive and negative allometric growth, respectively.

Relationships between fish size, GSI, and spermatological parameters were evaluated using bivariate correlation analysis. Pearson correlation coefficients were used for normally distributed variables, whereas Spearman's rank correlation coefficients were used when the normality assumption was not met. All correlation analyses were two-tailed, and statistical significance was accepted at $p < 0.05$. Data were expressed as mean ± standard error of the mean (SEM), unless otherwise stated.

3. RESULTS

During the study, a total of 24 individuals were examined. Length-weight relationships and frequency distributions for both sexes combined are given in Figure 1. The mean total length of the fish was 294.2 ± 3.4 mm (minimum: 220 mm and maximum: 350 mm), while the mean total weight was 192.3 ± 6.5 g (minimum: 77.1 g and maximum: 322.7 g). Size frequency distributions of males and females were not significantly different (Kolmogorov– Smirnov test, $P > 0.10$). Length–weight relationships were fitted by the equation $W = 0.0047\ TL^{3.126}$ ($R^2 = 0.924$) for both sexes combined.

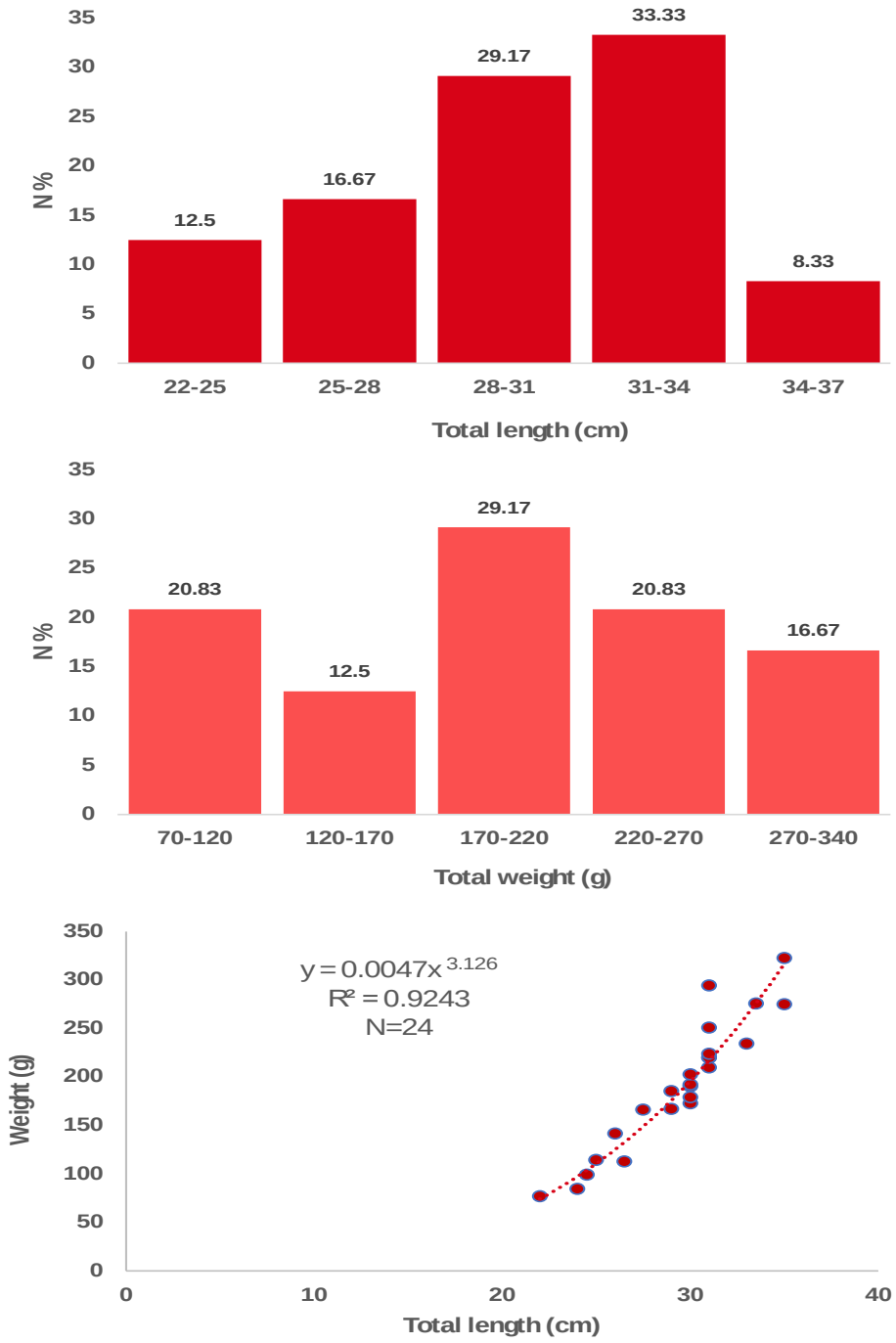

Figure 1. Length-weight relationship ($W = aTL^b$, in g and cm) and frequency distributions for *S. lessepsianus*, both sexes combined.

GSI was determined as 2.64 ± 1.62 in male individuals during the March–April sampling period. Spermatological parameters were evaluated in six male individuals and are presented in Table 1, with representative images provided in Figure 2.

Table 1. Descriptive statistics of spermatological parameters of male *S. lessepsianus* from the Gulf of Antalya.

	N	Mean ± SD	Minimum	Maximum
Viability (%)	6	61.76 ± 22.67	38.29	89.80
Concentration (× 10^6/ml)	6	871.83 ± 37.65	36	1470
Head width (µm)	30	3.07 ± 0.57	2.42	4.40
Tail length (µm)	30	41.57 ± 14.20	23.47	60.95

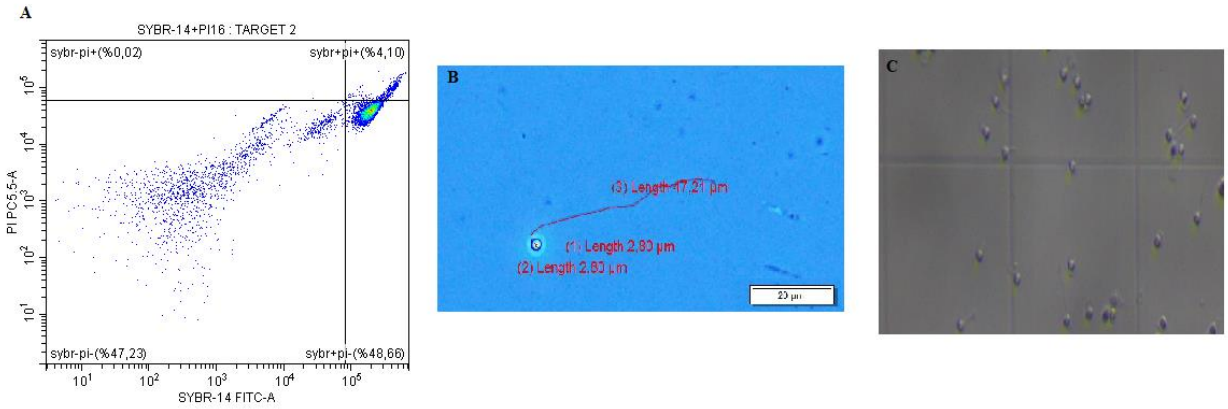

Figure 2. Evaluation of spermatological parameters of *S. lessepsianus*. A) Flow cytometry image demonstrating the viability parameter for sperm. B) Morphologic measurement of spermatozoon. C) Sperm concentration analysis was conducted on a Thoma counting chamber.

4. DISCUSSION

In the present study, the length–weight relationship of *S. lessepsianus* from the Gulf of Antalya was calculated as $W = 0.0047TL^{3.126}$ ($R^2 = 0.924$), indicating a positive allometric growth pattern. The estimated b value was within the expected range generally reported for teleost fishes (Froese, 2006). However, the positive allometric pattern observed in the present study differs from the negative allometric growth previously reported for *S. lessepsianus* from the same region by Uyan et al. (2024). Such differences may be associated with sampling period, sample size, size composition, reproductive condition, habitat characteristics, and temporal variation in population structure. Therefore, the present LWR result should be interpreted as a population- and sampling-period-specific finding rather than a fixed species-level characteristic.

The mean GSI value observed in male *S. lessepsianus* during the March–April sampling period was 2.64 ± 1.62. This value may indicate that the sampled males were reproductively active or approaching an active reproductive phase. However, this interpretation should be made cautiously because the present sampling was restricted to a two-month period. Previous studies on *Saurida* populations historically reported as *S. undosquamis* have shown that reproductive activity may vary regionally and seasonally in the Mediterranean and adjacent waters, with spawning activity generally extending over broad seasonal windows (Golani, 1993; Işmen, 2003; Roshdy et al., 2021). Therefore, the GSI value obtained in the present study should not be interpreted as evidence of the peak spawning period of *S. lessepsianus* in the Gulf of Antalya. Broader seasonal sampling is required to define the full reproductive cycle and to determine whether March–April represents the beginning, active phase, or peak of male reproductive activity in this population.

To the best of our knowledge, this study represents the first detailed spermatological examination of *S. lessepsianus*, including spermatozoon morphometry, spermatozoa concentration, and spermatozoa viability. Previous studies on this Lessepsian species have mainly focused on taxonomy, distribution, growth, length–weight relationships, otolith biometry, and general reproductive biology, whereas cellular-level male reproductive traits have remained poorly characterized (Bilecenoğlu, 2016; Dilgin & Başusta, 2023; Uyan et al., 2024). In this context,

the present findings provide baseline and preliminary reference data for future studies on the reproductive biology of this species.

In the present study, the spermatozoa viability of *S. lessepsianus* was determined as 61.76%. This value appears lower than the viability values reported for several freshwater teleosts evaluated using SYBR-14/PI staining. For example, Flajšhans et al. (2004) reported live spermatozoa proportions of 93.92–97.02% in common carp, 76.14–97.76% in tench, and 79.45–83.76% in wels. Therefore, the viability value observed in *S. lessepsianus* should be interpreted as moderate rather than close to the higher values reported in these species. However, direct comparisons should be made cautiously because sperm viability can be affected by species, reproductive phase, sampling time, handling procedure, dilution medium, ionic and osmotic conditions, and assessment method (Alavi & Cosson, 2006; Rurangwa et al., 2004; Fauvel et al., 2010).

A more relevant comparison may be made with Lessepsian or demersal marine teleosts. In *Nemipterus randalli*, another Lessepsian commercial fish species from the Gulf of Antalya, spermatozoa viability was reported as 51.71 ± 17.01%, while spermatozoa concentration was 160.0 ± 45.63 × 10^6 spz/ml (Güngör et al., 2025). Compared with *N. randalli*, *S. lessepsianus* showed a higher spermatozoa concentration and a moderately higher viability value. Nevertheless, this comparison should be considered descriptive rather than definitive because the two species differ taxonomically and biologically, and both datasets are based on limited sampling periods.

The spermatozoa of *S. lessepsianus* showed a rounded head structure, with mean head dimensions of approximately 3 µm and a mean tail length of about 42 µm. These values are broadly comparable to those reported for other round-headed teleost spermatozoa. For example, in the marine teleost *Pogonias courbina*, spermatozoon head length, head width, and tail length were reported as 2.50 ± 0.21 µm, 2.12 ± 0.22 µm, and 37.97 ± 2.01 µm, respectively (Benato et al., 2023). Similarly, in the freshwater teleost *Colossoma macropomum*, spermatozoa were described as having a roundish head, with head length of 2.73 ± 0.21 µm, head width of 2.58 ± 0.18 µm, and flagellar length of 29.84 ± 1.63 µm (Maria et al., 2010). These comparisons suggest that the spermatozoon morphology of *S. lessepsianus* is consistent with the general pattern observed in many externally fertilizing teleosts, although species-specific differences in tail length and head dimensions are evident.

From an ecological perspective, the moderate viability value observed in *S. lessepsianus* does not necessarily contradict its successful establishment in the Mediterranean. Invasion success is not determined by sperm viability alone, but by multiple interacting traits such as reproductive seasonality, fecundity, spawning frequency, larval survival, dispersal capacity, ecological tolerance, and habitat suitability. Moreover, sperm quality is multidimensional, and concentration, motility, membrane integrity, morphology, energetic status, DNA integrity, and fertilizing capacity may contribute differently to reproductive success (Rurangwa et al., 2004; Fauvel et al., 2010). Since motility and fertilization capacity were not evaluated in the present study, the viability value alone cannot be used to infer the overall reproductive success or invasion potential of this species.

Correlation analysis provided exploratory information on the relationships among biometric, gonadosomatic, and spermatological parameters. As expected, total length was strongly and positively correlated with body weight ($r = 0.986$, $p < 0.001$) and gonad weight ($r = 0.894$, $p = 0.003$). Similarly, body weight was positively correlated with gonad weight ($r = 0.917$, $p = 0.001$). GSI was also positively correlated with total length ($r = 0.786$, $p = 0.021$), body weight ($r = 0.807$, $p = 0.015$), and gonad weight ($r = 0.963$, $p < 0.001$). These findings suggest that larger and heavier males tended to show greater gonadal development during the March–April sampling period, supporting the interpretation that the sampled males were within or approaching a reproductively active phase.

In contrast, spermatozoa viability and spermatozoa concentration were not significantly correlated with total length, body weight, GSI, or gonad weight. Although spermatozoa viability showed a negative tendency with GSI ($r = −0.750$, $p = 0.086$), and spermatozoa concentration showed a positive tendency with spermatozoon head width ($r = 0.748$, $p = 0.087$), these relationships did not reach statistical significance. Therefore, they should not be interpreted as confirmed biological

associations. Given the limited number of males included in the spermatological analyses, these correlation results should be considered exploratory and hypothesis-generating rather than definitive.

Several limitations of the present study should be acknowledged. First, spermatological analyses were performed on only six male individuals. This small sample size limits the generalizability of the findings and restricts the strength of statistical interpretations. Although correlation analyses were performed between biometric, gonadosomatic, and spermatological parameters, the results should be interpreted cautiously due to the limited number of males. Second, sampling was restricted to March–April, and therefore the study does not represent the entire reproductive season. Seasonal changes in spermatozoa concentration, viability, motility, and morphology may occur in fish, and broader temporal sampling is required to establish reliable species-specific reference intervals (Rurangwa et al., 2004; Fauvel et al., 2010).

Another important methodological limitation is the use of a PBS-based testicular sperm suspension. Fish spermatozoa are highly sensitive to the ionic and osmotic characteristics of the surrounding medium, and sperm handling procedures may influence measured sperm quality parameters (Alavi & Cosson, 2006; Cosson et al., 2008; Beirão et al., 2019). Although the samples were processed at room temperature and used immediately, the possibility that PBS exposure influenced spermatozoa viability cannot be completely excluded. This limitation is particularly relevant because motility was not evaluated in the present study; therefore, no inference can be made regarding sperm activation, motility duration, or fertilizing capacity. Future studies should use species-specific or marine teleost-optimized collection and dilution media and should include motility analysis, membrane integrity assessment, and fertilization trials.

Overall, the present study provides the first detailed spermatological data for *S. lessepsianus* from the Gulf of Antalya. However, because the study was based on a limited number of male individuals collected during a restricted March–April sampling period, the findings should be interpreted as preliminary baseline data. Future studies with larger sample sizes, broader seasonal sampling, optimized sperm handling protocols, motility assessment, and fertilization experiments are needed to better evaluate the male reproductive capacity of this Lessepsian species.

FUNDING

No financial support was received for the present study.

CONFLICT OF INTEREST

The authors have stated that there are no identifiable competing financial interests or personal ties that may have seemingly influenced the work presented in this study.

AUTHOR CONTRIBUTIONS

Conceptualization: Dİ; Methodology: Dİ, ŞG; Experimental work: MH, FM, MEİ; Data analysis: ŞG, MH, Dİ; Manuscript writing: ŞG, MH; Supervision: FM, MEİ, Dİ. All authors approved the final version of the manuscript.

ETHICAL STATEMENTS

All procedures carried out in this study complied with applicable international, national, and institutional regulations governing the collection and experimental use of fish specimens. The species under investigation is not included in the IUCN Red List of Threatened Species and is not categorized as endangered, vulnerable, rare, or legally protected in Türkiye. Additionally, the sampling was conducted in areas outside of officially designated protected zones; therefore, formal ethics approval was not required for this study.

DATA AVAILABILITY STATEMENT

Data supporting the findings of the present study are available from the corresponding author upon reasonable request.

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