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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

Biological properties of southern pond loach (*Seminemacheilus ispartensis*) in Lake Eğirdir

Eğirdir Gölü Isparta pınar balığı (*Seminemacheilus ispartensis*)'nın biyolojik özellikleri

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Abstract: In this study, the biological characteristics of the southern pond loach (*Seminemacheilus ispartensis* Erk'akan, Nalbant & Özeren, 2007), distributed in Lake Eğirdir and its basin, were investigated. Sampling was conducted monthly at nine stations in Lake Eğirdir between June 2010 and May 2011. A total of 315 individuals were collected during the sampling period. Of these specimens, 51.4% were identified as female, 43.2% as male, and 5.4% as immature. The total length of the specimens ranged from 3.7 to 12.2 cm, body weight from 0.43 to 18.50 g, and age from I to V years. The mean total length and mean body weight were calculated as 8.18±0.13 cm and 6.31±0.24 g, respectively. The Von Bertalanffy growth parameters of the population were estimated as L_∞=17.48, k=0.22, and t_0=−0.33; the asymptotic weight (W_∞) was calculated as 55.30. The length–weight relationship was determined as $W=0.0067L^{3.15}$. Based on gonadosomatic index (GSI) values, the reproductive period of *S. ispartensis* was identified as occurring between March and May. The total fecundity of the population in Lake Eğirdir ranged from 1,440 to 16,938 eggs. The relative fecundity was determined to be 900 eggs g^{-1}. Based on the stomach content analysis, *S. ispartensis* was found to exhibit a predominantly carnivorous feeding habit, with its diet mainly composed of aquatic insects (Trichoptera, Ephemeroptera) and Amphipoda.

Keywords: Nemacheilidae, Türkiye, endemic, freshwater, growth, feeding, reproduction

Öz: Bu çalışmada Eğirdir Gölü ve havzasında yayılım gösteren Isparta pınar balığı (*Seminemacheilus ispartensis* Erk'akan, Nalbant & Özeren, 2007)'nın biyolojik özellikleri incelenmiştir. Örnekleme çalışmaları Eğirdir Gölü'nde belirlenen 9 istasyonda, Haziran 2010 – Mayıs 2011 tarihleri arasında aylık olarak gerçekleştirilmiştir. Örneklemeler sonucunda toplam 315 birey elde edilmiştir. Elde edilen bireylerin %51,4'ünün dişi, %43,2'sinin erkek, %5,4'ünün immatür olduğu belirlenmiştir. Örneklemin total boyu 3,7-12,2 cm, ağırlığı 0,43-18,50 g, yaşı I-V yaş arasında dağılım göstermiştir. Örneklemin ortalama total boyu 8,18±0,13 cm, ortalama ağırlığı ise 6,31±0,24 g olarak bulunmuştur. Örneklemi oluşturan bireylerin Von Bertalanffy büyüme parametrelerinden L_∞=17,48, k=0,22, t_0=-0,33; W_∞=55,30 olarak hesaplanmıştır. Örneklemin boy ağırlık ilişkisi $W=0,0067.L^{3,15}$ olarak bulunmuştur. Gonadosomatik indeks değerlerine göre *S. ispartensis*'in üreme döneminin mart – mayıs ayları arası olduğu belirlenmiştir. Eğirdir Gölü'nde populasyonun total fekonditesi 1.440-16.938 adet arasında değişim göstermiştir. Nisbi fekondite 900 adet/g olarak bulunmuştur. İncelenen mide içeriklerine göre *S. ispartensis*'in ağırlıklı olarak karnivor bir beslenme tarzı gösterdiği, besin organizmalarını çoğunlukla sucul böcekler (Trichoptera, Ephemeroptera) ve Amphipoda'nın oluşturduğu belirlenmiştir.

Anahtar kelimeler: Nemacheilidae, Türkiye, endemik, tatlı su, büyüme, beslenme, üreme

INTRODUCTION

Türkiye harbors 390 freshwater fish species, with a notably high endemism rate of 53.5%, highlighting the country as an important region in terms of biodiversity (Kaya et al., 2026). The genus *Seminemacheilus*, belonging to the family Nemacheilidae, is represented by six species (*Seminemacheilus ahmeti, S. attalicus, S. dursunavsari, S. ekmekciae, S. ispartensis, S. lendlii*), all of which are endemic to Türkiye (Erk'akan et al., 2007; Sungur et al., 2018; Çiçek, 2020; Yoğurtçuoğlu et al., 2020; Çiçek et al., 2023). Although numerous studies have addressed the taxonomic characteristics of this genus (Erk'akan et al., 2007; Sungur et al., 2018; Çiçek, 2020; Yoğurtçuoğlu et al., 2020) and its distribution in Türkiye (Küçük et al., 2007; Gülle and Küçük, 2016; Şahin et al., 2022; Çiçek et al., 2023), studies focusing on its biological characteristics remain limited and have largely been restricted to length–weight relationships (Erk'akan et al., 2013; Seçer et al., 2021, 2022; Apaydın Yağcı et al., 2022).

S. ispartensis, has been classified as Endangered (EN) by the International Union for Conservation of Nature (IUCN) (Kaya et al., 2026). The species is distributed in the basins of Lakes Eğirdir and Salda (Sungur, 2024). Its largest population occurs in Lake Eğirdir; however, this population is threatened by reservoirs constructed on inflowing water sources, as well as by declining water levels and associated habitat loss driven by climate change (Freyhof, 2014). In the present study, the growth, reproduction, and feeding characteristics of the Southern pond loach (*Seminemacheilus ispartensis*), an endemic fish species of Anatolia, were investigated.

MATERIALS AND METHODS

Lake Eğirdir is a tectonic lake located within the borders of Isparta Province, between 37°50'41"-38°16'55" N and 30°57'43"-30°44'39" E, with an approximate surface area of 480 square kilometers (Saraçoğlu, 1990). Sampling studies

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were conducted at nine stations identified in the lake (five littoral, four limnetic) between June 2010 and May 2011 (Figure 1). Gill net (100 mm x 100 mm mesh size), seine net, and electroshocker were used according to sampling station's structure (depth, bottom structure, vegetation type and density) in the sampling studies.

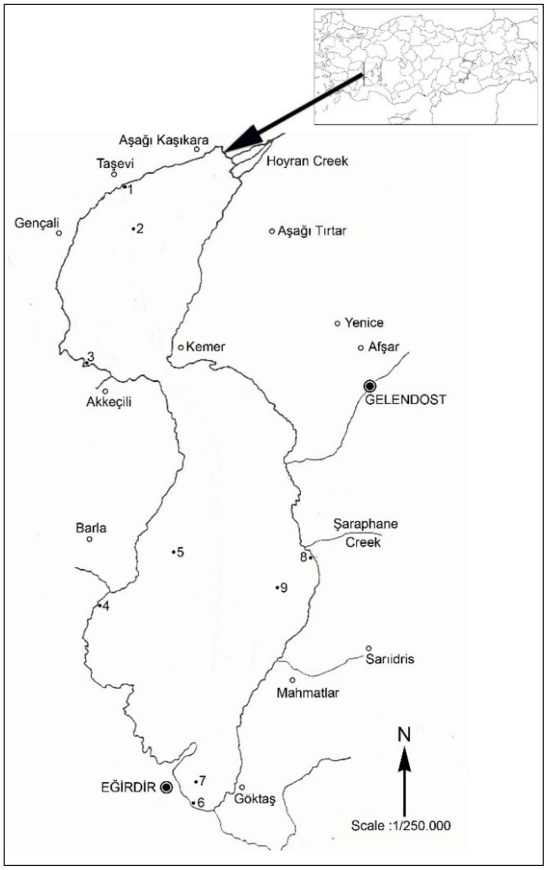


Figure 1. Lake Eğirdir and sampling stations

Specimens obtained during the sampling surveys were transported to the laboratory on ice. Total length (TL) was measured to the nearest 1 mm using a measuring board, while body weight (W) was recorded to the nearest 0.01 g using a digital balance. To determine the most suitable calcified structure for age estimation, the samples were grouped into 0.5 cm length classes, and a total of 30 individuals were selected by subsampling from each class. The vertebrae (4th to 10th) and utricular (lapillus) otoliths extracted from these individuals were cleaned using appropriate preparation techniques. To remove residual tissues, the vertebrae were immersed in boiling distilled water for 1–2 min and subsequently dried in an oven at 100°C for 10 min.

The membranous tissues surrounding the lapillus otoliths were removed in water using fine forceps or a soft brush; following alcohol treatment, the otoliths were air-dried at room temperature and preserved (Chugunova, 1963). Both calcified structures were initially examined by a single reader under a stereo-binocular microscope using reflected light at 10× magnification. During this preliminary assessment, the suitability of each structure for age estimation was evaluated based on several criteria, including core clarity, definition of the first annulus, continuity and readability of annuli, edge characteristics, and the presence and frequency of false rings. Lapillus otoliths, which demonstrated superior characteristics compared to vertebrae across all evaluated criteria, were selected as the primary structure for age determination. During the age estimation process, no auxiliary data beyond capture date and gonadal maturity were considered; morphological parameters, such as total length and body weight, were explicitly excluded to prevent bias.

To characterize the length–frequency distribution of the *S. ispartensis* population, individuals were categorized into 1 cm size classes, and the corresponding proportional frequency distributions were determined. The minimum, maximum, average length, and weight values of the identified female, male, and all fish were determined, and whether the difference in length between female and male individuals was analyzed using the f-test (Sümbüloğlu and Sümbüloğlu, 2010).

The age-sex composition of the species and the Von Bertalanffy length and weight growth equations were calculated from the samples whose age and sex were determined. Immature individuals were excluded from this calculation, thereby eliminating potential bias associated with selectivity (Ricker, 1975; Sparre and Venema, 1998). Length-weight relationships, length frequency, age-length distribution, descriptive statistics and inferential analyses were used Microsoft Office Excel 2021. The FISAT II program was used to calculate the growth parameters.

The von Bertalanffy growth model formulas are indicated below.

Age–Length Relationship equation:

$$L_t = L_\infty(1-e^{-k(t-t_0)})$$

Age–Weight Relationship equation:

$$W_t = W_\infty(1-e^{-k(t-t_0)})^b$$

In the equations: L_t: The length of the fish at time (t), W_t: The weight of the fish at time (t), L_∞: The asymptotic length, W_∞: The asymptotic weight, K: Brody growth coefficient (year^{-1}), t_0: theoretical age of the fish at zero length (years), b: Growth exponent in the length–weight relationship, e: Base of the natural logarithm.

The length-weight relationship of the sample was calculated using the regression equation $W=aL^b$ (Le Cren, 1951). In the formula, W: Total weight (g), L: Total length (cm), a: the intercept (growth coefficient), b: the slope (allometric coefficient). The growth type was tested with Student's t-test (Sümbüloğlu and Sümbüloğlu, 2010). The b coefficient was used to determine the growth type of the fish (Le Cren, 1951; Froese, 2006). Fulton's condition factor equation $K=(W/L^3)x100$ was used to determine

the condition factor of *S. ispartensis* (Ricker, 1975). In the formula, K: Condition factor, W: Weight (g), L: Total Length (cm).

Length distribution, growth characteristics based on length and weight, the length–weight relationship, and condition factor were analyzed separately for three groups: females, males, and the total population.

To determine the sex and reproductive characteristics of *S. ispartensis*, specimens were transported to the laboratory on ice and underwent a ventral incision from the anus to the head, and the gonads were examined macroscopically and microscopically to determine sex (Nikolsky, 1963; Avşar, 2005). The maturity status of the gonads of the specimens whose sex was determined was identified (Holden and Raitt, 1974). After weighing the ovaries of specimens selected from mature females through subsampling, they were labeled and preserved in a 4% formalin solution.

The reproductive season was determined using the gonadosomatic index values of female fish, calculated using the formula:

GSI=(Gonad Weight/Total Weight)x100 (Avşar, 2005).

The gravimetric method was used to determine egg production (fecundity). The ovaries preserved in formalin were dried, and their weights were measured using an AND GX-4000 precision balance with a sensitivity of 0.01 g then samples weighing 0.01–0.05 g were taken from three different regions of the ovary (front, middle, and rear) according to the size of the ovary, and the eggs were counted. The total fecundity of the specimen was calculated using the following equation from the data obtained (Avşar, 2005).

$$F=\frac{n \times G}{g}$$

F: Fecundity, n: Egg number of sub-sample, G: Gonad weight (g), g: Weight of sub-sample gonad (g).

Egg diameter measurements were performed on an average of 100 eggs selected by egg counting and random sampling using an Olympus SZX-10 stereo microscope. The Kameram 318 CU imaging attachment and software were used in both applications. Descriptive statistical analyses of egg diameters were performed using Microsoft Office Excel 2021.

To analyze the dietary characteristics of *S. ispartensis*, stomachs were extracted from specimens transported to the laboratory on ice by performing a ventral incision from the anus to the head. The excised stomachs were subsequently preserved in a 4% formalin solution. The stomach contents were subjected to both macroscopic and microscopic examination, with prey items identified to the family or higher taxonomic levels. The frequency of occurence and numerical percentages of the organisms found in the stomach content analyses were calculated. The following formulas were used to calculate these percentages (Yazıcı et al., 2025).

$$FO\%=\frac{\text{Number of stomachs containing prey i}}{\text{Number of stomach with any food item}} x100 ;$$

$$N\%=\frac{\text{Total number of prey i}}{\text{Total number of all prey items}} \times 100$$

RESULTS

A total of 315 individuals were obtained during the sampling period. It was determined that 51.4% (162 individuals) were female, 43.2% (136 individuals) were male, and 5.4% (17 individuals) were immature of the samples.

Growth properties

The total lengths ranged from 3.7 to 12.2 cm, while weights varied between 0.43 and 18.50 g (Table 1). The homogeneity test between females and males was found to be statistically significant ($F=1.32$; $p\leq0.05$). Individuals within the 8.0–10.9cm length range accounted for 53% of the total sample (Figure 2).

Table 1. Sex, total length and weight distribution of *S. ispartensis* samples

	N	Total Length (cm)			Weight (g)		
		Min.	Max.	Mean±S.E	Min.	Max.	Mean±S.E.
Immature	17	3.70	4.50	4.22±0.06	0.43	0.87	0.68±0.03
Females	162	4.30	12.20	9.09±0.16	0.62	18.50	8.17±0.35
Males	136	4.20	11.00	7.59±0.15	0.55	13.90	4.80±0.27
All fish	315	3.70	12.20	8.18±0.13	0.43	18.50	6.31±0.24

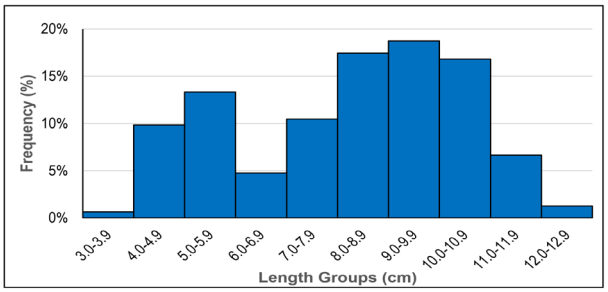


Figure 2. Length frequency distribution of *S. ispartensis* samples

During the study period, the ages of 159 individuals of *S. ispartensis* selected through subsampling for age determination ranged from I to V years. The majority of the individuals obtained from the lake were of ages II (27.0%) and III (41.5%). When examining the sex distribution of the specimens according to age, it was observed that 25% of the individuals in the I age group and approximately 2% of the individuals in the II age group had not reached sexual maturity. Males were more abundant in the II age group, females were more abundant in the III age group, and the IV and V age groups consisted entirely of female individuals (Table 2).

Table 2. Age – length key for *S. ispartensis* samples

Length Groups (cm)	Age Groups				
	I	II	III	IV	V
3.0 – 3.9	1	-	-	-	-
4.0 – 4.9	14	2	-	-	-
5.0 – 5.9	8	14	-	-	-
6.0 – 6.9	2	5	-	-	-
7.0 – 7.9	-	15	3	-	-
8.0 – 8.9	-	4	22	1	-
9.0 – 9.9	-	2	24	2	-
10.0 – 10.9	-	-	17	9	-
11.0 – 11.9	-	-	-	10	1
12.0 – 12.9	-	-	-	1	2
n	25	42	66	23	3
Mean L±SD (cm)	4.83±0.69	6.59±1.25	9.31±0.88	10.82±0.79	11.90±0.36
Mean W±SD (g)	1.03±0.48	2.79±1.57	8.03±2.32	12.67±3.07	13.83±0.74
Immature (n%)	7(4.4)	0	0	0	0
Female (n%)	9(5.7)	16(10.1)	43(27.0)	23(14.5)	3(1.9)
Male (n%)	9(5.7)	26(16.4)	23(11.0)	0	0
F : M	1:1	1:1.63	1:0.53	1:0.00	1:0.00

Von Bertalanffy growth equations were computed for females as $L_t=15.33\ (1-e^{-0.28(t+0.35)})$, for males as, $L_t=13.72\ (1-e^{-0.31(t+0.24)})$ for all fish $L_t=17.48\ (1-e^{-0.22(t+0.33)})$ The asymptotic size that females will reach ($L\infty=15.33$ cm) is higher than that of males ($L\infty=13.72$ cm).

Von Bertalanffy weight growth equations were computed for females as $W_t=36.90\ (1-e^{-0.28(t+0.35)})^{3.1665}$ for males as, $W_t=27.42\ (1-e^{-0.31(t+0.24)})^{3.2308}$ for all fish $W_t=55.30\ (1-e^{-0.22(t+0.33)})^{3.1521}$. The based on these values, the asymptotic weight $W\infty=55.30$ g was calculated for the sample. The asymptotic weight that females will reach ($W\infty=36.90$ g) is higher than that of males ($W\infty=27.42$ g).

The length-weight relationships were calculated for the females, males, and all fish in the sample. Based on the Student's t-test applied to the b values, females, males, and the combined sample all exhibited positive allometric growth. According to the significance test applied to the coefficient of determination, all three values were found to be significant ($t_{females}=8.89$, $p<0.05$; $t_{males}=7.19$, $p<0.05$; $t_{all\ fish}=7.96$, $p<0.05$) (Table 3).

Table 3. Length–weight relationships of *S. ispartensis* samples

	n	a	b ± S.E.	R^2	t_C
Females	162	0.0065	3.1665±0.0336	0.982	4.9557[a]
Males	136	0.0058	3.2308±0.0467	0.972	4.9390[b]
All fish	315	0.0067	3.1521±0.0231	0.983	6.5792[c]

a, (*t*-test, $t_C>t_{T\ 0.05,\ 162}=1.66$); b, (*t*-test, $t_C>t_{T\ 0.05,\ 136}=1.66$); c, (*t*-test, $t_C>t_{T\ 0.05,\ 315}=1.65$)

The average condition factor for the *S. ispartensis* sample was calculated as 0.94±0.01 for females, 0.91±0.01 for males, and 0.93±0.01 for the entire sample. When examining the average condition factors by age, an increase is observed at 3 years of age (Table 4).

Table 4. Condition factor values according to the ages of *S. ispartensis* samples

Age	Females		Males		All fish	
	N	Mean±SE (min-max)	N	Mean±SE (min-max)	N	Mean±SE (min-max)
I	9	0.84±0.02 (0.78-0.92)	9	0.87±0.03 (0.78-1.04)	25	0.87±0.02 (0.72-1.04)
II	16	0.90±0.03 (0.70-1.11)	26	0.86±0.02 (0.73-1.07)	42	0.88±0.02 (0.70-1.11)
III	43	0.97±0.02 (0.78-1.27)	23	0.97±0.02 (0.80-1.19)	66	0.97±0.01 (0.78-1.27)
IV	23	0.98±0.02 (0.83-1.14)	-	-	23	0.98±0.02 (0.83-1.14)
V	3	0.82±0.05 (0.73-0.89)	-	-	3	0.82±0.05 (0.73-0.89)
Overall	94	0.94±0.01 (0.73-1.19)	58	091±0.01 (0.73-1.19)	159	0.93±0.01 (0.72-1.27)

Reproduction properties

Gonadosomatic Index (GSI) values were calculated from 155 specimens for determine reproductive characteristics. Based on the GSI values, the reproductive period of *S. ispartensis* was identified as occurring between March and May (Table 5, Figure 3).

To estimate the fecundity of the *S. ispartensis* population, gonads were collected periodically, beginning from the initial appearance of macroscopic oocytes until the completion of spawning. Egg diameters were measured and summarized (Table 6).

Table 5. Monthly GSI values of *S. ispartensis*

Months	n	GSI		
		Minimum	Maximum	Mean±S.E.
June 2010	3	0.00	13.26	6.89±3.84
July 2010	5	*C.M.	*C.M.	-
August 2010	3	* C.M.	*C.M.	-
September 2010	4	* C.M.	*C.M.	-
October 2010	6	2.07	5.13	3.69±0.45
November 2010	14	3.70	9.77	6.65±0.48
December 2010	11	3.79	14.38	9.09±0.63
January 2011	9	2.69	12.92	9.09±1.18
February 2011	13	3.77	22.65	11.10±1.58
March 2011	31	1.90	27.73	13.30±1.46
April 2011	24	4.15	20.03	9.92±1.02
May 2011	32	0.00	13.89	1.13±0.57

*Couldn't measure

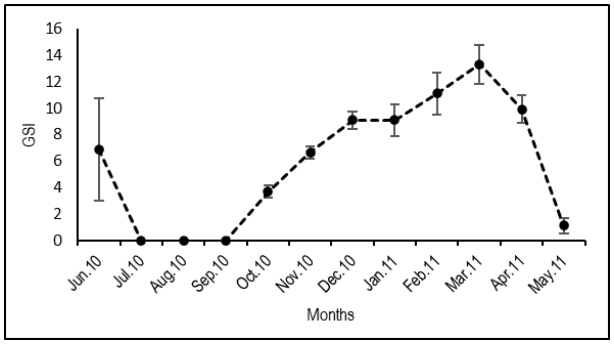


Figure 3. GSI values of *S. ispartensis* samples

Table 6. Egg diameters according to months of *S. ispartensis* samples

Months	n	Measured Eggs	Egg Diameter		
			Minimum	Maximum	Mean±S.E.
November 2010	13	4,698	0.200	1.090	0.527±0.002
December 2010	15	5,141	0.220	1.110	0.572±0.003
January 2011	7	2,460	0.210	1.100	0.520±0.003
February 2011	11	3,696	0.210	1.170	0.611±0.004
March 2011	27	9,107	0.160	1.300	0.627±0.003
April 2011	19	6,460	0.200	1.190	0.653±0.003
May 2011	3	946	0.280	1.230	0.789±0.007

The absolute fecundity of the population ranged from 1,440-16,938 eggs. The relative fecundity value was calculated as 900 eggs/g.

Feeding properties

Dietary analysis of 50 stomachs indicated that *S. ispartensis* is a predominantly carnivorous species. The dietary composition consisted primarily of aquatic insects (Trichoptera, Ephemeroptera) and Amphipoda (Table 7).

DISCUSSION

Due to the scarcity of existing literature regarding the biological characteristics of *S. ispartensis*, direct intra-specific comparisons were not possible. Consequently, the findings of this study were evaluated in relation to other species within the same genus to provide a broader biological context.

Table 7. Food composition of *S. ispartensis* samples

Food Items	N	%N	FO	%FO
FISHES				
Digested Fish	1	0.28	1	0.94
ARTHROPODA				
Corophiidae	112	31.82	14	13.21
Gammariidae	124	35.23	30	28.30
Crustaceae	1	0.28	1	0.94
INSECTA				
Odonata larvae	25	7.10	10	9.43
Trichoptera larvae	16	4.55	6	5.66
Ephemeroptera larvae	6	1.70	3	2.83
Chrinomidae larvae	18	5.11	8	7.55
Formicidae		0.28	1	0.94
MOLLUSCA				
Gastropoda	1	0.28	1	0.94
ANNELIDA				
Oligochaeta	26	7.39	10	9.43
DIATOME				
Bacillarophyta*	10	2.84	10	9.43
OTHER ORGANISMS				
Digested organisms	11	3.13	11	10.38

(N): Food composition, (FO): Frequency of occurence * Benthic diatoms that were accidentally ingested as food.

In the sampling studies, non-selective fishing gear such as electroshocker, seine-net, and fyke-net and selective fishing gear gillnets were used. The largest number of specimens was obtained using electroshocker (184). This was followed by gillnet (117), fyke-net (10), and seine-net (4). While the ages of specimens obtained using non-selective fishing gear (electroshocker, seine-net, and fyke-net) ranged from 1 to 5 years, the ages of specimens caught using selective fishing

gear gillnet ranged from 2 to 5 years. Immature and adult individuals were obtained using electroshocker, seine-net, and fyke-net whereas only adult individuals were obtained using gillnet. The total lengths of individuals obtained using gillnet ranged from 6.7 to 12.2 cm, whereas the total lengths of specimens obtained using electroshocker, seine-net, and fyke-net ranged from 3.7 to 12.2 cm.

The length–frequency distribution of the population exhibited a bimodal pattern. While the age of the sampled individuals ranged from I to V years, those in age group III represented the largest portion of the population at 41.51%. Age groups I and IV collectively accounted for approximately 30% of the sample. Notably, the length–frequency distribution revealed a clustering pattern where the size ranges of individuals in age groups I and IV showed a significant overlap. This distribution pattern results from the use of both non-selective fishing equipment such as electroshock devices, nets, and trap nets, and selective fishing equipment such as gill nets in sampling studies. Due to the absence of existing literature regarding the age–sex distributions of other members of the *Seminemacheilus* genus, a comparative analysis of these parameters was not possible.

In the present study, the total length of *S. ispartensis* ranged from 3.70 to 12.20 cm (Table 1). In comparison, total length ranges have been reported as 4.4–6.9 cm for *Seminemacheilus lendlii*, 4.4–10.3 cm for various Nemacheilidae species distributed across Türkiye, and 3.7–8.4 cm for those distributed in Iran (Golzarianpour et al., 2011; Erk'akan et al., 2013, 2014). When comparing the maximum total length values of other species with the maximum total length value obtained in our study, it is observed that only one species out of 43 has a total length value higher than that in our study (Table 8). The discrepancies between the maximum lengths recorded in our study and those in previous reports may be attributed to interspecific variations, differences in sampling gear selectivity.

The Brody growth coefficient (K) for *S. ispartensis* was calculated as 0.22. Based on this value, *S. ispartensis* can be categorized as a slow-growing species, characterized by a relatively gradual approach toward its asymptotic length.

For *S. ispartensis*, the "a" value of the length-weight relationship parameters was calculated as 0.007 and the "b" value as 3.15. According to Table 8 the species *O. angorae, O. eregliensis*, and *O. simavicus* from the *Oxynoemacheilus* genus of the Nemacheilidae family, as well as the other members of the *Seminemacheilus* genus, *S. ahmeti, S. attalicus, S. dursunavsari*, and *S. ekmekciae*, also show a similar positive allometric growth pattern, while other *Oxynoemacheilus* species and *S. lendlii* have shown negative allometric growth in studies conducted by other researchers in the same basin (Heydarnejad, 2009; Golzarianpour et al., 2011; Erk'akan et al., 2013, 2014).

According to Minns (1995), the spatial extent of a home range significantly influences fish size; because lakes provide broader and more expansive environments compared to rivers, lentic system fish tend to exhibit larger body sizes than those inhabiting lotic systems. Furthermore, the length-weight relationship and condition factor of fish are closely correlated with various parameters, including seasonality, gonadal maturity, sex, nutritional status, and the length distribution of the sampled population. Given the dynamic nature of any population, these indices are subject to temporal variations on both a monthly and interannual basis (Kuriakose, 2017). The observation of a positive allometric growth type and condition factor higher than those reported in the other studies, in our sampling, can be attributed to several factors. These include, conducting the research within a lake ecosystem, encompassing a continuous one-year study period with monthly sampling intervals, collecting a larger sample size relative to other studies, and a broader range of length distribution within the sample cohort.

The fact that the monthly average GSI (Gonadosomatic Index) values began to rise starting in December indicates that the eggs of this species began to grow starting that month (Figure 3). The mean GSI peaked in March (13.30±1.46), before initiating a decline in April (9.92±1.02) and reaching its minimum in May (1.13) confirms that spawning occurs between March and May (Table 5). This significant reduction in GSI values confirms that the spawning period for this species occurs between March and May (Table 5). In May 2011, four out of 32 specimens were observed not to have participated in spawning. An isolated case of late-stage gonadal development recorded in June was treated as an individual anomaly and subsequently excluded from the analysis. Furthermore, as gonadal development only reached quantifiable levels in October, GSI values could not be determined for the period between July and September (Figure 3, Table 5). Analysis of monthly variations in egg diameter revealed that the maximum individual value (1.300 mm) occured in March, while the highest mean egg diameter (0.789±0.007) was recorded in May (Table 6). These data further corroborate the finding that the spawning period for this species extends from March to May.

Examination of the dietary habits of the species confirmed a carnivorous feeding strategy (Table 7). When the frequency of occurrence of food organisms was examined, it was seen that members of Gammaridae (28.30%) and Corophiidae (13.21%) were the organisms preferred by the species (Table 7). The prevalence of Gammaridae in the stomach contents of specimens from the Kayaağzı station, contrasted with the predominance of Corophiidae in individuals from other lacustrine stations, likely reflects the site-specific abundance of these macroinvertebrates. Furthermore, the presence of Bacillariophyta (diatoms) is attributed to either accidental intake during benthic feeding or secondary ingestion via the consumption of primary prey items.

Table 8. Minimum, maximum length values (Total length - TL), length – weight relationships and condition factor (CF) of some Nemacheilidae species

Species	Locality	TL (cm) Min.-Max.	n	a	b	R^2	CF (Mean±SE)	Literature
O. angorae	Iran	3.7–8.0	79	0.008	3.06	0.94	-	Heydarnejad (2009)
O. angorae	Jojroud Stream – Iran	3.8–7.6	21	0.008	3.01	0.98	-	Golzarianpour et al. (2011)
O. brandtii	Zarrineh Stream – Iran	5.5–7.8	325	0.009	2.97	0.96	-	Golzarianpour et al. (2011)
O. farsicus	Kor Stream – Iran	3.8–7.6	35	0.012	2.88	0.94	-	Golzarianpour et al. (2011)
O. kermanshahensis	Gamasiab Stream – Iran	4.6–8.4	38	0.015	2.89	0.97	-	Golzarianpour et al. (2011)
O. angorae	Balıklı Creek - Türkiye		30	0.006	3.24	0.88	-	Gaygusuz et al. (2012)
O. eregliensis	Melendiz Creek – Türkiye	1.7–10.3	76	0.005	3.20	0.98	-	Erk'akan et al.(2013)
S. lendlii	Salur Creek – Türkiye	4.4–6.9	22	0.010	2.94	0.82	-	Erk'akan et al. (2013)
O. angorae	Beynam Creek – Türkiye	4.4–8.3	24	0.006	3.23	0.99	-	Erk'akan et al. (2014)
O. evreni	Çayır Creek – Türkiye	5.4–9.4	27	0.013	2.79	0.92	-	Erk'akan et al. (2014)
O. mesudae	Küfi Creek – Türkiye	6.6–8.9	14	0.016	2.63	0.95	-	Erk'akan et al. (2014)
O. samanticus	Karaboğaz Creek – Türkiye	4.5–8.6	40	0.009	2.92	0.92	-	Erk'akan et al. (2014)
O. simavicus	Karaçaltı Creek – Türkiye	4.6–7.1	17	0.004	3.26	0.95	-	Erk'akan et al. (2014)
O. angorae	Kılıçözü Creek – Türkiye	3.5–9.8	103	0.001	2.93	0.96	-	Yazıcıoğlu and Yazıcı (2016)
O. angorae	Kızılırmak - Türkiye	2.8–8.6	127	0.008	3.10	0.94	-	Sungur Birecikligil et al. (2016)
O. veyseli	Bozkuş Creek – Türkiye	3.9–10	46	0.011	2.82	0.97	-	Özdemir et al. (2019)
O. angorae	Asartepe Dam – Türkiye	4.0–7.8	50	0.017	2.65	0.80	0.96±0.04	Saylar et al. (2020)
S. ahmeti	Sultan Marsh – Türkiye	3.3–7.5	125	0.006	3.28	0.97	-	Seçer et al. (2021)
S. attalicus	Kırkgöz Wetland – Türkiye	4.0–7.9	35	0.005	3.48	0.99	-	Seçer et al. (2021)
S. dursunavsari	Alanözü Pond – Türkiye	4.0–9.1	32	0.008	3.12	0.98	-	Seçer et al. (2021)
S. ekmekciae	Kulu – Türkiye	4.3–8.2	65	0.006	3.30	0.97	-	Seçer et al. (2021)
S. ispartensis	Isparta Creek – Türkiye	4.2–8.6	15	0.019	2.62	0.99	-	Seçer et al. (2021)
S. lendlii	Hacıbeyli village – Türkiye	4.2–7.7	15	0.021	2.56	0.97	-	Seçer et al. (2021)
O. seyhanensis	Çakraz Stream (Akdağmadeni) – Türkiye	4.6–9.8	29	0.006	3.24	0.95	1.06±0.18	Seçer et al. (2022)
O. seyhanensis	Zamantı River (Büyükpotuklu) – Türkiye	3.8–6.3	18	0.004	3.52	0.97	1.01±0.10	Seçer et al. (2022)
O. seyhanensis	Zamantı River (Örenşehir) – Türkiye	6.2–9.1	15	0.007	3.21	0.98	1.15±0.90	Seçer et al. (2022)
O. seyhanensis	Zamantı River (Pınarbaşı) – Türkiye	3.5–6.6	21	0.006	3.22	0.97	0.92±0.10	Seçer et al. (2022)
O. seyhanensis	Kizilirmak River (Suşehri) – Türkiye	4.8–9.6	29	0.045	2.29	0.92	1.05±0.08	Seçer et al. (2022)
O. seyhanensis	Gökırmak River (Taşköprü) – Türkiye	4.6–8.9	27	0.005	3.37	0.98	1.03±0.11	Seçer et al. (2022)
O. seyhanensis	Yıldız Stream (Yıldızeli) – Türkiye	4.5–8.9	27	0.005	3.33	0.98	1.05±0.09	Seçer et al. (2022)
O. anatolicus	Dalaman Stream – Türkiye	4.5–8.2	11	0.007	3.17	0.98	0.92±0.10	Çiçek et al. (2022)
O. angorae	Çubuk Stream – Türkiye	3.8–8.9	25	0.011	2.90	0.98	0.91±0.09	Çiçek et al. (2022)
O. argyrogramma	Keysun Stream – Türkiye	4.5–7.3	54	0.013	2.77	0.95	0.91±0.09	Çiçek et al. (2022)
O. arsaniasus	Haçlı Lake – Türkiye	4.6–7.2	13	0.012	2.92	0.92	1.01±0.08	Çiçek et al. (2022)
O. atili	Eflatun Pınarı – Türkiye	4.3–8.3	47	0.011	2.88	0.98	0.89±0.06	Çiçek et al. (2022)
O. banarescui	Alaçam Stream – Türkiye	4.4–7.8	63	0.007	3.11	0.93	0.81±0.09	Çiçek et al. (2022)
O. bergianus	Handere Stream – Türkiye	3.0–8.4	43	0.007	3.05	0.98	0.74±0.07	Çiçek et al. (2022)
O. bergianus	Digor – Türkiye	3.3–8.4	74	0.008	2.92	0.99	0.72±0.06	Çiçek et al. (2022)
O. cf. Bureschi	Uluçay Stream – Türkiye	5.3–7.7	7	0.006	3.10	0.99	0.76±0.03	Çiçek et al. (2022)
O. ceyhanensis	Ceyhan River – Türkiye	3.3–7.8	50	0.007	3.15	0.95	0.86±0.13	Çiçek et al. (2022)
O. ciceki	Sultan Marsh – Türkiye	4.3–7.5	103	0.005	3.13	0.91	0.61±0.06	Çiçek et al. (2022)
O. cilicicus	Kızıl Stream – Türkiye	3.4–9.9	105	0.006	3.27	0.95	0.91±0.13	Çiçek et al. (2022)
O. cyri	Kura River – Türkiye	3.2–8.6	31	0.007	3.20	0.97	1.06±0.14	Çiçek et al. (2022)
O. ercisianus	Ilıca Stream – Türkiye	2.9–7.7	103	0.009	3.04	0.98	0.91±0.07	Çiçek et al. (2022)
O. eregliensis	Melendiz Stream – Türkiye	5.1–9.5	123	0.009	2.96	0.97	0.83±0.07	Çiçek et al. (2022)
O. euphraticus	Aşkale – Türkiye	2.8–9.3	119	0.008	2.96	0.96	0.74±0.07	Çiçek et al. (2022)
O. evreni	Ceyhan River – Türkiye	3.1–6.5	17	0.008	3.16	0.99	0.98±0.08	Çiçek et al. (2022)
O. frenatus	Arpaçay Stream – Türkiye	4.1–8.0	31	0.008	3.11	0.92	1.02±0.16	Çiçek et al. (2022)
O. germencicus	Kadın Stream – Türkiye	5.1–7.8	19	0.007	3.11	0.98	0.91±0.05	Çiçek et al. (2022)
O. hamwii	Orontes River – Türkiye	3.1–8.4	63	0.005	3.26	0.91	0.81±0.16	Çiçek et al. (2022)
O. hazarensis	Hazar Lake – Türkiye	4.1–7.2	13	0.011	2.89	0.94	0.90±0.12	Çiçek et al. (2022)
O. insignis	Karasu Stream – Türkiye	3.4–6.5	29	0.006	3.05	0.92	0.60±0.10	Çiçek et al. (2022)
O. kaynaki	Input of Dumluca Lake – Türkiye	4.0–7.5	82	0.007	3.15	0.94	0.94±0.11	Çiçek et al. (2022)
O. mediterraneus	Input of Sücüllü Dam Lake – Türkiye	3.6–7.6	144	0.009	2.94	0.97	0.78±0.07	Çiçek et al. (2022)
O. namiri	Orontes River – Türkiye	4.1–8.7	88	0.007	3.19	0.92	1.01±0.15	Çiçek et al. (2022)
O. nasreddini	Siyek Stream – Türkiye	4.7–9.9	77	0.011	2.98	0.93	1.07±0.13	Çiçek et al. (2022)
O. paucilepis	Mancınık Stream – Türkiye	4.2–8.2	15	0.009	3.05	0.98	1.02±0.07	Çiçek et al. (2022)
O. samanticus	Zamantı Stream – Türkiye	4.4–6.6	21	0.006	3.18	0.97	0.86±0.05	Çiçek et al. (2022)
O. seyhanensis	Zamantı Stream – Türkiye	3.3–9.1	56	0.009	3.10	0.98	1.00±0.10	Çiçek et al. (2022)
O. seyhanicola	Ceyhan River – Türkiye	4.2–9.5	29	0.005	3.24	0.98	0.76±0.09	Çiçek et al. (2022)
O. simavicus	Yağcılı Stream – Türkiye	4.8–8.0	10	0.007	3.24	0.98	1.03±0.08	Çiçek et al. (2022)
O. theophilii	Sevişler Dam Lake – Türkiye	3.5–7.7	54	0.006	3.29	0.95	0.92±0.13	Çiçek et al. (2022)
O. tigris	Seve Dam Lake – Türkiye	3.0–8.4	36	0.006	3.14	0.94	0.72±0.10	Çiçek et al. (2022)
O. veyselorum	Bozkuş Stream – Türkiye	4.6–12.6	46	0.011	2.89	0.97	0.91±0.20	Çiçek et al. (2022)
S. ispartensis	Eğirdir Lake – Türkiye	6.7–12.2	64	0.029	2.54	0.89	-	Apaydın Yağcı et al. (2022)
S. ispartensis	Eğirdir Lake – Türkiye	3.7–12.2	315	0.007	3.15	0.98	0.93±0.01	This study

Our findings indicate that individuals captured using selective sampling gear exhibited a narrower range in terms of age, total length, and sex, whereas non-selective methods yielded a broader and more representative demographic spectrum. This disparity demonstrates that the integrated use of both selective and non-selective sampling techniques is essential for ensuring accurate and reliable results in population studies of small-bodied species, such as *S. ispartensis*. Relying solely on a single gear type may lead to significant bias in estimating the age structure and growth parameters of such populations.

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AUTHORSHIP CONTRIBUTIONS

Fieldwork and laboratory studies was conducted by Vedat Yeğen, data analysis was conducted by Hasan Musa Sarı. All authors participated in writing and reviewed the final version of the manuscript.

CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

ETHICAL APPROVAL

No special ethical approval was requested at the time the study began, so it was not obtained.

DECLARATION OF AI USE

Generative artificial intelligence tools were not utilized in the preparation of this study. All text, analysis, and content were produced exclusively by the authors through human input.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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