

Research Article

Phenotypic and biological variations between the sexes of pike perch, *Sander lucioperca* (Teleostei, Percidae): Emphasizing sexual dimorphism

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Keywords

Sander lucioperca,
Length-weight relationships,
Condition factor,
Sexual dimorphism,
Al Massira Dam Lake

Abstract

To phenotypically and biologically characterize the population of pike perch *Sander lucioperca* and to detect any potential variability between sexes, this study focused on analyzing sexual dimorphism and morphological differences based on morphometric and meristic characters, along with examining the length-weight relationships and condition factor. The growth type reveals positive allometry in both sexes. The Fulton's condition factor (K_F) value exceeded 1 for both males and females, suggesting that the fish were in good conditions. No sexual dimorphism was found in the meristic characters of either sex. However, morphometric characteristics show that male individuals are distinguished by deeper bodies and extended pectoral and pelvic fins in comparison to females. The results of this study highlight six morphological differences between male and female *Sander lucioperca*, showing pronounced sexual dimorphism. These findings play a crucial role in the successful management and preservation of this species' population in Morocco, particularly in the Al Massira Dam Lake.

Article info

Received: August 2024

Accepted: April 2025

Published: July 2025



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Introduction

Pike perch (*Sander lucioperca*) is a semi-anadromous percid species that occurs in both freshwater and brackish environments (Coad, 2016). It can be found in rivers, lakes, canals, also in estuaries and coastal marine areas with low salinity (Nikolić *et al.*, 2023). The pike perch, native to the major rivers of Eastern Europe, is naturally found from the Elbe to the Baltic Sea and southwest Russia (Coad, 2016). Due to its importance for sport and commercial fishing (Nikolić *et al.*, 2023) and for regulating phytophagous populations (Ribeiro *et al.*, 2021), it has been introduced to several European countries and the Maghreb, as well as to the Azores and several lakes in the United States (Poulet, 2004). The pike perch was first introduced to Morocco in 1939 by the HCEFLCD, and it has adapted perfectly to the conditions of Moroccan freshwater environments in several water bodies (Mouslih, 1987; Bousseba *et al.*, 2025). Due to the quality of its flesh, pike perch holds an important place in the sectoral economy of fisheries resources. It is therefore a species of great significance in the commercial and professional fishing sector, with a notable socio-economic interest. Large predatory fish, like pike perch, play a crucial role as keystone species, and their status can significantly influence ecosystem functioning through important indirect effects (Nikolić *et al.*, 2023).

Phenotypic variability within a species can be influenced by environmental, ecological, and ontogenetic factors, as well as by sex-linked changes (Martinez *et al.*, 2019). Sex-linked variability frequently appears as sexual dimorphism, typically

evident through differences in color, size, or the shape of morphological structures (Zajitschek *et al.*, 2020). This phenomenon is widespread throughout the animal kingdom and is an essential source of intraspecific variability (Berns, 2013; Martinez *et al.*, 2019). Natural selection, as well as, Intrasexual and intersexual selection, can play crucial roles in the development of sexual dimorphism within a species (Li and Kokko, 2021).

The length-weight relationship (LWR) and the condition factor (K_R) are important parameters that provide essential information on fish growth and health status, and are therefore widely used in fish biology (Narzary and Khangembam, 2022). These biological parameters have been studied by several authors around the world (M'Hetli *et al.*, 2011; Pérez-Bote and Roso, 2012; Bouamra *et al.*, 2017; Ibănescu *et al.*, 2019; Gago *et al.*, 2021). Analyzing the length-weight relationship is essential for sustainable resource conservation and fisheries research (Azrita *et al.*, 2024). It is also essential for developing recommendations regarding aquatic resource management (Sonowal *et al.*, 2019; Ergüden, 2021).

Morphological measurements and length-weight relationships are frequently utilized to identify sexual dimorphism (Karadurmuş *et al.*, 2022). The allometric variations in the morphological characteristics of fish often reflect differences between the sexes (Kim *et al.*, 2008). Several studies have confirmed the phenotypic variation of *S. lucioperca* between the two sexes, resulting in sexual dimorphism marked by morphological differences between males and females,

particularly in terms of head length and body height (Goubier, 1975). The use of geometric morphometric techniques in the study of Parés-Casanova and Cano (2014), from Ivars and Vila-sana lake in Spain, also revealed sexual dimorphism in pike perch morphology, mainly in terms of body length and dorsal fins, with males having a shorter body and more pronounced dorsal convexity. In addition, Turki *et al.* (2009) detected phenotypic variability between the two sexes of the same species in the Nebhana dam reservoir in Tunisia, particularly in terms of different body lengths and ventral and pectoral fin lengths. In terms of coloration, sexual dimorphism in *S. lucioperca* is reflected by a darker belly in the male during the breeding period (Poulet, 2004). This study aims to provide, for the first time in Morocco's Al Massira Reservoir, data on the potential sexual dimorphism in the morphometric and meristic characteristics of *S. lucioperca*. Additionally, it aimed to evaluate the

species' biological characteristics, including the length-weight relationship and the condition factor. These findings contribute significantly to future research on the ecology, conservation, and management of *S. lucioperca*.

Materials and methods

Study site and sampling

A total of 83 *S. lucioperca* specimens used in the study were sampled from commercial fisheries in March 2022. These specimens were captured by professional fishermen using gillnets with mesh sizes of 25 and 65 mm in the Al Massira Dam Lake, situated on the Oum Errabia River, and located 120 kilometers south-east of Casablanca (Alaoui *et al.*, 2000) (between 32°28'32" N and 7°32'15" W) (Fig. 1). This reservoir represents an important reserve of water for public supply, irrigation, fishing, as well as a significant source of hydroelectric power.

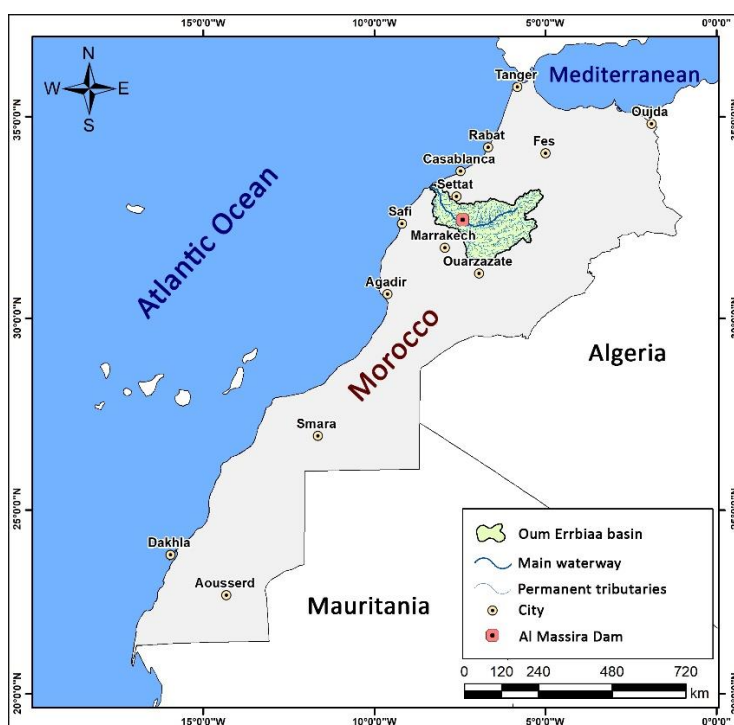


Figure 1: Map of study site: Al Massira Dam Lake, Morocco.

Morphometric analyses

In the laboratory, 20 morphometric characters were measured for each fish using a caliper with a precision of 0.1 mm. These measurements included: Head length (HL), Maximum height (H), Minimum height (h), Snout to eye distance (SE), Snout to pre-operculum distance (SPO), Snout to ventral fin distance (SV), Snout to pectoral fin distance (SP), Snout to first dorsal fin distance (SD1), Snout to second dorsal fin distance (SD2), Snout to anal fin distance (SA), Eye diameter (ED), Eye to post-operculum distance (EPO), Length of first dorsal fin basis (LD1), Length of second dorsal fin basis (LD2), Length of anal fin basis (LA), Ventral fin length (LV), Pectoral fin length (LP), Ventral fin-anal fin distance (VA), Pectoral fin to anal fin distance (PA), Insertion point of the last spine of the first dorsal fin to the tip of the caudal fin distance (PoD). The following meristic counts were registered: Number of gill rakers on the first gill arch (GR), Number of first dorsal fin rays (D1), Number of second dorsal fin rays (D2), Number of ventral fin rays (V), Number of anal fin rays (A), Number of caudal fin rays (C). The body weight (W) of the samples was measured by an electronic balance with a precision of 0.01 g. Morphometric measurements were standardized to eliminate any effects related to size (Lahnsteiner and Jagsch, 2005). Thus, the different morphometric characteristics were represented as a percentage of the standard length (SL).

Sex differentiation was initially determined macroscopically and then confirmed microscopically through histological examination of the gonads. After

dissection, the gonads were fixed in a 10% formaldehyde solution for 24 hours and then preserved in 70% ethanol at room temperature until they were analyzed. Portions of the gonadal tissue were cut, dehydrated in increasing ethanol concentrations (70%, 95%, and 100%), embedded in paraffin, and sectioned into 2 to 5 μm thick slices with a microtome. These sections were colored using hematoxylin-eosin, and sex was confirmed by examining the stained tissues under a light microscope.

The regression coefficients a and b for the relationship between SL and W were estimated using a linearized logarithmic function according to Froese (2006): $\ln(W) = \ln(a) + b \ln(SL)$. The length-weight relationship indicates isometric growth where $b = 3$ and allometric growth where $b \neq 3$.

The Fulton's condition factor was estimated based on the following formula (Fulton, 1904):

$$KF = 100 \times W/SL^b \quad (1)$$

Statistical analysis

All represented data were expressed as mean \pm SD. The Mann-Whitney test (non-normal data distribution) was used to assess the statistical differences between females and males with regard to length, weight, and meristic characters. Morphometric differences between the sexes were examined according to Student's t-test. In addition, a Student's t-test was conducted to determine if the estimated b value significantly differs from 3, which corresponds to the isometric value (Pauly, 1984). The coefficient of determination (r^2) measures the accuracy of a linear regression

model, with values approaching 1 indicating a more precise prediction. All tests were conducted with a significance level set at $p < 0.05$. The statistical analyses were conducted with the R-Studio software version (4.3.1).

Results

Histological examination of the gonads of 83 specimens of *S. lucioperca* indicated that 58 were female (275-390 mm SL) and 25 were male (280-380 mm SL) (Table 1). There were no significant differences

observed between the sexes in both SL (Mann-Whitney $U=246.5$, $p=0.72$) and W (Student test $t=0.65$, $p=0.52$).

Table 2 provides the statistical data necessary for evaluating the length-weight relationship of *S. lucioperca* by sex, including the estimated parameters of the regression, the growth type of the population, and the coefficient of determination. The b value obtained for LWR suggests positive allometry in both sexes ($b > 3$, $p < 0.05$).

Table 1: Summary of standard length (SL) and weight (W) data for male and female *S. lucioperca*.

Sex	N	SL, mm	W, g
Female	58	347.90 ± 28.04 275.0-390.0	362.37 ± 99.38 149.3-530.7
Male	25	343.23 ± 30.97 280.0-380.0	383.99 ± 116.71 153.4-546.3

Table 2: Descriptive statistics and parameters of the length-weight relationships (LWR) of *S. lucioperca*.

Sex	N	$a \pm SE$	$b \pm SE$	r^2	Growth type	p-value
Female	58	0.031 ± 0.024	3.18 ± 0.162	0.89	A+	$1.837 \times 10^{-11}^{***}$
Male	25	0.021 ± 0.064	3.09 ± 0.42	0.88	A+	$2.023 \times 10^{-7}^{***}$

^aIntercept, ^bslope, SE standard error, r^2 coefficient of determination, A+ positive allometry, $^{***}p < 0.001$.

The Fulton's condition factor of *S. lucioperca* varied significantly between sex categories ($p < 0.05$), and the value was significantly highest in females (1.20 ± 0.12) than in males (1.13 ± 0.06) (Table 3).

Table 3: Summary of parameters condition factors (K_F) of *S. lucioperca*.

Sex	N	K_F
Female	58	1.20 ± 0.12 0.98-1.37
Male	25	1.13 ± 0.064 1.01-1.27

The examination of meristic characteristics of all males and females revealed no significant difference between the sexes ($p > 0.05$) (Table 4). However, the

examination of morphometric characteristics revealed sex-related differences.

Compared to females, males had greater maximum height (H) and minimum height (h) ($t=5.698$, 2.378 and $p=0.0002$, 0.037 , respectively), a longer distance between the snout and the second dorsal fin (SD2) ($t=2.553$, $p=0.020$), a longer ventral fin length (LV) and pectoral fin length (LP) ($t=2.638$, 2.360 , and $p=0.039$, 0.032 , respectively), and a greater distance between the pectoral fin and the anal fin (PA) ($t=2.976$, $p=0.008$) (Table 5).

Here and in Tables 3,4 and 5: Values above the line represent the mean \pm SD (standard

deviation), while those below the line indicate the min–max range, n is the number of samples.

Table 4: Summary of meristic characteristics and statistical analysis of the rank sum of sexual differences.

Character	Female (n = 58)	Male (n = 25)	Significance	
			<i>U</i>	<i>p</i>
GR	$\frac{12.55 \pm 1.47}{9-15}$	$\frac{12.55 \pm 1.13}{11-14}$	187	0.97 ^{ns}
D1	$\frac{13.90 \pm 0.65}{13-16}$	$\frac{14.00 \pm 0.71}{13-15}$	205.5	0.645 ^{ns}
D2	$\frac{21.26 \pm 2.04}{11-24}$	$\frac{21.33 \pm 0.71}{20-22}$	158	0.414 ^{ns}
V	$\frac{5.76 \pm 0.43}{5-6}$	$\frac{6.00 \pm 0.50}{5-7}$	229	0.185 ^{ns}
A	$\frac{13.05 \pm 1.06}{9-15}$	$\frac{13.55 \pm 1.13}{12-16}$	223	0.373 ^{ns}
C	$\frac{16.50 \pm 1.09}{13-18}$	$\frac{17.11 \pm 1.61}{14-19}$	241.5	0.18 ^{ns}

GR, Number of gill rakers on the first gill arch; D1, Number of first dorsal fin rays; D2, Number of second dorsal fin rays; V, Number of ventral fin rays; A, Number of anal fin rays; C, Number of caudal fin rays; ns, not significant.

Table 5: Summary of morphometric characters, expressed as percentages of standard length (% of SL), and statistical analysis of the rank sum of sex differences.

Character	Female (n = 58)	Male (n = 25)	Significance	
			<i>t</i>	<i>p</i>
HL	$\frac{30.89 \pm 2.79}{25.38-37.27}$	$\frac{30.40 \pm 0.93}{29.39-31.58}$	-0.718	0.48 ^{ns}
H	$\frac{29.78 \pm 2.46}{24.23-34.04}$	$\frac{35.00 \pm 1.87}{32.65-36.84}$	5.698	0.0002***
h	$\frac{12.91 \pm 1.31}{10.00-16.67}$	$\frac{14.01 \pm 0.92}{12.36-14.92}$	2.378	0.037*
SE	$\frac{8.17 \pm 1.69}{6.15-14.17}$	$\frac{7.57 \pm 1.17}{5.26-8.36}$	-1.016	0.331 ^{ns}
SPO	$\frac{22.31 \pm 2.15}{18.26-27.73}$	$\frac{24.52 \pm 3.58}{21.22-30.43}$	1.440	0.200 ^{ns}
SV	$\frac{33.05 \pm 2.53}{28.26-37.55}$	$\frac{33.34 \pm 0.46}{32.65-34.03}$	0.524	0.604 ^{ns}
SP	$\frac{30.73 \pm 2.62}{26.00-36.36}$	$\frac{31.13 \pm 1.11}{29.82-32.73}$	0.574	0.572 ^{ns}
SD1	$\frac{33.20 \pm 2.76}{27.39-37.73}$	$\frac{32.72 \pm 1.59}{30.16-34.38}$	-0.547	0.593 ^{ns}
SD2	$\frac{61.71 \pm 4.14}{54.35-71.43}$	$\frac{64.66 \pm 1.92}{62.54-67.72}$	2.553	0.020*
SA	$\frac{62.57 \pm 5.59}{51.92-72.92}$	$\frac{65.16 \pm 3.59}{58.96-69.56}$	1.398	0.187 ^{ns}

Table 5 (continued):

Character	Female (<i>n</i> = 58)	Male (<i>n</i> = 25)	Significance	
			<i>t</i>	<i>p</i>
ED	$\frac{5.93 \pm 0.89}{4.35-7.50}$	$\frac{5.94 \pm 0.69}{5.52-7.35}$	0.039	0.970 ^{ns}
EPO	$\frac{20.94 \pm 4.13}{15.22-31.82}$	$\frac{20.00 \pm 3.25}{16.33-24.21}$	-0.601	0.562 ^{ns}
LD2	$\frac{24.47 \pm 2.72}{20.00-30.61}$	$\frac{25.46 \pm 1.14}{23.27-26.53}$	1.360	0.188 ^{ns}
LA	$\frac{12.50 \pm 1.51}{9.20-14.89}$	$\frac{13.05 \pm 0.70}{12.07-14.03}$	1.306	0.208 ^{ns}
LV	$\frac{16.20 \pm 1.05}{14.54-18.20}$	$\frac{18.46 \pm 2.01}{16.90-22.45}$	2.638	0.039*
LP	$\frac{15.75 \pm 1.55}{12.69-18.64}$	$\frac{16.85 \pm 0.83}{15.86-18.24}$	2.360	0.032*
VA	$\frac{31.33 \pm 3.44}{23.85-36.54}$	$\frac{32.74 \pm 2.60}{30.34-36.96}$	1.106	0.294 ^{ns}
PA	$\frac{33.81 \pm 3.86}{23.46-40.00}$	$\frac{36.97 \pm 1.74}{34.48-39.13}$	2.976	0.008**
PoD	$\frac{63.01 \pm 4.64}{54.35-74.54}$	$\frac{63.75 \pm 1.34}{62.07-65.31}$	0.676	0.504 ^{ns}

HL, Head length; H, Maximum height; h, Minimum height; SE, Snout to eye distance; SPO, Snout to pre-operculum distance; SV, Snout to ventral fin distance; SP, Snout to pectoral fin distance; SD1, Snout to first dorsal fin distance; SD2, Snout to second dorsal fin distance; SA, Snout to anal fin distance; ED, Eye diameter; EPO, Eye to post-operculum distance; LD1, Length of first dorsal fin basis; LD2, Length of second dorsal fin basis; LA, Length of anal fin basis; LV, Ventral fin length; LP, Pectoral fin length; VA, Ventral fin-anal fin distance; PA, Pectoral fin to anal fin distance; PoD, Insertion point of the last spine of the first dorsal fin to the tip of the caudal fin distance; ns, not significant; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. All morphometric measures are in mm.

Discussion

Research on the morphometric and meristic characteristics of *S. lucioperca* in Moroccan freshwater environments is non-existent. This study represents the first detailed and informative analysis of the morphometric and meristic characteristics of pike perch in Al Massira Dam Lake. This data is crucial for understanding the dynamics of local populations, assessing their health status, and establishing a solid foundation for the conservation and management of this species in Moroccan aquatic ecosystems.

Sexual dimorphism in growth is a common phenomenon among teleost fish. Generally, it is observed that males reach a larger size than females in adulthood. This phenomenon, for instance, has been

documented in various tilapia species (Toguyeni *et al.*, 1997), as well as in salmonids including *Salmo trutta* and *Oncorhynchus mykiss* (Bonnet *et al.* 1999). Conversely, several studies have shown that in many species of flatfish, Females are larger than males, This is demonstrated in species such as the dab (*Limanda limanda*) (Lozan, 1992), the carp (*Cyprinus carpio*) (Hollebecq and Haffray, 1994), and the perch (*Perca fluviatilis*) (Fontaine *et al.*, 1997). However, our results indicate that there are no significant differences in total length and weight between the sexes.

The length-weight relationship provides crucial baseline data for several biological studies, enabling the assessment of the sustainability of the species' fisheries and the management of its population (Srihari *et*

al., 2018). In this study, the b values estimated from the LWR fell within the typical range of 2.5 to 3.5 for teleosts (Froese, 2006). The results indicated positive growth ($b > 3$) in the two sexes, indicating that the pike perch increases more in weight than in length, for both males and females. Similarly, positive allometry has been reported for this species in both sexes by M'Hetli *et al.* (2011) in three Tunisian reservoirs, by Perez-Bote and Roso (2012) in the Alcántara Reservoir in Spain, by Bouamra *et al.* (2017) in the Ghrib Reservoir in Algeria, and by Koca and Küçükköse (2023) in Eğirdir and Beyşehir Lakes in Turkey.

Determining the condition factor typically relies on the length-weight relationship, under the principle that fish of a given length are in better condition if they weigh more. The Fulton's condition factor is an effective indicator of the overall health or 'fitness' of the population being considered (Bolger and Connolly, 1989). In general, a high K_R value suggests that the fish exhibit relatively good physiological status (Hossain *et al.*, 2017). Variations in K_R from 1 offer detailed insights into changes in food supply and the impact of water's physicochemical properties on fish life cycles, as well as their relationship with intrinsic fish characteristics (Le Cren, 1951; Jisr *et al.*, 2018). The K_R value in our study exceeded 1 for both sexes, indicating a healthy state (Froese, 2006), which could be related to food availability and habitat quality (i.e. the physiochemical properties of habitat). Indeed, *S. lucioperca* in Al Massira Reservoir feeds on a diverse range of prey fish (Bousseba *et al.*, 2020a; Bousseba *et al.*, 2020b; Bousseba *et al.*,

2024), suggesting a varied diet that supports good health. Although we did not evaluate abiotic factors at this site, the high K_R values observed could be linked to the rich availability of prey and the suitable habitat conditions in this Lake.

The study of meristic variables of pike perch specimens from the Al Massira Reservoir showed that these variables are not influenced by sex. The previous results of Krpo-Ćetković and Stamenković (1996) from the Yugoslav part of the Danube, of Turki *et al.* (2009) in the Nebhana Reservoir (Tunisia), and those of Akbarzadeh *et al.* (2009) in the southern Caspian Sea (Iran) perfectly demonstrate this. Added to these works is that of Poulet (2004), which shows that none of these variables significantly discriminate between pike perch samples, sexes, or even age classes. This is not the case for morphometric variables, which is probably why several other studies indicate that meristic variables are relatively ineffective in detecting variability (Meng and Stocker, 1984; Hurlbut and Clay, 1998; Poulet *et al.*, 2004; Akbarzadeh *et al.*, 2009).

The analysis of morphometric traits reveals marked variability between the sexes. Males exhibit significantly higher averages for several measurements: maximum height (H), minimum height (h), ventral fin length (LV), and pectoral fin length (LP). Additionally, they are distinguished by a greater distance between the snout and the second dorsal fin (SD2), as well as a greater distance between the pectoral fin and the anal fin (PA). It is therefore clear that males have a greater body depth, and These differences indicate that there are significant variations in maneuverability

between the sexes during foraging (Webb, 1984).

The findings of this study clearly reveal the presence of sexual dimorphism in fin length in *S. lucioperca*. Males possess longer pectoral and pelvic fins compared to females. Similar observations were reported by Turki *et al.* (2009) in the Nebhana Reservoir in Tunisia. This difference in length could be related to the males' reproductive behaviors. Indeed, males of *S. lucioperca* use their pectoral fins to defend the nest and aerate the eggs (Simon, 2015). Additionally, in other fish species, females often prefer males with longer fins (Basolo, 1990; Karino *et al.*, 2011), which might also be the case for pike perch. Rival males use fin extension during male-male competitions, indicating that fin length has a role in sexual selection (Mieno and Karino, 2017). Therefore, further studies would be valuable to uncover the role of longer fins in male sexual selection in *S. lucioperca*.

Morphometric characters result from the combined interaction between genotype and environmental factors and are influenced by natural selection (Dobzhansky, 1970). Certain biological factors, such as sexual behavior, body coloration patterns, spawning periods, and external morphology, can also drive changes in morphological characteristics over time (Lythgoe and Lythgoe, 1992; Dulčić *et al.*, 2000; Golani *et al.*, 2006).

In conclusion, this study describes sexual dimorphism based on morphological characteristics for the first time in *S. lucioperca*. Our results clearly indicate an intra-specific morphological variation favoring males. Sexual dimorphism could

be the result of ecological and behavioral variations. Future research should therefore focus on understanding these differences to elucidate the observed sexual dimorphism by supporting morphometric studies with genetic studies, to further develop population management and species conservation strategies for pike perch population in Al Massira Dam Lake.

Conflicts of interest

It is hereby declared that the authors declare no conflict of interest.

References

- Akbarzadeh, A., Farahmand, H., Shabani, A.A., Karami, M., Kaboli, M., Abbasi, K. and Rafiee, G.R., 2009. Morphological variation of the pikeperch *Sander lucioperca* (L.) in the southern Caspian Sea, using a truss system. *Journal of Applied Ichthyology*, 25, 576–582. DOI:10.1111/j.1439-0426.2009.01308.x
- Alaoui, L., Agoumi, A., Moncef, M. and Mokhliss, K., 2000. Etude du régime thermique de la retenue Al Massira (Maroc). *Hydroécologie Appliquée*, 12, 183–206.
- Azrita, A., Syandri, H. and Aryani, N., 2024. Length and Weight Relationship, Condition Factor, and Morphometric Characteristics of Eleven Freshwater Fish Species in Koto Panjang Reservoir, Indonesia. *International Journal of Zoology*, 2024, 9927705. DOI:10.1155/2024/9927705
- Basolo, A.L., 1990. Female preference for male sword length in the green swordtail (*Xiphophorus helleri*). *Animal Behaviour*, 39, 332–338. DOI:10.1016/S0003-3472(05)809285
- Berns, C.M., 2013. The evolution of sexual dimorphism: Understanding mechanisms of sexual shape differences. In: Moriyama,

- H. (ed.) Sexual Dimorphism. InTech, Rijeka, Croatia. pp.1- 16.
- Bolger, T. and Connolly, P.L., 1989.** The selection of suitable indices for the measurement and analysis of fish condition. *Journal of Fish Biology*, 34, 171–182. DOI:10.1111/j.1095-8649.1989.tb03300.x
- Bonnet, S., Haffray, P., Blanc, J.M., Vallee, F., Vauchez, C., Faure, A. and Fauconneau, B., 1999.** Genetic variation in growth parameters until commercial size in diploid and triploid freshwater rainbow trout (*Oncorhynchus mykiss*) and seawater brown trout (*Salmo trutta*). *Aquaculture*, 173, 359–375. DOI:10.1016/S0044-8486(98)00460-8
- Bouamra, A., Belaifa, B., Chaoui, L., Kara, M.H. and Arab, A., 2017.** Age and growth of pike perch *Sander lucioperca* (Percidae) in the Ghrib reservoir (Northwest Algeria). *Revue d'Écologie*, 72, 83–93.
- Bousseba, M., Ferraj, L., Ouahb, S., Ouizgane, A., El Moujtahid, A., Droussi, M. and Hasnaoui, M., 2020a.** Food preferences of pike perch, *Sander lucioperca* (Linnaeus, 1758) in Morocco. *E3S Web of Conferences*, 150, 02011. DOI:10.1051/e3sconf/202015002011
- Bousseba, M., Ouahb, S., Ferraj, L., El Moujtahid, A., Ouizgane, A., Droussi, M. and Hasnaoui, M., 2020b.** Preliminary study of the stomach contents of pikeperch (*Sander lucioperca* (Linnaeus, 1758)) in Moroccan freshwaters. *Proceedings of the 4th edition of International Conference on Geo-IT and Water Resources 2020*, Geo-IT and Water Resources 2020. Association for Computing Machinery, New York, USA.
- Bousseba, M., Ouahb, S., Ferraj, L., Droussi, M. and Hasnaoui, M., 2024.** Diet and feeding ecology of the pike perch (*Sander lucioperca*), an invasive fish species: seasonal diet shifts. *Environmental Biology of Fishes*, 107, 971–982. DOI:10.1007/s10641-024-01599-y
- Bousseba, M., Ferraj, L., Ouahb, S., Droussi, M. and Hasnaoui, M., 2025.** Quantitative Fishery Assessment of Data-Limited *Sander lucioperca*: Tools for Fisheries Management and Conservation. *Turkish Journal of Fisheries and Aquatic Sciences*, 25, TRJFAS26223. DOI:10.4194/TRJFAS26223
- Coad, B.W., 2016.** Review of the perches of Iran (Family Percidae). *International Journal of Aquatic Biology*, 4, 143–170.
- Dobzhansky, T., 1970.** *Genetics of the Evolutionary Process*. Columbia University Press, New York, USA. 505 P.
- Dulčić, J., Kraljević, M., Grbec, B. and Cetinić, P., 2000.** Age, growth and mortality of blotched picarel *Spicara maena* L. (Pisces: Centranchidae) in the eastern central Adriatic. *Fisheries Research*, 48, 69–78. DOI:10.1016/S0165-7836(00)00112-0
- Ergüden, S.A., 2021.** Length-weight relationships and condition factor of *Garra turcica* Karaman, 1971 from Asi River Basin, Turkey. *Natural and Engineering Sciences*, 6, 102–111. DOI:10.28978/nesciences.970548
- Fontaine, P., Gardeur, J.N., Kestemont, P. and Georges, A., 1997.** Influence of feeding level on growth, intraspecific weight variability and sexual growth dimorphism of Eurasian perch, *Perca fluviatilis* L., reared in a recirculation system. *Aquaculture*, 157, 1–9. DOI:10.1016/S0044-8486(97)00092-6
- Froese, R., 2006.** Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. *Journal of Applied Ichthyology*, 22, 241–253. DOI:10.1111/j.1439-0426.2006.00805.x

- Fulton, T.W., 1904.** The rate of growth of fishes. *Twenty-Second Annual Report*, 3: 41-241.
- Gago, J., Neves, A., Gkenas, C., Ribeiro, D. and Ribeiro, F., 2021.** Condition and size of the non-native pikeperch *Sander lucioperca* (Linnaeus, 1758) in Portuguese river basins. *Ecology and Evolution*, 11, 5065–5074. DOI:10.1002/ece3.7394
- Golani, D., Öztürk, B. and Başusta, N., 2006.** Centranchidae. In: Golani, D., Öztürk, B. and Başusta, N. (eds) Fishes of the Eastern Mediterranean. Turkish Marine Research Foundation, Istanbul, Turkey. pp. 168–169.
- Goubier, J., 1975.** Biogeography, biometrics, and biology of *Sander lucioperca* (L.), Osteichthyes, Percidae (PhD Thesis, Claude Bernard University, Lyon, France) (in French).
- Hollebecq, M.G. and Haffray, P., 1994.** L'amélioration génétique de la carpe commune *Cyprinus carpio* L.: état des connaissances. *Bulletin Français de la Pêche et de la Pisciculture*, 333, 93–124.
- Hossain, M.Y., Hossen, M.A., Khatun, D., Nawar, F., Parvin, M.F., Rahman, O. and Hossain, M.A., 2017.** Growth, condition, maturity and mortality of the Gangetic leaf fish *Nandus nandus* (Hamilton, 1822) in the Ganges River (Northwestern Bangladesh). *Jordan Journal of Biological Sciences*, 10, 57–62.
- Hurlbut, T. and Clay, D., 1998.** Morphometric and meristic differences between shallow- and deep-water populations of white hake (*Urophycis tenuis*) in the southern Gulf of St. Lawrence. *Canadian Journal of Fisheries and Aquatic Sciences*, 55, 2274–2282. DOI:10.1139/f98-110
- Ibănescu, D. C., Popescu, A. and Nica, A., 2019.** Growth and mortality estimation parameters for the pikeperch (*Sander lucioperca*, Linnaeus, 1758) population in the Romanian section of the Danube River. *Scientific Papers: Series D, Animal Science*, 62, 451–455.
- Jisr, N., Younes, G., Sukhn, C. and El-Dakdouki, M.H., 2018.** Length-weight relationships and relative condition factor of fish inhabiting the marine area of the Eastern Mediterranean city, Tripoli-Lebanon. *Egyptian Journal of Aquatic Research*, 44, 299–305. DOI:10.1016/J.EJAR.2018.11.004
- Karadurmuş, U., Ustaoglu, D. and Aydın, M., 2022.** Sex inversion, sexual dimorphism, and morphological differences of *Spicara flexuosa* (Sparidae). *Journal of Ichthyology*, 62, 777–785. DOI:10.1134/S0032945222050058
- Karino, K., Ishiwatari, T., Kudo, H. and Sato, A., 2011.** Female mate preference for a costly ornament in male guppies. *Behavioral Ecology and Sociobiology*, 65, 1305–1315. DOI:10.1007/s00265-011-1144-z
- Kim, Y.J., Zhang, C.I., Park, I.S., Na, J.H. and Olin, P., 2008.** Sexual dimorphism in morphometric characteristics of Korean chub *Zacco koreanus* (Pisces, Cyprinidae). *Journal of Ecology and Field Biology*, 31, 107–113. DOI:10.5141/JEFB.2008.31.2.107
- Koca, H.U. and Küçükköse, A.G., 2023.** Otolith biometry of pikeperch *Sander lucioperca* from the Lakes Region of Turkey. *Inland Water Biology*, 16, 193–197. DOI:10.1134/S1995082923020116
- Krpo-Četković, J. and Stamenković, S., 1996.** Morphological differentiation of the pikeperch *Stizostedion lucioperca* (L.) populations from the Yugoslav part of the Danube. *Annales Zoologici Fennici*, 33, 711–723.
- Lahnsteiner, F. and Jagsch, A., 2005.** Change in phenotype and genotype of Austrian *Salmo trutta* populations during the last century. *Environmental Biology of*

- Fishes*, 74, 51–65. DOI:10.1007/s10641-005-4420-9
- Le Cren, E.D., 1951.** The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *Journal of Animal Ecology*, 20, 201. DOI:10.2307/1540
- Li, X. and Kokko, H., 2021.** Sexual dimorphism driven by intersexual resource competition: Why is it rare, and where to look for it? *Journal of Animal Ecology*, 90, 1831–1843. DOI:10.1111/1365-2656.13487
- Lozan, J.L., 1992.** Sexual differences in food intake, digestive tract size and growth performances in dab (*Limanda limanda*). *Netherlands Journal of Sea Research*, 29, 223–227. DOI:10.1016/0077-7579(92)90022-7
- Lythgoe, J. and Lythgoe, G., 1992.** *Fishes of the Sea: The North Atlantic and Mediterranean*. The MIT Press, pp. 123–124.
- Martinez, C.M., Kao, B.H., Sparks, J.S. and Wainwright, P.C., 2019.** Pectoral dimorphism is a pervasive feature of skate diversity and offers insight into their evolution. *Integrative Organismal Biology*, 1, 1–14. DOI:10.1093/iob/obz012
- Meng, H.J. and Stocker, M., 1984.** An evaluation of morphometrics and meristics for stock separation of Pacific herring (*Clupea harengus pallasii*). *Canadian Journal of Fisheries and Aquatic Sciences*, 41, 414–422. DOI:10.1139/f84-049
- M'Hetli, M., Ben Khemis, I., Hamza, N., Turki, B. and Turki, O., 2011.** Allometric growth and reproductive biology traits of pikeperch *Sander lucioperca* at the southern edge of its range. *Journal of Fish Biology*, 78, 567–579. DOI:10.1111/j.1095-8649.2010.02878.x
- Mieno, A. and Karino, K., 2017.** Sexual dimorphism and dichromatism in the cyprinid fish *Puntius tittैया*. *Ichthyological Research*, 64, 250–255. DOI:10.1007/s10228-016-0559-y
- Mouslih, M., 1987.** Introduction de poissons et d'écrevisses au Maroc. *Revue d'Hydrobiologie Tropicale*, 20, 65–72.
- Narzary, B. and Khangembam, B.K., 2022.** A study on the length-weight relationship and condition factor of five small indigenous fish species of Sareswar Beel in lower Assam, Northeast India. *Iranian Journal of Ichthyology*, 9, 204–212. DOI:10.22034/iji.v9i4.929
- Nikolić, D., Poleksić, V., Tasić, A., Smederevac-Lalić, M., Djikanović, V. and Rašković, B., 2023.** Two age groups of adult pikeperch (*Sander lucioperca*) as bioindicators of aquatic pollution. *Sustainability*, 15, 11321. DOI:10.3390/su151411321
- Parés-Casanova, P. M. and Cano, L., 2014.** Geometric morphometric assessment of shape sexual dimorphism in pikeperch (*Sander lucioperca*). *Global Journal of Biology, Agriculture and Health Science*, 3, 148–152.
- Pauly, D., 1984.** *Fish population dynamics in tropical waters: a manual for use with programmable calculators*. *ICLARM Studies and Reviews*, 8, 1–325.
- Pérez-Bote, J.L. and Roso, R., 2012.** Growth and length-weight relationships of *Sander lucioperca* (Linnaeus, 1758) in the Alcántara Reservoir, South-Western Spain: comparison with other water bodies in Eurasia. *Journal of Applied Ichthyology*, 28, 264–268. DOI:10.1111/j.1439-0426.2011.01918.x
- Poulet, N., 2004.** Le sandre (*Sander lucioperca* (L.)): biologie, comportement et dynamique des populations en Camargue (Bouches du Rhône, France) (PhD Thesis, University of Toulouse III, France) (in French).

- Poulet, N., Berrebi, P., Crivelli, A.J., Lek, S. and Argillier, C., 2004.** Genetic and morphometric variations in the pikeperch (*Sander lucioperca* L.) of a fragmented delta. *Archiv für Hydrobiologie*, 159, 531–554. DOI:10.1127/0003-9136/2004/0159-0531
- Ribeiro, D., Gkenas, C., Gago, J. and Ribeiro, F., 2021.** Variation in diet patterns of the invasive top predator *Sander lucioperca* (Linnaeus, 1758) across Portuguese basins. *Water*, 13, 2053. DOI:10.3390/w13152053
- Simon, C., 2015.** Effect of maturation diets on the reproductive quality of pikeperch, *Sander lucioperca* (Linnaeus, 1758). MSc Thesis, Faculty of Bioscience Engineering, University Gent, Ghent, Belgium.
- Sonowal, N., Nayak, N., Dohutia, S., Borah, R. and Biswas, S.P., 2019.** Length-Weight Relationship of Fingerlings of *Channa stewartii* (Family: Channidae) Reared under Captive Condition. *Journal of Bioresources*, 6, 80–84.
- Srihari, M., Sreekanth, G.B. and Jaiswar, A.K., 2018.** Length–weight relationship of seven finfish species from Mandovi-Zuari estuarine system, Goa, India. *Journal of Applied Ichthyology*, 34, 1384–1386. DOI:10.1111/jai.13816
- Toguyeni, A., Fauconneau, B., Boujard, T., Fostier, A., Kuhn, E.R., Mol, K.A. and Baroiller, J.F., 1997.** Feeding behaviour and food utilisation in tilapia, *Oreochromis niloticus*: effect of sex ratio and relationship with the endocrine status. *Physiology & Behavior*, 62, 273–279.
- Turki, O., M’Hetli, M., Chriki, A. and Kraïem, M.M., 2009.** Caractérisation et variation phénotypique et biologique des deux sexes du Sandre *Sander lucioperca* (L. 1758) (téléostéen, percidés) dans la retenue de barrage de Nebhana (Tunisie centrale). *Bulletin de l’Institut National des Sciences et Technologies de la Mer Salammbô*, 36, 75–85. DOI:10.71754/instm.bulletin.v36.622
- Webb, W.W., 1984.** Form and function in fish swimming. *Scientific American*, 251, 72–83.
- Zajitschek, S.R., Zajitschek, F., Bonduriansky, R., Brooks, R.C., Cornwell, W., Falster, D.S., Lagisz, M., Mason, J., Senior, A.M., Noble, D.W., Nakagawa, S., 2020.** Sex dimorphism in trait variability and its eco-evolutionary and statistical implications. *eLife*, 9, e63170. DOI:10.7554/eLife.63170