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DORSAL AND PELVIC FIN DEFORMITIES IN *EGIRDIRA NIGRA* (TELEOSTEI, LEUCISCIDAE), AN ENDANGERED AND ENDEMIC SPECIES COLLECTED FROM EĞIRDIR LAKE, TÜRKIYE

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Dorsal and Pelvic Fin Deformities in *Egirdira nigra* (Teleostei, Leuciscidae), an Endangered and Endemic Species Collected from Eğirdir Lake, Türkiye. Jawad, L. A., Güçlü, S. S., Küçük, F. & Yıldırım, U. G. — Abnormal specimens of *Egirdira nigra* (Kosswig & Geldiay, 1952) were gathered from Eğirdir Lake, Akkeçili Village, Türkiye, during standard ichthyological investigations in the area from May–September 2021. These specimens exhibited irregularities in the dorsal and pelvic fin. The abnormalities noted in these fins encompass the complete absence of the fin and various degrees of distortions in the fin's components. The X-ray images revealed skeletal deformities are deliberated. Our findings underscored the necessity for enhanced monitoring of the freshwater environment and pinpointing the precise factor responsible for these irregularities.
Key words: Anatolia, fin anomaly, abnormality, freshwater environment, water temperature.

Introduction

Egirdira nigra (Kosswig & Geldiay, 1952), a species endemic to Eğirdir Lake and its basin in Central Anatolia, has undergone taxonomic revisions over the years. Initially described as *Pararhodeus niger* by Kosswig and Geldiay in 1952, it was later reclassified as *Phoxinellus egridiri* by Karaman (1972). The most recent taxonomic study, conducted by Freyhof (2022), redefined the species as *Egirdira nigra*.

While the population of *E. nigra* in lake remains substantial and stable, populations in tributaries exhibit smaller sizes and are in decline. Observations over the past two decades have noted an increase in the lake's population, coinciding with a rise in carnivorous species, as reported by Güçlü & Küçük (2017). However, recent field studies, particularly those conducted within the last five years, reveal concerning changes in the species' habitat and environment conditions, suggesting a potential threat to its survival. Factors such as climate change, drought, habitat loss, pollution, and increased predation risk, as highlighted by Küçük et al. in 2021, pose significant risks to the species' long-term viability.

Anomalies in fish morphology have garnered attention since Dawson's seminal work on the subject in the mid-20th century (Dawson, 1964, 1971; Tutman et al., 2000; Al-Mamry et al., 2010; Manizadeh et al. 2018; Jawad & Al-Mamry, 2011, 2012; Näslund & Jawad, 2021). These anomalies, encompassing various aspects of fish anatomy, serve as indicators of environmental health, particularly in polluted ecosystems (Bengtsson, 1979). While abnormalities have been observed in both wild and hatchery-reared populations, they appear more frequently in controlled environments due to survival pressures (Houde, 1971; Komada, 1980; Verhaegen et al., 2007).

Despite limited research on fish abnormalities in Türkiye, notable cases have been reported in various species. Notably, Bayhan (2010) documented a caudal fin deformity in *Chelon ramada* from Izmir Bay, while Jawad et al. (2018) reported anomalies in *Conger conger* and Jawad et al. (2022) reported on some incidences of pectoral and pelvic fin anomalies observed in the freshwater blenny *Salaria fluviatilis* from the Aegean Sea and Kızılırmak River.

This study presents the first documented cases of dorsal and pelvic fin anomalies in *Egirdira nigra* (Kosswig & Geldiay, 1952) collected from Eğirdir Lake, Akkeçili Village, Türkiye.

Materials and methods

Studied area

Akkeçili station, where fish samples are caught, is located northwest of the Hoyran of Lake Eğirdir (fig. 1). The depth of the sampling area is around 4–5 m. However, due to the decrease in water level in recent years, the entire lake has turned into a littoral zone and the lake floor is covered with a very dense macrophyte cover. Due to the decrease in the water level in the lake and the increase in vegetative production, the pelagic zone of the system has narrowed considerably. The macro-benthic fauna of Lake Eğirdir is rich in qualitative and quantitative terms due to high dissolved oxygen, soft sediment and intense macrophyte development.

Material

Specimens were collected in March 2021 and April 2022 from the Eğirdir Lake-Akkeçili Village location (Türkiye) (38°08′27.28″ N 30°47′40.49″ E) (fig. 1). Fish samples were caught using multi-mesh gillnets (35 x1.5 m and 35 x 6 m in size, 10, 15, 20, 40, 55-, 70-, 80- and 100-mm mesh size) according to modified TS EN 14757 and beach seine net (5- and 15-mm mesh size). Eighty-one fish specimens of different sizes were collected. There were 13 abnormal individuals in the total catch. The deformed specimens were collected in May–September 2021. Fish were collected for faunal surveys, preserved in 5 % formaldehyde or 96 % ethanol, and stored in 70 % ethanol after anesthesia using tricaine methane sulfonate.

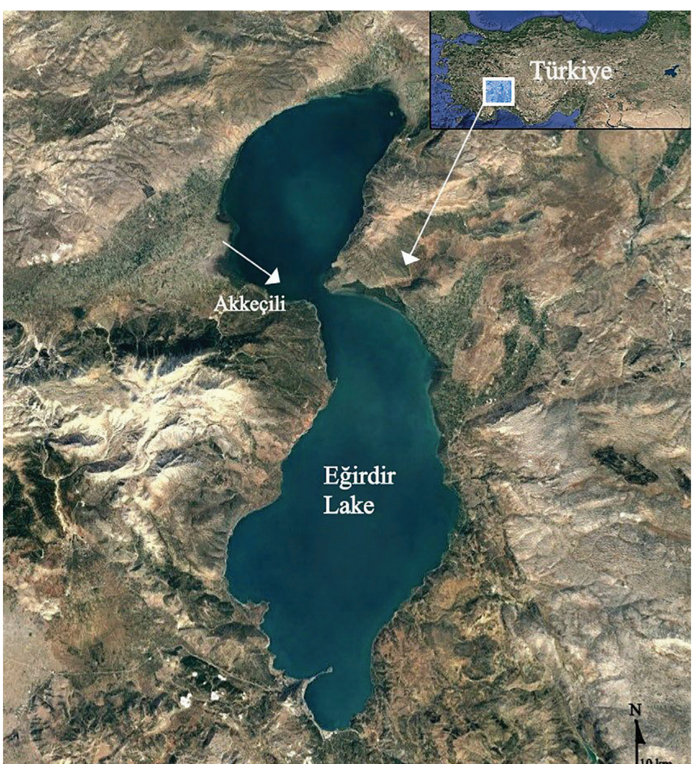

Fig. 1. Map showing the location of fish sampling.

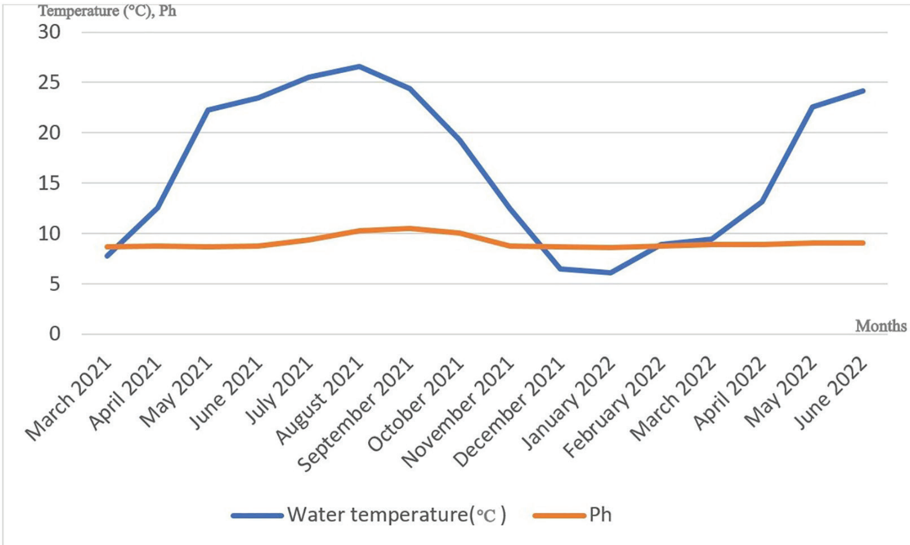

Fig. 2. Annual change of pH and water temperature (°C) values measured at the sampling point in Lake Eğirdir.

Methods

The skeletons of the abnormal specimens were examined using a mammography unit (Siemens/Mammomat Inspiration 2013) at an exposure time of 2.1 seconds available at Med-dem Hospital, Department of Radiology, Mammography Section, Isparta, Türkiye. The care of experimental animals was consistent with the Republic of Türkiye's animal welfare laws, guidelines and policies approved by the Isparta University of Applied Sciences Local Ethics Committee for Animal Experiments (Permit reference number 2020/01). Surgical procedures were only performed for the excision of fin clips. Measurements were recorded to the nearest millimeter using a digital caliper. The body and fins were examined carefully for malformations, amputations, and other morphological deformities. Water quality variables (temperature, pH) were determined in the field using a YSI Pro Plus brand portable measuring device (fig. 2).

Results

Dorsal fin deformity

A normal specimen of *E. nigra* (83.21 mm SL) typically exhibits an average of three spines and seven soft rays in the dorsal fin (fig. 3). Abnormal specimens displayed two primary types of anomalies: complete absence of the dorsal fin and varying degrees of deformities of this fin.

Externally, the complete absence of the dorsal includes the absence of all dorsal fin components (spines and soft rays) (89.79 mm SL (upper specimen), 81.09 mm SL (middle specimen), 79.73 mm SL (lower specimen)) (fig. 4, A). X-ray images of specimens with this anomaly reveal the presence of several pterygiophores supporting the dorsal fin elements (spines and soft rays) (fig. 4, B).

Fig. 3. Normal specimen of *Egirdira nigra*, 83.21 mm SL, male (+3 age).

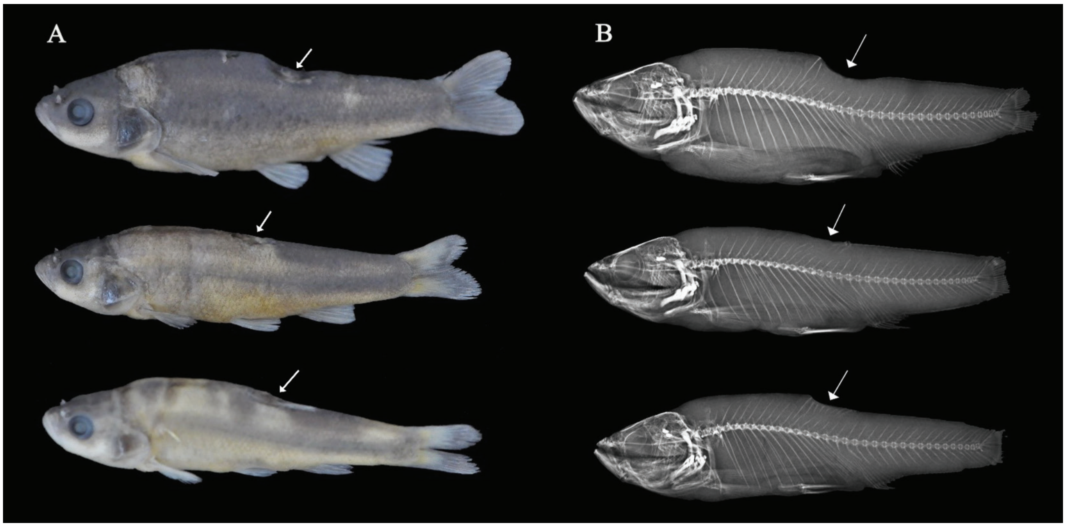

Fig. 4. Abnormal specimen of *Egirdira nigra* taken from views side. A — external view of the absence of the dorsalfin, 89.79 mm SL-female (+4 age), 81.09 mm SL-male (+3 age), 79.73 mm SL-male (+3 age); B — X-ray of the abnormal specimen showing the absence of the dorsal fin.

Deformities in the dorsal fin elements (spines and soft rays) were observed in various specimens (88.04. mm SL (upper specimen), 85.71 mm SL (upper middle specimen), 80.43 mm SL (lower middle specimen), 73.89 mm SL (lower specimen)) (fig. 5, A). X-ray images show deformed dorsal fins with varying numbers of dorsal fin elements and associated pterygiophores (fig. 5, B).

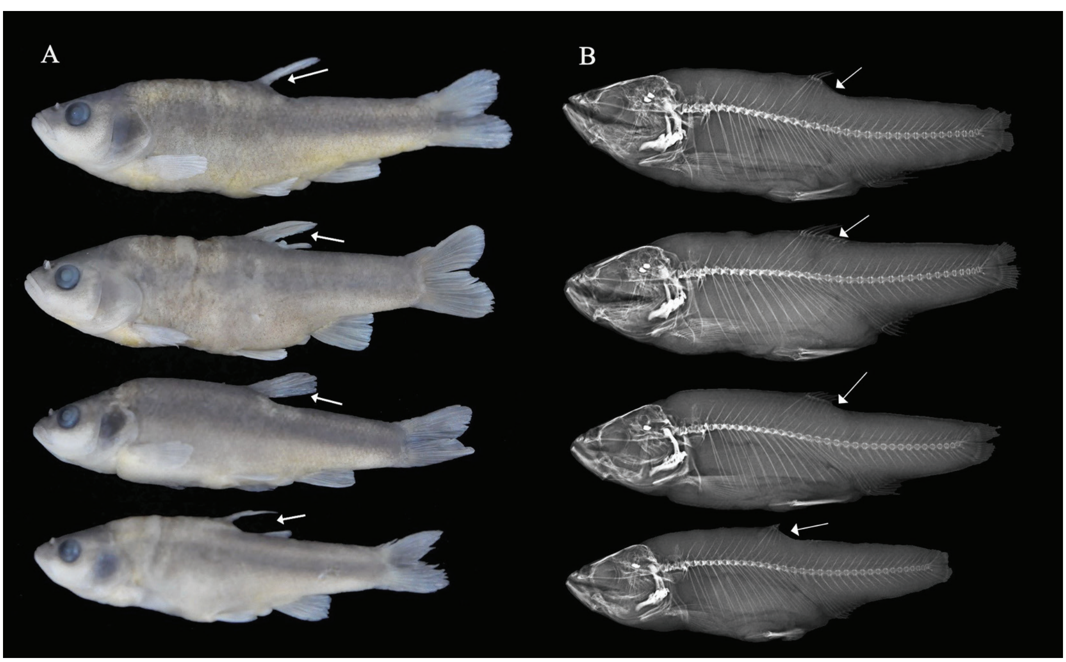

Fig. 5. Four specimens of *Egirdira nigra* show different levels of the dorsal fin elements. A — external view, 88.04. mm SL-female (+4 age), 85.71 mm SL-female (+4 age), 80.43 mm SL-male (+3 age), 73.89 mm SL-male (+2 age); B — X-ray of the four abnormal specimens with a deformed dorsal fin.

Pelvic fin abnormality

The average number of pelvic fin elements consists of one spine and seven soft rays. Pelvic anomalies in *E. nigra* encompasses complete absence of the pelvic fin (either left or right pelvic fin) (99.71 mm SL (upper and middle specimens) (figs 6, A, B) and varying degrees of deformation in pelvic fin elements (spines and soft rays) (either left or right pelvic fin) (76.77 mm SL) (figs 7, A, B).

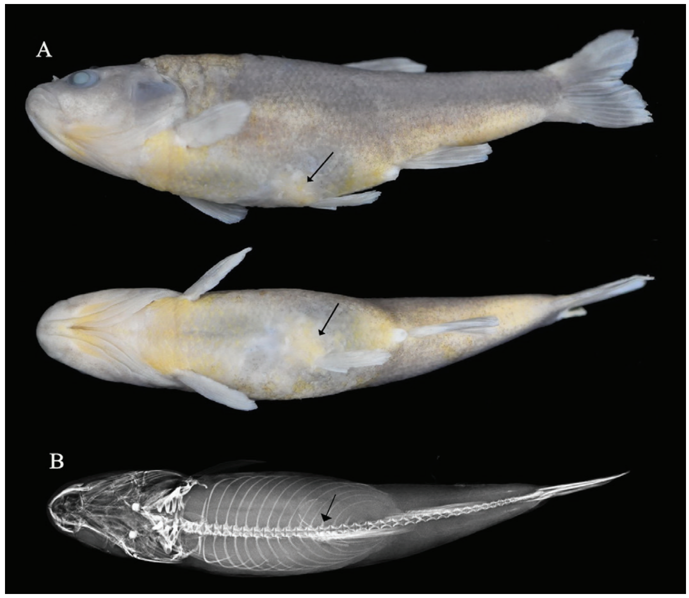

Fig. 6. Abnormal specimens of *Egirdira nigra* show a complete absence of the left pelvic fin. A — lateral-ventral view, 99.71 mm SL-female (+5 age); B — X-ray of the abnormal specimen lacking left pelvic fins.

External examination reveals normal scale covering in the area where the bases of pelvic fins should be present, indicating underdeveloped of these structures. Meristic counts of abnormal specimens fall within the range of the normal specimens, and despite pelvic fin absence, other characteristics remain like normal specimens, with no significant impact on average growth (figs 6, B; 7, B). The shadows of the pelvic fins and the basipterygia were distinct in the normal specimen (fig. 3, B). In contrast, no trace of the pelvic girdle and the total absence of the basipterygia were evident in the deformed specimen (figs 6, B; 7, B).

The specimens (79.42 mm SL) with a deformed left pelvic fin showed an abnormality in the five inner soft rays (figs 8, A, B, C), and another specimen (75.46 mm SL) showed a deformation of the whole soft rays (figs 9, A, B). A similar anomaly was noticed in the right pelvic fin, where the inner soft rays are shown as severely deformed (74.26 mm SL) (figs 10, A, B). Another specimen (80.94 mm SL) showed a deformity in the right pelvic fin. In this specimen, the soft middle rays were lost (figs 11, A, B, C, D).

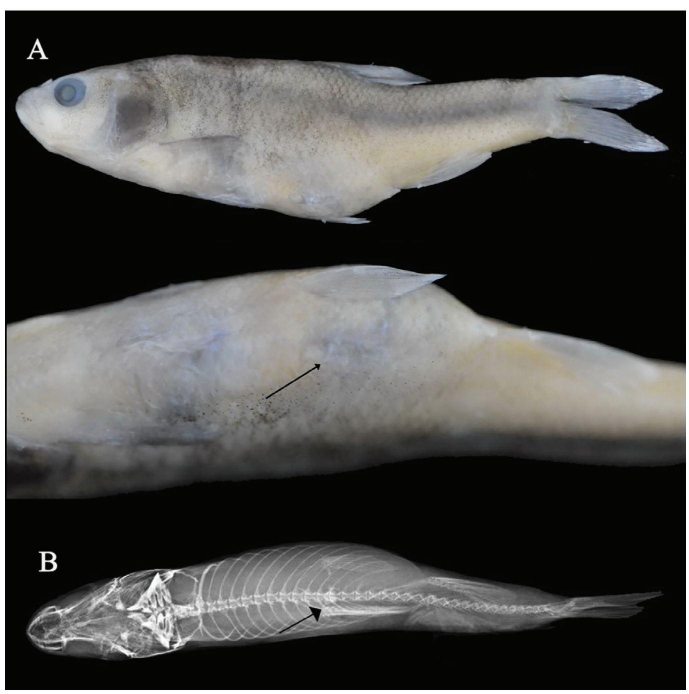

Fig. 7. Abnormal specimens of *Egirdira nigra* show a complete absence of the right pelvic fin. A — lateral-ventral view, 76.77 mm SL-male (+2 age); B — X-ray of the abnormal specimen lacking right pelvic fins.

The annual variation in water temperature in Eğirdir Lake ranges between 6.1°C in winter and 26.6 °C in summer.

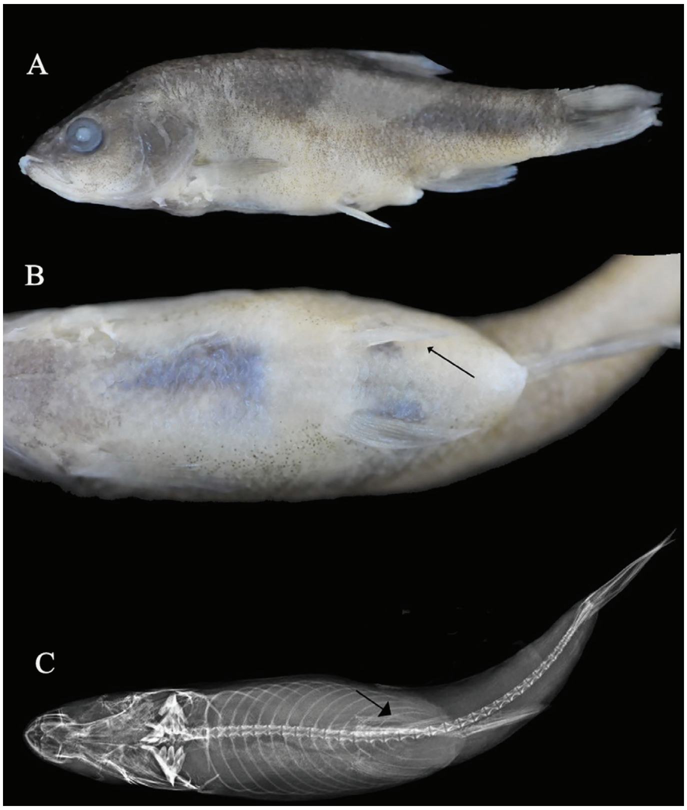

Fig. 8. Abnormal specimens of *Egirdira nigra* show deformation in the left pelvic fin. A — lateral view, 79.42 mm SL-female (+3 age); B — a ventral view; C — an X-ray of the abnormal specimen with a deformed left pelvic fin.

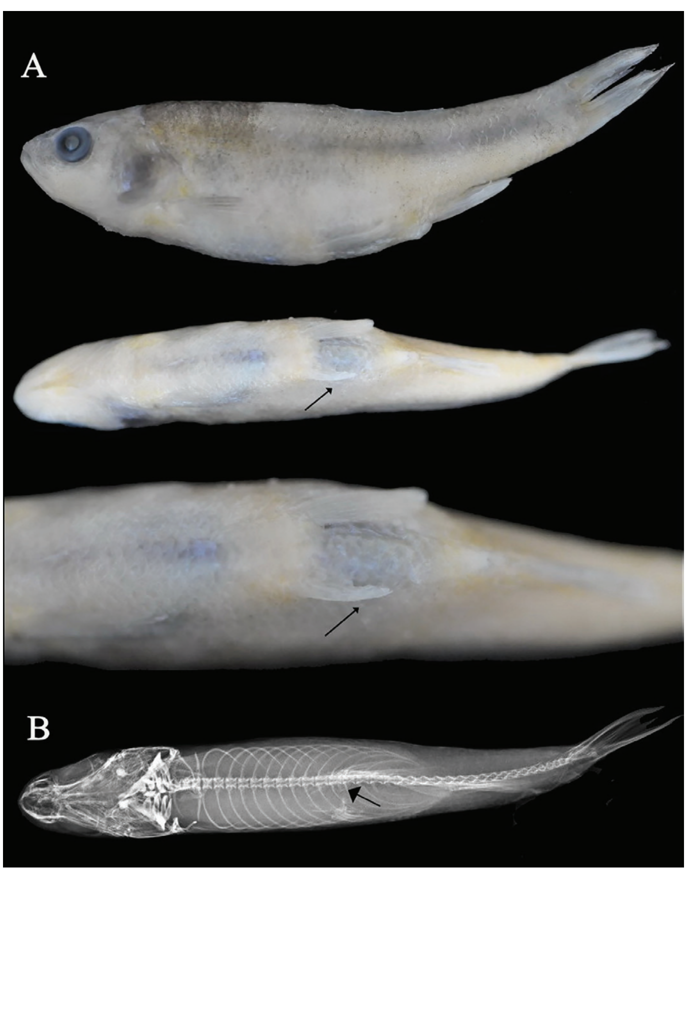

Fig. 9. Abnormal specimens of *Egirdira nigra* show deformation in the right pelvic fin. A — lateral and ventral views, 75.46 mm SL-male (+2 age); B — X-ray of the abnormal specimen, with a deformed right pelvic fin.

Fig. 10. Abnormal specimens of *Egirdira nigra* show deformation in the right pelvic fin. A — different view, 74.26 mm SL-male (+2 age); B — X-ray of the abnormal specimen, with a deformed right pelvic fin.

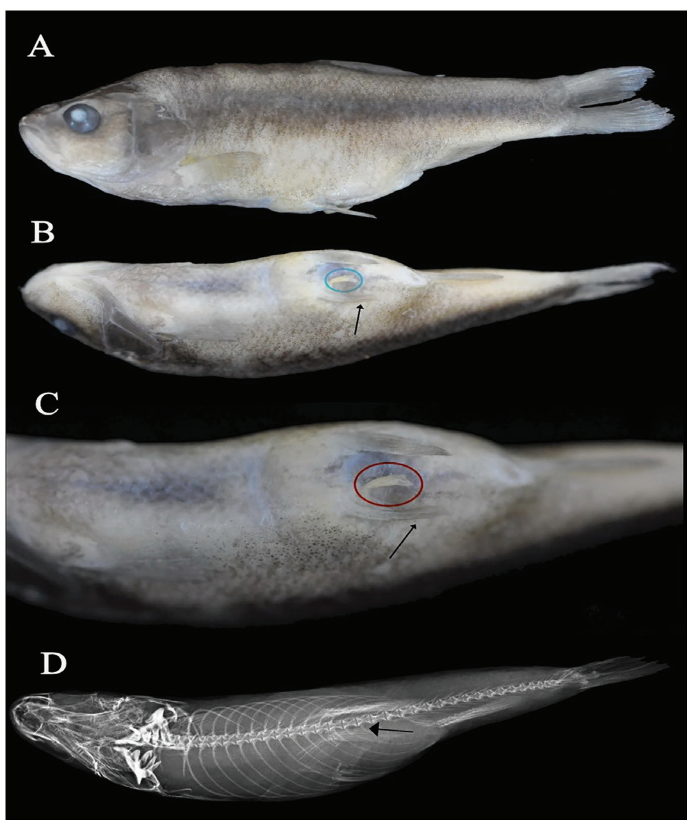

Fig. 11. Abnormal specimens of *Egirdira nigra* show deformity in the right pelvic fin. In this specimen, the soft middle rays were lost. A — lateral view, 80.94 mm SL-female (+3 age); B — a ventral view, (red/blue round external *Lernaea cyprinacea* parasite); C — a close-up ventral view, (red/blue round external *Lernaea cyprinacea* parasite); D — an X-ray of the abnormal specimen with a deformed right pelvic fin.

Discussion

This study represents the first investigation into various skeletal anomalies of fins in adult wild teleosts fish species from Eğirdir Lake, Akkeçili Village, Türkiye. Of the normal-healthy *E. nigra* population, 42.25 % are male and 57.75 % are female (totally 68 samples). Of the individuals with anomalies, 53.84 % are male and 46.16 % are female (totally 13 samples).

Among the documented anomalies, those affecting the dorsal and pelvic fins are of particular interest due to their roles in fish locomotion and stability (Tandon, 1965). During swimming, the pelvic fins act as static trimming foils rather than dynamic moving structures (Tandon, 1965). Dawson (1964) has proposed that pelvic fins play a more complex role in swimming, such as moving vigorously against imposed hydrodynamic loads and producing powered correction forces during steady swimming. The dorsal fin, crucial for propulsion and maneuvering, is susceptible to deformities that can impair the fish's performance (Standen & Lauder, 2005) with the slightest conceivable expenditure of energy (Boglione et al., 1993). Similarly, pelvic fins, while traditionally considered static structures, may play a more complex role in swimming dynamics than previousely thought. Gudger (1930) was the first to report on abnormalities in fish when he defined the history of pughead deformity. Later, these anomalies were reported from reared and wild fish populations (Komada, 1980) and showed numerous features of the fish body such as body shape, jaws, operculum, scales, spinal column, or fins (Divanach et al., 1996). Cases of fusion, dysgenesis, different formation, displacement of the fin supporting elements (Koumoundouros et al., 2001) and curvature of the rays and spines (Daoulas et al., 1991) are reported for a wide range of fish species.

The dorsal fin anomaly can arise from the combination of genome, environment, and developmental noise (Scheiner, 1993). Diversities in the genetic pool can control variations in developmental patterns. Growth deviation is a factor which can theoretically persuade phenotype variations in genetically identical individuals developing in similar environments (Divanach et al., 1996). Therefore, Soulè (1982) argues that an expansion of the phenotypic variability is a characteristic of biological systems exposed to stress (like intensive rearing conditions) and that developmental noise discloses itself as a decrease of the intracellular order. The second factor is the environment, which involves the impacts employed by external conditions, such as biotic and abiotic conditions (Divanach et al., 1996).

Skeletal deformities in fish can arise during embryonic and postembryonic phases due to complex mechanisms (Koumoundouros et al., 1995; Cataudella et al., 1996). While biotic and abiotic factors may contribute to these anomalies, further research is required to ascertain the primary causes, as seen in the case of dorsal fin aberrations in *E. nigra*. Influences of an abiotic aspect, such as heavy metals, in creating fin anomalies were demonstrated by Sloof (1982). Photo and thermo-period induction of reproduction might give rise to a complete or partial absence of the fin. For example, the caudal complex (Koo & Johnston, 1978) and vitamin C deficiency have been linked with fin degeneration in fish. Deformities in paired fins have been reported in various fish species, often attributed to genetic variation, environmental factors, or pollutants. A complete absence of these fins was noted in the clupeid species *Brevoorita patronus* Goode, 1878, from the Gulf of Menhaden (Marichammy, 1970). The lack of pelvic fins was noted in *Trissina baelana* (Forsskål, 1775) by Hettier (1971), *Brevoorita smithi* Hildebrand, 1941 by Kroger & Guthrie (1973), Atlantic menhaden *B. tyranus* (Latrobe, 1802) by Radhakrishnan (1973), rainbow sardine *Dussumieria acuta* Valenciennes, 1847 by Babu (1975) and Baburao (1975), *Nematalosa nasus* (Bloch, 1795) by Hore & Ahmad (2010), *Cirrhinus mrigala* (Hamilton, 1822) by Jose et al. (2020) and in the cichlid species *Oreochromis niloticus* (Linnaeus, 1758) by Ugbomeh et al. (2022). Pelvic fin malformations are very complex regarding the degree and way the fins are malformed (Kaushik, 1960; Maxfield, 1958; Valladolid & Przybylski, 2000) and thus lead to the development of abnormal phenotypes. The abnormal specimens of *E. nigra* examined here revealed degeneration in the left or right of the pelvic fins. Despite the absence of the left or right pelvic fins in the specimens of *E. nigra* examined, all the other traits were analogous to those of the normal specimen, and it did not affect the average growth of the fish. Similar outcomes were found by Gangan et al. (2018), where deformities in specimens of *Setipinna phasa* (Hamilton 1822) and *S. taty* (Valenciennes 1848) were observed. The causes for such anomalies were allocated to the rare development of the muscle buds during the early development period (Gangan et al., 2018).

Currently, deformities in fish are prevalent, and the increasing human activities in aquatic habitats can explain this. Additional studies are required to investigate the reasons behind the case of pelvic fin absence in *E. nigra* examined in the present study. The abnormalities in the dorsal and pelvic fins detected in the specimen of this species can be considered because of the influences of many environmental and biological agents such as water temperature, vitamins, and trace elements factors (Sahashi, 2015). However, there is no indication in this study to support these effects. The other causative agent that could be the real reason behind such anomalies, as Shikano et al. (2005) and Yamamoto et al. (2013) proposed, is the absence of genetic variation in the fish population. These causes must be confirmed in further investigating this species collected from the waters of Eğirdir Lake. Pollutants can produce the aberrations in the skeletal system of the fish in two ways, either (1) by modification of the biological procedures essential for keeping the biochemical integrity of bone or (2) through neuromuscular impacts, which cause anomalies without a chemical change in vertebral composition (Raj et al., 2004).

Shapiro et al. (2004) found that genome-wide linkage mapping in three spine stickleback fish shows that pelvic reduction is controlled by one major and four minor chromosome regions. Pelvic-reduced fish show the same left–right asymmetry seen in Pitx1 knockout mice but do not show changes in the Pitx1 protein sequence. Instead, pelvic-reduced sticklebacks show site-specific regulatory changes in Pitx1 expression, with reduced or absent expression in pelvic and caudal fin precursors. Further data in the future on the genetics of the populations of *E. nigra* will provide similar information provided by Shapiro et al. (2004).

Environmental factors, such as water temperature, may influence fish in development. Based on experimental studies on *Solea senegalensis* Kaup, 1858, Dionísio et al. (2012) suggested that the influence of temperature on developmental plasticity will cause osteological anomalies in fishes. Their results demonstrated a remarkable effect of water temperature on the Senegalese sole's skeletal development during the egg's incubation. These findings highlight the significance of temperature variation during the early development of fish. The annual variation in water temperature from Eğirdir Lake, where the abnormal fish specimens were collected, ranges between 6.1 °C in winter and 26.6 °C in summer. Such wide ranges in water temperature could impact the morphological features of fish living in this environment during the spawning period and can increase pH values (fig. 2) affecting the growth of fish or developmental anomalies.

The deterioration of the paired fins in *E. nigra* may affect swimming performance and other biological activities. Further investigations are needed to elucidate the reasons behind these deformities and their potential impacts on fish survival. The pelvic fins are involved in the manipulation by fish (as well as body bending). The intricacy of relations among fins and the hydrodynamic roles of different fins in generating propulsive movements are not new and it is known more than 60 years ago (Aleev, 1963). From the recent analyses of turning and maneuvering in fish, fish actively use their pelvic fins as control surfaces during turning maneuvers (Lauder & Drucker, 2004). Therefore, any deformity in the structure of the paired fins will directly affect the swimming ability and the survival of the fish. Further studies are needed to find the actual reasons behind the deformity of the pelvic fins in *E. nigra*. On the other hand, the deformities in the dorsal fin will lead to a significant reduction of the body weight, indicating that such deformities not only affected the appearance, but also decreased growth performance (Yue et al., 2022). Moreover, the relatively weak fish larvae might benefit from a normal developed dorsal fin with its spines to avoid predation (Iwasaki et al., 2018).

The *E. nigra* population is declining. Loss of water in the lake due to drought has also led to habitat loss. As a result of intensive agricultural activities around the lake, on the shores of the lake, life in the lake is negatively affected. Rainwater and pesticides from agricultural areas mix directly with the lake. Waste from the cold stores around the lake flows at least partly into the lake. Sewage from the settlements around the lake is discharged into the lake because the water treatment plants are not working at full capacity.

In conclusion, the various deformities examined in this study reflect the degree of degradation of the environment in which the fish live. Urgent plans are therefore needed in the near future to reduce the levels of toxic substances that can cause the anomalies examined in this study, in order to give the fish a chance to recover morphologically.

Ethical approval and consent to participate

The care of experimental animals was consistent with Republic of Türkiye animal welfare laws, guidelines and policies approved by the Isparta University of Applied Sciences Local Ethics Committee for Animal Experiments (Permit reference number 2020/01).

Conflicts of interest

The authors declare that they have no conflict of interest. Funding No funding is used in performing this study.

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Data availability statement

There is no supporting data to make available.

Author contributions

Laith A. Jawad: Conceptualization; Investigation; Writing — original draft; Methodology; Validation; Visualization; Writing — review & editing; Formal analysis; Project administration; Data curation; Supervision.

Salim Serkan Güçlü: Conceptualization; Investigation; Methodology; Visualization; Validation; Data curation; Resources.

Fahrettin Küçük: Resources; Data curation; Investigation; Methodology.

Ufuk Gürkan Yıldırım: Investigation; Methodology; Resources.

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