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Investigation of asymmetry in some morphological characteristics of two freshwater fishes from Iraq

by

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Abstract

This research aims to investigate the levels of fluctuating asymmetry (FA) in six external morphological traits, along with four meristic traits in two commercially exploited fish species, *Cyprinus carpio* and *Leuciscus vorax*. Additionally, the data for this study were collected as part of a broader project on these two species. The bilateral symmetry index employed to measure this variation showed large departures, as confirmed by the results obtained. Of those considered traits, snout length (SnL) was the best predictor of FA in both *C. carpio* and *L. vorax*. The remaining nine traits had asymmetry indices of different signs, indicating a species-specific response to habitat degradation. Finally, the possible link between bilateral asymmetry and fish taxonomy was also investigated; however, future research is needed to assess this relationship.

Key words: morphological asymmetry, Iraq ichthyofauna, variation, *C. carpio, L. vorax*

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1. Introduction

Random morphological variation in bilaterally symmetric characteristics that is attributed to unfavorable conditions is denominated fluctuating asymmetry (FA) (Al-Hassan et al., 1990; Hermita et al., 2013; Palmer, 1994). High FA is related to low adaptability across species (Almeida et al., 2008; Gonçalves et al., 2002; Hermita et al., 2013; Van Valen, 1962). As an indicator of population fitness and health of the habitat, the use of FA for ecological and biocontrol studies is on the rise (Al-Hassan & Shawafi, 1997; Graham et al., 2010; Jawad, 2000, 2003, 2004, 2013; Jawad et al., 2016; Kristoffersen & Magoulas, 2009). The concept of bilateral asymmetry and specifically of FA can be of importance in fish taxonomy, because it can unveil the presence of cryptic species and hidden diversity when the use of some traditional approaches presents limitations, particularly in complex natural systems. This sort of characterization has been useful for taxonomic purposes in that it exposes differences that may not necessarily have been detected from the standard ones (e.g., see Graham et al., 2010; Palmer & Strobeck, 1986).

High FA has been associated with reduced productivity, growth, reproduction, and survival (Morris et al., 2012), but the latter varies among taxa (Jawad et al., 2001; Lens et al., 2002). Low FA is generally associated with traits in which there is strong directional selection (Gonçalves et al., 2002; Jawad et al., 2001), and different body shapes react to environmental stress in different ways (Ayoade et al., 2004; Graham et al., 1998; Jawad et al., 2012). Multi-trait assessments are preferred because they help to reduce such bias (Leary & Allendorf, 1989; Palmer, 1994).

Fish are the most numerous group of vertebrates and are found virtually in every aquatic environment, thereby not only being vulnerable to the impacts of ecological settings during their growth but also appealing to researchers to evaluate the probability of FA as a marker of ecological well-being (Allenbach, 2011). Almost all endogenic pressures associated with FA in fish are related to congenital, crossing, and hereditary disorders (Fries et al., 2004; Hermita et al., 2013; Palmer & Strobeck, 1986, 2003), while general natural influences include the intensity of progeny and the extent of contest depredation (Allenbach, 2011; Palmer, 1994; Palmer & Strobeck, 2003). Exogenic influences include changes in the environment, differences in water quality, and even climate changes (Jawad et al., 2012; Palmer, 1994). Even though other studies find the relationship between bilateral asymmetry and fish characteristics (Allenbach, 2011), there are few instances in which FA in fish is associated with habitat degradation (Al-Mamry et al., 2011; Ayoade et al., 2004; Jawad et al., 2012).

Among Cyprinidae, Linnaeus conducted the first description of *Cyprinus carpio* in 1758, and it was imported to Iraq from 1960 to 1972 (Jawad, 2003). They are freshwater species occasionally found in brackish waters (Riede, 2004) living at depths of 0–29 m (New York Department of Environmental Conservation, 2019) and are native to Asia and Europe, the Black, Caspian, and Aral Sea basins, but feral populations are rarely found naturally in rivers that drain into these basins (Kottelat & Freyhof, 2007). Although the average length of this species is 310 cm, they can grow up to a maximum length of 1200 cm (Murdy et al., 1997), and the maximum weight recorded so far is 40.1 kg (Chugunova, 1959; Machacek, 2007). They are capable of living up to 38 years (Murdy et al., 1997). Common carp typically reside in deep, warm waters that are either still or have a gentle flow, such as those found in lowland rivers and lakes with abundant vegetation (Kottelat & Freyhof, 2007), preferring soft-bottomed areas but adapting to various conditions (Scott & Crossman, 1973). They serve as biological indicators of water pollution and resist oxidative damage from low-concentration heavy metals (Hammoud & Aldhamin, 2024), feeding on plant matter and benthic organisms while spawning in backwaters or along riverbanks (Kottelat & Freyhof, 2007).

Heckel (1843) first described the Tigris asp (*Leuciscus vorax*) as *Aspius vorax* from the Heri Rud River area, close to Herat, Syria, where the syntypes (NMW 16527, 1, dry) were found, and this species is typically distributed in Asia via the Tigris-Euphrates basin (Coad, 1996), with additional documentation in the Orontes River (Bogutskaya, 1997). In Iraq, these species live in lakes and reservoirs, and from these aquatic environments, migrate to rivers or streams to reproduce, exposing them to pollutants. Despite this vulnerability, they have considerable economic significance (Coad, 1996). The maximum length of *L. vorax* is 1020 mm, with a highest recorded weight of 10.0 kg and a maximum lifespan of 24 years (Fishing World Records.Com e.U. 2013). In Major Channel Drain, the feeding activity peaked between August and November and was at a minimum in February and December (Al-Zaidy and Parisi, 2025), suggesting the predatory nature of *L. vorax* and also the dietary plasticity of the same, according to the size. Salih et al. (2019) also investigated its feeding behavior and reported the species to exhibit various dietary adaptations, adding that smaller individuals exhibited more pronounced food preferences than larger ones. Besides, Oymak et al. (2011) studied the growth and reproduction of this species and found that the age ranged between II and IX, with mean somatic condition for females of 1.669 and for males of 1.662, with the maximum in November (K = 1.23) for females and September–October (K = 1.13) for males. Mature males reach full sexual maturity by age three, and there were no potentially fully mature, young females, but all females aged four and above were mature (Oymak et al., 2011).

The present study investigates the deviation from bilateral symmetry in 10 morphological traits (six morphometric and four meristic) of *C. carpio* and *L. vorax* obtained from Al-Tharthar at the Euphrates River and from the Tigris River at Al-Zubaydia City, Iraq, respectively. The key aim of the research is to explore the degrees of FA between the eight morphological characteristics of *L. vorax* and *C. carpio*. Moreover, the reliability of employing fish as a biomarker of the freshwater system's health and FA is carefully considered. In addition, the possibility of using FA as a potential taxonomic feature was conferred.

2. Materials and methods

2.1. Research area

Al-Tharthar Lake and the Tigris River in Al-Zubaydia City, Iraq, were the sources of *C. carpio* and *L. vorax*, respectively (Fig. 1). As the name indicates, Al-Tharthar is an artificial lake which lies between the Tigris and Euphrates Rivers, 120 km northwest of the capital, Baghdad, at coordinates 33°58′N 43°11′E. Its surface area ranges from 1875 km^2 to 2710 km^2 with a maximum depth of 68.4 m (Kornijów et al., 2001; Majeed et al., 2022, 2023). Situated northwest of Tikrit and north of Anbar Governorate in Iraq, the Tharthar Depression can be found (Zdanowski et al., 2001). This reservoir is one of Iraq's largest natural reservoirs, which was constructed in 1956 AD to hold excess water from the Tigris during the flood season. This is facilitated through a diversion canal commencing at the Samarra Dam (in Samarra City). Built in 1955 AD, it subsequently connected the Tharthar Depression

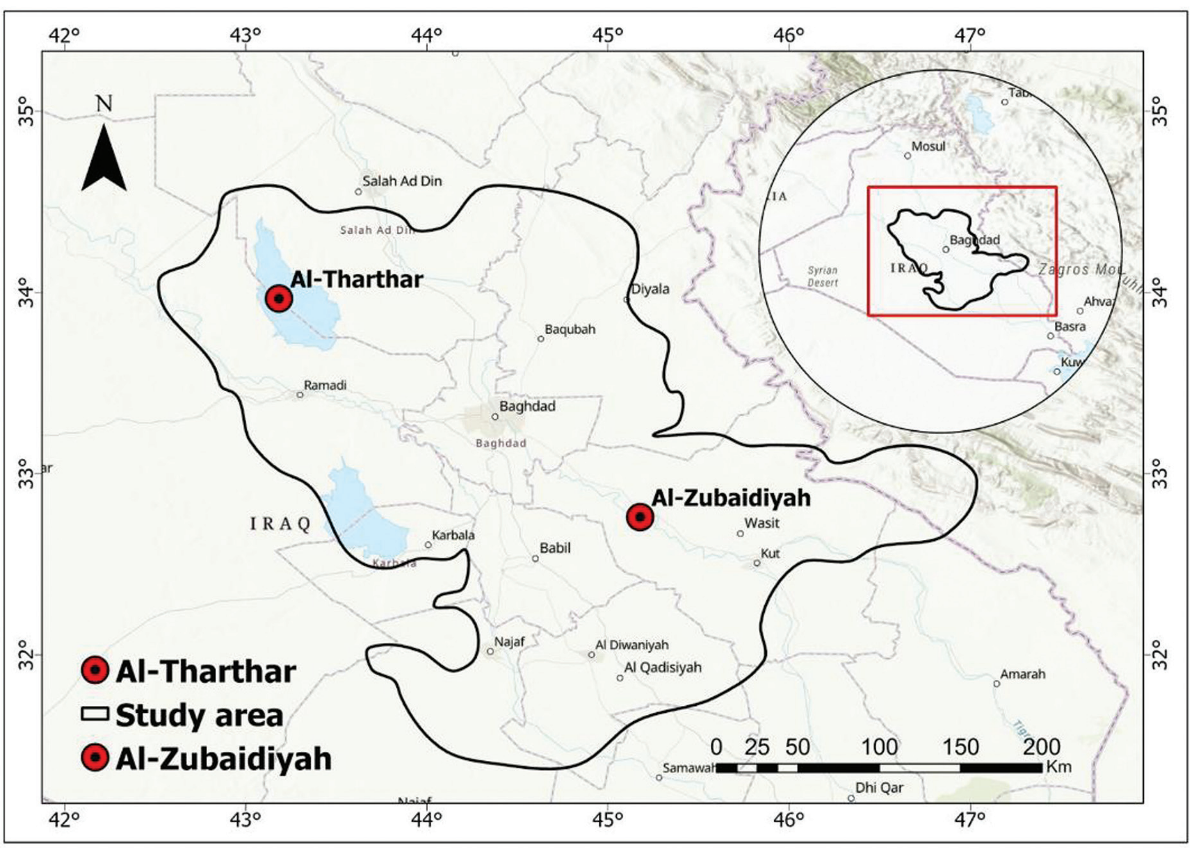

Figure 1

A map presenting the areas from which the samples of *Cyprinus carpio* and *Leuciscus vorax* were collected.

to the Tigris and Euphrates Rivers (Al-Ubaidy, 2009). Situated in south-eastern Baghdad, Al-Zubaidiyah sits approximately 50 km to the south of Al-Suwaira and 85 km north of Kut City (32°45′38.1″N 45°10′38.5″E). Considered the second-longest river in Western Asia (Oleiwi & Al-Dabbas, 2022), the Tigris River flows across the Al-Zubaidiyah region, which is arid-semi-arid with annual rainfall that seldom exceeds 166 mm. The river is thus a vital water supply. The Tigris River flows through flat alluvial plains at Al-Zubaidiyah, part of the Mesopotamian Basin that contains highly fertile soils that support agriculture but suffer due to salinization and sedimentation (Al-Ansari et al., 2019, 2021).

2.2. Fish specimens

Gill and throwing nets were used to collect the *C. carpio* (250 specimens) and *L. vorax* (220 specimens) samples (Figs. 2A and 2B). Fish specimens were collected randomly, so the results will not be biased. Fish species were identified in accordance with Coad (2010). The work of Hubbs et al. (2004) served as the basis for the morphological feature measurement techniques. In earlier studies, the physical characteristics (Fig. 3) evaluated for bilateral asymmetry were used (Hechter et al., 2000; Jawad et al., 2010, 2016). Several encompassed exterior attributes (six characters) and meristic traits (four features) were assessed, namely (1) snout length (SnL); (2) eye diameter (ED); (3) length of the upper jaw (LUJ); (4) head length (HL); (5) caudal peduncle length (CPL); (6) caudal peduncle depth (CPD); (7) number of the lateral line scales (LLS); (8) number of pectoral fin rays (PFR); (9) number of the ventral fin rays (VFR); and (10) number of gill rakers on the first gill arch (NGR) (Fig. 3).

2.3. Statistical analysis

Digital calipers were employed to measure external bodily features to the nearest 0.1 cm. The measurement methodology (e.g., the formula by Valentine et al., 1973) is presented, and the fact that all measurements were conducted by the same individual enhances the reliability of the results.

$$CV^2_a = S_{l-r}\, X\, 100/x\; l + r$$

where S_{l-r} is the standard deviation of signed variance, and X_{l+r} is the mean of the character. It is calculated by summing up the final score of the two

Figure 2

Fish species investigated in the present work. **(A)** *Cyprinus carpio*, 190 mm SL, 230 mm TL, **(B)** *Leuciscus vorax* 310 mm SL, 360 mm TL. SL, standard length; TL, total length.

sides and dividing by 2. The exterior bodily features were categorized using a predicted standardized assessment (HL, from the mouth to the rearmost point on the operculum in cases with head-related features, and standard length of the area from the snout to the hypural bone in the caudal fin skeleton for other body features) so that any deviations related to growing morphological attributes (non-discrete, measurable) could be removed.

The squared asymmetry coefficient was calculated by equally weighing each external factor. Different total length groups were compared using an analysis of variance (ANOVA) test to detect differences in asymmetry coefficients. To determine if the differences between pair computations of length groups were significant, a Tukey HSD post hoc test was used in addition to the ANOVA test (StatSoft Inc., 1991). Fish samples were ranked based on their overall length for each attribute that was investigated. The total lengths were then employed to separate the fish samples into three groups (100–150, 151–200, and 201–250 mm TL, respectively). Asymmetry coefficients were then equated between each species of fish and then assigned to collaborative groups after performing ANOVA tests.

3. Results

The bilateral asymmetry results for the 10 external body traits analyzed for both *C. carpio* and *L. vorax* samples are given in Table 1. The two species were found to have high asymmetry values for SnL and low asymmetry values for the NGR.

Individually, *C. carpio* and *L. vorax* were assigned to length groups (Table 2). Each external body feature was found to have increasing values of asymmetry.

In the case of the two studied species, the proportion of individuals with asymmetric SnLs was the greatest. On the contrary, asymmetry in the NGR showed the lowest percentage of individuals with this deviation from perfect laterality (Table 1). Regardless of whether an individual is sinistral or dextral, all features analyzed are dextral and found right in higher value than left. The one exception here is the PFR count, which is sinistral, with the left side having a higher count than the right.

4. Discussion

Fish species have been found to exhibit extensive bilateral asymmetry in terms of SnL (Al-Hassan et al., 1990; Jawad, 2013; Jawad & Abed, 2021; Jawad et al., 2016, 2023a, 2023b). The direct differences in the habitat may explain the tendency of this feature, as well as this convergence in the consequence of bilateral asymmetry. It may therefore be considered a useful impact bioindicator in aquatic animal habitats. In both of the fish species studied, the NGR showed reduced bilateral asymmetry estimations,

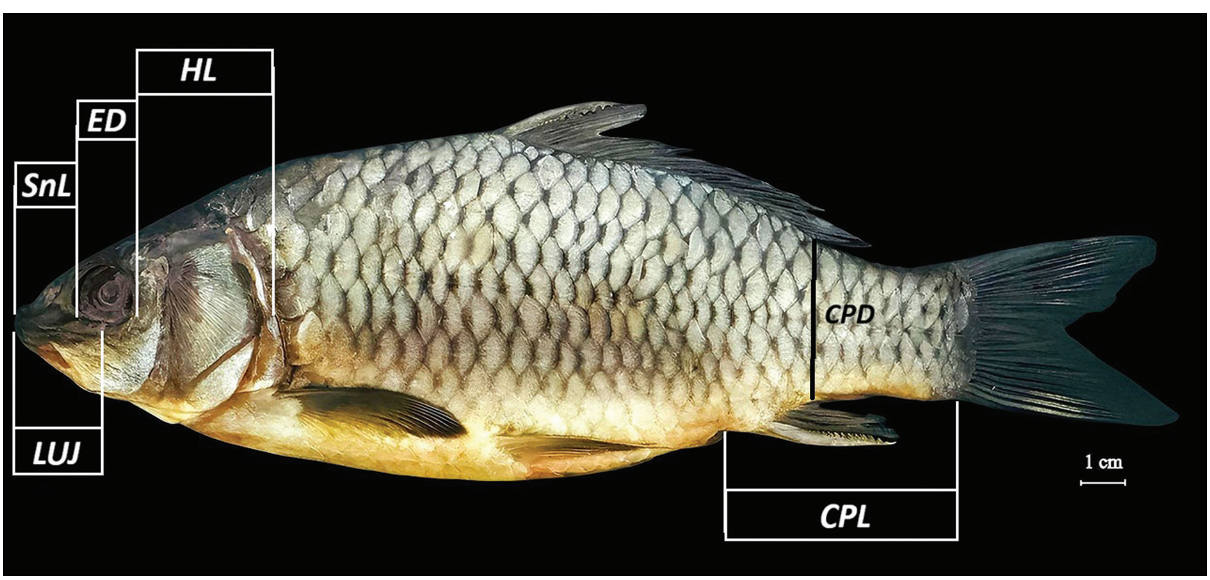

Figure 3

Cyprinus carpio, 233 mm TL and 190 mm SL. This figure presents the morphological features employed in the asymmetry study, namely SnL, CPD, CPL, ED, HL, and LUJ. CPD, caudal peduncle depth; CPL, caudal peduncle length; ED, eye diameter; HL, head length; LUJ: length of the upper jaw; SnL, snout length.

Table 1

Squared coefficient asymmetry (CV^2_a) values and character means (X_{r+l}) for the *Cyprinus carpio* and *Leuciscus vorax* taken from Al-Tharthar Lake and the Tigris River at Al-Zubaidiyah in Iraq.

	1	2	3	4	5	6	7	8	9	10
Cyprinus carpio										
CV^2_a	87.732	86.512	76.143	77.891	73.482	80.711	84.250	79.127	70.156	69.971
N	250	250	250	250	250	250	250	250	250	250
Character mean	19.5	23.4	27.3	100.1	57.2	58.5	33.3	15.4	8.3	20.6
(X_{r+l}) (SD)	(0.453)	(0.487)	(0.554)	(0.641)	(0.553)	(0.217)	(0.762)	(0.664)	(0.442)	(0.571)
% of individuals with asymmetry	92	90	82	83	80	87	88	85	78	75
Leuciscus vorax										
CV^2_a	93.728	92.619	89.912	81.561	79.981	89.135	90.512	84.482	78.171	76.781
N	220	220	220	220	220	220	220	220	220	220
Character mean	24.7	14.3	36.4	106.4	39	58.5	96.3	17.5	8.7	12.3
(X_{r+l}) (SD)	(0.832)	(0.631)	(0.552)	(0.332)	(0.455)	(0.621)	(0.764)	(0.553)	(0.641)	(0.723)
% of individuals with asymmetry	97	95	91	86	84	90	93	88	82	80

Morphometric measurements (mm) are 1, SnL; 2, ED; 3, LUJ; 4, HL; 5, CPD; 6, CPL. Meristic characters are: 7, number of the LLS; 8, number of PFR; 9, number of VFR; and 10, NGR.

CPD, caudal peduncle depth; CPL, caudal peduncle length; ED, eye diameter; HL, head length; LLS, lateral line scales; LUJ, length of the upper jaw; NGR, number of gill rakers on the first gill arch; PFR, pectoral fin rays; SD, standard deviation; SnL, snout length; VFR, ventral fin rays.

suggesting that this trait may be more vulnerable to ecological influence events involving pollution. The smaller bilateral asymmetry values acquired for gill rakers on the first gill arch in both species may possibly be clarified on the assumption that the mounting time of gill rakers on the first gill arch may not accord with the existence of contrasting ecological issues (Jawad, 2003).

Toxic chemical and organic wastes in Iraq's freshwater environments affected animals, leading to abnormalities in their external body attributes (Jawad et al., 2017).

The ANOVA test outcomes showed that the samples included in the higher fish size bounds of *C. carpio* and *L. vorax* had larger bilateral asymmetry estimates than those found in the smaller fish length grouping ($p < 0.001$). Table 2 presents the discrepancies in bilateral asymmetry for the 10 morphological and meristic features of *C. carpio* and *L. vorax*, which increased as fish length increased (Table 2). This pattern is likely due to a reduction in fish growth. Further, when considered by young versus large individual groups, the former have lower typical averages than the latter do (Valentine et al., 1973). Valentine et al. (1973) observed comparable outcomes in fish species from California, suggesting that differences related to age might be linked to greater bilateral asymmetry, as the fish grow longer.

The values achieved within the present study are compared with the FA values for the body external traits of other freshwater fish species in Iraq and around the world in order to highlight any discrepancies in the promptness of the 10 morphological body attributes of *C. carpio* and *L. vorax*. The asymmetry index estimations for the 10 morphological traits that were the subject of the current inquiry are compared with similar data for freshwater fish species that were taken from the freshwater system of Iraq and other freshwater areas, as can be seen in Table 3.

The degree of SnL asymmetry exhibited by the two species is analyzed in this study. This morphological feature shows high FA, in accordance with what was found for *Heteropneustes fossilis* sampled from Shatt al-Arab River, Iraq, by Al-Hassan et al. (1990) (Table 3, 95.8). Higher FA for this trait might indicate the effects of stressors like pollution, habitat disturbance, or variability in the aquatic environment, among other factors present at the site of the study. Given the importance of the snout as a functional trait related to feeding, respiration, and sensory functions, this structure may be more susceptible to suffering from damaging environmental or genetic influences, and hence it would exhibit a higher level of asymmetry. The remaining nine morphological features, with the exceptions of the number of VFR, the number of LLS, and the NGR, show lower asymmetry values when

Table 2

Squared coefficient of variation (CV^2_a) measurements and character means (X_{r+l}) by size class for *Cyprinus carpio* and *Leuciscus vorax* obtained from the Tigris River at AL-Zubaidiyah and Al-Tharthar Lake in Iraq.

Fish total length group	CV^2_a	*N*	Character mean (X_{r+l}) (SD)	% of individuals with asymmetry	Fish total length group	CV^2_a	*N*	Character mean (X_{r+l}) (SD)	% of individuals with asymmetry
Cyprinus carpio					*Leuciscus vorax*				
SnL					SnL				
100–150	85.3	100	18.9	76	100–150	92.0	105	24.5	56
151–200	86.9	110	18.7	79	151–200	92.5	80	23.9	63
201–250	87.7	40	18.8	82	201–250	93.7	35	24.4	87
ED					ED				
100–150	81.5	100	23.3	56	100–150	90.5	105	14.2	73
151–200	84.2	110	22.9	61	151–200	91.8	80	14.1	81
201–250	86.3	40	22.8	87	201–250	92.4	35	13.9	96
LUJ					LUJ				
100–150	71.9	100	27.5	76	100–150	88.7	105	36.3	92
151–200	74.5	110	26.4	87	151–200	89.0	80	35.9	96
201–250	76.2	40	26.8	99	201–250	89.3	35	35.8	99
HL					HL				
100–150	73.8	100	100.5	75	100–150	80.9	105	106.3	76
151–200	75.6	110	99.87	78	151–200	81.3	80	105.9	79
201–250	77.3	40	99.91	82	201–250	81.4	35	106.1	83
CPD					CPD				
100–150	70.8	100	57.1	78	100–150	79.0	105	38.9	56
151–200	71.7	110	56.9	79	151–200	79.3	80	38.8	59
201–250	73.5	40	56.8	82	201–250	79.8	35	38.7	67
CPL					CPL				
100–150	79.1	100	58.4	83	100–150	88.5	105	58.4	42
151–200	79.4	110	57.9	86	151–200	88.9	80	57.9	65
201–250	80.5	40	57.7	89	201–250	89.0	35	58.1	78
Number of the LLS					Number of the LLS				
100–150	81.2	100	33.1	75	100–150	89.9	105	96.2	72
151–200	81.9	110	32.9	88	151–200	90.0	80	95.9	78
201–250	84.3	40	33.5	94	201–250	90.4	35	96.4	81
Number of the PFR					Number of the PFR				
100–150	78.8	100	15.3	78	100–150	83.8	105	17.4	81
151–200	79.0	110	15.7	88	151–200	84.0	80	16.9	86
201–250	79.2	40	14.9	96	201–250	84.3	35	17.3	90
Number of the VFR					Number of the VFR				
100–150	69.8	100	8.5	90	100–150	77.5	105	8.6	65
151–200	70.1	110	8.3	93	151–200	77.8	80	8.5	69
201–250	70.4	40	8.1	97	201–250	78.0	35	7.9	79
NGR					NGR				
100–150	68.7	100	20.7	76	100–150	77.0	105	12.2	88
151–200	69.0	110	19.9	78	151–200	77.2	80	11.9	89
201–250	69.3	40	20.5	86	201–250	77.6	35	12.1	95

CPD, caudal peduncle depth; CPL, caudal peduncle length; ED, eye diameter; HL, head length; LLS, lateral line scales; LUJ: length of the upper jaw; NGR, number of gill rakers on the first gill arch; PFR, pectoral fin rays; SD, standard deviation; SnL, snout length; VFR, ventral fin rays.

compared to species listed in Table 3. The observed overall lower FA in such traits might depend on a stronger stabilizing selection acting on phenotypic features that are functionally critical, which would decrease developmental variation. Among such characteristics of body depth and position and number of fins may be genetically more constrained, as they are likely to play more relevant roles in locomotion and hydrodynamic efficiency. Additionally, some morphological features (e.g., meristic traits like scale counts) may exhibit lower FA because they are determined earlier in development and are less susceptible to later environmental disruptions.

These higher asymmetry values than those in Table 3 could indicate more environmental stress, environmental variables not examined, such as pollution, temperature changes, or water quality, affecting the populations sampled. Alternatively, genetic factors, such as inbreeding or reduced genetic variation within the study populations, might also play a role in the increase of developmental instability. It would be necessary to use both ecological and genetic data to determine the causes of the observed patterns of asymmetry. One of the most common features examined in studies of fish asymmetry is the number of gill rakers (Allenbach, 2011; Jawad et al., 2012; Øxnevad et al., 2002). Consistent with our findings,

Table 3

Comparing the asymmetry coefficients (CV^2_a) for the nine morphologic features of *Cyprinus carpio* and *Leuciscus vorax* obtained from the Tigris River at Al-Zubaidiyah and the Al-Tharthar Lake in Iraq in the present study with those of other fish species from other areas.

	Coefficient of asymmetry (CV^2_a)								
Species	**1**	**2**	**3**	**4**	**7**	**8**	**9**	**10**	**Reference**
Labeo dero	-	-	-	-	35.7–42.6	40.0–49.0	2.0–5.7	-	Sinha and Tilak (1968)
Heteropneustes fossilis	95.8	-	-	-	-	87.2	-	-	Al-Hassan et al. (1990)
Mystus pelusius	79.2	-	-	-	-	57.8	-	-	Al-Hassan and Hassan (1994)
Planiliza abu	48.9	-	-	-	-	32.1	-	45.2	Jawad (2004)
Sarotherodon melanotheron	6.2–44.0	8.43–90.1	-	-	6.7–81.8	-	-	-	Jawad et al. (2016)
Coptodon guineensis	5.3–77.2	4.6–91.4	-	57.9–58.4	5.8–48.7	58.6–59.7	-	-	Jawad et al. (2016)
Chrysichthys auratus	59.3–61.3	55.7–60.4		59.6–62.8		58.9–62.1			Jawad and Gnohossou (2019)
Mugil cephalus	58.2–62.2	58.1–59.6	-	57.9–58.4	-	58.6–59.7	-	-	Jawad and Gnohossou (2019)
Silurus triostegus	119.9	123.4	120.3	112.2	-	-	-	-	Jawad et al. (2020)
Heteropneustes fossilis	75.2–94.3	44.2–44.9	33.3–39.4	45.2–48.6	-	-	-	-	Jawad and Abed (2021)
Barbus escherichii	17.8	20.1	19.2	-	19.5	19.1		19.6	Jawad et al. (2023a, 2023b)
B. ida	19.9	17.5	19.1	-	19.1	-	-	19.0	Jawad et al. (2023a, 2023b)
B. niluferensis	20.3	20.1	19.2	-	19.5	19.1	-	19.6	Jawad et al. (2023a, 2023b)
B. oligolepis	20.4	19.2	19.1	-	18.9	19.2	-	19.0	Jawad et al. (2023a, 2023b)
B. pergammonensis	16.2	16.9	15.5	-	15.0	15.2	-	15.2	Jawad et al. (2023a, 2023b)
B. xanthos	29.4	29.6	28.9	-	28.7	28.7	-	28.9	Jawad et al. (2023a, 2023b)

1, SnL; 2, ED; 3, LUJ; 4, HL; 6, number of the LLS; 7, number of PFR; 8, number of the VFR; and 9, NGR.
ED, eye diameter; HL, head length; LLS, lateral line scales; LUJ, length of the upper jaw ; NGR, number of gill rakers on the first gill arch; PFR, pectoral fin rays; SnL, snout length; VFR, ventral fin rays.

other researchers have found similar significant levels of environmental-related asymmetry in gill rakers of the striped bass *Morone saxatilis* (Fries et al., 2004), European perch *Perca fluviatilis* (Øxnevad et al., 2002), and African carp *Labeo parvus* (Ayoade et al., 2004). In line with our results, other studies reported comparable high degrees of environment-associated asymmetry among gill rakers of the striped bass *Morone saxatilis* (Fries et al., 2004), the European perch *Perca fluviatilis* (Øxnevad et al., 2002), and the African carp *Labeo parvus* (Ayoade et al., 2004). Similar to other earlier studies, this work highlighted moderate levels of asymmetry in terms of the NGR. Thus, the number of gill rakers is a key component involved in verifying asymmetry in fish.

Various other given accounts from around the world have verified that contamination was overall probably liable for high estimates of bilateral asymmetry (Elie & Girard, 2014). Common trace metals and other compounds are known to become more toxic when temperatures and salinities increase (Elie & Girard, 2014). Such results were given by Majeed et al. (2022) in finding that the two regions studied had quite high water temperatures on average.

It has been demonstrated that different fish body components react differently to pollution in their respective niches. For example, Michaelsen et al. (2015) found that oil contamination has noticeable effects on the eye but not on the length of the paired fins. These researchers observed that the effects of asymmetry on fish eyes were less severe than those on paired fins. Conversely, Allenbach (2011) found that eye asymmetry is more often considered an ecological consequence than paired fin asymmetry. This belief was supported by Palmer and Strobeck (1986), who suggested that characteristics that are active during development are less susceptible biomarkers of an animal's growing unsteadiness.

Concerning ED asymmetry, the present study found high values that were consistent in magnitude with the variability reported for other morphological traits. The conclusions of this research are in line with those made in earlier studies, verifying the species-specific competencies of fish attributes in order to determine asymmetry (Allenbach, 2011; Al-Mamry et al., 2011; Jawad et al., 2012; Øxnevad et al., 2002).

The high pollution estimates at both the Tigris River near Al-Zubaydia City and Al-Tharthar at the Euphrates River are reported. Al-Rubayi et al. (2011) noted that the heavy pollution with particulate organic matter is affecting the distribution of the fish species *Mystus pelusius* and *Silurus triostegus*. Furthermore, Al-Kinany and Almukhtar (2014) reported heavy pollution of different chemicals and organic matter levels at the Tigris River south of Baghdad. Muslim et al. (2019) investigated surface soil samples from various localities in Wasit Province. The samples' soil may be blown to the Tigris River near Wasit Province. This will transfer the soil's pollutants to the river, increasing its pollution. The soil samples collected by Muslim et al. (2019) were found to be highly polluted by heavy metals such as nickel (188.9 ppm), titanium (72.7 ppm), molybdenum (9.85 ppm), strontium (431.6 ppm), chromium (226 ppm), cadmium (2.2 ppm), and bromine (27.ppm). moderate levels of pollution for copper (54.7 ppm), cobalt (13.4 ppm), manganese (781.8 ppm), vanadium (104.3 ppm), and zinc (117.6 ppm) were also highlighted. Meanwhile, research by Issa et al. (2020) revealed that the Tigris River was polluted with high levels of titanium (71.9 ppm), nickel (226.6 ppm), chromium (425.2 ppm), cadmium (2 ppm), and molybdenum (15.8 ppm). Furthermore, moderate levels of pollution with cobalt (25.1 ppm), strontium (839.3 ppm), copper (56.2 ppm), niobium (9.79 ppm), manganese (106.1 ppm), and vanadium (135 ppm) were found to be present in sediment samples. Morphological asymmetry in the jaws of scale-eating cichlids, *Perissodus microlepis,* was assessed by Hata et al. (2013) as a unique lateral dimorphism. Similarly, Lee et al. (2015) explored the environmental and genetic impacts of morphological asymmetry in the *P. microlepis*, which was deemed to be a strong taxonomic feature. The *P. microlepis* in Lake Tanganyika was also examined by Raffini et al. (2018), who found that head asymmetry in *P. microlepis* is a taxonomic feature. However, there tends to be great diversity in nature, which influences relationships between the hereditary foundations of different (possibly separate) characteristics.

Continuing with water contamination, on one hand, Al-Tamimi and Al-Gafily (2009) indicate that the sewage treatment plant in Ramadi greatly affects the water quality of the Euphrates River in al-Ramadi Province, site of the Al-Tharthar reservoir. They also concluded that this effect leads to a significant reduction in the dissolved oxygen levels in the river water, which in turn has an ecological impact.

FA is used in fish taxonomy to identify cryptic species or ecologically impacted populations, as it often reflects genetic disruptions, hybridization, or habitat degradation (Palmer & Strobeck, 1986). For example, FA in guppy meristic traits helps distinguish genetically distinct groups (Van Valen, 1962), while otolith or cranial asymmetry may reveal intraspecific variation (Palmer & Strobeck, 1986). However, not a standalone tool, FA complements molecular and morphological data in studying parallel evolution and population resilience (Møller & Swaddle, 1997). In cichlids, FA has aided taxonomic studies, such as jaw dimorphism in *P. microlepis* (Hata et al., 2013; Lee et al., 2015), though natural variation and gene-environment interactions complicate its use (Raffini et al., 2018).

The findings show that, in comparison to other species, the asymmetry values for the 10 exterior morphological body features of *C. carpio* and *L. vorax* are almost equal. This evaluation demonstrates how the habitat has an effect on the external morphology of the fish, actually experiencing this natural condition, even though the fish species derived from the sources in this study are distinct (Jawad et al., 2012). Overall, given the results of this study, a management plan should be enacted that serves to inform about the physical state of the freshwater ecosystems in Iraq from this critical period.

In addition, our results show that, during the departures from bilateral symmetry reported in *C. carpio* and *L. vorax*, the environmental conditions at the Tigris River at Al-Zubaydia City are in general better than those at Al-Tharthar at the Euphrates River, according to the outcome of the asymmetry obtained in the morphological traits analyzed on *C. carpio* and *L. vorax*. Measurements of water quality clearly display the distinction between the rivers of the Tigris in Zubaydia City and the Euphrates in Al-Tharthar. Awad et al. (2022) mention the levels of pollution detected in the Tigris adjacent to Zubaydia, which are superior to those found in previous studies due to urban and agricultural runoff which cause high turbidity, electrical conductivity (EC), and concentration of heavy metals like lead (Pb) and cadmium (Cd). On the contrary, the Euphrates in Al-Tharthar, also affected by reservoir conditions, has less salinity and turbidity; however, it is affected by nutrient eutrophication, nitrates, phosphates, and the presence of stagnant water and algal growth (Majeed et al., 2023). Both are under high anthropogenic pressure, but the sources of pollution are different, with discharges of industrial and municipal origin prevailing in the Tigris, while agricultural return flows and evaporation are the prevalent human influences in the Euphrates (UNEP, 2016). As was also the case for others, these results support attempts to analyze biochemical or inorganic markers.

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