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Analysis of morphometric and meristic characteristics of three cichlid species in central Iraq: farmed and wild

by

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Abstract

This study is designed to assess morphological dissimilarities between aquaculture and feral groups of three cichlid fish species, *Coptodon zillii* (Gervais, 1848), *Oreochromis aureus* (Steindachner, 1864), and *Oreochromis niloticus* (Linnaeus, 1758). Feral groups were collected from fishers operating in the Tigris River at Al-Zubaidiyah City, while aquaculture groups were attained from a breeding facility at Al-Zubaidiyah City, Iraq. Boxplots by variable and habitat revealed significant group disagreement. The cultured population exhibited higher meristic counts, and eventually, the two groups diverged. The cross-validated discriminant analysis using morphometric characters from all 896 specimens correctly classified 93.9% by variant of each species (Wilk's lambda = 2.63 E-8, $p < 0.001$). The boxplot of meristic characteristics indicates that number of dorsal fin ray, number of anal fin ray, and number of pectoral fin ray values were higher in aquaculture habitat for all species except number of pectoral fin ray for *C. zillii* and pectoral fin ray for *O. aureus*. For number of gills rakers, number of the lateral line scales, and number of vertebrae all counts were higher in aquaculture specimens. The connection between the results of comparing the reared and feral groups of the three cichlid species' identification and taxonomy is discussed.

Key words: morphometric, meristic, escapes, body shape variation, Cichlidae, Iraq

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1. Introduction

Unintended or deliberate releases of aquaculture-generated fish into the feral have sparked unease among fishery experts (Ryman et al., 1995; Youngson et al., 1991). Even though such exercises (purposeful) are regularly accomplished to assess the decline yield triggered by human-stimulated habitat destruction, a selection of feasible habitat impairments could be concurrent with this application (Bostanci et al., 2021). First, providing larger numbers of fish in a controlled spot will disrupt the inhabitants' mass, at least primarily. This may disrupt the density-dependent characteristics of the fish or the habitat (Elliott, 1990). Changes in the amount of food available, the existence of competitive contacts, or the reaction of predators are all examples of factors that may affect the development and presence of wild fish. Aquaculture system fluxes may be a clue to seasonal changes in group strength, according to theoretical beliefs (Fagen & Smoker, 1989). Second, aquaculture fish may differ from feral fish in terms of external characteristics or genetics. Such differences might disrupt the cooperation between feral and given fish, which would subsequently lead to an impact on providing outside of those areas due to obvious density dependence.

Researchers widely used morphometric and meristic features to identify fish species (Turan et al., 2004), as they continue to be the most straightforward methods for distinguishing different species. Evidence from previous studies suggested that morphological variation in meristic traits is the most common way to classify fish (Bronte et al., 1999; Creech, 1992; Hockaday et al., 2000; Mamuris et al., 1998). Researchers, frequently used statistical procedures to split and group fish (Agnew, 1988; Avsar, 1994). Swain and Foote (1999) noted that using methods that directly study biochemical or molecular differences in heredity, such as traditional strategies, is still very important for understanding how populations differ. Changes in a species' morphometric and meristic characteristics from different locations might result in changes to its genetic makeup and territorial problems that influence the genotype, or both at the same time (Parish & Sharman, 1958). While changes in ecological sources affect morphometric and meristic features equally, these responses might vary depending on the situation and can display species-specific changes.

Phylogenetics and studies on group genetic evolution rely heavily on analyses of morphometric and meristic differences and irregularities in fish groups. According to Turan et al. (2006), many years of introducing and domesticating a fish species—especially one that comes from the wild—means that it has adapted well to a wide variety of geographical locales, which in turn causes phenotypic alterations in the progeny populations. The cause might be environmental variables or hybrids created by extensive inbreeding (El-Serafy et al., 2007; Lehoczky et al., 2025).

For three main reasons, domesticated fish could look different from their feral species. First, since fish have very flexible exterior characteristics, the breeding process may significantly alter their shape (Pakkasmaa, 2000). Second, the strength and route of selection vary between aquaculture and wild fish, which is why they could differ. Third, the use of non-wild fish for provision is one reason why farmed fish might differ from wild ones. Fortunately, the practice of releasing non-wild fish has declined, and the potential consequences of territorial modifications are increasingly recognized (Taylor, 1991). Similar to what has happened with economically viable farmed fish, planned artificial selection may likewise cause genetic alterations in populations of cultured fish (Einum & Fleming, 1997; Fleming & Einum, 1997). Fish that originate from aquaculture facilities are usually confronted with circumstances very different from those faced by their feral equivalents, which might lead to behavioral, morphological, and physiological changes (Beecham et al., 2007). One of the first natural facts provided by Hanson et al. (2007) is the association between morphology and the swimming event. For many fish and other aquatic animal species, swimming performance is the most important trait determining ability (Plaut, 2001).

People widely exploit the remaining species of cichlids in aquaculture around the world and sell them as high-protein food fish internationally. Researchers believe that almost 4000 years ago, the Egyptians were the pioneers of tilapia farming. After being considered for cultivation in the Far East in the late 1940s, a number of tilapia species were eventually transported to the Americas a decade later (Gupta & Acosta, 2004). For many reasons, including its adaptability to a wide range of salinities, its high tolerance to organic pollutants and low levels of dissolved oxygen in water, and its resistance to diseases, tilapia have achieved great success in the aquaculture sector (Cruz & Ridha, 1994). Moreover, as shown by their biology, these fish have a short food cycle, are delicious, and can convert leftover food and waste into excellent protein sources (Galemoni de Graaf and Huisman, 1999; Penña-Mendoza et al., 2005; Yi et al., 1996).

Unlike other nations (Barriga-Sosa et al., 2004), Iraq has not been informed when or how the tilapia species would be introduced. Coad (1996) believed that the tilapia species had made their way to Iraq from Syria via the Euphrates River. Reports of three tilapia species in Iraq's southern and central regions date back to 2007. No tilapia from northern Iraq has been reported as of yet. The first tilapia species documented in Iraq is *C. zillii,* which was gathered from two locations on the waters of the Euphrates by Saleh (2007). *O. aureus* was detected by Mutlak and Al-Faisal (2009) in Basra City's major outfall drain (3rd River), located in southern Iraq. Al-Faisal and Mutlak (2015) recently documented *O. niloticus* in Iraq's Basrah region. Based on findings in two different locations—the third river outflow drain in Basra City (Mutlak & Al-Faisal, 2009) and the Al-Delmj Marsh in the country's central region (Al-Zaidy, 2013)—*C. zillii* seems to be the most prevalent tilapia species in Iraq. Although many authors in Africa have already compared the morphology of cultured and wild tilapia stocks (e.g. Anane-Taabeah, 2019; El-Zaeem et al., 2012; Hassanien et al., 2011; Ikpeme et al., 2017; Jawad et al., 2020; Ndiwa et al., 2016; Teugels & Vreven, 1997; Tibihika et al., 2020), such studies are conspicuously absent for tilapia species in Iraq.

This research aimed to study the morphological and meristic characteristics of three cichlid species in central Iraq—*C. zillii, O. aureus,* and *O. niloticus*—caught from two different environments (wild and farmed). Accurate fisheries management and resource optimization rely on morphometric and meristic data. This will be useful for developing further strategies for the production and preservation of these species. The results of this study will also highlight the problems caused by the accidental and deliberate release of farmed fish into the wild, which may have a negative impact on populations of wild fish. The findings will be of particular importance to Iraqi decision-makers.

2. Materials and methods

2.1. Study area

The farmed fish specimens of *C. zillii*, *O. aureus*, and *O. niloticus* used in this study were sourced from the fish farming facility in Al-Zubaidiyah, which is southeast of Baghdad, around 85 km north of Kut City, at coordinates (32°45′38.1″N 45°10′38.5″E). Fishermen operating in the Tigris River at Al-Zubaidiyah City provided us with wild specimens of three species of tilapia. The area has a hot, semi-arid climate that lasts for about 8 months, with brief, cold winters that last for about 3 months. High humidity and dryness in the subtropical regions affect the weather in Iraq, where the maximum temperatures in winter reach 12°C, minimums reach 4°C, and summer maximums exceed 45°C, with constant bright sunshine (Al Ramahi & Al Bahadly, 2017; Muslih & Abbas, 2024). The area under investigation is heavily reliant on chemical fertilizers and is mostly an agricultural setting with densely populated areas around the Tigris River (Ali et al., 2019). Between October 2018 and November 2019, specimens of the three species were gathered, including those from both farmed and feral populations.

2.2. Fish specimens

A total of 896 fish specimens of *C. zillii* (130 and 145 cultured and wild specimens, respectively), *O. aureus* (155 and 153 cultured and wild specimens, respectively), and *O. niloticus* (158 and 155 cultured and wild specimens, respectively) were attained from aquaculture and feral environments. The 1300-square-meter fish farm facility focuses on fish farming and performs acts that include the production of tilapia fry, semi-intensive and intensive on-growing, and commercialization for the species *C. zillii*, *O. aureus*, and *O. niloticus*. Hormonal feed was used to raise the farmed tilapia species, containing 1.5 grams of 17α-2-methyl testosterone per 20 kg of feed. In recirculating aquaculture systems, tilapia was reared in tanks. Aeration devices were provided to the nursery site.

2.3. Measurement of morphometric and counting of meristic characteristics

In the laboratory, meristic counts of *C. zillii, O. aureus, and O. niloticus*, as well as morphometric assessments, were conducted as soon as the fish samples were received. Vreven et al. (1998) provided the basis for the identification of the three cichlid species. The well-established approach of Hubbs and Lagler (1958) was followed to achieve all morphological and meristic features. We took all morphological measures from the fish's left side (following the recommendation of FAO (2023), which states that for morphometric data, measurements are usually taken from the left side of the fish to avoid any bias due to natural asymmetry), adjusting the Vernier caliper to the closest 0.01 mm to ensure consistency. The following six meristic and nine morphometric traits were identified: total length (TL); standard length (SL); eye diameter (ED); body depth (BD); head length (HL); predorsal fin length (PreDFL); postdorsal fin length (PosDFL); prepectoral fin length (PrePFL); preanal fin length (PreAFL); number of dorsal fin rays (NDFR); number of pectoral fin rays (NPFR); number of anal fin rays (NAFR); number of gill rakers (NGR) on the first gill; number of scales on the lateral line (LL); and number of vertebrae (NV) (Fig. 1). The fin rays of the dorsal and pectoral fins were enumerated utilizing

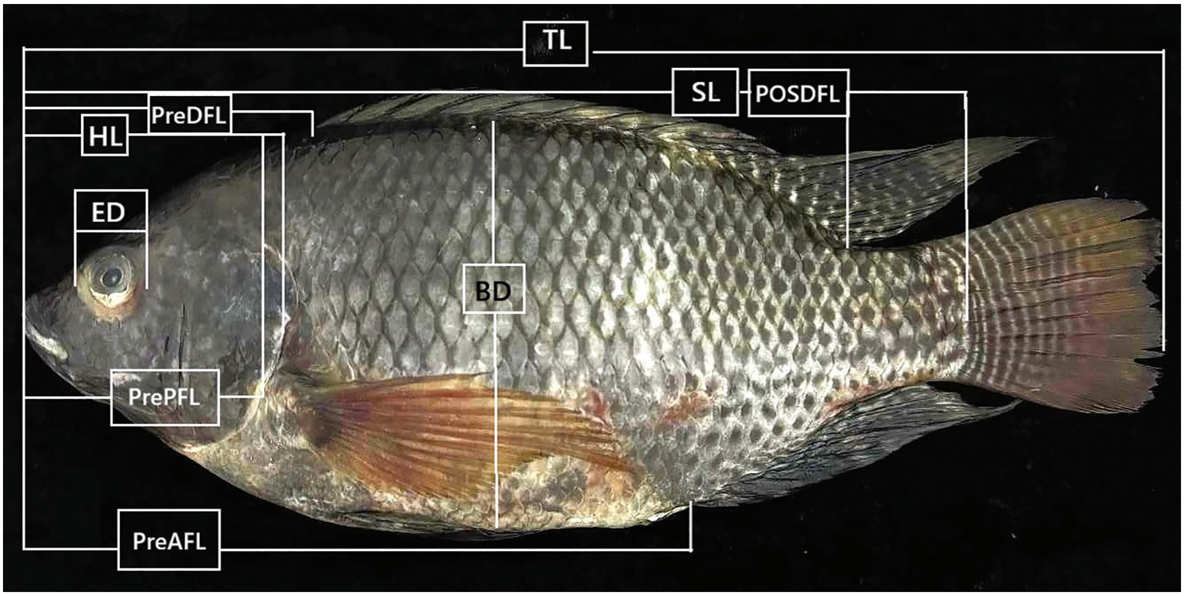

Figure 1

O. niloticus, TL 350 mm and SL 290 mm showing the nine morphometric characteristics (mm) examined. BD, body depth; ED, eye diameter; HL, head length; PosDFL, postdorsal fin length; PreAFL, preanal fin length; PreDFL, predorsal fin length; PrePFL, prepectoral fin length; SL, standard length; TL, total length.

hand-held magnifying lenses. A stereo microscope was used to count the fish's gill rakers after the first gill arch was removed.

2.4. Statistical analysis

Boxplots were made for displaying the meristic dataset in accordance with a four-number summary, which included the sample mean, the sample minimum, the sample maximum, and the sample standard error. The mean ± standard deviation (SD), minimum, and maximum morphometric variable values for the species from both wild and farmed sites are shown in Table 1. The Mann–Whitney *U* test was used for comparisons since normality was never achieved (SPSS V26.0, IBM Corporation Software Division: IBM Analytics (formerly SPSS Inc., Armonk, New York, USA)). The *t*-test's non-parametric counterpart is used when the normalcy assumption is broken.

Tocheck for differences in shape when categorizing specimens, we used discriminant analysis (SPSS V26.0) to calculate generalized Mahalanobis' distances and discriminant functions and to see how well these functions worked for classification. Cross-validation was used for this, suggesting that a single individual was excluded from the creation of the discriminant function in numerous repeated analyses before this individual was categorized based on the function. Correct classification rates were documented as percentages. Prior the discriminant analysis, the data were transformed since TLs were different between culture and wild specimens for the three species. The transformation consisted of ratios of the measured variables for an individual by one of them (TL in this case) to eliminate size differences. The validation that the size effect was eliminated can be observed in the correlation matrix. This matrix of correlations (Table S1 in Supplementary Materials) shows that these were different in sign and magnitude, a pattern that expresses variation in shape' but not in 'size' (Corti et al., 1988; Cuadras, 2019).

The sexes were not separated because the study was designed to see if the overall, population-level signal is distinct enough to be diagnostically useful for management, regardless of the internal variation caused by sex. This is a classic approach in stock identification, where the practical need is to characterize the group, not its constituent parts (Booke, 1981).

3. Results

All morphometric characteristics of the three species showed differences between those raised in aquaculture and those found in the wild, with the wild specimens being shorter overall than the aquaculture ones (Table 1). Therefore, the boxplot of meristic characteristics in

Table 1

Mean ± SD, minimum, and maximum values of morphometric (eight and six morphometric and meristic characters, respectively) (length in mm) variables in aquacultured and wild specimens of (A) *C. zillii,* (B) *O. aureus* and (C) *O. niloticus*. *p* values of the Mann–Whitney test (M–W)

(A)	Aquaculture			Wild			M–W	
Character	*N*	Range	Mean ± SD	*N*	Range	Mean ± Std	*Z*	*p*
TL	130	140.0–170.0	153.4 ± 11.2	145	50.0–120.0	80.5 ± 24.2	−14.323	<0.01
SL	**130**	**120.0–130.0**	**121.3 ± 24.1**	**145**	**35.0–110.0**	**73.1 ± 30.1**	**−13.006**	**<0.01**
HL	130	30.0–31.0	30.6 ± 0.4	145	33.0–50.0	43.7 ± 6.5	−14.341	<0.01
ED	130	10.0–12.0	11.5 ± 0.6	145	6.0–8.0	7.4 ± 0.7	−14.444	<0.01
BD	**130**	**50.0–65.0**	**57.7 ± 6.7**	**145**	**23.0–40.0**	**29.4 ± 6.6**	**−14.341**	**<0.01**
PreDFL	130	45.0–50.0	48.2 ± 1.7	145	20.0–40.0	24.1 ± 3.7	−14.327	<0.01
PosDFL	130	50.0–65.0	57.8 ± 6.7	145	25.0–45.0	35.7 ± 7.6	−14.331	<0.01
PrePFL	130	55.0–62.0	59.8 ± 2.4	145	22.0–50.0	32.8 ± 9.6	−14.326	<0.01
PreAFL	130	90.0–95.0	92.7 ± 1.9	145	30.0–85.0	66.4 ± 20.6	−14.330	<0.01
(B)	**Aquaculture**			**Wild**			**M–W**	
Character	***N***	**Range**	**Mean ± SD**	***N***	**Range**	**Mean ± Std**	***Z***	***p***
TL	155	135.0–159.7	152.3 ± 9.0	153	110.0–130.0	124.5 ± 6.1	−15.165	<0.01
SL	**155**	**130.0–140.0**	**135.7 ± 3.9**	**153**	**100.0–120.0**	**113.1 ± 6.7**	**−15.181**	**<0.01**
HL	155	42.0–45.0	44.1 ± 1.1	153	30.0–40.0	36.4 ± 3.2	−15.178	<0.01
ED	155	18.0–19.0	18.7 ± 0.4	153	16.0–17.0	16.7 ± 0.4	−15.293	<0.01
BD	**155**	**83.0– 89.0**	**85.9 ± 2.4**	**153**	**30.0–80.0**	**62.2 ± 19.1**	**−15.161**	**<0.01**
PreDFL	155	55.0–65.0	59.9 ± 3.4	153	34.0–50.0	41.2 ± 6.4	−15.144	<0.01
PosDFL	155	60.0–72.0	68.4 ± 4.0	153	40.0–56.0	49.7 ± 5.8	−15.155	<0.01
PrePFL	155	70.0–82.0	77.7 ± 4.8	153	55.0–66.0	61.7 ± 4.3	−15.174	<0.01
PreAFL	155	65.0–75.0	71.6 ± 3.5	153	30.0–60.0	44.9 ± 10.7	−15.158	<0.01
(C)	**Aquaculture**			**Wild**			**M–W**	
Character	***N***	**Range**	**Mean ± SD**	***N***	**Range**	**Mean ± Std**	***Z***	***p***
TL	158	260.0–275.0	268.6 ± 5.8	153	230.0–250.0	241.0 ± 7.6	−15.300	<0.01
SL	**158**	**230.0–235.0**	**233.5 ± 1.8**	**153**	**210.0–225.0**	**218.2 ± 5.0**	**−15.300**	**<0.01**
HL	158	79.0–85.0	81.9 ± 2.2	153	72.0–75.0	74.3 ± 1.1	−15.385	<0.01
ED	158	17.0–18.0	17.3 ± 0.5	153	12.0–16.0	14.9 ± 1.3	−15.649	<0.01
BD	**158**	**315.0–320.0**	**317.7 ± 1.8**	**153**	**250.0–310.0**	**282.8 ± 23.4**	**−15.297**	**<0.01**
PreDFL	158	87.0–90.0	88.7 ± 1.1	153	82.0–85.0	84.3 ± 1.0	−15.336	<0.01
PosDFL	**158**	**24.50–26.0**	**25.3 ± 6.5**	**153**	**23.0–24.0**	**23.5 ± 3.2**	**−15.316**	**<0.01**
PrePFL	158	82.0–96.0	89.6 ± 5.2	153	75.0–80.0	76.8 ± 1.6	−15.300	<0.01
PreAFL	**158**	**22.0–23.50**	**22.8 ± 5.9**	**153**	**19.0–21.0**	**20.4 ± 7.2**	**−15.291**	**<0.01**

BD, body depth; ED, eye diameter; HL, head length; PosDFL, postdorsal fin length; PreAFL, preanal fin length; PreDFL, predorsal fin length; PrePFL, prepectoral fin length; SD, standard deviation; SL, standard length; TL, total length.

Figs 1 and 2 indicated that NDFR, NAFR, and NPFR values were higher in the aquaculture habitat for all species except NPFR for *C. zillii* and NPFR for *O. aureus* (Fig. 2). For NGR, LLS, and NV, all counts were higher in aquaculture specimens (Fig. 3). Since none of the meristic traits overlapped (Figs 2 and 3), it was possible to distinguish between the fish from the two habitats using any variable. Consequently, all morphometric and meristic characteristics showed substantial habitat-to-habitat changes ($p < 0.01$) (Tables 1 and 2).

In Figs 1 and 2, in the boxplots for all variables, it is observed that neither in the medians, quartiles, nor for the whiskers was there overlap. The variability was greater for specimens from aquaculture, where it was

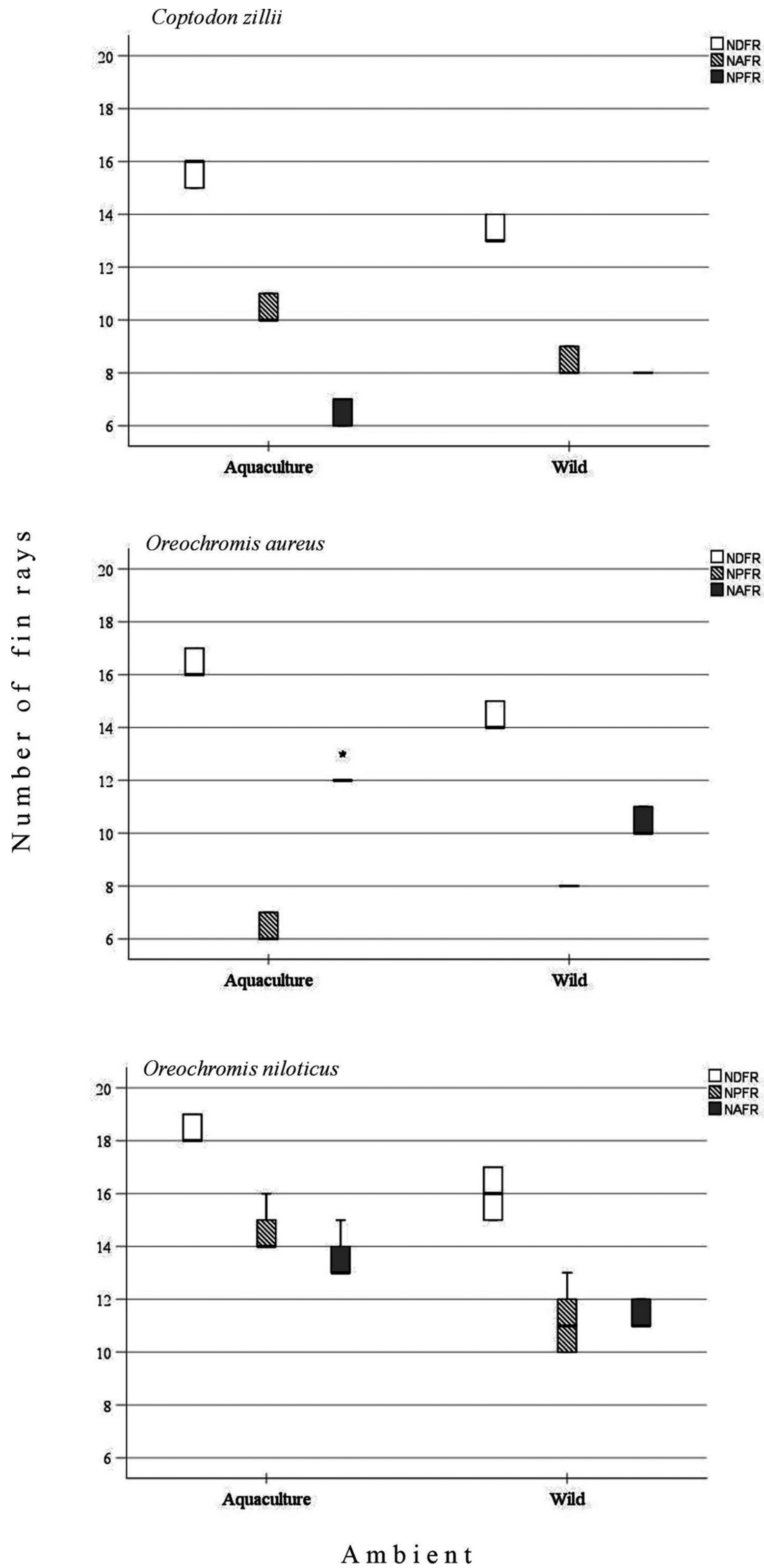

Figure 2

Boxplot. Samples from farmed and wild cichlids of three species: *C. zillii*, *O. aureus*, and *O. niloticus* were analyzed for three meristic characters: NPFR, NDFR, and NAFR. The mean ± standard error for each character was calculated. NAFR, number of anal fin rays; NDFR, number of dorsal fin rays; NPFR, number of pectoral fin rays.

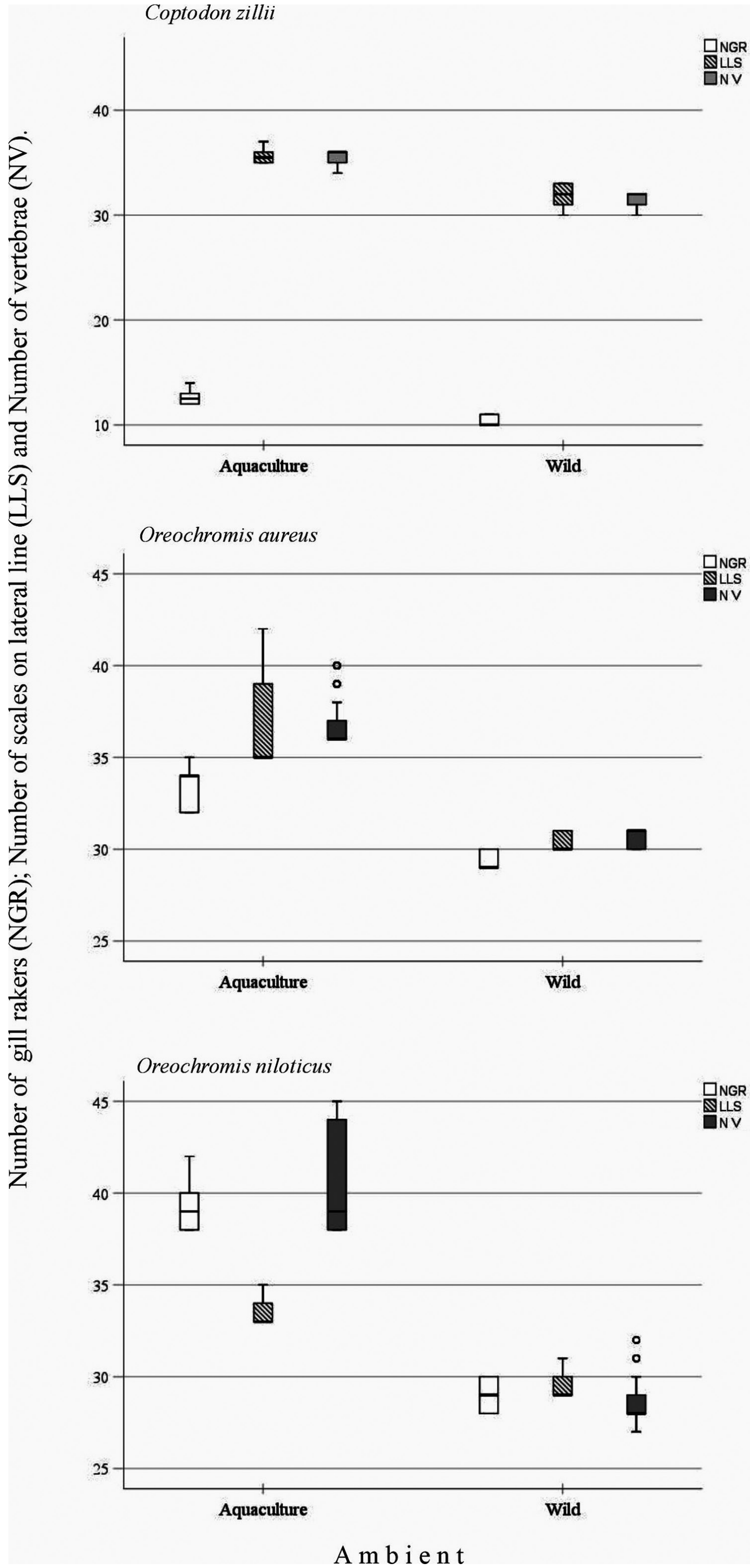

Figure 3

Boxplot. Three meristic characteristics (number of gills rakers on the first gill arch [NGR], NV, and number of LLS) and for both wild and farmed specimens of three cichlid species (*O. niloticus, C. zillii, and O. aureus*) are shown by the mean ± standard error. LLS, scales on the lateral line; NGR, number of gill rakers; NV, number of vertebrae.

observed, for example, for *O. aureus* and *for O. niloticus,* than for the NGR, LLS, and NV variables, with quartiles showing bias towards higher values, as well as whiskers. The rest of the variables show very low variation.

The cross-validated discriminant analysis using morphometric characters from all 896 specimens correctly classified 93.9% by variant of each species (Wilk's lambda = 2.63 E–8, $p < 0.001$). The lowest classification rate, 73.0%, was achieved using samples from *Oreochromis niloticus* from the wild (OAW), while samples from *C. zillii* from aquaculture and wild were the best, with a validated correct classification of 100.0, as well as *O. aureus* and *O. niloticus* from aquaculture (Table 2). Cross-validated analysis misclassified specimens from wild *O. niloticus*, where 8.4% were misclassified with *O. niloticus* from aquaculture (Table 2).

4. Discussion

It is widely believed that fish, being aquatic creatures, are particularly vulnerable to environmental and genetic influences on their external characteristics (Currens et al., 1989; Wainwright et al., 1991). Scientists have found that both types of influences affect fish's appearance. Conversely, factors beyond genetics and the environment, such as nutrition, have been found to modify the exterior features of crucian carp, *Carassius carassius* (L.), or enhance predator resistance, while optimal nutritional conditions have been noticed to induce a deeper body morphology in this species (Brönmark & Pettersson, 1994).

The three cichlid species studied were from the aquaculture facility and the wild. The samples from the first group, which lived in nature, were completely different from the samples from the second batch, which dwelt exclusively in the tanks. The disparities in the habitats induced dissimilarities in various morphological characteristics within the two lots of fish, which might indicate that such deviations are caused by ecological impacts, distinctions in the hereditary framework, or both.

Even so, disparities between feral and cultivated groups were primarily the outcome of habitat differentiations. Former reports demonstrated the main part of circumstances acting in morphological distinction among groups of inherently identical fish (Kinsey et al., 1994; Ryman et al., 1984).

Jawad et al. (2020) investigated the meristic features of the cichlid species *O. niloticus*, which is native to the Republic of Benin in West Africa, in an introduction study. A total of 5 meristic and 10 morphometric characteristics were determined and tallied in this investigation. In both the wild and farmed *O. niloticus* populations, the values of 6 for the number of pelvic rays and 31 for the number of scales on the LL were invariable. There was no significant difference in the NPFR ($p = 0.814$), anal fin rays ($p = 0.328$), and dorsal fin spines ($p = 0.255$) among the three other estimates. These three meristic traits had extremely comparable values.

Numerous morphological attributes (i.e., body color, size, and shape), behavioral issues, and immunological (changes in chief histocompatibility intricate), biochemical (isoenzymes), and molecular simple sequence length polymorphism (SSLP) (Sharp et al., 2002) attributes have been enjoyed recognizing distinct inbred stocks. Yet, different from other attempts, morphological assessment proposes substantial sums of records in a brief time with no need for utilizing advanced talent or costs. Combined with the use of box plots by regions (habitats) vs.

Table 2

Classification results[a] of discriminant analysis of morphometric variables for the three-cichlid species for aquacultured and wild variants.

Variants	Predicted group membership						Total
	CZA	CZW	OAA	OAW	ONA	ONW	
CZA	100.0	0	0	0	0	0	100.0
CZW	0	100.0	0	0	0	0	100.0
OAA	0	0	100.0	0	0	0	100.0
OAW	0	0	27.0	73.0	0	0	100.0
ONA	0	0	0	0	100.0	0	100.0
ONW	0	0	0	0	8.4	91.6	100.0

Total classification success for cross-validated predicted species variant membership.
[a]93.9% of cross-validated grouped cases correctly classified.
CZA, *Coptodon zillii* from aquaculture; CZW, *Coptodon zillii* from wild; OAA, *Oreochromis aureus* from aquaculture; OAW, *Oreochromis aureus* from wild; ONA, *Oreochromis niloticus* from aquaculture; ONW, *Oreochromis niloticus* from wild.

the parameters used in the current study, complete partitioning of wild and cultivated groups with significant changes in external features was noted. This finding proves that this technique is a convenient means for distinguishing between groups of the three cichlid species explored. Moreover, the nine body characteristics utilized in the current assessment played a major part in morphological discrimination.

This study found that compared to the wild group, samples from the aquaculture facility group had larger values for all nine body proportions. Possible causes of these differences between the two species' habitats include different water temperatures, turbidities, food availability, and water depths and flows. Specifically, variations in turbidity among the aquaculture establishment and the natural environment may have caused the increased eye dimension in the samples from the aquaculture facility group (Matthews & Robison, 1988). This was probably a significant habitation preference, which Aleev (1969) linked to the location of the eyes in the skull. These morphological discrepancies may possibly have originated from the discriminating rearing procedures utilized in aquaculture, inherited drift after establishing cohorts, or the distinct source of fish utilized in breeding groups (Karaiskou et al., 2009). Likewise, the aquaculture group's estimations of the meristic traits were higher than those of the feral group. This suggests that it was possible to distinguish between the two groups. Furthermore, there seemed to be intraspecific variances since the two groups' meristic estimation trends were not equal or similar.

The present investigation onto the evaluation of the three cichlid species' wild and farmed populations uncovered differences in meristic traits and highlighted the most prominent distinctions between the two sets of fish. In the feral group, the range of modification in meristic characteristics, such as the NDFR, anal fin rays, NGR on the 1st gill arch, number of scales on the LL, and NV, was higher in the samples attained from the aquaculture facility than those of the feral groups of the three cichlid species searched. In addition, the number of pectoral fin ray counts was observed to be higher also in the aquaculture samples of *C. zillii* than in those from the feral group of the same species (Table 1). Matsuoka (1987) and Boglione et al. (2003) stated results regarding these characteristics. The discrepancies in the range of the meristic attributes are believed to be impacted by both ecological and inherited issues (Foote et al., 1999); even so, in certain examples, various researchers (Davidson et al., 1985; Hedgecock et al., 1989; Kinsey et al., 1994; Shepherd, 1991) associated such inconsistencies primarily with habitat influences and phenotypical flexibility (Lindsey, 1981; Stearns, 1989; Swain & Foote, 1999; West-Eberhard, 1989).

The aquaculture group of the three cichlid species' morphological characteristics deviated from the familial model, as shown by the feral group, the body proved to be more powerful with more fin rays. This shift in body durability is in contrast to findings from research on marine-farmed salmon, where a reversal tendency toward feral fish was seen and deemed to be mostly caused by environmental factors (Fleming et al., 1994; Swain et al., 1991; Taylor, 1991). This could be attributed to the various methods of raising fish. Conversely, to the feral group of the three cichlid species, the aquaculture group fish were raised throughout their lifetimes and at no time came into interaction with the natural habitat. Likewise, they were put through a controlled, artificial variety test that focused on weight for fast development (Gjedrem et al., 1988), which possibly caused a noticeable change in depth (Gjerde & Schaeffer, 1989).

Since there were no previous investigations on the morphological and meristic attributes of the aquaculture and feral groups of *C. zillii* and *O. aureus* and investigations only exist on *O. niloticus*, discrepancies in fin morphological attributes of the aquaculture group of *O. niloticus* were likewise stated by other researchers (Anane-Taabeah, 2019; Ikpeme et al., 2017; Jawad et al., 2020; Tibihika et al., 2020). Non-interfering swimming diversification associated with unnatural selection likely followed significant degrees of fin nibbling (Abbott & Dill, 1985) and abrasion (Bosakowski & Wagner, 1994).

Enhanced food availability may have directly affected changes in the outward characteristics of the three cichlid species' aquaculture groups. The lack of predators in aquaculture facilities (Einum & Fleming, 1997; Johnsson et al., 1996) may have changed the focus to food opposition since selection against predator-vulnerable species has been loosened. The basis of such discrepancies in anti-predation actions may perhaps have been increased via development hormone discharge, and consequently, desire for food is initiated (Johnsson et al., 1996).

The quality of growth in the three cichlid species in aquaculture establishments was of a higher quality than that found in nature (Metcalfe et al., 1988), which was disturbed by factors such as lipid or weight levels and the pace of adjustments in growing proportions at the time (Thorpe, 1986). Such fast development degrees are inherited in the aquaculture samples (Thorpe, 1986). The current findings displayed that the aquaculture groups of the three cichlid species examined disclosed discrepancies in health apart from those of the feral group that originated from taming and were associated with planned and not deliberate choice. As greatly of this variation figured to be an adaptable reaction to the aquaculture setting, it can be of importance for plans endeavoring to develop aquaculture invention (Doyle et al., 1991). However, this dissimilarity poses a threat to wild communities when fish escape and compete with and breed with three wild cichlid species. There is increased competition for resources and the introduction of new genetic traits into feral populations when samples from aquaculture flow off into rivers. Due to the non-native origins of the aquaculture group and the variations that have emerged over farming, numerous of these characteristics are thought to be harmful to local ecosystems (Einum & Fleming, 1997). Although natural selection has the potential to rid wild populations of these superfluous traits, the annual influx of aquaculture populations makes this process very difficult, if not impossible.

The present finding that distinguishes between aquaculture and feral populations of the three cichlid species focused on the external and meristic features shown by the results of Barriga-Sosa et al. (2004) and Narváez et al. (2005), who stated the morphological discrepancies amid feral and aquaculture groups of Nile tilapia (*O. niloticus*). Researchers have classified such distinctions into the categories of food, environment, and surroundings (feral and farmed). However, in the current investigation, all meristic characteristics were significantly unlike between the groups studied, which disagrees with the study conducted by Solomon et al. (2015) on *Clarias gariepinus*.

Compared to other vertebrates, fishes often exhibit more variety in morphological traits within and between species as well as across groups. According to Allendorf (1988), Thompson (1991), and Wimberger (1992), the change signifies a shift in feed areas, predator types, accessibility to food, and additional environmental issues.

The morphological and meristic evaluations of aquaculture and feral groups of three cichlid species investigated in this study disclose substantial phenotypical deviations induced by habitat settings. Aquaculture groups frequently demonstrated differing attributes, like modified body outlines, such as deeper bodies and shorter caudal peduncles, with meristic modifications like fin ray or scale count disparities, accountable to breeding methods, such as regulated alimentation, decreased preying on, and expanse restraints. Conversely, feral groups demonstrated morphology adjusted for ecological niches, highlighting attributes correlated to the ability to search for food, hunter avoidance, and hydrodynamic capability. Such naturally evoked lack of correspondence emphasizes the part that phenotypical flexibility plays in cichlids, proposing that external feature disparity only may not suggest taxonomical differences. These conclusions warn against dependence on conventional morpho-taxonomic techniques, as conflicting attributes in regulated habitats might hide actual developmental links or mock species dispersal.

The perceived dissimilarities between reared and feral cichlid groups give emphasis to serious encounters for cichlid classification. In case the morphological attributes deviation is taken the wrong way as a genetic distinction, systemists imperil incorrectly dividing groups that live in the same habitat into dissimilar taxa or concealing valid species borders. As an example, flexibility in meristic attributes such as NDFR could precede to expanded species accounts, while body measurements merging in aquaculture might obscure differences between species. Highlights the need to combine hereditary, habitat, and biogeographical information with conventional morphological methods to delimit species correctly. Likewise, such outcomes recommend a re-inspection of historic categorizations, specifically for cichlids with prevalent breeding instigations, where non-natural collection and habitat impacts could pose difficulties for taxonomic precision. Finally, these visions are a support for adaptable classification contexts that credit phenotypical flexibility, guaranteeing vigorous species control and protection approaches in both natural and man-made changed habitats.

Data for *C. zillii*, *O. aureus*, and *O. niloticus* from the wild and from the aquaculture facility after 2018–2019 sampling period were unavailable due to exceptionally low wild population density at the sampling site. Consequently, the analysis focuses on the datasets where robust paired comparisons between wild and farmed stocks were feasible. While this study utilized data from 2018 to 2019, its findings remain highly relevant. The results establish a crucial baseline for the morphological characteristics of key cichlid species in central Iraq prior to the accelerated environmental changes observed in recent years. The demonstrated efficacy of morphometric and meristic analysis for discriminating between wild and farmed stocks provides a cost-effective tool for ongoing monitoring programs. This is essential for managing potential ecological interactions, such as interbreeding or competition, between escaped aquaculture fish and native wild populations. Future studies building upon this baseline will be critical for assessing the long-term impacts of aquaculture and climate change on Iraq's aquatic biodiversity.

Further investigations on the operational meaning of the morphological distinctions attained in the existing examination on the three cichlid fish species might aid in explaining the influence of morphological discrepancy on the endurance of aquaculture samples in the wild. To conduct more comprehensive assessments of the impact of escaped fish samples from an aquaculture facility on feral fish groups or fishery landings or to evaluate supplying plans, collaborative methodology such as genetic, morphometric, and other biological markers (e.g., size and otolith growth patterns, fatty acids, and trace elements) will be used. This will help with the creation of plans for the long-term preservation and sustainability of natural stock and will also significantly enhance our knowledge of the species' biology and ecology.

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There are no financial or personal conflicts of interest that might have impacted this work.

Data availability statement

Upon reasonable request, the corresponding author may provide the data supporting the investigation's findings.

Ethics statement

This study used commercially caught fish. Ethics doesn't apply.

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Supplementary Materials

Table S1

Correlation matrix with the transformation of ratios of each measure by TL

	SL	HL	ED	BD	PreDFL	PosDFL	PrePFL	PreAFL
SL	1.000							
HL	0.041	1.000						
ED	−0.266	0.055	1.000					
BD	0.552	−0.016	−0.549	1.000				
PreDFL	0.186	0.018	0.041	0.580	1.000			
PosDFL	0.543	0.099	−0.631	0.976	0.519	1.000		
PreDFL	−0.216	−0.149	0.903	−0.531	0.093	−0.644	1.000	
PreAFL	0.441	0.449	−0.773	0.687	0.226	0.783	−0.802	1.000

BD, body depth; ED, eye diameter; HL, head length; PosDFL, postdorsal fin length; PreAFL, preanal fin length; PreDFL, predorsal fin length; PrePFL, prepectoral fin length; SL, standard length; TL, total length.