BULLETIN OF THE IRAQ NATURAL HISTORY MUSEUM
Iraq Natural History Research Center & Museum, University of Baghdad
https://jnhm.uobaghdad.edu.iq/index.php/BINHM/Home
Copyright © Bulletin of the Iraq Natural History Museum Online ISSN: 2311-9799, Print ISSN: 1017-8678

Bull. Iraq nat. Hist. Mus.
(2026) 19 (1): 139-193. https://doi.org/10.26842/binhm.7.2026.19.1.0139

ORIGINAL ARTICLE

OSTEOLOGICAL FEATURES OF THE AXIAL SKELETON OF TWO FRESHWATER FISHES FROM IRAQ

Fatema Ali Al Fatle* and Laith A. Jawad**♦

*Department of Biology, College of Science, University of Baghdad, Baghdad, Iraq.
**School of Environmental and Animal Sciences, Unitec Institute of Technology, 139 Carrington Road, Mt Albert, Auckland 1025, New Zealand.
♦Corresponding author: laith_Jawad@hotmail.com

Received: 7 Sep. 2025, Revised: 30 Jan. 2026, Accepted: 31 Jan. 2026, Published:20 June 2026

ABSTRACT

The present study is the first to provide a comprehensive analysis of the vertebral column, fin structure, and tail skeleton of *Cyprinus carpio* Linnaeus, 1758 and *Leuciscus vorax* (Heckel, 1843) (Cypriniformes, Cyprinidae), which were collected from Al-Tharthar on the Euphrates and from the Tigris River at Az Zubaydiyah City, Wasit Province-middle of Iraq, respectively. Radiographic imaging was used to investigate various traits of the vertebral column and caudal skeleton. These characteristics were verified for the two species studied. The outcomes disclose that osteological data vary among the two species examined, emphasising that the construction of the vertebral column and caudal skeleton can be deliberated as important gears in the taxonomic classification of *C. carpio* and *L. vorax*. This new set of anatomical characteristics contributes to an improved comprehension of the taxonomy and systematics of the two species in question. The functional or evolutionary significance of the osteological traits examined in these species is discussed.

Keywords: Anatomy, *Cyprinus*, Interdigitation, *Leuciscus*, Pterygiophore, Taxonomy.

INTRODUCTION

The status of freshwater fish in Iraq has recently been assessed, and an updated checklist of this fish group was published by Çiçek *et al*. (2023), in which they suggested that there are 98 species of freshwater fish identified in Iraq, belonging to 28 families and 56 genera among 16 orders. The proportion of foreign species is 21.4%, with three species being native to Iraq at 3.0%. There is a total of 57 species in Cypriniformes, 12 in Siluriformes, 6 in Mugiliformes and Cyprinodontiformes, 3 in Acanthuriformes and Cichliformes, 2 in Centrarchiformes and Gobiiformes, and one species in each of the remaining orders in Iraq's ichthyofauna (Çiçek *et al*., 2023). The carp family contains the largest number of species (28) and represents 28.3% of all species, followed by the Nemacheilidae with 16 species, the Leuciscidae with 8, the Mugilidae with 6, the Sisoridae with 5, and the Xenocyprididae with four (Mohammed *et al*., 2024).

The maximum length, weight, and longevity for *Leuciscus vorax* (Heckel, 1843) are 1020 mm, 10.0 kg, and 24 years, respectively (Al-Zaidy and Parisi, 2025). Based on a study conducted by Al-Zaidy and Parisi (2025) with regard to the feeding habits of *L. vorax* along the Major Channel Exhaust in Al-Qadisiyah Province, the fish were reported to be most active between August and November and less active between December and February. According to Al-Zaidy and Parisi (2025), *L. vorax* is assumed to be a predator, with the portions of its diet varying throughout its lifespan.

Members of the Cyprinidae family are generally described as the most abundant and widespread fish in the inland waters of Iraq (Hadi *et al.*, 2023 a). *Cyprinus carpio* Linnaeus, 1758 “was imported by the government into Iraq from 1960 to 1972” (Jawad, 2003). Hadi *et al*. (2023b) also reported this species as an exotic species._This species was introduced into Iraq by the government during the period 1960–1972 (Jawad, 2003). Hadi *et al*. (2024) also indicated that this species is considered an exotic fish.

Cyprinus carpio is a freshwater species that occasionally moves into briny water (Riede, 2004). It is widespread across Europe to Asia, including reports from the Black Sea, Caspian Sea, and Aral Sea basins. Furthermore, this species has established itself globally (Kottelat and Freyhof, 2007).

Considerable debate exists on the morphological characteristics that should define the tribe Cyprinini (Yang *et al*., 2010). According to Rendahl (1928), the tribe Cyprinini includes species that have a serrated spinous anal-fin ray or serrated anal spine (the last unbranching fin ray becomes hardened and has a serrated end) and an oblong dorsal fin with no fewer than 14-pronged rays. To distinguish cyprinins from the presumed closely related barbins, these two traits proved most useful. Despite Rendahl's (1928) inclusion of just *Cyprinus* Linnaeus, 1758 and *Carassius* Jarocki, 1822; Yang *et al*. (2010) state that the Cyprinini currently encompass four genera: *Cyprinus*, *Carassius*, *Carassioides* Oshima 1926, and *Procypris* L., 1933. This proof rendered Rendahl's (1928) categorization of the Cyprinini tribe invalid, leading to the widespread abandonment of his view. In contrast, Fang (1936) proposed a single characteristic—a serrated anal spine—as a means of categorising the tribe Cyprinini, and several follow-up studies corroborated this idea (e.g., Wang, 1979; Zhou and Chu 1986).

Chen *et al*. (1984) and Coburn and Cavender (1992) provided morphological evidence that supported the monophyly of the tribe Cyprinini sensu Fang, 1936. Established only on the barbel count and pharyngeal teeth shape, Chen and Huang (1977) and Wang (1979) explored the taxonomic relationships and groupings of cyprinid genera. In contrast to Rainboth (1981), who was hesitant to restrict the tribe Cyprinini to only these four genera, Zhou (1989) found evidence supporting the monophyly of the group consisting of *Cyprinus*, *Carassius*, *Carassioides*, and *Procypris.*

The majority of molecular studies on cyprinids use a small number of species, such as *Cyprinus carpio* and maybe one or two species of *Carassius*, to define the Cyprinini tribe. Such an arrangement makes testing the monophyly of the Cyprinini tribe extremely difficult and compounds the difficulty of finding their relationships to other cyprinine tribes (Yang *et al*., 2010).

Notwithstanding the zoogeographic and ichthyological significance of Iraq's freshwater fauna, there is a need for investigations to identify new taxonomic characteristics that validate the uniqueness of fish species besides the conventional morphological and molecular features (Çiçek *et al*., 2023).

It has been revealed in many findings that osteological characteristics comprise reliable data for such proof. Through osteological examinations focusing on bone morphology, fish species can be precisely recognized (Ward and Brainerd, 2007; Jawad, 2015). Vertebral column regional variations such as the length and width of vertebrae alongside their length has always been perceived in vertebrae (Jawad and Clements, 2004; Ward and Brainerd, 2007; Jawad, 2008; Jawad and Jig, 2016; Jawad *et al*., 2018). Biometric techniques have been used to differentiate diverse regions of the vertebral column (Jawad *et al*., 2014; Jawad, 2015). Hollister (1941) and Gosline (1971) conducted significant research on identifying parts within the tail fin skeleton. The tail fin skeleton is of utmost significance in fish investigation for physical, evolutionary, and operating analyses (Schultze and Arratia, 1989), worth highlighting since Nybelin's founding work in 1963. Osteological features provide a concealed insight into fish evolution, bone homologies, fish nomenclature, and fish taxonomy, facilitating the categorization of various fish species based on their skeletal structures. Perceptions based on fish species' evolutionary history also been suggested. In addition, these characteristics have been found to exhibit greater character consistency than non-osteological (soft tissue) traits when analyzed using molecular phylogenies, indicating a potential for use in evolutionary reconstructions. Accurate identification of fish species is essential, as biodiversity of freshwater fish is constantly increasing in Iraq. This research also seeks to provide a more detailed description of *C. carpio* and *L. vorax* by using morphological and molecular data. Additionally, it intends to introduce a new suite of characters influencing osteological traits and to develop mathematical models that connect these characters.

The goals of this examination are as follows: (1) to calculate the overlap formulas of the dorsal and anal fin pterygiophores with the neural and haemal spines of the vertebrae, together with the configuration of the fins' axial and adaxial procurrent posterior rays; (2) to examine the structure and biometrics of the vertebral column; (3) to describe the intermuscular bones (IMB) and their distribution in the body of *C. carpio* and *L. vorax* species**;** and (4) to generate an inclusive database of added bony features previously applied in the identification of *L. vorax* and *C. carpio* species. These findings aim to refine the taxonomic framework for *L. vorax* and *C. carpio* species in general, providing a more accurate basis for distinguishing between these species within their genera.

MATERIALS AND METHODS

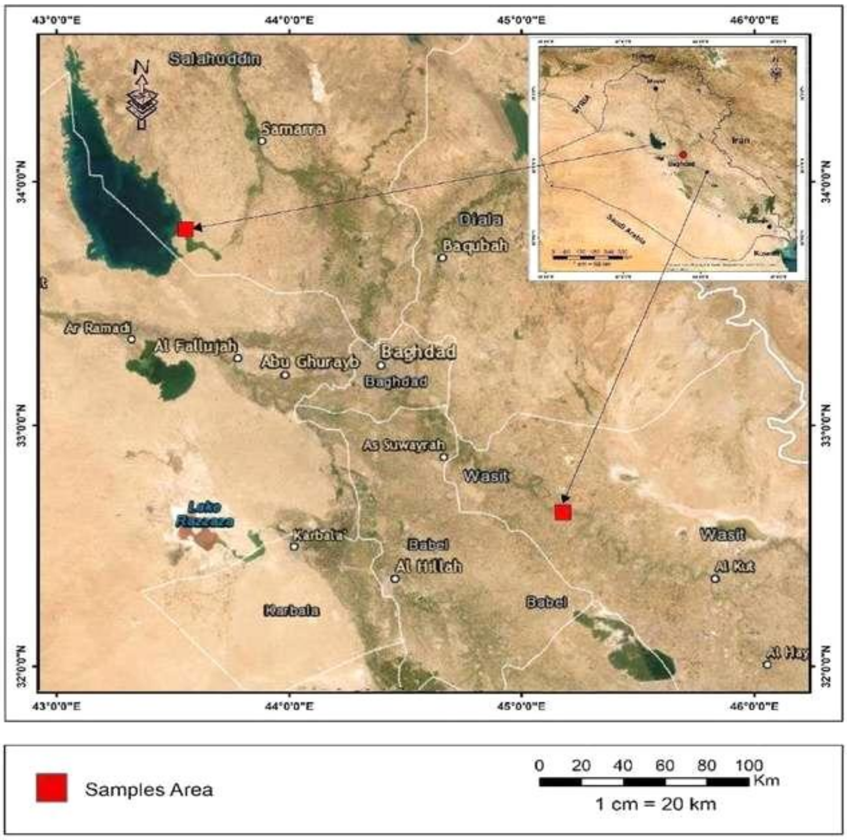
Specimens collection: Twenty specimens from each of the two species, *C. carpio* and *L. vorax* (Pl. 1 a, b), were collected using gill net and throwing net equipment from the man-made lake, Al-Tharthar at the Euphrates River, Al Anbar Province and from the Tigris River at

Az Zubaydiyah City, Wasit Province. The fish species examined were identified following Coad (2010). To the nearest millimetre, the total and standard lengths of the fish were measured using a ruler and always taken point-to-point to prevent projections errors. Measuring techniques were based on Hubbs *et al*. (2004). Standard length (SL) was determined by measuring the distance from the tip of the snout to the posterior end of the hypural complex. The measurement of total length (TL) was taken from the tip of the snout to the end of the caudal fin. Fish specimens were radiographed for 2.1 seconds using an X-ray device designed for veterinary digital radiography, model Vetix P8, manufactured by Shenzhen Mindray Animal Technology Co., Ltd., Shenzhen, China, located at Baghdad Veterinary Hospital, Iraq. The radiographs were used to visualize fish skeletal structures. Specimens of both fish species were deposited in the zoological collection of the College of Science, University of Baghdad, Iraq.

Plate (1): Fish species were studied in the current study; (A) *Cyprinus carpio*, 190 mm SL, 230 mm TL, (B) *Leuciscus vorax*, 310 mm SL, 360 mm TL.

Ethics statement: This work is based on commercial fish species, and the specimens were collected from a commercial catch. Therefore, ethical aspects are not applicable.

Study area: Specimens of *C. carpio* were taken at Al-Tharthar Lake, which is located 120 km northwest of Baghdad, between the rivers Tigris and Euphrates (33°58′N 43°11′E), (Pl. 2). The lake covers between 1875 and 2710 km², with a maximum depth of 68.4 m (Kornijów *et al*., 2001). In Iraq, Tharthar Lake is located north of Anbar province and northwest of Tikrit (Zdanowski *et al*., 2001). It is among the largest natural reservoirs in Iraq. It was constructed in 1956 AD and it connects the artificial Tharthar Lake to the Tigris and Euphrates rivers and it can to retain has the ability to retain surplus water from the River Tigris during the overflow season, which is diverted through a canal through Samarra Dam, in Samarra City, constructed in 1955 (Al-Ubaidy, 2009; Oleiwi and Al-Dabbas, 2022). Az Zubaydiyah City is in southeastern Baghdad, about 50 kilometres south of Al-Suwaira City and 85 kilometres north of Kut City (32°45'46.6"N 45°10'48. 7"E) (Map 1). The Tigris River at Az Zubaydiyah City lies in a semi-arid to arid region, where annual rainfall rarely exceeds 166 mm/year, making the river a critical water source. In Az Zubaydiyah City, the Tigris River crosses flat alluvium lands, within the Mesopotamian Basin, with good soil that is suitable for agriculture; nevertheless, it is very sensitive to deposition and salt accumulation (Al-Ansari *et al*., 2019; Al-Ansari *et al*., 2021).



Map (1): Map (1): Collection localities of *Cyprinus carpio* and *Leuciscus vorax*.

Materials examined: *Cyprinus carpio*: 20, 130 – 370 mm SL, 162 – 452 mm TL; man-made lake Al-Tharthar, F. Al-Fatle, 23 October – 17 November 2024.

Leuciscus vorax: 20, 161 – 331 mm SL, 192 – 352 mm TL; Tigris River at Az Zubaydiyah City, F. Al-Fatle, 18 October – 01 November 2024.

Osteological features of the axial skeleton

Vertebral column architecture: The configuration of a fish's vertebral column can be embodied by the following formula, adjusted to describe the characteristics of the studied *C. carpio* and *L. vorax* species: $T = (a_1)\ A\ (i) + C$. In this formula, (T) signifies the total number of vertebrae, (a_1) represents the number of predorsal vertebrae situated anterior to the first dorsal-fin pterygophore, (A) designates the number of abdominal vertebrae, (i) denotes the number of intermediate vertebrae—abdominal vertebrae with merged parapophyses and no articulation with ribs, and (C) implies the total number of caudal vertebrae, including the final compound preural centra. Usually, this formula involves five characters that define exclusive vertebral appearances and could be restricted to the species (Tab. 1, Pl. 2). A representative set of caudal and trunk fish vertebrae is illustrated in Figure (1).

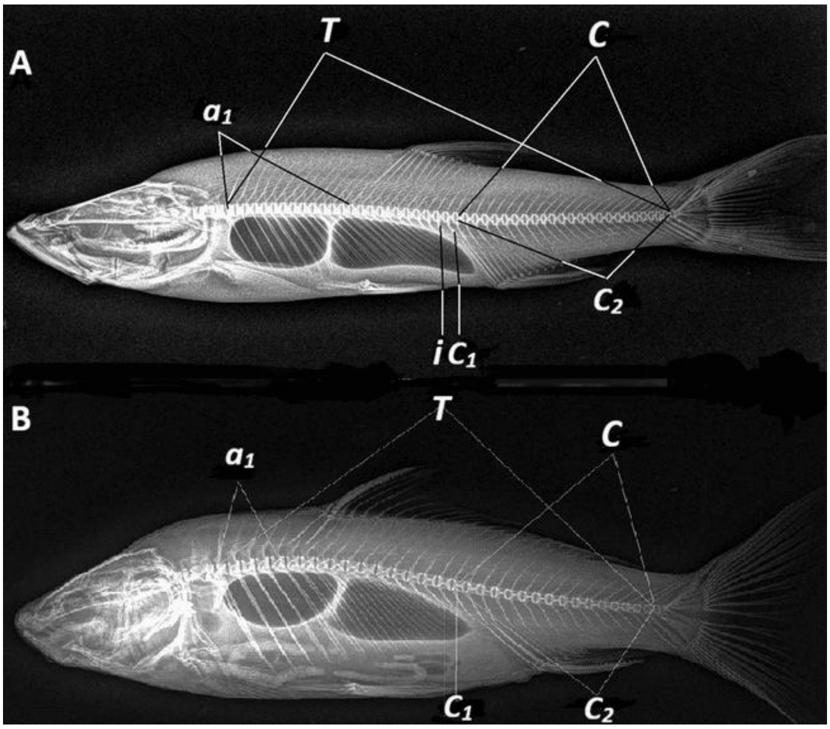


Plate (2): (A) *Leuciscus vorax*, 241 mm SL, 281 mm TL, (B) *Cyprinus carpio*, 190 mm SL, 230 mm TL. The radiograph clearly illustrates the terminology used to describe the vertebral column's construction.[(T), total number of vertebrae; (A), number of abdominal vertebrae; (C), number of caudal vertebrae, excluding the last complex of preural centra; (i) This represents the total number of intermediate vertebrae, which are those in the abdominal region that lack articulation with the ribs because their parapophyses have merged to the centra; (C1) count of caudal vertebrae that are before the first anal fin pterygophore, referred to as preanal vertebrae; (C2) number of caudal vertebrae, or postanal vertebrae, behind the first anal pterygophore].

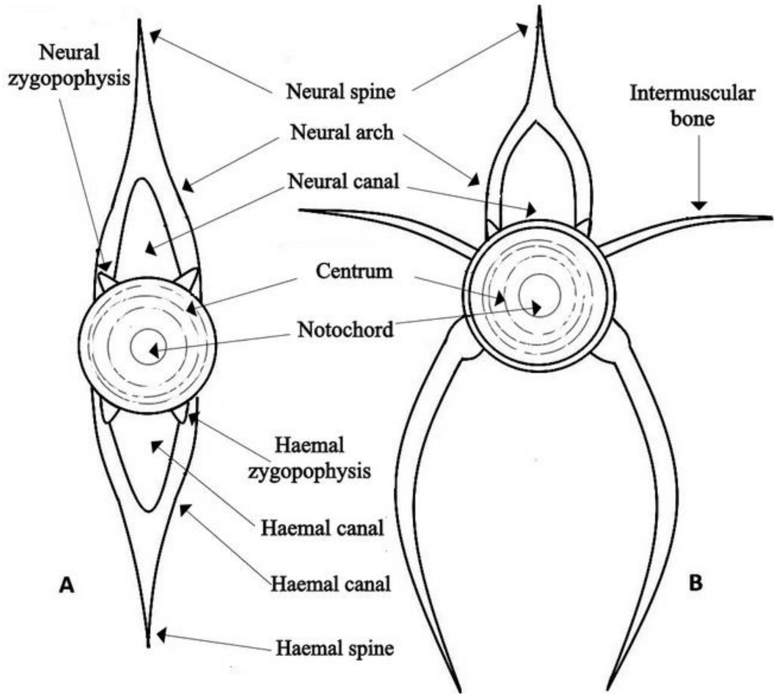


Figure (1): A, caudal; B, trunk (abdominal) fish vertebrae. Illustrative sketches.

Regionalization of the Vertebral Column: For assessments of the vertebral column, the vertebral centrum was measured in two diameters: vertebral height (*VH*), which corresponds to the greatest vertical measurement on the lateral side of the vertebra, and vertebral length (*VL*), referring to the length of the vertebra along the left mid-ventral line. Both measurements were obtained from X-ray images (see Pl. 3). Vertebral sizes were calculated into the vertebral index (Vi) as described by Ramzu and Meunier (1999), in order to enable subsequent comparisons with other samples, including a different species:

Vi = P/SL where *P* corresponds to the vertebral measure (either *VL* or *VH*) and *SL* is the standard length.

A graphic representation of the vertebral column was obtained by plotting VL and VH against the ordinal position of each vertebra in the series from the species *C. carpio* and *L. vorax* (Diag. 1). Thoracic vertebrae were categorized as those positioned anterior to the vertebrae with disconnected haemal arches, while the caudal zone was the area from the first united haemal arch to the last centrum incorporating the ural centrum. An ANOVA test was performed in order to determine if vertebral sizes among different portions of the column were significantly different.

Osteological features of the axial skeleton

Dorsal fin

Pterygiophore interdigitation with the neural spines of the dorsal fin: During this study, the modified gobioidis Dorsal fin formula was created (Birdsong, 1975, Birdsong *et al.*, 1988) and carangids dorsal fin formula was developed (Springer and Smith- Vaniz, 2008) (see Tab. 2). This formula enables the evaluation of the grouping and associations of the spiny dorsal fin pterygiophores with the vertebrae. The constituents of the formulation are as follows: (i) The letter N signifies the neural spine of the fifth vertebra; (ii) the digits, separated by hyphens, signify a sequence of interneural places positioned posterior to the fifth vertebra, with the numbers representing the number of pterygiophores placed there; (iii) The total number of neural spines connected to matching pterygiophores at the end of the dorsal fins is represented by the superior numeral. If a pterygiophore is placed facing a neural spine, it is denoted with an asterisk (*) (for example, 5-N-1-0-1^2-2-1*-0-1^5-0-1*-0-1*-0-1*-1).

Anal fin

Interdigitation of the pterygiophore with the anal fin's hemal spines: We created both the dorsal-fin and anal-fin formulas (Tab. 2). The formula comprises the subsequent components: (i) the letter "C" signifies the haemal spine of the first caudal vertebra; (ii) the Arabic numbers nearby to the letter "C" designate the interhaemal places engaged by anal fin pterygiophores; (iii) the digits, separated by hyphens, represent the succession of interhaemal places, with the numbers representing the count of pterygiophores existing in those locations; and (iv) the anal fin's pterygiophores correspond to the whole number of haemal spines, as shown by the superior number (e.g., 1-C-2-1-1*-1-1*-1-1*-1-1*).

Caudal fin formula: The caudal rays were referred to as "principal" or "procurrent" fin rays. Hubbs and Lagler (1947) considered the branched caudal fin rays, as well as the most ventral and dorsal unbranched rays, as the principal caudal fin rays. Rays were counted continuously from the midline towards the dorsal and ventral sides. The caudal-fin formula first proposed by Fricke (1983) to describe the arrangement of caudal fins in callionymid and draconettid fishes was refined and used in this investigation. Changes were necessary to adapt this formula to the caudal fin characteristics of species within the two species that we examined. The distribution of both divided and undivided rays in the caudal fin is described in the following way: (i) the leftmost Roman numeral represents the top lobe's number of undivided subdivided soft rays; (ii) the top lobe's number of segmented branching soft rays is indicated by the Arabic numeral; (iii) the two counts of lobes are separated by a dashed line; (iv) the numeric representation in Arabic designates the quantity of segmented branching soft rays in the inferior lobe; and (v) in the lower lobe, the Roman number represents the count of undivided soft rays.

Dorsal procurrent caudal fin distribution formula: Dorsalprocurrent caudal-fin ray assembly formula is presented for *C. carpio* and *L. vorax*. This formula is intended to enable assessments of the organization and links of the procurrent caudal-fin rays with the parts of the caudal skeleton. The basics that follow are necessary for the formula to work: (i) the symbols (NSPU2-NSPU4) denote the neural spines of the second to fourth preural vertebrae; (ii) an Arabic numeral denoting the number of procurrent caudal-fin rays positioned between the neural spines of the second and fourth preural vertebrae; (iii) the letter "E" denoting the epural bone; and (iv) the letters “PLS” for the pleurostyle. The procurrent ray is represented in the letter “0” meaning no procurrent ray. Presence of a procurrent ray on any of the caudal fin skeleton, is indicated by an asterisk (*) (Tab. 3).

Ventral procurrent caudal fin distribution formula: Ventral procurrent caudal-fin ray assembly follows a similar formula as dorsal procurrent caudal-fin ray assembly. However, it clearly shows HSPU2-4, which stands for the haemal spines of the second to fourth preural vertebrae, and PH, which demonstrates the parhypural bone (Tab. 3).

Caudal fin structure description: This section defines the bones that make up the caudal fin structure of the two fish examined, *C. carpio* and *L. vorax*, with emphasis on the differences in their composition between the two species. The subsequent bones will be considered alongside the differences in their configuration between the two species examined, the neural spine of the second preural vertebra, epural, pleurostyle, uroneural, neural arch of the second preural vertebra, hypural bones, parhypural bone, haemal spine of the second preural vertebra, as well as the neural, hypural, and parhypural foramina (Pl. 4). The size of the bones is determined by the form of the bones in (Tab. 4), which is in accordance with the profiles of the bones in Tables (4, 5) and Plate (4). The osteological vocabulary is from Haedrich (1967). According to Rosen and Patterson (1969) and Rosen (1973), the vertebrae that are considered ultimate, penultimate, and antepenultimate are called first preural (PU1), second preural (PU2), and third preural (PU3), respectively.

Intermuscular bones (IMB) and hypomerals (HM): The IMB were located on the caudal and trunk parts of the fish body and the intermuscular HM were investigated for *C. carpio* and *L. vorax* using X-rays. These bones were distinct to count them and to note their shape and dissemination. The total number of each kind of the IMB, the straight pin and the Y pin in *C. carpio* and the straight pin in *L. vorax* were computed as follows: Total number of the straight pin bone (S) = number of S pin bones in the dorsal most-posterior upper caudal region + the number of S in the dorsal most-posterior ventral caudal region X 2 both sides. Total number of the Y pin bone (Y) = the number of Y pin bones dispersed in the line dorsal to the vertebral column + the number of Y pin bones distributed in the line ventral to the vertebral column X 2 sides. The intermuscular HM as follows: Total number of intermuscular HM = the number of intermuscular HM found between the head and the pelvic fin + the number of intermuscular HM found between the pelvic fin and the anal fin.

RESULTS

Vertebral Column Architecture

Plate (2) shows the characteristics of the vertebral column of *C. carpio* and *L. vorax*, collected from inland waters of Iraq. In comparison to *L. vorax*, which has 47 vertebrae, *C. carpio* has just 29 (Tab. 1).

The number of vertebrae ranges from four in *L. vorax* to five in *C. carpio*. Across the species studied (Tab. 1). The formula of the configuration of the vertebral column showed variable patterns in the examined specimens of *C. carpio* and *L. vorax*. In *C. carpio*, the results showed that there are three common patterns that were repeated in the specimens examined. These are: T (31) = (5)16(1) + (1)15(14), T (32) = (5)17(1) + 1(15)14, and T (32) = (5)17(1) + (1)16(15). Out of 21 examined specimens of *C. carpio*, the pattern T (31) = (5)16(1) + (1)15(14) is observed in two specimens representing 9.52%, the common patter is T (32) = (5)17(1) + 1(15)14 is noted in three specimens signifying 14.29%, then the following pattern T (32) = (5)17(1) + (1)16(15) detected in two specimens each denoting 9.52% each. The remaining 16 patterns are variable patterns that differ from each in certain component of the formulation of the configuration of the vertebral column. These fluctuating patterns account for 76.19% of all patterns found in the 21 *C. carpio* fish specimens that were analyzed.

Table (1): The formula for the structure of the vertebral columns of *Cyprinus carpio* and *Leuciscus vorax* collected from the inland waters of Iraq. T: total vertebral number; A: number of abdominal vertebrae, including intermediate and Weberian vertebrae; a_1: number of predorsal vertebrae, i.e. vertebrae anterior to the first dorsal fin pterygiophore; *i*: the count of intermediate vertebrae, or abdominal vertebrae, which parapophises are joined to the centra and do not articulate with the ribs; c_1: number of preanal vertebrae, i.e. caudal vertebrae anterior to the first anal fin pterygophore; *C*, number of caudal vertebrae, excluding the last complex of preural centra; c_2: number of postanal vertebrae, i.e. caudal vertebrae posterior to the first anal pterygophore. The four Weberian vertebrae are included in this count.

$T = (a_1)\ A\ (i) + (c_1)\ C\ (c_2)$	
Cyprinus carpio	*Leuciscus vorax*
T = (31) = (5) 16 (1) + (1) 15 (14)	T = (46) = (14) 24 (4) + (1) 22 (21)
T = (33) = (5) 17 (1) + (0) 16 (16)	T = (47) = (15) 24 (5) + (0) 23 (23)
T = (30) = (5) 16 (2) + (1) 14 (13)	T = (48) = (15) 24 (4) + (0) 24 (24)
T = (32) = (4) 17 (1) + (1) 15 (14)	T = (48) = (15) 24 (4) + (0) 24 (24)
T = (33) = (5) 16 (1) + (1) 17 (16)	T = (47) = (15) 24 (4) + (0) 23 (23)
T = (31) = (5) 16 (2) + (0) 15 (15)	T = (47) = (14) 24 (5) + (0) 23 (23)
T = (32) = (5) 16 (1) + (1) 16 (15)	T = (47) = (15) 24 (4) + (0) 23 (23)
T = (32) = (5) 16 (2) + (1) 16 (15)	T = (47) = (15) 24 (4) + (0) 23 (23)
T = (31) = (5) 16 (2) + (1) 15 (14)	T = (47) = (15) 24 (4) + (0) 23 (23)
T = (32) = (5) 16 (2) + (1) 16 (15)	T = (47) = (15) 24 (3) + (0) 23 (23)
T = (32) = (5) 16 (1) + (1) 16 (15)	T = (47) = (15) 24 (4) + (0) 23 (23)
T = (32) = (5) 16 (2) + (1) 16 (15)	T = (47) = (14) 24 (4) + (0) 23 (23)
T = (31) = (5) 16 (1) + (1) 15 (14)	T = (46) = (14) 23 (4) + (0) 23 (23)
T = (31) = (5) 16 (2) + (1) 15 (14)	T = (47) = (15) 24 (4) + (0) 23 (23)
T = (32) = (5) 16 (1) + (1) 16 (15)	T = (46) = (15) 24 (4) + (0) 22 (22)
T = (32) = (5) 17 (1) + (1) 15 (14)	T = (47) = (14) 23 (4) + (0) 24 (24)
T = (32) = (5) 17 (1) + (1) 15 (14)	T = (47) = (15) 24 (4) + (0) 23 (23)
T = (32) = (5) 16 (1) + (1) 16 (15)	T = (47) = (15) 24 (4) + (0) 23 (23)
T = (32) = (5) 15 (0) + (1) 17 (16)	T = (46) = (14) 24 (4) + (0) 22 (22)
T = (29) = (5) 15 (2) + (0) 14 (14)	-
T = (31) = (4) 15 (2) + (1) 16 (15)	-

For *L. vorax*, the results showed that the formulation of the construction of the vertebral column is denoted by four main patterns each of which was detected in several individuals.

Out of the 19 specimens of *L. vorax* inspected, the different patterns are T = (46) = (15) 23 (4) + (0) 23 (23) was observed in eight specimens indicating 42.11%, T = (46) = (14) 23 (4) + (0) 23 (23) was also noted in three specimens representing 10.79%, T = (46) = (14) 24 (4) + (0) 22 (22) implied 10.53%., and T = (47) = (15) 24 (5) + (0) 23 (23) signified 10.53%. The leftover four varying patterns differ from each other in one or more elements of the formulation of the composition of the vertebral column represent 21.05% of the total number of models recorded in the specimens of *L. vorax* experimented. The number of predorsal vertebrae (a_1) demonstrated a narrow range, varying by two vertebral numbers in both *C. carpio* and *L. vorax*. The 21 specimens of *C. carpio* showed either four or five predorsal vertebrae, while the 19 specimens of *L. vorax* showed either 14 or 15 predorsal vertebrae (a_1) (Tab. 1).

In contrast to *L. vorax*, which had a range of 14 to 15 abdominal vertebrae (A), *C. carpio* had a range of 15 to 17 vertebrae (Tab. 1). The sum of intermediate vertebrae (i) extended from zero to two and from three to five in *C. carpio* and *L. vorax* respectively (Tab. 1). The number of preanal vertebrae (c_1) fluctuated between zero and one in both *C. carpio* and *L. vorax*, while the number of the caudal vertebrae changed between 14 and 17 in *C. carpio* and between 22 and 24 vertebrae in *L. vorax* (Tab. 1). The disparity in the number of the postanal vertebrae (c_2) slightly wider than that of the other components of the formulation of the construction of the vertebral column and ranged between 13 and 16 vertebrae in *C. carpio* and 21 and 24 vertebrae in *L. vorax*.

Regionalization of the Vertebral Column

In the vertebral column of *C. carpio* and L. vorax examined in the present study, there are six vertebrae situated immediately posterior to the Weberian apparatus (V5–V10). Their centra are at moderately less proportionate anteroposteriorly than in most other abdominal vertebrae. Surprisingly, the complex shape that develops from the attachment of the second and third vertebral centres provides articulation sites for the neural arches and parapophysis. Additionally, the neural arches of the third vertebra are much stronger than the ones in the abdominal vertebrae. Given the intricacy of the Weberian vertebrae and the difficulty in accurately depicting their limits, their measurements were excluded from the vertebral column study as a whole.

The vertebral columns of the examined *C. carpio* and *L. vorax* species contain 29 to 48 vertebrae. Every vertebra normally has a cylindrical appearance, with the centrum constructed by two hollow cones connected at their apexes. These two chordal cavities are linked by a little hole (Pl. 3). There are two major sectors that make up the vertebral axis: the anterior portion, which comprises the truncal vertebrae that lack haemal spines, and the caudal vertebrae, where two haemal arches are present, encircling a haemal spine (Pl. 3). The vertical line that marks them is on the first caudal vertebra. The caudalmost urophore-comprising vertebra presents a compound condition.

Sizes from all vertebrae imply a consistent pattern. Morphometric investigation exposes that the vertebral axis of *C. carpio* and *L. vorax* demonstrates a further complex split than earlier indicated by macroscopic notes. Grounded on the disparities in vertebral dimensions alongside the axis of the inspected two species, four distinct zones can be recognized: the postcranial zone positioned straight behind the four abdominal vertebrae developing the Weberian apparatus, the abdominal vertebral zone, which is separated into two sub-areas, the anterior and posterior abdominal vertebrae, and the caudal zone (Diag. 1).

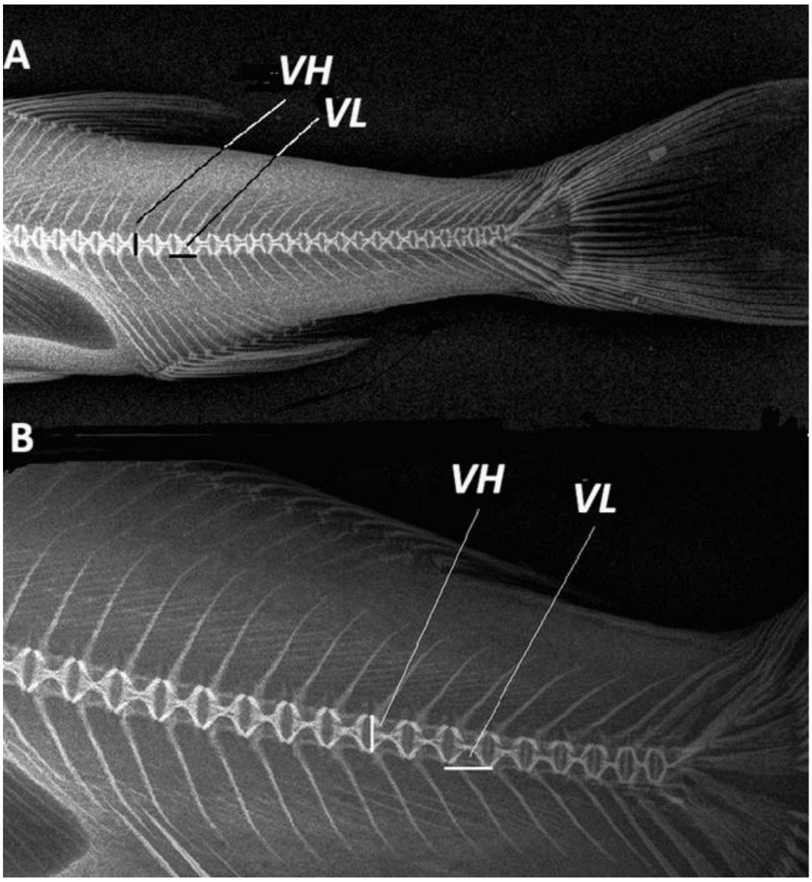


Plate (3): (A) *Leuciscus vorax*, 241 mm SL, 281 mm TL, (B) *Cyprinus carpio*, 190 mm SL, 230 mm TL. [vertebral measurements of vertebral height (VH) and vertebral length (VL) and the form of the vertebral centre].

Postcranial region

In the two studied species, the six abdominal vertebrae directly posterior to the Weberian apparatus (V5–V10) are dissimilar to the left abdominal vertebrae owing to adjustments correlated to the Weberian apparatus. The centra of these vertebrae are shorter in the anteroposterior dimension than those of other abdominal vertebrae. Irregularity in vertebral sizes (VL and VH) is apparent within the vertebral column of *C. carpio* and *L. vorax*.

In *C. carpio*, the VL in the postcranial region shows a rapid increase and VH shows a gradual increase, peaking at V10. However, in the case of *L. vorax* the increase in the vertebral size was gradual and reached the highest point at V10 (Diag. 1).

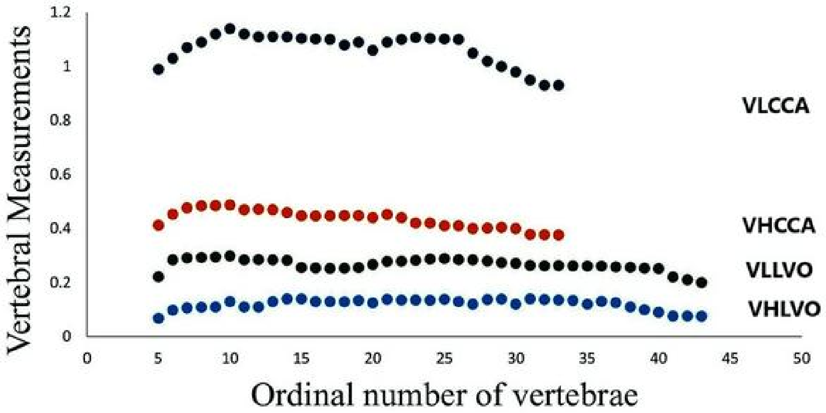


Diagram (1): Vertebral profiles by vertebral height (VH) and length (VL) of *Cyprinus carpio* and *Leuciscus vorax*. VHCCA, vertebral height of *Cyprinus carpio*; VLCCA, vertebral length of *Cyprinus carpio*; VHLVO, vertebral height of *Leuciscus vorax*; VLLVO, vertebral length of *Leuciscus vorax*.

Anterior abdominal region

The abdominal area of the vertebral column of *C. carpio* and *L. vorax* was shown to be divided into two sub-regions, the anterior and the posterior abdominal zones. In *C. carpio*, the anterior abdominal zone contains vertebrae V11–V20. In this zone, the highest vertebral values for VH are observed in V13 and the lowest value observed at V20, while the highest vertebral measurement values for VL are observed in V17 and the lowest value observed at V20, in *L. vorax*, the anterior abdominal zone includes vertebrae V21 – V30.

The highest vertebral measurement estimates for VH are observed in V15 and the lowest value observed at V20, while the highest vertebral measurement estimates for VL are observed in V24 and the lowest value observed at V20. In *C. carpio*, a steady tendency of increase was detected in the estimates of VH and VL, while a fast increase was observed in the values of VH and VL in *L. vorax*.

Posterior abdominal region

In *C. carpio*, the posterior abdominal zone comprises vertebrae V21 – V30. In this zone, the highest vertebral measurement values for VH are observed in V31 and the lowest value observed at V27. In *L. vorax*, the anterior abdominal zone includes vertebrae V26 – V40. The highest vertebral measurement estimates for VH is observed in V21 and the lowest value observed at V23. On the other hand, the highest vertebral measurement estimates for VL is observed in V32 and the lowest value observed at V31. A tendency of a steady increase was observed in the values of VH in both *C. carpio* species, while a slow increase was observed in the values of VL. In *L. vorax*, both values VH, and VL showed a steady increase.

Caudal region

In *C. carpio*, the caudal region comprises three vertebrae continuing to the last caudal vertebra. The overall trend in this region indicates a slow decrease in both vertebral measurement values (VH and VL). Conversely, in *L. vorax*, this region comprises six vertebrae that extend to the final caudal vertebra. The general course in this region implies a slow decrease in both vertebral measurement values (VH and VL).

Dorsal fin

Neural spines and dorsal fin pterygiophore interlace: The interdigitation length of the pterygiophore that supports the dorsal fin spines and rays, relative to the neural spines of the vertebral column, also differs between the species *C. carpio* and *L. vorax* examined. In *C. carpio*, the number of interneural spaces interdigitated with pterygiophores backing up the dorsal fin rays varies between three and nine, while in the case of *L. vorax*, this number differs between one and six (Tab. 2).

For both *C. carpio* and *L. vorax*, the formulas for the interdigitation of the pterygiophore with the neural spines of the dorsal fin, the first dorsal ray, has never been seen opposite the neural spine of any abdominal vertebra. Whereas, several of the pterygiophores that support other dorsal fin rays are located opposite the neural spines of abdominal vertebrae. The results indicate that the two species examined have different types of pterygiophores that are located opposite the neural spines of the abdominal vertebrae. For instance, the number of the incidences where pterygiophores opposite the neural spines of abdominal vertebrae occur ranges from one to four in *C. carpio*, while this number ranges between one and three. The number of the patterns of the formulae of the pterygiophore interdigitation with neural spines of dorsal showing no pterygiophore opposite the neural spine of the dorsal fin is five and 13 in *C. carpio* and *L. vorax* respectively.

Another difference between *L. vorax* and *C. carpio* is the number of vertebrae that support the dorsal fin. While nine abdominal vertebrae support the dorsal fin in *L. vorax*, eleven abdominal vertebrae and seven caudal vertebrae do the same in *C. carpio*.

A total of 19 distinct patterns exist in *C. carpio* for the interdigitation length of the pterygiophore that supports the dorsal fin spines; in contrast, *L. vorax* exhibits 18 distinct patterns with a single common pattern shared by two instances (14-N-1^9) (Tab. 2).

Table (2): Formula for interdigitating the anal fin pterygiophores with the haemal spines of *Cyprinus carpio* and *Leuciscus vorax* taken from Iraq's freshwater waterways. C, representing the haemal spine of the 1st caudal vertebra. N is the pterygiophore that supports the 1st dorsal fin spine.

Species	Interdigitation formulae for the dorsal fin and neural spines of the abdominal vertebrae	The anal fin pterygiophores' formula for interdigitation with the caudal vertebrae's haemal spines
Cyprinuscarpio	6-N-1^{3}-2-1^{6}-2-1^{4}-1*-0-1*-1^{3}	0-C-1-2-1^{2}-1*
	5-N-1^{2}-2-1^{3}-2-1^{6}-1*-1^{3}-1*-1^{2}	0-C-1^{5}-1*
	4- N-1^{4}-2-1^{12}-1*	0-C-1^{3}-1*-1^{2}
	4-N-1^{5}-2-1^{6}-0-1*-1-1*-1-1*-1	0-C-2-1^{3}-1*
	5-N-1-0-1^{2}-2-1*-0-1^{5}-0-1*-0-1*-0-1*-1	0-C-1^{6}
	4-N-1^{3}-2-1^{10}-1*-0-1*-1	0-C-1^{4}-2
	4-N-1-2-1^{12}	0-C-1^{4}-2
	3-N-1^{2}-2-1^{12}	0-C-1^{5}-1
	4-N-1^{7}-0-1^{10}	0-C-1^{3}-2
	4-N-1^{4}-2-1^{11}-2	0-C-0-1^{2}-2-1^{2}
	5-N-1^{4}-2-1^{10}-1*-1^{3}	0-C-1^{3}-2-1
	4-N-1^{4}-2-1^{13}	0-C-1^{4}-2
	4-N-1^{3}-2-1^{6}-1*-0-1*-1^{6}	0-C-1^{3}-2-1
	5-N-1^{3}-2-1^{5}-2-1^{7}-1*-0-1	0-C-2-1^{2}-2
	5-N-1^{7}-2-1^{6}-0-1*-1^{2}-1*-1	0-C-1^{2}-2-1
	5-N-1^{7}-2-1^{6}-1*-1^{2}-2	0-C-1^{2}-2-1-1*
	5-N-1^{8}-1^{2}-1*-1^{7}	0-C-1^{2}-2-1-1*
	5-N-1^{2}-2-1^{7}-2-0-1*-0-1*-1^{6}	0-C-1^{3}-2-1
	5-N-1^{6}-2-1^{3}-1*-1^{4}-1*-1	0-C-1-0-1-1^{2}-2
	4-N-1^{4}-2-1^{12}	0-C-1^{2}-2-1^{2}
	-	0-C-1^{6}-1*
Leuciscus vorax	14-N-1^{2}-0-1-2-1^{4}	1-C-2-1-1*-1-1*-1-1*-1-1*
	15-N-1^{2}-0-2-1^{4}	1-C-2-1-1*-2-1-2-1*
	15-N-1^{8}-1*	1-C-1^{2}-2-1-1*-1-2-1^{2}
	14-N-1^{5}-1*-1^{6}-1*-0-1*-1	1-C-1^{2}-2^{2}-1^{5}
	15-N-1^{7}-1*-1	1-C-1^{2}-2-1-1*-0-1*1-2-1*
	14-N- 1^{2}-0-1-2-1^{4}	2-C-1*-1^{3}-1*-1^{2}-2
	14-N-1^{2}-0-1^{3}-2-1*-2-1	1-C-1-1*-1-1*-1-1*-1^{5}
	14-N_ 1^{3}-2-1^{2}-0-1	1-C-1^{2}-2-1^{5}
	14-N-1^{5}-0-1*-1^{2}-1*	0-C-2-1^{2}-2-1-1*-1-1*-1-1-2
	14-N-1-0-1^{2}-2-1^{4}	2-C-0-1*-1-2-1-1*-1-1*
	14-N-1^{3}-2-1^{5}	2-C-2-1-2-1*-1^{2}-1*-1-2
	13-N-1-0-1^{2}-2-1^{3}-1*	1-C-1^{2}-2^{2}-1-2-1
	14-N-1^{9}	1-C-1^{4}-3-2-1*
	14-N-1^{9}	1-C-1*-0-1^{2}-2^{2}-1*-0-1*
	14-N-1^{6}-1*-1	2-C-1-2-1^{2}-1*-1-2-1
	13-N-1^{2}-0-1-2-1^{4}	1-C-1^{2}-2-1*-1^{6}
	14-N-1^{9}	1-C-1-2-1*-1-2-1^{3}
	14-N-1^{5}-2-1^{3}	2-C-1^{2}-2^{3}-1
	14-N-1^{2}-0-2-1^{5}	3-C-1^{2}-2^{3}-1
	13-N-1^{4}-0-1*-1^{6}	-

Anal fin

Pterygiophore interlace with haemal spines of the anal fin: *C. carpio* and *L. vorax* both have individual deviations in the number of patterns linking the pterygiophores to the haemal spines of the anal fin. The two species examined exhibited a wide range of patterns. In *C. carpio*, there are three common patterns. The most common pattern is observed in four formulae and two other common patterns are noted in two formulae for each of them (Tab. 2). In addition, there are 13 patterns with variable combinations of interdigitations. In *L. vorax*, there is only one common pattern observed in two formulae of the interlace of pterygiophores with the haemal spines of the anal fin. Moreover, there are 17 patterns with variable numbers of interdigitations. The length of the formulae for pterygiophore interdigitation also varies considerably between the two species examined. In *C. carpio*, the number of the filled spaces or interdigitation with the pterygiophores of the anal fin varies between four and seven, while in *L. vorax*, this number differs between seven and 12 (Tab. 2). The results also showed that the position directly posterior to the haemal spine of the first caudal vertebra is always filled with pterygiophore in *C. carpio*, while in *L. vorax*, it is either filled or vacant.

Formula for the distribution of dorsal procurrent caudal fins

The distribution of the dorsal procurrent rays is distinguished by its interdigitation with the neural spines of the preural vertebrae and the dorsal components of the caudal fin skeleton. In the case of *C. carpio*, three preural vertebrae are engaged in the process of interdigitation: the 2nd to 4th preural vertebrae, while four preural vertebrae were involved in the case of *L. vorax*: the second to fifth preural vertebrae (Tab. 3, Pl. 4).

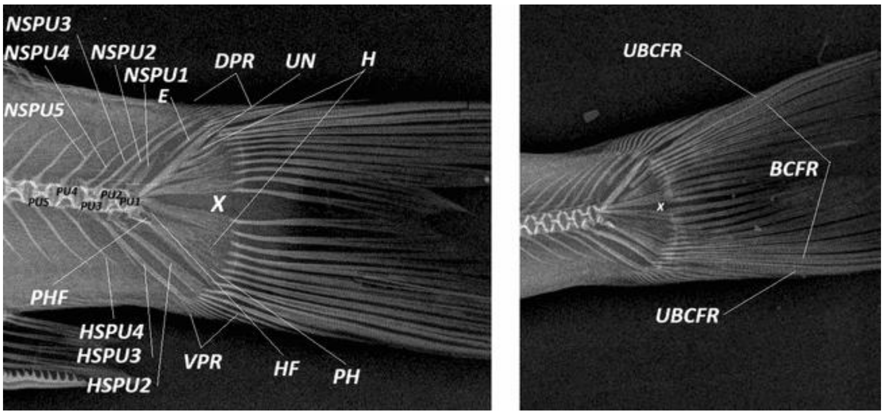


Plate (4): (A) *Cyprinus carpio*, 190 mm SL, 230 mm TL, showing the elements of the skeleton of the caudal fin, (B) *Leuciscus vorax*, 310 mm SL, 360 mm TL. [showing the branched and unbranched caudal fin rays and hypural diastema. BCFR, branched caudal fin rays; CFR, caudal fin rays; DPR, dorsal procurrent rays; E, epural bone; H, hypural bones; HF, hypural foramen; HSPU, 2, 3, 4, and 5 haemal spine of preural vertebrae; NAPU1, neural arch of 1st preural vertebra; NF, neural foramen; NSPU, 2, 3, 4, and 5 neural spine of preural vertebrae; PH, parhypural bone; PHF, parhypural foramen; PLS, pleurostyle bone; PU, 1, 2, 3, 4, 5 preural vertebrae; UBCFR, unbranched caudal fin ray; UN, uroneural bone; VPR, ventral procurrent rays. White X represents hypural diastema.

The outcomes of this study also showed a considerable individual alteration in the distribution of the dorsal procurrent rays. This variation results in numerous distinct patterns for the ray distribution. In *C. carpio*, there are 18 patterns, whereas in *L. vorax*, there are two patterns, each appearing in two dorsal procurrent ray distribution formulae for each of the two patterns. The remaining 16 patterns show various combinations of interdigitation of the dorsal procurrent rays with the neural spines of the preural vertebrae and the dorsal elements composing the skeleton of the tail fin (Tab. 3).

Table (3): Formulae for the distribution of *Leuciscus vorax* and *Cyprinus carpio* dorsal and ventral procurrent rays that were collected from Iraqi waters. The presence of a procurrent ray opposite to a caudal fin bone is indicated by the symbol (*). E, epural bone, HSPU2, 3, 4, and 5—haemal spines of 2nd, 3rd, 4th, and 5th preural vertebrae; NSPU2–5, neural spines of 2nd–5th preural vertebrae; PH, parhypural, PLS, pleurostyle.

Species	Formulae for the distribution of the dorsal procurrent rays	Formulae for the distribution of the ventral procurrent rays
Cyprinus carpio	(0)NSPU4(0)(0)NSPU3(0)(1)NSPU2(1)(2)E(1)(0)PLS(1)	(0)HSPU4(0)(3)HSPU3(2)(2)HSPU2(1)(0)PH(0)
	(0)NSPU4(1)(0)NSPU3(1)(1)NSPU2(1)(1)E(1)(2)PLS(0)	(2)HSPU4(1)(1)HSPU3(2)(1)HSPU2(1)(0)PH(0)
	(1)NSPU4(1)(0)NSPU3(1)(1)NSPU2(1)(2)E(2)(0)PLS(0)	(0)HSPU4(0)(1)HSPU3(2)(2)HSPU2(1)(0)PH(0)
	(0)NSPU4(0)(1)NSPU3(0)(1)NSPU2(2)(1)E(3)(0)PLS(0)	(0)HSPU4(0)(3)HSPU3(2)(1)HSPU2(1)(0)PH(0)
	(1)NSPU4(1)(1)NSPU3(2)(1)NSPU2(1)(1)E(1)(1)PLS(0)	(2)HSPU4(2)(1)HSPU3(2)(1)HSPU2(1)(0)PH(0)
	(1)NSPU4(0)(1)NSPU3(1)(1)NSPU2(1)(1)E(2)(0)PLS(1)	(0)HSPU4(0)(2)HSPU3(1)(1)HSPU2(2)(0)PH(0)
	(0)NSPU4(0)(0)NSPU3(0)(1)NSPU2(1)(1)E(1)(1)PLS(0)	(0)HSPU4(0)(0)HSPU3(2)(1)HSPU2(2)(1)PH(0)
	(0)NSPU4(0)(0)NSPU3(0)(0)NSPU2(0)(0)E(2)(0)PLS(1)	(0)HSPU4(0)(3)HSPU3(2)(1)HSPU2(3)(0)PH(0)
	(0)NSPU4(0)(0)NSPU3(1)(1)NSPU2(2)(1)E(2)(0)PLS(1)	(0)HSPU4(0)(0)HSPU3(2)(2)HSPU2(2)(1)PH(0)
	(0)NSPU4(0)(1)NSPU3(1)(1)NSPU2(2)(1)E(1)(1)PLS(1)	(0)HSPU4(0)(0)HSPU3(2)(2)HSPU2(2)(0)PH(0)
	(0)NSPU4(1)(1)NSPU3(1)(1)NSPU2(2)(1)E(1)(0)PLS(1)	(0)HSPU4(0)(2)HSPU3(2)(1)HSPU2(2)(0)PH(0)
	(0)NSPU4(0)(2)NSPU3(1)(1)NSPU2(1)(1)E(2)(1)PLS(0)	(0)HSPU4(0)(2)HSPU3(2)(1)HSPU2(2)(0)PH(0)
	(0)NSPU4(0)(1)NSPU3(1)(1)NSPU2(2)(1)E(2)(1)PLS(0)	(0)HSPU4(0)(2)HSPU3(3)(1)HSPU2(1)(0)PH(0)
	(0)NSPU4(0)(1)NSPU3(1)(2)NSPU2(1)(2)E(3)(0)PLS(0)	(0)HSPU4(0)(3)HSPU3(2)(1)HSPU2(1)(2)PH(0)
	(0)NSPU4(0)(1)NSPU3(2)(0)NSPU2(1)(1)E(2)(0)PLS(2)	(0)HSPU4(0)(2)HSPU3(2)(1)HSPU2(1)(0)PH(0)
	(0)NSPU4(0)(2)NSPU3(1)(1)NSPU2(2)(1)E(2)(0)PLS(2)	(0)HSPU4(0)(2)HSPU3(2)(1)HSPU2(1)(0)PH(0)
	(0)NSPU4(0)(0)NSPU3(1)(1)N	(0)HSPU4(0)(2)HSPU3(2)(0)HSPU2

	SPU2(2)(1)E(2)(0)PLS(1)	(4)(0)PH(1)
	(0)NSPU4(0)(0)NSPU3(0)(1)NSPU2(1)(1)E(2)(0)PLS(1)	(0)HSPU4(0)(3)HSPU3(2)(0)HSPU2(4)(0)PH(0)
	-	(0)HSPU4(0)(0)HSPU3(2)(1)HSPU2(2)(1)PH(0)
	-	(0)HSPU4(0)(2)HSPU3(2)(0)HSPU2(3)(0)PH(0)
Leuciscus vorax	(0)NSPU5(1)(1)NSPU4(1)(1)NSPU3(1)(0)NSPU2(2)(0)E(2)(0)PLS(1)	(0)HSPU5(2)(1)HSPU4(1)(2)HSPU3(3)(1)HSPU2(1)(0)PH(0)
	(0)NSPU5(1)(1)NSPU4(1)(1)NSPU3(1)(1)NSPU2(2)(0)E(3)(1)PLS(1)	(1)HSPU5(0)(2)HSPU4(2)(1)HSPU3(2)(1)HSPU2(2)(0)PH(0)
	(1)NSPU5(1)(0)NSPU4(1)(1)NSPU3(1)(1)NSPU2(1)(1)E(1)(1)PLS(0)	(0)HSPU5(0)(1)HSPU4(2)(3)HSPU3(2)(0)HSPU2(2)(1)PH(0)
	(0)NSPU5(2)(2)NSPU4(1)(1)NSPU3(2)(0)NSPU2(2)(1)E(2)(0)PLS(1)	(0)HSPU5(0)(2)HSPU4(2)(1)HSPU3(3)(1)HSPU2(2)(0)PH(0)
	(0)NSPU5(0)(0)NSPU4(0)(1)NSPU3(1)(1)NSPU2(2)(1)E(3)(0)PLS(1)	(0)HSPU5(0)(1)HSPU4(1)(3)HSPU3(3)(0)HSPU2(1)(0)PH(0)
	(0)NSPU5(1)(0)NSPU4(1)(1)NSPU3(1)(1)NSPU2(2)(1)E(2)(1)PLS(0)	(0)HSPU5(0)(1)HSPU4(2)(1)HSPU3(2)(1)HSPU2(1)(0)PH(0)
	(0)NSPU5(0)(1)NSPU4(1)(0)NSPU3(1)(1)NSPU2(1)(1)E(2)(1)PLS(0)	(0)HSPU5(0)(1)HSPU4(2)(1)HSPU3(3)(2)HSPU2(2)(0)PH(0)
	(0)NSPU5(0)(1)NSPU4(1)(1)NSPU3(1)(1)NSPU2(2)(1)E(2)(0)PLS(1)	(0)HSPU5(0)(0)HSPU4(0)(2)HSPU3(2)(2)HSPU2(2)(0)PH(0)
	(0)NSPU5(1)(0)NSPU4(1)(1)NSPU3(1)(1)NSPU2(3)(0)E(2)(1)PLS(0)	(0)HSPU5(1)(1)HSPU4(2)(3)HSPU3(2)(1)HSPU2(1)(0)PH(0)
	(0)NSPU5(0)(0)NSPU4(1)(0)NSPU3(1)(2)NSPU2(1)(1)E(2)(1)PLS(1)	(0)HSPU5(0)(2)HSPU4(2)(1)HSPU3(1)(0)HSPU2(0)(0)PH(0)
	(1)NSPU5(1)(0)NSPU4(1)(1)NSPU3(1)(0)NSPU2(2)(1)E(2)(0)PLS(1)	(0)HSPU5(0)(2)HSPU4(1)(1)HSPU3(2)(1)HSPU2(2)(0)PH(0)
	(0)NSPU5(0)(1)NSPU4(1)(1)NSPU3(1)(1)NSPU2(2)(1)E(2)(1)PLS(0)	(0)HSPU5(0)(1)HSPU4(2)(2)HSPU3(2)(1)HSPU2(1)(0)PH(0)
	(0)NSPU5(1)(0)NSPU4(1)(1)NSPU3(1)(1)NSPU2(1)(1)E(3)(1)PLS(0)	(0)HSPU5(0)(0)HSPU4(2)(1)HSPU3(3)(1)HSPU2(1)(0)PH(0)
	(0)NSPU5(1)(1)NSPU4(1)(0)NSPU3(2)(0)NSPU2(2)(0)E(2)(1)PLS(1)	(0)HSPU5(0)(2)HSPU4(2)(1)HSPU3(2)(1)HSPU2(1)(0)PH(0)
	(0)NSPU5(1)(1)NSPU4(1)(0)N	(0)HSPU5(0)(2)HSPU4(2)(1)HSPU3

	SPU3(1)(1)NSPU2(2)(1)E(2)(0)PLS(1)	(2)(0)HSPU2(1)(0)PH(0)
	(0)NSPU5(0)(1)NSPU4(1)(0)NSPU3(1)(1)NSPU2(2)(1)E(2)(0)PLS(1)	(0)HSPU5(0)(1)HSPU4(2)(1)HSPU3(3)(1)HSPU2(2)(0)PH(0)
	(0)NSPU5(0)(1)NSPU4(1)(1)NSPU3(1)(1)NSPU2(1)(1)E(2)(0)PLS(1)	(0)HSPU5(1)(1)HSPU4(2)(2)HSPU3(2)(0)HSPU2(1)(0)PH(0)
	(0)NSPU5(1)(0)NSPU4(1)(1)NSPU3(1)(0)NSPU2(2)(1)E(2)(1)PLS(1)	(0)HSPU5(0)(0)HSPU4(2)(1)HSPU3(2)(1)HSPU2(1)(0)PH(0)
	(0)NSPU5(0)(1)NSPU4(1)(1)NSPU3(1)(2)NSPU2(2)(1)E(2)(1)PLS(0)	(0)HSPU5(0)(0)HSPU4(2)(1)HSPU3(2)(1)HSPU2(1)(0)PH(0)
	(0)NSPU5(0)(1)NSPU4(1)(1)NSPU3(1)(2)NSPU2(2)(1)E(2)(1)PLS(0)	(0)HSPU5(0)(0)HSPU4(2)(1)HSPU3(2)(1)HSPU2(1)(0)PH(0)

Only two of the eighteen patterns seen in *C. carpio* indicated the existence of dorsal procurrent rays prior to the neural spine of the 4th preural vertebra. Similarly, in *L. vorax*, only two of the twenty patterns of dorsal procurrent ray distribution were found to reveal the presence of a single dorsal procurrent ray anterior to the fifth preural vertebra (Tab. 3).

In *C. carpio*, it is common for the 4th preural vertebra not to have any dorsal procurrent rays located anterior to the neural spine. The 18 patterns of the dorsal procurrent rays interdigitated with the neural spines of the preural vertebrae and the dorsal sections of the caudal fin skeleton showed only four patterns with dorsal procurrent rays anterior to the neural spine of the 4th preural vertebra. In the case of *L. vorax*, the presence of dorsal procurrent rays in front of the neural spine of the 5th preural vertebra is a common condition, and the absence of such a condition is rare, where there are only five out of 20 patterns of the dorsal procurrent rays distribution formula that showed a dorsal procurrent ray opposite the neural spine of the 5th preural vertebra (Tab. 3).

Generally, the patterns of the dorsal procurrent ray formulae of the dorsal procurrent rays in both species showed the existence of a dorsal procurrent ray opposite the pleurostyle, which is not an uncommon state (Tab. 3).

Formula for the ventral procurrent caudal fin distribution

The presence of ventral procurrent rays reveals their association with haemal spines of the preural centra and ventral portions of caudal fin skeleton (Tab. 3, Pl. 4). The results of this study revealed that the haemal spines of the second, third, and fourth preural vertebrae contribute to the interdigitation of the ventral procurrent rays and the caudal fin skeleton in species of *C. carpio*, while the haemal spines of the second, third, fourth, and fifth preural vertebrae.

Substantial individual deviation was detected in the propagation of the abdominal procurrent rays across the tail fin, resulting in noticeable patterns for *C. carpio* and *L. vorax*. The outcome revealed that there are 20 connections when the presence of the ventral procurrent rays combined with the presence of haemal spines of preural vertebrae and ventral components of the caudal fin skeleton were contemplated. Out of this number, there are two patterns that repeated twice for each pattern in the specimens of *C. carpio*. A similar number of patterns (20) was also observed in *L. vorax*. Out of this number there is only one pattern that can be considered as common as it was repeated three times in the specimens of *L. vorax* examined.

The allocation of ventral procurrent rays comparative to the haemal spine of the 4th and 5th preural vertebrae also showed slight variation in *C. carpio* and *L. vorax* species. In the case of *C. carpio*, there is only one pattern of the dispersal of the ventral procurrent rays that showed two ventral procurrent rays anterior to the haemal spine of the 4th. We also detected a pattern in *L. vorax*, which displayed a single ventral procurrent ray anterior to the 5th preural vertebra (Tab. 3).

In *C. carpio*, the non-existence of a ventral procurrent ray facing the haemal spine of the 4th preural vertebra was common. The present study results revealed that out of 20 patterns of the dissemination of the ventral procurrent rays, there are only two patterns shown to hold one and two ventral procurrent rays opposite the 4th preural vertebra. In *L. vorax*, there are three patterns with such a distribution. Two of these patterns have one ventral procurrent ray, and one pattern has two rays (Tab. 3). Except for one spreading pattern of the ventral procurrent rays that showed one ray opposite the parhypural bone in *C. carpio*, no such state is observed in the rest of the dispersal patterns of the ventral procurrent rays of *C. carpio* and *L. vorax*.

Caudal fin

Caudal fin formula: This study found that both *C. carpio* and *L. vorax* have two distinct lobes in their caudal fins, both upper and the lower. The third to sixth hypurals compose the upper lobe, and the first and second hypurals along with the parhypural make up the lower lobe. The caudal fin rays join these two lobes, with some splitting at their posterior ends and others continuing to unbranched. The caudal fin typically has unbranched rays running along its dorsal and ventral edges, with branched rays seizing the space in between. Each lobe's number of branching rays is distinct (Pl. 6). Caudal fin rays of the top and lower lobes do not differ in an individual manner among *C. carpio* and *L.vorax*. In all specimens examined of *C. carpio* and *L. vorax*, the number of the caudal fin rays in both the top and the lower lobes was conservative. One undivided ray and nine split rays were present in the upper lobe of the caudal fin, while one unbranched and eight branched rays occupied the inferior lobe.

Caudal fin skeleton description

As in other cyprinids, the tail fin rays of *C. carpio* and *L. vorax* are supported by the posterior four and five vertebrae in *C. carpio* and *L. vorax*, respectively. The first preural vertebra features a composite centrum that provides support for the epural, uroneural, pleurostyle, six hypurals, and a parhypural. This merged centrum is embodied by a short, blunt neural spine. The next three vertebrae in *C. carpio* and four in *L. vorax* are preural centra, each acquiring a single neural spine and a haemal spine.

The neural spines of the preural centra, together with the epural, pleurostyle, uroneurals, and the third to sixth hypurals, offer structural support to the superior lobe of the caudal fin. The pleurostyle is wide, approximately square, and strongly merged with the complex centrum. The hypurals bear the main rays of the upper lobe, while the procurrent rays are maintained by the uroneurals, epural, and the neural spines of the second, third, and fourth preural vertebrae as *in C. carpio* or the second, third, fourth, and fifth preural vertebrae as in *L. vorax* (Pl. 4).

Support for the rays of the lower lobe is given by the haemal spines of the 2nd to 4th preural centra in *C. carpio* and by the haemal spines of the 2nd to 5th preural centra in *L. vorax*, in addition to the parhypural and the 1st and 2nd hypurals. The haemal spine of the second preural centrum is autogenic. The first and second hypurals differ in structure: the first hypural has a slender, tapered base that widens distally, while the second hypural is united with the composite centrum and has a rectangular shape. The hypurals and parhypurals as a group support the primary rays of the lower lobe, with the haemal spines of the 2nd, 3rd, and 4th preural vertebrae reinforcing the ventral procurrent rays as in *C. carpio,* and in *L. vorax*, the haemal spine of the 5th preural vertebra is included (Pl. 4).

Generally, the features of the caudal fin skeletons of *C. carpio* and *L. vorax* are Consistent with slight variations in their shape among the fish specimens of different sizes of the two species examined. The hypural diastema, a space located between the second and third hypural bones, exhibits a similar shape in the caudal skeletons of *C. carpio* and *L. vorax*, and is wide and straight (Tabs. 4, 5).

Table (4): Definition of bones composing the skeleton of *Cyprinus carpio* and *Leuciscus vorax* collected from the freshwater of Iraq. NAPU1, neural arch of the 1st preural vertebra; NSPU2, neural spine of the 2nd preural vertebra.

Bone	Definition
Neural spine of the 2nd preural vertebra (NSPU2)	A lengthy bone is one that is no shorter than 1.5 times the length of the epural bone. A short bone is one that is ≤ to the epural bone's length. A broad bone is one that is twice as wide as an epural bone. A narrow bone is one that is ≤ the epural bone's breadth.
Epural bone	The definition of long bone is ≥ the length of the 2nd preural vertebra's neural spine. A bone that is medium length is one that is > ½ the length of the 2nd preural vertebra. A short bone is one that is < the breadth of the 2nd preural vertebra. The definition of a very short bone is < ½ the length of the 2nd preural vertebra. Narrow bones are defined as being ≤ of the second preural vertebra, whereas broad bones are defined as being > width of the second preural vertebra.
Pleurostyle bone	The definition of long bone is > the length of the 2nd preural vertebra's neural spine. A short bone is one that is < the length of the second preural vertebra's neural spine. Narrow bone is described as < the width of the neural spine of the 2nd preural vertebra, whereas broad bone is characterized as ≥ the width of the neural spine.
Uroneural bone	Long bones are those that are > ¼ epural bone length, short bones are those that are < ¼ epural bone length, broad bones are those that are ≥ the epural bone width, and narrow bones are those that are < epural bone width.
Neural arch of the 1st preural vertebra (NAPU1)	Bones are considered long when they extend to the midlength of the neural spine of the 2nd preural vertebra. Extending to the ¼ length of the 2nd preural vertebra's neural spine is referred to as a short bone. A very short bone is one that is less than ¼ the length of the 2nd preural vertebra's neural spine. Narrow bones are characterized as having a width comparable to the neural spine of the 2nd preural vertebra, whereas broad bones are twice as wide as the neural spine of the 2nd preural vertebra.
Hypural bones	A long bone is one that is > the parhypural bone's length, while a short bone is one that is ≤ the parhypural bone's length. A broad bone is twice as wide as the parhypural bone, a narrow bone is < the parhypural bone's breadth, and a very narrow bone is < ½ the parhypural bone's width.
Parhypural bone	A bone is considered long if it is longer than the 1st hypural bone, and short if it is shorter than that. A broad bone is one that is > the width of the 1st hypural bone, while a narrow bone is one that is ≤ the width of the first hypural bone.
2nd preural vertebra's hemal spine	A long bone is one that is ≥ the parhypural bone's length, while a short bone is one that is < that. Broad bones are 1.5 times wider than parhypural bones, whereas narrow bones are less wide than parhypural bones.

Table (5): Morphology of the different elements of the caudal skeleton of *Cyprinus carpio* and *Leuciscus vorax* caught from the freshwater of Iraq. "DEFB" refers to the fish's dorsal edge, "PLS" to its pleurostyle, "NSPU2" to its neural spine of the 2nd preural vertebra, "HSPU2" to its hemospine of the 2nd preural vertebra, and "PU2" to its 2nd preural vertebra.

Species	**NSPU2**	**Epural**	**Pleurostyle**	**Uroneural**	**Neural arch of PU2**	**Hypural**	**Parhypural**	**HSPU2**	**Neural foramen**	**Hypural foramen**	**Parhypural**	**Hypural diastema**
Cyprinus carpio	Long, broad, waved or straight, rea-ching DEFB	Narrow, straight, medium, dorsal end wider, ventral end pointed	Short, not reaching to DEFB, broad, straight	Short, narrow, pointed ends	Long, narrow, located closer to the NSPU2, with pointed and broad dorsal and ventral ends respectively	Short, broad, dorsal edge of the 1st and 2nd hypurals bones curved	Short, narrow, with con-cave dorsal edge	Short, narrow, slightly curved anteriorly	Absent	Elongated shape	Elongated shape	Wide and straight
Leuciscus vorax	Long, narrow, slightly curved-ed, rea-ching DEFB	Broad, medium, twisted	=		Very short, narrow, located closer to the NSPU2, pointed and broad dorsal and ventral ends respectively	Short, broad, with straight dorsal edge	Short, narrow, with con-cave dorsal edge	Short, narrow, convex dorsal posteriorly and concave ventral posteriorly	=	=	=	=

The intermuscular bones (IMB)

The IMBs are small and very thin bones inserted in the muscles found above and below the vertebral column. The outcomes of the current investigation disclosed the existence of two kinds of IMB: Y-shaped and Pin-shaped. The number, shape, and distribution of these two sorts of bones are conferred in (Tab. 6; Pl. 5). *Cyprinus carpio* is indicated to have a lower number of the pin- shaped (96-110) than *L. vorax* (140-160), the number of Y- shaped IMBs in *C. carpio* ranges between 120 and 130, and that is absent in *L. vorax*.

In *C. carpio*, both types of the IMB (S and Y) are distributed in straight two lines dorsal and ventral to the vertebral column in the tail region of the fish body. In *L. vorax*, only “S” shaped IMBs are present, and they are distributed in two straight lines dorsal and ventral to the vertebral column in the caudal region of the fish body (Pl. 5).

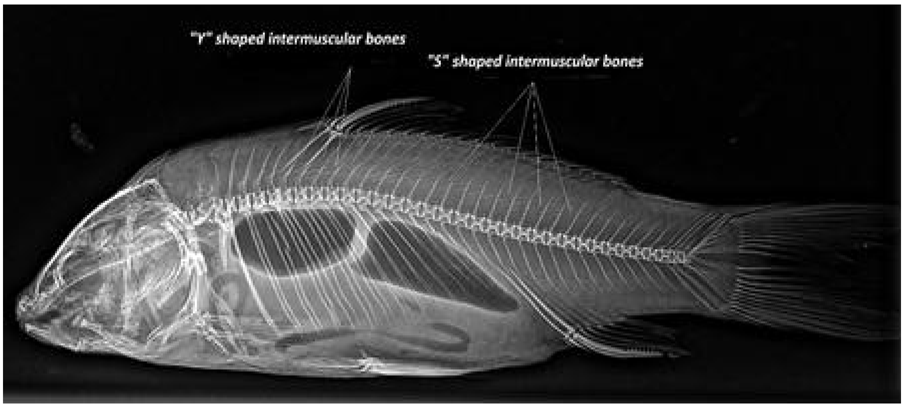


Plate (5): Radiograph of *Cyprinus carpio*, 340 mm SL, 422 mm TL, showing two types of intramuscular bones (IMB).

Table (6): Number, shape, and distribution pattern of intermuscular bones of *Cyprinus carpio* and *Leuciscus vorax* collected from the freshwater waters of Iraq.

Species	Number of the straight pin bone (S)	Number of the Y pin bone (Y)	Distribution pattern of the straight and Y pin bones	Start and end of distribution of (S) pin bone in the line dorsal to the vertebral column	Start and end of Distribution pattern of the straight and Y pin bones
Cyprinus carpio	96-110	120-130	Straight line parallel to the vertebral column	From the 2nd preural vertebra until the 1st caudal vertebra	From the Weberian Apparatus until the 5th caudal vertebra
Leuciscus vorax	140-160	Absent	The "S" bones distributed in a straight line parallel to the vertebral column. No "Y" bones	From the 3rd preural vertebra until the 1st caudal vertebra	Absent

DISCUSSION

This study assesses explicit osteological traits to enrich the description of skeletal components previously used to recognize the two species (*C. carpio* and *L. vorax)* and to reduce misidentification. Systematic study of fish relies heavily on osteological characteristics (Tyler *et al*., 2003; Prokofiev, 2009). Our findings highlight the significance of skeletal architecture in the two investigated species. Osteological aspects can be grouped into two sets:

(1) unique features that evidently separate a species and (2) attributes that are common between the two examined.

Osteological traits, such as bone construction and skeletal morphology, play a significant part in the recognition of fish species, comprising the two species under consideration in the current investigation. These skeletal attributes and features are frequently included with external morphological characteristics, like coloration or fin structure, to classify strongly associated species (Doadrio, 2002; Kottelat and Freyhof, 2007). Specifically, the structure of the bones in the cranium, the pectoral and pelvic girdles, and the vertebral column can offer essential indicative benchmarks for *C. carpio* and *L. vorax*. The tail skeleton configuration of bony fishes (Actinopterygii: Osteichthyes) was initially investigated by Schultze and Arratia (1989). More recently, Schultze and Arratia (2013) continued their investigation into the teleost caudal skeleton, examining its distinctive features as a distinctive evolutionary feature in the temporal dimension. In their studies, Schultze and Arratia (1989, 2013) included examples of members of the order Cypriniformes, which reflect the importance of the osteological characteristics in the systematics of this group. These osteological attributes are mainly advantageous since they are not as greatly affected by ecological settings, proposing a further a more stable and consistent base for species affinity than some exterior features, which may display flexibility owing to natural influences (Diogo *et al.*, 2008).

In the perspective of the *C. carpio* and *L. vorax* species, osteological evaluation can enhance a necessary means for taxonomic interpretation, specifically given the difficulty and continuing arguments concerning the taxonomic position of these two species within their genera (Howes, 1984; Perea *et al*., 2010; Yang and Mayden, 2010; Pourshabanan *et al*., 2021). Primarily, the utilization of osteological attributes has enabled the discrimination of species that are morphologically alike but genetically dissimilar. For instance, Jawad and Jig (2016) verified how vertebral column traits support separating species within the genus *Pampus* Bonaparte 1834, while Jawad and Alwan (2020) showed that there are many zones within the *Capoeta damascina* (Valenciennes, 1842) complex's vertebral column that may enable accurate species identification. Such methodologies highlight the chief function of osteological characteristics in systematics of numerous fish groups.

The configuration of the vertebral column

The quantity of vertebrae in *C. carpio* and *L. vorax* exhibits a moderate deviation among the fish specimens examined. This variantion is mostly individual and determined by the given specimens investigated. In these two species, abdominal vertebrae (A) generally number more than the caudal vertebrae (C), resulting in an A:C ratio greater than one. This ratio signals an elongated abdominal zone owing to the bigger number of vertebrae in the abdominal section. Such a discovery highlights the capability of the A:C to serve as a distinguishing trait between genera, indicating its utility as a means of addressing taxonomic issues within these taxa. Table 1 shows that there are 15–17 vertebrae in the abdomen region of *C. carpio*, while 22–24 vertebrae are present in *L. vorax*. This indicates that the abdominal region of *C. carpio* is either slightly shorter or approximately equal in length to the caudal region. Similar results were observed in the vertebral column of *L. vorax*. The higher A:C ratios observed in the examined species in the current findings support the findings by Arsovska *et al*. (2021) in *Gobionidae* species from Ohrid Lake and the Vardar River basin. Consequently, the vertebral column structure in these species can serve as an important diagnostic feature.

According to McDowall's (2008) research on Jordan's and other ecogeographic guidelines and fish vertebral numbers, some fish species change from a firm, rigid body to a slimmer, more flexible body. A rise in vertebral number and wider variation within species accompanies this change. There are firm-bodied species in this family that usually have twenty-five or twenty-six vertebrae (such as the genera *Seriolella* Guichenot, 1848 and *Centrolophus* Gilchrist and von Bonde, 1923), but there are also species that occasionally have 29 or 30 vertebrae (like the somewhat slimmer *Schedophilus*), and there is no intraspecies difference between the two. However, there are some intraspecific variation and much higher counts in the related genera *Icichthys* (Jordan and Gilbert, 1880) (43–45 vertebrae) and *Tubbia* (Whitley, 1943) (48–50 vertebrae). Both of these peculiar taxa are often referred to as ragfish because of the remarkable degree of body flexibility shown by these long, slim, and thin-bodied fish (McDowall, 1982). This tendency may be common across a variety of fish species (McDowall, 2008). Jordan (1892) documented this, saying that '…with growing number of vertebrae, the body grows correspondingly longer…', or more objectively, that there is a correlation between the quantity of vertebrae and the depth of the body. The phenomenon that larger fish have additional vertebrae is known as pleomerism (McDowall, 2008). Such a phenomenon was observed in the specimens of both species examined. The specimens of *C. carpio* showed two phenotypes, the tall-bodied short specimens and the short-bodied slender specimens. The vertebral number in the short specimens ranges between 29 and 30, while this number in slender specimens varies between 31 and 33 vertebrae (Tab.1). On the other hand, the specimens of *L. vorax* were arranged into three total lengths groups: 100-200, 201-300, and 301-400 mm TL, and the number of vertebrae in each group increased positively with the size of the specimen to 44, 46, and 47 vertebrae for the three fish length groups, respectively (Tab.1).

The number of predorsal vertebrae (a_1) reveals a restricted deviation, varying from four to five vertebrae in *C. carpio* and from 14 to 15 vertebrae in *L. vorax*. By examining more species of the genera *Cyprinus* and *Leuciscus*, the role of the number of the predorsal vertebrae (a_1) will show whether it is a reliable taxonomic measure to separate these two species from closely related species.

The number of predorsal vertebrae is also associated with the length and place of the predorsal and dorsal fins. A lower number of predorsal vertebrae is linked to a shorter predorsal fin length. The species *C. carpio* has four to five abdominal vertebrae. Therefore, this species has a shorter predorsal fin length, while *L. vorax* has 14 to 15 abdominal vertebrae, resulting in a longer predorsal fin length than *C. carpio*.

The number of intermediate vertebrae (i) in *C. carpio* ranges between one and two abdominal vertebrae, while in *L. vorax* it ranges between four and five vertebrae. This investigation implies that the number of intermediate vertebrae (*i*) is a reliable taxonomic trait to distinguish between the two species in question, but whether it can be considered so among closely related species of *C. carpio* and *L. vorax*, this requires further studies that can take into consideration more species of the genera *Cyprinus* and *Leuciscus*.

Caudal vertebrae (C) were slightly varying among specimens of the species *C. carpio* and *L. vorax*. The former species exhibited between 14 and 16 caudals, and the latter between 22 and 23. As for the quantity of intermediate vertebrae, the same count of caudal vertebrae is considered a taxonomically advantageous character, but this trait should be examined in the related species of *Cyprinus* and *Leuciscus* to assess its reliability as a beneficial taxonomic trait that could be used to separate the related species in both *Cyprinus* and *Leuciscus*.

Morphological flexibility is defined as the capability of a genotype to generate a selection of morphological features in response to connections with the surroundings (Via *et al*., 1995). The external morphology is often the first feature of reaction to variations in the habitat and might participate in an influential part during the initial phases of adjustment to new surroundings (Gröhsler *et al*., 2013). The morphological flexibility itself may also develop due to inherited differences among individuals in the actual habitat of the organism (Clausen *et al*. 2015). Moreover, advantageous plastic characteristics might ultimately develop and be incorporated into the genetic mechanisms of inhabitants who colonize unique habitats (Berg *et al*., 2017). Consequently, investigating morphological flexibility is essential for recognizing how morphological adaptation is produced and might also deliver perception into the evolutionary potential of lineages (Gröhsler *et al*., 2013).

The different ecological conditions during the development to adulthood, in particular temperature, is a particular vulnerability for bony fish. In some freshwater communities, the habitat conditions can change rapidly, inducing strong local ecological setting divergence across short spatial scales. Along with other factors, such as lower gene flow, this habitat divergence has contributed to high levels of fish diversity in freshwater systems worldwide (González Vilas *et al*., 2016). Among ecological factors that are related to flexible morphological responses, temperature is particularly important as it influences fish diversity and morphology. Among the traits most likely that could be influenced by temperature during development are associated with the morphology and body form, such as vertebral number and others that vary broadly in terms of morphology and physiology (Ackerly et al., 2016). Indeed, species that have extremely elongate body forms tend to have a higher number of vertebrae, a positive relationship that also occurs within and between species (Aguirre *et al*., 2014).

Besides influencing the overall number of vertebrae, temperature might likewise influence the ratio of pre- to caudal vertebrae, a trait that varies greatly across fish species (Ward and Brainerd, 2007) and is related to adaptively significant characteristics like predator escape ability (Swain, 1992a, b) and predation strategy (Maxwell and Wilson, 2013). Several studies have also shown that fish raised at lower temperatures tend to have shallower bodies (Georgakopoulou *et al*., 2007), suggesting that temperature variation may sometimes lead to a correlation between adaptive vital traits, such as vertebral number and body shape (extra vertebrae and longer torsos in colder climates, and the inverse is also true). The annual variations in the water temperature in Al-Tharthar at the Euphrates River and the Tigris River at Al-Zubaydia City, where the specimens of the species were collected might have effects on the osteological features. Majeed *et al*. (2022) studied the impact of the Tharthar-Tigris Canal on the ecological features of the Tigris River in Northern Baghdad City, Iraq. They showed that summer (and July in particular) water temperature estimates were higher than winter ones. The annual variation reported by Majeed *et al*. (2022) ranged between 12.1 and 28.4 °C., similarly, they investigated how Tharthar Water affected the Tigris water quality in Northern Baghdad City. Majeed *et al*. (2023) confirmed that there is a wide range of variation in water temperature between summer and winter. Salman *et al*. (2017) studied water properties at Al-Kut Province, located on the Tigris River, Iraq. Their results showed that the annual variation in water temperature is between 13.5 and 35°C. The discrepancy in the number of vertebrae found in the specimens examined may be due to wide temperature variation in the water at both locations where the fish specimens of both species were gathered.

Regionalization of the Vertebral Column

The assessment of vertebral length (VL) and vertebral height (VH) differences between the two species, *C. carpio* and *L. vorax*, investigated in the current study disclose that their vertebral columns are more complicated than a regular split into precaudal and caudal zones. Based on this biological data, we may deduce that the spinal column is anatomically divided into four separate areas: the postcranial area, the anterior abdominal area, the posterior abdominal area, and the caudal area. These four zones display exclusive attributes that perform as efficient taxonomic signs for distinguishing the two species studied.

In the two species observed, the four Weberian vertebrae, positioned next to the skull, are clearly interconnected with the posterior region of the skull, forming a connection between the two prime constituents of the axial skeleton (Videler, 1993). In *C. carpio* and *L. vorax* explored, the vertebrae in the fore part of the abdominal zone exhibit a denoted changeover, with a major modification in vertebral parameters such as VH and VL (Ramzu and Meunier, 1999). These transitional vertebrae, traversing V5–V10, mark the borderline separating the precaudal and caudal regions, parallel with the closing of the haemal arch. The vertebrae in this transitional area reveal a steady rise in VH and VL, which increases before gradually declining. Anatomical features such as thinner haemal arches and spines, as well as hypural plates support the lepidotrichia of the caudal fin, are noticeable on the posterior vertebrae of the caudal zone.

The changes in vertebral dimensions between the postcranial and caudal regions can be accredited to their roles: the postcranial vertebrae articulate with the head, while the posterior caudal vertebrae underwrite to the caudal peduncle (Kacem *et al*., 1998). Among the potential traits that might be influenced by habitat setting in the transitional zone could be skeletal elements, such as vertebral centra and atrophic ribs through their reaction to environmental changes (De Clercq *et al*., 2017). Differences in area or somite number may also explain the change in vertebral size between the transition zone and the remainder. Investigations on three-spined sticklebacks (*Gasterosteus aculeatus*) have advocated that such variations in vertebrae, markedly in the caudal area, are due to disparities in somite development (Ahn and Gibson, 1999a). Alternatively, a homeotic change could explain specific adaptations of a region, as recommended for actinopterygians (Ward and Brainerd, 2007). Both processes-changes in somite numbers and homeotic swings-could describe regional variation in Chinook salmon, with the probability that both act together to generate these differences (Ahn and Gibson, 1999b). Ahn and Gibson (1999b) also claim that segmentation and axial regionalization are independent developmental procedures in incorrect apostrophe, a theory confirmed by proof from amniotes (Müller *et al*., 2010). However, a strong correlation between vertebral quantity and vertebral uniqueness (i.e., vertebral column regions) is seen in the anterior section of the mammalian vertebral column (De Clercq *et al*., 2017).

None of the species studied here—*C. carpio and L. vorax*—have transitional centra previously characterized as a separate zone. Nevertheless, this unique structural trait seems to separate these vertebrae from abdominal or caudal vertebrae and testifies supporting its classification as a morphologically independent region. Similar transitional regions have been indicated for several groups of fish, including basal actinopterygians such as *Lepidosteus* (Balfour and Parker, 1882) and numerous bony fish species like *Carangoides caeruleopinnatus* (Rüppell, 1830), *Morone saxatilis* (Walbaum, 1792), *Leiognathus equulus* (Forsskål, 1775), *Lutjanus bengalensis* (Bloch, 1790), *Lagocephalus sceleratus* (Gmelin, 1789), *Pseudorhombus arsius* (Hamilton, 1822), *Rastrellinger kanagurta* (Cuvier, 1816), *Auxis thazard* (Lacepède, 1800), *Coptodon zillii* (Gervais, 1848), and *Oreochromis aureus* (Steindachner, 1864) (Bird and Mabee, 2003; Jawad and Al-Hassani, 2013, 2014; Jawad *et al*., 2013, 2014, 2018). These transitional vertebrae have the outer shape of the parapophyses. Specifically, neoscopelid fishes, according to Miyashita and Fujita (2000), have both ventral and lateral parapophyses. Anterior transitional vertebrae have lobe-like parapophyses in the onion trevally *Carangoides caeruleopinnatus* while parapophyses are long and flanged on the posterior transitional vertebrae (Jawad, 2015). (Jawad *et al*., 2013) found that the parapophyses on vertebrae 8–12 of frigate tuna (*Auxis thazard*) had a blade form with distal ends that are curved posteriorly. Parapophyses may also have specific purposes, such as, in black mackerel (*Scombrolabrax heterolepis* Roule, 1921), they project dorsolaterally to create bullae, which are hemispherical pouches that contain evaginations of the gas bladder (Bond and Uyeno, 1981).

The variation in the location of the highest and the lowest values of the vertebral dimensions, VH and VL, in the four vertebral regions observed in *C. carpio* and *L. vorax* may result from mechanical restraints inflicted by these vertebrae, which are explicitly modified to handle utmost mechanical pressures (Sankar *et al*., 2024). The maximum vertebral length detected in these species could be used as a diagnostic feature for the species *C. carpio* and *L. vorax* when compared with closely related species.

The minimal vertebral sizes were positioned at the end of the vertebral column in both species investigated, making this feature unsuitable as a reliable taxonomic phenomenon for distinguishing between species explored and their close relatives. In the caudal region, nonetheless, divergences in vertebral values manifest the fundamental participation of the caudal vertebrae in movement. The caudal skeleton responds to lateral merging of intrinsic muscles, creating force in the caudal peduncle and modifies the surface area of the caudal fin with each beat (Bainbridge, 1963), thus giving propulsion.

The outcomes of this examination signal that the vertebral proportions, VH and VL, in *C. carpio* and *L. vorax* differ substantially from each other. This is because they belong to two different genera within Cypriniformes. In a future study, the outcomes of this investigation should be compared with those of closely related species of *C. carpio* and *L. vorax*.

Dorsal fin

Interlink of pterygiophores by means of neural spines of the dorsal fin: This assessment considers the variation in the interdigitation models between the dorsal pterygiophores and neural spines of *C. carpio* and *L. vorax*. It signifies the first thorough evaluation of these interdigitation models specific of these two species. Earlier examination has emphasized the importance of dorsal-fin pterygiophore and neural spine interdigitation in the recognition of fish species, comprising scombrids (Matsui, 1967; Potthoff, 1974, 1975), temperate basses (Marone species; Fritzsche and Johnson, 1980; Olney *et al*., 1983, excluding hybrids, see Harrell and Dean, 1987), gobioid fishes (Birdsong, 1975; Birdsong *et al*., 1988), as well as investigations of soleid fishes (Chapleau, 1989) and symphurine tonguefishes (Munroe, 1992). Lately, a study by Springer and Smith-Vaniz (2008) on carangid species, Jawad and Alwan (2020) on six species of *Capoeta*, Jawad and Jig (2016) on *Pampus*, and Jawad (2020) on *Antimora* species has extended our insight into these interdigitation models.

The outcomes of this investigation reveal substantial inconsistency in the interlinking of pterygiophores, which support the dorsal fin rays, with the neural spines of the vertebral column of the two species explored. This variation is a significant trait of dorsal fin morphology and might indicate evolutionary modifications within these species (Birdsong *et al*., 1988; Munroe, 1992).

A remarkable note is the variability in the number of interneural spaces that interdigitate with pterygiophores. This number varies between three and nine, while in the case of *L. vorax*, it differs between one and six (Tab. 2). This proposes that various species might have developed definite ways to make the dorsal fin stable, possibly in reaction to habitat impacts like habitat varieties or swimming activities (Jawad *et al*., 2020). The number of pterygiophores could also show biomechanical restraints and operative requirements on the dorsal fin, affecting swimming competence and flexibility (Olney *et al*., 1983; Jawad and Jig, 2016).

Furthermore, it is noteworthy that the pterygiophore backing the first dorsal fin ray is constantly not anterior to the neural spine of any abdominal vertebra in both species explored. This may denote a conservative morphological trait, probably allied to the definite operational function of the first dorsal ray, which may differ from the other dorsal fin rays (Jawad *et al*., 2024). Conversely, the left pterygiophores are placed opposite to the neural spines of abdominal vertebrae, with variable numbers of interdigitation points. This inconsistency emphasizes the evolutionary tractability of the structural association between the vertebral column and dorsal fin pterygiophores, which could be related to species-specific disparities in movement or habitat acclimatization (Jawad and Jig, 2016).

The pterygiophores and neural spines of abdominal vertebrae are plesiomorphically present or absent and vary between the two species discussed. Results of this study suggest variation in the count of pterygiophores opposite the neural spines of the abdominal vertebrae between the two species included in this study, with several pterygiophores counts observed in these regions. As an example, the cases in which there are pterygiophores opposed to the neural spines in the abdominal vertebrae range from one to four in *C. carpio*. The number of the patterns of the formulae of the pterygiophore interdigitation with neural spines of the dorsal showing no pterygiophore opposite the neural spine of the dorsal fin is shown to be five and 13 in *C. carpio* and *L. vorax,* respectively. This irregularity could be associated with variations in vertebral morphology, with the absence of this feature in some species proposing a decreased dependence on neural spines for backing the dorsal fin. Such species may rely more on other structural or muscular adjustments to accomplish the dorsal fin's function (Jawad and Alwan, 2020).

The allocation of the dorsal fin across abdominal vertebrae also indicates substantial deviation. Both *C. carpio* and *L. vorax* have different quantities of vertebrae that support the dorsal fin. While nine abdominal vertebrae support the dorsal fin in *L. vorax*, eleven abdominal vertebrae and seven caudal vertebrae also support the dorsal fin in *C. carpio*. In the case of *C. carpio*, there are 19 different patterns of the interdigitation length of the pterygiophore sustaining the dorsal fin spines, with no dominant pattern, while in *L. vorax*, there are 18 different patterns, and one common pattern shared by two instances (14-N-1^9) (Tab. 2). This disparity signals that the spatial layout of the dorsal fin is probably influenced by the species' ecological requirements, such as body size, swimming dynamics, and niche specialization. Species with a more extensive dorsal fin may benefit from enhanced steadiness and control in their environment, a benefit for species encountered in compound swimming behaviours or navigating turbulent waters (Birdsong *et al*., 1988). Conversely, species with a more compacted dorsal fin may embrace adaptive policies that select speed or flexibility and be subject to their ecological setting (Harrell and Dean, 1987).

Anal fin

Interdigitation of pterygiophores with the anal fin's haemal spines: The disparity in the number of pterygiophore interdigitation models sustaining the spines and rays of the anal fin, along with their interaction with the haemal spines of the caudal vertebrae, reveals noteworthy individual inconsistency within the examined two species. In *C. carpio*, there are three shared models. The considerable common model is noted in four formulae and two other common models are recorded in two formulae each (Tab. 2). Moreover, there are 13 models with varying interdigitation arrangements. The interdigitation of pterygiophores with the haemal spines of the anal fin is the only pattern shared by both formulae in *L. vorax*. Moreover, there are 17 patterns with varying numbers of interdigitations. This irregularity in the number of models probably reflects variations in the structural intricacy of the anal fins and caudal vertebrae of the two species. Such an outcome agrees with investigations on cyprinid fishes, where structural variety in pterygiophores is diagnosed as a taxonomically substantial feature (Jawad and Alwan, 2020).

Concerning the length of the pterygiophore interdigitation formula with the haemal spines, the number of insertions varies considerably between the two species studied. In *C. carpio*, the number of filled spaces or interdigitation with pterygiophores of the anal fin varies between four and seven, while in *L. vorax* this number ranges from seven and 12 (Tab. 2). This modification probably corresponds to operational changes in the anal fin's structure, perchance related to swimming mechanics or defensive activities. The larger number of insertions may present stronger support for the fin's spines and rays. Jawad and Jig (2016) perceived that variation in fin structure among fish species is often related to ecological adaptations, specifically in terms of locomotion and predator evasion.

The results also showed that the position directly posterior to the haemal spine of the first caudal vertebra is always filled with a pterygiophore in *C. carpio*, while it is either filled or vacant. The occurrence or absence of this feature in the two species may denote an evolutionary adaptation to specific ecological places or result from morphological limitations (Jawad et al., 2020). It also indicates changes in the growth routes that shape the anal fin and its supporting structures (Jawad and Jig, 2016). Jawad *et al.* (2020) proposed that the non-existence of certain morphological components in some species may be an outcome of the relaxed evolutionary stresses or changes in environmental requirements.

The outcomes of this investigation increase our perception of the operative and evolutionary meaning of pterygiophore patterns in the two species studied. The variation in these models brtween the two species explored might serve as a valuable morphological indicator for phylogenetic interpretations and ecological adjustments. Forthcoming investigations surveying the ontogeny and genetic basis of these traits might offer deeper awareness into the evolutionary routes that shape the variety of fin-backing structures within the families to which the two species investigated.

Dorsal procurrent caudal fin distribution formula

The procurrent rays usually act as connection positions for the muscles in the tail (Nag, 1967), with a primary dorsal focus of muscular structure (Flammang and Lauder, 2008), which is associated with subsequent asymmetry in the skeletal structure (Schultze and Arratia, 1986; Ishikawa, 1992). Enclosed in connective tissue, the dorsal procurrent rays have a vital part in maintaining the dorsal edges of the fin, guaranteeing that they remain as stiff as possible (Nag, 1967). The number of these rays is fundamental to the operational performance of the caudal fin, immediately affecting swimming effectiveness, flexibility, and hydrodynamic performance. This trait changes between species, exhibiting their environmental requirements, varying from slow navigation in complicated surroundings to high-speed swimming in open waters. Continuing investigation maintains searching for how these changes affect fish locomotion and the evolutionary adjustments that have changed diverse aquatic species (Jawad and Alwan, 2020).

The dissemination of dorsal procurrent rays, remarkably in relation to their interdigitation with the neural spines of the preural vertebrae, proposes important comprehension into the structural variety of caudal fins between species. This study features the involvement of the three preural vertebrae involved in the interdigitation: the second, third, and fourth preural vertebrae in *C. carpio*, while four preural vertebrae are implicated in *L. vorax*: the second, third, fourth, and fifth preural vertebrae. The degree of interdigitation with the vertebrae changes substantially among species, implying important distinctions in the structural organization of the caudal fin skeleton (Desvignes *et al*., 2018).

Among the attained outcomes of this study is a considerable degree of deviation in the distribution of dorsal procurrent rays, with various species displaying diverse models. In *C. carpio*, 18 patterns were observed, while in *L. vorax*, there are two models that acted in two dorsal procurrent ray spreading formulae for each of the two models. The remaining 16 patterns show variable arrangements of interlinking between dorsal procurrent rays with the neural spines of the neural spines of the preural vertebrae and the dorsal constituents of the caudal fin skeleton. In *C. carpio,* and of the 18 models observed, there are only two models that showed the presence of dorsal procurrent rays anterior to the neural spine of the 4th preural vertebra. Similarly, in the case of *L. vorax*, and out of the 20 patterns of the dissemination of the dorsal procurrent rays, there are only two patterns that showed the occurrence of one dorsal procurrent ray anterior to the 5th preural vertebra. This irregularity features the complication of the caudal fin structure within the two species investigated, with important implications for species identification and classification. The results also showed that the mean number of dorsal procurrent rays surpassed that of the ventral procurrent rays, a feature regarded as primitive for leuciscinids (Bird and Mabee, 2003).

Interestingly, the existence of dorsal procurrent rays in front of the neural spine of the 4th preural vertebra was a relatively common trait in *C. carpio*. The 18 models of the dorsal procurrent rays interlinked with the neural spines of the neural spines of the preural vertebrae and the dorsal constituents of the caudal fin skeleton presented only four models with dorsal procurrent rays in front of the neural spine of the 4th preural vertebra. In the case of *L. vorax*, the presence of dorsal procurrent rays anterior to the neural spine of the 5th preural vertebra is a common case, and the absence of this form is rare, where there are only five out of 20 patterns of the dorsal procurrent rays' distribution formula that showed a dorsal procurrent ray positioned opposite the neural spine of the 5th preural vertebra. This feature may indicate an adaptive or phylogenetic model that could assist in separating the two species examined from closely related species within the same genera.

Regarding the dorsal procurrent ray formulae, the general condition in both species is the presence of a dorsal procurrent ray that is placed opposite the pleurostyle, a condition that is not uncommon. This observation suggests that the pleurostyle may influence the position and formation of the procurrent rays (Nag, 1967). Additional research is needed to uncover the relationship between caudal fin morphology and ecological factors to deepen understanding of this pattern.

Formula for ventral procurrent caudal fin distribution

The ventral procurrent rays in fish are fundamental structures placed in the tail region of several species. They have an important task in managing and pointing tail movements, primarily by generating force and aiding guidance (Nag, 1967; Desvignes *et al*., 2018). Change in the number of ventral procurrent rays has substantial effects, influencing swimming performance, ecological adjustments, and proposing perceptions into evolutionary history. The number of these rays precisely influences how fish produce propulsion, control their movement, and work together with their environment. Accordingly, realizing these differences is required for investigating the functional morphology and behaviour of different fish species (Bird and Mabee, 2003).

The rearrangement of the ventral procurrent rays and the way they intercalate with the haemal spines of the preural vertebrae and other structures in the caudal fin, as seen in *C. carpio* and *L. vorax*, represents the main dissimilarity at the anatomical level. This overlap represents the species-specific modifications that improve swimming performance. The outcomes stated above indicate the participation in such phenomena in *C. carpio* of haemal spines of the second, third and fourth preural vertebrae and of the second, third, fourth and fifth preural vertebrae in the function of the caudal fin of this type of the species. These findings support those already reported in established studies regarding the functional role of haemal spines in the assistance and support of the fin rays movement in teleosts (Lauder, 2000; Jawad and Alwan, 2020).

The disparity in how ventral procurrent rays are distributed in the two species examined is specifically significant. Individual variations in the position of these rays in the caudal fin guided them to conspicuous models. The outcomes displayed that there are 20 models of the interdigitation between ventral procurrent rays with the haemal spines of the preural vertebrae and the ventral elements of the caudal fin skeleton. Out of this number, there are two models that demonstrated recurring twice for each model in the specimens of *C. carpio*. An analogous number of models (20) was likewise found in *L. vorax*. Out of this total there is only one model that can be considered common, as it recurs three times in the specimens of *L. vorax* examined. This deviation proposes that the arrangement of these rays is extremely adaptable and probably modelled by ecological and swimming needs. These models confirm results from other investigations, which demonstrate that traits of the caudal fin, such as the quantity and dissemination of procurrent rays, are frequently revised to enhance swimming activity in precise habitats (Lauder and Drucker, 2004).

An additional remarkable tendency detected in this investigation was the interdigitation of the ventral procurrent rays with the haemal spine of the fourth and fifth preural vertebrae. The distribution of ventral procurrent rays relative to the haemal spine of the 4th and 5th preural vertebrae also showed slight variation in both species. In *C. carpio*, there was only one model of the dissemination of the ventral procurrent rays that showed two ventral procurrent rays anterior to the haemal spine of the 4th. There was a model in *L. vorax* that showed a ventral procurrent ray anterior to the 5th preural vertebra as well. This flexibility could reflect variations in swimming activities or ecological habitats employed by these species. Species demonstrating interdigitation may profit from augmented firmness and mobility during swimming (Flammang and Lauder, 2008).

In *C. carpio*, the non-existence of a ventral procurrent ray facing the haemal spine of the 4th preural vertebra was common. The results of the present study revealed that out of 20 patterns of the dissemination of the ventral procurrent rays, only two patterns were shown to have one and two ventral procurrent rays corresponding to the 4th preural vertebra. In *L. vorax*, there were three patterns with such distribution. Two of these patterns have one ventral procurrent ray, and one pattern has two rays.

Apart from one distribution model of the ventral procurrent rays, one ray appeared opposite the parhypural bone in *C. carpio*; no such state was observed in the rest of the distribution patterns of the ventral procurrent rays of *C. carpio* and *L. vorax*. These unique features may propose a specified adjustment that improves control over the tail during swimming. This adjustment may possibly be related to the species' ecological habits or swimming style (Lauder and Drucker, 2004). Upcoming research may possibly provide additional information into the performing applications of these changes, specifically concerning their influences on swimming functioning and ecological adaptation.

Tail fin

Tail fin formula: The structure of the caudal fin in *C. carpio* and *L. vorax* species displays substantial disparity in the dissemination of rays between the upper and lower lobes. This study reveals that the caudal fin divided into two parts, with each lobe containing apparent hypural bones. The upper lobe contains the 3rd, 4th, 5th, and 6th hypurals, while the lower lobe involves the 1st and 2nd hypurals, along with the parhypural bone. This functional diversity supports the outcomes in other teleosts, where caudal fin morphology is frequently close to useful and ecological roles (Gosline, 1997; Lauder, 2000).

Tail fin rays may be either branched or unbranched, which provides insight into fin anatomy (Fricke, 1983). Undivided rays, located along the dorsal and ventral edges, probably offer stability and strength, while the divided rays in the centre may improve forward motion competence during swimming. This model of ray spreading is also seen in other fish species, such as those in the family Cyprinidae, where fin ray dissemination notably affects swimming mechanics and flexibility (Bogutskaya and Coad, 2009; Jawad and Alwan, 2020). Significantly, *C. carpio* and *L. vorax* showed no variations in the number of caudal fin rays between the upper and lower lobes. Caudal fin rays in both lobes, in all analyzed specimens of both species, were constant. The caudal fin has one unbranched and nine branched rays in the upper lobe and eight bifurcate rays in the lower lobe. It may represent a potential ecological or evolutionary adaptation and should be explored further. The two species that were studied also have a level of morphological stability when it comes to the number of caudal fin rays in the superior and inferior lobes, which are usually nine in the upper lobe and eight in the lower.

This result agrees with other analogous outcomes on cyprinid fishes, where caudal fin ray counts often show species-specific constancy (Bogutskaya and Coad, 2009; Jawad and Alwan, 2020).

Caudal fin skeleton description

Osteologically, the caudal skeleton is crucial for functional mobility, especially in relation to swimming speed, prey capture, and predator evasion (Lauder, 2000; Flammang and Lauder, 2008). Hollister (1936), Gosline (1960, 1961), Nybelin (1963), Monod (1968), and de Pinna (1996) are among the many works that provide crucial taxonomic information on the caudal skeleton, which is justified by its operational value. Both Arratia and Schultze (1992) and Arratia (2008), Arratia (2009) state that the caudal skeleton structure offers significant insights into the study of teleost fishes at higher taxonomic stages.

Both the vertebral column and the caudal skeleton of fish are compound assemblies of bones that may develop from dermal tissues or cartilage (Rojo, 1991). Rojo (1991), Arratia and Schultze (1992), and Purrafee Dizaj *et al*. (2020) all cite this anatomical complexity as a crucial data source for understanding the systematics and evolutionary relationships among ray-finned fishes.

The outcomes of this investigation offer a thorough perception into the caudal skeleton of *C. carpio* and *L. vorax* species, disclosing both conservative and varying morphological features that contribute to caudal fin structure and function. The posterior-most four vertebrae, particularly the preural centra, have a fundamental part in providing the caudal fin rays, a characteristic consistent with the cyprinids (Silva *et al*., 2012). The complex centrum of the first preural vertebra, along with the connected neural spines, hypurals, and uroneurals, forms a composite structure that supports both the upper and lower lobes of the caudal fin. As with earlier investigations on cyprinids, these skeletal essentials are vital to the propulsion and flexibility of the fish, chiefly in fast-flowing habitats where effective caudal fin drive is vital for upholding place and escaping predators (Webb and Gerstner, 2021).

The caudal skeleton has a significant part in fish movement and has experienced several structural and morphological modifications as a consequence of evolution (Rojo, 1991; Schultze and Arratia, 2013). This demonstrates the importance of the caudal skeleton concerning taxonomy and fish categorization. For instance, the epural is a modified neural spine whose function is to sustain the upper caudal fin rays. Both species had an epural posterior to the neural spine of PU3 as well as a fairly developed neural spine of PU2. The epural appeared to have widened and thickened in order to buttress the fragile neural spine of PU2 in the species analyzed. This feature, involving the epural and neural spine of PU3, is a structure that is responsible for the small, spine-like dorsal procurrent rays of the caudal fin and it is likely to improve swimming activity (Echreshavi *et al*., 2021). According to Echreshavi *et al*. (2021), the parhypural is an auxiliary structure that has an important function in the tail fin strength as well as the fish's ability to move and swim. In the studied species, the parhypural bone was shorter than the 1st hypural bone and appeared to be broad and strong. This structure could potentially enhance swimming abilities as well.

Most bony fishes are easily identified by symmetrical dorsal and ventral lobes in their homocercal tails, which they use to generate horizontal forces along their body axis (Monod, 1968). While the caudal fin of *C. carpio* and *L. vorax* species examined appear symmetrical visibly, the structure of their caudal skeleton is asymmetrical (Monod, 1968). Our outcomes designate a general dorsal bias. These outcomes support those of Arratia (1987), who perceived a ventral bias in the number of procurrent caudal rays among several Characiformes species across diverse size classes.

Both *C. carpio* and *L. vorax* had short uroneurals in their caudal skeletons. A decline in the number of these bones is often linked to a lack of dorsoventral caudal fin movement. This leads in the rigidifying the distal end of the vertebral column, which assists reject the strong seizure and drag forces of the caudal fin (Nag, 1967).

The high inconsistency viewed in various parts of the caudal skeleton of the two species proposes that these characteristics might be affected by evolutionary impacts linked to ecological issues, like habitat category and swimming behaviour (Lukač *et al*., 2023). For instance, the pleurostyle, uroneural, neural foramen, hypural foramen, and parhypural foramen showed comparatively similar shapes between the two species, possibly representing efficient restraints linked with swimming proficiency in riverine habitats (Lindsey, 1978). Conversely, a substantial difference in the shape and size of the neural spine of the second preural vertebra, the epural, and the hypural bones likely suggests adaptive differentiation between species dominating diverse ecological regions.

In bony fishes, the orientation of the hypural diastema with the horizontal body axis is thought to provide functional advantages, such as improved flexibility and power (Desvignes *et al*., 2018). Variability in the shape of the hypural diastema may manifest discrete swimming designs and specified movement models needed by diverse riverine habitats, where stream velocity and water turbulence fluctuate (Wiley *et al*., 2015). In the *C. carpio* and *L. vorax* species, the hypural diastema is wide and straight, but the shape of the hypural diastema might show some variations among related species of the genera *Cyprinus* and *Leuciscus*. Therefore, further studies are needed to explore this possibility. Gosline (1961) demonstrated that the evolution of the caudal skeleton in advanced bony fishes aims toward reduction and generalization through the union of components. For example, the substitution of six hypurals by two triangular hypural plates in species like *Hippoglossoides platessoides* (Fabricius, 1780) (Frame *et al*., 1978) is regarded as a developed feature. Likewise, in species such as *Cybiosarda elegans* (Whitley, 1935), *Sarda chiliensis* (Cuvier in Cuvier and Valenciennes, 1832), *Sarda sarda* (Bloch, 1793), *Gymnosarda unicolor* (Rüppell, 1836), and *Allothunnus fallai* Serventy, 1948 the substitution of six hypurals by a single triangular bone is seen a further evolutionary footstep (Collete and Russo, 1978). Consequently, species with a larger number of hypurals and divided rays are deemed more primitive (Gosline, 1961; Nybelin, 1963). By these standards, the two species are contemplated as more primitive than numerous other species. These species also maintain other primitive characteristics, such as the shape of the epural, which approximately matching to the neural spines of the caudal vertebrae, and the firm articulation of the first uroneural with the urostyle (Kotalawala, 1991).

The intermuscular bones (IMB)

The examination of fish intermuscular bone began in the 1950s of the 20th century, and the exploration work chiefly centred on the carp, salmon, pike, and smelt. The IMB of cyprinids has been shown some outstanding efforts, and a thorough study could be beneficial (Patterson and Johnson, 1995; Dong *et al*., 2006; Danos and Ward, 2012).

In the myosepta, the small, spicule- like bones known as intermuscular are found. They run along the back and slightly angled downwards along either side of the muscular fillet of bony fish (Bird and Mabee, 2003). The IMBs are rudimentary traits observed in primitive Ostariophysi (Chang *et al*., 2008), which have been gradually reduced or lost in other, more derived fish taxa, such as the Perciformes (Patterson and Johnson, 1995). While paired IMBs are immobile inside the muscle, Patterson and Johnson (1995) demonstrated that they are securely fastened to the vertebrae via a ligament that runs the length of their unbranched ends. Other names for these spicule-shaped bones include epineural bones, false ribs, ossified myoseptal tendons, and "pin bones." (Gemballa, 2001; Sahu *et al*., 2012). Anatomical landmarks for IMBs are located on the vertebral body to which they attach. For instance, epineurals connect to the neural arches, epicentrals are ligamentous, in horizontal septum; epipleurals are present on median vertebrae, are posteroventrally directed, and are united to hemal arches (Nursall, 1956). These outcomes agree with those attained in the current investigation about the distribution of the IMB of the *C. carpio* and *L. vorax* searched.

Li *et al*. (2013) proposed that there are several forms of IMB described in diverse species of fishes; these encompass non- forked (I), one-end-unequal-bi-fork (卜), one-end-equal-bi-fork (Y), one-end multi-fork, two-end-bi-fork, two-end-multi-fork, and tree-branch forms. In the current investigation, the shape of the IMB in the *C. carpio* and *L. vorax* species examined can be either non- forked (I) or Y pinpoint. Comparable outcomes were obtained by Meske (1968), Vallod and Arthaud (2009), and Andria-Mananjara *et al*. (2016) on *C. carpio*; Sahu *et al*. (2012) on *Labeo rohita*, *Catla catla*, and *Cirrhinus mrigala* Hamilton, 1822. Cao *et al*. (2015) on *C. carpio* found that hilsa pin bones are embedded in muscles and they are extremely fine bones. In addition, they suggested that the intermuscular bone counts were not significantly related to standard or total body length. Neither the quantity nor the shape of intermuscular bones varied from side to side. Consistent with Cao *et al*. (2015), our examination has shown similar results. Paterson and Johnson (1995) stated that there are three kinds of pin bones, these are single unbranched, branched, and brushy at a single end.

The purpose of IMB is depated between ichthyologists. Nursall (1956) assumed that these bones appear to react to tensions that go throughout the muscles. Different results have suggested roles in force transmission in muscle segments, the acquisition of body stiffness, and adjusting myomere bending during tightening (Danos and Ward, 2012).

The number, morphology, and spreading of IMB have been recorded in numerous species of fish, including *Hypophthalmichthys molitrix* (Valenciennes, 1844) (Ke *et al*., 2008); common carp *C. carpio* (Kossmann, 1972; Moav *et al*., 1975; Vallod and Arthaud, 2009); Indian carps *Labeo rohita*, *Catla catla* (Hamilton, 1822) and *Cirrhinus mrigala* (Sahu *et al*., 2012); crucian carp *Carassius auratus* (Linnaeus, 1857) (Li *et al*., 2013); and Wuchang bream *Megalobrama amblycephala* Yih, 1955 (Wan *et al*., 2014). Several investigations have shown that IMB may vary greatly across strains (Vallod and Arthaud, 2009; Cao *et al*., 2015) and even within the same species (Meske, 1968).

Disparity in the number of IMBs in fish has been recorded (Cao *et al*., 2015; Li *et al*., 2013; Meske, 1968; Moav *et al*., 1975; Sengbusch and Meske, 1967). The results of these studies follow those of the present investigation. *Cyprinus carpio* is indicated to have a lower number of the Pin- shaped (96-110) than *L. vorax*, (140-160), the number of "Y" shaped IMB in *C. carpio* ranges between 120 and 130, while they are absent in *L. vorax*.

Sahu *et al*. (2012) suggested that the number of the IMB can be deliberated as individual characteristics in studies on northern pike, salmon (Mathiassen *et al*., 2011), Indian major carps (Sahu *et al*., 2012). As no more than a single species of each of the genera *Cyprinus* and *Leuciscus* was examined in the current findings, it is not possible at this point to support the suggestion of Sahu *et al*. (2012) in considering the number of IMB as a taxonomic criterion to separate species until more species from each *Cyprinus* and *Leuciscus* are experimented with.

The range of the intermuscular bone number varies from that of *C. carpio*. Lieder (1966) suggested that the total number of pin bones in *C. carpio* changed from 99 to 104. Indian major carps, catla, rohu, and mrigal contain more IMB than the common carp, while milkfish (*Chanos chanos*) has 180 numbers of pin bones, which can be removed during deboning and filleting. The total number of S- and Y- shaped pin IMBs in *C. carpio* studied ranges between 96 and 110 and 120-130, respectively. These ranges appear higher than those reported by Lieder (1966). Vallod and Arthaud (2009) showed that a relationship between strains and geographic origin and the number of ventral forked IMBs compared to the total number of bones. They found that carps, *C. carpio,* of Dombes have fewer bones and fewer forked bones in ventral position than the others; carps of Allier are distinguished by the higher number of forked bones. Such geographical variation in the number of certain IMB may explain the reason behind the disparity in the total number of IMB in *C. carpio* studied in the present investigation and that of Lieder (1966).

The layout of the "S and "Y" types of the IMB in *C. carpio* investigated in the current study is distributed in a straight two lines dorsal and ventral to the vertebral column in the caudal region of the fish body. In *L. vorax*, only "S" shaped IMBs are present, and they are allocated in two straight lines dorsal and ventral to the vertebral column in the caudal region of the fish body. Jawad *et al*. (2024), in their study on the osteological features of some clupeid fishes of Iran. They discovered several models of distribution of the IMB; among these are the straight, low- and high-curved line models. They suggested that the straight- line distribution model can be deliberated as an indicative trait as it separates *Alosa braschnikowi* (Borodin, 1904) (Clupeiformes, Clupeidae) from the remaining species of clupeid species they investigated, while the low and high curves were observed across species" the species and genera examined by Jawad *et al*. (2024) and cannot be attained as a good taxonomic criterion. It is not possible at the present time to do any taxonomic valuation for the type of dispersal of the IMB in the cases of *C. carpio* and *L. vorax* until further study considers more species of both genera *Cyprinus* and *Leuciscus* are experimented with.

Similarly, the start and end of distribution of (S) and (Y) pin bones also showed to cross between species and genera in the study of Jawad *et al*. (2024) on clupeid fish species from Iran, and therefore they considered it not a good characteristic to separate the clupeid species investigated. In *C. carpio,* both types of the IMB (S and Y) are distributed in two straight lines dorsal and ventral to the vertebral column in the caudal region of the fish body. In *L. vorax*, "S" shaped IMBs are only present, and they are distributed in two straight lines dorsal and ventral to the vertebral column in the caudal region of the fish body. Until further studies consider several species of the two genera *Cyprinus* and *Leuciscus*, the issue of considering the dispersal of the types of IMB in the fish body cannot be valued as a taxonomic criterion.

The functional or evolutionary significance of the osteological traits of *C. carpio* and *L. vorax*

The vertebral column in *Cyprinus carpio* (common carp) and *Leuciscus vorax* (Tigris asp) reveals adjustments to their natural habitats and swimming schemes. In both species, the vertebral column is segregated into four apparent zones, which enhance elasticity and impose spread. The three precaudal vertebrae areas, supported with strong neural and haemal spines, secure axial muscles vital for maintained swimming, while the caudal vertebrae region reduce to assist propulsion creation through the tail. This zone segregation has evolutionarily significance, as it has balances firmness and flexibility, attributes necessary for carp crossing benthic habitats and Tigris asp takes advantage of in the surface zones. Disparity in vertebral centra shape may link with territory favourites: carp, which are frequently found in turbid, vegetated waters, benefit from firmer trunks for sudden twists, while Tigris asp, a chase predator, is expected to depend on smooth elasticity for quick spurt.

The interdigitation of pterygiophores with neural spines (dorsal fin) and haemal spines (anal fin) features operating specialty. In *C. carpio*, securely interconnected pterygiophores in the dorsal fin improve steadiness through substratum searching, while in *L. vorax*, a further elastic plan might assist in accurate dorsal fin alterations throughout feeding. The anal fin's pterygiophore-haemal spine articulation assists braking and guiding; carp demonstrates wider interdigitation for low-speed mobility, compared with *L. vorax* lowered overlay, preferring hydrodynamic effectiveness. Caudal fin configurations further separate their habitats: both species are observed to have a heterocercal-like form or structure with dorsal procurrent rays sustaining lift, suitable to benthic surroundings and enhancing propulsion for open-water activity. The caudal skeleton's hypural plates and urostyle morphology exhibit these needs, with *L. vorax* firmer hypurals aiding fast increase in velocity against carps flexible lepidotrichia for subtle activities.

Intramuscular bones in both species fulfil as biomechanical devices, conducting muscular powers throughout propulsion. *Cyprinus carpio* displays intense, branched intramuscular ossifications, which might moderate predation hazards by strengthening the body during running away reactions, whereas *L. vorax* has less, smooth bones, decreasing pull through high-speed hunts. Evolutionarily, these bones denote adjustments to feeding schemes: carp's herbivorous-detritivorous behaviour requires stout axial reinforcement for excavation, while *L. vorax* is a piscivory chooses for decreased skeletal mass to boost responsiveness. These osteological merits, modelled by Iraq's freshwater ecosystems— changeable flow systems and source accessibility—feature how skeletal structural design highlights ecological accomplishment in contradictory habitats.

CONCLUSIONS

The current study aims to offer a complete evaluation of the vertebral column, fin structure, and caudal skeleton of *Cyprinus carpio* and *Leuciscus vorax* collected from two localities on Al-Tharthar at the Euphrates and from the Tigris Rivers, Iraq. The outcomes disclose that osteological data vary among the two species examined, emphasising that the construction of the vertebral column and caudal skeleton can be deliberated as important gears in the taxonomic classification of *C. carpio* and *L. vorax*. Additionally, the study recognizes definite osteological traits that can be counted as an operational taxonomic criterion to designate the two species and separate them from the closely related species in the genera that they belong to. This new anatomical set of characteristics take part in an improve comprehension of the taxonomy and systematics of these two species.

CONFLICT OF INTEREST STATEMENT

"The authors declare no conflicts of interest".

DATA AVAILABILITY STATEMENT

Data available on request.

ACKNOWLEDGEMENTS

We would like to thank the fisherman Mahdi Saleh Al-Saeedi, who helped us collect fish samples. We are also grateful to Drs. Rahim Abdul Jalil, Dr. Mona Ahmed, Dr. Taif Nahedh, and Dr. Mohammed Watheq from Baghdad Veterinary Hospital for their assistance in X-raying our fish samples.

LITERATURE CITED

Ackerly, K. L. and Ward, A. B. 2016. How temperature-induced variation in musculoskeletal anatomy affects escape performance and survival of zebrafish (*Danio rerio*). *Journal of Experimental Zoology*, 325(1): 25-40. [CrossRef]

Aguirre, W. E., Walker, K. and Gideon, S. 2014. Tinkering with the axial skeleton: vertebral number variation in ecologically divergent three spine stickleback populations. *Biological Journal of the Linnean Society*, 113(1): 204-19. [CrossRef]

Ahn, D. G. and Gibson, G. 1999a. Axial variation in the three-spine stickleback: genetic and environmental factors. *Evolution and Development*, 1(2): 100-112. [CrossRef]

Ahn, D. G. and Gibson, G. 1999b. Axial variation in the three-spine stickleback: relationship to Hox gene expression. *Development Genes and Evolution*, 209(8): 473-481. [CrossRef]

Al-Ansari, N., Adamo, N. and Sissakian, V. K. 2019. Hydrological characteristics of the Tigris and Euphrates Rivers. *Journal of Earth Sciences and Geotechnical Engineering*, 9(4): 1-26. [ResearchGate]

Al-Ansari, N., Saleh, S., Abdullah, T. and Abed, S. A. 2021. Quality of surface water and groundwater in Iraq. *Earth Sciences and Geotechnical Engineering*, 11(2): 161-199. [CrossRef]

Al-Ubaidy, G. Y. 2009. Estimate the flooded area and land use of Al-Tharthar Lake northwest of Baghdad by using satellites images from Aqua MODIS Satellite. *Al-Rafidain Engineering Journal*, 17(6): 45-53. (In Arabic with English abstract) [Click here]

Al-Zaidy, K. J. L. and Parisi, G. 2025. The diet and feeding habits of *Leuciscus vorax* fish in the main outfall drain middle Iraq. *Iraqi Journal of Agricultural Sciences*, 56(Special): 303-310. [CrossRef]

Andria-Mananjara, D. E., Rasamoelina, H. and Vandeputte, M. 2016. Comparison of rearing performances and intermuscular bone number in the mirror and nude genotypes of common carp (*Cyprinus carpio* L.) in a controlled field test in Madagascar. *Aquaculture Reports*, 3: 77-81. [CrossRef]

Arratia, G. 1987. Anaethalion and similar teleosts (Actinopterygii, Pisces) from the Late Jurassic (Tithonian) of southern Germany and their relationships. *Palaeontographica A (Paläozoologie, Stratigraphie)*, 200(1-2): 1-44. [Click here]

Arratia, G. 2008. Actinopterygian postcranial skeleton with special reference to the diversity of fin ray elements, and the problem of identifying homologies. Arratia, G., Schultze, H.-P. and Wilson, M. V. H. (eds.), Mesozoic Fishes 4 – Homology and Phylogeny, p. 49-101 [ResearchGate]

Arratia, G. 2009. Identifying patterns of diversity of the actinopterygian fulcra. *Acta Zoologica*, 90(S1): 220-235. [CrossRef]

Arratia, G. and Schultze, H.-P. 1992. Reevaluation of the caudal skeleton of certain actinopterygian fishes: III. Salmonidae. Homologization of caudal skeletal structures. *Journal of Morphology*, 214(2): 187-249. [CrossRef]

Arsovska, J., Ristovska, M., Simonović, P., Kostov, V. and Slavevska-Stamenkovič, V. 2021. First data on the structure of the vertebral column in *Gobio* and *Romanogobio* species

(Actinopterygii, Cypriniformes, Gobionidae) from Ohrid Lake and the Vardar River basin. *Acta Ichthyologica et Piscatoria*, 51(1): 37-45. [CrossRef]

Bainbridge, R. 1963. Caudal fin and body movement in the propulsion of some fish. *Journal of Experimental Biology*, 40(1): 23-56. [CrossRef]

Balfour, F. M. and Parker, W. N. 1882. VII. On the structure and development of *Lepidosteus*. *Philosophical Transactions of the Royal Society*, 173: 359-442. [CrossRef]

Berg, F., Slotte, A., Johannessen, A., Kvamme, C., Clausen, L. A. W. and Nash, R. D. M. 2017. Comparative biology and population mixing among local, coastal and offshore Atlantic herring (*Clupea harengus*) in the North Sea, Skagerrak, Kattegat and western Baltic. *PLoS ONE*, 12(10): e0187374. [CrossRef]

Bird, N. C. and Mabee, P. M. 2003. Developmental morphology of the axial skeleton of the zebrafish, Danio rerio (Ostariophysi: Cyprinidae). *Developmental dynamics: an official publication of the American Association of Anatomists*, 228(3): 337-357. [CrossRef]

Birdsong, R. S., Murdy, E. O. and Pezold, F. L. 1988. A study of the vertebral column and median fin osteology in gobioid fishes with comments on gobioid relationships. *Bulletin of Marine Science*, 42(2): 174-214. [ResearchGate]

Birdsong, R.S. 1975. The osteology of Microgobius signatus Poey (Pisces: Gobiidae), with comments on other gobiid fishes. *Bulletin of the Florida State Museum Biological Sciences*, 19: 134-186. [CrossRef]

Bogutskaya, N.G. and Coad, B.W. 2009. A review of vertebral and fin-ray counts in the genus *Alburnoides* (Teleostei: Cyprinidae) with a description of six new species. *Zoosystematica Rossica*, 18(1): 126-173. [CrossRef]

Bond, C. E. and Uyeno, T. 1981. Remarkable changes in the vertebrae of Perciform fish *Scombrolabrax* with notes on its anatomy and systematics. *Japanese Journal of Ichthyology*, 28: 259-262. [Click here]

Cao, D. C., Kuang, Y. Y., Zheng, X.H., Tong, G. X., Li, C. T. and Sun, X. W. 2015. Comparative analysis of intermuscular bones in three strains of common carp. *Journal of Applied Ichthyology*, 31(1): 32-36. [CrossRef]

Chang, M., Wang, X., Liu, H., Miao, D., Zhao, Q., Guoxuan Wu, G., Liu, J., Li, Q., Sun, Z. and Wang, N. 2008. Extraordinarily thick- boned fish linked to the aridification of the Qaidam Basin (northern Tibetan plateau). *PNAS*, 105(36): 13246-13251. [CrossRef]

Chapleau, F. 1989. Etude de la portion supracranienne de lanageoire dorsale chez les Soleidae (Teleosteens, Pleuronectiformes). *Cybium*, 13: 271-279. [CrossRef]

Chen, X. L. and Huang, H. J. 1977. Cyprininae. *In*: Wu, H. W. (Ed.), The cyprinid fishes of China. Part 2 (pp. 395-438). Shanghai: Shanghai People's Press.

Chen, X. L., Yue, P. Q. and Lin, R. D. 1984. Major groups within the family Cyprinidae and their phylogenetic relationships. *Acta Zootaxonomica Sinica*, 9: 424-440 (in Chinese with English summary).

Çiçek, E., Jawad, L., Eagderi, S., Esmaeili, H. R., Mouludi-Saleh, A. T. T. A., Sungur, S. and Fricke, R., 2023. Freshwater fishes of Iraq: a revised and updated annotated checklist—2023. *Zootaxa*, 5357(1): 1-49. [CrossRef]

Clausen, L. A. W., Staehr, K.-J., Rindorf, A. and Mosegaard, H. 2015. Effect of spatial differences in growth on distribution of seasonally co-occurring herring *Clupea harengus* stocks. *Journal of Fish Biology*, 86(1): 228-247. [CrossRef]

Coad, B. W. 2010. Freshwater fishes of Iraq. Pensoft Series Faunistica No. 93, 274 pp. Pensoft Publishers, Moscow. [Click here]

Coburn, M. M. and Cavender, T. M. 1992. Interrelationships of North American Cyprinid Fishes. *In*: Mayden, R. L. (Ed.), Systematics, Historical Ecology, and North American Freshwater Fishes. Stanford University Press, Stanford, California, p. 328-373. [Click here]

Danos, N. and Ward, A. B. 2012. The homology and origins of intermus cular bones in fishes: Phylogenetic or biomechanical determinants? *Biological Journal of the Linnean Society*, 106(3): 607–622. [CrossRef]

De Clercq, A., Perrott, M.R., Davie, P.S., Preece, M.A., Wybourne, B., Ruff, N., Huysseune, A. and Witten, P.E. 2017. Vertebral column regionalisation in Chinook salmon, *Oncorhynchus tshawytscha*. *Journal of Anatomy*, 231(4): 500-514. [CrossRef]

De Pinna, M. C. C. 1996. Chapter 7-Teleostean monophyly. *In*: Stiassny, M. L. J., Parenti, L. R. and Johnson, J. D. Interrelationships of Fishes, Academic Press, P. 147-162. [CrossRef]

Desvignes, T., Carey, A. and Postlethwait, J. H. 2018. Evolution of caudal fin ray development and caudal fin hypural diastema complex in spotted gar, teleosts, and other neopterygian fishes. *Developmental Dynamics*, 247(6): 832-853. [CrossRef]

Diogo, R., Doadrio, I. and Vandewalle, P. 2008. Teleostean phylogeny based on osteological and myological characters [Filogenia de teleosteos basada en características osteológicas y miológicas]. *International Journal of Morphology*, 26(3): 463-522. [CrossRef]

Doadrio, I. (ed) 2002. Atlas y libro rojo de los peces conti- nentales de Espanã (Atlas and red book of Spanish freshwater fishes). Ministerio de Medio Ambiente, Madrid: Ministerio de Medio Ambiente (in Spanish), 358pp. [Click here]

Dong, Z. J., Huang, D. Z., Li, L. J., Yuan, X. H., Miao, W. M., Chen, Q. Q., Lu, Z. B. and Zhang, B. L. 2006. Preliminary study on intermuscular bones of several cultured cyprinids. *Journal of Shanghai Fisheries University*, 15(4): 425-429. [Google Scholar]

Echreshavi, S., Esmaeili, H. R., Teimori, A. and Reichenbacher, B. 2021. A comparative study on the caudal skeleton of goatfishes (Teleostei: Perciformes: Mullidae) from the Western Indo-Pacific region: An additional taxonomic tool. *Regional Studies in Marine Science*, 48: 102066. [CrossRef]

Fang, P. W. 1936. Chinese fresh–water fishes referring to Cyprininae (sen.str.). *Sinensia*, 7: 686-712. [Click here]

Flammang, B. E. and Lauder, G. V. 2008. Speed-dependent intrinsic caudal fin muscle recruitment during steady swimming in bluegill sunfish, Lepomis macrochirus. *Journal of Experimental Biology*, 211(4): 587-598. [CrossRef]

Frame, D. W., Andrews, T. J. and Cole, C. F. 1978. Osteology of the American Plaice *Hippoglossoldes platessoides*. Postilla, 173: 1-32. [Click here]

Fricke, R. 1983. A method of counting caudal fin rays of actinopterygian fishes. *Braunschweiger Naturkundliche Schriften*, 1(4): 729-733. [Click here]

Fritzsche, R. A. and Johnson, G. D. 1980. Early osteological development of white perch and striped bass with emphasis on identification of their larvae. *Transaction of the American Fisheries Society*, 109: 387-406. [Click here]

Gemballa, S. 2001. Myoseptal tendons in vertebrates: Spatial arrangement, functional and evolutionary implications. *American Zoologist*, 41: 1452.

Georgakopoulou, E., Sfakianakis, D. G., Kouttouki, S., Divanach, P., Kentouri, M. and Koumoundouros, G. 2007. The influence of temperature during early life on phenotypic expression at later ontogenetic stages in sea bass. *Journal of Fish Biology*, 70(1): 278-291. [CrossRef]

González Vilas, L., Guisande, C., Vari, R. P., Pelayo-Villamil, P., Manjarrés-Hernández, A., García-Roselló, E., González-Dacosta, J., Heine, J., Pérez-Costas, E., Granado-Lorencio, C. and Palau-Ibars, A. 2016. Geospatial data of freshwater habitats for macroecological studies: an example with freshwater fishes. *International journal of geographical information science*, 30(1): 126-141. [CrossRef]

Gosline, W. A. 1971. Functional morphology and classification of teleostean fishes. University of Hawaii Press: Honolulu, 208 pp.

Gosline, W. A. 1960. Contribution towards a classification of modem Isospondylous fishes. *Bulletin of the British Museum* (*Natural History*), 6: 327-365. [Click here]

Gosline, W. A. 1961. Some osteological features of modern lower teleostean fishes. *Smithsonian Miscallinious Collections*, 142(3): 1-42. [Click here]

Gosline, W. A. 1997. Functional morphology of the caudal skeleton in teleostean fishes. *Ichthyological Research*, 44(2): 137-141. [CrossRef]

Gröhsler, T., Oeberst, R., Schaber, M., Larson, N. and Kornilovs, G. 2013. Discrimination of western Baltic Spring spawning and central Baltic herring (*Clupea harengus* L.) based on growth vs. natural tag information. *ICES Journal of Marine Science*, 70(6): 1108-1117. [CrossRef]

Hadi, H. D., Baraaj, A. H. and Ali, A. H. 2023. Morphological and molecular studies of kais kingfish *Cyprinion kais* Heckel, 1843 (Pisces, Cypriniformes, Cyprinidae) from the middle of Iraq. *Bulletin of the Iraq Natural History Museum*, 17(4): 611-628. [CrossRef]

Hadi, H. D., Baraaj, A. H., Ali, A. H. and Sajet, M. R. 2024. First record of the north African catfish *Clarias gariepinus* (Burchell, 1822) (Siluriformes, Clariidae) in Tigris River, Iraq. *Bulletin of the Iraq Natural History Museum*, 18 (2): 477-485. [CrossRef]

https://doi.org/10.1093/icesjms/fst064

Haedrich, R. L. 1967. The stromateoid fishes: systematics and a classification. *Bulletin of the Museum of Comparative Zoology*, 135 (1): 31-139. [Click here]

Harrell, R. M. and Dean, J. M. 1987. Pterygiophore interdigitation patterns and morphometry of larval hybrids of *Morone* species. *Transactions of the American Fisheries Society*, 116(5): 719-727. [CrossRef]

Heckel, J. J. 1843. Ichthyologie [von Syrien]. *In*: von Russegger, J., Reisen in Europa, Asien und Afrika, mit besonderer Rücksicht auf die naturwissenschaftlichen Verhältnisse der betreffenden Länder unternommen in den Jahren 1835 bis 1841, etc. E. Schweizerbart'sche Verlagshandlung. Stuttgarter Beiträge zur Naturkunde. Serie A, Biologie [von Syrien], 1 (2): 991-1099. [Click here]

Hollister, G. 1936. Caudal skeleton of Bermuda shallow water fishes. I. Order: Isospondyli: Elopidae, Megalopidae, Albulidae, Clupeidae, Dussumieridae, Engraulidae. *Zoologica*, 21(4): 257-290. [CrossRef]

Hollister, G. 1941. Caudal skeleton of Bermuda shallow water fishes. V. Order Percomorphi: Carangidae. Zoologica. *Scientific Contributions of the New York Zoological Society*, 26(1): 31-45. [CrossRef]

Howes, G. J. 1984. Phyletics and biogeography of the aspinine cyprinid fishes. *Bulletin of the British Museum (Natural History)*, *Zoology*, 47: 283-303. [CrossRef]

Hubbs, C. L. and Lagler, K. F. 1947. Fishes of the Great Lakes Region. *Zoology*, 26: 1-186. [Google Scholar]

Hubbs, C. L., Lagler, K. F. and Smith, G. R. 2004. Fishes of the Great Lakes region, revised edition. Ann Arbor: The University of Michigan Press. Michigan USA, xvii + 276 pp. [Google Scholar]

Ishikawa, Y. 1992. Innervation of the caudal-fin muscles in the teleost fish, medaka (*Oryzias latipes*). *Zoological Science*, 9(5): 1067-1080. [Click here]

Jawad, L. 2003. Impact of environmental change on the freshwater fish fauna of Iraq. *International Journal of Environmental Studies*, 60: 581-593. [CrossRef]

Jawad, L. A. 2008. Second revision of the New Zealand triplefin genus *Forsterygion* Whitley and Phillips, (Pisces: Tripterygiidae). *Journal of Natural History*, 42: 2943-2989. [CrossRef]

Jawad, L. A. 2015. Study of the vertebral column of the onion trevally, *Carangoides caeruleopinnatus* (Teleostei: Carangidae) collected from the Sea of Oman. *Italian Journal of Zoology*, 82: 41-47. [CrossRef]

Jawad, L. A. and Clements, K. D. 2004. *Matanui*, a new genus of deepwater triplefin fishes (Pisces: Tripterygiidae) from New Zealand. *Journal of the Royal Society of New Zealand*, 34(1): 81-103. [CrossRef]

Jawad, L. and Al-Hassani, L. 2013. Some morphological studies on the vertebral column of the Silver-cheeked toadfish *Lagocephalus sceleratus* (Gmelin, 1789) (Family: Tetraodontidae) collected from the Sea of Oman. *Quaderni del Museo di Storia Naturale di Ferrara*, 1: 69-74. [Click here]

Jawad, L. and Al-Hassani, L. 2014. Morphological aspect of the vertebral column of the Indian Mackerel *Rastrellinger Kanagurta* (Osteichthyes: Scombriadae) collected from the Sea of Oman. *Thalassia Salentina*, 36: 3-12. [Click here]

Jawad, L. A. and Alwan, N. 2020. Osteological characters define six species of the *Capoeta damascina* species complex (Cypriniformes: Cyprinidae). *Journal of Ichthyology*, 60: 182-203. [CrossRef]

Jawad, L. A. and Jig, L. 2016. Comparative osteology of the axial skeleton of the genus *Pampus* (Family: Stromateidae, Perciformes). *Journal of the Marine Biological Association of the United Kingdom*, 97: 277-287. [CrossRef]

Jawad, L. A., Al-Hassani, L. and AL-Kharusi, L. H. 2013. On the morphology of the vertebral column of the frigate tuna, *Auxis thazard* (Lacepedea, 1800) (family: Scombridae) collected from the sea of Oman. *Acta Musei Nationalis Pragae*, 69(1): 101-105. [CrossRef]

Jawad, L. A., Al-Hassani, L. and Al-Kindi, A. 2014. Vertebral column morphology of the Bengal snapper, *Lutjanus bengalensis* (Bloch, 1790), from the Oman Sea. *Cahiers Biologie Marine*, 55(4): 491-497. [CrossRef]

Jawad, L. A., Dizaj, L. P. and Esmaeili, H. R. 2024. Osteological features of some clupeid fishes (Teleostei: Clupeiformes) of Iran. *Anatomia, Histologia, Embryologia*, 53(4): e13070. [CrossRef]

Jawad, L. A., Fricke, R. and Näslund, J. 2018. Comparative osteology of the family Tripterygiidae (Teleostei: Blenniiformes). *Journal of the Marine Biological Association of the United Kingdom*, 98(6): 1487-1511. [CrossRef]

Jawad, L. A., Orlov, A. M. and Grigorov, I. V. 2020. Identification of two species of the genus *Antimora* Günther, 1878 (Pisces: Moridae) using some osteological characters. *Cahier de Biologia Marina*, 61(3): 323-342. [CrossRef]

Jordan, D. S. 1892. Relations of temperature to vertebrae among fishes. *Proceedings of the United States National Museum*, 1891(1): 107-120.

Kacem, A., Meunier, F. J. and Bagliniere, J. L. 1998. A quantitative study of morphological and histological changes in the skeleton of *Salmo salar* during its anadromous migration. *Journal of Fish Biology*, 53(5): 1096-1109. [CrossRef]

Ke, Z., Zhang, W. and Jiang, Y. 2008. Developmental morphology of the intermuscular bone in *Hypophthalmichthys molitrix*. *Chinese Journal of Zoology*, 43(6): 88-96. [Google Scholar]

Kornijów, R., Szczerbowski, J. A., Krzywosz, T. and Bartel, R. 2001. The macrozoobenthos of the Iraqi lakes Tharthar, Habbaniya and Razzazah. *Archives of Polish Fisheries*, 9(1): 127-145. [ResearchGate]

Kossmann, H. 1972. Untersuchungen über die genetische Varianz der Zwischenmuskelgräten des Karpfens. *TAG Theoretical and Applied Genetics*, 42(3): 130-135. [CrossRef]

Kotalawala, A. B. 1991. Interrelationships among genera of Cyprinidae (Teleostei) as indicated by the caudal skeleton. *Vidyodaya Journal of Science*, 3(2): 47-59. [CrossRef]

Kottelat, M. and Freyhof, J. 2007. Handbook of European freshwater fishes. Publications Kottelat, Cornol and Freyhof, Berlin, 646 pp. [Click here]

Lauder, G. V. 2000. Function of the caudal fin during locomotion in fishes: kinematics, flow visualization, and evolutionary patterns. *American Zoologist*, 40(1): 101-122. [CrossRef]

Lauder, G. V. and Drucker, E. G. 2004. Morphology and experimental hydrodynamics of fish fin control surfaces. *IEEE Journal of Oceanic Engineering*, 29(3): 556-571. [CrossRef]

Li, L., Zhong, Z. Z., Zeng, M., Liu, S. J., Zhou, Y., Xiao, J. Wang, J. and Liu, Y. 2013. Comparative analysis of intermuscular bone in different ploidy fish. *Science China Life Sciences*, 56: 341-350. [CrossRef]

Lieder, U. 1966. Untersuchungsergebnisse Uber die Gratenzahlenbei 17 Subwasser Fischarten. *Zeitschriff fur Fischerai*, Band XNF., 4/5: 329-350.

Lindsey, C. C. 1978. Form, function, and locomotory habits in fish. *Fish Physiology*, 7: 1-100. [CrossRef]

Lukač, M., Ludoški, J., Dekić, R. and Milankov, V. 2023. Evolutionary body shape diversification of the endemic Cyprinoidei fishes from the Balkan's Dinaric karst. *Organisms Diversity and Evolution*, 23(4): 983-1004. [CrossRef]

Majeed, O. S., Al-Azawi, A. J. and Nashaat, M. R. 2022. The effect of Tharthar-Tigris canal on the environmental properties of the Tigris River Northern Baghdad, Iraq. *Baghdad Science Journal*, 19(6): 1177-1190. [CrossRef]

Majeed, O. S., Nashaat, M. R., Al-Azawi, A. J. M. and Drira, Z. 2023. Application of the Canadian Water Quality Index (CCME-WQI) for aquatic life to assess the effect of Tharthar water upon the quality of the Tigris water, Northern Baghdad City, Iraq. *Ibn Al-Haitham Journal for Pure and Applied Sciences*, 36(4): 21-31. [CrossRef]

Mathiassen, J. R., Misimi, E., Bonde, M., Veliyulin, E. and Østvik, S. O. 2011. Trend in application of imaging technologies to inspection of fish and fish products. *Trends in Food Science and Technology*, 22(6): 257-275. [CrossRef]

Matsui, T. 1967. Review of the mackerel genera *Scomber* and *Rastrelliger* with description of a new species of *Rastrelliger*. *Copeia*, 1: 71-83**.** [CrossRef]

Maxwell, E. E. and Wilson, L. A. 2013. Regionalization of the axial skeleton in the 'ambush predator' guild–are there developmental rules underlying body shape evolution in ray-finned fishes? *BMC Evolutionary Biology*, 13 (1): 265. [CrossRef]

McDowall, R. M. 1982. The centrolophid fishes of New Zealand (Pisces: Centrolophidae). *Journal of the Royal Society of New Zealand*, 12: 103-142. [Click here]

McDowall, R. M. 2008. Jordan's and other ecogeographical rules, and the vertebral number in fishes. *Journal of Biogeography*, 35(3): 501-508. [CrossRef]

Meske, C. 1968. Breeding carp for reduced number of intermuscular bones and growth of carp in aquaria. *Bamidgeh*, *Bulletin of Fish Culture in Israel*, 20(4): 105-119. [Click here]

Miyashita, T. and Fujita, K. 2000. Two series of parapophyses in neoscopelid fishes (Teleostei: Myctophiformes). *Ichthyological Research*, 47: 143-148. [CrossRef]

Moav, R., Finkel, A. and Wohlfarth, G. 1975. Variability of intermuscular bones, vertebrae, ribs, dorsal fin rays, and skeletal disorders in the common carp. *Theoretical Applications of Genetics*, 46: 33-43. [CrossRef]

Mohammed, H. H., Ebrahim, M., Youssef, M. I., Saleem, A. S. Y. and Abdelkhalek, A. 2024. Behavior and management of carp fish: A review. *Open Veterinary Journal* 14(1):1-11. [CrossRef]

Monod, T. 1968. Le complexe urophore des Poissons téléostéens. *Memoire Institut Fondamental d'Afrique Noire*, 81(1): 1-705. [Click here**]**

Müller, J., Scheyer, T. M., Head, J. J., Barrett, P. M., Werneburg, I., Ericson, P. G., Pol, D. and Sánchez-Villagra, M. R. 2010. Homeotic effects, somitogenesis and the evolution of vertebral numbers in recent and fossil amniotes. *Proceedings of the National Academy of Sciences*, 107(5): 2118-2123. [CrossRef]

Munroe, T. A. 1992. Interdigitation pattern of dorsal fin pterygiophores and neural spines, an important diagnostic character for symphurine tonguefishes (*Symphurus*: Cynoglossidae: Pleuronectiformes). *Bulletin of Marine Science*, 50(3): 357-403. [Click here]

Nag, A. C. 1967. Functional morphology of the caudal region of certain clupeiform and perciform fishes with reference to the taxonomy. *Journal of Morphology*, 123(4): 529-558. [CrossRef]

Nursall, J. R. 1956. The lateral musculature and the swimming of fish. *Proceedings of the Zoological Society of London*, 126: 127-143. [CrossRef]

Nybelin, O. V. 1963. Zur morphologie und terminologie des schwanzskelettes der Actinopterygier. *Arkiv för Zoologi*, 15: 485-516.

Oleiwi, A. S. and Al-Dabbas, M. 2022. Assessment of contamination along the Tigris River from Tharthar-Tigris canal to Azizziyah, middle of Iraq. *Water*, 14(8): 1194. [CrossRef]

Olney, J. E., Grant, G. C., Schultz, F. E., Cooper, C. L. and Hageman, J. 1983. Pterygiophore-interdigitation patterns in larvae of four Morone species. *Transactions of the American Fisheries Society*, 112(4): 525-531.

Patterson, C. and Johnson, G. D. 1995. The intermuscular bones and ligaments of teleostean fishes. *Smithsonian Contribution to Zoology*, 559: 1-85. [CrossRef]

Perea, S., Böhme, M., Zupančič, P., Freyhof, J., Šanda, R., Özuluğ, M., Abdoli, A. and Doadrio, I. 2010. Phylogenetic relationships and biogeographical patterns in Circum-Mediterranean subfamily Leuciscinae (Teleostei, Cyprinidae) inferred from both mitochondrial and nuclear data. *BMC Evolutionary Biology*, 10: 1-27. [CrossRef]

Potthoff, T. 1974. Osteological development and variation in young tunas, genus *Thunnus* (Pisces, Scombridae), from the Atlantic Ocean. *Fishery Bulletin*, 72(2): 205-231. [Click here]

Potthoff, T. 1975. Development and structure of the caudal complex, the vertebral column, and the pterygiophores in the blackfin tuna (*Thunnus atlanticus*, Pisces, Scombridae). *Bulletin of Marine Science*, 25(2): 205-231.

Pourshabanan, A., Yazdani-Moghaddam, F., Ghassemzadeh, F., Mousavi-Sabet, H., Rossi, G. and Aliabadian, M. 2021. Morpho-species of the genus *Leuciscus* Cuvier, 1816 (Teleostei: Leuciscinae) from Iran revisited using molecular approaches. *Zoology in the Middle East*, 67(2): 126-132. [CrossRef]

Prokofiev, A. M. 2009. Problems of the classification and phylogeny of *Nemacheiline loaches* of the group lacking the preethmoid I (Cypriniformes: Balitoridae: Nemacheilinae). *Journal of Ichthyology*, 49(10): 874-898. [CrossRef]

Purrafee Dizaj, L., Esmaeili, H.R., Jawad, L., Ebrahimi, M., Gholamhosseini, A. and Valinasab, T. 2020. Taxonomic significance of vertebral column and caudal skeleton of clupeid fishes (Teleostei: Clupeiformes) of Iran. *Acta Zoologica*, 103(2): 1-14. [CrossRef]

.

Rainboth, W. J. 1981. Systematics of the Asiatic Barbins (Pisces, Cyprinidae). Ph. D. Dissertation, The University of Michigan, Ann Arbor, MI, 253 pp. [Click here]

Ramzu, M. and Meunier, F. J. 1999. Descripteurs morphologiques de la zonation de la colonne vertébrale chez la truite arc-en-ciel *Oncorhynchus mykiss* (Walbaum, 1792)(Teleostei, Salmoniforme). *Annales des Sciences naturelles-Zoologie et Biologie animale*, 20 (3): 87-97. [CrossRef]

Rendahl, H. 1928. Beiträge zur Kenntnis der Chinesischen Süsswasserfische. I. *Systematischer Teil. Arkiv för Zoologi*, 20A 1: 148-152.

Riede, K. 2004. Global register of migratory species - from global to regional scales. Final Report of the R&D-Projekt 808 05 081. Federal Agency for Nature Conservation, Bonn, Germany, 329 pp. [ResearchGate]

Rojo, A. L. 1991. Dictionary of Evolutionary Fish Osteology. CRC Press, London. New York, 273 pp. [CrossRef]

Rosen, D. E. 1973. Interrelationships of higher Euteleostean fishes. Academic Press, 117pp. [Click here]

Rosen, D. E. and Patterson, C. 1969. The structure and relationships of the paracanthopterygian fishes. *Bulletin of the American Museum of Natural History*, 141: 357-464. [Click here]

Sahu, B. B., Samal, R. P., Raghunath, M.R., Mohanty, S., Adhikari, S., Sahu, A.K. and Jayashankar, P. 2012. Record of skeletal system and pin bones in table size Indian major carps: Rohu (*Labeo rohita*, Hamilton 1822), catla (*Catla catla*, Hamilton 1822) and mrigal (*Cirrhinus mrigala* Hamilton 1822). *World Journal of Fish Marine Sciences*, 4: 382-385. [Click here]

Salman, R. M., Nashaat, M. R. and Sh, M. F. 2017. Estimating the water properties which effluent from sewage treatment plants of Al-Kut Province into the Tigris River, Iraq. *European Academic Research*, 4(12): 10672-10687. [Google Scholar]

Sankar, M., Kryvi, H., Fraser, T. W., Philip, A. J. P., Remø, S., Hansen, T.J., Witten, P. E. and Fjelldal, P. G. 2024. A new method for regionalization of the vertebral column in salmonids based on radiographic hallmarks. *Journal of Fish Biology*, 105(4): 1189-1199. [CrossRef]

Schultze, H. -P. and Arratia, G. 1986. Reevaluation of the caudal skeleton of actinopterygian fishes. I. *Lepisosteus* and *Amia*. *Journal of Morphology*, 190(2): 215-241. [CrossRef]

Schultze, H. -P. and Arratia, G. 1989. The composition of the caudal skeleton of teleosts (Actinopterygii: Osteichthyes). *Zoological Journal of the Linnean Society*, 97: 189-231. [CrossRef]

Schultze, H. -P. and Arratia, G. 2013. The caudal skeleton of basal teleosts, its conventions, and some of its major evolutionary novelties in a temporal dimension. *In*: Arratia, G., Schultze, H.-P. and Wilson, M. V. H. (eds.), Mesozoic Fishes 5 – Global Diversity and Evolution, p. 187-246, München, Germany. [ResearchGate]

Sengbusch, R. and Meske, C. 1967. Auf dem Wege zum grä tenlosen Karpfen. *Der Züchter*, 37(6): 271-274. [CrossRef]

Silva, A. T., Katopodis, C., Santos, J. M., Ferreira, M.T. and Pinheiro, A. N. 2012. Cyprinid swimming behaviour in response to turbulent flow. *Ecological Engineering*, 44: 314-328. [CrossRef]

Springer, V. G. and Smith-Vaniz, W. F. 2008. Supraneural and pterygiophore insertion patterns in carangid fishes, with description of a new Eocene carangid tribe, † Paratrachinotini, and a survey of anterior anal fin pterygiophore insertion patterns in Acanthomorpha. *Bulletin of the Biological Society of Washington*, 16(1): 1-73. [CrossRef]

Swain, D. P. 1992a. Selective predation for vertebral phenotype in *Gasterosteus aculeatus*: reversal in the direction of selection at different larval sizes. *Evolution*, 46(4): 998-1013. [CrossRef]

Swain, D. P. 1992b. The functional basis of natural selection for vertebral traits of larvae in the stickleback *Gasterosteus aculeatus*. *Evolution*, 46: 987-997. [CrossRef]

Tyler, J. C., O'Tool, B. and Winterbottom, R. 2003. Phylogeny of the genera and families of zeiform fishes, with comments on their relationships with Tetraodontiformes and caproids. *Smithsonian Contribution to Zoology*, 618: 1-110. [CrossRef]

Vallod, D. and Arthaud, F. 2009. Nombre, type et répartition des arêtes de filets de carpes communes (*Cyprinus carpio*, L.) originaires de six régions françaises de production. *Cybium*, 33(4): 305-308. [Click here]

Via, S., Gomulkiewicz, R., De Jong, G., Scheiner, S. M., Schlichting, C. D. and Van Tienderen. P. H. 1995. Adaptive phenotypic plasticity: consensus and controversy. *Trends in Ecology and Evolution*, 10(5): 212-217. [CrossRef]

Videler, J. J. 1993. Fish swimming. Chapman & Hall: London, 260 pp. [Click here]

Wan, S., Yi, S., Zhong, J., Wang, W., Jiang, E., Chen, B. and Gao, Z. 2014. Development and morphological observation of intermuscular bones in *Megalobrama amblycephala*. *Acta Hydrobiologica Sinica*, 38(6): 1143-1151. (In Chinese) [Click here]

Wang, Y. H. 1979. On the classification, distribution, origin and evolution of the fishes referred to the subfamily Cyprininae of China, with description of a new species. *Acta Hydrobiological Sinica*, 6: 419-438 (in Chinese with English summary). [CrossRef]

Ward, A. B. and Brainerd, E. L. 2007. Evolution of axial patterning in elongate fishes. *Biological Journal of the Linnean Society*, 90(1): 97-116. [CrossRef]

Webb, P. W. and Gerstner, C. L. 2021. Fish swimming behaviour: predictions from physical principles. *In*: Biomechanics in animal behaviour (p. 59-77). Garland Science.

Wiley, E. O., Fuiten, A. M., Doosey, M. H., Lohman, B. K., Merkes, C. and Azuma, M. 2015. The caudal skeleton of the zebrafish, Danio rerio, from a phylogenetic perspective: a polyural interpretation of homologous structures. *Copeia*, 103(4): 740-750. [CrossRef]

Yang, L. and Mayden, R. L. 2010. Phylogenetic relationships, subdivision, and biogeography of the Cyprinid tribe Labeonini (sensu Rainboth, 1991) (Teleostei: Cypriniformes), with comments on the implications of lips and associated structures in the labeonin classification. *Molecular Phylogenetics and Evolution*, 54: 254-265. [CrossRef]

Yang, L., Mayden, R. L., Sado, T., He, S., Saitoh, K. and Miya, M. 2010. Molecular phylogeny of the fishes traditionally referred to Cyprinini sensu stricto (Teleostei: Cypriniformes). *Zoologica Scripta*, 39(6): 527-550. [CrossRef]

Zdanowski, B., Lossow, K., Bartel, R. and Szczerbowski, J.A. 2001. Salinity levels and the trophic state of Iraqi dam reservoirs and lakes. *Archives of Polish Fisheries*, 9 Supplement 1: 35-52.

Zhou, W. 1989. Phylogeny of the subfamily Cyprininae (Pisces: Cyprinidae). *Acta Zootaxonomica Sinica*, 14: 247-256. (In Chinese with English abstract)

Zhou, W. and Chu, X. -L. 1986. Systematic study of the genus *Cyprinus* (Pisces: Cyprinidae) in Yunnan, China. *Zoological Research*, 7(3): 297-310. [Click here]

Bull. Iraq nat. Hist. Mus.
(2026) 19 (1): 139-193.

الصفات العظمية للهيكل المحوري لسمكتين من المياه العذبة في العراق

*فاطمة علي الفتلي و **ليث جواد

*قسم علوم الحياة، كلية العلوم، جامعة بغداد، بغداد، العراق.

**كلية العلوم البيئية والحيوانية، معهد يونيتيك للتكنولوجيا، 139 كارينغتون رود، ماونت ألبرت، أوكلاند 1025، نيوزيلندا.

الاستلام: 2025/9/7، المراجعة: 2026/1/30، القبول: 2026/1/31، النشر: 2026/6/20

الخلاصة

تعد هذه الدراسة الأولى من نوعها التي تُقدم تحليلًا شاملًا للعمود الفقري، و بنية الزعانف، والهيكل العظمي للذيل لهذه الأنواع من سمك الكارب الشائع *Cyprinus carpio* Linnaeus, 1758 و سمك الشلك *Leuciscus vorax* (Heckel, 1843) الذي ينتمي الى عائلة Cyprinidae و رتبة Cypriniformes. جُمعت النماذج من الثرثار على نهر الفرات ومن نهر دجلة في مدينة الزبيدية، محافظة واسط-وسط العراق، على التوالي. تم استخدام التصوير الشعاعي لدراسة السمات المختلفة للعمود الفقري والهيكل العظمي للذيل، وتم التحقق من هذه الخصائص لكلا النوعين. تُشير النتائج إلى وجود تباين في البيانات العظمية بين النوعين، مما يُؤكد أهمية بنية العمود الفقري والهيكل العظمي للذيل في التصنيف العلمي لسمك الكارب الشائع وسمك الشلك. تُساهم هذه المجموعة الجديدة من الخصائص التشريحية في تحسين فهمنا لتصنيف ومنهجية هذين النوعين. كما تُناقش الدراسة الأهمية الوظيفية والتطورية للسمات العظمية التي تم فحصها في كلا النوعين.