Iran. J. Ichthyol. (2025) 12(4): 300-311
P-ISSN: 2383-1561; E-ISSN: 2383-0964

ORIGINAL ARTICLE

Taxonomical perspective of osteological features in *Garra arunachalensis* (Nebeshwar & Vishwanath, 2013), a native hill stream fish of upper Brahmaputra basin, India

Mintumoni PEGU, Simi GOGOI, Moirangthem Kameshwor SINGH*, Bijoy NEOG

Department of Life Sciences, Dibrugarh University, Dibrugarh - 786004, Assam.

Correspondence
kameshworm@dibru.ac.in

Abstract
The genus *Garra* of Cyprinidae family comprises of 170 species inhabiting in the subtropical and tropical regions of Africa, Asia and Middle-eastern countries. The genus is specialized in having lower lip modified into mental adhesive disc which help the fishes in thriving fast flowing mountain streams. This study provides a comprehensive osteological description of *Garra arunachalensis* by using double staining method for skeletal visualization. Twenty specimens were used to study the structures of neurocranium, infraorbital series, branchial apparatus, axial skeleton, and fin structures of the species. Comparative analysis with congeners revealed similarities in neurocranium, branchial apparatus and pectoral and pelvic radial bones with species like *G. mullya, G. annandalei* and *G. rossica* while some notable differences were also found in hypural plates of caudal fin skeleton, number of axial skeletons, fin ray counts and infraorbital elements with the species like *G. persica*. The findings will underscore the utility of osteological characters in resolving taxonomic and phylogenetic complexities within the genus *Garra* for further systematics and evolutionary investigations.

Keywords: Axial skeleton, *Garra arunachalensis*, Neurocranium, Osteology, Taxonomy, Upper Brahmaputra Basin

INTRODUCTION

The genus *Garra* (Hamilton 1822) is one of the most diverse genera with over 170 recognized species, within the Cyprinidae family, which is found throughout the tropical and subtropical regions of Asia, Africa, and the Middle East (Menon 1964; Vatandoust et al. 2019). The distinctive feature of the genus is a modified lower lip that forms a mental adhesive disc with a posterior boundary that is not continuous along the mental region. The lateral end of each side's anteromedian fold typically reaches the mental adhesive disc's anterolateral lobe, and the crescentic anteromedian fold of the disc is equal to or wider than the central callous pad (Roni & Vishwanath 2017). They inhabit the swift-moving waters of hill streams and rivers, where their horizontally orientated pectoral and ventral fins and oral sectorial disc frequently stick to rock surfaces on the bottom (Li et al. 2008). In the genus *Garra*, osteological features can help provide additional distinguishing characters, as there are a few morphologically identifiable features within the genus that can be used to develop taxonomic keys. Osteological features can yield useful information for a number of applications, including fish ontogeny and developmental studies (Britz & Conway 2009; Fiaz et al. 2012), archaeology (Carnevale et al. 2011), and phylogenetic analysis (Jalili et al. 2015; Nasri et al. 2016). Compared to other phenotypic tools, osteological features are thought to be crucial diagnostic qualities for evaluating systematics and evolutionary relationships within Teleostei (Keivany 2014, 2017). Therefore, this study has been carried out on *Garra arunachalensis* to understand the detailed osteological features of the species.

MATERIALS AND METHODS

Twenty specimens of *G. arunachalensis* (Fig. 2a) were collected from lower Dibang valley (27°33'21"N, 96°30'13"E) of Arunachal Pradesh (Fig. 1), India during 2023-2025 using electro-fishing devices and fixed in 10% formalin and preserved in 70% alcohol

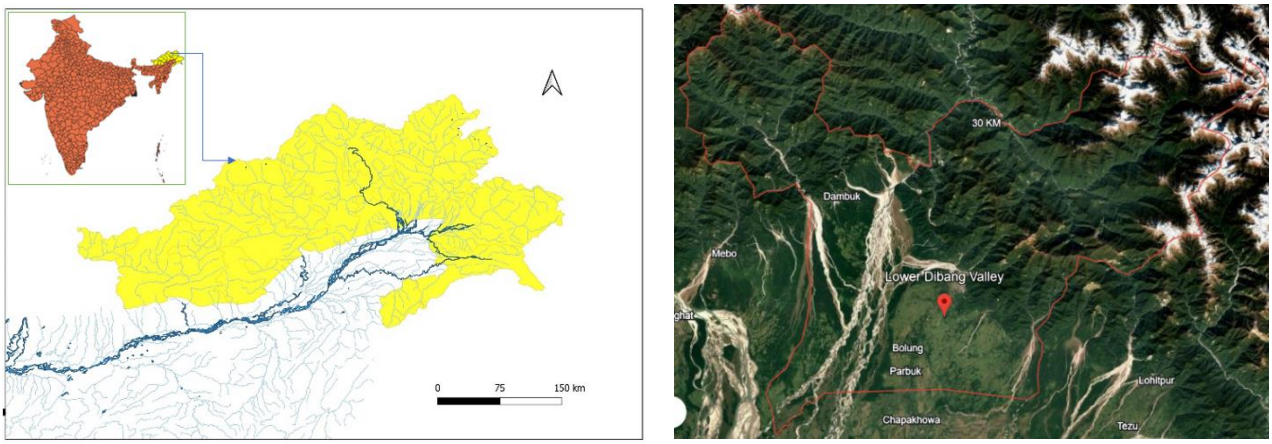

Fig.1. Fish collection site (upper Brahmaputra basin).

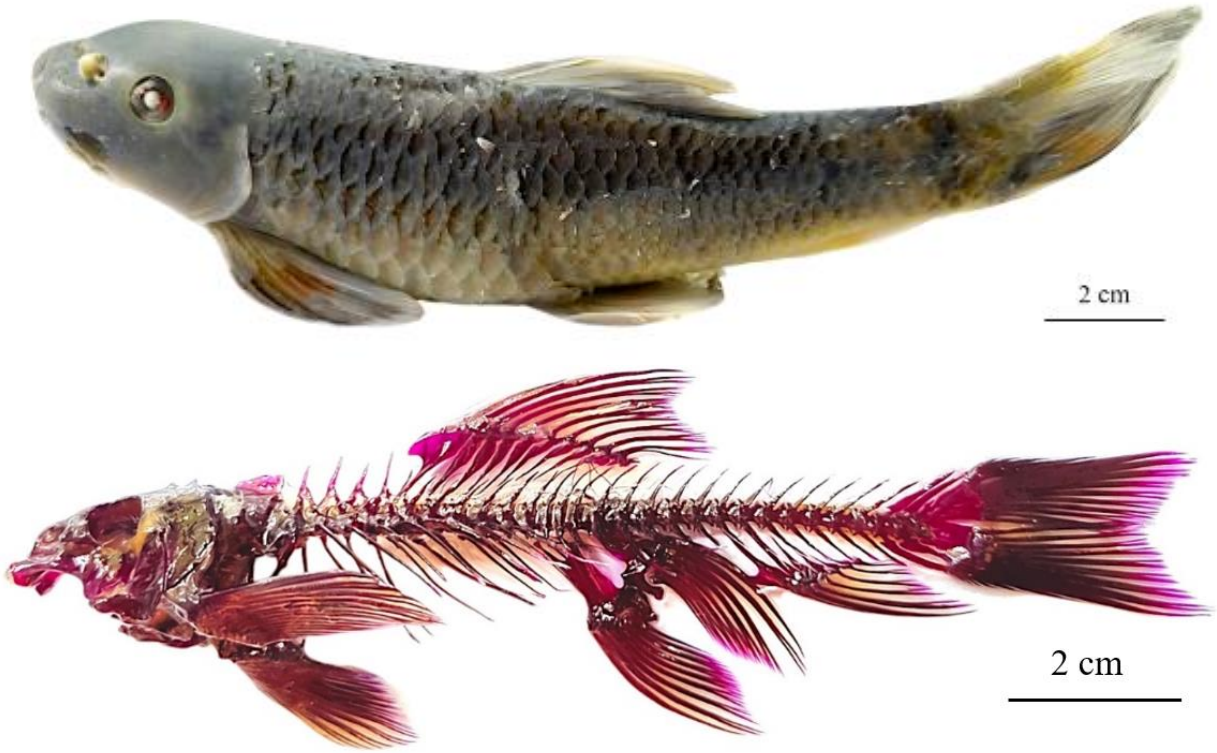

Fig.2. *G. arunachalensis* (above) lateral view, (below) skeletal framework.

for further analysis. Then, for osteological examination, clearing and staining of 20 specimens with alizarin red S and alcian blue were performed according to Taylor and Van Dyke (1985) (Fig. 2b). The formalin fixative was carefully cleaned from the specimens by keeping it in distilled water for 24 hours with several changes. After keeping the specimens in Alcian blue solution for 24 hours for cartilage staining, the specimens were moved to two changes of 95% ethanol for 24 hours each, followed by successive solutions of 75% and 50% ethanol for 24 hours each. The specimens were submerged in trypsin solution for one month until the bones become visible. In order to remove the enzyme and create a KOH environment which facilitate Alizarin red S's penetration into bone, the specimens were thereafter placed in 0.5% potassium hydroxide (aqueous) for four hours at room temperature. The specimens were then placed in a solution of Alizarin Red S for 24 hours, or till the bones were clearly coloured (reddish

purple). Further the specimens were placed in 0.5% KOH for two to three hours to bleach and remove extra stains. To avoid fading of stain and diffusion, the specimens were subsequently passed through solutions of 30%, 50%, and 70% ethanol for three hours, respectively. Before being preserved in 100% glycerine with thymol, the specimens were moved to 30% glycerine and 0.5% KOH until they sank. Skeletal structures were studied and visualized under stereomicroscope (Leica DFC425). Osteological nomenclature was done following Weitzman (1962), Britz & Hoffman (2006), Britz & Conway (2009) and Conway (2011).

RESULTS

Neurocranium

The neurocranium is flat, broad, and tapering towards the front. Lateral ethmoid, ethmoid complex, preethmoid, and vomer make up the ethmoid region (Fig. 3a). The largest bone in the ethmoid region, the lateral ethmoid is one of the most distinctive features of the neurocranium. It has a large lateral process that rims the entire orbit's anterior border and extends ventrally. The medial aspect of infraorbital 2 is firmly attached to the ventrolateral side of the lateral ethmoid process. The preethmoid is a small and spherical endoskeletal ossification. The orbital region is made up of the frontal, orbitosphenoid, pterspheniod, parasphenoid and circumorbital elements. The frontal is medially broad, and the orbitosphenoid and pterspheniod are attached to its ventro-medial margin (Fig. 3a, b). In the centre, the parasphenoid is broader (Fig. 3b). Ventrally, the parasphenoid is attached to the two orbitosphenoids (Fig. 3b). The parasphenoid forms a part of the base of the neurocranium and extends from the basioccipital to the vomer.

Infraorbital series

The infraorbital series of *G. arunachalensis* is illustrated in Figure 4. The posterior and ventral edges of the eye are bounded by five distinct bones. Among the infraorbital series, infraorbital 1 is its largest bone. It is large and leaf-like, stretching from the snout to the anterior edge of the eye. The anterior section of the infraorbital sensory canal passes through the lower

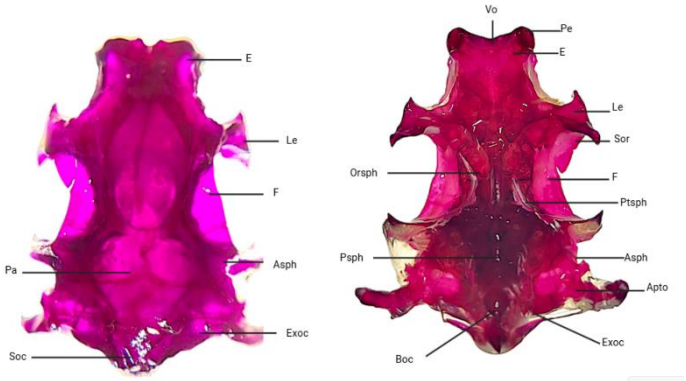

Fig.3. Neurocranium of *Garra arunachalensis* dorsal (a) and ventral (b) view. *Abbreviations: Apto, autopterotic; Asph, autosphenotic; Boc, basioccipital; E, ethmoid complex; Exoc, exoccipital; F, frontal; LE, lateral ethmoid; Orsph, orbitosphenoid; Pa, parietal; PE, prethmoid; Psph, parasphenoid; Ptsph, pterosphenoid; Soc, supraoccipital; Sor, supraorbital; Vo, vomer.

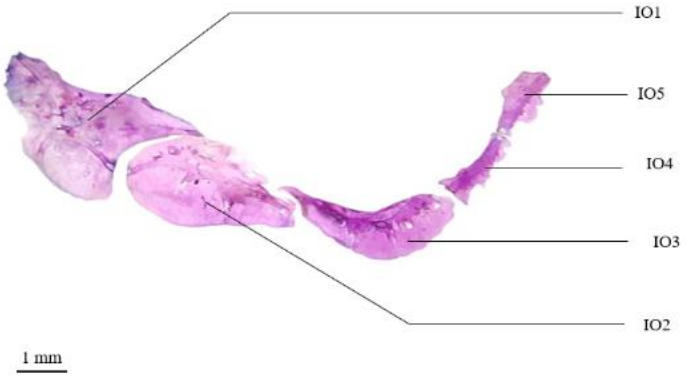

Fig.4. Infraorbital series of *G. arunachalensis.* *Abbreviations: IO1–5, infraorbitals 1–5.

part of infraorbital 1. The other infraorbital bones (infraorbital 3, 4 & 5) progressively diminish in size towards the back. The infraorbital sensory canal contains four openings along infraorbitals 1 and 2, two or three openings along infraorbital 3, and two along infraorbital 4 & 5.

Gill arches

The gill arches of *G. arunachalensis* consist of three pairs of the hypobranchials, three unpaired basibranchials, five pairs of the ceratobranchials, four pairs of epibranchials, and two pairs of pharyngobranchials (Fig. 5a, b). The last pair of ceratobranchials modified into pharyngeal teeth bearing eleven (11) teeth on each pharyngeal bone with the dental formula of 2,4,5-5,4,2 (Fig. 5c). The first pair of hypobranchial is roundish, second pair is elongated, while the last pair is pear shaped.

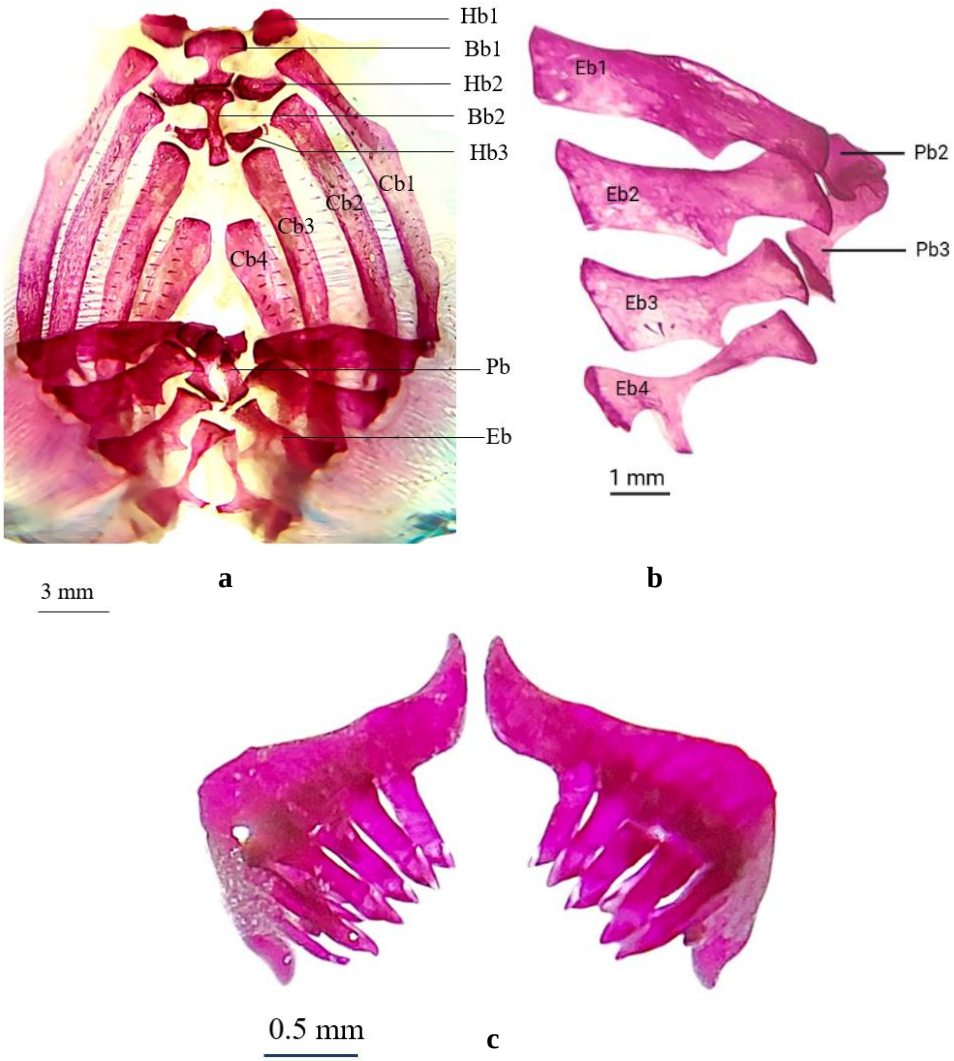

Fig.5. Gill arches of *G. arunachalensis*, ventral elements (a), dorsal elements (b), pharyngeal teeth (c). *Abbreviations: Bb, basibranchial; Cb, ceratobranchial; Eb, epibranchial; Hb, hypobranchial; Pb, pharyngobranchial.

Basibranchial 1 is the largest of the basibranchials and is positioned between hypobranchial 1. Basibranchial 2 is elongated and stretches from the area just behind hypobranchial 2 to the front end of hypobranchial 3. Basibranchial 3 is smallest and positioned behind hypobranchial 3. The ceratobranchials are approximately rod-shaped elements and hold a series of elongate gill-rakers along their front edges. Ceratobranchial 1 is significantly larger than ceratobranchial 4. The short epibranchials connect with the dorsolateral tip of their corresponding ceratobranchial (Fig. 5a, b).

Pectoral girdle and pectoral fin

The pectoral girdle and pectoral fin of *G. arunachalensis* are shown in Figure 6a & b. The largest bone of the pectoral girdle is cleithrum, a big, curving bone that is firmly attached to its antimere and extends furthest anteriorly along the lower midline. With the exception of the point where it contacts the front part of the coracoid along its medial margin, where it twists dorsally, the ventrally flattened cleithrum resembles a plate. Along its lateral face, the cleithrum has a superficial groove on the dorsal side that holds the posteroventral portion of the supracleithrum. The elongated supracleithrum has an enlarged ventral section that resembles a spoon. In addition to varied number of distal radials and radial cartilages, there are four pectoral radials (Fig. 6a). Pectoral radial 1 is tiny and asymmetrical that is firmly attached to the scapula's posterior border. The

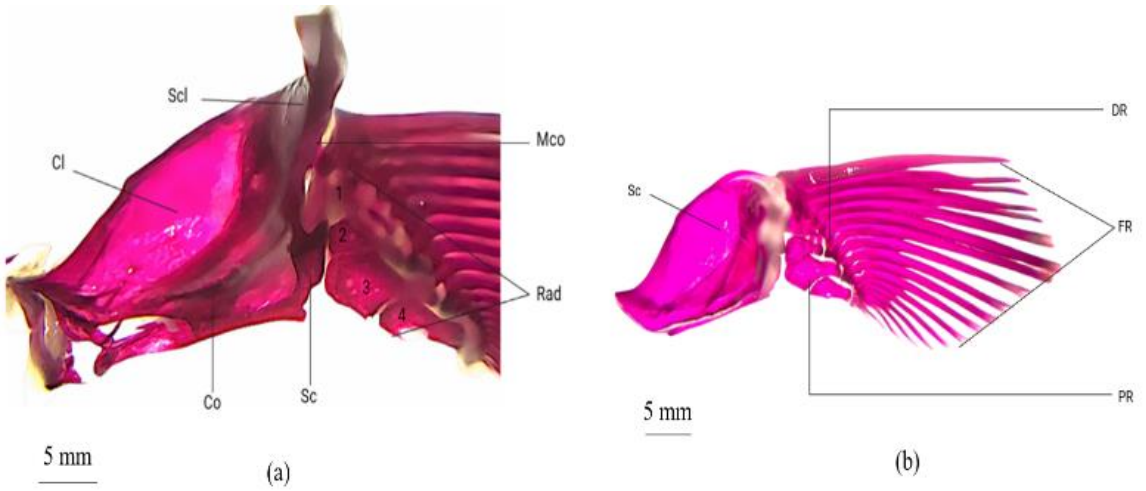

Fig.6. Pectoral girdle (a) and pectoral fin (b) of *G. arunachalensis.* *Abbreviations: Cl, cleithrum; Co, coracoid; Mco, mesocoracoid; Rad 1–4, pectoral radial 1–4; Sc, scapula; Scl, supracleithrum.

posterior margin of the coracoid connects with pectoral radials 2 & 3, which are essentially rod-shaped bones. The species comprises of sixteen pectoral fin rays where two fin rays are unbranched and thirteen fin rays are branched.

Dorsal fin skeleton

Nine dorsal fin rays are placed among the neural spines of V9/V10–V17/V18 (Fig. 7). The initial three pterygiophores consist of a large proximal– middle radial and a small distal radial. The other remaining pterygiophores are comprised of proximal, middle, and distal radials. The first pterygiophore assists a large unbranched ray (the first principal ray of Arratia 2008) as well as a smaller unbranched supernumerary ray (procurrent ray of Arratia 2008), with the subsequent ray being half the length of the earlier. The last pterygiophore can support either one branched and one unbranched ray or two branched rays. A single branching ray is supported by each of the remaining pterygiophores, which also envelop the distal radials terminally and rest others on the anterodorsal edge of the subsequent proximal middle or middle radials. On the anterior and posterior margins of each proximal-middle and proximal radial, there is a membrane bone flange. Ideally, membrane bone flanges grow on the first proximal to middle radial. There is also a significant, wing like extension of membrane bone along the lateral borders of the first proximal-middle radial.

Axial skeleton

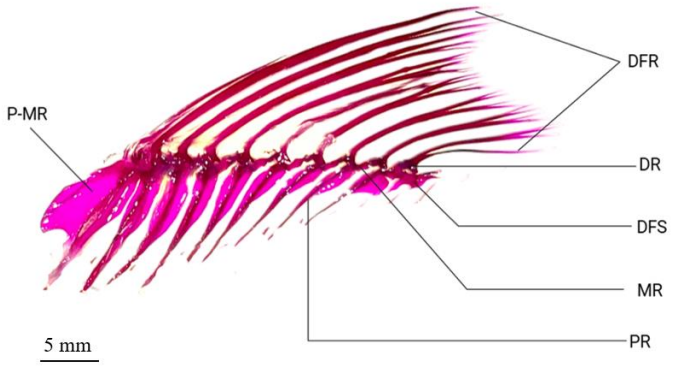

Fig.7. Dorsal fin of *G. arunachalensis.* *Abbreviations: DFR, dorsal fin ray; DFS, dorsal fin stay; DR, distal radial; MR, middle radial; P–MR, proximal–middle radial; PR, proximal radial.

The axial skeleton of *G. arunachalensis* is demonstrated in Figure 8. There is a total of 33-34 vertebrae (V) present, consisting of 17-18 abdominal and 15-16 caudal vertebrae excluding the compound centrum. Ribs begin on V5 and extend to V17-V18. On V21 the first haemal spine lies. Except for the terminal compound centrum and V1-V3, all of the centra have an hourglass form and are elongated, with the exception of the second and the third pleural centra. Prominent, rounded parapophyses are present around the anterior margin of the centra of V18/19 (Fig. 8f). The first parapophysis is the largest and located in an anterodorsal position on its corresponding centrum. Neural spines starting from V5 bear pointed tips with exclusion of second and third preural centra. Prezygapophyses are present

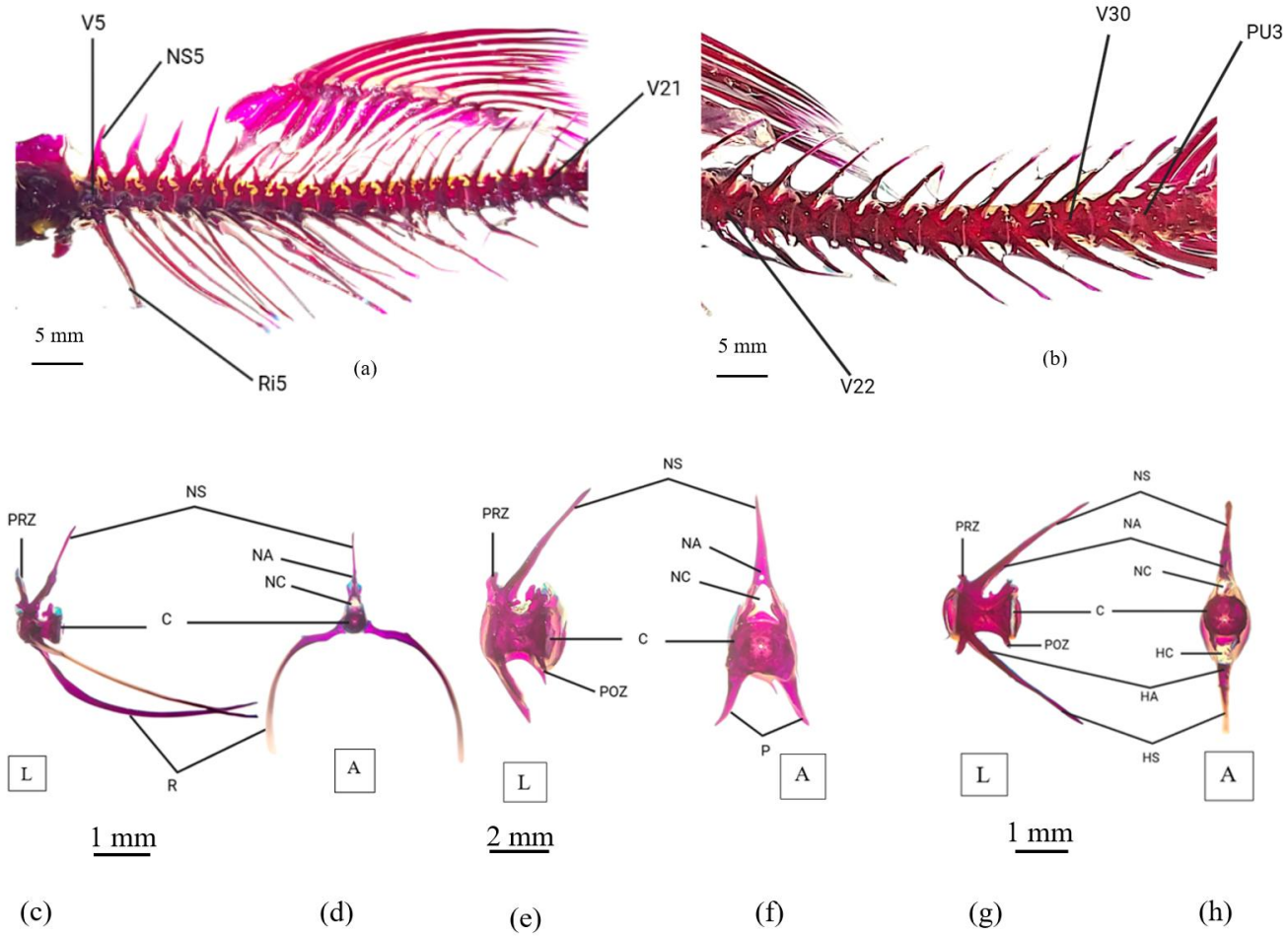

Fig.8. Axial skeleton (a, b), abdominal vertebrae (c, d), precaudal vertebrae (e, f), caudal vertebrae (g, h). *Abbreviations: A, anterior; C, centrum; HA, haemal arch; HC, haemal canal; HS, haemal spine; L, lateral; NA, neural arch; NC, neural canal; NS, neural spine; P, parapophysis; POZ, postzygapophysis; PRZ, prezygapophysis; PU, preural centra; R, rib; V, vertebrae.

anteriorly in the neural arches while pointed postzygapophyses are found posteriorly (Fig. 8c, e, g). Haemal spines are found from V20/V21 to V29/V30. The ribs are slender and curved bones that gradually reduce in length and width near the posterior end.

Pelvic girdle and pelvic fin

The pelvic girdle and pelvic fin of *G. arunachalensis* is shown in Figure 9a & b. A pair of elongated basipterygia that holds two unbranched and seven branched fin rays each make up the pelvic girdle. The basipterygium has two spine-like structures on its anterior surface. The basipterygium broaden slightly towards posterior side where it connects with the pelvic fins. On the posterior-medial end, the basipterygium ends into ischiac process after narrowing in width following to the first unbranched fin ray. Located anterodorsally to the first unbranched fin ray is a little spindle-like bone called the pelvic splint by Gosline (1961). It is securely connected to the 11/12 pleural rib by a ligamentous attachment, with its anteriormost point just below the tip of pleural rib.

Anal fin skeleton

The anal fin skeleton of *G. arunachalensis* is showed in Figure 10. Seven anal fin rays are hold by a series of pterygiophores found between the haemal spines of V23/V24–V27/V28. A short distal radial and a large proximal middle radial make up the initial two anal fin pterygiophores. The remaining other pterygiophores are comprised of distal, middle, and proximal radials. The first proximal middle radial supports a large, unbranched ray (first principal ray by Arratia in 2008)

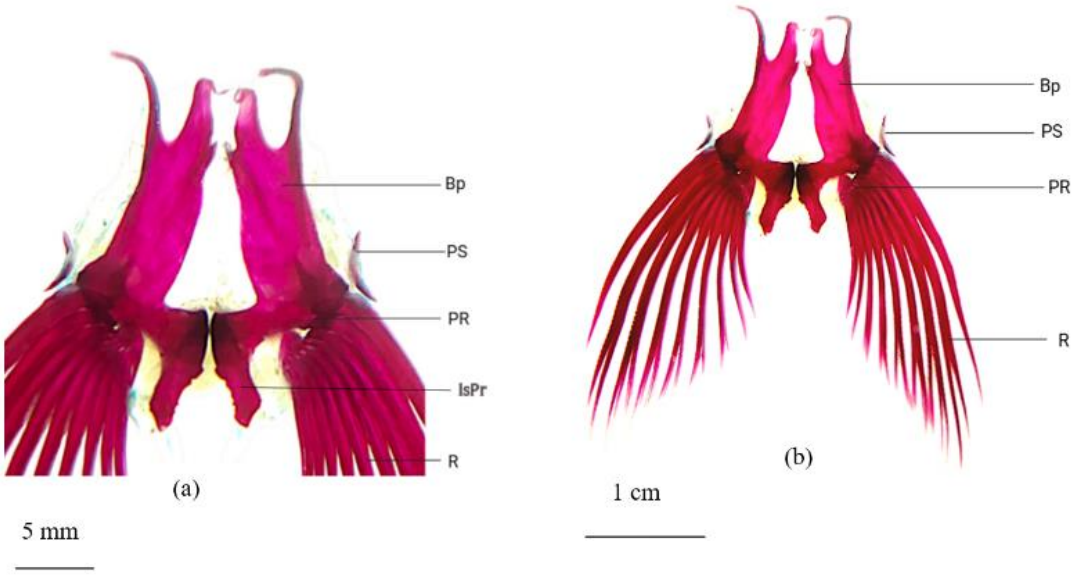

Fig.9. Pelvic girdle (a) and pelvic fin (b) of *G. arunachalensis.* *Abbreviations: Bp, basipterygium; IsPr, ischiac process; PR, pelvic radial; PS, pelvic splint; R, pelvic fin ray.

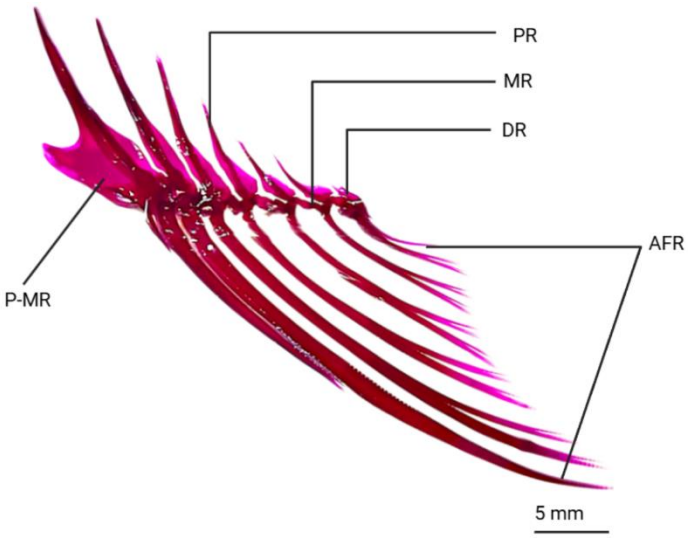

Fig.10. Anal fin of *G. arunachalensis.* *Abbreviations: AFR, anal fin ray; DR, distal radial; MR, middle radial; P–MR, proximal–middle radial; PR, proximal radial.

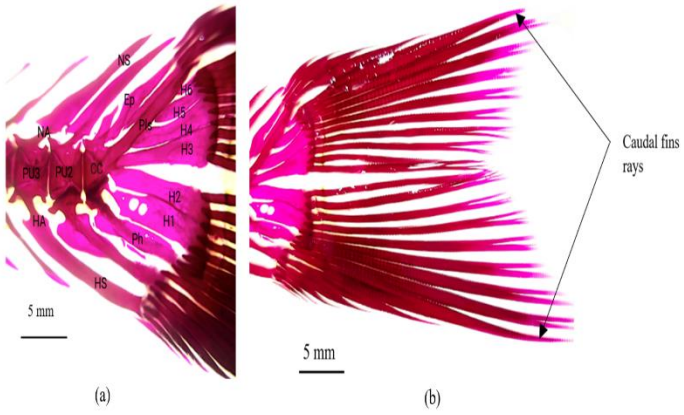

Fig.11. Caudal fin skeleton of *G. arunachalensis* (a-caudal skeleton, b-caudal fin rays). *Abbreviations: CC, compound centrum; Ep, eplural; H1–6, hypurals 1–6; HA, haemal arch; HS, haemal spine; NA, neural arch; NS, neural spine; Ph, parhypural; Pls, pleurostyle; PU2–3, preural centra 2–3.

along with two smaller, unbranched supernumerary rays (procurrent rays by Arratia in 2008). The posteriormost anal pterygiophore holds one branched and one unbranched ray. In addition to supporting a single branched ray, the remaining pterygiophores lie on the anteroventral edge of the subsequent proximal middle (the final unbranched ray) or middle radials and envelop the distal radials distally.

Caudal fin skeleton

The caudal fin skeleton of *G. arunachalensis* is shown in Figure 11a & b. There are nineteen (19) principal rays, comprising seventeen (17) branched and two (2) unbranched rays. There is also presence of three or four ventral and dorsal procurrent rays. The caudal fin rays are hold by the neural and haemal spines of second and third preural centra, along with the pleurostyle, one single epural, six hypural elements and the parhypural. The neural and haemal spines of second and third preural centra hold the dorsal and ventral procurrent rays respectively. There is a short neural process attached to the compound centrum of *G. arunachalensis*. The fused anteriormost ends of the first hypural and parhypural firmly adhere to the compound centrum. The posteroventral margin of the

Table 1. Osteological description of *G. arunachalensis.*

Sl. No.	Skeletal structure	Characters
1.	Neurocranium	a. Divided into five regions, i.e., the ethmoidal, orbital, otic, occipital, and basicranial region. b. Presence of small ethmoid which continues with the frontal. Frontal is the largest bone. c. Parasphenoid exhibits a large flange along its ventral surface. d. Presence of a deeply concave vomer.
2.	Infraorbital Series	a. Consist of five (5) infraorbital bones. b. Io2 largest and leaf like; Io5 smallest.
3.	Gill arches	a. Consist of three pairs of the hypobranchials, three unpaired basibranchials, five pairs of the ceratobranchials, four pairs of epibranchials, and two pairs of pharyngobranchials. b. Last pair of ceratobranchials modified into pharyngeal teeth bearing eleven (11) teeth on each pharyngeal bone with the dental formula of 2,4,5-5,4,2.
4.	Vertebral column	a. Total of 33-34 vertebrae (V) present, consisting of 17-18 abdominal and 15-16 caudal vertebrae excluding the compound centrum. b. Ribs begin on V5 and extend to V17-V18. On V21 the first haemal spine lies.
5.	Pectoral girdle and pectoral fin	a. Largest bone of the pectoral girdle is cleithrum b. Supracleithrum has an enlarged ventral section that resembles a spoon. c. Presence of four pectoral radials. d. sixteen pectoral fin rays; two unbranched and thirteen branched.
6.	Dorsal fin	a. Nine (9) dorsal fin rays are placed among the neural spines of V9/V10–V17/V18. b. Presence of proximal, middle and a small distal radial. c. The first pterygiophore assists a large unbranched ray and a smaller unbranched supernumerary ray.
7.	Pelvic girdle and pelvic fin	a. A pair of elongated basipterygia that holds two unbranched and seven branched fin rays each make up the pelvic girdle. b. The basipterygium has two spine-like structures on its anterior surface. c. Located anterodorsally to the first unbranched fin ray is a little spindle-like bone called the pelvic splint.
8.	Anal fin skeleton	a. Seven (7) anal fin rays are found between the haemal spines of V23/V24–V27/V28. b. The first proximal middle radial supports a large, unbranched ray and two smaller, unbranched supernumerary rays.
9.	Caudal fin skeleton	a. Nineteen (19) principal rays, comprising seventeen (17) branched and two (2) unbranched rays. b. Presence of three or four ventral and dorsal procurrent rays. c. The caudal fin rays are hold by the neural and haemal spines of second and third preural centra, along with the pleurostyle, one single epural, six hypural elements and the parhypural.

compound centrum is securely joined to the anterior point of both the second hypural as well as the pleurostyle. The third hypural is almost similar in length with second hypural and its anteriormost edge connects with the compound centrum in the position between pleurostyle and the second hypural. The rest of the hypurals are loosely attached to the pleurostyle and gradually get smaller dorsally.

Present study summarized a detailed osteological description of *G. arunachalensis* and represented in Table 1.

DISCUSSION

There is a little data available on the skeletal structure of the fishes including genus *Garra* found in northeastern part of India. The present study provides a detailed skeletal description of *G. arunachalensis* from lower Dibang valley, Arunachal Pradesh, India.

There are some similarities and differences in the neurocranium, infraorbital series elements, branchial apparatus, pectoral and pelvic girdles, dorsal, anal and caudal fins skeleton, between *G. arunachalensis* of this study with previously studied species of *Garra* by different researchers viz., *G. persica* (Zamani-Faradonbe & Keivany 2017), *Garra barreimiae* (Pichler et al. 2018), *G. annandalei* and *G. parastenorhynchus* (Dey 2020), *G. rossica* (Saemi-Komsari et al. 2020) *Garra* sp. (Sungur et al. 2020) and *G. mullya* (Raut 2021).

In the neurocranium, the vomer of *G. arunachalensis* is highly concave and the lateral ethmoid is the largest bone of ethmoidal region, similar result was found in *G. mullya*, *G. annandalei*, *G. parastenorhynchus* and *G. rossica* (Dey 2020; Saemi-Komsari et al. 2020; Raut 2021). The frontal is the largest bone in the neurocranium of *G. arunachalensis* and its ventro-medial edge is connected to the orbitosphenoid and pterspheno id which is also similar in case of *G. annandalei*, *G. parastenorhynchus* and *G. mullya*. The anterior part of the parasphenoid is narrower in *G. arunachalensis* similar to *G. rossica* and *G. persica* (Zamani-Faradonbe & Keivany 2017), whereas it is wider than its posterior part similar to *G. annandalei*, *G. parastenorhynchus*, *G. mullya* and *G. rossica* (Zhang 2005). *Garra arunachalensis* has four infraorbital elements same as that of *G. mullya* from Pune, India, whereas *G. rossica* from Nahang River had five infraorbital elements. The branchial apparatus in *G. arunachalensis* has four pairs of ceratobranchials similar to *G. persica* while *G. rossica* contains five pairs of ceratobranchials. *G. arunachalensis* contains two pairs of pharyngobranchials similar to *G. rossica* whereas *G. persica* contain three pairs of pharyngobranchials. The dorsal fin in *G. arunachalensis* has two unbranched rays and eight branched rays, whereas *G. rossica* has one unbranched ray and nine branched rays examined by Saemi-Komsari et al. (2020), *G. persica* had two to three unbranched rays and eight to ten branched rays studied by Zamani-Faradonbe & Keivany (2017). The anal fin in *G. arunachalensis* has three unbranched and five branched rays on the other hand *G. rossica* has two unbranched and seven branched rays. Moreover, *G. arunachalensis* contains four ossified pectoral radial bones in the pectoral girdle which is equal in number in *G. rossica* while in *G. persica* three radial bones are present (Zamani-Faradonbe & Keivany 2017; Saemi-Komsari et al. 2020). In the axial skeleton, *G. arunachalensis* contains 33-34 numbers of vertebrae which can be divided into 17-18 abdominal and 15–16 caudal vertebrae whereas the vertebral number is 29 in *G. persica* and the abdominal and caudal parts of the vertebral column have 15 and 14 vertebrae, respectively (Zamani-Faradonbe & Keivany 2017). On the other hand, *Garra barreimiae* found to contain 31-34 numbers of vertebrae which were further divided into 17-19 precaudal vertebrae, 1-3 intermediate vertebrae and 12-14 caudal vertebrae (Pichler et al. 2018). The caudal fin skeleton of *G. arunachalensis* contains 6 hypural plates, one long epural, and slender and long neural and haemal spines, on the other hand *G. gymnothorax* has five hypural plates and *G. lorestanensis* has six or seven hypurals examined by Sungur et al. (2020), *G. annandalei* and *G. parastenorhynchus* bear 4 hypural plates studied by Dey (2020).

From the twenty studied specimens of *G. arunachalensis,* following anatomical characteristics were observed. It was found that the species possesses a flat and broad neurocranium with a highly concave vomer, a large lateral ethmoid, a frontal bone that is largest in the neurocranium. The infraorbital region of the species consists of four infraorbital elements. The dorsal fin in *G. arunachalensis* has one unbranched ray and eight branched rays while the anal fin has two unbranched and five branched rays. Besides, the species comprises of four ossified pectoral radial bones in the pectoral girdle. In the axial skeleton, *G. arunachalensis* has 33-

34 numbers of vertebrae which can be divided into 17-18 abdominal and 15–16 caudal vertebrae. The caudal fin skeleton contains 6 hypural plates, one long epural, and slender and long neural and haemal spines.

The current study provides a thorough osteological examination of some specific bones of *Garra arunachalensis* sampled from lower Dibang Valley, Arunachal Pradesh belonging to upper Brahmaputra basin, India. Some similarities and dissimilarities in the neurocranium, infraorbital series, branchial apparatus, axial skeleton, dorsal, anal and caudal fin skeleton of the species with other members of the genus were recorded from the study. The variations underline how osteological characters can be used as an important diagnostic tool in the systematics and taxonomy of the genus *Garra*. Species like *G. mullya* and *G. rossica* share some similarities with the neurocranium such as concave vomer and the predominance of the lateral ethmoid, however infraorbital structure is unique for *G. arunachalensis*. The structural modification in the caudal skeleton along with different counts of fin rays further underscores the evolutionary adaptation of the species in the specialized ecological niche. Documentation of the skeletal morphology of *G. arunachalensis* shall further contribute in enhancing the broader understanding of the species, serving as a foundational framework for upcoming phylogenetic and comparative studies.

ACKNOWLEDGEMENTS

The Authors are grateful to the Department of Life Sciences, Dibrugarh University for providing necessary facility and CSIR, New Delhi for providing Senior Research Fellowship to MP for carrying out the present research work.

REFERENCES

Arratia, G. 2008. Actinopterygian postcranial skeleton with special reference to the diversity of fin ray elements, and the problem of identifying homologies. Mesozoic fishes 4: 49-101.

Britz, R. & Conway K.W. 2009. Osteology of Paedocypris, a miniature and highly developmentally truncated fish (Teleostei: Ostariophysi: Cyprinidae). Journal of Morphology 270(4): 389-412.

Britz, R. & Hoffmann, M. 2006. Ontogeny and homology of the claustra in otophysan Ostariophysi (Teleostei). Journal of Morphology 267(8): 909-923.

Carnevale, G.; Haghfarshi, E.; Abbasi, S.; Alimohammadian, H. & Reichenbacher, B. 2011. A new species of silverside from the Late Miocene of NW Iran. Acta Palaeontologica Polonica 56(4): 749-756.

Conway, K.W. 2011. Osteology of the South Asian Genus *Psilorhynchus* McClelland, 1839 (Teleostei: Ostariophysi: Psilorhynchidae), with investigation of its phylogenetic relationships within the order Cypriniformes. Zoological Journal of the Linnean Society 163(1): 50-154.

Dey, A. 2020. Studies on the Taxonomic Diversity of the Fish Fauna in Kameng River, Arunachal Pradesh with special reference to the genus *Garra* Hamilton, 1822 and *Psilorhynchus* McClelland, 1839. Ph. D. Thesis, Department of Zoology, Gauhati University 1-221.

Fiaz, A.W.; Léon-Kloosterziel, K.M.; Gort, G.; Schulte-Merker, S.; van Leeuwen, J.L. & Kranenbarg, S. 2012. Swim-training changes the spatio-temporal dynamics of skeletogenesis in zebrafish larvae (*Danio rerio*). PLoS ONE 7(4): e34072.

Fink, S.V. & Fink, W.L. 1981. Interrelationships of the ostariophysan fishes (Teleostei). Zoological Journal of the Linnean Society 72(4): 297-353.

Gosline, W.A. 1961. Some osteological features of modern lower teleostean fishes. Smithsonian Miscellaneous. Collections 142: 1-42.

Jalili, P.; Eagderi, S.; Nikmehr, N. & Keivany, Y. 2015. Descriptive osteology of *Barbus cyri* (Teleostei: Cyprinidae) from southern Caspian Sea basin. Iranian Journal of Ichthyology 2(2): 105–112

Keivany, Y. 2014. Comparative osteology of the suspensorial and opercular series in representatives of the eurypterygian fishes. Iranian Journal of Ichthyology 1(2): 73-90.

Keivany, Y. 2017. Osteological features of eurypterygian pelvic girdles. Iranian Journal of Science and Technology, Transactions A: Science 41: 989-1002.

Li, F.L.; Zhou, W. & Fu, Q. 2008. *Garra findolabium*, a new species of cyprinid fish (Teleostei: Cypriniformes) from the Red River drainage in Yunnan, China. Zootaxa 1743(1): 62-68.

Menon, A.G.K. 1964. Monograph of the cyprinid fishes of the genus *Garra* Hamilton. Memoirs of the Indian

Museum 14: 173-260.

Nasri, M.; Eagderi, S.; Farahmand, H. & Segherloo, I.H. 2013. Body shape comparison of *Cyprinion macrostomum* (Heckel, 1843) and *Cyprinion watsoni* (Day, 1872) using geometric morphometrics method. International Journal of Aquatic Biology 1(5): 240-244.

Pichler, A.; Ahnelt, H.; Kirchner, S.; Sattmann, H.; Haring, E.; Handschuh, S. & ... Kruckenhauser, L. 2018. The morphological diversity of *Garra barreimiae* [Teleostei: Cyprinidae]. Environmental Biology of Fishes 101: 1053-1065.

Raut, R.N. 2021. Osteology and Morphological Relationships Among Family Cyprinidae Fishes. Ph.D Thesis, Department of Modern College of Arts Science and Commerce Pune, Savitribai Phule Pune University 1-187.

Roni, N. & Vishwanath, W. 2017. *Garra biloborostris*, a new labeonine species from north-eastern India (Teleostei: Cyprinidae). Vertebrate Zoology 67: 133-137.

Saemi-Komsari, M.; Mousavi-Sabet, H.; Sattari, M.; Eagderi, S.; Vatandoust, S. & Doadrio, I. 2020. Descriptive osteology of *Garra rossica* (Nikolskii, 1900). FishTaxa-Journal of Fish Taxonomy 16: 19-28.

Sungur, S.; Eagderi, S.; Jalili, P. & Çiçek, E. 2020. Caudal osteology and its application to reconstruct phylogenetic relationship in the genus *Garra*. Ege Journal of Fisheries and Aquatic Sciences 37(3): 245-249.

Taylor, W. & Van Dyke, G.C. 1985. Revised procedures for staining and clearing small fishes and other vertebrates for bone and cartilage study. Cybium (Paris) 9(2): 107-119.

Vatandoust, S.; Mousavi-Sabet, H.; Geiger, M.F. & Freyhof, J. 2019. A new record of Iranian subterranean fishes reveals the potential presence of a large freshwater aquifer in the Zagros Mountains. Journal of Applied Ichthyology 35(6): 1269-1275.

Weitzman, S.H. 1962. The osteology of *Brycon meeki*, a generalized characid fish, with an osteological definition of the family. Stanford Ichthyological Bulletin 8: 1-77.

Zamani Faradonbe, M. & Keivany, Y. 2017. Descriptive osteology of Persian stone lapper (*Garra persica*) from Sistan basin. Journal of Animal Research (Iranian Journal of Biology) 30(3): 318-332.

Zhang, E. 2005. Phylogenetic relationships of labeonine cyprinids of the disc-bearing group (Pisces: Teleostei). Zoological Studies 44(1): 130-143.

Iran. J. Ichthyol. (2025) 12(4): 300-311
P-ISSN: 2383-1561; E-ISSN: 2383-0964
http://www.ijichthyol.org

doi: 10.22034/iji.v12i4.1093

مقاله کامل

دیدگاه تاکسونومیک ویژگی‌های استخوان‌شناختی در گونه *Garra arunachalensis* (Nebeshwar & Vishwanath, 2013)، یک ماهی بومی رودخانه‌های کوهستانی حوضه بالادست رود برهماپوترا، هند

مینتومونی پگو، سی می گگوئی، مویراگتم کامشورسینگ*، بیجوی نئوگ

گروه علوم زیستی، دانشگاه دیبروگاره، دیبروگاره – ۷۸۶۰۰۴، آسام.

چکیده: جنس *Garra* از خانواده Cyprinidae شامل ۱۷۰ گونه است که در مناطق نیمه‌گرمسیری و گرمسیری آفریقا، آسیا و کشورهای خاورمیانه پراکنش دارند. این جنس دارای سازگاری ویژه‌ای است که در آن لب تحتانی به یک صفحه چسبنده (دیسک منتال) تبدیل شده است؛ ساختاری که به ماهیان امکان زیست در جریان‌های سریع رودخانه‌های کوهستانی را می‌دهد. این مطالعه به ارائه توصیف جامع استخوان‌شناختی گونه *Garra arunachalensis* با استفاده از روش رنگ‌آمیزی دوگانه برای آشکارسازی ساختارهای اسکلتی می‌پردازد. تعداد ۲۰ نمونه برای بررسی ساختارهای جمجمه عصبی، سری استخوان‌های تحت چشمی، دستگاه آبششی، اسکلت محوری و ساختار باله‌های این گونه مورد استفاده قرار گرفت. تحلیل تطبیقی با گونه‌های هم‌جنس نشان داد که شباهت‌هایی در جمجمه عصبی، دستگاه آبششی و استخوان‌های شعاعی باله‌های سینه‌ای و شکمی با گونه‌هایی مانند *G. mullya*، *G. annandalei* و *G. rossica* وجود دارد. در عین حال، تفاوت‌های قابل‌توجهی نیز در صفحات هیپورال اسکلت باله دمی، تعداد عناصر اسکلت محوری، تعداد شعاع‌های باله و عناصر تحت چشمی در مقایسه با گونه‌هایی مانند *G. persica* مشاهده شد. یافته‌های این پژوهش بر اهمیت و کارآمدی ویژگی‌های استخوان‌شناختی در حل پیچیدگی‌های تاکسونومیک و فیلوژنی درون جنس *Garra* تأکید می‌کند و می‌تواند مبنایی برای مطالعات نظام‌مند و تکاملی بیشتر فراهم سازد.

کلمات‌کلیدی: اسکلت محوری، *Garra arunachalensis*، neurocranium، استخوان‌شناسی، آرایه‌شناسی، حوضه بالادست برهماپوترا