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ORIGINAL ARTICLE

Osteological characteristics of *Paraschistura abdolii* (Nemacheilidae) from Hamun-e Jaz Murian Basin, south-east of Iran

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Abstract
This study aimed to provide detailed osteological characteristics of *Paraschistura abdolii* due to the restricted studies on the skeletal structure of this genus in recent years. A total of 5 *P. abdolii* specimens were collected from Hamun-e Jaz Murian Basin and were cleared and stained. Based on the results, this species can be distinguished from other species of this genus by having 4 basibranchials, 9 pterygiophores, 5 hyporals, swim bladder with a dentate, a sesamoid bone, extra urohyal bone, a distance between the epiural and the centrum body, and strong dentition of the supraneoral-3 bone.

Keywords: Bone, Loach, Osteology, Freshwater, Iran

INTRODUCTION

Nemacheilidae is a family of small-sized freshwater fish found in Asia, Europe, and Northeast Africa (Ethiopia) (Prokofiev 2010). With 45 species, members of this family constitute 15.42% of Iran's inland water fish (Esmaeili et al. 2018; Eagderi et al. 2022). *Paraschistura* is one of the eight genera in this family, with its members distributed from the Sistan Basin in the east to the Tigris Basin in western Iran (Azimi 2014). Until now, 11 species of this genus have been identified and reported in Iran, including *Paraschistura. abdolii* Freyhof et al. 2015, *P. bampurensis* (Nikol'skii, 1900), *P. delvarii* Mousavi-Sabet & Eagderi, 2015, *P. hormuzensis* Freyhof et al. 2015, *P. ilamensis* Vatandoust & Eagderi, 2015, *P. naumanni* Freyhof et al. 2015, *P. nielseni* (Nalbant & Bianco,1998), *P. sargadensis* (Nikolskii, 1900), *P. susiani* Freyhof et al. 2015, *P. turcmenica* Freyhof et al., 2015 and *P. alta* (Nalbant and Bianco, 1998) (Mousavi-Sabet & Eagderi 2015; Jouladeh-Roudbar et al. 2015; Esmaeili et al. 2017; Eagderi et al. 2019, 2022).

The complexity of this group has made their taxonomy and phylogenetic relationships challenging for researchers to resolve. To address this issue, various methods, such as morphological and osteological characteristics and body color patterns, have been used to overcome this deficiency. Regan (1911) published the first osteological study on Nemacheilinae. Sawada (1911) provided a comprehensive osteological study on loach fishes, which covered the details of bone structure in 21 species belonging to nine genera and subgenera. Prokofiev (2009, 2010) recently proposed a new classification for Nemacheilidae genera based on osteological features. In recent years, studies have also been conducted in Iran by Jalili et al. (2014, 2015) Mafakheri (2014), Mafakheri et al. (2014), Azimi (2014), Noroozei et al. (2018, 2021) and Mousavi-Sabet et al. (2022). This study aimed to provide detailed osteological characteristics of *Paraschistura abdolii* species that will be used for future taxonomic studies of this genus.

MATERIALS AND METHODS

Five samples of *P. abdolii* species were collected from the Hamun-e Jaz Murian Basin, anesthetized in a solution of clove extract, and fixed in 10% buffered formalin after capture. The samples were stained according to the Hanken & Wassersug (1981) protocol, and their bone elements were separated under a stereomicroscope and scanned in an Epson V600 Scanner equipped with a glycerin bath. Then, the bone images were drawn digitally using Corel Draw 17 software and finally identified and described. The bones were named according to Prokofiev (2009),

Fig.1. *Paraschistura abdolii* collected from Halil River.

Jalili (2013), and Noroozei (2018, 2021).

Abbreviation used in this study: Adp: anal distal pterygiophore; **Apl:** autopalatine; **Art:** articular; **Bbr:** basibranchial; **Bhy:** basihyal; **Bo:** basioccipital; **Br:** branchiostegale; **Cbr:** ceratobranchial; **Chy:** ceratohyal; **Cl:** cleithrum; **Cm:** coronomeckelian; **Cor:** coracoid; **Den:** dental; **Dfr:** dorsal fin rays; **Dfs:** dorsal fin spin; **Dhy** and **Vhy:** dorsal and ventral hypohyal; **Dpr-2-4:** descending processes of the second and fourth centra; **Dr:** distal radial; **Ebr:** epibranchial; **Ect:** ectopterygoid; **Ehy:** epihyal; **End:** endopterygoid; **Epo:** epiotic; **Epu:** epural; **Exo:** exoccipital; **fon:** fontanelle; **Fr:** frontal; **fr-Exo:** foramen exoccipital; **Hbr:** hypobranchial; **Hm:** hyomandibular; **Hp:** hypural; **Hpu2:** hemal processes of the second preural centrum; **Ihy:** interhyal; **Io:** interopercle; **Ke:** kinethmoid; **Let:** lateral ethmoid; **Mcor:** mesocoracoid; **Mp:** mesial pterygiophore; **Mr:** medial radial; **Mtp:** metapterygoid; **Mx:** maxilla; **Na4:** neural arch 4; **Npu2:** neural spine of the second preural centrum; **Op:** opercle; **Orb:** orbitosphenoid; **Pa:** parietal; **Pbr:** pharyngobranchial; **Pe:** prevomer; **pect-R:** ray of the pectoral fin; **Peth-II:** preethmoid-II; **Ph:** parhypural; **Pmx:** Premaxilla; **Po:** preopercle; **Pp:** pterygiophore; **Ppl:** prepalatine; **pr-Bo:** basioccipital process; **Pro:** prootic; **Ps:** parasphenoid; **Pst:** pleurostyle; **Pto:** pterotic; **Pts:** pterosphenoid; **Q:** quadrate; **Rad:** ossified pectoral radial; **Rar:** Retroarticular; **Sc:** scapula; **Sca:** scaphium; **Se:** supraethmoid-ethmoid; **Sn2:** supraneural2; **Sn3:** supraneural 3; **So:** subopercle; **Soc:** supraoccipital; **Spo:** sphenotic; **Sty:** stay; **Sym:** sympletic; **Uhy:** urohyal.

RESULTS

Morphological characteristics: The body shape was cylindrical, and the scales collapsed or detached at the caudal fin. In some specimens, the front of the upper back is colorless and lacks scales. A regular or irregular 11-19 dark or light brown band is on the side. This species lacks scales on its back or only has them on the front dorsal fin. The male flap and cracks under the eye are absent, the dorsal keel is not seen in this species, and procurrent rays are absent if present. The lateral line is also an incomplete type in this species (Freyhof et al. 2015) (Fig. 1).

Morphometric and meristic characteristics: The meristic characteristics of the studied species (Table 1) include the number of vertebrae (including four modified vertebrae in the swim bladder capsule), the number of unbranched rays in the dorsal fin and anal fin, the number of branched rays in the dorsal fin and anal fin, and the number of the first vertebra where the first neural spines of the dorsal fin and anal fin are located. Morphometric characteristics (Table 2) include the ratio of occipital length to neurocranial width, the ratio of the length of fontanelle to neurocranial length, the ratio of horizontal to vertical process in upper jaw one, and the ratio of width to height in the metapterygoid bone.

Neurocranium: The neurocranium comprises four regions, viz. ethmoid, orbital, otic, and occipital, with a wider posterior part. The ethmoid region consists of six elements, including the supraethmoid-ethmoid,

Table 1. Merestic characteristic of *Paraschistura abdolii*

Species	Number of anal-fin petrigephores	Number of caudal-fin petrigephores	Number of branched rays of anal-fin	Number of unbranched rays of anal-fin	Number of dorsal-fin petrigephores	First vertebrate of dorsal-fin petrigephore	Number of branched rays of dorsal-fin	Number of unbranched rays of dorsal-fin	Number of centrum
P. abdolii	7	18(9+9)	6	3	9	9	7	4	37

Table 2. Morphometric characteristic of *Paraschistura abdolii*

Species	Width to length ratio of the hyomandibular	Hyomandibular length	Hyomandibular width	Vertical to horizontal	Length of horizontal processes	Length of vertical	Occipital region ratio	Length of the occipital region	Ratio of skull length to body	Length to width ratio of the neuracoranium	Ratio of the length of the fontanelle to the Neuracoraniu	Length of the fontanelle cavity	Neuracoraniu	Length of the Neuracoraniu	Body length
P. abdolii	1.04	1.91	1.99	1.08	1.66	1.53	32.04	2.57	18.69	49.88	27.31	2.19	4	8.02	42.91

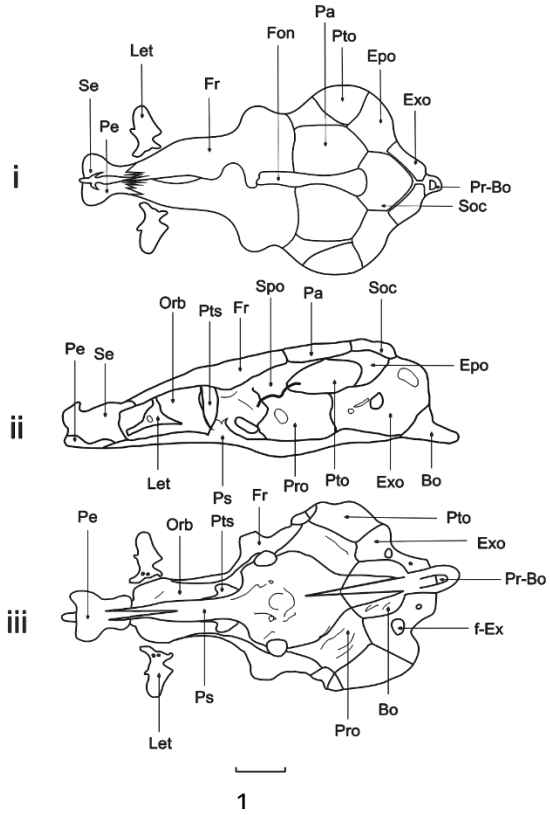

Fig. 2: Neuracoranium of Paraschistura abdolii (from the dorsal (I), lateral (II), and ventral (III): **pr-Bo:** basioccipital process; **Bo:** basioccipital; **Epo:** epiotic; **Exo:** exoccipital; **fon:** fontanelle; **Fr:** frontal; **fr-Exo:** foramen exoccipital; **Let:** lateral ethmoid; **Orb:** orbitophenoid; **Pa:** parietal; **Pe**: prevomer; **Pro:** prootic; **Ps:** parasphenoid; **Pto:** pterotic; **Pts:** pterosphenoid; **Se:** supraethmoid-ethmoid; **Soc:** supraoccipital; **spo:** sphenotic. Scale bar 1mm.

preethmoid-II, lateral ethmoid, kinethmoid, prevomer, prepalatine, and sesamoid. Supraetmoid-ethmoid is perpendicular to the middle part of the prevomer as a blad-shape element. The supraethmoid-ethmoid bone is connected to the frontal by a zigzag suture. The paired preethmoid-II is located in the front part of the

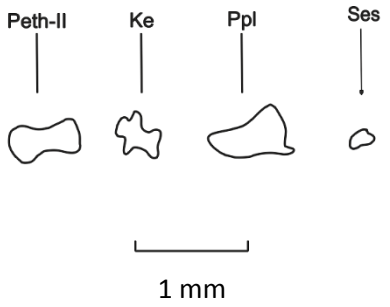

Fig.3. The lateral view of Preethmoid-II, Prepalatin, Kinethmoid, Sesamoid of *Paraschistura abdolii*.
Peth-II: preethmoid-II, **Ppl:** Prepalatine, **Ke**: kinethmoid, **Ses:** sesamoid. Scale bar 1mm.

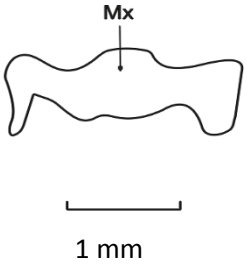

Fig.4. The lateral view of Maxilla of *Paraschistura abdolii*
Mx: maxilla. Scale bar 1mm.

prevomer. A pair of preethmoid-2 is situated in the anterior part of the pre-vomer bone (Fig. 3). Ventral depression with the anterior part of the prevomer and dorsal depression with prepalatine bone are present. A small ethmoid bone is placed between the two jaw bones, completely ossified. The sesamoid bones are freely located in the ethmoid region and between the preethmoid-II bones (Fig. 3).

The visual area includes the frontal bone, orbitosphenoid, pterosphenoid, sparaphenoid, lacrimal bone, and sclerotic. The frontal is the largest element of the neurocranium, narrow and band-shaped in the anterior portion and broader posteriorly. The medial margin of its posterior portion participates in forming the fontanelle. The pterosphenoid connects to the orbitosphenoid in the anterior portion, to the frontal bone posteriorly, and the parasphenoid bone in the ventrally. A cavity exists at the junction of these bones. The elongated and stretched parasphenoid begins from the prevomer and continues to the basioccipital base, bifurcated at both ends. It widens in its middle part and has two protrusions connecting to the pterosphenoid. This area comprises 55-70% of the total length of neurocranium.

The otic region comprises five bony elements: parietal, sphenoid, prootic, pterotic, and epiotic (Fig. 2-i). The medial edge of the parietal participates in forming fontanelle. The Parietal connects to the supraoccipital at its posterior edge. The triangular-shaped sphenoid connects from its ventral-anterior margin to the parasphenoid, ventral-posterior to the pterotic, and dorsal margin to the frontal. The pair of prootic bones has a cavity in the middle anterior region, and is connected to the pterootic from the rear region, and has a pointed appendage in its posterior region. It has a protruding tip on its posterior edge that connects to the basioccipital base on its dorsal edge and exo-occipital protuberance posteriorly (Fig. 2-ii). The pterotic, which is also triangular in shape, forms the lateral and widest part of the neurocranium (Fig. 2-i). It connects anteriorly to the incus and prootic bone and posteriorly to the epitympanic recess. The epiotic connects to the parietal, and pterotic anteriorly and to the supraoccipital and exo-occipital posteriorly (Fig. 2).

The occipital region is composed of three exo-occipital, supraoccipital, and basioccipital bones (Fig. 2-i). The supraoccipital has a concave anterior edge

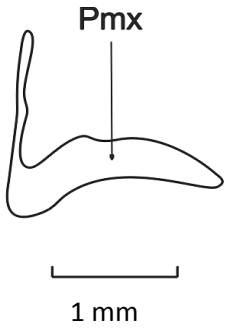

Fig.5. The lateral view of Premaxilla of *Paraschistura abdolii*.
Pmx: Premaxilla. Scale bar 1mm.

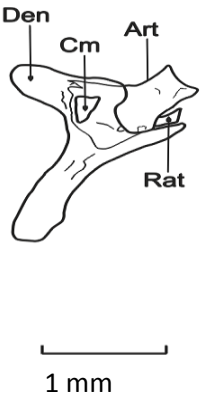

Fig.6. The lateral view of lower jaw of *Paraschistura abdolii*.
Art: articular; **Cm:** coronomeckelian; **Den:** dental; **Rat:** ratroarticular. Scale bar 1mm.

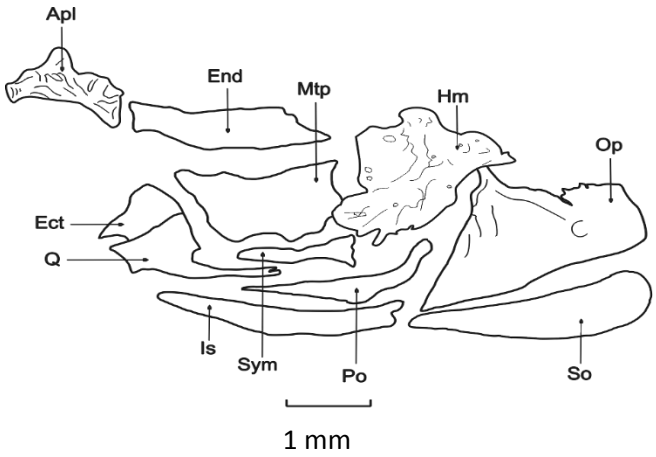

Fig.7. The lateral view of Suspensorium, palatine and opercular series of *Paraschistura abdolii*.
Apl: autopalatine; **Ect:** ectopterygoid; **End:** endopterygoid; **Hm:** hyomandibular; **Io:** interopercle; **Mtp:** metapterygoid; **Op:** preopercle; **Q:** quadrate; **So:** subopercle; **Sym:** sympletic. Scale bar 1mm.

forming the fontanelle and is slightly narrowed posteriorly. This bone connects to the anterior lateral region antero-lateraly and exo-occipital postero-laterally. The exo-occipital bone pair has a large cavity in the postero-dorsal region and a small cavity ventrally. The exo-occipital has a condyle in its posterior region to attach the vertebral column. This bone connects to the parasphenoid and prootic at its anterior edge.

The branchiocranium: The upper jaw consists of two maxillary bones (Fig. 4) and one premaxillary bone (Fig. 5). The Premaxillary is narrow and L-shaped,

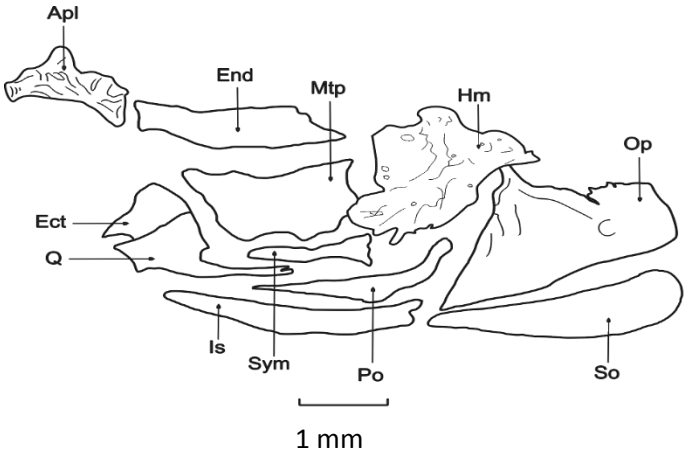

Fig.7. The lateral view of Suspensorium, palatine and opercular series of *Paraschistura abdolii*.
Apl: autopalatine; **Ect:** ectopterygoid; **End:** endopterygoid; **Hm:** hyomandibular; **Io:** interopercle; **Mtp:** metapterygoid; **Op:** preopercle; **Q:** quadrate; **So:** subopercle; **Sym:** sympletic. Scale bar 1mm.

consisting of horizontal and vertical parts, with the former being arch-shaped and wider than the latter. The maxillary bones have two downward processes at both ends. The lower jaw is a pair of L-shaped bones consisting of dental, retroarticular, articular, and coronomckaelian processes (Fig. 6). The dental has a long ventral process in its anterior part. This bone overlaps with the articular bone posteriorly. The retroarticular is located at the posteroventral part of the rarticular, while the retroarticular is at its posterodorsal part. The coronomckaelian is situated on the medial surface of the dental.

The suspensorium includes the quadrate, symplectic, and hyomandibular bones (Fig. 7). The hyomandibular is wide posteriorly and has two condyles connecting to the neurocranium. Another condyle is located at its posterior edge to connect to the opercle. The quadrate has a long and backward-inclined process with a forked tip, connecting the anterior ventral part of the retroarticular posteriorly. The symplectic is narrow and elongated, wider in its posterior part, and has a posterior edge overlapping the quadrate.

The palatine complex includes the metapterygoid, ectopterygoid, endopterygoid, and autopalatine (Fig. 7). The metapterygoid is wedge-shaped. The ectopterygoid is located in the posterior-anterior region of the quadrate. The endopterygoid is elongated with a condyle in the anterior region to connect the autopalatine bone. The autopalatine has a posterior protrusion that articulates with the preethmoid.

Opercular series included the opercle, preopercle, subopercle, and interopercle (Fig. 7). The preopercle has a process anterior-posteriorly, and beneath it, there is an articular depression that connects this bone to the lower hyomandibular. This bone is long, pointed in the ventral-anterior part, and overlaps with the subopercle. The postero-ventral part of the opercle curves and connects to the posterior margin of the subopercle. The subopercle is spindle-shaped, with its anterior part narrower, which connects to the interopercle. The interopercle is long and connected to the interhyal medially.

The branchial apparatus includes five pairs of ceratobranchial bones, four pairs of epibranchial bones, three pairs of hypobranchial bones, two pairs of pharyngobranchial bones, and four basibranchial bones (Fig. 8). The hyoid arch included unpaired urohyal and basihyal, paired dorsal and ventral hypohyal, ceratohyal, epihyal, interhyal, and three pairs of branchiostegal bones (Fig. 9). The Y-shaped urohyal is located in the ventral region of the basihyal bone. The basihyal is T-shaped. This bone connects to the paired hypohyal on its anterior and posterior margins. The hypohyal bones have two posterior and

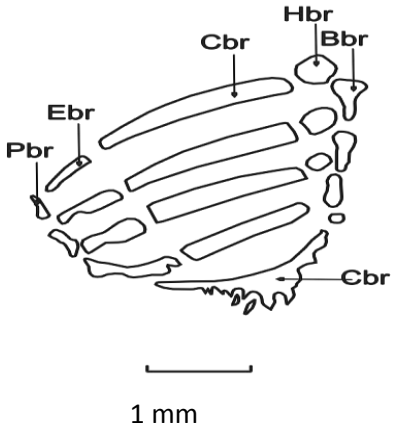

Fig.8. Branchial apparatus of *Paraschistura abdolii*.
Bbr**: basibranchial;** Cbr**: ceratobranchial;** Ebr**: epibranchial;** Hbr**: hypobranchial;** Pbr**: pharyngobranchial. Scale bar 1mm.**

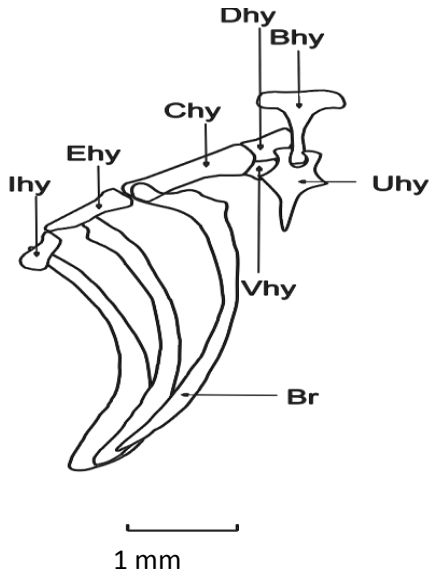

Fig.9. Hyoid arch of *Paraschistura abdolii*
Bhy: basihyal; **Br:** branchiostegale; **Chy:** ceratohyal; **Dhy and Vhy:** dorsal and ventral hypohyal; **Ehy:** epihyal; **Ihy:** interhyal; **Uhy:** urohyal. Scale bar 1mm.

ventral parts (Dhy, and Vhy). The hypohyal connects to the posterior margin of the ceratohyal. The posterior part of the Dhy has a downward process in its ventral region. The ceratohyal in the middle section is narrower, and the first ray of the basibrachial bone is connected to the point of attachment of this bone to the epihyal bone. The second ray is connected to the middle section of the epihyal. The third ray is attached to the interhyal bone. Additionally, the basibrancial rays extend to the posterior edge of the opercle.

Fin skeleton: The pectoral girdle consists of the cleithrum, supercleithrum, coracoid, mesocoracoid, scapula, posttemporal, supratemporal, and radial bones (Fig. 10). The small supratemporal is located in the lateral-inner region of the posttemporal bone. The supercleithrumbone is square-shaped, connecting ventrally to the coracoid. The posttemporal is a long bone located between the supercleithrum and supratemporal. This bone also connects posteriorly to the epiotic, connecting the pectoral girdle to the neurocranium. The coracoid is the largest element of the pectoral girdle and connects postero-anteriorly to the supercleithrum and from its lateral-middle region to the mesocoracoid. The scapula has a large cavity

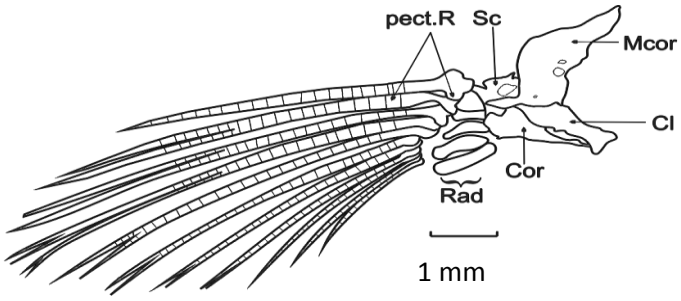

Fig.10. Pectoral gridle of *Paraschistura abdolii*.
Cl**: clethrum;** Cor**: coracoid;** Mcor**: mesocoracoid;** pect-R**: ray of the pectoral fin;** Rad**: ossified pectoral radial;** Sc**: scapula. Scale bar 1mm.**

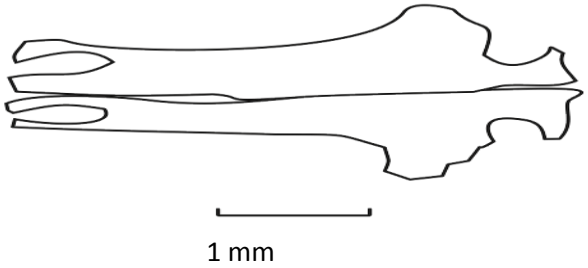

Fig.11. Pelvic gridle of *Paraschistura abdolii*. Scale bar 1mm.

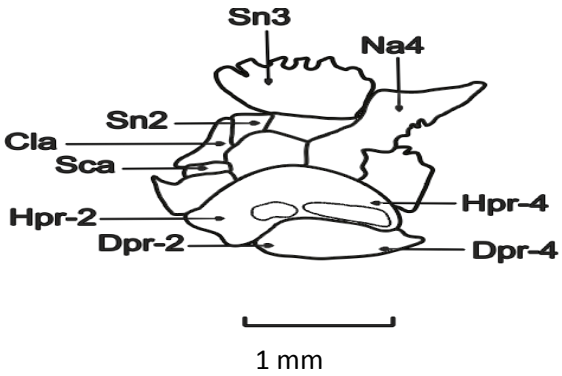

Fig.12. Swim blader capsul of *Paraschistura abdolii*
Cla: claustrum; **Dpr-2-4:** descending processes of the second and fourth centra; **Na4:** neural arch 4; **Sca:** scaphium; **Sn2:** supraneural 2; **Sn3:** supraneural 3. Scale bar 1mm.

located between the coracoid and cleithrum. There are four radials in this structure. The pectoral fin has one unbranched and ten branched rays.

The pelvic girdle consists of the paired pubic and styloid bones (Fig. 11). The pubic bone forks in its anterior region, widens in its middle-posterior region, and is smaller posteriorly. The styloid is located in the outer region and is the first unbranched ray of the pelvic fin.

The dorsal fin has four unbranched rays and eight branched rays (Table 1), and nine pterygiophores and one sty (Fig. 14). It is located at the beginning of this fin on the first distal of the three unbranched rays. The first and last distal are singular, while the rest are paired. It has nine rows of pterygiophores with 12 distal. The anal fin has three unbranched rays, six branched rays (Table 1), seven rows of the pterygiophores, and one stay (Fig. 15). The first and

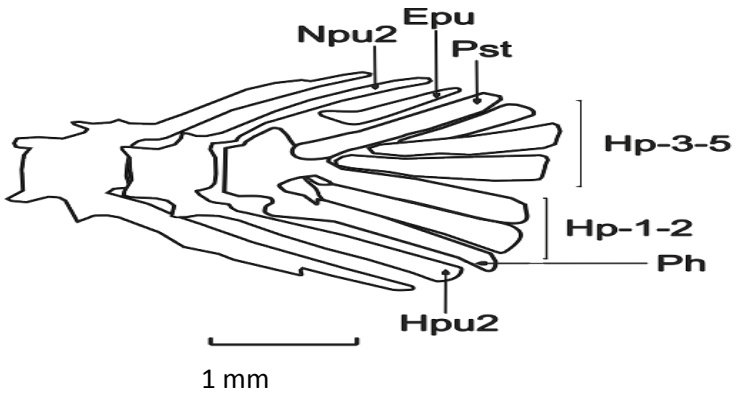

Fig 13. Caudal skeleton of *Paraschistura abdolii*
Epu: epural; **Hp:** hyporal; **Npu2:** neural spine of the second preural centrum; **Hpu2:** hemal processes of the second preural centrum; **Ph:** parhypural; **Pst:** pleurosryle. Scale bar 1mm.

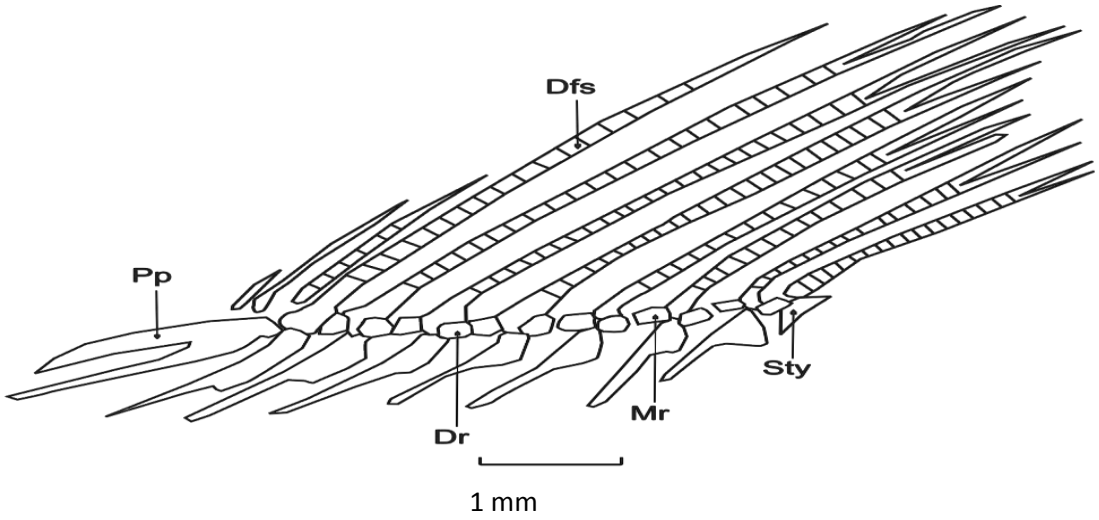

Fig. 14: Dorsal fin of *Paraschistura abdolii*
Dfr: dorsal fin rays; **Dfs:** dorsal fin spin; **Dr:** distal radial; **Mr:** medial radial; **Pp:** pterygoiphore; **Sty:** stay. Scal bar 1mm.

last distal are singular.

Axial skeleton

The axial skeleton of the studied species consists of 37 vertebrae (Table 1), with the first four vertebrae forming the weberian apparatus and swim bladder capsule. The Tripus, Intercalarium, Scaphium, and Claustrum bones also contribute to the form of the Weberian apparatus (Fig. 12). The fourth vertebra undergoes a shape change to form the swim bladder capsule. There are two openings on the lateral margin of this capsule, with the posterior opening being larger. The swim bladder capsule is porous. Additionally, the supraneural is heavily toothed.

The caudal skeleton comprises the last vertebrae, main rays and procurrent, and a set of bony projections. The caudal projections include five hypurals, singular epurals, parahypurals, and pleurostyle bones (Fig. 13). This fin has a pair of unbranched rays at the top and bottom and 16 branched rays in between.

DISCUSSION

Neurocranium: In this study, the superethmoid-ethmoid and prevomer are connected; however, Prokofiev (2010) pointed out that these two are completely fused in all nemachilid species except *Lefua* spp., *Oreonectes platycephalus*, *Triplophysa microphthalma*, *Yunnanilus pleurotaenia*, and *T. tenuis*. Sawada (1989) reported that this character could be used as a phylogenetic feature, while

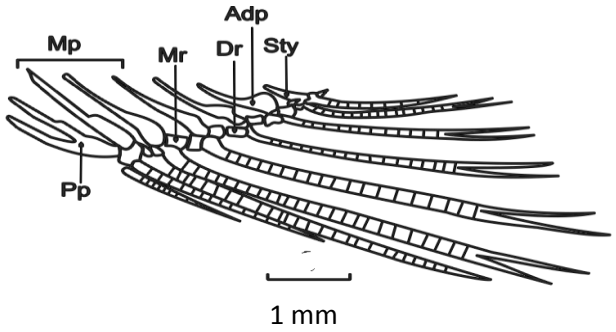

Fig.15. Anal fin of *Paraschistura abdolii*
Adp: anal distal pterygoiphore; **Dr:** distal radial; **Mp:** mesial pterygoiphore; **Mr:** medial radial; **Pp:** pterygoiphore; **Sty:** stay. Scale bar 1mm.

Prokofiev (2010) stated that this recent character is not a phylogenetic feature because in *Orthrias barbatulus toni* and *Triplophysa Stoliczkae* showed both states of the fused and unfused states. The connection between these two bones has been reported in other loaches e.g. in *Cobitis avicennae*, and *C. linea* (Jalili et al. 2015), *Paracobitis hircanica* (Azimi et al. 2015), *Oxynoemacheilus kermanshahensis* (Mafakheri et al. 2015), *O. kiabii* (Mafakheri 2014), *P. alta* (Noroozei et al. 2018), and *P. delvarii* (Noroozei et al. 2021).

The superethmoid-ethmoid was connected to the frontal bone in *P. abdolii*. In *Indoreonectes evezardi*, these two bones are not connected, an apomorphic feature of this genus (Prokofiev 2004, 2009). The sesamoid bone was observed in *P. abdolii*. Sawada (1982) rejected its existence in loaches, but later, it was reported in *Dzihunia amudarjensis*, *Oxynoemacheilus angorae*, *Paracobitis longicauda*, *P. malapterurus* (Prokofiev 2004, 2009, 2010). Noroozei et al. (2021) reported this bone in *P. delvarii*. The lateral ethmoid is connected to the anterior margin of the orbitosphenoid in *P. abdolii*, while Prokofiev (2010) stated that the lateral ethmoid bone is firmly attached to the supraethmoid in all loaches. The prevomer is spearhead-shaped in *P. abdolii*, however, Mafakheri et al. (2014) reported it in the *Oxynoemacheilus kiabi* as a square-shaped prevomer.

In the otic region, the sphenoid is connected to epiotic in *P. abdolii*. This connection has been reported in *Metaschistura*, *Paracobitis*, *Paraschistura*, *Oxynoemacheilus* (Prokofiev 2010), *P. alta* (Noroozei et al. 2018), and *P. delvarii* (Noroozei et al. 2021). The studied species of *P. abdolii* had a fontanelle but was not found in *Triplophysa nanpanjiangensis* (Zhou & Cui 1993).

The caudal fin structure is one of the most important characteristics in phylogenetics for understanding the relationships between fish species (Gosline 1961; Monod 1968; Sawada 1982). In loaches, the caudal skeleton is composed of 5-6 hyporal bones (Prokofiev 2010). *Paraschistura abdolii* has 5 hyporals, and the number of hyporals in *P. alta* was reported to be 6 (Noroozei et al. 2018) and 5 in *P. delvarii* (Noroozei et al. 2021). The number of main rays in the caudal fin in *P. abdolii* is 18 (9+9), with the first rays above and below unbranched, and the others branched, similar to *P. alta* (Noroozei et al. 2018) and *P. denarii* (Noroozei et al. 2021). Sawada (1982) reported that the number of these rays in Nemacheilinae loach fish ranged from 15 to 20, while Prokofiev (2010) reported it as being 12-17.

In the lower jaw, the coronomecklian of *P. abdolii* is located on the dorsomedial region of the articular bone, similar to the studies of Sawada (1982) and Noroozei et al. (2018). While Prokofiev (2010) pointed out that this bone is located on the coronoid processes of the dental bone.

In the hyoid arch, the pairs urohyal bone was absent in *P. abdolii*, similar to *P. delvarii* (Noroozei et al. 2021), while the presence of this bone is reported in *P. alta* (Noroozei et al. 2018). Prokofiev (2010) did not examine this small bone, but Sawada (1982) confirmed its presence as a sublingual bone in the Nemacheiinae.

The number of basibranchial, ceratobranchial, and pharyngobranchials and their characteristics are important features of this group (Prokofiev 2010). *Paraschistura abdolii* has four basibrancial, also reported for *O. bergianus* and *T. kosswigi* (Azimi 1393). Prokofiev (2010) reported the number of basibrancial in the genera *Hedinicthys*, *Lefua*, *Metaschistura*, *Nun*, *Paraschistura*, and *Seminemacheilus*, and species of *Acanthocobitis botia*, *Indoreonectes evezardi*, *Iskandaria kuschakewitschi*, *Nemacheilus masyae*, *Oreonectes platycephalus*, *Paracobitis longicauda*, and *Yunnanilus pleurotaenia* are three. Additionally, three basibrancials are reported in *P. alta* (Noroozei et al. 2018) and *P. delvarii* (Noroozei et al. 2021). Sawada (1982) reported four basibrancials in *O. jordanicus*, while Prokofiev (2010) reported three in *O. brandti* and *O. panthera*. Mafakheri et al. (2014) reported four basibrancials in *O. kiabii*. The number of basibranchial can be a derived feature in the family. The present study reports two pairs of the pharyngobranchials. The presence of this bone has been confirmed in *N. postventralis* by Sawada (1982) and *Afronemacheilus kaffa*, *O. angorae* and *Triplophysa* by Prokofiev (2010). Additionally, three pharyngobranchial bones were reported in *O. bergianus* (Azimi 2014).

Swim bladder capsule can be considered a derived feature of Cobitoidea (Prokofiev, 2010). In the family Nemacheilidae, this bony capsule is divided into two parts by lateral divisions and participates in forming the descending parapophysis process of the second vertebra (Prokofiev 2010). This feature can be considered an autapomorphy in the family Balitoridae (Sawada 1982). The first vertebrae in the formation of the bone capsule did not play a role, but in all Nemacheilidae, the second and third centrum have fused together, and their parapophysis has well-developed. As an exception, in the genus *Hedininchthys*, the fifth vertebra also plays a role in capsule formation; this phenomenon was first reported by Rendahl (1933). In the genus *Hedininchthys*, the parapophysis of the fifth centrum is bifurcated and its thick anterior process forms part of the dorsal, posteriodorsal wall of the bone capsule. The recent bone parapophyses are divided horizontally into two descending processes, each forming part of the anterior portion of the bone capsule. The fourth centrum parapophysis has similarly changed and forms part of the posterior portion of the swimming capsule.

Paraschistura abdolii has two anterior and posterior cavities on the lateral sides of the swim bladder capsule, with the anterior cavity being smaller than the posterior one, similar to *P. alta* (Noroozei et al. 2018) and *P. delvarii* (Noroozei et al. 2021). In *Nun galilaeus*, there is no bridge between two cavities and they are attached to each other (Prokofiev 2010). A non-porous bone capsule has also been observed in *P. abdolii*. According to Sawada (1982) and Banarescu & Nalbant (1995), this feature can be considered as plesiomorphy in relation to other Nemacheilidae. Based on this feature, Banarescu and Nalbant (1995) separated *Vaillantella* genus from Nemacheilidae. The dorsal margin of the supraneoral-3 is strongly dentate in *P. abdolii*. This feature has not been studied by any researcher, but Noroozei et al. (2018) have observed in *P. alta* with a smooth edge.

In the axial skeleton, the number of vertebrae (including the four modified anterior centra) in *P. abdolii* is 37. Many species of loach fish in South and Southwest Asia have 28 to 40 (mostly 32 to 39) vertebrae (Sawada 1982; Krupp & Schneider, 1989, 1991; Roberts 1989). This feature can be as apomorphic character. The number of dorsal petrigephores in *P. abdolii* is nine, and the number of its distals is twelve.

CONCLUSION

This species can be distinguished from other species of this genus with features such as the presence of a sesamoid bone, the presence of extra urohyal bone, the presence of a distance between the epiural and the centrum body, and the strong dentition of the supraneoral-3 bone.

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مقاله کامل

صفات استخوان‌شناسی *Paraschistura abdolii* (Nemacheilidae) از حوضه هامون جازموریان، جنوب شرق ایران

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چکیده: این مطالعه با هدف ارائه ویژگی‌های دقیق استخوان‌شناسی گونه *Paraschistura abdolii* با توجه به مطالعات محدود بر روی ساختار اسکلتی این جنس در سال‌های اخیر انجام شد. در مجموع ۵ نمونه *P. abdolii* از حوضه هامون جازموریان جمع‌آوری، شفاف‌سازی و رنگ‌آمیزی شدند. براساس نتایج به‌دست آمده، این گونه را می‌توان با داشتن ۴ باسی برانشیال، ۹ پترجیفور، ۵ هیپورال، کیسه شنای دندانه‌دار، یک استخوان سزاموئید، استخوان اضافی اوروهیال، فاصله بین ایپورال و جسم مرکزی و دندانه‌های قوی استخوان سوپرانئورال-۳ از سایر گونه‌های این جنس متمایز کرد.

کلمات‌کلیدی: استخوان، جویبارماهیان، استخوان‌شناسی، آب شیرین، ایران