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DESCRIPTIVE OSTEOLOGY OF *Oxynoemacheilus kermanshahensis* (Bănărescu and Nalbant, 1966) (CYPRINIFORMES, NEMACHEILIDAE)

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ABSTRACT

Oxynoemacheilus kermanshahensis is an endemic species of the family Nemacheilidae from the Karkheh River drainage of the Tigris basin. This study was conducted to provide the detailed osteological characters of this species, comparing it with those of other endemic species of the genus *Oxynoemacheilus* from inland water basins of Iran viz. *O. kiabii*, *O. persa* and *O. bergianus*. For this purpose, eight specimens of *O. kermanshaensis* were collected and cleaned and stained for the osteological examination. Then a detailed description of its skeletal structure was provided. The results showed that *O. kermanshahensis* can be distinguished from other three compared *Oxynoemacheilus* species on the basis of the connection pattern of the frontal and parietal, presence of a supratemporal commissure and orbital shelf, connection pattern of two prootics, possessing a maxilla with convex margin, having the more vertebrae, bearing the least number of the branched ray in the dorsal fin, presence of the five hypurals, possessing fine and thin neural and hemal spines and the shape of swim bladder capsule.

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INTRODUCTION

Stone loaches, the family *Nemacheilidae*, are small fishes occurring in fresh waters of Asia and its islands, Europe and northeast Africa (Coad, 2014). They inhabit a variety of inland waters, e.g. turbulent mountain streams to salty rivers in dry lowlands (Golzarianpour et al., 2011; Mafakheri et al., 2014). *Nemacheilidae* has about 72 genera and more than 800 species (Nelson, 2006; Eschmeyer and Fong, 2011; Freyhof et al., 2015), with more species expected to be described (Coad, 2014; Kamangar et al., 2014). This family has a great diversity in Iranian inland waters (Coad, 2006) with about 40 reported species and about 24 of them are endemic to Iran indicating their importance (Esmaeili et al., 2010; Abdoli et al., 2011; Kamangar et al., 2014; Esmaeili et al., 2014; Freyhof et al., 2014; Freyhof et al., 2015; Mousavi-Saber et al., 2015).

The phylogenetic relationship of the family Nemacheilidae is completely unknown because of the confused definitions of genera and high number of poorly described species (Prokofiev, 2009; Esmaeili et al., 2010; Freyhof et al., 2011). Osteology is a useful tool to study the taxonomy and phylogenetic relationships among fishes (Nasri et al., 2013; Jalili et al., 2015), hence various osteological studies about Nemacheilidae are performed by various authors such as Hora (1932), Berg (1940), Mester-Bacescu (1970), Sawada (1982) and Prokofiev (2009, 2010). The most important osteological studies are related to Sawada (1982) and Prokofiev (2009, 2010).

The genus *Oxynoemacheilus* has 11 reported species

from Iran and three of them, including *O. kurdistanicus*, *O. chomanicus* and *O. zagrosensis*, were recently described from the Choman River drainage of the Tigris basin (Kamangar et al., 2014). *Oxynoemacheilus kermanshahensis* and *O. kiabii* are two endemic species of this genus from the Karkheh River drainage of the Tigris basin (Coad, 2015). Since there is no information available about osteological features of *O. kermanshahensis* (Fig. 1), this study was conducted to provide the detailed osteological characters of this species, comparing it with those of other endemic species of the genus *Oxynoemacheilus* from the inland water basins of Iran viz. *O. kiabii, O. persa* and *O. bergianus* whose osteological data are available. In addition, *O. kermanshahensis* is sympatric with *O. kiabii* in its distribution area. Little morphological differences were reported to discriminate these two sympatric species. Therefore, the findings of this study can provide those osteological features that can help to discrete these two species and be used as a basis for further phylogenetic studies of the members of this genus based on the osteological data.

MATERIALS AND METHODS

Eight specimens of *O. kermanshahensis* (with 56.84 ± 1.53 mm (Mean ± SD) in standard length) were collected using electrofishing device from the Gamasiab River (Kermanshah Province, Iran). Specimens were anesthetized with 1% clove solution and fixed in 4% formalin. For osteological examination, the specimens were cleared and stained using alcian blue and alizarine red based on Taylor and Van Dyke (1985). Images of the stained skeletal structure were obtained by Epson V700 scanner equipped to a glycerol bath. The skeletal structure of each sample was observed and studied by an MS5 Leica stereomicroscope. The scanned images were illustrated by CorelDraw X6 software. Nomenclature and abbreviation of skeletal elements follow Prokofiev (2009, 2010) and Bird and Hernandez (2007). Detailed descriptions of the osteological features of *O. kiabii*, *O. bergianus* and *O. persa* were provided by Mafakheri et al. (2014), Jalili and Eagderi (2013) and Mafakheri et al. (2015), respectively. In addition, the available cleared and stained materials of these studied species (Mafakheri et al., 2014; Jalili and Eagderi, 2013; Mafakheri et al., 2015) were used for drawing and comparing with those of *O. kermanshahensis*.

Fig 1. Lateral view of *Oxynoemacheilus kermanshahensis*.

RESULTS

Neurocranium. The orbito–rostral region of the neurocranium is narrow, whereas its postorbital region is wider with almost equal length to the former part. The maximum width of the neurocranium is about 59% of its length. The ethmoid region consists of the unpaired prevomer, unpaired supraethmoid-ethmoid and paired lateral ethmoids (Fig. 2a, 2b, 2c). The supraethmoid-ethmoid complex is vertically fused to the prevomer and firmly jointed to the frontal posteriorly (Fig. 2a, 2b). The prevomer has a square shape which is connected to the preethmoid-II anteriorly, to the autopalatine laterally and

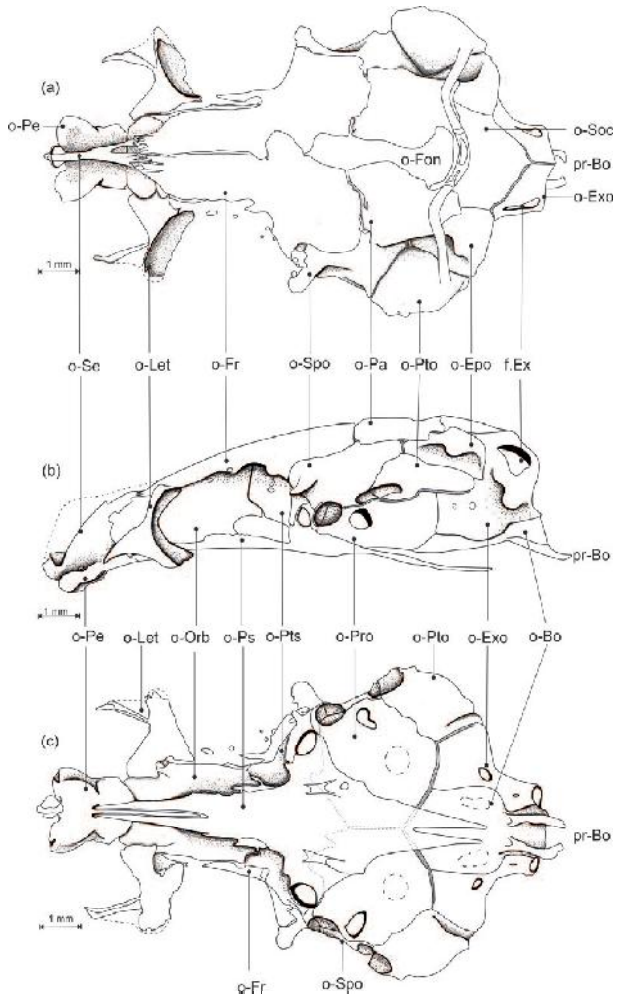

Fig 2. (a) dorsal, (b) lateral and (c) ventral view of the neurocranium of *Oxynoemacheilus kermanshahensis*. pr-Bo: basioccipital process; **Bo: basioccipital; Cst: comissura** supratemporalis; Epo: epiotic; Exo: exoccipital; fon: fontanelle; Fr: frontal; fr-Exo: foramen exoccipital; Let: lateral ethmoid; O-shelf: orbital shelf; **Orb: orbitosphenoid**; Pa: parietal; Pe: prevomer; ppl: prepalatine; pr.ant: anterior processes of the premaxilla; Pro: prootic; **Ps: parasphenoid; Pto: pterotic; Pts: pterosphenoid**; Se: supraethmoid-ethmoid; Soc: supraoccipital; Spo: sphenotic

to the orbitosphenoid posteriorly (Fig. 2c). The anterior part of the lateral ethmoid is pointed and its posterior part has a convex shape forming anterior part of the orbit (Fig. 2a, 2b, 2c). This bone is attached to the orbitosphenoid laterally (Fig. 2a, 2b, 2c).

There are small bones between the ethmoid region and the upper jaw including paired preethmoid-II, prepalatine and sesamoid, and unpaired kinethmoid. The preethmoid-II is rod-shaped situated between the prevomer and maxilla and connected to the prepalatine laterally. The prepalatine bears two wings posterolaterally where they are connected to the autopalatine. The prepalatine is anteriorly connected to the maxilla. The kinethmoid is laminar and cylindrical in shape, and vertically located between upper jaws in a ligamentous space that also enclosed a small, round sesamoid bone.

The orbital region comprises the frontal, orbitosphenoid, pterosphenoid, parasphenoid and sclerotic (Fig. 2a, 2b, 2c). The frontal is the largest element of the skull roof and almost forms 46% of the neurocranium length. This bone is narrow anteriorly and wider posteriorly. At the midline, the antimeres of the frontals overlap each other posteriorly (Fig. 2a). The frontal is connected to the lateral ethmoid by a lateral narrow band, to the orbitosphenoid, pterosphenoid and sphenotic laterally and to the parietal posteriorly (Fig. 2a, 2b). The fontanelle is enclosed by the frontal, parietal and supraoccipital (Fig. 2a). The orbitosphenoid is a cylindrical bone whose two sides are concaved. This bone is posteriorly connected to the pterosphenoid (Fig. 2b). In ventral plan, the orbitosphenoid is attached to the parasphenoid (Fig. 2c). In posteroventral part, the orbitosphenoid along with the pterosphenoid and parasphenoid form the orbital foramen (Fig. 2b). The heavy bone of the pterosphenoid forms posterior wall of the orbit. The pterosphenoid, sphenotic and prootic form anterior articulatory facet for articulating the anterior condyle of the hyomandibular, and the sphenotic and pterotic form the posterior articulatory facet for articulating the posterior condyle of the hyomandibular (Fig. 2b, 2c). The elongated parasphenoid is bifurcated at its two ends (Fig. 2c). This bone bears two narrow wings laterally which meets the pterosphenoid and prootic (Fig. 2c).

The otic region consists of the epiotic, parietal, pterotic, prootic and sphenotic (Fig. 2a, 2b). The epiotic is almost triangular in shape and is connected to the supraoccipital and pterotic laterally, also to the sphenotic anteriorly (Fig. 2a, 2b). The connection of the epiotic to the sphenotic avoids relationship between the parietal and pterotic (Fig. 2b). The epiotic is posteriorly connected to the exoccipital (Fig. 2b). The parietal is almost square-shaped and its posterior part is slightly narrower (Fig. 2a). This bone is overlapped with the sphenotic anterolaterally, to the epiotic posterolaterally and to the supraoccipital posteriorly (Fig. 2a, 2b). The triangular pterotic is connected to the sphenotic and epiotic dorsolaterally, and to the prootic and exoccipital venterolaterally (Fig. 2a, 2c). The prootic is large and possesses large foramina laterally (Fig. 2c). Posteriorly, the prootic is connected to the basioccipital and exoccipital (Fig. 2c). The sphenotic is a heavy bone that is posterodorsally connected to the supraoccipital beneath the parietal.

The occipital region consists of two unpaired supraoccipitals and basioccipitals and paired exoccipitals (Fig. 2a, 2b, 2c). The supraoccipital bears two wings anterolaterally. The supratemporal canal is enclosed by this bone (Fig. 2a). The supraoccipital is posteriorly connected to the exoccipital (Fig. 2a). The exoccipitals are large and form the posterior face of the skull. This bone has a large foramen (Fig. 2a, 2b). The basioccipital is located between two exoccipitals (Fig. 2c). The basioccipital possesses an elongated ring-shaped process (Fig. 2c).

Jaws. The upper jaw consists of the premaxilla and maxilla (Fig. 3a). The premaxilla is L-shaped and possesses a narrow vertical process, i.e. pr. Ascenden, and curved horizontal process, i.e. pr. Alveolar. The premaxilla is connected to the kinethmoid by strong ligamentous connection. The maxilla is a large laminar bone which has a small anterodorsal process that is connected to the preethmoid II and prepalatine, and an anteroventral process that is tilted downward the side reaching its counterpart (Fig. 3a).

The lower jaw is composed of the dental, articular, retroarticular and coronomeckelian (Fig. 3b). The dental is the largest bone of this series and possesses two parts, including narrow ramus dentalis and a wide coronoid process. The anterior part of the coronoid process is slightly triangular in shape and its posterior margin is serrated. The anterior part of the articular is wider than its posterior part and attached to the dental. The articular is posteriorly articulated to the quadrat and connected to the small retroarticular. The coronomeckelian is attached to the anterior part of the articular (Fig. 3b). The meckelian cartilage is present between the dental and articular.

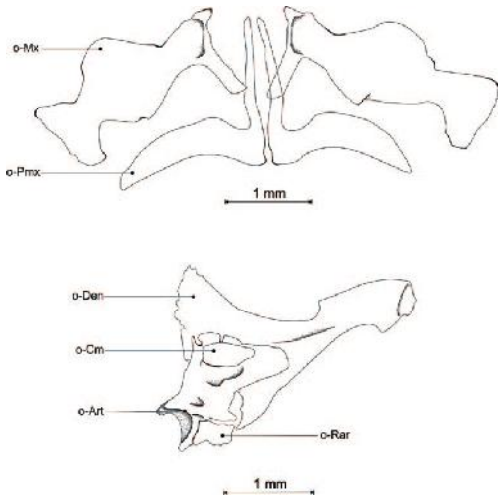

Fig 3. (a) Upper jaw and (b) medial view of lower jaw in *Oxynoemacheilus kermanshahensis* Art: articulare; Cm: coronomeckelian; Den: dentale; Mx: Maxillare; Pmx: Premaxillare Rar: retroarticulare

Branchial apparatus. The branchial arch consists of the basibranchials, hypobranchials, ceratobranchials, epibranchials and infrapharyngobranchials (Fig. 4). There are four unpaired basibranchials and the last one is the smallest (one of the specimens had five unpaired basibranchials and the two last basibranchials were positioned adjacent to each other). The anterior part of the first and second basibranchials is wider than those of the posterior ones. Third basibranchial is almost rectangular in shape. In each half, there are three hypobranchials and the first two hypobranchials are similar in shape and the last one is the smallest one. Five pairs of the ceratobranchials are located between the hypobranchials and epibranchials, and the last pair is modified as the tooth plats, i.e. pharyngeal teeth bearing 12 teeth on each. The number of epibranchials and infrapharyngobranchials are four and three pairs, respectively (Fig. 4).

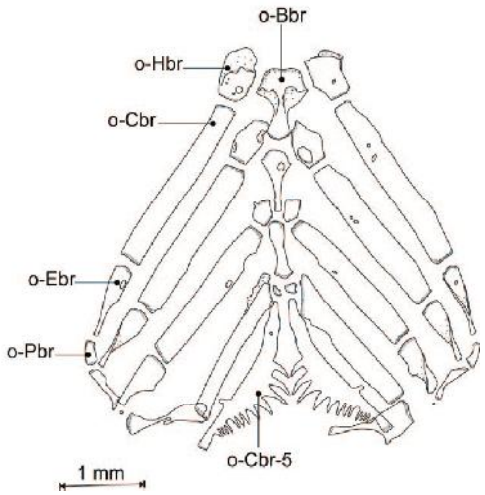

Fig 4. Branchial apparatus of *Oxynoemacheilus kermanshahensis*. Bbr: basibranchials; Cbr: ceratobranchials (cbr5: pharyngeal bones); Ebr: epibranchials; Hbr: hypobranchials; Pbr: infrapharyngobranchials

Hyoid arch. The hyoid arch is composed of the basihyal, dorsal hypohyal, ventral hypohyal, ceratohyal, epihyal, interhyal, urohyal, extra urohyal and branchiostegals (Fig. 5). The ceratohyals are the largest elements of the hyoid arch and have a cylindrical shape. The subtringular epihyal bears a lateral depression for connecting to the small rod-shaped interhyal. The dorsal and ventral hypohyals are connected firmly. The dorsal hypohyal has a process anteriorly and ventral hypohyal has a process posteriorly. Between the paired hypohyals, there are the two small rod-shaped extra urohyals. The laminar urohyal is located above the extra urohyals and possesses a depression anteriorly, two wings anterolaterally and a crest along its midline dorsally. The basihyal is T-shaped and slightly bow-shaped anteriorly. This bone has a depression on its anterior part. The basihyal is located under extra urohyals. There are three curved long branchiostegals; the first one is attached to the ceratohyal, the second one located between ceratohyal and epihyal, the third one attached to the epihyal.

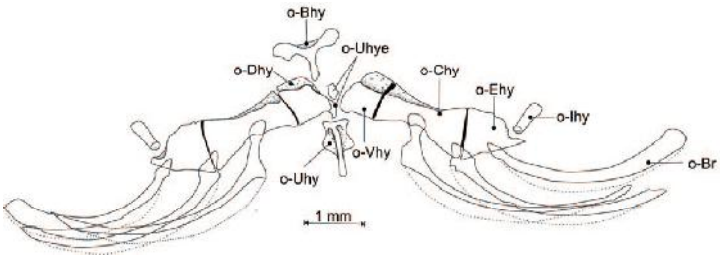

Fig 5. Hyoid arch of *Oxynoemacheilus kermanshahensis*. Bhy: basihyal; Br: branchiostegale; Chy: ceratohyal; Dhy and Vhy: dorsal and ventral hypohyal; Ehy: epihyl; Ihy: interhyal; Uhy: urohyal; Uhye: urohyal extra

Suspensorium. The suspensorium consists of the autopalatine, endopterygoid, ectopterygoid, metapterygoid, hyomandibular, quadrate and symplectic (Fig. 6). The metapterygoid is rectangular in shape and is connected to the quadrate anteriorly. The endopterygoid is elongated and connected to the ectopterygoid anteroventrally. The endopterygoid is anteriorly articulated to the heavy bone of the autopalatine. The autopalatine has wings laterally which are connected to the prevomer. The anterior part of the quadrate is deep with a posteroventral projected process. The quadrate bears a condyle anteroventerally where it is articulated to the articular. In addition, the quadrate has an incisures posteriorly where the subtriangular symplectic is located. The hyomandibular has no regular shape and its anterior part is wider than the posterior part. This bone dorsally possesses two articulatory condyles for articulating with the nuerocranium and one articulatory condyle posterolaterally for articulating to the operculum. The anterior margin of the hyomandibular is serrated and has a posterodorsal process next to the hyomandibular articulatory condyle.

Opercular series. This series consist of the opercular, subopercular, interopercular and preopercular bones (Fig. 6). The opercular is the largest element and its dorsal margin is concaved. The paddle-shaped subopercular is slightly covered by the opercular posteriorly. The narrow curved preopercular and the interopercular are positioned anteriorly. The interopercular is not completely ossified and covered by the preopercular dorsally.

Pectoral girdle. The pectoral girdle includes the cleithrum, coracoid, scapula, mesocoracoid, supratemporal, posttemporal, supracleithrum and radials of the pectoral fin (Fig. 7). The posttemporal is elongated and slightly curved in the middle part. The anterior part of the posttemporal is slightly bifurcated and narrower than its posterior part and attached to the epiotic. This bone is fused to a small supratemporal posterolaterally. The posttemporal and supratemporal are located in a depression of the

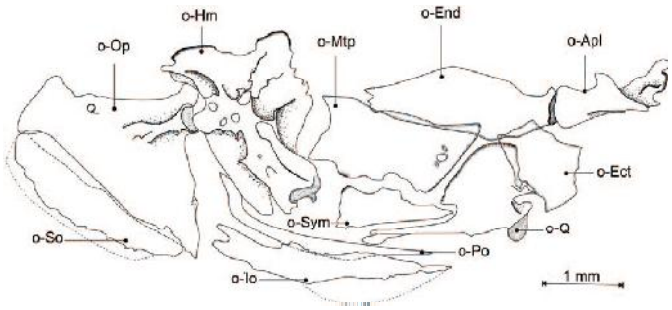

Fig 6. Medial view of the suspensorium from internal side: Apl: autopalatine; Ect: ectopterygoid; End: endopterygoid; Hm: hyomandibulare; Io: interopercle; Mtp: metapterygoid; Op: opercle; Po: preopercle; Q: quadrate; So: subopercle; Sym: symplectic

supracleithrum. The anterior part of the supracleithrum is narrow and its posterior part is flattened connecting to the cleithrum. The cleithrum is a large laminar bone with vertical and horizontal sections. The scapula is a trapezoid in shape and laterally connected to the cleithrum and coracoid. This bone has a large foramen, i.e. scapula foramen. The elongated coracoid is narrow anteriorly and wider posteriorly. This bone is connected to the horizontal section of the cleithrum anteriorly and posteriorly connected to the vertical section of the cleithrum indirectly via the mesocoracoid. The pectoral girdle has four radials and two medial ones have almost equal length and are longer than two lateral radials. There are three small bones between radials and rays, and those lateral ones are larger (Fig. 7). There is one unbranched ray and 10-11 branched rays.

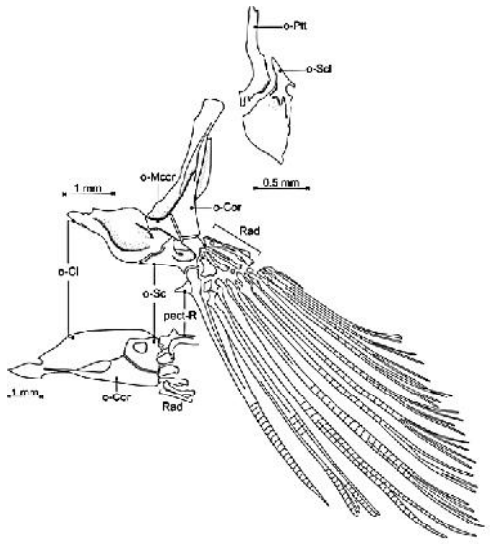

Fig 7. Medial and lateral views of the pectoral girdle of *Oxynoemacheilus kermanshahensis*. Cl: cleithrum; Cor: coracoid; Mcor: mesocoracoid; pect.R: ray of the pectoral fin; Ptt: posttemporal; Rad: ossified pectoral radial; Sc: scapula; Scl: supracleithrum; Stt: supratemporal

Pelvic girdle. The pelvic girdle consists of the paired pelvic bones and radials (Fig. 8). The pelvic bone is horizontally positioned in the ventral plan of the belly. The anterior part of the pelvic bone is narrow and is wider posteriorly. The anterior process of the pelvic bone, i.e. pubic process, has some projected processes that can be homogeneous or heterogeneous. In the posterior part of the pelvic bone, there are two processes: one is located laterally viz. pr. Iliacus and the other one posteriorly viz. pr. Ischiadicus. The rays are connected between these two processes. Two pelvic bones in the medial part are firmly connected by strong ligament. Along the midline, the connection of two pelvic bones is not straight. There are three radials which are located between rays and the iliacus process. The most medial radial is the largest one. There is one unbranched ray, seven branched rays and one small curved pelvic splint in the pelvic fin (Fig. 8).

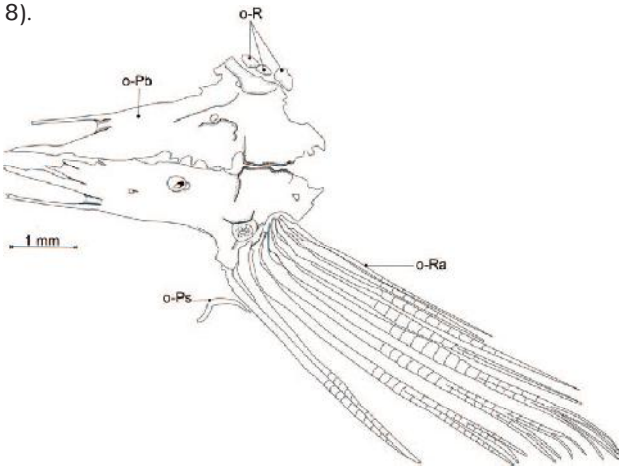

Fig 8. Pelvic fin of *Oxynoemacheilus kermanshahensis*: Pb: pelvic bone; Ps: pelvic splint; R: radial; Ra: fin rays

Axial skeleton and unpaired fins. The centra are cylindrical in shape with longitudinal crests and depressions between the adjacent centra. The numbers of the centra are 39-40. The hemal spines start from 24th centrum. Some of the centra processes (hemal and neural) are bifurcated, e.g. 37th, 27th hemal spine and 37th neural spine. The dorsal fin is supported by six-seven pterygiophores and the first one is the largest reaching the 15th vertebra. There are four unbranched rays and $6_{1/2}$-$7_{1/2}$ branched rays in the dorsal fin (Fig. 9a). The number of the pterygiophors in the anal fin is six and the first one reaches the 26th centrum and is larger than others. There are four unbranched rays and $5_{1/2}$ branched rays in the anal fin (Fig. 9b).

Caudal skeleton. Caudal complex includes the second preural centrum and its neural and hemal processes (spine and arch), first preural centrum, ural1+ural2, pleurostyle, hypurals, parhypural, epural, principal caudal rays and procurrent rays (Fig. 10). The centrum of the preural-2 is dorsally fused to its neural process and ventrally articulated to its hemal process. These two processes are almost elongated

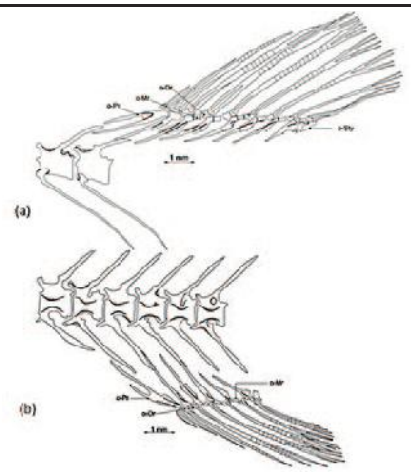

Fig 9. (a) Dorsal fin, (b) anal fin of *Oxynoemacheilus kermanshahensis*. dr: distal radial; mr: medial radial; pr: proximal radial; sty: stay

and rectangular in shape and support some procurrent rays. The neural process of the preural-2 is wider than those of others; also its hemal process is similar to the adjacent hemal process and is wider than others. The last centrum is formed by fusing the centra of the preural-1, ural-1 and ural-2. The pleurostyle is elongated and fused to the preural-1 centrum. There are 4-5 hypurals that support principal caudal rays. The hypural-1 is connected to the last centrum and is autogenous (also in some examined specimens); this bone is fused to the hypural-2 or the parhypural and/or both (Fig. 10). The hypural-2 is fused with last centrum, and third to fifth (or fourth) hypurals are located in the ventral groove of the pleurostyle. The last hypural is the smallest one and, in the specimens with 4 hypural, is the widest one. There is one epural between the neural process of the preural-2 and pleurostyle which supports some of the procurrent rays (Fig. 10). In some specimens, this bone is absent (i.e. it is fused to the neural rudimentary). The parhypural is rectangular in shape and articulated to the preural-1 centrum. This bone is autogenous and has a developed parhypurapophysis. The number of principal rays is 18 (9+9).

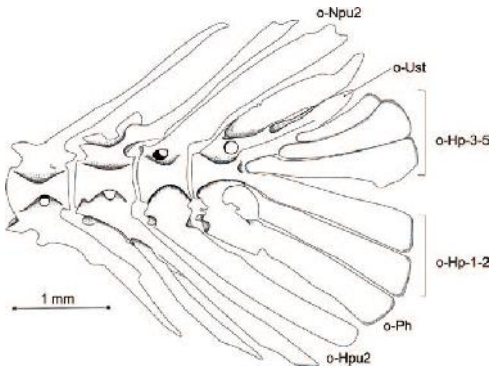

Fig 10. Caudal skeleton of *Oxynoemacheilus kermanshahensis*. Epu: epural; Hp: hypural; Hpu2: hemal process of the second preural centrum; Npu-2: neural process of the second preural centrum; Ph: parhypural; Ust: pleurostyle

Weberian apparatus and swim bladder capsule. Weberian apparatus is composed of four Weberian ossicles and four vertebral elements. Weberian ossicles include the claustrum, scaphium, intercalarium and tripus (Fig.11). The anteriormost ossicle is the claustrum and posteriormost one is the tripus. The claustrum is elongated and dorsally abutted with the supraneural 2 (Fig. 11c, 11b). The ventral part of the claustrum is convex in shape and caps medial side of the scaphium (Fig. 11c). The scaphium is bowl-shaped which along with the ventral part of the claustrum forms an ellipse shape. The scaphium is posteriorly attached to a small rod-shaped intercalarium by ligamentous connection. The tripus bears two branches anteriorly; the short branch is attached as ligamentous to the intercalarium and another one is longer and attached to the compound centra 2-3. The first vertebra is anteriorly connected to the basioccipital and has two lateral elongated processes (Fig. 11a). This vertebra does not participate in the forming of the bony capsule. The centra 2 and 3 are fused to each other. The second lateral process of the centrum-2 expands as two processes: second horizontal process (hp 2) and second descending process (dp 2) that form the anterior part of the swim bladder capsule. The third neural arch is connected to the supraneural 2 anteriorly and to the neural arch 4 posteriorly, and to the supraneural 3 dorsally. The parapophysis of the fourth vertebra is modified and forms the fourth horizontal process and fourth descending process, and these two processes form the posterior face of the swim bladder capsule (Fig. 11c). In the lateral plan, two openings are observed and the anterior

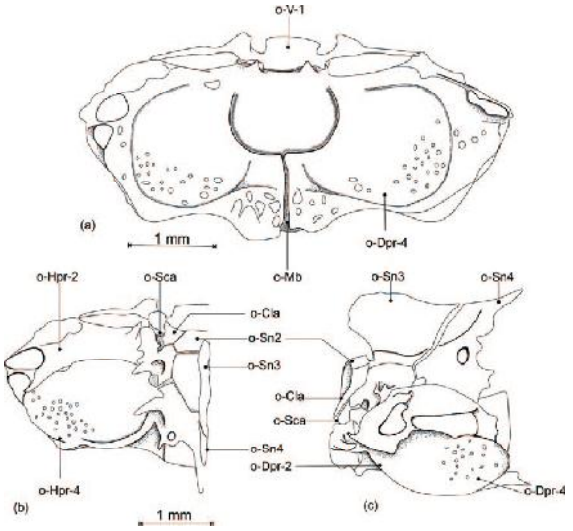

Fig 11. (a) Ventral, (b) dorsal and (c) lateral views of the Weberian apparatus in *Oxynoemacheilus kermanshahensis*. o-Cla: claustrum; o-Dpr-2 -4: processes of descendens et horizontalis of the second and fourth centra; o-Hpr-2-4: processes of descendens et horizontalis of the second and fourth centra; o-Mb: manubrium; o-Na4: neural arch 4; o-Sca: scaphium; o-Sn2: supraneural 2; o-Sn3: supraneural 3; o-V-1: first centrum

opening is slightly smaller than the posterior one (Fig. 11c). In ventral plan, two lobes of the swim bladder capsule are posteriorly connected to the manubrium (Fig. 11a). The right and left lobes of the bony capsule are symmetrical and have rectangular shape (Fig. 11a).

DISCUSSION

The members of the genus *Oxynoemacheilus*, with 11 reported species, are distributed in most of the inland water basins of Iran and their identification is based on their external morphology with difficulty. Hence, the osteological features are suitable characteristics for their distinction (Prokofiev, 2009, 2010). The osteological characters are witness of the past existence and repositories of an enormous amount of biological and ecological information (Rojo, 1991). Therefore, the present study provided detailed osteological characters of *O. kermanshahensis* for further taxonomical studies of these taxa.

The native loach of *O. kermanshahensis* is found in the Iranian part of the Tigris basin. Based on the results, this species shows some osteological features that can be considered as osteological identification key when compared to *O. kiabii* (Mafakheri et al., 2014), *O. bergianus* (Jalili and Eagderi, 2015) and *O. persa* (Mafakheri et al., 2015). The connection of the frontal and parietal in *O. kermanshahensis* is almost smooth and straight, whereas this connection in *O. kiabii* is serrated (Fig. 12a, 12b, 12c). In addition, a small bone is present between these two bones in *O. persa* (Fig. 12c). There is no orbital shelf of the frontal in *O. persa* or is less-developed, whereas it is well-developed in *O. kermanshahensis* (Fig. 12a, 12b, 12c). The connection of the frontal antimeres in *O. kermanshahensis* is straight in anterior and middle parts compared to those of *O. bergianus* and *O. kiabii* (Fig. 12a, 12b, 12c). The process of the orbitosphenoid in *O. persa* is well-developed unlike that of *O. kermanshahensis* (Fig. 12d, 12e). The connection of two prootics in *O. kermanshahensis*, *O. persa* and *O. bergianus* are similar and restricted to the middle and posterior parts, whereas in *O. kiabii* this connection is restricted to the posterior part (Fig. 12f, 12g). There is supratemporal commissure on the supraoccipital in *O. kermanshahensis*, *O. persa* and *O. bergianus* but not in *O. kiabii* (Fig. 12a, 12b, 12c).

The superior margin of the maxilla in *O. kermanshahensis* is convex in shape versus straight one of three other species (Fig. 13).

The shape of the metapterygoid is elongated and rectangular in *O. kermanshahensis*, *O. persa* and *O. bergianus* versus the square-shaped metapterygoid of *O. kiabii* (Fig. 14). The processes of the hypohyals in *O. kiabii* are more developed than that of other three species. The ventral hypohyal of *O. kiabii* has three small processes versus two processes in *O. kermanshahensis*, *O. persa* and *O. bergianus* (Fig. 15).

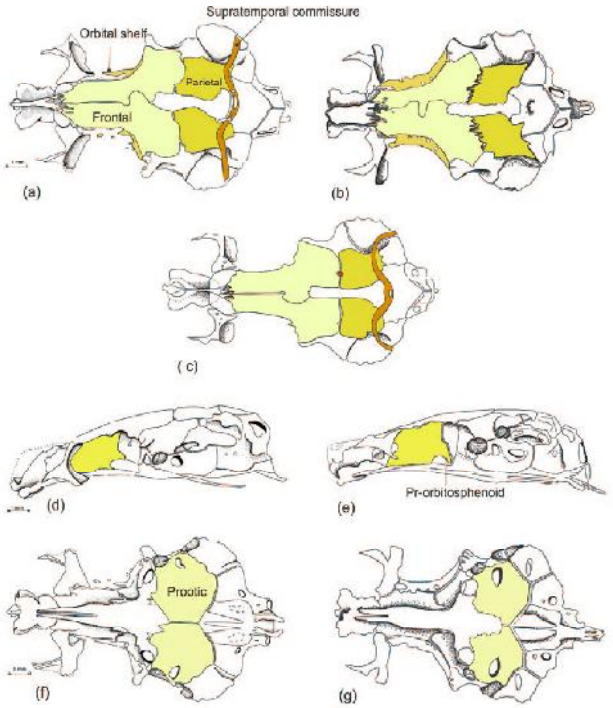

Fig 12. (a) Dorsal, (d) lateral and (f) ventral views the neurocranium of *O. kermanshahensis*; (b) dorsal and (g) ventral views the neurocranium of *O. kiabii*; (c) dorsal and (e) lateral views of the neurocranium of *O. persa*

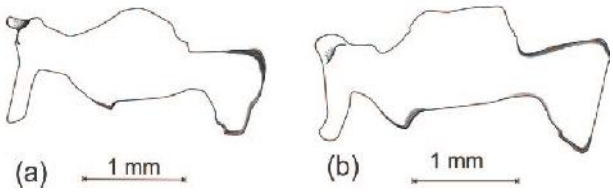

Fig 13. Maxilla of *O. kermanshahensis* (a) and *O. kiabii* (b)

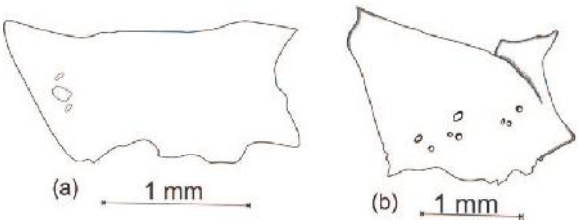

Fig 14. Metapterygoid of *Oxynoemacheilus kermanshahensis* (a) and *Oxynoemacheilus kiabii* (b)

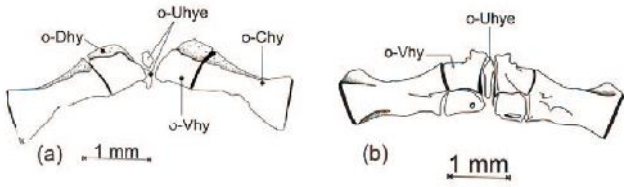

Fig 15. Hyoid of *Oxynoemacheilus kermanshahensis* (a) and of *Oxynoemacheilus kiabii* (b)

In *O. kermanshahensis*, the number of the hypural is five, whereas *O. bergianus* has six hypurals (Fig. 16). In *O. bergianus*, the vertebrae have been densely placed and the angle between the neural and hemal spines is smaller than that of other three *Oxynoemacheilus* species. In addition, the processes of the neural and hemal arch in *O. bergianus* are more developed. *O. kermanshahensis* has most number of the vertebrae (39-40) and least number of the branched ray ($6_{1/2}$-$7_{1/2}$) in the dorsal fin which can be a proper identification key to distinct *O. kermanshahensis*. One of the important structures for distinction of loach species is bony capsule of the swim bladder (Prokofiev, 2009, 2010). This bony capsule in *O. kermanshahensis*, *O. persa* and *O. bergianus* is rectangular, whereas it is round with smaller pores in *O. kiabii* (Fig. 17). In lateral plan of the capsule, there are two openings and the posterior one is larger in *O. kiabii*, whereas in other species, these two openings are almost similar in size (Fig. 17).

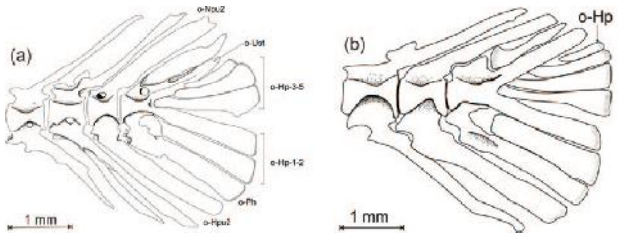

Fig 16. Caudal skeleton of *Oxynoemacheilus kermanshahensis* (a) and *Oxynoemacheilus bergianus* (b)

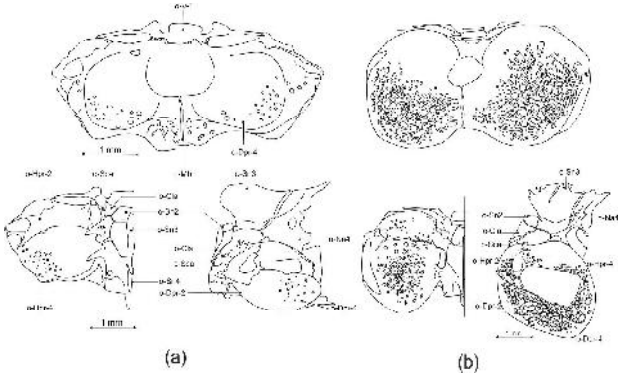

Fig 17. Weberian apparatus of *Oxynoemacheilus kermanshahensis* (a) and *Oxynoemacheilus kiabii* (b)

Based on the results, the connection pattern of the frontal and parietal, presence of a supratemporal commissure and orbital shelf, connection pattern of two prootics, possessing a maxilla with convex margin, having the more vertebrae, bearing the least number of the branched ray in the dorsal fin, presence of the five hypurals, possessing fine and thin neural and hemal spines and the shape of swim bladder capsule can be offered as osteological characters to distinct *O. kermanshahensis* from the other three *Oxynoemacheilus* species.

Sažetak

DESKRIPTIVNAOSTEOLOGIJA *Oxynoemacheilus kermanshahensis* (BĂNĂRESCU AND NALBANT, 1966) (CYPRINIFORMES, NEMACHEILIDAE)

Oxynoemacheilus kermanshahensis je endemska vrsta iz obitelji Nemacheilidae iz rijeke Karkheh koja pripada slivu rijeke Tigris. Ovim istraživanjem se prikazuju detaljne osteološke karakteristike ove vrste, uspoređujući je s drugim endemskim vrstama roda *Oxynoemacheilus* iz otvorenih voda Irana: *O. kiabii*, *O. persa* i *O. bergianus*. Za ovu svrhu osam primjeraka *O. kermanshaensis* je skupljeno, očišćeno i bojano za osteološka ispitivanja te je potom dat detaljan opis njihove skeletne strukture. Rezultati su pokazali da se *O. kermanshahensis* može razlikovati od ostale tri vrste preko veze frontalnog i parijetalnog dijela neurokranijuma, prisutnosti supratemporalnih usana kao i orbitalnog pojasa, vezom od dva *prootica*, posjedovanjem čeljusti s konveksnom marginom te više kralježaka i najmanjeg broja mekih žbica u dorzalnoj peraji, prisutnosti pet hipurala, posjedovanjem fine i tanke živčane i hemalne košćice te oblikom capsule plivajućeg mjehura.

Ključne riječi: vijuni, kosti, slatkovodne ribe, taksonomija

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