

CHAPTER 2

Taxonomy of Stone Loaches of The Genus *Mustura* Kottelat, 2018 (Teleostei: Nemacheilidae) From the Brahmaputra and Barak River Basins, Northeast India – A Mini Review

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Abstract

The genus *Mustura* was first erected by Kottelat (2018) with the type species as *Mustura celata*. Currently, there are 11 species of *Mustura* distributed in the river basins of northeast India, of which, six species, viz., *M. daral*, *M. dikrongensis*, *M. harkishorei*, *M. subhashi*, *M. tuivaiensis* and *M. walongensis* are endemic to the Brahmaputra and Barak River basins. Prior to erection of the genus *Mustura*, few members were originally described as belonging to the nemacheilid genus '*Physoschistura*'. Based on morphology and anatomy, Kottelat (2018) revised their statuses and placed, with caution, to the genus

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Mustura. In the present review, the taxonomic identities and differential diagnosis of each of these species are provided. Additional notes on the existing taxonomic ambiguities and the generic placement of a few members of *Mustura* are also reviewed.

Keywords: Taxonomy, Freshwater fish, Stone loach, *Mustura*, Northeast India

Introduction

Stone loaches are small to medium-sized, bottom-dwelling freshwater fishes belonging to the family Nemacheilidae (Kottelat, 1990, 2012, 2018). These fishes typically inhabit fast-flowing stretches of rivers and streams typically with a rocky substrate in hilly areas, with few exceptions residing in large rivers (Kottelat, 1990, 2012, 2017a–f, 2018). Currently, there are 49 valid genera of stone loaches with some 837 valid species distributed throughout Eurasia and Ethiopia (Fricke *et al.*, 2024).

Among the stone loaches, the genus *Mustura* was first erected by Kottelat (2018) with *M. celata* as the type species. Presently, there are 11 species of *Mustura* distributed in the river basins of northeast India, viz., *M. chhimtuipuiensis*, *M. chindwinensis*, *M. daral*, *M. dikrongensis*, *M. harkishorei*, *M. prashadi*, *M. subhashi*, *M. taretensis*, *M. tigrina*, *M. tuivaiensis* and *M. walongensis*, respectively (Chinglemba *et al.*, 2021; Choudhury *et al.*, 2021; Rameshori *et al.*, 2022). Prior to erection of the genus *Mustura*, few members were originally described as belonging to the nemacheilid genus '*Physoschistura*'. Based on morphology and anatomy, Kottelat (2018) revised their statuses and placed, with caution, to the genus *Mustura*. Among these, six species, viz., *M. daral*, *M. dikrongensis*, *M. harkishorei*, *M. subhashi*, *M. tuivaiensis* and *M. walongensis* were described from the Brahmaputra and Barak River basins. Almost all members of *Mustura* have a narrow range of distribution, i.e., they are strictly restricted to a single river and its tributaries. In the present context, several unexplored deep, forest areas of the northeastern region of India still demand exploratory surveys and, positively, await discovery of new species including those belonging to this genus.

Generic diagnosis. The genus *Mustura* can be diagnosed in the presence of a upwardly-curved pectoral fin on males that expands laterally due to a thick first branched ray being wider than the following fin rays, the ray branching only once and lacks an intermembrane in between except at the tip; proximal halves of pectoral-fin branched rays with wide, thick unculiferous pads, bearing small to medium conical tubercles on the dorsal surface (Fig. 1a); an air bladder is enclosed within two ossified capsules, positioned laterally and associated with each other another by a manubrium, and a free, small posterior chamber (may be absent in some species) (Fig. 1b); an acutely-arched mouth with a lower lip having wide median interruption and each half is wide, fleshy, forming “cushion-like” pads, partially free from the lower jaw and linked to the isthmus by thin frenum (Fig. 1c); suborbital flap of males always having small tubercles on its postero-ventral edge (Fig. 1d); a suborbital slit may sometimes be present on females at a position corresponding to the posterior portion of the suborbital flap on males (Kottelat, 2018).

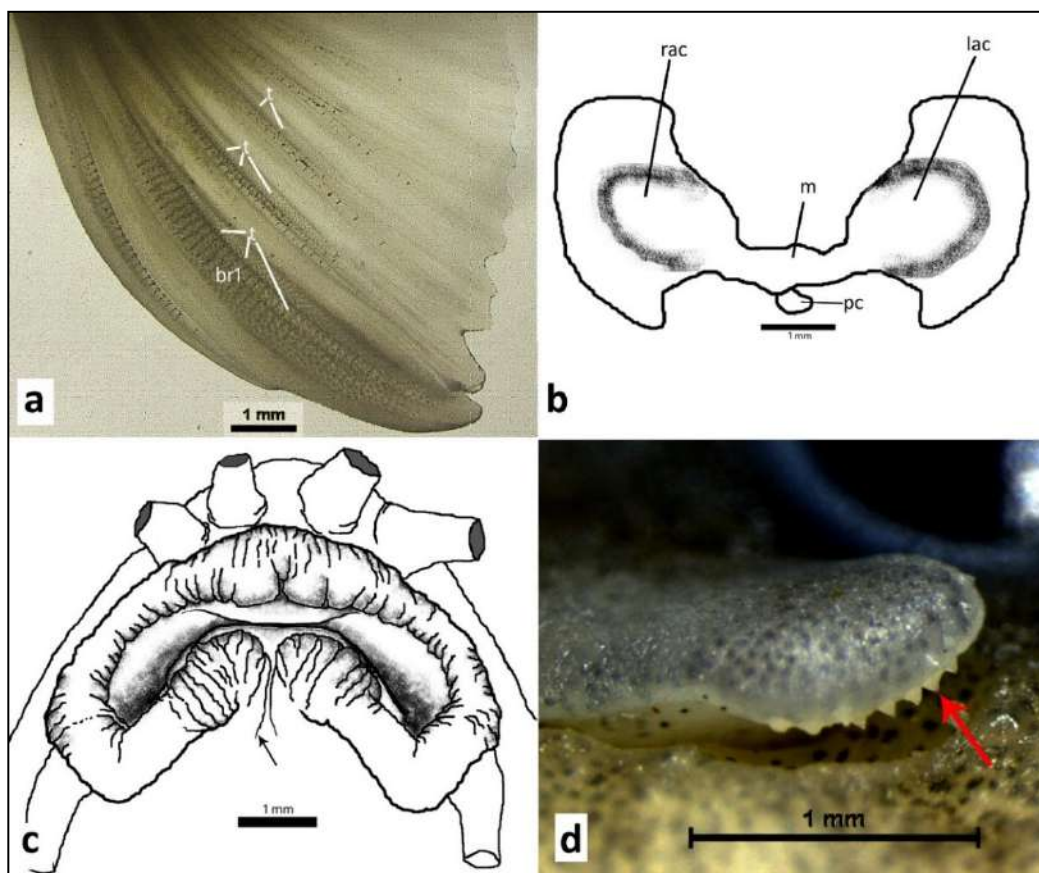


Fig. 1. Diagnostic features of the genus *Mustura* - a. Dorsal view of a male's left pectoral fin showing the thick branched ray I (br1) with tubercles (t); b. Illustration showing structure of a swim bladder [rac & lac: right and left bony anterior chambers, pc: free posterior chamber, m: manubrium]; c. Illustration showing the features of mouth and lips [arrow indicates frenum connecting posterior end of lower lip]; d. a sub-orbital flap of male with tubercles (red arrow) on posterior extremity.

Field diagnosis. Species of *Mustura* can be identified in field primarily based on their colouration. Typically, the colour pattern consists of bars, blotches and/or saddles in combination, with bars and blotches in lateral view on flank alternating with saddles on the dorsum (Fig. 2a), or, rarely, the bars from flank continue as saddles on dorsum to meet the contralaterals (Fig. 2b). Moreover, the colour pattern on caudal-fin base is an important diagnostic tool in field, which usually consists of a thin bar with the upper half aligned in an oblique fashion and the lower half sometimes resembling an elongate blotch (Fig. 2c).

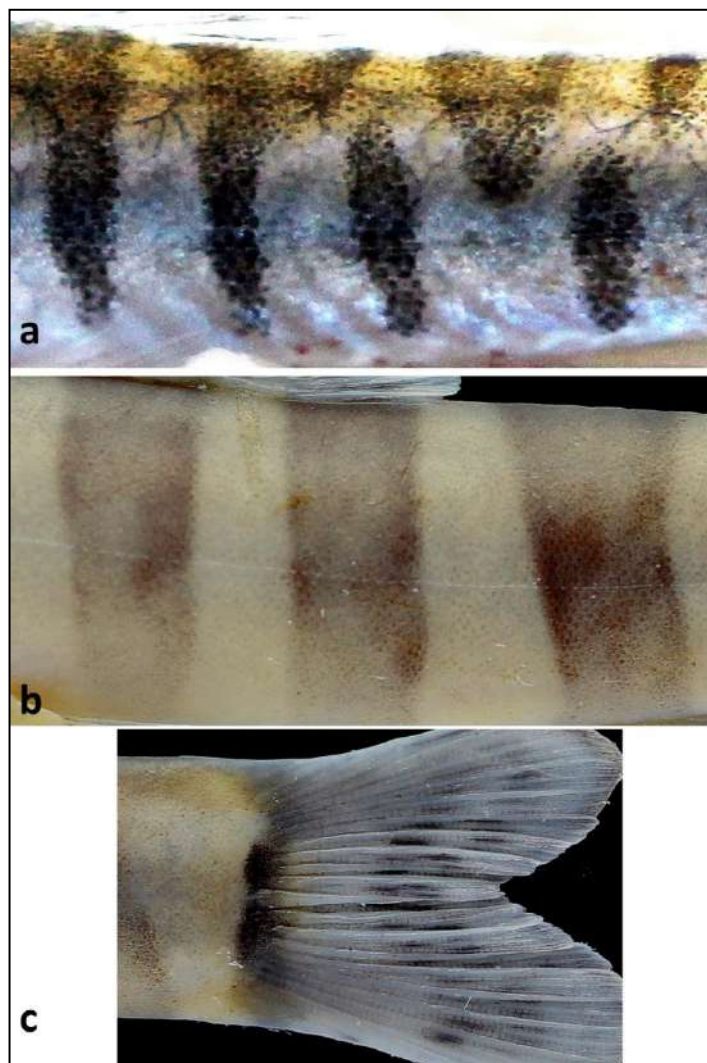


Fig. 2. Colour pattern of *Mustura* sp. - **a.** Bars alternating with saddles on dorsum; **b.** Bars continuous with saddles on dorsum; **c.** Caudal bar pattern.

Methodology

The present review is based on ichthyological explorations carried out in river systems of the Brahmaputra and Barak River basins from October 2015 to November 2022. All specimens were collected from local fishermen as by-catch, and hence, did not require any special permissions from authorities. Experimental fishing were carried out using locally fabricated fishing gears viz., caste nets, scoop nets and bamboo traps. Before fixing the specimens in 10% formalin, they were euthanized in a solution of clove oil following Davis *et al.* (2015). All collected materials are deposited in the Gauhati University Museum of Fishes (GUMF), Assam.

For differential diagnosis of each species, the measurements of body parts were taken on the left-hand side of specimens using a slide calliper. Procedure for the measurements of head and body parts as well as the counts of fin rays follow Kottelat (1990). Descriptions of the lips and mouth characters and shape of the air bladder follow Kottelat (2018). The identity of species was confirmed following the original descriptions of the species (Lokeshwor & Vishwanath, 2012; Lokeshwor *et al.*, 2012; Das & Darshan, 2016; Tamang & Sinha, 2016; Choudhury *et al.*, 2021; Rameshori *et al.*, 2022).

Additionally, type specimens were physically examined in registered national and state museums, viz., Zoological Survey of India's Arunachal Pradesh Regional Station of (ZSI-APRC), Itanagar, Manipur University Museum of Fishes (MUMF), Imphal, and Rajiv Gandhi University Museum of Fishes (RGUMF), Itanagar, respectively. To further review the existing status of species, additional notes were taken from Kottelat (2018) and Chinglemba *et al.* (2021).

Systematic Index and Species Distribution

Phylum: Chordata
 Class: Osteichthys
 Subclass: Actinopterygii
 Series: Otophysi
 Subseries: Cypriniphysi
 Order: Cypriniformes
 Superfamily: Cobitoidea
 Family: Nemacheilidae

Genus: *Mustura* Kottelat, 2018

Taxa	Brahmaputra basin	Barak basin
<i>Mustura daral</i> Rameshori <i>et al.</i> , 2022	+	-
<i>M. dikrongensis</i> (Lokeshwor & Vishwanath, 2012)	+	-
<i>M. subhashi</i> Choudhury <i>et al.</i> , 2021	+	-
<i>M. tuivaiensis</i> (Lokeshwor <i>et al.</i> , 2012)	-	+
<i>M. walongensis</i> (Tamang & Sinha, 2016)	+	-
<i>M. harkishorei</i> (Das & Darshan, 2016)	+	-

Species Account

***Mustura daral* Rameshori, Chinglemba, Darshan & Vishwanath, 2022**

(Plate 1: Fig. a)

Mustura daral Rameshori *et al.* 2022: 286 (type locality: Siang River at Pasighat, Brahmaputra drainage, Arunachal Pradesh, India)

Material examined. GUMF 311/6, six specimens, 41.8–71.1 mm SL; India: Assam: Dhansiri (north) River near Indo-Bhutan border at Bhairabkundo (Brahmaputra basin)

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Diagnosis. A species of *Mustura* that is distinguished from other northeast Indian congeners in having dark-brown saddles descending on flank to from 9–10 regular bars; 10–11 branched pectoral-fin rays; caudal bar comprising of two dissociated black blotches; complete lateral line; moderately arched mouth with halves of lower lips separated widely, each half forming cushion-like pads medially; males with thick branched ray 1 of pectoral fin, tubercles on posterior flanges of each ray.

Remarks. The largest species among its congeners of the Brahmaputra and Barak drainages with a maximum recorded size length of 71.1 mm SL. The species is most likely to occur in adjacent river systems apart from its type locality along the Arunachal Himalayas.

***Mustura dikrongensis* (Lokeshwor & Vishwanath, 2012)**

(Plate 1: Fig. b)

Physoschistura dikrongensis Lokeshwor & Vishwanath 2012: 250 (type locality: Dikrong River at Doimukh, Brahmaputra drainage, Arunachal Pradesh, India)

Mustura dikrongensis: Kottelat 2018: 4 (generic revision and tentative placement). - Choudhury *et al.* 2021: 9 (as valid)

Material Examined. MUMF 11091/3, holotype, 44.2 mm SL; 11090/2, 40.0–46.0 mm SL, two specimens; India: Arunachal Pradesh: Papum Pare District: Dikrong River near Doimukh (Brahmaputra basin). GUMF 272/4, four specimens, 40.9–48.0 mm SL; India: Assam: Udalguri District: Dhansiri (north) north near Indo-Bhutan border at Bhairabkundo (Brahmaputra basin). GUMF 275/5, 5 specimens, 38.3–48.5 mm SL; India: Arunachal Pradesh: West Kameng District: Kameng River between Tippri and Bhalukpong (Brahmaputra basin). GUMF 278/2, 2 specimens, 37.8–39.7 mm SL; India: Arunachal Pradesh: East Kameng District: Dikal River near Upper Dikalmukh (Brahmaputra basin)

Diagnosis. A species of *Mustura* that is distinguished from other northeast Indian congeners in having 11–15 irregular dark brown bars, alternating with saddles on dorsum, sometimes continuing on dorsum to meet contralaterals; complete thin caudal bar; a rigid, upwardly curved pectoral fin with its first branched ray about 2½–3 times wider than the adjacent rays, prominent conical tubercles on and along the posterior and anterior flanges of branched rays 1; proximal 2/3rd of the posterior margin of the following branched rays; postero-ventral edge of the suborbital flap on males; suborbital slit on females at a position corresponding to the posterior margin of flap on males; variable length of lateral line, mostly incomplete, reaching beyond pelvic fin base, sometimes complete.

Remarks. The species presents high variability in the extension of the lateral line, which usually extends up to a point slightly beyond the base of pelvic fin or may reach a vertical line through the origin of anal fin origin, or rarely may be completely reaching the hypural flexure. A prominent but small posterior chamber of air bladder is present. Besides its type locality, the species is abundantly found along the foothills of Arunachal and Bhutan Himalayas in Assam.

***Mustura subhashi* Choudhury, Das, Bharali, Sarma, Tyagi, Lal & Sarma, 2021**

(Plate 1: Fig. c)

Mustura subhashi Choudhury *et al.* 2021: 451 (type locality: Dikal River (Brahmaputra basin) at Upper Dikalmukh, Arunachal Pradesh, India)

Material Examined. NEMMSUB/NBFGR, 69.2 mm SL, holotype; India: Arunachal Pradesh: East Kameng District: unnamed tributary of the Dikal River (Brahmaputra basin) near Upper Dikalmukh; ZSI 8787, 52.9–57.6 mm SL, two specimens; data same as holotype.

Diagnosis. A species of *Mustura* that is distinguished from all other northeast Indian congeners in having 14–23 dark-greyish black or dark brown irregular bars on a greyish to pale beige body; bars below the dorsal fin thin, weakly-contrasted and numerous, wider than the interspaces, uniting towards the dorso-lateral one-third (or midway) on flank to form thicker, further coalescing further at dorso-lateral one-fifth to continue on dorsum and meet the contralaterals from the opposite; all pre-dorsal bars may sometimes fuse together to become greyish black anterior half of body with inconspicuous bars; saddles appearing as ‘X-shaped’ on dorsum; sub-dorsal bars displaying similar condition but slightly wider than the pre-dorsals, continue dorsally to meet the contralaterals as 2–3 saddles; post-dorsal bars most thicker on comparing to the previous bars, with narrow interspaces, prominent and sharply-contrasted, continuing dorsally to form 3–4 saddles; bars posterior to the origin of anal fin form complete rings; a caudal bar along the lateral midline that most often appears as a vertically-elongate blotch; 9 + 7–8 caudal-fin branched rays; a caudal peduncle as deep as 12.0–13.8% SL.

Remarks. A comparatively large-sized species among its congeners of the Brahmaputra and Barak basins that attains a maximum length of 69.2 mm SL.

***Mustura tuivaiensis* (Lokeshwor, Vishwanath & Shanta, 2012)**

(Plate 1: Fig. d)

Physoschistura tuivaiensis Lokeshwor *et al.* 2012: 6 (type locality: Tuivai River (Barak basin) at Likhailok, Churachandpur district, Manipur, India)

Mustura tuivaiensis: Kottelat 2018: 4 (generic revision and placement)

Material Examined. MUMF 5089, holotype, 46 mm SL; MUMF 5082–5086, 2 paratypes, 40.7–45 mm SL; India: Manipur: Churachandpur District: Tuivai River at Likhailok, Barak basin.

Diagnosis. A species of *Mustura* that can be distinguished from other northeast Indian congeners in having 12–14 dark olivaceous oval to elongate blotches on flank alternating with saddles; colour on caudal-fin base comprising of an upper oblique blotch and a thin bar below; 2–3 rows of irregular black spots on caudal fin; acutely arched mouth, about 1.5–2.2 times broader than long; each half of lower lip forming broad triangular cushion-like pads, widely separated medially; complete lateral line.

Remarks. The generic placement of the species as a *Mustura* is correct and valid (refer below).

***Mustura walongensis* (Tamang & Sinha, 2016)**

(Plate 1: Fig. e)

Physoschistura walongensis Tamang & Sinha 2016: 281 (type locality: Lohit River at Walong (Brahmaputra basin), Arunachal Pradesh, India)

Mustura walongensis: Kottelat 2018: 4 (generic revision and tentative placement)

Material Examined. ZSI/APRC 1190, 50.5 mm SL, holotype, male; ZSI/APRC 1268, 44.5 mm SL, paratype, male; ZSI/APRC 1269/12, paratypes, four specimens, 45.0–56.5 mm SL; India: Arunachal Pradesh: Anjaw District: Lohit River at Walong, Brahmaputra basin.

Diagnosis. A species of *Mustura* that can be distinguished from other northeast Indian congeners in having 11–18 irregular, greyish-black bars that coalesce on dorso-lateral half, and continues to meet saddles on dorsum and contralaterals thereafter; saddles as irregular blotches on pre-dorsal area; prominent, W-shaped caudal bar; acutely-arched mouth, each half of lower lip separated by narrow median incision; incomplete lateral line reaching point up to adpressed anal fin.

Remarks. With the presence of an acutely-arched mouth, with each half of the lower lip bearing thick, medial “cushion-like” pads and attached to the isthmus via frenum, a thick and modified branched ray I of the pectoral fin and presence of tubercles along posterior flanges of first to fifth branched rays, the species is confirmed as a *Mustura*.

? *Mustura harkishorei* (Das & Darshan, 2017)

(Plate 1: Fig. f)

Physoschistura harkishorei Das & Darshan 2017: 404 (type locality: Dibang River at Lower Dibang valley (Brahmaputra basin), Arunachal Pradesh, India)

Mustura harkishorei: Kottelat 2018: 4 (generic revision and tentative placement)

Material Examined. RGUMF 290, holotype, 41.1 mm SL; India: Arunachal Pradesh: Dibang and Lohit rivers, Brahmaputra basin; RGUMF 291, paratype, 53 mm SL; data same as holotype.

Diagnosis. A species that can be distinguished from other northeast Indian congeners in having the branched ray 2 of pectoral fin as a long filamentous extension reaching up to pelvic-fin base; 9–10 brownish oval to vertically-elongate blotches on flank, alternating with saddles above; short, broad caudal bar; complete lateral line; 7+8 branched caudal rays.

Remarks. As the species exhibits high similarity with the sympatric ‘*Nemacheilus*’ *corica*, it is kept as a “species inquirendum” (with a ‘?’ mark put ahead). An integrative taxonomic approach to resolve this ambiguity is warranted pending collection of fresh topotypic materials of the species and ‘*N.*’ *corica*.

Additional Taxonomic Notes on Generic Placements and Species Identities

Among the six species of *Mustura* as diagnosed above, three species were tentatively-placed in this genus, viz., *M. dikrongensis*, *M. harkishorei* and *M. walongensis*, (refer to Kottelat, 2018). In their original descriptions, *M. dikrongensis* and *M. walongensis*, both, neither have any information on the presence of any specific modifications of the pectoral fin nor the nature of the sub-orbital flap on males and data on

shape of the air bladder (Kottelat, 2018). Further, a revision on the placement of *M. harkishorei* [as a *Mustura*] was recommended by Kottelat (2018) by restudying the type specimens. These confusions were, however, clarified and resolved by Choudhury *et al.* (2021) upon re-examination of the registered type specimens as well as collecting freshly materials from the field.

M. dikrongensis shares with *Mustura* the rigid pectoral fin having the modified first branched ray and tubercles on the dorsal surface and posterior flanges of the branched ray 1 as well as on the following rays, and on the postero-lateral margin of the suborbital flap; and the presence of a suborbital slit on females at a position corresponding to the posterior margin of the flap on males (Fig. 3). Similar observations were also made by Chinglemba *et al.* (2021).

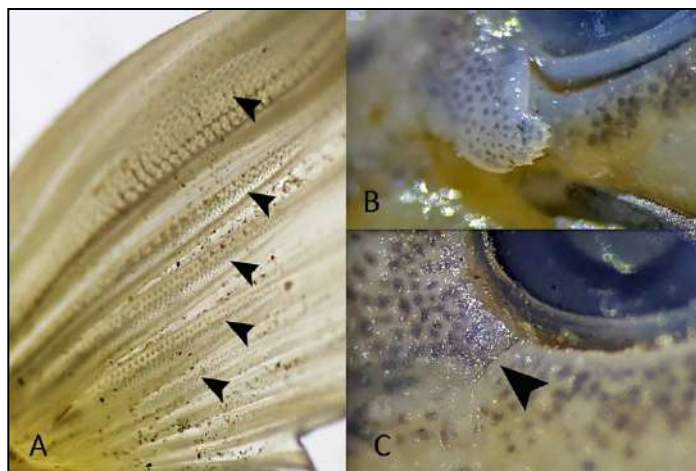


Fig. 3. Characteristic features of *Mustura dikrongensis* — A. Dorsal view of a male's pectoral fin showing tubercles (arrowheads) on thickened first branched ray and posterior flanges of following branched rays; B. Suborbital flap of male; C. Suborbital slit of female (arrowhead).

Additionally, Choudhury *et al.* (2021) noted that the original description of *Mustura harkishorei* has close resemblance with the characters of '*Nemacheilus*'*corica*, which include — (A) 8–10 lateral blotches on flank, more often alternating with 8–13 saddles on dorsum, rarely merging; (B) the second branch of the branched ray 2 elongated and extending nearly to reach the origin of pelvic fin; (C) the modified and thickened first branched ray of the pectoral fin; (D) the lower lip with both halves well separated, each half forming 'cushion-like' pads medially; (E) the air bladder comprising of two anterior chambers connected by a manubrium and a small, free posterior chamber in between; (F) dorsal fin with iii–iv, 8½ rays; (G) 9 + 8 = 17 total caudal-fin rays or (8 + 7 branched)); and (H) the intestine bent behind the stomach. Further, the dorsal surface and posterior margin of the branched ray 1, the posterior flanges of the branched rays 2–5, the postero-ventral margin of the suborbital flap, and the nape and opercles of well-preserved males bear prominent tubercles. The distribution of *M. harkishorei* overlaps with '*N.*' *corica* (Choudhury *et al.*, 2021). Apparently, Das and Darshan (2016) were not aware of these facts, for which they do not include a character-by-character comparison of both the species. For this reason, *M.*

harkishorei is placed tentatively in the synonymy of '*N.*' *corica*, and the name is headed with a question mark (as '? *Mustura harkishorei*').

Although Kottelat (2018) suggested *Mustura walongensis* to be less related the genus *Mustura* based on the more elongated body with a lesser-forked nature of the caudal fin, re-examination of the type materials clearly revealed that the generic placement of the species as under *Mustura* is accurate (Fig. 4). Likewise, the generic placement of *Mustura tuivaiensis* holds true after physical verification of the type specimens (Fig. 5).

Conclusion

All the six species of *Mustura* discussed herein have not yet been assessed by the IUCN (ICUN, 2024). This is a matter of concern as all members of *Mustura* are stenotopic, i.e., they can only tolerate a narrow range of habitat attributes. Through personal observation, these species are exclusive residents of hill streams with clear water having dissolved oxygen (D.O.) not less than 7 mg/L, pH ~7.4 (approx.) and water temperature ~22–26 °C. Although no threats have so far been recorded in the areas of their occurrence, studies are demanding on their population, biology, ecology and threats so that their assessment can be carried with immediate effect.

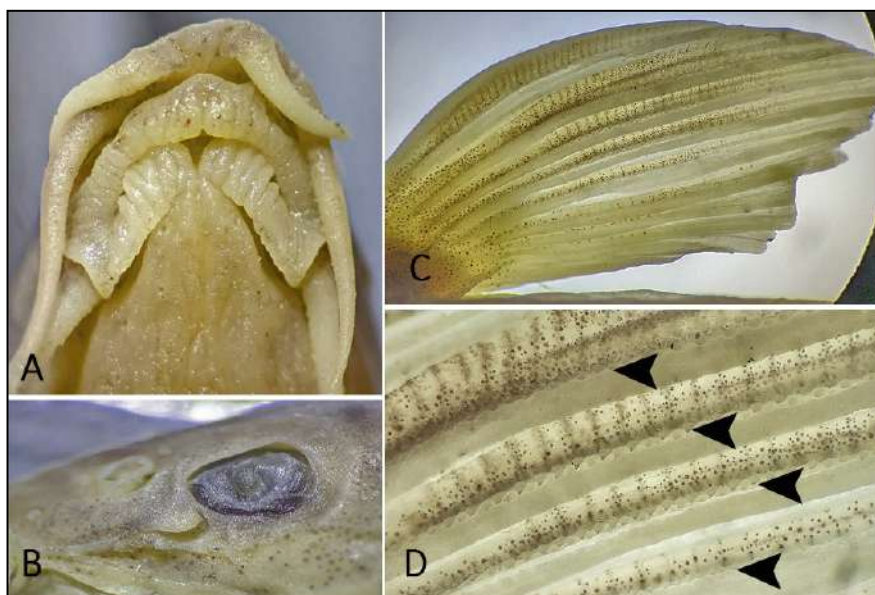


Fig. 4. Characteristic features of *Mustura walongensis* — **A.** Arched mouth; **B.** suborbital flap on male; **C. & D.** Right pectoral fin of a male individual showing first branched ray and tubercles on posterior flanges of the fin rays.

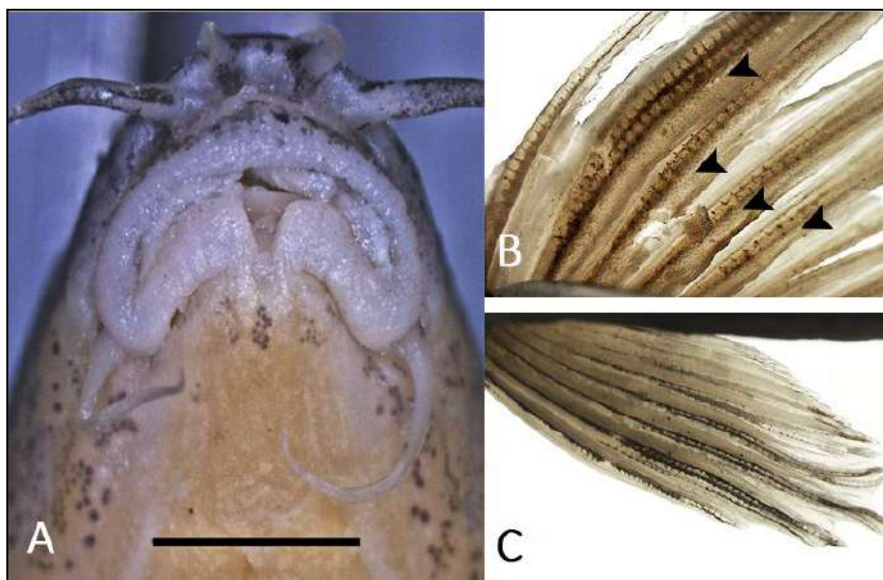


Fig. 5. Characteristic features of *Mustura tuivaiensis* — **A.** Arched mouth; **B.** Dorsal view of the right pectoral fin of a male individual showing the thick branched ray 1 and tubercles on posterior flanges of the fin rays; **C.** pectoral fin of female without any modification.

The genus *Mustura* demands an integrative taxonomic approach of study, viz., morphology, anatomy, biology, molecular biology, ecology and karyology. As there are several hidden species complexes within a population, it often becomes difficult for a taxonomist to distinguish two cryptic species in sympatry. Known to discolour soon after collection (part as post mortem change and/or part of preservation), incorporation of concepts of photogrammetry and TRUSS in systematic studies, additionally, will aid in better species identification and diagnosis.

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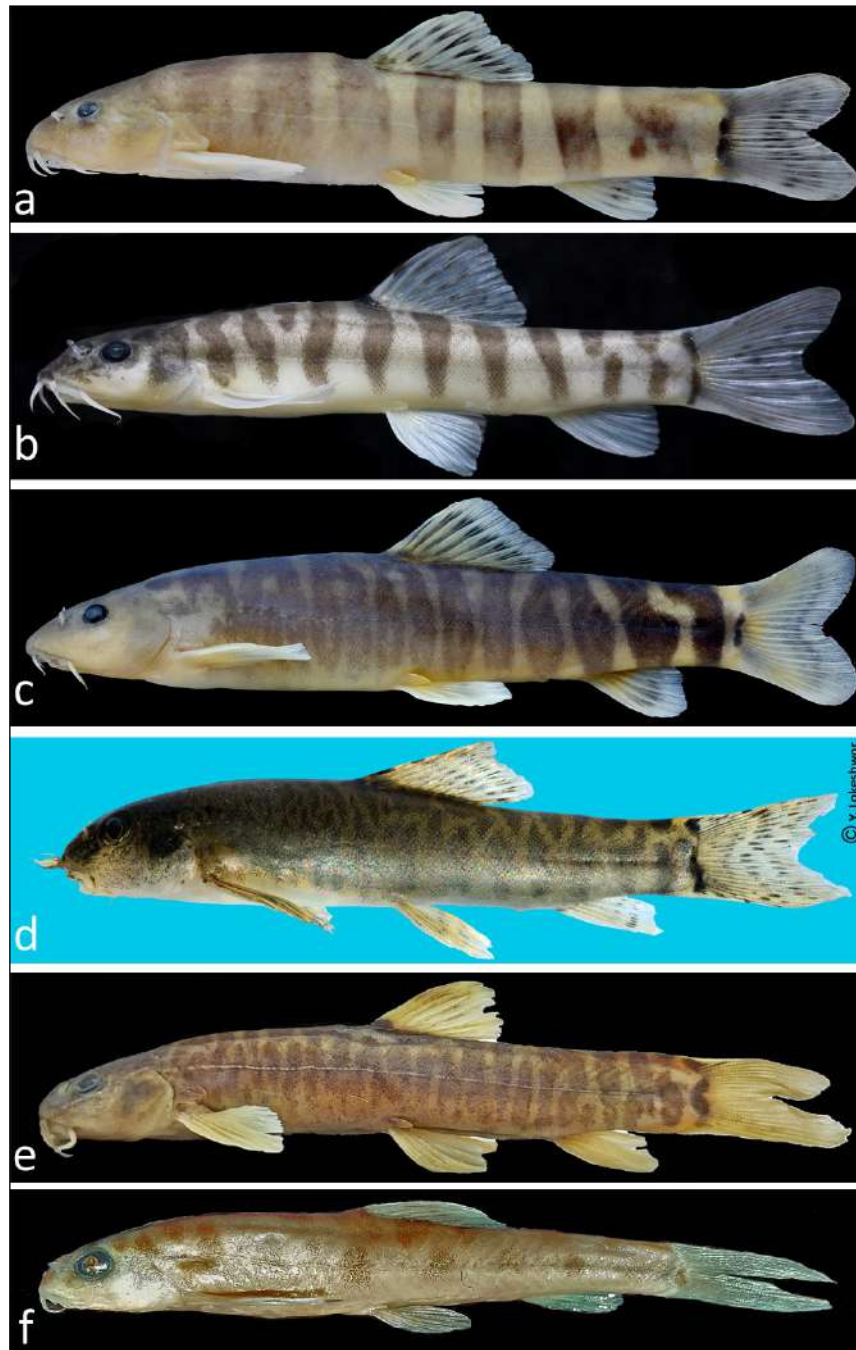


PLATE 1. Species of *Mustura* from the Brahmaputra and Barak River basins — **a.** *Mustura daral*, GUMF 311/6, 66.2 mm SL; **b.** *Mustura dikrongensis*, GUMF 272/4, 42.9 mm SL; **c.** *Mustura subhashi*, NEMMSUB/NBFR, 69.2 mm SL; **d.** *Mustura tuivaiensis*, MUMF 5089, 46 mm SL; **e.** *Mustura walongensis*, ZSI/APRC 1269/12, 56.5 mm SL; **f.** ? *Mustura harkishorei*, RGUMF 290, 41.1 mm SL.