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Comparative osteology of caudal skeleton of some cyprinids from north-east, India

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Abstract
The comparative osteology of caudal skeleton in nine species of *Labeo, Bangana* and *Neolisochilus* was studied to find out inter-specific as well as intergeneric variations. In all the studied species last three vertebrae is participating in the formation of caudal skeleton. The morphology of rudimentary neural arch exhibited variation in all the species which is considered to be a species specific character. The long uroneural forms a gap in *Neolisochilus hexasticus* while such gap is absent in rest of species. The distal broad end of the parhypural supported three branched lepidotrichs in *Bangana devdevi, Labeo gonius, Labeo bata, Labeo calbasu, Labeo boga* and *Neolisochilus hexagonolepis* but four branched lepidotrichs in *B. dero, N. hexasticus* and *N. stracheyi*. The hypural diastema formed between upper and lower hypural lobes is comparatively wider in *B. dero, B. devdevi, N. hexasticus, N. hexagonolepis, L. gonius, L. bata* and *L. calbasu* while narrow in *N. stracheyi* and *L. boga.* The hypural foramen (HF) between proximal regions of the HYPI and HYPII is present in all the studied species. The neural spine arising from second preural vertebrae is incompletely divided in *B. dero* and *N. stracheyi*; completely divided in *L. gonius* but undivided in rest of the species. Hence based on the present findings envisaged that caudal skeleton exhibited species specific variation in respect width of parhypural and hypural, size of epural, bifurcation of neural spine and hypural diastema.

Keywords: Osteology, Diastema, Hypural, Lepidotrichs

Introduction
The caudal skeleton played an essential role in systematics of teleost fish, particularly depicting phylogenetic information at different taxonomic level [15, 5]. Hence, a number of researchers [33, 24 & 11] used it in taxonomic study as well as in phylogenetic study [32, 4, 2, 6]. The importance of osteological study in phylogeny is of great significance [8, 28] if illustrated properly. The character of caudal skeleton has been also used to divide the cyprinids fishes into different groups [14] as well as in other family [13]. Proper understanding and knowledge on systematics and phylogeny of commercially important group is necessary to know the intraspecific [1, 30] as well as intergeneric relationship [16]. The taxonomic validation of genus *Puntius* based on morphology characters is also supported by osteological tools [26] to construct three new genera signifies the importance of osteological analysis in taxonomic study.
It was noted that there is great confusion in taxonomically describing the fishes of genus *Labeo Bangana* and *Neolisochielus* [27, 12, 22, 20]. Therefore, to solve the taxonomical ambiguity caudal skeleton of nine species belonging to the above mentioned three genera are studied.

Materials and Methods
To compare the osteological variations based on caudal skeleton between the nine species of fish belonging to family Cyprinidae from three different genera is undertaken. The studied species included two species of genus *Bangana* (*Bangana dero* and *B. devdevi*), four species of genus *Labeo* (*Labeo bata, L. gonius, L. calbasu* and *L. boga*) and three species belonging to genus *Neolissochilus* (*N. hexasticus, N. hexagonolepis* and *N. stracheyi*). Fresh samples of all the studied species are collected from their respective distributional ranges by employing different gears such as gill net, cast net and traps and samples are fixed in 10% formalin and brought to the laboratory for further identification and osteological study. For osteological study the specimens were cleared and stained by following Hollister [9] with some modifications.

Results and Discussion

The comparative osteology of studied species revealed certain differences in morphology and arrangement of caudal bones and as such exhibits inter-specific as well as intergeneric variations. The freshwater Cyprinid fishes of the genus *Labeo*, *Bangana and Neolissochilus* have general caudal plan. In all the studied species last three vertebrae is participating in the formation of caudal skeleton same as those found in genus *Puntius* [31, 10] where as in Cyprinidontiformes [5] and some Cyprinids [24] last four or five vertebrae supported the caudal skeleton. The caudal bone consists of paired uroneural (UNU), five unpaired free median hypurals (HYPI-HYP5), one unpaired Parhypural (PH) and single Epural (EPU) all of which are cartilaginous bones. The last caudal vertebra (or compound centrum) is modified into pleurostyle (PS) and is turned upward, along with the diural i.e. penultimate or the first preural (PU2) and the anti-penultimate or the second preural (PU3) of the axial skeleton provide caudal support. The pleurostyle (uroneural or urostyle) is laterally compressed bone projecting posterodorsally to from the terminal vertebrae, rest the paired uroneural. The rudimentary neural arch (RNA) (or Specialized Neural Process) is short bone with blunt and wide posterior part. The dorsal neural spine and ventral haemal spine originating from diural also provide support to the caudal lepidotrichs.

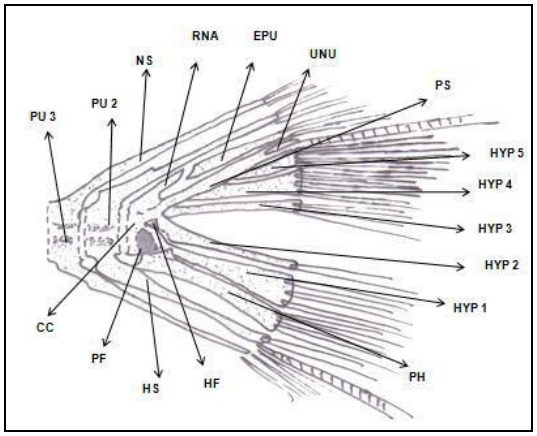
Epural is single rod shaped bone lies dorsal to the pleurostyle. Rojo [29] reported that this bone is remnant of neural spine of last vertebrae. Unlike all the examined Cyprinid fishes is having single epural, the caudal skeleton of eurypterygiian fishes consists of one to three epurals [19]. The length of this bone varies with respect to urostyle as small in *L. gonius, N. hexasticus* and *N. straychei* whereas relatively larger in *L. boga*. The distance between the distal end of the rudimentary neural arch (or uroneural 1) and the proximal end of the epural (i.e. epural distance) seems to vary in all the species as such coincide the view [10]. The bone is very much extended and reach very close to the posterior margin of rudimentary neural arch in *L. gonius and N. hexagonolepis* same as those reported in *Pethia sanjaymoluri* [18]. In *L. bata, L. boga, B. dero, B. devdevi and N. hexasticus* the anterior tip of bone reaches beyond the posterior margin of rudimentary neural arch, similar findings was reported in *Cyprinion kais* [24] while in *L. calbasu* and *N. straychei* it does not reach to the posterior margin of rudimentary neural arch. In all the studied species, it is found that anterior tip of this bone is narrow except in *N. straychei* where it has oval shaped anterior end. Due to the difference in length of rudimentary neural arch and epural, a gap exists in between this bone which is narrow in *L. bata, L. boga, B. dero and N. hexasticus* while it is much wider in *L. calbasu and N. straychei, L. gonius* and *B. devdevi.* The morphology of rudimentary neural arch is also varying in all the species which is considered to be a species specific character.

Uroneural are paired thin rod like bone rest over the posterior dorsal part of the pleurostyle. The long uroneural present between the branched and unbranched lepidotrichs forms a gap in *N. hexasticus* while such gap is absent in other species. In *Pethia sanjaymoluri* this paired bone was reported to be absent [18]. Similarly, while studying 12 species of genus *Puntius* from Manipur found that uroneural is present only in *P. jayarami, P. sarana* and *P. orphoides* while absent in all other studied species [31].

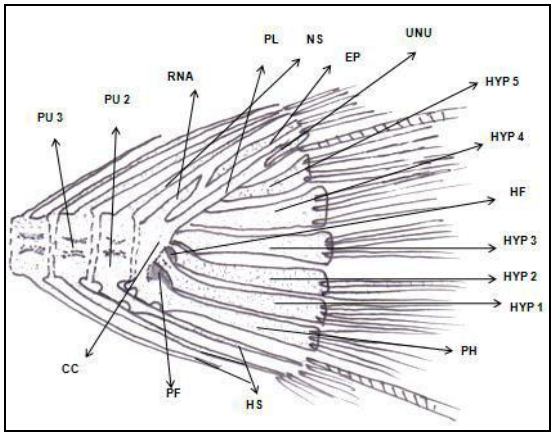
Parhypural is long and broad unpaired bone which is loosely articulated with ventral side of the pleurostyle. The distal broad end of the parhypural supported three branched lepidotrichs in *B. devdevi, L. gonius, L. bata, L. calbasu, L. boga* and *N. hexagonolepis.* However, in *B. dero, N. hexasticus* and *N. stracheyi* this bone supported four branched lepidotrichs. A parhypural foramen is present in all the studied species (except *N. hexasticus*) at the proximal region between the parhypural and the first hypural same as those found in *P. sarana* [10].

Hypurals are wide laterally compressed bone forming broad base for the attachment of branched lepidotrichs. There are series of 5 hypurals in all the presently studied species, same as those reported by other researcher [23] while it differs in other fishes as six hypurals [16, 31, 10, 11, 18] and seven hypurals [7, 34]. The variation in the number of hypurals was due to fusion or loss [35]. The last haemal spine is considered as parhypural and reported the presence of six hypurals in *Barbus cyri* [11]. The three hypurals are present on the upper lobe and two on the lower lobe of caudal fin. The narrow proximal end of the HYP I is firmly articulated the parhypural which is ventrally attached with the pleurostyle. The second hypurals (HYP II) directly articulate with the posterior end of the pleurostyle. While the HYP III, HYP IV and HYP V is loosely articulated with post ventral margin of pleurostyle. Unlike Cyprinids, it is reported that the fishes belonging to Cyprinidontiformes have upper and lower hypural plates fused (except Anablepidae) [5]. The arrangement of lepidotrichs and wideness of posterior basal part of hypural is species specific and all five hypurals supported ten to fifteen branched lepidotrichs. The hypural diastema [35] formed between upper and lower hypural lobes is comparatively wide in *B. dero, B. devdevi, N. hexasticus, N. hexagonolepis, L. gonius, L. bata* and, *L. calbasu* while it is narrow in *N. stracheyi* and *L. boga*. The hypural foramen (HF) between proximal regions of the first and second hypurals is present in all the studied species same as those reported in *P. sarana* [10]. The presence of less number of hypurals (5), epural (1) and caudal fin rays (19) in all the studied species are evolutionary advanced characters and as such follows the view of earlier workers [21, 25].

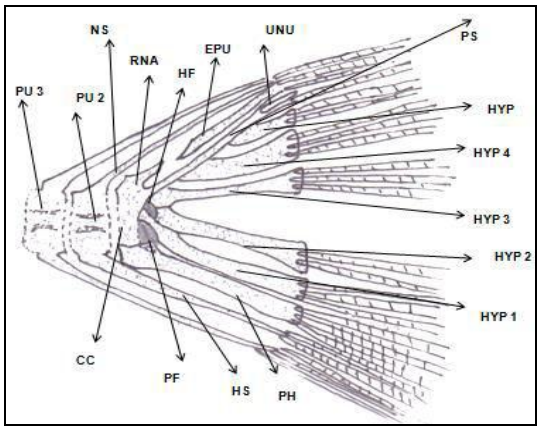
The neural and haemal spine arising from the diural is extended beyond to support the lepidotrichs. The neural spine arising from second preural vertebrae is incompletely divided in *B. dero* and *N. stracheyi* as in that of *Raiamas bola* [16], completely divided in *L. gonius* as in genus *Barilius* [16] and *Barbus* [11] and undivided in other species. Doubling of first and second neural spine is also reported in minnows [3] and only second neural spine in *P. sarana* [10]. The divided neural spine of second preural centra was considered as epural 1 and 2 and called it as remnants of neural arches; hence, reported presence of three epurals [21]. While describing *P. punctata* it was found that doubling of both neural and haemal spine of second preural centra is characteristic of female sexed fish [17]. However, the doubling of neural spine was reported as Cyprinid character [30] which is not found in agreement of present study. The caudal lepidotrichs are supported by neural and haemal spine of diural, an epural, pleurostyle, five hypurals and parhypural. The number of branched caudal lepidotrichs in all the studied species is 10+9 which is found to be same as those reported in other Cyprinid genus *Puntius* [31]. In some other Cyprinid fishes the number is found to be varying as 9+8 in *Pethia sanjaymoluri* [18] and 10+8 in *Puntius sarana* [10].



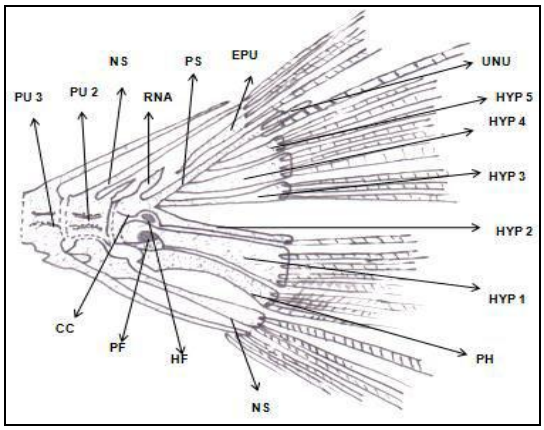
Labeo bata



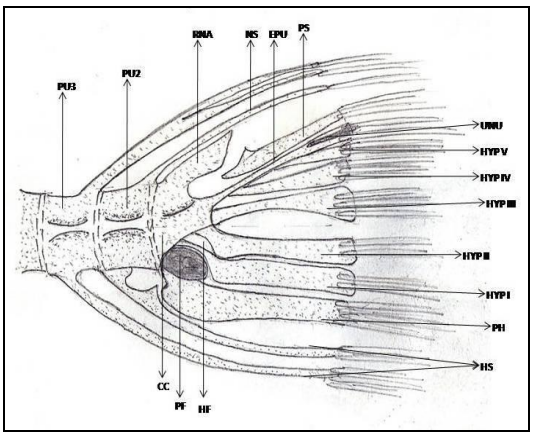
Labeo boga



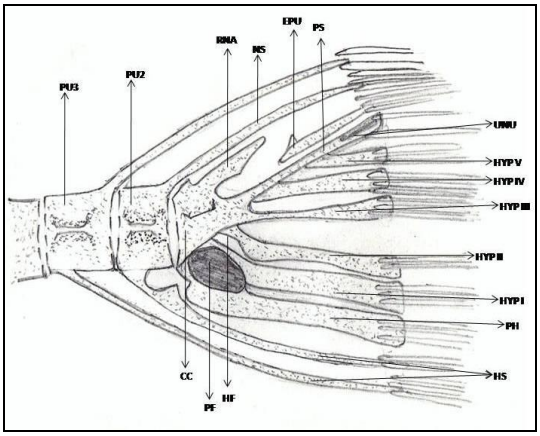
Labeo calbasu



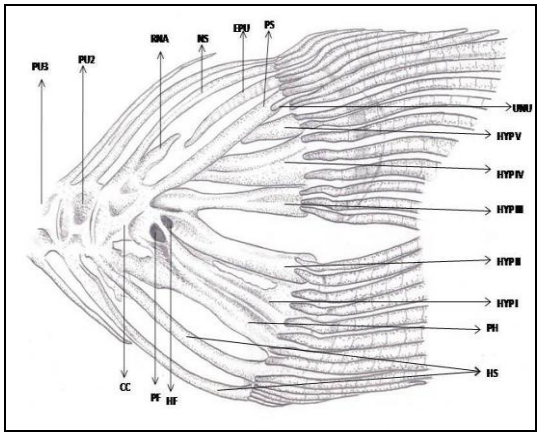
Labeo gonius



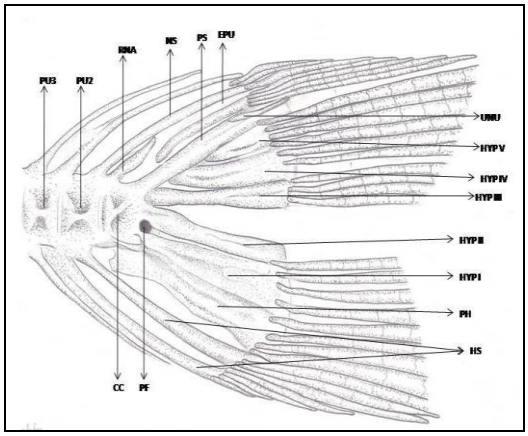
Bangana dero



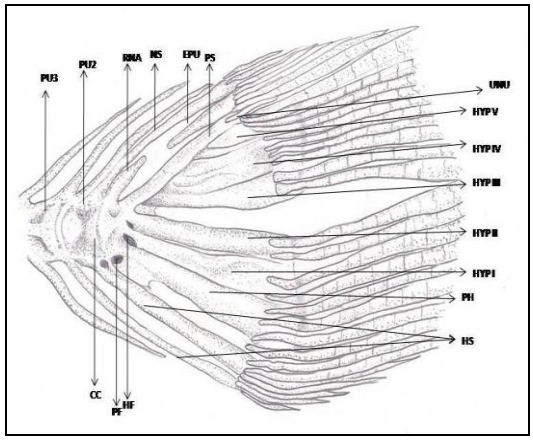
Bangana devdevi



Neolissochilus hexagonolepis



Neolissochilus hexasticus



Neolissochilus stracheyi

Conclusion

The comparative morphology of the caudal skeleton of the studied Cyprinid fishes has showed that they are more advance forms. The caudal skeleton exhibits species specific variation in respect to width of parhypural and hypural, size of epural, bifurcation of neural spine and hypural diastema.

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