

PHYLOGENETIC RELATIONSHIPS OF THE ENDEMIC CHINESE CYPRINID FISH *Pseudogyrinocheilus prochilus*

Zhang E

(Institute of Hydrobiology, the Chinese Academy of Sciences, Wuhan 430072)

Abstract Evidence is provided to support the hypothesis that the taxa *Pseudogyrinocheilus*, *Semilabeo*, and *Discolabeo* form a monophyly in which *Semilabeo* and *Discolabeo* are sister groups, and both together constitute the sister group of *Pseudogyrinocheilus*. On the basis of phylogenetic relationships of *Pseudogyrinocheilus* to others, it is proposed that the taxon *Pseudogyrinocheilus* be a valid genus. In addition, comments are made on importance of some features used in the traditional taxonomy of the subfamily Labeoninae.

Key words *Pseudogyrinocheilus prochilus*, Phylogenetic relationships, Taxonomy

1 Introduction

The endemic Chinese cyprinid fish *Pseudogyrinocheilus prochilus* (Sauvage and Dabry) is known from the upper reach of the Yangtze River (above Yichang), the tributaries of the Yangtze River in Sichuan and the Wujiang River (above Yichang), the tributaries of the Yangtze River (Wu *et al.*, 1977). There this fish, a bottom-dweller, requires the swiftly flowing mountain stream or cavity with running water and feeds on the benthic creatures which the species scrapes off the substrates (Chu *et al.*, 1989). On account of the peculiar morphology of the mouth structure, this fish has received considerable taxonomical attention.

Sauvage and Dabry (1874) first described it as *Discognathus prochilus*. Followingly, Tchang (1929) identified it as two species *Gyrinocheilus pellegrini* and *G. roulei*. After a closer examination of the type species and specimens collected from their geographical ranges, Fang (1933) however recognized *Discognathus prochilus* Sauvage and Dabry, *G. pellegrini* Tchang and *G. roulei* Tchang as a single species, and erected the genus *Pseudogyrinocheilus* under which *P. procheilus* (Sauvage and Dabry) was only listed. Furthermore, he pointed out that *Pseudogyrinocheilus* is

phylogenetically related to the genus *Gyrinocheilus* and also to the genera *Labeo*, *Garra*, *Cirrihini* and *Crossocheilus*, and all these genera may phylogenetically be considered as the forms derived from *Barbus*. As a whole, in Fang's opinion *Pseudogyrinocheilus* may be considered as the intermediate form between *Barbus* and *Gyrinocheilus*. Finally, Wu *et al.* (1977) assigned *P. procheilus* (Sauvage and Dabry) into the genus *Semilabeo*; this classification has been currently accepted.

However, data employed in the Sauvage and Dabry's, Tchang's and Wu *et al.*'s studies only included the external characters; and little attention has been paid to the internal skeleton features. Despite Fang (1933) erected the genus *Pseudogyrinocheilus* for this fish and introduced the skeletal features to study its taxonomical position, no advanced taxonomical technique such as Hennigian phylogenetic analysis (Hennig, 1966; Wiley, 1988) was available. While the taxa which were previously considered to be related to *Pseudogyrinocheilus* have different taxonomical placements nowadays, some newly-described taxa are found to bear a closer relationship to it. Hence, phylogenetic relationships of *P. procheilus* are still so poorly understood that the problem about its taxonomical position remains unresolved.

The endemic Chinese group *Semilabeo* has been ranked as a genus since its erection, and its systematic position in Labeoninae leaves uncertain. *Discolabeo*, a newly-described genus (Chen, 1992), is restricted in Xijiang River. In original paper, it is considered as the relative of *Garra* and *Discogobio*. However it seems to me that both have somewhat resemblance to *Pseudogyrinocheilus* in the mouth structure.

The present analysis, on the basis of the study of their external

morphology and internal osteology, aims to provide the evidence to support the hypothesis that the taxa *Pseudogyrinocheilus* (Fang, 1933), *Semilabeo* (Peter, 1980), and *Discolabeo* (Chen, 1992) constitute a monophyly in which *Discolabeo* and *Semilabeo* are sister groups, and both together form the sister group of *Pseudogyrinocheilus* (Fig. 1).

2 Methods and Materials

The studies were based on specimens from the Fresh-water Fishes Museum of the

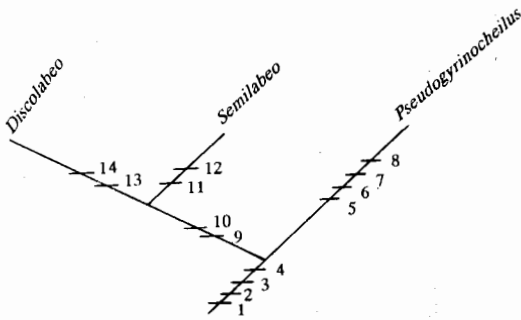


Figure 1 Hypothesized relationship among the taxa *Semilabeo*, *Discolabeo*, and *Pseudogyrinocheilus* Numbers refers to the synapomorphies described in the text

Chinese Academy of Sciences (CAS). Osteology was studied from alizarin stained specimens. Character polarization was performed by the outgroup comparison (Wiley, 1981). The plesiomorphic character state is indicated by "0", the apomorphic character state is indicated by "1". The data were analyzed by Phylogenetic Analysis Using Parsimony (PAUP). Outgroup taxa examined included *Rectoris*, *Parasinilabeo*, *Discogobio*, *Placochilus* and *Garra*. Among them, *Garra* and *Rectoris* were selected as the first and the second outgroup. Ingroup included *Pseudogyri-nocheilus prochilus*, *Semilabeo notabilis* and *D. wui*. Materials examined are listed below.

D. wui: 89XII 0001 (stained), 85VII 0058-70, 89XII 0002-15; *G. pingi pingi*: 76V 9063 (Stained), 79IV 0688-90 0379 0377, 78IV 0208 0148; *S. notabilis*: 85 I 0252 0236 0113, 63V 0016 (stained), 86VI 8236 8262 2394 2393; *Parasinilabeo assimilis*: 75IV 2634 (stained), 87VI 5707 5555 5731 5652; *R. luxiensis*: 88IV 2426 (stained), 81X 0234 87VI 0003 0005 0008 0160; *D. yunnanensis*: 87VII 0549 (stained) 0200-03 0179 0198; *Placochilus cryptonemus*: 81X 4308 (stained) 4303 4311-12 4308. *Pseudogyri-nocheilus prochilus*: 78IV 0384 (stained), 58V 0023 0025-26 0043 0272 0397 0254.

3 Results

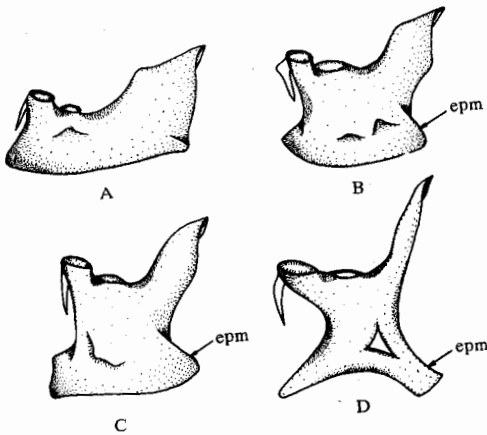


Figure 2 Anterior view of the maxilla:

(A) *Garra pingi pingi*; (B) *Discolabeo wui*;
(C) *Semilabeo notabilis*; (D) *Pseudogyri-*
nocheilus prochilus

epm = extrolateral process on the maxilla

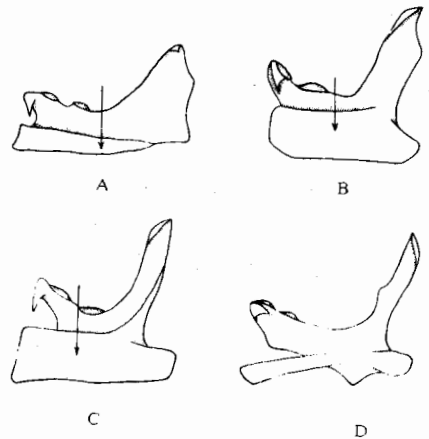


Figure 3 Ventral view of the maxilla:

(A) *Garra pingi pingi*; (B) *Discolabeo wui*;
(C) *Semilabeo notabilis*; (D) *Pseudogyri-*
nocheilus prochilus

A cladogram for the taxa *Pseudogyri-nocheilus*, *Semilabeo*, and *Discolabeo* is obtained by using PAUP program (Fig. 1).

The monophyletic group, including the taxa *Pseudogyri-nocheilus*, *Semilabeo* and *Discolabeo* is supported by four synapomorphies:

(1) Exterolateral process on the maxilla (State 0, maxilla with exterolateral process; state 1, maxilla without exterolateral process) In the outgroup taxa examined, the maxilla is vertically shallow and transversely wide, with its lateral part slightly directed backwards (Fig. 2A). However the maxillae within *Pseudogyrinocheilus*, *Semilabeo* and *Discolabeo* have a deep anterior part, with a shallow or slender lateral part so sharply curved backwards as to form an exterolateral process (Fig. 2B, 2C, 2D).

(2) Mouth-opening (state 0, mouth-opening wide; state 1, mouth-opening narrow) The mouth-opening of the outgroup taxa examined is wide, more than half the head width (Fig. 4A, 4B). But the mouth-opening in *Pseudogyrinocheilus*, *Semilabeo* and *Discolabeo* is narrow, less than half the head width (Fig. 4C, 4D, 4E).

(3) Margin of the rostral cap (state 0, rostral cap with fringed margin; state 1, rostral cap without fringed margin) In the outgroup taxa examined, the rostral cap bears many vertical furrows on its outer surface, thus forming a fringed margin (Fig. 4A, 4B); meanwhile no presence of vertical furrow among *Pseudogyrinocheilus*, *Semilabeo* and *Discolabeo* is on the outer surface of rostral cap where there does not appear a fringed margin (Fig. 4C, 4D, 4E).

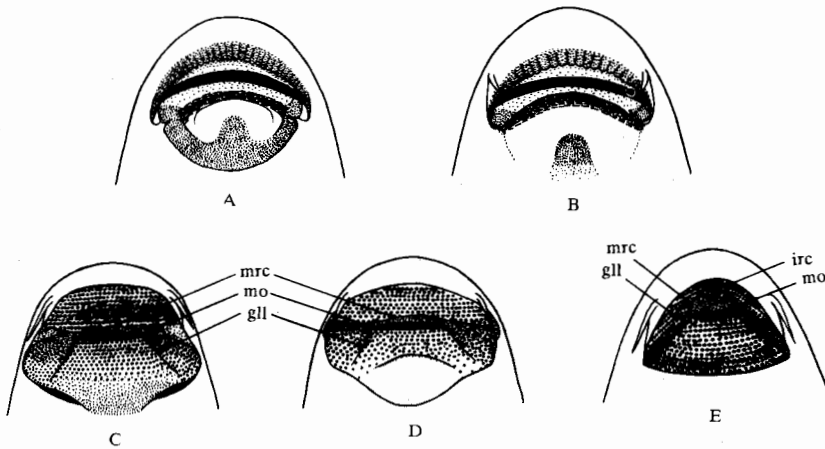


Figure 4 Diagram of the ventral view of the mouth structure: (A) *Garra pingi pingi*; (B) *Rectoris luxiensis*; (C) *Semilabeo notabilis*; (D) *Discolabeo wuis*; (E) *Pseudogyrinocheilus prochilus*. Among them, C and D are the structures of the mouth part when opened. mrc = margin of the rostral cap; mo = mouth-opening; irc = indentation on the rostral cap; gll = lateral groove on the lower lip.

(4) Lateral grooves on the lower lip (state 0, long lateral grooves on lower lip; state 1, no lateral groove on lower lip) Instead of the absence of lateral grooves on the lower lip of the outgroup taxa examined (Fig. 4A, 4B), the lower lips within *Pseudogyrinocheilus*, *Semilabeo* and *Discolabeo* have long lateral grooves which extend

posteriorly from the mouth corner to the margin of the lower lip (Fig. 4C, 4D, 4E).

Four autapomorphies are found for *Pseudogyrinocheilus*.

(5) Articulation between the maxillae (state 0, maxillae articulating with a symphysis; state 1, maxillae articulating via a long band of cartilage) The maxilla in *Pseudogyrinocheilus* articulates with its partner via a long band of cartilage. But in the other labeonine fishes, the maxilla meets with its partner with a symphysis.

(6) Anterior notch on the supraethmoid (state 0, supraethmoid with one deep anterior notch; state 1, supraethmoid with three anterior notches) In comparison to *Semilabeo*, *Discolabeo* and most of the outgroup taxa examined whose supraethmoids have a medial notch and two lateral notches (Fig. 5A, 5B, 5D), the supraethmoid in *Pseudogyrinocheilus* possesses a deep anterior notch (Fig. 5C).

(7) Extension of the supraethmoid (state 0, supraethmoid anteriorly extending far from vomer; state 1, supraethmoid anteriorly extending beyond vomer) The supraethmoid of *Pseudogyrinocheilus* anteriorly extends beyond the vomer when dorsally viewed (Fig. 5C). This situation never occurs in the outgroup taxa examined, *Semilabeo* and *Discolabeo* (Fig. 5A, 5B, 5D).

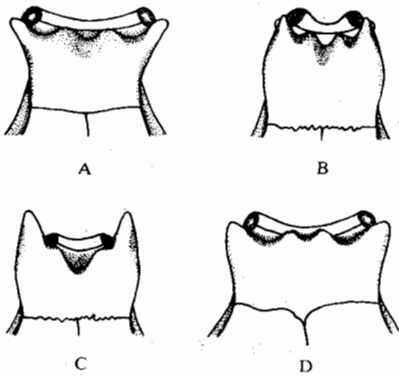


Figure 5 Dorsal view of the ethmo-vomerine region: (A) *Rectoris luxiensis*; (B) *Semilabeo notabilis*; (C) *Pseudogyrinocheilus prochilus*; (D) *Discolabeo wui*.

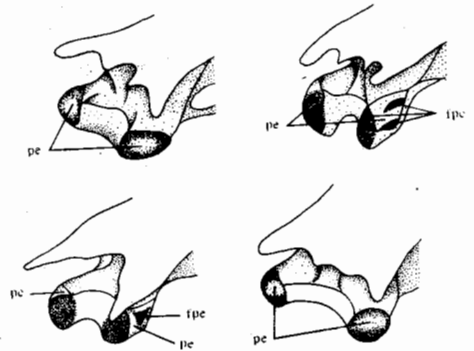


Figure 6 Dorso-lateral view of the ethmo-vomerine region: (A) *Rectoris luxiensis*; (B) *Semilabeo notabilis*; (C) *Pseudogyrinocheilus prochilus*; (D) *Discolabeo wui*

pe = preethmoid; fpe = facet on the preethmoid

(8) Indentation on the rostral cap (state 0, indentation on rostral cap present; state 1, indentation on rostral cap absent) The presence of the indentation on the rostral cap is unique to *Pseudogyrinocheilus* in Cyprinidae (Fig. 4E).

Semilabeo and *Discolabeo* are sister groups for the possession of two synapomorphies.

(9) Modified anteroventral border of the maxilla (state 0, maxilla with slightly modified anteroventral border; state 1, maxilla with greatly modified anteroventral border) The anteroventral borders of the maxillae in *Semilabeo* and *Discolabeo* are greatly thickened to appear like a oblong plain (Fig. 3B, 3C) compared with those of the outgroup taxa examined and *Pseudogyrinocheilus* which are slightly thickened (Fig. 3A, 3D).

(10) Edge of rostral cap (state 0, rostral cap without cutting edge; state 1, rostral cap with cutting edge) No other taxon in Cyprinidae shares a cutting edge of the rostral cap with *Semilabeo* and *Discolabeo* (Fig. 4C, 4D).

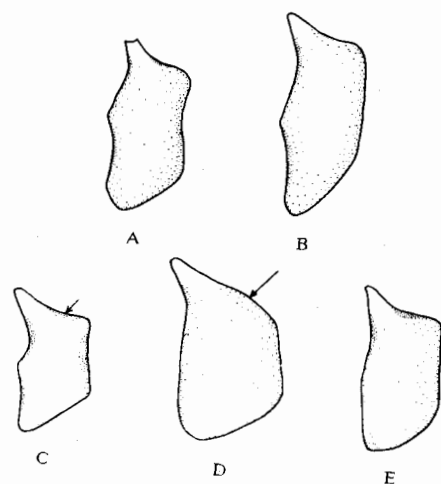


Figure 7 Lateral view of the opercle:

(A) *Rectoris luxiensis*; (B) *Garra pingi pingis*

(C) *Pseudogyrinocheilus prochilus*; (D) *Discolabeo wui*; (E) *Semilabeo notabilis*

Labeoninae, some taxa have an adhesive disc on the chin, their lower lip with a free posterior margin. The others, however, do not have an adhesive disc on the chin, and have their lower lip continuous with the chin and covered by the horny projections instead. Among them, only *Semilabeo* has a lower lip which extends backwards to the chin without free posterior margin (Fig. 4C).

Two autapomorphies are for *Discolabeo*:

(13) Round dorsal border of the opercle (state 0, Opercle with projected dorsal border; state 1, opercle with round dorsal border) In the outgroup taxa examined, *Pseudogyrinocheilus* and *Semilabeo*, there is a projection on the dorsal border of the opercle (Fig. 7A, 7B, 7C, 7E). At the same time, the opercle in *Discolabeo* bears

Semilabeo has two autapomorphies:

(11) Facets on the preethmoid (state 0, one convex facet on preethmoid; state 1, three facets on preethmoid) Within the outgroup taxa examined plus *Pseudogyrinocheilus* and *Discolabeo*, the preethmoid forms one convex facet which meet with the fossa on the palatine (Fig. 6A, 6C, 6D). However, only *Semilabeo* possesses the preethmoid with three independent facets, one of which, together with anterior facet on the vomer, articulates with the ascending process of the maxilla and the others articulate with the fossa of the palatine (Fig. 6B).

(12) Extension of the lower lip (state 0, lower lip not extending backwards; state 1, lower lip extending backwards) In the subfamily

a round dorsal border (Fig. 7D).

(14) Posterior projection on the supraethmoid (state 0, posterior projection on supraethmoid absent; state 1, posterior projection on supraethmoid present) Many kinds of the meeting between the supraethmoid and the frontals among Cyprinidae were discussed by Howes (1978). Here, it is unique that the supraethmoid in *Discolabeo* has a prominent projection which invades into the suture of the frontals (Fig. 5D).

4 Discussion

4.1 Taxonomical position of *Pseudogyrinocheilus prochilus*

Among most of investigators, the agreement has been reached that this endemic Chinese cyprinid fish forms a single species; but the argument has still remained upon the generic status that the species merits. This fish was previously classified in the genus *Discognathus* by Sauvage and Dabry (1874); *Gyrinocheilus* by Tchang (1929), in terms of the resemblance of its mouth in appearance to that of this taxon; *Semilabeo* by Wu *et al.* (1977), on the basis of general similarity of their mouth structures. These researchers mentioned above have taken for granted that this fish is taxonomically not enough to be generic rank. However, Fang (1933) argued that this fish differs from the genus *Gyrinocheilus* in the followings: a single gill-opening, the presence of the pharyngeal teeth, two pairs of barbels, the absence of the upper and lower lips coming together to form an involuted prolongation, and no anterosuperior furrows in the snout; then, as opposed to the others, he erected a new monogeneric *Pseudogyrinocheilus* for it.

To the best of my knowledge, distinguished by a pair of barbels from its related taxa *Garra* and *Ageniogarra* (Garman, 1912), the genus *Discognathus* has universally been considered as an invalid taxon in Cyprinidae (Wu *et al.*, 1977), and the genus *Gyrinocheilus* has widely been elevated to be the family rank Gyrinocheilidae (Wu *et al.*, 1979). Therefore, neither Sauvage and Dabry's nor Tchang's classification for this fish is satisfactory one.

The present analysis indicates that *Pseudogyrinocheilus*, *Discolabeo* and *Semilabeo* form a monophyly in which *Discolabeo* and *Semilabeo* are sister groups, and constitute the sister group of *Pseudogyrinocheilus*. According to the Hennig's phylogenetic classification that a taxon represents monophyletic lineage and the sister groups share with the same rank, *Pseudogyrinocheilus* should be considered to be a higher taxon than the generic rank now that *Discolabeo* and *Semilabeo* have been widely treated as two valid genera in Cyprinidae. The other alternative is that *Pseudogyrinocheilus* should be a generic rank if its sister group including *Semilabeo* and *Discolabeo* is treated as a genus. In this way *Discolabeo* should be a synonymy of *Semilabeo* in terms of law of priority. But no matter what the alternative is, *Pseudogyrinocheilus* is enough to merit a generic rank. As such, the genus *Semilabeo* in which *Pseudogyrinocheilus*

prochilus is classified and *Discolabeo wui*. is not included is a paraphyletic group rather than a monophyletic one. The fact that this classification is out of harmony with the Hennig's phylogenetic classification is responsible for this paraphyly. Hence, for the sake of convenience and keeping changes of the current classification to a minimum, I agree with Fang's classification that this endemic Chinese cyprinid fish merits the generic status, and propose that the taxon *Pseudogyriinocheilus* be a valid genus in Cyprinidae.

4.2 Comments on importance of some features employed in the traditional taxonomy of the subfamily Labeoninae

Previously affiliated to the subfamily Barbininae in Cyprinidae (Wu *et al.*, 1977), the Labeonine fishes are adapted for inhabiting in the torrential water, with great diversity in their mouth structures. No matter which subfamily these fishes belong to, their mouth structures bear a great taxonomical significance on the generic level. At the same time, within these fishes there exists some intraspecific variation in the number of pharyngeal teeth in rows. In view to phylogeny of these fishes, Wu *et al.* (1977) considered that the *Garra*-like group composed of *Garra*, *Discogobio* and *Placochilus* may be the more derived group for the shared possession of an adhesive disc on the chin, and *Discogobio* and *Placochilus* may be the most derived taxa for the shared possession of an adhesive disc on the chin and having the number of pharyngeal teeth 2 in rows. Therefore, the presence of an adhesive disc on the chin is heavily weighted by these researchers to be of phylogenetic importance; so is the number of pharyngeal teeth 2 in rows.

Chen (1992) erected the genus *Discolabeo* and stated that it is related to the genera *Garra* and *Discogobio* for the shared possession of an adhesive disc on the chin and is distinguished from them by the pharyngeal teeth in 2 rows and other characters. From the traditional taxonomist's point of view, *Discolabeo* altogether with *Discogobio* and *Placochilus* should be the most derived taxa.

The present analysis however shows that *Semilabeo*, *Discolabeo* and *Pseudogyriinocheilus* form a monophyletic group for the possession of four synapomorphies. Apparently, although the genus *Discolabeo* shares an adhesive disc on the chin with the genera *Discogobio*, *Placochilus*, *Discolabeo* and *Garra*, this genus has a close relationship with the genera *Pseudogyriinocheilus* and *Semilabeo*. In my opinion, the so-called *Garra*-like group defined by the presence of an adhesive disc on the chin is maybe not a natural group but a paraphyletic or polyphyletic group. The present analysis also indicates that *Pseudogyriinocheilus* should be the most derived taxa for the possession of the more autapomorphies among three taxa *Pseudogyriinocheilus*, *Semilabeo* and *Discolabeo*. If not the most derived group in Labeonine fishes, *Pseudogyriinocheilus* should at least be the more derived group than *Discolabeo*. It seems to me that the groups which possess an adhesive disc on the chin and the number of pharyngeal teeth 2 in rows are probably not the most derived groups. I therefore ven-

ture to conclude that neither the presence of the adhesive disc on the chin nor the pharyngeal teeth 2 in rows is probably of phylogenetic importance. However further research work is still needed for my conclusion to be carry out on the higher level of universality than that in this study.

It is worth mentioning that identification of the genera in the subfamily Labeoninae mainly depends on the external morphological character of the mouth structures. I have learnt from the present analysis that much attention paid to the external morphological characters and little reference made to the internal osteological characters result in the emergence of a paraphyletic group such as the genus *Semilabeo* which *Pseudogyrinocheilus prochilus* is classified and *Discolabeo wui* is not included. I hence consider that validity of the taxa on the generic level in Labeoninae should deserve no suspect unless their diagnosing character receive the support from their internal osteology.

5 Taxonomy and Diagnosis

Pseudogyrinocheilus Fang, 1933 (type species *Discognathus prochilus* Sauvage et Dabry, 1874).

Diagnosis: body elongate, cylindrical; upper lip absent; rostral cap with indentation, without fringed margin, continuous with lower lip; mouth-opening narrow; long lateral grooves on lower lip; maxilla with an exterolateral process, meeting with its partner via a long band of cartilage, its lateral part shallow or slender; supraethmoid bearing a deep anterior notch, anteriorly extending beyond vomer when dorsally viewed; pharyngeal teeth 3 in rows. Of these characters, maxilla articulating with its partner via a long band of cartilage; supraethmoid bearing a deep anterior notch, anteriorly extending beyond vomer and indentation on rostral cap are autapomorphic and, therefore, truly diagnostic of *Pseudogyrinocheilus*.

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泉水鱼的系统发育关系

张 鸮

(中国科学院水生生物研究所 武汉 430072)

摘要 泉水鱼(*Pseudogyrinocheilus prochilus*)是我国特有的一种鲤科鱼类,它广泛分布于宜昌以上长江上游干流、长江在四川境内的支流和乌江中,常栖息于山溪溪流及具流水的岩洞中;以舔刮底栖生物为食。它具有十分独特的口唇结构。不少学者对其分类作过研究,Sauvage *et* Dabry (1880)将泉水鱼认作一个种,置于 *Discognathus* 属中,名之为 *D. prochilus*; Tchang; (张春霖, 1929)将泉水鱼鉴定为两个种,归入 *Gyrinocheilus* 属中,命名为 *G. pellegrini* 和 *G. roulei*; Fang(方炳文, 1933)也将泉水鱼看作一个种,可是他以 *D. procheilus* Sauvage *et* Dabry 为模式种建立一新属 *Pseudogyrinocheilus*; 而伍献文等(1977)则将泉水鱼并入 *Semilabeo* 属。在已有的研究中,虽然多数学者将泉水鱼认作一个种,但对其归属则不同。这主要是因为泉水鱼分类归属的确立并不是依据其系统发育关系,而是仅凭其口唇外部形态结构与相关分类单元的相似性比较。方炳文曾试用骨骼学特征来探讨 *Pseudogyrinocheilus* 与其相关类群的系统发育关系,但所选择进行比较的类群不太恰当,因而其结论难以令人置信。此外,随鱼类分类学研究的不断深入,其部分相关分类单元有了新的归属,而新的相关分类单元又被发现。因此,泉水鱼的系统发育关系至今仍然不很清楚,以至其分类地位难以确立。

本文采用了 Hennig 系统发育系统学的外类群比较方法(outgroup comparison method),对泉水鱼及其相关类群的外部形态学和内部骨骼学进行研究后的结果表明:*Pseudogyrinocheilus*、*Semilabeo* 和 *Discolabeo* 构成一个单系类群,其中 *Semilabeo* 和 *Discolabeo* 是姐妹群,且二者共同组成了 *Pseudogyrinocheilus* 的姐妹群。据此,对泉水鱼的分类地位以及野鲮亚科鱼类分类中所用的某些特征的分类学意义进行了讨论。其结论是:*Pseudogyrinocheilus* 仍为鲤科中一有效的属;野鲮亚科中某些类群鱼类其颊部具有口吸盘(adhesive disc)或下咽齿 2 行可能为不具有系统发育系统学重要性的特征。

关键词 泉水鱼, 系统发育关系, 分类