CHARACTERS

The character descriptions below refer only to those specimens examined in this analysis. Statements such as "most Loricariinae" refer only to most of those species of the Loricariinae examined.

HYOID AND BRANCHIALS

Anterohyal

1. Anterohyal shape - 0: greatest width less than half of length (Fig. 8B-D); 1: greatest width greater than half of length (Fig. 8A, E). CI = 0.06.

In *Corydoras*, *Lithogenes* Eigenmann, most Ancistrini, Hypoptopomatinae, some *Hypostomus*, *Isbrueckerichthys*, most Loricariinae, *Neoplecostomus*, some *Pterygoplichthys*, and some Rhinelepini, the anterohyal has its greatest width less than half of length (Fig. 8B-D). In *Hoplosternum*, *Dianema*, *Astroblepus*, some Ancistrini, *Corymbophanes* Eigenmann, *Harttia*, most Neoplecostominae, most Pterygoplichthini, and most Rhinelepini, the anterohyal has its the greatest width greater than half of length (Fig. 8A, E). Length is defined as the distance along the longest axis of the hyoid arch and width is the distance along the shortest axis of the hyoid arch.

2. Anterohyal shape - 0: anterior edge flat or with a single hump (Fig. 8A, C-E); 1: anterior edge sinusoidal (Fig. 8B). CI = 0.20.

In callichthyids, Astroblepus, Lithogenes, and most loricariids, the anterior edge of the anterohyal gently slopes anterolaterally from its anterior contact with the hypohyal or is flat (state 0; Fig. 8A, C-E). In most *Chaetostoma*, *Exastilithoxus fimbriatus* (Steindachner), *Lithoxancistrus* Isbrücker, Nijssen, and Cala, and *Lamontichthys*, the anterior margin of the anterohyal is wide mesially, then narrows, and then widens again so that the anterior margin appears sinusoidal (state 1; Fig. 8B).

Basibranchials

3. Second basibranchial - 0: ossified; 1: cartilaginous; 2: absent. CI = 0.10.

In callichthyids, the *Acanthicus* group, the *Chaetostoma* group, some *Hypostomus*, *Lithoxancistrus*, the Loricariinae, some *Panaque* Eigenmann and Eigenmann, and some *Peckoltia* Miranda Ribeiro the second basibranchial is ossified (state 2). In *Hemipsilichthys cameroni* and most Hypostominae the second basibranchial is cartilaginous (state 1). In *Astroblepus,* the Hypoptopomatinae, some *Hypostomus*, *Lithoxus*, most of the Neoplecostominae, *Peckoltia oligospila* (Günther), some *Pterygoplichthys*, and the Rhinelepini, the second basibranchial is absent (state 2). This state was not observable in *Lithogenes*.

4. Third basibranchial shape - 0: elongate; 1: short and wide, almost square. CI = 0.25.

In callichthyids, *Astroblepus*, and most loricariids, the third basibranchial is elongate anteroposteriorly (state 0). In *Crossoloricaria*, *Hemipsilichthys*?, the *Hypostomus unicolor* group, and *Isbrueckerichthys*, the third basibranchial is short and wide, almost square (state 1; Armbruster, 1998a). This state was not observable in *Lithogenes*.

Branchiostegals

5. Number of Branchiostegals - 0: 4; 1: 3. CI = 0.67.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, there are four branchiostegals (state 0). In *Lasiancistrus* sensu stricto and *Lithoxancistrus* there are three branchiostegals (state1).

6. Mesial facing process on third branchiostegal - 0: absent; 1: present. CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the branchiostegals are gently curving structures (state 0). In the *Chaetostoma* group, the third basibranchial has a process mesially at the point of greatest curvature (state 1; Schaefer, 1986).

Ceratobranchials

7. Length of accessory process of the first ceratobranchial (ordered) - 0: absent (Fig. 9A); 1: less than length of main body of ceratobranchial (Fig. 9B-C); 2: same length as ceratobranchial (Fig. 9D-E). CI = 0.18

In callichthyids, *Astroblepus, Lithogenes*, and some loricariines, the first ceratobranchial (CB1) lacks an accessory process (state 0; Fig. 9A). In most loricariids, CB1 has a sheetlike, anterior accessory process (Schaefer, 1986). In *Delturus*, most hypoptopomatines, some loricariines, most neoplecostomines, *Leporacanthicus*, the *Lithoxus* group, and *Upsilodus* the process is not as long as the main body of the ceratobranchial (state 1; Fig. 9B-C). In some hypoptopomatines, some neoplecostomines, and hypostomines, the accessory process is at least as long as the main body of the ceratobranchial (state 2; Fig. 9D-E). The accessory process supports additional gill rakers. In most loricariids, the gill rakers are covered in an epithelium which helps trap food particles (Schaefer, 1986; 1987). It is hypothesized that the greater size of the accessory process, the more gill tissue that can be supported, and that the accessory process have become expanded through evolution to increase the ability of the fishes to strain food; hence, this character is coded as ordered.

8. Width of accessory process of the first ceratobranchial (ordered) - 0: absent (Fig. 9A); 1: thin (Fig. 9B-D); 2: wide (Fig. 9E). CI = 0.20.

In callichthyids, *Astroblepus, Lithogenes*, and some loricariines, the first ceratobranchial (CB1) lacks an accessory process (state 0; Fig. 9A). In *Delturus*, most hypoptopomatines, some hypostomines, some loricariines, most neoplecostomines, *Leporacanthicus*, the *Lithoxus* group, and *Upsilodus* the process is a thin structure less than the width of the main body of the ceratobranchial (state 1; Fig. 9B-D). In most hypostomines, some neoplecostomines, and some *Otocinclus*, the accessory process is wider than the main body of the ceratobranchial (state 2; Fig. 9E). The character is ordered using the same reasoning in 8.

9. Third ceratobranchial - 0: approximately same width as other ceratobranchials; 1: at least twice as wide as other ceratobranchials. CI = 0.50.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the third ceratobranchial is approximately the same width as the other ceratobranchials (state 0). In most of the Loricariini examined, the third ceratobranchial is at least twice as wide as the other ceratobranchials (state 1).

10. Shape of fifth ceratobrancial - 0: thin, uniform width (Fig. 10A); 1: wide (Fig. 10B). CI = 0.10.

In callichthyids, *Astroblepus, Lithogenes*, some of the Ancistrini, *Delturus*, some hypoptopomatines, most loricariines, neoplecostomines, and *Upsilodus*, the fifth ceratobranchial is a narrow structure with a nearly uniform width (state 0; Fig. 10A). In some hypoptopomatines, most of the Hypostominae, and most of the Loricariinae, the fifth ceratobranchial is widened at least anteriorly into a hatchetlike structure (state 1; Fig. 10B).

11. Posteromedial invagination of fifth ceratobranchial - 0: absent, 1: present. CI = 0.19.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the posteromedial edge of the fifth ceratobranchial is without an invagination (state 0). In some loricariines, *Otocinclus*, and several hypostomines a posteromedial invagination is present on the fifth ceratobranchial giving it a battle-axe shape (state 1; from Schaefer, 1986 and Schaefer and Stewart, 1993).

12. Connection of fifth ceratobranchials - 0: absent (Fig. 11A); 1: present (Fig. 11B). CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the fifth ceratobranchials do not contact one another mesially, and the teeth are fine (state 0; Fig. 11A). In *Crossoloricaria* and *Loricaria* the fifth ceratobranchials are enlarged, thickened, and sutured or held tightly to one another and have large, molariform teeth (state 1; Fig. 11B). There are pulverized seeds in the guts of *Crossoloricaria* and *Loricaria* suggesting that the molariform teeth and strengthened pharyngeal jaws are adaptations for granivory. All of the seeds found in the guts examined are highly mottled, a condition stated by Goulding (1980) to be found in plants that do not have fruits. Goulding suggests that the mottling of the seeds is for camouflage from granivores; however, the guts of *Crossoloricaria* and *Loricaria* attest to a well-developed ability to find the seeds. Because the seeds are all crushed, it is apparent that the granivorous loricariines are not dispersing viable seeds.

13. Posterolateral process on the fifth ceratobranchial - 0: absent (Fig. 11A); 1: present (Fig. 11B). CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the fifth ceratobranchial does not have a posterolateral process (state 0; Fig. 11A). In *Crossoloricaria* and *Loricaria*, there is a posterolateral process on the fifth ceratobranchial that appears to be associated with the increased musculature needed for crushing seeds (state 1; see 12; Fig. 11B).

Epibranchials

14. Accessory process on first epibranchial - 0: absent; 1: thin; 2: thickened. CI = 0.20.

In callichthyids, *Astroblepus, Lithogenes*, *Hemiancistrus megacephalus* (Günther), most hypoptopomatines, the *Lithoxus* group, and some loricariines, the first epibranchial lacks an accessory process (state 0). In *Delturus*, most neoplecostomines, most hypostomines, *Otocinclus*, and *Upsilodus*, there is a small, accessory process located anteromesially on the first epibranchial (state 1; Schaefer, 1986; 1987). In the Loricariini, there is also an accessory process; however, it is very broad (state 2).

15. Mesial surface of first epibranchial - 0: rounded; 1: forms a blade. CI = 0.09.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the ventral surface of the first epibranchial is rounded or slightly keeled (state 0). In most hypoptopomatines and several groups of hypostomines, the ventral surface is highly keeled with the mesial edge expanded such that it appears bladelike (state 1).

16. Anterior-facing process on the fourth epibranchial located basally to the gill rakers - 0: absent or short (Fig. 12A); 1: very long (Fig. 12B). CI = 0.10.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the fourth epibranchial either does not have an anterior-facing process or the process is short, not much longer than wide (state 0; Fig. 12A). In most of the Ancistrini, the Corymbophanini, hypoptopomatines, some *Hypostomus*, and neoplecostomines the anterior process of the fourth epibranchial is very long, at least four times longer than wide (state 1; Fig. 12B).

17. Posterior shelf of fourth epibranchial - 0: absent; 1: present. CI = 0.20.

In most callichthyids, *Astroblepus, Lithogenes*, *Delturus*, *Leporacanthicus*, the *Lithoxus* group, the Loricariini, and *Upsilodus*, the fourth epibranchial lacks a posterior shelf and is a cylindrical bone (state 0). In *Hoplosternum* and most loricariids, a posterior shelf of the fourth epibranchial is present and short (state 1).

18. Gill rakers on the fourth epibranchial - 0: absent; 1: present. CI = 0.50.

In callichthyids, *Astroblepus, Lithogenes*, and some loricariines, there are no gill rakers on the fourth epibranchial (state 0). In most loricariids, gill rakers are present on the fourth epibranchial (state 1).

Hypohyal

19. Anteromesial projection on hypohyal - 0: absent; 1: present. CI = 0.50.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the hypohyal does not have anteromesial projections (state 0). In *Pogonopoma* and *Rhinelepis*, the hypohyal has anteromesial projections that nearly contact one another along the midline (state 1; (Armbruster, 1998b).

20. Hypohyal - 0: wide; greatest width approximately equal to or greater than length (Fig. 8C); 1: narrow, greatest width less than length (Fig. 8A-B, D-E). CI = 0.06.

In callichthyids, *Lithogenes*, and hypoptopomatines, some hypostomines, most loricariines, and some neoplecostomines, the hypohyal is wide with the greatest width approximately equal to or greater than the length (state 0, Fig. 8C). In most loricariids, the hypohyal is narrow with the greatest width less than the length (state 1, Fig. 8A-B, D-E). Length is defined as the distance along the longest axis of the hyoid arch and width is the distance along the shortest axis of the hyoid arch.

21. Hypohyal spindle-shaped - 0: no (Fig. 8A, C-E); 1: yes (Fig. 8B). CI = 0.13.

In callichthyids, *Lithogenes*, and most loricariids, the hypohyal is a roughly square to circular bone with the anterior and posterior edges straight to convex (state 0; Fig. 8A, C-E). In *Astroblepus, Lithogenes*, and several groups of the Ancistrini, the anterior and posterior edges of the hypohyal are concave making the bone spindle-shaped (state 1; Fig. 8B).

Hypobranchials

22. Hypobranchial 1 - 0: rectangular to square, sometimes thinner at one end; 1: fan shaped, lateral end much wider than the mesial end. CI = 0.33.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the first hypobranchial is rectangular to square, sometimes thinner at one end (state 0). In some of the Loricariini, the first hypobranchial is fan shaped with the lateral end much wider than the mesial end (state 1).

23. Hypobranchial 1 - 0: short and stout; 1: elongated. CI = 0.06.

In callichthyids, *Lithogenes*, and most loricariids, the first hypobranchial is short and stout (state 0). In *Astroblepus*, *Acanthicus*, *Delturus*, the *Hypostomus emarginatus* group, the *Lithoxus* group, *Leporacanthicus*, some loricariines, *Nannoptopoma* Schaefer, most neoplecostomines, *Rhinelepis*, and *Upsilodus*, the first hypobranchial is elongated (state 1; Armbruster and Page, 1996).

24. Hypobranchial 2 - 0: short and stout; 1: elongated. CI = 0.33.

In callichthyids, *Lithogenes*, and most loricariids, the second hypobranchial is short and stout (state 0). In *Astroblepus*, *Hemipsilichthys nudulus* Reis and Pereira, and the *Hypostomus unicolor* group, the second hypobranchial is elongated (state 1; Armbruster and Page, 1996).

Infrapharyngobranchials

25. Infrapharyngobranchial 4 - 0: no process; 1: with lateral process. CI = 0.50.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the fourth infrapharyngobranchial is a circular-shaped bone that is oriented dorsoventrally (state 0). In some *Hypostomus*, some *Pterygoplichthys multiradiatus*, *Loricariichthys*, *Pogonopoma*, and *Rhinelepis*, the fourth infrapharyngobranchial has a lateral process located approximately in the center of the bone (state 1).

Interhyal

26. Interhyal - 0: on or behind hyomandibula (Fig. 13B); 1: contacts the cartilaginous section between the hyomandibula and the quadrate; 2: contacts bony part of quadrate (Fig. 13A, C-D). CI = 0.13.

In *Astroblepus, Lithogenes*, *Acanthicus*, *Dekeyseria* Rapp Py-Daniel, *Delturus*, hypoptopomatines, some *Hypostomus*, *Leporacanthicus*, most loricariines, neoplecostomines, *Pterygoplichthys*, the Rhinelepini, and *Upsilodus*, the interhyal is located posterior to the cartilaginous section between the quadrate and the hyomandibula or is absent (state 0; Fig. 13B). In callichthyids, some *Hypostomus*, most loricariines, *Megalancistrus*, *Parancistrus* Castelnau, and *Pseudacanthicus*, the anterior margin of the interhyal contacts the cartilaginous section between the quadrate and hyomandibula but does not contact the bony part of the quadrate (state 1). In most of the Ancistrini, the *Hemiancistrus annectens* group, most of the Hypostomini, *Sturisoma*, and *Sturisomatichthys*, the anterior margin of the interhyal contacts the bony part of the quadrate or reaches a point just ventral to the posteroventral corner of the bony part of the quadrate (state 2; Fig. 13A, C-D).

27. Interhyal - 0: large (Fig. 13A); 1: medium (Fig. 13B-D); 2: very small or absent. CI = 0.15.

In *Astroblepus*, the *Chaetostoma* group, *Delturus*, *Pseudolithoxus*, loricariines, *Lithoxancistrus*, *Panaque albomaculatus* Kanazawa, and *Upsilodus*, the interhyal is a large, almost rectangular bone (state 0; Fig. 13A). In callichthyids, *Lithogenes,* and most loricariids, the interhyal is a medium-sized, rod-shaped or oval bone (state 1; Fig. 13B-D). In *Hemipsilichthys* sp., hypoptopomatines, some *Hypostomus*, *Kronichthys*, *Pareiorhina* sp., *Pterygoplichthys*, and *Pseudorinelepis* the interhyal is a diminutive ossification or is absent (state 2).

28. Interhyal - 0: ventral; 1: dorsal. CI = 0.33.

In callichthyids, *Astroblepus*, and most loricariids, the interhyal is located at or below the ventral margin of the hyomandibula (state 0; Fig. 13). In *Lithogenes, Delturus*, loricariines, *Pseudolithoxus*, and *Upsilodus*, the interhyal is located well above the ventral margin of the hyomandibula (state 1).

Pharyngeal Jaw

29. Upper pharyngeal jaw - 0: without invagination in shelf (Fig. 14A, C); 1: with invagination in shelf (Fig. 14B; arrow points to invagination). CI = 0.13.

In most loricariids, the upper pharyngeal jaw consists of a bulbous section and a mesial shelf or is stout across the entire length (see also 30). In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the mesial shelf is complete or is absent (state 0; Fig. 14A, C). In several groups of the Ancistrini, *Delturus*, *Harttia*, most hypoptopomatines, most neoplecostomines, and *Upsilodus*, the shelf has an invagination (state 1; Fig. 14B; arrow points to invagination).

30. Upper pharyngeal tooth plate - 0: round, teeth uniformly distributed (Fig. 14C); 1: with a mesial shelf and a raised bulbous area, teeth restricted to bulbous area and posterior edge of shelf (Fig. 14A-B). CI = 0.13.

In callichthyids, *Astroblepus, Lithogenes*, *Corymbophanes*, some hypoptopomatines, *Leporacanthicus*, the *Lithoxus* group some loricariines, and *Neoplecostomus*, the upper pharyngeal toothplate is rounded with the teeth evenly distributed across the surface (state 0; Fig. 14C). In most loricariids, the upper pharyngeal tooth plate has a mesial shelf and a raised bulbous area and the teeth are restricted to bulbous area and the posterior edge of shelf (state 1; Fig. 14A-B).

31. Upper pharyngeal tooth plate with a shelf lateral to the bulbous section - 0: absent; 1: present. CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the upper pharyngeal tooth plate is either round or has a rounded bulb with a mesial shelf (state 0). In the Rhinelepini, there is an additional lateral shelf on the upper pharyngeal tooth plate (state 1; Armbruster, 1998b).

Posterohyal

32. Lateral edge of posterohyal - 0: pointed with a ridge along lateral margin (Fig. 8A-C, E); 1: ridge absent so that the posterohyal forms a half cylinder (Fig. 8D). CI = 0.50.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the posterohyal has a ventral pouch (state 0; Fig. 8A-C, E). In *Ancistrus* Kner, *Lasiancistrus*, the *Lithoxus* group, and *Neblinichthys* Ferraris, Isbrücker, and Nijssen, the lateral wall of the pouch is reduced or absent and the lateral margin of the posterohyal is concave and widened so that the posterohyal appears to form a half cylinder (state 1; Fig. 8D).

SUSPENSORIUM

Hyomandibula

33. Contact of mesial surface of hyomandibula with quadrate posteroventrally - 0: none (Fig. 13B); 1: projection towards or sutured (Fig. 13A, C). CI = 0.18.

In callichthyids, *Astroblepus, Lithogenes*, some of the Ancistrini, *Delturus*, hypoptopomatines, most loricariines, neoplecostomines, and *Upsilodus*, the mesial surfaces of the hyomandibula and the quadrate do not have a bony contact with one another mesially (state 0; Fig. 13B). In most of the Ancistrini, the Hypostomini, *Lamontichthys*, and most of the Pterygoplichthini, the hyomandibula, quadrate, or both develop mesial processes that project toward one another and may form a suture (state 1; Fig. 13A, C).

34. Hyomandibula sutured to pterotic-supracleithrum posterior to cartilaginous condyle of hyomandibula - 0: absent; 1: present. CI = 0.25.

In callichthyids, *Astroblepus*, most basal loricariids, *Chaetostoma*, *Hemiancistrus megacephalus*, and *Pseudancistrus* Bleeker, the hyomandibula and the pterotic-supracleithrum are not sutured together (state 0). In *Lithogenes,* most of the Ancistrini, the Hypostomini, *Loricariichthys*, and the Pterygoplichthini, the hyomandibula is sutured to the pterotic-supracleithrum posterior to the cartilaginous condyle to the hyomandibula (state 1). Based on Schaefer (1986).

35. Hyomandibula contacts prootic - 0: yes; 1: no, pterotic-supracleithrum only. CI = 0.11.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the hyomandibula has a cartilaginous condyle dorsally to the prootic or to the prootic and the pterotic-supracleithrum (state 0). In most *Hemipsilichthys*, *Pogonopoma*, *Chaetostoma platyrhyncha* , *Hemiancistrus megacephalus*, *Nannoptopoma*, *Otocinclus*, and *Pseudancistrus*, the contact is solely on the pterotic-supracleithrum (state 1).

36. Anterior margin of hyomandibula sutured to posterior metapterygoid along entire length - 0: yes, no notch between the two (Fig. 15A, H-I); 1: no, slight to large notch between the two (Fig. 15B-G). CI = 0.13.

In callichthyids, *Astroblepus*, the *Acanthicus* group (except *Megalancistrus*), the *Hypostomus cochliodon* group, *Panaque*, *Pareiorhina* sp., *Pogonopoma parahybae*, *Scobinancistrus* Isbrücker and Nijssen, and *Spectracanthicus* Nijssen and Isbrücker, the entire anterior edge of the hyomandibula dorsal to the cartilaginous intersection of the metapterygoid, hyomandibula, preopercle, and quadrate is sutured to the metapterygoid or there is a cartilaginous contact throughout their entire contact surfaces (state 0; Fig. 15A, H-I). In

Lithogenes and most loricariids, the anterodorsal section of the hyomandibula is not sutured to the metapterygoid leaving a slight to large notch between the two bones (state 1; Fig. 15B-G).

37. Opercular condyle of hyomandibula on a process extended beyond posterior margin of hyomandibula - 0: absent (Fig. 13A-C); 1: present (Fig. 13D). CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the opercular condyle of the hyomandibula is either flush with the posterior edge of the lateral face of the hyomandibula or anterior to the posterior margin (state 0; Fig. 13A-C). In *Neblinichthys*, the condyle is separated by a pedicle from the main body of the hyomandibula so that it is posterior to the posterior margin of the lateral face of hyomandibula (state 1; Fig. 13D).

38. Length of opercular condyle of hyomandibula - 0: short (Fig. 13B-D); 1: long (Fig. 13A). CI = 0.50

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the opercular condyle of the hyomandibula does not extend far below the posterior margin of the hyomandibula and is shorter than it is wide (state 0; Fig. 13B-D). In the *Chaetostoma* group, *Hypostomus francisci*, and *Peckoltia ucayalensis* (Fowler), the opercular condyle of the hyomandibula is elongated and is longer than it is wide (Fig. 13A).

39. Thin, posterior process on hyomandibula just dorsal to opercle - 0: absent (Fig. 13B); 1: present (Fig. 13A, C-D; HP). CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the hyomandibula has a broad extension posterior to the condyle for articulation with the opercle or the posterior border of the hyomandibula is flush with the posterior border of the condyle for articulation with the opercle (state 0; Fig. 13B). In some of the Ancistrini, there is a pointed process extending posteriorly from the condyle to which the opercle has a secondary attachment. In *Ancistrus*, the *Chaetostoma* group, *Dekeyseria*, *Lasiancistrus*, the *Lithoxus* group, and *Neblinichthys* the process is present (state 1; Fig. 13A, C-D; HP). The process acts as a pivot point for the opercle when the opercle is used to evert the cheek plates. The *Lithoxus* group is coded as state 1 although the condition in the group appears to be a further modification of the process as is discussed in character 41.

40. Posterior part of hyomandibula beyond opercle - 0: not well developed (Fig. 15A-F, H-I); 1: developed (Fig. 15G). CI = 0.33.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the posterior section of the hyomandibula is not particularly well developed (state 0; Fig. 15A-F, H-I). In *Ancistrus*, *Lasiancistrus*, the *Lithoxus* group, and *Parancistrus*, the posterior section of the hyomandibula is developed into a shelf dorsally such that the suture to the pterotic-supracleithrum is nearly at a right angle to the preoperculo-hyomandibular ridge (state 1; Fig. 15G).

41. Posterior process of hyomandibula incorporated into hyomandibula - 0: posterior projection either absent or not incorporated; 1: present. CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the posterior process of the hyomandibula is either absent, or is not incorporated into the posterior section of the hyomandibula (state 0; see 39). In the *Lithoxus* group the thin posterior process described in 39 is incorporated into an expanded posterior shelf of the hyomandibula (state 1).

42. Posterior region of hyomandibula greatly deflected - 0: absent; 1: present. CI = 0.17.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the hyomandibula is not deflected to moderately deflected mesially, but the opercle is always oriented parallel or nearly parallel to the main body axis (state 0). In most of the Ancistrini, the posterior margin of the hyomandibula is strongly deflected mesially (state 1) causing the opercle to almost sit at a right angle to the main body axis.

43. Ridge on mesial side of hyomandibula located anterodorsally - 0: present; 1: absent. CI = 0.11.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, there is no ridge present on the mesial side of the hyomandibula that runs from about the center of the bone to the dorsal edge a few millimeters posterior to the anterior edge (state 0). In some hypoptopomatines, some *Hypostomus*, some loricariines, some neoplecostomines, and most of the Pterygoplichthini such a ridge is present (state 1).

44. Levator arcus palatini crest (ordered) - 0: absent (Fig. 15A); 1: short (Fig. 15B-I); 2: tall. CI = 0.12.

In callichthyids, *Astroblepus*, some loricariines, and some hypoptopomatines, the levator arcus palatini crest is absent (state 0; Fig. 15A). In most loricariids, there is a short to tall ridge on the hyomandibula for attachment of the levator arcus palatini (Fig. 15B-I). In most loricariids, the ridge is rounded and short (state 1). In *Lithogenes,* most of the Ancistrini, some *Hypostomus*, *Isbrueckerichthys*, *Neoplecostomus*, and *Pareiorhina*, the ridge forms a tall shelf (state 2). It is most parsimonious to suggest that the crest first evolved as a short, rounded ridge and then became more pronounced; hence, this character is coded as ordered.

45. Levator arcus palatini crest of hyomandibula - 0: without strong dorsal upswing, straight (Fig. 15A-D, F-I); 1: with strong dorsal upswing (Fig. 15E). CI = 0.33.

Generally, when present, the levator arcus palatini crest has an accessory ridge dorsally that is perpendicular to the levator arcus palatini crest. This accessory ridge is usually shorter in height than the levator arcus palatini crest and may be indistinct. In *Lithogenes, Exastilithoxus fimbriatus*, *Hemipsilichthys nudulus*, *Isbrueckerichthys*, *Leptoancistrus*, and some *Pareiorhina* sp., the accessory ridge is the same height as the levator arcus palatini crest which either does not continue beyond the accessory ridge, or becomes very short beyond the accessory ridge. This modification makes the levator arcus palatini crest appear curved such that it ends near the dorsal, cartilaginous condyle of the hyomandibula (state 1, Fig. 15E). Species without a levator arcus palatini crest, without an accessory ridge, or with an accessory ridge shorter than the levator arcus palatini crest are coded as state 0 (Fig. 15A-D, F-I).

46. Hyomandibula deflected beyond posterior margin - 0: not deflected (Fig. 15A-C, E-H); 1: deflected (Fig. 15D, I). CI = 0.17.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the preoperculo-hyomandibular crest is not strongly deflected (state 0; Fig. 15A-C, E-H). In some of the Ancistrini, *Hemipsilichthys* sp., and some *Hypostomus*, the preoperculo-hyomandibular ridge is deflected posteriorly such that is passes beyond the posterior margin of the hyomandibula and is visible when the mesial surface of the hyomandibula is viewed (state 1; Fig. 15D, I).

47. Process on preoperculo-hyomandibular ridge - 0: absent (Fig. 15A-F, H-I); 1: present (Fig. 15G, HRP). CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, there is no process on the preoperculo-hyomandibular ridge (state 0; Fig. 15A-F, H-I). In *Lithoxus*, there is a small process located along the preoperculo-hyomandibular ridge above the levator arcus palatini crest (state 1; Fig. 15G, HRP).

48. Preoperculo-hyomandibular ridge continuous - 0: yes; 1: no, ridge branches. CI = 0.20.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the preoperculo-hyomandibular ridge is continuous (state 0; Fig. 15A-F, H-I). In *Ancistrus*, *Lasiancistrus*,

Leptoancistrus, the *Lithoxus* group, *Parancistrus*, and *Pseudorinelepis*, the ridge branches dorsally into an anterior and posterior section (state 1; Fig. 15G).
49. Ridge on hyomandibula (contiguous with ridge on quadrate) - 0: absent; 1: present. CI = 0.25.

In callichthyids, *Astroblepus*, and most loricariids, there is no ridge on the ventrolateral part of the hyomandibula (state 0; Fig. 15A-G, I). In *Lithogenes, Hypancistrus* Isbrücker and Nijssen, *Leporacanthicus*, *Megalancistrus*, and *Pseudacanthicus*, there is a short ridge on the ventrolateral part of the hyomandibula that is contiguous with a ridge on the quadrate (state 1; Fig. 15H; see character 67); in *Pseudacanthicus*, this ridge is much better developed than in the other species.

Metapterygoid

50. Zipperlike connection of metapterygoid to lateral ethmoid - 0: absent; 1: present. CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the metapterygoid does not contact the lateral ethmoid or the contact is simple (state 0, see 51). In the Loricariini, there is a serrated, zipperlike connection between the metapterygoid and the lateral ethmoid (state 1).
51. Anterior connection between metapterygoid and lateral ethmoid - 0: none; 1: present. CI = 0.25.

In callichthyids, *Astroblepus*, *Hypancistrus*, and *Otocinclus*, the metapterygoid does not contact the lateral ethmoid anteriorly (state 0). In *Lithogenes* and most loricariids, the metapterygoid has an anterior, bony contact with the lateral ethmoid or is held tightly to the lateral ethmoid by ligament (state 1). Typically, there are no modified contact surfaces, and the metapterygoid and the lateral ethmoid simply touch; however, some loricariids have developed a more well-developed contact surface (see 50). Based on Schaefer (1986; 1987).
52. Metapterygoid channel - 0: absent (Fig. 15A); 1: dorsal surface of metapterygoid split and forming slight furrow (Fig. 15C, arrow points to furrow); 2: dorsal surface of metapterygoid split to the anterior process of the metapterygoid and forming a channel (Fig. 15B, D-F, H-I) (ordered). CI = 0.20.

In callichthyids, *Astroblepus, Lithogenes*, *Ixinandria*, *Neoplecostomus microps* (Steindachner), *Otocinclus*, and *Rineloricaria*, the metapterygoid lacks a channel laterally (state 0; Fig. 15A). In *Delturus*, *Exastilithoxus*, *Lithoxus*, *Scobinancistrus*, and *Upsilodus*, the dorsal margin of the metapterygoid is split and forms a slight furrow. The split of the metapterygoid creates a larger and stronger contact surface with the lateral ethmoid, but does not form a channel for the passage of the levator arcus palatini muscle (state 1, Fig. 15C). In most loricariids, the dorsal margin is further split to the anterior process of the metapterygoid which results in the presence of a channel for passage of the levator arcus palatini muscle (state 2; 15B, D-F, H-I). It is hypothesized that the dorsal surface of the metapterygoid became further split through evolution, and that what had originally evolved as an increase in the attachment of the metapterygoid secondarily became a channel for the levator arcus palatini muscle; hence, this character is coded as ordered. Presence of a channel would limit the lateral movement of the levator arcus palatini muscle allowing it to pull the palatine posteriorly and, hence, pull the premaxilla posteriorly more strongly and more efficiently. Some loricariids have only a slight ridge to denote the lateral wall of the pterygoid channel, but are coded as possessing the channel. *Lithoxus* has state 1, but the furrow is not visible in figure 15G.

53. Lateral wall of metapterygoid channel - 0: absent (Fig. 15A, G); 1: long and rounded along entire length (Fig. 15B, F); 2: triangular (Fig. 15D-E, H); 3: broad ridge perpendicular to metapterygoid (Fig. 15I); 4: just a slight ridge. CI = 0.27.

In callichthyids, *Astroblepus, Lithogenes*, *Delturus*, *Exastilithoxus*, *Lithoxus*, *Ixinandria*, *Neoplecostomus microps*, *Otocinclus*, *Rineloricaria*, *Scobinancistrus*, and *Upsilodus*, the pterygoid channel is absent (state 0; Fig. 15A, G). In some loricariids, a pterygoid channel is present with the lateral wall long and convex (state 1; Fig. 15B, F). In most loricariids, the lateral wall is roughly triangular (state 2; Fig. 15D-E, H). In *Spectracanthicus murinus* Nijssen and Isbrücker, the lateral wall is present, but as a low, broad ridge perpendicular to the metapterygoid (state 3; Fig. 15I). In *Hypancistrus*, some loricariines, and *Megalancistrus*, the lateral wall exists only as a low weak ridge (state 4). The morphology of states 3 and 4 are similar, but distinct enough to suggest that they evolved separately.

54. Walls of metapterygoid channel - 0: lateral wall slightly smaller to just slightly larger than mesial wall or lateral wall absent; 1: lateral wall taller. CI = 0.33.

In most loricariids, the lateral and mesial walls of the pterygoid channel are approximately the same height or the lateral wall is absent (state 0). In *Hypoptopoma*, *Lamontichthys*, *Nannoptopoma*, and *Pogonopoma*, the lateral wall of the pterygoid channel is much taller than the mesial wall (state 1; Armbruster, 1998c). Species without a pterygoid channel are coded as state 0 because it is hypothesized that the channel first formed as a furrow (52); in species with the furrow, both sides of the furrow are equal in height.

55. Walls of metapterygoid channel - 0: lateral wall slightly smaller to just slightly larger than mesial wall or lateral wall absent; 1: mesial wall much taller. CI = 0.11

In most loricariids, the lateral and mesial walls of the pterygoid channel are approximately the same height, the lateral wall is absent, or the lateral wall is shorter (state 0). In most of the *Chaetostoma* group (except *Cordylancistrus torbesensis* [Schultz]), *Hemiancistrus* sp. 1, *Hemipsilichthys* sp., *Hypancistrus*, some hypoptopomatines, some loricariines, *Megalancistrus*, *Parancistrus*, *Spectracanthicus*) the lateral wall is much shorter than the mesial wall (state 2). Species without a pterygoid channel are coded as state 0 because it is hypothesized that the channel first formed as a furrow (52); in species with the furrow, both sides of the furrow are equal in height.

56. Section of metapterygoid dorsal to the anterior process - 0: short; 1: very tall. CI = 0.20.

In most loricariids, the walls of the pterygoid channel are not particularly tall and in those species without the channel, the section above the anterior process of the metapterygoid that is homologous to the two walls of the metapterygoid channel is short (state 0). In *Hemiancistrus megacephalus*, *Loricariichthys*, *Pseudancistrus*, some *Pterygoplichthys*, and *Dekeyseria pulcher* (Steindachner), both walls of the pterygoid channel are tall (state 1).

57. Articulating surface between metapterygoid and lateral ethmoid - 0: absent (Fig. 15A, C); 1: present, not directly connected to wall of metapterygoid (Fig. 15E-G); 2: present, directly connected via a straight ridge (Fig. 15B, D, H-I). CI = 0.13.

In callichthyids, *Astroblepus, Lithogenes*, *Delturus*, some hypoptopomatines, some loricariines, and *Upsilodus*, the metapterygoid lacks an articulating facet for contact with the lateral ethmoid (state 0; Fig. 15A, C). In some *Hemipsilichthys*, some *Hypostomus*, *Leporacanthicus*, the *Lithoxus* group, *Neoplecostomus microps*, *Parancistrus*, *Pogonopoma*, and most of the Pterygoplichthini, a facet is present, but it is not directly connected to the lateral wall of the pterygoid channel (state 1; Fig. 15E-G). In most loricariids, the lateral wall of the pterygoid channel continues as a low ridge onto the articulating facet (state 2; Fig. 15B, D, H-I).

58. Anterior process on metapterygoid - 0: process pointed or absent (Fig. 15 A-C, E-F, H); 1: spoon shaped, straight (Fig. 15D; *Spectracanthicus* also has state 1, but the metapterygoid is angled such that the spoon-shaped process cannot be seen in figure 15I); 2: spoon shaped, angled ventrally (Fig. 15G); 3: curved, wider anteriorly than posteriorly (*Corydoras* only). CI = 0.50.

In *Dianema*, *Hoplosternum*, *Astroblepus, Lithogenes*, and most loricariids, the anterior process of the metapterygoid is either absent or pointed (state 0; Fig. 15 A-C, E-F, H). In *Corymbophanes*, *Hemiancistrus* sp., *Hemiancistrus megacephalus*, *Lithoxancistrus*, *Pseudancistrus*, and *Spectracanthicus* (state 1; Fig. 15D), the anterior process is straight and widened anteriorly making it appear spoon-shaped. In *Lithoxus* the anterior process is also spoon-shaped, but it is angled ventrally (state 2; Fig. 15G). The state in *Corydoras* (curved, wider anteriorly than posteriorly) is not directly comparable to other loricarioids and was coded as state 3.

Palatine

59. Ventromesial process of palatine - 0: short; 1: long. CI = 1.00

In loricariids, *Astroblepus, Lithogenes*, and callichthyids, the palatine has a mesial and a lateral process ventrally. In most, the mesial process is short (state 0). In *Pareiorhina* and the Rhinelepini, the mesial process is elongated (state 1).

60. Palatine - 0: elongate; 1: with mesial flap, very wide. CI = 1.00.

In most loricariids, the palatine is a long, slender bone (state 0). In the Loricariini, the palatine has a mesial flap which makes the bone appear very wide (state 1).

Preopercle

61. Orientation of preopercle - 0: horizontal; 1: almost vertical. CI = 0.08.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the posterior section of the preopercle is long and the preopercle appears to be oriented horizontally if the ventral edge of the quadrate is taken as the horizon (state 0). In some of the Ancistrinae, *Pogonopoma*, *Rhinelepis*, *Loricaria*, and *Rineloricaria*, the posterior section of the preopercle is very short, giving the preopercle the appearance of being oriented at an angle to almost vertically (state 1; Armbruster, 1998b).

62. Exit of preopercular latero-sensory canal - 0: posterior to posteroventral edge of quadrate; 1: anterior to posteroventral edge of quadrate; 2: latero-sensory canal does not enter preopercle. CI = 0.15.

In *Astroblepus, Lithogenes* and most loricariids, the exit of the preopercular latero-sensory canal is located posterior to the posterior edge of the quadrate (state 0). In callichthyids, most of the Ancistrini, *Corymbophanes*, some loricariines, and most of the Rhinelepini, the exit of the preopercular latero-sensory canal is located anterior to the posteroventral edge of the quadrate (state 1; Armbruster, 1998b). In some hypoptopomatines and in *Hemipsilichthys nudulus*, the preopercle does not have a section of the latero-sensory canal system (state 2).

63. Preopercular latero-sensory canal extended posteriorly - 0: absent; 1: present. CI = 0.50.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the preopercular latero-sensory canal is flush with the posterior edge of the hyomandibula at the posterior opening of the preopercular latero-sensory canal (state 0). In *Corymbophanes*, the Hypoptopomatinae, and the Neoplecostominae, the preopercle is extended posteriorly as a shelf at the posterior opening of the preopercular latero-sensory canal.

Quadrate

64. Quadrate - 0: thin; 1: wide; 2: very wide. CI = 0.22.

In *Corydoras*, *Astroblepus, Lithogenes*, and most loricariids, the quadrate is a roughly triangular bone whose width is approximately half its length (state 1). In *Ancistrus*, *Dekeyseria scaphirhyncha* (Kner), *Lasiancistrus* sensu stricto, and *Rineloricaria*, the quadrate is very narrow with a width approximately one quarter its length (state 0). In *Dianema*, *Hoplosternum*, some *Chaetostoma*, *Delturus*, *Otocinclus*, *Pseudorinelepis*, and *Upsilodus*, the quadrate is nearly as wide as long (state 2).

65. Ventral process on quadrate for articulation with canal plate - 0: absent (Fig. 13B, D); 1: present (Fig. 13A, C). CI = 0.20.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the quadrate does not have a ventral process that articulates with the canal plate (state 0; Fig. 13B, D). In the *Chaetostoma* group, *Hemiancistrus* sp., *Lasiancistrus* sensu stricto, *Lithoxus*, *Neblinichthys*, and *Peckoltia oligospila*, a process is present on the quadrate that articulates with the canal plate (state 1; Fig. 13A, C).

66. Quadrate with flap extending below symplectic foramen - 0: absent; 1: present. CI = 0.20.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the quadrate is a triangular bone (state 0). In the Hypostomini, the Pterygoplichthini, and most of the Ancistrini (except the *Acanthicus* group and *Exastilithoxus*), the quadrate has a ventral flap that extends below the symplectic foramen (state 1).

67. Articulating condyle of quadrate - 0: thin, pointed; 1: wide, blunt. CI = 0.14.

In callichthyids, *Lithogenes*, and most loricariids, the condyle of the quadrate that articulates with the lower jaw is thin and pointed, half as wide as long or less (state 0). In *Astroblepus*, the *Chaetostoma* group, some *Hemipsilichthys*, *Leporacanthicus*, *Lithoxancistrus*, *Panaque*, and *Scobinancistrus*, the articulating condyle is very wide and blunt, approximately as wide as long (state 1).

68. Longitudinal ridge on quadrate laterally - 0: absent (Fig. 15A-G); 1: present (Fig. 15H-I). CI = 0.10.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the quadrate is smooth laterally (state 0; Fig. 15A-G). In the *Acanthicus* group, *Chaetostoma pearsei* Eigenmann, *Hemiancistrus landoni* (Eigenmann), some *Hypostomus*, *H. panamensis*, *Hypancistrus*, *Leporacanthicus*, the *Lithoxus* group, *Megalancistrus*, *Panaque*, *Parancistrus*, most *Peckoltia*, and *Scobinancistrus*, there is a ridge running the length of the quadrate laterally (state 1).

Supraoccipital

JAWS

Lower Jaw

69. Angle of dentaries - 0: the two dentaries meet to form an oblique angle (usually >90°; Fig. 16A); 1: the two dentaries meet to form an acute or right angle (usually ≤80°; Fig. 16B). CI = 0.20.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the dentaries meet to form an oblique angle (>90°; state 0; Fig. 16A). In *Hypancistrus*, the *Hypostomus cochliodon* group, *Leporacanthicus*, the *Lithoxus* group, the Loricariini, *Megalancistrus*, *Panaque*, *Parancistrus*, *Peckoltia*, *Pseudancistrus*, and *Spectracanthicus*, the jaws typically meet at an acute angle (typically ≤80°; state 1; Fig. 16B).

Upper Jaw

70. Shape of maxilla - 0: angled dorsally to slightly angled ventrally (Fig. 17A-B, D); 1: well angled ventrally, almost forming right angle (Fig. 17C). CI = 0.08.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the maxilla ranges from being angled slightly ventrally to slightly dorsally (state 0; Fig. 17A-B, D). In some *Hypostomus*, *Hemiancistrus holostictus*, *Hemiancistrus landoni*, most *Panaque*, some *Peckoltia*, *Pseudacanthicus*, *Pterygoplichthys punctatus* (Kner), *Scobinancistrus*, and *Spectracanthicus punctatissimus* (Steindachner), the maxilla is strongly angled ventrally to almost form a right angle (state 1; Fig. 17C).

71. Maxilla shaped like a bowling pin (wide and rounded distally, narrowing proximally to form a neck, and then widening slightly to form a head) - 0: no (Fig. 17A-C); 1: yes (Fig. 17D). CI = 0.33.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the maxilla is long and narrow and is uniformly wide (state 0; Fig. 17A-C). In the *Lithoxus* group, *Leporacanthicus*, and *Spectracanthicus murinus*, the maxilla is wide and rounded distally, narrows proximally to form a neck, and then widens slightly to form a head (much like a bowling pin; state 1; Fig. 17D).

72. Premaxilla with cartilaginous connection to mesethmoid - 0: no; 1: yes. CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the premaxilla contacts the mesethmoid directly (state 0). In the Loricariini, the premaxillas have a cartilaginous contact with one another and the mesethmoid (state 1).

OPERCULAR SERIES

Interoperclular elements

73. Interopercular sesamoid - 0: absent; 1: present. CI = 0.17.

Schaefer (1986, 1987, 1988) and Schaefer and Lauder (1986, 1996) state that loricariids have lost both the interopercle and the interoperculo-mandibular ligament. In *Deltuus*, *Harttia*, *Lithogenes*, *Neoplecostomus*, *Pogonopoma*, and *Upsilodus*, there is a small ossification mesial to the preopercle and connected by a ligament to the opercle and the angulo-articular (state 1, Fig. 18A). Homologies of the bone are difficult to ascertain. In *Delturus*, the bone has the same shape as the interopercle of *Hoplosternum*, but it is smaller (Fig. 18B) suggesting that the bone may be a true interopercle. In *Lithogenes, Harttia*, *Neoplecostomus*, and *Pogonopoma*, the bone is likely a neomorph and is probably a sesamoid ossification based on its size, shape, and the fact that it develops at what appears to be a friction point on the interoperculo-mandibular ligament. There has been some contention as to the presence or absence of the interopercle in Loricarioids. Schaefer (1988) suggests that a bone located ventrolaterally to the opercle in *Astroblepus* is homologous to the interopercle based on positional homology; however, the putative interopercle is lateral to the opercle instead of directly ventral and slightly mesial as in callichthyids. It is most likely that the putative interopercle of Schaefer (1988) is actually a bony plate. A similar plate is found in *Lithogenes* and it often supports odontodes. As the position of an interopercle in *Lithogenes* could be denoted by the presence of an interoperculo-mandibular ligament, it is very unlikely that the plate near the opercle in both *Astroblepus* and *Lithogenes* is the interopercle. In order to be as unbiased as possible, the bone occasionally found inside of the interoperculo-mandibular ligament was coded as a unique ossification and not the interopercle, and all callichthyids, *Astroblepus*, and all loricariids not mentioned above are coded as state 0. Further discussion on this characteristic is below.

74. Interoperculo-mandibular ligament - 0: present; 1: absent. CI = 0.06.

The presence of an interoperculo-mandibular ligament in loricariids is actually quite broad. *Lithogenes,* most of the *Acanthicus* group, *Delturus*, *Harttia*, *Hemipsilichthys bahianus* (Gosline), most *Hypostomus*, *Isbrueckerichthys alipionis* (Gosline), some loricariines, *Neoplecostomus*, the *Hemiancistrus annectens* group, *Pogonopoma*, some *Pterygoplichthys*, and *Upsilodus* possess the ligament. Given that the ligament does not have an interopercle associated with it, it is possible that the ligament found in loricariids is not homologous to the interoperculo-mandibular ligament of other catfishes; however, it is also possible that basal loricariids lost the interopercle, but not the ligament, the ligament acquiring a new attachment directly to the opercle. The ligament shares a positional and operational homology with the interoperculo-mandibular ligament, it acts as a mechanical couple between the opercle and the angulo-articular. Given that the ligament is present in *Lithogenes*, it is most likely that the ligament is the interopeculo-mandibular ligament; *Astroblepus* and several groups of loricariids lost the ligament and the loss of the ligament may not be synapomorphy for *Astroblepus* + loricariids as suggested by Schaefer (1987) and Schaefer and Lauder (1986; 1996). Most loricariids and *Astroblepus* lack the interoperculo-mandibular ligament (state 1).

Opercle

75. Ancistrine opercle (ordered) - 0: no (Fig. 19A-B); 1: *Peckoltia* type (Fig. 19C); 2: *Ancistrus* type (Fig. 19D). CI = 0.67.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the opercle is roughly oval or triangular (state 0; Fig. 19A-B). Schaefer (1986; 1987) diagnosed the Ancistrini based on modifications of the opercle. Basally in the Ancistrini, the opercle has a sickle-shape (state 1; Fig. 19C). In *Ancistrus*, the *Chaetostoma* group, *Dekeyseria*, *Lasiancistrus*, the *Lithoxus* group, and *Neblinichthys*, the opercle has a bar-shape with the lateral section deflected laterally (state 2; Fig. 19D). Schaefer (1986; 1987) hypothesized that the opercle first lost the posterolateral shelf and then the lateral section of the opercle became deflected; hence, this character is coded as ordered. The modified opercle is in all members of the Ancistrini except *Hemiancistrus* sp. Brazil and *Spectracanthicus murinus*.

76. Double attachment of opercle - 0: absent (Fig. 13B); 1: present (Fig. 13A, C-D). CI = 1.00

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the opercle contacts the hyomandibula only at the opercular condyle of the hyomandibula (state 0; Fig. 13B). In the Ancistrini with a bar-shaped opercle (75-2), the opercle has an additional posterior connection (and sometimes also an anterior connection) to the hyomandibula (state 1; Fig. 13A, C-D; based on Schaefer, 1986).

77. Maximum forward position of opercle (ordered) - 0: below hyomandibula; 1: to posteroventral corner of quadrate; 2: to posterodorsal corner of quadrate. CI = 0.22.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the opercle is located posteriorly so that no part is located below the quadrate (state 0). In most of the Ancistrini with a bar-shaped opercle (75-2) and *Hemiancistrus* sp. 1, the opercle is lengthened anteriorly such that the anterior border is located below the posteroventral corner of the quadrate (state 1). In *Ancistrus*, *Chaetostoma pearsei*, *Lasiancistrus*, and *Lithoxus lithoides* Eigenmann, the anterior border of the opercle is further anterior and is located below the posterodorsal corner of the quadrate (state 2). It is most parsimonious to assume that the opercle moved successively forward; hence, this character is coded as ordered.

78. Hatchet-shaped opercle - 0: absent (Fig. 19A, C-D); 1: present (Fig. 19B). CI = 0.17.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the opercle is either straight along its anterior margin or convex (state 0; Fig. 19A, C-D). In *Hypostomus*, *Kronichthys*, *Neoplecostomus*, *Hemiancistrus holostictus*, *Pareiorhina*, *Spectracanthicus*, and *Harttia*, the opercle has at least a moderately concave anteroventral margin making it shaped as a hatchet (state 1; Fig. 19B).

79. Opercle - 0: supports odontodes; 1: does not support odontodes. CI = 0.25.

In callichthyids and most loricariids, the opercle supports odontodes (state 0). In *Astroblepus, Lithogenes*, *Hypancistrus*, *Panaque*, *Parancistrus*, *Peckoltia*, and *Pterygoplichthys punctatus*, the opercle is covered by skin or plates in at least adults and does not support odontodes. In at least *Hypancistrus* and *Peckoltia*, there is an ontogenetic change in the exposure of the opercle. In most juvenile *Hypancistrus* and *Peckoltia*, the opercle supports several rows of odontodes; in the largest adults, the opercle supports few or no odontodes. The specimens examined of *Hypancistrus* and *Peckoltia* that lack odontodes on the opercle appear to be males, so it is possible that there is also sexual dimorphism in the character. All *Panaque* examined lack odontodes on the opercle. Some members of the *Hypostomus cochliodon* group not analyzed in this study also lack odontodes on the opercle.

Suprapreopercle

80. Suprapreopercle - 0: absent; 1: present (in *Astroblepus* it is present as an ossified tube). CI = 0.14.

In *Astroblepus* and most loricariids, the suprapreopercle is located posterior to the preopercle and bears a branch of the lateralis system (state 1). In callichthyids, *Lithogenes*, some hypoptopomatines, and some neoplecostomines, the suprapreopercle is absent (state 1).

81. Number of rows of plates between suprapreopercle and exposed portion of opercle (ordered) - 0: none; 1: one; 2: two to three. CI = 0.20.

In callichthyids, *Astroblepus, Lithogenes*, *Corymbophanes*, *Exastilithoxus*, *Hemipsilichthys cameroni* (Steindachner), *H. nudulus*, hypoptopomatines, *Lithoxancistrus*, most loricariines, *Pareiorhina*, *Pogonopoma parahybae*, *Pseudorinelepis*, and *Rhinelepis* there are no plates between the suprapreopercle (or area the suprapreopercle would be) and the exposed opercle (state 0). In most of the Ancistrini, *Delturus*, *Harttia*, most *Hypostomus*, *Lamontichthys*, the remainder of the neoplecostomines, and *Upsilodus*, there is one plate between the suprapreopercle and the exposed opercle (state 1). In *Acanthicus*, *Ancistrus*, *Dekeyseria pulcher*, *Hypancistrus*, some *Hypostomus*, *Lasiancistrus*, *Parancistrus*, the Pterygoplichthini, and *Scobinancistrus*, there are 2-3 plates between the suprapreopercle and the exposed opercle (state 2). Because increased fragmentation of the cheek plates is concomitant with the increased evertibility of the cheek plates (Schaefer, 1986; 1987) this character is coded as ordered. Most species without suprapreopercles are coded as state 0 because it appears as if there is not enough room for plates between where the suprapreopercle would be and the exposed opercle. In *Hemipsilichthys splendens* Bizerril, the preopercular latero-sensory canal enters the preopercle much more dorsally than in other species without suprapreopercles, and there is a plate between the area where the suprapreopercle would be and the opercle; hence *H. splendens* was coded as having state 1.

LATERO-SENSORY CANAL SYSTEM

Hemipsilichthys nudulus lacks much of the lateralis system. The lateral line canal is only a few plates long, the infraorbital canal and preopercular latero-sensory canal are missing, and the other canals of the head are weak. However, it is possible to recognize most of the plates that are pierced by the lateralis system in most other loricariids. Hence a canal plate and most infraorbitals are recognizable and are coded as present and/or their position is noted.

Canal Plate

82. Canal plate: 0: absent; 1: present. CI = 1.00.

Schaefer (1986, 1987, 1988) describes a plate located ventral to the preopercle that bears a portion of the preopercle latero-sensory canal that he terms the canal plate. Callichthyids, *Astroblepus, Lithogenes*, *Delturus* and *Upsilodus* either lack the canal plate or it is marked only by a slight ossification no wider than the latero-sensory canal (state 0). All loricariids except *Delturus* and *Upsilodus* have a canal plate that is larger than the canal and that generally supports odontodes (see 84; state 1).

83. Canal plate size, number - unknown (?): canal plate absent; 0: present, large; 1: present, small (Fig. 13A, C-D); 2: two canal plates present (Fig. 13B). CI = 0.22.

The size, number, and shape of the canal plate in loricariids is variable. Callichthyids, *Astroblepus, Lithogenes*, *Delturus* and *Upsilodus* lack the canal plate and were coded as unknown (?). The canal plate can either be large with the ventral part deflected mesially so that it is visible from below as in hypoptopomatines, *Leporacanthicus*, some loricariines, most neoplecostomines, and *Pogonopoma* (state 0), small as in most other loricariids (state 1; Fig. 13A, C), or there may be two small plates as in *Isbrueckerichthys*, *Pareiorhina rudolphi* Gosline, and *Rhinelepis* (state 2; Fig. 13B). In *Astroblepus*, *Delturus*, *Lithogenes*, and *Upsilodus* the canal plate is represented only by an ossified tube. Because ossified tubes occasionally occur around the lateralis system in catfishes, an ossified tube was not considered to be a canal plate; however, the ossified tube was used to mark the location of the canal plate for the following characters.

84. Canal plate – unknown (?): canal plate absent - 0: exposed, supporting odontodes; 1: covered in skin or plates and not supporting odontodes. CI = 1.00.

Callichthyids, *Astroblepus, Lithogenes*, *Delturus* and *Upsilodus* lack the canal plate and were coded as unknown (?). In most loricariids, the canal plate supports odontodes (state 0). In the *Chaetostoma* group, the canal plate is located slightly mesially to the lateral plates and does not have any odontodes attached to it (state 1).

85. Contact of canal plate with suspensorium - unknown (?): canal plate absent; 0: does not contact suspensorium; 1: contacts suspensorium. CI = 0.10.

Callichthyids, *Astroblepus, Lithogenes*, *Delturus* and *Upsilodus* lack the canal plate and were coded as unknown (?). In most loricariids, the canal plate does not contact the suspensorium (state 0). In several groups of loricariids (including most of the Ancistrini) the canal plate has a bony or ligamentous connection with the suspensorium, either on the preopercle, quadrate, or both (state 1).

86. Canal in canal plate branched - 0: absent; 1: present. CI = 0.50.

In callichthyids, *Astroblepus, Lithogenes*, and loricariids, the laterosensory canal is not branched either in or in the region of the canal plate (state 0). In *Hemipsilichthys*, *Isbrueckerichthys*, *Neoplecostomus*, and *Pareiorhina* sp., the latero-sensory canal in the canal plate is branched (state 1).

87. Preopercular latero-sensory canal leaves preopercle at first exit and enters a plate - 0: no (Fig. 13A, C-D); 1: yes (Fig. 13B). CI = 0.25.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the preopercular latero-sensory canal gives off a branch medially to the posterior of the preopercle and then continues to the ventral margin of the preopercle (state 0; Fig. 13A, C-D). In some of the Hypoptopomatinae, *Isbrueckerichthys*, *Neoplecostomus paranensis* Langeani, and *Pareiorhina rudolphi*, the preopercular latero-sensory canal exits at the level of the first branch along the posterior margin of the preopercle and does not continue to the ventral margin of the preopercle (state 1; Fig. 13B).

88. Number of plates between the canal plate and opercle (ordered) - 0: none; 1: one; 2: two to four; 3: five or more. CI = 0.23.

Schaefer (1986; 1987) hypothesized that the plates on the cheek became successively fragmented during evolution. Schaefer assessed this partially by the number of plates between the canal plate and the exposed section of the opercle. The Ancistrini and the Pterygoplichthini tend to have the most fragmented cheek plates and this may be associated with the ability to evert the plates. In the Ancistrini that have the opercle unexposed, counts are made to the area where the opercle normally is exposed. The above categories of plate counts appear to hold phylogenetic signal. State 0 (no plates between opercle and canal plate) is found in *Astroblepus, Lithogenes*, some hypoptopomatines, and some neoplecostomines. State 1 (one plate) is present in *Corymbophanes*, *Delturus*, most hypoptopomatines, most loricariines, most neoplecostomines, and *Upsilodus*. State 2 (two to four plates) is found in *Ancistrus*, the *Chaetostoma* group, *Hemipsilichthys*?, the Hypostomini, the *Lithoxus* group, some loricariines, *Pseudacanthicus*, *Spectracanthicus murinus*, and the Rhinelepini. State 3 (five or more plates) is found basally in the Ancistrini and in the Pterygoplichthini. It is hypothesized that the cheek plates became more fragmented so that the opercle could be better rotated outwards; hence, this character is coded as ordered. Callichthyids lack cheek plates and are coded as unknown (?). *Astroblepus, Lithogenes*, *Delturus*, and *Upsilodus* lack true canal plates, but there is an ossified tube denoting the position of the canal plate and allowing the number of plates between the opercle and where the canal plate would be to be counted (see 82 above).

Schaefer (1986; 1987; 1988) describes a bone in *Astroblepus* of unknown homology. Schaefer (1988) suggests that the bone, based on positional homology, is an interopercle that lacks a ligamentous contact with the angulo-articular. However, the position of the bone is ventral to the opercle rather than anterior to the opercle and is lateral rather than on the same plane or slightly mesial to the opercle as is the interopercle in other catfishes (Fig. 15A). *Lithogenes* lacks plates on the anterior half of the body except for a large, odontode-bearing plate in the same area as the putative interopercle of the Astroblepidae. *Lithogenes* does have an interoperculo-mandibular ligament and a bone within it that is possibly homologous to the interopercle (see 73 above). Given that both a plate on the cheek similar to that of *Astroblepus* and an interopercle are present in *Lithogenes* and that the cheek plate in *Astroblepus* is not positionally or operationally homologous to the interopercle of other catfishes, the plate on the cheek of *Astroblepus* is not the interopercle and is coded here as the presence of a single plate between the opercle and the area where an ossified tube denotes the area of the canal plate.

Infraorbitals

Infraorbitals are numbered in loricariids starting posteriorly with IO6 because most loricariids have six infraorbital canal plates; however, some loricariids lack an IO1 and some have infraorbitals anterior to IO1; therefore, IO0 or lower is possible.

89. IO6 - 0: forms only the posteroventral corner of the orbit; 1: forms entire ventral border of orbit. CI = 0.50.

In *Astroblepus, Lithogenes*, and most loricariids, the posteriormost canal plate (IO6) forms only a small portion of the posteroventral corner of the orbit with much of the ventral border formed by IO5 (state 0). In *Lasiancistrus* sensu stricto and *Panaque nigrolineatus* (Peters), IO6 forms the entire ventral border of the orbit (state 1). The infraorbital series in callichthyids is resticted to just two plates (Reis, 1998), neither of which forms the entire ventral border of the orbit; hence, callichthyids were coded as state 0.

90. IO4 - 0: absent; 1: contacts orbit through much of its posterior edge; 2: contact with orbit slight or absent. CI = 0.40.

In callichthyids, a plate homologous to IO4 in *Astroblepus, Lithogenes* and loricariids is likely absent (state 0; Reis, 1998). In most loricariids, IO4 normally forms the anterior border of the orbit (state 1). In *Astroblepus, Lithogenes*, some members of the *Hypostomus emarginatus* group, *Leporacanthicus*, and *Panaque nigrolineatus*, IO4 is either completely or partially separated from the orbit and forms little or no part of the border of the orbit (state 2).

91. Number of infraorbitals (ordered) - 0: two; 1: five to six; 2: seven to ten. CI = 0.30.

Callichthyids have two infraorbital canal plates (state 0), while most loricariids have five or six canal plates (state 1). Seven to ten canal plates are found in *Delturus*, *Baryancistrus* Rapp Py-Daniel, some *Cordylancistrus* Isbrücker, some *Dekeyseria scaphirhyncha*, *Exastilithoxus fimbriatus*, the *Hypostomus emarginatus* group, *H. albopunctatus* (Regan), *H. francisci*, *Leporacanthicus*, *Loricariichthys*, *Megalancistrus*, some *Panaque*, *Peckoltia*, *Pseudacanthicus*, *Pseudancistrus barbatus* (Valenciennes), most *Pterygoplichthys*, and some *Spectracanthicus punctatissimus* (state 2).

Lateral Line

92. Lateral line continuing beyond hypural plate - 0: no; 1: yes, continues into the elongated plate covering base of the caudal rays. CI = 0.17.

In callichthyids, *Astroblepus*, and most loricariids, the lateral line does not continue beyond the hypural plate (state 0). In *Lithogenes*, *Acanthicus*, *Leporacanthicus*, the Loricariinae, most of the *Hypostomus emarginatus* group, and *Peckoltia ucayalensis*, the lateral line continues into the elongate plate posterior to the hypural plate and covering the insertion of the caudal-fin rays (state 1).

CRANIUM

Baudelot's Ligament

93. Height of ridge formed by Baudelot's ligament - 0: does not form more than a slightly rounded ridge; 1: forms a shelf. CI = 0.33.

In most callichthyids, *Astroblepus, Lithogenes*, *Delturus*, *Lithoxus*, and *Upsilodus*, Baudelot's ligament forms a slight, rounded, ossified ridge (state 0). In most loricariids, Baudelot's ligament forms a distinct wall that varies from short to very tall (state 1).

Frontal

94. Frontal contacts orbit - 0: present; 1: absent. CI = 0.33.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the frontal forms the dorsal border of the orbit (state 0). In the Hypostomini, most *Lasiancistrus* sensu stricto (some *L. maracaiboensis* Schultz are polymorphic), *Panaque*, *Peckoltia*, the Pterygoplichthini, the Rhinelepini, and *Scobinancistrus*, the frontal is separated from the orbit by a small plate (state 1).

Lateral Ethmoid

95. Shape of lateral ethmoid - 0: square to triangular; 1: triangular with ventrolateral corner greatly expanded. CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the lateral ethmoid is roughly rectangular to triangular (state 0). In some hypoptopomatines, the posterolateral corner of the lateral ethmoid is greatly expanded (state 1).

96. Nasal capsule - 0: completely encased ventrally by the lateral ethmoid (Fig. 20A-B, D); 1: open ventrally (Fig. 20C); 2: anterior to the lateral ethmoid. CI = 0.67.

In callichthyids, *Lithogenes*, *Delturus*, the Hypostominae, the Loricariinae, *Neoplecostomus*, and *Upsilodus*, the nasal capsule is completely supported below by the lateral ethmoid (state 0; Fig. 20A-B, D). In the Hypoptopomatinae and most of the Neoplecostominae, the anterolateral part of the nasal capsule is not supported by the lateral ethmoid (state 1; Fig. 20C). In *Astroblepus* (and also most other catfishes), the naris is located anterior to the lateral ethmoid and the nasal capsule is formed by the palatine (state 2).

97. Ridge on the lateral ethmoid from metapterygoid contact to near the anterior margin of the bone - 0: absent; 1: present, rounded ridge or moderately tall ridge; 2: tall ridge. CI = 0.09.

In callichthyids, *Astroblepus*, *Hypostomus emarginatus*1, and *Otocinclus*, the lateral ethmoid lacks a ridge ventrally for contact with the metapterygoid (state 0). Basally in loricariids, the ridge is generally present as a short to moderately tall ridge (state 1). In *Lithogenes,* several taxa of the Ancistrini, some *Hypostomus*, loricariines, neoplecostomines, *Schizolecis*, and *Upsilodus*, the ridge is very tall (state 2).

98. Pouch on ventral surface of lateral ethmoid - 0: absent (Fig. 20B-D); 1: posterior wall developed (Fig. 20A). CI = 0.09.

In callichthyids, *Astroblepus*, and most loricariids, the lateral ethmoid is flat posteriorly or else just slightly concave (state 0; Fig. 20B-D). In *Lithogenes,* several taxa of the Ancistrini, *Delturus*, some hypoptopomatines, *Hypostomus albopunctatus*, the Loricariini, neoplecostomines, and *Upsilodus*, the posterolateral corner of the lateral ethmoid is deeply concave such that the posterolateral edge of the lateral ethmoid appears as a ridge and a deep pouch is formed (state 1; Fig. 20A).

99. Posterior contact of the lateral ethmoid and metapterygoid - 0: contacting posterior margin of lateral ethmoid (Fig. 20A-C); 1: separated from posterior margin of lateral ethmoid (Fig. 20D). CI = 0.20.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, there is either a condyle on the lateral ethmoid for contacting the metapterygoid and this condyle is in contact with the posterior margin of the lateral ethmoid, or the condyle is absent and the posterior of the metapterygoid is aligned with the posterior margin of the lateral ethmoid (state 0; Fig. 20A-C). In the *Hypostomus emarginatus* group, *Panaque*, *Pterygoplichthys multiradiatus*, *Peckoltia ucayalensis*, the Rhinelepini (except *Pseudorinelepis*), and *Scobinancistrus*, the contact of the metapterygoid to the lateral ethmoid is shifted anteriorly and the condyle on the lateral ethmoid does not contact the posterior margin of the lateral ethmoid (state 1; Fig. 20D).

Mesethmoid

100. Mesethmoid disk (ordered) - 0: absent; 1: reduced; 2: developed. CI = 0.33.

In callichthyids, *Lithogenes,* and *Exastilithoxus*, the mesethmoid lacks a disk ventrally at its distal end (state 0). In *Astroblepus, Lithogenes*, *Crossoloricaria venezuelae*, and *Lithoxus*, the disk is present, but small (state 1); and in all other loricariids, the disk is large (state 2). It is hypothesized that the disk became larger through evolution; hence, this character is coded as ordered.

101. Mesethmoid disk relative placement – unknown (?): disk absent; 0: not beyond anterior margin of mesethmoid; 1: beyond anterior margin. CI = 0.20.

In *Astroblepus, Lithogenes* and most loricariids, the main body of the mesethmoid extends anterior to the mesethmoid disk (state 0). In *Ancistrus*, *Hemiancistrus megacephalus*, *Hypancistrus*, *Leporacanthicus*, *Lithoxus*, *Megalancistrus*, *Panaque*, *Parancistrus*, *Peckoltia*, *Pseudacanthicus* and *Spectracanthicus*, the mesethmoid disk extends beyond the anterior margin of the main body of the mesethmoid such that the disk is visible when the mesethmoid is viewed from above (state 1).

102. Mesethmoid flares anteriorly - 0: no; 1: yes. CI = 0.25.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the mesethmoid does not flare at its anterior edge (state 0). In the *Chaetostoma* group, *Dekeyseria scaphirhyncha*, *Hemipsilichthys nudulus*, and *Hemipsilichthys splendens*, the mesethmoid flares widely anterior to the mesethmoid disk and the anterior margin of the mesethmoid disk does not contact the anterior margin of the main body of the mesethmoid (state 1). See Character 103.

103. Mesethmoid anterior edge serrate - 0: absent; 1: present. CI = 0.33.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the anterior tip of the mesethmoid is smooth and either not widened or rounded anteriorly (state 0). In *Crossoloricaria*, *Harttia*, hypoptopomatines, and *Lamontichthys*, the mesethmoid flares out laterally at its tip, and the anterior edge is straight, but serrate (state 1).

104. Mesethmoid continued as a long blade anterior to disk (or well beyond the jaws in species without a disk) - 0: no; 1: yes. CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the tip of the mesethmoid does not form an elongate blade (state 0). In *Sturisoma* and *Sturisomatichthys*, the mesethmoid is greatly extended beyond the mesethmoid disk and forms a blade (state 1).

Nasal

105. Size of nasal - 0: very thin; 1: elongate but wide; 2: very large, almost square. CI = 0.22.

In callichthyids, *Astroblepus, Lithogenes*, *Acanthicus*, the *Chaetostoma* group, *Hemiancistrus megacephalus*, and *Pseudancistrus*, the nasal is a very thin bone not much wider than the segment of the latero-sensory canal passing through it (state 0). In most loricariids, the nasal is elongate, but it is widened such that it is wider than the canal (state 1). In *Ancistrus*, *Hypoptopoma*, *Nannoptopoma*, *Otocinclus*, some *Pterygoplichthys*, and the Rhinelepini, the nasal is very wide and almost square (state 2).

Parasphenoid

106. Parasphenoid on orbitosphenoid (Armbruster, 1998c) - 0: narrow, tall; 1: wide, slightly raised to flat. CI = 0.25.

In *Corydoras*, *Astroblepus, Lithogenes*, and most loricariids, the parasphenoid forms a tall, thin ridge less than a fifth the width of the basioccipital. (state 0). In *Dianema*, *Hoplosternum*, *Lithoxus bovallii* (Regan), some loricariines, and the Rhinelepini, the parasphenoid is very wide (nearly half or greater than the width of the basioccipital and is only slightly raised (state 1).

Pterotic-Supracleithrum

107. Pterotic-supracleithrum expanded anteroposteriorly - 0: no; 1: yes. CI = 0.25.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the pterotic-supracleithrum is a trapezoidal (108-1) or oval bone with the anteroposterior axis shorter than the dorsoventral axis (state 0). In *Acanthicus*, *Panaque nigrolineatus*, and *Megalancistrus*, the pterotic-supracleithrum is oval with the anteroposterior axis longer than the dorsoventral axis (state 1).

108. Shape of pterotic-supracleithrum - 0: square to oval, widest medially; 1: trapezoidal, widest at ventral margin. CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the pterotic-supracleithrum is oval to square and is widest medially (state 0). In the Loricariini, the pterotic-supracleithrum is roughly trapezoidal and widest ventrally (state 1).

109. Perforations in pterotic-supracleithrum - 0: many small; 1: present; 2: complex; 3: only a few, large perforations. CI = 0.60.

In most loricariids, the pterotic-supracleithrum is perforated with numerous small foramina (state 0). In *Acanthicus*, *Megalancistrus*, *Parancistrus*, and *Pseudacanthicus*, the perforations are very large (state 1). In most hypoptopomatines (except *Hypoptopoma*), the perforations are complex with the ventral foramina comparatively large and oval (state 2; see Schaefer, 1991). Callichthyids have only a few (1-4), large perforations (state 3).

110. Pterotic with a process that projects towards the opercle upon which the dilatator operculi muscle attaches - 0: absent; 1: present (Fig. 21). CI = 0.14.

In callichthyids, *Delturus*, some hypoptopomatines, *Ixinandria*, some neoplecostomines, *Rhinelepis*, *Rineloricaria*, and *Upsilodus*, the ventral margin of the pterotic-supracleithrum is straight and lacks an anterior process upon which the dilatator operculi muscle attaches (state 0). In *Lithogenes, Hemipsilichthys bahianus*, *Hemipsilichthys* sp., most of the Hypostominae (except *Rhinelepis*), *Kronichthys*, some of the Loricariinae, *Hisonotus*, *Parotocinclus*, and *Schizolecis*, there is a process extending anteroventrally from the pterotic-supracleithrum that is the origin of the dilatator operculi (state 1; Fig. 21). Based on Schaefer (1986).

111. Anterior process of the pterotic-supracleithrum separated mesially from main body of pterotic-supracleithrum, connected by a ridge (ordered) - 0: process absent to just slightly deflected (Fig. 21A); 1: process deflected with small gap (Fig. 21B); 2: gap large (Fig. 21C). CI = 0.13.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the anterior process of the pterotic-supracleithrum is either absent, present but flush with the pterotic-supracleithrum, or just slightly deflected mesially (state 0; Fig. 21A). In some of the Ancistrini, *Harttia*, most of the Hypostomini, most of the Pterygoplichthini, and *Schizolecis*, the process is deflected mesially such that there is a gap between the main body of the pterotic-supracleithrum and the process into which a sharp probe can be inserted (state 1; Fig. 21B). In most of the Ancistrini, the gap is very large with a strut between the process and the main body of the pterotic-supracleithrum and the dilatator operculi attaches laterally (state 2; Fig. 21C). This character appears to be related to an increase in evertibility of cheek odontodes. It is hypothesized that this character evolved by increasing the deflection of the process in response to increased reliance on the evertible cheek odontodes. By attaching the dilatator operculi laterally, the cheek plates could be better everted; hence, this character is coded as ordered. Based on Schaefer (1986).

112. Forward extent of process of pterotic-supracleithrum - 0: process absent or less than halfway through orbit; 1: halfway through the orbit or greater. CI = 0.17.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the anterior process of the pterotic-supracleithrum is either absent, or short (passing just anterior to the posterior margin of the orbit) (state 0). In several taxa of the Ancistrini, *Hypostomus*, and the *Hemiancistrus annectens* group, the process is longer and passes beyond halfway through the orbit (state 1).

113. Anterior process of the pterotic-supracleithrum bifurcated - 0: process absent or pointed; 1: present. CI = 0.33.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the anterior process of the pterotic-supracleithrum is either absent or pointed (state 0). In *Lasiancistrus* and *Parancistrus*, the anterior process of the pterotic-supracleithrum bifurcates anteriorly such that it has two points (state 1).

114. Strut of the pterotic-supracleithrum directed ventrally so that it is visible from below - 0: absent (Fig. 22A); 1: present (Fig. 22B). CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the anterior process of the pterotic-supracleithrum is either absent or simple when viewed from below (state 0; Fig. 22A). In *Lasiancistrus* sensu stricto (*Lasiancistrus* sp. and *L. maracaiboensis*), there is a posteriorly directed strut leading from the anterior process of the pterotic-supracleithrum to the main body of the pterotic-supracleithrum which is visible from below and which causes the dilatator operculi muscle chamber to be open posteriorly (state 1; Fig. 22B; PTS). Based on Schaefer (1986).

115. Dorsomesial process on pterotic-supracleithrum - 0: absent; 1: present. CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the pterotic-supracleithrum is fairly smooth mesially and does not have a dorsomesial process (state 0). In *Delturus* and *Upsilodus*, there is a long, thin, laminar process that attaches just ventral to where the hyomandibula contacts the pterotic-supracleithrum; the process runs along the anterior margin of the pterotic-supracleithrum and ends well dorsal of the ventral margin of the pterotic-supracleithrum; the dilatator operculi lies between the process and the main body of the pterotic-supracleithrum (state 1). The process in *Delturus* and *Upsilodus* is in no way similar to that of 110-1.

Sphenotic

116. Sphenotic - 0: with a thin ventral process or ventral process absent (Fig. 23B-C); 1: ventral process wide, at least half as wide as main body of sphenotic (Fig. 23A). CI = 0.11.

In callichthyids, *Astroblepus*, and most loricariids, the sphenotic is either round, or round with a thin ventral process along the posterior margin of the orbit with the ventral process less than one fourth the width of the main body of the sphenotic (state 0; Fig. 23B-C). In *Lithogenes*, some *Ancistrus*, *Cordylancistrus*, *Crossoloricaria* sp., *Dolichancistrus* Isbrücker, *Leptoancistrus*, the *Lithoxus* group, *Loricariichthys*, *Parancistrus*, *Pterygoplichthys punctatus*, and *Neoplecostomus*, the ventral process is at least half as wide as the main body of the sphenotic (state 1 Fig. 23A).

117. Sphenotic does not contact posterior-most infraorbital externally - 0: absent, sphenotic and IO6 contact one another externally (Fig. 23A-B); 1: present (Fig. 23C). CI = 0.22.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the sphenotic has an exterior contact with the posteriormost infraorbital (state 0, Fig. 23A-B). In most *Kronichthys*, *Lasiancistrus* sensu stricto, *Lithoxancistrus*, *Megalancistrus*, *Panaque*, *Peckoltia* sp. 2, and *Pseudancistrus*, the sphenotic does not have an external contact with the posteriormost infraorbital (state 1, Fig. 23C).

Supraoccipital

118. Supraoccipital crest - 0: short or absent; 1: raised into a tall crest. CI = 0.50.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the supraoccipital either does not have a crest or the crest is broad and rounded (state 0). In *Leporacanthicus, Pterygoplichthys gibbiceps* (Kner), and *P. lituratus* (Kner), the supraoccipital has a tall, narrow crest (state 1; see Weber, 1992; Page et al., 1996).

VERTEBRAL COLUMN AND RIBS

Centra

119. Anteriorly-directed projection laterally on eighth vertebra - 0: short and broad, or absent; 1: long and pointed, passing between the capitulum and tuberculum of the rib of sixth vertebral centrum. CI = 0.17.

In *Corydoras*, *Astroblepus, Lithogenes*, and most loricariids, the eighth vertebral centrum either lacks anteriorly directed transverse processes or the transverse processes are short and broad (state 0). In all of the Hypostominae except *Acanthicus*, the *Chaetostoma* group, *Dekeyseria scaphirhyncha*, *Leporacanthicus*, and the *Lithoxus* group, the eighth vertebral centrum has long, pointed transverse processes that pass between the capitulum and tuberculum of the rib of the sixth vertebral centrum (state 1).

120. Number of vertebrae from first normal neural spine behind dorsal fin to spine under preadipose plate – unknown (?): preadipose plate absent; 1: 3-8; 2: 9+. CI = 0.67.

In callichthyids, *Astroblepus, Lithogenes*, some *Hypostomus*, and *Isbrueckerichthys duseni* (Miranda Ribeiro), there are more than nine vertebrae from the first normal neural spine posterior to the dorsal fin (loricariids and *Astroblepus, Lithogenes* have bifid neural spines below the dorsal fin) up to and including the vertebra with its neural spine below the preadipose plate (state 0). The number of vertebrae between the dorsal and adipose fins is generally low in most loricariids (3-8; state 1). Species without adipose fins or preadipose plates are coded as unknown (?). In *Astroblepus*, the adipose fin is long and fleshy, and an external view would suggest that there are no bony elements; however, some *Astroblepus* have a small, weak, V-shaped structure located posteriorly within the fleshy adipose fin that appears to be homologous to the adipose-fin spine in callichthyids and loricariids. The spine is not always present, and counts were based on those individuals that do have the spine. In those species with more than one median, preadipose plate, counts were taken to the vertebra below the posterior-most plate. In callichthyids, bifid neural spines are absent, so counts were made from the first centrum posterior to the dorsal fin.

121. Number of vertebrae from first normal neural spine behind dorsal fin up to, but not including, hypural plate (ordered) - 0: 16-20; 1: 12-15; 2: 8-11. CI = 0.28.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the number of vertebrae from first normal neural spine behind dorsal fin up to, but not including the hypural plate is variable. In *Astroblepus, Lithogenes*, some *Hypostomus*, *Isbrueckerichthys duseni*, loricariines, and *Upsilodus*, there are 16-20 vertebrae. In callichthyids and most loricariids, there are 12-15 vertebrae (state 1). In most of the Ancistrini, *Delturus*, *Hemipsilichthys nudulus*, some *Hypostomus*, *Pseudorinelepis*, *Pterygoplichthys*, and *Rhinelepis*, there are 8-11. This character was coded as ordered.

Hemal Spines

122. Bifid hemal spines - 0:absent; 1: present. CI = 0.25.

In callichthyids, *Delturus*, *Hemipsilichthys nudulus*, *Hemipsilichthys splendens*, most hypostomines, and *Upsilodus*, there are no bifid hemal spines (state 0). In *Astroblepus, Lithogenes*, *Acanthicus*, *Corymbophanes*, *Dolichancistrus*, hypoptopomatines, the *Lithoxus* group, loricariines, most neoplecostomines, and *Pogonopoma*, there are one to several centra above (and sometimes behind) the anal fin with bifid hemal spines (state 1). Based on Schaefer (1986; 1987).

Hypurals

123. Hypurals - 0: 2 halves even (Fig. 24A); 1: lower half longer than upper (Fig. 24B). CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and loricariids, hypurals one and two and hypurals three and four are fused to one another, and the lower and upper halves are fused to the last vertebra and form the hypural plate (Schaefer, 1986; 1987). In callichthyids, *Astroblepus, Lithogenes*, *Delturus*, hypoptopomatines, loricariines, neoplecostomines, and *Upsilodus*, the upper and lower lobes of the hypural plate are of the same length (state 0; Fig. 24A). In hypostomines, the lower lobe is longer than the upper lobe (state 1; Fig. 24B). Based on Schaefer (1986, 1987).

124. Posterior margin of the hypural plate - 0: straight, or straight but offset; 1: a posteriorly directed point. CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the posterior margin of the hypural plate is straight, or straight but offset as in 123-1 (state 0). In loricariines, the posterior margins of the upper and lower lobes of the hypural plate are angled such that they form a posteriorly directed point (state 1; Schaefer, 1986; 1987).

Neural spines

125. First neural spine - 0: below first dorsal-fin pterygiophore; 1: in front of first dorsal-fin pterygiophore. CI = 0.43.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the first dorsal-fin pterygiophore contacts the first neural spine ventrally with an occasional, small anterior contact (state 0). In *Dolichancistrus*, *Dekeyseria*, hypoptopomatines, the *Lithoxus* group, loricariines, neoplecostomines, some *Hypostomus panamensis*, and some *Panaque maccus* Schaefer and Stewart, the first neural spine is tall and located anterior to the first dorsal-fin pterygiophore providing a large anterior contact of the neural spine and pterygiophore (state 1).

126. Perforations in the bifid neural spines - 0: absent; 1: present. CI = 0.20.

In callichthyids, *Astroblepus*, and most loricariids, the neural spines under the dorsal fin are not perforated except at the level of the spinal cord (state 0). In *Lithogenes,* most hypoptopomatines, most neoplecostomines, some *Pseudancistrus*, *Scobinancistrus*, and *Upsilodus*, some of the bifid neural spines under the dorsal fin are perforated above the spinal cord (state 1).

127. Trifid neural spines posterior to dorsal fin - 0: absent; 1: present. CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, there are no trifid neural spines behind the dorsal fin, or there may be a trifid neural spine under the last dorsal-fin ray (state 0). In the Loricariinae, all of the centra posterior to the dorsal fin have lateral, accessory neural spines that are not as wide as the central spine making the spines trifid (state 1).

Ribs

128. Shape of distal margin of the rib of the sixth vertebral centrum - 0: about same width as rest of rib (Fig. 25B-D); 1: flared out distally so that the tip is much wider than the shaft (Fig. 25A). CI = 0.08.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the rib of the sixth vertebral centrum is of approximately equal width along its entire length, flaring slightly at the distal end (state 0). In *Acanthicus*, *Corymbophanes kaiei* Armbruster and Sabaj, *Delturus*, *Hemipsilichthys cameroni*, *Lasiancistrus* sensu stricto, *Lithoxus*, *Neblinichthys*, *Neoplecostomus*, *Otocinclus*, *Parotocinclus*, some *Pseudancistrus*, and *Upsilodus*, the distal tip of the rib of the sixth vertebral centrum is approximately one and one half or more times wider than the shaft (state 1).

129. Ribs beyond enlarged rib of the sixth vertebral centrum - 0: thin; 1: absent (Armbruster, 1998b); 2: thick. CI = 0.14.

In callichthyids and most loricariids, the ribs are present and very thin (state 1). In *Hypoptopoma* and the Rhinelepini, ribs are absent posterior to the enlarged rib of the sixth vertebral centrum (Armbruster, 1998b). In *Astroblepus, Lithogenes*, most of the Ancistrini, *Crossoloricaria*, *Delturus*, *Hemipsilichthys nudulus*, *Pterygoplichthys punctatus*, *Upsilodus* the ribs are considerably widened (state 2).

Weberian Complex

130. Complex centrum of Weberian apparatus - 0: relatively short, square (Fig. 25B-D); 1: elongated, rectangular (Fig. 25A). CI = 0.50.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the complex centrum of the Weberian apparatus is short and almost square (state 0; Fig. 25B-D). In *Acanthicus*, *Panaque nigrolineatus*, and *Megalancistrus*, the complex centrum is elongated anteriorly to posteriorly and is at least twice as long as wide (state 1; Fig. 25A).

131. The distal margin of the transverse process of the Weberian complex centrum - 0: thin, about the same width distally as proximally or narrowing distally (Fig. 25B-D); 1: widened, flared distally (Fig. 25A). CI = 0.20.

In most callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the distal margin of the transverse process of the Weberian apparatus is either about the same width as the shaft or the transverse process narrows to a point distally (state 0; Fig. 25B-D). In *Acanthicus*, most hypoptopomatines, *Megalancistrus*, and *Pogonopoma*, the distal margin of the transverse process of the Weberian apparatus is flared distally and much wider than the main shaft of the transverse process (state 1; Fig. 25A).

132. Distal margin of the transverse process of the Weberian complex centrum - 0: wide or rounded (Fig. 25A, C-D); 1: pointed (Fig. 25B). CI = 0.23.

In callichthyids, *Astroblepus*, and most loricariids, the distal margin of the transverse process of the Weberian apparatus is wide or rounded (state 0; Fig. 25A, C-D). In *Lithogenes, Cordylancistrus*, most *Hypostomus*, *Loricariichthys*, most *Panaque*, some *Pterygoplichthys*, *Scobinancistrus*, some *Spectracanthicus punctatissimus*, *Sturisoma*, *Sturisomatichthys*, and *Upsilodus*, the distal margin of the transverse process of the Weberian apparatus is pointed (state 1; Fig. 25B).

133. Anterior edge of the transverse processes of the complex centrum of the Weberian apparatus indistinguishable from the pterotic-supracleithrum - 0: absent; 1: present. CI = 0.14.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the tip of the transverse process of the Weberian apparatus is clearly separated and distinguishable from the pterotic-supracleithrum (state 0; Fig. 25A, C-D). In most *Hypostomus*, *Peckoltia* sp. 1, *Peckoltia oligospila*, some of the *Hemiancistrus annectens* group, and *Pterygoplichthys etentaculatus* (Spix and Agassiz), the anterior margin of the tip of the transverse process of the Weberian apparatus is nearly indistinguishable from the pterotic-supracleithrum with the two bones appearing to fuse (state 1; Fig. 25B). The appearance of fusion in state 1 is caused by the presence of a ridge on the pterotic-supracleithrum. The anterior edge of the transverse process of the Weberian apparatus is flush with this ridge and tightly held to it causing the two to be nearly indistinguishable. The only evidence of the separate nature of the two bones can be found in the quality of the bones; the transverse process of the Weberian apparatus is thin, laminar bone while the pterotic-supracleithrum is thick, more porous bone.

134. Transverse process of the complex centrum of the Weberian apparatus highly perforated distally - 0: no; 1: yes. CI = 0.17.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the transverse process of the Weberian apparatus is not perforated or only moderately perforated distally (state 0). In some of the Ancistrini, most neoplecostomines, most hypoptopomatines, and some *Hypostomus*, the distal end of the transverse process of the complex centrum of the Weberian apparatus is perforated distally with large foramina (state 1).

135. Tip of the transverse processes of Weberian complex centrum - 0: at least partially contacting the pterotic-supracleithrum (Fig. 25B, D); 1: not contacting the pterotic-supracleithrum (Figs. 25A, C). CI = 0.21.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the distal tip of the transverse process of the Weberian complex centrum at least partially contacts the pterotic-supracleithrum (state 0; Fig. 25B, D). In *Acanthicus*, *Chaetostoma sovichthys* Schultz, *Cordylancistrus*, *Corymbophanes andersoni* Eigenmann, some *Dekeyseria scaphirhyncha*, *Dolichancistrus*, *Delturus*, hypoptopomatines, *Leptoancistrus*, *Lithoxancistrus*, some loricariines, *Megalancistrus*, *Neblinichthys roraima*, neoplecostomines, *Pogonopoma*, *Pseudacanthicus*, *Rhinelepis*, and *Upsilodus*, the distal tip of the transverse process of the Weberian complex centrum does not contact the pterotic-supracleithrum (state 1; Figs. 25A, C).

136. Lateral process of tripus (see Fig. 26, LPT) - 0: absent or short (Fig. 26A); 1: long (Fig. 26B). CI = 0.50.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the tripus of the Weberian apparatus forms an almost rectangular arch and may have short processes at the ventrolateral corners of the arch (state 0; Fig. 26A). In *Hypostomus cochliodon* Kner, *H. hondae*, and the *Panaque dentex* group, these lateral processes of the tripus are almost as long as the tripus is tall (Fig. 26B).

DORSAL AND ADIPOSE FINS

Adipose Fin

137. Adipose fin - 0: absent; 1: present. CI = 0.09.

Presence or absence of the adipose fin is quite variable in loricarioids. In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the adipose fin is present (state 0). In *Acanthicus*, most hypoptopomatines, *Leptoancistrus*, loricariines, some neoplecostomines, and most of the Rhinelepini, the adipose fin is absent (state 1).

138. Preadipose plates - 0: 3 or more (Fig. 27C); 1: 0-2 (Fig. 27A-B). CI = 0.20.

In callichthyids, *Delturus*, *Hemipsilichthys nudulus*, *Hemipsilichthys splendens*, *Leptoancistrus*, and *Upsilodus*, there are three or more median, unpaired plates (state 0, Fig. 27C). In loricariids, there is usually a single (rarely two) median, unpaired plate anterior to the adipose-fin spine or the plate is missing (state 1, Fig. 27A-B).

Connecting Bone

139. Connecting bone - 0: absent; 1: a tendon; 2: ossified (Fig. 28). CI = 1.00.

Most catfishes and *Hemipsilichthys nudulus* lack a bone or tendon attaching one of the anterior supporting bones of the dorsal fin to the large rib of the sixth vertebra (state 0). In callichthyids, there is a tendon that attaches the transverse process of the second dorsal-fin pterygiophore to the rib of the sixth vertebral centrum (state 1). In loricariids and *Astroblepus, Lithogenes* (and also in scoloplacids), the tendon is ossified and has been termed the connecting bone by Bailey and Baskin (1976; state 2; Fig. 28). In loricariids, the connecting bone may attach to either the second dorsal-fin pterygiophore or to the nuchal plate or to both (see 141).

140. Connecting bone/tendon – unknown (?): connecting bone absent; 0: flat; 1: cylindrical. CI = 1.00.

In callichthyids and most loricariids, the connecting bone or tendon is a flat, planar structure (state 0). In *Astroblepus, Lithogenes*, the connecting bone is cylindrical (state 1). Species without the connecting bone or tendon were coded as unknown (?).

141. Connecting bone attaches to nuchal plate - 0: no (Fig. 28A); 1: connects with the transverse process of the second dorsal-fin pterygiophore and/or the nuchal plate (Fig. 28B). CI = 0.17.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the connecting bone or tendon originates at the transverse process of the second dorsal-fin pterygiophore (state 0; Fig. 28A). In some hypoptopomatines, most neoplecostomines, and some loricariines, the connecting bone has at least partial contact with the nuchal plate (state 1; Fig. 28B). Some loricariids, such as *Neoplecostomus*, lack contact of the connecting bone and the transverse process of the second dorsal-fin pterygiophore.

Dorsal Fin

142. Number of dorsal-fin rays - 0: six to seven; 1: eight or more. CI = 0.25.

In most callichthyids, *Astroblepus, Lithogenes*, and most loricariids, there are either six or seven dorsal-fin rays (most loricariids have 7; state 0). An increase in the number of dorsal-fin rays to 8 or more has occurred several times including the *Acanthicus* group, the *Chaetostoma* group, *Delturus*, and *Pterygoplichthys* (state 1).

143. Dorsal-fin membrane expanded posteriorly - 0: absent (Fig. 27A); 1: present (Fig. 27B-C). CI = 0.25.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the dorsal-fin membrane continues for a short distance posterior to the base of the last dorsal-fin ray (state 0; Fig. 27A). In *Baryancistrus*, *Delturus*, *Parancistrus*, and *Spectracanthicus*, the dorsal-fin membrane is expanded posteriorly and contacts the preadipose plate (state 1; Fig. 27B-C). In *Delturus*, the dorsal-fin membrane contacts the anteriormost median preadipose plate only in adults.

Dorsal-fin pterygiophores

144. Chain-link of proximal dorsal spine to second dorsal-fin pterygiophore - 0: absent; 1: present. CI = 0.50.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the proximal end of the dorsal spine pivots on a dorsal condyle of the second dorsal-fin pterygiophore (state 0). In most of the Loricariinae examined (except *Harttia*), the second dorsal-fin pterygiophore forms a loop which passes through a foramen at the proximal end of the dorsal-fin spine linking the two structures together like a chain (state 1; Schaefer, 1986; 1987).

145. Number of dorsal-fin radial elements with transverse processes (ordered) - 0: five to six; 1: one to four; 2: none. CI = 0.42.

In callichthyids, some hypoptopomatines, some *Kronichthys* sp. 1, most loricariines, and most *Pterygoplichthys*, there are five to six (state 0) dorsal-fin radial elements with transverse processes. In most loricariids there are one to four radials with transverse processes (state 1). In *Astroblepus, Lithogenes* and *Hemipsilichthys nudulus*, none of the dorsal-fin radial elements have transverse processes (state 2). It is most parsimonious to assume that the number of radials with transverse processes decreased gradually; hence, this character is coded as ordered. Counts begin at the third radial. Based on Schaefer (1991).

Nuchal Plate

146. Nuchal plate - 0: present; 1: absent. CI = 0.50.

In callichthyids and most loricariids, the nuchal plate is present and acts in the functioning of the dorsal-fin spine locking mechanism (state 0). In *Astroblepus, Lithogenes* and *Hemipsilichthys nudulus*, the nuchal plate has been lost (state 1).

147. Nuchal plate – Unknown (?): absent; 0: exposed (Fig. 28); 1: covered entirely by skin or plates. CI = 0.25.

In callichthyids and most loricariids, the nuchal plate is exposed and supports odontodes (state 0; Fig. 28). In *Ancistrus* sp. 1, the *Chaetostoma* group, *Delturus*, *Exastilithoxus* sp., and *Upsilodus*, the nuchal plate is covered by lateral plates and thick skin and usually does not support odontodes except in some large adults (state 1). Species without nuchal plates are coded as unknown (?).

Spinelet

148. Spinelet - 0: V-shaped (Fig. 28A); 1: reduced and rectangular (Fig. 28B) or absent. CI = 0.20.

In callichthyids and most loricariids (as well as most other catfishes), the first dorsal-fin spine is a short, V-shaped structure (often termed the spinelet, Fig. 28, DS1) in front of, and firmly attached to, the second, much longer, dorsal-fin spine (Fig. 28, DS2). The spinelet slips under the nuchal plate to lock the dorsal-fin spine in an upright position by friction (Alexander, 1962; state 0; Fig. 28A). In some hypoptopomatines, many loricariines, most neoplecostomines, and *Upsilodus*, the spinelet is reduced to a rectangular, platelike structure and can no longer lock the dorsal-fin spine into an upright position (Fig. 28B), and in *Astroblepus, Lithogenes*, some *Hemipsilichthys bahianus*, *Hemipsilichthys nudulus*, some hypoptopomatines, *Isbrueckerichthys*, and some loricariines, the spinelet is absent (state 1).

149. Spinelet - Unknown (?): absent; 0: exposed, covered with odontodes; 1: covered with skin. CI = 1.00.

In most loricariids and *Corydoras*, the spinelet is exposed and supports odontodes (state 0). In the *Chaetostoma* group, the spinelet is covered with skin and does not support odontodes or the odontodes do not pierce the skin except in the largest adults (state 1). Species without spinelets are coded as unknown (?).

ANAL FIN

150. Number of branched anal-fin rays (ordered) - 0: six; 1: five; 2: four; 3: three; 4: zero. CI = 0.52.

In examined *Astroblepus, Lithogenes*, there are six branched anal-fin rays and one unbranched ray (state 0). Loricariids have a reduction in the number of branched anal-fin rays with some of the Ancistrini, hypoptopomatines, loricariines, neoplecostomines, and the Rhinelepini having five (state 1), and most of the Hypostominae having four (state 2). In *Chaetostoma platyrhyncha* and *Spectracanthicus murinus*, there are three anal-fin rays (state 3), and the anal-fin rays are lost in *Leptoancistrus* (state 4). Callichthyids, *Delturus*, and *Upsilodus* have 5 or 6 anal-fin rays. *Hemipsilichthys nudulus* has three or four anal-fin rays. It is most parsimonious to assume that the number of anal-fin rays has increased or decreased gradually; hence, this character is coded as ordered. *Leptoancistrus* retains two anal-fin pterygiophores despite losing all anal-fin rays.

151. First anal-fin pterygiophore with a lateral ridge posterior to the widened anterior surface - 0: absent (Fig. 29A); 1: present (Fig. 29B). CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the first anal-fin pterygiophore has a wide anterior surface with a posterior pointing, flat blade (state 0; Fig. 29A). In *Neoplecostomus*, the blade has a strong, lateral ridge which forms a deep trough laterally (state 1; Fig. 29B).

PECTORAL GIRDLE

Adductor Fossa

152. Adductor fossa complete - 0: fossa is incomplete (Fig. 30B); 1: is complete (Fig. 30A). CI = 0.20.

In callichthyids, *Astroblepus, Lithogenes*, and loricariids, there is a fossa for the adductor ventralis muscle of the pectoral girdle that forms an oval ventrally. In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the posterior lip of the fossa terminates at the level of the contact between the coracoid and the cleithrum or just slightly anterior (state 0; Fig. 30B). In some *Hemipsilichthys*, *Isbrueckerichthys*, *Neoplecostomus*, *Pareiorhina* sp., *Schizolecis*, and *Upsilodus*, the posterior lip of the fossa is complete to the anterior lip giving the impression of the fossa being displaced laterally (state 1; Fig. 30A).

153. Adductor ventralis fossa (Armbruster, 1998b)- 0: deep to midline; 1: nearly flat anteromesially. CI = 0.17.

In *Dianema*, *Hoplosternum*, and most loricariids, the adductor fossa of the pectoral girdle forms a cup and is deep to the midline (state 0). In *Corydoras*, *Astroblepus, Lithogenes*, *Lithoxus*, some loricariines, *Pareiorhina* sp., and *Rhinelepis*, the fossa is nearly flat anteromesially (state 1).

154. Adductor fossa exposure (ordered) - 0: exposed; 1: only partially exposed; 2: completely covered in bone. CI = 0.67.

In *Astroblepus, Lithogenes*, and most loricariids, the adductor fossa of the pectoral girdle is exposed ventrally (state 0). In callichthyids and *Schizolecis*, the fossa is partially covered by bone leaving only a small part exposed (state 1). In most of the Hypoptopomatinae, the fossa is completely encased in bone (state 2). It is hypothesized that this character evolved by the successive increase in the size of the shelf; hence, this character is coded as ordered (based on Schaefer, 1991).

Cleithrum

155. Shape of cleithrum (Armbruster, 1998b) - 0: rectangular; 1: trapezoidal. CI = 0.25.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the cleithrum is roughly rectangular (state 0). In *Dekeyseria*, *Lithoxus*, the Loricariini, and *Rhinelepis*, the anterolateral margins of the cleithrum are angled mesially making the cleithrum appear roughly trapezoidal (State1).

156. Shape of posterior margin of the exposed cleithrum - 0: mostly straight and tall; 1: tapers posteriorly to a point. CI = 0.06.

In callichthyids and most loricariids, the cleithrum has an exposed process that passes posterodorsally to the pectoral-fin insertion that is nearly straight posteriorly and tall, roughly forming a rectangle (*Astroblepus, Lithogenes* are similar except that the process is not exposed; state 0). In several loricariids (most notably *Hypostomus*), the process is pointed posteriorly (state 1).

157. Shape and presence of exposed cleithral process - 0: large; 1: reduced. CI = 0.13.

In callichthyids and most loricariids, the cleithral process described in 156 above is exposed and this exposed section is large (state 0). In *Astroblepus, Lithogenes*, *Chaetostoma anomala* Regan, *Crossoloricaria* sp., *Dolichancistrus*, *Leptoancistrus*, the *Lithoxus* group, *Isbrueckerichthys*, *Neoplecostomus*, *Pareiorhina* sp., and *Upsilodus*, the exposed part of the cleithral process is much reduced (state 1).

Coracoid

158. Posterior process of coracoid - 0: posterior section extremely widened (Fig. 31C); 1: posterior section widened (Fig. 31B); 2: elongated, thin, pointed (Fig. 31A). CI = 0.16.

The shape of the posterior process of the coracoid is variable in loricariids. In callichthyids, some hypoptopomatines, some *Hypostomus*, *Panaque*, *Parancistrus*, *Peckoltia*, the Pterygoplichthini, and *Sturisoma* the distal end of posterior process is much wider than the shaft of the process (state 0; Fig. 31C). In some of the Ancistrini, some *Hypostomus*, *Parotocinclus*, *Pogonopoma*, and *Rhinelepis*, the distal end of the posterior process is widened, but about the same width as the shaft of the process (state 1; Fig. 31B). In *Astroblepus, Lithogenes*, most of the Ancistrini, *Delturus*, most loricariines, neoplecostomines, *Rhinelepis*, *Schizolecis*, and *Upsilodus*, the posterior process is pointed distally (state 2; Fig. 31A).

159. Posterior process of coracoid - 0: short; 1: very elongate. CI = 0.33.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the posterior process of the coracoid is not particularly elongate (state 0). In *Acanthicus*, *Harttia*, and *Otocinclus*, the process is extremely elongate (state 1).

160. Posterior section of coracoid - 0: angled upwards mesially, tall; 1: straight, short. CI = 0.17.

In callichthyids, and most loricariids, the coracoid forms part of the posterior wall of the pectoral girdle posteriorly and the contact between the coracoid and the cleithrum is angled dorsomesially and tall (state 0). In *Astroblepus, Lithogenes*, several Ancistrini, *Delturus*, most loricariines, neoplecostomines, *Pterygoplichthys punctatus*, *Rhinelepis*, *Schizolecis*, and *Upsilodus*, the posterior section of the coracoid is reduced with the contact with the cleithrum being low and almost parallel with the ventral margin of the pectoral girdle (state 1).

161. Lateral strut of coracoid - 0: thin (Fig. 30A); 1: wide (Fig. 30B). CI = 0.13.

In *Corydoras*, *Astroblepus, Lithogenes*, and most loricariids, there is a thin, lateral strut on the ventral surface of the coracoid ventral to which the arrector ventralis runs (state 0; Fig. 30A). In *Dianema*, *Hoplosternum*, *Hemipsilichthys bahianus*, *Hemipsilichthys*?, hypoptopomatines, most loricariines, *Pogonopoma parahybae*, and *Pseudorinelepis* the coracoid strut is wide (state 1; Fig. 30B; Armbruster, 1998b).

162. Lateral strut of coracoid (Armbruster, 1998b) - 0: at least partially exposed and bearing odontodes; 1: covered in skin or plates. CI = 0.10.

In most callichthyids, hypoptopomatines, some *Hypostomus*, some loricariines, *Peckoltia ucayalensis*, most *Pterygoplichthys*, and the Rhinelepini, the lateral strut supports at least some odontodes directly (state 0). In *Astroblepus, Lithogenes* and most loricariids, the lateral strut of the coracoid does not support odontodes and is covered either by skin or by bony plates (state 1).

163. Passage of arrector ventralis through a channel - 0: present (Fig. 32A); 1: absent (Fig. 32B-C). CI = 0.13.

In callichthyids, *Lithogenes, Hemipsilichthys bahianus*, *Hemipsilichthys*?, hypoptopomatines, most loricariines, *Pogonopoma parahybae*, and *Pseudorinelepis*, the arrector ventralis passes through a channel in the coracoid strut (state 0; Fig. 32A). In *Astroblepus* and most loricariids, the arrector ventralis passes ventral to the coracoid strut and attaches onto the posterior condyle of the pectoral-fin spine (state 1; Fig. 32B-C). Based on Schaefer (1987; 1991) and Armbruster (1998b).

164. Space between posterior process of coracoid strut and posterior process of coracoid - 0: large (Fig. 32C); 1: absent to small (Fig. 32A-B). CI = 0.13.

In callichthyids, the *Chaetostoma* group, *Crossoloricaria*, *Delturus*, *Hemipsilichthys cameroni*, *Isbrueckerichthys*, *Lithoxancistrus*, the *Lithoxus* group, *Loricaria*, *Neoplecostomus*, *Sturisoma*, and *Upsilodus*, the space between the coracoid strut and the posterior process of the coracoid is much greater than the width of the coracoid strut (state 1; Fig. 32C). In *Astroblepus, Lithogenes* and most loricariids, the coracoid strut has a posterior nub that, fuses with, touches, or is only slightly separated (less than width of coracoid strut) from the posterior process of the coracoid (state 0; Fig. 32A-B).

General

165. Suture of pectoral girdle - 0: present and strong; 1: weak or absent. CI = 0.33.

In callichthyids and most loricariids, the suture between the two halves of the pectoral girdle is very strong (state 0). In *Astroblepus, Lithogenes*, *Delturus*, *Pareiorhina* sp., and *Upsilodus*, the two halves are only weakly held to one another or have no contact (state 1).

166. Pectoral-fin spine greatly elongated in males - 0: no; 1: yes. CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the pectoral-fin spines are either not greatly elongated or are elongated in both sexes (state 0). In *Dolichancistrus*, the pectoral-fin spines are greatly elongated in males only (state 1; Schaefer, 1986).

PELVIC GIRDLE

The basipterygium normally consists of an anterolateral process, an anteromesial process, and a posterior process on each side (Fig. 33).

Basipterygium - Anterolateral Processes

167. Anterolateral processes of basipterygium - 0: curved such that the processes meet or nearly meet at the midline (Fig. 33D-E). 1: slightly angled, do not converge at midline (Fig. 33A, C, F); 2: straight (Fig. 33B). CI = 0.11.

The shape of the anterolateral process is variable. In callichthyids, *Lithogenes*, most of the Ancistrini, *Corymbophanes kaiei*, hypoptopomatines, some loricariines, most neoplecostomines, the anterolateral processes of the basipterygium are curved such that the two anterolateral processes meet or almost meet at the midline (state 0; Fig. 33D-E). In *Astroblepus*, some of the Ancistrini, *Corymbophanes andersoni*, *Delturus*, *Hemipsilichthys nudulus*, the Hypostomini, some loricariines, *Pseudorinelepis*, the Pterygoplichthini, *Rhinelepis*, and *Upsilodus*, the anterolateral processes of basipterygium are slightly angled, but do not converge at the midline (state 1; Fig. 33A, C, F). In *Cordylancistrus*, *Dekeyseria*, some loricariines, *Pogonopoma*, and *Pseudancistrus* sp., the anterolateral processes of basipterygium are straight (state 2; Fig. 33B). In some groups, the anterolateral processes are probably fused to the anteromesial processes and are coded as state 0 (see 168, Fig. 36D).

168. Anterolateral processes fused to anteromesial processes - 0: yes (Fig. 33D); 1:no (Fig. 33A-C, E-F). CI = 0.13.

In callichthyids, *Exastilithoxus*, some hypoptopomatines, *Kronichthys*, some loricariines, and *Pareiorhina* sp., the anterolateral processes are fused to the anteromesial processes (state 0; Fig. 33D). In *Astroblepus, Lithogenes* and most loricariids, the anterolateral processes are free from the anteromesial processes (state 1; Fig. 33A-C, E-F). It is hypothesized that the apparent absence of anterolateral processes is due to fusion rather than loss of either process based on some anomalous specimens where the fusion is not complete on one side and both the anterolateral process and the anteromesial process are visible.

169. Anterolateral process of the basipterygium - 0: thin (Fig. 33A-E); 1: wide through entire length (Fig. 33F). CI = 0.07.

In callichthyids, *Astroblepus*, and most loricariids, the anterolateral process of the basipterygium is thin or tapers to a point (state 0; Fig. 33A-E). In *Lithogenes,* some of the Ancistrini, *Hemipsilichthys* sp., *Hypostomus albopunctatus*, *Isbrueckerichthys alipionis*, *Neoplecostomus*, and the Rhinelepini, the anterolateral process is widened along its entire length (state 1; Fig. 33F). Some hypostomines have a widening at the base of the anterolateral process, but the process tapers to a point distally and these species are considered to have state 0. Those species with the anterolateral processes fused to the anteromesial processes (except *Exastilithoxus*) were coded as having state 0 based on specimens where the fusion is not complete. In *Exastilithoxus*, the anterolateral process clearly contributes more to the fused anterior process than the anteromesial process; hence, *Exastilithoxus* is coded as state 1.

Basipterygium - Anteromesial Processes

170. Anteromesial processes of basipterygium - 0: present (Fig. 33A, C-F); 1: absent (Fig. 33B). CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the anteromesial processes are present (state 0; Fig. 33A, C-F). In *Delturus* and *Upsilodus* the anteromesial projections are absent (state 1; Fig. 33B).

Basipterygium - Main Body

171. Fenestra present anterior to cartilaginous section - 0: absent (Fig. 33A-B, D); 1: present (Fig. 33C, E-F; PF). CI = 0.17.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the basipterygium has a cartilaginous connection posteriorly and lack a large, mesial fenestra anteriorly (state 0; Fig. 33A-B, D). In some loricariines and all hypostomines except *Exastilithoxus*, there is a large, medial, round to oval fenestra on the basipterygium anterior to the cartilaginous section (state 1; Fig. 33C, E-F; PF).

172. Ventral ridge of the basipterygium - 0: tall (Fig. 33C, E); 1: short to absent (Fig. 33A-B, D, F). CI = 0.09.

In most callichthyids and most loricariids, there is a tall ridge anteroventrally on the basipterygium (state 0; Fig. 33C, E; VRPB). In *Astroblepus, Lithogenes*, *Dekeyseria pulcher*, *Delturus*, most neoplecostomines, *Otocinclus*, *Pareiorhina*, *Pogonopoma*, some *Pseudancistrus*, *Pseudorinelepis*, *Pterygoplichthys lituratus*, and *Schizolecis*, this ridge is slight and rounded or is absent (state 1; Fig. 33A-B, D, F).

173. Posteroventral ridge of the basipterygium - 0: absent (Fig. 33A-B, D); 1: present (Fig. 33C, E-F). CI = 0.17.

In callichthyids, *Astroblepus, Lithogenes*, *Delturus*, hypoptopomatines, the *Lithoxus* group, most loricariines, most neoplecostomines, and *Upsilodus*, the basipterygium lacks a ridge at posteroventral margin of the cartilaginous section of the basipterygium (state 0; Fig. 33A-B, D). In *Hemipsilichthys nudulus*, most hypostomines, *Loricariichthys*, *Neoplecostomus*, *Sturisoma*, and *Sturisomatichthys*, there is a short, rounded ridge at the posterior part of the cartilaginous section of the basipterygium (state 1, 35C, E-F; PVRP).

Basipterygium - Posterior Processes

174. Posterior process of the basipterygium (Armbruster, 1998b) - 0: rounded (Fig. 33B-F); 1: pointed (Fig. 33A). CI = 0.33.

In callichthyids, *Lithogenes*, and most loricariids, the posterior processes of the basipterygium are rounded posteriorly (state 0; Fig. 33B-F). In *Astroblepus*, *Nannoptopoma*, and *Pogonopoma*, the processes are pointed posteriorly (state 1; Fig. 33A).

Lateropterygium

175. Lateropterygium of pelvic girdle - 0: absent; 1: wedge shaped; 2: thin; 3: triangular with ventral part widest; 4: disk shaped. CI = 0.57.

The lateropterygium is absent in callichthyids, *Crossoloricaria* and *Loricariichthys* (state 0). In *Astroblepus, Lithogenes* and most loricariids, there is a unique bone of the pelvic girdle called the lateropterygium located at the anterolateral corner of the basipterygium and articulating with the base of the anterolateral process of the basipterygium. In *Neoplecostomus*, the lateropterygium is wedge-shaped (state 1). In most loricariids, the lateropterygium is a thin, rod-shaped bone (state 2). In *Ixinandria*, *Loricaria, Rineloricaria*, and *Sturisoma*, the lateropterygium is triangular with the base of the triangle ventral (state 3). In *Astroblepus*, the lateropterygium is disc-shaped (state 4). Regan (1904) suggested the widening seen in the lateropterygium of *Astroblepus* and *Neoplecostomus* is homologous; however, although the lateropterygium in both is considerably wider than in most loricariids, they are differently shaped. The lateropterygium of *Astroblepus* is circular and widest in the middle, while the lateropterygium of *Neoplecostomus* is wedge-shaped and widest dorsally. Because the two states differ significantly in their shape, they are not homologous.

First Pelvic-fin ray

176. The two halves of the first pelvic-fin ray - 0: fused; 1: separated. CI = 1.00.

The first pelvic-fin ray is composed of two rows of segmented lepidotrichia, one row anterior and one row posterior. In callichthyids and loricariids, the two rows of lepidotrichia of the first pelvic-fin ray are held tightly together and generally fuse distally (state 0). In *Astroblepus, Lithogenes*, the two rows of lepidotrichia of the first pelvic-fin ray are completely and widely separated making it appear as if there are two separate rays (state 1).

177. First pelvic-fin rays greatly widened in adults - 0: absent; 1: present. CI = 0.17.

In callichthyids and most loricariids, the first pelvic-fin ray is fairly thin (state 0). In most of the *Chaetostoma* group, most neoplecostomines, and *Peckoltia ucayalensis*, the first pelvic-fin ray is greatly widened in adults (state 1). *Astroblepus* and *Lithogenes* were coded as state 0 although they also have widened first pelvic-fin rays because the widening in *Astroblepus* and *Lithogenes* is not due to a widening of the lepidotrichia, but a separation of the two rows of lepidotrichia (176-1).

EXTERNAL ANATOMY

Buccal Papillae and Barbels

178. Central buccal papilla - 0: absent or small; 1: large. CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, there is either no central buccal papilla behind the upper jaw or else it is small (state 0). In the *Hypostomus emarginatus* group, there is at least a central papilla and it is large (state 1; see photo in Armbruster and Page, 1996).

179. Many buccal papillae - 0: absent; 1: present behind upper jaw. CI = 0.50.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, there are not numerous papillae to either side of the centra papilla of 178 (state 0). In *Crossoloricaria*, the *Hypostomus unicolor* group, and *Loricaria*, there are numerous papillae in the buccal cavity surrounding the central papilla in 178 (state 1). See Isbrücker and Nijssen (1982) and Armbruster and Page (1996) for photographs of state 1.

180. Single papilla located behind each dentary – 0: absent; 1: present. CI = 0.33.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, there are no large papillae behind the dentary teeth (state 0). In most *Chaetostoma* and *Lithoxancistrus*, each dentary has a single large papilla just behind the teeth (state 1). See Isbrücker et al. (1988) for a photograph of state 2.

181. Barbel adnate or free - 0: free; 1: adnate. CI = 0.33.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the maxillary barbel has at least a small section free from the lip (state 0). In some *Hemipsilichthys*, *Isbrueckerichthys*,

Neoplecostomus, and *Pareiorhina* sp., the barbel has no free section and is completely attached to the lower lip (adnate; state 1).
182. Number of barbels - 0: two to three; 1: one. CI = 1.00.

In callichthyids, there are two to three barbels surrounding the mouth (state 0). In *Astroblepus, Lithogenes*, and loricariids, there is only a single barbel, the maxillary barbel (state 1).

Cheek and Side of Snout

183. Hypertrophied odontodes on cheeks - 0: absent (Fig. 34A); 1: present in nuptial males; 2: present regardless of season or sex (Fig. 34B). CI = 0.18.

In most callichthyids, astroblepids, and most loricariids, there are no hypertrophied odontodes on the cheek (state 0; Fig. 34A). Males of *Delturus*, *Hemipsilichthys*, *Isbrueckerichthys*, *Hypostomus spinosissimus*, and several loricariines develop hypertrophied odontodes on the cheek during the breeding season (state 1). In most of the Ancistrini, *Pogonopoma*, *Pseudorinelepis*, and most of the Pterygoplichthini, both males and females develop hypertrophied odontodes on the cheek and the odontodes are not restricted to the breeding season (they may be better developed in nuptial males; state 2; Fig. 34B). Isbrücker and Nijssen (1992) provide an excellent set of photographs of the various modifications of the cheek armature in loricariids.

184. Evertible cheek plates (ordered) - 0: absent (Fig. 34A); 1: slightly evertible; 2: fully evertible (Fig. 34B). CI = 0.50.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the cheek plates are either absent or secured tightly to the preopercle (state 0). Evertible cheek odontodes are generally referred to as evertible interopercular spines or the Ancistrini are referred to as having an evertible interopercular area, but because loricariids lack interopercles (Schaefer, 1987; 1988) it is incorrect to dub the cheek as being the interopercular area. In addition, referring to evertible cheek odontodes is not precise. The structures that are evertible are the plates that support the odontodes, and the cheek plates may be evertible but lack hypertrophied odontodes. For these reasons, I use the phrase "evertible cheek plates", and I separate the condition of having hypertrophied odontodes on the cheek (183-1 and 2) from having evertible cheek plates.

Recent authors (Isbrücker, 1980; Burgess, 1989; Schaefer, 1987) usually just refer to members of the Ancistrini and the *Hemiancistrus annectens* group as having evertible cheek plates; however, earlier authors (for example, Regan, 1904) also recognize *Pterygoplichthys* as having evertible cheek plates. Weber (1991) also suggests that some *Pterygoplichthys* have evertible cheek plates. Problems in observing the evertibility of cheek plates in some species of *Pterygoplichthys* (the *P. multiradiatus* group) are made difficult because the cheek plates do not support hypertrophied odontodes. However, in life, the evertibility of the cheek plates of the *P. multiradiatus* group can be readily observed and there is no difference in this ability between species of the *P. multiradiatus* group and other members of *Pterygoplichthys* (Regan, 1904; pers. obs.). Clearly, there is some variability in the ability to evert the cheek plates in the Hypostominae that has been causing problems for researchers. Examination of the cheek plates of all of the loricariids in this study suggest that there are two relatively distinct states of evertibility of the cheek plates based on the angle the cheek plates can be everted from the head.

Hypostomus is intermediate in the ability to evert the cheek plates between noneverters such as the Rhinelepini and everters of the Pterygoplichthini + Ancistrini. In *Hypostomus*, *Pseudancistrus*, and *Spectracanthicus murinus*, the cheek plates are slightly loosened from the preopercle posteriorly (connected only by loose connective tissue and muscle) and can be everted up to approximately 30° from the head (state 1); the states in *Pseudancistrus* and *Spectracanthicus murinus* represent reversals. In the remainder of the Ancistrini and the Pterygoplichthini, the posterior cheek plates are only loosely connected to the preopercle by connective tissue and muscle and can be everted greater than 75° from the head (state 2). Although there is wide variation in the ability of species with state 2 to evert the cheek plates, all species of *Pterygoplichthys* can evert the cheek plates at least as well as *Chaetostoma*, *Spectracanthicus punctatissimus*, and *Leporacanthicus*. This character was coded as ordered because state 1 is clearly intermediate in the ability to evert the cheek plates.

185. One or two extremely hypertrophied odontodes on cheek - 0: absent; 1: present. CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, hypertrophied odontodes are either absent, the odontodes are fairly short, or there are much more than one or two (state 1). In *Dolichancistrus* and *Leptoancistrus*, the evertable cheek plates usually have only one (occasionally two) extremely hypertrophied odontode that is about the same length or longer than the head (state 1). *Dolichancistrus* and *Leptoancistrus* appear to occasionally shed their hypertrophied cheek odontodes, so it is fairly common for specimens to either not have hypertrophied cheek odontodes or have odontodes that are still in a state of growth.

186. Whiskerlike odontodes - 0: absent (Fig. 34A); 1: present (Fig. 34B). CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, there are no whiskerlike odontodes on the cheek (state 0; Fig. 34A). In *Lasiancistrus* sensu stricto, there are some extremely long and thin odontodes on the cheek plates that look like whiskers among the stout, evertible cheek odontodes (state 1; Fig. 34B; WO); the whiskerlike odontodes can also be found along the snout in some species. The whiskerlike odontodes appear to be best developed in nuptial males, but are also present in females and juveniles.

187. Fleshy pad covering odontodes on cheeks of nuptial males - 0: absent; 1: present. CI = 0.50.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, there are no hypertrophied odontodes on the side of the snout embedded in thick skin (state 0). Normally in loricariids, hypertrophied odontodes appear to be correlated with a thickening of the skin of the plates supporting the odontodes. In nuptial males of *Hemipsilichthys* and *Isbrueckerichthys* this swelling reaches an extreme and usually forms a thick fold of skin around the snout (state 1). The posterior process of the cleithrum also develops a thick layer of skin in fishes with state 1.

188. Hypertrophied odontodes along snout anterior of cheek spines - 0: absent; 1: present. CI = 0.08.

In most callichthyids, *Astroblepus, Lithogenes*, and most loricariids, there are no hypertrophied odontodes along the snout margin (state 0). In the *Acanthicus* group, *Dekeyseria*, *Delturus*, *Dolichancistrus*, most *Hemipsilichthys*, *Hypostomus spinosissimus*, *Isbrueckerichthys*, *Ixinandria*, *Lasiancistrus*, *Leptoancistrus*, *Neblinichthys*, *Pogonopoma*, *Pseudancistrus*, *Pseudorinelepis*, *Rineloricaria*, *Sturisoma*, *Sturisomatichthys*, and *Upsilodus*, there are hypertrophied odontodes anterior to the cheek along the snout margin in at least nuptial males (state 1). Size of the snout odontodes is variable with the extreme in some *Hemipsilichthys* and in *Pseudancistrus*. *Pseudancistrus* and *Pseudolithoxus*, are notable because females also possess hypertrophied odontodes along the snout. See Isbrücker and Nijssen (1992) for photographs.

General

189. Optic notch - 0: absent; 1: present. CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the sphenotic posterior to the orbit does not develop a concavity (state 0). In the Loricariini there is a distinct notch posterior to the eye referred to as an optic notch (state 1).

190. Position of pectoral fins in relation to first pelvic-fin ray when depressed parallel to body axis - 0: above and separated from first pelvic-fin ray; 1: even with or resting on top of first pelvic-fin ray. CI = 0.33.

In callichthyids, *Astroblepus, Lithogenes*, *Corymbophanes*, *Delturus*, *Exastilithoxus fimbriatus*, hypoptopomatines, loricariines, neoplecostomines, most of the Rhinelepini, and *Upsilodus*, when the pectoral fin is adpressed parallel to the body axis, it rests above and does not contact the first pelvic-fin ray (state 0). In most of the Ancistrini, the Hypostomini, *Pogonopoma*, and the Pterygoplichthini, the pectoral fins insert on the same plane as the pelvic fins so that when adpressed, the pectoral-fin spine rests on top of the first pelvic-fin ray and there is no space between the two (state 1). Some fishes have the pectoral fin angled slightly dorsally, so it is necessary to lower the spine so that it is parallel to the main axis of the body to examine this characteristic.

191. Number of caudal-fin rays - 0: 10 or 12; 1: 14. CI = 0.33.

In callichthyids, *Astroblepus, Lithogenes*, and loricariines, there are either 10 or 12 principal caudal-fin rays (state 0). In *Lithogenes* and most loricariids, there are 14 principal caudal-fin rays (state 1).

192. Postdorsal ridge - 0: absent; 1: present. CI = 0.33.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the dorsum lacks a ridge posterior to the dorsal fin (state 0; Fig. 27A-B). In *Delturus*, *Leptoancistrus*, and *Upsilodus*, a ridge made up of raised, median plates is present posterior to the dorsal fin; the ridge is referred to as a postdorsal ridge below (state 1; Fig. 27C).

193. Lips forming suckerlike disc - 0: absent; 1: present. CI = 1.00.

In callichthyids and most other catfishes, the lips do not form a sucking disc (state 0). In *Astroblepus, Lithogenes* and loricariids, the lips are expanded into a suckerlike disc (state1).

Plates

194. Numerous small plates behind pterotic-supracleithrum (Armbruster, 1998b) - 0: no; 1: yes. CI = 0.33.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, there are either just a few small plates (1-3), a naked area, or a medium-sized plate posterior to the pterotic-supracleithrum at the level of the lateral line (state 0). In *Isbrueckerichthys*, *Neoplecostomus paranensis*, *Pareiorhina*, *Pogonopoma*, and *Rhinelepis*, there is a patch of numerous small plates just posterior to the pterotic-supracleithrum (state 1; Armbruster, 1998b).

195. Plates meet prior to anal fin - 0: present; 1: absent. CI = 0.25.

In callichthyids, hypoptopomatines, loricariines, and *Pterygoplichthys zuliaensis* Weber, at least one pair of lateral plates contact one another externally along the ventral midline between the anus and the anal fin (state 0). In most loricariids, the lateral plates do not meet along the midline between the anus and the anal fin (state 1).

196. Number of plate rows at thinnest part of caudal peduncle - 0: none; 1: two; 2: three; 3: five or more. CI = 0.33.

Astroblepus has no plates (state 0). There are two rows of lateral plates in callichthyids (state 1). In *Lithogenes*, *Ancistrus*, *Lasiancistrus*, *Dekeyseria*, the *Lithoxus* group, loricariines, hypoptopomatines, and most neoplecostomines, there is at least one transverse column of three rows of plates on the thinnest part of the caudal peduncle (state 2). In the remainder of the Loricariidae, there are usually five, rarely more (*Isbrueckerichthys duseni* often has more than five rows), transverse rows of plates on the caudal peduncle (state 3).

197. Number of predorsal plates - 0: plates absent; 1: two to three; 2: four or more. CI = 0.14.

The number of predorsal plates are the number of median plates between the supraoccipital up to and including the nuchal plate (when present). The nuchal plate is also included in those species with the nuchal plate covered in skin or lateral plates (147-1). In *Astroblepus, Lithogenes* and *Hemipsilichthys nudulus*, there are no predorsal plates (state 0). In callichthyids, most of the Ancistrini, most of the Hypostomini, some loricariines, *Hisonotus*, the Pterygoplichthini, and the Rhinelepini, there are two to three predorsal plates (state 1). In *Ancistrus*, the *Chaetostoma* group, *Corymbophanes*, *Delturus*, most hypoptopomatines, *Hypostomus albomaculatus*, *Lasiancistrus* sensu stricto, *Leporacanthicus*, *Lithoxancistrus*, the *Lithoxus* group, some loricariines, *Neblinichthys*, most neoplecostomines, *Spectracanthicus murinus*, and *Upsilodus*, there are four or more predorsal plates.

198. Plates keeled - 0: plates absent or unkeeled to moderately keeled; 1: very well-developed keel. CI = 0.33.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, there are either no lateral plates, the plates are smooth, or the plates do not develop extremely strong keels of bone and odontodes (state 0). In the *Acanthicus* group, *Dekeyseria*, and *Pterygoplichthys punctatus*, the keels are particularly well developed and the odontodes forming them are long, stout, and sharp (state 1).

199. Hypertrophied odontodes on bodies of nuptial males - 0: absent; 1: present. CI = 0.17.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, there are no hypertrophied odontodes on the sides of nuptial males (state 0). In the *Hypostomus emarginatus* group, *Neblinichthys*, *Panaque albomaculatus*, *P. maccus*, *Parancistrus*, and *Peckoltia*, males develop hypertrophied odontodes on the lateral plates during the breeding season (Isbrücker and Nijssen, 1992; Armbruster and Page, 1996; state 1). Some of the species with state 1 appear to develop the hypertrophied odontodes only during the breeding season, and lose them after the breeding season (Armbruster and Page, 1996).

200. Extremely elongated odontodes on top of the snout; 0: absent; 1: present. CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the snout lacks hypertrophied odontodes dorsally (state 0). In *Neblinichthys*, nuptial males develop extremely hypertrophied odontodes on the snout that are oriented anteriorly (state 1; Ferraris et al., 1986).

201. Snout - 0: naked from just anterior to nares to lip; 1: with plates. CI = 0.25.

In *Astroblepus, Lithogenes*, callichthyids, *Ancistrus*, and most *Chaetostoma*, there are no odontode-bearing plates on the snout (state 0). In most loricariids, the entire margin of the snout is covered in plates (state 1). *Ancistrus* actually does have small, weak ossifications at the base of each of the large tentacles; however, these plates do not support odontodes.

202. Snout – 0 naked or with many plates; 1: one or two solid plates. CI = 1.00.

In *Astroblepus, Lithogenes*, callichthyids, and most loricariids, there are no odontode-bearing plates on the snout or the plates are numerous and small (state 0). In *Hypoptopoma*, *Hisonotus*, *Nannoptopoma*, and *Otocinclus*, the snout margin consists of one or two large plates (state 2; Schaefer, 1991).

203. Abdominal plating - 0: absent; 1: present. CI = 0.14.

Callichthyids, *Astroblepus, Lithogenes*, *Ancistrus*, *Baryancistrus*, the *Chaetostoma* group, *Corymbophanes*, *Delturus*, *Dekeyseria*, *Hemiancistrus megacephalus*, most *Lasiancistrus*, *Leporacanthicus*, the *Lithoxus* group, *Neblinichthys*, most neoplecostomines, *Spectracanthicus murinus*, and *Upsilodus*, completely lack plates on the abdomen (state 0). Most of the *Acanthicus* group, most *Hemiancistrus* Bleeker, *Hypancistrus*, the Hypostomini, *Isbrueckerichthys*, most loricariines, *Panaque*, *Parancistrus*, *Peckoltia*, the Pterygoplichthini, and the Rhinelepini, *Scobinancistrus*, and *Spectracanthicus punctatissimus*, have at least some small plates on the abdomen (state 1).

Teeth

204. Unicuspid teeth in nuptial males (Armbruster and Page, 1996) - 0: bicuspid or unicuspid in all individuals; 1: unicuspid and elongated only in nuptial males. CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the teeth are either unicuspid in all individuals or are bicuspid (state 0). In members of the *Hypostomus unicolor* group, females, non-nuptial males, and juveniles have bicuspid teeth, but nuptial males develop hypertrophied, unicuspid teeth, particularly mesially (state 1).

205. Teeth - 0: viliform (Fig. 35A-B); 1: spoon-shaped (Fig. 35C); 2: large, but not spoon-shaped (Fig. 35D). CI = 0.29.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the teeth are viliform (threadlike; state 0; Fig. 35A-B). In the *Hypostomus cochliodon* group and *Panaque*, the teeth are enlarged and spoon shaped and the lateral cusp is absent or reduced; the teeth are used to scrape off small bits of wood which are then consumed (Schaefer and Stewart, 1993; state 1; Fig. 35C). In *Leporacanthicus*, the *Lithoxus* group, *Hypancistrus*, *Megalancistrus*, *Pseudacanthicus*, *Scobinancistrus*, and *Spectracanthicus*, the teeth are wide and long, but are not spoon-shaped (state 2; Fig. 35D). *Hypostomus hemicochliodon* has teeth that approach the spoon-shaped teeth of *Cochliodon*, but were not coded as state 1 (Fig. 35B). The diet of *Hypostomus hemicochliodon* consists mostly of wood, but the percent of wood in its diet is not as high as in the *H. cochliodon* group or *Panaque*.

Tentacles

206. Fleshy appendages around both jaws - 0: absent; 1: present. CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, there are no fleshy appendages (often referred to as barbels) around the jaws (state 0). In *Crossoloricaria* and *Loricaria*, the entire mouth is surrounded by long, thin, barbel-like structures (state 1).

207. Lower lip fimbriate – 0:absent; 1: present. CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the lower lip is either smooth or with numerous barbel-like structures (state 0). In *Exastilithoxus*, the posterior margin of the lower lip has elongate, fleshy extensions (fimbriae; state 1).

208. Fleshy tentacles on snout (ordered) - 0: absent; 1: present, sheath mostly attached to an odontode; 2: present - sheath long and well separated from odontode; 3: present - very long, odontodes missing. CI = 0.75.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, there are no fleshy tentacles on the snout (state 0). Primitively, odontodes have a sheath which may be responsible for the growth of the odontode. This sheath normally surrounds the odontode equally on all sides (state 0). In *Dekeyseria*, *Pseudolithoxus*, *Neblinichthys*, and *Pseudancistrus*, the sheath has become partially detached from the odontode and exists as a tentacule (tentacule is the word used by Sabaj et al., 1999 to describe a small tentacle associated with an odontode; state 1). In *Lasiancistrus* sensu stricto, the tentacule is long and sometimes branched with the tentacule longer than the supporting odontode (state 2). *Ancistrus* has lost the odontodes and well-developed snout plates and the tentacles develop without odontodes (state 3). It is hypothesized that the tentacules first formed by the odontode erupting from the side of the odontode sheath rather than the middle. Because most of the skin of loricariids contains taste buds, the formation of a small tentacule probably increases the efficiency of the skin to taste particles. In some groups, the increased sensitivity led to an increase in the size and complexity of the tentacules such that they are branched and larger than the associated odontode. In *Ancistrus*, the tentacules became even larger (now a tentacle) and the supporting odontode is lost. Sharp odontodes may be a liability to male loricariids when they are tending eggs inside of nest cavities and the tentacules may have a secondary purpose to blunt the point of the odontodes when attending eggs, but retain the sharp odontodes for fighting. In addition, *Ancistrus* do have small ossifications at the base of most of the tentacles; these ossifications are very thin, weak plates that do not support odontodes. Plates are found nowhere else along the snout of *Ancistrus* except at the base of tentacles. This character is coded as ordered because it is most parsimonious to assume that the character increased in size for an increase in surface area for taste and for the potential use of the structures as larval mimics as suggested by Sabaj et al. (1999).

209. Tentacules on pectoral fins (ordered) - 0: absent; 1: present, small, mostly attached to odontode; 2: present, larger than odontode. CI = 0.40.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, there are no tentacules on the pectoral-fin spine (state 0). As in Character 28, *Chaetostoma platyrhyncha*, *Dekeyseria*, *Lithoxancistrus*, *Pseudolithoxus*, *Neblinichthys*, *Parancistrus*, develop short tentacules slightly separated from the odontodes as in 208-1 (state 1). *Lasiancistrus* sensu stricto and *Ancistrus* have large tentacules free from the odontodes and longer than them (state 2). This character is coded as ordered (see above for reasoning). See Sabaj et al. (1999) for more detail.

GASTROINTESTINAL SYSTEM

Esophagus

210. Esophagus - 0: bent; 1: straight. CI = 0.33.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the esophagus bends to the right upon entering the visceral cavity (state 0). In *Lithoxus*, the Rhinelepini, and *Otocinclus*, the esophagus passes straight to the stomach (state 1). See Armbruster (1998b) for more detail.

211. U-shaped diverticulum off stomach (ordered) - 0: absent; 1: present, expandable, loosely attached to abdominal wall; 2: present, expandable, firmly attached to abdominal wall; 3: present, swim-bladderlike. CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the digestive tract lacks a diverticulum that holds air or else the diverticulum is not U-shaped (state 0). The Rhinelepini is diagnosed by a large, two part, U-shaped diverticulum at the level the esophagus and the stomach meet. In *Pseudorinelepis*, the diverticulum is loosely held to the abdominal wall and is intraperitoneal (state 1). In *Rhinelepis*, the diverticulum is still intraperitoneal, but is firmly attached to the abdominal wall (state 2). In *Pogonopoma*, the diverticulum is much wider, is retroperitoneal, and has a reduced first section (state 3). It is hypothesized that the diverticulum evolved first as an intraperitoneal organ, became firmly attached to the abdominal wall, and then became retroperitoneal. Because the digestive tract is intraperitoneal, it is unlikely that the diverticulum would first evolve as a retroperitoneal organ and then move back inside the peritoneum; hence, this character is coded as ordered. See Armbruster (1998c) for more detail. Armbruster (1998b) tested the ordering of this character by removing it from his analysis; the resultant tree was the same as with the character added, thereby supporting the ordering of this character. Armbruster (1998b) suggests that *Pogonopoma parahybae* is unique among the Rhinelepini in lacking the initial, short, anteriorly directed section of the second part of he diverticulum; however, after further scrutiny, this characteristic is more variable in the Rhinelepini than first believed.

212. Diverticulum off of stomach nearly completing a ring - 0: absent; 1: present. CI = 1.00.

In callichthyids, astroblepids, and most loricariids, the digestive tract lacks a diverticulum that holds air or else the diverticulum is not shaped like a ring (State 0). In *Otocinclus*, there is a ringlike diverticulum that begins on the right side of the body, passes anteriorly, runs down the left side of the body, passes through the peritoneum, and terminates at about the same level it started (State 1, Schaefer, 1997; Armbruster 1998).

Stomach

213. Stomach greatly expanded and connected to the abdominal wall by a connective tissue sheet - 0: absent; 1: present. CI = 1.00.

In many loricariids, the stomach may be expanded to hold air or is not expanded as in *Astroblepus, Lithogenes* and callichthyids (state 0). In the Pterygoplichthini, the stomach is greatly expanded, highly vascularized, and is covered ventrally with a connective tissue sheet made up of numerous interconnecting and overlapping bands that attach the stomach to the abdominal wall (state 1). See Armbruster (1998c) for more detail.

214. Stomach expanded such that it extends anteriorly to the pectoral girdle and exits dorsally of expanded region - 0: absent; 1: present. CI = 1.00.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the stomach is not expanded such that the intestine exits the stomach dorsal to the stomach (state 0). In *Lithoxus*, the stomach is expanded such that the anterior margin is just posterior to the pectoral girdle. The stomach narrows prior to the pylorus which is located dorsal to the expanded stomach (state 1). See Armbruster (1998c) for more detail.

Swim Bladder

215. Swim bladder - 0: restricted to a small area anterior to the rib of the sixth vertebral centrum (Fig. 25B-D); 1: extremely large, to or beyond the rib of the sixth vertebral centrum (Fig. 25A). CI = 0.50.

In callichthyids, *Astroblepus, Lithogenes*, and most loricariids, the swim bladder is reduced and restricted to an encapsulated region anterior to the rib of the sixth vertebral centrum (state 0; Fig. 25B-D). In *Acanthicus*, *Panaque nigrolineatus*, and *Megalancistrus*, the swim bladder is greatly expanded and extends to or beyond the rib of the sixth vertebral centrum (state 1; Fig. 25A). In at least *Megalancistrus* and *P. nigrolineatus*, the size of the swim bladder increases with body size. *Acanthicus* has the most extreme development of the swim bladder and the rib of the sixth vertebral centrum fits into a groove ventral to the swim bladder capsule (Fig. 25A).