Geological Magazine, Earliest North American articulated freshwater acanthomorph fishes (Teleostei: Percopsiformes) from the Late Cretaceous of Alberta, Canada, Alison M. Murray, Donald B. Brinkman, Michael G. Newbrey, and Andrew G. Neuman, Supplementary Material, Appendices 1–3.

**Appendix 1. Characters used in phylogenetic analysis.**

Abbreviations for references are P&R89 – Patterson and Rosen, 1989; M94 – Murray 1994; W&M96 – Wilson and Murray, 1996; M&W99 – Murray and Wilson, 1999; TG13 – Grande, T., et al., 2013; D16 – Davense et al., 2016; TG18 – Grande, T., et al., 2018. Characters found in the course of this study are identified as ‘new’.

1. Postmaxillary process of premaxilla [P&R89]: 0) present; 1) present with a gadoid notch; 2) absent. A postmaxillary process is present in *Polymixia*. The process is notched posteriorly (the ‘gadoid notch’) in *Sphenocephalus, Xenyllion, Lota* and *Microgadus*. In the other taxa, the process is absent. The premaxilla is not clear in Pisces Point, *Cumbaaichthys* and *Boreiohydrias*.
2. Alveolar process of premaxilla [P&R89]: 0) single element, not segmented; 1) ‘segmented’ or the alveolar process is followed by several lateromaxillae (see Armbruster et al., 2016 for justification of terminology). This is a feature of amblyopsids, *Aphredoderus* and *Trichophanes*. None of the other taxa have lateromaxillae.
3. Dorsal process of maxilla [M&W99]: 0) absent; 1) present. The maxilla bears a dorsal process in *Amphiplaga, Percopsis, Erismatopterus, Massamorichthys,* and *Lateopisciculus*. We think the process is present in Pisces Point, but there is some uncertainty so we have coded it as unknown.
4. Relative length of upper jaw bones [M&W99]: 0) premaxilla equal to or longer than maxilla; 1) premaxilla clearly shorter than maxilla. Murray and Wilson (1999) coded all taxa in their Paracanthopterygii (excluding *Sphenocephalus*) to have the premaxilla shorter than the maxilla; however, their coding was in part based on figured material in which the relative lengths of the upper jaw bones can be difficult to determine. Here, we code only *Zeus, Lota, Percopsis*, *Massamorichthys* and *Lateopisciculus* as having a premaxilla that is clearly shorter than the maxilla.
5. Number of supramaxillae [M&W99]: 0) two; 1) one; 2) none. There are two supramaxillae in *Polymixia, Cumbaaichthys* and *Boreiohydrias*. The anterior supramaxilla in *Polymixia* and *Boreiohydrias* are small, square bones, that abut the much larger posterior supramaxilla that lacks a projection over the anterior supramaxilla. The posterior supramaxilla of *Cumbaaichthys* appears to have an anterior projection. *Sphenocephalus* and *Xenyllion* have a single long, narrow supramaxilla. All the other taxa in the matrix have no supramaxillae.
6. Large ventral excavation of dentary [new]: 0) absent; 1) present. The dentary in *Libotonius, Amphiplaga, Percopsis, Erismatopterus, Massamorichthys, Lateopisciculus, Trichophanes* and Pisces Point has a deep excavation on the lateral surface ventral to the lamina that bears the teeth. A similar condition is also found in *Lota* and *Microgadus*, although the dentary of these two is proportionally longer than that of the others. The rest of the taxa have a deep lateral wall of the dentary with no excavation.
7. Dorsal process of lacrimal [M&W99]: 0) absent; 1) present. All included taxa have a strong spike-like dorsal process except *Polymixia, Cumbaaichthys, Boreiohydrias* and *Zeus*.
8. Lacrimal and infraorbital ornamentation [M&W99]: 0) absent; 1) serrations or small spines present. Serrations or small spines are found in *Boreiohydrias, Sphenocephalus, Xenyllion, Trichophanes,* and *Aphredoderus*; all other taxa have smooth infraorbital bones.
9. Infraorbitals (excluding lacrimal), depth of most [TG18]: 0) deep; 1) relatively slender and tubular. The states of this character have been modified to suit the included taxa. The infraorbital bones of most included taxa are deep, with a flange over the sensory canal. The infraorbitals are slender and tubular only in *Zeus* in this study, causing this character to be uninformative here.
10. Vomerine teeth [TG18]: present (0); absent (1). Most of the fossil taxa cannot be coded for this character. They are coded as absent only in the fossil taxon in which the vomer can be clearly seen (*Massamorichthys*), and in *Percopsis*. Teeth are coded as present only in *Polymixia, Trichophanes, Amblyopsis, Zeus* and *Lota*. The vomer is not clear in our specimens of *Microgadus*.
11. Metapterygoid, size and articulation [TG18]: 0) relatively large, length c. 3/4 or more of the length of the quadrate, and articulating with it; 1) reduced, length c. or less of the length of the quadrate, and not articulating with it, or absent. We combined the reduction of the metapterygoid (only in *Zeus*) with its complete absence (in *Lota* and *Microgadus*) although these were separate states in the previous studies. In all other taxa where the metapterygoid can be clearly seen it is large and articulates along the dorsal edge of the quadrate.
12. Orbitosphenoid [D16]: 0) present; 1) absent. According to Rosen and Patterson (1969) the orbitosphenoid is present in *Polymixia*, but absent in *Sphenocephalus, Percopsis, Aphredoderus, Amblyopsis* and gadiforms. We also code it as present in *Cumbaaichthys*; in the other fossil taxa it is not clear whether the orbitosphenoid is truly absent or only appears absent based on preservation, so we have left those as unknown.
13. Length of supraoccipital crest [M&W99]: 0) short, not reaching first neural spine; 1) reaching posteriorly beyond level of first neural spine. This feature is different from character 36 which refers to the contact between the first neural spine and the back of the skull, in that the supraoccipital crest in *Percopsis* extends posteriorly past the first neural spine, but the spine is not in contact with the posterior skull. The long supraoccipital crest is found in *Mcconichthys, Percopsis and Massamorichthys,* as well as the gadiforms *Lota* and *Microgadus*. In the other taxa, the supraoccipital crest is short, not reaching the first neural spine.
14. Opercular shape [modified from M&W99]: 0) rounded ventrally with no strong posterior spine; 1) sharply pointed ventrally with strong horizontal ridge extending posteriorly as a spine. The distinctive opercle with strong anterior and horizontal ridges extending to the edges of the bone in sharp points is found in all included taxa except *Polymixia, Cumbaaichthys, Boreiohydrias,* and *Zeus*. In these four taxa, the ventral tip of the opercle is more rounded, and in all but *Zeus*, the horizontal ridge extending from the facet for articulation with the hyomandibular does not extend to the posterior edge of the opercle.
15. Dorsal portion of opercle above horizontal ridge from facet for articulation with hyomandibula [modified from M&W99]: 0) broadly rounded, extends across width of bone with no excavations; 1) vertical anteriorly with an excavation or absence of the process posteriorly; 2) constricted to the middle portion of the bone; 3) absent. The broadly rounded dorsal projection is found in *Polymixia, Cumbaaichthys, Boreiohydrias* and *Amblyopsis*. In *Spenocephalus, Xenyllion, Lota* and *Microgadus*, the anterior edge of the dorsal process is more or less vertical from the facet for articulation with the hyomandibula, but posteriorly is excavated or absent. In the rest of the taxa except *Zeus*, the dorsal process of the opercle is confined to the middle part of the bone. In *Zeus*, there is no dorsal extension of the opercle above the horizontal ridge from the hyomandibular facet.
16. Posterodorsal edge of opercle [W&M96]: 0) not recurved; 1) recurved. The posterior end of the dorsal process in *Sphenocephalus* and both species of *Xenyllion* is distinctively recurved, unlike any other taxon examined.
17. Preopercular spines [M94, W&M96]: 0) absent, edges smooth; 1) small serrations present; 2) a few strong spines present. In most taxa the preopercle is either smooth (*Cumbaaichthys, L. blakeburnensis, Percopsis, Erismatopterus, Aphredoderus, Amblyopsis, Zeus, Lota, Microgadus*), or has small serrations or denticles irregularly placed along the edges (*Polymixia, Boreiohydrias, L. pearsoni, Mcconichthys, Amphiplaga, Massamorichthys, Lateopisciculus, Trichophanes,* andPisces Point). In *Sphenocephalus* and both species of *Xenyllion*, the preopercle bears three or four very large spines around the angle of the bone.
18. Preopercle shape [M94]: 0) distinct vertical and horizontal limbs forming a distinct angle; 1) limbs not distinct, rounded overall. The majority of the included taxa have vertical and horizontal limbs of the preopercle forming a 90 degree angle; only *Amblyopsis* and *Zeus* have preopercles that are more curved, lacking a strong angle.
19. Relative lengths of vertical and horizontal limbs of the preopercle when they form a distinct angle: 0) more or less equal in length; 1) vertical limb distinctly longer (1.5 or more times as long). Most taxa have limbs that are equal in length or one limb is only slightly longer; however, *Sphenocephalus* and both species of *Xenyllion* have the horizontal limb only about half as long as the vertical. In none of the included taxa was the horizontal limb significantly longer than the vertical.
20. Subopercle anterior projection [M94]: 0) with a strong spike; 1) blunt; 2) absent (no projection). Anteriorly, the ventral tip of the subopercle has a sharp spike in *Polymixia, Sphenocephalus, X. stewarti, Aphredoderus* and *Zeus*. The subopercle of *Percopsis, Amphiplaga,* and *Massamorichthys* has a distinct upturned portion anteriorly, but it is flat or blunt. The subopercle is overall oval in shape with no anterior projection in *Amblyopsis*, *Microgadus*,and *Lota*. In the rest of the examined taxa, the anterior portion of the subopercle could not be seen.
21. Anterior and posterior ceratohyals [M94]: 0) not sutured together; 1) with at least a few strong sutures between the two bones. In the gadiforms, there are strong spars of bone crossing between the anterior and posterior ceratohyals forming an obvious suture. McAllister (1968:110) reported an ‘incipient suture’ in *Zeus*, but noted sutures characterized the Zeiformes, so we have coded sutures as present for *Zeus*. McAllister (1968) also reported strong sutures in *Aphredoderus* and *Amblyopsis*. In the rest of the taxa which we could code, the two bones are joined by cartilage with no sutures evident. We could not determine the state in most of the fossil taxa.
22. Beryciform foramen in anterior ceratohyal [M&W99]: 0) present; 1) absent. There is a large foramen in the anterior ceratohyal of *Polymixia, Sphenocephalus, Xenyllion,* and *Zeus. Percopsis* retains a very small foramen. The condition of the ceratohyal could not be determined for *Cumbaaichthys*, but the rest of the examined taxa have no foramen visible,
23. Number of branchiostegal rays [M&W99]: 0) seven or more; 1) six or fewer. *Cumbaaichthys*, both species of *Xenyllion*, and one species of *Libotonius* (*L. pearsoni*), all have eight branchiostegal rays. *Zeus* normally has seven branchiostegals, and *Lota* normally has seven or eight (McAllister, 1968). Our examined *Microgadus* has seven, as does *Polymixia* (Zehren, 1979). The rest of the taxa have six branchiostegal rays.
24. Percopsoid projections on branchiostegal rays [M&W99]: 0) absent; 1) present on at least some. McAllister (1968:fig. 1) illustrated percopsoid projections as angularities on the anteroventralmost point of the branchiostegal ray. We here interpret them to be present when there is a clearly deeper anterior ‘head’ compared to the narrower body of the ray, and the head has an angular projection. Therefore, we have coded *Mcconichthys* as having percopsoid projections on at least the fourth ray and maybe the fifth, based on the photograph and drawing of Grande (1989), even though he coded this character as absent in *Mcconichthys*. Percopsoid projections are found in all the included taxa with the exception of *Polymixia, Boreiohydrias, Cumbaaichthys* and *Amblyopsis*.
25. Branchiostegal ray length [modified from D16]: 0) length of rays gradually increases posteriorly in series; 1) first few anterior rays are distinctly shorter than the posterior rays, with an abrupt change in length. Polymixia has the first three branchiostegal rays much reduced in size and associated with the hyoid barbell (Zehren, 1979). The first three rays are also clearly shorter than the rest in *Zeus,* and *Microgadus*, although they are not modified in a similar manner to those of *Polymixia*. *Mcconichthys* appears to have a very short first branchiostegal (Grande, 1989:fig. 4), although this may be an artifact of preservation, but the second and third rays are not particularly short.
26. Number of postcleithra [M&W99]: 0) two; 1) one, with an enlarged dorsal plate; 2) single rod-shaped or absent. There are two separate postcleithra in *Polymixia, Sphenocephalus*, and *X. stewarti* (unknown condition in *X. zonensis, Boreiohydrias* and *Cumbaaichthys*). A single rod-shaped postcleithrum is present in *Amblyopsis, Aphredoderus, Zeus,* and *Lota*. The postcleithrum of *Microgadus* has an enlarged dorsal portion, similar to that found in the rest of the included taxa.
27. Cleithrum shape [M&W99]: 0) relatively uniform thickness throughout; 1) with a distinct dorsal plate. The cleithrum of *Amblyopsis* and *Zeus* is more elongate and of similar anterior-posterior width overall, whereas in the other taxa the cleithrum has an expanded posterodorsal plate.
28. Scapular foramen [P&R89]: 0) fully in scapula; 1) between scapula and coracoid. Having the foramen between the scapula and coracoid was considered a character of the Gadiformes by Patterson and Rosen (1989), and here this state is found only in Lota and Microgadus. The other taxa have the foramen completely encompassed by the scapula; however, the condition cannot be determined in *Cumbaaichthys, Boreiohydrias, Xenyllion, L. blakeburnensis, Lateopisciculus, Trichophanes* and Pisces Point.
29. Pelvic girdle position [M&W99]: 0) does not reach postcleithrum; 1) reaches to or overlaps postcleithrum. We interpret this character as referring to the anterior extent of the pelvic girdle. In *Amblyopsis*, the pelvic fin is posteriorly positioned and the girdle does not reach the postcleithrum (in other amblyopsids, the pelvic girdle is absent; e.g., Armbruster et al., 2016). In the majority of the included taxa, the pelvic girdle overlaps the postcleithrum, although it is impossible to determine if there was a ligamentous connection between the elements in the fossil taxa. In *Lota* and *Microgadus*, the pelvic girdle is positioned anterior to the postcleithrum.
30. Pelvic fin position [TG18]: 0) approximately midway between the anus and the pectoral-fin base or closer to the anus; 1) slightly behind the pectoral-fin base; 2) under or anterior to the pectoral-fin base. We coded this character based on the anterior origin of the pelvic fin rays. Although this character seems very similar to the preceding one, the state differs for *Libotonius* in which the pelvic girdle overlaps the postcleithra, but the pelvic fins are positioned more posteriorly than in the other taxa, with the anterior origin of the fin rays being closer to the anus than the pectoral fin.
31. Insertion of first dorsal pterygiophore [D16]: 0) posterior to the fourth neural spine; 1) between the second and fourth neural spines; 2) between the first and second neural spines. The original character in Davesne et al. (2016) included a fourth state, ‘anterior to the first neural spine,’ which we exclude as it is not applicable to any taxa in our matrix. *Zeus* has an anteriorly positioned dorsal fin, with the first pterygiophore inserting between the first and second neural spines. *Xenyllion stewarti* is coded the same as *Zeus*, but this could be an artifact of preservation as the anterior part of the vertebral column is displaced and it is perhaps possible that the first centrum is obscured under the postcleithrum (Newbrey et al., 2013:fig. 2). *Cumbaaichthys, Boreiohydrias, Sphenocephalus, Trichophanes, Microgadus* and Pisces Point, all have the first dorsal pterygiophore inserting between the second and fourth neural spines, and in the rest of the taxa, the dorsal fin is positioned slightly more posteriorly, behind the fourth neural spine or further back.
32. First dorsal-fin pterygiophore shape [new]: 0) of uniform size along its length (essentially the same shape as the rest); 1) bearing a distinct distal expansion anteriorly. *Sphenocephalus, Xenyllion, Percopsis, Libotonius, Mcconichthys, Amphiplaga, Erismatopterus, Massamorichthys Lateopisciculus, Microgadus* and Pisces Point all have an expanded first dorsal-fin pterygiophore, which makes it much larger than the following pterygiophores. *Polymixia, Cumbaaichthys, Boreiohydrisa, Trichophanes, Amblyopsis, Zeus* and *Lota* have no such expansion. We could not code the condition in *Aphredoderus*. The first anal pterygiophore of *Polymixia* is expanded with an anterior hook distally, but this is an autapomorphy for that taxon.
33. Anal-fin spine number [TG18]: 0) none; 1) one or two; 2) three; 3) four or more. *Percopsis* may have one or two anal fin spines, so we combined those two states of Grande, T. et al. (2018). There are four anal-fin spines in *Polymixia, Boreiohydrias, Lateopisciculus, and Zeus. Sphenocephalus* has five spines; neither species of *Xenyllion* preserves spines.Three spines are present in *Cumbaaichthys, Mcconichthys, Amphiplaga, Massamorichthys, Trichophanes,* and Pisces Point. There are two anal-fin spines in *Libotonius,* and *Erismatopterus*. *Amblyopsis, Lota* and *Microgadus* have no anal fin spines, although the latter two have unbranched rays in the anal fin.
34. Vertebrae, total number [modified from TG18]: 0) 26 or fewer; 1) 27 to 32; 2) 33 to 36; 3) 37 or more. Grande, T. et al. (2018) gave ten states for this character, which did not allow us to group any taxa. Additionally, some of our taxa with multiple specimens didn’t fit the ranges of the original states. We grouped the states into non-overlapping bins based on the data for our taxa, resulting in the four states given here.
35. Abdominal vertebrae, number [modified from TG18]: 0) 10 to 15; 1) 18 or more. Similar to the preceding character, we reduced the original eight states down to two states to reflect the data for our included taxa.
36. First vertebra, association of the neural arch and spine with the skull [TG18]: 0) the neural arch and spine are not closely applied to the skull; 1) the neural arch and spine are closely applied to the skull, primarily to the exoccipitals. *Zeus, Lota* and *Microgadus* all have the first neural spine pressed against the back of the skull. This is also the condition in *Mcconichthys*, but all other taxa have a clear gap between the first neural spine and the skull.
37. Second or second and third vertebral centra [P&R89]: 0) of similar length to the following centra; 1) foreshortened compared to the rest. Patterson and Rosen (1989) noted that the foreshortened centra were generally about half the length of the adjacent centra. They coded this character as present in *Sphenocephalus*, which we follow here, although we could not see this feature in the photographs of *Sphenocephalus* that were available to us. The second centrum is clearly shorter than the rest in *Lota, Microgadus* and *Zeus*. Grande (1989) considered the second centrum to be shorter than the others in *Mcconichthys*; however, based on his figures, this centrum is not half the width of the adjacent centra, so we consider this feature to be absent in *Mcconichthys*. There are no foreshortened centra in any of the other taxa.
38. Number and orientation of supraneurals [P&R89]: 0) two or more upright elements interdigitate with neural spines; 1) single irregularly shaped element dorsal to neural spines; 2) none. There is no supraneural in *Amblyopsis*, the gadiforms and *Zeus*. The presence of several upright elements that reach between the neural spines are characteristic of *Polymixia, Cumbaaichthys, Boreiohydrias* and other acanthomorph fishes such as the beryciforms. Patterson and Rosen (1989) considered a single supraneural positioned dorsal to the neural spines to be characteristic of Percopsiformes, and all our other included taxa have this condition.
39. Number of epurals [P&R89]: 0) three; 1) two; 2) one or none. There are three epurals in *Polymixia* and *Cumbaaichthys*, one is present in *Amblyopsis* and *Zeus*. The rest of the taxa have two epurals, with the condition unknown in *Boreiohydrias, Mcconichthys* and *Xenyllion*.
40. Number of uroneurals [modified from TG13]: 0) two; 1) one; 2) none. We count the stegural as one uroneural, following Borden et al. (2013). The condition in *Mcconicthys* and *Xenyllion* is unknown, as none of the specimens has a clear caudal skeleton. *Lota, Microgadus* and *Zeus* have no uroneurals, whereas *Aphredoderus* and *Amblyopsis* have a single uroneural. The other taxa have two uroneurals.
41. Hypurals 1 and 2 [TG13]: 0) separate from one another; 1) fused to each other. Most of the taxa have hypurals one and two free from one another. *Percopsis, Trichophanes, Aphredoderus, Amblyopsis, Lota, Microgadus* and *Zeus* have the two fused together.
42. Hypurals 3 to 6 [modified from TG13]: 0) all separate from one another; 1) at least some fused together. *Percopsis* has hypurals three and four fused together, *Aphredoderus* has hypurals three, four and five fused together, with some fusion of the sixth as well. *Amblyopsis, Lota,* and *Microgadus* have fusion of all upper hypurals. In *Zeus* there is some variation in amount of fusion (see Tyler et al., 2003). We therefore coded species with some fusion and complete fusion as the same state. Taxa in which the caudal skeleton is not clear were coded as unknown.
43. Parhypural articulation [M94 and TG13]: 0) reaches or is fused to centrum via haemal arch; 1) free from centrum with loss of haemal arch. We removed one of the states from Grande, T. et al. (2013; ‘fused to hypural one’) as inapplicable in our taxa. In the majority of taxa that could be coded, the parhypural meets the centrum. In *Trichophanes, Aphredoderus, Amblyopsis, Zeus* and the gadiformes, the parhypural has apparently lost the hypural arch, and the rest of the element does not meet the centrum.
44. Haemal spine on second preural centrum [new]: 0) of more or less equal width along its length; 1) expanded by a distinct flange proximally. In most taxa the haemal spine of the second preural centrum is of uniform thickness along its length, or broadens only slightly at the arch. In Pisces Point there is a distinct anterior flange near the arch. This flange is also present in *Polymixia, Cumbaaichthys, Sphenocephalus, Percopsis* and *Libotonius*. *Zeus* (see Tyler et al., 2003:fig. 88) has an elongated flange unlike that of the other taxa, and is coded as the haemal spine being of similar width all along its length.
45. Scales [M&W99]: 0) only cycloid scales present; 1) spinoid or peripheral ctenoid scales present. Although spinoid scales differ from peripheral ctenoid (see Roberts, 1993), it is not possible to distinguish these from one another in most of the fossil material, so we have grouped them here. In *Sphenocephalus* and *Xenyllion*, both cycloid and spinoid scales are present, so they are coded as having state 1. Cycloid scales are found in *Lota, Microgadus, Cumbaaichthys* and *Amblyopsis*. The other taxa have a marginal row of ctenii on the scales, which may or may not be separate from the scale body.
46. Position of vent [P&R89]: 0) posterior on body; 1) in a jugular position. This character was considered by Patterson and Rosen (1989) to be very strong indication that Aphredoderidae and Amblyopsidae are sistergroups. The position of the vent is not correlated with the position of the anal fin in these taxa, which means that the vent position cannot be determined for any of the fossils, as they do not preserve indication of the digestive tract. All fossil taxa have therefore been coded as unknown. The other extant taxa included (*Polymixia, Percopsis, Zeus, Lota,* and *Microgadus*) all have the vent in the normal position.

**Appendix 2. Taxa included in analysis.**

Taxa with catalogue numbers were examined by us for this study. Information for taxa not available to us is from the references listed for each taxon. Daggers indicate fossil taxa; c&s denotes specimens cleared and stained for bone, or both bone and cartilage; skeleton indicates specimens that are osteological preparations, and alcohol indicates whole specimens stored in alcohol.

Polymixiiformes

 incertae sedis

 †*Cumbaaichthys oxyrhynchus* UALVP 54046 (holotype)

 Polymixiidae

 *Polymixia lowei* photographs of c&s specimen provided by T. Grande; Zehren, 1979

 †Boreiohydriidae

 †*Boreiohydrias dayi* UALVP 56113 (holotype)

†Sphenocephaliformes

†Sphenocephalidae

 †*Sphenocephalus fissicaudus* Rosen and Patterson, 1969; Newbrey et al., 2013 †*Xenyllion zonensis* UALVP 32133 (holotype)

 †*X. stewarti* Newbrey et al., 2013 (additional information from Stewart, 1996)

Percopsiformes

 incertae sedis

 †*Libotonius blakeburnensis* Wilson, 1977

 †*L. pearsoni* UALVP 13466 (holotype), and paratypes UALVP 13469 and 14765; UALVP 14771, 14772

 Percopsidae

 †*Amphiplaga brachyptera* UALVP 13401, 19827, 20565

 *Percopsis omiscomaycus* UAMZ 1577, 2048, 3062, 5274, 5275 (all c&s)

 †*Erismatopterus levatus* (Cope, 1870) UALVP 12358, 12366, 12367, 12368, 12369, 12370, 12371, 12636

 †*Massamorichthys wilsoni* UALVP 30842 (holotype) and UALVP 21660, 23535, 31683, 39094 (paratypes)

 †*Lateopisciculus turrifumosis* UALVP 34771 (holotype) and UALVP 21541, 22870, 34775 (paratypes)

 †Mcconichthyidae

 †*Mcconichthys longipinnis* Grande, G. 1988

 Aphredoderidae

 *Aphredoderus sayanus* UAMZ F2497 (alcohol); Boltz and Stauffer, 1993; Murray, 1994

 †*Trichophanes foliarum* Cope 1870 17441 (cast); Rosen and Patterson, 1969

 Amblyopsidae

 *Amblyopsis* Murray, 1994; Chakrabarty et al., 2014; Armbruster et al., 2016.

Zeiformes

 Zeidae

 *Zeus faber* UAMZ F8899 (skeleton); Tyler et al., 2003

Gadiformes

 Lotidae

 *Lota lota* UAMZ F2265 (3 specimens, c&s); 3 skeletons uncatalogued

 Gadidae

 *Microgadus proximus* UAMZ F7954 (2 specimens, c&s)

**Appendix 3. Data matrix for phylogenetic analysis.**

Polymixia 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 0 0 0 0 0 1 0 1 0 1 1 0 0 3 1 0 0 0 0 0 0 0 0 0 1 1 0

Cumbaaichthys ? 0 0 ? 0 0 0 0 0 ? ? 0 0 0 0 0 0 0 1 ? ? ? 0 0 0 ? 1 ? 1 1 1 0 3 0 0 0 0 0 0 0 0 0 ? 1 0 ?

Boreiohydrias ? 0 0 0 0 0 0 1 0 ? 0 ? 0 0 0 0 1 0 1 ? ? ? 1 0 0 ? 1 ? 1 1 1 0 2 2 0 0 0 0 ? ? ? ? ? ? 1 ?

Sphenocephalus 1 0 0 0 1 0 1 1 0 ? 0 1 0 1 1 1 2 0 1 0 0 0 1 1 0 0 1 0 1 1 1 1 3 1 0 0 1 1 1 0 0 0 0 1 1 ?

X.\_zonensis 1 0 0 0 ? ? 1 ? ? ? 0 ? ? 1 1 1 2 0 1 ? 0 0 0 1 0 ? 1 ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ?

X.\_stewarti 1 0 0 0 1 0 1 1 0 ? ? ? 0 1 1 1 2 0 1 0 ? 0 0 1 0 0 1 ? 1 1 2 1 ? 0 0 0 0 1 ? ? ? ? ? ? 1 ?

L.\_pearsoni 2 0 0 0 2 0 1 0 ? ? 0 ? 0 1 2 0 1 0 0 ? 0 1 0 1 0 1 1 0 1 0 0 1 1 1 0 0 0 ? 1 0 0 0 0 1 1 ?

L.\_blakeburnensis 2 0 0 0 2 0 1 0 0 ? 0 ? ? 1 2 0 0 0 0 ? ? 1 1 1 ? 1 1 ? 1 1 0 ? 1 2 ? ? ? ? 1 0 0 ? 0 1 1 ?

Mcconichthys 2 0 0 0 2 0 1 0 0 ? 0 ? 1 1 2 0 1 0 0 0 ? 1 1 1 0 1 1 0 1 1 0 1 2 3 1 1 0 1 ? ? ? ? ? ? 1 ?

Amphiplaga 2 0 1 0 2 1 1 0 0 ? ? ? 0 1 2 0 1 0 0 1 0 1 1 1 0 1 1 0 1 1 0 1 2 1 0 0 0 1 1 0 0 0 0 0 1 ?

Percopsis 2 0 1 1 2 1 1 0 0 1 0 1 1 1 2 0 0 0 0 1 0 0 1 1 0 1 1 0 1 1 0 1 1 2 0 0 0 1 1 0 1 1 0 1 1 0

Erismatopterus 2 0 1 0 2 1 1 0 0 ? 0 ? 0 1 2 0 0 0 0 ? 0 1 1 1 0 1 1 0 1 1 0 1 1 1 0 0 0 1 1 0 0 0 0 0 1 ?

Massamorichthys 2 0 1 1 2 1 1 0 0 1 0 ? 1 1 2 0 1 0 0 1 0 1 1 1 0 1 1 0 1 1 0 1 2 3 1 0 0 1 1 0 0 0 0 0 1 ?

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