

Supplementary Materials:

A new large †pachycormid fish (Teleostomorpha: †Pachycormiformes) from the Lower Jurassic of Holzmaden, Germany, with affinities to the suspension-feeding clade and comments on the gastrointestinal anatomy of pachycormid fishes

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This document contains:

Supplementary Figures 1 – 10 (Figs S1 – S10)

Description of the caudal fin of *Martillichthys renwickae*

Phylogenetic analysis including character lists and taxa scoring.

See also:

File S2 = Updated TNT file of the Friedman (2012) phylogenetic analysis matrix, including scoring for *Germanostomus pectopteri* gen. et sp. Nov.

File S3 = TNT file of the Gouiric–Cavalli and Arratia (2022) phylogenetic analysis matrix, with updated scoring for *Saurostomus esocinus* and *Germanostomus pectopteri* gen. et sp. nov.

Fig. S1 - Historic photograph of SMNS 15815

An undated black-and-white photograph of specimen SMNS 15815 (*Germanostomus pectopecteri* gen. et sp. nov.) apparently taken inside of the former museum building at Neckarstraße (Stuttgart), was discovered in the archives of the SMNS (Fig. S1). The building was destroyed in a fire following air raids in 1944, although thankfully a large portion of the collection had already been evacuated in the few years prior (1941-1943). The architecture of the windows, display cases and the wooden floor in the background of the photograph perfectly match the museum's interior seen in other surviving photographs of the former exhibition hall at Neckarstraße. In the photograph, the specimen has been removed from display and has been hastily propped up on a wooden table to be photographed – seemingly done so in a hurry. We can surmise therefore that the photograph was most likely taken for inventory purposes before the material was evacuated sometime during WWII, but prior to 1944. Evacuated material was hidden across numerous secure, make-shift storage sites around Stuttgart, utilizing old mine shafts, wine cellars and remote castles. No surviving documentation exists to suggest what happened to the specimen between 1944 and its return to the SMNS in the 1980's. The specimen today has survived relatively undamaged, with only minor damage to the wooden frame and some general wear-and-tear of the specimen label.

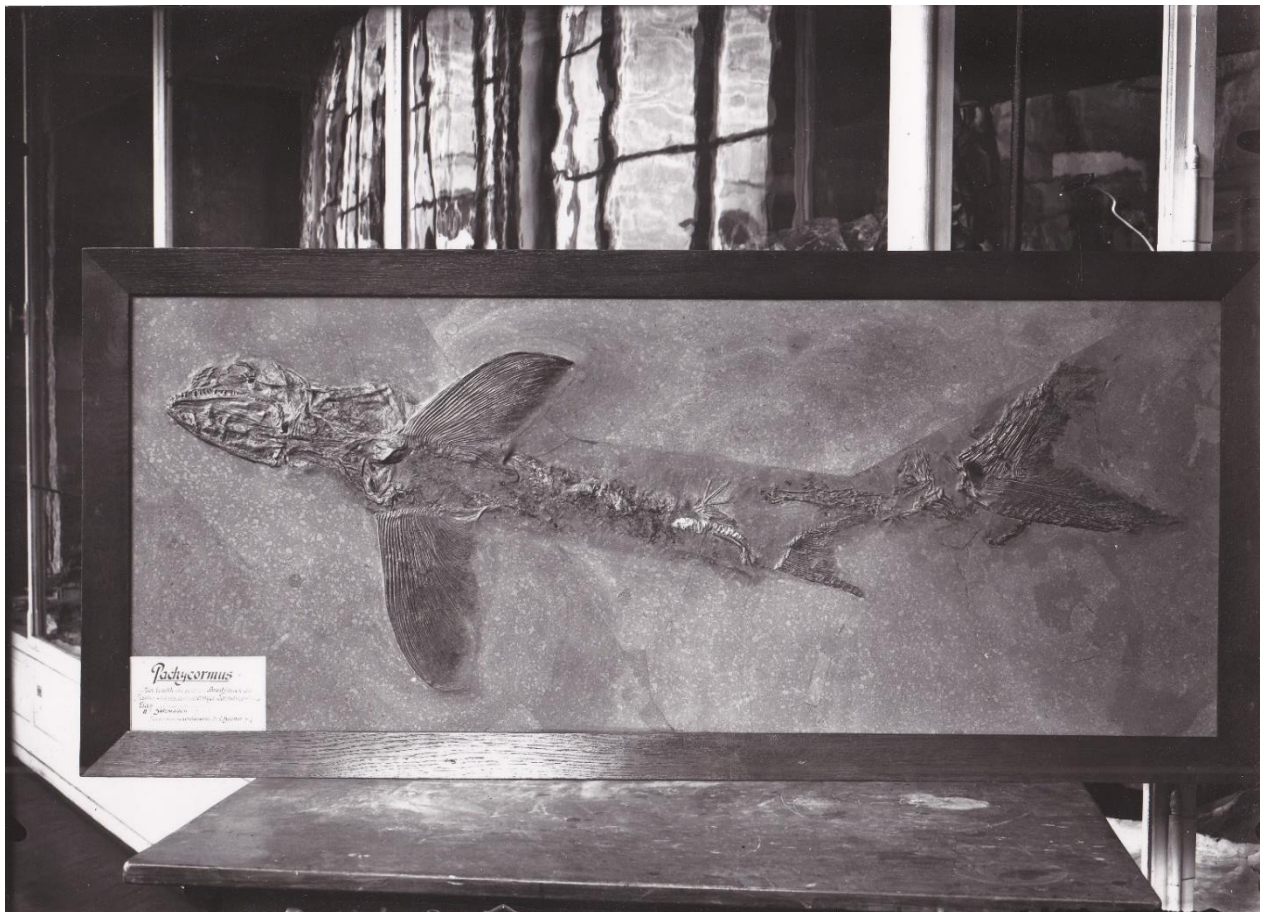


Fig. S1. Historical photograph (undated – photographer unknown) of SMNS 15815 taken in the old Württemberg Natural History Collection (now SMNS) building at Neckarstraße (Stuttgart). The building was entirely destroyed in a fire resulting from allied bombing in 1944, where most of the original collection was lost. The photograph, showing the framed specimen propped up on a wooden table and resting against a grand display case, was likely taken for inventory purposed before the specimen was moved off-site for safe guarding at the beginning of WWII. Following the aftermath of WWII, with no museum building to house them, the surviving fossil collection of the Natural History cabinet was stored in the former horse stables of the decommissioned military barracks in Ludwigsburg. SMNS 15815 likely remained here until it was eventually transferred to the newly opened Museum am Löwentor (SMNS) in 1985 – more than four decades after it was originally evacuated. Original photograph in the collection of the SMNS (uncatalogued).

2. Caudal fin of *Martillichthys renwickae* Liston 2008.

The caudal fin of the holotype of the Callovian (Middle Jurassic) edentulous pachycormid *Martillichthys renwickae* Liston 2008, NHMUK PV P. 61563, is remarkably well-preserved. The specimen originates from Bed 12 of the Dogsthorpe Pit, Lower Oxford Clay Formation (Callovian), at Whittlesey, Cambridgeshire, England (Martill 1986; Liston, 2008). The specimen remains partially prepared, broken into more than a dozen blocks from the initial excavation, with the posterior-most block (Block 14: measuring 450 mm x 395 mm) containing the caudal fin and sections of the caudal peduncle region. Liston (2008) figured the caudal fin, although he did not provide a detailed anatomical description. Here we present a brief description for the caudal fin of *Martillichthys renwickae* used as a basis for comparisons with *Germanostomus pectopteri* gen. et sp. nov. in the main text. See ‘Materials and Methods’ in the main text for anatomical terminology usage.

Subclass ACTINOPTERYGII COPE, 1887

Order PACHYCORMIFORMES BERG, 1937

Family PACHYCORMIDAE WOODWARD, 1895

Genus MARTILlichthys LISTON, 2008

Martillichthys renwickae LISTON, 2008

Material. Block 14 of NHMUK PV P. 61563 – Holotype: Fig. S2

Description. The caudal fin is incompletely preserved on the terminal block (block 14) of NHMUK PV P. 61563, where it is prepared in left lateral view. The bones retain their original articulation on the bedding plane of block 14, which on the underside has been reinforced in a foam-based plaster jacket for stability. The caudal fin rays are mostly complete, except for the distal portion of the ventral (hypaxial) lobe which is broken. The caudal peduncle is poorly preserved, with the hypural plate, preural neural spines, most of the preural haemal spines and the ventral portions of the ‘uroneural-like elements’ missing (see Arratia, 2008 for issues with homology). The caudal fin is strongly forked, although the ventral lobe has deformed slightly towards the dorsal during compaction, obscuring the original angle of lobe bifurcation. The complete epaxial lobe is perfectly articulated and measures approximately 216 mm in height, with the total length of the lower lobe unknown due to damage. Approximately 21 fin rays are present in the epaxial lobe, although the fin ray/fulcra boundary is difficult to precisely pinpoint due to the absence of the hypural plate. All fin rays are unsegmented and stiff, with the only bifurcation occurring close to the distal-most margins of the rays where they bifurcate free from joints in an asymmetrical pattern. The upper and lower lobes meet at the medial-posterior of the fin, although the specialised posterior fan-like fin rays present in a few other pachycormids (e.g. *Saurostomus esocinus*: Cooper and Maxwell, 2022) are absent in *Martillichthys*. A continuous single row of epaxial basal fulcra extend along the entirety of the leading edge of the epaxial lobe, with fringing fulcra irrefutably absent. Epaxial basal fulcra number at least 13, although this value is conservative because of damage obscuring the precise boundary of the fulcra/fin ray transition. Epaxial basal fulcra are morphologically similar to the fin rays, in both width and the lack of segmentation, although they are relatively shorter (shortest anteriorly and becoming longer posteriorly along the leading edge), have proximally bifurcated bases, and have lanceolate-like distal terminations along the leading edge. The basal fulcra articulate dorsoposterior to the ‘epurals’, ‘uroneural-like elements’ and the missing hypural plate.

The caudal endoskeleton is poorly preserved in *Martillichthys*, with only the dorsal basal scute, ‘epurals’, and the broken dorsal section of the ‘uroneural-like elements’ remaining. A field of broken bone fragments, some of which display elongated morphologies anterior of the caudal fin most likely represent the decayed preural haemal and neural spines. The hypural plate is not exposed. The large dorsal basal scute is well preserved, albeit damaged, in dorsal view where it lies immediately in front of the ‘epurals’. Liston (2008) misinterpreted the scute as the possible first preural vertebra; it is reinterpreted based on shared morphology with the basal scute in *Asthenocormus titanius* (described and figured as a midline element preceding the caudal fin rays by Vetter [1881]). The dorsal scute is

short and wide, measuring 35 mm (width) x 20 mm (length), with the lateral margins of the bones expanded laterally to form a pair of 'wing-like' processes which slightly arch forwards at their distal ends. The left process has broken away, although the impression left in the matrix confirms their original paired nature. Bone thickness is equal between the medial position and lateral processes of the bone, with the cortex only becoming thinner along the anteromedial and posteromedial margins. The anteromedial margin is characterised by a wide and short anterior notch, supported on both sides by a small convex protuberance. A similar structure is also shared in the dorsal scute of *Asthenocormus* (Vetter, 1881), with a bifurcating 'V'-shaped notch present in *Saurostomus esocinus* (Fig. 7e-f, in main document). The dorsal surface the bone is strongly convex, with the medial midline characterised by an anteriorly branching medial keel and groove respectively (see Fig. S2b, and Fig. 7e, in main document). An anteriorly-projecting medial spine as seen in the dorsal scute of *Ohmdenia multidentata* (see Figs A7d, and Fig. 7h in main document) is not present in *Martillichthys*. Four rectangular 'epurals' are partially exposed, articulating anteroventral to the anterior epaxial basal fulcra (FIG. S2). They are tightly aligned lateral to one another, rounded in cross section, and are approximately three times as wide as each epaxial basal fulcrum. At least three 'uroneural-like elements' ventrally succeed the 'epurals', where they are mostly overlaid by the bases of the epaxial basal fulcra. The 'uroneural-like elements' are fractionally wider relative to the 'epurals' and are differentiated by their denser rectangular cross-sections. Their original articulation in relation to the preurals and hypural plate is unknown in *Martillichthys*.

Patches of brownish-beige coloured pigment preserved as a phosphatic film on the caudal peduncle appear to represent soft tissue preservation. The nature of the original soft tissues are unknown, although they most likely derive from the epidermis. Scales are entirely absent along the entirety of the skeleton, including the caudal fin. The combination of possible epidermal preservation and absence of scales implies that *Martillichthys renwickae* was naked as opposed to having had a scale covering. This interpretation coincides with the condition seen in *Asthenocormus* (Lambers, 1992), and is inferred for all members of the edentulous clade of suspension-feeding pachycormids (Liston, 2008; Friedman et al., 2010; Schumacher et al., 2016; Dobson et al., 2019). The possible argument that the scales were somehow removed during decay is not tenable, as the processes which would have done so would also have removed the soft tissues preserved in block 14 and elsewhere on the skeleton.

Concluding remarks on the caudal fin of *Martillichthys renwickae*

1 - The dorsal basal scute, 4 'epurals' and at least three 'uroneural-like elements' are described here. The morphology of the dorsal basal scute is very similar to the equivalent bone in *Asthenocormus*, but strikingly variant from the dorsal basal scutes of the Early Jurassic 'transitional-suspension-

feeding' taxa, *Saurostomus esocinus*, *Germanostomus pectopteri*, and *Ohmdenia multidentata* (Fig. 7, in main document).

2 - Presence of unsegmented fin rays, absence of fringing fulcra and apparent loss of the posterior lepidotrichia fans reveals close anatomical affinities to the caudal fins of *Leedsichthys problematicus* (Liston and Noe, 2004) and *Asthenocormus titanius* (Lambers, 1992), as well as possibly *Ohmdenia multidentata* (Fig. S7).

3 – The new information can improve character scoring in phylogenetic analyses.

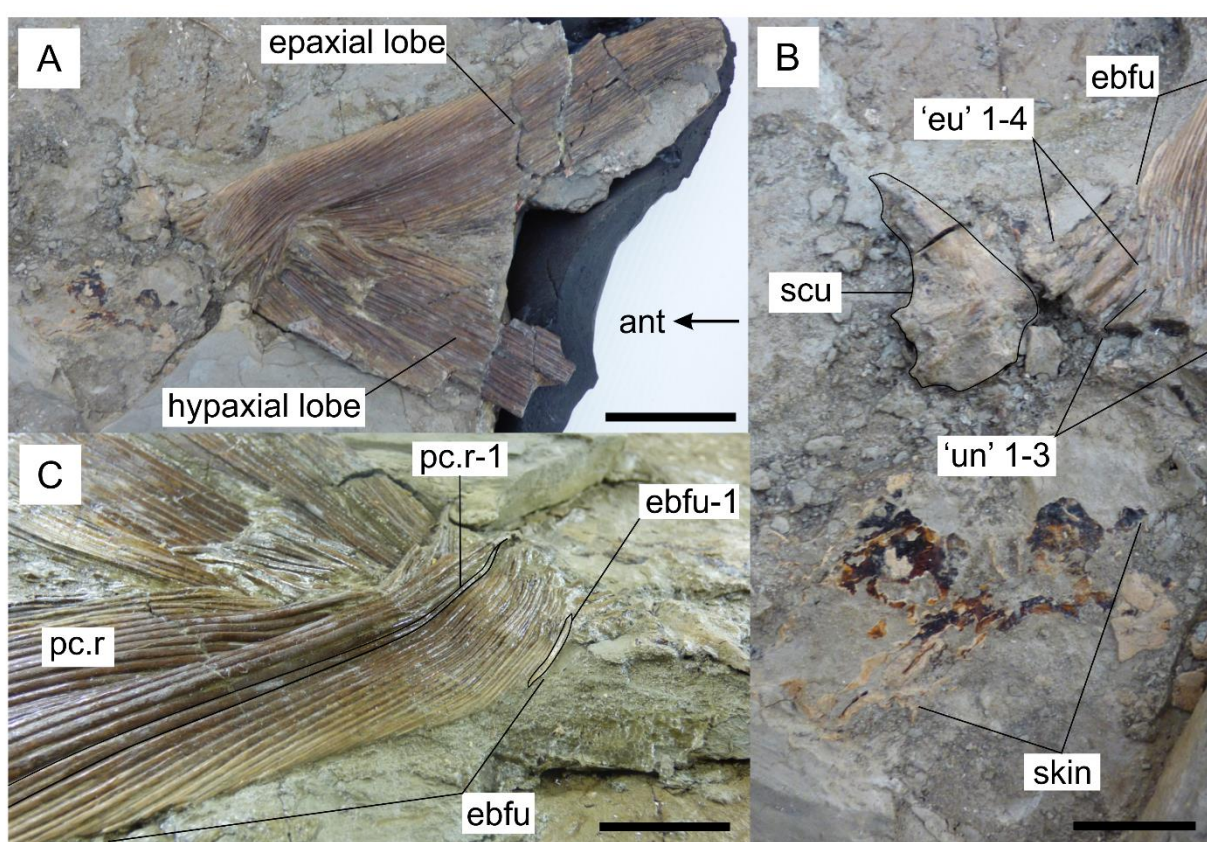


Fig. S2 – Caudal fin of *Martillichthys renwickae*, NHMUK PV P. 61563 - Holotype. (A) = Block 14 preserving the caudal fin in left lateral view with disrupted and incomplete elements of the caudal endoskeleton and vertebral column. (B) = Remains of the caudal endoskeleton including the dorsal basal scute, and phosphatic brownish-beige material which is evidence of soft tissue preservation. Note the absence of scales. (C) = Details of the epaxial lobe (dorsal view) showing divisions between the epaxial basal fulcra and the unsegmented principle fin rays (lepidotrichia). *Abbreviations*: **ebfu** = epaxial basal fulcra; **ebfu-1** = first epaxial basal fulcrum; **'eu' 1-4** = 'euroneural-like elements' 1-4; **pc.r**

= principle fin rays; **pc.r-1** = first principle fin ray; **scu** = dorsal basal scute; '**un**' **1-3** = 'uroneural-like elements 1-3. Scale bars are equal to 50 mm (A) and 20 mm (B-C).

3. Phylogenetic analysis

To test the phylogenetic placement and taxon identity of SMNS 15815 we performed two different phylogenetic analyses of Pachycormiformes (see main document for details). In the first analysis we used the matrix for Pachycormiformes presented by Friedman (2012), with updated scorings for *Saurostomus esocinus*, *Martillichthys renwickae* and *Simocormus macrolepidotus* carried over from Cooper and Maxwell (2022). This character-by-character matrix includes 125 characters retained from the original analysis, three additional characters added by Cooper and Maxwell (2022), and one new character (char. 129) for 129 total. References for individual character formulations, indicated in brackets after character descriptions, are retained from Friedman (2012) (Fig. S3).

Retained characters

1. *Ethmoid ossification(s)* [G]*: **(0)** Present; **(1)** Absent.
2. *Anterior myodome* [P77, GML, A, C, CS, H, F]: **(0)** Present; **(1)** Absent.
3. *Basipterygoid process* [P73, GS, GML, H, F]: **(0)** Well-developed dermal process with endoskeletal component; **(1)** Basipterygoid process absent.
4. *Posterior myodome* [P73, P77, GS, GML, C, CS, H, F]*: **(0)** Present; **(1)** Absent.
5. *Endoskeletal floor of posterior myodome* [P73, P77, GS, GML, C, CS, H, F]*: **(0)** Complete; **(1)** Fenestrate.
6. *Lateral commissure breadth* [H, F]: **(0)** Anteroposteriorly broad; **(1)** Slender.
7. *Spiracular canal* [P77, P82, GS, A, H, F]: **(0)** Present; **(1)** Absent.
8. *Dermal component of sphenotic bone or sphenotic region of braincase* [G]*: **(0)** Absent; **(1)** Present.
9. *Opisthotic* [CS, H, F]: **(0)** Present; **(1)** Absent.
10. *Pterotic* [H, F]: **(0)** Present; **(1)** Absent.
11. *Pterotic fused with dermopterotic* [GML, H, F]: **(0)** Absent; **(1)** Present.
12. *Epioccipital* [GML, H, F]: **(0)** Epioccipital bordered anteriorly by cranial fissure; **(1)** Epioccipital

contacts otic region.

13. *Intercalar* [P73, GML, CS, H, F]*: **(0)** Present; **(1)** Absent.
14. *Membranous outgrowths of intercalar* [GML, H, F]*: **(0)** Minor; **(1)** Extensive.
15. *Position of membranous outgrowths of intercalar* [GML, H, F]*: **(0)** Medial to jugular; **(1)** Lateral to jugular.
16. *Lateral cranial canal* [C, F]: **(0)** Present; **(1)** Absent.
17. *Subtemporal fossa* [GS, H, F]: **(0)** Absent; **(1)** Present.
18. *Posttemporal fossae* [P73, P77, GS, GML, CS, H, F]*: **(0)** Absent; **(1)** Present.
19. *Communication between posttemporal fossa and fossa Bridgei* [P73, P77, GS, GML, CS, H, F]*: **(0)** Absent; **(1)** Present.
20. *Cranial fissures* [PR, G, H, F]: **(0)** Ventral otic and otico-occipital fissure confluent via vestibular fontanelle; **(1)** Fissures non-persistent (closed), or pattern obscured by incomplete ossification.
21. *Foramen for vagus nerve enclosed completely within exoccipital* [GML, CS, H, F]*: **(0)** Absent; **(1)** Present.
22. *Relationship of dorsal aorta to basicranial region (in taxa where this vessel is not enclosed)* [GML, A, C, H, F]*: **(0)** Accommodated in a pronounced aortic groove; **(1)** Accommodated in a shallow depression.
23. *Vertebrae fused into adult occipital condyle* [G10]*: **(0)** Absent; **(1)** Present.
24. *Vomer(s)* [P73, P77, F]: **(0)** Paired; **(1)** Unpaired (median).
25. *Parasphenoid corpus in sphenethmoid region* [F]: **(0)** Narrow; **(1)** Broad.
26. *Parasphenoid dentition* [A, F]: **(0)** Present; **(1)** Absent.
27. *Internal carotid foramen through parasphenoid* [P77, GML, H, F]: **(0)** Absent; **(1)** Present.
28. *Efferent pseudobranchial foramen through parasphenoid* [P77, GML, H, F]: **(0)** Absent; **(1)** Present.
29. *Ornament on dermal bones of skull*: **(0)** Absent; **(1)** Present.
30. *Rostral bone* [GML, L, H, F]*: **(0)** Cap on snout apex partially or wholly separating the nasals; **(1)** Reduced to a narrow tube with lateral process.

31. *Contribution of rostral bone to oral margin**: **(0)** Absent; **(1)** Present.
32. *Rostrodermethmoid [M, L, Li, F]*: **(0)** Terminates at anterior tip of mandibular symphysis; **(1)** Forms a produced rostrum, extending anterior to mandibular symphysis.
33. *Marginal teeth on rostrodermethmoid [F]*: **(0)** Present; **(1)** Absent.
34. *Paramedial fangs on rostrodermethmoid [M, L, Li, F]*: **(0)** Absent; **(1)** Present.
35. *Parietals [A, F]*: **(0)** Paired; **(1)** Single midline ossification.
36. *Posterior boss on skull roof [M, L, Li, F]*: **(0)** Absent; **(1)** Present.
37. *Posterior margin of skull roof [F]*: **(0)** Straight or concave; **(1)** 'W'-shaped.
38. *Free, elongated posterior processes of dermopterotics [F]**: **(0)** Absent; **(1)** Present.
39. *Independent extrascapulars [M]**: **(0)** Present; **(1)** Absent.
40. *Number of extrascapulars on each side of the skull [G]**: **(0)** Single; **(1)** Multiple.
41. *Dermosphenotic [P73, GML, H, F]*: **(0)** Hinged to skull roof; **(1)** Bound or fused to anterior margin of sphenotic.
42. *Dermosphenotic forms dorsal margin of orbit [M, L, Li, F]*: **(0)** No; **(1)** Yes.
43. *Supraorbitals [H, F]*: **(0)** Absent; **(1)** Present.
44. *Contact between anterior supraorbitals and bones carrying the infraorbital canal (infraorbitals or antorbital) [GML, H, F]**: **(0)** Absent; **(1)** Present.
45. *Anterior supraorbitals contact [GML, H, F]**: **(0)** Antorbital; **(1)** Infraorbitals only.
46. *Suborbitals [P73, CS, F]*: **(0)** Present; **(1)** Absent.
47. *Suborbital size [M, L, Li, F]*: **(0)** Equal in size or smaller than adjacent infraorbital(s); **(1)** Much larger than adjacent infraorbital(s).
48. *Suborbital number [M, L, CS, Li, H, F]*: **(0)** Single; **(1)** Two; **(2)** Numerous bones.
49. *Broad overlap of preoperculum by the suborbitals**: **(0)** Absent; **(1)** Present.
50. *Antorbital shape [H, F]**: **(0)** Platelike, with minimal (if any) distinct anterior process; **(1)** Tapering towards slender anterior process; tri-radiate canal with broader, posterior portion.
51. *Infraorbitals behind orbit [L, Li, F, C+M]*: **(0)** one to Six; **(1)** More than six. **(2)** Absent
52. *Infraorbitals anterior to circumorbital ring [OM, CS, H, F]*: **(0)** Absent; **(1)** Present.

53. *Posteriorly extensive infraorbital [F]: (0) Present; (1) Absent.*
54. *Preoperculum [OM, L, H, F]: (0) With broad dorsal margin; (1) With narrow ascending limb.*
55. *Dorsal limb of preoperculum*: (0) Plate like; (1) Narrow splint with no posterior lamina.*
56. *Marginal dentition [F]: (0) Present; (1) Absent.*
57. *Carinae extending length of teeth [F]: (0) Absent; (1) Present.*
58. *Supraorbital canal in premaxilla [G]*: (0) Absent; (1) Present.*
59. *Premaxilla forms much of dermal skull roof in snout region [G]*: (0) No; (1) Yes.*
60. *Form of premaxillary dentition [L, Li, F]: (0) Similar to maxillary teeth; (1) Enlarged relative to maxillary teeth.*
61. *Mobile premaxilla [P73, P77, GS, GML, CS, H, F]: (0) Absent; (1) Present.*
62. *Grooved, notched or perforated premaxillary ascending process [P73, GS, GML, CS, H, F]: (0) Absent; (1) Present.*
63. *Maxilla [P73, GS, GML, H, F]: (0) Fixed to cheek; (1) Free.*
64. *Maxilla length [GML, L, CS, H, F]: (0) Long, extends beneath mid-orbit; (1) Short.*
65. *Position of orbit relative to maxilla [L]: (0) Centered over maxilla; (1) Restricted to posterior half of maxilla.*
66. *Posterior margin of maxilla [GML, L, CS, H, F]: (0) Straight or convex; (1) Indented.*
67. *Thickened ridge on external surface of maxilla [F]: (0) Absent; (1) Present.*
68. *Supramaxilla [P73, GS, GML, A, CS, H, F]: (0) Absent; (1) Present.*
69. *Supramaxilla position [L, Li, F]: (0) Dorsal to maxilla; (1) Posterodorsal to maxilla.*
70. *Hyomandibular*: (0) Strongly waisted, with concave anterior and/or posterior margins; (1) Straight anterior and posterior margins.*
71. *Quadratojugal [P73, P77, GML, CS, H, F]*: (0) Present; (1) Absent.*
72. *Jaw joint [P73, OM, GML, CS, H, F, G]*: (0) Single; (1) Double.*
73. *Symplectic [G]*: (0) Slender and splint shaped; (1) Broad and hatchet shaped.*
74. *Symplectic position relative to quadrate [P73, OM, GML, CS, H, F]*: (0) Medial to quadrate; (1) Posterior to quadrate.*

75. *Membranous ossification binding symplectic and preoperculum [GML]*: (0) Absent; (1) Present.*
76. *Position of jaw joint [M, L, A, CS, Li, F]: (0) Well behind orbit; (1) Below or anterior to orbit.*
77. *Quadrate with elongate posteroventral process [A, CS, H, F]: (0) Absent; (1) Present.*
78. *Contact or close association between quadrate and metapterygoid [G]*: (0) Present; (1) Absent.*
79. *Ectopterygoid participation in the palate [G]*: (0) Makes up less than half of palate; (1) Makes up majority of palate.*
80. *Entopterygoid/dermopalatine contact [G]*: (0) Present; (1) Absent.*
81. *Dentary tooth row(s) [M, L, Li, F]: (0) Labial row plus lingual row; (1) Single row.*
82. *Form of anterior dentary dentition [M, L, Li, F]: (0) Similar to posterior teeth; (1) Enlarged, procumbent fangs.*
83. *Surangular in lower jaw [P77, PR, P82, GS, H, F]: (0) Present; (1) Absent.*
84. *Coronoid process of lower jaw [G]*: (0) Absent; (1) Present.*
85. *Coronoid bones [G]*: (0) Present; (1) Absent.*
86. *Anterior coronoid plate [M, F]: (0) Not inflated; (1) Inflated.*
87. *Prearticular [P77, PR, F]: (0) Present; (1) Absent.*
88. *Prearticular dentition [F]: (0) Present; (1) Absent.*
89. *Hypohyal [P77, F]: (0) Single ossification; (1) Separate dorsal and ventral ossifications.*
90. *Exposed dorsal projection of suboperculum between preoperculum and operculum [F]: (0) Absent; (1) Present.*
91. *Gulars [L, A, GML, C, CS, H, F]: (0) Present; (1) Absent.*
92. *Number of hypobranchials [G]*: (0) Three; (1) Four.*
93. *Uncinate processes on epibranchials [P73, GS, GML, H, F]*: (0) Absent; (1) Present.*
94. *Relative position of dorsal and anal fins [M, L, Li, F]: (0) Overlap between dorsal- and anal-fin bases; (1) Dorsal-fin base lies anterior to anal-fin base.*
95. *Caudal fin segmentation [L, Li, F]: (0) Segmented; (1) Unsegmented.*

96. *Ossification of vertebral centra [L, Li, F]*: (0) Absent; (1) Present.*
97. *Opisthocoelus vertebral centra [G]*: (0) Absent; (1) Present.*
98. *Long epineural intermuscular bones [G]*: (0) Absent; (1) Present.*
99. *Caudal diplospondyly [GML]*: (0) Absent; (1) Present.*
100. *Lateral keels of caudal peduncle (greatly expanded urodermals) [L, F]: (0) Absent; (1) Present.*
101. *Uroneurals [P73, P77, GML, A, CS, H, F]: (0) Absent; (1) Present.*
102. *Hypural plate [L, Li, F]: (0) Absent; (1) Present.*
103. *Geometry of hypural plate [F]*: (0) Length of vertical axis equivalent to or slightly longer than horizontal axis; (1) Vertical axis substantially longer than horizontal axis.*
104. *Main hypural plate notched posterodorsally (incomplete fusion with accessory hypurals) [F]: (0) Present; (1) Absent.*
105. *Clavicle [P73, GML, L, H]*: (0) Present; (1) Absent.*
106. *Medial wing of cleithrum [G]*: (0) Absent; (1) Present.*
107. *Supracleithrum*: (0) Broad and plate like; (1) Splint like.*
108. *Long axis of supracleithrum*: (0) Straight; (1) With prominent elbow or kink.*
109. *One or more accessory postcleithra [A, H, F]: (0) Absent; (1) Present.*
110. *Endoskeletal shoulder ossification reduced to mesocoracoid arch [OM, CS, H, F]: (0) No; (1) Yes.*
111. *Pectoral propterygium [P77, P82, CS, F]: (0) Free; (1) Fused to first pectoral-fin ray.*
112. *Pectoral-fin radial morphology [F]: (0) Cylindrical; (1) Broad distal area and narrow proximal stalk (paddle-shaped).*
113. *Scythe-like pectoral fins [M, L, Li, F]*: (0) Absent; (1) Present.*
114. *Complete fusion of fin rays along length of leading edge of pectoral fin [F]: (0) Absent; (1) Present.*
115. *Bifurcations in pectoral-fin rays [F]: (0) Present; (1) Absent.*
116. *Bifurcations of pectoral lepidotrichia occurring independently of joints [L, Li, F]: (0) Absent; (1) Present.*

117. *Pelvic fins* [*M, L, Li, F*]: **(0)** Present; **(1)** Absent.
118. *Pelvic fin position* [*F*]: **(0)** At or posterior to midpoint between anal and pectoral fins; **(1)** Anterior to midpoint between anal and pectoral fins.
119. *Scales**: **(0)** Present; **(1)** Absent.
120. *Ridge scales* [*GML, CS, H, F*]: **(0)** Absent; **(1)** Present.
121. *Scale morphology* [*P73, P77, PR, F*]: **(0)** Rhombic; **(1)** Round.
122. Dentary shape **(0)**, relatively straight; **(1)** strongly bowed laterally
123. Edentulous upper and lower jaws **(0)** toothed; **(1)** no teeth
124. Skull roof **(0)** tightly sutured; **(1)** unsutured
125. Opercular process of hyomandibular **(0)**, absent; **(1)** present
126. Scaly caudal apparatus [*C+M*]: **(0)** Absent; **(1)** Present.
127. Differentiated dorsal basal scute [*C+M*]: **(0)** Absent; **(1)** narrow and elongate; **(2)** short and wide.
128. Hypural plate dimensions [*C+M*]: **(0)** short and deep, with anterior margins close to dorsoventral plane; **(1)** more anterioposteriorly elongate with anterior margins angled posteriorly.

New Character

129. Pre-caudal scaly keel: (0) Present; (1) Absent.

The pre-caudal scaly keel is a specialised lateral expansion on the lateral flanks of the caudal peduncle supported by a single row of large specialised scales. The structure is unique to *Saurostomus esocinus* and *Germanostomus pectopteri*. The pre-caudal scaly keel is not structurally homologous to the scaly caudal apparatus (see Character 126) first described by Arratia and Schultze, 2013 for *Orthocormus roeperi*, *Hypsocormus* spp. and *Sauropsis* spp. (see Cooper and Maxwell, 2022 for discussion of the homology of these structures).

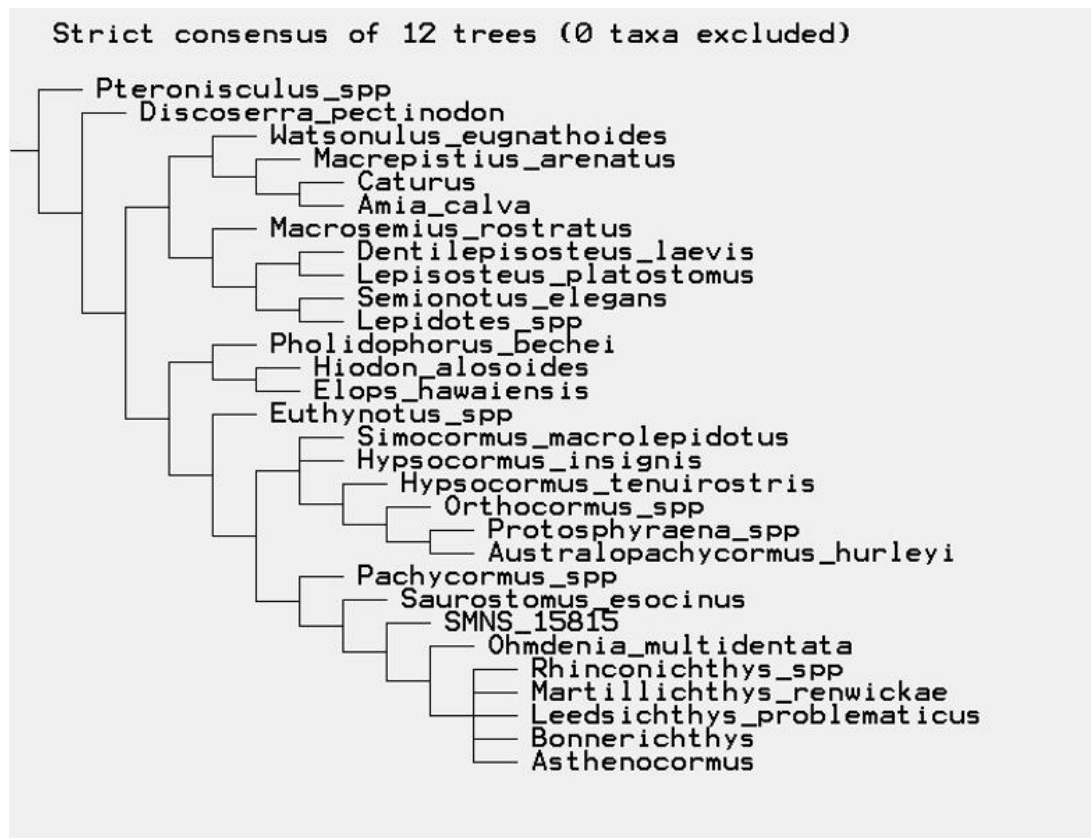


Fig. S3. Strict consensus of 12 trees based on the Friedman (2012) matrix. *Germanostomus pectopecteri* gen. et sp. nov., holds an intermediate position between *Saurostomus esocinus* and *Ohmdenia multidentata*.

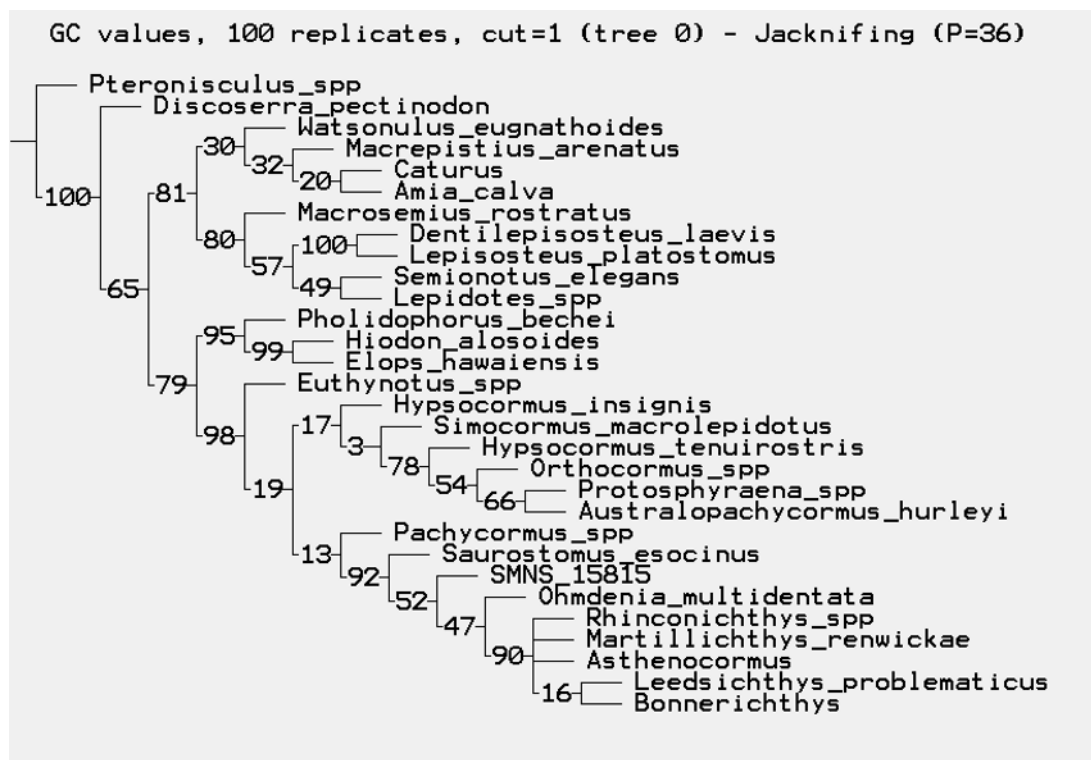


Fig. S4. Strict consensus tree of the Friedman (2012) matrix resampled with Jackknife (36) showing values of node stability.

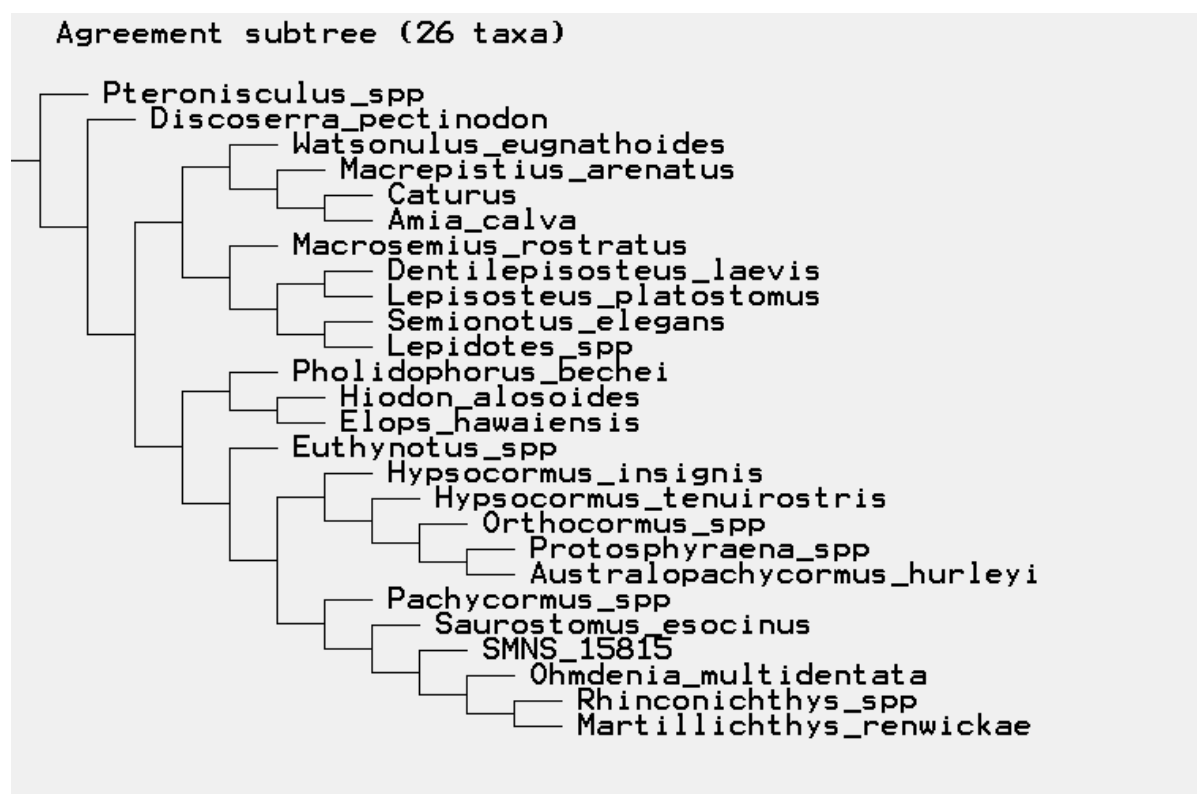


Fig. S5 – Agreement subtree of the results from the Friedman matrix. Four taxa recognised as unstable or poorly supported have been eliminated: *Simocormus macrolepidotus*; *Leedsichthys problematicus*; *Bonnerichthys* and *Asthenocormus*.

Gouiric-Cavalli and Arratia (2022) Matrix

We also tested the phylogenetic position of SMNS 15815 using a different Pachycormiformes matrix in order to test the reliability of its phylogenetic placement and to assess how different character matrixes would change the topology of the clade when we introduced a new taxon. For this we used the recent matrix in Gouiric-Cavalli and Arratia (2022), who included a total of 48 taxa scored by one continuous and 185 discrete characters in their character-by-taxon matrix. All previous characters and character states are retained from the original analysis, as are all original taxa with exception to ‘*Saurostomus esocinus* Stuttgart’ that has been removed. Gouiric-Cavalli and Arratia (2022) understandably regarded the phylogeny and taxonomic identity of *Saurostomus esocinus* as “unresolved and controversial”, highlighting the need for this taxon to be revised. The authors

decided to score material described as *S. esocinus* by Wenz as *Saurostomus esocinus* in their analysis, but undescribed material in the SMNS was scored separately as '*Saurostomus esocinus* Stuttgart'. We have recently revised *Saurostomus esocinus* (Cooper and Maxwell, 2022), and concluded that all of the material of *Saurostomus esocinus* examined by Gouiric-Cavalli and Arratia (2022) at the SMNS and the material described by Wenz (1968) are a single taxon, *Saurostomus esocinus*. Therefore we removed the OTU '*Saurostomus esocinus* Stuttgart' from the analysis. We also updated the scoring for *Saurostomus esocinus* and scored several missing character states based on new observations described in Cooper and Maxwell (2022). In the attached Mesquite File (Supplementary File 3) we have highlighted changes to the original Gouiric-Cavalli and Arratia (2022) matrix in red. Both SMNS 15815 and *Saurostomus esocinus* were scored using the existing character states. We identified a few issues when it came to scoring in this matrix, notably character 48 (number of infraorbitals), which does not provide a suitable character state for taxa which either have zero or have secondary lost these bones (e.g. *Saurostomus*). A new character state of (3): infraorbitals absent, should be added in a revision of the matrix. A full review of the matrix of either Friedman (2012) or Gouiric-Cavalli and Arratia (2022) is outside the scope of the present paper.

The matrix was opened and edited in Mesquite (edited cells highlighted in red), and was analysed in TNT V.1.5. (see Goloboff and Catalano, 2016). Similar to the Friedman matrix we ran a New Technology Search, with the following settings: Ratchet, sector search and drift activated; Find minimum length increased to x50; random seed set to 10. A consensus tree was then produced (Fig. S4). To analyse percentages of node stability we analysed the tree using the Jackknifing (P = 36) resampling tool (Fig. S5). We then pruned problematic taxa using an agreement subtree which collapsed nodes with a stability of ≤ 1 , and removed highly unstable or poorly supported taxa (Fig. S6).

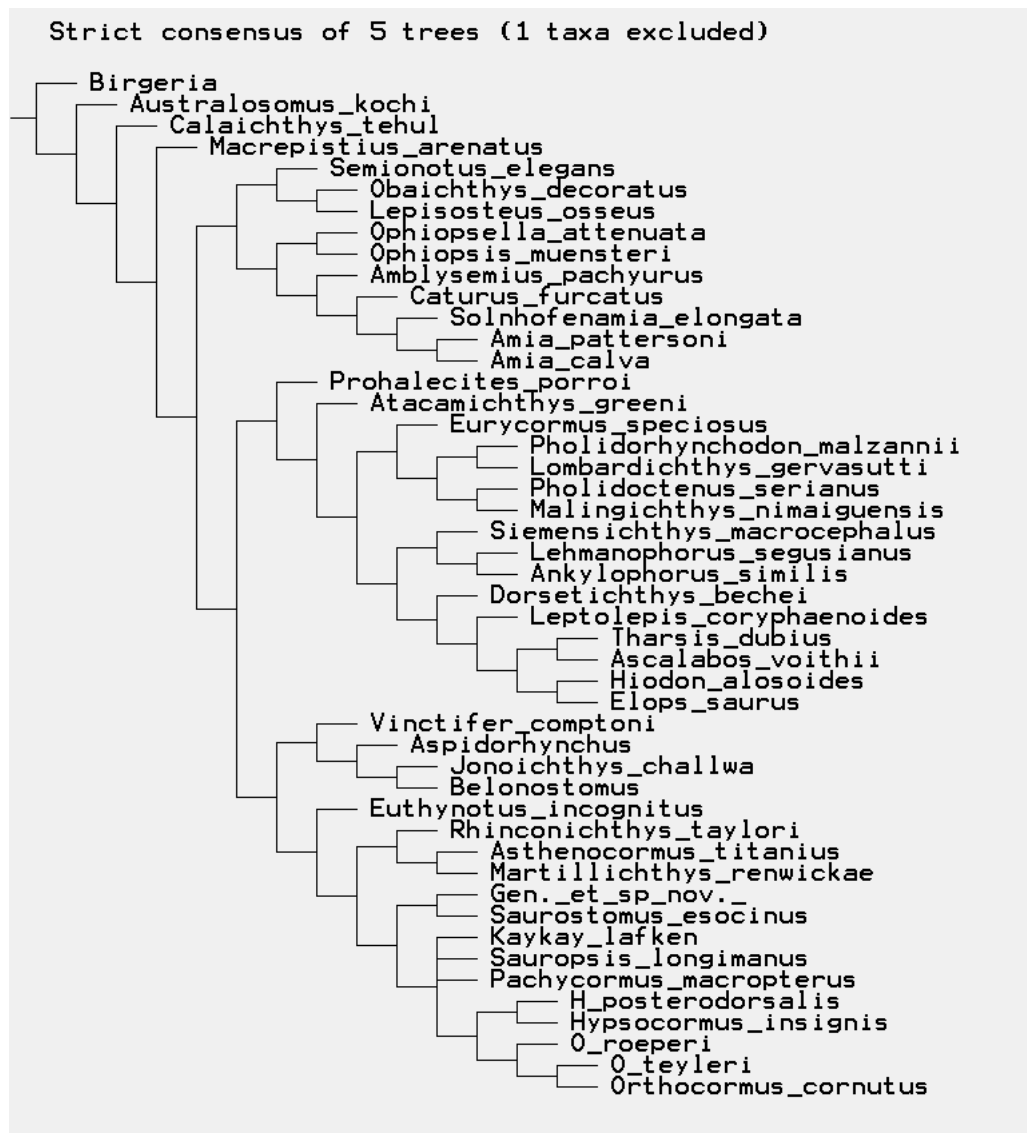


Fig. S6 – Strict consensus of 5 trees obtained from parsimony analysis of the Gouiric-Cavalli and Arratia (2022) matrix. SMNS 15815 *Germanostomus* comes out as the sister to *Saurostomus esocinus* at the base of Hypsocorminae.

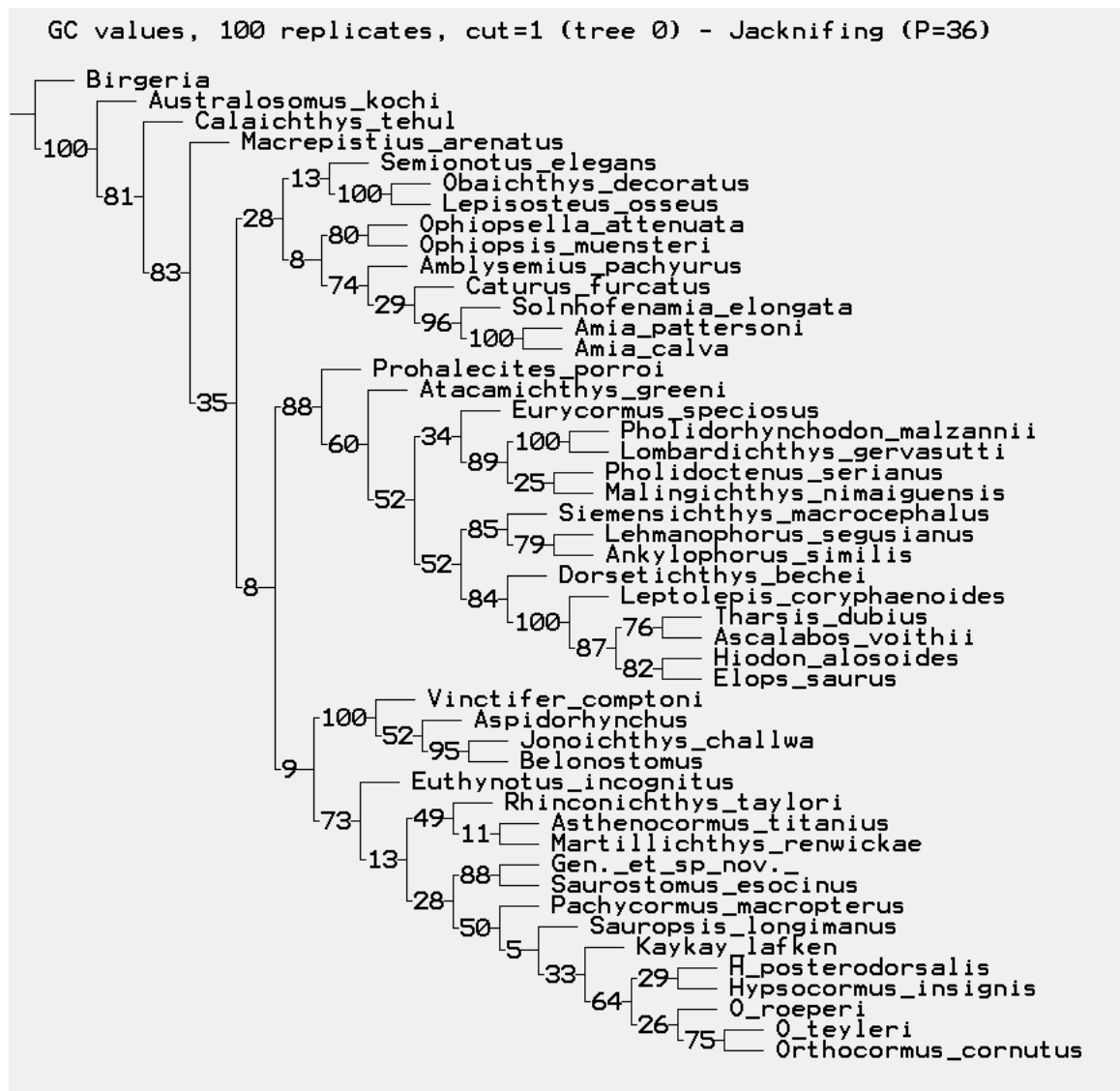


Fig. S7 - Strict consensus tree of the Gouiric-Cavalli and Arratia's (2022) matrix with Jackknifing enabled to show percentages of node stabilities. The sister group relationship between *Saurostomus* and *Germanostomus* is well-supported (88), support for their inclusion at the base of Hypsocorminae rather than Asthenocorminae is weak.

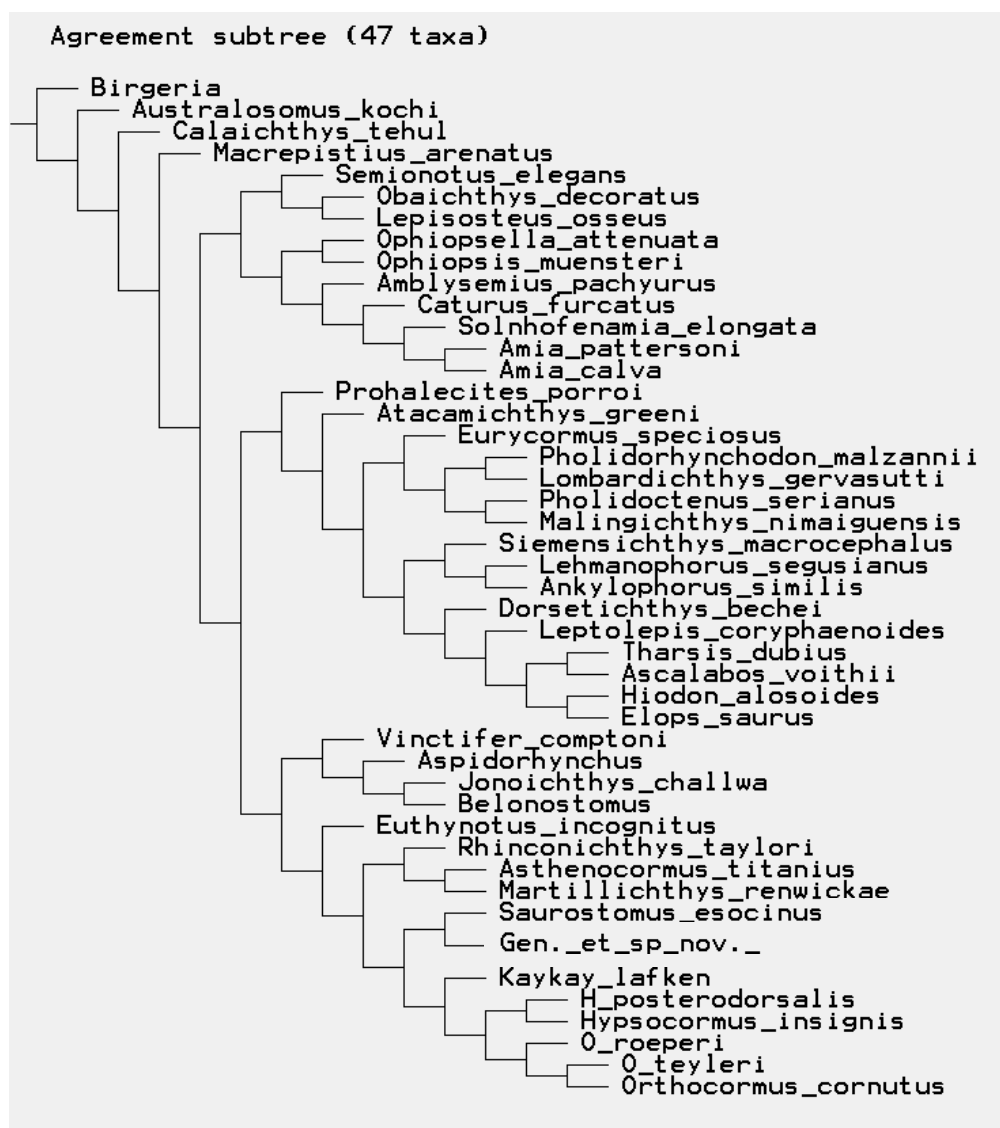


Fig. S8 – Agreement subtree of the consensus tree produced using the Gouiric-Cavalli and Arratia matrix. *Sauropsis longimanus* and *Pachycormus macropterus* have been pruned.

Continuous character:

Birgeria 9.28

Australosomus_kochi 9.15

Macrepistius_arenatus 9.46

Ophiopsis_muensteri 9.46

Ophiopsella_attenuata 9.51

Semionotus_elegans 9.53

Calaichthys_tehul	8.55
Vinctifer_comptoni	9.74
Aspidorhynchus	9.67
Belonostomus	9.81
Jonoichthys_challwa	9.76
Amia_calva	9.28
Amia_pattersoni	9.3
Caturus_furcatus	9.41
Amblysemius_pachyurus	9.26
Lepisosteus_osseus	9.83
Obaichthys_decoratus	9.75
Solnhofenamia_elongata	9.3
Euthynotus_incognitus	9.43
Hypsocormus_insignis	9.4
H_posterodorsalis	9.59
Orthocormus_cornutus	9.43
O_teyleri	9.23
O_roeperi	9.45
Saurostomus_esocinus	9.38
Saurostomus_esocinus_Sttut	9.38
Gen._et_sp_nov._	9.78
Pachycormus_macropterus	9.43
Sauropsis_longimanus	9.26
Kaykay_lafken	9.28
Martillichthys_renwickae	?

Rhinconichthys_taylori ?

Asthenocormus_titanius 9.68

Ankylophorus_similis 9.46

Ascalabos_voithii	9.51
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Atacamichthys_greeni 9.34

Elops_saurus 9.28

Eurycormus_speciosus 9.51

Hiodon_alosoides	9.48
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Lehmanophorus_segusianus 9.26

Leptolepis_coryphaenoides 9.7

Malingichthys_nimaiguensis 9.3

Dorsetichthys_bechei ?

Lombardichthys_gervasutti 9.36

Pholidoctenus_serianus 9.26

Pholidorhynchodon_malzannii 9.28

Prohalecites_porroi 9.11

Siemensichthys_macrocephalus 9.26

Tharsis_dubius 9.51

Discrete (numeric) characters

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[illegible]

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Tharsis_dubius 011101----0-0001021100--000020111101001200-00001-
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Fig. S9 – *Ohmdenia multidentata*

The type and only specimen of the large transitional suspension-feeding asthenocormine, *Ohmdenia multidentata* Hauff, 1953, was re-examined for comparative purposes with *Germanostomus pectopecteri* gen. et sp. nov.. The skeleton, housed in the Palaeontology department collection in Tübingen (GPIT), consists of an incomplete and highly disrupted skeleton, originating from the Posidonienschiefer at Ohmden, Baden-Württemberg. *Ohmdenia* was originally considered by Hauff (1953) as belonging to a toothed chondrosteian, on account of the large and robust nature of the bones being similar to those of *Stronglyosteus hindenburgi*. Lambers (1992) correctly identified *Ohmdenia* as a pachycormid, but erroneously regarded it as a large individual of *Saurostomus esocinus*. Friedman briefly re-described the specimen and identified *Ohmdenia* as the sister to the entire suspension-feeding clade (Asthenocorminae sub-fam. nov.) and drew comparisons between convergent evolutionary trajectories in pachycormids and mycetid cetaceans. We identified several key anatomical features in the specimen which have not previously been reported in previous works (e.g. Hauff, 1953; Friedman 2012). These include the differentiated dorsal scute (Fig. S7D), the fused anterior rod of the pectoral fin (Fig. S7F), anteriorly directed dentary teeth at the mandibular symphysis (Fig. S7C), the pre-anal scute (not figured), and certain anatomical landmarks in the hyomandibula (Fig. S7E: see discussion in main text). A re-description of this taxon is outside the scope of this work.

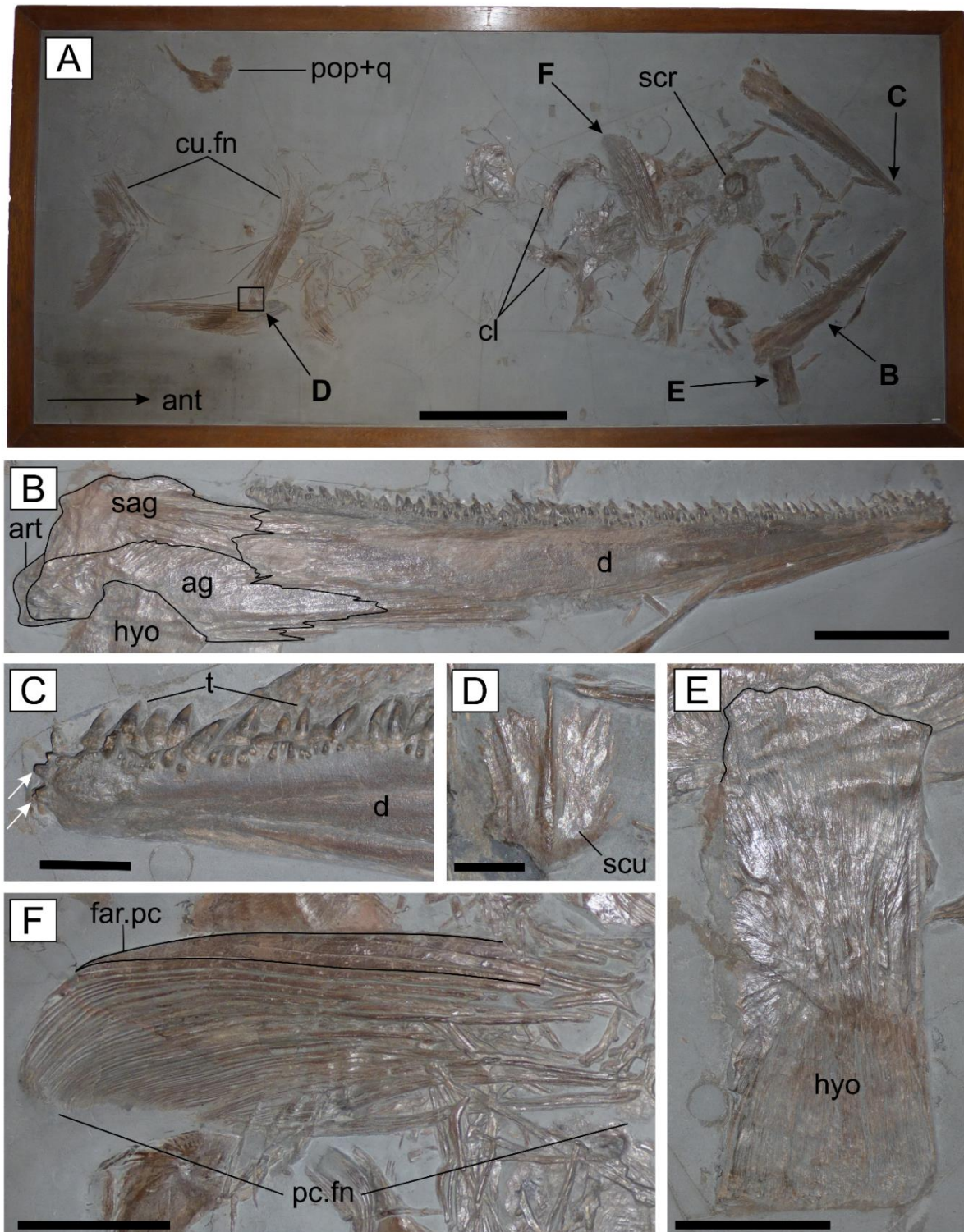


Fig. S9 – *Ohmdenia mulitdentata* Hauff, 1953. **A** = GPIT-PV-31531, holotype and only known specimen. Note that the Left lower jaw (indicated by **C**) was originally found more than two meters away from the rest of the skeleton and thus its placement is not representative of its original position (Hauff, 1953). **B** = right lower jaw in external view. **C** = close up of the anterior portion of the left dentary showing tooth morphology. Arrows indicate the anteriormost teeth projecting forward at 180° to the long axis of the dentary. **D** = Dorsal scute in external view, displaying a well-developed

anteriorly projecting spine. **E** = hyomandibula. **F** = (? Right) pectoral fin. The posterior-most lepidotrichia are disarticulated but in situ. *Abbreviations:* **ag** = angular; **art** = articular; **cl** = cleithra; **cu.** = caudal fin; **d** = dentary; **far.pc** = fused anterior rod of pectoral fin; **hyo** = hyomandibula; **pc.fn** = pectoral fin; **pop+q** = preopercle and quadrate; **sag** = surangular = **scr** = sclerotic ring; **scu** = dorsal scute; **t** = teeth. Scale bars equal to 500 mm (A); 100 mm (B-C, E-F) and 20 mm (D).

Examples of *Pachycormus macropterus* preserving the alimentary canal and spiral valve organ

Few of the examined specimens of *Pachycormus macropterus* from the Posidonia Shale preserve elements of their gastrointestinal anatomy useful for comparison with other pachycormids (Fig. S10). The midgut intestine is folded and attaches to the ventroposterior region of the stomach. The spiral valve is short and deep with fewer rotations than in more derived asthenocormines (Fig. 10, in main document). The alimentary canal is also preserved via cololite infill in specimens of *Pachycormus* from the Toarcian deposits of Strawberry Bank, Ilminster, UK. Portions of the midgut are visible on the surface, and CT scanning allows buried regions and part of the spiral valve to be visualised. The stomach is located dorsal to the intestine, with the midgut intestine attaching to its venteroposterior margin. The midgut intestine is elliptical in cross section and forms an s-shape, with three elongate limbs that lie parallel to each other. Although incomplete, this region is comparatively shorter in BRLSI M.1297 (referred to *Pachycormus macropterus*) than in BRLSI M.1384 and 1384 (referred to *Pachycormus* sp., which form part and counterpart), and morphological variation in the skull suggests they may represent different taxa (S. Giles pers. obs.). Posteriorly, the midgut extends dorsally, and comparison with SMNS 56220 indicates it formed another short loop. The anterior portion of the spiral valve is preserved in BRLSI M.1356, and comprises at least three rotations.

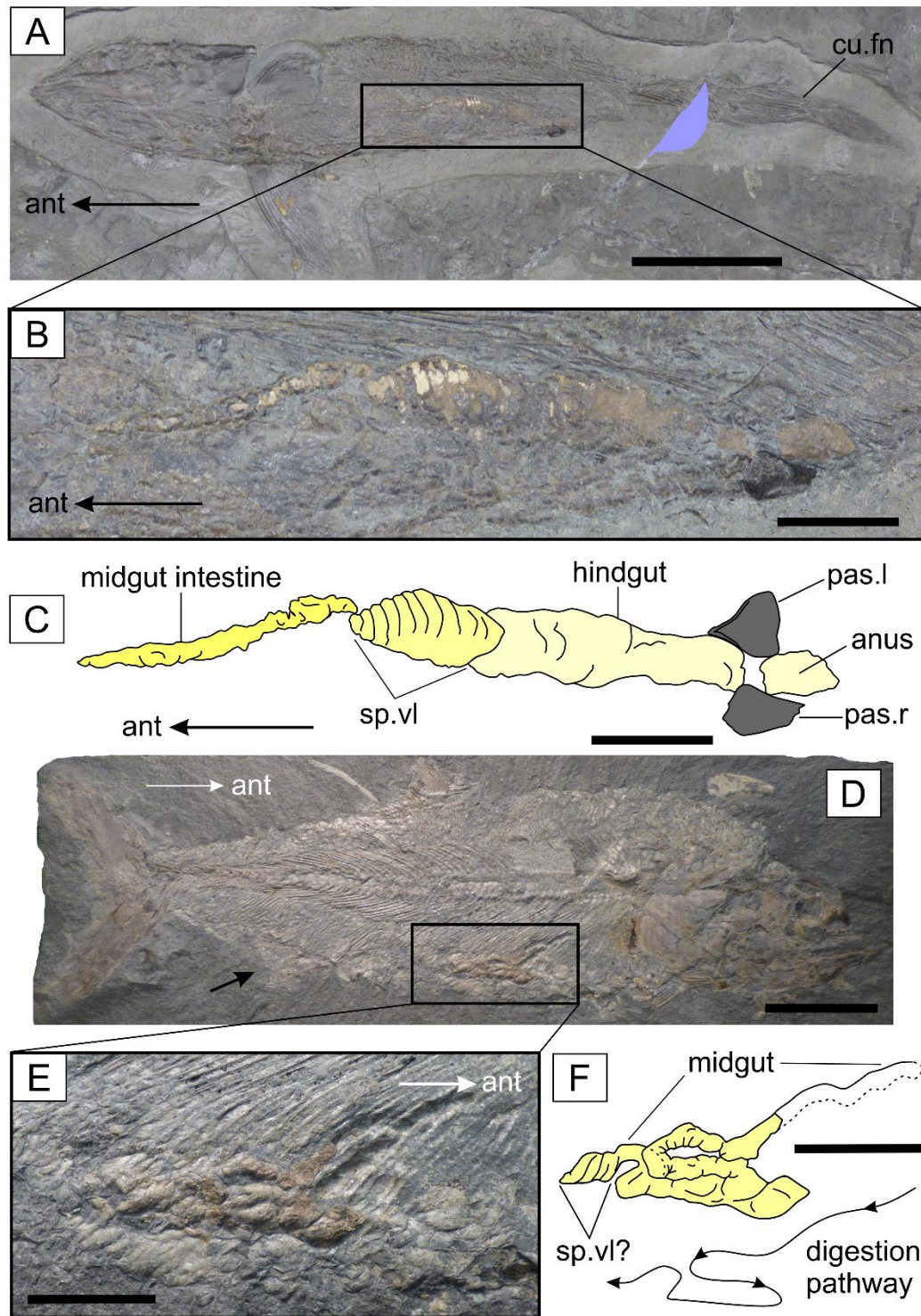


Fig. S10. Gastrointestinal anatomy in two examples of *Pachycormus macropterus*. **A** = SMNS 56230, complete skeleton from Dotternhausen in left-ventroposterior view. Alimentary canal is preserved by cololite infill. **B** = close up of cololite, with **C** = interpretive drawing. The hindgut portion of the cololite passes continuously between the left and right preanal scutes. **D** = SMNS 4415, showing good intestinal preservation. **E** = close up of the folded midgut intestine, with **F** = line drawing. The midgut is set close to the ventral margin and is neatly folded with a double 'S'-shaped path. *Abbreviations:*

ant = anterior; **cu.fn** = caudal fin; **pas.l** = left preanal scute; **pas.r** = right preanal scute; **sp.vl** = spiral valve organ. Scale bars are equal to: 100 mm (A), 50 mm (D), and 20 mm (B-C, E-F).

Literature cited

BERG, L.S., 1937. A classification of fish-like vertebrate. *Bulletin de l'Académie des Sciences de l'URSS*, **4**, 1277-1280.

COOPER, S.L.A. & MAXWELL, E.E., 2022. Revision of the pachycormid fish *Saurostomus esocinus* AGASSIZ from the Early Jurassic (Toarcian) of Europe with new insight into the origins of suspension-feeding in Pachycormidae. *Papers in Palaeontology*, IN PRESS.

COPE, E.D., 1887+. Zittel's Manual of Palaeontology. *American Naturalist*, **21**, 1014–1019.

DOBSON, C.E, GILES, S., JOHANSON, Z., LISTON, J., and FRIEDMAN, M., 2019. Cranial osteology of the Middle Jurassic (Callovian) *Martillichthys renwickae* (Neopterygii, Pachycormiformes) with comments of the evolution of ecology of edentulous pachycormids. *Papers in Palaeontology*, **2019**, 1-26.

FRIEDMAN, M., 2012. Parallel evolutionary trajectories underlie the origins of giant suspension-feeding whales and bony fishes. *Proceedings of the Royal Society, Series B*, **279**, 944-951.

FRIEDMAN, M., SHIMADA, K., MARTIN, L.D., EVERHART, M.J., LISTON, J., MALTESE, A., and TRIEBOLD, M., 2010. 100-million-year dynasty of giant planktivorous bony fishes in the Mesozoic seas. *Science*, **327**, 990-993.

GOLOBOFF, P.A. & CATALANO, S.A., 2016. TNT version 1.5, including a full implementation of phylogenetic morphometrics. *Cladistics* 32(3), 221-238.

GOUIRIC-CAVALLI, S. & ARRATIA, G., 2022. A new †Pachycormiformes (Actinopterygii) from the Upper Jurassic of Gondwana sheds light on the evolutionary history of the group. *Journal of Systematic Palaeontology*, DOI: 10.1080/14772019.2022.2049382.

LAMBERS, P.H., 1992. On the ichthyofauna of the Solnhofen Lithographic Limestone (Upper Jurassic, Germany). Unpublished PhD thesis, Rijkuniversiteit Groningen, 336 pp.

LISTON, J.J., 2004. An overview of the pachycormiform *Leedsichthys*. In: ARRATIA, G., and A. TINTORI, A. (eds.), Mesozoic Fishes 3 – Systematics, Paleoenvironments and Biodiversity, 379 – 390. Verlag Dr. Friedrich Pfeil, München.

LISTON, J.J., 2008. A review of the characters of the edentulous pachycormiforms *Leedsichthys*, *Asthenocormus*, and *Martillichthys* nov. gen. – pp. 181-191, In: ARRATIA, G., SCHULTZE, H.P., and WILSON, M.V.H. (eds.), Mesozoic Fishes 4 – Homology and Phylogeny. Verlag Dr. Friedrich Pfeil, München.

LISTON, J.J., 2010. The occurrence of the Middle Jurassic pachycormid fish *Leedsichthys*. *Oryctos*, **9**, 1-36.

LISTON, J.J. & NOË, L.F. 2004. The tail of the Jurassic fish *Leedsichthys problematicus* (Osteichthyes: Actinopterygii) collected by Alfred Nicholas Leeds – an example of the importance of historical records in palaeontology. *Archives of Natural History*, **31**, 236-252.

MARTILL, D.M., 1986. The stratigraphic distribution and preservation of fossil vertebrates in the Oxford Clay of England. *Mercian Geologist*, **10**, 161-186.

SCHUMACHER, B.A., SHIMADA, K., LISTON, J., and MALTESE, A., 2016. Highly specialised suspension-feeding bony fish *Rhinconichthys* (Actinopterygii: Pachycormiformes) from the mid-Cretaceous of the United States, England, and Japan. *Cretaceous Research*, **61**, 71-85.

VETTER, B. 1881. Die Fische aus dem lithographischen Schiefer im Dresdner Museum. – *Mittheilungen aus dem Koeniglichen Mineralogisch-Geologischen und Praehistorischen Museum in Dresden*. **4**: 1-118.

WENZ, S., 1968. Complements a l'étude des poissons actinoptérygiens du Jurassique Français. *Cahiers de Paleontologie*, Paris, 276 pp.

WOODWARD, A.S., 1895. Catalogue of the fossil fishes in the British Museum (Natural History), **3**, xlii + 544 pp. London: British Museum (Natural History).