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New *Saurorhynchus* (Actinopterygii: Saurichthyidae) material from the Early Jurassic of Alberta,
Canada

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Abstract. Saurichthyidae are a family of elongate, piscivorous actinopterygian fishes with a stratigraphic range extending from the late Permian to the Middle Jurassic. There are four recognized Early Jurassic species, all from Europe and all referred to the genus *Saurorhynchus*. Only a single non-European Jurassic occurrence has been reported, a partial *Saurorhynchus* skull from the Fernie Formation of western Alberta, Canada. Here, we evaluate the *Saurorhynchus* material from Canada, including a new skull from Ya Ha Tinda, Alberta, and a fragmentary mandible from Canyon Creek, Alberta. All diagnostic Canadian *Saurorhynchus* specimens are consistent with the European species *Saurorhynchus acutus*, on the basis of external narial morphology and reduced dermal ornamentation. *S. acutus* was present in the Toarcian of western North America from the *tenuicostatum* Zone to the late *serpentinum*/early *bifrons* Zone, similar to the stratigraphic range documented in Europe. The absence of divergence between eastern Panthalassan and western Tethyan saurichthyids is surprising, given that divergence has been well-documented in coeval invertebrates. *Saurorhynchus* may have had slower rates of morphological evolution than contemporaneous marine invertebrates; alternatively greater mobility, broader environmental tolerance, or both in these fish may have allowed ongoing gene flow between the two oceanic basins in the early Toarcian.

Keyword: Actinopterygii, Saurichthyidae, Palaeobiogeography, Toarcian, Early Jurassic

The Early Jurassic is an important interval in the evolution of marine communities. While much attention has focused on the largest mass extinctions, relatively little is known about biotic turnovers during lesser global extinctions. Following the end-Triassic mass extinction, marine communities experienced another substantial extinction in the late Pliensbachian to early Toarcian interval (Bambach 2006). Significant, multi-phased turnover is recorded in both the pelagic and benthic realms; extinctions in these realms can be temporally decoupled and are interpreted to have been driven by different environmental factors (e.g., Harries and Little 1999; Caruthers et al. 2013, 2014; Caswell and Coe 2014; Danise et al. 2015; Martindale and Aberhan 2017). Our understanding of (non-molluscan) pelagic predator extinction and diversification following the end-Triassic mass extinction is hampered by the limited fossil record. This is especially true for the marine ichthyofauna, for which documented Early Jurassic occurrences outside of Europe are relatively sparse (e.g., Wilson and Bruner 2004; López-Arbarelo et al. 2008).

The Fernie Formation is a marine sedimentary unit that promises to provide important insights into the diversity dynamics, ecology, and biogeography of Early Jurassic fish faunas outside of the western Tethys. This formation crops out in the central and southern Foothills of the Canadian Rockies, and has yielded relatively abundant marine fish remains (Wilson and Bruner 2004). Although for the most part undescribed, these include small teleosts (e.g., Wilson and Bruner 2004; Martindale et al. 2017), at least one large non-teleostean taxon (EEM, pers. observ.), and the saurichthyid *Saurorhynchus* (e.g., Neuman and Wilson 1985; Hall et al. 1998). The last genus is represented by two well-preserved but laterally compressed partial skulls, only one of which has been described (Neuman and Wilson 1985). Recent taxonomic

revision of the European material referred to *Saurorhynchus* (Maxwell and Stumpf in press) makes reconsideration of the North American record appropriate.

Saurichthyidae, a family of elongate, piscivorous actinopterygian fishes, were most diverse in the Triassic (Romano et al. 2012), but are also well-documented from Lower Jurassic marine localities throughout Europe and the UK, as well as from the earliest Middle Jurassic of Europe (reviewed by Maxwell (2016); Table 1). A recent reappraisal of the Early Jurassic European saurichthyid occurrences supports the presence of a single lineage, the *Saurorhynchus* species group, and four valid diagnosable species: two Sinemurian species (*Saurorhynchus brevirostris* and *S. anningae*) and two Toarcian species (*S. acutus* and *S. hauffi*), all distinguished on the basis of cranial osteology (Maxwell and Stumpf in press; note that *Acidorhynchus* is herein considered a subjective junior synonym of *Saurorhynchus* following Kogan (2016)). Only a single non-European occurrence has been reported, a partial *Saurorhynchus* skull from the Lower Jurassic Fernie Formation of Alberta, Canada (Fig. 1), attributed to *Saurorhynchus* cf. *acutus* on the basis of overall skull shape, the presence of interrostrals, and the morphology of the maxilla-rostropremaxilla suture (Neuman and Wilson 1985). However, the characters used to identify the Canadian specimen are no longer considered to have diagnostic value (Maxwell and Stumpf in press). Here, we re-evaluate the *Saurorhynchus* material from Canada, including both the skull described by Neuman and Wilson (1985) and two previously unreported cranial specimens from more southerly localities in western Alberta. We also discuss the implications for paleobiogeography of Toarcian fishes.

Materials and Methods

Institutional abbreviations: TMP, Royal Tyrrell Museum of Palaeontology, Drumheller, Alberta, Canada; UALVP, University of Alberta Laboratory for Vertebrate Paleontology, Edmonton, Alberta, Canada.

Neuman and Wilson (1985) described a partial skull lacking the lower jaw (UALVP 17750) from the Poker Chip Shale Member of the Fernie Formation, from a locality just south of Cadomin, Alberta (52°58'30"N, 117°19'30"W) (Fig. 1). Invertebrates from the locality indicated that the specimen originated from the lower Toarcian part of the formation (Neuman and Wilson 1985), corresponding to the *kanense* Zone (correlated with the *tenuicostatum*–*serpentinum* Zones of Europe: Jakobs et al. (1994)). The presence of the ammonites *Leptaleoceras pseudoradians* and *Dactylioceras* cf. *kanense* in particular suggest that this specimen originated from near the Pliensbachian-Toarcian boundary; i.e. at the base of the *tenuicostatum* Zone (Jakobs et al. 1994; Caruthers 2013).

A second specimen, TMP 1996.076.0001, consists of a slightly more complete skull with an articulated lower jaw. It was collected by the late Russell Hall in 1996 from the East Tributary of Bighorn Creek locality, Ya Ha Tinda, Alberta (Royal Tyrrell Museum of Palaeontology locality L2428), from the upper surface of a thin, resistant siltstone bed ~20 m above the base of the Poker Chip Shale, Fernie Formation, correlating with the *serpentinum*–*bifrons* Zones (Hall et al. 1998) (Fig. 1). Recent field work at this locality suggests a latest *serpentinum* Zone – earliest *bifrons* Zone age for this horizon (Them et al. 2017; Fig. 2).

Lastly, a fragmentary lower jaw (TMP 2014.005.0016) was collected in 2014 from the Pliensbachian portion of the Fernie Formation at Canyon Creek, Alberta (50°53'19"N, 114°45'28"W).

Systematic paleontology

Actinopterygii Cope, 1887

Saurichthyidae Owen, 1860

Saurorhynchus Reis, 1892

***Saurorhynchus acutus* (Agassiz, 1843)**

REMARKS: Two incomplete skulls from western Alberta, Canada, are assigned to *Saurorhynchus acutus* on the basis of diagnostic features recently listed by Maxwell and Stumpf, in press).

Specimen 1: UALVP 17750

(Fig. 3)

DESCRIPTION: UALVP 17750 was previously described and figured in detail (Neuman and Wilson 1985); here we mention only those observations that are of taxonomic utility or differ from the previous interpretation.

The skull has a preorbital length of ~95 mm (anterior edge of orbit to rostral tip), and preserves the narial region and rostromaxilla (Fig. 3A). It has been strongly dorsolaterally compressed. The narial region has been prepared from both sides of the skull (Fig. 3). The shape of the anterior narial opening is strongly affected by shear deformation (compare Fig. 3C, D). We interpret the original shape as being narrower and more elongate than currently visible on the left (Fig. 3C), but wider and shorter than the state preserved on the right (Fig. 3D), and set quite high on the skull. The maxilla is strongly deflected ventral to the orbit. The element previously interpreted as the interrostral is here interpreted as a broken fragment of the portion of the rostromaxilla dorsal to the sensory canal; the suture between the nasal and antorbital noted by Neuman and Wilson (1985) may also be attributed to breakage. Dermal ornamentation is weakly

developed. The teeth are fine and conical, and are curved anteriorly. There is an almost complete absence of accessory (non-laniary) teeth.

REMARKS: UALVP 17750 is inconsistent with the Sinemurian species *Saurorhynchus brevirostris* on the basis of the absence of subnarial laniary dentition and the conical shape of the posterior laniaries. The strong ventral deflection of the maxilla and shape of the anterior narial opening are also inconsistent with the Sinemurian species *S. anningae* and the Toarcian species *S. hauffi* (Maxwell and Stumpf, in press). The long, narrow shape and dorsal position of the anterior narial opening closely agrees with that of *S. acutus* from the Toarcian of Europe, similar to the assessment of Neuman and Wilson (1985) although for slightly different reasons.

Specimen 2: TMP 1996.076.0001

(Fig. 4A–D)

TMP 1996.076.0001 has a lower jaw length (jaw joint to rostral tip) of 126 mm, a maximum lower jaw depth of 20 mm, and a preorbital length of 94 mm. The upper and lower jaws are similar in length, and both bear incisivulücken (depressions along the external surface of the jaws) to accommodate the laniary dentition. The anterior external narial opening is narrow and elongate, positioned dorsally relative to the small, round posterior opening (Fig. 4D). The small dermal bones surrounding the orbit are for the most part damaged or missing, making the orbit appear very large. The anterior dermal skull roof is not well exposed; however, ornamentation appears to consist of pitting, with some development of a reticular pattern medially. The posterior part of the dermal skull roof is missing. The parasphenoid is exposed in lateral view. The parasphenoid rostrum is curved ventral to the orbit, and is edentulous. Posterior to the orbit, a large, laterally directed foramen for the internal carotid and efferent pseudobranchial arteries is situated between the basisphenoid and parasphenoid (Fig. 4C).

The left mandible is preserved as an impression posteriorly. The angular is massive, contacting the dentary along a 'V'-shaped suture typical for *Saurorhynchus* (Fig. 4A, B). The angular contains the mandibular sensory canal, which gives rise to a series of ventral branches.

The laniary teeth are conical, decrease in size anteriorly, and bear acrodin caps.

REMARKS: A suite of characters unite TMP 1996.076.0001 with the European Toarcian saurichthyids to the exclusion of the Sinemurian species *S. anningae* and *S. brevirostris*. These include the absence of an overbite, the absence of heterodonty in laniary teeth shape, the relatively dorsal position of the mandibular sensory canal, and the position of the foramen for the internal carotid and efferent pseudobranchial arteries. There are fewer characters available to differentiate *S. acutus* and *S. hauffi*; however, the long, narrow shape of the anterior external narial opening in TMP 1996.076.0001 is more consistent with *S. acutus* (Fig. 4E) than with *S. hauffi*.

***Saurorhynchus* sp.**

(Fig. 4F)

DESCRIPTION AND REMARKS: TMP 2014.005.0016 is a fragment of an anterior mandible, broken posteriorly. The anteriormost portion exposes the left dentary in lateral view, and posteriorly the right dentary is preserved as an impression on the fine-grained matrix. Teeth are also preserved. Although clearly from a saurichthyid fish bearing incisivulücken and, thus, most likely referable to *Saurorhynchus*, it cannot be assigned to a species.

Discussion

TMP 1996.076.0001 represents the youngest occurrence of *Saurorhynchus acutus* in North America, and also the most southerly, with Ya Ha Tinda being located approximately 180

km to the southeast of the UALVP locality (Fig. 1). The taxonomically indeterminate Canyon Creek jaw fragment TMP 2014.005.0016 is currently the most southerly occurrence of a Jurassic saurichthyid in North America, 100 km southeast of Ya Ha Tinda, and also the oldest post-Anisian occurrence of the family in eastern Panthalassa (Romano et al. 2012).

Although UALVP 17750 and TMP 1996.076.0001 are from the Panthalassan oceanic basin rather than from the Tethys, both show distinct morphological similarities with, and are here considered referable to the European species *Saurorhynchus acutus*. *Saurorhynchus acutus* was originally described on the basis of a partial skull from the Toarcian of the Cleveland Basin (Whitby, England) (Agassiz 1833–1843), but has since been identified from the Southwest German Basin, suggesting a broad distribution across Europe (Maxwell and Stumpf in press). The referral of the Canadian Jurassic saurichthyids to this species is based primarily on the shape of the anterior narial opening and weak development of dermal ornamentation, and is also supported by braincase and lower jaw morphology, which, although relatively uninformative in differentiating the two European Toarcian *Saurorhynchus* species, differs greatly between the Sinemurian and Toarcian species (Maxwell and Stumpf in press). The narial morphology in *S. acutus* is currently unique within Saurichthyidae, making it a shared derived feature uniting European specimens of *S. acutus* and the two Canadian Jurassic saurichthyid skulls.

Globally, no saurichthyid material diagnostic at the species level is known from the Pliensbachian or earliest Toarcian (Hauff 1938; Maxwell 2016; Maxwell and Stumpf in press; Table 1), making the first appearance of *Saurorhynchus acutus* in Europe difficult to pinpoint. However, *S. acutus* was certainly present in the Southwest German Basin immediately prior to the negative $\delta^{13}\text{C}$ isotopic excursion associated with the Toarcian Oceanic Anoxic Event, first occurring in the Fleins bed of the Posidonienschiefer Formation (Bed number ϵII_3 ; *tenuicostatum* Zone, late *semicelatum* Subzone: Maxwell and Stumpf in press). The ammonites recovered from

the locality of UALVP 17750 are suggestive of a *tenuicostatum* Zone (lowermost Toarcian) age (Jakobs et al. 1994), and so it is probable that this occurrence is either coeval with, or even older than, the first documented European occurrence of *S. acutus*. In contrast, TMP 1996.076.0001 was found in the latest *serpentinum* or earliest *bifrons* Zone (Fig. 2), well above the initial $\delta^{13}\text{C}$ isotopic excursion (Them et al. 2017) and coincident with, or slightly younger than, the last confirmed European occurrence of this species, the latter of which falls in the *serpentinum* Zone, *elegans* Subzone. Thus, the European and North American stratigraphic ranges of *S. acutus* have extensive overlap in the first two Ammonite Zones of the Toarcian.

With preorbital lengths of 95 and 94 mm, respectively, UALVP 17750 and TMP 1996.076.0001 are two of the largest individuals of *S. acutus* known and, thus, are unlikely to have been juveniles. By comparison, the holotype from the Cleveland Basin has a preorbital length of 84 mm, and material from the Southwest German Basin has preorbital lengths from 59–92 mm (Maxwell and Stumpf in press). Assuming similar proportions to the second European Toarcian species, *S. hauffi*, the Canadian specimens would have had fork lengths (from the anterior end of the rostrum to the end of the middle caudal fin rays) of ~44 cm.

The Posidonienschiefer Formation and Poker Chip Shale Member of the Fernie Formation have been interpreted as being very similar in depositional environment and faunal composition (Martindale and Aberhan 2017; Martindale et al. 2017). Among invertebrates, species-level differences between oceanic basins (i.e., eastern Panthalassa vs. Tethys) appear to have been the norm (Martindale et al. 2017). In addition, no fishes with ganoid squamation have been identified at the Ya Ha Tinda locality (RCM pers. observ.) in stark contrast with the Posidonia Shale community. Thus, it is somewhat surprising that the saurichthyid fishes from both basins can apparently be referred to a European species. At least some Middle Triassic saurichthyids were viviparous (Bürgin 1990; Renesto and Stockar 2009) and structures interpreted as intromittent

organs have also been reported in the *Saurorhynchus* species group (Griffith 1977), raising the possibility that *S. acutus* may have been viviparous. Viviparity has been theoretically linked with increased dispersal capability relative to demersally spawning fishes, because a disjunct population can be founded by a single gravid female (Wourms and Lombardi 1992). Viviparity is also correlated with higher rates of speciation (Helmstetter et al. 2016). Three possibilities need to be considered for *Saurorhynchus acutus*. It is possible that European *S. acutus* and the Canadian *Saurorhynchus* material described here are closely related species that do not show much difference in cranial morphology, rather than being conspecifics. The second possibility is that *Saurorhynchus* evolved more slowly than contemporaneous marine invertebrates. Finally, greater mobility, broader environmental tolerance, or both allowed ongoing gene flow between *Saurorhynchus* populations in the two oceanic basins during the early Toarcian. The wider geographic range is also more likely with a Hispanic Corridor (Aberhan 2001, 2002; see Fig. 1) between the Tethys and Panthalassa Oceans, which would have allowed organisms to move between ocean basins.

Conclusions

New taxonomic information, as well as well-constrained stratigraphic and geographic occurrences, allow precise comparisons between the relatively poorly known marine vertebrate fauna of the Early Jurassic of North America with that of the much better characterized European epicontinental basins. The specimens from Europe and Alberta show a high degree of similarity considering their geographic separation, and raise the possibility of a relatively homogenous ichthyofauna in the Northern Hemisphere during the early Toarcian. However, the apparent rarity of ganoid fishes at Ya Ha Tinda may indicate some major differences between the basins, and requires further investigation.

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References

- Aberhan, M. 2001. Bivalve palaeobiogeography and the Hispanic Corridor: time of opening and effectiveness of a proto-Atlantic seaway. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **165**: 375–394. doi: 10.1016/S0031-0182(00)00172-3.
- Aberhan, M. 2002. Opening of the Hispanic Corridor and Early Jurassic bivalve biodiversity. Geological Society, London, Special Publications, **194**: 127–139. doi: 10.1144/gsl.sp.2002.194.01.10.
- Agassiz, L. 1833 – 1843. *Recherches sur les Poissons Fossiles*. II. Contenant l'Histoire de l'Ordre des Ganoïdes. Petitpierre, Neuchatel.
- Bambach, R.K. 2006. Phanerozoic biodiversity mass extinctions. *Annual Review of Earth and Planetary Sciences*, **34**: 127–155.
- Bürgin, T. 1990. Reproduction in Middle Triassic actinopterygians; complex fin structures and evidence of viviparity in fossil fishes. *Zoological Journal of the Linnean Society*, **100**: 379–391.
- Caruthers, A.H. 2013. Pliensbachian–Toarcian (Early Jurassic) extinction in western North America. PhD, Geological Sciences, University of British Columbia, Vancouver, B.C.

- Caruthers, A.H., Smith, P.L., and Gröcke, D.R. 2013. The Pliensbachian-Toarcian (Early Jurassic) extinction, a global multi-phased event. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **386**: 104–118.
- Caruthers, A.H., Smith, P.L., and Gröcke, D.R. 2014. The Pliensbachian-Toarcian (Early Jurassic) extinction: a North American perspective. *Geological Society of America Special Papers*, **505**: 225–243.
- Caswell, B.A., and Coe, A.L. 2014. The impact of anoxia on pelagic macrofauna during the Toarcian Oceanic Anoxic Event (Early Jurassic). *Proceedings of the Geologists' Association*, **125**: 383–391.
- Cope, E.D. 1887. Geology and palaeontology. Zittel's manual of palaeontology. *American Naturalist*, **22**: 1014–1019.
- Danise, S., Twitchett, R.J., and Little, C.T.S. 2015. Environmental controls on Jurassic marine ecosystems during global warming. *Geology*, **43**: 263–266.
- Delsate, D. 1998. L'ichthyofaune du Toarcien luxembourgeois. Cadre général et catalogue statistique. *Travaux Scientifiques du Musée National d'Histoire Naturelle de Luxembourg*, **30**: 1–101.
- Firion, F., and Schneider, E. 1975. *Acidorrhynchus* im Unteren Lias der Zaberner Senke. *Annales Universitatis Saraviensis*, **12**: 7–12.
- Griffith, J. 1977. The Upper Triassic fishes from Polzberg bei Lunz, Austria. *Zoological Journal of the Linnean Society*, **60**: 1–93.
- Hall, R., Poulton, T.P., and Monger, J.W.H. 1998. Field Trip A1: Calgary-Vancouver. *In* Field guide for the fifth International Symposium on the Jurassic System. *Edited by* P.L. Smith. International Union of Geological Sciences Subcommittee on Jurassic Stratigraphy, Vancouver. pp. 29–61.

- Harries, P.J., and Little, C.T.S. 1999. The early Toarcian (Early Jurassic) and the Cenomanian-Turonian (Late Cretaceous) mass extinctions: similarities and contrasts. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **154**: 39–66.
- Hauff, B. 1938. Über *Acidorrhynchus* aus den Posidonienschiefern von Holzmaden. *Paläontologische Zeitschrift*, **20**: 214–248.
- Helmstetter, A.J., Papadopoulos, A.S.T., Igea, J., Van Dooren, T.J.M., Leroi, A.M., and Savolainen, V. 2016. Viviparity stimulates diversification in an order of fish. *Nature Communications*, **7**: 11271. doi: 10.1038/ncomms11271.
- Jakobs, G.K., Smith, P.L., and Tipper, H.W. 1994. An ammonite zonation for the Toarcian (Lower Jurassic) of the North American Cordillera. *Canadian Journal of Earth Sciences*, **31**: 919–942.
- Kogan, I. 2016. *Acidorrhynchus* Stensiö, 1925 or *Saurorrhynchus* Reis, 1892: how to call the Jurassic saurichthyid? *Neues Jahrbuch für Geologie und Paläontologie Abhandlung*, **279**: 123–126.
- López-Arbarello, A., Rauhut, O.W.M., and Moser, K. 2008. Jurassic fishes of Gondwana. *Revista de la Asociación Geológica Argentina*, **63**: 586–612.
- Martindale, R.C., and Aberhan, M. 2017. Response of macrobenthic communities to the Toarcian Oceanic Anoxic Event in northeast Panthalassa (Ya Ha Tinda, Alberta, Canada). *Palaeogeography, Palaeoclimatology, Palaeoecology*. doi: 10.1016/j.palaeo.2017.01.009
- Martindale, R.C., Them, T.R.I., Gill, B.C., Marroquín, S.M., and Knoll, A.H. 2017. A new Early Jurassic fossil Lagerstätte from Ya Ha Tinda, Canada (~183 Ma). *Geology*. **45**: 255–258 doi: 10.1130/G38808.1
- Maxwell, E.E. 2016. First Middle Jurassic record of Saurichthyidae (Actinopterygii). *Paläontologische Zeitschrift*, **90**: 287–291. doi: 10.1007/s12542-015-0281-5.

- Maxwell, E.E., and Stumpf, S. In press. Revision of *Saurorhynchus* (Actinopterygii: Saurichthyidae) from the Early Jurassic of England and Germany. *European Journal of Taxonomy*.
- Neuman, A.G., and Wilson, M.V.H. 1985. A fossil fish of the family Saurichthyidae from the Lower Jurassic of western Alberta, Canada. *Canadian Journal of Earth Sciences*, **22**: 1158–1162.
- Owen, R. 1860. *Palaeontology or a systematic summary of extinct animals and their geological relations*. A. and C. Black, Edinburgh.
- Reis, O.M. 1892. Zur Osteologie und Systematik der Belonorhynchiden und Tetragolepiden. *Geognostische Jahreshefte*, **4**: 143–171.
- Renesto, S., and Stockar, R. 2009. Exceptional preservation of embryos in the actinopterygian *Saurichthys* from the Middle Triassic of Monte San Giorgio, Switzerland. *Swiss Journal of Geosciences*, **102**: 323–330.
- Romano, C., Kogan, I., Jenks, J., Jerjen, I., and Brinkmann, W. 2012. *Saurichthys* and other fossil fishes from the late Smithian (Early Triassic) of Bear Lake County (Idaho, USA), with a discussion of saurichthyid palaeogeography and evolution. *Bulletin of Geosciences*, **87**: 543–570.
- Scotese, C.R. 2014. Atlas of Jurassic paleogeographic maps, PALEOMAP Atlas for ArcGIS. PALEOMAP Project, Evanston, IL.
- Them, T.R., Gill, B.C., Caruthers, A.H., Gröcke, D.R., Tulskey, E.T.T., Martindale, R.C., Poulton, T.P., and Smith, P.L. 2017. High-resolution carbon isotope records of the Toarcian Oceanic Anoxic Event (Early Jurassic) from North America and implications for the global drivers of the Toarcian carbon cycle. *Earth and Planetary Science Letters*, **459**, 118–126. doi: 10.1016/j.epsl.2016.11.021.

- Wenz, S. 1967. Compléments a l'étude des poissons actinoptérygiens du Jurassique Français. *Cahiers de Paléontologie*, **1967**: 1–276.
- Wilson, M.V.H., and Bruner, J.C. 2004. Mesozoic fish assemblages in North America. *In* Mesozoic Fishes 3 – Systematics, paleoenvironments and biodiversity. *Edited by* G. Arratia and A. Tintori. Dr. Friedrich Pfeil, München. pp. 575–595.
- Wourms, J.P., and Lombardi, J. 1992. Reflections on the evolution of piscine viviparity. *American Zoologist*, **32**: 276–293.

Figure captions

Fig. 1. Paleogeographic and modern location of study sites. (A) Toarcian paleogeography, showing the locations of the Southwest German Basin (SWGB), Cleveland Basin (CB) in the UK, and Western Canadian Sedimentary Basin (WCB) (simplified from Scotese (2014)). (B) Map of Canada showing the location of the province of Alberta (in grey), and (C), the relative locations of the *Saurorhynchus*-bearing localities: 1 = Cadomin (specimen UALVP 17750), 2 = Ya Ha Tinda (specimen TMP 1996.076.0001), 3 = Canyon Creek (specimen TMP 2014.005.0016).

Fig. 2. Lithostratigraphy of the East Tributary of Bighorn Creek locality, modified from Them et al. (2017). The dashed line indicates the approximate position of TMP 1996.076.0001; note there are some discrepancies in measurements between the stratigraphic column as presented here based on more recent field observations and that of Hall et al. (1998).

Fig. 3. *Saurorhynchus acutus* from the Lower Jurassic of western Alberta, Canada. UALVP 17750, a posteriorly incomplete skull lacking lower jaws, from Cadomin. Complete skull in left

(A) and right (B) lateral views; and magnified views of the external narial openings (outlined in white) from the left (C) and right (D) sides of the skull. Scale bars = 20 mm (A), 10 mm (B), 5 mm (C-D). Abbreviations: n_1 , anterior narial opening; n_2 , posterior narial opening.

Fig. 4. *Saurorhynchus acutus* from the Lower Jurassic of western Alberta, Canada. (A–D), TMP 1996.076.0001, posteriorly incomplete skull with articulated lower jaws from Ya Ha Tinda: photograph (A) and interpretive drawing (B) of entire specimen in right lateral view and magnified views of orbitotemporal (C) and narial (D) regions from the right side of the skull. Parasphenoid and basisphenoid outlined in black (C); narial openings outlined in white (D). In B and E, large dashes represent broken areas, fine dashes represent the sensory canals. (E) Cranial reconstruction for *Saurorhynchus acutus* based on Lower Jurassic material from the Southwest German Basin (redrawn from Maxwell and Stumpf in press, fig. 2D). Grey lines represent sutures that are uncertain due to poor preservation in the European material. (F), *Saurorhynchus* sp., TMP 2014.005.0016, portion of anteriormost left lower jaw in lateral view and lateral surface of right lower jaw preserved as an impression, from Canyon Creek. Scale bars = 30 mm (A, B), 2 mm (C), 5 mm (D), and 20 mm (E, F). Abbreviations: ang, angular; bs, basisphenoid; d, dentary; f, frontal; f.ic+ep, foramen for the internal carotid and efferent pseudobranchial arteries; m, maxilla; md.c, mandibular sensory canal; n_1 , anterior narial opening; n_2 , posterior narial opening; na-ao, nasaloantorbital; orb, orbit; pm, rostromaxilla; ps, parasphenoid; psr, parasphenoid rostrum.

Figure 1

91x52mm (300 x 300 DPI)

Figure 2

123x188mm (300 x 300 DPI)

Figure 3

118x88mm (300 x 300 DPI)

Figure 4

209x275mm (300 x 300 DPI)

Table 1. Distribution of *Saurorhynchus* spp.

Species	Age	Occurrence	Reference
<i>Saurorhynchus brevirostris</i>	Sinemurian	England	Maxwell and Stumpf (in press)
<i>Saurorhynchus anningae</i>	Sinemurian	England	Maxwell and Stumpf (in press)
<i>Saurorhynchus</i> sp.	Sinemurian	France	Firtion and Schneider (1975)
<i>Saurorhynchus</i> sp.	Pliensbachian	Germany	Maxwell and Stumpf (in press)
<i>Saurorhynchus</i> sp.	Pliensbachian	Canada	This paper
<i>Saurorhynchus acutus</i>	Toarcian	England, Germany, Canada	Maxwell and Stumpf (in press); this paper
<i>Saurorhynchus hauffi</i>	Toarcian	England, Germany	Maxwell and Stumpf (in press)
<i>Saurorhynchus</i> sp.	Toarcian	France	Wenz (1967)
<i>Saurorhynchus</i> sp.	Toarcian	Luxembourg	Delsate (1998)
<i>Saurorhynchus</i> sp.	Aalenian	Germany	Maxwell (2016)