A New Miocene Scorpaenoid Fish, Raususetarches sakurai gen. et sp. nov. (Teleostei: Scorpaeniformes) from Rausu, Hokkaido, Japan

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Source: Paleontological Research, 25(2) : 93-104

Published By: The Palaeontological Society of Japan

URL: https://doi.org/10.2517/2020PR013

Paleontological Research, vol. 25, no. 2, pp. 93–104, April 1, 2021

doi:10.2517/2020PR013

A new Miocene scorpaenoid fish, *Raususetarches sakurai* gen. et sp. nov. (Teleostei: Scorpaeniformes) from Rausu, Hokkaido, Japan

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Received September 1, 2019; Revised manuscript accepted February 24, 2020

Abstract. ***Raususetarches sakurai*** **gen. et sp. nov. is described from the late Miocene Koshikawa Formation in Kasuga, Rausu, Shiretoko Peninsula, Hokkaido, Japan based on several specimens found in the same rock, as a new genus and species. This new species belongs to the family Scorpaenidae of Scorpaenoidei in having short, triangular posterior spines of preopercle, two ridges and spines of opercle and the first pterygiophore of the anal fin inclined. This species belongs to the subfamily Setarchinae in having lateral line scales forming grooves and cycloid scales. This new species, however, differs from all other genera of the subfamily in having large triangular spines of preopercle; 14 spines and 13 soft rays of the dorsal fin; three spines and eight soft rays of the anal fin; 19 rays of the pectoral fin; hypurals 1 and 2 fused; and hypurals 3 and 4 are also fused. This is the first fossil species of the subfamily Setarchinae.**

Key words: Japan, Miocene, *Raususetarches sakurai*, Scorpaeniform, Setarchinae, Shiretoko Peninsula

Introduction

The Late Miocene Koshikawa Formation is distributed along the Ponshunkarikotangawa River in Shiretoko Peninsula, Hokkaido, Japan.

Mitani *et al*. (1963) mentioned bones of fish fossils found in the mud rocks from the Koshikawa Formation without description and the systematic position of the fish fossils. A rock containing many fish fossils was found on the northern bank of the Ponshunkarikotangawa River in Rausu Town, Hokkaido by Kenji Sakurai. All fish fossils in the same rock are considered as the same species. In the present study, we describe this fish as a new genus and species of the subfamily Setarchinae (family Scorpaenidae). This is the first fossil species of the subfamily Setarchinae in the world.

The recent Setarchinae is a small group of fishes, consisting of three genera and seven species (Nelson *et al*., 2016). These are the comparatively deep-water, bathydemersal dwellers, widely distributed in the Atlantic, Indian and Pacific oceans. Most of the species are venomous. Among the morphological features distinguishing them from other Scorpaenidae are the absence of the bony roof of the lateral line scales and the presence of only cycloid scales on the body.

Comparative materials.—The specimens of Recent Setarchinae from the collection of the Zoological Institute of the Russian Academy of Sciences, Saint-Perersburg, Russia (ZIN): *Ectreposebastes imus*, ZIN 49840, 140 mm SL (standard length), Pacific Ocean, 1°03′S, 97°10′W, 1974 January 19, RV "Akademician Kurchatov", Cruise 17, Station 1454; *Setarches guentheri*, ZIN 22711, 257 mm SL, Pacific Ocean near Japan, 1910 March 28, coll. by P. Ju. Schmidt.

Systematic description

Suborder Scorpaenoidei *sensu* Nelson, 2006
Family Scorpaenidae *sensu* Nelson, 2006
Subfamily Setarchinae Matsubara, 1943
Genus ***Raususetarches*** nov.

Type species.—Raususetarches sakurai sp. nov.

Etymology.—Rausu, after the name of the locality, *setarches*, generic name of scorpaenid fish.

Diagnosis.—Same as for type species.

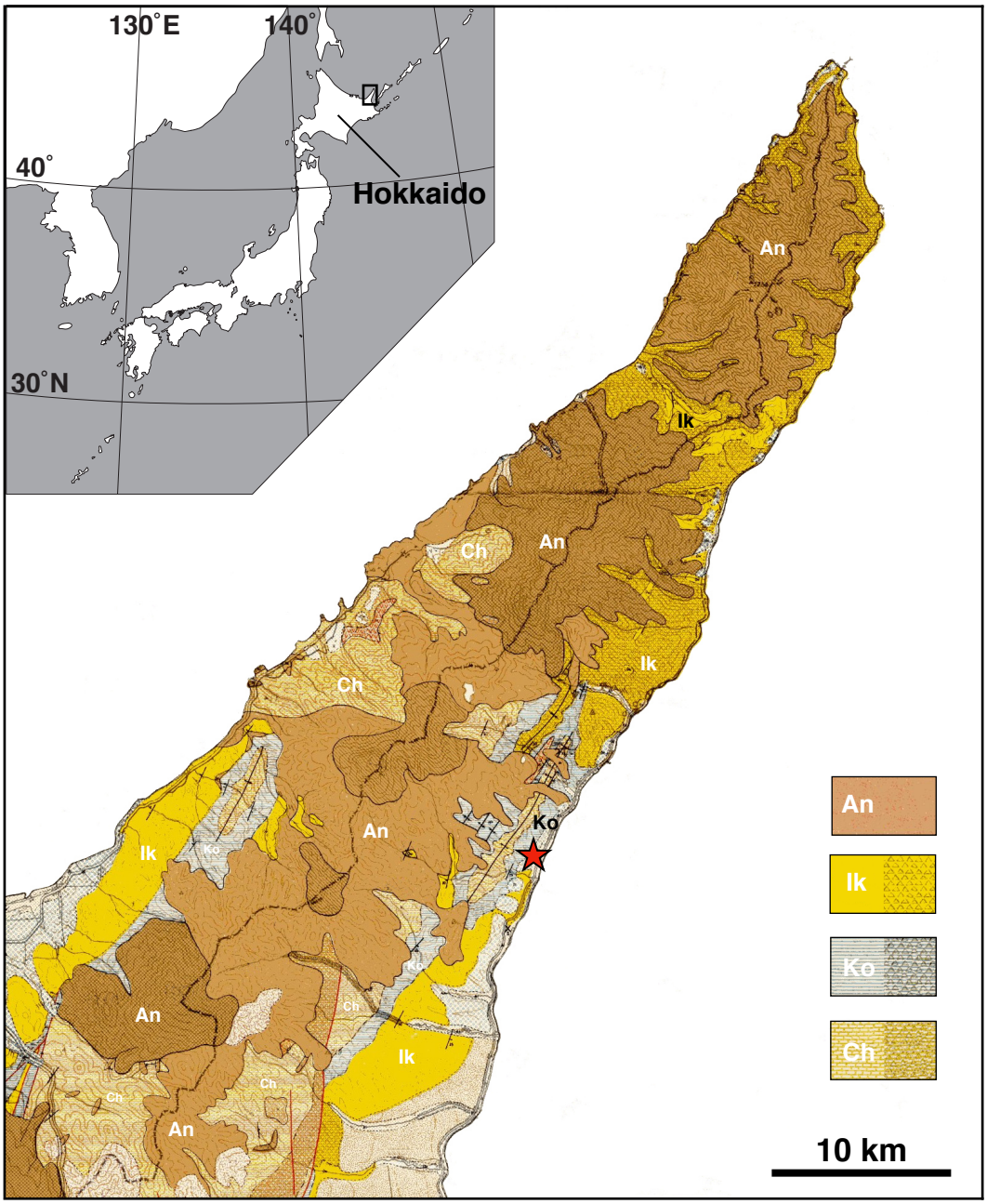

Figure 1. Geological map of Shiretoko Peninsula, Hokkaido based on Geological survey of Hokkaido (1957). A star indicates the locality of holotype and paratypes of *Raususetarches sakurai* gen. et sp. nov. Abbreviations: An = Andesite; Ch = Churui Formation (middle Miocene); Ik = Ikushina Formation (early Pliocene); Ko = Koshikawa Formation (late Miocene).

Raususetarches sakurai sp. nov.

Figures 1–7

Diagnosis.—A member of the Setarchinae distinguished from other species of the Setarchinae by the following combination of characters: large triangular spines of preopercle; 14 spines and 13 soft rays of the dorsal fin; three spines and eight soft rays of the anal fin; 19 rays of the pectoral fin; 10 abdominal and 15 caudal vertebrae; hypurals 1 and 2 fused and forming a large ventral plate; hypurals 3 and 4 fused and forming a large dorsal plate; posterior margin of the caudal fin truncate with slightly concave at the middle and round most dorsal and ventral tips.

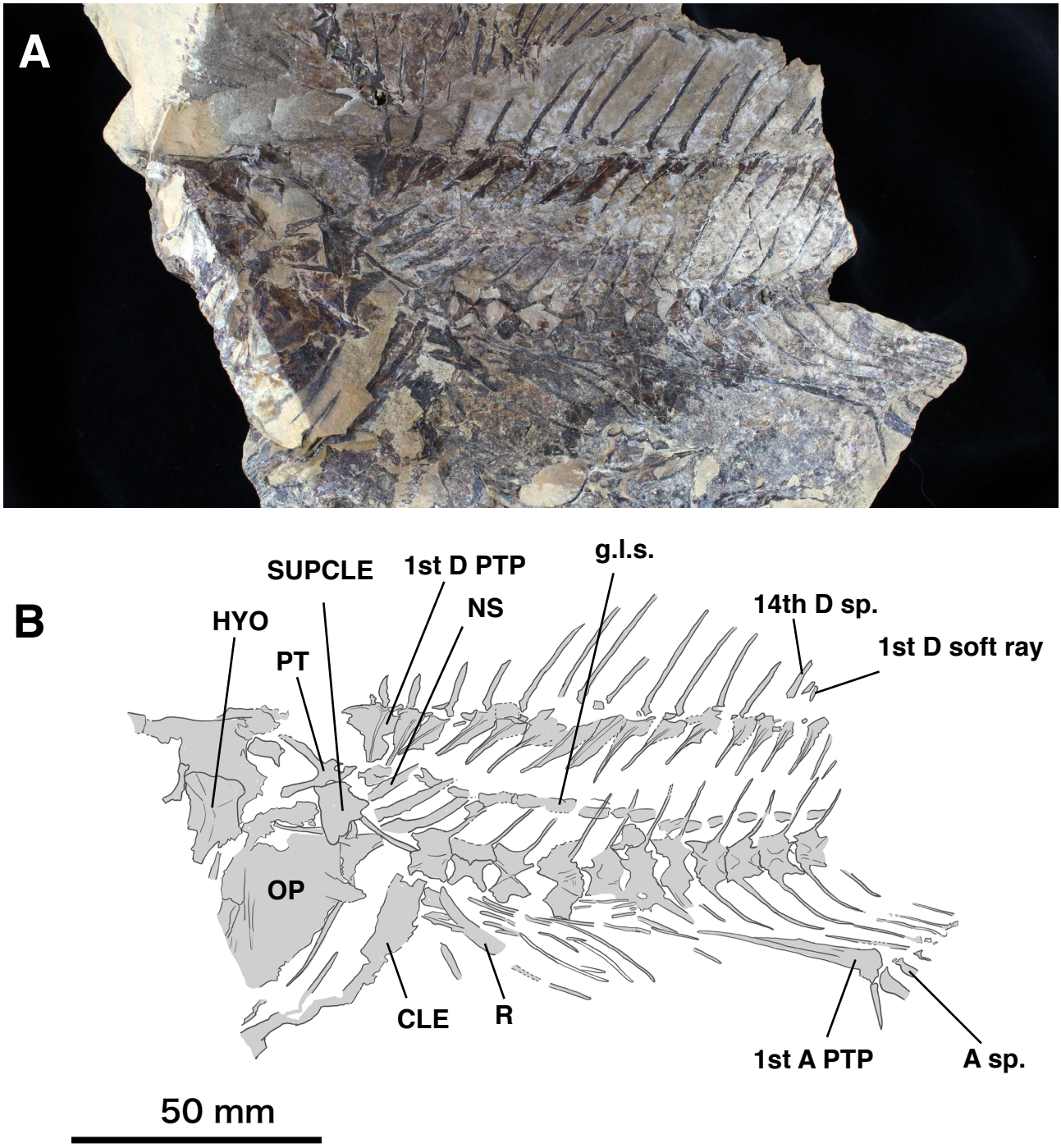

Figure 2. *Raususetarches sakurai* gen. et sp. nov., holotype, RMM 1 from Kasuga, Rausu, Hokkaido, Japan. **A,** photo; **B,** line drawing of A. Abbreviations: 1st A PTP = first proximal pterygiophore of anal fin; 1st D PTP = first proximal pterygiophore of dorsal fin; 1st D soft ray = first soft ray of dorsal fin; 14th D sp. = 14th spine of dorsal fin; A sp. = spine of anal fin; CLE = cleithrum; g.l.s. = groove of lateral line scale; HYO = hyomandibula; NS = neural spine; OP = opercle; PT = posttemporal; R = rib; SUPCLE = supracleithrum.

Material.—Holotype, RMM (Rausu Municipal Museum, Hokkaido) 1, the middle part of the body with anterior parts of the dorsal fin and the anal fin, without the anterior part of the head and the caudal fin. Rausu Municipal Museum is located in Rausu Town, Menashi County, Hokkaido, Japan.

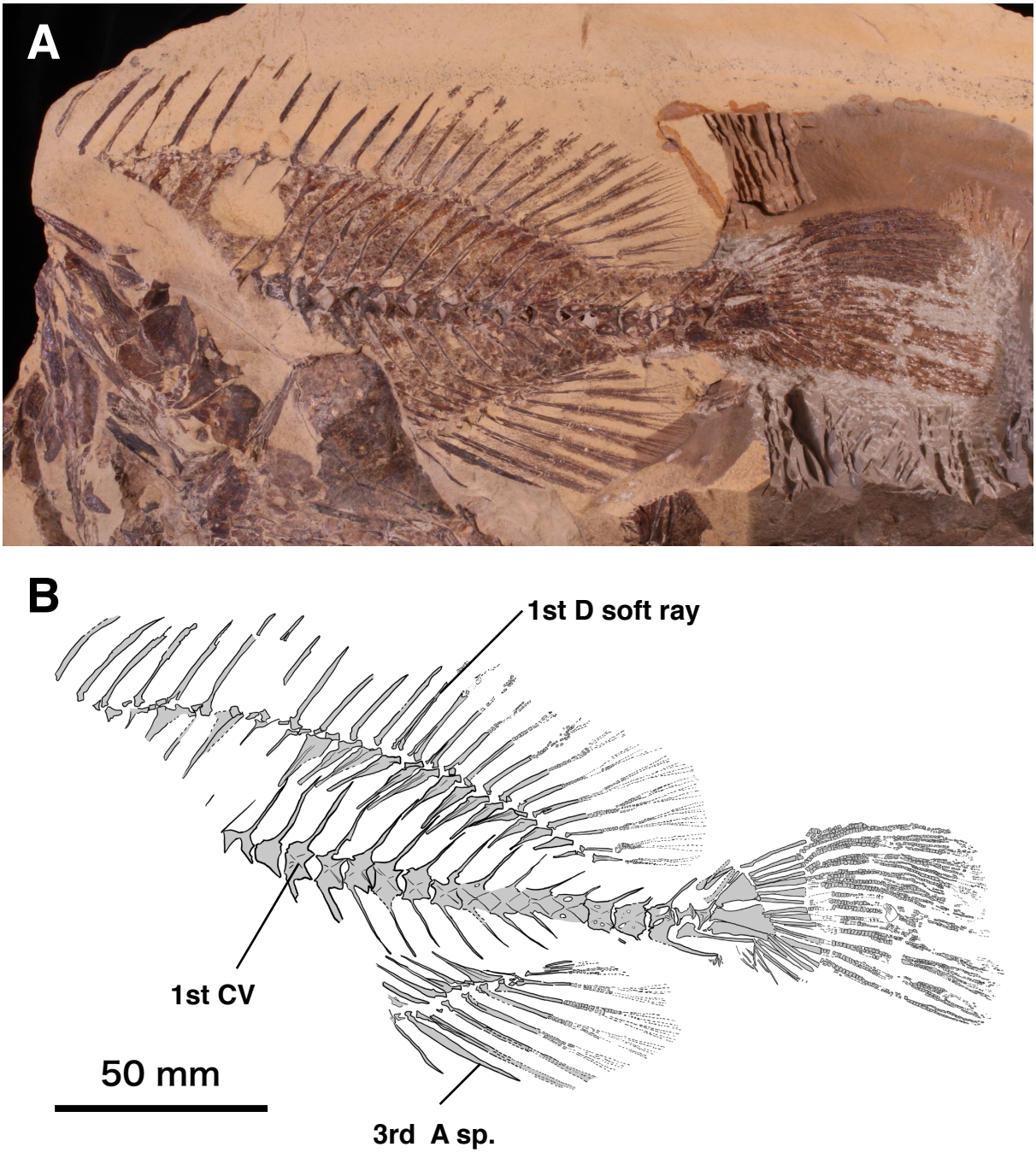

Figure 3. *Raususetarches sakurai* gen. et sp. nov., paratype, RMM 2 from Kasuga, Rausu, Hokkaido, Japan. **A,** photo; **B,** line drawing of A. Abbreviations: 1st CV = first caudal vertebra; 3rd A sp. = third spine of anal fin. Other abbreviations see Figure 2.

Paratypes, RMM 2, the body with almost complete dorsal and anal fins without the head and abdomen; RMM 3, a right preopercle; RMM 4, a left preopercle; RMM 5, a opercle and subopercle; RMM 6, a pectoral fin. All paratypes are in the same rock with holotype.

Locality and horizon.—North bank of Ponshunkarikotangawa River, Kasuga, Rausu, Hokkaido, Japan (Figure 1). The Late Miocene Koshikawa Formation.

Etymology.—The species is named for Kenji Sakurai who collected and donated the type specimens to the Rausu Municipal Museum.

Description of holotype.—The body is laterally com-

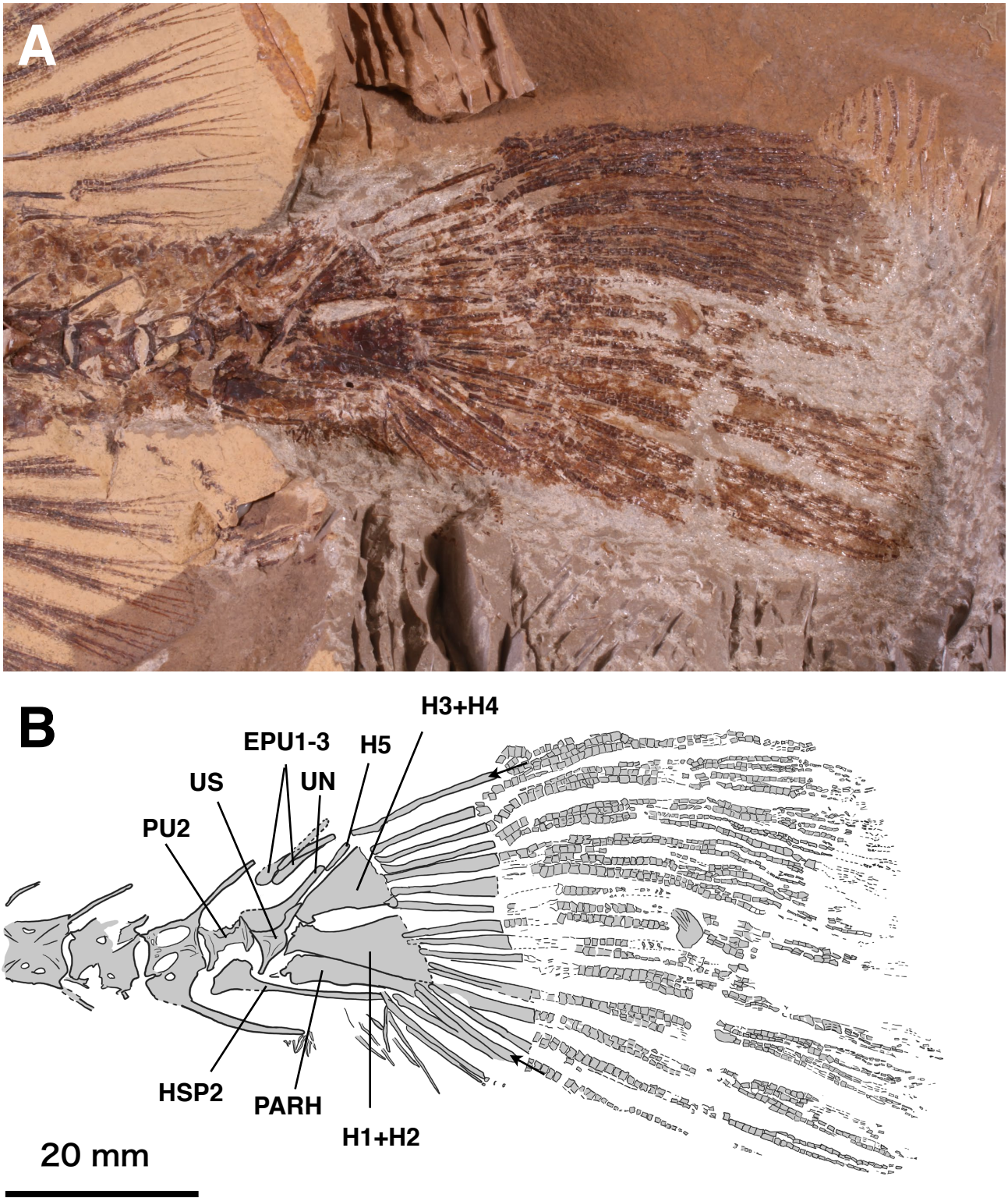

Figure 4. Caudal skeleton and fin of *Raususetarches sakurai* gen. et sp. nov., paratype, RMM 2 from Kasuga, Rausu, Hokkaido, Japan. **A,** photo; **B,** line drawing of A. Abbreviations: EPU1–3 = first to third epurals; H1+H2 = fused first and second hypurals, ventral hypural plate; H3+H4 = fused third and fourth hypurals, dorsal hypural plate; H5 = fifth hypural; HSP2 = haemal spine of the second preuralcentrum; PARH = parhypural; PU2 = second preural centrum; UN = uroneural; US, urostyle.

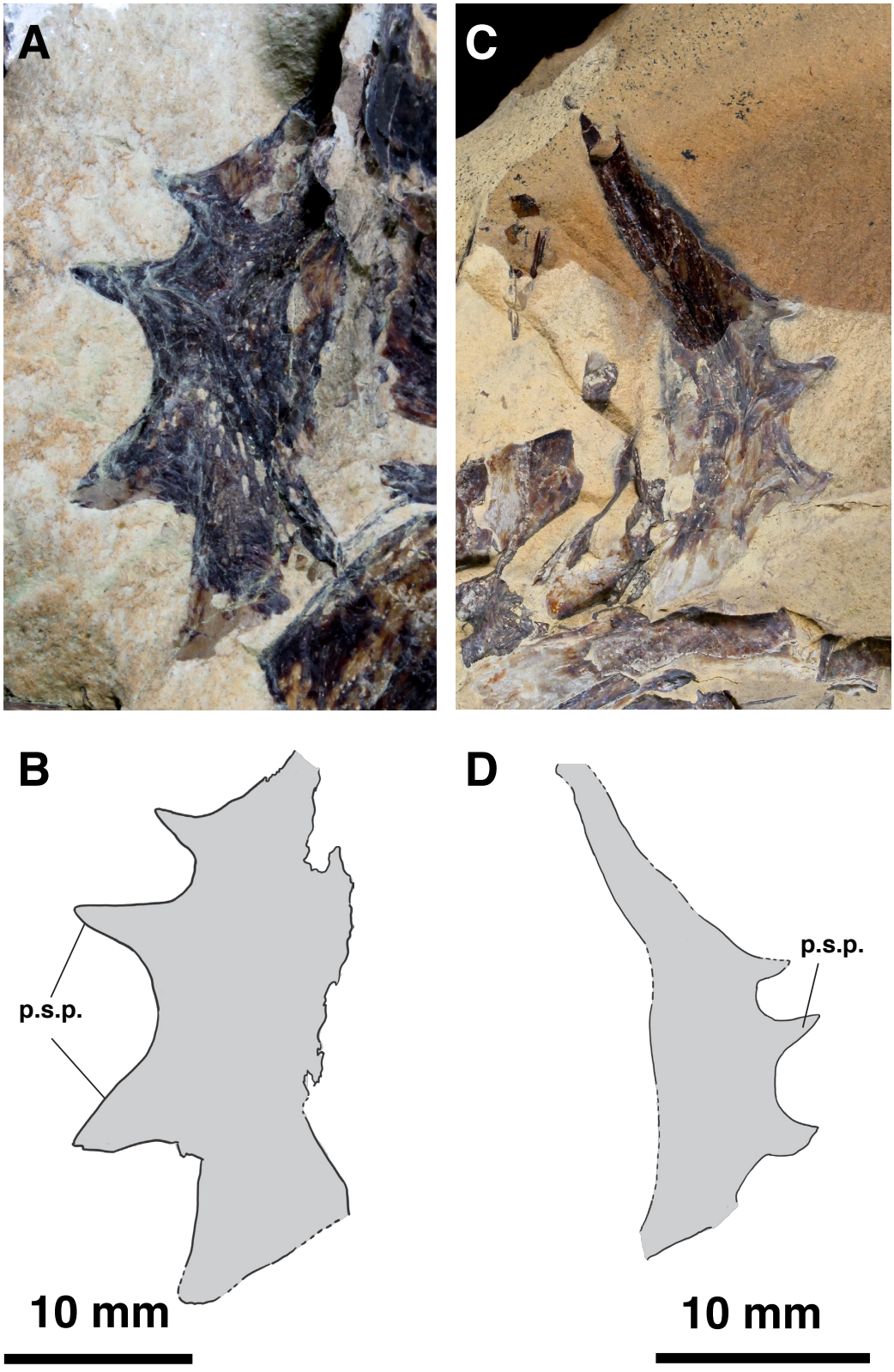

Figure 5. *Raususetarches sakurai* gen. et sp. nov. from Kasuga, Rausu, Hokkaido, Japan. **A,** paratype, RMM 3, right preopercle; **B,** line drawing of A; **C,** paratype, RMM 4, left preopercle; **D,** line drawing of C. Abbreviation: p.s.p. = posterior spine of preopercle.

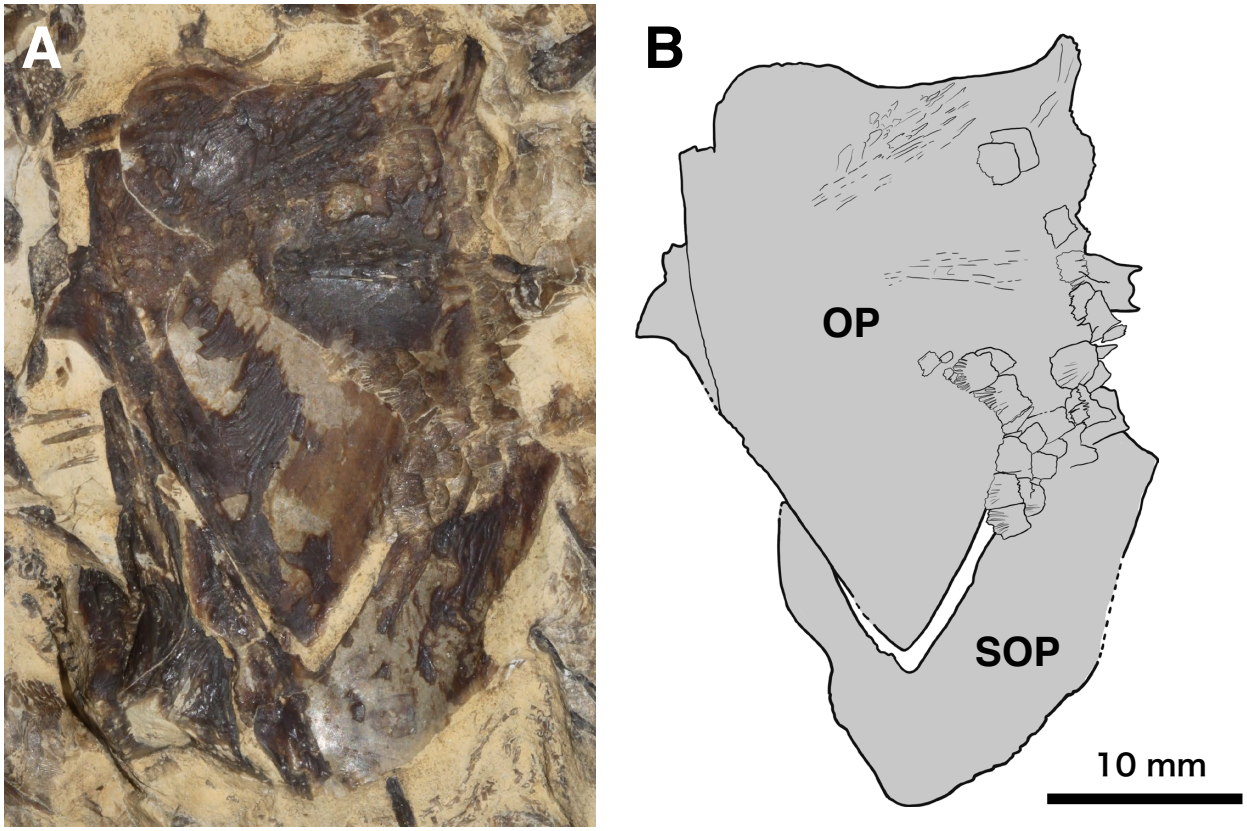

Figure 6. Opercle and subopercle of *Raususetarches sakurai* gen. et sp. nov., paratype, RMM 5 from Kasuga, Rausu, Hokkaido, Japan. **A,** photo; **B,** line drawing of A. Abbreviations: OP = opercle; SOP = subopercle.

pressed (Figure 2). The dorsal fin and the anterior part of the anal fin are well preserved. The posterior part of the neurocranium is preserved, however it is difficult to identify each bone. The pectoral and pelvic fins are lost.

Eleven vertebrae are discernible, of them five are posterior abdominal vertebrae and six are anterior caudal ones (Figure 2). Five anteriormost vertebral centra are in matrix, but three neural spines of these are discernible. Thus, there were 10 abdominal centra in this fossil fish. The vertebral centra are slightly elongated and rectangular. Five anterior neural spines are wide and stout; those following are thin. Abdominal centra with wide, prominent parapophyses. Ribs are long and slender, occupy the most part of abdominal cavity. The haemal spines are slender.

Fourteen spines and 17 proximal pterygiophores of the dorsal fin are recognized (Figure 2). The first two spines are in the supernumerary association. The distal parts from the first to fifth dorsal spines are not preserved, but these do not shortened. The sixth to 13th spines are long, slender.

The first proximal pterygiophore of the dorsal fin is supported by two struts (Figure 2): one extends forward along the dorsal margin of the body and the other is vertical. The horizontal strut is shorter than the vertical one. There is a bony wing between both struts and a wing along the posterior margin of the vertical strut. Other proximal pterygiophores have a strut with anterior and posterior bony thin wings. The base of the first soft ray behind the 14th spine is preserved. In the recent representatives of the subfamily the anterior proximal pterygiophores of the dorsal fin are nested usually by 1 per each interneural space, except of the first two, placed together between neural spines of the second and third vertebrae (see Mandrytsa, 2001: 198). In this fossil fish the pterygiophores look displaced due to fossilization, and three anterior pterygiophores are seen behind the second vertebra.

The first proximal pterygiophore of the anal fin is long and inclines forward (Figure 2). The first spine of the anal fin is shortest, the second and third are long and stout.

The lateral line scale forms a groove (Figure 2). The scales are cycloid. The dorsal fin is covered by small oval scales, which are about one-third of the body scales in size.

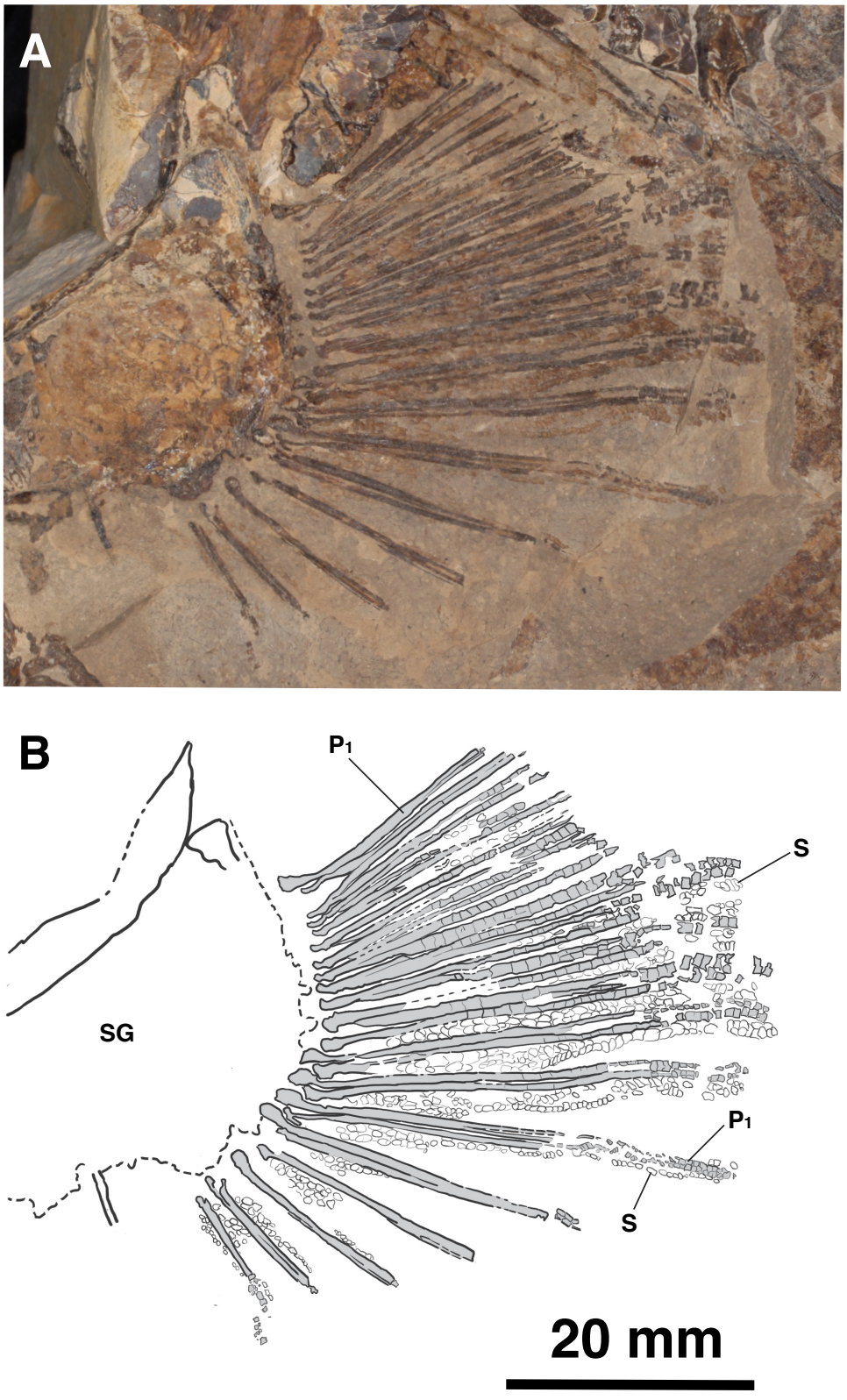

Figure 7. *Raususetarches sakurai* gen. et sp. nov. from Kasuga, Rausu, Hokkaido, Japan. Paratype RMM 6, pectoral fin rays in gray. **A,** photo; **B,** line drawing of A. Abbreviations: P_1 = pectoral fin ray; S = scale; SG = shoulder girdle.

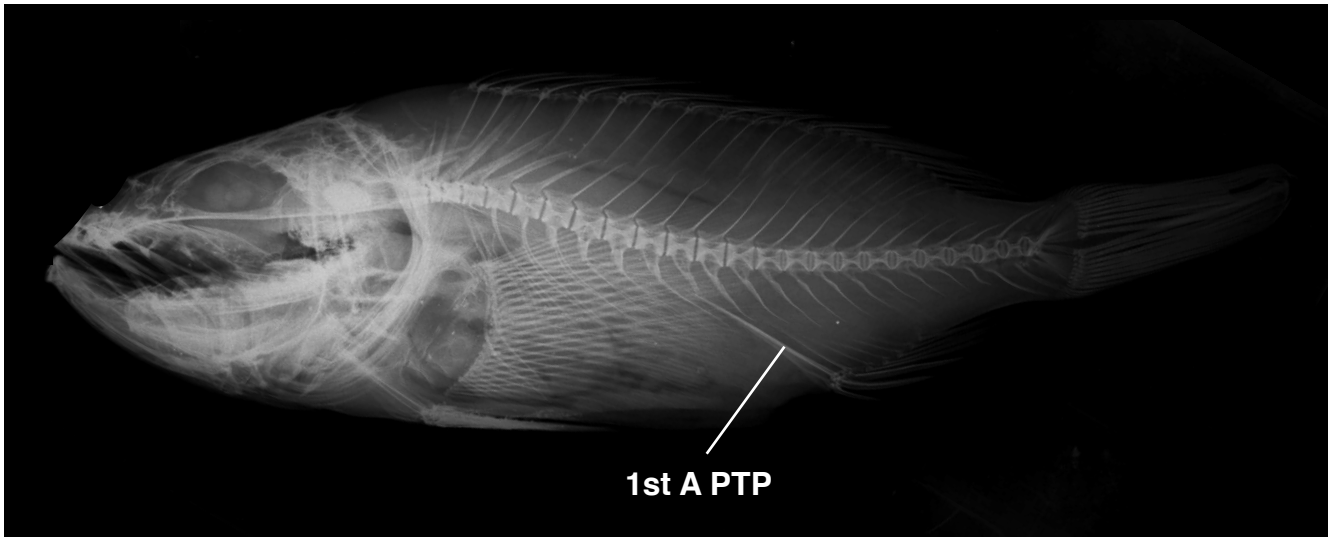

Figure 8. Soft X-ray image of Recent Setarchinae. *Starches guentheri*, ZIN 22711, 257 mm SL (standard length), showing the first pterygiophore of the anal fin inclined forward. Abbreviation see Figure 2.

Description of paratypes.—RMM 2 has well preserved posterior part of the body with 15 caudal vertebrae, dorsal, caudal and anal fins (Figure 3). The body is deep. The body depth is about one-third of the estimated standard length. The anterior part of the dorsal fin is missing, but 12 spines are preserved, probably the first two spines are missing because the holotype has 14 spines of the dorsal fin. Thirteen soft rays of dorsal fin continue from the spines. The dorsal margin of soft-rayed dorsal fin is rounded. The anterior end of the anal fin is missing, but two long spines are preserved with 8 soft rays, which are very long, longer than the soft rays of the dorsal fin. The entire dorsal and anal fins are covered by small oval scales that are one-third or one-fourth of the body scales' length.

The caudal fin has 12 branched rays, by six in the lower and the upper lobes (Figure 4). The posterior margin of the caudal fin is truncate, but slightly concave at the middle with rounded most dorsal and ventral tips. The anterior part of the parhypural is deeper than its posterior part. The first and second hypurals are fused forming the large ventral hypural plate. The third and fourth hypurals are also fused forming the large dorsal hypural plate, which is slightly shorter than the ventral one. The fifth hypural is short and its length is less than half the length of the hypural 3+4. The parhypural and the ventral and dorsal hypural plates are articulated with the urostyle. There are three epurals, the first one is largest and its ventral part is slightly broader. The uroneural is long and extends along to the ventral end of the fifth hypural. The ventral part of the uroneural is deeper, but not well preserved. The haemal spine of the second preural centrum is long and extends near to the end of the parhypural. The neural and haemal spines of the third preural centrum are long.

The specimen RMM 3 is a right preopercle, which has at least four (probably five) triangular spines along the posterior margin (Figure 5A). These spines are stout and triangular, not needle-like. The most dorsal spine is smallest and other spines gradually became lager ventrally.

The specimen RMM 4 is a left preopercle with the spines (Figure 5B) are almost the same as RMM 3 (Figure 5A). The dorsal arm is long. The opercle and subopercle are well preserved in RMM 5 (Figure 6). The opercle has two ridges, which posterior ends form sharpened spines. The length of the opercle is shorter than its depth. The ascending process at the anterior end of subopercle is large and extends to the point at almost one-third from the ventral end of the anterior margin of the opercle. The pectoral fin is large and has 19 rays covered by cycloid scales in RMM 6 (Figure 7).

Discussion

Many fish fossils are preserved in a yellowish white fine sandstone. At least 6 individuals are counted in the slab. All individuals appear to belong to the same species, because the features of vertebrae, fins and scales are almost the same. This new species is a member of the family Scorpaenidae of the order Scorpaeniformes because of four (probably five) spines on the posterior margin of the preopercle, two ridges on the opercle (see Nelson *et al*., 2016), the first pterygiophore of the anal fin

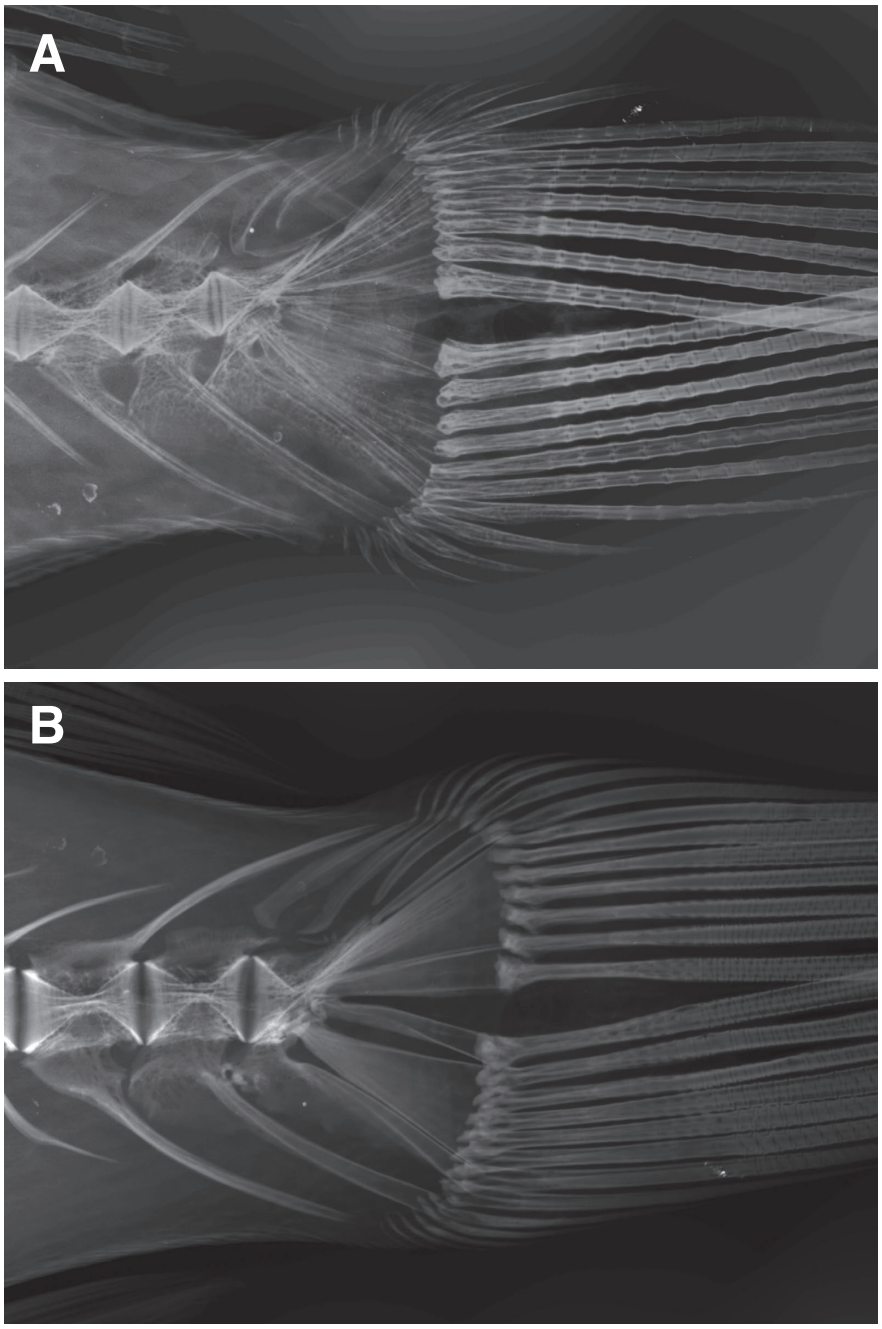

Figure 9. Soft X-ray images of Recent Setarchinae. **A,** *Ectreposebastes imus*, ZIN 49840, 140 mm SL; **B,** *Setarches guentheri*, ZIN 22711, 257 mm SL.

inclined forward, which is one of the characteristics of scorpaenids recognized in this study (Figure 8).

The classification of the Scorpaeniformes is complex and controversial, and the placement of this order is very provisional (Nelson, 2006). There are many detailed studies about the classification, phylogeny and placement of the order Scorpaeniformes (Matsubara, 1943; Ishida, 1994; Mooi and Gill, 1995; Mooi and Johnson, 1997; Mandrytsa, 2001; Imamura, 2004; Imamura and Shinohara, 1998 and Imamura and Yabe, 2002). Nelson (2006) discussed and mentioned these studies in detail, but he did not make the formal change of the classification because he thought there was no comprehensive and convincing phylogeny to do this. Nelson *et al*. (2016) retained the

Table 1. Some diagnostic characters of Recent genera of the subfamily Setarchinae with the fossil new genus, *Raususetarches*. Data of the Recent genera from Eschmeyer and Collette (1966). Abbreviations: D = dorsal fin rays; A = anal fin rays; P_1 = pectoral fin rays.

	D	A	P_1	Spines of preopercle
Raususetarches gen. nov.	XIV, 13	III, 8	19	large triangular
Lioscorpius	XII, 9–10	II, 5–6	23–25	short and small
Ectreposebastels	XII, 9–12	III, 5–7	18–20	long and sharp
Setarches	XI–XIII, 9–11	III, 4–6	20–25	long and sharp

subfamily ranking as seen in Nelson (2006) excepting the subfamily Caracanthinae, which was classified as a family in Nelson (1994, 2006), because there is some molecular evidence (e.g. Betancur-R *et al*., 2013) that it should be a tribe within Scopaeninae, or even included within the tribe Scorpaenini (see Nelson *et al*., 2016). In the present study, the classification of the suborder Scorpaenoidei and the subfamilies of the family Scorpaenidae are followed Nelson *et al*. (2016).

It is interesting that this new genus and species has the lateral line scales forming grooves (character 23-1 in Mandrytsa, 2001: the lack of a bony roof in all segments of the trunk lateral-line canal) and cycloid scales covering entire body (Figures 2, 3) that indicates it belongs to the subfamily Setarchinae (Setarchinae in Matsubara, 1943, 1971, and Nelson, 2006; the family Setarchidae in Ishida, 1994; and the tribe Setarchini in Mandrytsa, 2001). The subfamily Setarchinae (*sensu* Nelson, 2006) is an unique group within the family and the suborder in having the grooved lateral line scales. This subfamily consists of three genera, *Ectreposebastes* Garman, *Lioscorpius* Günther and *Setarches* Johnson, and seven species (Nelson *et al*., 2016). The new genus described here differs from other genera of the subfamily Setarchinae in having 14 spines and 13 soft rays of the dorsal fin, three spines and eight soft rays of the anal fin and 19 rays of the pectoral fin (Table 1). The large triangular spines of the preopercle are also very distinctive character for the new genus because in the Recent setarchines they are either long and sharp or very short (Eschmeyer and Collette, 1966: fig. 1). The caudal skeleton of this new genus and species is very different from that of Recent Setarchinae (Figures 4, 9). The first and second hypurals are fused (autonomous in Recent Setarchinae) and the third and fourth hypurals are also fused (autonomous in Recent Setarchinae) (Figures 4, 9). The upper hypural plate is shorter than the lower one (equal in Recent Setarchinae). The length of the fifth hypural is less than half the length of the hypural 3+4 (more than half the length of the hypural 4 in Recent Setarchinae). All recent species of the subfamily Setarchinae live in deep sea from 150 m to 700 m depth. This can be an evidence of the comparatively deep-water deposition of the Koshikawa Formation strata. The new genus and species described here is the first fossil record for the subfamily Setarchinae.

Acknowledgments

We wish to express our sincere gratitude to Kenji Sakurai for allowing us to study the specimens and his donation of the specimens to Rausu Municipal Museum. We would like to thank Nobuo Gochi of Shiretoko Museum for his comments on the locality and the deposit which yielded the type specimens. We would like to thank anonymous referees for their critical reading of the manuscript. This study was supported by the Russian Foundation for Basic Research (project 17-04-00596) to M. V. N.

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Author contributions

Y. Y. was primarily responsible for the taxonomic aspects and made a first draft of this manuscript and M. V. N. added many parts of the text and x-ray images of Figures 8 and 9. All authors contributed to the writing of this paper.